The AgTEM Manual

Continuous Mobile Acquisition Transient
Electromagnetics on Agricultural Land

AGTEM-WALLABY
AGTEM-WALLAROO

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GROUNDWATER IMAGING

THE AGTEM MANUAL

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THE STRUCTURE OF THIS MANUAL

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WHAT IS AGTEM

AgTEM is a transient electromagnetic survey system designed specifically for continuous acquisition across land or water. It is made in Australia by Groundwater Imaging P/L who began conducting towed TEM surveys in 2002.

AGTEM APPLICATIONS

AgTEM has been designed for affordable groundwater exploration on agricultural land but its application is much broader now covering the following:

- Siting bores for individual farmers
- Alluvium depth definition over and around mine sites
- Mapping groundwater recharge pathways
- Detailed sub-crop mapping in geological investigation of areas masked with soil
- Groundwater conceptual model detailing to assist groundwater flow modelers
- Salinity mitigation and seawater intrusion studies
- Groundwater pollution plume mapping
- Irrigation infrastructure moisture deep drainage mapping
- Seepage investigation
- Detailed geotechnical mapping on construction and roadwork sites
- Mapping of fill depth at waste disposal sites
- Moisture and rock competency mapping in benches of open cut mines prior to blasting
- Mine slope stability assessment
- Mineral exploration (using a separated receiver to see extra deep)
- UXO sterilization (larger metal objects only) &
- Metal object sterilization of ore stockpiles.

In most cases, AgTEM has the advantage of low cost of detailed resolution of resistivity at depths from meters to tens of meters. Due to the need for accurate microsecond timing, it is not as robust as direct current electrical resistivity tomography but is about 100 times more productive. Airborne TEM should be preferred on large scale projects and over dense vegetation while hand held Frequency domain EM instruments and ground penetrating radar should be preferred for root zone transects.

WHAT AGTEM DOES DO

AgTEM maps electrical resistivity within layers in the earth beneath wherever it is towed. Electrical resistivity reflects groundwater salinity and saturation in the earth so it is used for mapping groundwater resources and pollution. It is also great at sub-crop mapping as moisture and salinity levels are dependent on the different weathering of different rock types.

AgTEM was originally designed to be towed across agricultural land, hence the title AgTEM-Wallaby (Agricultural transient electromagnetic Cart). Now there is also AgTEM-Wallaroo which is more suited to vegetated and non-drivable terrain. In the USA these have been re-badged as AgTEM-Wallaby and AgTEM-Wallaroo.

AgTEM is very similar in design to more traditional TEM systems such as the Monex Geoscope TerraTEM24 with implementation of wire loops laid on the ground by walking workers. **As most groundwater exploration cannot tolerate the slow production of manually laid loop surveys, AgTEM was invented to speed matters up and bring cost per unit distance surveyed way down.** It also fills in data density such that many additional features can be identified.

AgTEM can see layers in the earth from 1m to 100m when configured appropriately. Imaging beyond 30m deep, especially in conductive terrain, requires higher power settings.

AgTEM can recover useful data as close as possible to metallic and electrical sources of interference. It is not uncommon for it to be successfully collecting data along powerline and some fence tracks. With focused pickup AgTEM can collect data from areas where, and at scales where, suitable collection of airborne electromagnetic data is impossible. The AgTEM strategy to collecting data near infrastructure is to drive as close as possible to the infrastructure, determine the infrastructure interference, and then determine what data needs rejecting in post-processing.

AgTEM can be used to collect very detailed data prior to mine blasting.

AgTEM can additionally be operated with nuclear magnetic resonance electronics for rapid permeability, porosity and saturation investigations within the possible range of depth of exploration.

WHAT AGTEM DOES NOT DO

For survey focused on topsoil and plant root zones readers are generally directed to use more compact frequency domain electromagnetics such as DualEM or Geonics FDEM instruments instead. Shallow facilitation of AgTEM is an area of ongoing experimentation.

AgTEM can respond to metal items – it is a giant metal detector, but it is not designed for detecting small isolated items like gold nugget and UXO detectors. Geonics and GAP Geophysics among others focus on UXO detection. AgTEM could be configured with an array of receivers for such a task but AgTEM marketing and development focus is primarily agricultural instead.

AgTEM is not airborne electromagnetics but is conducted in an almost identical manner to airborne EM. Airborne EM is great at detailed mapping of large areas at a level of detail typical of 1:100,000 maps. AgTEM can do reconnaissance of road, track and fence networks in remote areas but in built up areas it will be affected by telephony cables laid along the roads and by traffic restrictions. It is applied best at multi-farm, farm and paddock scale where it can travel back and forth across paddocks one at a time. In some configurations it can see deep mineral deposits in 3D detail, given comprehensive survey arrangement (proposed). It has a much lower loop moment than airborne EM systems but makes up for it in relatively slow survey speed which means longer stacking time per unit distance. Airborne STOL drone deployment of AgTEM is a possible, perhaps unlikely, area of further experimentation with a focus on soil survey applications but for deeper exploration there are many systems out there already suitably designed so airborne deployment otherwise does not fit the AgTEM niche market.

Time-lapse AgTEM is not generally preferred over time lapse direct injected current geo-electric tomography survey (DC ERT) because DC ERT calibration and drift can be very effectively controlled – something of great importance in time lapse survey. For such survey AgTEM will be most useful for identifying, in detail, a representative site at which a buried permanent DC ERT cable can be established.

FORMS OF AGTEM

AgTEM comes in forms *AgTEM-Wallaby* and *AgTEM-Wallaroo*. It may also be used with a transmitter loop walked along by walking workers. The Wallaby form is towed by a motorized vehicle – in this form it has occasionally achieved productivity in excess of 100km of transect per day. The Wallaroo form if much lighter and can be walked through terrain or mounted on a lightweight undercarriage. Another form, AgTEM-Barrow, involves an electrically propelled barrow platform was still in development in 2021. For most applications AgTEM is used independently but envisaged development would see it applied to detailed deep 3D exploration where it must be used as a mobile transmitter moving through a matrix of permanently occupied static or independently temporarily occupied receiver locations.

AgTEM-Wallaby can be used on water substituting floats for wheels.

AGTEM-WALLABY

AgTEM-Wallaby (AKA Cart) is the original form of AgTEM. It is preferred where substantial areas of open trafficable country can be surveyed such as broad-acre farms. Operated typically towed by a 4wd or all-terrain-vehicle such as a quad-bike, it can typically cover up to 60km of transect in a single day. In contrast to the lighter AgTEM-Wallaroo or AgTEM-Barrow, it has a mutual inductance null-coupled receiver loop on the Wallaby such that everything is self-contained. The operational computer and touchscreen are mounted in the towing vehicle. It may be used with an optional additional receiver on a boom mounted on the front of the towing vehicle or, possibly in future, with independent walked or static receivers travelling in its vicinity.

Figure 1 AgTEM-Wallaby prepared for survey

Figure 2 AgTEM-Wallaby and front loop assembly within the dedicated shipping box.

AGTEM-WALLABY ON WATER

Substituting polyethylene floats for AgTEM-Wallaby wheels, an AgTEM-Wallaby may be used on water, being towed by a boat.

AGTEM-WALLAROO

AgTEM-Wallaroo (AKA Trek) is a very lightweight mobile TEM system using booms like AgTEM-Wallaby. It can be carried by two persons or mounted on a lightweight undercarriage propelled and driven by just one person.

It is useful for:

- Very dense shallow survey – for instance blast pattern design,
- Geotechnical site characterization for new developments or road corridor assessment,
- Pollution plume characterization and other survey in sites with complex traffic logistics,
- Where airfreight to a job site must be quick and economical,
- Survey in terrain that is inaccessible except on foot,
- Survey where local labor costs and availability favor employment of a larger team rather than increased vehicle use.
- Mineral exploration in difficult terrain – this might be with additional technology.

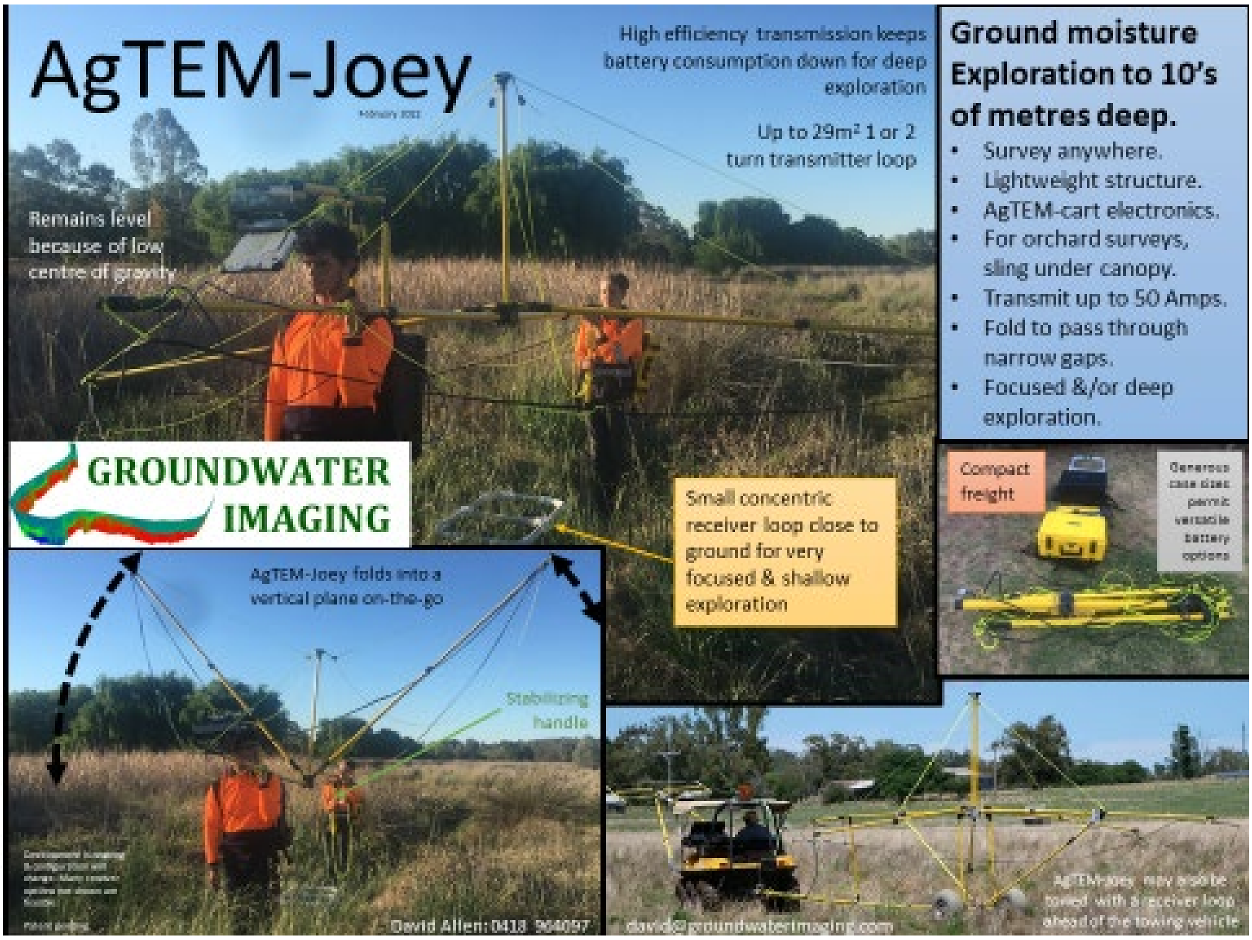


Figure 3 The AgTEM-Wallaroo.

The Wallaroo beam and fold out loop are compact, of low cost and lightweight.

DOUBLE-WALLAROO

A Double-Wallaroo system is twice as long but requires an extra person to carry it and can see deeper so it is a possible choice for sulfide ore mineral exploration in difficult terrain. The size and moment of the loop will disqualify it as a candidate for exploration many hundreds of meters deep but detail of coverage, mobility, and the fact that it can continue stacking data all the time a crew is moving it along make it a formidable competitor to traditional 100 x 100m moving loop TEM.

HAND HELD LOOP VERSION

In most rudimentary form, the same AgTEM backpack equipment may be used excluding the beam and fold out loop if a team of walkers simply carry the loop. Up to 100m by 50m loops have been carried in this mode.

In this form, the AgTEM electronics and receiver loop are carried on foot but the transmitter loop is simply held in place by four persons walking. Acquisition is continuous, occurring while all persons walk along, the receiver carriers many meters in front or behind of those carrying the transmitter system. Such a system is great where plentiful low cost labor is available on site and/or minimal equipment mobilization costs are essential. Further, it can be conducted through difficult terrain and vegetation where there remains predominantly clear country. In forest a conventional TEM survey where loops are laid out statically, or airborne TEM are the only options.

AgTEM-Barrow is a single wheel electrically propelled barrow – with or without 'training wheels' and has a loop suspended from a central post and booms. It requires a person walking with it to keep it upright and to steer it. It can cover as much ground in a day as that person can walk. It is amenable to use in rough un-trafficable terrain should walking workers choose to carry it on their shoulders across places where it cannot be rolled on its wheel. It does not have the on-board null-coupled receiver of AgTEM-Wallaby but is rather typically used with a receiver loop moving in its vicinity. The receiver loop may be walked along or boom mounted to the towing vehicle. For shallow exploration another receiver loop may be added directly to AgTEM-Barrow but it is not null coupled and will need to be operated in conjunction with an independent receiver loop if both shallow and deep exploration are to occur.

AgTEM-Barrow is more compact for shipping and quicker to deploy than AgTEM-Wallaby.

AGTEM-STOL SOIL MAPPER – SHELVED PROJECT

AgTEM-STOL (Short Take-Off & Landing Drone) Soil Mapper, under design and experimentation is for paddock scale soil mapping where crops or soil tillage make terrestrial survey impractical. If interested please indicate your support – this is a costly product to bring to market and this will only occur if considerably more support occurs. It is not intended to replace SkyTEM, Tempest, VTEM, BIPTEM and other airborne electromagnetic systems that can see much deeper but have deployment costs that preclude farm by farm survey.

AGTEM FOR NUCLEAR MAGNETIC RESONANCE (NMR) SURVEY

AgTEM is conventionally operated with Transient Electromagnetic electronics but can also be connected to nuclear magnetic resonance equipment from Iris Instruments or Vista Clara for more direct mapping of soil moisture at the meters to tens of meters depth range. Typically it may first be used for TEM survey and then, in a second pass, used for NMR survey which must occur slowly due to very low signal to noise ratios.

WHY AGTEM USES LARGE LOOPS

In contrast to competing instruments, AgTEM uses as large as practical large air core transmitter and receiver loops. Competing instruments may use ferrite cores in loops, numerous loop turns and very high signal pre-amplification to try to achieve similar results. All these methods affect data considerably by shifting the data in time, low-pass filtering the data, and adding extra system response. Methods such as system response subtraction or de-convolution may be used to recover from such effects but only with information loss and mis-representation.

Further, movement noise, coming from moving the loop through the magnetic field of the earth, can be extreme in coils that vibrate finely in the wind or from other resonant movement and on highly amplified loop signal the movement noise too is amplified whereas if the loop just had a large area then movement, especially vibration movement, of individual loop sides does not considerably increase compared to movement of sides of small loops but the signal picked up is increased with the square of the loop side length.

Further, self-induction within the loop increases with the square of the number of loop turns, so, once other limitations are surpassed, the few the loop turns the better.

KEY DISPLAYS

Data is acquired while viewing both a sounding display, and a raster map display colored according to the voltage of a particular time gate. Additionally, in a vehicle, a separate navigation display is viewed – presently this is a Trimble Agriculture product that can alternatively mount in the AgTEM receiver case in such a way that it can be viewed on a quad bike front rack.

HOW TO SELECT THE RIGHT DEVICE FOR A SURVEY

Wallaby is most productive on large drivable jobs as it is designed with robustness for driving 10 hours per day behind off road vehicles suited to all-day driving without considerable fatigue and at maximum practical speed.

Typical Wallaby production is 40km/day including day 1.

Wallaroo can achieve about the same depth of investigation as Wallaby if the front loop is used so its choice is more about practicality than capability.

Wallaby is only practically mobilized with specialized large float trailers. Deployment by one person is practical within half an hour. This means there is a large initial outlay and considerable mobilization cost involved but once on site, a lot can be achieved in a single day.

Wallaroo, with an electric tractor, can be mobilized to site on a dual cab ute with roof racks. This will however take an hour to set up once packed away so compactly. The electric tractor is walked along so productivity is limited to walking speed and endurance (unless equipped with autonomous guidance). Wallaroo is far weaker than Wallaby but so is the towing vehicle. This means that when it is caught up and about to get damaged, quick action to stop can be taken.

Typical Wallaroo electric tractor productivity is 10km on the first day and 15km on subsequent days.

Wallaroo walked is most taxing on endurance. Three persons are required should the front loop be carried, and without the front loop depth of investigation is compromised by the high primary field coupling of the in-loop receiver. Wallaroo walked is perhaps the most challenging to set up due to difficulty acquiring, paying for, training, and coordinating survey crews. Where employment and training are objectives, it is most appropriate! It is possibly to achieve 15-20km per day with Wallaroo walked but weaker, lazy, unfit crews will jack-up early in the day and refuse to come to work the next day. Endurance required is similar to overnight bushwalking.

Typical Wallaroo walked productivity is 10km per day.

THE SOUNDING DISPLAY

Key to real time quality control is the sounding display (dB/dt versus time). The hashed area is the ramp. Within the ramp time, the sounding is unstable because it is null mutually coupled inductively. Beyond the ramp the voltage decays, first through the receiver coil self-response, then transitioning into ground response. Data is plotted on Inverse Hyperbolic Sine axes which are basically logarithmic but transitioning to linear over the polarity change. Observe a curve steepening as it passes through this gradual log-linear transition at 1 on the vertical axis. This system is great at enhancing errors and making data look as poor as is possible – just what is needed when doing quality control.

In order to keep track of changes on the sounding display, a reference sounding is fixed for comparison.

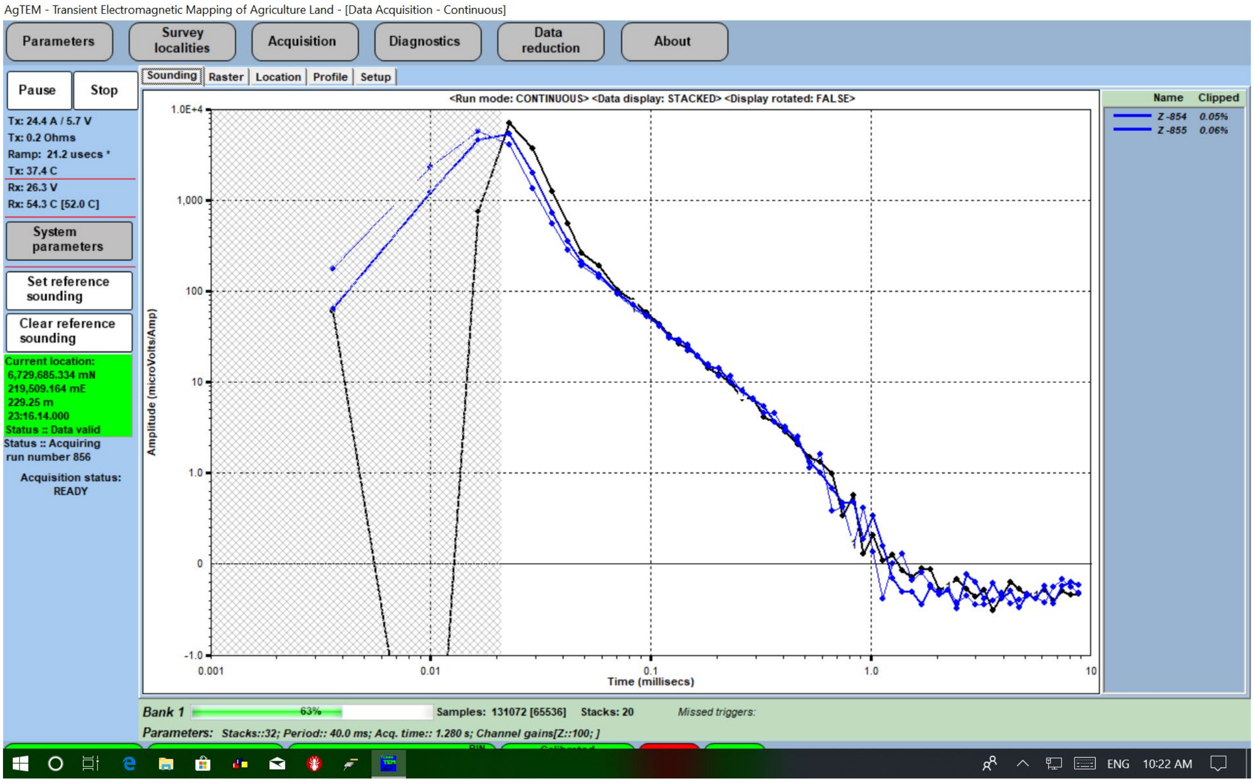
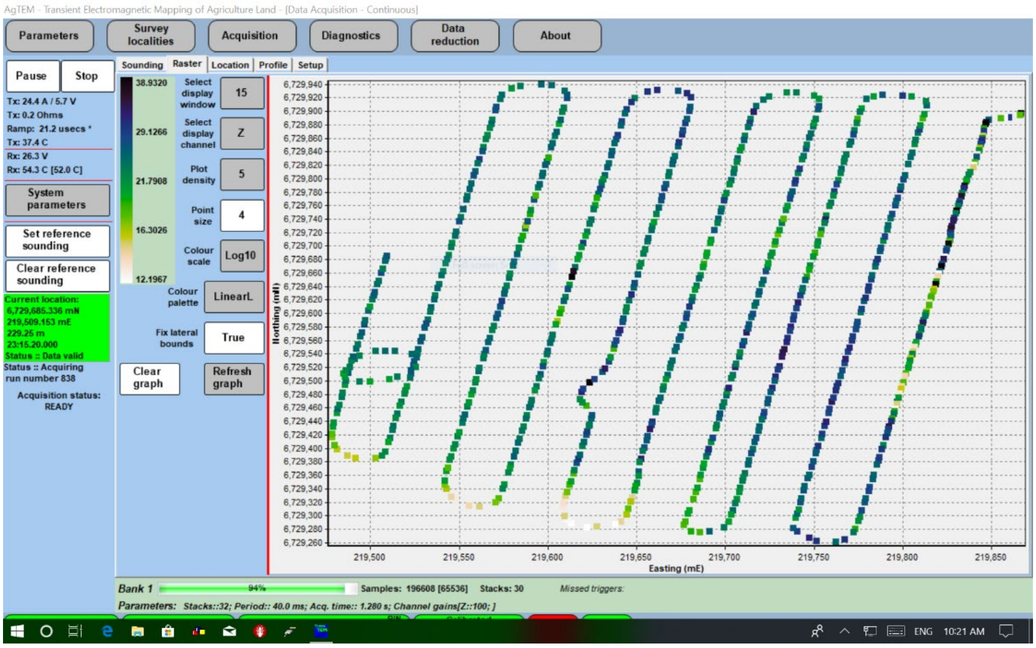


Figure 4 The AgTEM sounding display provides real-time comparison of soundings.

THE RASTER MAP DISPLAY

The raster map display plots a single time gate as colored dots as progress occurs. On the display below evidence of fence effect in the south can be correlated from line to line. On-the-fly infill decisions and grid density change decisions can be made using this display.

On a second image below, including coverage through forested steep areas where a straight path could not be maintained, evidence of out of character data is present, some due to passing through gates, and along fences, and some simply due to display parameter changes during acquisition.



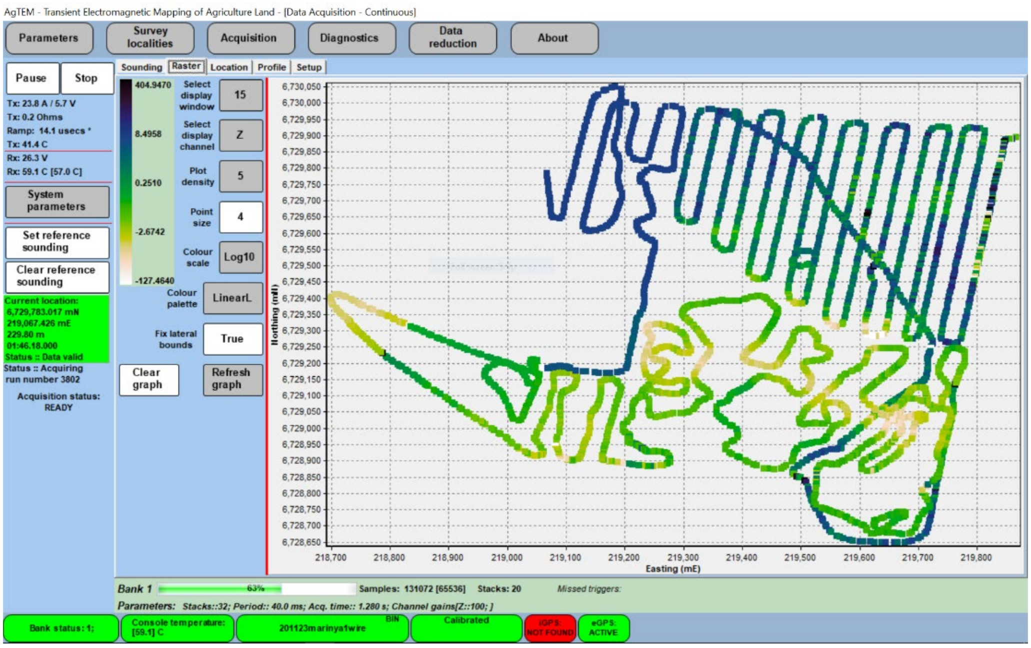


Figure 5 The AgTEM Raster display provides real time map view as survey proceeds.

NAVIGATION

External GPS display: The following photo reveals the external Trimble GFX350 GPS display. Swaths are being covered and a 'light bar' at the top shows track correction needed to keep driving straight next to the previous line. This may remain external as there is lots of investment in these displays and the costly but better value differential corrections needed for precision survey are tied into deals that require such displays for authentication.

Alternative GPS with differential corrections include

Arrow Gold – used with 3rd party Android Tablet navigation software such as FieldBee https://www.fieldbee.com/product/gps-app-subscription/ . This equipment is of much lighter weight and more suitable for use with AgTEM-Wallaroo.

ROUGH TERRAIN CAPABILITY AND VEGETATION CLEARANCE

AgTEM is able to brush through some rather dense vegetation. Although booms and rigging are attached by sacrificial cable ties, beware of any branch stubs that protrude at right angles and may catch wires and ropes. Barb wire on gateposts creates a similar risk. Fold booms back before passing when the hazards are over prolonged distance or definite problems, otherwise simply observe rear vision mirrors very carefully while driving slowly and prepare to stop very quickly if you see wire start to pull backwards. When breaks do happen they typically will be in the sacrificial cable ties. NEVER BYPASS THE SACRIFICIAL CABLE TIES nor replace them with strong links. Carry a packet of spare cable ties of appropriate strength.

Figure 6 AgTEM-Wallaby may pass through difficult vegetation when necessary.

Figure 7 AgTEM-Wallaby side profile

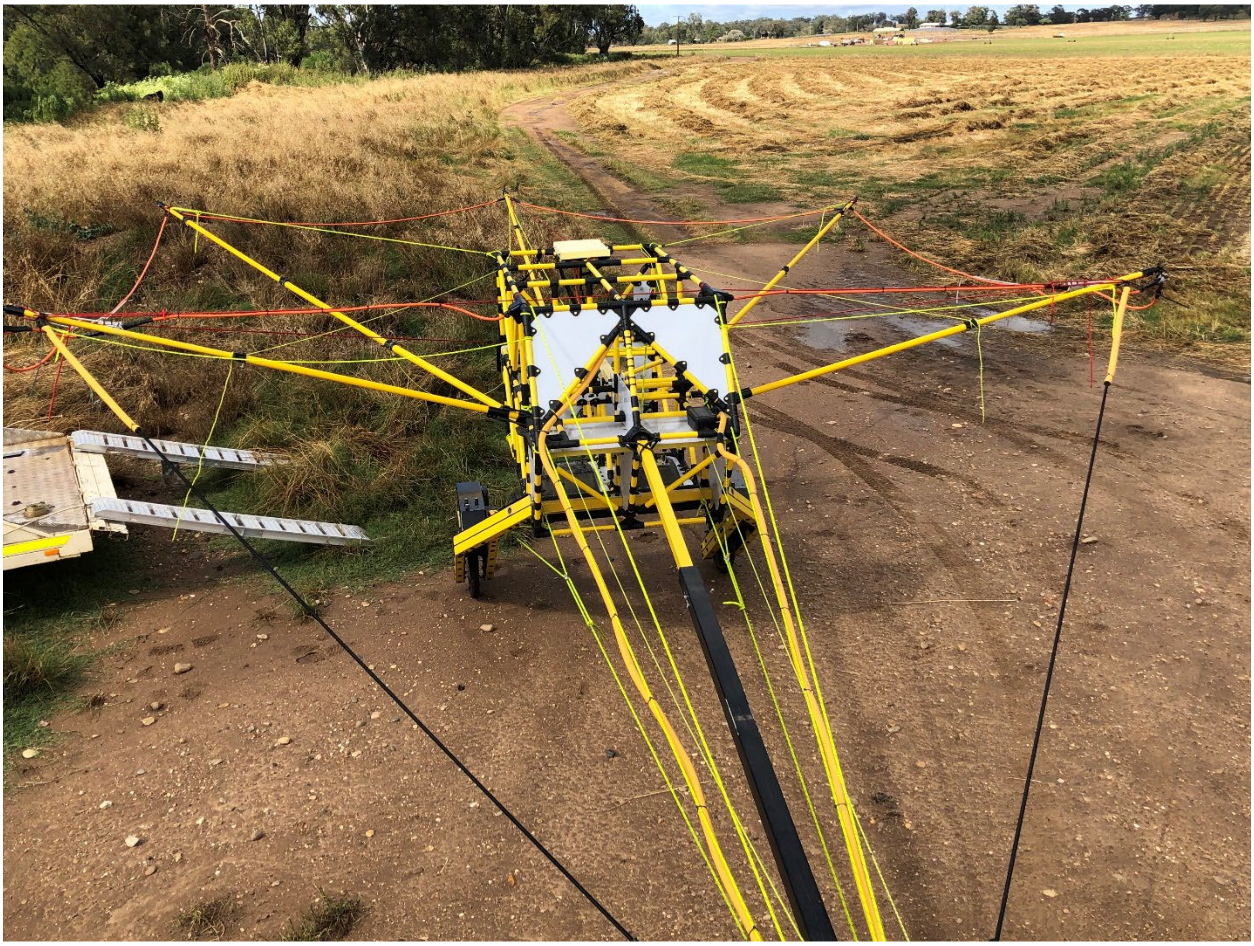


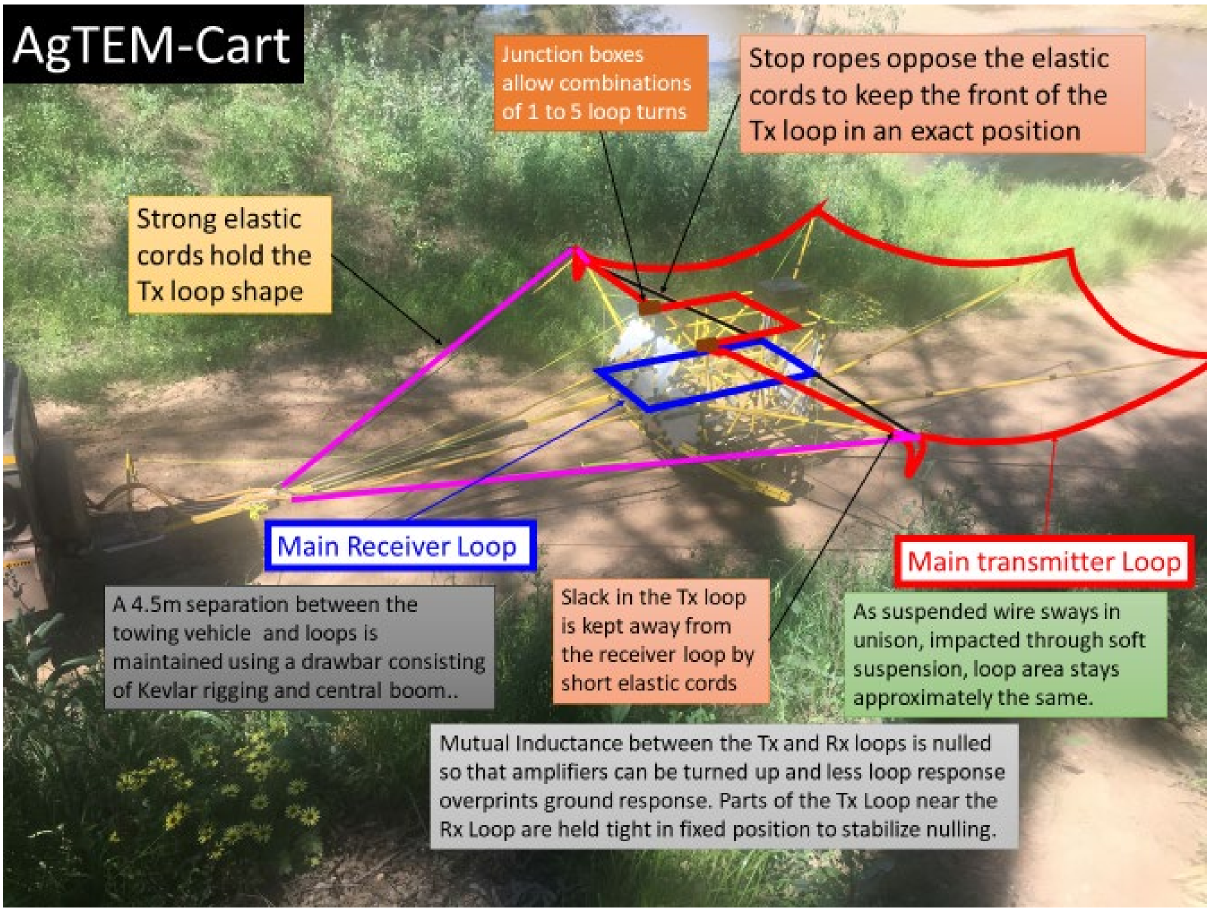
Figure 8 AgTEM-Wallaby view from above (oblique)

DESCRIPTION OF PARTS

AGTEM PARTS AND VARIANTS

AgTEM can come in 3 variants, made of some common, and some interchangeable parts.

AgTEM-Wallaby[1] is the highest productivity system and its use is limited to where it can be towed by motorized vehicles. It is good for open farmland, some tracks and open woodland. Groundwater is typically sourced in valleys covered by open farmland where AgTEM-Wallaby is productive. Up to 110 line kilometers have been surveyed in a day with AgTEM- Wallaby.



1

AgTEM-Wallaroo is walked around and is the base level system, capable of both shallow and deep exploration even in steep terrain and some tall vegetation and where no vehicle can be driven. Wallaroo rests in horizontal attitude as a large loop but folds vertically, to pass narrow gaps, when cords are pulled. Operation is however limited to walking speed and requires several people. Challenges involving proximity of metal parts to loops are enhanced in Wallaroo-walking mode of operation and it our most difficult design challenge. Very low voltage operation means that a very large, deep penetrating moment can be sustained all day using batteries light enough to carry. Wallaroo packs into an airfreight case.

Figure 9 AgTEM-Wallaroo system – see website for variants released January 2025.

AgTEM-Barrow is for extended duration productivity on mines and geotechnical sites or where 4 wheeled vehicles are impractical. It may resolve variation in rock moisture and competence important to slope stability, foundation stability, ore and overburden consistency and blast pattern design. The operator balances the equipment as the single large diameter electrically propelled wheel pulls the equipment, and the operator, without the sideways jolting common to side by side wheel vehicles in rough terrain. It may also function in orchards.

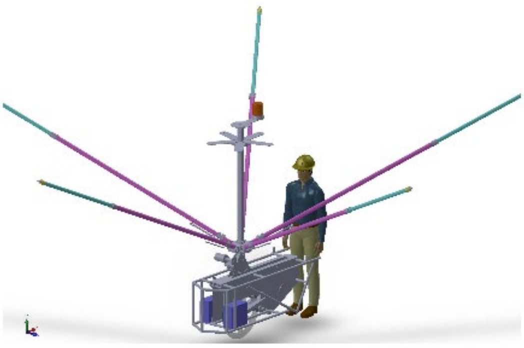


Figure 10: - electrically propelled AgTEM-Barrow can be completed as a prototype upon request. As of January 2025, modifications are required as testing indicated practicality challenges removing the wheel and motor for mainentance are not sufficiently addressed – investor interest is welcolmed.

AgTEM Front Loop and other loop separation options possible with AgTEM products suite different applications. The Wallaby has a large cross section area receiver loop within the core with stable null mutual inductance with the transmitter loop. This is highly productive and suites rapid deployment jobs, **many of which are unaffordable with any other option**. Receiver loops placed with or close to the transmitter loop of AgTEM-Wallaroo or AgTEM-Barrow can operate using the 24 bit dynamic range of AgTEM electronics even without mutual inductance nulling.

Separated loop options for all AgTEM variants are possibly. These variant are also referred to as Slingram variants. For the Wallaby, booms extending in front of the motorized vehicle can hold a receiver loop – this has proved to be effective. More troublesome is a towed receiver behind the Wallaby. Such towed receivers should be attended by a walking person who can direct it away from gate posts and other obstacles. AgTEM Wallaroo functions very well with separated loops as does AgTEM-barrow.

The next two images present a front loop on the AgTEM- Wallaby system, mounted on two tow balls on the bull bar.

Below is a AgTEM mat slingram receiver typically towed behind Wallaroo or Barrow variants to get a large cross section area. Wires are welded into seams. It is normally towed resting on a 1.6mm thick polyethylene sheet (irrigation canal liner) for added durability.

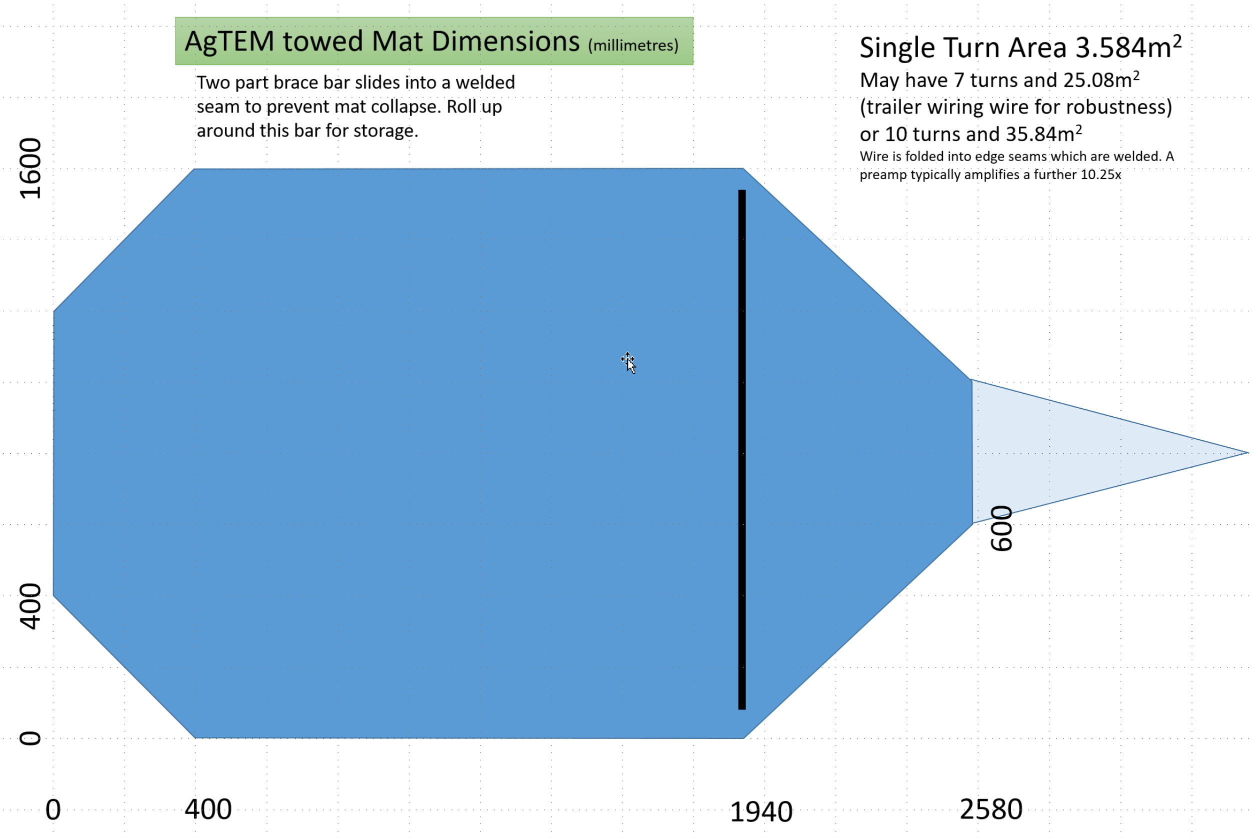


Figure 11 AgTEM towed mat is often used with AgTEM- Wallaroo in order to reveal deeper features with little extra physical effort. It is appropriate to tow it on top of a sacrificial piece of HDPE about 1.6mm thick.

AGTEM CORE AND VARIANT PARTS

A core of equipment is common to these three variant as follows:

- **AgTEM Receiver** (3 channel simultaneous – Typically configured to 156.25kHz with 50kHz low pass filter but capable of up to 625kHz), Includes custom cables for compact lightweight connection of the Trimble GFX350 and NAV500 (or 900).
- **Panasonic Toughpad computer** hosting operational software with real time transient decay and coloured map display.
- **AgTEM Transmitter** rated to 50 Amps with on/off period adjustable down to 1.25mS (Europe, Australia) or 1mS (USA). Includes a **24V to 5V DCDC down-converter** and power stabilizer facilitating efficient power delivery from 2x included large capacity 12.8V battery cases to be housed in the towing vehicle.
- **6 x 3Amp LiFePO4 4 cell battery chargers** for control electronics battery charging

- **Simple test equipment - Adaptor – Receiver to flying leads** for connection to a test loop - Incorporates a switch-in damping resistor; transmitter to alligator clamps – Incorporates a switch-in damping resistor; 8m Synchronization cable.
- **Data download, visualization and cleaning software interfacing with Aarhus Workbench towed TEM module.**
- **Client supplied equipment**
  - **2 x 12.8V 12AmpHr batteries (for receiver electronics)** dimensions 150mmx100mmx100mm
  - **2 x 12.8V 7AmpHr batteries (for transmitter console)** dimensions 150mm x 100mm x 76mm
  - **One trainee operator**
  - **Inversion software (Aarhus Workbench towed TEM module is compatible)**
  - **General repair equipment:** clamp multimeter with 80 amp measuring clamp; Anderson, Mil Spec and Deutsch connector replacement equipment and competency**;** Wheel changing equipment (jack, sockets and wrench); stock of cable ties of various sizes and bicycle tyre pump for airbag pressure adjustment, abundant electrical tape (for bundling and adhoc repair), knife and cutters, screwdrivers and other general tools.

The parts of the three variants are:

AgTEM- Wallaby –

- **Common core equipment**
- **A quick release vehicle dash-mount** for the operational computer.
- **24V to 5V DCDC down-converter** and power stabilizer facilitating efficient power delivery from 2x included large capacity 12.8V battery cases to be housed in the towing vehicle.
- **AgTEM Wallaby** with airbag suspension undercarriage, 6m wide booms, core, drawbar and suspended loop suitable for 1 or 2 turn operation at close to 50Amps. The core also houses a 10 or 20 turn x 2.06m^2 receiver loop, with pre-amp, in the mid-plain with stable cancellation of mutual inductance with the main 32.5m^2 transmitter loop. All loops are equipped with vibration damping. Small upper and lower transmitter loops which collectively cancel fields at the plane of the receiver loop are also housed in the core for shallow investigations. With two turns, operating at 50 Amps, the main transmitter moment is 3250Am^2 (NIA). The main transmitter loop has 5 x 4mm^2 cores connectable in various configurations and is detachable. Synchronization, Receiver loop, Transmitter loop power, Transmitter electronics power and trailer lights cables run through hoses with strain members to the towing vehicle. Although space in the transmitter case is provided for batteries, when used in the Wallaby, alternate wiring and cases are provided for storing batteries remote in the towing vehicle. This reduces trailer weight and wear and tear in rough terrain.
- **AgTEM- Wallaby shipping container** (for use in airfreight, truck freight, and with forklifts). Designed to fit within aircraft ULD dimension limits and onto a double shipping pallet. It has space beneath for forklift prongs. It is equipped with gas struts to facilitate easy unpacking. A tarp wrap shields from rain.
- **6 spare wheels**
- **2 x 30Amp LiFePO4 4 cell battery chargers**
- **Client supplied parts**

    - **AgTEM rapid deployment float trailer** (Unistrut – plans supplied)
    - Floatation (if to be used amphibiously)
    - **2 x 12.8V 100AmpHr batteries or 8 x 12.8V 7AmpHr batteries.**
    - Trimble GFX-350 Navigation display and NAV-500 DGPS antenna (or suffice with fall back AgTEM-GPS and basic navigation aids or any other GPS with NMEA0183 output)

Note: As of January 2025, AgTEM-Wallaroo is suitable for limited commercialization.

- AgTEM-Wallaroo –
  - **Common core equipment**
  - A quick-release computer mount suspended in front of the operator for viewing while walking.
  - Within the transmitter case, space and fixtures for mounting loop power batteries and console batteries are provided.
  - Backpacks for walking with the transmitter and receiver and their batteries and GPS.
  - AgTEM Wallaroo loop suspension system with 4 x 4m transmitter loop and suspended loop suitable for 1 or 2 turn operation at up to 50Amps.
  - AgTEM Wallaroo shipping cases
  - AgTEM small receiver loop and sled for shallow focused exploration and/or AgTEM large flexible receiver towed mat for deep exploration, all with vibration damping.
  - 2 x 10Amp LiFePO4 1 cell battery chargers
  - GPS receiver
  - 8m synchronization cable (fixed to Wallaroo structure)
  - 6m receiver loop cable for central loop receiver or boom mounted receiver.
  - 8 or 12m receiver loop cable with strain member and abrasion hose for towed receiver.
  - Client supplied parts
    - Either 8 x 12.8V 7AHr batteries (i.e. a morning and afternoon set) or 4 x 3.2V 100AmpHr cells (i.e. a morning and afternoon set of two cells for 6.4V supplies – about the lightest most efficient power source possible which is important for operations conducted on foot) (Alternative heavier sources also can be facilitated)
    - Optional DGPS if close spaced survey is to be conducted. Note that DGPS also permits an elevation dataset to be obtained which is highly complimentary to AgTEM TEM data.
    - To assist the operator, at least one assistant (two will save exhaustion on long jobs)
  - A Triple- Wallaroo variant is possible combining two Wallaroo structures, a join kit and a special loop of triple the area and 3 turns. This is for very deep investigation using Slingram (separated loop) configuration. Given that it acquires continuously, it may rival 100 x 100m moving loop surveys for investigation depth while adding the horizontal resolution needed to 3D-model out near surface effects that mask deeper features.

Note: As of January 2025, AgTEM-Barrow is still in Proof of Concept.

- AgTEM-Barrow –
  - **Common core equipment**
  - 24V to 12V DCDC down-converter and power stabilizer
  - AgTEM walk-behind electric rough terrain wheelbarrow with airbag suspension, 6m wide booms, training wheels (trike configuration) and suspended loop suitable for 1 or 2 turn operation at close to 50Amps.

- AgTEM-Barrow shipping case
- 2 spare wheels
- 2 x 30Amp LiFePO4 4 cell battery chargers
- Client supplied parts
    - 4 x 12.8V 100AmpHr batteries (morning and afternoon – also propels electric barrow)
    - Optional DGPS if close spaced survey is to be conducted.
    - One assistant to the operator is recommended on long or rough terrain jobs to save exhaustion and to help stabilize the equipment.
    - Trimble GFX-350 Navigation display and NAV-500 DGPS antenna or alternative NMEA0183 source.

Optional accessories are:

- AgTEM- Wallaby front loop and support – mounting via two tow balls onto vehicle bull bars.
- **36V to 12V DCDC down-converter** and power stabilizer facilitating efficient power delivery from included large capacity battery cases to be housed in the towing vehicle. This is an alternative to the 24V to 5V DCDC converter and is suitable for driving large currents through multiple turn loops.
- AgTEM mat and long flexible conduit encased receiver cable and tow rope.

POWER SUPPLIES

Typically, all AgTEM variants can be powered by combinations of lots of 7AmpHour 12.8V LiFePO4 batteries https://www.jaycar.com.au/12-8v-7ah-lithium-deep-cycle-battery/p/SB2210 that can be carried as hand luggage on aircraft. Our standard cabling facilitates this option. We supply caps with Mini-Anderson connectors to keep the terminals safe from shorting. Such batteries are used with an internal 24V to 5V DCDC converter and our low resistance transmitter loops for efficiency. On lower amperage surveys no change of batteries will be needed in a small day of survey. Where airfreight dangerous goods restrictions are not a problem, it is great to use larger capacity batteries that the user may source, adding commonly available Grey 50amp Anderson connectors for compatibility with the AgTEM systems. Compatible large capacity LiFePO4 batteries with integrated power management systems are now sold in caravan stores and are readily available. 100 Amp.Hours 12.8V batteries typically will last several days between charges. A single 56 or 60 Amp.Hour 25.6V LiFePO4 battery, now available from several outlets, will drive the system all day and is perhaps the most elegant solution when not backpacking the equipment nor air freighting.

OUR CONNECTOR CONVENTIONS

We use the following conventions for connectors.

Connector	Volts	Max. Amps	Comment
	12.8	30	Mini-Anderson typically on 7Amp.Hr **battery caps**

	12.8 Variable, typically 5V	50 50	Used with **12.8V batteries going to a Y connector** to one blue 25.6V output. 50% bipolar square wave outputs at **loop turn connectors** but not direct to the transmitter. In this case current in both cores flows in the same direction. Such connectors are always part of the transmitter loops.
	25.6	50	Common **19 to 36V transmitter input**. Can interchange with Hirschmann connectors if using the standard 24V to 5V DCDC converter as it only draws <15 Amps.
	Variable, typically 5V	50	**50% bipolar square wave** outputs from the transmitter.
	25.6	15	**22V to 30V Hirschmann 4 conductor** – screw terminals easy to wire in the field. Suites **Transmitter loop power, transmitter control power and receiver power**.
	control	Low power	**Synchronization** cables
	signals	Very low	**Receiver** cables – 3 components plus pre-amps power.

Figure 12 Standard caps and connectors are supplied with AgTEM to facilitate carriage, on aircraft as hand luggage, up to 20 7Amp.Hr LiFePO4 batteries with integrated battery management systems (BMS) for operating AgTEM.

OTHER BATTERY OPTIONS RARELY USED:

1. **Normal operation** involved coupling batteries to form approximately 24V and feeding a DCDC converter to create a stable 5V for loop power. Electronics power also uses 24V so more of the same batteries can be used.
2. **12V loop power regulated.** An option to convert to regulated 12V (from 36V-72V) is available and fits in the transmitter case lid space and is subject to dust ingress – it is useful for high loop moment surveys.
3. **24V direct.** Using 4 or 5 loop turns it is possible to make use of 24V to create maximum moment, without exceeding 50Amps per turn, for deep exploration.
4. **6.4V lightest weight Wallaroo supply.** AgTEM- Wallaroo transmitter packaging has been set up to directly draw from a couple of standard dimension 100AmpHour 3.2V cells but these require custom battery cutoff for each of two cells which combine to give 6.4V and this circuitry is not yet available. They are the ideal option for minimizing backpack weight but another alternative seems like it is better to focus upon because the 100Ahr cells are not airfreight compatible and getting their battery monitoring occurring individually, rather than as a pair and transmission shut down should one go under-voltage is an expensive development task. As an interim measure 2 multimeters are wired into the transmitter to check these 3.2V cells are not overstressed. For Wallaroo it now seems better to adopt a heavier to carry solution with the 5V DCDC converter encapsulated in the transmitter and lots of 7AHr 12V batteries driving it. These can be carried as hand luggage in airliners as they are under 99 Watt.Hour and this might be more important than backpack weight and service longevity. They also have their own safety circuitry – eg. https://www.jaycar.com.au/12-8v-7ah-lithium-deep-cycle-battery/p/SB2210 Four of these, correctly connected, are sufficient to drive 50 Amps into the Wallaroo loop via the 5V DCDC converter.

7AMPHOUR BATTERY PREPARATION FOR USE

The 12.8V 7Ahr batteries will often be purchased locally. Groundwater Imaging Supply caps and wired mini-Anderson connectors designed to make them suitable for carriage as carry-on baggage on airlines or for easy miscellaneous dangerous goods shipment on freight aircraft. Below is a picture of a battery prepared in such a way plus photos of the parts supplied for equipping batteries purchased locally.

Figure 13 Parts supplied for local capping of 7AHr LiFePO4 batteries. A polycarbonate cap protects terminals from shorting, a wired mini-Anderson connector allows quick disconnection for shipping, and a decal wraps the battery to hold all together.

Figure 14 Slide connectors over terminals (red +, black -) and bend wires to fit in the protective cap. Then follow instructions on the decal to wrap all these parts. While the cap covers the terminal tabs, the tabs themselves prevent the cap from sliding out of position.

Figure 15 The finished prepared battery.

Experienced geophysicists will be well aware of the danger, frustrations and tedium involved in using exposed battery terminals directly in routine operations. These caps are intended as a compact alternative to dangerous exposed battery terminals.

7AMPHOUR BATTERY CONNECTION LOOMS

The 7Amp hour batteries, limited in size by air carriage restrictions, are rejoined together into useable capacities by wiring looms leading from Mini-Anderson connectors to Hirschmann connectors. These batteries can typically be connected in series up to 24V and in parallel – the limiting factor being the BMS systems within them. For control electronics a pair is connected in series while, in order to get sufficient current, for loop power via the 24V to 5V DCDC converter, a set of 4 is connected as parallel connection of two series pairs. The next photo presents a wiring loom on a series pair. Battery chargers are set up to connect directly to the wiring looms to save time.

LEAD ACID GEL CELL SUBSTITUTION

Note that sealed lead acid batteries of similar dimensions can be substituted in a difficult situation but this is highly disadvantageous as they have no BMS and their voltage decays during use – quickly dropping below useable limits. Further they are quite heavy.

7AMPHOUR BATTERY CHARGER BANKS

The use of multiple <99 Watt hour batteries to meet air carriage restrictions results in an additional practical problem – complexity of charging. A bank of chargers has been arranged in a box that can also house 12 7AmpHr 12.8V batteries and it is set up so that charging can be achieved using the wiring looms discussed above. This means that 6 chargers with 4 connectors is sufficient for charging all batteries used in a day. The photo below presents this charger bank, which doubles as a case suitable for carriage of batteries on aircraft.

Figure 16 A bank of battery chargers and batteries designed for meeting air carriage restrictions.

Two of the battery chargers are equipped with Amp.Hour, Amperage, Watt and Volt meters. Keeping track of charging effectiveness is extremely important in troubleshooting so these meters are considered as an essential part of the kit. It is recommended that the Wattmeters be connected to different battery sets on a rotation basis on successive charging episodes.

Figure 17 Wattmeters used with the battery chargers to monitor energy consumption and recharge compared to battery capacities.

USING THE CHARGERS

The 7AmpHr battery chargers have various functions. Unless you have swapped in Lead Acid Gel Cells, then you must choose the LiFePO4 option by long-pressing the mode button.

Figure 18 7AmpHr 12.8V battery charger. The Charger is not working correctly unless the Mode mutton has been long-pressed to get the Lithium light to illuminate, and the charge percentage lights in a row at the top have started to illuminate.

TOW HITCH OPTIONS

AgTEM- Wallaby is now always supplied with an extreme articulation and rotation hitch. It is unnecessarily heavy, being rated for 3.5 tonnes, but having extreme articulation is greatly important when driving over contour banks, through dry creeks etc. Other hitch options have lead to breakage in extreme articulation situations – something we commonly manage to encounter in AgTEM surveys.

LIMITED STRESS DECOUPLER

Limited stress de-couplers were used on AgTEM- Wallaby in the past but now we find the new structure generally stalls the towing vehicle instead of requiring decoupling so the de-coupler is no longer added.

When towed behind very heavy, powerful vehicles it may be advantageous to implement AgTEM limited stress de-coupler so that AgTEM is preserved should it be driven into a bridge buttress, metal bore casing, large tree stump or other senseless travel path obstacle during cornering. This can occur in long grass and/or when the operator becomes tired and careless.

The de-coupler will release off a tow ball if forward angular or upward force is too great. Upward force may occur as a 4wd descends off a sharp high drop. Angular force will occur at high ramp-off angles especially during sharp cornering.

The de-coupler should be disabled on public and other trafficked roads. On other occasions it is not most important as tow balls have a lot of angular range and AgTEM is designed to glance off obstacles of most types. In straight line travel the towing vehicle will always bear the impact of collision instead.

WHEELS

AgTEM uses as large diameter wheels as is practical. Metal bead in tyres are not suitable for AgTEM so choice is limited. Large diameter low weight wheels are chosen as they travel more gently over rough terrain.

Two choices are:

- 24 inch glass fibre filled polypropylene jog cart wheels with ‘solid urethane fill’ or ‘self-healing puncture-proof’ tubes and Kevlar bead tyres. The standard undercarriage is designed for these wheels and can also accept 26 inch wheels.
- Urethane balloon wheels. These are a simple low cost alternative to the standard undercarriage. They are an obvious choice for any use of AgTEM in STOL mode. They require only a simple axle and undercarriage as the wheels themselves provide impact absorption. They can be punctured and then repaired using a soldering iron and some skill (see suppliers video). When filled with puncture arresting slime they can function in thorny ground with occasional re-inflation. Urethane balloon wheels also are appropriate for shallow survey as the undercarriage allows AgTEM to site close to the ground such that the two opposite polarity transmitter coils can get a better differential coupling with the near surface ground.

WHEEL PROBLEMS AND MAINTENANCE

If not solid-urethane-filled, the jog cart wheels suffer from slow deflation from thorns such as the tetrahedral cat-head seed. The tube’s self-healing process involves loss of small amounts of air. As the tires must be at around 50 psi to keep them from rolling off on steep side slopes, regular checking and possibly re-inflation may be necessary when travelling over such thorns. Carriage of a stock of spare wheels is recommended. Repair is as per bicycle tires.

The balloon wheels also may puncture and may be filled with puncture filling compound which will slow the deflation process. Repair of these wheels is with a soldering iron. The wheels are great for impact absorption and suspension only at low weights and pressures. They are only designed for low pressure and bearing capacity use. For durable all-purpose application they are only recommended on lightweight AgTEM systems.

Wheel bearings are chosen for robustness, nevertheless seizures are possible and replacements may be necessary after extended use. A similar issue is wear around the axle bolt mountings. A replaceable reinforcing bush may need to be changed to accommodate the wear.

Care should be taken to observe wheels frequently while driving. A poorly inflated tyre will quickly lead to failure and possible jamming/wedging of tyre in the wheel well. Similarly, occasionally a forked bone or stick is flicked up in such a manner that it wedges in the wheel well and locks up the wheel. Prompt observation will avert wheel destruction.

QUICK DEPLOYMENT FLOAT TRAILER

A quick deployment trailer is designed for compact light weight long distance travel. The Wallaby is winched up by its tow hitch along a 7.5m track and rear booms slide, without catching obstacles, into a long tube. The weight of the Wallaby is lifted up skids as it is winched on so no ramps are needed. Spare wheels go in the box provided.

Figure 19 The quick deployment float trailer. The Wallaby is shown at 4.5m drawbar length but the trailer can also accommodate it set at 5m drawbar length.

CONFIGURATION OF AGTEM SYSTEMS

SELECTING TRANSMITTER LOOPS

AgTEM-Wallaby offers many combinations of loop turns and wire cross section area (CSA). The large loop contains 5 cores, each of 4mm CSA There is also a pair of rigid small loops.

Using 5V various amperages up to 50Amps can be fed through the main loop. As turnoff time, which limits shallow exploration if too large, increases with the square of the number of loop turns, it is better to operate with fewer turns and optionally with greater cross section area, which is achieved by doubling or tripling wires in parallel.

Many are the possibilities but most common are:

- 1 wire, 1 turn – for shallowest and resistive terrain survey.

- 2 wires, 1 turn – intermediate depth and resistivity.
- 2 wires, 2 turns – deep exploration.

There are many more combinations. Some are very practical with dual transmitters and are there for forward compatibility with such products. The figure below shows how various loops may be connected in parallel or series at the transmitter. Note that these connections work in conjunction with crossover leads above the side boom pivots. Y-leads allow additional flexibility.

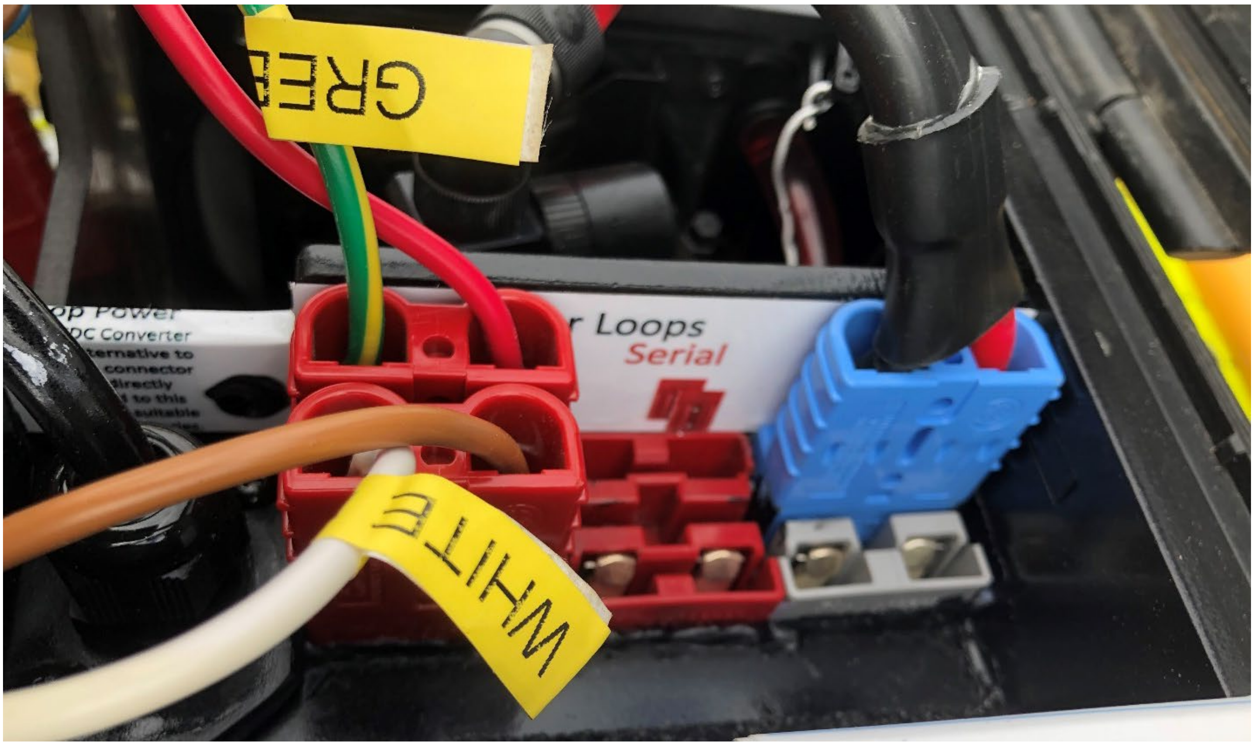


Figure 20 At the transmitter, loop wires can be connected in parallel or in series.

The transmitter and 5V DCDC converter offer **internal resistance of 0.0714 ohms** and each 4mm^2 loop wire in the main **loop has resistance of 0.112 ohms**. The small rigid upper and lower loops each have 2.5mm^2 wire with resistance of 0.061 ohms (**0.122 ohms with the opposing pair combined** in series excluding the internal resistance of the transmitter). The table below shows many options. Various use options can be calculated. The full 5 wires in the main loop are there for when dual transmitters (or a relay switching transmitter loads) are installed in the transmitter case.

Using V=IR, possible combinations are determined. For example:

3 turns at 12.8V with 1 wire per turn gives a current of I=V/R=12.8/(0.0714+3x0.112)=31.4 Amps

2 turns at 12.8V with 1 wire per turn gives a current of I=V/R=12.8/(0.0714+2x0.112)=43.3 Amps

4 turns at 25.4V with 1 wire per turn gives a current of I=V/R=25.6/(0.0714+4X0.112)=49.29 Amps. This may be operated in dual moment with 1 turn at 5.68V with 1 wire per turn which gives a current of I=V/R=5.68/(0.0714+1x0.112)=30.97Amps.

For Wallaroo loop of 27.3m with 4mm^2 wire of resistance 0.139 ohms

1 turn at 5.68V with one 4mm^2 wire per turn gives a current of 5.68/(0.0714+1x0.139)=27.0 Amps

1 turn at 5,68V with two 4mm^2 wires per turn gives a current of 5.68/(0.0714+0.5x0.139)=40.3 Amps

COMPARISON WITH AIRBORNE SYSTEMS

With 4 turns operating at 42 Amps and loop area of 32m^2 the moment is 5400 which is small by airborne system standards but speed across ground also should be considered, thus AgTEM travelling at 6km/hr with this configuration has equivalent moment entering the ground per unit time as an airborne system travelling at 120km/hr with a NIA moment of 108,000 A.m^2 . This can be considered when planning use with 3D modelling of deep conductors as in such cases, with proper survey design and processing, AgTEM may be better than high moment airborne systems at resolving deep targets, especially since shallow interference from fences and other features, including shallow geology, may be far more effectively removed in 3D modelling of smaller footprint data.

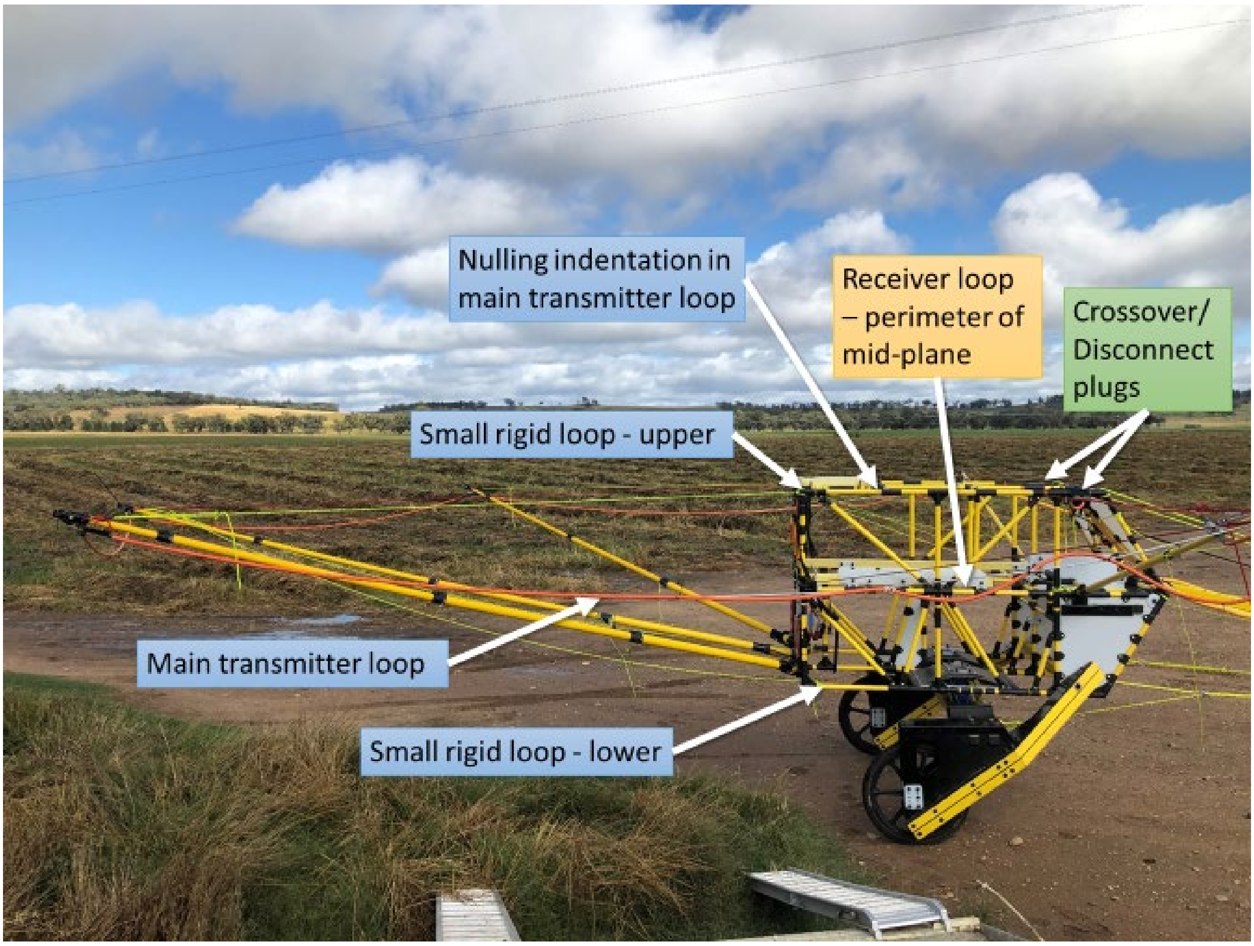
Number of turns	$4mm^2$ wires per turn	Volts	Current (A)	Ramp (uS)	Notes
1	1	5.68	31.0	<7	Shallow and resistive surveys
1	2	5.68	44.6	<10	Mid depth – high power
2	2	5.68	31.3	22	Deep and conductive surveys
4	1	24	42	110	Very deep imaging (NIA = $5400Am^2$)
Opposing	1 @ $2.5mm^2$	5.68	29.3	<4	Shallowest & metal detection
small rigid	1 @ $2.5mm^2$	5.68	42	<2	Shallow & metal detection using lower rigid loop and low receiver gain
4	1	5.68	9.85	26	Never recommended (0.57 ohms)
4	1	12.18	21.5	56	Never recommended
2	1	5.68	18.2	14	Never recommended
1	3	5.68	>50	n.a.	Cannot use 5V: >50Amp limit
5	1	24	38	>130	Better to use 4 turns unless using Meanwell SD1000L-24 at capacity.
2	1	12.8	43.3	?	Using one 12.8V battery directly
3	2,2,1	12.8	43.3	?	Using one 12.8V battery directly or 36V to 12V DCDC converter PLUS one Y-adaptor
Combinations					With dual transmitters, combinations are possible – eg. 2 turns using 2 wires per turn and 1 turn using 1 wire.

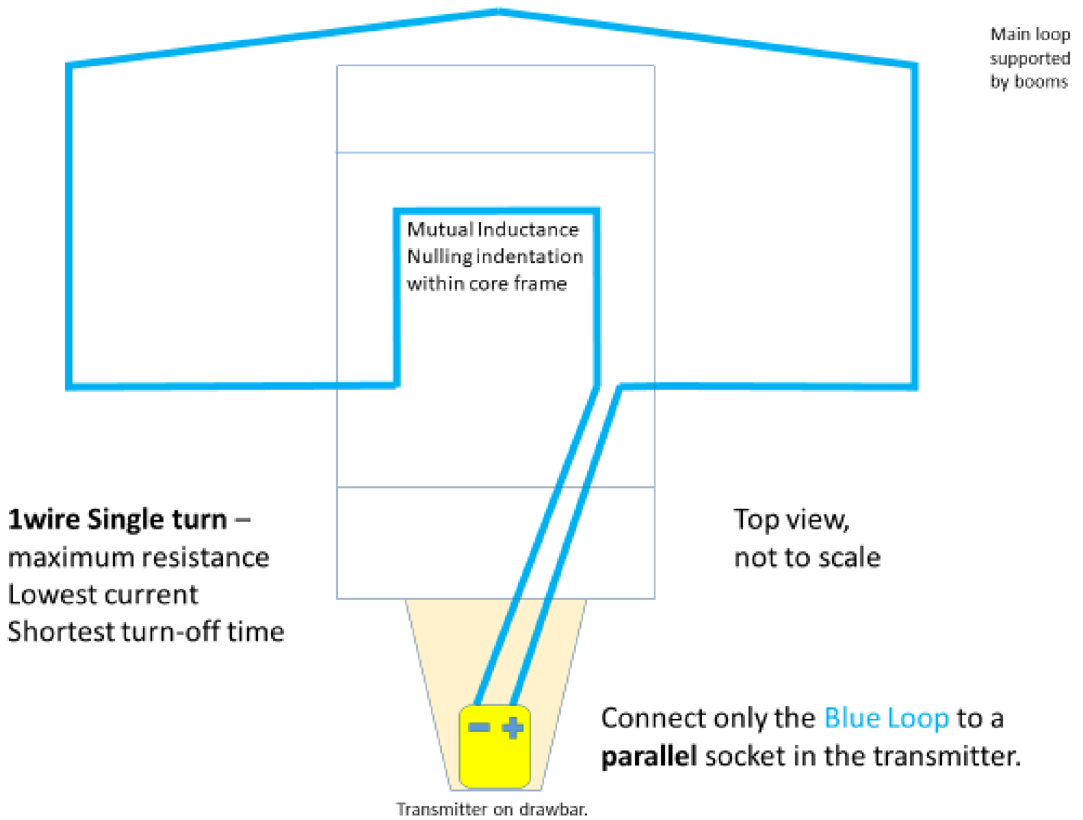
CURRENT LIMITS AND WIRE HEATING

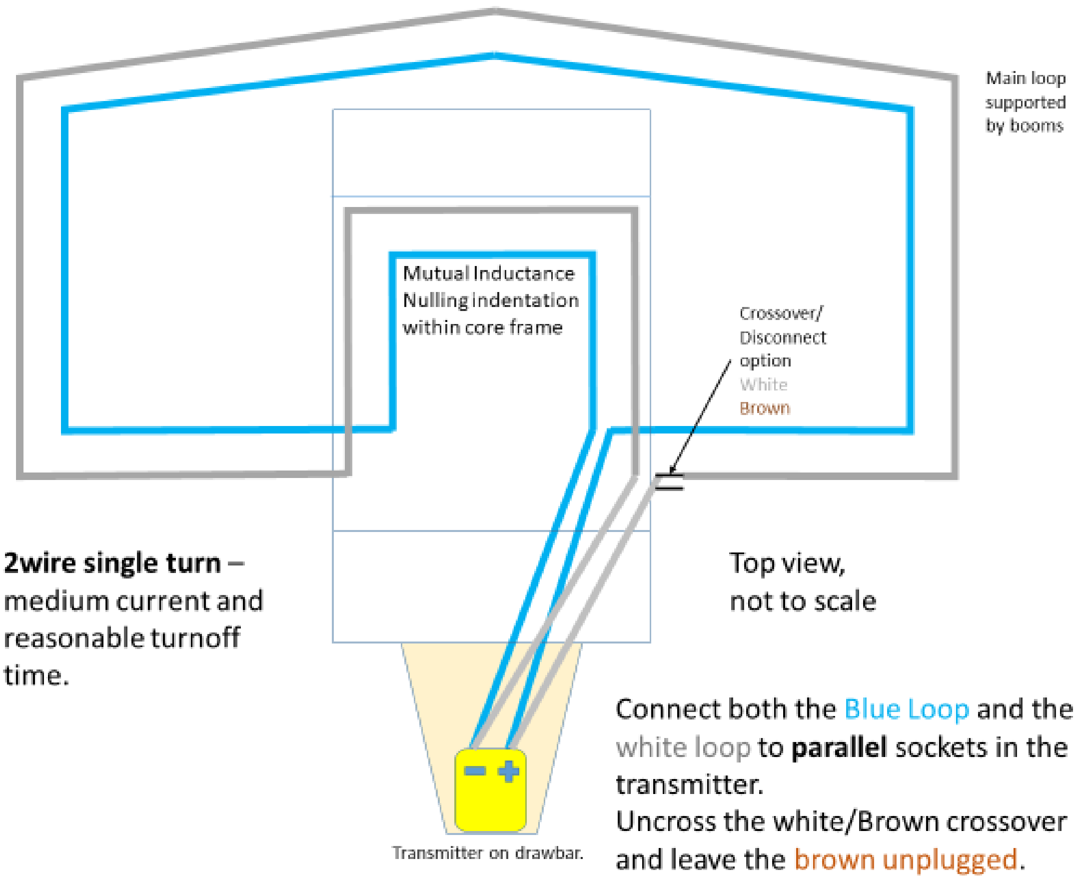
Wires are of $4mm^2$ wire. With 50% duty cycle loading these wires are capable of withstanding 50 Amps without melting. Insulation will get warm. Connectors are rated at 50 Amps per wire or greater. Wires and wire combinations have been carefully selected to balance requirements of heat dissipation, need to exactly match driving voltage with load, need to keep wire robust, need to minimize driving voltage for efficiency, and need to keep wire as light as practical as any increase in wire weight is multiplied greatly in required increase in weight of structural support. For 1 and 2 wire configurations, a lighter weight replacement loop can be fitted for more efficient survey and wear and tear minimization.

LOOP LAYOUTS AND CONNECTIONS

A Photo & diagrams below present how to connect various loops wires and turns to the transmitter.



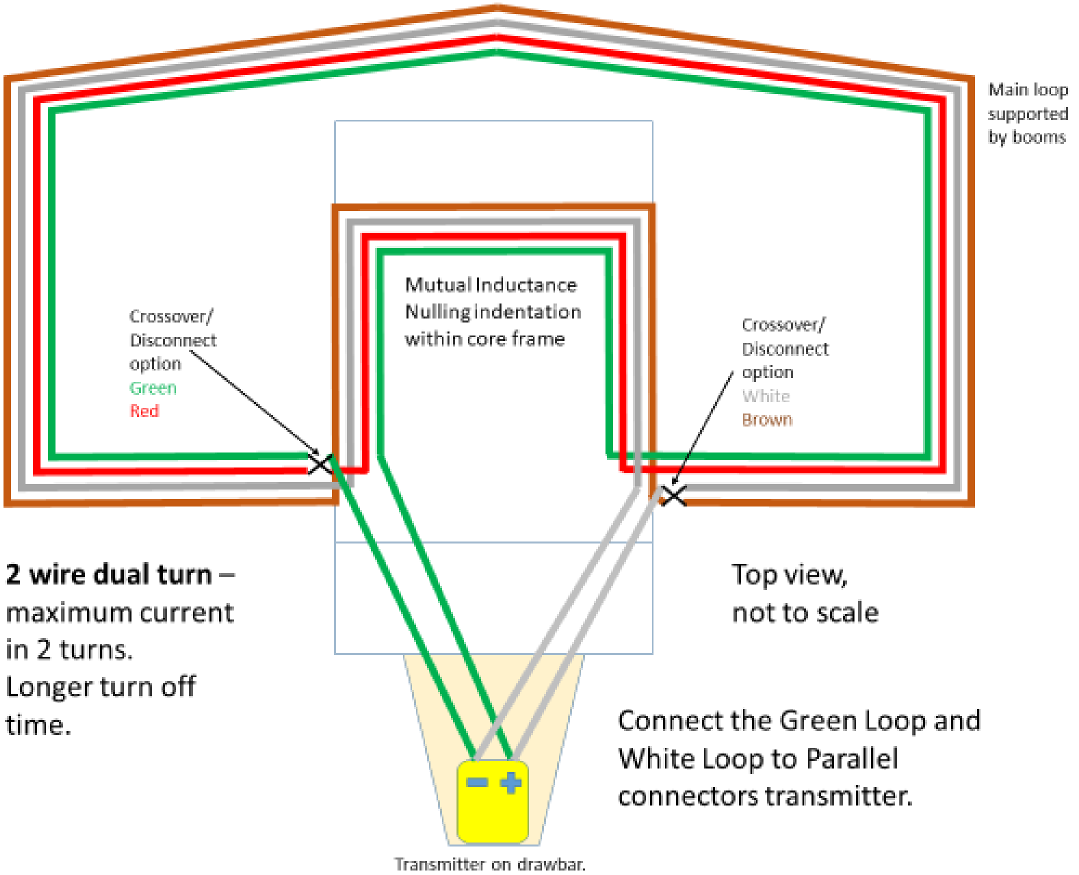

Main loop
supported
by booms
Mutual Inductance
Nulling indentation
within core frame
1wire Single turn –
maximum resistance
Lowest current
Shortest turn-off time
Top view,
not to scale
Connect only the Blue Loop to a
parallel socket in the transmitter.
Transmitter on drawbar.

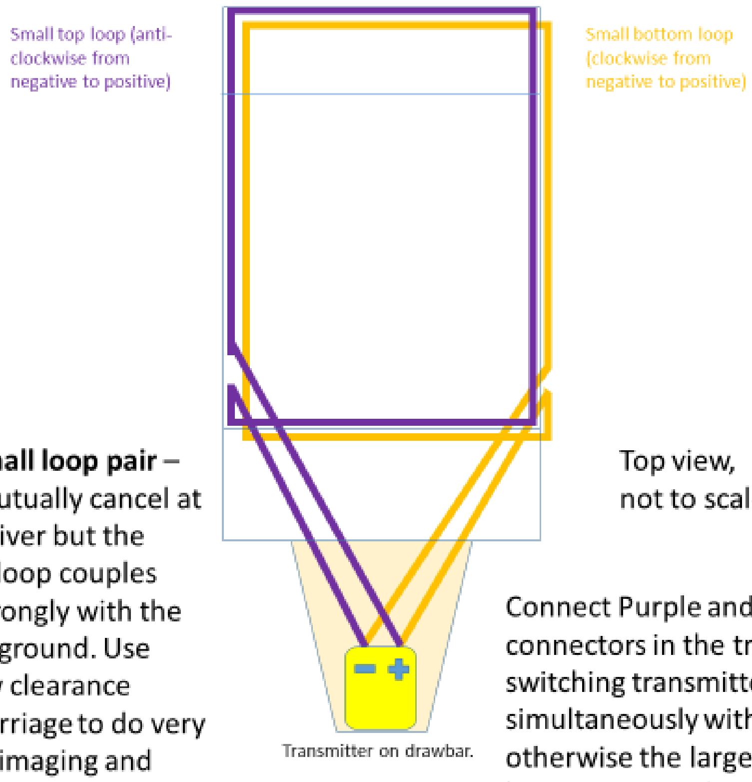


2wire single turn – medium current and reasonable turnoff time.

Top view, not to scale

Connect both the Blue Loop and the white loop to **parallel** sockets in the transmitter.
Uncross the white/Brown crossover and leave the brown unplugged.

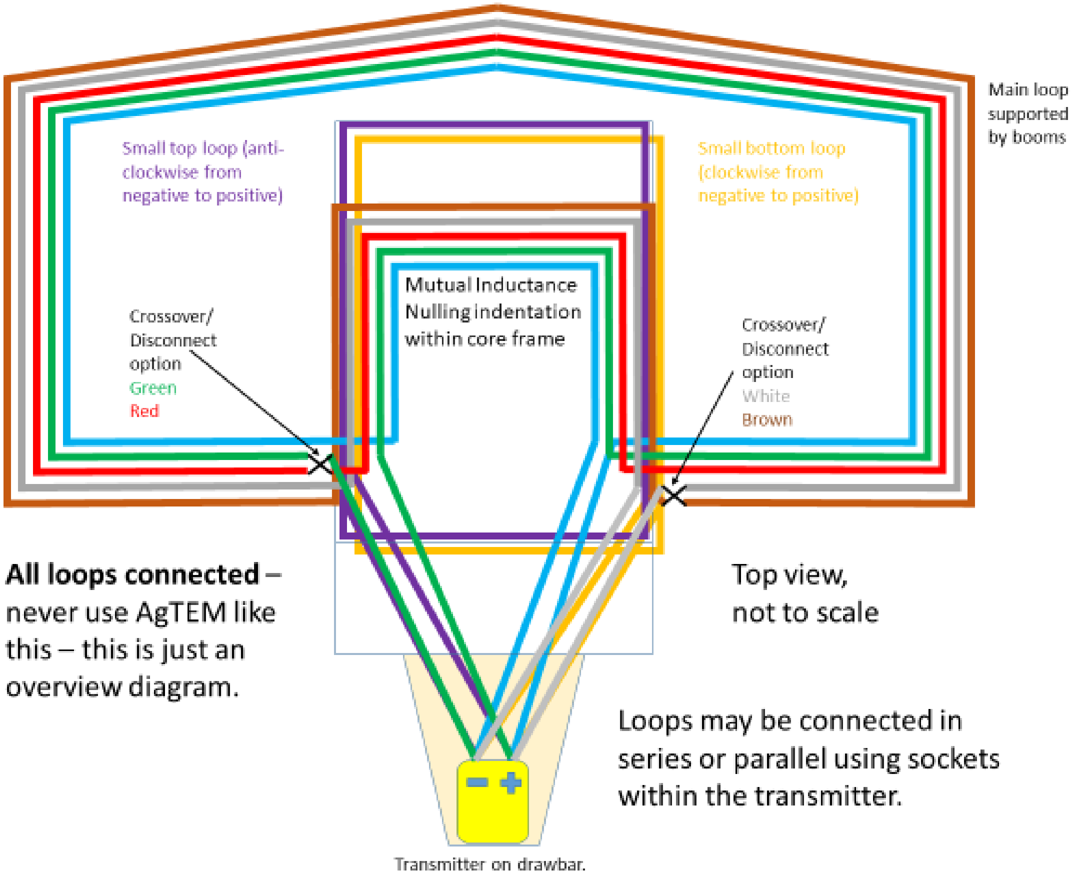

Main loop
supported
by booms
Mutual Inductance
Nulling indentation
within core frame
Crossover/
Disconnect
option
Green
Red
Crossover/
Disconnect
option
White
Brown
2 wire dual turn –
maximum current
in 2 turns.
Longer turn off
time.
Top view,
not to scale
Connect the Green Loop and
White Loop to Parallel
connectors transmitter.
Transmitter on drawbar.

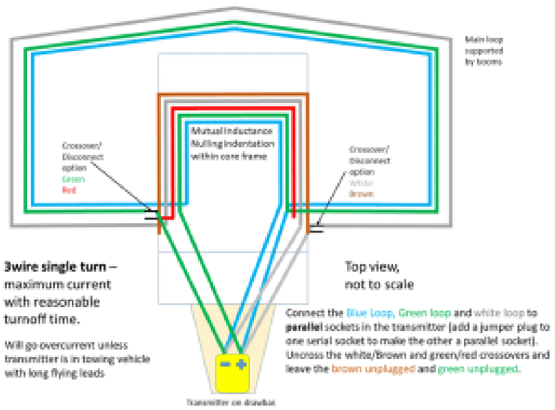


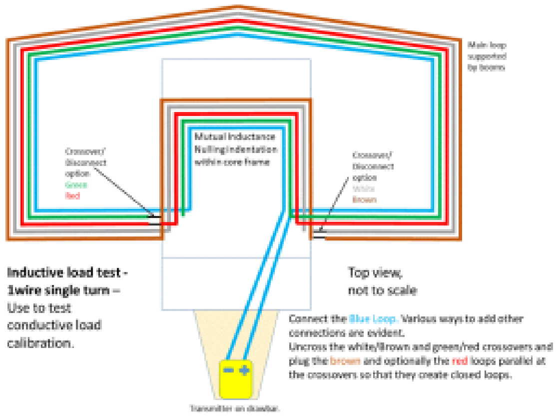
Rigid small loop pair – these mutually cancel at the receiver but the bottom loop couples more strongly with the shallow ground. Use with low clearance undercarriage to do very shallow imaging and UXO investigation.

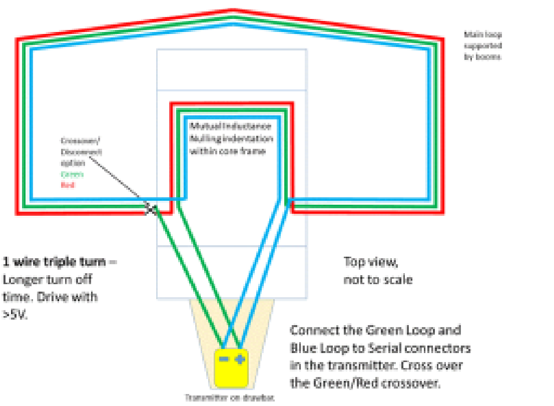
Top view, not to scale

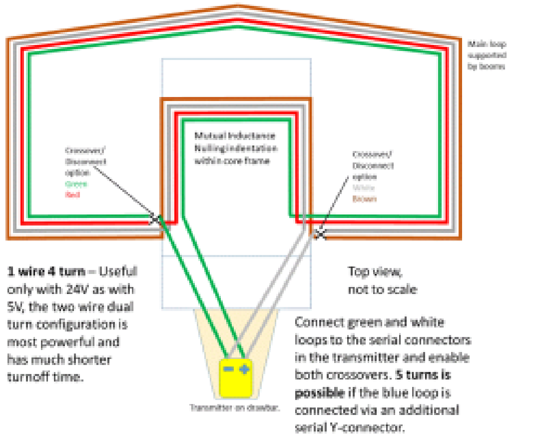
Connect Purple and Orange loops to serial connectors in the transmitter. In a dual or switching transmitter these may be used simultaneously with the large loop otherwise the large loop and booms may be removed in this mode of operation.


Main loop supported by booms
Small top loop (anti-clockwise from negative to positive)
Small bottom loop (clockwise from negative to positive)
Mutual Inductance Nulling indentation within core frame
Crossover/ Disconnect option Green Red
Crossover/ Disconnect option White Brown
All loops connected – never use AgTEM like this – this is just an overview diagram.
Top view, not to scale
Loops may be connected in series or parallel using sockets within the transmitter.
Transmitter on drawbar.









TRANSMITTER LOOP DAMPING

The transmitter has internal damping resistors, and when connected almost directly to the transmitter loop without long flying leads the internal damping resistors are effective. Alternatively damping resistors can be added across the Anderson connectors at the end of flying leads.

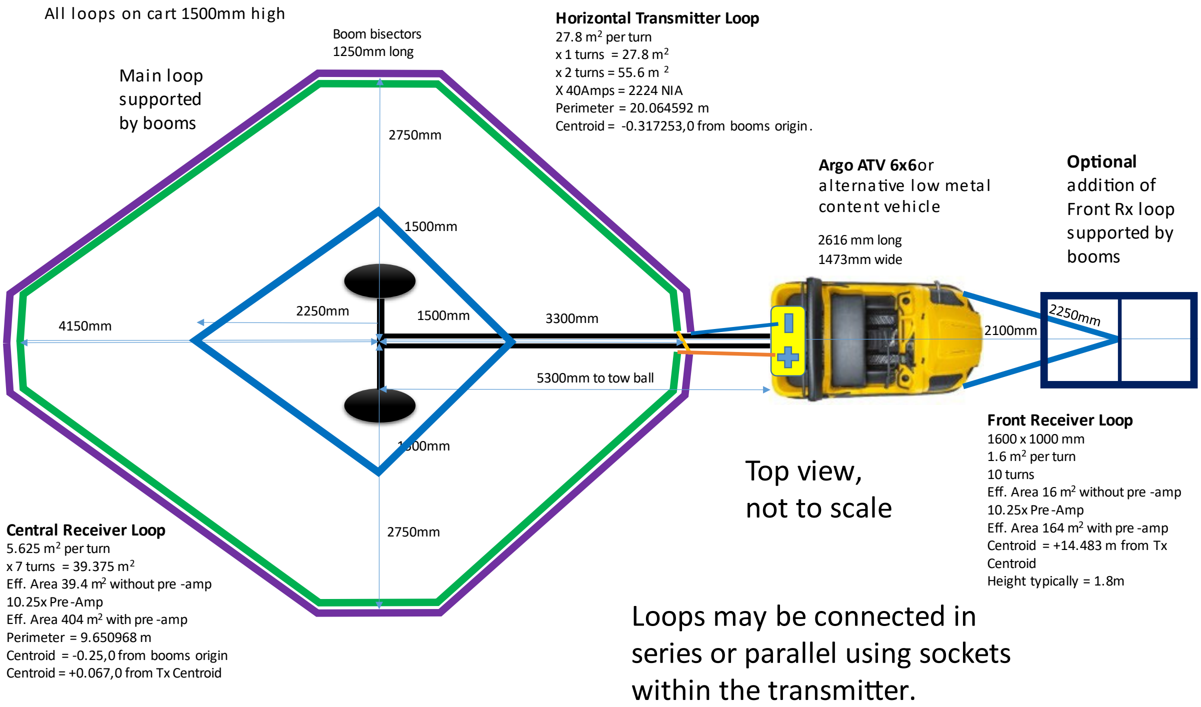
Damping of 150 ohms is recommended but 330 ohms is sufficient and system responses for such damping with various options have been recorded. Switching through the various damping options and measuring for each, AT A RESISTIVE SITE and with low receiver loop turns and damping, will give the user a good indication of the impact on system response. Too much damping affects shallow resolution and too little leaves overshoots, oscillations and a very confusing signal.

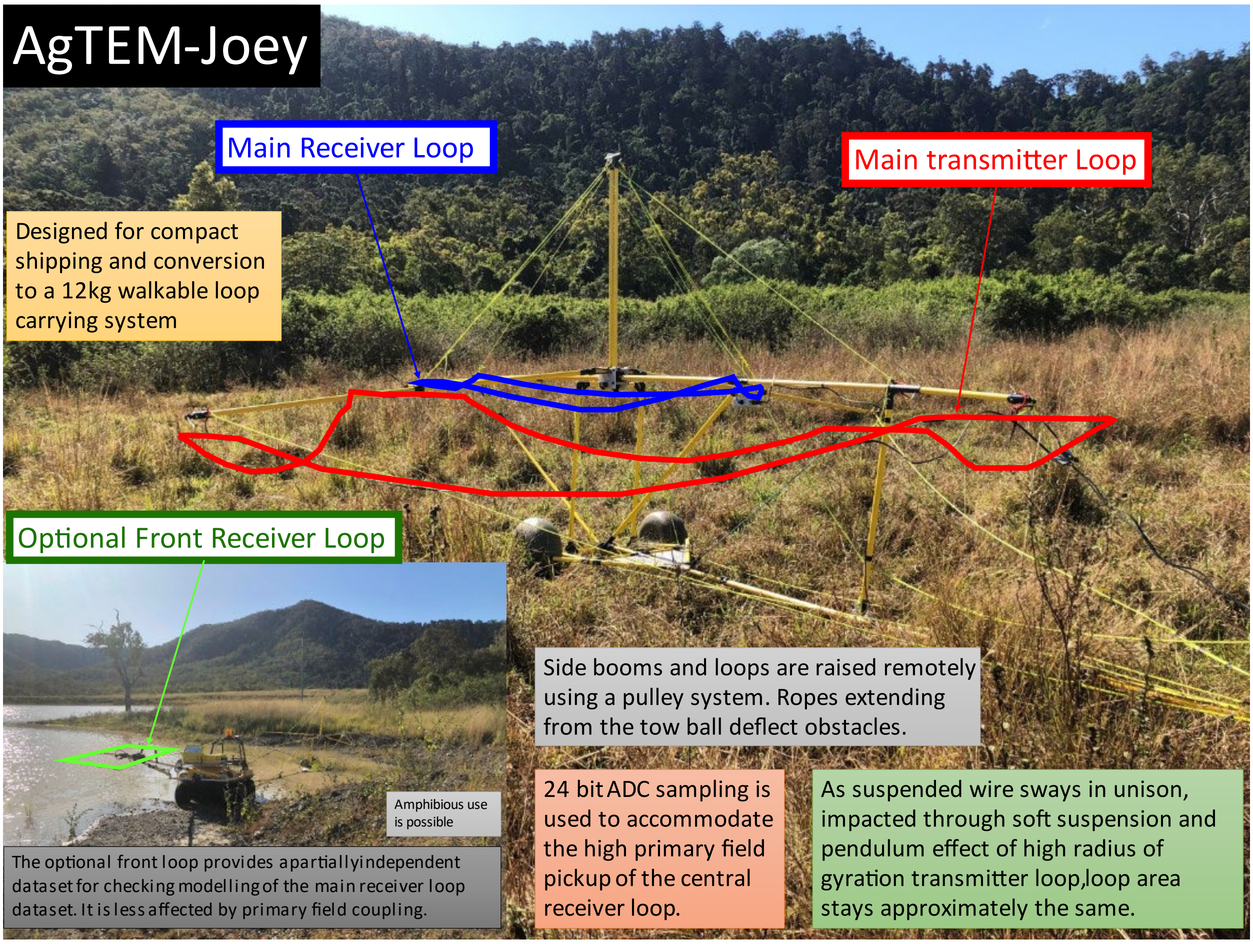
AgTEM.exe ‘Parameters’ tab allows selection of a transmitter. If this is pressed then, after a few seconds pause, options for transmitter parameter variation can be selected. A drop down list allows selection of between 4kOhm and 330 ohm damping of the transmitter loop using a set of resistors within the transmitter. Further damping can be applied externally if desired – typically soldering resistors across Anderson connector pins. Beware that back-EMF may blow ¼ watt or ½ watt resistors.

WALLAROO LOOPS

The loops on Wallaby (AKA Joey) are as per the following diagram

Joey with front loop





SELECTING A TRANSMITTER LOOP POWER SOURCE

As of January 2025, newer versions of AgTEM-electronics have a 3.3V to 18V variable regulated output providing much greater power management flexibility, eliminating need for power resistors completely. Furthermore, the new electronics also has a filtered 24V supply coming off the loop power batteries so one supply is used for all requirements. The following relates mainly to the older electronics.

Figure 21 The new AgTEM electronics released by January 2025 has 3.3V to 18V variable loop power and air cooling internally so much of the old power management configuration is no longer required. An interim model in the USA in 2024 still with water cooling and in the old larger 6000 series case required adjustment of the variable voltage via a potentiometer. The new electronics is backpackable and one power supply can drive all parts due to extra filter circuits.

Under most circumstances a 24V to 5V DCDC converter is used as the direct transmitter power source. Recommended power for this DCDC converter is either four 7AHr 12.8V LiFePO4 batteries or two larger 12.8V LiFePO4 batteries. Up to twenty of the smaller LiFePO4 batteries can be carried in luggage on most aircraft. Depending on transmission options expect to use up to three sets of four 7AHr batteries in a day. Six 7AHr batteries fit, at one time, into the transmitter case and these can be paired to provide 3 x parallel sources of 25.6V to both the DCDC converter and the transmitter electronics.

If an alternative loop input voltage is desired, then one pair of 7AHr or smaller 12.8V batteries must be used to drive the transmitter control electronics.

If the transmitter has not got an MG212 board then one set must be dedicated to the electronics even when 24V is also used to feed the DCDC converter. The pair of batteries will last two days. The MG210 board alone cannot handle voltages varying significantly from 24V. (Remove this message if MG212 becomes the default).

Loop power sources are compared in the following table:

Batteries	DCDC converter	Where batteries are stored	When to use
One to three sets of six 12.8V 7AHr LiFePO4 with integrated BMS	Default 19-36V to 5V 57Amp	Six in the transmitter case at any one time or all in towing vehicle.	AgTEM Wallaby & Wallaroo surveys where mobilization is by air.
Two 12.8V, 18 to 100 AHr LiFePO4 with BMS	Default 19-36V to 5V 57Amp	In the towing vehicle	AgTEM Wallaby surveys mobilized by road.
Batteries of opportunity giving 24V	Default 19-36V to 5V 57Amp	In the towing vehicle	AgTEM Wallaby surveys where batteries are procured locally.
Two 3.3V 100AHr LiFePO4 cells with BMS in series	None	Transmitter case (backpack)	AgTEM Wallaroo surveys mobilized by road. This is by far the lightest Wallaroo option for full day operation as the DCDC converter can be removed and its 70% efficiency cost is eliminated. Battery protection is needed. Slight system response drift will occur.
Three or more 12.8V 18 to 100AHr LiFePO4 with BMS in series	Meanwell SD1000L-24	In towing vehicle	AgTEM Wallaby driving higher current through 5 loop turns for maximum penetration
One 12.8V battery (>50Amp capacity) and BMS	None	In towing vehicle	Using batteries of opportunity procured locally, transmitting 43 Amps through 2 turns of AgTEM Wallaby this is less efficient than using the DCDC converter and 2 turns x 2 wires per turn.

DCDC CONVERTERS

The Meanwell 19 to 36V input to 5V output 57 Amp DCDC converter is installed within the water cooling circuit in the sealed section of the transmitter as it is most useful for all applications involving batteries than can safely and legally be carried when mobilizing by air. Such batteries tend to have power limiting battery management systems integrated within and use the DCDC converter to keep their output amperages within BMS limits. When used on the Wallaby with external batteries it means that supply leads do not need to be of very thick gauge.

This Meanwell SD-350B DCDC converter can also be positioned, using appropriate fixing plates, over the connector space in the Transmitter case. Such fixing allows optional installation but does not seal dust from the converter. The alternative Meanwell SD-1000L-12 or SD-1000L-24 DCDC converters can be positioned similarly – efforts to design the case to fit them have been made in advance.

The 24V to 5V DCDC converter specifications are given below:

350W Single Output DC-DC Converter **SD-350 series**

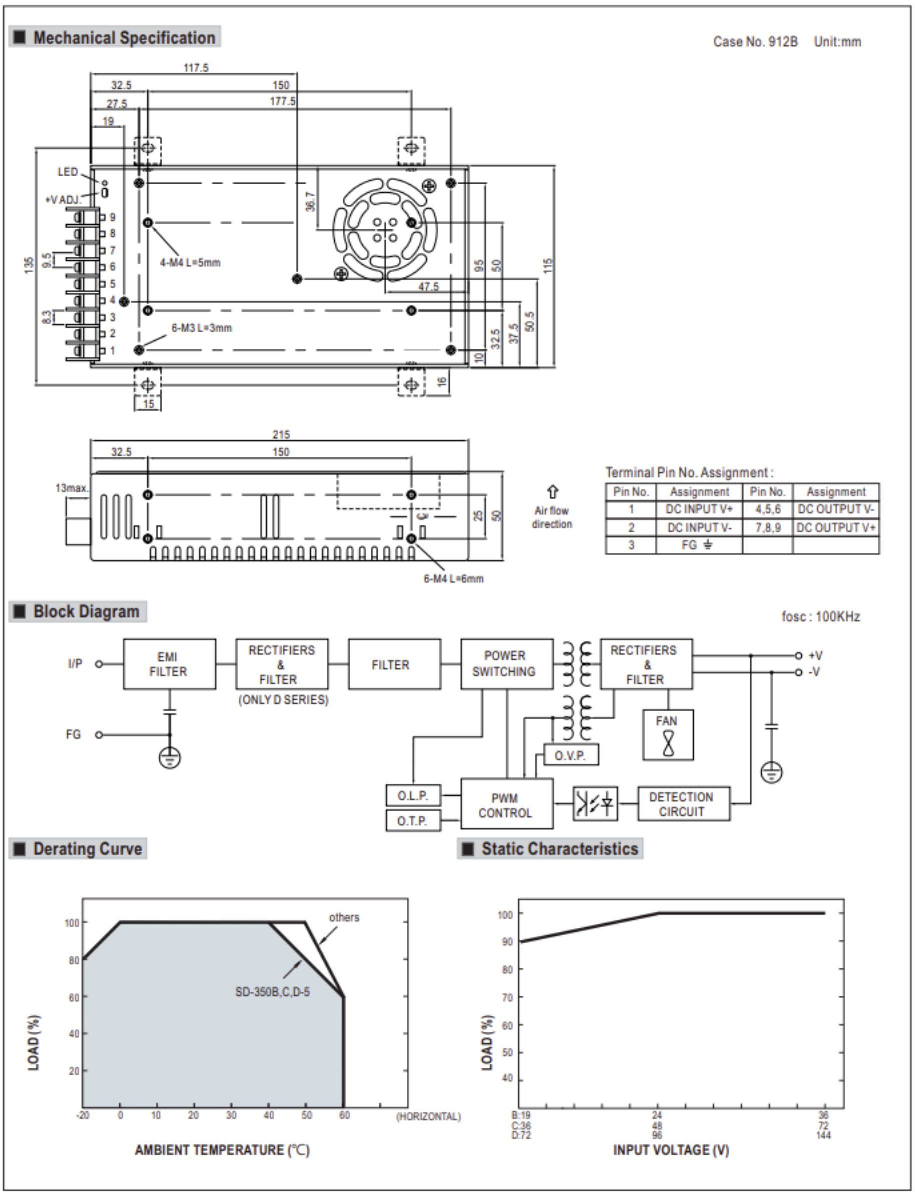
■ Features :

- 2:1 wide input range
- Protections: Short circuit / Overload / Over voltage / Over temperature
- 1500VAC I/O isolation
- Forced air cooling by built-in DC Fan
- 100% full load burn-in test
- 24V and 48V input voltage design refer to LVD
- 2 years warranty

EN62368-1 CB (for D type only) IEC62368-1 TPTC004

SPECIFICATION

MODEL		SD-350B				SD-350C			
OUTPUT	DC VOLTAGE	5V	12V	24V	48V	5V	12V	24V	48V
	RATED CURRENT	57A	27.5A	14.6A	7.3A	60A	27.5A	14.6A	7.3A
	CURRENT RANGE	0 ~ 57A	0 ~ 27.5A	0 ~ 14.6A	0 ~ 7.3A	0 ~ 60A	0 ~ 27.5A	0 ~ 14.6A	0 ~ 7.3A
	RATED POWER	285W	330W	350.4W	350.4W	300W	330W	350.4W	350.4W
	RIPPLE & NOISE (max.) Note.2	100mVp-p	120mVp-p	150mVp-p	200mVp-p	100mVp-p	120mVp-p	150mVp-p	200mVp-p
	VOLTAGE ADJ. RANGE	4.5 ~ 5.5VDC	11 ~ 16VDC	23 ~ 30VDC	43 ~ 53VDC	4.5 ~ 5.5VDC	11 ~ 16VDC	23 ~ 30VDC	43 ~ 53VDC
	VOLTAGE TOLERANCE Note.3	±2.0%	±1.0%	±1.0%	±1.0%	±2.0%	±1.0%	±1.0%	±1.0%
	LINE REGULATION	±0.5%	±0.3%	±0.2%	±0.2%	±0.5%	±0.3%	±0.2%	±0.2%
	LOAD REGULATION	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%
	SETUP, RISE TIME	300ms, 50ms at full load							
INPUT	VOLTAGE RANGE	B:19 ~ 36VDC C:36 ~ 72VDC D:72 ~144VDC							
	EFFICIENCY (Typ.)	74%	80%	80%	84%	76%	81%	81%	82%
	DC CURRENT (Typ.)	14.4A/24V	16A/24V	17.6A/24V	17.6A/24V	7.6A/48V	8.8A/48V	9.0A/48V	9.0A/48V
	INRUSH CURRENT (Typ.)	C:45A/48VDC D:45A/96VDC							
PROTECTION	OVERLOAD	105 ~ 135% rated output power							
		Protection type : Shut down o/p voltage, re-power on to recover							
	OVER VOLTAGE	5.75 ~ 6.75V	16.8 ~ 20V	31.5 ~ 37.5V	53 ~ 65V	5.75 ~ 6.75V	16.8 ~ 20V	31.5 ~ 37.5V	53 ~ 65V
		Protection type : Shut down o/p voltage, re-power on to recover							
	OVER TEMPERATURE	Shut down o/p voltage, recovers automatically after temperature goes down							
ENVIRONMENT	WORKING TEMP.	-20 ~ +60℃ (Refer to "Derating Curve")							
	WORKING HUMIDITY	20 ~ 90% RH non-condensing							
	STORAGE TEMP., HUMIDITY	-40 ~ +85℃, 10 ~ 95% RH							
	TEMP. COEFFICIENT	±0.03%/℃ (0 ~ 50℃)							
	VIBRATION	10 ~ 500Hz, 2G 10min./1cycle, 60min. each along X, Y, Z axes							
SAFETY & EMC (Note 4)	SAFETY STANDARDS	IEC62368-1 CB approved by TUV (for D type only), EAC TP TC 004 approved							
	WITHSTAND VOLTAGE	I/P-O/P:1.5KVAC I/P-FG:2KVAC O/P-FG:0.5KVAC							
	ISOLATION RESISTANCE	I/P-O/P, I/P-FG, O/P-FG:100M Ohms / 500VDC / 25℃/ 70% RH							
	EMC EMISSION	Compliance to EN55032 (CISPR32) Class B, EAC TP TC 020							
	EMC IMMUNITY	Compliance to EN61000-4-2,3,4,6,8, light industry level, criteria A, EAC TP TC 020							
OTHERS	MTBF	209.4K hrs min. MIL-HDBK-217F (25℃)							
	DIMENSION	215*115*50mm (L*W*H)							
	PACKING	1.1Kg; 12pcs/14.4Kg/0.92CUFT							
NOTE	1. All parameters NOT specially mentioned are measured at 24,48,96VDC input, rated load and 25℃ of ambient temperature. 2. Ripple & noise are measured at 20MHz of bandwidth by using a 12" twisted pair-wire terminated with a 0.1uf & 47uf parallel capacitor. 3. Tolerance : includes set up tolerance, line regulation and load regulation. 4. The power supply is considered a component which will be installed into a final equipment. All the EMC tests are been executed by mounting the unit on a 360mm*360mm metal plate with 1mm of thickness. The final equipment must be re-confirmed that it still meets EMC directives. For guidance on how to perform these EMC tests, please refer to "EMI testing of component power supplies." (as available on http://www.meanwell.com) 5. The ambient temperature derating of 3.5℃/1000m with fanless models and of 5℃/1000m with fan models for operating altitude higher than 2000m(6500ft)								



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The alternative of a 19 to 72V to 12V DCDC converter is presented below. This can fit into the Transmitter case with a kit of ventilation directing panels but compromises some battery space. For all presently anticipated cases it seems that the 24V to 5V DCDC converter is the best option but in order to drive four or five loop turns use this DCDC converter. Note its derating at less than 48V.

MEAN WELL 1000W Single Output DC-DC Converter **SD-1000 series**

■ Features :
- 1U low profile 41mm
- High power density 10.7w/inch³
- 2000VAC I/O Isolation
- Protections: Short circuit / Overload / Over voltage / Over temperature
- Output OK signal
- Built-in remote ON-OFF control
- Built-in remote sense function
- Forced air cooling by built-in DC fan with fan speed control
- 12V, 0.25A auxiliary output
- 3 years warranty

TPTC004 IEC62368-1

SPECIFICATION

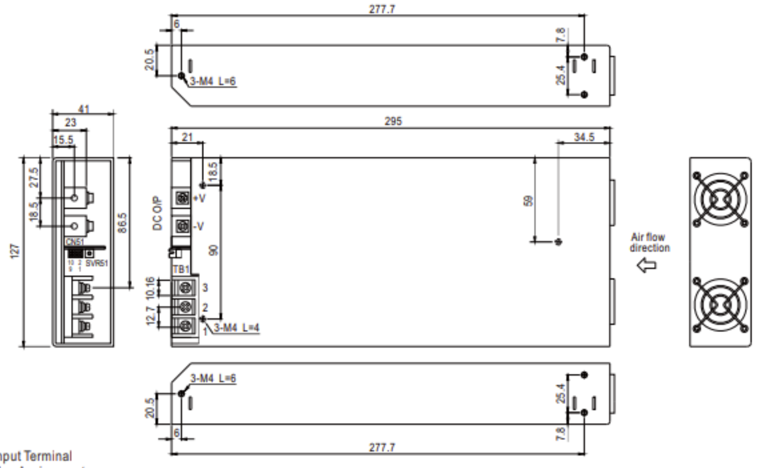
MODEL		SD-1000L-12	SD-1000L-24	SD-1000L-48	SD-1000H-12	SD-1000H-24	SD-1000H-48
OUTPUT	DC VOLTAGE	12V	24V	48V	12V	24V	48V
	RATED CURRENT	60A	40A	21A	60A	40A	21A
	CURRENT RANGE	0 ~ 60A	0 ~ 40A	0 ~ 21A	0 ~ 60A	0 ~ 40A	0 ~ 21A
	RATED POWER	720W	960W	1008W	720W	960W	1008W
	RIPPLE & NOISE (max.) Note.2	150mVp-p	150mVp-p	150mVp-p	150mVp-p	150mVp-p	150mVp-p
	VOLTAGE ADJ. RANGE	11 ~ 15V	23 ~ 30V	46 ~ 60V	11 ~ 15V	23 ~ 30V	46 ~ 60V
	VOLTAGE TOLERANCE Note.3	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%
	LINE REGULATION	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%
	LOAD REGULATION	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%
	SETUP, RISE TIME	500ms, 50ms at full load					
INPUT	VOLTAGE RANGE Note.5	19 ~ 72VDC			72 ~ 144VDC		
	EFFICIENCY (Typ.)	84%	88%	90%	85%	89%	92%
	DC CURRENT (Typ.)	23.5A/48VDC			11.6A/96VDC		
	INRUSH CURRENT (Typ.)	-----			100A/96VDC		
PROTECTION	OVERLOAD	105 ~ 125% rated output power					
		Protection type : Constant current limiting, unit will shut down o/p voltage after about 5sec. Re-power on to recover					
	OVER VOLTAGE	16 ~ 19V	30.8 ~ 35.2V	62 ~ 68V	16 ~ 19V	30.8 ~ 35.2V	62 ~ 68V
		Protection type : Shut down o/p voltage, re-power on to recover					
	OVER TEMPERATURE	Shut down o/p voltage, recovers automatically after temperature goes down					
FUNCTION	REMOTE ON/OFF CONTROL	Please refer to function manual					
	OUTPUT OK SIGNAL	Open collector signal low when PSU turns on, maximum, sink current :10mA					
ENVIRONMENT	WORKING TEMP.	-20 ~ +60℃ (Refer to "Derating Curve")					
	WORKING HUMIDITY	20 ~ 90% RH non-condensing					
	STORAGE TEMP., HUMIDITY	-40 ~ +85℃, 10 ~ 95% RH non-condensing					
	TEMP. COEFFICIENT	±0.02%/℃ (0 ~ 50℃)					
	VIBRATION	10 ~ 500Hz, 2G 10min./1cycle, 60min. each along X, Y, Z axes					
SAFETY & EMC (Note 4)	SAFETY STANDARDS	IEC62368-1 CB approved by TUV, AS/NZS62368.1, EAC TP TC 004 approved					
	WITHSTAND VOLTAGE	I/P-O/P:2KVAC I/P-FG:2KVAC O/P-FG:0.5KVAC					
	ISOLATION RESISTANCE	I/P-O/P, I/P-FG, O/P-FG:100M Ohms / 500VDC / 25℃/ 70% RH					
	EMC EMISSION	Compliance to EN55032 (CISPR32), EAC TP TC 020					
	EMC IMMUNITY	Compliance to EN61000-4-2,3,4,6,8, light industry level, criteria A, EAC TP TC 020					
OTHERS	MTBF	106.7K hrs min. MIL-HDBK-217F (25℃)					
	DIMENSION	295*127*41mm (L*W*H)					
	PACKING	1.94Kg; 6pcs/12.6Kg/1.15CUFT					

NOTE
1. All parameters NOT specially mentioned are measured at 48, 96VDC input, rated load and 25℃ of ambient temperature.
2. Ripple & noise are measured at 20MHz of bandwidth by using a 12" twisted pair-wire terminated with a 0.1uf & 47uf parallel capacitor.
3. Tolerance : includes set up tolerance, line regulation and load regulation.
4. The power supply is considered a component which will be installed into a final equipment. All the EMC tests are been executed by mounting the unit on a 720mm*360mm metal plate with 1mm of thickness. The final equipment must be re-confirmed that it still meets EMC directives. For guidance on how to perform these EMC tests, please refer to "EMI testing of component power supplies." (as available on http://www.meanwell.com)
5. Derating may be needed under low input voltages. Please check the derating curve for more details.
6. The ambient temperature derating of 3.5℃/1000m with fanless models and of 5℃/1000m with fan models for operating altitude higher than 2000m(6500ft).

※ Product Liability Disclaimer : For detailed information, please refer to https://www.meanwell.com/serviceDisclaimer.aspx

Mechanical Specification

Case No. 952B Unit:mm



DC Input Terminal Pin No. Assignment

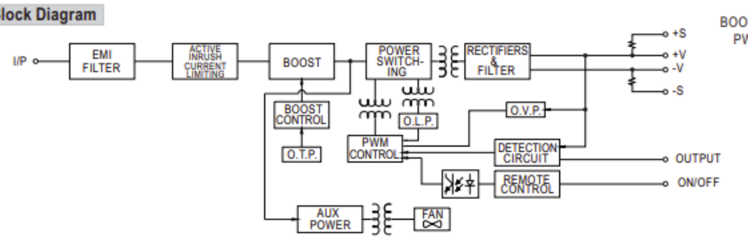
Pin No.	Assignment
1	DC INPUT V+
2	DC INPUT V-
3	FG ⏚

Control pin number assignment (CN51) : HRS DF11-10DP-2DS or equivalent

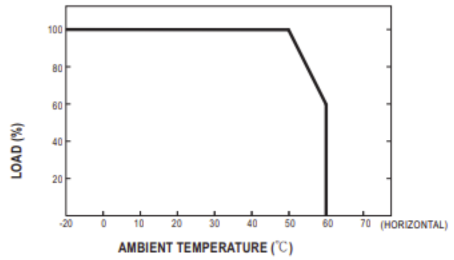
Pin No.	Assignment	Pin No.	Assignment	Pin No.	Assignment	Mating Housing	Terminal
1	+S	5	AUX	9	RCG	HRS DF11-10DS or equivalent	JST SPHD-002T-P0.5 or equivalent
2	-S	6	AUXG	10	NC		
3	OUTPUT OK	7	RC1				
4	GND	8	RC2				

Block Diagram

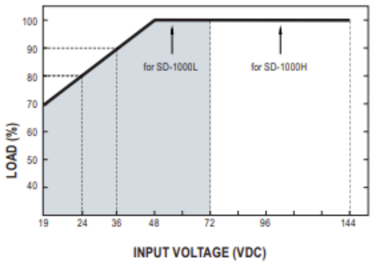
BOOST fosc : 70KHz
PWM fosc : 90KHz



Derating Curve



Static Characteristics



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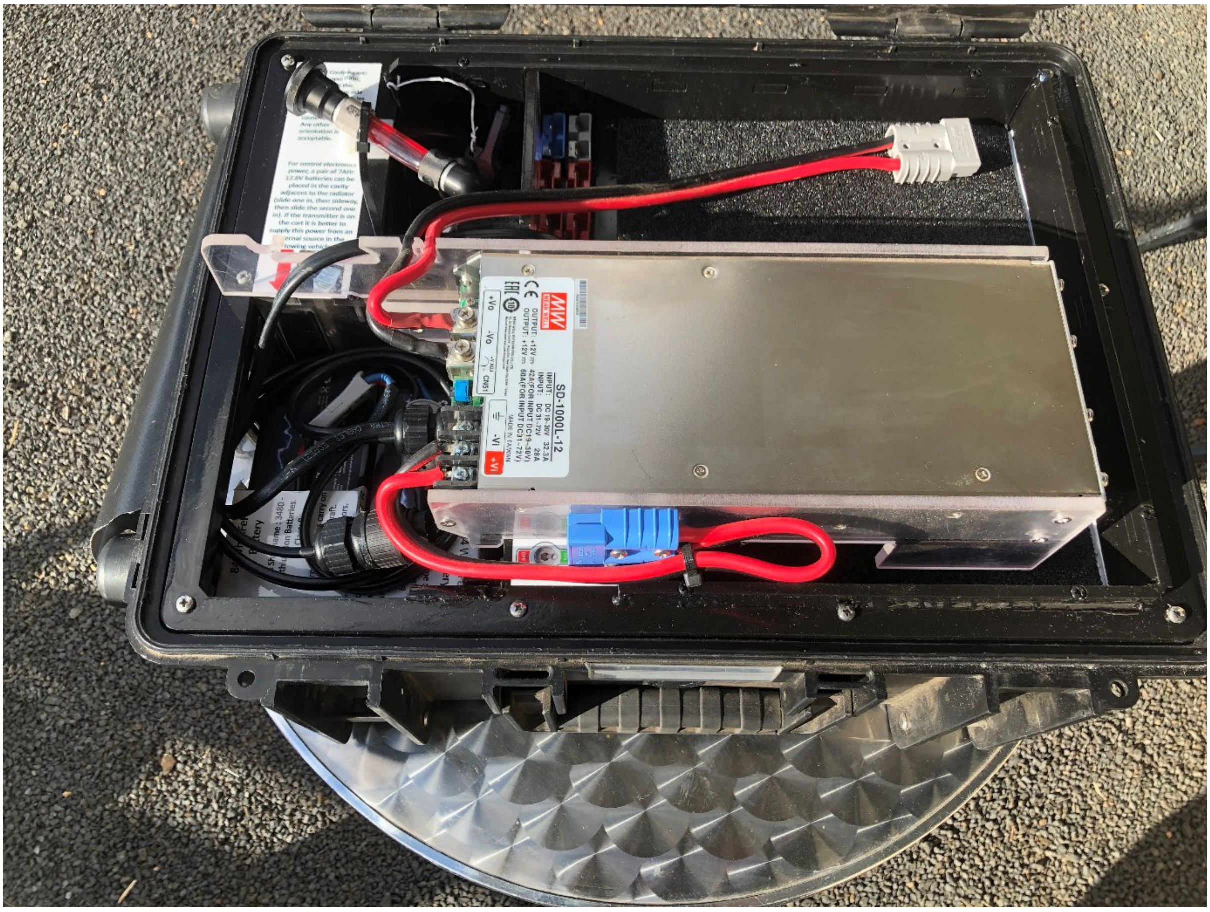


Figure 22 The SD-1000 19-72V to 12V converter is an optional removable item that is placed temporarily in the top of the transmitter with structure attached that directs airflow to ensure cooling occurs. As of January 2025 this design is superceded by an air cooled design not requiring the Meanwell DCDC converter. There is also a water cooled version in the USA not yet converted fully, that internally has a 3.3 to 18V DCDC output from 19 to 32V input.

SELECTING RECEIVER LOOPS, DAMPING, AND AMPLIFICATION

In AgTEM-Wallaby the main receiver loop is in the perimeter of the mid-plane of the core of the cart. A small black box on the front corner contains a pre-amplifier, connectors, switch-in damping resistors, and switch-in loop turns. Signal is amplified about 10x by this pre-amplifier, which has a related purpose of adjusting input impedance for effective transmission down the long shielded cable to the in-receiver amplifier. It has considerable effect, reducing impact of systematic signals created, at least partly, in the shielded cable. Random noise also is reduced by the pre-amplifier but random noise can alternatively be largely minimized by increased amplification in the receiver.

DEEP OR SHALLOW?

The receiver loop has 20 turns, 10 of which can be switched in or out of service.

If imaging deeply in conductive terrain then you may switch in the additional 10 turns to give 20 turns in series rather than leaving ten open circuit. The additional turns will considerably draw out receiver loop self-response so that early time ground signals are mixed with receiver loop self-response.

USE ONLY TEN TURNS UNLESS YOU KNOW WHAT YOU ARE DOING.

The receiver loop connection board prototype has damping resistors of 220 ohms and 330 ohms on it along with switches for invoking each. It also has a switch for either 10 turns or 20 turns. As the preamp board also has low-pass cut off filtering and damping on it the connection board damping resistors may be left disconnected. The connection board also has a connector that allows the pre-amp to be completely bypassed. This is great for testing and assessment of necessary receiver delay to accommodate the pre-amp influence but it is otherwise recommended that the pre-amp remain in line and damping not be changed. See the wiring diagrams appendix for more details.

WHEN TO USE THE FRONT LOOP

Additional deep investigation may be possible using a front loop suspended in front of the towing vehicle off booms. This loop is unaffected by instability on system response due to mutual inductance nulling and has less shallow signal mixed with deep signal at late times. It has equal chance of detecting deep information as the in-cart loop but offers additional confidence that instability is not affecting deep data. Use it when additional confidence in deep data is sought and when deciphering induced polarization effects of shallow clays.

Front loops need to be smaller than the Wallaby loop and do not have as much cross section area. Two sizes are offered:

1. 1m x 1.4m which packs on top of AgTEM-Wallaby.
2. 0.4m x 0.8m which packs in a ½ palette box and ships with AgTEM-Wallaroo.

Each front loop option has the same black box, pre-amp and loop turn switch-in circuit as the AgTEM-Wallaby mid-plane loop. Select 10 or 20 turns depending on anticipated ground conductivity and desired exploration depth.

The front loop suffers more movement noise from rough driving than the in-cart loop.

OPERATING PROCEDURE

GETTING TO AND FROM JOBS

AgTEM-Wallaby can be packed into a compact air-freight and truck-freight suitable aluminum enclosure. The enclosure will fit into ute trays and modest trailers and is designed for lifting with a forklift. On site it may be opened in clam shell mode such that one person can remove and assemble AgTEM-Wallaby.

As full assembly of AgTEM-Wallaby is time consuming it is not appropriate where daily or part-daily refloating of AgTEM is a necessity. For this purpose AgTEM-Wallaby must be floated on a much larger trailer set up but with booms retracted OR see the following section:

SHORT DISTANCE TRAVEL ON PUBLIC ROADS DURING JOBS

Conditional road registration, if obtained for your area, facilitates movement of AgTEM-Wallaby short distances on public or other trafficked roads with side booms folded backwards.

For longer distances, if full registration is obtained in your area, AgTEM-Wallaby may be towed with booms fully retracted and restrained, optionally substituting highway rated motorcycle wheels for the non-metallic wheels used for survey. Observation for signs of wear is regularly necessary should such a mode of transport be used for very long distance travel. Care in strong wind or cross-buffeting from oncoming traffic is necessary due to light weight of AgTEM-Wallaby. Aerodynamic design improves stability at higher speeds as more weight is forced onto the wheels by this design.

SETUP OF AGTEM

PARTS OF AGTEM-WALLABY

1. Parts and tools bag.
2. Core
3. Front side booms
4. Rear side booms
5. Drawbar boom
6. Drawbar rigging and collective restraint system
7. Rear central boom
8. Transmitter loop
9. Undercarriage
10. Spare wheels

REMOVAL FROM THE QUICK DEPLOYMENT TRAILER

The figure below shows AgTEM stored on the quick deployment trailer.

Figure 23 AgTEM stored on the quick deployment trailer

Dismounting is as follows:

- Removed the rear lights bar (pins and R-clips) and set aside under the trailer.
- Remove ratchet straps that tie down the undercarriage.
- Disconnect the elastic hook and loops that hold down the tarpaulins.
- Remove tape from rigging taped to the rear of the Wallaby.
- Pull out the rigging and rear booms and lay on the ground behind the Wallaby.
- Pull out the pin near the AgTEM-hitch and dislodge the ratchet on the winch.
- Let AgTEM roll down the gantry roller track – you will need to roll it backwards by force once it touches down on the ground – continue until the hitch is at the rear of the float trailer.
- Dismount the AgTEM hitch.
- Move on to the instructions for assembly from quick-deployment mode given below – bypassing all the shipping box unpacking and assembly steps.

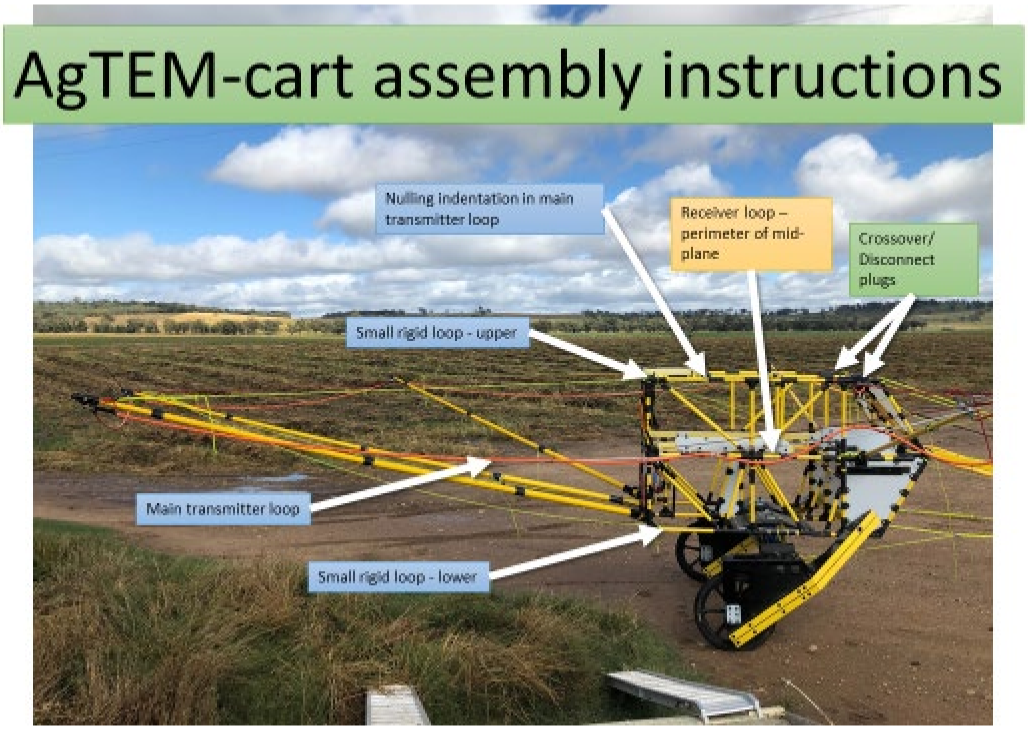
Figure 24 AgTEM Wallaby rolling down the track.

UNPACKING AND ASSEMBLY OF AGTEM WALLABY FROM THE SHIPPING BOX

AgTEM is delivered in a shipping box as shown in the photo below. As it is a 22.5m x 6m vehicle that packs into a 2.3 x 1.2m box there is considerable setup required from this form.

Figure 25 AgTEM packed into the shipping box. Weight 448kg with spare parts included.

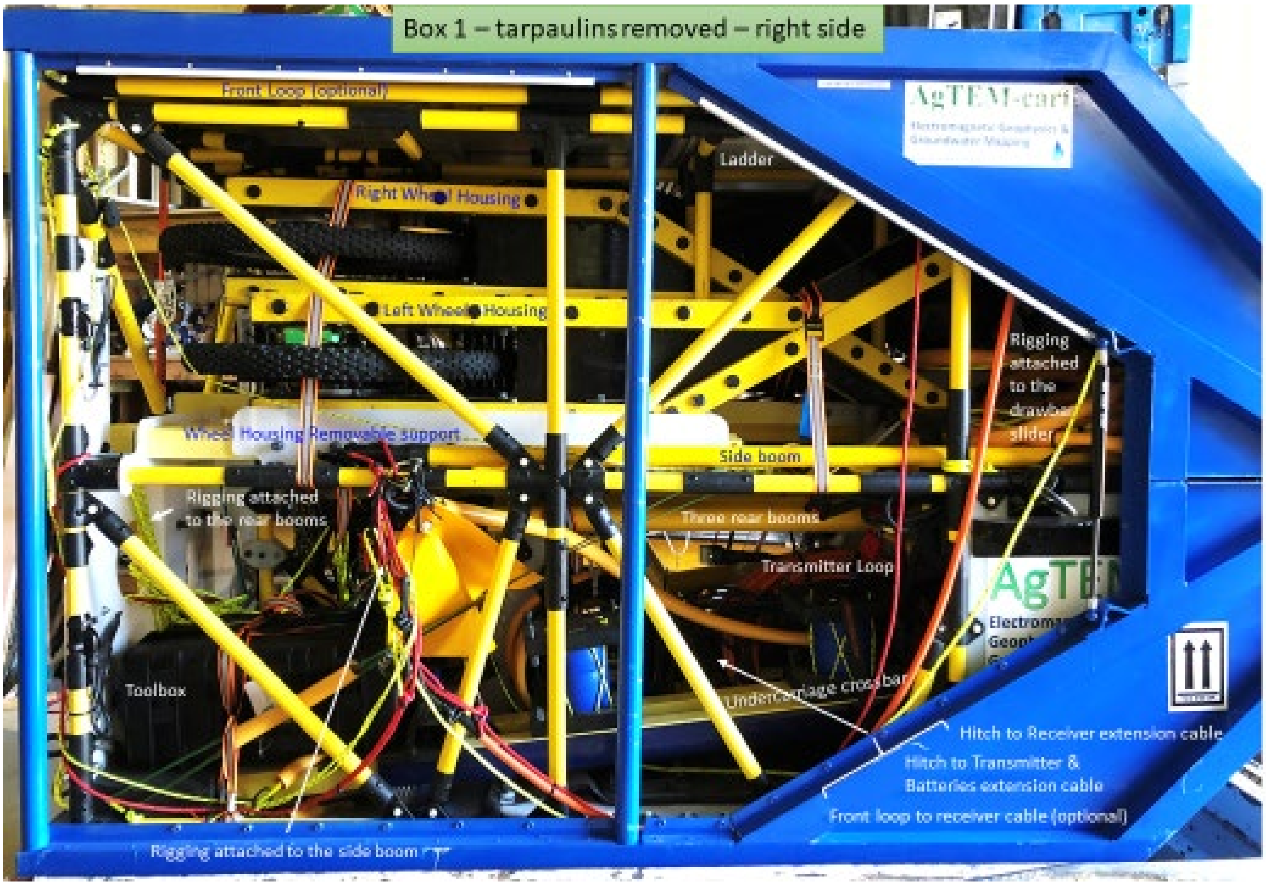
A separate MS power Point document lists the procedure for unpacking and assembly of AgTEM Wallaby. The slides are included here in case the original is lost.

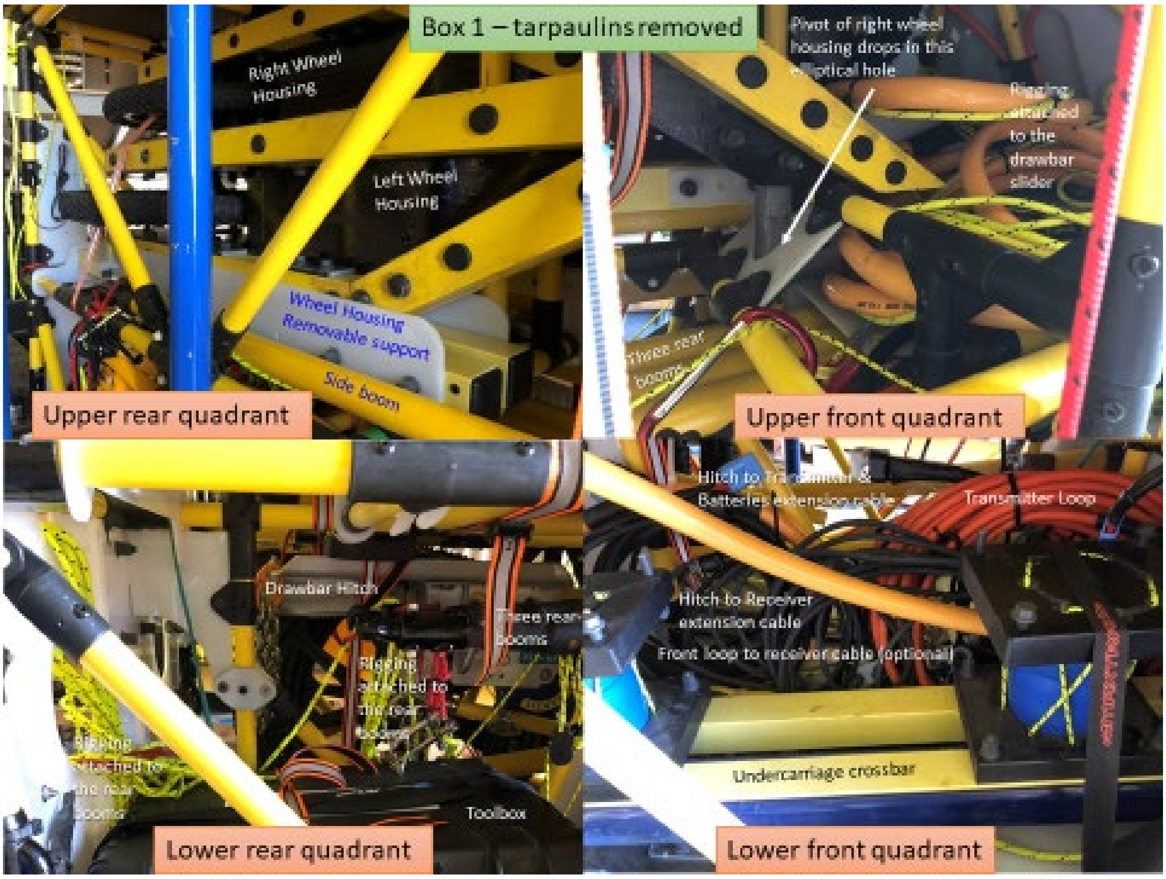


BOX 1 UNPACKING – WHAT GOES WHERE IN WHAT ORDER (USE REVERSE ORDER FOR PACKING)

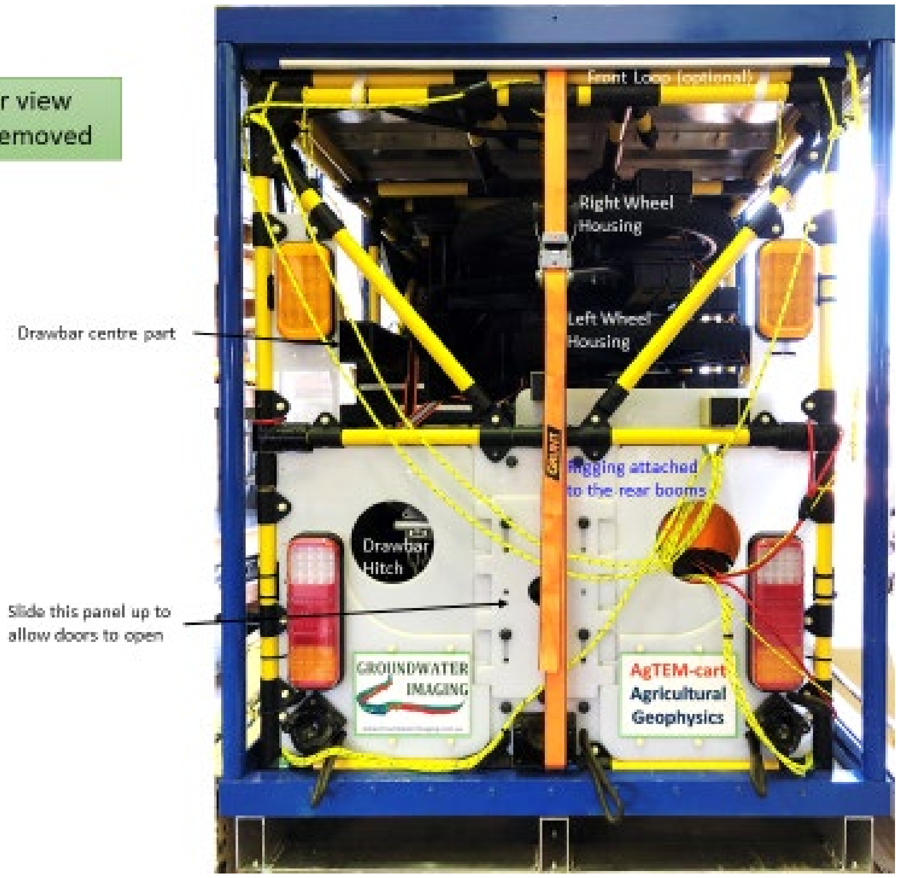
- Remove tarps – (never transit without tarps as they provide cross-brace support). The bead in the top tracks must be pulled inwards to the posts midway along each side.
- Undo ratchet strap at rear that holds down the lid – gas struts will then lift it.
- Loosen all straps that hold items down
- Remove small loose items such as the transmitter loop and other cables.
- Open the rear doors of the AgTEM core – lifting rear boom rigging from the notch in the top of the right door.
- Remove tape and remove the ladder and front loop (optional) from the top of the core.
- Lift up the pivot of the right wheel housing from the locating elliptical hole in the sloping plate near the front of the core, then push it backwards. Walk around the back and lift this wheel housing out.
- Pry up the left wheel housing from its locating fixture and slide out backward – remove.
- Lift the front of the wheel housings packing support then slide the rear of it forward until it comes free – remove and put aside.
- Lift out the optional front loop booms assembly and front loop booms mount from lower left quadrant. Remove related packing support and winch handle and put aside.
- Lift out tool box and foam support from lower right quadrant.
- Lift front end of drawbar cross-member and slide a little backwards then go to the rear door and lift it right out.

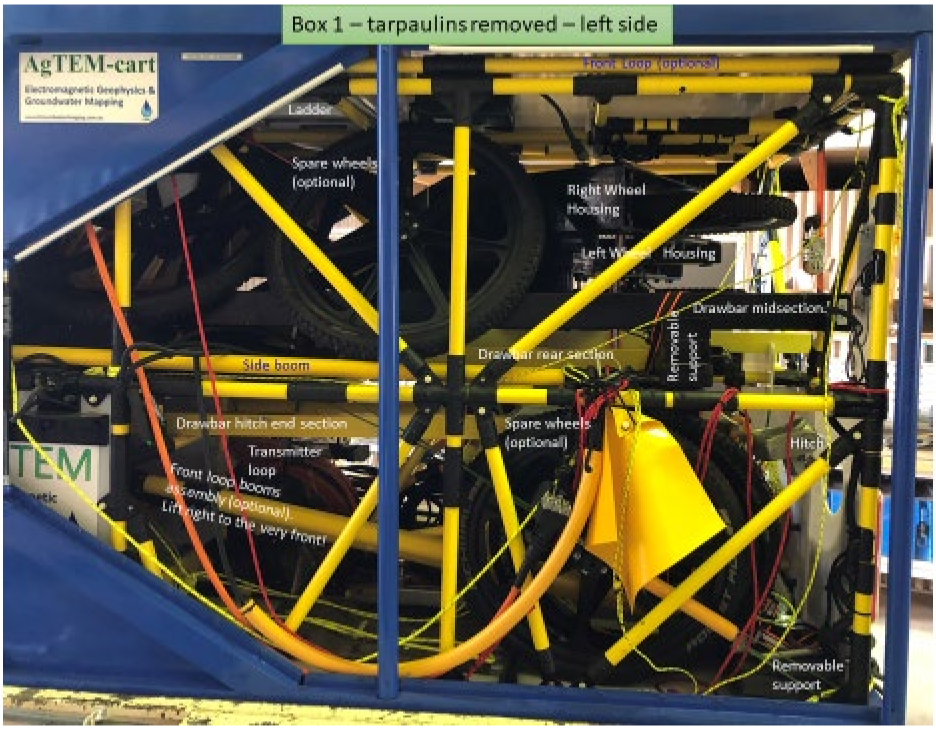
- From the Upper left quadrant remove the drawbar midsection and rear section.
- The hitch end of the drawbar will be supported in cantilever manner by structure at the front of the core now the suspending strap is removed – lift the weight of the hitch so it can be slid backwards and lifted out. Warning – if repacking it is most important to ensure the suspending strap is replaced so cantilever forces do not break the core.
- Remove spare wheels if present – working them around other items.



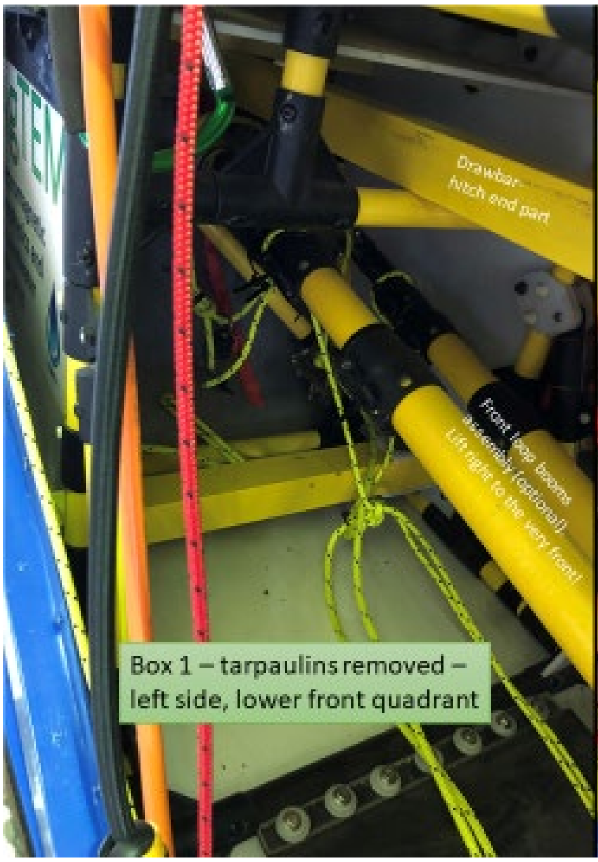


Shipping box rear view with tarpaulins removed



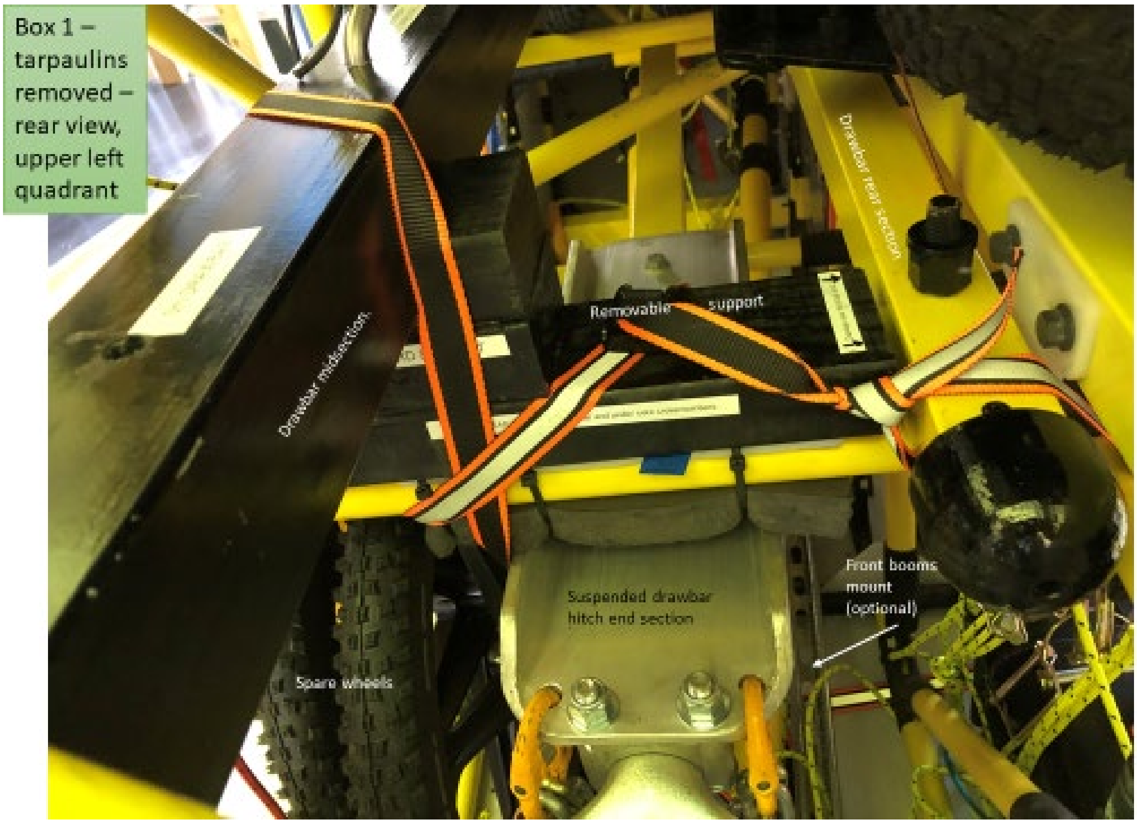


Box 1 – tarpaulins removed – left side



Box 1 – tarpaulins removed – left side, lower front quadrant

Box 1 – tarpaulins removed – left side, lower rear quadrant



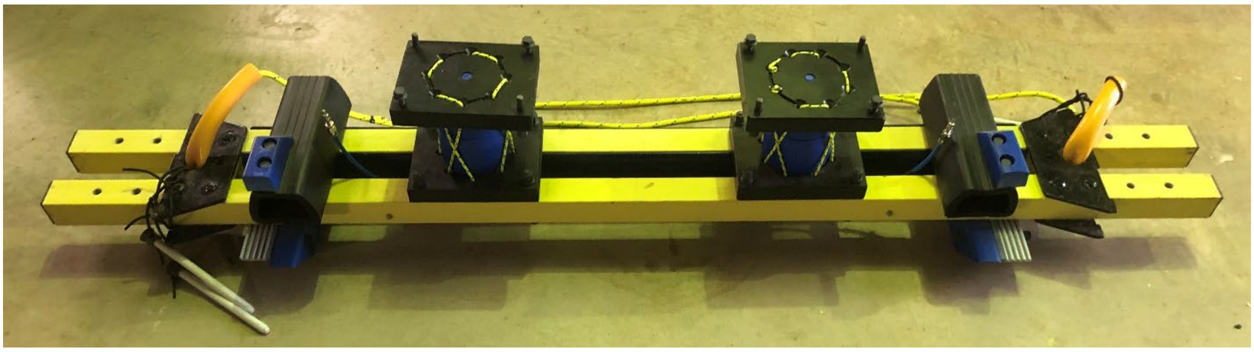
Box 1 – tarpaulins removed – rear view, upper left quadrant

Box 1 – tarpaulins removed – right side upper rear quadrant

ONCE OUTSIDE OF THE SHIPPING BOX – ASSEMBLY OF THE WALLABY CORE, UNDERCARRIAGE AND DRAWBAR

- Leaving all booms and the drawbar slider and attached rigging within the core, lift the core out backwards from the shipping box and lower it to the ground rotating it onto its back like a rocket ready to launch (pad to avoid damage to lights). This is a practical one person lifting operation.

- Drive the shipping box forward (if on a trailer otherwise slide it forward) far away enough to leave space to attach the 4.5m long drawbar.
- Rotate the core onto its lower nose.
- Place the undercarriage cross-member into one wheel housing and drop in pins which are elastically attached (there are 4 holes but only 2 pins are needed). The photo below shows the cross-member.



- Place the attached wheel housing pivot into the core being careful not to crack anything as it is only part way in – if aligned without weighty forces it will slide in all the way. Inspect for wear when doing so. The photo below reveals the wheel housings.

Figure 26 AgTEM-Wallaby wheel housings

- Slide the other wheel housing onto the cross-member and into the pivot hole simultaneously being careful to align and avoid racking as you push it into place – again it will slide easily if aligned. Drop in pins, elastically attached, to fix onto the cross-member.

- Remove fibreglass nuts from four of eight locator studs on top of the airbags and carefully lower the core down onto the undercarriage aligning the locator studs into receptors as you do so. Replace and lightly tighten the fibreglass nuts (lift hand force on a spanner – they are only fibreglass so using forces as you would for steel will destroy them). The core will now be tilted forward but resting on the wheels.

- The transmitter support that rests on the drawbar is folded upwards against the front of the Wallaby – remove the strap holding it there in preparation for concertina folding it down onto the drawbar. Temporarily fold it down to allow access to drawbar rigging.

- Lift the drawbar slider and attached rigging from the shelf in the front of the core and lay it out on the ground in front. Examine this rigging and rearrange until all rigging is laid untangled with free passage to attachment points. The lower left and lower right rigging will be bundled up (not attached) – unbundle them and extend them towards attachment points. This lower rigging attaches via a looped end to rigging coming from the wheel housings that passes through the looped ends and then must be attached, using D-bolts, to rigging that is passed out from the lower front of each side of the core.

- Slide the drawbar slider onto the hitch end part of the drawbar. The photo below shows the three parts of the drawbar.

- Pull pins out of the drawbar mid-section and slide the two end sections in until the 4.5m length holes align and reinsert the pins.

- Cross-over the elastic tendons ('dog-bones') at the drawbar socket on the front centre of the core and lift the rear of the drawbar up to its socket and attach these tendons by pulling them over protruding nuts.

- Free the winch ratchet and pull out the dyneema rope pair and attach to the drawbar slider. The pair will initially be hooked together and retracted over the spring loaded vertical post attached to the hitch so that it is kept parallel with the drawbar during shipping Get the winch handle and winch the slider towards the hitch so that the core front lifts. The beginning of this lift can be very stressful so a helper or a support such as a lump of wood lifting the front of the core at this point is most appropriate. The winch has 3 gears – use 10:1. As the rigging pulls tight examine to ensure that all ropes pull evenly tight right and that the Wallaby levels out simultaneously. If adjustment is needed then collapse it again and make fine adjustments using the 6 rope clutches then retighten – iteratively until adjustment is satisfactory. Vehicles with different tow ball heights may require optimization of this rigging to keep the Wallaby level (just like with any trailer or caravan).

- Engage the winch ratchet and remove the handle and put it in a safe place.

- Check the airbag pressure – about 20psi is typically used and much more will cause damage. The airbags may have been deliberately deflated if the shipping box has been airfreighted. If left deflated then the Wallaby tends to slump sideways on the undercarriage.

REMOVING & EXTENDING WALLABY BOOMS & SETUP WITH TX SUPPORT PLATFORM IN QUICK DEPLOYMENT FORM.

- Slide front side booms up and back to the Wallaby centre rear to free them up then lift the ball end forward rotating it into free space and then pull the boom tips, with rigging attached, out the sides of the Wallaby. The elastic rigging attached ends in carabiners which will be clicked onto Wallaby structure – unclip them to fully release the rigging and then clip them onto the two holes at the top rear of the drawbar sliding tensioner.

- Slide the rear booms out the rear right door of the Wallaby and lower them to the ground.

- Place each rear side boom out to its respective side, inspecting rigging as you do to ensure it is not lifted out the wrong space within the pile of connected rigging. The hooks at the boom tips should face upward and outward. Similarly, place the rear centre boom back as far as the rigging allows and inspect to see if it has been lifted out through the correct gap in the pile of connected rigging.

- With all the booms, rotate the clamping levers so that they allow boom extension. Slide until small black recessed dots appear and line up with the clamp seams. D-pins, temporarily attached to the rigging at boom tips should now be removed and slid into the boom extension clamps in holes provided. The clamping levers, at full adjusted tension, do not provide enough friction to stop booms sliding when the Wallaby is driven very roughly over uneven ground so these additional D-pins are worthwhile. The small ends of the extendable booms take 8mm pins and the rest take 10mm pins.

Figure 27 Small black indented marker dots align with clamp seams to indicate when boom extensions are aligned for inserting fixing pins.

- Place the balls of the front side booms into their sockets and attach tendons to tendon hooks. The front side booms will now be fixed elastically into survey position. If not surveying you will need to stretch them backwards until they are beside the Wallaby core and tie their remote retraction ropes around the top of the core using a clove hitch.

- The rear booms will now be on the ground behind the Wallaby – if it were to be placed on a quick deployment trailer then they would be gathered up and lifted as one onto the trailer. Another carriage option is to slide the bundle under the Wallaby and to tie it front and back suspended underneath.
- Take the transmitter loop and plug in each end at the front side boom tips. Push the cable ties that suspend it over the spring loaded clasps at the tips of each boom so that they are fixed to each boom by a sacrificial cable tie.

Figure 28 THe transmitter loop is fixed to flying leads pulled elastically out each side of the Wallaby so that cable slack, needed for connecting the connector, is not near the Wallaby core where it would strongly affect mutual inductance nulling.

Figure 29 The transmitter loop is attached to booms via cable ties (weak links) that hang over hook-clasps at tips of booms

- Fold down the transmitter support platform onto the drawbar. Wedged under the foam pad on the platform is a bracing plate – place this under the drawbar and attach it at the front of the platform using the bolts and wingnuts provided. This will both secure the platform and help to prevent the drawbar from rotating on its axis.
- Four elastic cords extend from sides of the transmitter platform – hook these under the mid-plane drawbar rigging and lift upwards and connect to the upper drawbar rigging using the carabiners provided. This assists in stopping the drawbar from rotating on its axis.

ASSEMBLY – FROM QUICK DEPLOYMENT FORM TO OPERATIONAL

- At this stage booms will be fully extended and laid out on the ground. Side booms will be attached to the Wallaby, if tied back then untie the clove hitches in the remote retraction cords and watch you head as the elastic cords force the booms to swing forward rapidly.
- Inspect the boom pivot sockets for any sand that may cause abrasion – remove.
- Lift the rear centre boom and put the ball end into the centre rear socket. Ropes going to each rear lower corner are of length just sufficient to allow this to happen – without tension on these ropes the whole rigging would collapse. Attach tendons to tendon hooks.
- Lift each side boom into its socket and attach tendons to tendon hooks.
- If remote boom retraction while driving is required then attach the intermediate 4mm rope rigging, that passes through pulleys on the rear centre boom, to appropriate nodes on the rear side booms and to the D-bolt attachment to the pulling cord that extends down the drawbar. This 4mm rigging is annoying as it adds to tangles and is best removed or bundled up and taped on if not in use. The D-bolt is best detached to allow booms to be stowed away as the attached cord will need to be extended otherwise and adds to potential for tangles. The three remote boom retraction cords typically are bundled up at the drawbar tensioning slider – to use them either connect a remote control electric winch on the top of the slider or unbundle them and drop them into the driver-side window so the driver can pull them when necessary (this is hard work).
- Cables within conduit are attached to drawbar rigging – lift the ends through the rope sling attached to an eyelet on a spring loaded post at the hitch to ensure they cannot slump near the ground and hook over obstacles.
- If the transmitter is going on the drawbar then put it on the pad provided. Adjustable straps pass underneath through holes in the support plate and around rods in cavities on each side of the transmitter and are tensioned beneath the Wallaby drawbar. Relevant cables should be attached.
- Note if the transmitter is left on overnights unattended then placing a chain around it with a lock overnight is an option.
- At the tow-hitch, attach receiver and transmitter wiring looms extending into the survey vehicle to batteries and equipment. If GPS is not permanently set up then set it up on the survey vehicle too.

MECHANICAL SETUP OF AGTEM-WALLABY SUMMARY

1. Fix undercarriage to core.
2. Extend and fix rear and side booms to core with rigging and elastic tendons (at sockets).
3. Attach transmitter loop to booms and core.
4. Put drawbar rigging slider onto drawbar boom front section and assemble drawbar telescoping sections.
5. Put drawbar boom ball in socket and restrain with elastic tendons.
6. Pull Wallaby into shape using the drawbar rigging tensioning winch.
7. Attach side boom elastic tensioners to drawbar rigging slider to pull transmitter loop into shape.
8. Attach to towing vehicle.
9. Install electronics and GPS in towing vehicle and run cables to tow ball. If the transmitter is to be situated on the drawbar for more direct loop connection then install it there.

10. Attach electrical cables in vicinity of tow ball.

OPERATION OF THE DRAWBAR FIXING RIGGING

The drawbar consists of a central compressive member and high strength low strain Kevlar ropes which are attached at quickly-adjustable lengths to a collective restraining device. This device also has elastic side boom restraint attachment points. The restraining device is fitted over the telescopic drawbar compressive member and wound tight by a geared hand winch just behind the tow hitch. AgTEM-Wallaby core frame must be lifted a little for the lower restraining ropes to start to lift AgTEM-Wallaby into shape otherwise they will pull over-center or directly on-center with inappropriate results. Use the winch ratchet pawl to fix the rigging taught in position. Observe if any ropes lengths are inappropriate and adjust (not under tension) if necessary using the quick-adjust rope retainers.

Make particular care to remember to return the winch crank handle to the AgTEM parts bag before continuing or you will lose it.

LEAVING THE WALLABY OUT OVERNIGHT

If the Wallaby is left out overnight in a paddock away from vandals attention it can save considerable time on multi-day surveys. Consider the possibility of condensation forming in electronics if the transmitter is left out overnight. A blanket may help on humid nights. A chain may be placed over the transmitter at night to deter vandals and thieves as shown below.

Figure 30 Chain restraint of the transmitter overnight to prevent theft - remove the chain before surveying. As of January 2025 this location for the transmitter is rarely used – preferring to locate it on the towing vehicle to make daily setup and packup quicker.

MECHANICAL SETUP OF THE FRONT LOOP

The front loop is designed to stably move along in front of the towing vehicle at a height clear of most vegetation and fences. It is attached to extremities of bull-bars of vehicles via 50mm tow balls fixed onto the bull bars by a separation not less than 1.2m. If the separation is too small then rigging will twist and bow and the receiver loop will not remain level. A long wheel base towing vehicle is preferable for use of the front loop. Installation procedure is:

1. Extend the front loop booms assembly – that is two booms attached together as a pair by a hinge plate as shown below. Fix locking pins in place to oppose the extreme compressive forces the booms endure. A boom length of 4m to 4.5m is sufficient for small pickup trucks. Shorter length may suite lightweight all terrain vehicles but if too short then inductive pickup of the tow vehicle will become problematic.

Figure 31 The front loop booms assembly collapsed for freighting.

2. Attach the front loop via a rotating socket at its center of gravity, fixing it on by looping over and stretching an elastic rubber loop and hooking it back onto the hook provided near the assembly tip. Rest one edge on booms via use of the two short struts that exist at one end of the receiver loop. These attach to two connectors on the booms that must be slid into place after loosening wingnuts.
3. A ratchet strap attached via low stretch Kevlar rope to the booms' hinge plate must be extended to the headwall on the pickup or some other central elevated fixture.
4. The towing vehicle must have two 50mm tow balls (provided) attached to bull bar extremities, or to an on-site custom made fixture bolted onto the bulbar. A dummy mount is displayed below and provided with the apparatus. The hitches on the booms are 50mm as are the tow balls. 50.8mm (2") balls do not fit these hitches.

Figure 32 A dummy mount for the front loop booms assembly.

5. Drop and click the two hitches over the towballs. Lift the hinged boom tips about 800mm(using an assistant or a support such as a short step ladder and tighten the ratchet strap to lift the front loop to about 2.2 to 2.8m high. Lifting all the way from the ground using the ratchet is possible with care but applies large forces to the booms.
6. Plug in the receiver cable at both ends and check the pre-amp and loop turn settings.
7. Rigging at an intermediate position along the pair of booms keeps the loop level and prevents booms bowing under their own weight. Adjust this rigging if the loop is not level.

Figure 33 The Loop mounting end of the front loop booms.

Figure 34 The front loop mounted on a pickup vehicle.

Figure 35 The front loop mounted on tow balls mounted on an Isuzu D-Max bullbar.

Note that the Front loop hitches which are quick and lightweight to use and fit the booms elegantly fit only 50mm tow balls such as are supplied with the dummy mount bar. For additional installations either change the hitches to 50.8mm tow balls or source additional 50mm tow balls.

MECHANICAL SETUP OF AGTEM-BARROW

AgTEM-Barrow is a vertical post restrained transmitter loop on an electric wheelbarrow. From the post a transmitter loop is draped outward. Metal in the barrow motor etc. cause a system response which is subtracted from data. It is designed for very quick deployment for small scale dense surveys such as blast pattern planning surveys. Setup is as follows.

1. AgTEM-Barrow is supported in a pickup tray by a structure that supports each side of the propelling wheel, keeping weight off the wheel during long distance transit and reducing load and tethering slippage risk.
2. Put a ramp from the pickup tray to ground. If batteries are not present (100 AmpHr 12.8V LiFePO4 each side of the wheel (keeping weight low and symmetrical around the propelling wheel) then place on the batteries and connect. Untie the barrow, de-isolate and start the electric motor and propel it down the ramp while holding handles.
3. The central post will be folded backwards. Lift it up to vertical and insert the fixing pin.
4. A rear axle and two balloon shaped ‘training wheels’ can be fitted across the barrow legs and this is a good idea in clear terrain such as blast preparation sites. In difficult vegetation it is better to have an assistant or two to prevent the barrow tipping by walking along lightly holding side booms. To move the rear wheels normally are lifted off the ground as the tilting action they add when on uneven ground is not desired.
5. Using the central winch, lower the five transmitter booms to extend the loop. Extend out the telescopic sections.
6. Either a small rigid receiver loop may be attached to a front boom extension (for small footprint investigation) or a dragged mat receiver towed behind (for deep investigation).

7. If electronics is not already placed in the barrow then place it and operate. The transmitter is placed in the front, to keep weight low and over the propelling wheel, and the receiver, computer, & DGPS in the rear, where it can be observed.

MECHANICAL SETUP OF AGTEM-WALLAROO

AgTEM-Wallaroo can be setup at standard size, or, if there are enough people to carry it, at triple the loop area and double the length by connecting two Wallaroo frames end to end for the purpose of greatest depth exploration over rough terrain. Standard setup is as follows:

1. AgTEM-Wallaroo structure comes in an airfreight shipping tube along with a large area floppy receiver loop. A second ½ pallet box contains the electronics and smaller rigid receiver loops.
2. Detach the end cap and slide out the polyethylene sheet containing AgTEM-Wallaroo structure. Untether the rolled sheet to reveal the parts.
3. Being careful to avoid tangles. AgTEM-Wallaroo comes with rigging assembled, even though it is packed up. If you do get tangles and are challenged, rigging can be detached then reattached after resolving tangles.
4. Lift the central upright post and slide it into the fixture on the center of the longitudinal telescopic boom.
5. Also fix, via rubber tendons integrated into the central fixture, the lighter transverse telescopic booms with attached rigging.
6. Extend out all the telescopic sections of all three booms and fix with pins provided – noting that the central longitudinal boom needs to endure twisting forces.
7. Another short post is placed under the central fixture and has structural rigging extending along the longitudinal boom. Fit that post in now.
8. If the transmitter loop is not already attached, then clip it onto the 4 boom tips now, noting that parts at longitudinal boom tips may short-cut the tips, instead being restrained to the tips via short extension ropes. This is to allow less inductive coupling with transmitter and receiver electronics in back packs.
9. There are 3 possible receiver loop attachment options, and all may be used simultaneously or just one or two chosen, central, on boom and dragged mat. The central receiver (small rigid with low or no pre-amp gain) is placed on the base of the central post using a connecting pin in a fixture at its center of gravity. Similarly, the boom mounted coil may be fixed at the end of an extension boom from the rear of the longitudinal boom. The towed sled uses a long receiver cable in flexible conduit with tension restraining low strain rope extending backwards to where the rope is to be fixed onto the rolled polyethylene mat. On the mat either, preferably, a large area flexible receiver loop, or a small rigid receiver loop may be placed and fixed for dragging.
10. The transmitter and receiver must have batteries installed for mobile use and backpack frames mounted.
11. At this date, an issue with variable coupling of metal parts of electronics with loops precludes practical use of them carried within the transmitter loop structure and further research is happening to resolve this limitation. This means that for now, at least three people are needed to carry AgTEM Wallaroo. Research also is occurring to fit lightweight compact wheeled structure to it – if you want this promptly then please negotiate.

BACKPACK MOUNTING OF THE RECEIVER AND TRANSMITTER

AgTEM electronics used in Wallaroo mode will require mounting on back pack frames. The cases are specifically chosen to facilitate this option and the mounting is very quick so electronics can be swapped back and forth for various applications.

Backpack mount instructions are given below and at

https://www.b-w-international.com/wp-content/uploads/2018/05/Anleitung_BPS_web.pdf

To keep weight down in Wallaroo mode, the entire lid of the case, with the friction hinge mounts can be easily unclipped using instructions given in the temporary vehicle mount option below. It can either be left off during survey or swapped with the lighter lid of the battery charger case which unclips in identical manner. Keeping a lid on the backpack case improves weather resistance and durability especially considering damage that may occur when equipment is transported to-and from survey lines in motorized vehicles. The extra space available in a swapped 'blank' lid may facilitate carriage of lunch and water, or extra loop power batteries during extended remote area treks.


flexible Halterung (längenverstellbar)
flexible mounting (adjustable)
Griff
handle
Klettgurte (längenverstellbar)
hook-and-loop fasteners (adjustable)
Schnapphaken/
Schrauben
snap hook/
screw
Hüftgurt
abdominal belt
ergonomische Polsterung
ergonomic padding
längenverstellbare Gurte
adjustable tightening straps

DO NOT USE EXCESSIVE FORCE TO REMOVE THE HINGES. Very light force is all that is required! The removal process involves pushing and levering in directions that are at first not intuitive. Quick release hinges are marketed due to the non-intuitive operation but once an operator learns the procedure they will find it very easy even with the standard hinges.

Figure 36 B&W cases offer both quick release and standard hinges - the swapping procedure here is provided to assist those struggling to understand how to remove the lid. In AgTEM operation lid removal can be useful but full hinge swapping is not required. For robustness and security in freighting operations there is perhaps a reason to avoid the quick release hinge, instead simply learning the procedure to release the lid with the standard hinges.

The same AgTEM electronics is common to all forms of AgTEM and is operated generally in a common way with each form. Various means of propulsion do however require different display and battery solutions. Display options include:

- Dashboard Mount mode
- Displays propped up within the case for temporary vehicle installation
- Display suspended overhead from a Wallaroo backpack
- WiFi linked touchscreens using Windows remote Desktop or similar software.

ELECTRONICS PACKING

Both the transmitter and receiver fit into a half pallet box.

Figure 37 AgTEM electronics packaging. A test loop is beneath.

Some 7AmpHr batteries and battery chargers fit in an additional box but 14 such batteries are needed for a full day of survey. For Wallaby use where weight is not critical additional 60AmpHr 25.6V LiFePO4 batteries should be added to the towing vehicle with chargers permanently connected – it saves a lot of time.

Figure 38 7AmpHr battery charger and housing box. Leaving this in the towing vehicle with batteries inside is an efficient way to operate - providing loop and electronics power to the transmitter but 60AmpHr 25.6V batteries will be better should you not need to airfreight. As of January 2025 these have been replaced with Victron chargers as the type shown cannot restart the BMS on LiFePO4 batteries if the battery triggers the low voltage cutoff.

AGTEM RECEIVER CASE

The AgTEM receiver itself is a fully aluminum heatsinking sealed case which is typically packaged in a ventilated external case with batteries and optionally the GPS display/interface and computer. In Wallaroo mode or when using mounts on vehicle dashboards these peripherals are removed and mounted externally but when used temporarily on a quad bike or in a hired vehicle all may mount for use within the external case.

Figure 39 The AgTEM receiver without accessories

Figure 40 The AgTEM receiver in an outer case with batteries, protected cable connections, external ventilation, Toughpad computer and Trimble GPS display.

The lid of the external case, which holds the displays and interfaces may also be removed for use independently as may suit in some vehicles.

Figure 41 Displays packed within the outer receiver accessories case - detach elastic cords and hinge at double friction hinges to set up for display or remove them altogether for dashboard mounting. This lid housing is provided mainly as a stop-gap measure for temporary installations and freighting – dashboard mounting is the preferred and intended mode of operation of these displays for Wallaby survey.

Space for two 12AmpHr 12.8V LiFePO4 batteries or two 7AmpHr 12.8V LiFePO4 batteries is provided within the case when fully packed and closed. The 12AmpHr batteries will last ½ to 2/3 of a day and the 7AmpHr batteries will last about 1/3 of a day on full charge. High precision fast amplifiers must consume considerable power for optimum results so the receiver uses much power and generates much heat. Two receiver battery connectors are present in the case so that the system need not be shut down to change batteries. Once the case is opened, two sets of batteries may be simultaneously connected for full day survey and still all sit within the case. Battery space is displayed in the photo below:

Figure 42 Battery space in the receiver accessories case houses either two 7AmpHr or two 12AmpHr 12.8V batteries even when the case is fully packed and closed. More can be housed and connected while the case is open in operating mode or if the display housing lid is swapped to another case.

Figure 43 The receiver accessories case has power distribution incorporated. The On/off switch isolates all peripherals plus forced external ventilation. Connectors shown lead to batteries and to the computer power supply. More lead to the GPS display and receiver.

The next photo shows a small keyboard supplied within the receiver accessories case, attached by velcro. It has an on/off switch. Use as an optional alternative to the touchscreen.

Figure 44 A small keyboard supplied with the receiver (not essential to operation)

The three modes of display of the receiver are given as follows:

DISPLAY IN VEHICLE DASHBOARD MOUNT MODE

For vehicle dashboards where AgTEM is frequently used it is best to permanently mount the computer and GPS to the vehicle dashboard and only place back in the external case for storage and freight. Both the computer and GPS displays have 3rd party dash mounting products. Be aware that the computer requires a dash mount option involving an Ethernet port such as the iKey MiniDock or the Panasonic Toughpad optional Ethernet port or the Havis vehicle dock https://www.roamingtech.com.au/havis-vehicle-dock-for-panasonic-toughpad-fz-g1-port-replication-and-antenna-pass-through.

In vehicle dashboard mounting mode is very helpful, not only in making survey easier, but in facilitating both a driver and passenger to interact during a survey. A client such as a farmer may see the survey map in preparation in real time so they can direct survey optimally. They will know their property and it helps if they can come along, discuss results as they are collected and help opening farm gates. When training new operators it is also important to have dash mounting so both driver and passenger can view and interact with the system. The passenger seat also is useful if a person should assist occasionally getting out to assist movement of the AgTEM-Wallaby through difficult vegetation.

Warning: COM port assignments accessed via the USB ports can change if the USB cable is plugged into a different USB socket such as might happen when switching from the dock in the case to one in a vehicle dock. Assignments must then be changed manually to suit (defaults are 7, 8, 9 & 10). The GPS port assignment also may be different.

DISPLAY WITHIN THE CASE IN TEMPORARY VEHICLE INSTALLATIONS

Friction hinges within the external receiver case facilitate use of the computer and GPS displays/interfaces within the cases with the lid propped up to act as a shade for use in sunlight or light rain. For use in heavy rain, the case lid may be lowered or closed temporarily or water accumulation in the external case periodically drained through the cable entry hole.

This is useful in three circumstances:

1. Benchtop or static field test mode where added complexity and interconnectivity of a mobile system is best avoided.
2. Hire or temporary use vehicles where the case is simply placed on the passenger seat, fixed by seatbelt, and viewed/operated from the driver’s seat. In this mode, training or client interaction is often not possible as there is nowhere left for a trainee to sit.
3. Front rack mount on quadbike or side by side ATV. In this case the whole case is typically strapped down, over a thick sheet of foam padding, on the front rack of an All Terrain Vehicle. With the lid propped open and the displays tilted appropriately beneath, monitoring and control is possible, in sunlight under the shade of the lid, while driving. Another possibility is just mounting of the lid on the front rack and this may suit in some side by side vehicles.

The lid of the receiver external case is removed and swapped, for instance, with the lid of the battery charger box, by the procedure given below and at:

https://www.b-w-international.com/wp-content/uploads/2019/04/outdoor.cases_manual_QRhinge.pdf

DO NOT USE EXCESSIVE FORCE TO REMOVE THE HINGES. Very light force is all that is required! The removal process involves pushing and levering in directions that are at first not intuitive. Quick release hinges are marketed due to the non-intuitive operation but once an operator learns the procedure they will find it very easy even with the standard hinges.

Figure 45 B&W cases offer both quick release and standard hinges - the swapping procedure here is provided to assist those struggling to understand how to remove the lid. In AgTEM operation lid removal can be useful but full hinge swapping is not required. For robustness and security in freighting operations there is perhaps reason to avoid the quick release hinge, instead simply learning the procedure to release the lid with the standard hinges.

DISPLAY IN WALLAROO MODE

In Wallaroo mode the receiver case is backpack mounted such that displays are not visible unless removed. The backpack must be clipped on using 4 clips as per instructions. A special mount that holds the computer in front of the operator is provided. Take the computer from the mount in the case and place it in the mount in front of the operator. It is likely you will like to shed weight by swapping this lid with one from another case when operating in Wallaroo mode. The Trimble GPS system is most inappropriate for Wallaroo survey as it is heavy, requiring redundant parts simply to ensure it is not used other than with Trimble's suite of products. For Wallaroo survey a less accurate USB GPS puck can be used such as the Transystem one provided for test purposes – see photo or a highly accurate compact GPS such as the EOS Arrow Gold+. If using these alternate GPS then you can use the AgTEM raster display for rudimentary navigation or with the EOS product set up a Bluetooth link to a handheld navigation display.

Figure 46 Low cost standard accuracy GPS from Transystem is all that is needed for Wallaroo survey positioning.

Figure 47 EOS Arrow Gold+ DGPS useful for precision elevation and position in Wallaby or Wallaroo surveys.

WIFI TOUCHSCREEN SETUP

Windows Remote Desktop or similar software is very useful for remote operation of AgTEM on touchscreen devices including remote Panasonic Toughpads, iPads and Android or iOS phones.

This will require activating WiFi on the Toughpad computer and it has been found that acquisition at faster than 33Hz at high amperages eventually crashes if WiFi and internet connection are occurring – no doubt due to long delays when unwanted internet communication is occurring.

Using a lightweight viewing device is particularly pertinent when operating AgTEM-Wallaroo.

In temporary vehicle installations it negates any need to run cables to a dash-mount computer.

Keeping the computer with the receiver eliminates common failures caused by intermittent cable connection and poor harsh environment performance of exposed computer connectors. A Windows Remote Desktop connection will withstand intermittent WiFi connection while the AgTEM system just keeps on collecting data.

To set up Windows Remote Desktop a Router is needed – preferably a WiFi equipped router. The MAC address of the computer must be sought and various permissions arranged.

There is much literature on the web guiding in setup of Windows Remote Desktop and the reader is referred to that literature.

Remote restarting of AgTEM requires even more setup and again literature is available on the web explaining the complicated setup process.

CONNECTING THE RECEIVER CABLES

The synchronization, 24V power, USB and Ethernet cables all need to be connected to the internal receiver box. The external receiver box has a toggle switch that also turns on external forced ventilation when batteries are connected via it. It also distributes power via appropriate cables to a Panasonic computer power supply (removing need for in-computer battery swapping) and DGPS equipment and navigation displays.

Connecting receiver loops requires some thought. There are three connectors but all three allow connection of three receiver loops, but inappropriate use will lead to double connection of receiver loops. Each has pins for loops rotated around by one and are intended to permit the same types of cable to connect to either Z, X or Y inputs or for two or three loops to be connected by one cable.

Figure 48 Receiver connections. Single or three component receiver cables may be connected to three different connectors however the components are rotated around successively in each connector such that Z is component 1 in the first, X in the second, and Y in third. Typically the Wallaby receiver loop will attach to the first connector (ZXY) and the front loop will attach to the second connector (XYZ). Note that the blue GPS connector is not currently in use.

CONNECTING THE TRANSMITTER CABLES

The transmitter must be connected to the receiver using the Synchronization cable which has the same gender at both ends. For the AgTEM-Wallaby use a two part synchronization cable with one part in the vehicle wiring loom going to the tow ball and the other from the tow hitch to the transmitter.

A GPS synchronisation option is available for independent roving of the transmitters and receivers however this is not provided in a standard AgTEM. A specific GPS antenna must be connected via the blue port for such synchronization. Contact your AgTEM distributor for further information.

24V power must be connected to the electronics that drives the transmitter via a Hirschmann 4 pin connector.

Loop power must be connected either directly using a Grey Anderson connector, or indirectly via either a Hirshmann 4 pin connecter or a Blue Anderson connector that leads to an Internal 370watt 24V to 5V DCDC converter. A switch near the coolant pump switches between these two sources. This facilitates some options for batteries and supplies but one must be careful. The Hirshmann 4 pin connectors are reserved for 24V supplies less than 15 Amps. An alternative 19-72V to 12V external DCDC converter can be supplied to connect to the grey Anderson connector for precision 12V loop power and is fitted with airflow management parts for housing within the case in place of internal batteries.

Loop power out is via red Anderson connectors and options of series and parallel are possible via 4 outputs, Y cables and a jumper connector. A damping resistor may also be connected across a relevant red Anderson connector instead of using the internal damping resistors within the transmitter. There are lots of options and one should refer to the section on choosing transmitter loops to understand how to make a good choice.

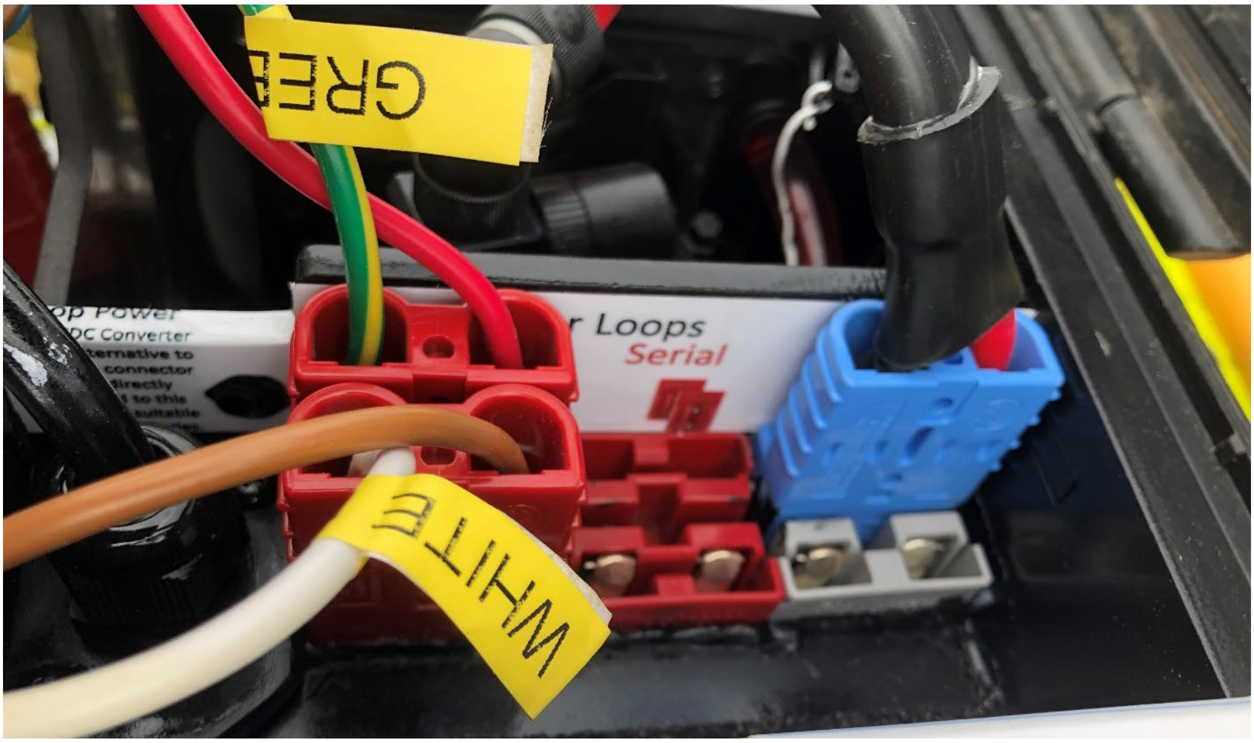


Figure 49 Loop power connection - in this instance power enters an internal 24V to 5V DCDC converter via the Blue Anderson connector - passes through the transmitter to exit via the red Anderson connectors as a 50% duty cycle square wave. There are both parallel and serial outputs - in this case two 2-turn loops are connected in parallel to maximize current flow.

Battery supplies are typically either: large external 60 to 100 AmpHr 25.6V batteries connected via blue Anderson connectors, large 20 to 100AmpHr 12.8V batteries connected using Grey Anderson connectors to Y cables to one Blue Anderson connector or collections of small 7AmpHr 12.8V batteries connected using Anderson SBS Mini Connectors to Y cables to form 25.6V which are paired into a Blue Anderson connector or Hirschmann connector. These small batteries should be used in a group of at least 4 (2 parallel x 2 in series) to drive the 24V to 5V DCDC converter when outputting 50Amps. This option is designed to facilitate carriage by air as permission to carry up to 20 such smaller batteries as hand luggage is granted by most airlines. In

Wallaroo mode they are housed in the case but in Wallaby mode they are better housed in the towing vehicle with chargers.

Ensure batteries are disconnected to avoid current drain when not in use. A toggle switch cuts power to the cooling circuit and receiver electronics and a momentary button held in for a couple of seconds turns the transmitter on and off. Pressing the switch momentarily will boot the transmitter – leading to a red ring of light around the boot switch however if the receiver is turned on already the boot will happen automatically as soon as master power is switched on. The DCDC converter is running whenever power is plugged into it but at idle it consumes little power.

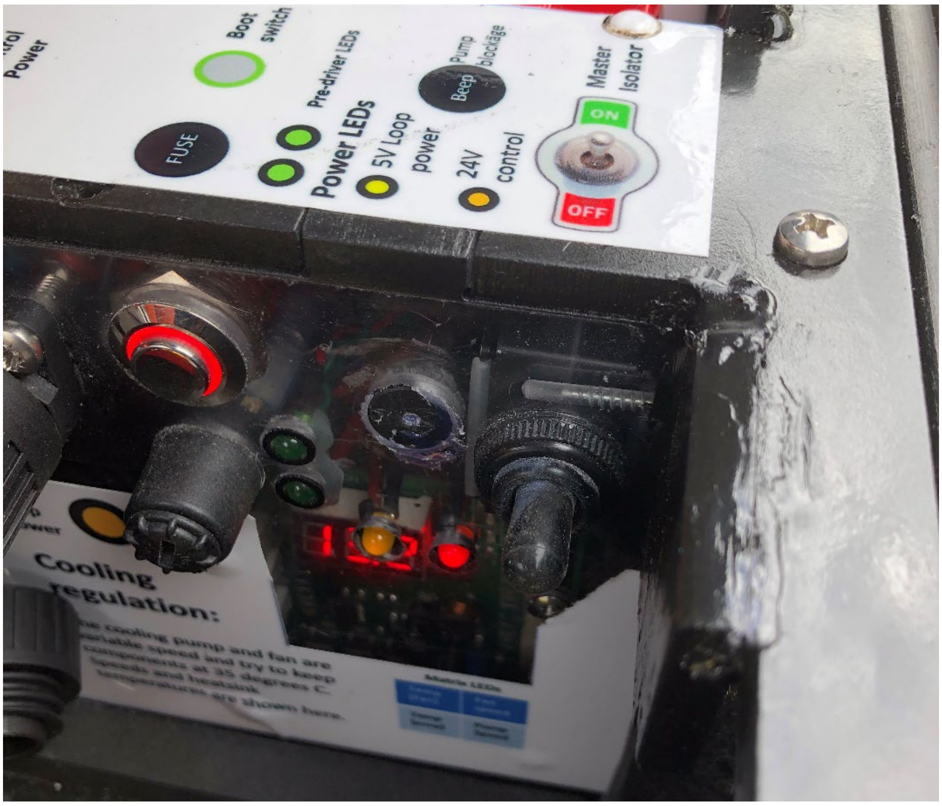
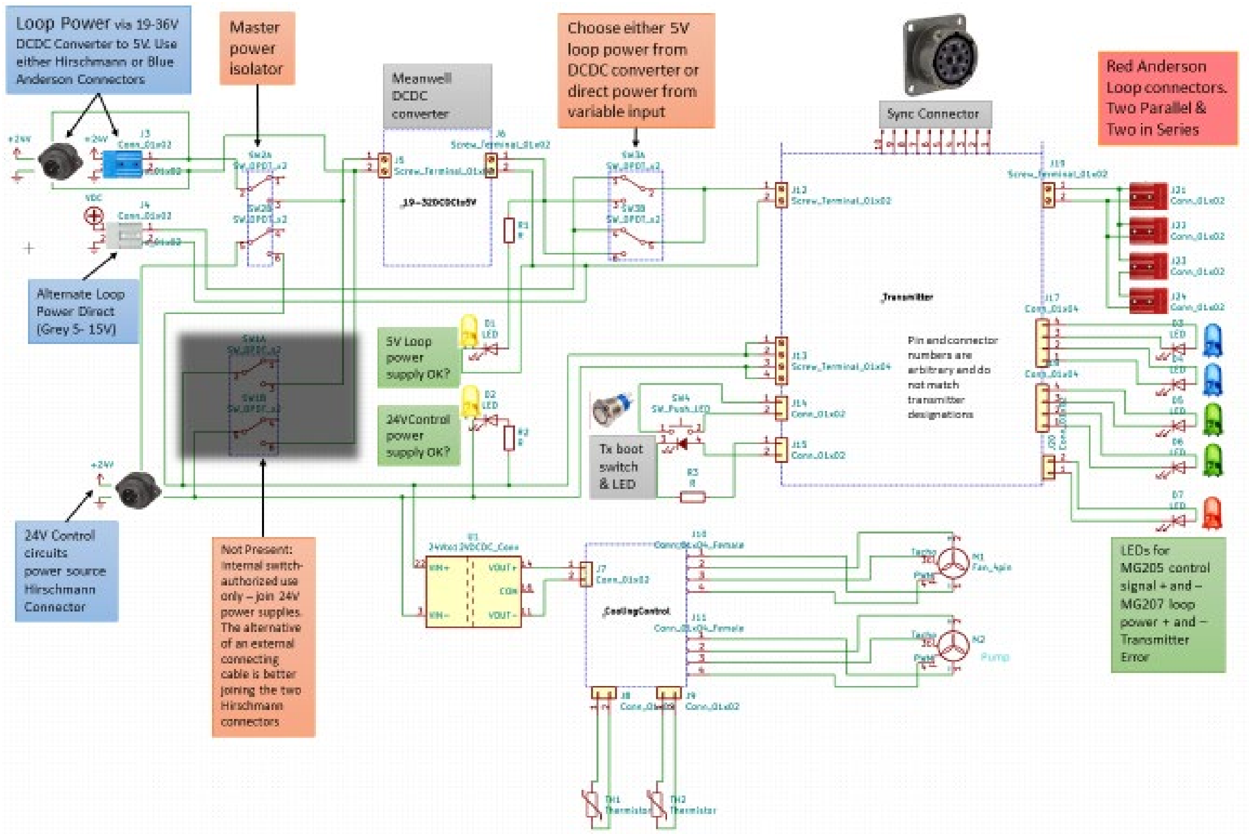


Figure 50 Illuminated transmitter boot button and master isolator switch. If both loop power and control power are connected then both Orange and Red LEDs will light when master power is turned on. Below them cooling performance is displayed but this must be observed from a lower viewing angle than in this photo.

The diagram below explains graphically the transmitter case connections discussed above.



TURNING ON THE WHOLE SYSTEM

There are a lot of parts of the system to turn on and boot up.

Unwanted behavior I hope is soon resolved by software revision is: **A mistake or failure in any one of the activation activities or sequence will lead to complete failure and requirement to restart the entire sequence from scratch. Starting some procedures before others complete will not work. Starting is a major achievement but once operational survey is simply a process of driving and observing. Much of this behavior is because the operating software booting also changes transmitter operation so software must reinitialize again if anything affects the transmitter or its cables or batteries and to do this it shuts down the receiver which must reboot before the operating software even starts to initialize. GPS connection further complicates the scenario.**

Startup procedure is as follows and should be strictly followed:

1. Ensure all batteries are suitably charged. In the photo below a small device is shown designed to check voltages of all the battery supplies fitted with Hirschmann connectors. Other checking devices indicating Amp.Hours and Watt.Hours of charge energy are supplied attached to the battery chargers and observation of these on a nightly basis is strongly recommended.

Figure 51 A small stand-alone volt meter that can connect to any battery prior to use to check it is OK and charged. LiFePO4 BMS may switch one of a pair of batteries off altogether while the other still has charge – the dual display will indicate whether both batteries are still OK to use without recharging. Each of the pair is charged individually so balancing problems do not develop.

2. Connect all cables required (each discussed in turn below).
3. If you have purchased large external 25.6V batteries then switch them on at their battery management systems – if so equipped.
4. With power connected to the transmitter for both Loop power and control power, two separate connections as discussed in a section above, turn on the master power isolator of the transmitter. In newer versions of AgTEM (aircooled in the 5000 size case), the two power supplies will be merged.
5. Momentarily press the transmitter boot button (on newer versions the button is on/of, not momentary). Note that if the receiver was turned on and booted first then the transmitter may get remotely booted as soon as it turns on. Bug: On earliest versions when the computer software later initializes it turns off the power supply to the transmitter boot button illuminator which is very confusing. You may hear a faint slosh sound as the coolant pump starts up and if you stick your finger in the radiator fan you can notice if it is spinning at idle – both are very quiet at idle. The cooling circuit display will sequentially show temperatures and fan/pump revolutions per minute/10. Initially both should show idling speeds and before spin-up occurs a small beep will be heard – the alarm that indicates if coolant flow has stopped.
6. Switch on the master power isolator switch in the receiver accessories case. If all cables are connected then power will now flow to: The Trimble GFX350, the external cooling fan, the computer power supply, and the receiver. Note that the receiver consumes a little standby power even if it is not booted up.
7. Boot the Trimble GFX 350 display using the green button on its rear and following screen prompts. Power and authorization codes are then sent to the GPS antenna through one cable and it will start transmitting GPS data to both the display, and external port on the antenna (12pin Deutsch) if authorized. Bug: early Trimble GFX350s need a firmware update before they will permit the antenna to transmit data externally – see the dealer for this as it is only available to them. Note that for quality DGPS data, prior payment and authorization with Trimble must be conducted before the GFX-350 will do its job.
8. Ensure a cable is connected from the GPS antenna to a serial port connected to the computer. Ensure also that cables lead from the computer to both USB and Ethernet ports on the receiver. In future it is proposed that the USB data will go via the Ethernet cable (or all by WiFi) and the USB cable will no longer be required. Intermittent USB comms has been a problem with AgTEM-electronics. Check that either you have charged batteries on the computer or power from the external supply or both.
9. Boot the computer, type user Pin 'agtem' (you will need to tap twice to get the touchscreen keyboard to show up). Wait for the Startup program to display a button 'Acquisition' but do not press it yet. If

you press it before the receiver fully boots up then errors will occur, shutdown will occur, and it is likely it will also shut down the receiver should it manage to boot in time.

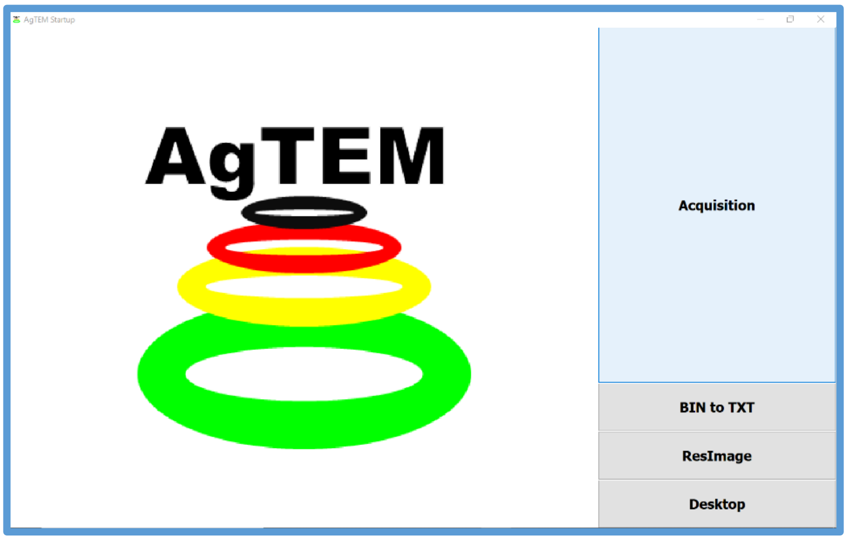


Figure 52 AgTEM startup screen. The windows task bar is hidden unless you tap the lower left of the screen.

10. Momentarily press the boot button on the Receiver – it will illuminate as green. Listen and a series of relays will eventually switch in sequence, then a beep will occur. Wait considerably longer. Two beeps in quick succession will occur. Only then may you proceed.

Figure 53 The receiver boot button

11. Press the ‘Acquisition’ button on the computer touchscreen. AgTEM.exe will start up and run through an initialization sequence. When it gets to initializing the transmitter, you will hear a relay in the transmitter click. When it finds data from the GPS port it will turn a box at the bottom of the screen green, displaying ‘eGPS Active’. If all goes to plan then the Parameters tab of the software will then

display.

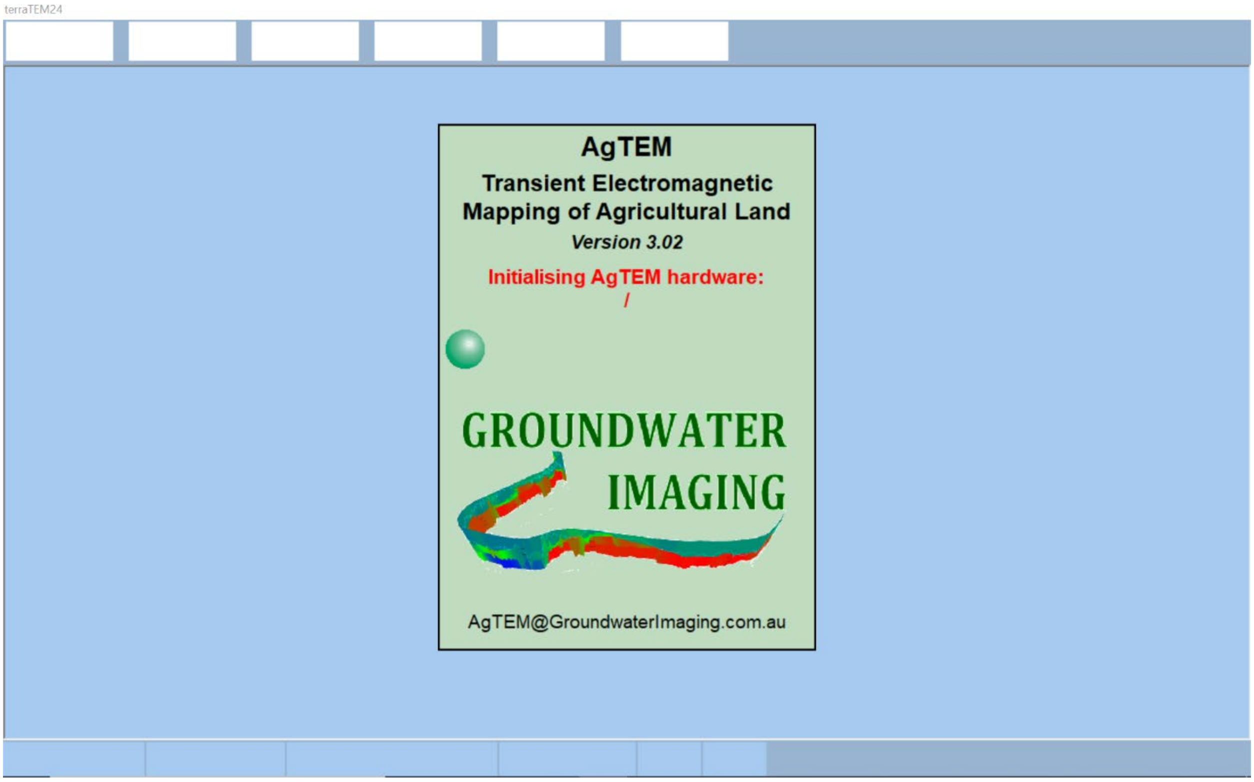


Figure 54 AgTEM.exe initialization screen

12. If all does not go to plan then the following may happen: If the receiver has not booted or is not connected then an 'Ethernet Error' will display – accept and the software will shut down, potentially shutting down the receiver as it does so. If the transmitter is not connected and booted, or even if booted then temporarily been disrupted or triggered an error internally, or if USB cable or Synch cables are faulty or not connected or USB port addresses are mixed up then you will be advised of a transmitter communication error (COM port error) and given three attempts to correct the situation before shutdown is initiated. If GPS is not incoming then the GPS interface will be deactivated but this can be fixed after booting completes. If the computer software manages to fully lock up then realize that tapping the lower left screen corner will bring up the taskbar and you can shut down the computer – but if you do it twice (such as by shaking slightly as you touch) then the task bar will disappear and you will have to tap elsewhere on the screen before you can try again. If startup does not go to plan then it is safest to turn the transmitter and receiver off and restart the relevant procedure again otherwise the transmitter or receiver may have triggered an error flag or other

situation that will prevent subsequent attempts at startup from succeeding.

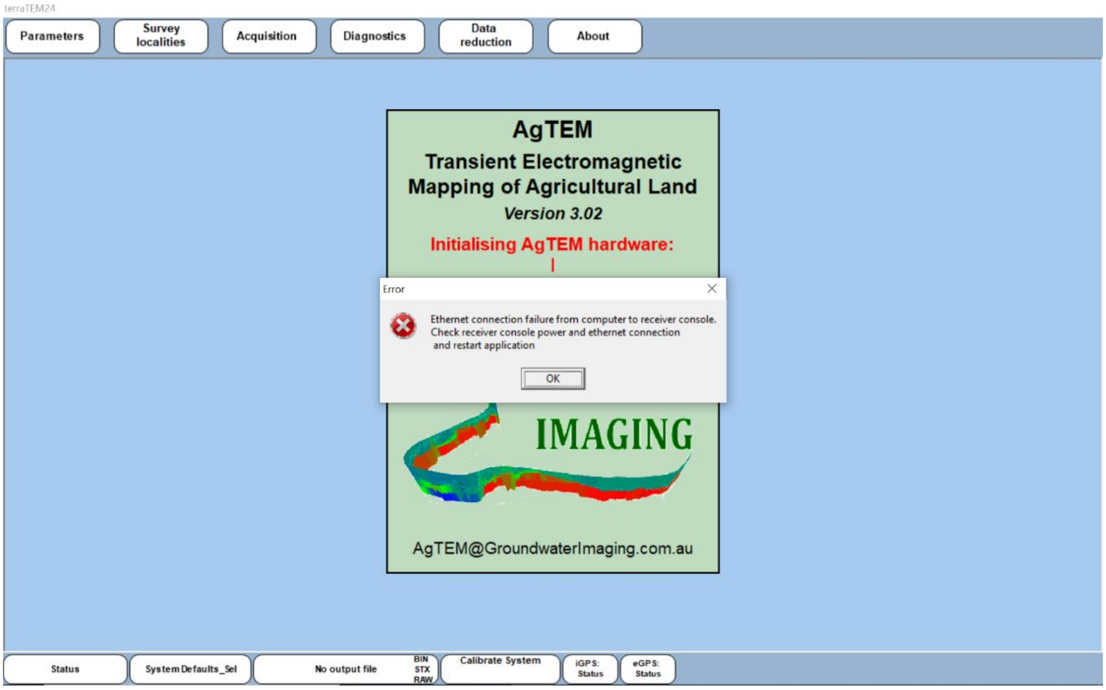


Figure 55 If the receiver has not finished booting before AgTEM.exe initializes then this error appears and shutdown follows.

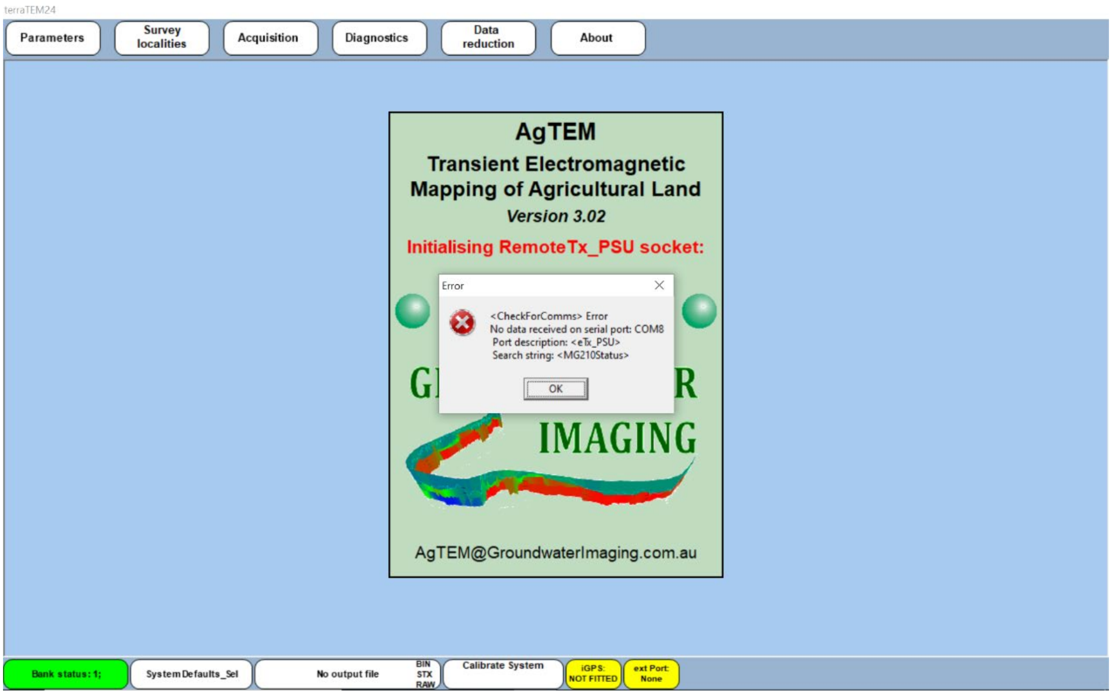


Figure 56 If the transmitter is not booted, has booted but then an error occured elsewhere and a restart attempted, or if USB connection or Synchronization connection or USB port assignment are faulty then this error appears.

13. Check the parameters screen to observe all parameters are suitably set for your circumstances. Recommended starting parameters are displayed below and others will be learnt with experience and by reading further. If you have the front loop connected then click the Chn 2 tab and turn its ‘State’ to ‘ON’ too otherwise just press the tab and ensure it is turned ‘Off’ or you will see spurious noise data recorded later.

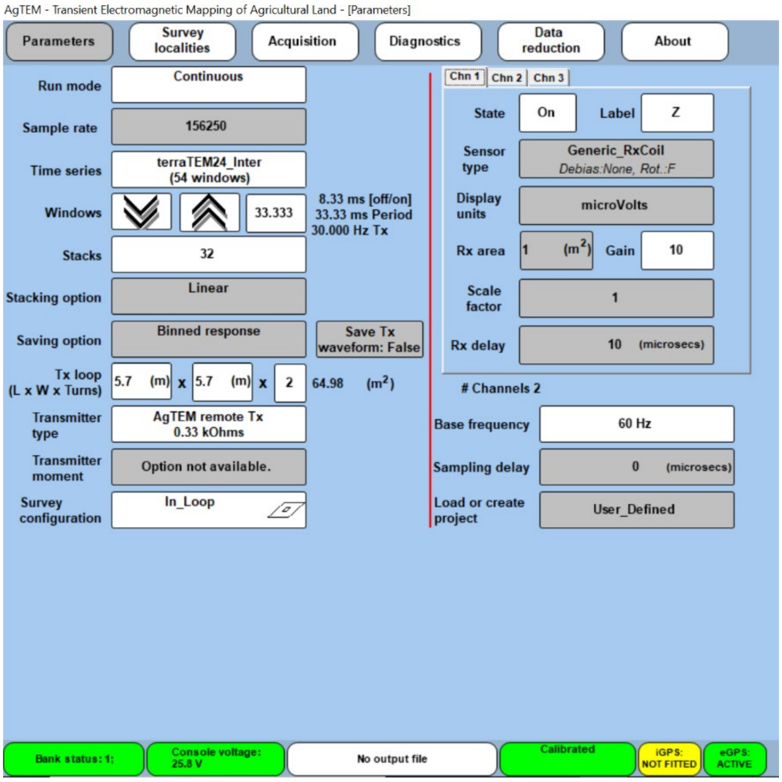


Figure 57 The Parameter screen displays once AgTEM.exe initializes. Displayed are recommended starting parameter.

14. Change run mode from 'Continuous' to 'Calibration' to conduct initial testing (unless you are sure of your setup).

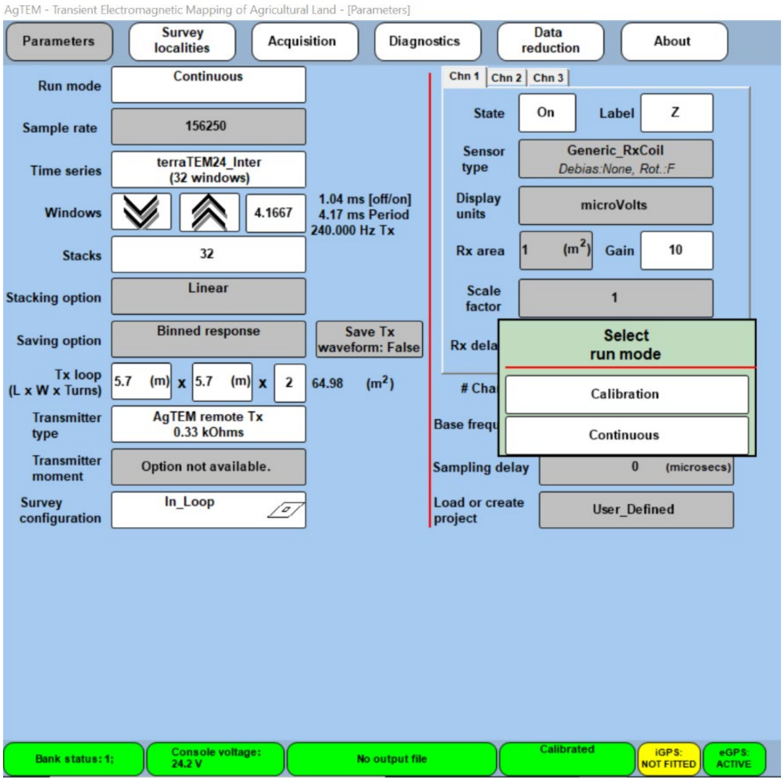


Figure 58 Changing from Continuous mode to Calibration mode changes what tabs and controls appear on the 'Acquisition' tab. The popup box is hard to notice so it is easy to think the system has frozen when actually it is just waiting for your response.

TAKING AN INITIAL MEASUREMENT FOR USE AS A REFERENCE

Once mechanical and electronic setup is complete the system should be towed to an area free of metallic interference in order to get a reference decay curve with which the rest of the survey will be compared. If at first this does not succeed then a trial and error approach will be required until a suitable site is found. Take a few readings at the site to confirm stability and lack of overprinting noise. This is achieved using the following steps:

15. Touch the ‘Acquisition’ tab.

Figure 59 The Acquisition tab in 'Calibration Acquisition' mode.

Figure 60 The Acquisition tab - in 'Continuous' mode. In contrast to 'Calibration' mode, notice that 'Full Waveform', 'Data', and 'Current Waveform' tabs are absent and 'Setup' tab is added. A location box now also is present along with display of volts of the receiver battery.

16. After checking you have the receiver loop connected, LEDs at the receiver displaying that both the + and – 15V power supplies are present, and the transmitter loop connected, press 'Loop Parameter' in calibration mode or 'System Parameters' in Continuous mode. Measurements will occur and the parameters at the left of the screen will fill or an error will appear indicating why measurement cannot occur – either the transmitter loop is open circuit, shorted, or power supply is not adequate.

Various other messages may occur – if very small currents are transmitted such as when putting 5V through the test loop then a warning that current varied more than 30% may be ignored. Similarly if putting high current through a loop at high repetition rate then the same warning may appear but this time it is worth taking notice. Other errors may occur if connections or transmitter control power are compromised – BUG – in older firmware versions, once this occurs even instantaneously then the errors will never leave until full reboot of all parts occurs. Check the values are as expected.

17. Press Acquire and measurement will occur. Below is data resulting from pressing acquire twice measuring with the 300x300mm test loops and an aluminum plate acting as a conductor.

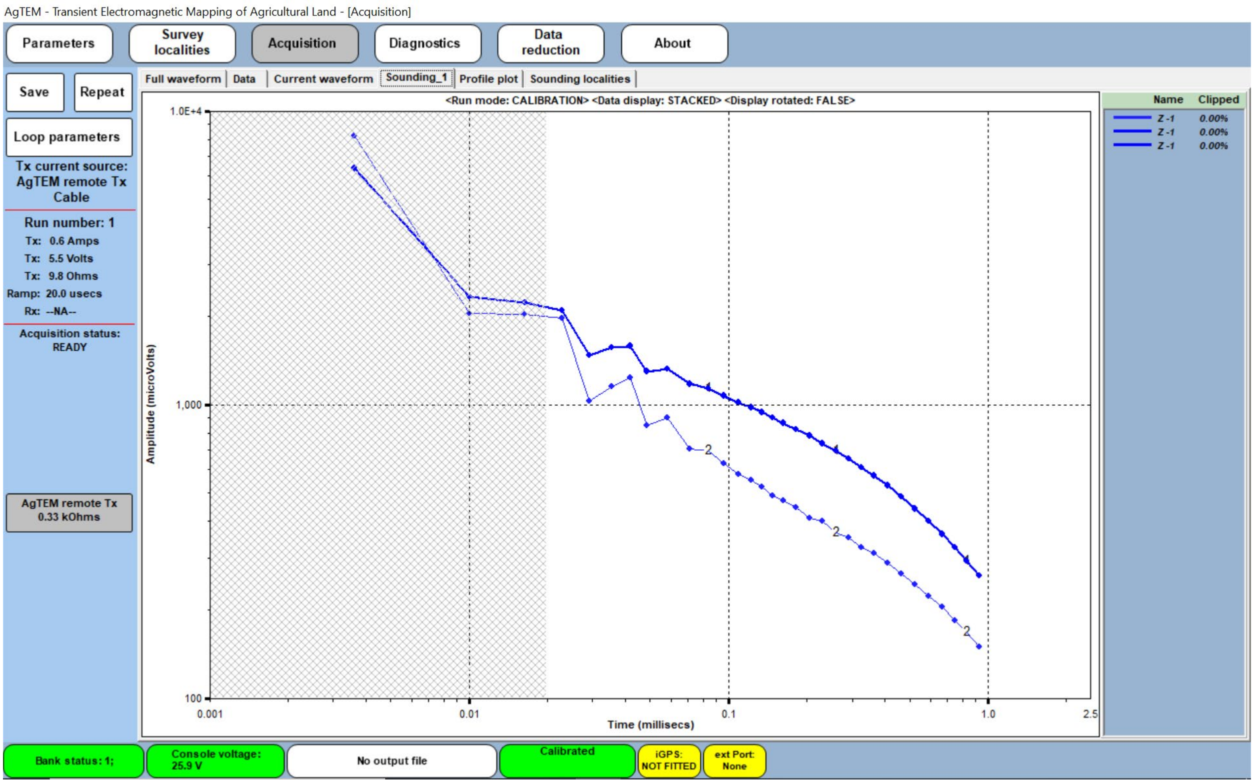


Figure 61 Two soundings recording the response of the 300x300mm test loops with an aluminum plate at different offset. The ramp displayed is not correct as current is too small in the test loop for practical ramp measurement in apparatus optimized for large currents.

18. Pressing 'Repeat' is a good idea to test that data is repeatable. Do not necessarily bother to save at this stage – you are just testing for functionality at this stage.

SURVEY PARAMETER ADJUSTMENT

It is only at this stage, or shortly after, if survey is to start again after some initial travel, that survey parameters may be set. Number of loop turns, transmitted current, decision on whether to run on-cart and/or off cart slingram receiver loops, decision on whether to run dual moment operation and the like must be decided at this point.

Expert input at this point will often make the difference between success and failure of a survey to achieve its objectives.

19. You typically will start right near the metal float trailer so drive the Wallaby a little, making sure to move away from known metal objects and buried services and test for repeatability again. Being at least 50m from the nearest fence is a great idea. Now repeat acquisition again and look for changes.

At a conductive site you will see a strong decay but at a highly resistive site like in the example below you will see only the oscillating zero crossings of the system response. It is important to have read the chapter of the manual on ‘Observation’ to make good sense of data obtained and to check that initial setup is done to suit characteristic data for the location rather than spurious or anomalous data.

20. Now is the time to decide, or have decided, how many loop turns should be used in the transmitter loop and how many parallel wires per turn. You will also need to decide how many turns to use in the receiver loop, whether to invoke the pre-amp, and if it is appropriate to also attach and use the front loop. We recommend you start with 10 turns in the receiver loop and the pre-amp invoked unless you are knowledgeable and experienced. The front loop should not be used in production unless extra reliability of processing and interpretation is warranted at greater cost per kilometer. For shallow or resistive survey optimization please start with a single turn loop and either 1 or 2 parallel 4mm^2 wires depending on if you also want to optimize for deep imaging or battery longevity. For deep exploration in conductive terrain use two parallel two turn loops. Look at the ‘Configuration’ chapter of this manual to understand further your choices of configuration.
21. Flick to the ‘Current Waveform’ tab to check that you are adequately transmitting at your selected repetition rate. Cross back and forth to the ‘Parameters’ Tab, conducting more test sounding if you need to make changes to either ‘Base Frequency’ (to match your country’s power line frequency) or ‘Windows’. Choosing a faster repetition rate will help acquire more data to stack for quality improvement but could clip off your deeper signal or require that you use less than optimal current. Using a longer base frequency will allow post processing to sample signal-free gates to model and reject stacked movement noise – this is particularly useful if driving over undulating ground such as ploughed paddocks or grass tussocks.
22. In parameters number of stacks generally should be 32 to 64 is 33.33Hz as this will give data generally at about 10m spacing.

COMMENCEMENT OF CONTINUOUS MODE ACQUISITION

23. With a reference sounding selected, select ‘Continuous Mode’ under the ‘Parameters’ tab and go back to the ‘Acquisition’ tab. Test ‘Loop Parameters’ then press ‘Acquire’ – a filename will then be requested and continuous mode may be commenced. File naming convention recommended is ‘yymmddfffffff.bin’ where ffffff is a site descriptor and the rest is a date that will auto-sort in directory listings. From this point on, acquisition is started and stopped using the pause button until the operator decides to press stop or the system is stopped another way such as running out of battery power. Data is continuously saved during acquisition. Files can be appended if stopped – when this is done then existing data is pre-loaded into the raster display so you can carry on navigating from where you left off should you have been stopped for a battery change or similar.
24. Watch data start to stream in, checking for repeatability. If it is suitable then press ‘Set reference sounding’ and a firm curve of the last acquired sounding will permanently overprint the display until you choose to clear it or replace it. This is critical for observing subtle features in the ground as you travel along.

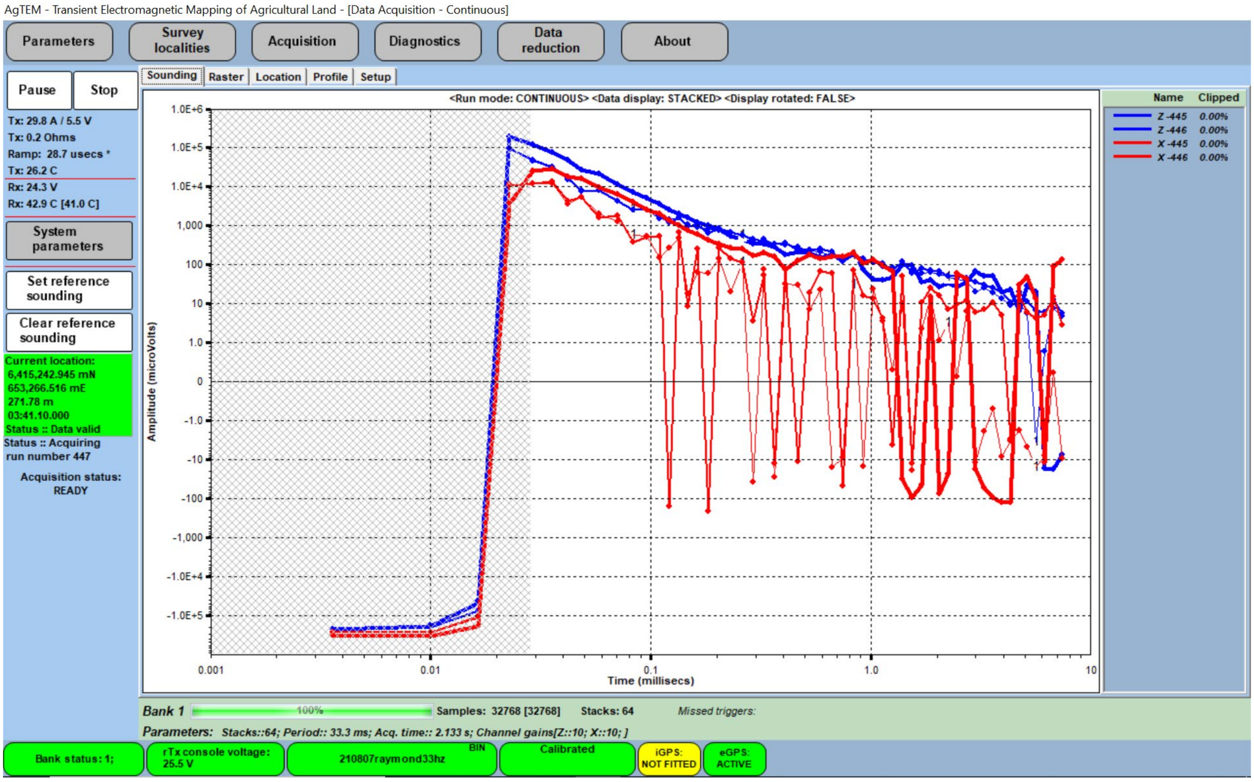


Figure 62 Display of soundings with acquisition commenced. The blue is in-loop data and the red is front loop data. Firm curves are the reference soundings. Each component is presented along with one repeat. This is a very resistive site so data is almost completely noise rather than signal from the ground. The display is scaled to make data look as poor as possible as this is what is done when conducting quality control. The zero crossover is enhanced so that ripples of noise dominate the display.

TRAVELLING AROUND

Selection of a travel route requires careful thoughtful balancing of logistical observation, planning ahead to ensure a continuous route is possible without backtracking, reaction to observations of noise and travel restrictions such as gate locations, and geological consideration. Geological considerations are most important and for this reason it is most appropriate for geologists to be at the controls. There is no point going out and surveying blindly and only a geologically trained person will be able to recognize what is to be observed underground. They will watch the data continuously as it is acquired and continuously refocus survey in order to cover geological targets appropriately and efficiently. In most cases the geology observed will be a surprise such that forward planning will not be a solution. Of course a novice operator may be instructed to simply infill a grid at a dense spacing if terrain allows but in most cases survey logistics and break even costs will not facilitate such blanket dense coverage.

25. Periodically switch tabs to 'Raster' to observe map based data. See the example below.

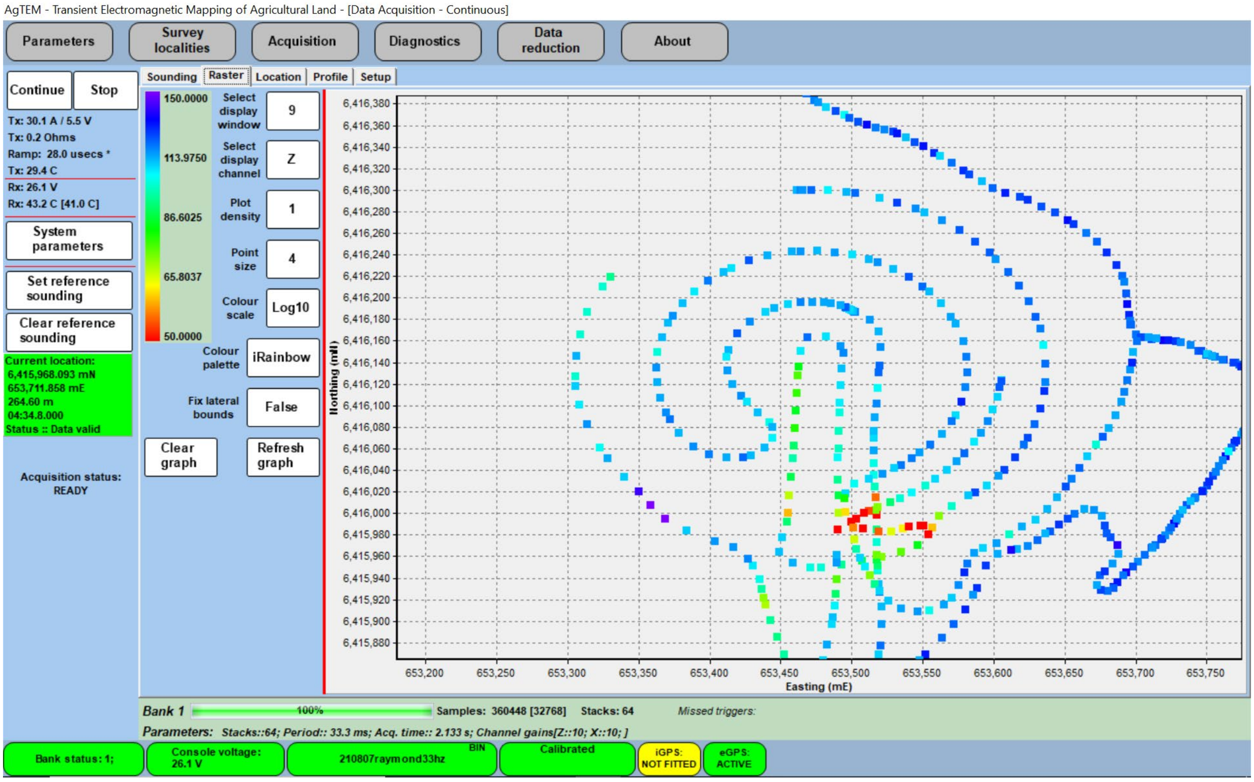


Figure 63 Real time map based display reveals features as driving occurs so the driver can check for adequate feature coverage, check for repeatable crossing of features of interest, and disinterest such as buried services crossings and navigate appropriately (if external navigation is not in use).

26. After a while, the automatic raster color scaling will get sent askew by crossing of a feature such as a road culvert. At this point it is necessary to press ‘Pause’ to activate the raster parameters adjustment capability. To change the color scale to a manually limited range you now need to double-tap on the color bar. A histogram is displayed and you can select limits that exclude outliers. See the example below.

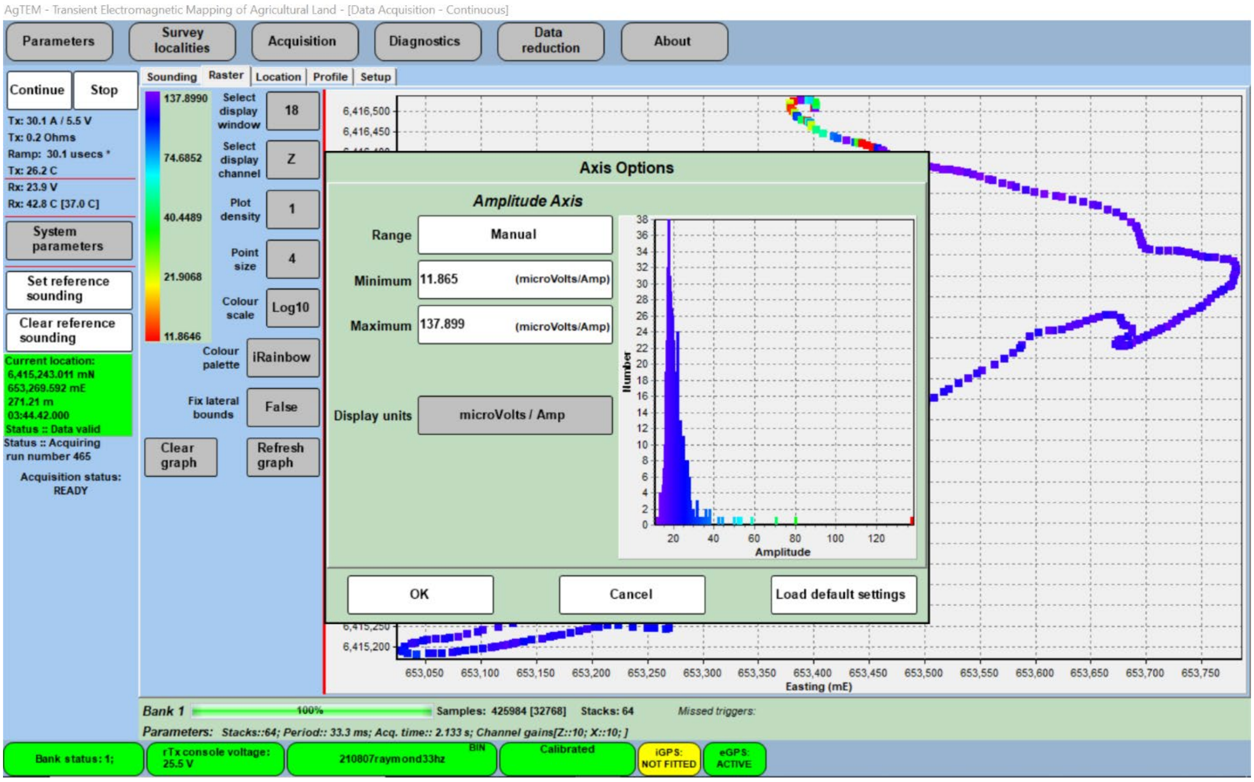


Figure 64 Changing the raster color bar to exclude outliers.

27. Display window and Plot density may also need changing to reveal the features you find most appropriate and to balance update speed with comprehensiveness of coverage. Points will be plotted at a density of 1 point per sounding until a redraw is required but after redraw the density will become, in the case above, 1 point per 4 soundings. Only a fixed number of points will be displayed so as to keep update speed manageable and efficient so choosing a larger number for plot density will allow you to plot a longer history of acquisition. You may change point size to approximate your desired point or line spacing at the scale of the display to help with line-to-line navigation. Once you are pleased with your parameter selection then press ‘Continue’ and recommence driving.
28. Make sure you observe the sounding tab most of the time while driving, or frequently cycle back and forth with the raster tab. The sounding display is crucial for observing more subtle problems so you can quickly stop or change direction or procedure to resolve or improve matters. If the sounding display is not adequately scaled to make suitable observations then press ‘Pause’ then double-tap the sounding display and adjustment parameters will display as shown below.

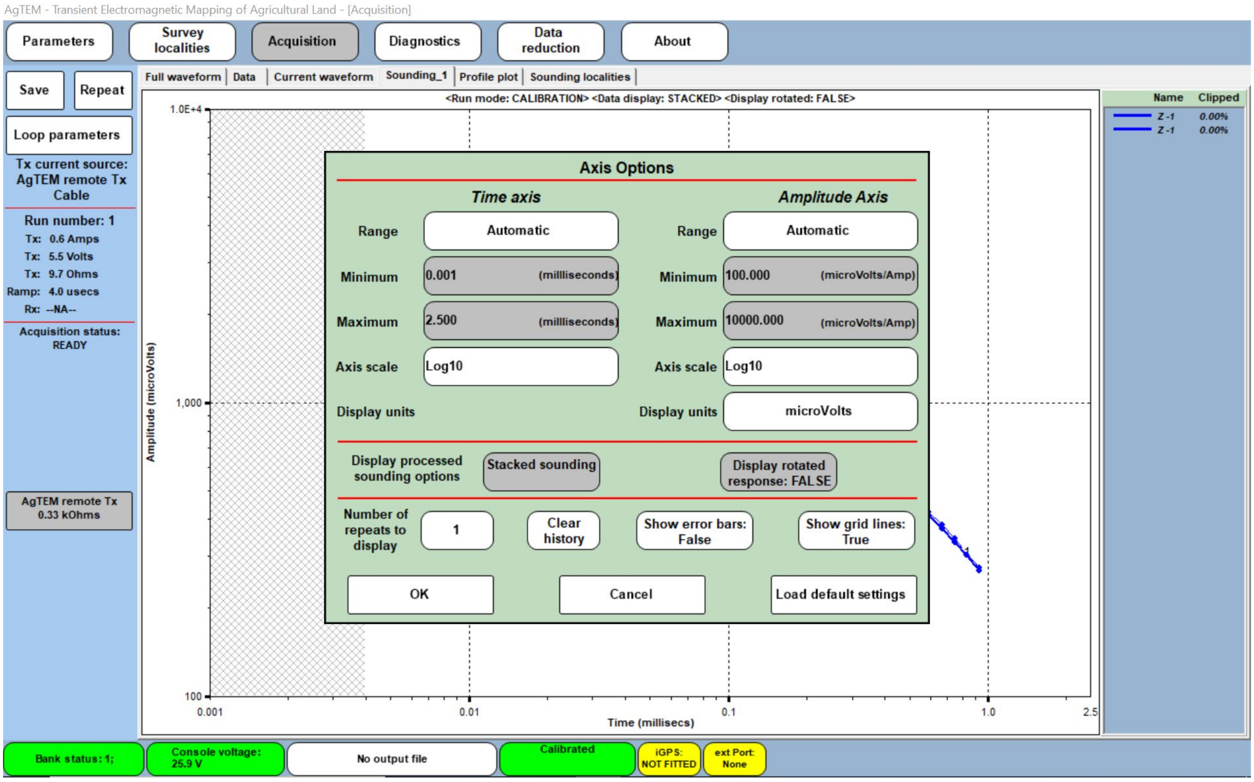


Figure 65 Sounding display parameters adjustment

RETRACTING BOOMS TO PASS THROUGH NARROW GAPS

Side booms are held elastically in place. They can brush against tree branches or trunks and then spring back into position as one drives along. Most tree branches will not be problematic but ones which branch at right angles or broken off stubs of branches on tree trunks can catch on rigging and tear parts off. For this reason, heightened observation and rapid response is recommended when brushing trees and weak joins are installed at boom tips. Even better operation is possible if either a person walks behind and manually retracts booms or the remote boom retraction rigging is installed so the operator can retract booms from the driver's seat.

Booms are mounted such that they clear vegetation up to 1.8m high without retraction. Similarly, expect them to clear most gate posts should careful driving occur.

In traffic, if survey is not required, booms are retracted to prevent collision with passing traffic. Wide load flags may be added should survey need to occur in traffic but permission must also be sought from relevant authorities. An intermediate strategy involves travel with booms retracted but with frequent moving onto road reserve margins (away from telephony cables and other problems) to extend booms and collect data.

TAKING A SYSTEM RESPONSE MEASUREMENT

AgTEM cannot be lifted 1km into the sky like airborne EM systems in order to detect a system response regularly. System response has a tendency to drift and change with modifications to hardware and parameters so it needs to be repeatedly measured. Again this is a job best attended to by an expert upon job initiation. The operator normally drives around until a most resistive site is found free of complications. The system is then made stationary and data stacking continues for a few minutes to minimize noise. This is normally done within the continuous acquisition mode and the relevant soundings are later extracted in processing. If the site is suitably resistive then it alone can be used as a system response. More frequently, it may be partially used (for early channels) with a tail from a stored response or it may be used with a modelled response, obtained independently with other technique such as DC ERT, subtracted away from it to give system response.

TIE LINES

It is important practice to add tie lines to a survey where every while a site is revisited to check for drift. Ideally this will involve one perpendicular line across many parallel lines but fences and obstacles tend to make tying data together more complicated. Tie lines are most important on fine spaced surveys where very fine changes are being mapped and it is on such surveys that they are easiest to obtain. On broad regional surveys they may not be obtainable but neither are they so important.

Tie lines may be used just as a check on data integrity or may be used with drift correction tools to repair drifted data in post processing.

Whenever a major change occurs in acquisition such as stretching of parts by tangling and hooking with a tree or gatepost a check on data shift/drift is important along with notification of the incident to the processor. Datasets with undetected drift are certainly worth avoiding.

CEASATION OF CONTINUOUS MODE OPERATION

29. When survey is finished simply press ‘Stop’ on the continuous mode acquisition screen. In cases where batteries have failed, overheating has occurred or other faults have occurred continuous mode of operation may have alternatively been ceased automatically.
30. If batteries went flat or a cable became detached then a restart is necessary – restart all parts of the system as before but when reaching the point of starting continuous mode and selecting the filename, then select the file you were acquiring before and then select ‘Append’ so you can carry on where you left off.

SAVING STORED DATA

31. Data is saved to a USB drive at the end of the day using the file button in the footer of the screen. One must first fix a USB thumb drive to a USB port of the computer or a connected hub and wait for drivers to install. The save screen is shown below.

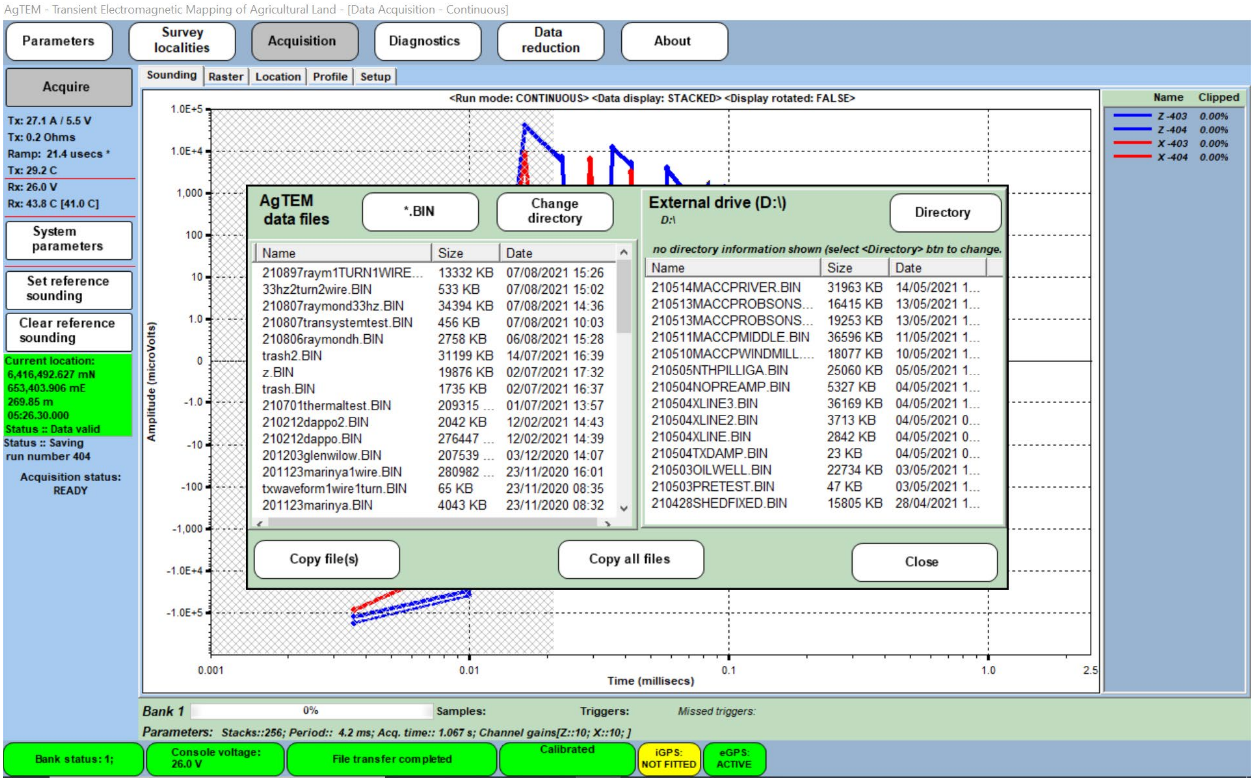


Figure 66 Saving data to an external drive - access via the green box at the bottom of the screen that, in this case currently, says 'File transfer completed'.

32. Data is saved to a *.BIN file. This is a Monex propriety format without disclosed documentation. Pressing the ‘Data Reduction’ tab will bring up BINtoTXT.exe to allow for file conversion to a readable TXT file. These and other files are extracted from the computer via normal Windows explorer access but this is normally not done – instead BINtoTXT is normally run on a processing computer back at the motel or office. **By taking the data off the AgTEM-computer and processing on another computer you are backing up the data. This is a really good idea.**
33. File conversion uses the temporary BINtoTXT solution at present, creating a TXT file which then is converted to a DBF file in ResImage. The TXT file remains as raw data storage should processing need restarting from scratch. A version of ResImage is accessible from the Startup menu on the acquisition computer but may not be an up to date version – it will facilitate basic processing and imaging suitable for field data quality control for survey planning and initial display for clients.
34. Shut down the computer, turn of master power to the transmitter and to the receiver system. The computer task bar is hidden and only appears if you press near the bottom left of the screen (or elsewhere on the bottom of the screen but this will start whatever you invisibly press upon so use the lower left). You may now select shutdown. Pressing the Green button on the lower left of the display will alternatively bring up a menu where you can select shutdown (but you will still need to shut down the computer as only the software and receiver will shut down).
35. At this point, after perhaps 10 hours of continuous driving over rough ground, expect to feel disorientated and very tired. The high concentration driving is tiring. Pack up and charge batteries. Do not expect to be able to keep this up for many days at once without rest days. If you do it will be counter-productive as mistakes will result. A driver swap procedure is recommended for big jobs.

PACKUP ONTO QUICK DEPLOYMENT TRAILER

A much more effective business model is possible where quick deployment is possible. This enables conduct of small jobs and disjointed jobs that otherwise would be unaffordable.

The quick deployment trailer has a roller track from the rear to up over the towing vehicle and allows AgTEM-Wallaby to be hitched on at the rear of the trailer and simply winched up onto the trailer without use of ramps.

The following procedure will typically take **one person** about **15 minutes**:

1. Fold side booms against side of trailer and tie onto the top side members of the core using clove hitches in the retraction pulley lines. The clove hitches will not come undone while tension from the elastic straps keeps them tight.
2. Remove the tailgate and drop it at the rear of the trailer.
3. Line up the AgTEM-Wallaby with the trailer and detach from the tow vehicle. Remove the towing vehicle and hook it onto the float trailer. Do all the routine safety checks – tow hitch is properly clicked on, safety chains are on, electrical connections are made, and the jockey wheel is lifted up and secured.
4. Lift the AgTEM-Wallaby tow hitch onto the tow ball on the rollers on the rear of the float trailer. Ensure the hitch clicks over the ball and locks on. The tow hitch fits both 50mm (Australian) and 50.8mm (USA) tow balls. Warning – the **hitch weighs around 50kg**. A chain loop is provided to allow a direct lift – take care to lift in an ergonomically safe manner.
5. **Ensure you remember to** use electrical tape to **bind all connectors** very well onto firm members so they are not destroyed by whip lash action during road travel.
6. Using the float trailer winch, taking advantage of the different gear ratios, winch the AgTEM tow hitch, ensuring undercarriage slide pads guide correctly onto the sloping skids on the trailer, right up the roller track to the stop at the top. Reach up and slide in the securing pin. Secure the winch handle.
7. Tie down each side of the undercarriage using the tie down straps provided.
8. Rear booms remain fixed behind AgTEM but are now more accessible. They are left on until this stage as they make weight distribution better, during lifting, and they make packing easier if left. For short distance travel it is possible to simply tie the side booms to the center boom and drive with care and oversize signs. Most times, however, one must detach the rear three booms at the elastic tendons and slide them into the long tube on the trailer.
9. With booms in the long tube there remains a lot of cables and rigging which should be lifted into the upholstered tray on the trailer. Stretch the tarpaulins over the straps. Using electrical tape, tape cables and rigging hanging down from parts like the side booms to the rear of the core of AgTEM-Wallaby.
10. Re-attach the tailgate.

PACK-UP ONTO AD-HOC FLOAT TRAILERS OF OPPORTUNITY

AgTEM-Wallaby is very long and does not fit onto car trailers easily. It is possible to make the essentials of the quick deployment trailer out of Unistrut track and rollers and other steel (either Unistrut bolted or simply 40 x 40 mm box section welded) and to bolt it onto a car trailer. If this is not possible, the next option is typically to un-winch the AgTEM-Wallaby drawbar and to drop the AgTEM-Wallaby core down on its front, then lay the drawbar beside it. There will be many parts to tie down and chaffing damage is very likely. This practice is strongly not recommended but if attempted please purchase much padding and use it.

PACKUP INTO THE AGTEM-WALLABY SHIPPING BOX

In contrast to use of the quick deployment trailer, packing AgTEM into the dedicated shipping box will take one lone person about 2 hours.

AgTEM shipping box is of a clam shell design.

The box is good for commercial freighting and will fit the entire AgTEM-Wallaby and accessories, as well as the front loop and booms, into one double palette sized box (1164mm wide x 2228mm long x 1444mm high; 45.83"Wx87.72"Lx 56.85"H). This box is also sized and 'contoured' for use with airfreight unit load devices.

When packing for airfreight particular caution needs to be taken when packing batteries. AgTEM typically uses LitFePO4 batteries classified as miscellaneous dangerous goods. Large LiFePO4 batteries require very particular packaging and documentation and generally cannot travel by air so AgTEM is designed to alternatively, and effectively, work using numerous <99WattHour batteries. Up to 20 can be carried as hand luggage when suitably isolated and packed and a full day (8 hours continuous transmission using the 24V to 5V DCDC converter) of AgTEM operation will use between fourteen to eighteen 12.8V 7AmpHr LiFePO4 batteries depending on current transmitted. Such batteries should never be sent as airfreight within the dedicated shipping box. **When airfreighting, always make separate arrangements for batteries as this is how the system works**.

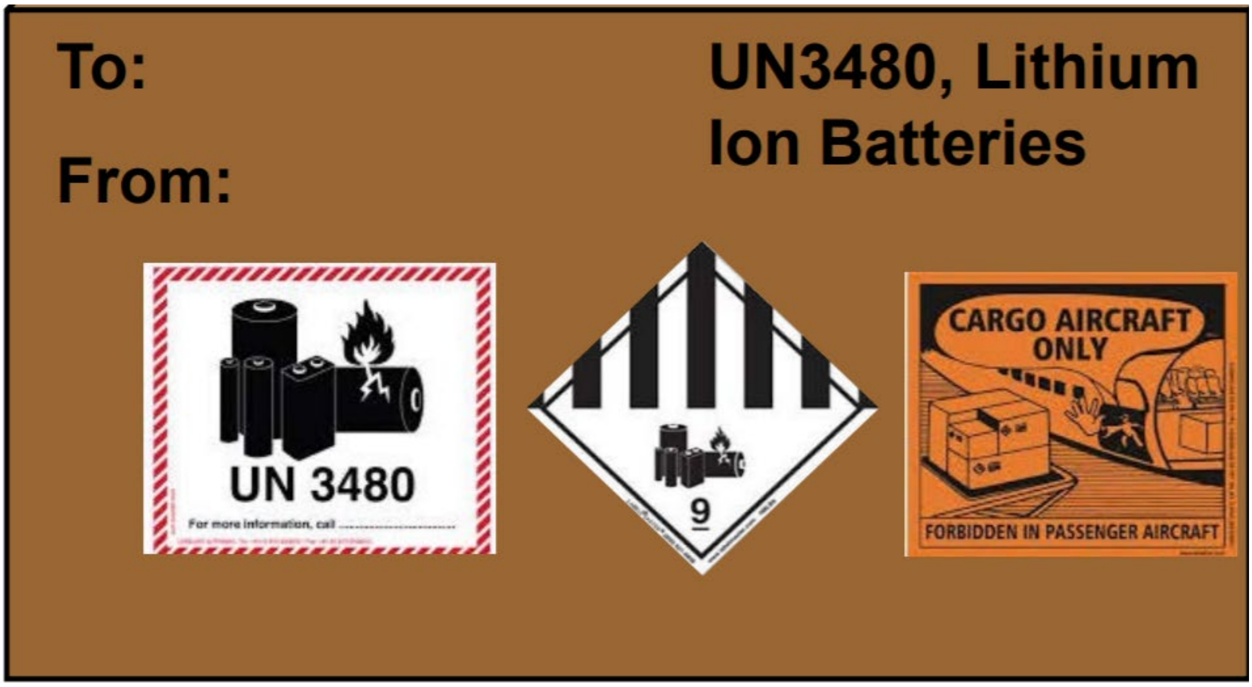


Figure 67 A sample of Lithium Iron Phosphate Battery packaging for commercial freight. Avoid the trouble of this packaging if possible by using <99Whr batteries carried on board aircraft as luggage instead. The above labels are used with dangerous goods declaration 3480 PI 965 IB and either MSDs or 'Lithium battery test summaries'. If carried as luggage all this paperwork and related fees can be avoided.

The front loop and booms also fit in the shipping case.

Package of AgTEM Wallaby into the shipping box is as follows:

1. Detach the shipping box side tarpaulins, first undoing press-studs and then sliding along fixing tracks. The gas struts will then lift the clam-shell-type lid giving access to inside and allowing the 4 upright posts to fall from their upper guide holes in the lid and tilt outwards. Lift the 4 upright posts from their lower guide holes and place them aside.

2. Before adding any weight to the box, decide where you want it to end up and how you will get it there. It is practical to load AgTEM-Wallaby even when the box is situated on a trailer but it sure is not practical for one person to lift once it is full. Rolling and sliding the core up into a box on a trailer is easy to do.
3. Place AgTEM-Wallaby with the hitch facing the open rear of the box.
4. Remove the transmitter.
5. Detach the transmitter loop and roll it up. This is not essential but is practical.
6. Disconnect the elastic straps attached to the drawbar tensioner.
7. Remove and telescope down all the booms – note they can remain attached to rigging if you prefer. Note the black recessed dots at the telescoping joins (see photo). They make re-aligning to re-insert pins easy.

Figure 68 A recessed black dot aligns with the telescoping fixture seam to make re-aligning pins easy - booms should be extended to precise lengths for AgTEM requirements (including mutual inductance nulling) but generic ability to extend further exists.

8. Support the front of the core (use a short step ladder, similar object, or simply an assistant holding it). Using a winch handle from the accessories bag, locate the winch on the drawbar tensioner and un-winch the tension off the drawbar rigging (Do not detach individual rigging ropes from the tensioner – they conserve fine adjustments and do not need detaching). The AgTEM-core will fall forward onto whatever support you provided. Now remove that support and lower the nose of the AgTEM-core to the ground.
9. Detach the drawbar from the core by lifting off the tensioning tendons at the pivot point.
10. The airbag assemblies are held onto the AgTEM-core by two pins each and two threaded rods each. Undo the nuts off the threaded rods carefully – understanding that fiberglass nuts do not accept the same torque as equivalent sized steel nuts). These nuts are simply there to prevent misalignment of rods above the airbags should the Wallaby ever become airborne, otherwise detaching from its suspension.
11. Break apart the drawbar segments by removing 12mm pins that keep it together. Slide off the drawbar tensioner, leaving all the rigging attached except the two winch ropes and two elastic cords, and lift the whole lot onto the tray in the front of the AgTEM-Wallaby core. Note the black recessed dots that help with alignment when you later put the drawbar back together.
12. With the AgTEM-Wallaby core tilted onto its nose so weight is taken from the undercarriage, pull the four 12mm pins out of the tops of the wheel assemblies and slide each wheel assembly outwards so the pivot bars come out of the AgTEM-core and the suspension support bar falls out of one of the

wheel assemblies. Lift the suspension support bar away from the other wheel assembly and lay it on the ground.

13. Now you are left with draw bar segments, the AgTEM-core (on its nose and with booms optionally attached by rigging), a suspension assembly, a transmitter loop, electronics, cables, batteries and two wheel assemblies.
14. Lift, roll, or slide the core into the shipping box. Slide it in across the padded base of the box and push it right to the front.
15. If you are packing the front loop then rest it on top of the core, in the box, now.
16. Lift in all the parts as per the packing photos on the underside of the clam shell lid, using the designed supporting structural aids to facilitate safe placement. The wheel assembles and their support structure are bulky so should go in first – be careful how you support the weight as you lift it. Booms can be lifted in with rigging attached if desired.
17. Replace the four box support posts and pull down the clam shell lid against the gas struts. Beware of pinch points near the clam shell hinge and ensure no rigging gets caught in there as closing occurs. Guide the tops of the four posts into their upper fixing holes as the lid is closed the last few centimeters.
18. Slide and press-stud the box tarpaulin back onto the box. Beware: if the press studs cannot be aligned precisely due to being stretched away by the tight fabric then they cannot be pressed on even if hit with a hammer; - the trick is to press sideways on the press studs using a blade screwdriver so that they align before attempting to press downwards on them.
19. Separately pack the batteries, (typically as either hand luggage or miscellaneous dangerous goods) if using commercial freight services.
20. The box should be used with a wooden pallet. Forklifts can use the 60mm cavities beneath but the standard forking cavity is 90mm and this may be expected by freight companies – failure to add a wooden palet beneath may lead to damage by forklift tines.
21. Strap the box onto the ute tray, trailer, truck or other facility and drive away.

BATTERY CHARGING

Provided with AgTEM are 7Amp 25.6V LiFePO4 battery chargers. Batteries are used with connectors and cables that connect them as pairs in series or pairs in series of pairs in parallel. One particular connector type is dedicated to these 25.6V battery configurations and is also attached to the chargers so it is not possible to charge the wrong way. Care should be taken however not to un-pair matched age and charge batteries. Should pairs get unmatched then occasional maintenance charging of the individual batteries can be conducted with 12.8V LiFePO4 battery chargers.

Charging of alternate larger capacity batteries (or cells, as may be used in AgTEM-Wallaroo) is not documented here other than to say that 30Amp 12.8V LiFePO4 chargers are available.

Chargers provided have coulomb counters (observing the energy replaced in each charging event). Be careful to note down the replaced charge every morning after survey to ensure energy management is going to plan and to ensure you get an understanding of what energy you are using and how much reserve you have left. This simple observation is invaluable to efficient survey planning and battery maintenance.

NIGHTLY DATA ASSESSMENT AND CLEANING

AgTEM data is stored in a MONEX proprietary binary *.BIN file and needs conversion to a generically readable format using software BINtoTXT.exe provided.

Each night data downloaded should be displayed as a map of colored raster dots for various time slices in the ramp, in the range of data from the ground, and in late times where only effects like metal artifacts, electric fence pulses and excessive loop movement noise dominate. This can be done in either ResImage.exe provided or a generic mapping/plotting package such as Golden Software surfer. ResImage quickly facilitates plotting of colored raw voltage data raster worm images on Google Earth that load onto mobile phones and can be viewed the next day on site by yourself and/or your client to identify causes of features displayed related to features that can be observed on the ground.

Observe, particularly, any tie lines and other data crossings, especially in gates within the ramp. Check for data shifts and drift by doing so.

Also check for correlation with distance off fences to ascertain fence effects.

Decide if adequate quality data has been collected and spot any areas that could do with extension or added detail.

There is much more processing to do – this is just what is adequate to keep quality control happening during a job.

Repeating: By taking the data off the AgTEM-computer and processing on another computer you are backing up the data. This is a really good idea.

OBSERVING THE DATA DURING ACQUISITION

UNDERSTANDING TEM DECAY CURVES AND IDENTIFYING NOISE

Each sounding is presented as a decay curve after it is acquired. Observation of the decays is critical to successful survey. Almost all problems will be evident in the decay curves immediately. Sources of noise and interference will be observed such that the driver can adjust route to avoid further affected acquisition. Each geological feature encountered will be evident but deeper features will be hard to pick until post-processing is complete.

TYPES OF NOISE AND INTERFERENCE

Noise is fluctuating signal from non-geological sources while interference may be the response of metal objects or insulated cables.

Noise sources are independent and unresponsive to the AgTEM transmitted signal so they are not observed decaying in synchronization with the TEM decays. Bunching of time bins of the decay curve will however result in different aliasing and harmonic behavior with in different parts of decays should the noise be regular.

Noise sources:

1. Above ground power lines
2. Operating electric fences
3. Single line earth return power such as electric train lines
4. Natural – especially during thunderstorms
5. Underground power lines
6. Deep underground mine power lines.
7. Automotive circuits
8. VLF – Natural and Submarine comms.

Interference sources:

1. Telephony cables
2. Insulated underground power cables
3. Long electric fences – not necessarily operating
4. Well grounded wire fences (especially netting)
5. Railway lines
6. Buried metal objects (point sources)
7. Buried insulated metal pipes
8. Adjacent metal objects (point sources)
9. Underground mine metal objects
10. Conveyor belts
11. Concrete reinforcing (metal bars)
12. Concrete reinforcing (chopped strands)

RESPONSES NOT RELATED TO ELECTRICAL RESISTIVITY

Decay curves are affected not only by electrical conductivity but also by inductive and super-paramagnetic effects of geological bodies along with some less well known and observed phenomenon. These extra effects often provide influence similar in magnitude to system response and can be wrongly assumed to be system response drift and vice-versa.

In most cases processing will do the best it can trying to model an electrical resistivity model assuming these effects are not present. Where present they will then either crash the processing or be modelled falsely as features at some fictitious depth and electrical resistivity.

OBSERVING THE ON-SCREEN MAP

Course across ground is presented on an on-screen map such that the driver can identify areas already surveyed and adjust course to survey at the desired density. With color coding of data points, shallower features may be mapped in real time such that the driver can adjust course in order to optimize coverage of those features .

HOW IS DATA AFFECTED BY BOOM RETRACTION?

Because TEM data changes by orders of magnitude over typical geology it is possible that partial boom retraction will not make much practical difference, however, channels recorded within the transmitter current turn-off ramp time will be affected distinctly. Spatially abrupt changes in these channels are used to detect and reject affected data in post-processing.

HOW CAN CONSTANT NULLED MUTUAL INDUCTION OCCUR WHEN BOOMS ARE FIXED ELASTICALLY?

This sounds like a problem but it is managed successfully. Front side booms are pulled forward until they pull tightly against stopping ropes. This means that the loop is held in fixed position until a threshold force is exceeded. Connectors have been moved out near boom tips and stretched into position by attached elastic cords fixed to the boom tips such that no slack wire exists near the core where it strongly affects nulling.

FALSE NOISE

AgTEM data is typically displayed in sounding curves on axes severely expanded across the zero crossing. This makes the data look as poor as is practically possible, exactly as is appropriate for quality control purposes. This results in alarming display of oscillations across zero – to verify if they are really a problem always observe the actual values on the axis scale.

DIAGNOSING NOISE

Every AgTEM operator must learn how to diagnose and distinguish noise sources as data is acquired. Failure to identify noise quickly will result in costly repeating of surveys or worse.

In resistive areas, sources of noise are particularly troublesome while in conductive areas much noise and cultural interference may be swamped by ground response.

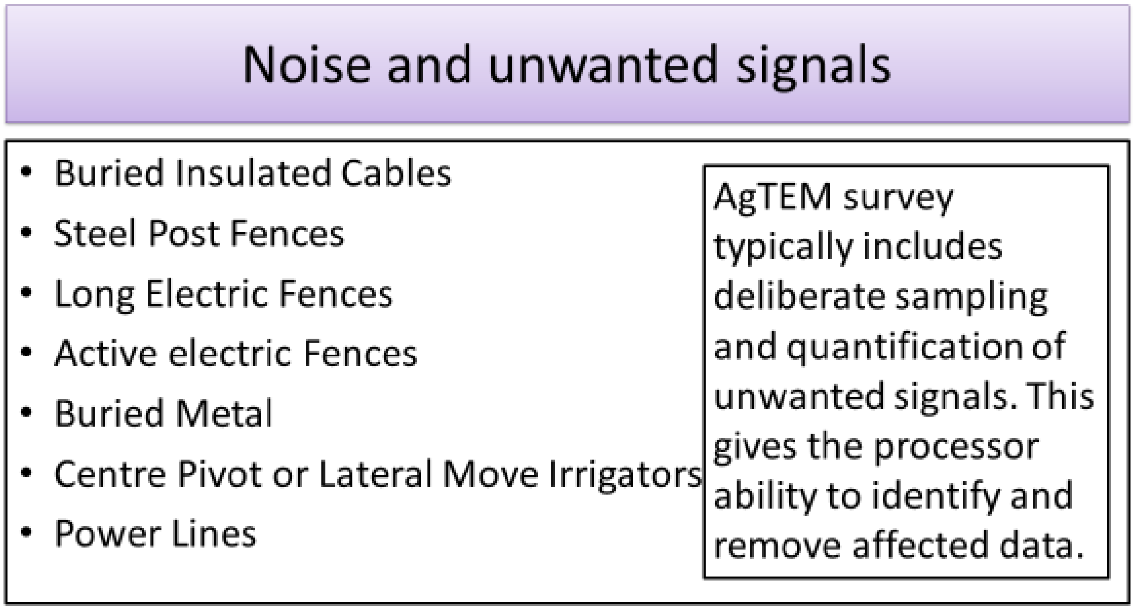
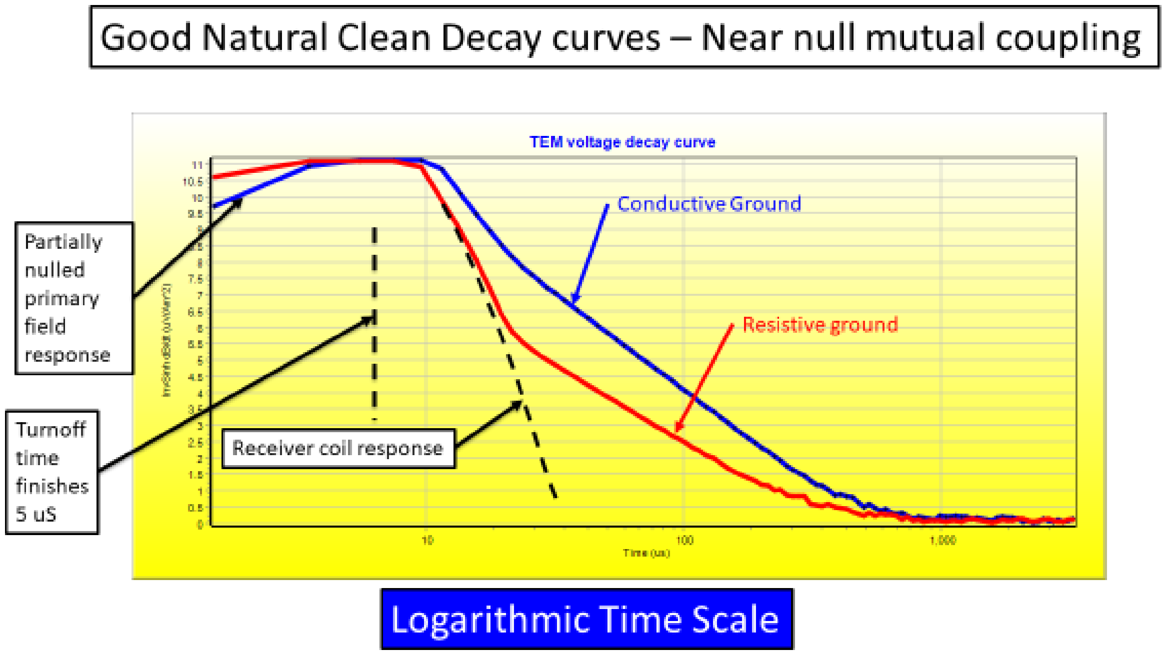


Figure 69 Some types of unwanted signals

Perhaps the first part of diagnosing noise is to identify what is normal. The figure below breaks up the decay curve into parts dominated by various equipment and ground behaviors. In the earliest channels within the 5 uS of turnoff, dimensional instability of the null coupled loop system dominates as fluctuations. Apart from this, also in these early gates, there is an inverse relationship with near surface ground conductivity in these gates. It is only noticeable over very conductive ground.

Next there is the combined coil responses of the transmitter and receiver coils – these extend beyond the end of the ramp and have a relatively steep, short time constant, decay, evident in time up until a clear break of slope where ground response begins to dominate. At resistive sites, ground response from the required depth of investigation may dominantly be overprinting the coil response – great care must be taken when this is the case as the data of value can be compromised if dimensional stability or temperature effects are allowed to vary significantly.



The figure below presents some clean data in both conductive and resistive environments. Use it to compare to the following figures that emphasize various types of noise.

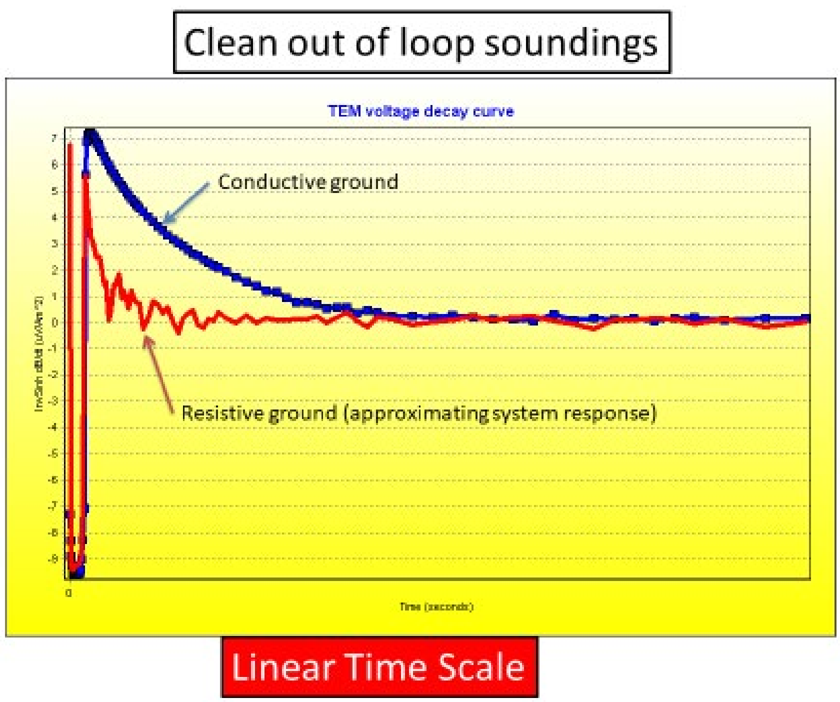


Figure 70 Clean decay curves at both conductive and resistive sites. A Linear time scale is presented so that the true significance of various oscillations can be gained - at early times the logarithmically spaced time gates detect higher frequency oscillations than at later times.

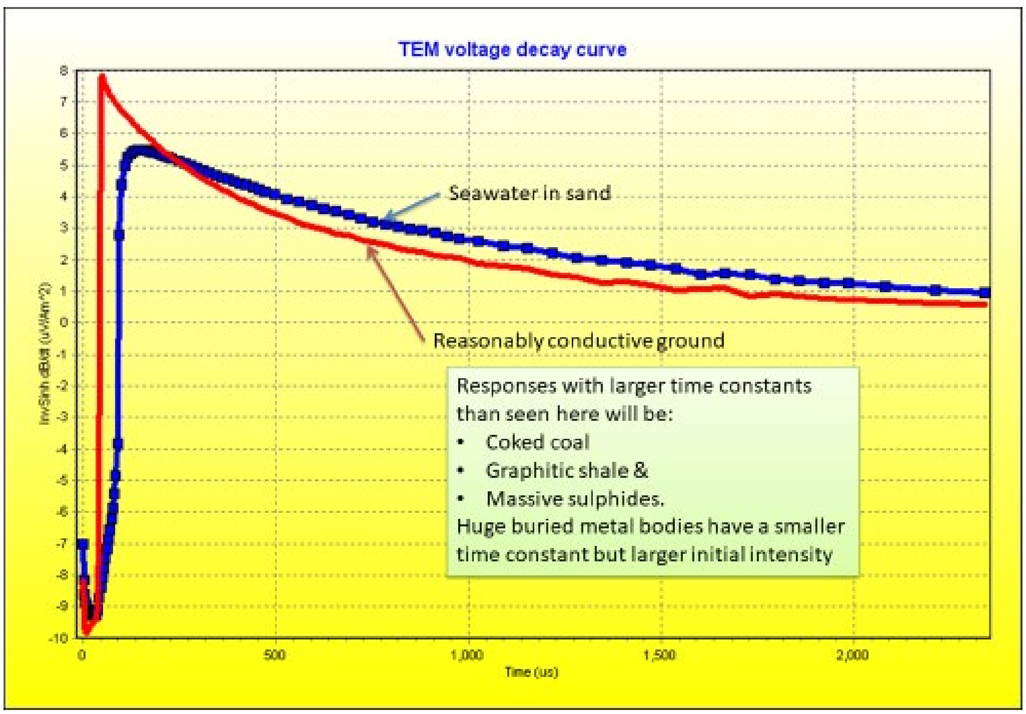
WHY USE LOGARITHMICALLY SPACED GATES?

TEM data is collected and binned into logarithmically spaced gates because small time changes, after current is turned off, are important for revealing shallow features while ability to resolve deeper features from later times tapers off so only broad late time gates are required. The wider a time gate is, the lower frequency noise it can remove. In practice it is suitable to sample with about 8 to 10 gates per decade. More will just unduly burden inversion software.

Linearly spaced stacked time gate datasets are additionally advantageous, in addition to logarithmically spaced datasets, as there are noise reduction and cleaning techniques that are simple to apply to linearly gated data that can later be reconverted to improved logarithmically spaced data gate datasets. This is particularly so if repetition frequency is long enough for ground signal to drop below noise level.

REAL CONDUCTIVE FEATURES

For comparison with the graphs below, all now on dual inverse hyperbolic sine scales (like log scale but with both positive and negative and approaching linear scale just about zero) the conductive responses in this graph are the maximum expected except in the rare cases listed. Anything greater is likely to be equipment related.



VEHICLE COMPONENT NOISE

Some vehicles create a lot of electrical noise. This may be permanent or intermittent, such as where a poor earth connection in some vehicle electrics intermittently contacts. This sort of noise will not be synchronized with AgTEM transmission and may appear as random or may resonate with groups of linearly spaced gates within the overall logarithmic spread of gates in the sounding curve.

Honda SXS Pioneer series off road vehicles are known to be electrically noisy (tested in 2020) and a test should be conducted before committing to newer versions of these.

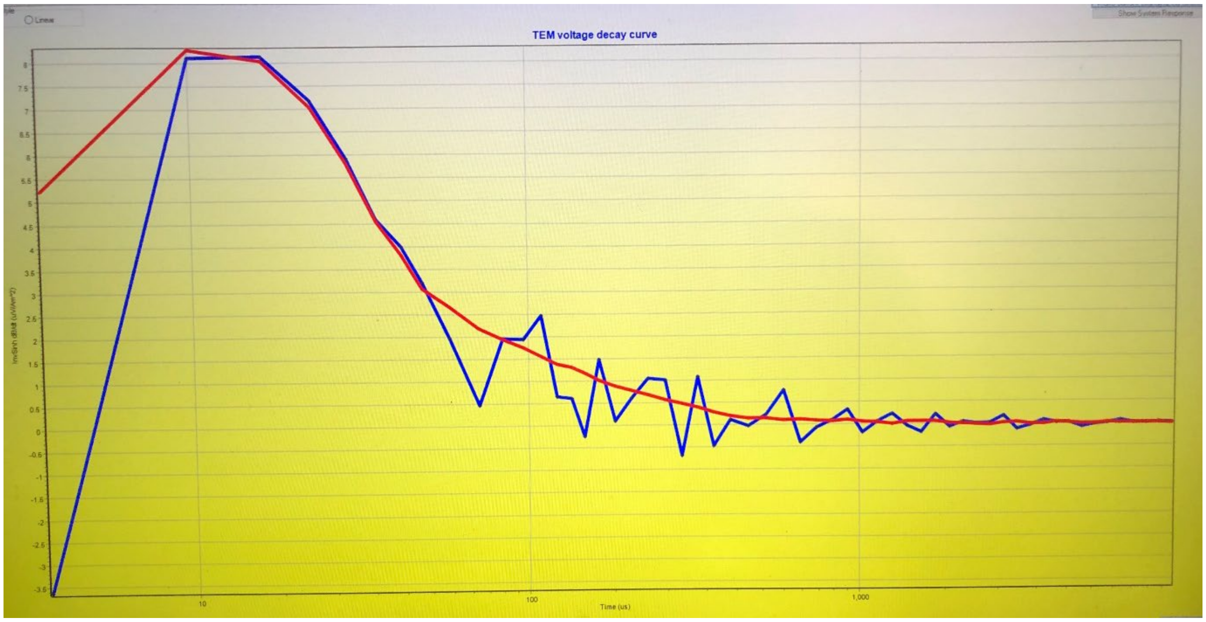


Figure 71 Electrical noise from an Isuzu dMax pickup transmission that occurs when the vehicle is in neutral or when trailer lights are activated. The red curve is without noise, and blue curve is with noise. At later time noise appears less only because late time gates are longer. Noise was eliminated by disconnecting trailer lights wiring.

The following is an example of Argo (Briggs and Stratton Vanguard Engine) RFI affecting AgTEM-Wallaroo data.

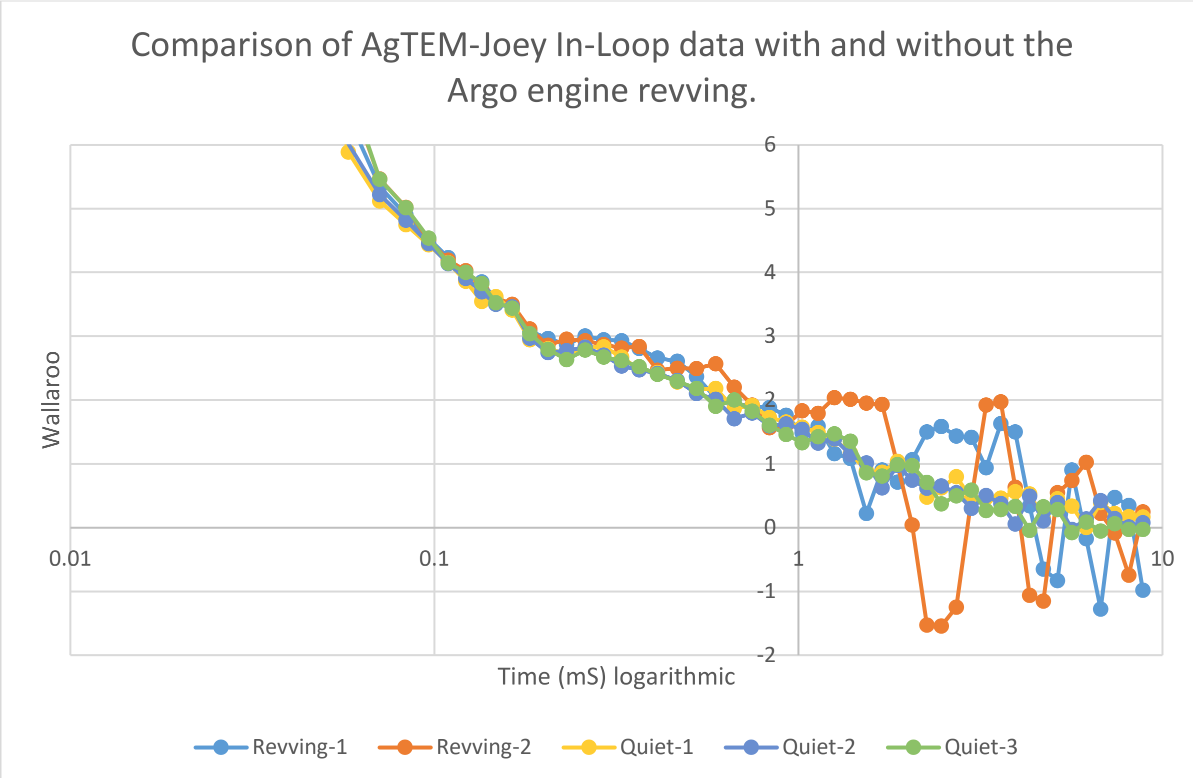


Figure 72 Radio Frequency Interference or EMI from an Argo engine is presented here. Logarithmically spaced time gates diminish the effect at later time. Data is sampled on a granite outcrop where there is very little ground response.

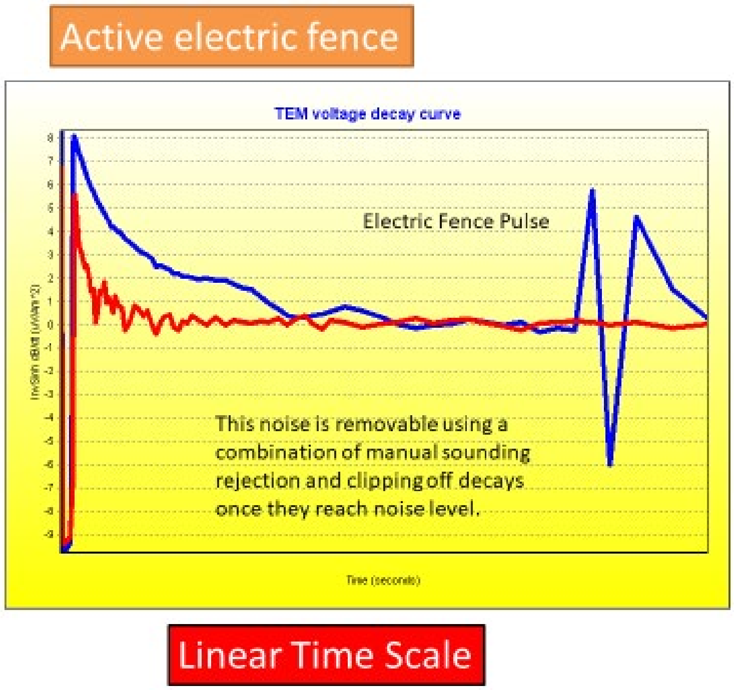
TRAILER LIGHTS WIRING

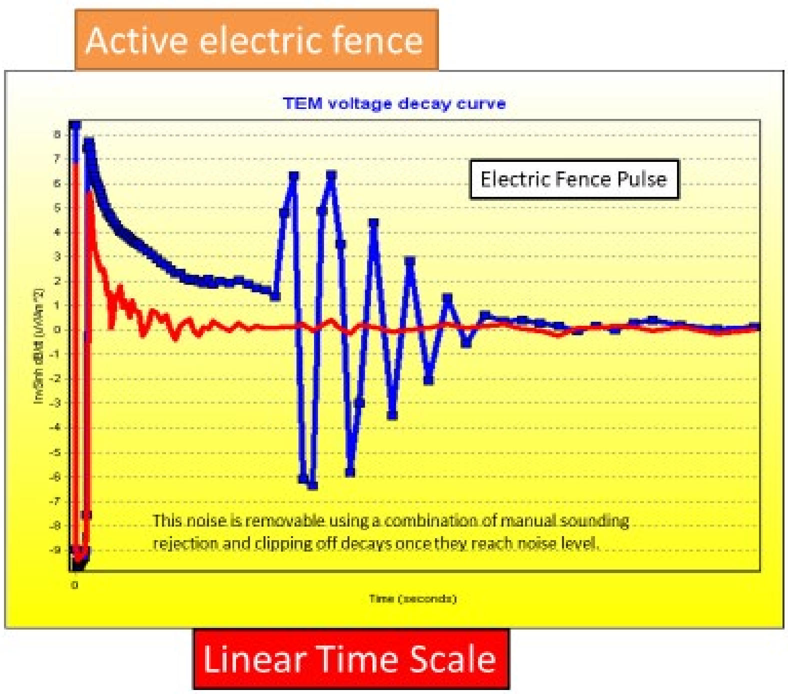
Modern trailer lights now typically have DCDC converters within them and these are noisy. AgTEM trailer wiring goes down the centre of the Wallaby to try to avoid noise transfer but this has proved to be insufficient to avoid noise tranfer – normal trailer cable has been replaced with shielded cable to reduce noise but most effective is to not use the lights while surveying and/or to remove the connector from the vehicle. Even when the lights are not in use there are noise signals in the vehicle that transmit out along the trailer lights wiring and disconnection is the only option to stop such noise. It is of too low a frequency to reject using noise suppressors clamped around the cables.

Any modification of trailer wiring must avoid ground loops that will act as inductive targets. Trailer wires should not run alongside receiver wiring even though it is shielded.

ELECTRIC FENCE NOISE PULSES

Electric fence noise pulses are a very small problem to TEM surveyors as they are not so frequent and can be turfed out in post processing. It is often easier to remove the spikes in post processing than it is to arrange to get the fences turned off. Welcome jobs with electric fences – they are the easiest type of fence with which to survey.





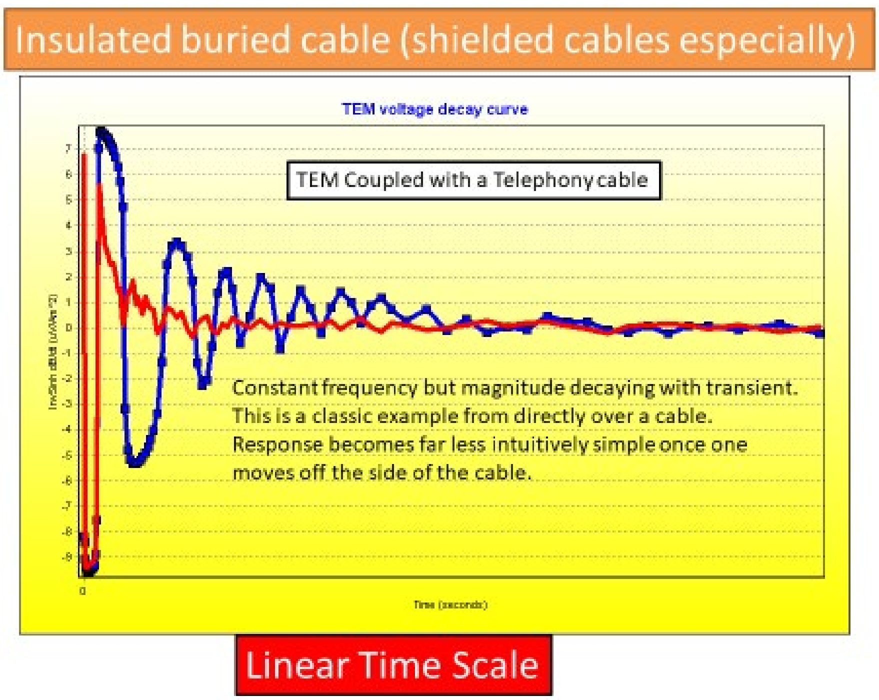
LONG ELECTRIC FENCE EFFECTS

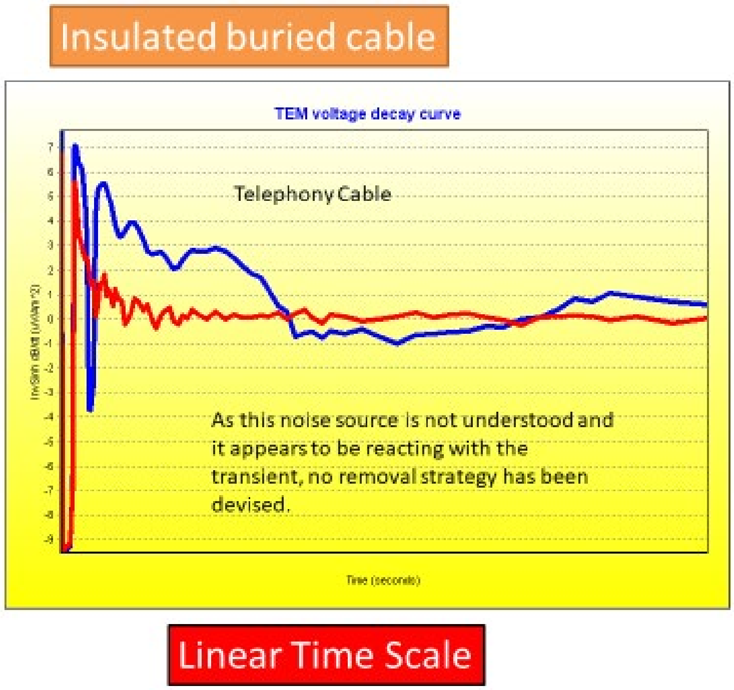
Long electric fences are problematic even when they are turned off. Active wires are not grounded and capacitively couple with the grounded wires and with the AgTEM transmitter such that a ringing is developed as the fence is approached. The ringing is absent at the ends of the ungrounded wires and a maximum at their centers. Runs over a kilometer long are problematic.

TELEPHONY AND OTHER BURIED INSULATED &/OR SHIELDED CABLE NOISE

Directly above an insulated cable AgTEM will detect strong decaying oscillations. They are of constant frequency but the logarithmically spaced AgTEM time gates can make their appearance a little complicated due to aliasing.

Telephony cables are one to the worst features for AgTEM survey as they often are along roads where the road margin is the only permitted access and it is impossible to move away from such cables. Their effect can significantly affect data collected anywhere within 10 - 20m of such cables. As one moves away the effect changes from simple decaying oscillations to more complicated response resembling buried conductors such that it is very confusing in modelled data. In post – processing be very careful to strip out affected data prior to any horizontal smoothing of data.

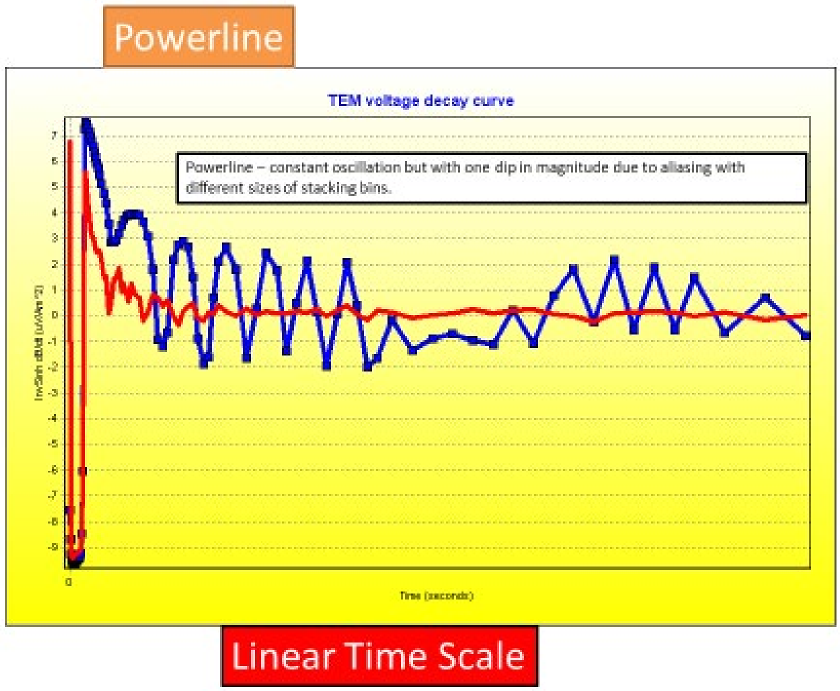




POWERLINE NOISE

It is possible to collect useful shallow data even under the most powerful of powerlines. Constant frequency oscillations, with harmonics and overtones will be evident and will overprint data. The principal frequency (50 Hz or 60 Hz) will be rejected by selection of appropriate operating frequency. Failure to select the appropriate frequency for a country will cause terrible noise. Once the repetition frequency is matched to powerline frequency the bulk of the noise is cancelled, some being left due to inaccuracies in frequency and load induced lag – appearing as wild DC offsets in stacked data as well as changes in amplitude of harmonics from one stacked record to another. Stacking at one spot under a power line, some stacks will appear as perfect noise free data while others will be moderately or strongly affected by the powerline signals.

It is common for the only drivable access at a site to be along a power line. Often this is quite OK, especially if it is to a pump that you can ask to get turned off. Compared to impact of buried telephony cables, power lines typically cause little impact on data.



SINGLE LINE EARTH RETURN POWERLINES

Single line earth return powerlines as are typically used in 3rd world countries are a terrible problem for TEM surveyors. One such heavily loaded line in the Brazillian Amazon affected survey up to 2km either side of it. Effects of good powerlines cancel at distance as the three phases cancel each other out. Single line earth return lines act as giant antennae – with both the line itself, and the deep path back through the ground, acting as antennae.

Do not be deceived by the insignificant physical structure of such powelines – they are the worst.

PERSISTENT NOISE INCLUDING VLF FROM NATURAL AND SUBMARINE COMMUNICATION SOURCES

Some forms of noise cannot be effectively stacked out of existence but repetition frequency and stacking algorithms can be adjusted to greatly improve signal to persistent noise ratio. Persistent noise will not appear as noise on stacked estimates of standard deviation or may exhibit some disproportionately small standard deviation if there is some drift in the noise while returning an unrepresentative mean.

Sources of persistent noise include VLF (Very Low Frequency) submarine communication and higher frequency natural magneto telluric signals. Poor frequency power, not rejected by stacking at an integer multiple of power line frequency, and power line harmonics can add to persistent noise.

Logarithmically spaced sampling gates can differently couple with persistent noise. Particular gates may strongly attenuate or accentuate persistent noise just like dual polarity stacking rejects power line noise.

The effect of gate choice is clearly explained in:

Jakob Juul Larsen, Stine Søgaard Pedersen, Nikolaj Foged, and Esben Auken, 2021, **Suppression of very low frequency radio noise in transient electromagnetic data with semi-tapered gates.** Geosci. Instrum. Method. Data

Syst., 10, 81–90, 2021 https://doi.org/10.5194/gi-10-81-2021 © Author(s) 2021. This work is distributed underthe Creative Commons Attribution 4.0 License.

This paper shows that time gates of boxcar shape within repetitive stacked sampling have frequency peaks and troughs at particular frequencies and that these may just coincide with a persistent VLF noise source.

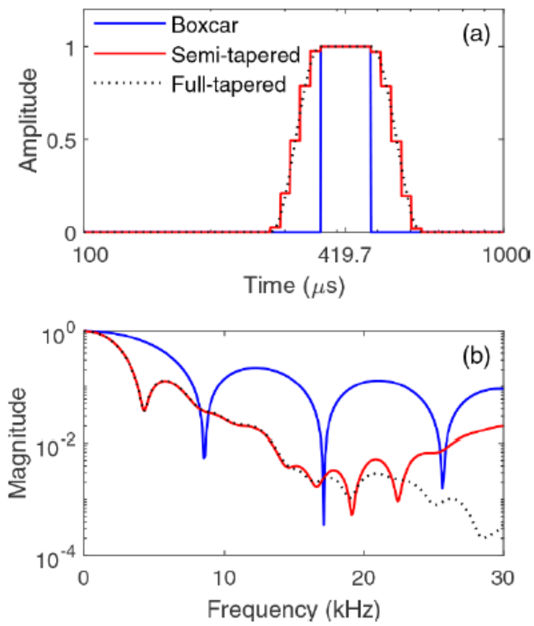


Figure 73 (from Larsen et. al., 2021) Larsen reveals how using semi-tapered gates in TEM acquisition can reduce pickup of noise in the range of 1kHz to 30kHz by transforming the gate shape to the frequency domain.

VLF noise typically picks on particular gates in a TEM decay curve. It seems like there is something wrong with that gate but then after perhaps an hour the gate is fine as the VLF noise has changed character.

A slightly related phenomenon is observed when driving a TEM system under high tensile power lines carrying lots of current. In this phenomenon, some stacks of soundings will be overwhelmed with persistent powerline signal, while others will cleanly show almost only ground signal, depending on powerline frequency mismatch with sampling repetition frequency.

By applying semi-tapered gating, Larsen et. al. 2021 have demonstrated a signal improvement factor on most affected gates of up to 2. The effect is demonstrated in the second figure below of profiled data.

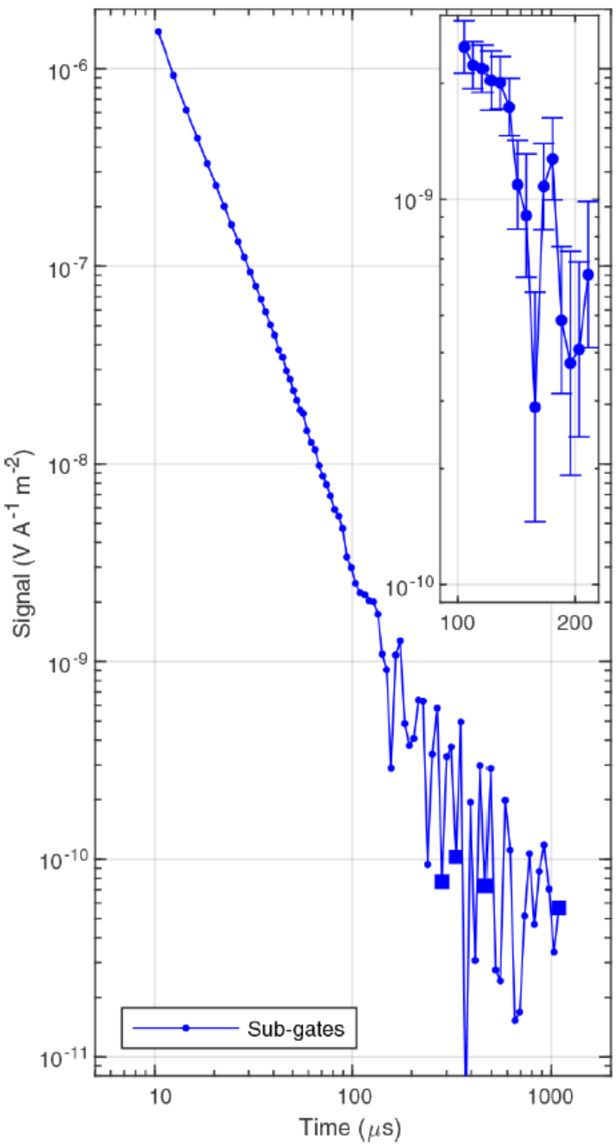


Figure 74 (from Larsen et. al. 2021) In this example, persistent noise from a VLF source is observed because the standard deviation bars (see insert) are much smaller than the distribution of points about the general trend of the decay.

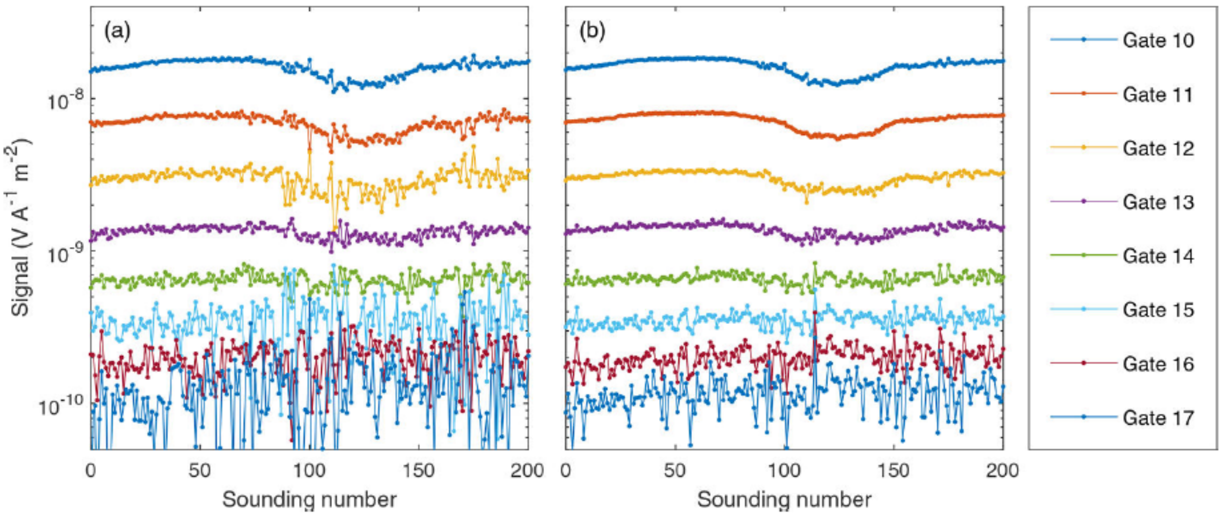


Figure 75 (From Larsen et. al. 2021) Profiled towed TEM data processed from fine time gates into logarithmically spaced gates using (a) non-overlapping boxcar gates, and (b) semi-tapered gates.

TRAVELLING IRRIGATORS

Travelling irrigators such as center pivots and lateral moves (Valley, Lindsay, Reinke etc.) are common on survey sites. They will generally have a buried insulated cable that creates an artefact in the data. The structures themselves form inductive targets and data immediately adjacent or under them must be rejected.

GROUNDED FENCES

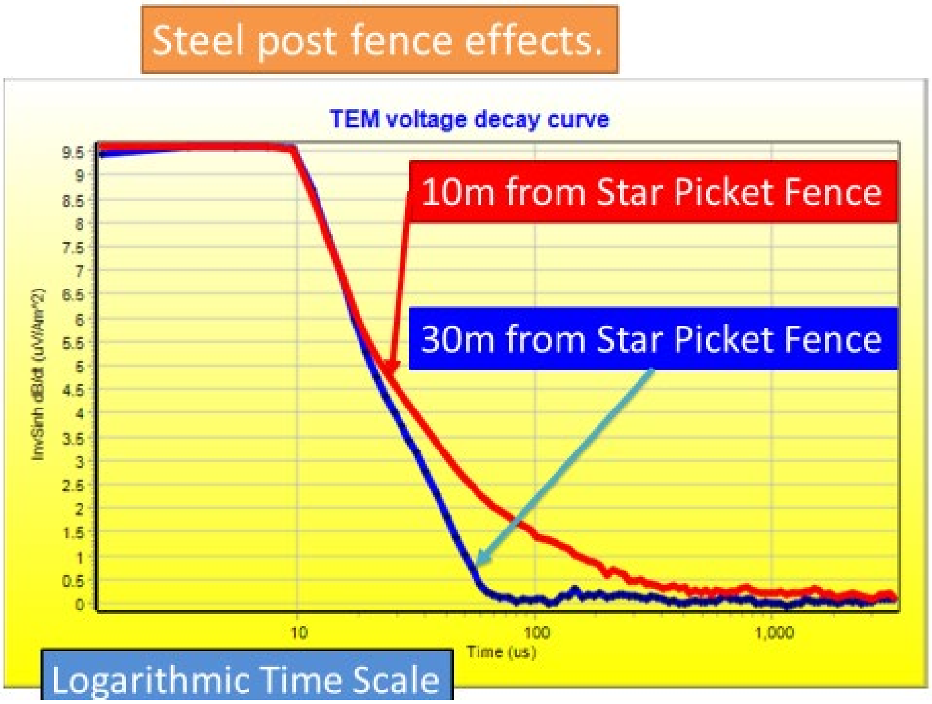
To test the effect of a fence, drive AgTEM, from a distance of >50m towards the fence until the transmitter loop straddles that fence, and then drive back away from it. Do this at least at two locations to double check the effect. This is an important practice on all jobs as if the interpreter or client questions a feature in the data near or overlapping a fence they will know the relative impact the fence has. Fence effects overlap ground effects and it is not always wise to throw out all fence affected data – it may be better to interpret cross cutting ground and fence features than to have a completely clean and inadequate dataset.

Grounded fences appear, in modelled data, as fixed depth linear conductors and can affect data as far as 50m from such fences. On an extremely conductive site it may be possible to collect useful data even with the side of the AgTEM loop hanging over the fence as one travels along it. This is far from so at resistive sites.

Fences with wooden strainer posts and ungrounded metal droppers typically are of no concern and survey often proceeds unaffected when AgTEM loop sides are straddling such a fence as one drives along the fence track.

Fence effects are strongly affected by grounding as current can flow along the fence and return via the ground. Steel strainer posts are bad as is buried netting. Even with such features the impact on AgTEM data is strongly affected by soil salinity and moisture around the grounding points such that it is hard to predict the effect of a fence.

Breaks in fences can considerably affect the effect of the fence on AgTEM data. It is common for no effect to exist near an open gate and for effect to increase as hundreds of meters along the fence are travelled away from the electrically open gate.



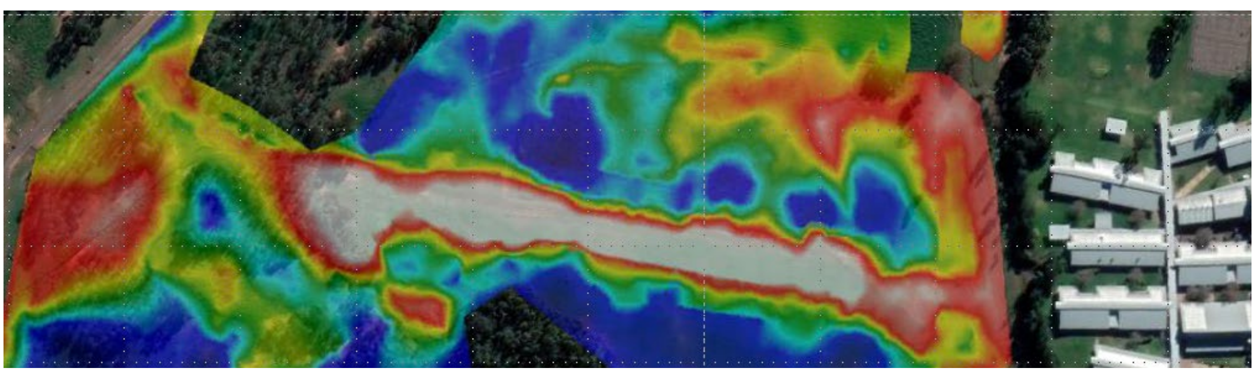


Figure 76 Effect of a 6' high steel post and mesh fence modelled at 20m deep.

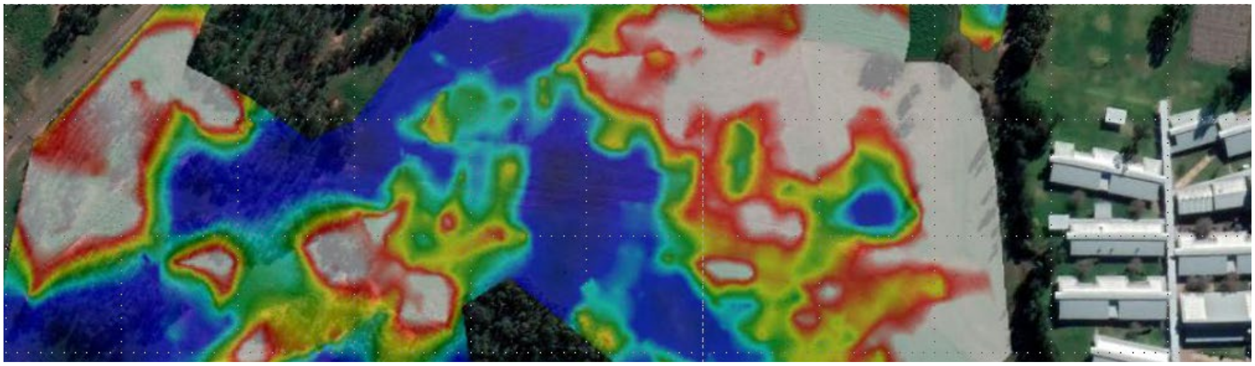
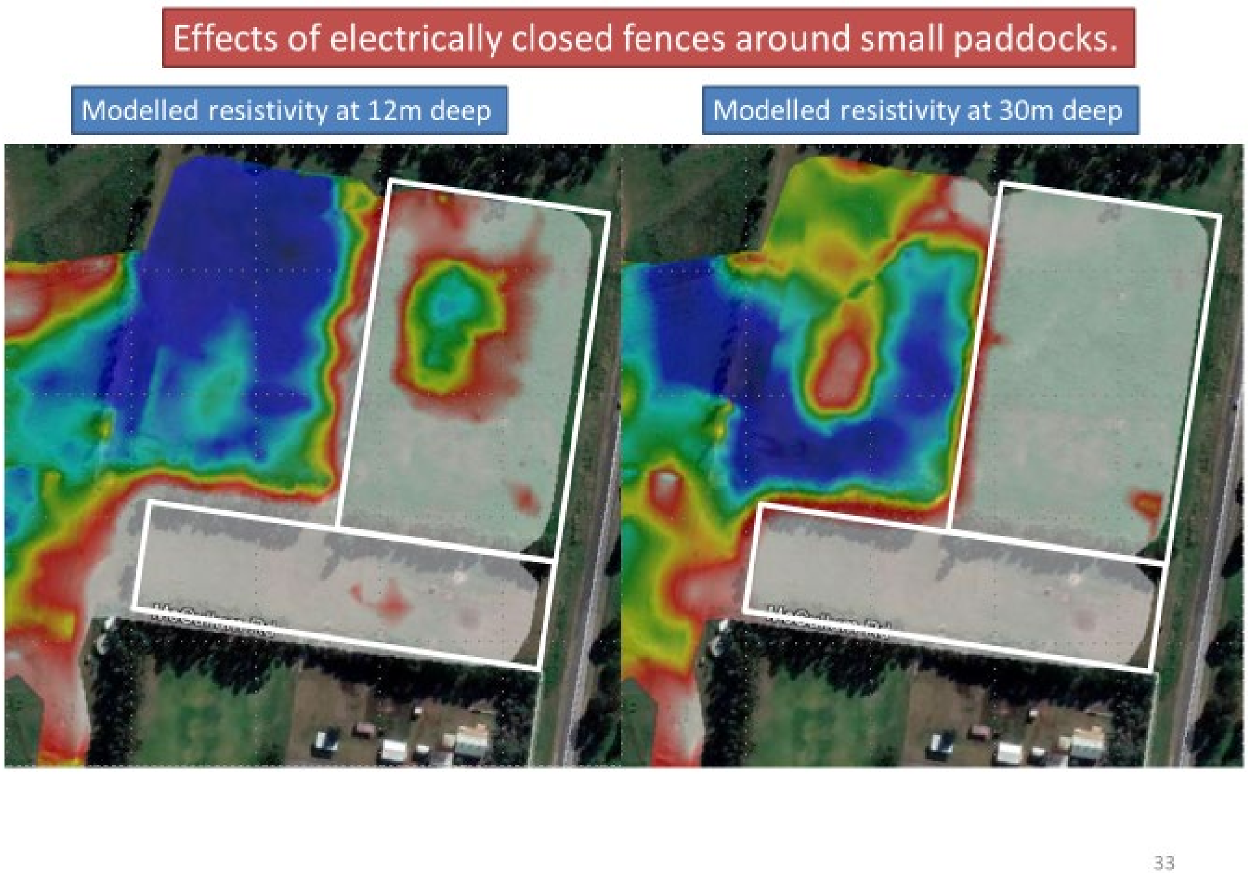


Figure 77 The effect of the same fence at 36m deep is totally removed by modelling. Fence effects can be considerable but modelling tends to isolate them and to present them as features at a particular depth by modelling them as isolated conductive horizontal layers.

FENCE LOOPS IN SMALL PADDOCKS

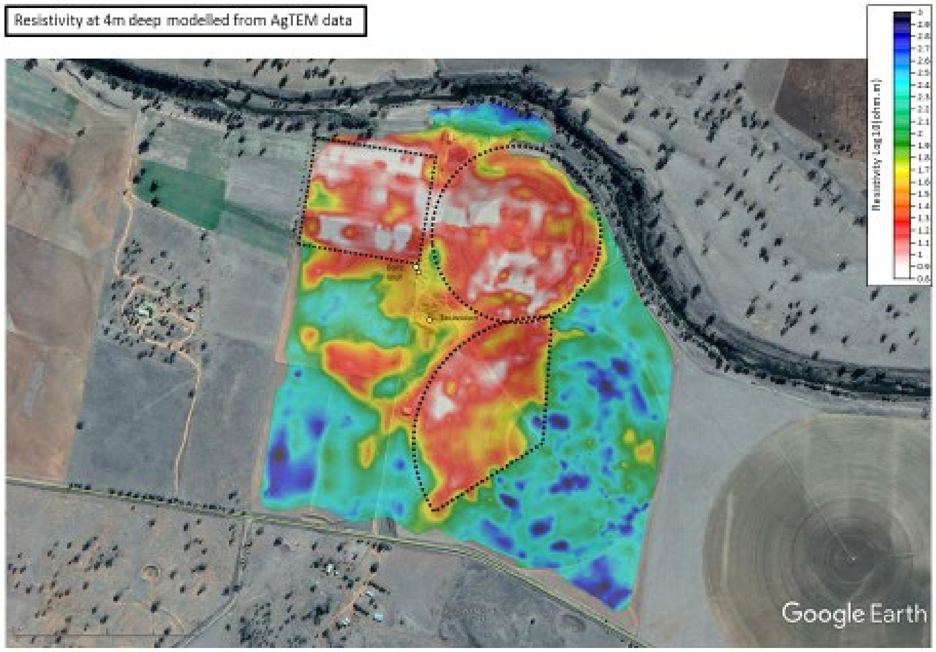
When paddocks are small and are surrounded by good electrically continuous fences then the whole paddock may seem conductive. In bigger paddocks the same effect applies but concentrated near the fences and is less significant as the total resistance of the loop fence is higher and less current flows through it as a result. Unless fences are very well grounded, the whole effect can simply be turned off by opening a metal gate latch. You may even find that you survey half a paddock and then someone opens the gate and the other half of the data looks completely different.

It is a good idea to refuse to conduct deeper groundwater investigations for hobby farmers and other intensive fencing operations for this reason. This observation raises doubt over the usefulness of some airborne TEM datasets over intensive farming areas.



EFFECT OF VARIABLE GROUND MOISTURE

Ground moisture variation can overprint geological features. This is real data but when from irrigation it can look rather odd and confusing. It is not an error but in some situations is problematic. In the image below the portions of paddocks irrigated is clearly evident.



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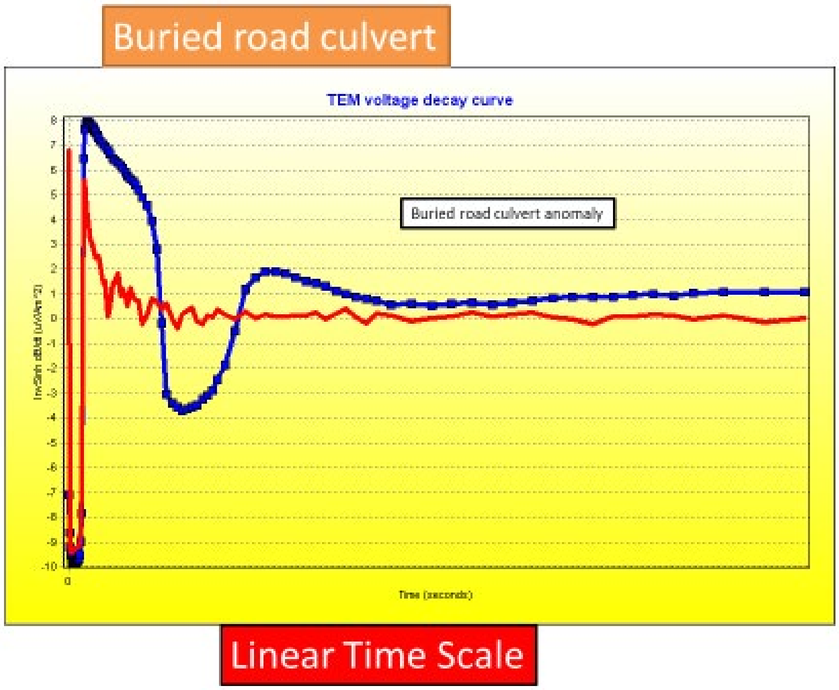
MISCELLANEOUS METALLIC JUNK ANOMALIES

AgTEM has a small footprint such that effects of isolated metal junk can be accurately targeted and segregated from the rest of the data. This is of great benefit at pollution plume sites where typically there is lots of junk. Driving within meters of car bodies, trucks, railway lines and the like often is not a significant problem but be weary. Structures that allow current to pass around a large ring are most trouble such as corrugated iron silos, metal sheds and the like. Reinforced concrete structures are trouble even though the metal cannot be seen.

AgTEM is not designed principally for buried metal object detection, rather it is designed to minimize effects of such items, however, it has considerable detection ability and is possibly the most capable device available for detecting deeply buried metal objects as it has a high inductive moment and, in nulled loop configuration, a very tight footprint. If the main loop and booms of AgTEM-Wallaby are removed then the core used alone, with horizontally opposed transmitter loops, will form an excellent system for detecting and discriminating between shallower metal objects.



SURVEYING CLOSE TO RAILWAY LINES

It is possible to survey along railway line corridors. If the AgTEM-loop is not near straddling the rails then useful data can be collected.

SHIELD TO GROUND CONNECTION ISSUES

When shielding is connected to ground at both ends of a cable or looped in some other way then odd effects can occur resembling deep conductive features. AgTEM typically uses shield as ground in twisted wire differential pair acquisition such that effects are minimized.

MECHANICAL VIBRATIONS

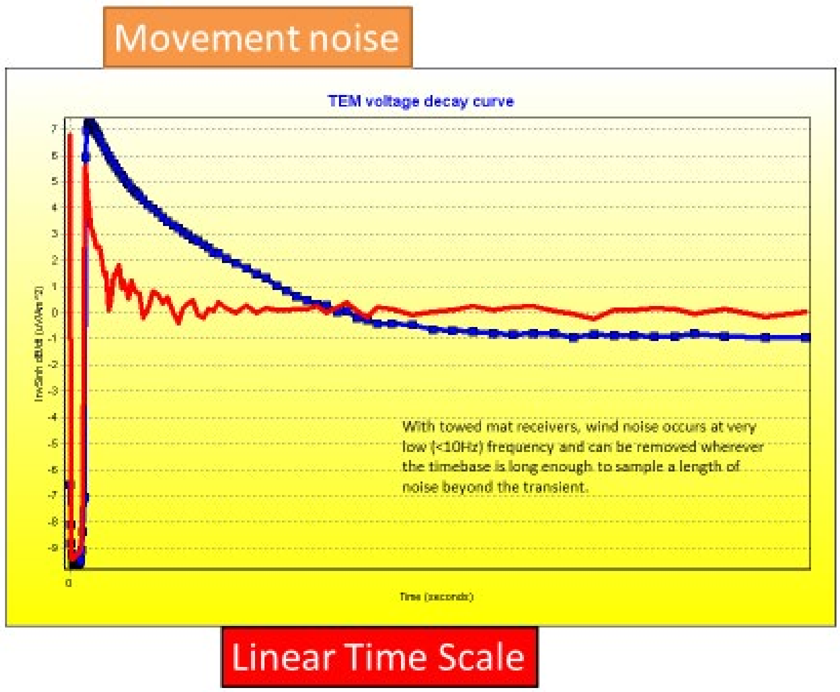
High frequency vibrations of receiver loops and connectors, although seemingly inconsequential to us can cause great harm to AgTEM data. Design has eliminated such effects but if any changes are made the problem can be re-introduced – take care. Of most extreme impact are vibrations that result in sonic frequency making and breaking of contact such as connector pins that do not fit tightly, cracked 'dry join' solder connecting wires to pins or sockets, or unduly and excessively flexed or stretched cables in which all strands of a conductor have snapped and only intermittently make contact while the external sheath remains intact. This is common in heavily used connectors just beyond the heat shrink on connectors where flexing action is concentrated. For more information on this extreme form of mechanical vibration noise see the section 'intermittent connections'.

DRIVING OVER ROUGH GROUND

Movement noise is created by moving components violently through the magnetic field of the earth. This inductively creates currents in the loops, particularly being problematic in the receiver loops.

One way of reducing the problem is to increase the receiver loop area (prior to pre-amplification). This has similar effect to lengthening a lever when trying to apply torque to an application.

AgTEM loops all include foam or other flexible vibration damping and hard rigid fixtures are avoided where possible. This is to keep all forms of vibration to as long oscillation periods longer than the repetition frequency of AgTEM. Notice that we prefer towing a flexible mat receiver over a rigid receiver coil for this reason. Once movement noise is translated to these lower frequencies it is partly stacked out but also appears principally as a DC offset on stacked records. Should the repetition rate be slow enough then late time gates can be averaged, or even fitted to a slope and offset, so that the noise can be removed in processing (an example of a solution involving both hardware and processing innovation combined).



INTERMITTENT CONNECTIONS

Intermittent connections cause the type of problem shown in the example for 'vehicle component noise'. Typically some decays will be good while others will be appallingly noisy, or all may be variably noisy. Know and remember typical noise levels as such problems are often introduced in transit between jobs and plague operators right when they are trying to start a job and get used to typical background response at a new job. In such cases often the survey should be started and data gathered until the problem is identified and clearly resolved and then the survey should be restarted and the trashed data thrown away.

Other techniques of resolving such problems involve running the equipment at one spot while changes are made. Ideally one person will observe while another makes changes, otherwise there is a lot of running back and forth to observe (or a hand held windows remote desktop connection to the AgTEM computer can be used). For subtle cracks and dry joins, a heat gun and/or aerosol can of freeze spray can help stress the system to reveal problems.

Intermittent failures typically occur at the back of the heat shrink covered connector shrouds where flexing is concentrated and whiplash movement can stress. This can include cracks in insulation that can short to the shield once moisture condenses overnight such that early morning data will be strongly affected after cold humid nights.

When major damage occurs resulting in tearing of the Wallaby from the towing vehicle, cables can be stretched, cracking insulation on internal conductors right along their length. Immediately they may still work fine but once moisture condenses shorting wires to shielding and to each other then the whole system will become completely unreliable and the only good solution is to throw away such cables and replace them. Persevering with the old cables may get a remote or time-pressured job finished but with inferior results.

INAPPROPRIATE CHOICE OF RECEIVER SELF RESPONSE

Receiver and transmitter loop self-response increases with the square of the number of turns, just as does the turn off time (for identical current). Self-response also is affected by the filtering characteristics of the pre-amplifier and loop oscillation damping resistors. Most surveys can be completed with a 10 turn loop while a few deep surveys may benefit from 20 turn loops. Use of 20 turn receiver loops on most surveys will overprint loop self-responses right over all useful data rendering the datasets useless – beware. Very shallow survey will benefit from 1, 2, or 5 turn receiver loops. Similarly, using more than 1 turn transmitter loops will prolong the ramp and transmitter loop self-response which may preclude shallow investigation.

INAPPROPRIATE CHOICE OF LOOP DAMPING

150 ohm transmitter and receiver loop damping will draw out and increase loop self-responses but also reduce overshoot and oscillations. 220 ohm or 330 ohm damping may be more appropriate for resistive sites as drawing out of loop self-responses also draws out null coupling dimensional and temperature instability, so that they affect later gates.

PROBLEMS WITH LONG FLYING LEADS

The transmitter ideally will be placed on the Wallaby drawbar as close as possible, without causing significant induction into the metal cooling components. In the event that it is placed in the towing vehicle instead there will be long flying leads with high self-inductance and some resistance – they change not only efficiency, due to resistance, but system response. Effects can be complex but it is noted that leads even 10m long are manageable and keeping the transmitter in the towing vehicle is practical and possible.

Long receiver cables are known to be manageable provided that pre-amplification is conducted and impedances are managed by the pre-amp. Without a pre-amp, considerable systematic effects will be introduced into long receiver cables even when they are shielded as no shielding is perfect.

ACCIDENTAL CLOSURE OF LOOP TURNS

In the AgTEM system there is the option of closing one or two loop turns in the transmitter to act as a conductive feature calibration source. Accidental closure will result in a conductive feature overprinting and swamping ground response.

Figure 78 REPLACE WITH A BETTER EXAMPLE - Calibration loop response with both 1 and 2 turns shorted. The black reference curve reveals typical slingram ground response (inverted). Red is Slingram data (inverted) and green is almost null coupled data.

PICKUP AND DRAG OF FENCING WIRE

Farm workers sometimes leave offcuts of barb wire and other fencing wire lying in long grass and these catch onto and wrap around axles and other parts, causing towing vehicle and AgTEM damage. Further, it can cause anomalous data when dragged long distances without notice, by the Wallaby. If data suddenly is not making sense it is a good idea to walk back and look for caught, dragged fencing wire.

LIGHTNING ANS SFERICS

Natural sources of distant noise will add to random noise levels and are often difficult to recognize without careful comparison of levels from different surveys. Survey normally proceeds regardless.

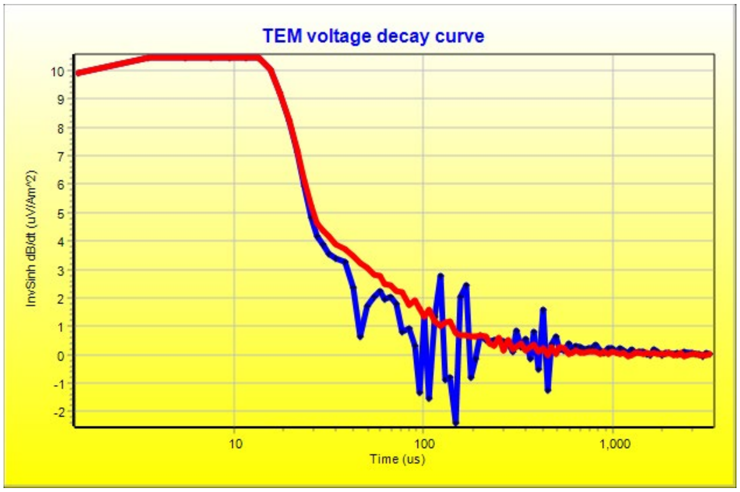


Figure 79 The blue decay shown was affected by lightning that was close.

ELECTRONICS WARM-UP

It is foolish to commence survey of key locations early on cold mornings – rather survey a redundant area and cross it later with tie lines. From a cold start it can take an hour for equipment to stabilize. The exact causes of this instability are not known – it seems that a combination of many components contribute to the system response dependence on temperature. Part of the dependence may actually be related to condensing humidity in cables and electronics rather than temperature itself.

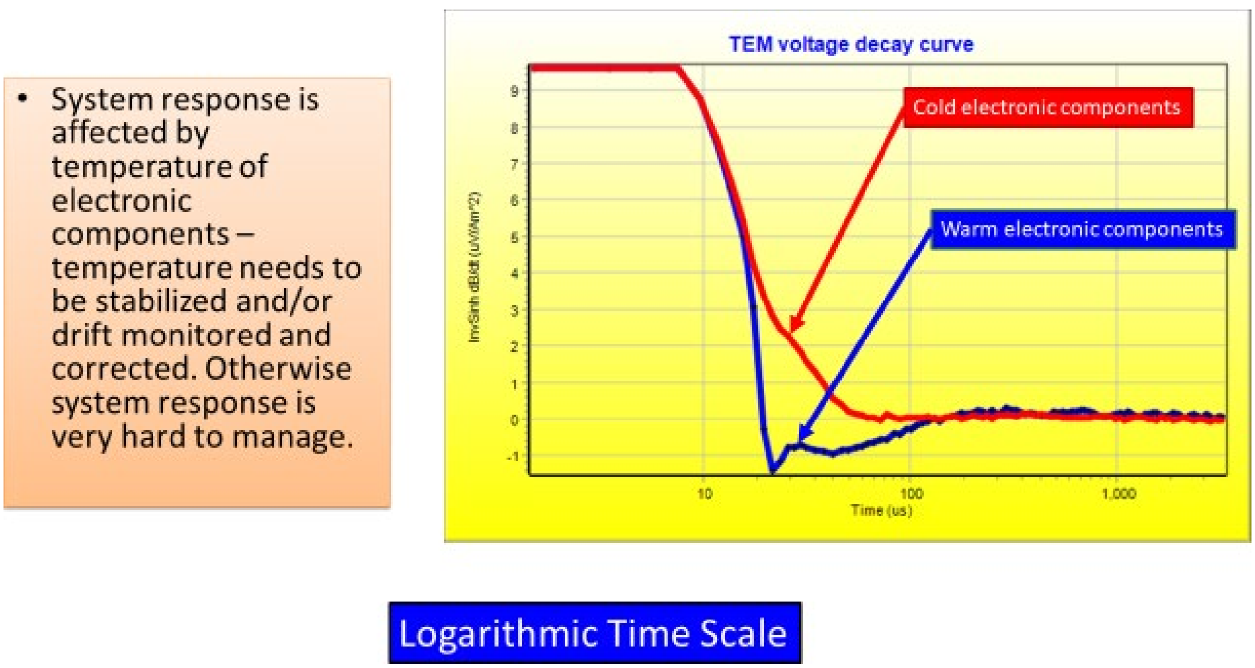


Figure 80 A very bad example of drift in electronics behavior over warm-up - at a very resistive site. In this example dimensional variation could also have contributed.

LOOP POLARITY WRONG

It is possible, and easy, to hook up loops in reverse or simply to put them upside down. Our loop connection boards have screw in wire terminals so that wires can be reversed if this happens for unforeseen reasons in the field where other wiring tools are not present. As there are many connections in the wiring paths, the easiest way to tell polarity is to record data and observe the polarity of the primary field (+ inloop, or – out of loop, or unknown and small for null coupled loops but slightly later time ground response from beneath should be positive over conductive ground). The figure below presents in-loop data that is positive but front loop data that is negative due to either the loop being attached upside down or reverse wired. Although such data is easily rectified in post-processing, it causes an additional fault documentation task, and makes careful comparison of soundings from multiple loops near impossible.

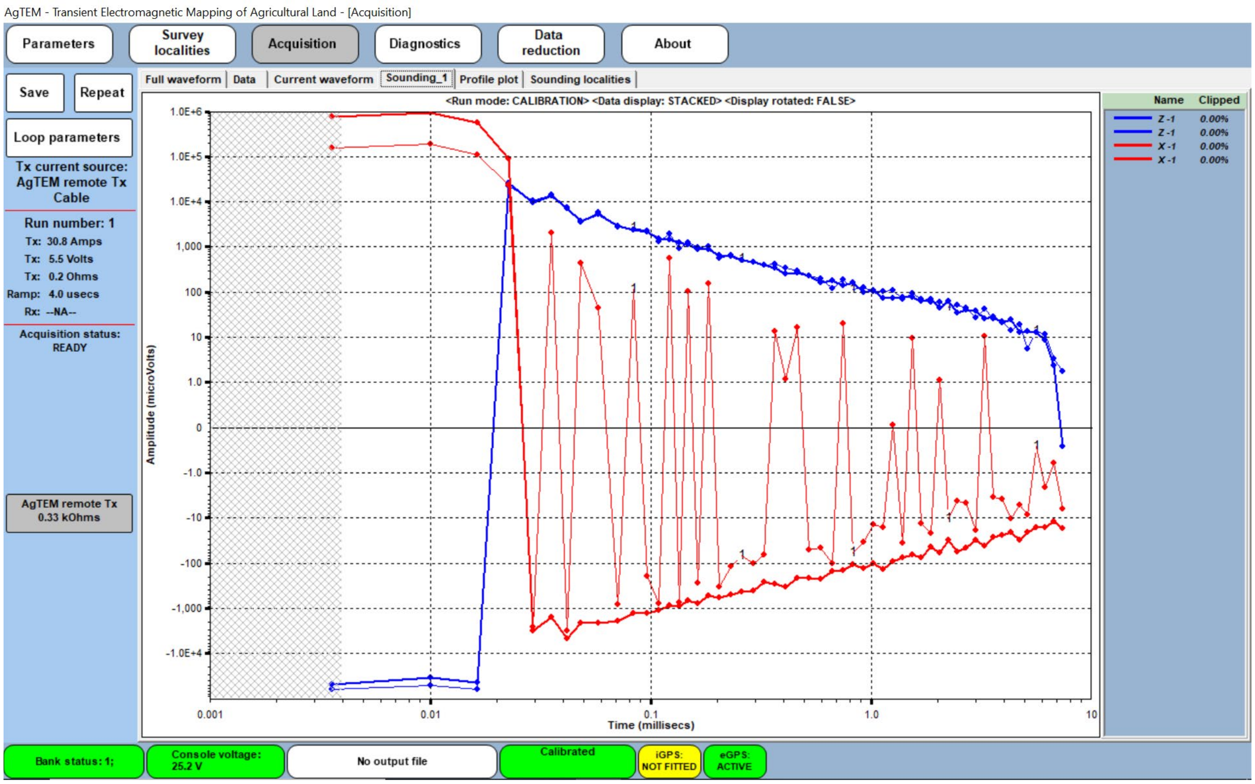


Figure 81 An example where the in-cart null-coupled loop is generating positive data (Blue) but the front loop data (red) is of reverse polarity. Notice how, even though the primary field data of the null coupled loop cannot be used to detect polarity, that later time data can and that the front loop data at later times would mimic the in loop data if reversed and normalized for receiver loop area. A repeat of the data is collected with low current so signal was close to zero and looks very bad as it crosses back and forth through the highly expanded zero crossing of the graph – this is partly simply to do with how the axes are scaled – that it to emphasize data problems.

TEST LOOP DATA

The test loop 300x300 mm square has almost no turnoff time and an aluminum plate is slid into it to act as a conductor. The graph below shows what this looks like. Beware that you do not rest it on other metal objects during a test. Because current is low, and the ramp measurement is designed to work with high currents, expect the ramp measurement may unrepresentative.

The conductive response will be a clean decay curve while the resistive response will be low amplitude oscillations present within the system response.

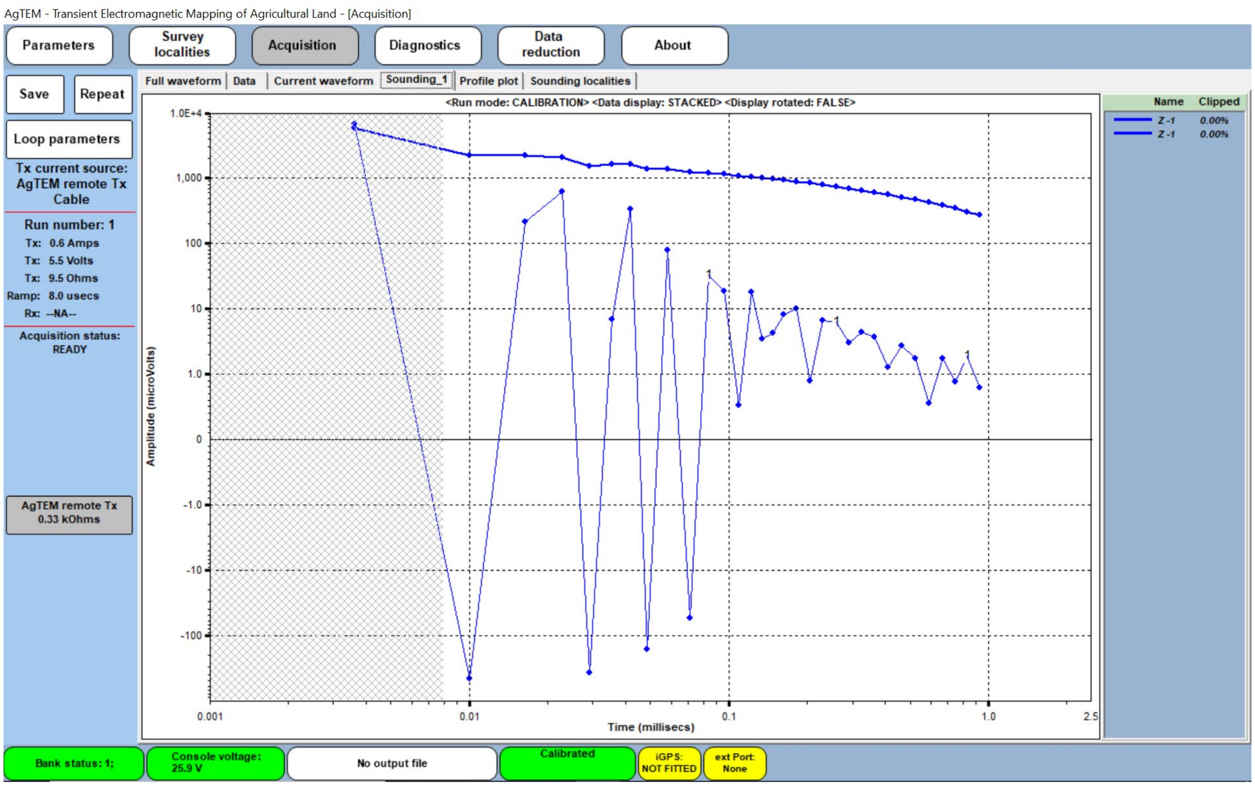


Figure 82 300x300 mm test loop data with and without an aluminum plate present.

MUTUAL INDUCTANCE NULLING STABILITY

During acquisition, booms brushing against trees and other occurrences affect mutual inductance nulling of the AgTEM-Wallaby mid-plane receiver loop with the large Wallaby transmitter loop. Operators should have a good grasp of the significance of such nulling. Although it helps greatly with keeping signal levels low enough to greatly increase amplification it does not greatly affect data beyond where receiver loop self-response dominates. Below is a graph showing the effect of pushing one front side boom backwards by 0.6m.

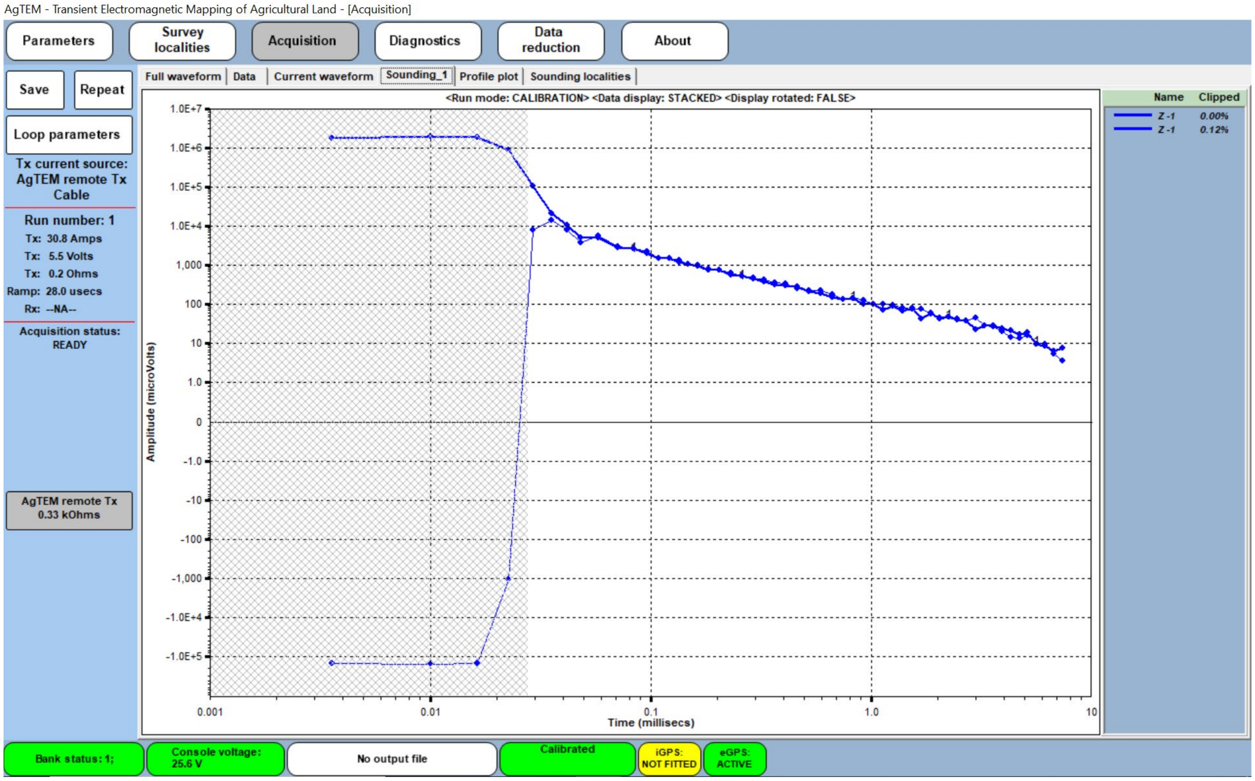


Figure 83 The effect, on AgTEM-Wallaby mid-plane receiver loop, of pushing a front side boom backward by 0.6m

TRANSMITTER CURRENT WAVEFORM

The transmitter current is simply a 50% duty cycle square wave is it not? In practice this can be far from the truth.

MEASUREMENT OF CURRENT WAVEFORMS

AgTEM has ability to measure very high current waveforms using a pair of on board Hall effect current sensors. This is very effective for high currents and less so for small currents used in test loops. Current waveform observations may be made using the ‘Calibration’ mode (Parameter menu) of the ‘Acquisition’ page ‘Current Waveform’ sub-tab.

OPTIMIZING CYCLE-TIME, VOLTAGE AND CURRENT TRADE-OFFS.

Short cycle-times are great for increasing stacking rates to reduce noise while adequately long cycle-times are essential for deeper observation.

The lower the resistance of a loop the lower the voltage needed to transmit equivalent current into it.

The higher the current in a loop the higher the signal to noise ratio in output data.

Because AgTEM is designed for efficient power consumption for a small loop the loop resistance is typically only a small fraction of an Ohm and only 5V is typically used to drive current through it. For high currents this results in very slow rise of current in the loop. At 33.333 mS cycle-time or longer this tends not to be a problem but with sub power-line cycle times high current transmission will not rise and level out before it is turned off again. To use such cycle times to increase the number of stacks collected either higher voltage transmission must be used (eg. 12V) or lower currents must be transmitted or both. Obviously this then requires high resistance loops or addition of pairs of low Ohm power resistors in-line with loops. The main AgTEM loop has 5 possible turns – instead of using two turns in parallel with close to 50 amps transmitted, for short cycle-times simply using one turn with 5V can be sufficient to get a suitable current waveform.

Using multiple in-series turn loops exacerbates the ramp up problem as self-induction increases with the square of the number of turns and it is self- induction that slows the rise of the current waveform. Use of any more than 1 turn with sub power-line cycle times is not recommended.

Highly affected current waveforms result in very different decays to true 50% duty cycle square waves so good modelling packages will require that the current waveform be measured and input into the model.

Below is an example of a high current dual cycle-time sounding. Lack of energy in the shorter cycle time waveform leads to a faster decay which must be modelled to create meaningful interpretation.

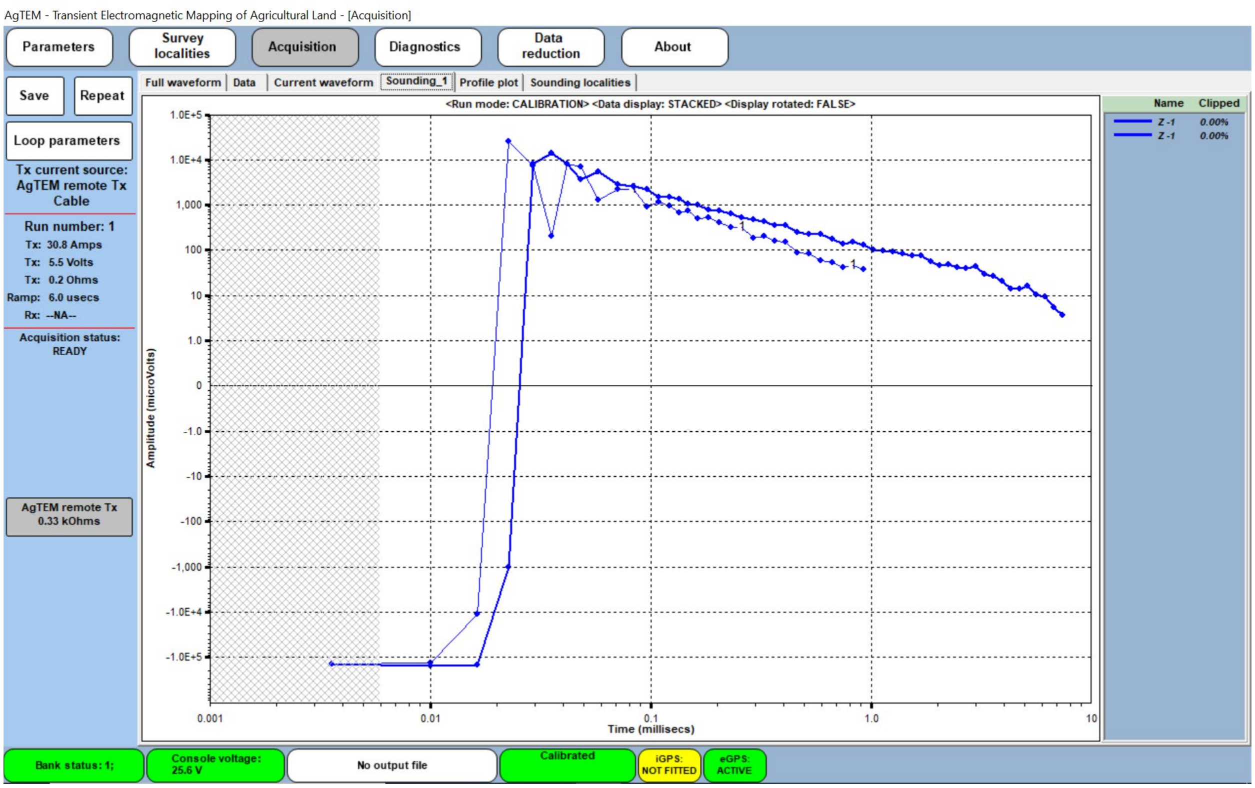


Figure 84 A high current sounding at two different cycle times. Lack of energy in the shorter cycle time leads to a faster decay.

Below is displayed a high current waveform at 33.333 mS cycle-time. This is adequate cycle-time for such current as the current is observed to have levelled off.

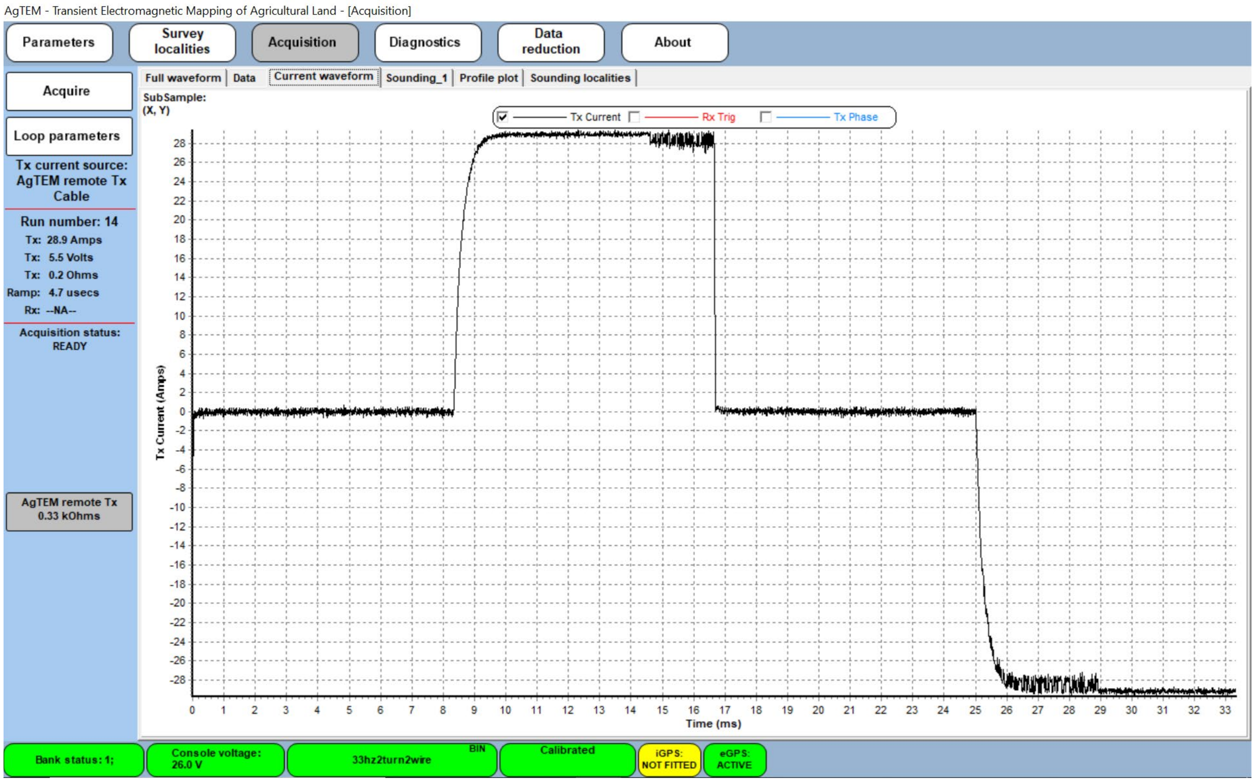


Figure 85 A high current waveform with adequate cycle-time (33.333 mS) for 5V transmission. observe that the waveform has had adequate time to level off. This is a 2 in-series turn loop with 2 wires in parallel in each turn driven by 5V.

The next figure shows the same system with 5V transmission into the same loop but at 8.333 mS cycle-time. Measured current remains almost the same and this current waveform could be practically used but only barely.

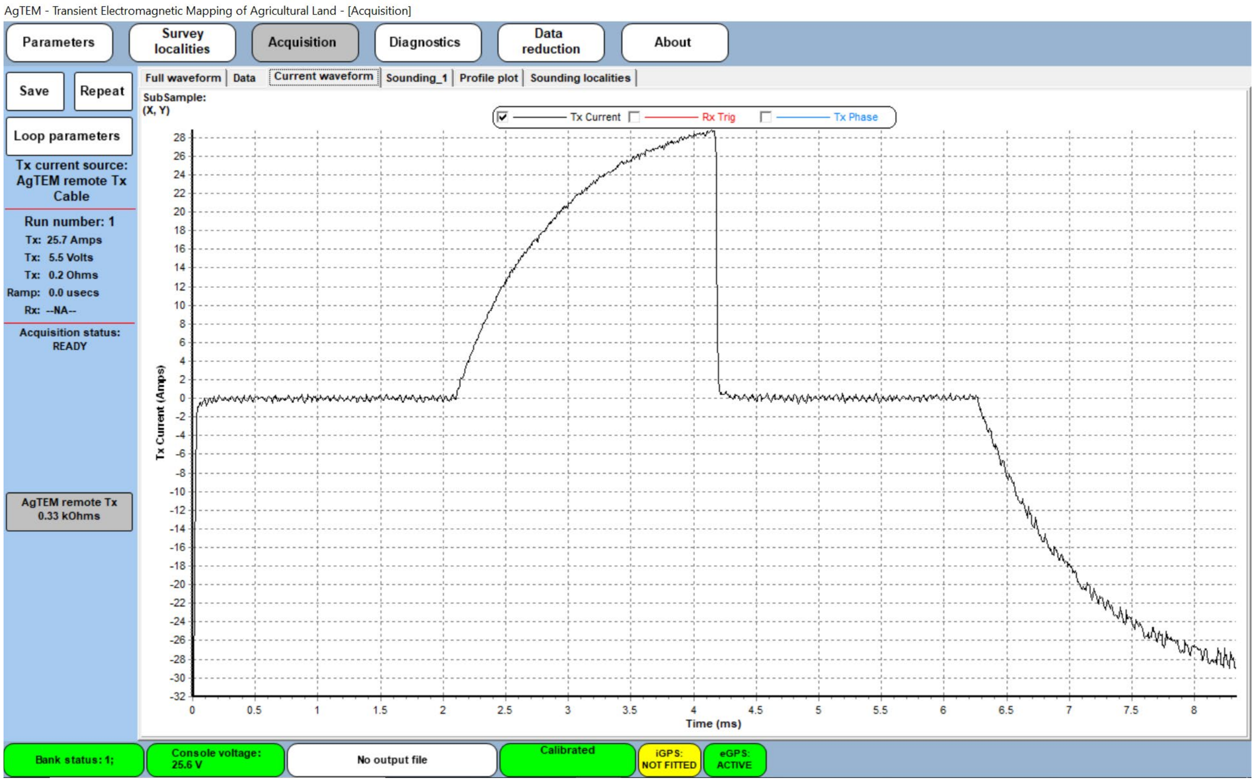


Figure 86 The same system as in the above graph but this time showing a current waveform for 5V transmitted at 8.333 mS cycle-time. It has not been able to level off but could practically be used (just). This is a 2 in-series turn loop with 2 wires in parallel in each turn driven by 5V.

The next figure shows the same system again but this time with just a 4.1667 mS cycle-time. Now the current reads only half of what it should read if the current was truly a 50% duty cycle square wave. Attempting to survey with such a compromised waveform could lead to increased instability and modelling challenges.

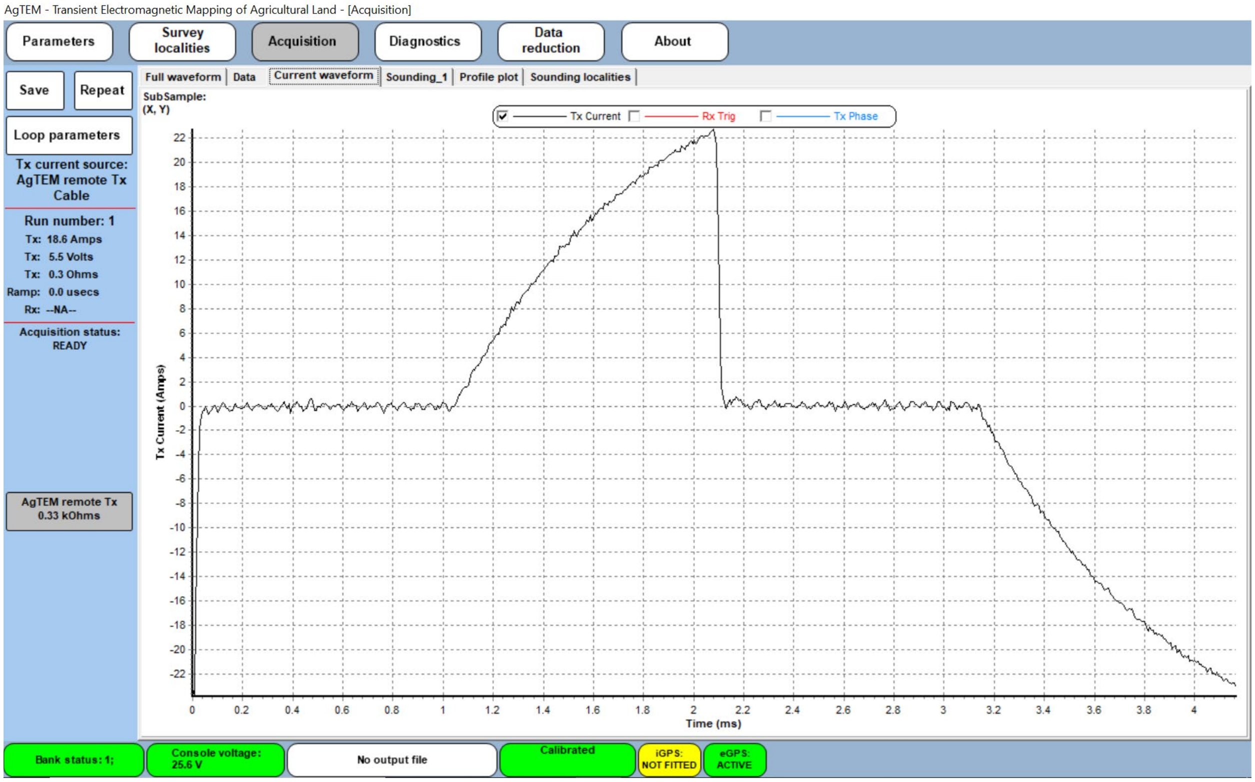


Figure 87 The same system as in the above graph but this time showing a current waveform for 5V transmitted at 4.1667 mS cycle-time. It has not been able to level off but could practically be used (just). This is a 2 in-series turn loop with 2 wires in parallel in each turn driven by 5V – not an appropriate choice for fast cycle-time due to high self-inductance.

VERY LOW CURRENT WAVEFORMS

When AgTEM transmits very low currents into resistive loops such as the 10 Ohm 300x300 mm test loop the current waveform will be rather clean however the Hall effect measurement of that current will be challenged. This is especially the case for low cycle-times. The figure below shows the current waveform for this worst case measurement scenario. Realize that this is noisy looking waveform is not problematic – it is just due to the accuracy of the Hall effect sensor.

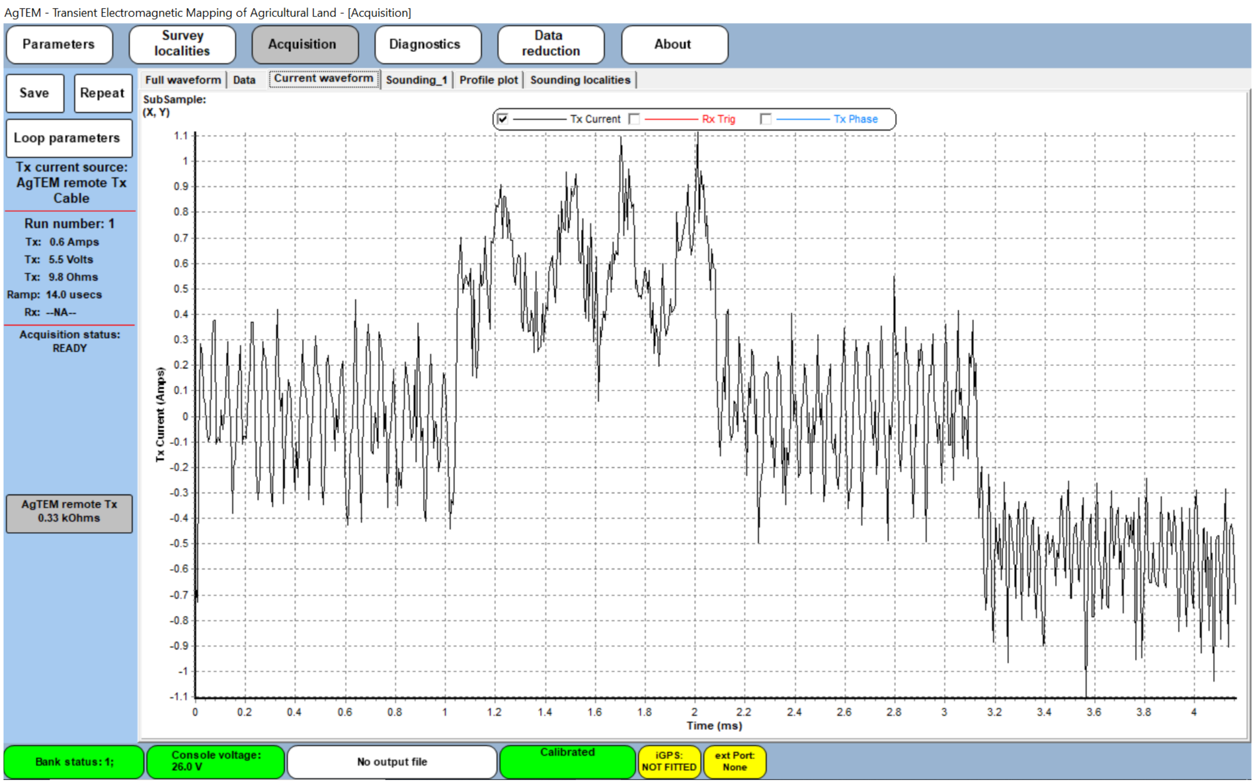
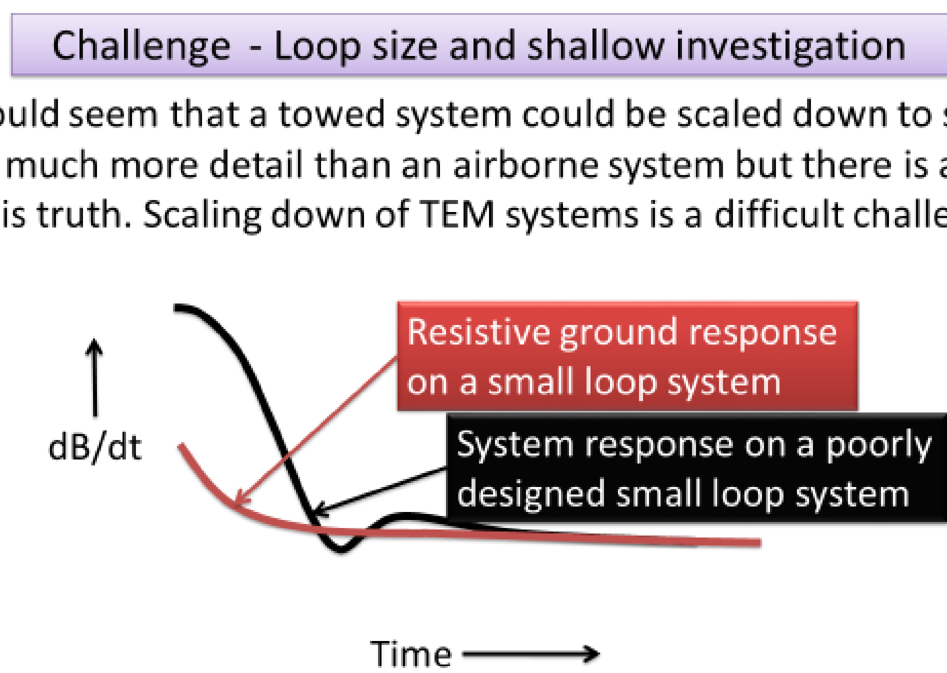


Figure 88 Current measurement of a high resistance low current fast cycle-time waveform using a Hall effect sensor pair is not very effective. The 50% duty cycle square wave actual waveform transmitted here is clean and soundings obtained from it will be fine.

SOME DESIGN CHALLENGES



- The loop sizes must be large enough to transmit/receive moments well in excess of EM noise levels.
- Inductance, which increases with the square of the number of loop turns, must be kept low in order to keep turn-off time and loop self response adequately low.

- Understating - adding lots of loop turns on a small loop cannot work!

ADVANCED TROUBLESHOOTING – OSCILLATIONS - COMPARISON OF TERRATEM16 AND AGTEM24

The TerraTEM 16 bit system and the new AgTEM 24 bit system acquired data at the same site with the same loops of the Wallaroo structure (see photo). Tests were done with the system stationary on top of a granitoid hill without much soil - thought to be very resistive. This was excellent for showing system response and noise problems as there was little ground response to overprint such effects.

Figure 89 The AgTEM-Wallaby system as used for these tests.

Figure 90 The front loop as used fro these tests.

There was an in-loop receiver with a pre-amp and damping resistor and there was a slingram front loop without a pre-amp but with 150 ohm damping.

The concepts of resonance, critical damping and aliasing (see diagrams) are important to understanding the following data. Remember that the sampling is in approximately logarithmically spaced gates. This makes understanding aliasing & resonance somewhat more complicated in the examples below. Near time zero, gates are linearly spaced at minimum spacing but become closer to logarithmically spaced at later time.

The TerraTEM16 samples at 500KHz (2uS gates) while AgTEM24 samples at 156.25KHz (6.25uS gates) (625 KHz is possible).

The in-loop receiver is not null-coupled but receives the full primary field in the centre of the transmitter loop so it can be expected to show maximum system response. The front loop shows a minor system response.

The TerraTEM16 and AgTEM24 receivers use different time gates so for comparison data has had to have been plotted against time rather than gate number.

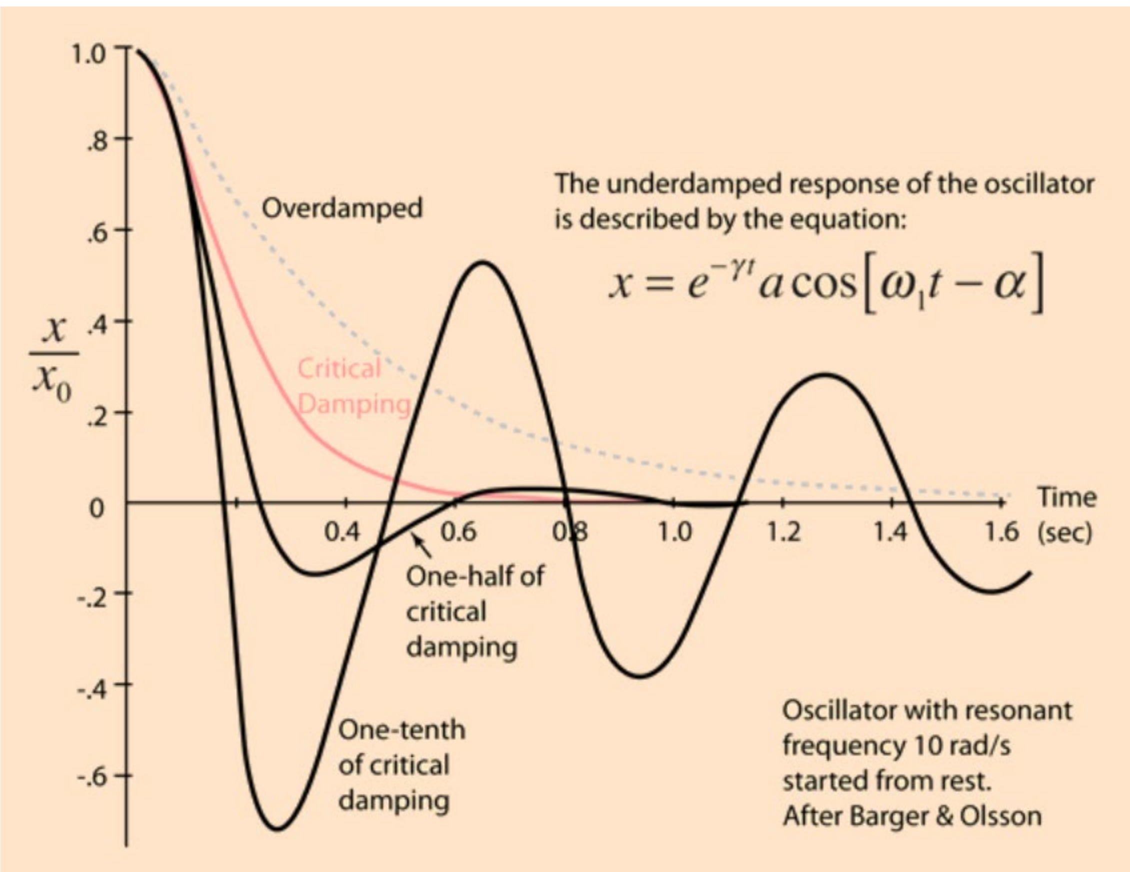


Figure 91 The principles of overdamping, critical damping and underdamping of resonant oscillations.

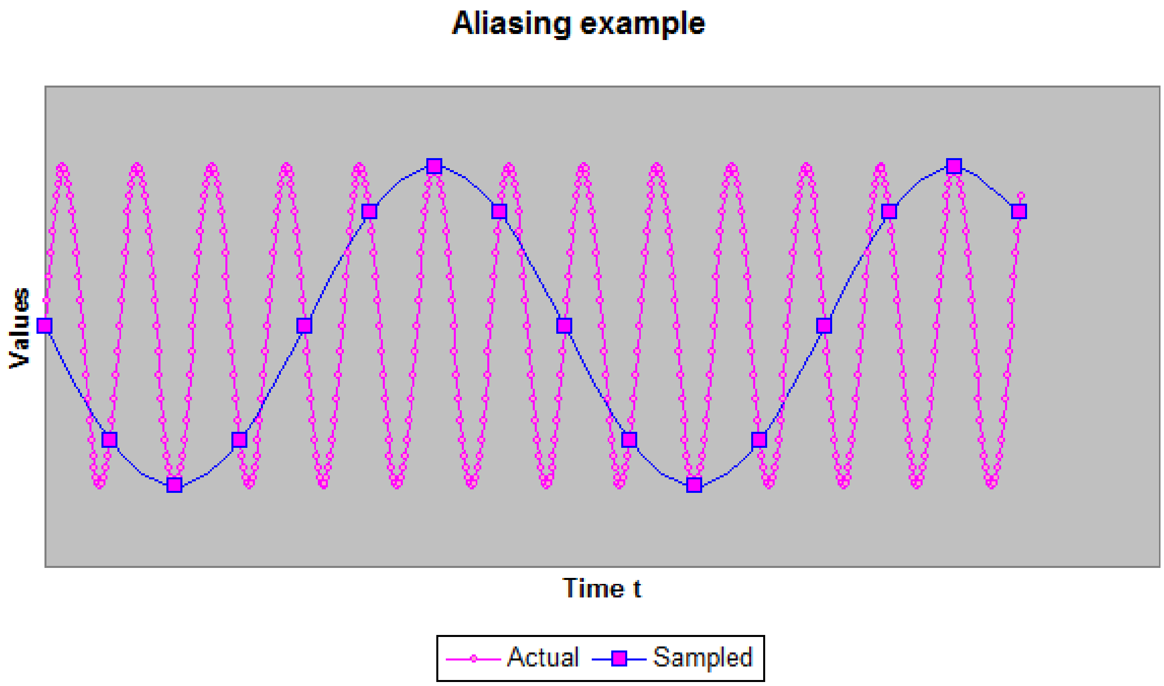


Figure 92 The principle of aliasing.

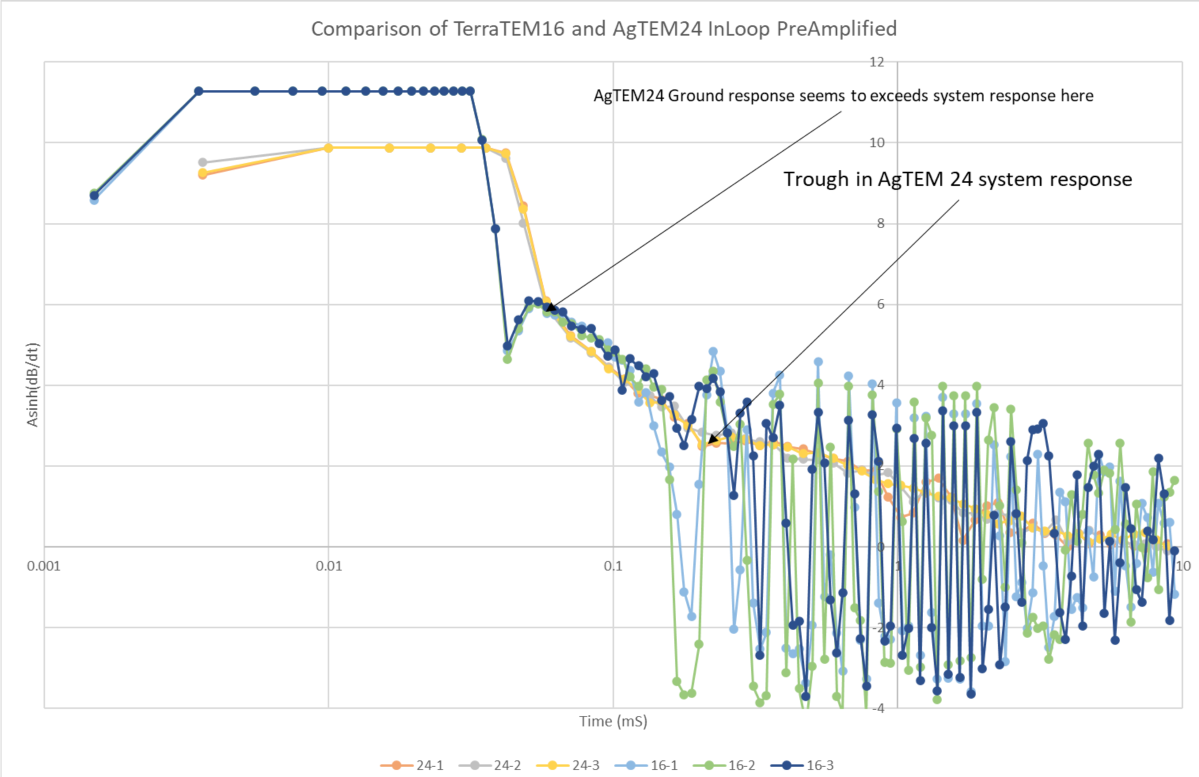


Figure 93 Comparison of TerraTEM16 and AgTEM24 data at a resistive site using the In-loop receiver of AgTEM-Wallaroo. AgTEM 24bit data is labeled 24-1, 24-2, and 24-3 while TerraTEM 16 bit is labeled 16-1, 16-2, and 16-3. Notice how well the repeats match until late times.

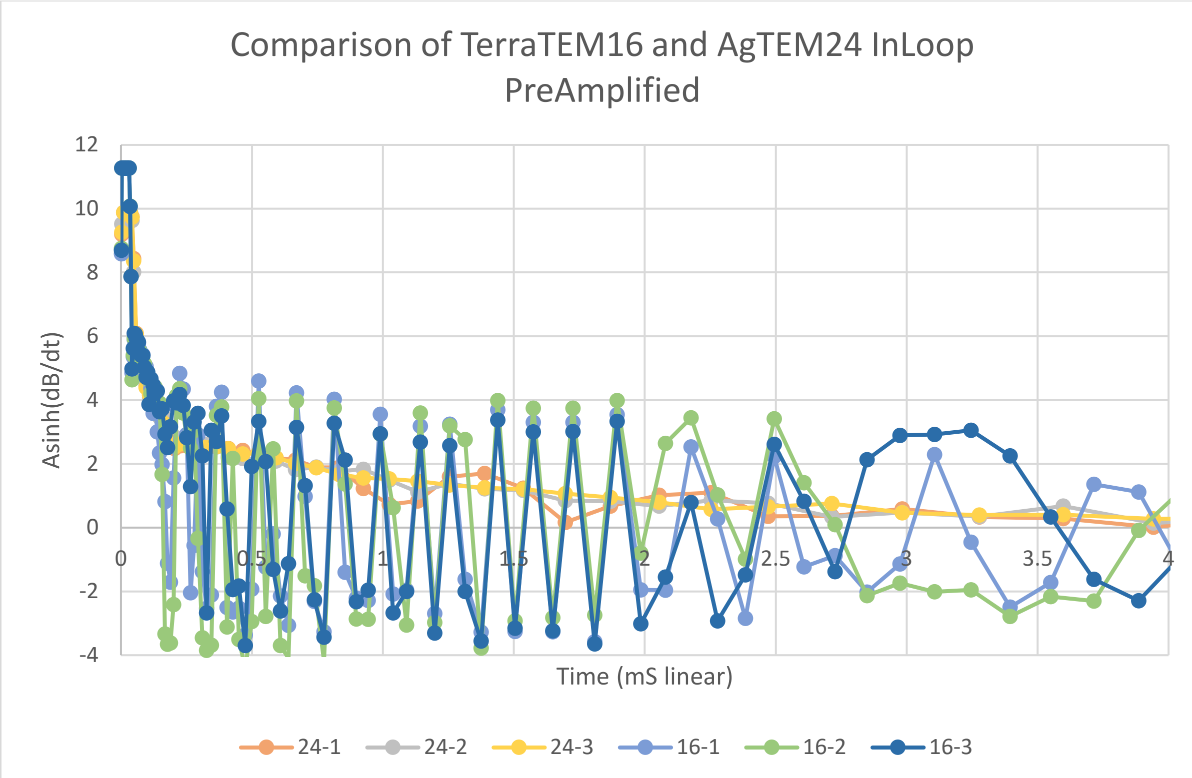


Figure 94 As above but shown on a linear time axis

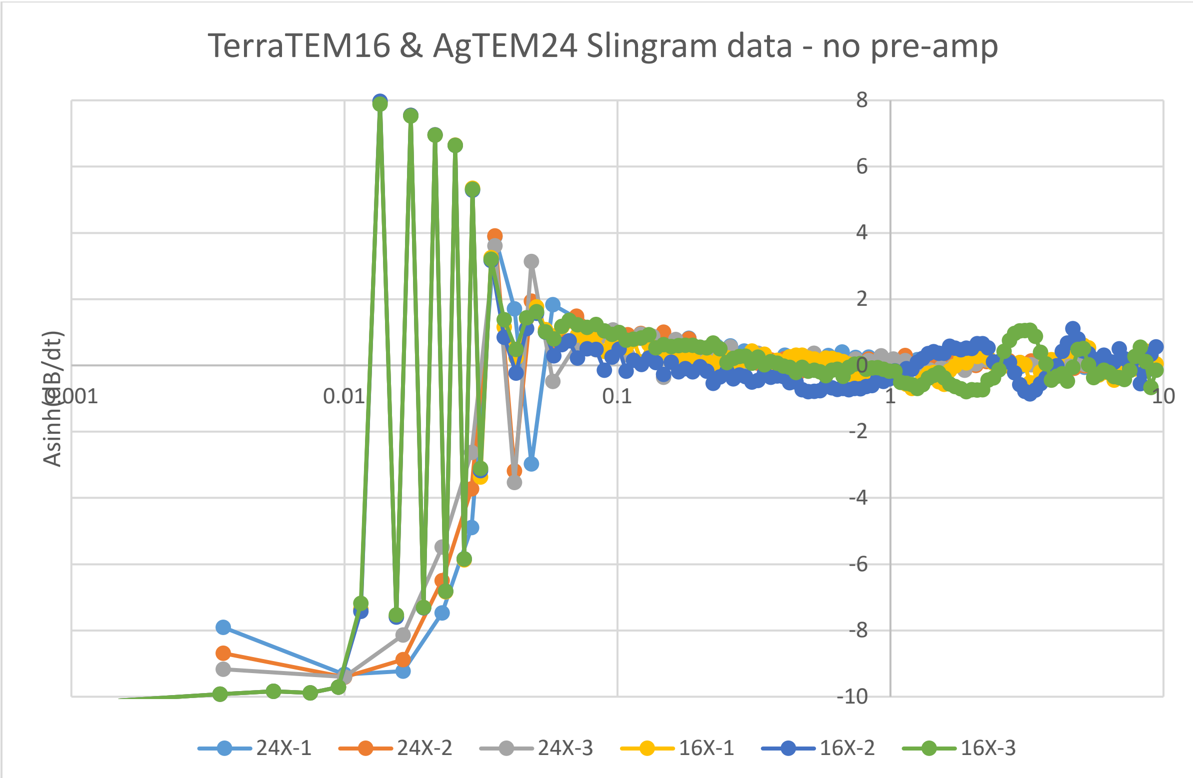


Figure 95 Comparison of TerraTEM16 and AgTEM24 data from a slingram loop with no preamp. Signal here includes little primary field from the transmitter loop and did not saturate amplifiers yet strong but very stable oscillations are present in the TerraTEM16 data. AgTEM24 data oscillates once at the crossover.

Oscillations observed are clearly electronics dependent rather than entirely loop dependent. Notice the replication of oscillations between repeats.

A trough in the AgTEM24 system response is evident in this and a lot of other data and is known, from results of modelling, to be part of system response. True system response would be easier to determine if we could model and remove ground response using independent verification of ground resistivity at one site.

Magnitude of TerraTEM16 and AgTEM24 receiver data seems to match fairly well in Figure 13 yet turnoff time differed from 11uS to 21uS due to tripling of current by the AgTEM24 system so good direct comparison is not possible until late time where the TerraTEM16 data is too noisy. Gain of the TerraTEM16 system was set to 32 while gain of the AgTEM24 system was set to 100. This should be considered when comparing the overflowed parts of the data in Figure 22. Both systems are known to be capable of cleanly absorbing overflow energy at these gains without dissipating it in the decays at later times.

INTERPRETATION OF AGTEM PRODUCTS

ELECTROMAGNETIC THEORY

Electromagnetic theory cannot be addressed in detail in this manual. For a really easy introduction to TDEM theory please see https://archive.epa.gov/esd/archive-geophysics/web/html/time-domain_electromagnetic_methods.html or ***Wightman, W. E., Jalinoos, F., Sirles, P., and Hanna, K. (2003). "Application of Geophysical Methods to Highway Related Problems." Federal Highway Administration, Central Federal Lands Highway Division, Lakewood, CO, Publication No. FHWA-IF-04-021, September 2003.***

DISCRIMINATING OBJECT RESOLVABILITY AND DEPTH OF INVESTIGATION

Depth of investigation in TDEM is a vague concept because it is extremely dependent on the resistivity model and its variation. Further training of interpreters is recommended on a site-specific basis by use of the ResImage forward modelling and type curve set generator. This reveals to the interpreter what can and cannot be realistically resolved by AgTEM or alternative tools at various depths and how adjusting configuration may help or hinder detection.

Even though Depth of Investigation Characteristic parameters are calculated by software to help assess reliability of modelling, validity varies strongly with the type of model being resolved.

HOMOGENEOUS HALFSPACE APPARENT RESISTIVITY

Initial interpretation of AgTEM data may be achieved using the homogeneous halfspace late time apparent resistivity formula:

$$\rho_a \approx \frac{I^{2/3}\mu_0 a^{4/3}}{20^{2/3}\pi^{1/3}t^{5/3}}\left(\frac{-\partial H_z}{\partial t}\right)^{-2/3}$$

which is valid only if the receiver coil is central to the transmitter loop and only after the induced current from the transmitter loop has migrated sufficiently to be able to assume it is a dipole field centred beneath the receiver coil. There are also other approximations and assumptions involved.

Pa = apparent resistivity in Ω.m

I = Transmitter loop current x number of loop turns (amps)

μ_0 = 4pi x 10^{-7} but **beware of different systems of units**

a = transmitter loop radius in metres (approximate for non-circular loops)

t = time in seconds after assumed instantaneous turnoff of current in the transmitter loop

dH_z/dt = voltage in the receiver loop normalized to assume the receiver has area of 1 m^2.

For out of loop receivers, at early times this will produce non-depth dependent negative response followed by an asymptote and then will taper back to approximate data collected with a central loop receiver.

From: http://www.swim-site.nl/pdf/swim16/barrocu.pdf

I B S Yogi and Widodo 2017 IOP Conf. Ser.: Earth Environ. Sci. 62 012029

It is easy to plot an apparent resistivity curve with respect to time but transformation to apparent resistivity with respect to depth is not as easy as for direct current methods. The depth that each time in a decay curve represents is hard to grasp, partly because it is extremely dependent on conductivity of layers and partly because initially, in early times, it is depth independent. Further complication stems from how the current distribution maxima, or equivalent current filament loci 'smoke ring' propagating into the ground is not the effective depth sensed by the receiver as the receiver has increased sensitivity to near surface current flow. We can plot apparent resistivity against various parameters, but it is anticipated that the simplest parameters overestimate effective depth (from which 50% of response is obtained) by 1.5 to 4 times (which often leads to misleading claims about depth of exploration of instruments). The formulae for the most common simple depth estimation parameters, along with what they physically represent are (from Nabighan and Macnae 1991 – see below):

$$d_{Electric\ Field\ Maximum} = \sqrt{\frac{2t}{\sigma\mu_0}}$$

$$d_{Equivalent\ Current\ Filament} = 4\sqrt{\frac{t}{\pi\sigma\mu_0}}$$

Where $\sigma = 1/\rho_a$

Note well that these equations are actually dependent on conductivity of the ground. Some elementary transformations take this approximation and apply it to data at successive times, cumulating the impact conductance of layers to correct depths.

There is more discussion on this subject in Combrick's Thesis (Uni of Pretoria) - https://repository.up.ac.za/bitstream/handle/2263/25339/04chapter4.pdf?sequence=5&isAllowed=y

Nabighian, M.N. and Macnae, J.C. (1991) Time Domain Electromagnetic Prospecting Methods. In: Nabighian, M.N., Ed., Investigations in Geophysics No 3. Electromagnetic Methods in Applied Geophysics, Society of Exploration Geophysicists, Oklahoma, 427-514.
http://dx.doi.org/10.1190/1.9781560802686.ch6

Near-surface conductive features strongly affect TDEM data at all decay times so apparent resistivity interpretation is very poor at revealing deeper features. Modelling involving inversion greatly improves deep feature discrimination.

SIGNAL DECAY RATE

It is useful to know how electromagnetic signals decay and interact with layers within the earth as it provides an accurate perspective on how easy it is to resolve layers. Observe from the late time homogeneous apparent resistivity formula that response decays with the -5/2 power of time (should the equation be rearranged). Similarly, if the halfspace is resistive, a thin sheet conductor, once the signal reaches it and focuses within it, will give a response decay with the -1/4 power of time. These create distinctive slopes on log-log decay plots and the experienced interpreter will become familiar with them, then able to identify anomalous behaviour.

It is also useful to know how much response resistivity models will create before any electric current 'smoke ring' migration occurs. The magnetic field in a thin plate will be:

$B_z = \mu M_T/(16\pi d^3)$

From that thin plate the voltage inducted in the receiver coil immediately after turnoff will be:

$V_z=3\mu b M_T M_R/(32\pi d^4)$

Where:

b = 2/(μσh)

h = plate thickness

d = depth

M_T = transmitter moment

M_R = receiver moment

Notice, as stated before, that response drops with the inverse fourth power of depth to the thin sheet.

AGTEM OPERATORS NEED TO BE ABLE TO INTERPET THE GEOLOGY THEY ARE SURVEYING

As hydrogeology can be complex, and AgTEM only presents electrical resistivity images, it is not generally easy to interpret AgTEM data. Rather, AgTEM data typically creates more questions than answers as it exposes real geology far removed from pre-conceived simplistic geological concepts and it does this very well and in great detail.

Unlike airborne TEM surveys, AgTEM surveys tend to be small projects where the operator must make coverage and project value decisions before and during acquisition. It is typical to be surveying with a farmer stilling in the passenger seat asking about the data as it streams in. If a water bore site can be accurately assessed and mapped there and then the survey can finish whereas if it cannot then survey will need to be conducted further with a limited budget. The operator tends to have to take the role of expert geological interpreter in such surveys.

Data observed in the field will not be accurately modelled to resistivities and depths but having an understanding of a suite of case studies will make a huge difference in ability to make good interpretation decisions during acquisition.

Some hydrogeology and a small sample of case studies is presented here to help trainee operators.

HYDROGEOLOGICAL FEATURES IDENTIFIABLE IN AGTEM DATA

As towed TEM is generally solely affected by groundwater related variation (saturation, salinity, permeability in hard rock, and sediment texture in alluvium) it is perhaps ideal for groundwater exploration. The interpreter knows that what they observe must map groundwater parameters in some way or other - but how?

Clearest surveys are perhaps where sandy or gravelly channels with fresh groundwater are hosted in clay floodplain sediment or weathered saline basement rock. In Australia, hydrogeology is rarely this simple.

A more common situation is where volcanic activity is mixed in with alluvial activity such that lava flows or reworked ash flows, weathered to clay, are interspersed in alluvial sediments which may then have cut through the volcanic features in places. Further, structural deformation during or after deposition is common and further affects groundwater flow.

In some places, sediment may be relatively homogeneous but groundwater of different salinity will enter from beneath in places such that isolated plumes are encountered – readily identifiable in detailed towed TEM.

In fractured rock, weathering extends down fractures to limited depth. Deeper down veins and faults are often silicified and cannot yield water. Towed TEM is very useful for targeting the right fractures and depth to drill, yet basement rock salinity variation may complicate interpretation.

Another common complexity is a result of different regimes of alluvial activity cutting into sediment or eroded land surfaces left by prior activity of different flow regimes. This may be mixed with aeolian (wind) deposition. Such complexity is best understood using detailed 3D data such as is generated by towed TEM.

AMBIGUITY IN INTERPRETATION

Despite the advantages of towed TEM systems, ambiguity generally is left in groundwater investigations utilizing such systems. The following are common causes of ambiguity:

1. Useful aquifers may be below DOI. Towed TEM can only help in such situations if geology continues upward from groundwater depths to the DOI. This is usually the case in fractured rock aquifers but often is not in layered alluvial systems.
2. Thick saline clay overlies and hosts thin freshwater aquifers. As TEM response is dominated by the clay, the thin aquifers become unresolvable.
3. Freshwater gravel and sand aquifer resistivity contrasts poorly with hard or weathered basement rock resistivity. In such situations, often compounded by limitation 2 above, survey detail is paramount. Geological geometric features, including alluvial features and bedrock features such as dipping rock layers can then be recognised and compared using geomorphological reasoning.
4. In fractured rock, the most resistive features may be hard rock and the most conductive may be excessively saline groundwater. Targets of intermediate resistivity may yield better quality water or may just be saline water in tighter fractures. This ambiguity is solved with some exploratory drilling.
5. Volcanic flows are very common in alluvial systems and may mimic the shapes of river channels into which they flowed. They introduce the ambiguities already mentioned and often their significance has never been considered prior to survey.
6. Deep drainage from irrigation obviously changes moisture and salinity in sediment. It is not uncommon to notice strong correlation between frequently irrigated parts of paddocks such as under centre pivots with deep resistivity anomalies and these will cross or even be complicated by geological features. Survey detail can reveal the super-position of such influences.
7. When drilling occurs, coring is rarely conducted and chips logged may look almost identical when drilling of either weathered rock or alluvium from the same source is occurring. One may be an aquifer and the other not. Although the contrast may be detected by towed TEM it may be missed in logging such that there is an apparent contradiction. The driller may describe a gravel yet when pump testing occurs it becomes obvious there is no yield as the rock was weathered granite and only looked like gravel once it was drilled. Such ambiguity is not introduced by towed TEM but does affect discussion with farmers and drillers.
8. There are also ambiguities left by modelling limitations. When 1D layered model assumptions are used, then descending conductive ends are modelled onto ends of outcropping or otherwise terminating conductive layers. Improper system response removal can readily add artificial features of extreme conductivity at around the limit of depth of investigation, particularly in resistive terrain so qualitative, as well as automated quantitative assessment of depth of investigation should occur.

CASE STUDIES – GROUNDWATER EXPLORATION USING TOWED TEM

In the following case studies, results are discussed from surveys performed on several farms. These surveys were conducted using line spacing of between 10m and 50m, generally in irregular grids taking advantage of orientation of cultivation and logical paths around obstacles. In many locations, separation from cultural features such as fences had to be considered. This was done by surveying up to the features, observing their response and then moving far enough away that the observed cultural response was no longer visible in the data. Various examples of such real time data observation, including wind noise, fence anomaly detection, telephony (buried insulated conductor) cable detection, powerline anomaly detection, electric fence spike detection, and buried road culvert response are given in the observation chapter. Using this system, data have been collected over a number of different target types, which demonstrate typical complexities and how they may be explored using electrical conductivity imaging (See Figure 2).

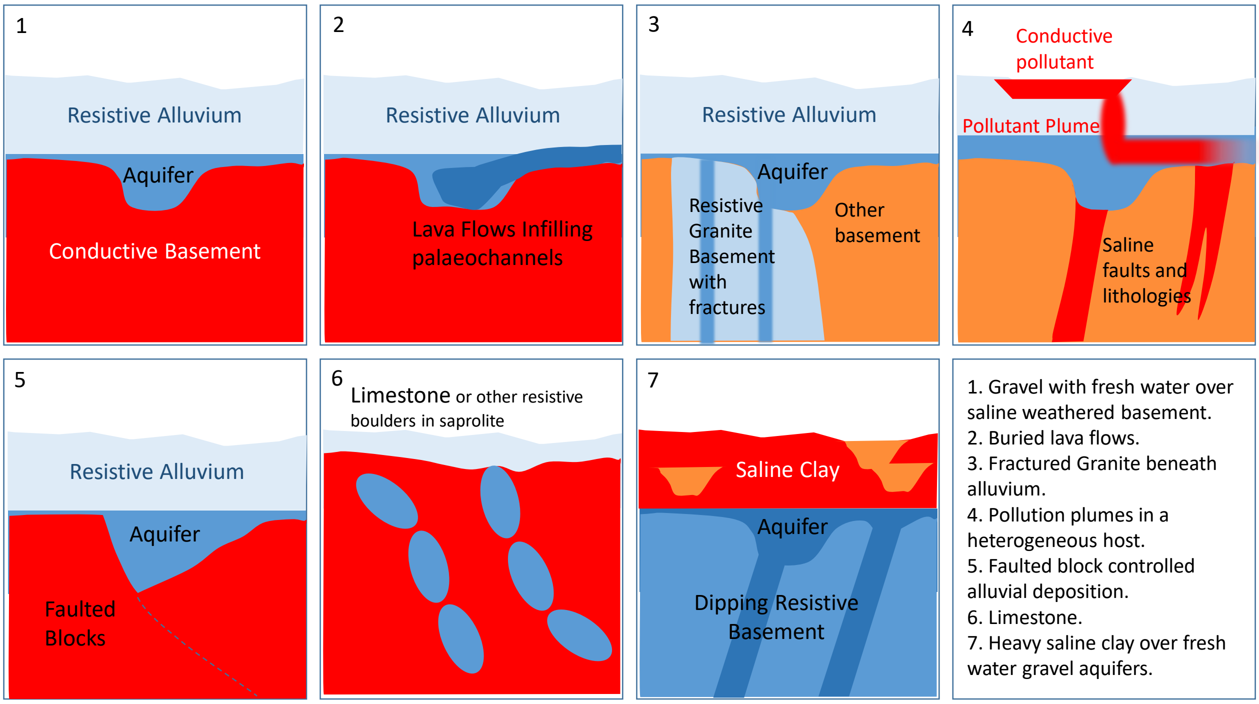


Figure 96 Conceptual models of typical TEM targets. Notice that in many cases the target is far from ideal in terms of resolvability using TEM yet, with sufficient consideration of survey design these problems can be resolved.

1. GRAVEL WITH FRESH WATER OVER SALINE BASEMENT.

This is a common situation in Australia where much of the older, folded, indurated rock is highly weathered. An example was presented in Allen (2012 – reproduced here in Figure 3), with resistive fresh water in gravel overlying an undulating conductive weathered basement – the ideal scenario for electromagnetic exploration. A deep, gravel-filled channel was detected 70m deep incised into high conductivity, weathered basement. This scenario is relatively easy to image and interpret.

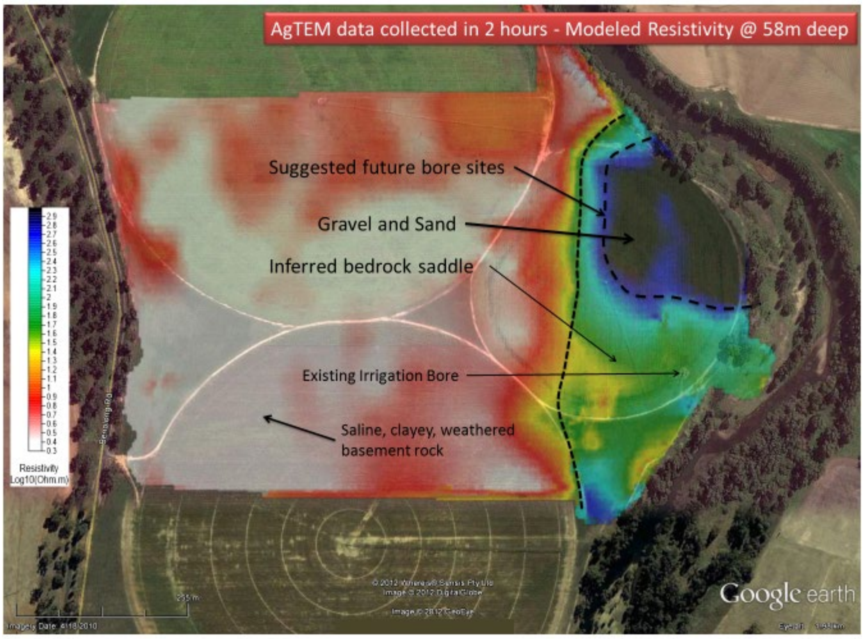


Figure 97 TEM response of gravel with fresh water overlying saline weathered basement.

2. BURIED LAVA FLOWS.

Lava flows within alluvial sediment generally are relatively resistive but pyroclastic layers within can be highly porous and weathered, therefore conductive both hydraulically and electrically. There are groundwater flow complications associated with such flows which typically have blocked and filled prior river channels, damming and redirecting those rivers. A lava flow typically appears as a sinuous resistive feature resembling a palaeochannel in some cases. Typically, one drill hole intersecting the flow is then needed to identify the whole flow as being of pyroclastic origin or a palaeochannel. Groundwater exploration in this environment may target permeable brecciated, or pyroclastic zones within flows or may look for sands and gravels beyond or crosscutting the flow. Resistivity contrasts may be subtle as shown in Figure 4.

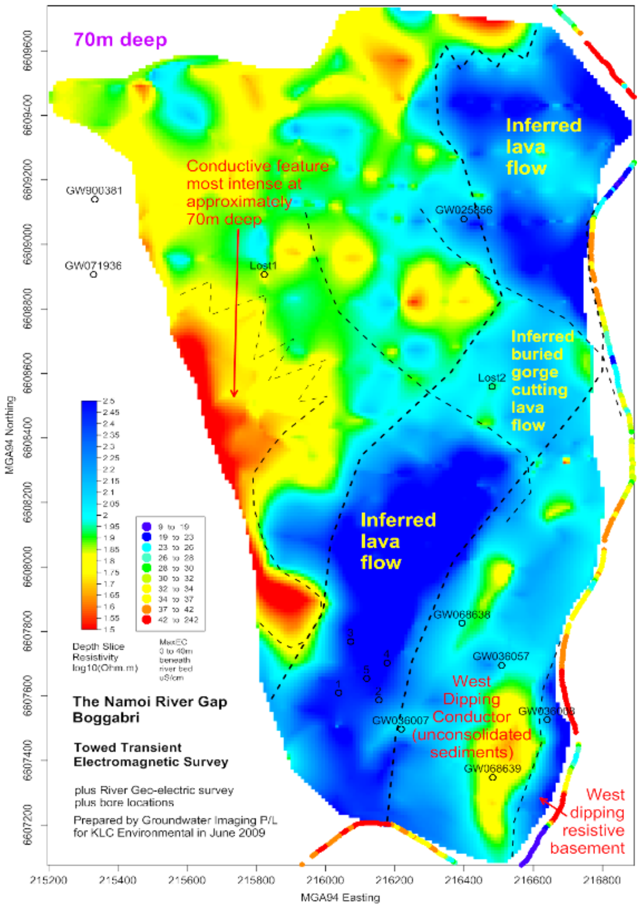


Figure 98 A lava flow in a palaeochannel subsequently cut by another palaeochannel and covered with sediment. Without both drill-hole data and detailed TEM data this complex conceptual model would never have been realized.

3. FRACTURED GRANITE BENEATH ALLUVIUM

Granite is resistive and does not form significant salt and clay when weathered so the weathered granite may be of similar resistivity to that of fresh water in gravel and sand. For this reason the gravel/sand and weathered granite may be indistinguishable based on comparisons of electrical conductivity alone. In this situation, however, detailed surveying distinguishes alluvial and fractured rock geometric features. Where fast flowing water has eroded through granite leaving steep buried terrain the interpretation is more difficult as a buried fracture zone may both underlie and resemble gravel filling a buried gorge. Nevertheless, a detailed survey in this type of environment (see Figure 5) reduces the number of drilling targets needed to get a full detailed understanding of the site.

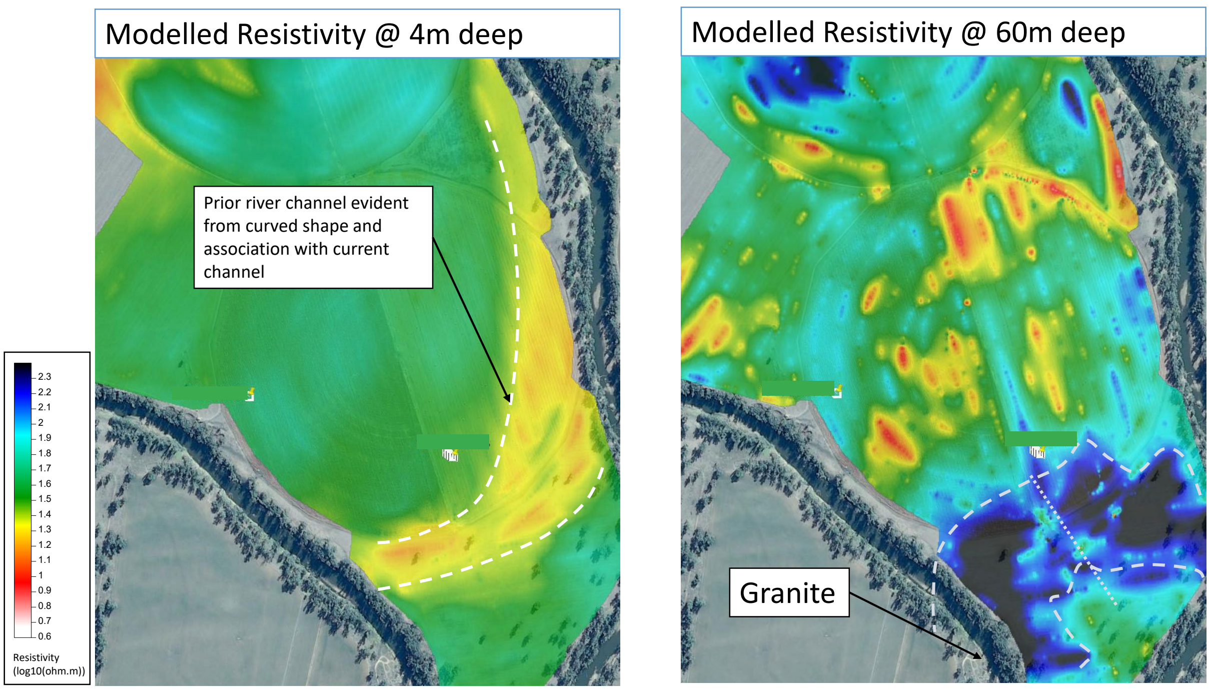


Figure 99: Towed TEM survey of alluvium over buried granite and other folded rock. Alluvial features are evident in shallow data above the water table. To find a good bore location, deeper data affected by granite and folded rock potentially cross cut by buried gorges filled with gravel must be interpreted. At this depth, data noise and inversion instability is also beginning to appear and can be disregarded by ignoring any trends that are not evident across multiple survey lines. In this case interpretation requires the assistance of some drill holes –the best bore site may not be targeted in the first hole.

4. POLLUTION PLUMES IN A HETEROGENEOUS HOST

It is usually simple to image a saline pollution plume within a homogeneous non-saline host but such a situation is not common and is more likely found only when oversimplified conceptual modelling is considered. It is more common for the host to also have saline sediments or natural fluids in fractures (see Figure 2). With sufficiently high data density it is possible to define plume shapes radiating from a source overprinting the background saline features. In this situation, detail is very important. Without sufficient data resolution it is possible to mistakenly attributing natural saline features as pollution from man-made sources. Pollution sources are typically also in areas where cultural features such as metal pipes and fences that affect electromagnetic data. Detailed acquisition identifies and isolates the effect of such features on data so they can be excluded. To correctly interpret natural lineaments and other features around plumes it is critical to survey well beyond the plumes.

5. FAULTED BLOCK CONTROLLED ALLUVIAL DEPOSITION

It is common for faulting to have occurred during alluvial deposition and this can alter and control deposition yet leave little evidence at the surface. Detailed electrical conductivity surveys reveal the difference between straight sets of faulted block edges and meandering alluvial features partially controlled at depth by the faulting. This type of interpretation can very quickly eliminate large areas from prospective groundwater exploration.

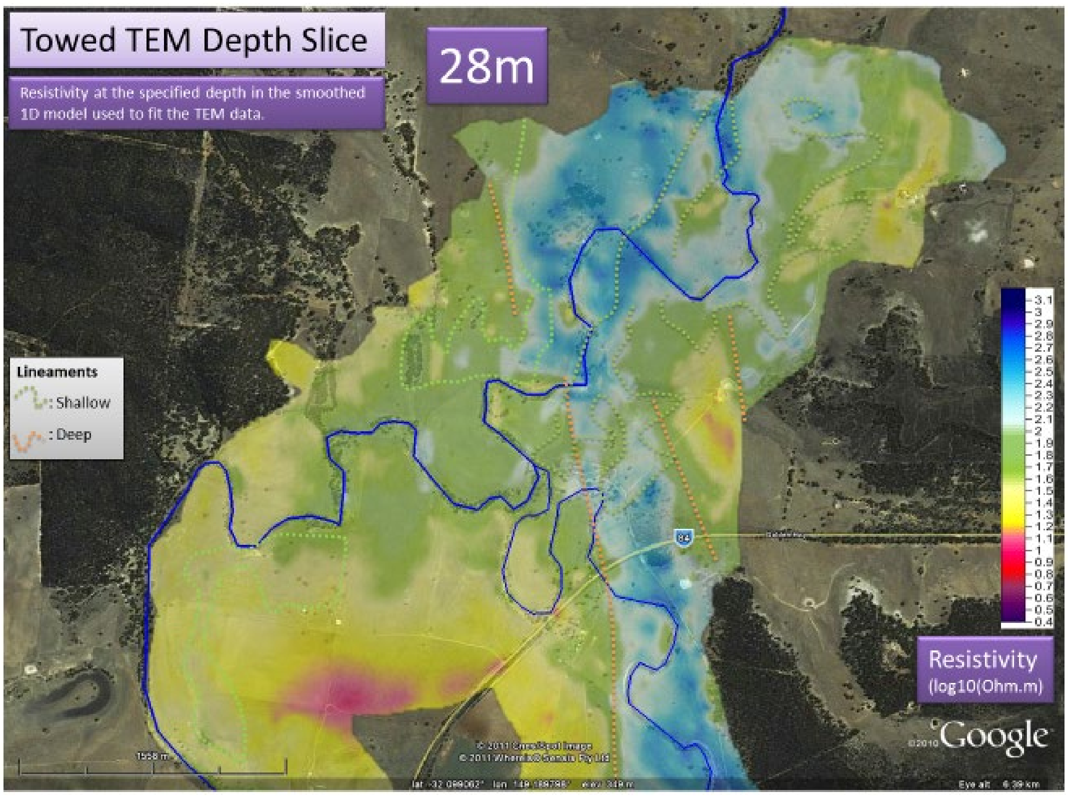


Figure 100 TEM data dominated by tilted and faulted rock where surface geomorphology reveals only meandering channels (green dotted lines superimposed from a shallower resistivity map). Note the straight approximately north-south lineaments (orange dotted lines interpreted from this and deeper resistivity maps).

6. DIFFERENTIATING HARD ROCK FROM WEATHERED ROCK

Limestone is an extremely resistive rock that weathers to an electrically conductive clay that retains ground moisture. This means that electromagnetic surveying over limestone can tell a lot about limestone boulder distribution by imaging the conductive clay surrounding resistive limestone boulders. Many igneous rocks also weather to conductive saprolite containing boulders (Figure 7). In this example the rock is to be mined as dimension stone. The approximate locations and depths of the most competent boulders have become evident. Similarly, such surveying is useful for blast pattern design optimization and excavation planning in any quarry or road cutting where resistivity contrasts exist.

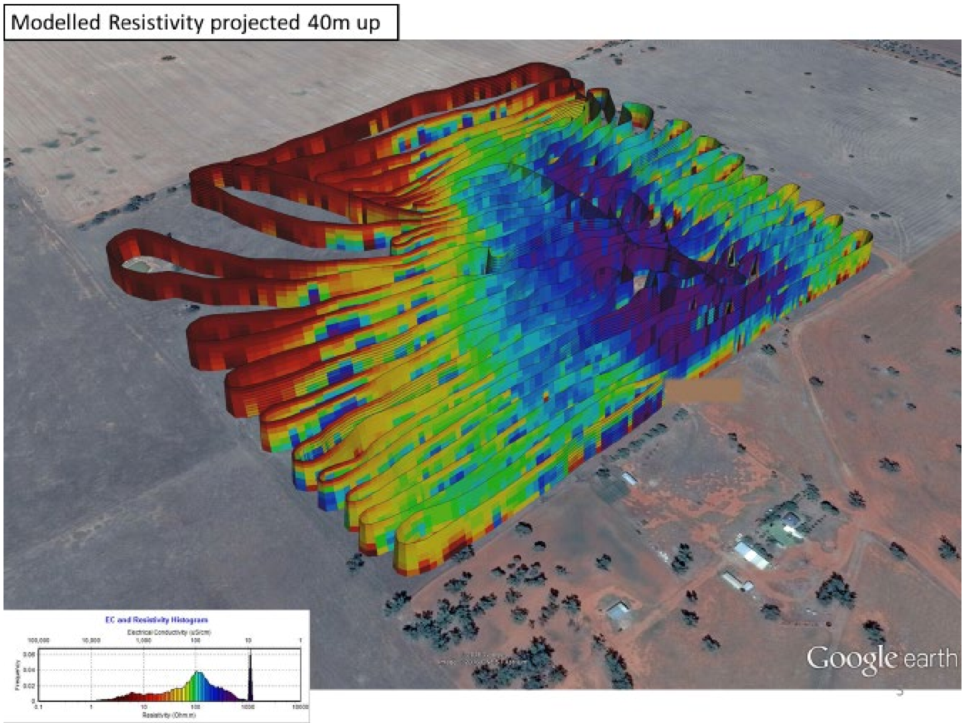


Figure 101 An example of hard rock (Monzodiorite) definition using mine-scale TEM survey (20m spaced lines).

7. HEAVY SALINE CLAY OVER FRESH WATER SAND AND GRAVEL AQUIFERS

A surficial layer of clayey and/or saline sediment may strongly impair depth of investigation and resolution of electromagnetic imaging systems but, with sufficient power, imaging beneath such sediment is possible. If deeper aquifers are sufficiently thick then it will be possible to image with sufficient loop moment and transmitter receiver loop separation. Figure 8 is a successful example of imaging through saline clay soil with the AgTEM Wallaby alone (without a Slingram loop).

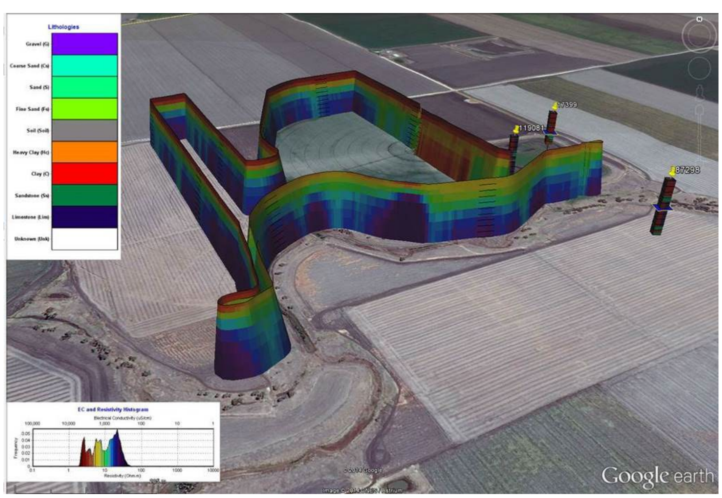


Figure 102 Imaging through saline clayey soil (Condamine Alluvium) to infer sands and accessible fresher water beneath (Purple deep features). Modelled resistivity here is projected 50m up.

8. WEATHERING IN FRACTURE ZONES IN PLUTONIC ROCK

The following case study shows how AgTEM survey interpretation sometimes can be very easy too, even in places where surface geology is void of sufficient helpful clues. In this case fracture zones in plutonic rock such as granodiorite host fresh groundwater. Where the deep moisture was inferred in fractures as shown in the figure below drilling occurred and so much water flowed that the hole kept collapsing and the screen had to be inserted at less than optimal depth.

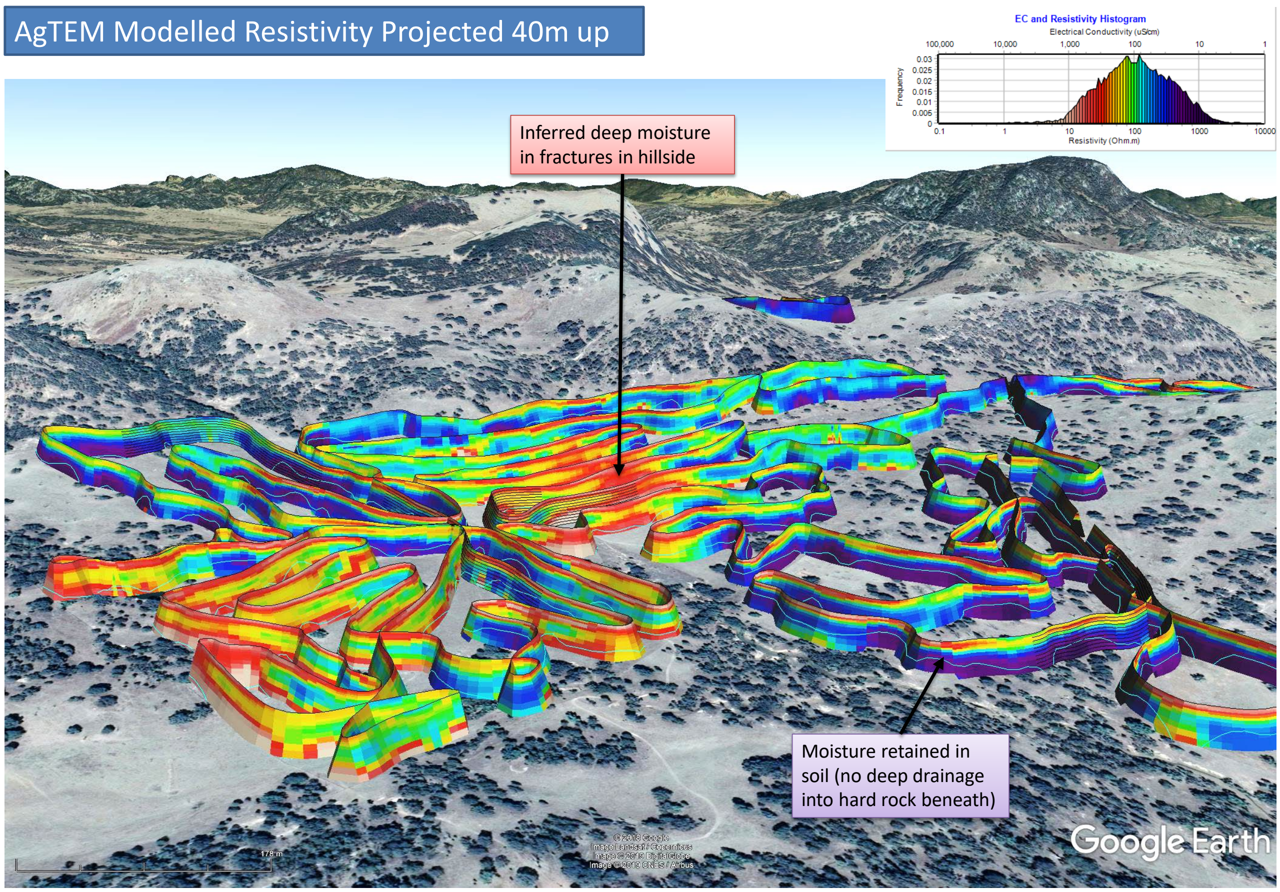


Figure 9. Part of a 1 day AgTEM-Wallaby farm survey over complex igneous terrain. An irregular survey path balances productivity with need for detail for siting bores. 3D orientable presentation is essential for pragmatic interpretation where data is not collected on a dense grid. Even though geology here is not well understood, we can be confident that resistivity data must correlate with dissolved salt ions in the terrain and therefore be relevant to groundwater investigation. Masked by soil, sub-crop that influences moisture distribution is very effectively mapped.

INTERPRETATION OF EFFICACY OF MODELLING

If modelling does not reveal what is expected, it is often due to poor modelling rather than due to the data itself. A strong near surface conductive layer, high resistivity in mid depths, a near surface resistive layer, excessive range in resistivities, and/or strong basement conductivity are typical artefacts of poor modelling.

Modelling of AgTEM data usually involves laterally constrained vertical dimension forward modelling and inversion, typically using the Aarhus Workbench product. Even small errors in seemingly obscure input parameters can drastically affect the output. As a large part of the AgTEM system is composed of uncalculated parasitic capacitance, inductance and resistance, exact parameters often have to be verified using an iterative trial and error approach. Ideally there would be modelled 'fuzzy' ranges for some parameters in the inversion routine. Of particular concern are:

- transmitter low pass filter,
- receiver low pass filter,
- turn off time,
- delays (sync, receiver),
- primary field damping proportion,
- coupling modelling (tx loop to rx loop)
- and system response.

Because AgTEM has loops in proximity these effects can be very significant.

Ideally, all parameters would be set right before modelling however the following is a list of ways to pick bad modelling and to iteratively optimize it.

HOW TO PICK BAD MODELLING

- **Fake conductive layers near the top**, combined with **non-sensical deep conductors.**
- **Fake or excessively thick resistive layer at the top**, with reasonable results beneath.
- **Excessive modelling residual** – for some cases residual can be OK but key, usually early, windows can be greatly in error without greatly increasing residual, while on extremely resistive sites residual can be bad but modelling OK due to lack of SNR.
- A fake near-consistent deep conductor typically indicates a lack of removal of system response and/or incorrect modelling.
- **In cases where modelling is good the range of resistivities narrows, becoming realistic, and the model complexity increases** - that is, the number of alternating resistive – conductive contrasts increases.
- The following examples show how bad even small errors in filter modelling choices can be and why **tweaking filter model values on a small sample of data is very important**.

The balance of all these indicated parameters must be accurate before sensible inversion will occur.

```
[General]
Description=GroundTEMsetup
GPSPosition1=0.00 0.00 0.00
AltimeterPosition1=0.00 0.00 0.00
InclinometerPosition1=0.00 0.00 0.00
RxCoilPosition1=1.83 0.00 -1.20
TxCoilPosition1=0.00 0.00 -1.80
FrontGateDelay=0.00
RxCoilLPFilter1=1.00 8.0E+04
LoopType=72
TxLoopPoint1=1.75 0.00
TxLoopPoint2=1.75 0.50
TxLoopPoint3=2.82 0.50
TxLoopPoint4=2.62 3.00
TxLoopPoint5=-1.98 3.00
TxLoopPoint6=-3.58 0.00
TxLoopPoint7=-1.98 -3.00
TxLoopPoint8=2.62 -3.00
TxLoopPoint9=2.82 -0.50
TxLoopPoint10=1.75 -0.50
TxLoopArea=32.02
CalculateRawDataSTD=0
WaveformPoint01=-10.00000E-02 0.00000E+00
WaveformPoint02=-9.85000E-02 7.00000E-01
WaveformPoint03=-9.65000E-02 1.00000E+00
WaveformPoint04=0.00000E+00 1.00000E+00
WaveformPoint05=1.40000E-06 0.00000E+00
NumberOfTurns=1
GateTime01=1.50000E-06 5.00000E-07 2.50000E-06
GateTime02=3.50000E-06 2.50000E-06 4.50000E-06
GateTime03=5.50000E-06 4.50000E-06 6.50000E-06
GateTime04=7.50000E-06 6.50000E-06 8.50000E-06
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GateTime07=1.35000E-05 1.25000E-05 1.45000E-05
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GateTime15=4.45000E-05 4.05000E-05 4.85000E-05
GateTime16=5.45000E-05 4.85000E-05 6.05000E-05
GateTime17=6.75000E-05 6.05000E-05 7.45000E-05
GateTime18=8.35000E-05 7.45000E-05 9.25000E-05
GateTime19=1.01500E-04 9.25000E-05 1.10500E-04
GateTime20=1.22500E-04 1.10500E-04 1.34500E-04
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GateTime24=3.13500E-04 2.72500E-04 3.54500E-04
GateTime25=3.96500E-04 3.54500E-04 4.38500E-04
GateTime26=4.88500E-04 4.38500E-04 5.38500E-04
GateTime27=6.12500E-04 5.38500E-04 6.86500E-04
GateTime28=7.60500E-04 6.86500E-04 8.34500E-04
GateTime29=9.49500E-04 8.34500E-04 1.06450E-03
GateTime30=1.20450E-03 1.06450E-03 1.34450E-03
GateTime31=1.51550E-03 1.34450E-03 1.68650E-03
GateTime32=1.90650E-03 1.68650E-03 2.12650E-03
GateTime33=2.45650E-03 2.12650E-03 2.78650E-03
GateTime34=3.12850E-03 2.78650E-03 3.47050E-03
GateTime35=3.91050E-03 3.47050E-03 4.35050E-03
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GateTime37=6.51450E-03 5.67050E-03 7.35850E-03
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GateTime43=2.51025E-02 2.29745E-02 2.72305E-02
[Channel1]
RxCoilNumber=1
GateTimeShift=0.000E-06
GateFactor=1.000E+00
RemoveInitialGates=7
PrimaryFieldDampingFactor=0.10
UniformDataSTD=0.03
NoGates=43
RepFreq=25.00
TxApproximateCurrent=1.00
ReceiverPolarizationXYZ=Z
FrontGateTime=-1
TiBLowPassFilter= 1 8.0E+4
```

Receiver low pass filter order and cut off

Ramp in Seconds

Delay must be added 9 to 10 uS for preamp or 0 uS without

Primary field damping

Transmitter low pass filter order and cut off

Turnoff time modelled as 1.4uS Turnoff time measured as 1.4uS

Tx and Rx LP filters 1MHz Primary Field Damping 0.1

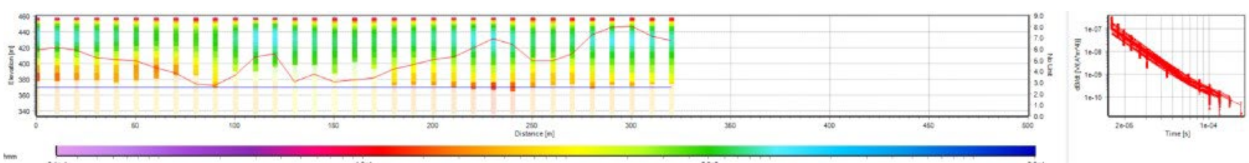
Too high!

Fake conductive layer on top – probably from lack of filter modelling – deep effects nonsensical

Avoid at all cost

A fake deep conductor is assisting models to correct for erroneous effect of the fake conductor at the top.

Early time undershoot compensated by mid-times overshoot



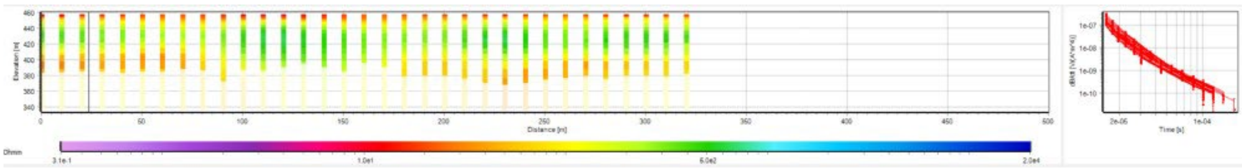
Turnoff time modelled as 1.4uS Turnoff time measured as 1.4uS

Tx and Rx LP filters 120kHz Primary Field Damping 0.1

Too high!

Fake conductive layer on top – probably from insufficient filter modelling – deep effects nonsensical
Avoid at all cost

OK total residual 1.3



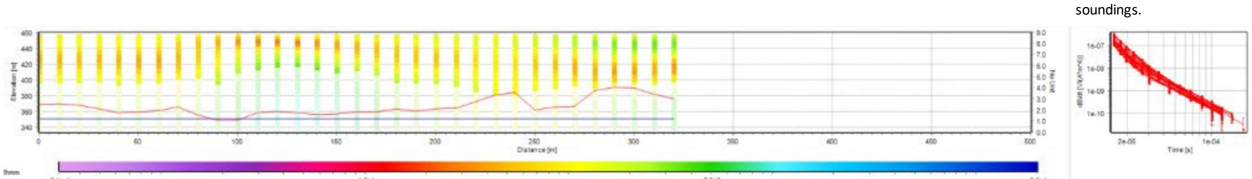
Turnoff time modelled as 1.4uS Turnoff time measured as 1.4uS

Tx and Rx LP filters 80kHz Primary Field Damping 0.1

Break of slope (high second derivative) where filter impact dominance is replaced by earth currents decay dominance is modelled accurately at the correct time. This is only evident on the more resistive soundings.

Great Result – total residual 1.16

Anticipated Realistic resistivity distribution. Suggestion of 3 to 4 layer model sensibly reflecting raw data trends.



Turnoff time modelled as 1.4uS Turnoff time measured as 1.4uS

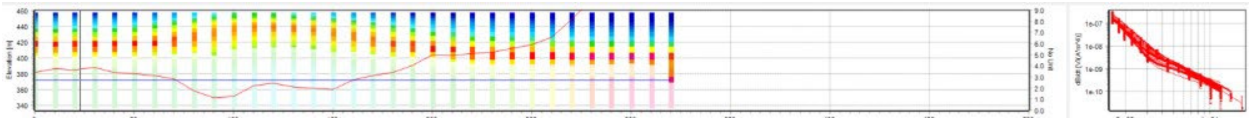
Tx and Rx LP filters 60kHz Primary Field Damping 0.1

Too low!

OK Result – total residual 2.8

Data mismatch at 6 earliest channels indicates excessive filter modelling choice.

Resistivity range is moving to extremes to compensate for wrong filter choice



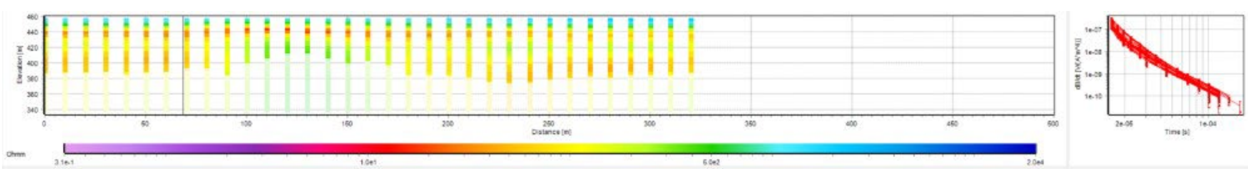
Turnoff time incorrectly modelled as 14uS – measured as 1.4uS

First 7 gates (about 14 uS not modelled)

Tx and Rx LP filters 1MHz Primary Field Damping 0.1

Good Result but with fake surface resistive layer total residual 1.6

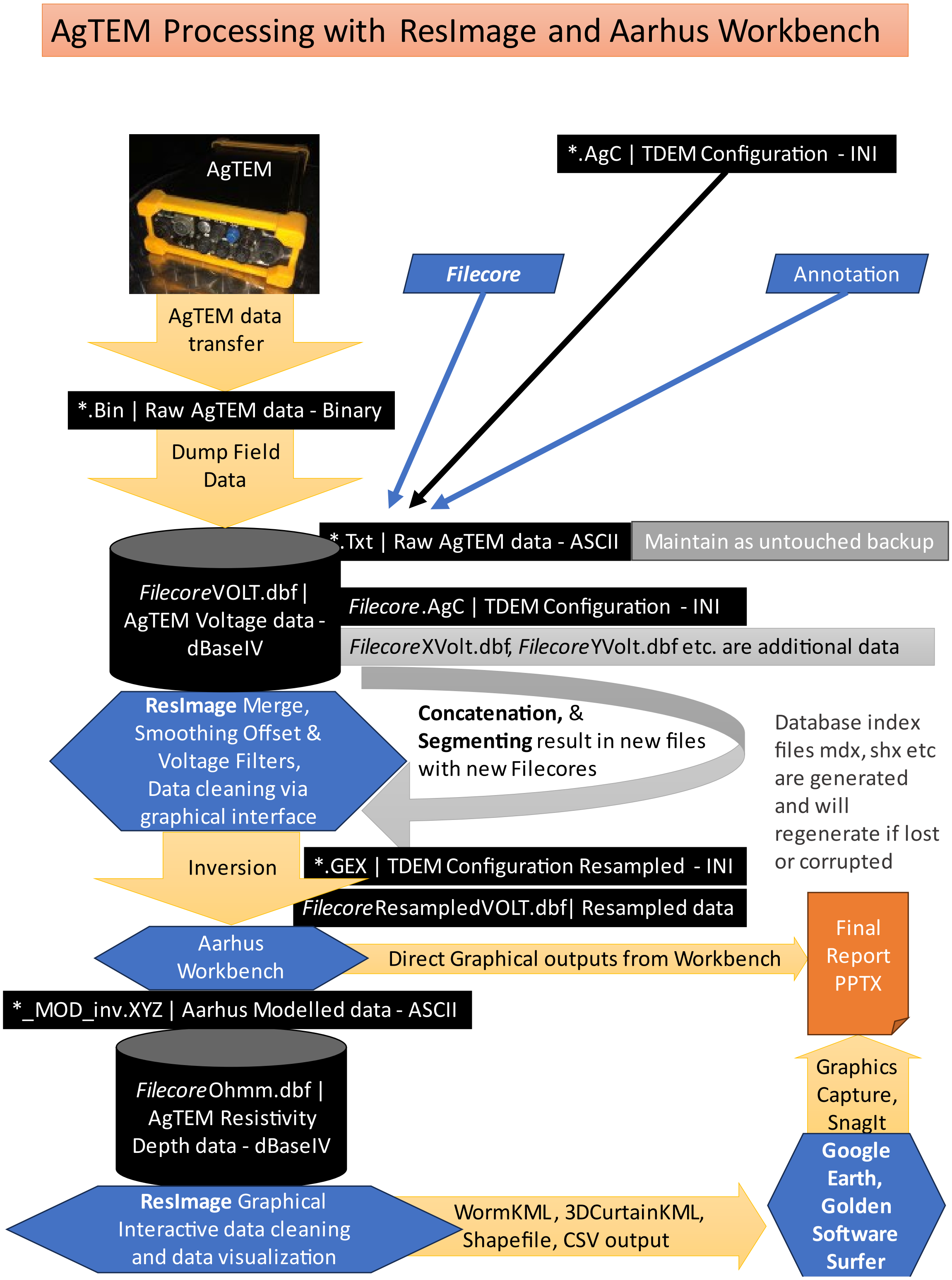
Perhaps excluding filters and increasing ramp from measured value makes good modelling but only because slower turnoff time has similar effect to slower filters.



Anticipated Realistic resistivity distribution. Suggestion of4 layer model but the resistive layer at the surface is fake.

MENU BY MENU – AGTEM SOFTWARE DESCRIPTION

The AgTEM processing sequence adopted in ResImage is summarized in the following schematic.

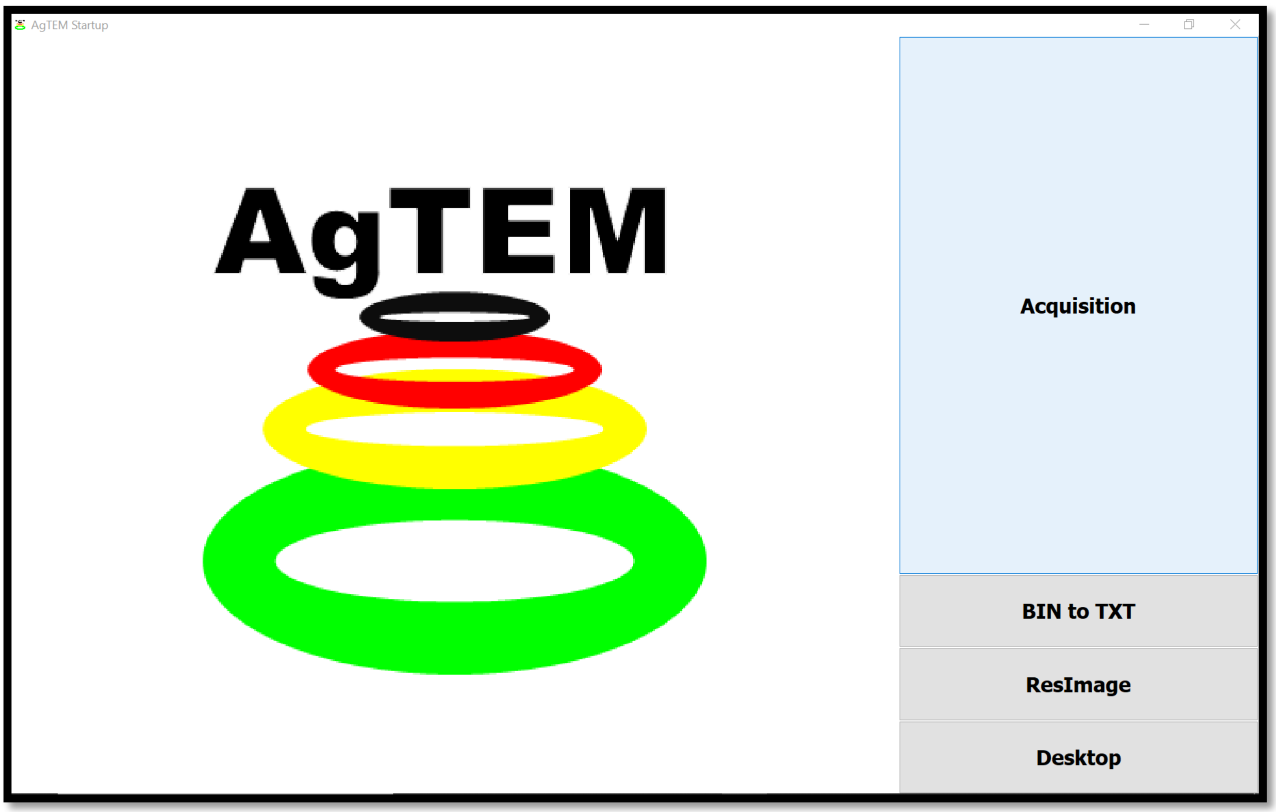


ResImage does not have a TDEM modelling code of its own. Instead, Aarhus Workbench is adopted – files can be sent to and received back from Aarhus Workbench. This modelling facility, however, requires data to be in windows similar to SkyTEM windows otherwise the filters it applies fail. That is why there are resampled volt files and GEX files generated from AgC files but with the resampled windows.

STARTUP DISPLAY

When the computer is booted a windows login screen appears and a pin 'agtem' needs to be entered.

Then, sometimes after some delay, a startup screen appears as shown below.



Touch to select 'Acquisition' to operate the equipment.

Later you may select 'BIN to TXT' to access BINtoTXT.exe to convert binary output files to ASCII form yet this may preferentially be conducted on a processing computer later or accessed from within AgTEM.exe using the 'Data processing' tab.

BINtoTXT.exe perhaps could convert preferentially to DBF and INI files as used by ResImage.exe but the intermediate TXT file serves as a raw data backup – an important role. Access to the ResImage 'TEM Configurator' is possible via the ResImage link on this startup screen and that makes it possible to load and modify loop configuration files.

The third option – 'ResImage' – operates Groundwater Imaging Pty Ltd processing software. Typically this will be operated on an external processing computer but as a stop gap measure it is provided here. It is feasible to take the Panasonic Toughpad from its mount and use it at nights for processing using this software. Beware that this practice may tempt the user to neglect independent backup of their data – backup each day is recommended.

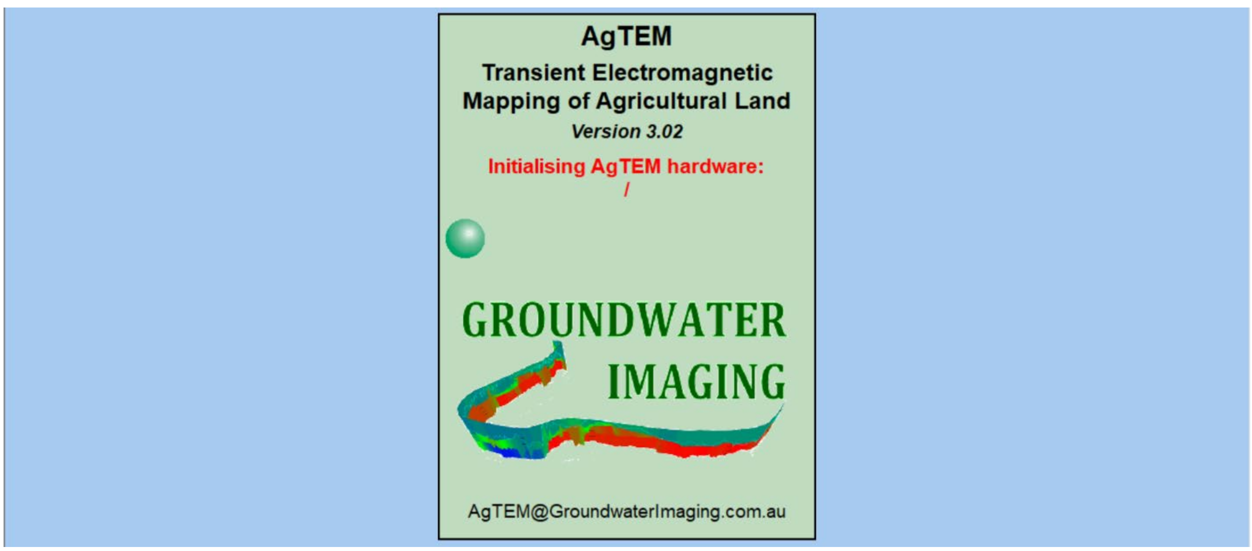
The 'ResImage' button, in older AgTEM computers, points to HydroGeoImager.exe – a software that has lacked maintenance for many years. 'ResImage' is the new maintained software ready as of January 2025 with a new GUI for AgTEM survey.

The fourth option is 'Desktop' which provides access to the Windows desktop.

Hidden off the bottom of the screen is the scroll-up windows taskbar. This must stay off-screen to permit access to AgTEM.exe menu items and displays. It is accessed by touching the bottom of the screen. Always touch only the lower left corner as other parts will activate programs that reside on the taskbar that you cannot see.

Use the windows taskbar when you wish to shut down the computer.

As AgTEM.exe starts up it displays a flash screen and updates a sequence of initialization actions on that screen as they are attempted. See the image below.



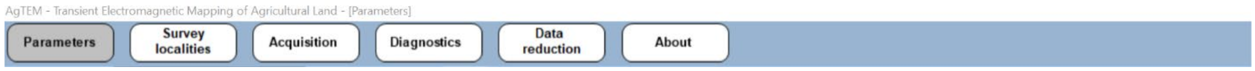
THE GUI ENVIRONMENT AND ITS CONFIGURATION FILES.

AgTEM.exe software operates the AgTEM electronics. The graphical user interface provides accessibility to all AgTEM functions. Menu parameters are stored in configuration files that are loaded at start-up, preserving all system settings (except previously opened data files). A default configuration file is loaded on start-up if the original has been deleted or has become corrupted. If manual editing of the configuration file is attempted, a key at the end of the file will not match the contents and the file will then be recognised as corrupted. The file stores COM port assignments so if you have a COM port change, such as due to using a different docking station, change the COM port assignments rather than changing the references in the configuration file.

MENUS & NAVIGATION

The initial start-up screen is split into three horizontal levels of display (Figure 2.4).

The top level provides the user with a horizontal control bar which contains six buttons:



The lowest level (bottom of screen) provides a status bar, consisting of six colored panels, which can be used to access popup forms to perform system operations, transfer files, verify power levels, and enable/disable the optional GPS:

The center of the screen provides the primary information display and input panels, which depend on which of the top six buttons has been selected.

Navigating through the acquisition and data reduction programs is achieved by touching any buttons that are colored white. If a button is grey, then it is either the current selected option or has been disabled or the option is not installed. Specific parameters or fields can be selected or changed by touching the relevant items.

When required, pop-up keyboards, or keypads appear, otherwise menu selections allow for rapid parameter entry. If preferred, all parameter selections may be made using a standard mouse and keyboard in place of the in-built touch screen method.

At all stages of data entry and signal acquisition, the AgTEM ensures that any chosen parameters are entered correctly and that signal levels are within the system specifications; if necessary the operator is notified of any conflicts.

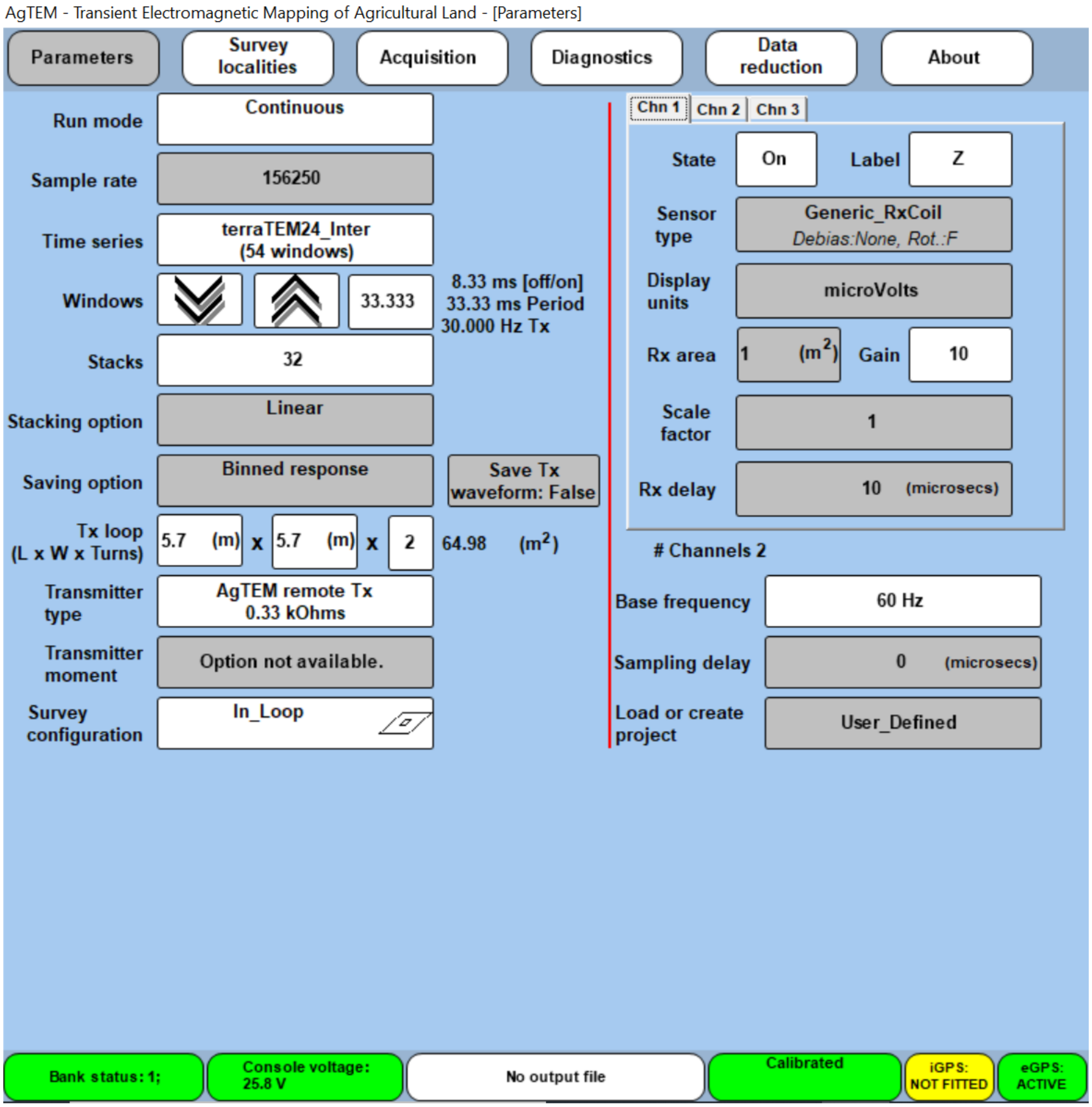
System messages can be grouped into 3 categories: **Confirmations, Warnings** and **Error messages**.

Confirmations are used to verify the operator of critical actions about to take place (for example, file overwrite or delete). **Warnings** alert the user to specific situations that may adversely affect the system performance or data acquisition process (for example, open Tx or Rx loops). **Error messages** indicate that a process cannot be completed and operator action or physical repairs may be required in order to proceed. Confirmations and warnings appear in a pop-up window and require operator acknowledgement.

Most messages appearing on the screen are self-explanatory. However error messages may, in some circumstances appear meaningless to the operator. If these occur, please consider if there are any background Windows processes running that are best turned off and attempt to re-start the system by removing power and reconnecting for a clean system boot of computer, receiver and transmitter. If the same error appears consistently and prevents the operator from acquiring data, please note the message and sequence of actions that results in the error message appearing and contact the Groundwater Imaging technical support (+61)418964097 (+10 time zone – Australia) or david@groundwaterimaging.com .

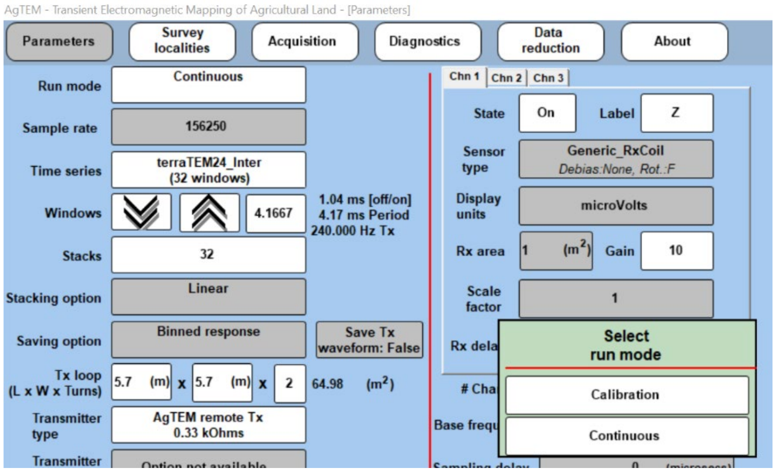
PARAMETERS

The parameters window shown below is the default window at start-up, but it can be accessed at any time through the **Parameters** tab at the top left of the screen. The operator can view or modify all relevant acquisition parameters in this window. Some are for display only and are modified only as part of external AgTEM configuration software. This external software, TEM Configurator, was prepared by January 2025. Others are display only due to license restrictions that prevent change.



Parameter values are described as follows:

RUN MODE



Run mode is usually set at 'Continuous' acquisition with automatic storing of data for towed or carried moving loop systems.

'Calibration Acquisition' mode records single records at a time and facilitates extra acquisition displays of text data, full waveform data, and current data. It does not prompt for GPS data at each record.

SAMPLE RATE

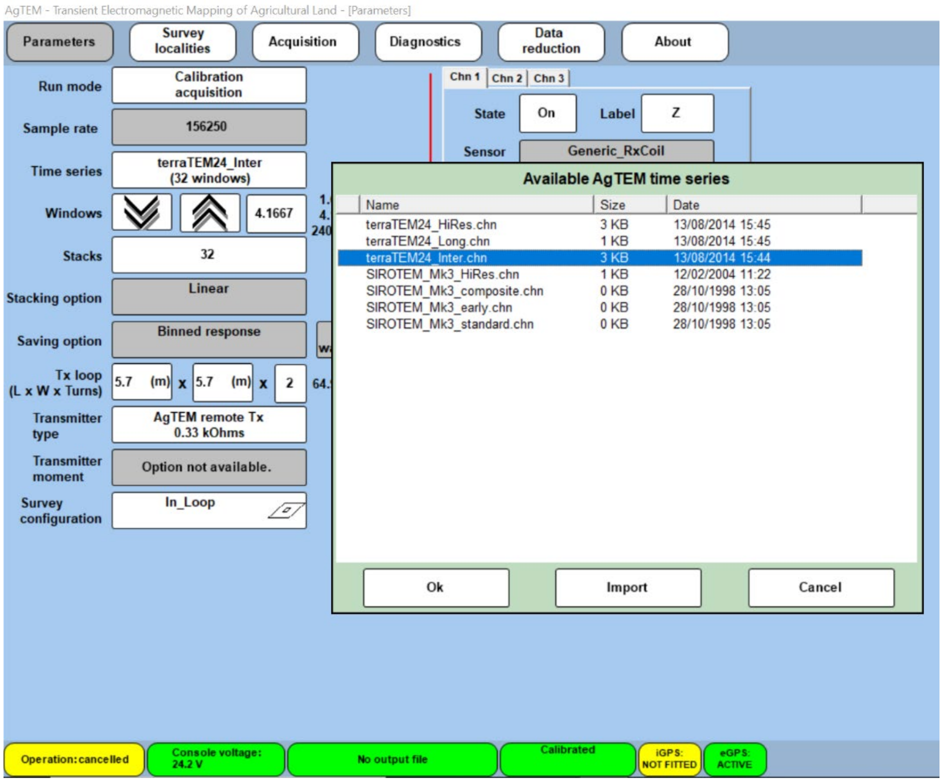
Sample rate is the base rate at which the Sigma-Delta Analogue to Digital Converter is set to operate. Ordinary acquisition is best conducted at 156,250 samples per second as faster acquisition will reduce ability to observe deeper low SNR data.

Initially at August 2021, sample rate is fixed at 156,250 but there is reason to implement faster sampling for dedicated shallow investigation purposes. A suite of changes is appropriate across the whole AgTEM system should shallow focus be sought – sample rate change alone would be inadequate. Request and negotiate an advance of priority of this development if you have significant need for it.

Compared to 156,250 samples per second, 312,500 samples per second will increase SNR slightly affecting late time data but will resolve early time 'shallow' data better.

625,000 samples per second is the maximum rate of acquisition possible with this system and 3 components cannot be simultaneously sampled at this rate.

TIME SERIES



This defines the number and width of time slices (bins or windows) within which the acquired data is averaged. High-resolution time series contain more and narrower time slices (bins or windows) and the long time series contains fewer, wider bins or windows. Selection of the appropriate time series depends on desired resolution, depth of investigation and ambient noise conditions.

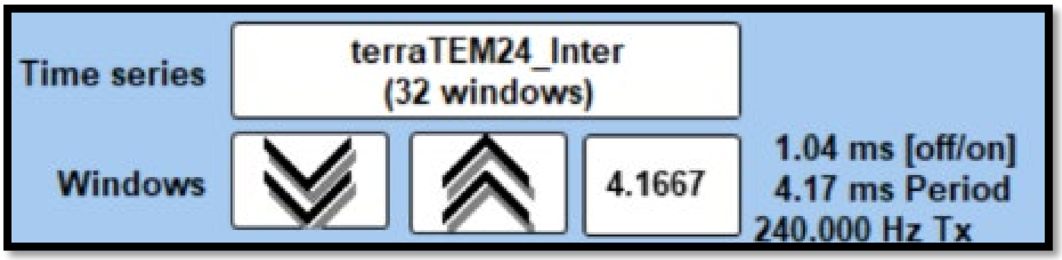
High resolution bins are useful for clear view of some noise sources and oscillatory capacitive or inductive coupling problems.

TerraTEM24_inter.chn is the default time series – using other options risks lack of support in processing software you may use later. In early times it is the same as terraTEM24_HiRes.chn and in later times it retains enough resolution to identify typical noise sources.

WINDOWS

The number of desired windows for a specific time series can be selected from the **Windows** control icon. Press the up arrow to increase, down arrow to decrease the number of windows. The cycle (off/on) time increments automatically to the next practical cycle time and the number of windows it accommodates is calculated and displayed at the bottom of the 'Time Series' button above. The number of windows and window time slices vary according to time series selected (see the series listing in the 'Miscellaneous Appendices' Chapter). The maximum cycle-time (for the built-in long time series) is 174483.0464 ms (3 minutes) but only the first 10ms (56 gates) are ever likely to be used in AgTEM surveys. At above the power line frequency the cycle-time is increased in multiples of 8.333 ms or 10 ms (depending on the power line frequency setting). This is necessary to ensure proper power line frequency rejection at all times. Two cycle-times for each power line frequency are permitted at frequencies exceeding the power line frequency and this is useful for dedicated shallow investigation only when used in conjunction with lots of co-dependent AgTEM configuration changes.

Beware that acquisition may cease at faster frequencies without warning should demanding background processes such as WiFi communication with the internet be invoked while surveying. This is a bug that has not been fully eliminated as of January 2025.



Off/On duration, Period and Repetition Frequency are all displayed so that there can be no confusion. The Off/On duration is evidently ¼ of the period of the 50% duty cycle square wave.

The figure below reveals soundings acquired at two different repetition rates. Observe that selection of the faster rate cuts the decay (over a conductive feature) too short. It also loses energy earlier as the on-pulse applied less energy to the ground.

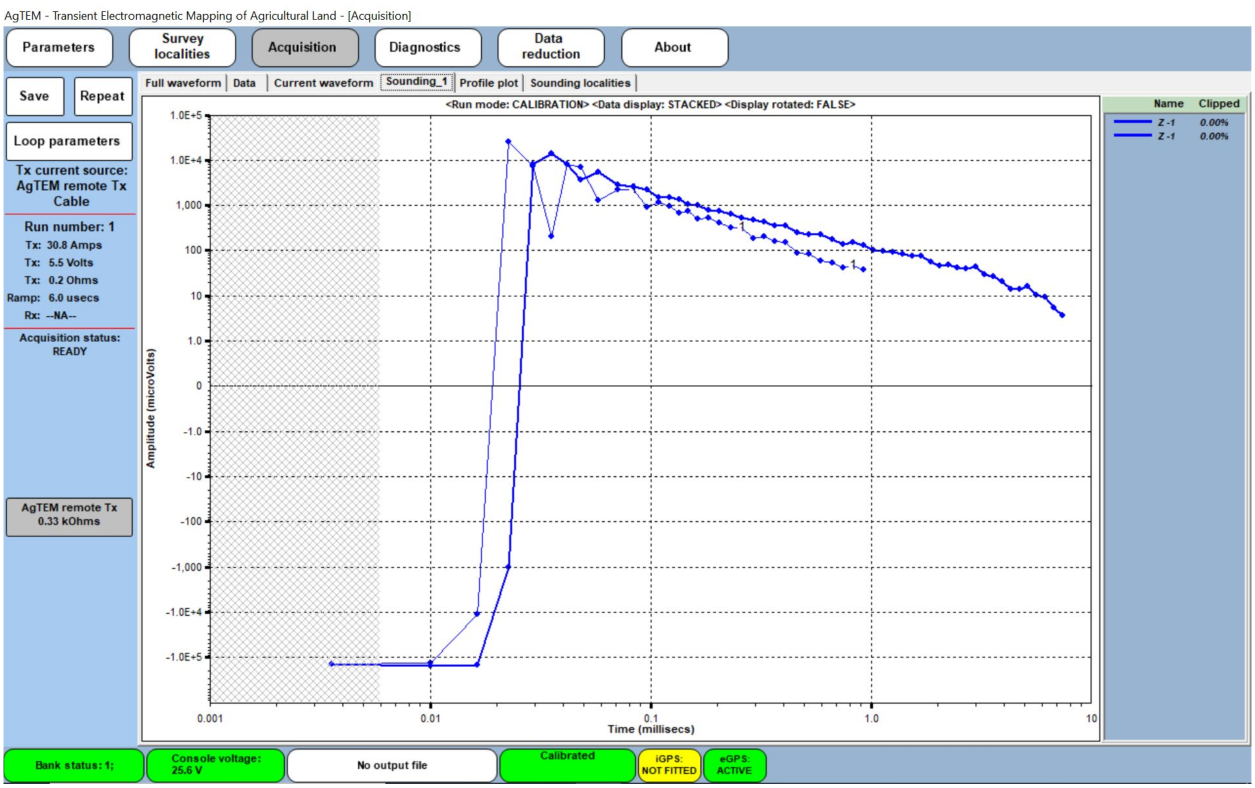


Figure 103 Soundings acquired at two separate cycle times, 4.167 mS and 33.333 mS, at the same location.

Below is an example of where too much current was applied for the repetition rate selected and the current did not have time to ramp up and level off. Always conduct a current waveform check before selecting a repetition frequency exceeding power line frequency should you be using low loop resistances and attempting to inject high currents.

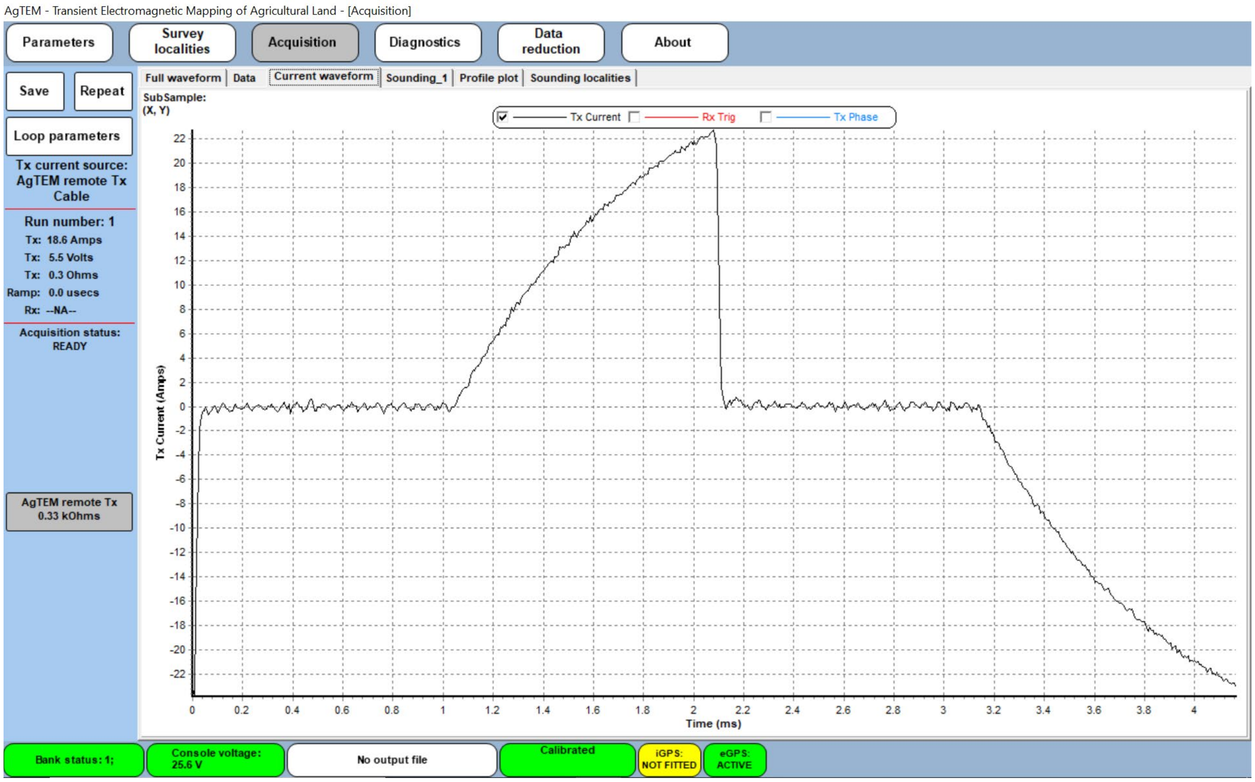


Figure 104 A current waveform that did not get a chance to level out due to selection of a combination of excessive current and inadequate cycle-time.

STACKS

Touching the **Stacks** field provides a pop-up keypad. The operator is required to enter an integer number in the range 1-65536 for data averaging and noise reduction. Values selected traditionally and conventionally are powers of 2 but any integer is permitted – it does not matter. For 40 mS cycle-time, 32 stacks are generally sampled to give minimum footprint per sounding and best ability to minimize records affected by electric fence pulses and other forms of sporadic noise while 64 stacks are common for 10m footprint measurements at 12km per hour. Realize that for every stack there are some time overheads where data is not being acquired so minimizing the number of stacks too much will drastically affect overall survey quality, especially if data is later spatially smoothed or constrained as is normally done in post-processing.

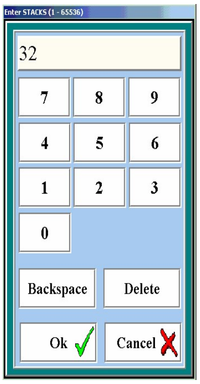


Figure 105 Popup keypad for stack selection

STACKING OPTION

This is not an option with an AgTEM software license and is fixed as 'Linear'. Each bin is simply filled arithmetically (linearly). This performs simple arithmetic averaging. Time series data within bins are first averaged and then the bins from successive decays are averaged to form a stacked and binned data set.

SAVING OPTION

A standard AgTEM license permits only storage of stacked data saved into logarithmically time-spaced bins.

A standard AgTEM license does not permit continuous saving of Tx waveform. This may be an inappropriate overhead during the fast paced acquisition of an AgTEM survey especially as survey is typically conducted with a DCDC converter which keeps the waveform consistent. Instead, an individual waveform may be saved in 'Calibration' mode acquisition. In August 2021 this was only an image save – to be improved. The waveform is an essential input to modelling software and is entered into modelling software as part of a system response and configuration.

TX LOOP (L X W X TURNS) AND AREA

AgTEM transmitter loops are typically complicated in shape and configuration is stored and applied in post processing from a stored file. It can be useful however to store approximate area and number of turns when in the field as a reminder. Nominal loop side lengths and number of turns may be entered and Area x number of turns will be calculated. In some software in some circumstances the number of turns will be incorporated into current normalization of data in post processing.

TRANSMITTER TYPE

AgTEM has its own specialized transmitter and an AgTEM license facilitates use only of this transmitter. Pressing this field will, after a considerable pause, display a box where damping resistors of various values may be selected. 330 ohms is the default choice.

TRANSMITTER MOMENT

This option is not presently available – dual moment facilitation is planned and partly inbuilt into the equipment as of August 2021.

SURVEY CONFIGURATION

This is a legacy field. It is suggested that what you enter here should refer to your Chn 1 component – that is if it is In-loop or Slingram. It is not used in processing as complex configuration files are used instead however it may help you with documentation. This field will be removed once full in-field configuration documentation management is facilitated.

This has no effect on data collection but is stored in the file header. The options are:

Coincident

Two separate loops (Tx and Rx) of equal size; fixed, interlocked geometry;

In Loop

Large Tx loop with small Rx loop in centre;

Fixed Loop

Stationary Tx loop and moving Rx loop(s);

Single Loop

Single combined Tx/Rx loop (parallel connection). This is the simplest configuration but also has the poorest S/N ratio;

Down hole

Surface Tx loop and down hole TEM receiver;

Slingram

Two separated loops moving in a fixed geometry;

Other

Custom transmitter configuration. Required if the Tx/Rx configuration is not in the above list.

CHN 1 CHN 2 CHN 3 & # CHANNELS

A set of three tabs allow selection of parameters for the various receiver loops connected in an AgTEM configuration. Below the options box for the presently displayed channel the '# channels' that are turned on is displayed.

A channel refers to a TEM signal obtained from an individual receiver (unlike some previous TEM systems which use the same term to identify specific bins or windows in any given time series). AgTEM is a three channel system. Channels are individually addressable and are **simultaneously** sampled at up to 625 kHz (presently 156.250 kHz) irrespective of what binning options the operator has selected.

All available input channels are indicated on the selection tabs. **Any channels not in use (ie not connected to a sensor) should be switched off.**

NB : Gains selected for receivers with a multi-channel option should be set at similar levels for each channel to avoid any possible cross-talk (if possible select gains within one decade to avoid gross contrasts eg 1,1,100).

STATE

This simply turns a channel on or off. In the acquisition screen there will be sounding curves for each of the channels that are turned on.

For AgTEM-Wallaby Channel 1 will typically be the mid-plane of the Wallaby and channel 2 will be the front loop, if in use.

For AgTEM-Wallaroo survey Channel 1 will typically be a small loop beneath the center of the transmitter loop and channel 2 will typically be one extended out on a boom while channel three may be another receiver on a towed mat.

In future, channel 3 may be used for dual moment operation with a third coil with few turns for revealing shallow features and layers.

LABEL

This historically represented orthogonal components Z, X and Y but recently has been applied to a variety of sensors of multiple orientations so the labels have become somewhat arbitrary. By convention we label in-loop Z, and Slingram X.

SENSOR TYPE

This has no effect on the data – it is presently fixed in AgTEM to 'Generic_RxCoil Debias:none, Rot.:F'. When full configuration files are setup this is to be changed to make it more meaningful – eg. 'Mid-plane 10 turn with pre-amp' or 'Front-loop 10 turn with pre-amp'.

DISPLAY UNITS

Receiver data display units presently default to 'microvolts' without receiver loop area or transmitter current normalization. Selection of these units have no effect on saved data. Data in 'microV/A.m^2' or 'microV/m^2' facilitate direct comparison of data from multiple receiver loops of different area. 'microvolts' is useful as it will always show data clipped at true saturation limits of the amplifiers. At August 2021 it is fixed and disabled but should be enabled.

RX AREA

This is the 'effective' area of the receiver loop as observed at the receiver – that is the actual area of the receiver loop in m^2 multiplied by the number of turns multiplied by pre-amp gain.

GAIN

Amplifier gains can be selected from this menu – options of 'AUTO', 1, 10, & 100 are available. Generally the gain should be set one step below the level that results in signal clipping. This will ensure that the late-time low-amplitude data has the highest signal to noise ratio. The AgTEM can detect and display signal clipping during acquisition; however, the operator may choose to proceed with the run if required. The clipping percentage is the proportion of pre-binned data that exceeds the ADC's threshold. The value is displayed in the top right corner of the decay plot.

In AgTEM survey it may be appropriate to slightly saturate early, primary field, data in order to improve signal to noise ratio in late time data critical to deep exploration. Excessive saturation will lead to decay distortion during a settling time after saturation and this can be observed using trial and error type tests. Unfortunately, when primary field data is saturated it cannot be used in post processing to indicate when the transmitter loop has been distorted by brushing through trees. It is common practice to reject such data in post processing by plotting gates within the primary field and looking for soundings that are not consistent at such gates. If gain causes saturation then only fringe channels can be used to detect primary field distortion and reject affected data.

Behaviour of the 'Auto' gain feature is untested by us at August 2021. *The '**Auto**' gain setting is designed to optimize gain over a transient with low gain applying to early times and high gain applying to late times. A transition point is marked on the decay curve by a market (TP). Testing by comparison with fixed gain settings still needs to occur to verify suspect data. This function should not be used in areas subject to significant EM noise. Tests still need to occur to indicate the impacts of telephone cables, power cables, movement noise and other forms of noise. Sporadic movement noise from hitting bumps in the terrain especially may cause trouble with high gains as offsets of individual transients may greatly exceed late time decay response. In this mode it is not possible to halt the acquisition cycle – testing of impact on 'pause'-'continue' is pending.*

SCALE FACTOR

Scale factor is suitable for correcting otherwise uncorrected data (for instance if pre-amp gain was not included in RxArea) and is not used in AgTEM survey at present. It may be appropriate to use it in future for pre-amp gain. It is not known if it is applied to data before saving or not so it is strongly recommended that any such scaling occur only in post processing instead.

RX DELAY

Receiver delay shifts all time gates with respect to the start of the ramp so drastically affects all data, especially at early times. A mistake in this parameter will require post-processing either involving documentation and compensation in modelling or involving data splining or other curve fitting then resampling.

Pre-amps, synchronization, and any form of real time filtering, either parasitic or intentional, all delay arrival of changes in signal at the receiver.

'RxDelay' is set at August 2021 to 10 microseconds in some older firmware versions. This compensates for the pre-amps delay measured as 8uS plus some delay for the length of synchronization cable typically used and synchronization delay. It is good to set this to zero and modify it in post processing if possible.

BASE FREQUENCY

Select the power line frequency appropriate to the survey region (for example, 60 Hz in the USA, 50 Hz in Europe). This sets the transmitter on/off period multiple to 8.333 or 10 ms to ensure proper 60/50 Hz rejection.

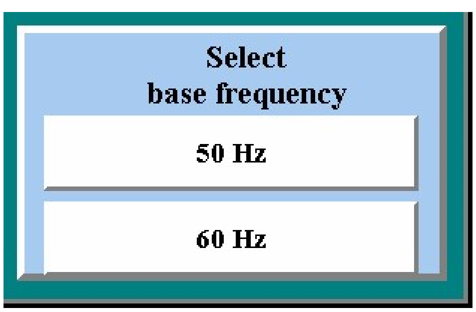


Figure 106 Base frequency selection.

SAMPLING DELAY

Sampling delay is similar to receiver delay in that it shifts time gates with respect to the start of the ramp but is recorded separately in saved data files. It maybe useful for unconventional processing and modelling but is not a facilitated nor useful part of current AgTEM processing thus it is disabled – preventing inexperienced operators from causing difficult processing challenges and ambiguity.

LOAD OR CREATE PROJECT

AgTEM configuration parameters are rather complicated involving many fields not discussed here so elaborate parameter files are created for post-processing, however the same configuration is used over and over again without any change in routine survey. Parameters in future are to be saved by external software, not yet written, and loaded here so that documentation is correct right from acquisition rather than being created in post-processing. These files will autofill many fields in the parameter display as well as storing many that are not displayed.

SURVEY LOCALITIES

In routine AgTEM survey, if a box at the base of the screen says 'eGPS: Active' then expect all the GPS is working suitably – no further checking is then necessary. **The 'Survey Locality' tab is therefore a redundant legacy tab.**

The 'Survey Locality' screen provides one of several easy ways to assess if GPS data is streaming in and being recognized by AgTEM.exe. Select the 'NMEA0183 data' sub-tab and press 'Monitor' to watch NMEA0183 data stream in. It is the $GPGGA strings that are used for positioning – if functional then real latitude and longitude values will be displayed rather than zeros. Top of screen tabs will all be disabled then, until you press 'Stop'.

If you select the 'Location' sub-tab you can generate a map of points but since at this stage you will be stationary it will simply be a scatter plot established over time indicating precision of the GPS. Note well the difference between accuracy and precision.

A third sub-tab 'Satellite data' displays graphs of signal strength from some satellites. As constellations now are comprehensive this too has become redundant – possibly not actually receiving the NMEA0183 string needed to fill these graphs.

Display option is fixed in AgTEM.exe as 'Ellipsoidal'.

GPS type for AgTEM is always 'External GPS' as a mobile system needs a GPS antenna positioned with a clear view of the sky if it is to accurately plot the closely spaced data acquired.

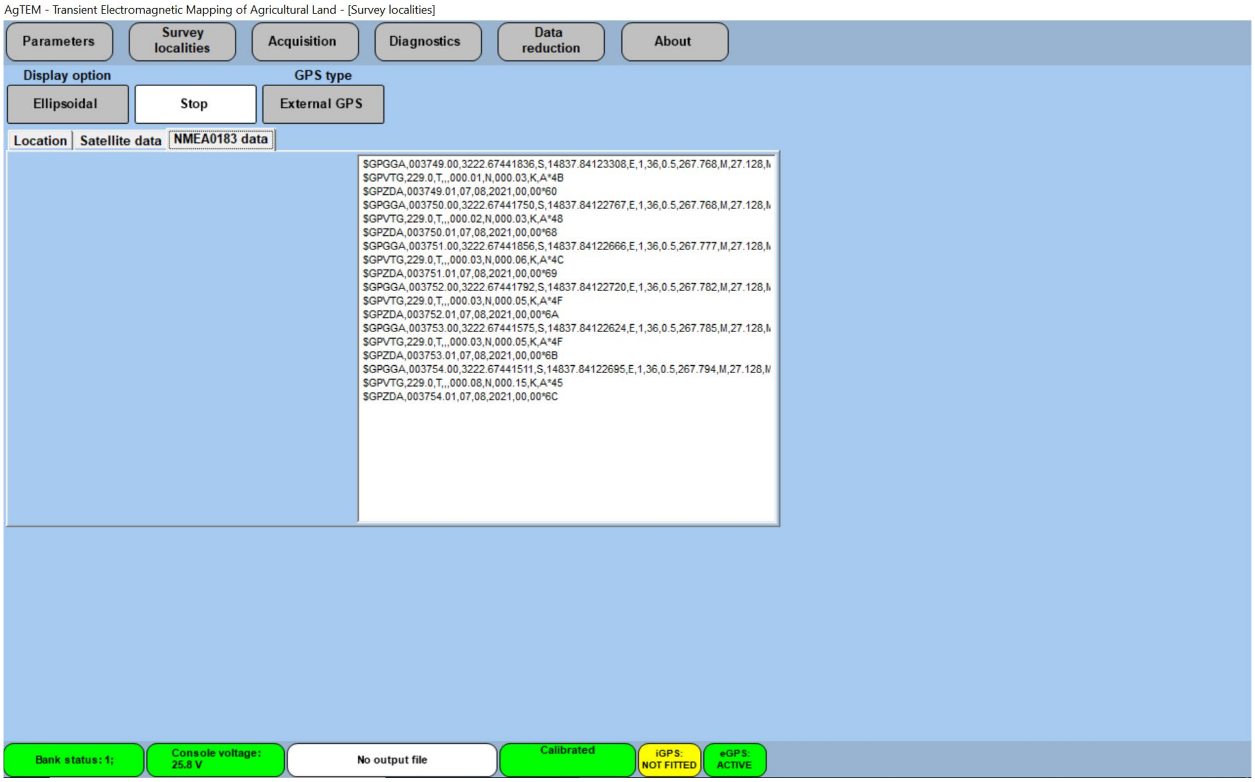


Figure 107 Observing NMEA0183 data collection in the Survey Localities Screen

ACQUISITION

The acquisition display is where all field data will be collected. Different tabs and position data display are activated depending on which 'Run Mode' is selected in the 'Parameters' tab. Either 'Calibration Acquisition' or 'Continuous' are the options. 'Continuous' is the default and always appears when the system is turned on.

If you are not confident with your choice of configuration then start with '**Calibration Acquisition**'. It allows only single soundings for each press of '**Acquire**' or '**Repeat**' to be measured while '**Continuous**' will commence a stream of sounding acquisition that does not stop nor pause until you tell it to or it can no longer keep going.

'**Calibration Acquisition**' opens viewing options:

1. Full Waveform,
2. Data,
3. Current Waveform,
4. Sounding_1,
5. Profile Plot, &
6. Sounding Localities.

'**Continuous**' opens viewing options:

1. Sounding,
2. Raster,

3. Location,
4. Profile, &
5. Setup &

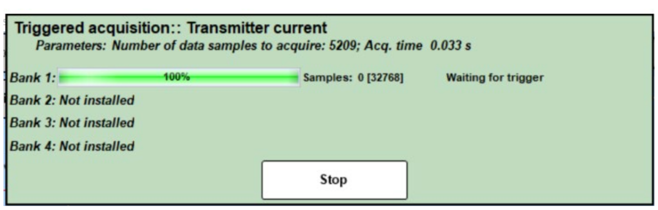
It also checks for valid GPS data, saves and displays it with for sounding.

CONTINUOUS ACQUISITION

The initial 'Continuous' acquisition display is revealed below.

Figure 108 The 'Acquisition' tab as it initially appears in 'Continuous' acquisition mode.

In 'Continuous' mode acquisition is not enabled until 'System parameters' are first checked by pressing the so named button. If all is OK then the display shown below will flash on the screen and the parameters at the left will become filled with valid entries for the operator to carefully check. If all are suitable then it is good to proceed to press 'Acquire'.



In 'Continuous' mode, once '**Acquire**' is pressed, a filename selection is requested and continuous acquisition begins. The 'Acquire' button is then replaced with two buttons: 'Pause' & 'Stop'. Just above the bottom taskbar a panel displaying 'Bank 1' includes a progress bar that progressively fills for each sounding. **At times soundings will**

all look very similar so watching the progress bar periodically is important to check that acquisition has not frozen.

Append or **Overwrite?** when you commence continuous acquisition and select an existing filename you may append or overwrite. This will happen in cases such as when you use small batteries and they go flat and need replacing. Should you then want the acquired data to appear on your raster map display for navigation and comparison, or you simply want to minimize post processing file management complexity then you will want to append to the data you were just obtaining. There is a chance that a file may be appended with incompatible parameters – a checklist display appears to verify, warn-about or prevent appending and to give all reasons why.

GPS coords display: Should GPS data be acquired successfully then the yellow 'Current Location' box in the image above will populate, turn green and the successive sounding will commence straight away.

System parameters display: On the left of the display, temperatures, currents, ramp and voltages will update for every sounding – or multiple of soundings, depending on how it is set up.

Ramp measurement accuracy - A Manageable Bug: In August 2021, the ramp measurements displayed and stored did not seem to be realistic. Even for small low induction loops the values chopped and changed randomly around the following values 0 uS, 6 uS, 14uS, 20uS and >999uS. For larger loops values generally changed back and forth to close to either 14 uS or 20uS. Because the transmitter uses a DCDC converter to keep current constant and the loop always stays the same the turn off ramp time only needs to be known, not constantly measured. **In later firmware after 2022, this problem was fixed** using long stack ramp measurement (see in TXT files these correspond to long stack records (another bug fixed by January 2025 but not in older firmware is the first occurrence will not report the accurate ramp). **Processing software Aarhus Workbench only permits entry of a single value for the whole dataset and this is supplied by a parameter file currently written independently – the continuous real time ramp measurements are therefore not used in modelling yet are appropriate for quality control.**

In the sounding display, the ramp time is shown as a grey hashed area for clear reference.

Reference Soundings: Once acquisition is commenced, two buttons '**Set Reference Sounding**', and '**Clear Reference Sounding**' can be used to add or remove the last acquired sounding permanently to or from the display for use as a visual reference critical for identifying minor but very significant changes in curves acquired over time that represent contrast between significant features in the ground beneath. The double thickness reference sounding is shown for two channel data in the display below:

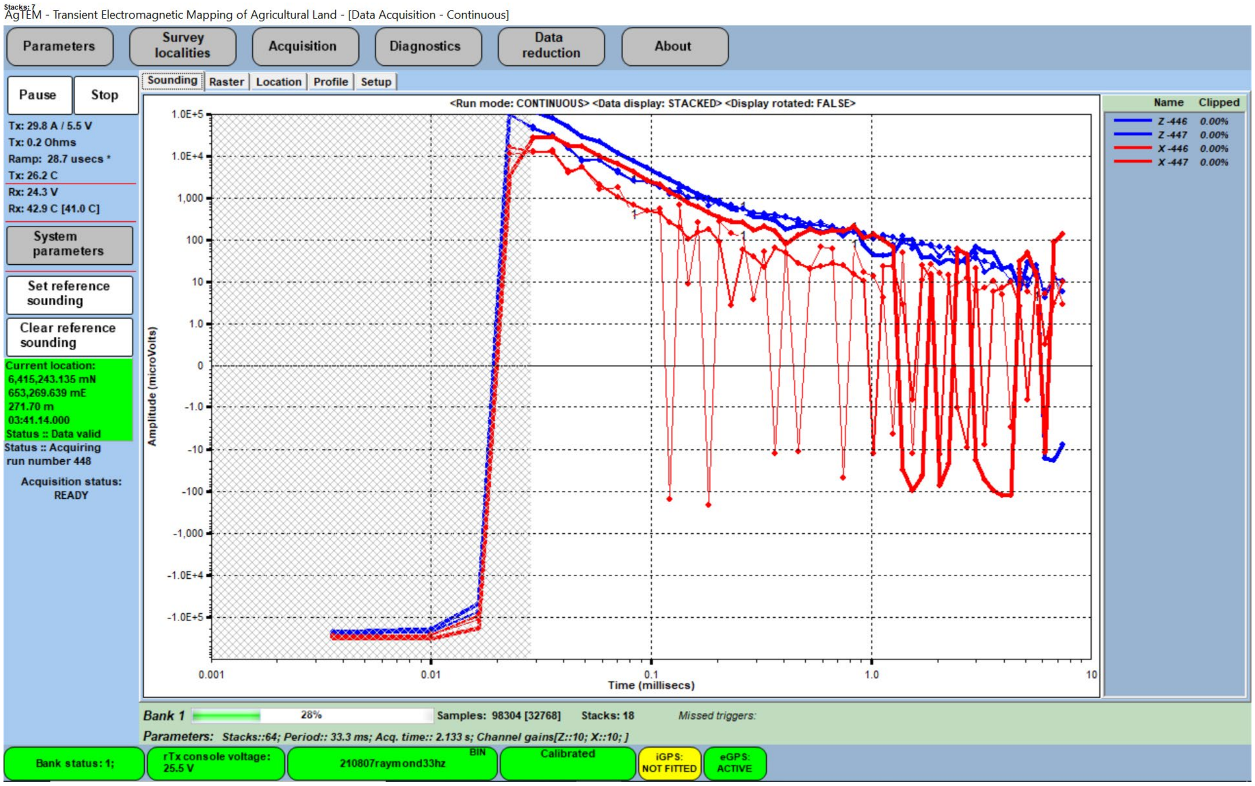
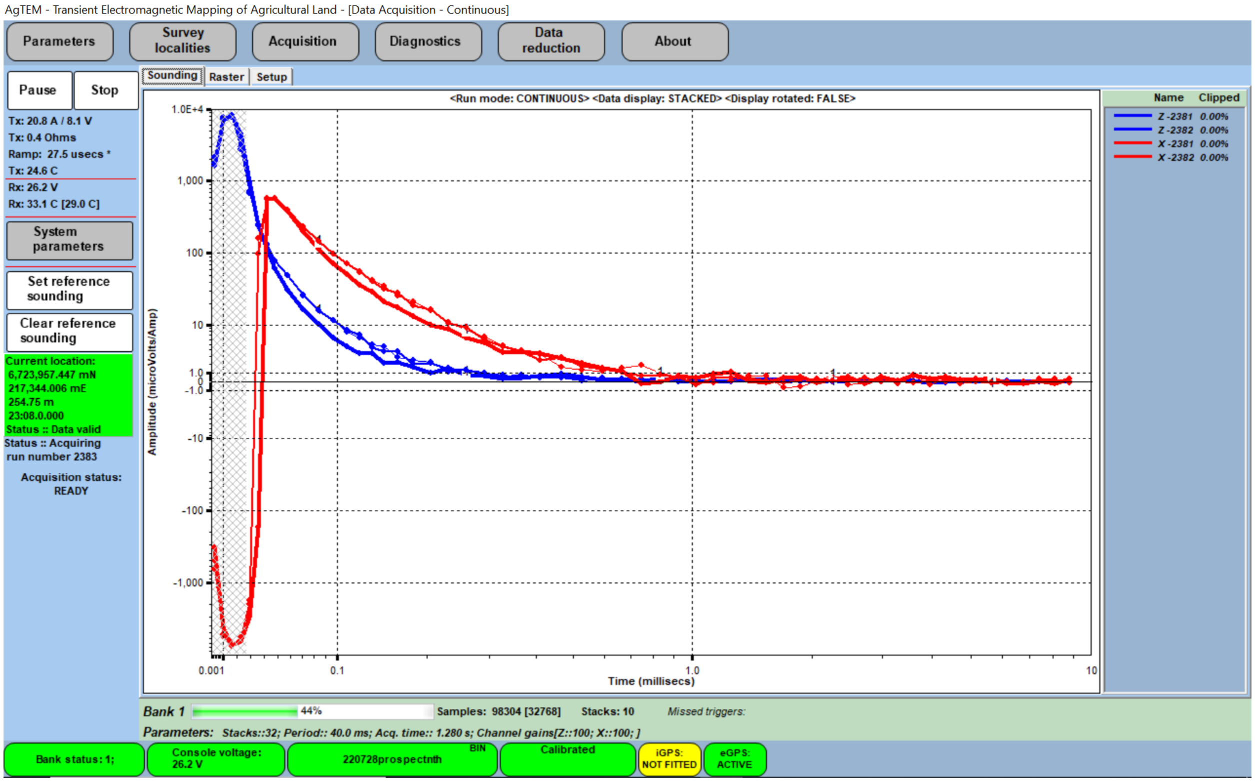


Figure 109 Reference soundings displayed on continuously acquiring 2 channel data with one repeat also showing for each channel. A log-log display has the zero crossing highly amplified so that noise level can be carefully and easily observed. Observe that front loop data shown in red mimics in-loop data at later times – in this case also at early times but that is co-incidental in this instance. The grey hashed area displays the ramp time which in this case is measured erroneously large.

Here is another example with Slingram and in-loop data on one plot plus reference soundings. In this case the noise is well behaved.



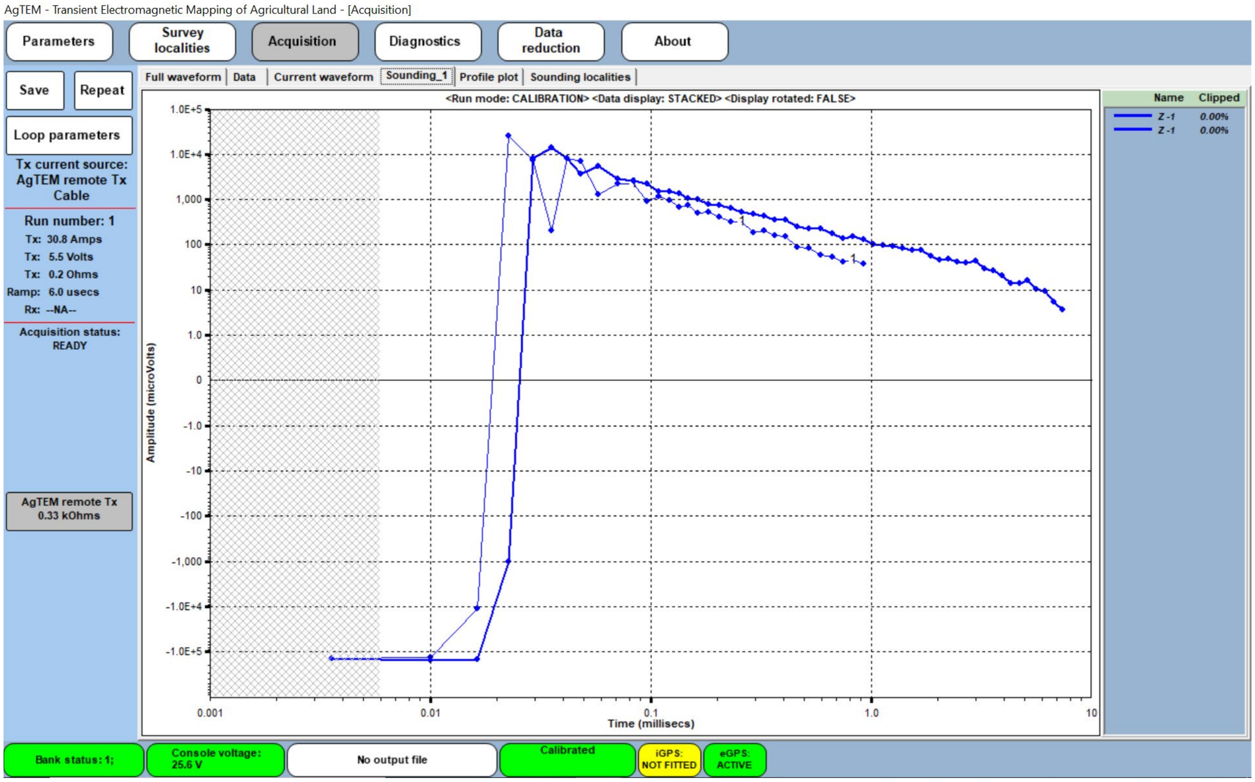
CALIBRATION ACQUISITION

The calibration acquisition screen lacks the progress bar at the base of the screen.

Acquisition can commence for a single sounding either before, or after, ‘Loop parameters’ is pressed – if commenced before, then the loop parameters are checked anyway.

Once ‘Acquire’ is pressed, a sounding is displayed, if on the ‘Sounding’ tab, and the ‘Acquire’ button is changed to two buttons: ‘Save’ and ‘Repeat’.

The image below is the ‘Acquisition’ – ‘Sounding’ display in ‘Calibration Acquisition’ mode.



Selecting 'Save' in this mode brings up a display where a file can be opened or created with a new filename and soundings can be attributed with line and station numbers. Auto-incrementing options are offered. It is usually used only for tests however, with notes written about each test in a notebook referencing station numbers in the file. It can be used to record resistive site system response however in practice even this typically is recorded with continuous mode during survey and data snipped out into a separate file graphically from a raster map display in post-processing.

SOUNDING – CONTINUOUS ACQUISITION DISPLAY OPTION

Sounding and Sounding_1 basically offer the same features and most of these have already been presented and discussed.

On the right of the display there exists a box indicating how much of each sounding decay curve is clipped. It is the number of records within the stack that exceeded gain saturation limits. This only reports saturation at the receiver and no record of any saturation occurring at the pre-amp is provided.

CHANGING SOUNDING PLOTTING PARAMETERS

Sounding plotting parameters can be adjusted by double tapping the screen anywhere on the graphical output (tap the screen twice in quick time). This pops up a display setup window, as shown below, with a variety of scaling options. The operator can scale the data display manually and apply a variety of scaling functions to enhance different aspects of the transient response. The range can be set manually to focus on particular portions of the data or set automatically (to display the maximum amplitude). Also, both time and amplitude axes can be scaled using a linear, logarithmic, or special variable Sinh function. The latter scaling function, unlike the logarithmic is continuous from positive and negative values and through 1 to –1. However, its main advantage is to emphasise the late-time, low amplitude response. This can be useful to visually amplify either the early-time or latetime portion of the transient response.

Another useful option available in this dialogue is selection of a "**Number of Repeats to Display**". This displays on the graphical interface previous responses superimposed on the current decay curve for direct comparison, or for quality assurance prior to saving any new data.

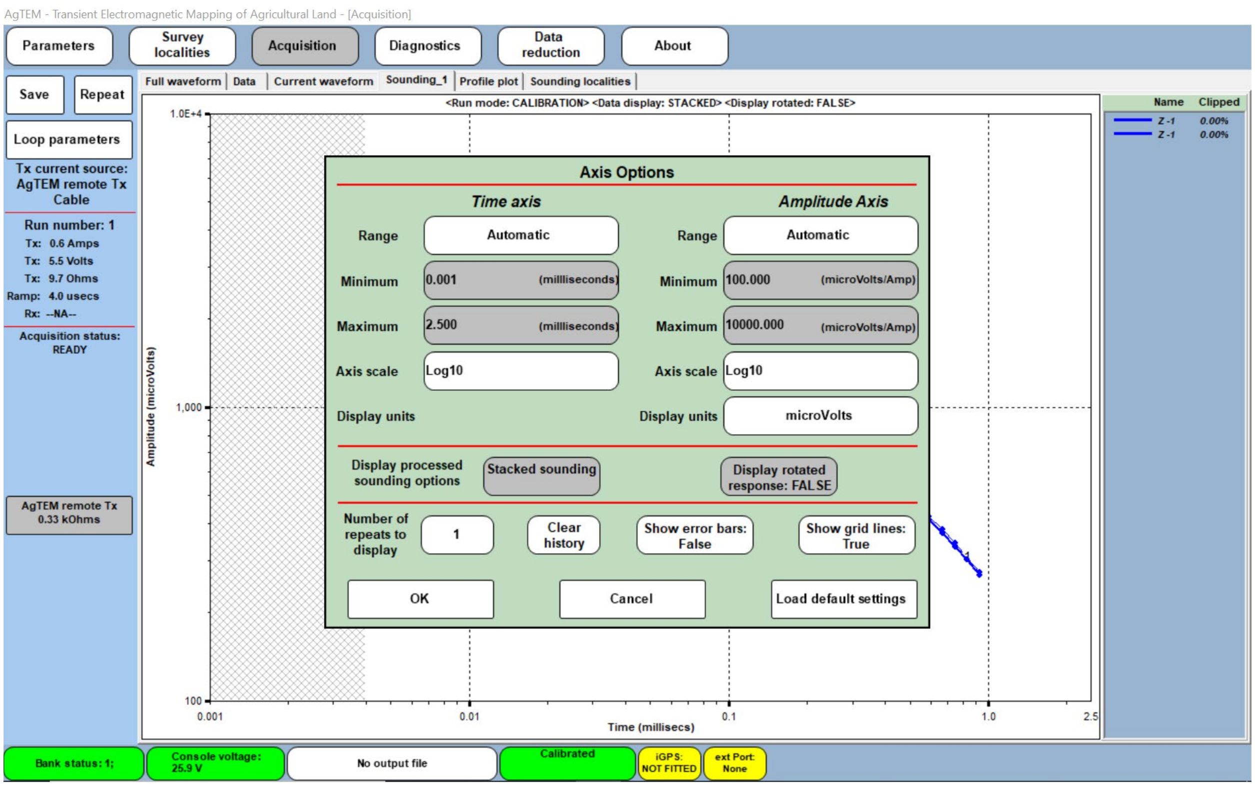
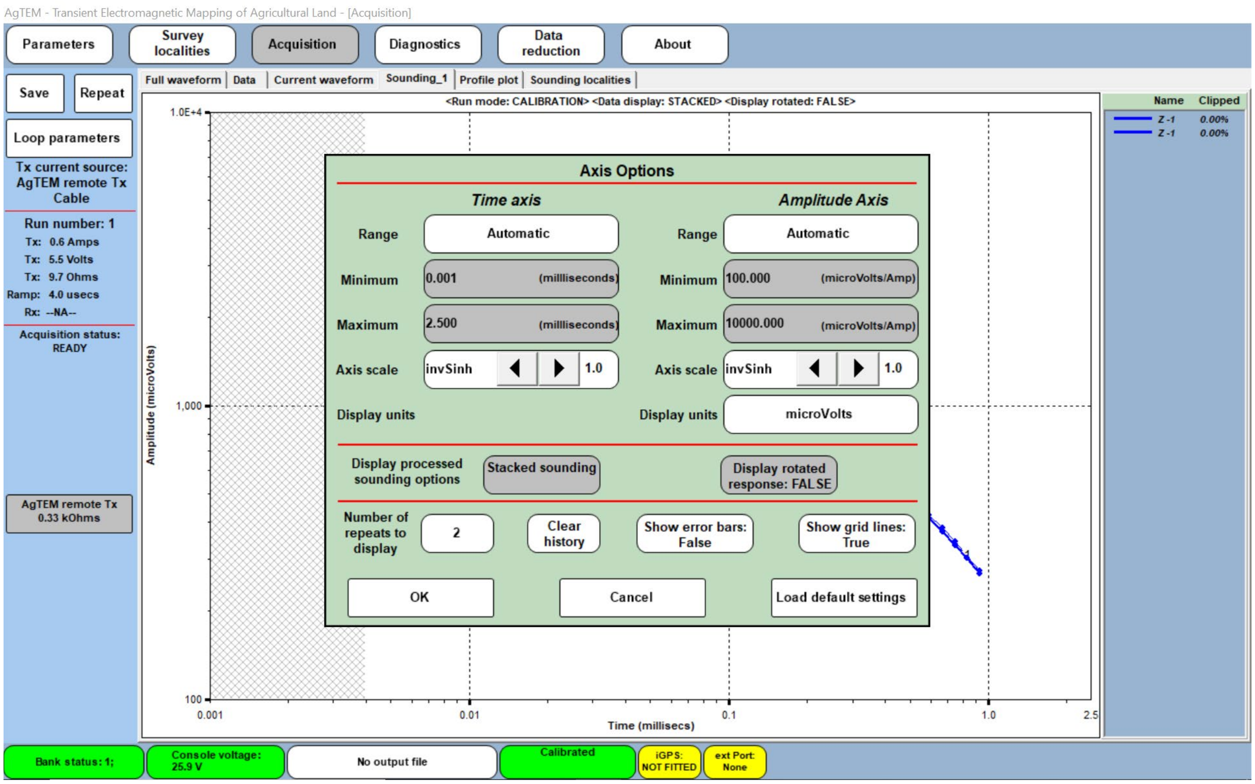


Figure 110 Double Tap the sounding display (when acquisition is paused or stopped) to access the Axis Options.

The Inverse Hyperbolic Sine Axis scaling options, shown below, allow effectively a dual polarity logarithmic scaling which blends to linear scaling as it crosses zero. The arrow keys allow for adjustment of the blending ranges so that noise across zero can either be compressed or amplified on the plot. This is very useful.

Similarly, the Log10 display axis option reverts to linear scaling across the zero crossing and displays (-1) x Log10 of absolute value of the negative data. With this option however there is no 'blending' flexibility and noise oscillating across zero appears messy on the display. Further, a conductive half space response will be a straight sloping line on a log-log display but where this enters the linear portion of the scaling the line will bend which can be confusing. **Do not be fooled by messy changes at the transition from logarithmic to linear scale around the zero crossing.**



RASTER – CONTINUOUS ACQUISITION DISPLAY OPTION

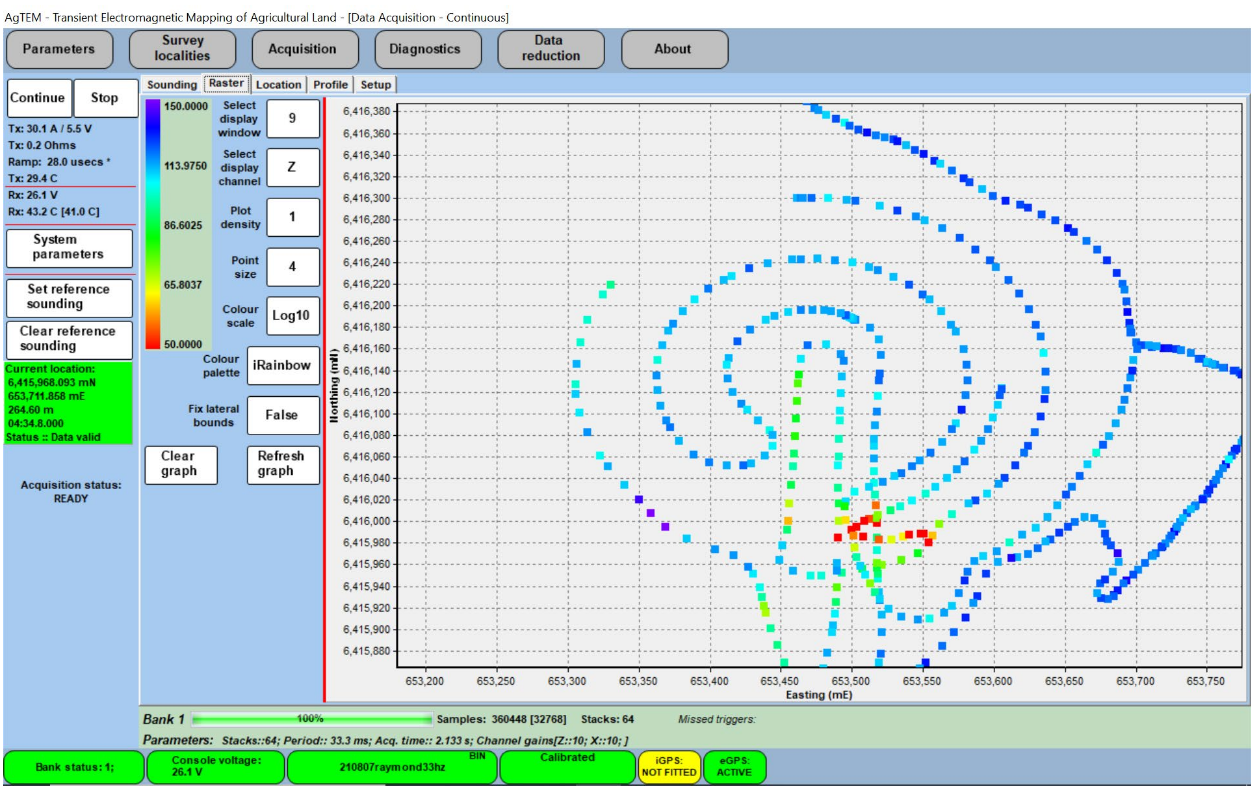
The 'Raster' display is a colored point map display updated in real time as acquisition occurs. Points are colored using the value of a selected gate in the decay curves of a selected channel. In continuous mode acquisition it is appropriate to toggle back and forth between 'Sounding' and 'Raster' displays while the other optional displays are best left turned off.

The raster display is useful as a basic navigation aid but the high-volume-market funded Ag-GPS guidance displays will probably always offer a more precise navigation and guidance solution. The raster display does offer a great way to check continuity of features across multiple survey lines and to observe mapped features as acquisition occurs. This advantage means that coverage decisions can be optimized on the fly and that fewer important features need to be found retrospectively to be inadequately resolved.

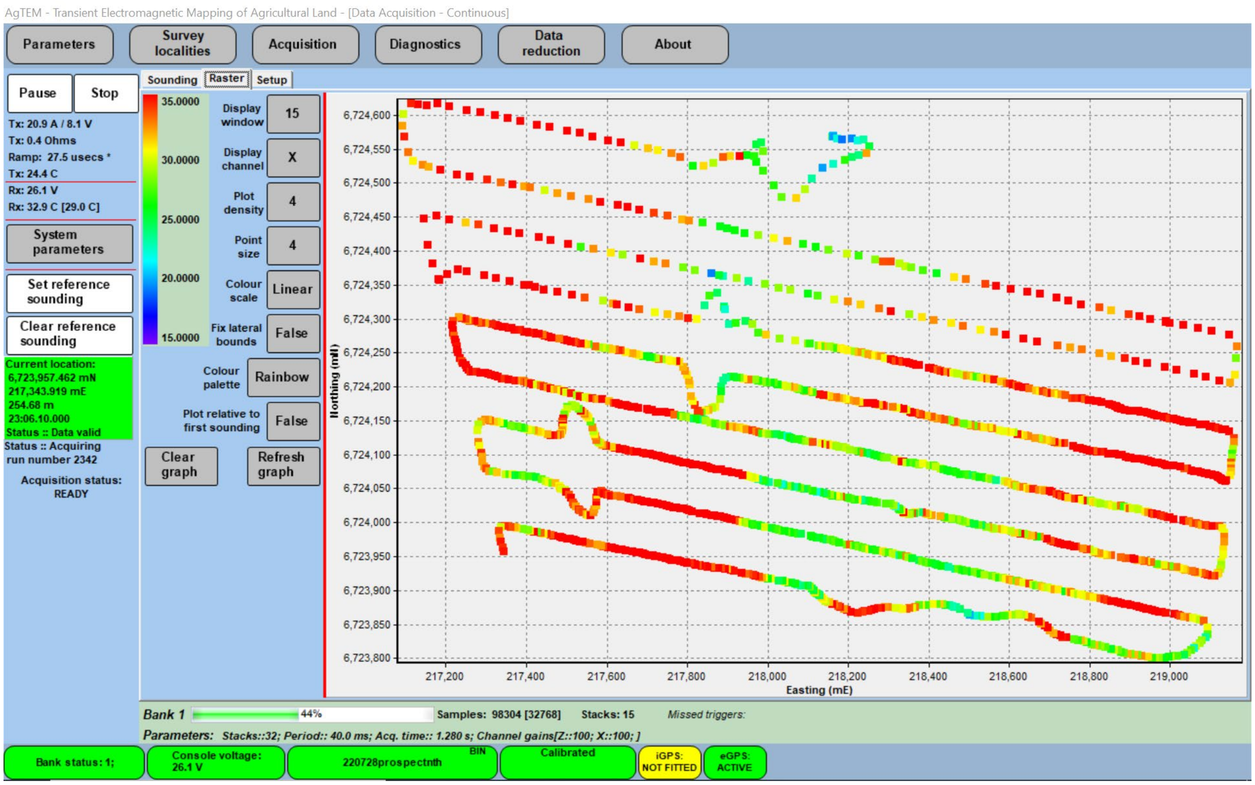
The raster display also facilitates on the fly checking of tie line fit to crossed lines.

The display below shows raster data collected across a center-pivot irrigator paddock and adjacent river gravels.

Zoom - Dragging down and right across this display zooms to an area. This technique has been used to zoom into the pivot paddock in the previous display.



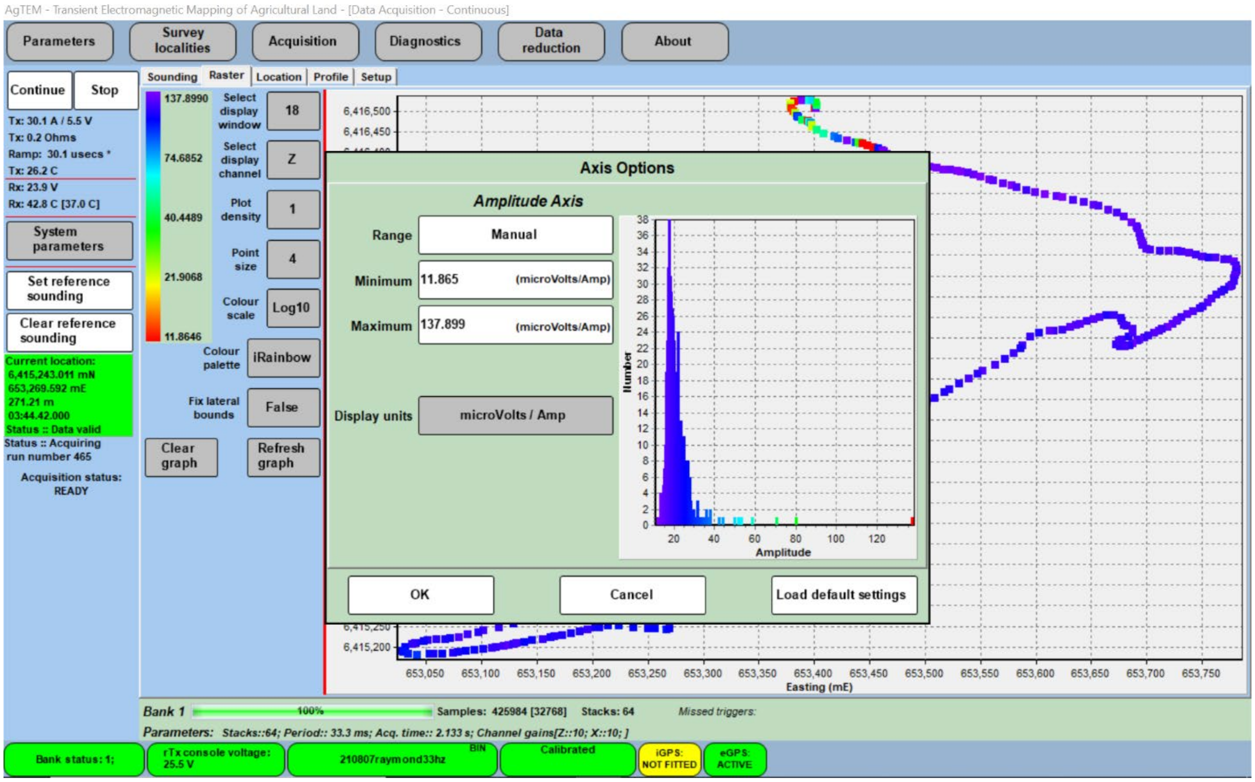
The display below shows a 2km wide survey in which plot density of early points has dropped to 1 in 4 while the more recent points are still 1 in 1.



To modify most of the parameters of the 'Raster' display one should first press the 'Pause' button which then changes to a 'Continue' button. After making changes press 'Continue'.

'**Amplitude Axis**': After a period of acquisition, invariably something like a culvert with metal re-enforcing will add a sounding outlier that blows away the automated color scaling. A survey should be commenced and data acquired until this happens so that a representative histogram can be generated of the values being displayed. Then press 'Pause' and double-click on the color bar. An 'Axis Options' box will appear. Change 'Range' from 'Automatic' to 'Manual' and assess the histogram to decide sensible values, that clip off outliers, for 'Minimum' and 'Maximum'.

After pressing 'OK' you may have to press 'Refresh graph' to see the changes take effect.



'**Select display window**' is critical to provision of a relevant raster display. Too late in time will record just noise and system response while too early will also be dominated by system response – the receiver loop self-response or primary field parts of it. It is common for only a range of channels to provide meaningful field data reflecting ground response. Some trial and error here will reveal which are most useful.

'**Select display channel**' lets you display data from different channels. The active channel 'Label' is displayed.

'**Plot density**' controls how many points are re-plotted in a refresh. To keep acquisition speed high the graph must refresh only a fixed number of points. At acquisition, all points will be plotted one by one but once an update occurs only 1 point in the 'Plot density', eg. 1 in 4, will be plotted. This means that some reference to points obtained long ago can be maintained.

'**Point size**' change can be an indirect way of assisting with estimating gap between an existing line and where you are travelling next.

'**Color Scale**' options including 'Log10' and 'Linear' are possible. Log scaling is the typical logical choice.

'**Color pallet**' can be changed or reversed to suit users preferences. Particular color scales typically accentuate different features.

'**Fix lateral bounds**' prevents boundaries from constantly changing as survey progresses further in any one direction than previously has occurred.

'**Clear graph**' will erase all points plotted already and may be useful where survey commenced then a fault was observed.

'**Refresh graph**' will redraw all points, adjusting color of each after parameters have been changed.

LOCATION – CONTINUOUS ACQUISITION DISPLAY OPTION

The legacy 'Location' display is similar to the 'Raster' display yet it has fixed color points. There seems to be no reason to use it now that the newer 'Raster' display is written.

PROFILE – CONTINUOUS ACQUISITION DISPLAY OPTION

'Profile' displays line trace plots of magnitudes of all gates in a continuous profile as acquisition occurs. There are some self-explanatory options.

Some geophysicists are trained and experienced in the viewing of TEM decay data in the form of profile plots. Features such as capacitive coupling problems show up effectively in profile plots. Personally, the author prefers a combination of the 'Raster' display and 'Sounding' display for data assessment.

SETUP – CONTINUOUS ACQUISITION DISPLAY OPTION

All the display options take time and this time is inserted in between acquisition of soundings. Leaving all displays active is therefore inappropriate. The setup display has a list of checkboxes available for deselecting unwanted display refreshing. By default the Location and Profile displays do not update. If you click on such a display when it is not selected in 'Setup' you will find it is blank.

FULL WAVEFORM – CALIBRATION ACQUISITION DISPLAY OPTION

'Full Waveform' display reveals the real proportional scale of different parts of the full-cycle waveform. It is very useful for identifying unusual features occurring during the on-time and for identifying unbalanced acquisition such as where there is a DC offset or one polarity of acquisition has failed or nearly failed.

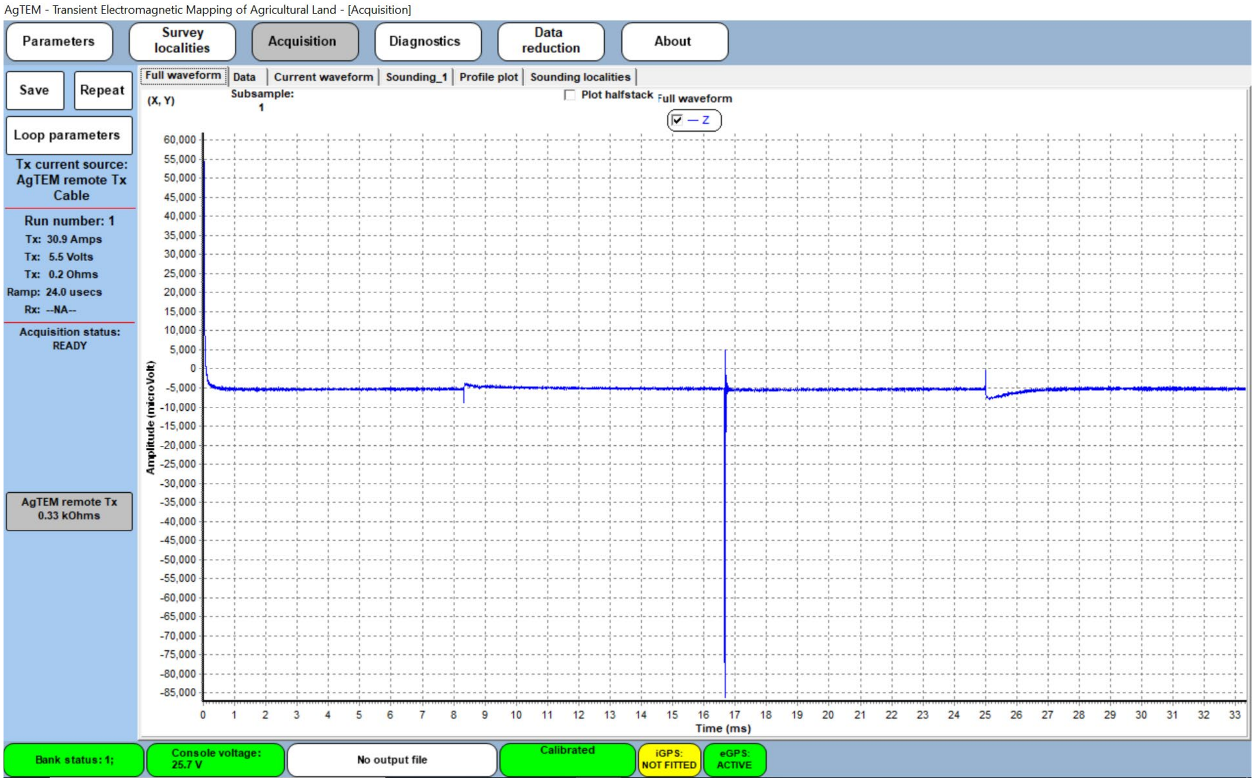


Figure 111 A sample of full waveform data from a receiver loop. Small broad pulses exist at each transmitter on-pulse. Large narrow spikes followed by oscillations exist at each transmitter off pulse. A considerable and stable DC offset is evident across the whole stacked cycle.

It is possible, and appropriate, to zoom in to parts of the 'Full waveform' display. Drag down and right across the part of the display to which zoom is to be applied. Dragging up and left will resize to original dimensions.

The checkbox 'plot halfstack' will add the absolute value of the second half of the cycle to the first and redisplay.

DATA – CALIBRATION ACQUISITION DISPLAY OPTION

'Data' displays a tabular list of floating point values – one for each gate in the time series used for stacking.

CURRENT WAVEFORM – CALIBRATION ACQUISITION DISPLAY OPTION

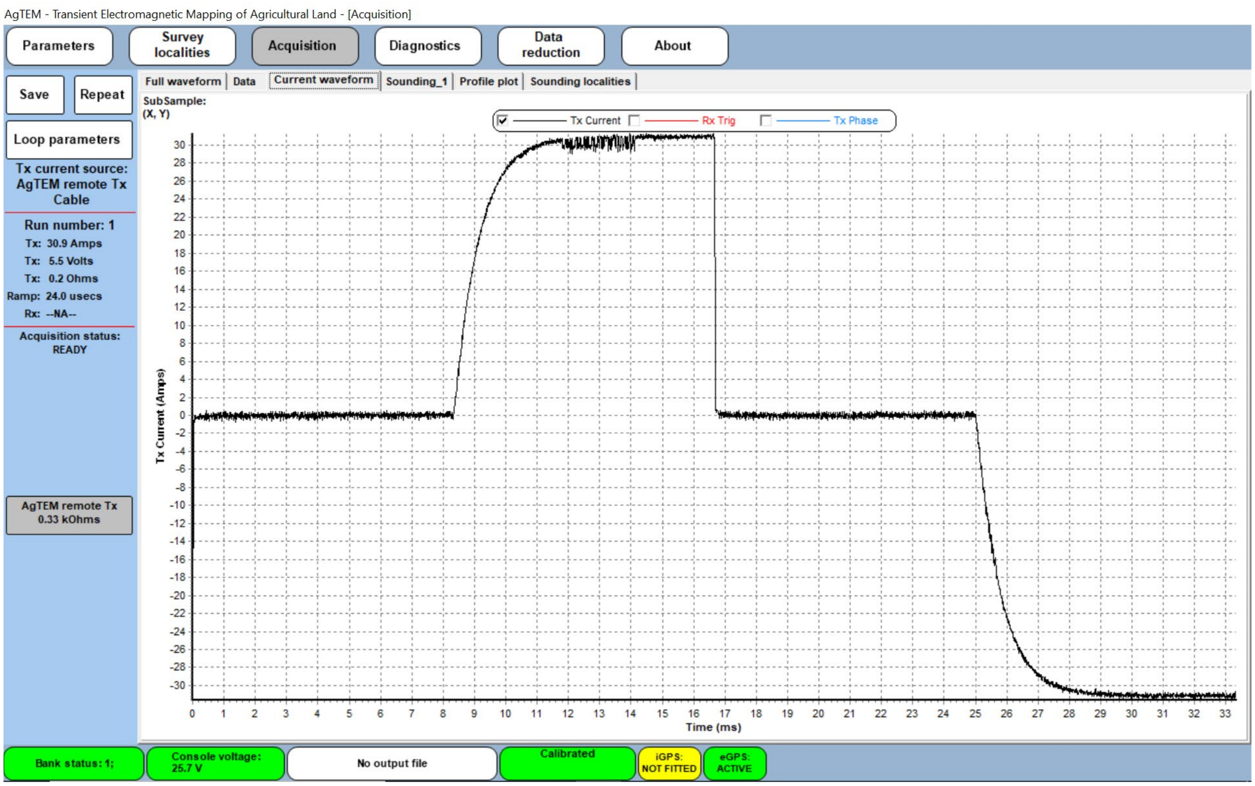
Assessment of the impact of and saving of the current waveform is critical to good acquisition and processing. The figure below provides an example. For low voltage transmission of high currents into very low resistance loops at short cycle times the waveform is far from the ideal 50% duty cycle square wave shape.

The waveform is measured by a pair of Hall effect sensors. These are capable of measuring very high currents but lack resolution on small currents such as used in test loops for bench top tests.

It is possible, and appropriate, to zoom in to parts of the 'Current waveform' display. Drag down and right across the part of the display to which zoom is to be applied. Dragging up and left will resize to original dimensions.

Digitization of this waveform is an essential input to modelling software. Only points representing all significant changes of slope are necessary. At August 2021 the only way to save this data is to zoom in to parts of the display and read off axes values, transcribing them to a notebook one by one. A better save feature is sought urgently and this will need to be integrated into the system configuration description file for each configuration.

'Rx trig' and 'Tx Phase' check boxes are there for checking working aspects of the electronics and are not used in routine data acquisition.



SOUNDING_1 – CALIBRATION ACQUISITION DISPLAY OPTION

'Sounding_1' is equivalent to the continuous acquisition 'Sounding' option.

PROFILE PLOT – CALIBRATION ACQUISITION DISPLAY OPTION

'Profile Plot' is equivalent to the continuous acquisition 'Profile' option. It is not enabled until at least 3 soundings are saved in one file. For some comparison tests it has merit.

SOUNDING LOCALITIES – CALIBRATION ACQUISITION DISPLAY OPTION

A legacy display – in AgTEM survey it may never be used but for moving loop surveys where soundings were manually assigned Line and Station identifiers it has a role. 'Sounding Localities' is equivalent to the continuous acquisition 'Location' option.

DIAGNOSTICS

This menu includes multiple options for undertaking system diagnostics, verification of standard decay curves, and spectrum analysis. The operator can perform an internal self-test and view relevant parameters to the left of the screen. In addition, a snap shot of the transmitter current waveform and channel inputs can be viewed together or separately. This allows in-depth diagnosis of the system by separating the transmitter and receiver components while applying a known signal source to the receiver inputs.

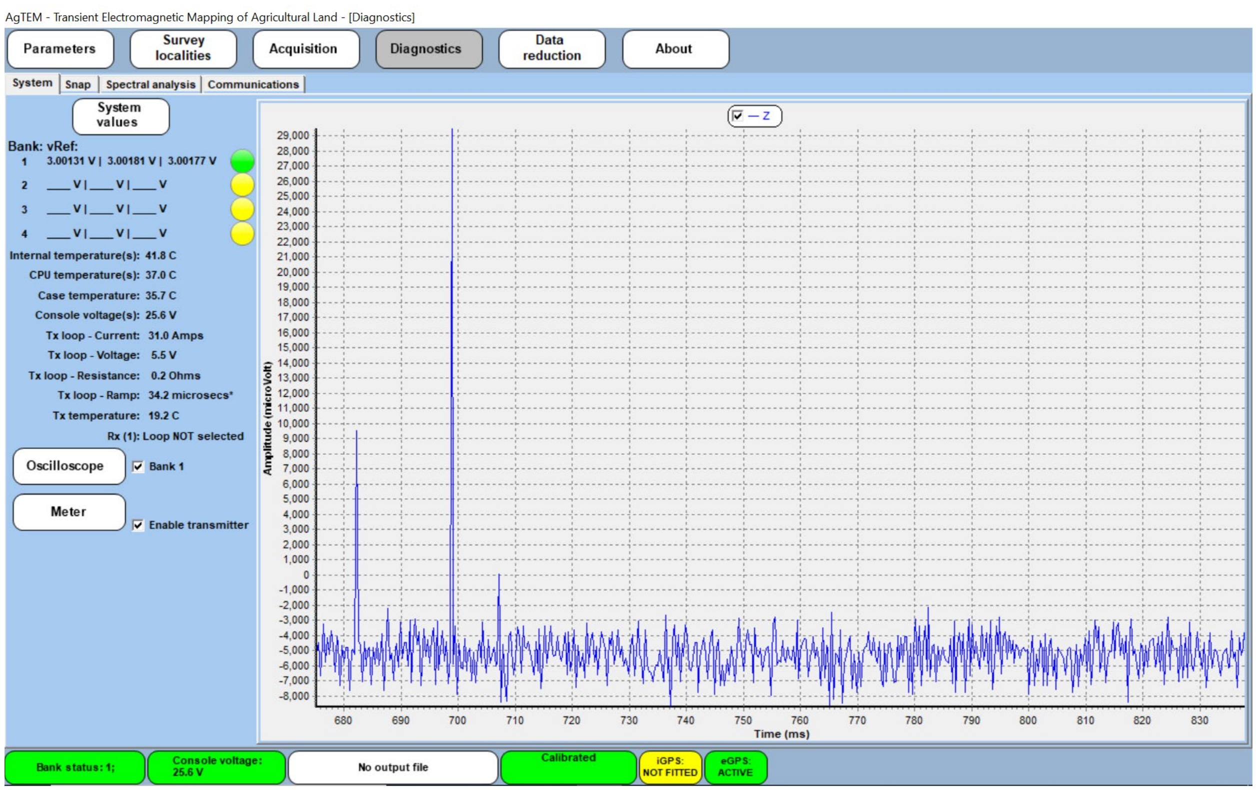
SYSTEM CHECK

Use this menu to test the analogue input and environmental factors for individual channel data.

Touching **System values** displays all the system critical parameters for acquiring a valid transient response, from both internal and external sources. Voltage reference values for the internal amplifiers are displayed along with a green or red ball indicating whether they are within bounds. Battery voltage, internal supply voltage, case temperature and core temperature are measured. A red ball on the analogue voltage, temperature and/or either voltage reference indicates a potentially serious internal error. Transmitter resistance values are also measured to verify external circuit integrity.

Selecting **Oscilloscope** results in a display of data from all available receiver channels (at a reduced sampling rate) with the screen acting as a real-time oscilloscope. The transmitter waveform influence on the receiver can be monitored using **Enable transmitter**. (If doing benchtop tests using a length of wire as a loop remember to attach a suitable power resistor to the transmitter outputs).

Selecting **Meter** results in a text box display of moving average voltage at the receiver inputs.



SNAP

The snapshot window shown below allows acquisition of one waveform cycle at the full sample rate. The Transmitter can be turned on or off, as can individual channels. All selected channels, as well as the transmitter current waveform, are recorded simultaneously. To acquire data without the transmitter on, deselect the 'Enable transmitter' checkbox and re-acquire data by touching **Acquire**.

Touching **Save** will save the image.

Dragging down and right zooms into an particular part of the image. Dragging up and left takes the image back to full extents.

The two images below show 'Snap' without and with the transmitter enabled. The scale has automatically been rescaled to fit the data range so the first image is just highly amplified noise.

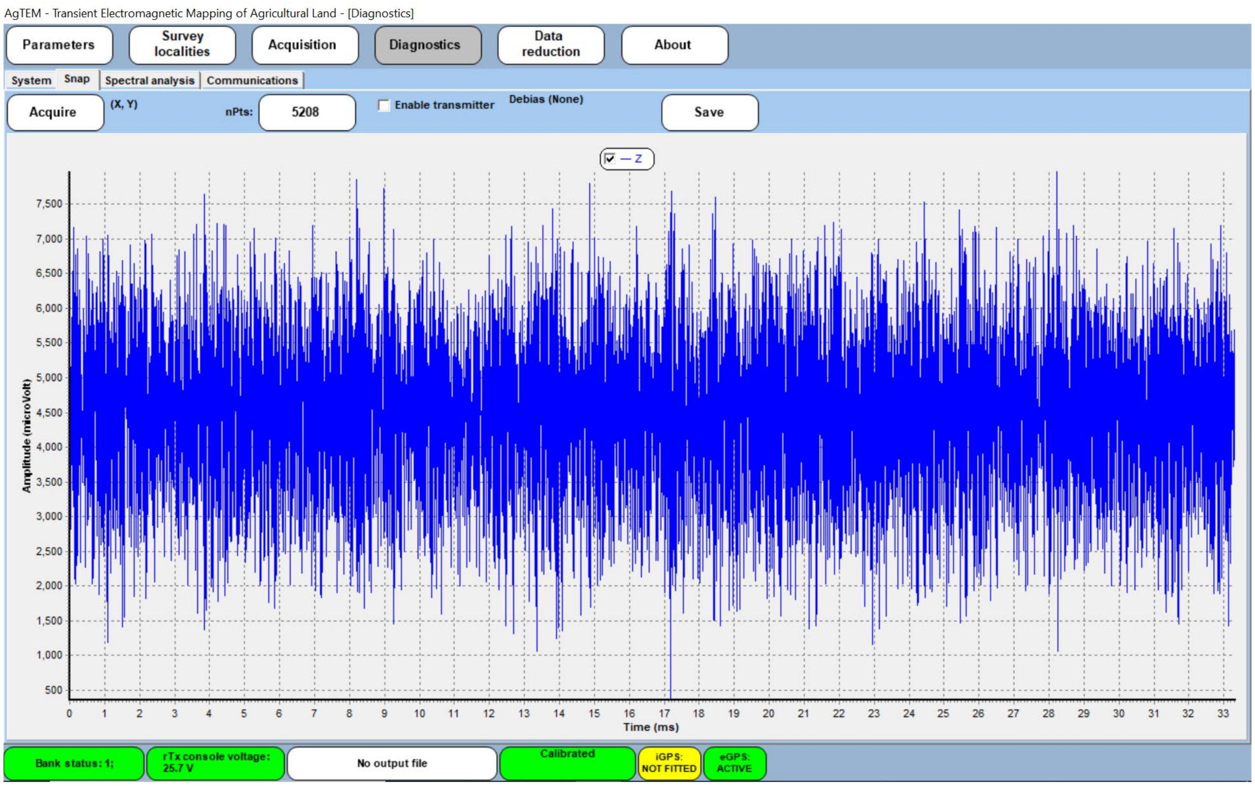


Figure 112 Snap acquisition without the transmitter enabled shows simply highly amplified noise.

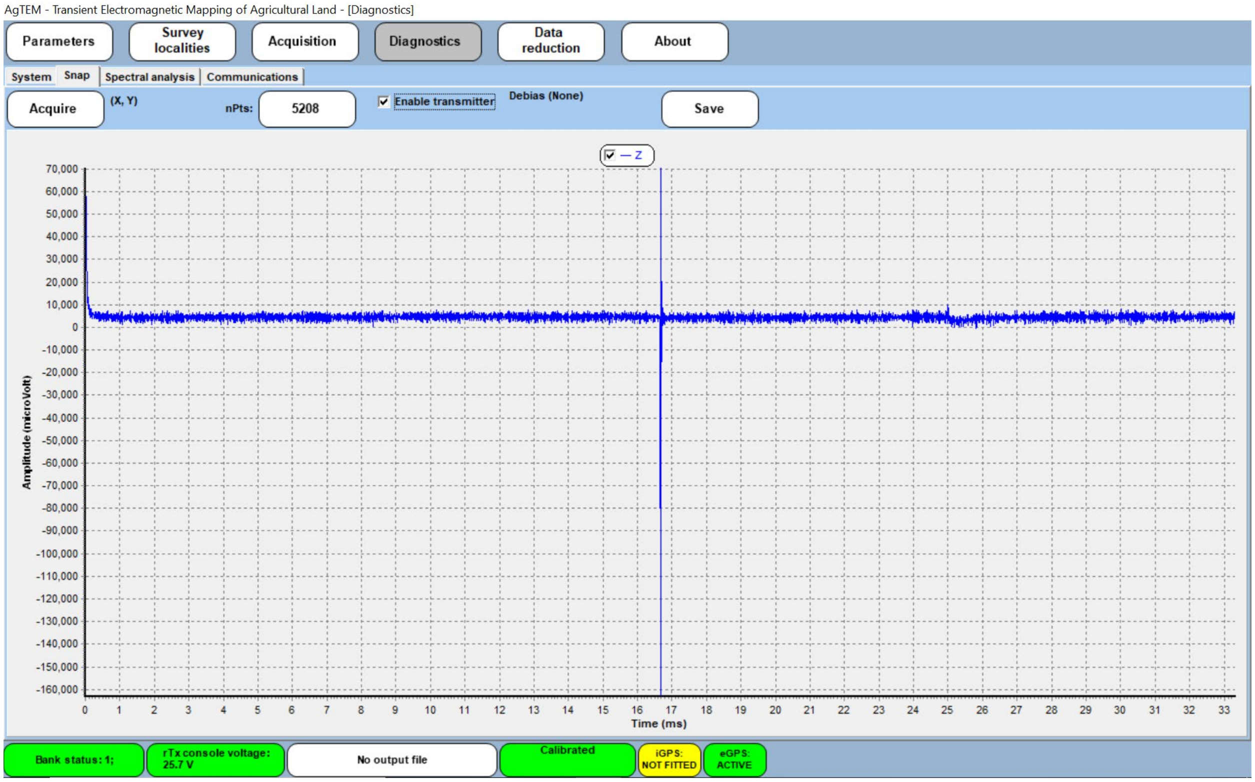
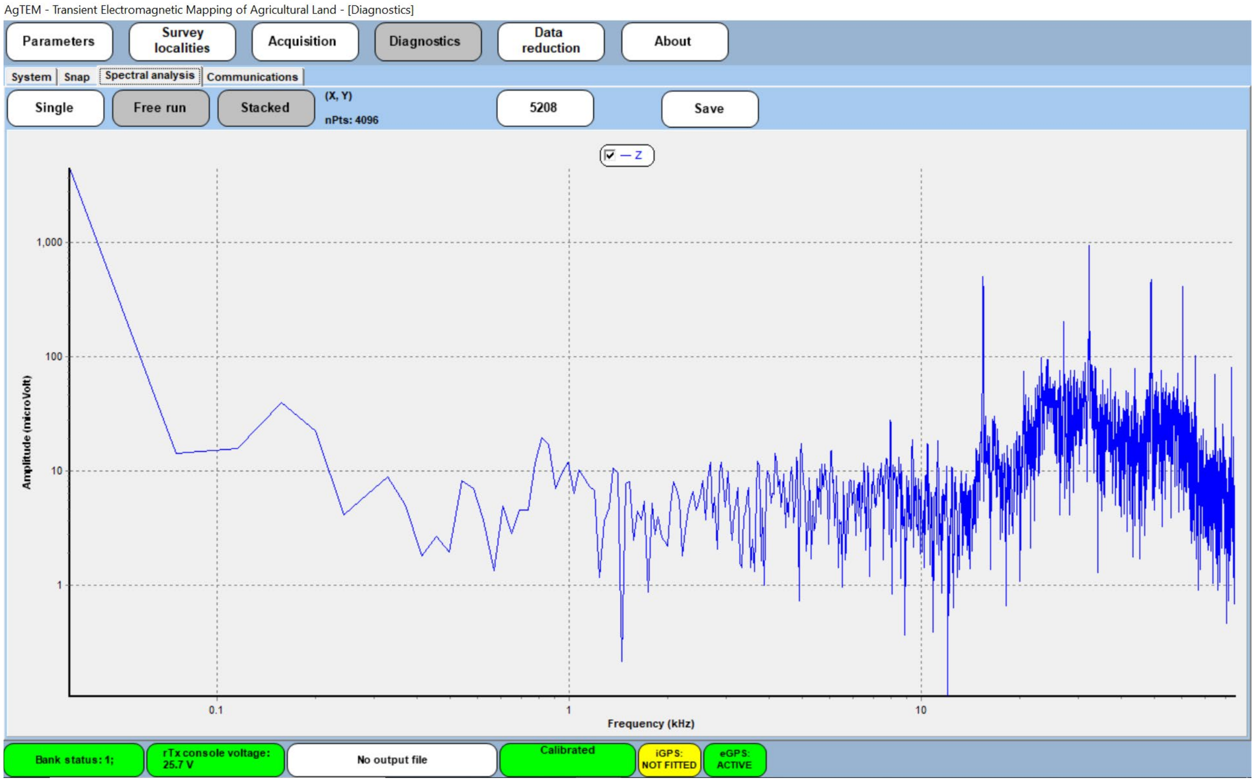


Figure 113 Snap acquisition with the transmitter enabled shows typical full waveform data.

SPECTRAL ANALYSIS

The spectrum analyser shown below allows capture of the entire frequency bandwidth of the acquisition system and is useful in localising sources of noise and interference, especially radio transmitters and power line harmonics.



COMMUNICATIONS

The communications tab provides the ability to check up on and monitor the various forms of communication that must essentially operate for AgTEM to work. It also lists many options not typically included as part of an AgTEM system and they will therefore report with yellow circles due to acknowledged lack of presence.

The display below reveals the result of pressing the 'Retry' button that runs a check of all communications and provides colored circles to verify integrity. In this example we can see that communication with the transmitter is down and needs fixing.

Figure 114 The Communications display after running a communications check by pressing the 'Retry' button.

Further investigation of individual communication streams is conducted after **touching the actual text label** of each on the left of the screen. When one of these labels is touched, the communication options near the bottom of the screen are populated for that label. Then some of them can be changed and pressing '**Monitor**' will then attempt to show a stream of the data on the large memo box. Remember to press 'Stop' when you wish to move on. In the example below this is achieved for the Power supply label at the top left of the screen.

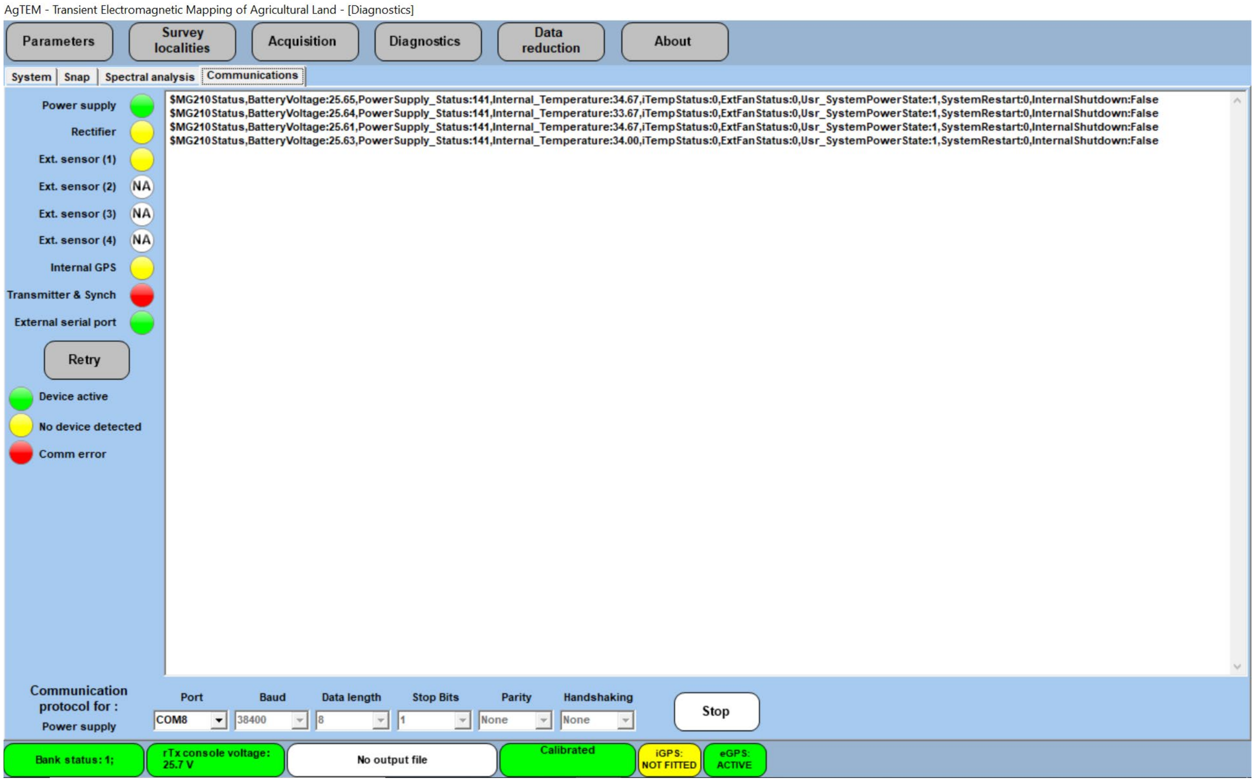


Figure 115 Monitoring of the receiver power supply communication stream.

As AgTEM has two power supplies – one in the receiver and one in the transmitter, if it is selected for monitoring then a message appears asking for a choice as in the figure below:

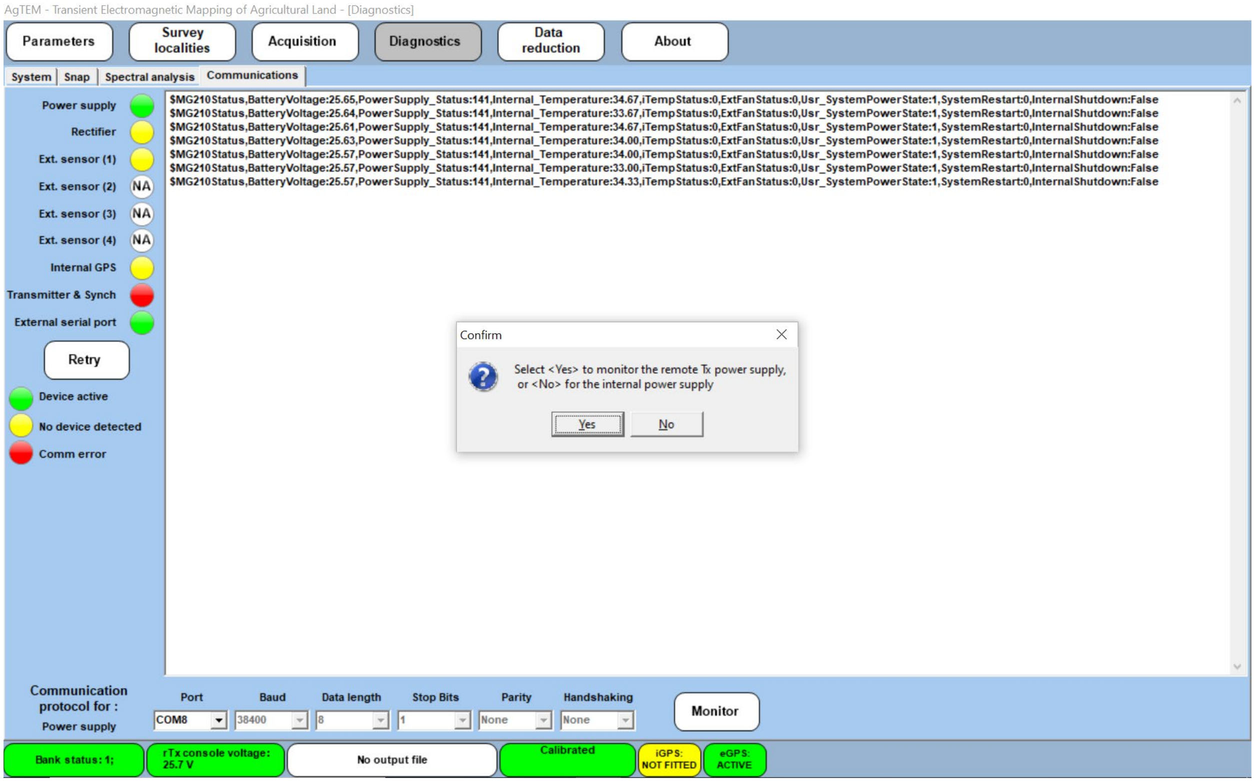


Figure 116 When monitoring of the Power Supply is requested, one has to select either the receiver or transmitter power supply - they communicate using different ports.

Monitoring of GPS data from external GPS can also occur here. If data is not recognizable asci data it will not display so baud rate must be set correctly. In older firmware, the GPS port assignment is fixed as COM11 – it would be much easier for users if this could be changeable so they can use different GPS systems as needs dictate without tricky external reassignment of ports. Firmware after 2023 allowed changing of this COM number.

The figure below shows GPS data streaming in from a Trimble NAV500.

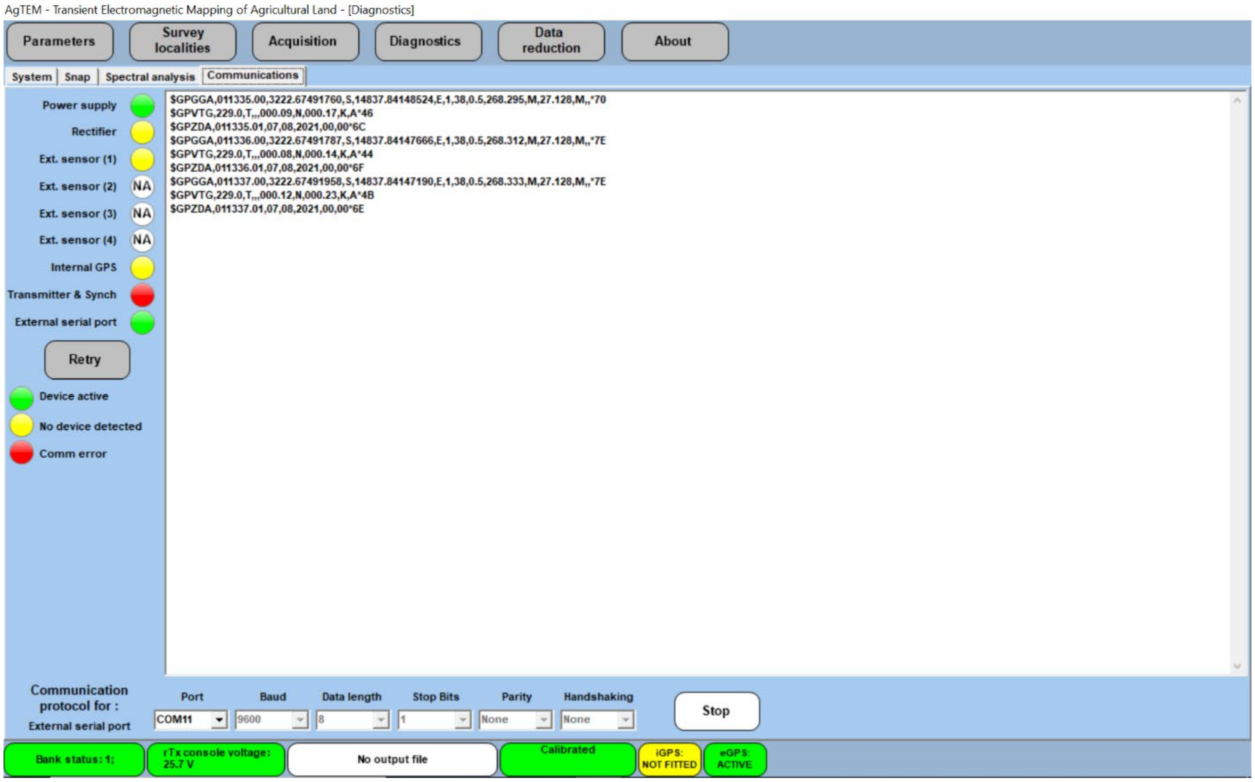


Figure 117 GPS data from a Trimble NAV500 being monitored in the diagnostics page.

The figure below shows the baud rate of GPS input being changed to 115200 to suit a transystem USB GPS puck.

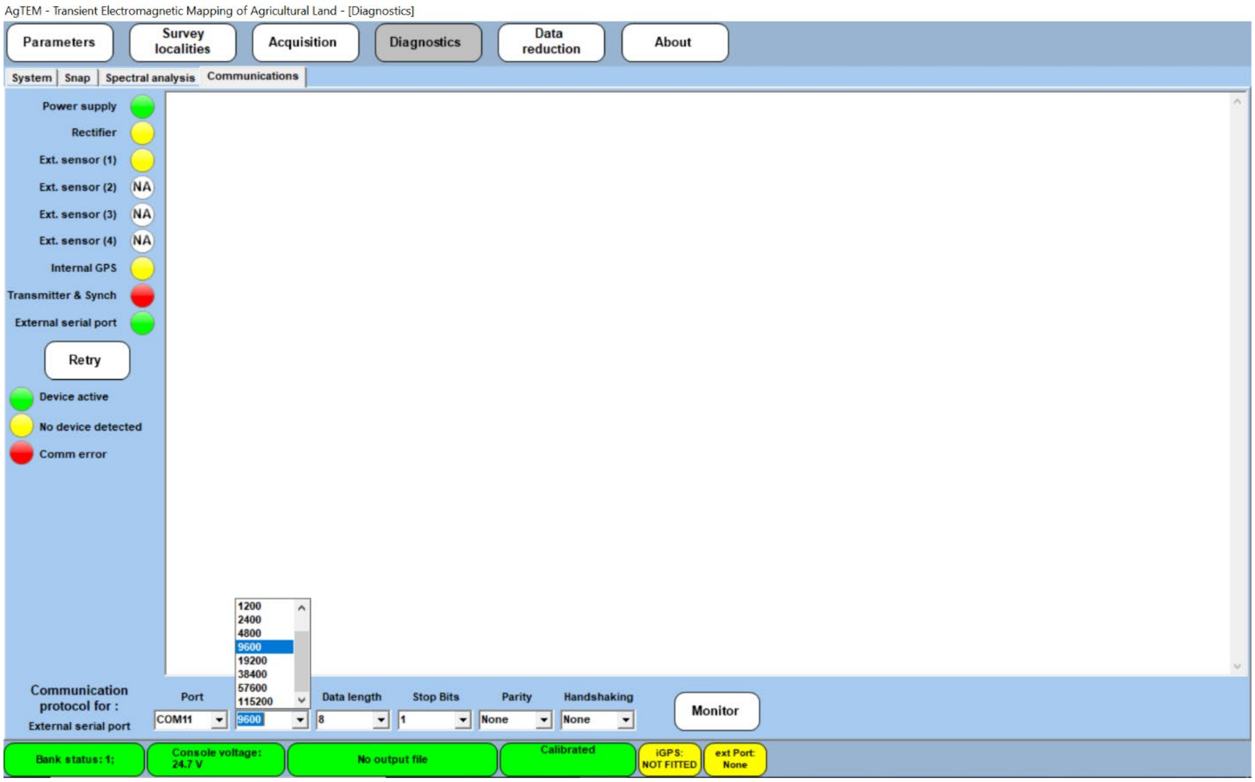


Figure 118 Changing the baud rate of GPS input to 115200 to suit a Transystem GPS puck. **In pre 2023 firmware, Port assignment needs to be done externally as Port COM11 is the only option permitted here.**

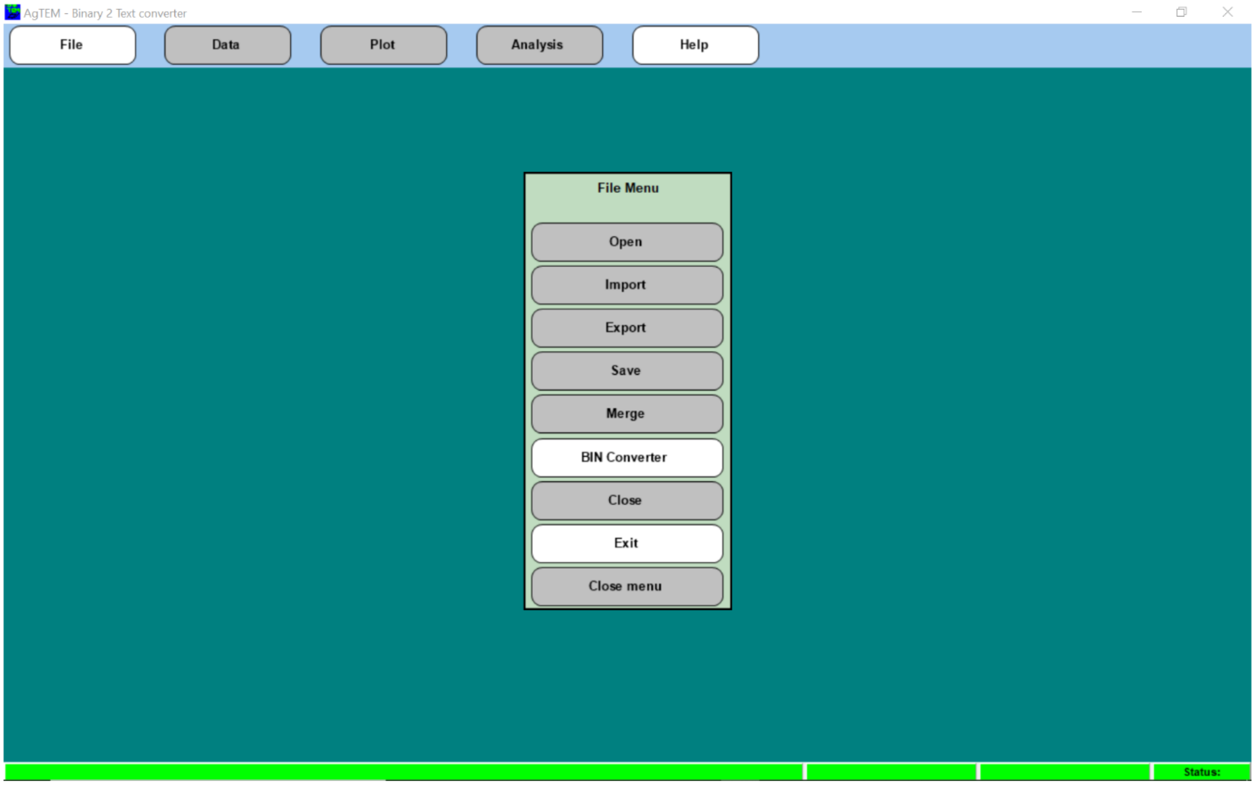
DATA REDUCTION

From this button, access to the file conversion program BINtoTXT.exe exists. It is also accessible from the Startup screen of AgTEM – this alternate access is necessary as AgTEM.exe will not run if the Receiver and transmitter are not connected and booted and you will most certainly not want to do all that at night in a motel just to convert your data. The program will open and you will be able to convert the Monex proprietary secret format BIN files generated by AgTEM to files readable with third party software.

As of August 2021 the only option is ASCII tabular TXT file output. Some unmaintained code exists for AMIRA TEM format file output. Our processing software,ResImage, accepts and converts these TXT files into DBF and INI files with additional configuration documentation and then outputs processed and resampled data to modelling software.

TXT files are a simple yet comprehensive ASCII list of columns with a header on each column and separation using TAB characters. They are appropriately read using MS Excel. Reading them using a text editor is possible but challenging.

BINtoTXT.exe, appears in the image below – shown after the 'File' button has been pressed. Obviously – select 'BIN Converter' then, later, 'Exit' to get back to AgTEM.exe.



A file menu will appear as shown below but it is unpopulated. This is a bug – you must press the 'data' subdirectory to get it to populate with files.

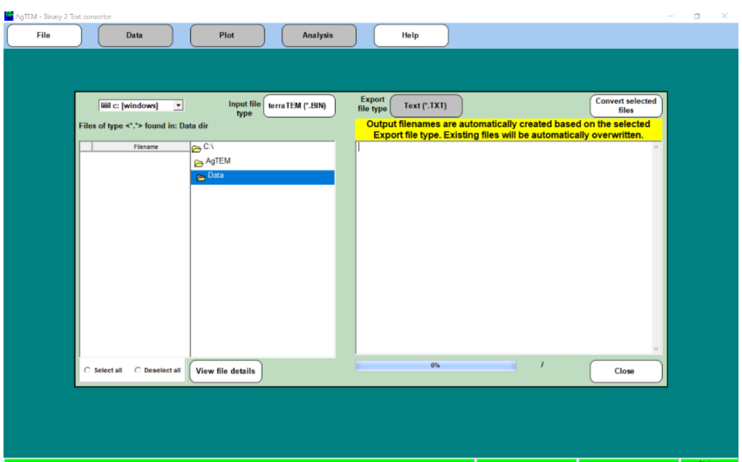


Figure 119 At August 2021 BINtoTXT.exe does not auto populate with filenames - a bug

As shown in the figure below, check the boxes next to the BIN files you wish to convert then press the 'Convert selected files' button. Observe in the right memo box that the files have been converted then press the 'Close' button.

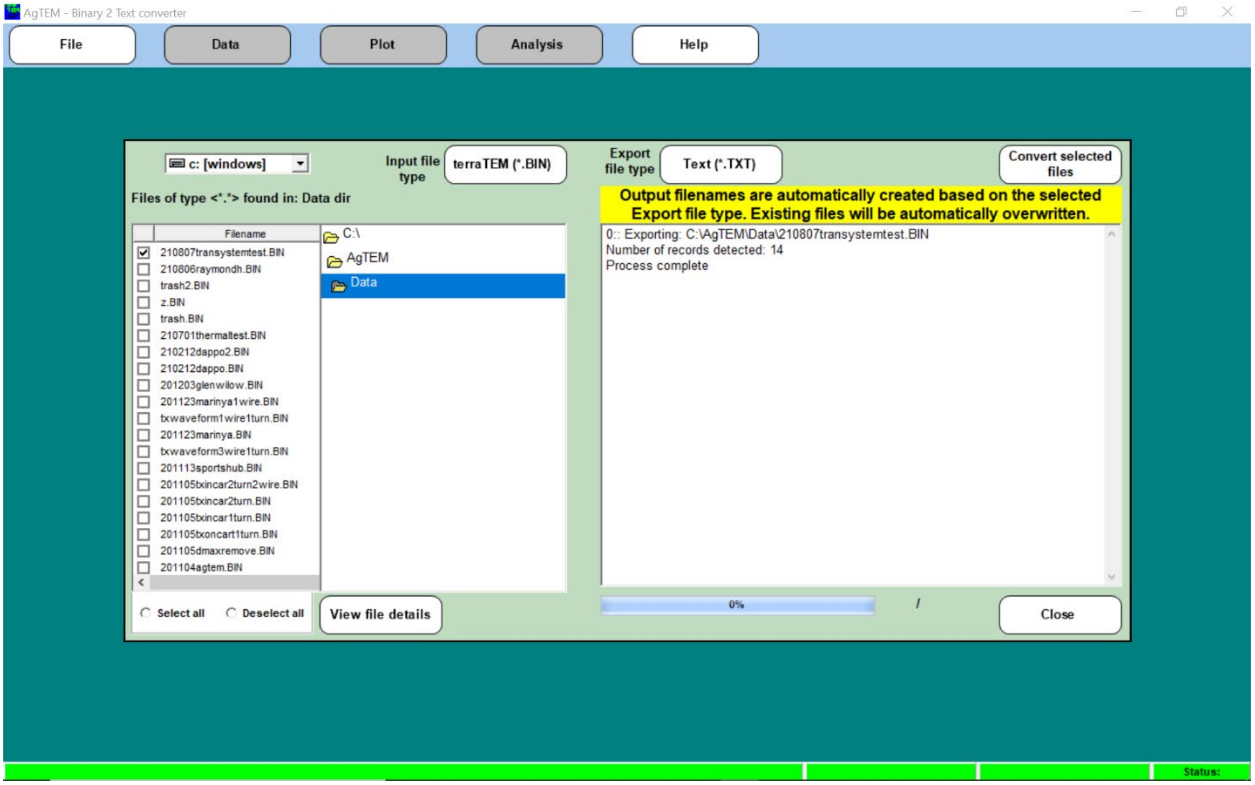
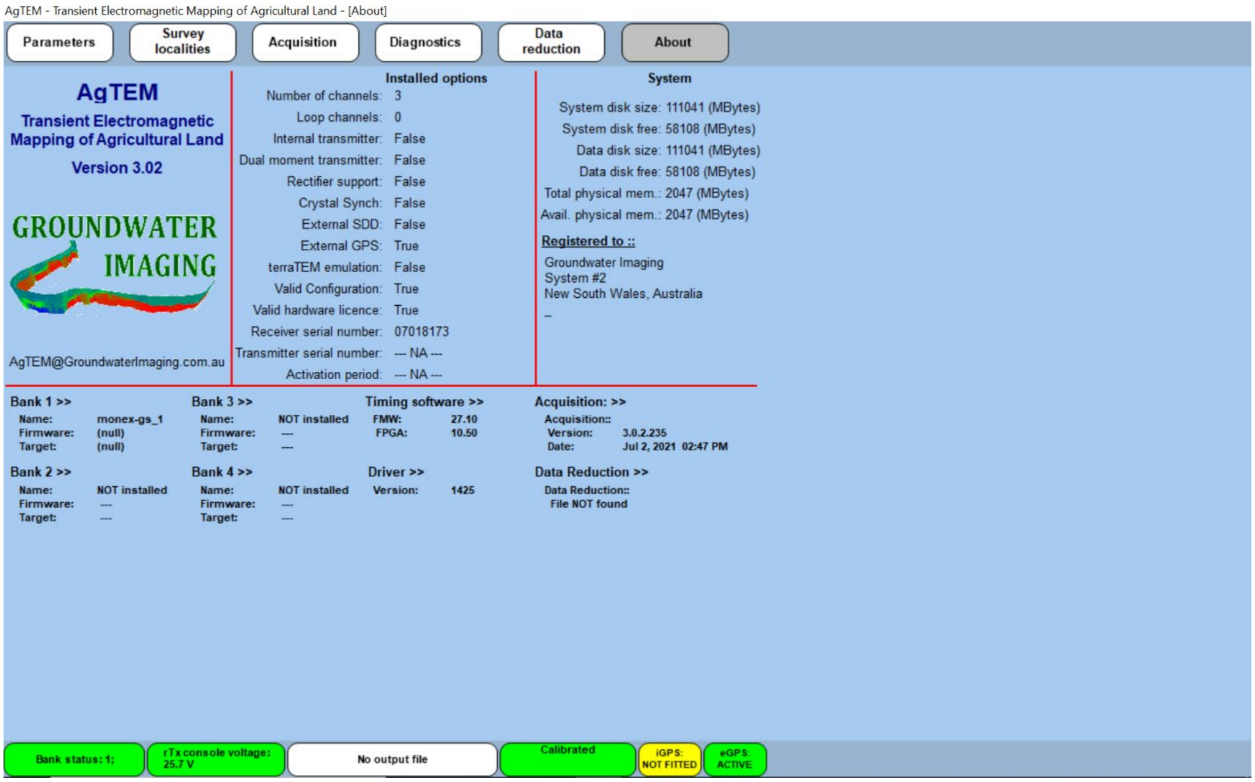


Figure 120 A finished BIN to TXT file conversion

ABOUT

The About menu simply lists all the licensing details of the present system and software – revealing all the parts that are active, to whom it is registered, the software version and the receiver serial number.



BUTTONS AT THE BOTTOM OF THE SCREEN – THE LOWER TASKBAR

Six buttons at the bottom of the screen typically are green suggesting no alert but change color when parameters shown become of concern. To save screen space they do not display the menus that they represent but rather simply one selected display parameter from each of those menus. Users must either tap them to get a reminder of the options they offer or memorize their purpose – this is not hard as what they display acts as a prompt.

There is a conflict between the windows taskbar and the buttons at the bottom of the screen. The windows taskbar is designed to slide up from being hidden when the base of the screen is touched and whatever part was touched will activate the program present on that part of the Windows taskbar. As an interim fix, be careful to touch the top, not the bottom, of these buttons so as to avoid activating programs on the hidden windows taskbar. One option that can help is to move the Windows Taskbar to the right of the screen in settings. Windows 11, however removed this option.

In order the buttons reveal the following menus:

1. System Parameters
2. Internal Parameters
3. File transfer options
4. System Calibration
5. Internal GPS
6. External GPS

LOWER TASKBAR BUTTON 1 - SYSTEM PARAMETERS

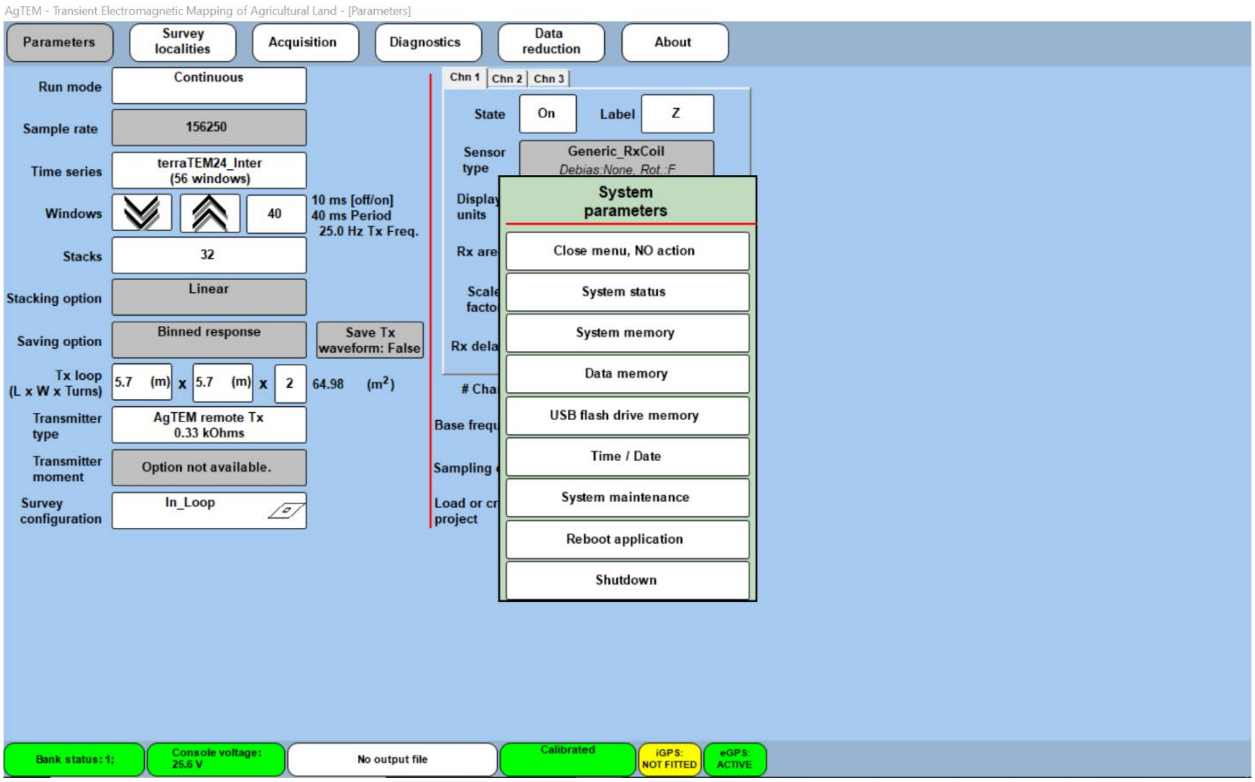


Figure 121 The System Parameters menu appears when the bottom left button is pressed.

SYSTEM STATUS

The default display is 'System Status'. Pressing this option will simply get the button to display 'Bank status: 1:' should the three channels of AgTEM be enabled. Other systems have multiple banks of channels but AgTEM has only one.

SYSTEM MEMORY

Amount of System memory free (percentage). In AgTEM this is just the disk free space on the computer.

DATA MEMORY

Amount of free data memory (percentage). This reflects the amount of space available for storing data. Data files can be transferred and/or deleted using the File control tab. In AgTEM this is just the disk free space on the computer.

USB FLASH DRIVE MEMORY

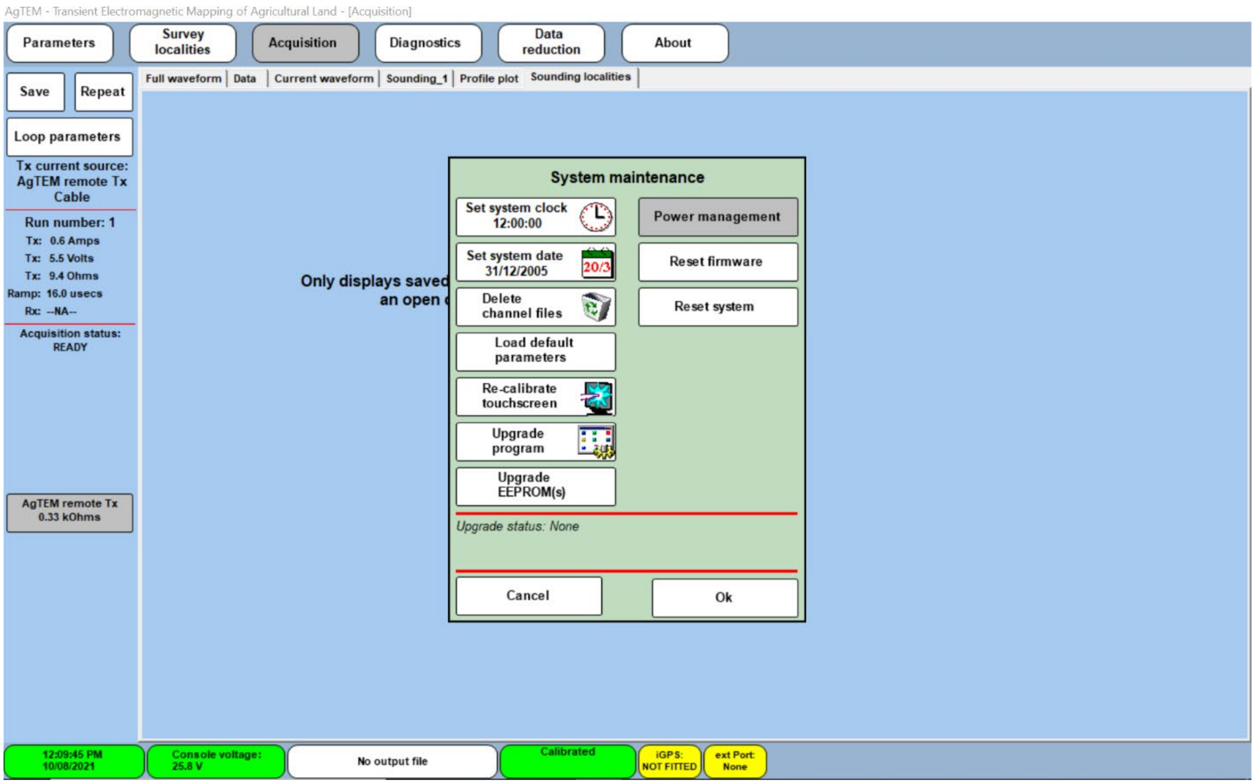
Available memory in a USB thumb drive device attached (if present).

TIME/DATE

Display the time and date on the button.

SYSTEM MAINTENANCE

This tab activates the system maintenance window shown below, allowing the operator to change the system date, time, format the data memory, delete window files and perform a firmware upgrade.



SET SYSTEM CLOCK

Use to set system time. Touch tab, then enter current (or future) time in 24 hour format (hhmmss). Touching **OK** will start the clock from the entered value; assuming it is a valid time. This can also be done through Windows by accessing the desktop.

SET SYSTEM DATE

Use to set system date. Touch tab, then enter current date in the following format: ddmmyyyy. Touching OK will set the date; assuming it is a valid date. This can also be done through Windows by accessing the desktop.

DELETE CHANNEL FILES

This allows removal of user-defined channel files from the system.

LOAD DEFAULT PARAMETERS

Should the system somehow become setup in a manner confusing to a new user or corrupted then default parameters can be loaded back.

UPGRADE PROGRAM

This tab is used to perform a firmware upgrade to the system. Consult your AgTEM distributor for available software upgrades and pricing.

LOAD DEFAULT PARAMETERS

Initialises all acquisition parameters with factory default values. RS232 ports are also reset.

RECALIBRATE TOUCHSCREEN

Do not use this untested option originally set up for a different touchscreen – The Panasonic Toughpad has its own recalibration option you should access from Windows.

UPGRADE PROGRAM

Use only under instruction – upgrade of AgTEM is typically done via windows file explorer.

UPGRADE EEPROMS

Use only under instruction.

POWER MANAGEMENT

This is disabled. Manage power consumption via the Panasonic utilities and Windows Setup provided. Beware that slowing down the wrong things may crash AgTEM.exe - for instance, if sleep on inactivity is selected.

RESET FIRMWARE

Use only under instruction.

RESET SYSTEM

Use only under instruction.

REBOOT APPLICATION

Ideally this would reboot the transmitter, receiver and then AgTEM.exe but it actually locks up the computer. Do not press this or you will need to force a reboot of the computer.

SHUTDOWN

Ideally this would shut down the entire system and place it all in standby mode. The operator must still switch the power off to the transmitter and receiver and accessories to complete the shutdown process. Actually it shuts down AgTEM.exe – returning to the startup screen, shuts down the receiver and does not affect the transmitter.

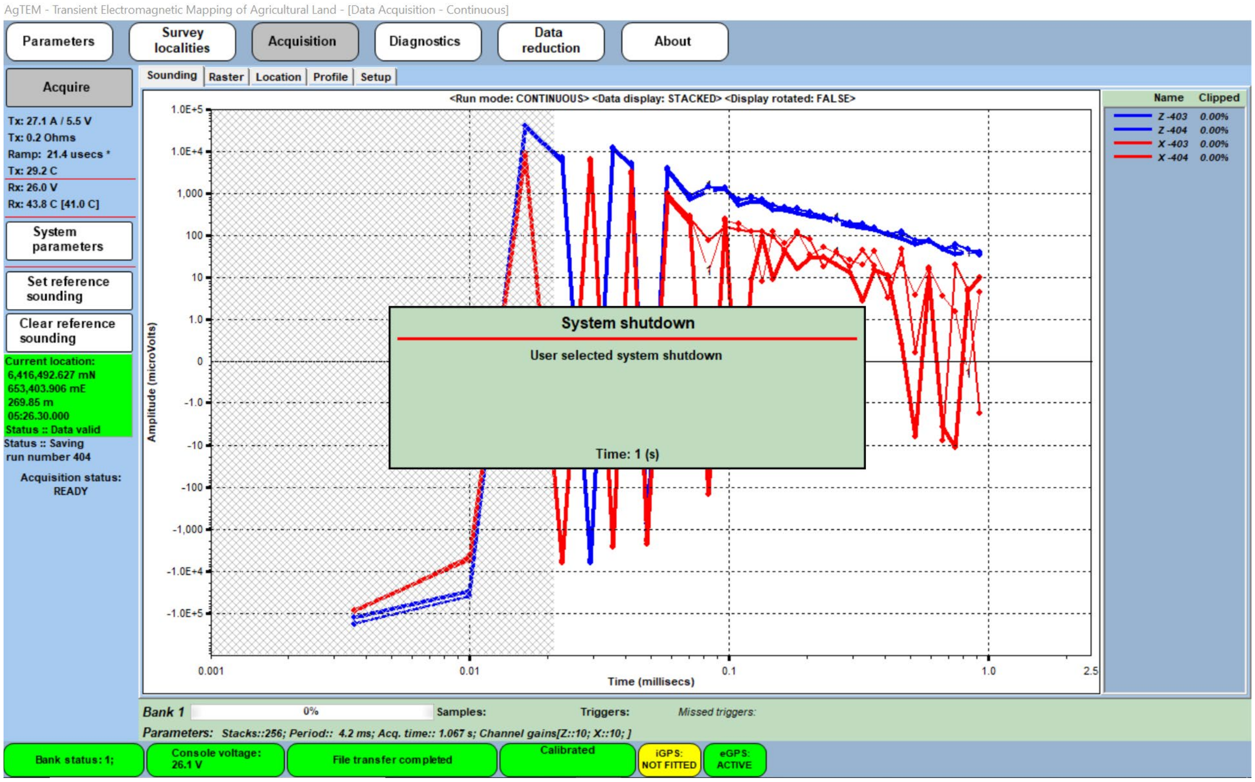


Figure 122 if the lower left button is pressed then System Shutdown is selected this is the screen that appears then the Startup screen appears.

LOWER TASKBAR BUTTON 2 - INTERNAL PARAMETERS

The **Internal Parameters** tab (2nd from left on the bottom bar) shows critical system parameters such as supply voltage and case temperature. If parameter values exceed factory defaults, a forced system shutdown will result to protect the console electronics from likely damage. The operator can have one set of parameters permanently displayed on the status bar by selecting the appropriate tab. For AgTEM survey it is common to set it to ‘rTx Console Voltage’ which otherwise cannot be observed. ‘rTx’ stands for ‘remote Transmitter’.

AgTEM typically operates from LiFePO4 batteries that maintain their voltage while discharging until almost flat and then the voltage plummets and their internal BMS disconnects them from load before AgTEM can detect an imminent problem nor any action can be taken. It can be appropriate to time usage and swap batteries ahead of unwanted shutdown.

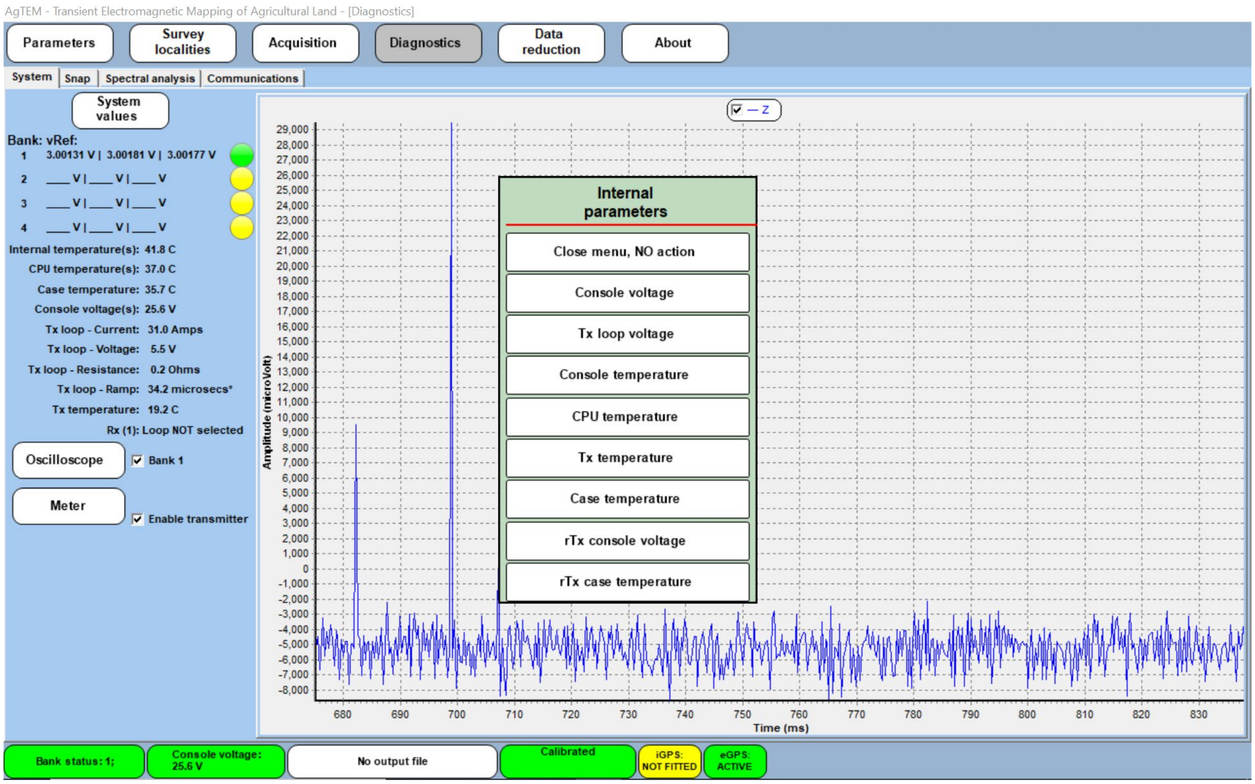


Figure 123 The Internal Parameters menus accessed by pressing the button 2nd from the lower left.

Important system parameters like battery voltage and internal temperature are monitored at regular intervals and warnings are displayed when pre-defined limits are approached or exceeded to warn the operator of imminent system shutdown. The relevant tab will change colour from green to yellow to indicate critical values are being approached. The colour changes to red to warn the operator that critical values have been reached and that a system shutdown is imminent.

The critical system parameters and the pre-set ranges are:

- <u>Supply Voltage</u> (normal range: 23-28 V; caution range: 22-23 V; the transmitter will be disabled at 22 V and the system will shutdown when the battery voltage reaches 20 V)
- <u>Internal Voltage</u> (normal range: 29 V to 31 V)
- <u>Case temperature</u> (normal range: -10 deg. C to 85 deg. C); caution warning also is provided.

LOWER TASKBAR BUTTON 3 - FILE TRANSFER OPTIONS

All file operations can be performed in this menu (center tab on bottom bar) yet users may choose to access files by Windows File Explorer instead. Files are in C:\AgTEM\Data. Files can be opened for writing, named, deleted, or transferred to a USB memory device using this menu as shown below.

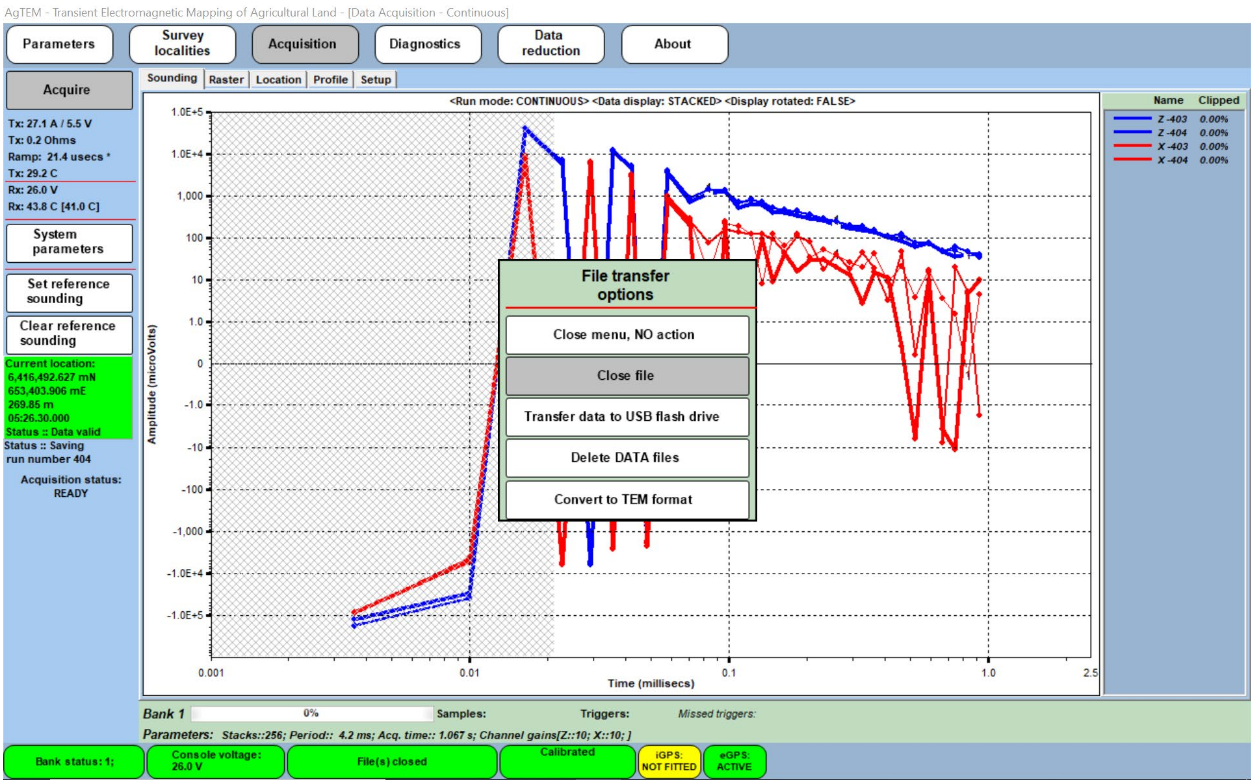


Figure 124 File transfer options menu accessed by touching the third button at the bottom of the screen.

The controls are:

CLOSE FILE

Closes the current file. No dialogue appears.

TRANSFER DATA TO USB DEVICE

This window shown below provides functionality to copy files from AgTEM to USB memory only; If not enough memory is available on the USB device, data must be deleted from the device first; this can be done via the '**Delete DATA files**' tab. Multiple files can be selected and de-selected (toggled) for copying by touching the file names to the left of the window. The tab '**Copy file(s)**' copies only selected files, it is disabled until one file is selected. The tab '**Copy all files**' copies all AgTEM files to the USB device.

Note that files are sorted according to date and time of creation, and the most recently saved files will appear at the top of the list. It is recommended to delete files off the AgTEM system once a project has been completed and the relevant data backed up in order to avoid cluttering up the directory with obsolete files. Remember, the memory capacity of the Panasonic Computer is large but limited – this limits its use as a long-term backup data storage device for redundancy of backup, particularly if storage of full-waveform data is attempted.

Converted TXT files also need to be copied to the USB drive but these are are only accessible from Windows File Explorer – use it instead.

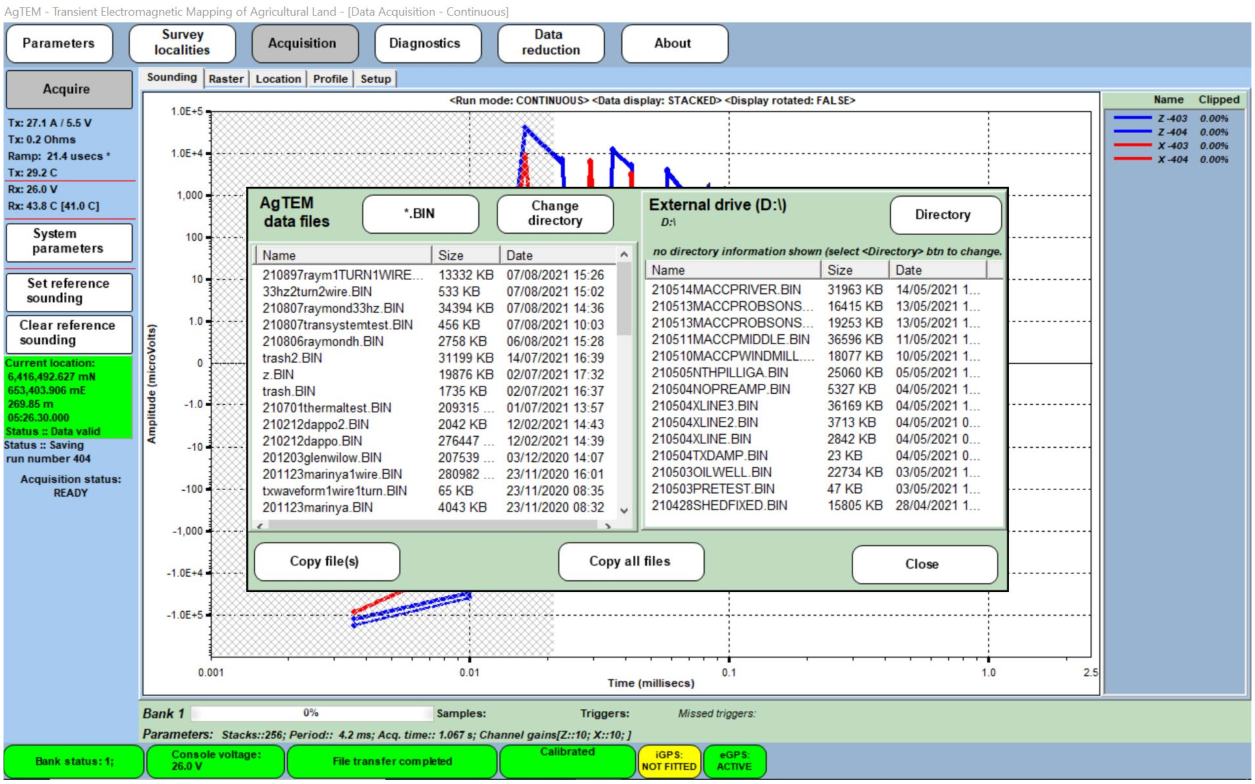


Figure 125 Saving datafiles - access this menu via the third button at the bottom of the screen.

Files are copied by touching the relevant file text (which highlights the file) and then touching the arrow at the bottom of the window. The file to be copied then appears in the right hand window. If no USB device is detected or present, an error message appears.

DELETE DATA FILES

A facility for deleting AgTEM data files without resorting to use of Windows File Explorer.

CONVERT TO TEM FORMAT

This facilitates conversion of BIN files to user readable formats using accessible non-proprietary software.

Untested as of August 2021 – This menu item was to access BINtoTXT.exe like the 'DATA REDUCTION' tab at the top or the access from the startup screen. TEM format conversion is no longer supported.

LOWER TASKBAR BUTTON 4 - CALIBRATION STATUS

Internal systems checks are performed automatically each time an acquisition run is activated, or once every minute the system is powered up. If any critical system parameters approach or exceed pre-set tolerance levels, the color code of the status display changes from green to yellow or red. Ignoring a red status indicator may lead to data corruption.

Comprehensive internal tests (normally performed during system start-up) can also be initiated at any time by the operator by touching the calibration tab (4th from left on lower bar). A message pops up asking for confirmation and indicating the system will not respond to operator inputs for 45 seconds.

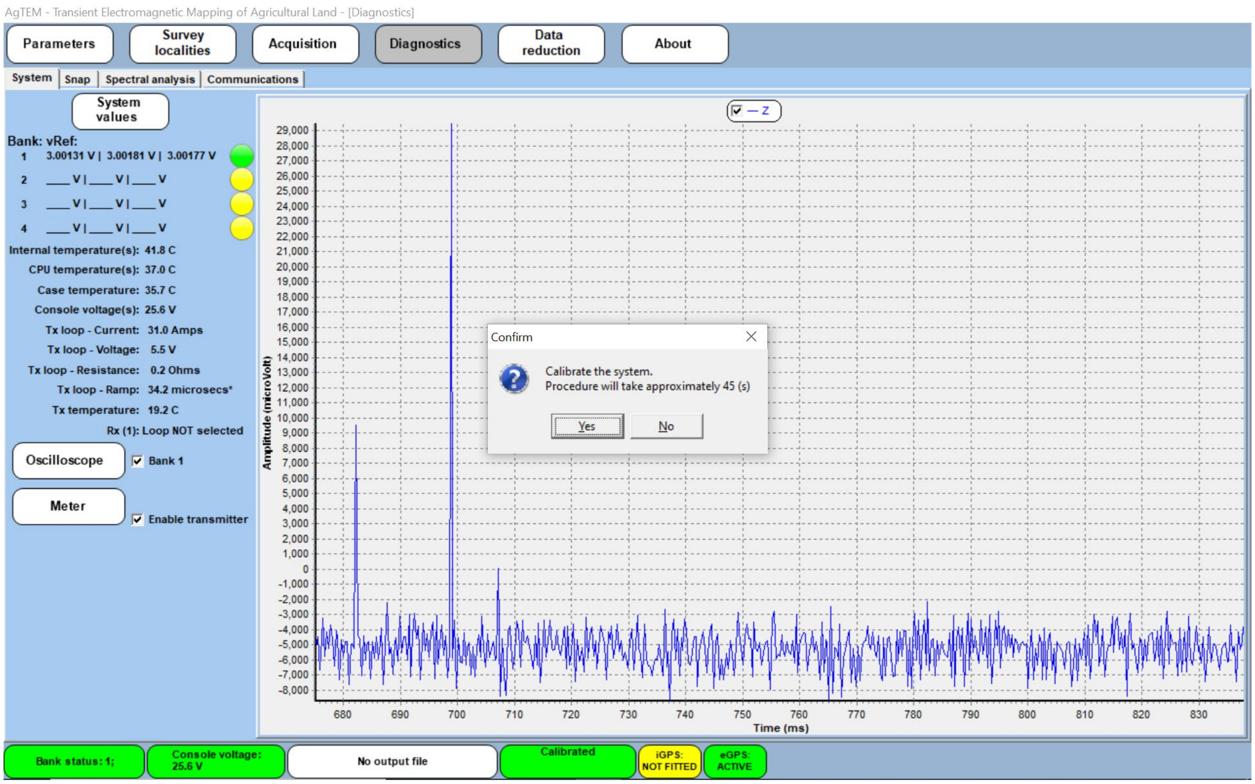


Figure 126 Pressing the Calibration button on the lower taskbar brings up the box shown.

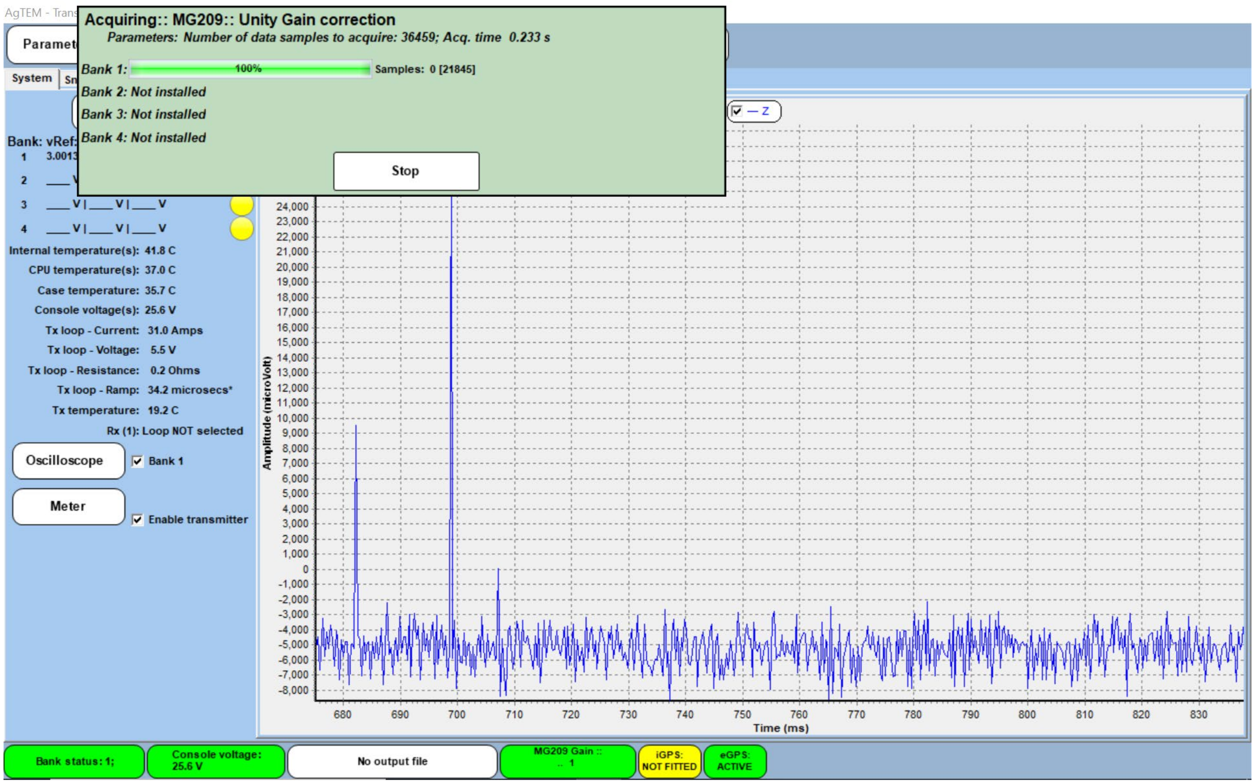


Figure 127 During calibration, the taskbar button and an update box provide progress information.

If the tab shows red; one or more internal test values have failed the Manufacturer's specifications, indicating some internal fault condition. At this stage, a survey should not proceed as data integrity may be compromised. If this should occur, please undertake a System check from the first button at the bottom of the screen and verify both internal temperatures are within appropriate bounds.

LOWER TASKBAR BUTTON 5 - INTERNAL GPS

This is a legacy button and can be ignored. AgTEM has not got an internal GPS as for a small footprint system accuracy in positioning from an internal GPS in a towing vehicle would be inadequate. Preference is for an external GPS with a clear view of the sky.

LOWER TASKBAR BUTTON 6 - EXTERNAL GPS

The eGPS (External GPS) button will be green if data streaming in from an external GPS is of suitable quality. It is expected that AgTEM will be operated with an external GPS or DGPS positioning system. The Trimble GFX350 Display and NAV500 (or NAV900) antenna are a common choice as they are common in agriculture with a comprehensive support base and they are designed to facilitate precision driving to cover paddocks just as required by AgTEM. A differential subscription service is an important addition as a ready-made topographic dataset exactly matching an AGTEM dataset is very useful for interpretation of the AgTEM data.

Other GPS options are the Transystem USB GPS puck supplied with the test loop or the very capable lightweight EOS Arrow Gold+ that can supply very accurate elevations and position. Either of these lighter weight systems are appropriate for Wallaroo surveys while the great weight and complexity of the Trimble system may fatigue an operator very prematurely.

The GPS button at the base of the screen shows the state of readiness of the external GPS. A red color indicates that the GPS is either not present or has not been properly initialized. A yellow color may indicate presence of the GPS but that it has not been selected (Harmless Bug: As it is the only option and data streams in regardless and gets used this is a bit pointless).

If the eGPS was not in use, or somehow disabled, last time AgTEM was used it may presently not be selected. In this case the eGPS button will be yellow as shown in the figure below. Click it to reveal the selection box shown and then observe the pop-up box in the second figure below. It allows you to toggle between the absent iGPS and eGPS. In the background you can observe the Diagnostics screen after monitoring the eGPS data. See the section on the diagnostics screen to see how to use this.

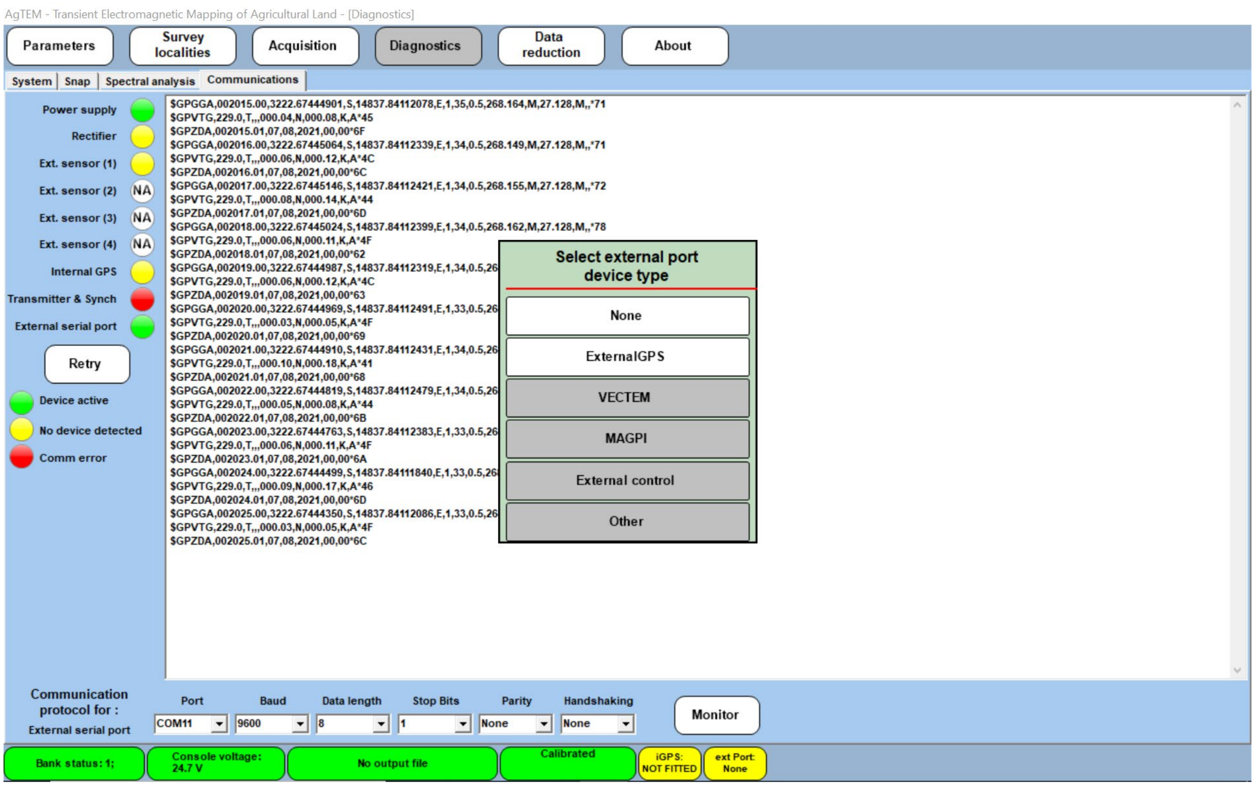


Figure 128 Pressing the yellow 'Ext Port: None' box brings up this popup selection list.

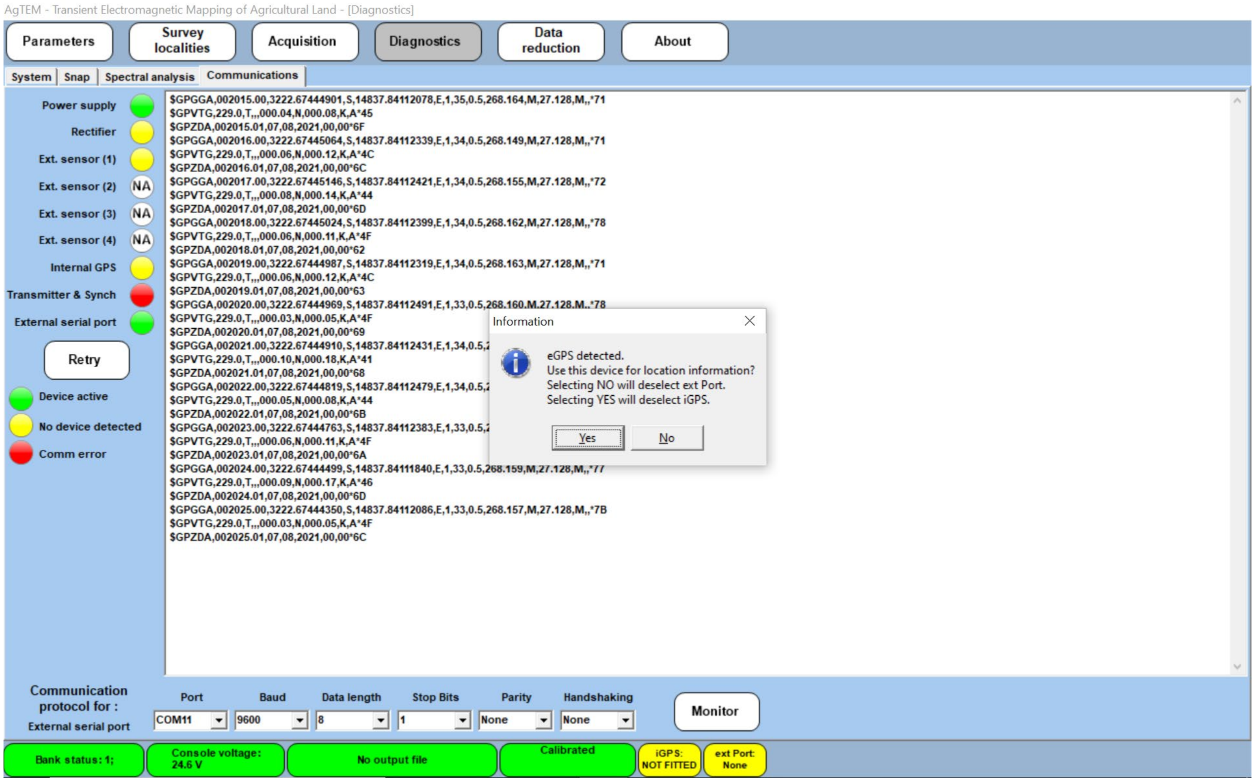


Figure 129 This popup box appears upon pressing of the yellow button, at the bottom of the screen, that says 'ext Port: none' then selecting external GPS from the list in the figure above. The box display test will change to 'eGPS: Active' and turn green if 'Yes' is selected.

Note that it can take 1-2 minutes to obtain the first position fix from a cold start (for example, if the system has been inactive for several days or weeks or if it has been relocated a significant distant from its last operation). Use the diagnostics menu to resolve connection problems or the alternatively the location menu to obtain more information on the current GPS status.

GPS connection is often surprisingly far from trouble free – if necessary, please see the troubleshooting section for comprehensive documentation of problems that may need fixing. GPS is connected by default through port COM11 and the access can be fully checked using the diagnostics page of AgTEM.exe.

SPECIFICATIONS

SPECIFICATIONS – PRESENTLY BEING ADJUSTED AND OPTIMIZED

System response tests and numerous tests on dimensional stability of nulling are in another documents created in 2024 that really needs incorporating into this document – funds do not permit as of Jan 2025. Missing are most Wallaroo specifications as of January 2025 it is still largely in Proof of Concept stage.

SYSTEM

Panasonic FZ-G1 Toughpad in quick release dock with permanent protected cables connections.

In later systems this is replaced with a WinMate console with IP68 connectors designed for tractor dashboards.

Display: 1920 x 1200 WUXGA sunlight readable 2-800nit touchscreen.

Storage: SSD 256GByte with heater.

I/O port – data transfer via USB, Ethernet or WiFi

GPS connection via Serial Port, USB or Bluetooth

See Panasonic Toughpad specification sheet for more.

System-Docks – iKey – allows quick release of toughpad and retains IP67 seal on all toughpad connectors. All connectors instead lead to the dock which is sheltered from rain and is a low cost replacement part. Connectors may remain sheltered and fixed, permanently attached to the dock.

AGTEM PRE AMPLIFIERS

Pre-amplifiers may optionally be added to any of the receiver coils to balance impedance. Details of specifications as coupled with various coils is given below. The Pre-amp detects the coil voltage across a high impedance and sends signal to the receiver along shielded cable differentially so the ratio of noise detected from the shielded cable to signal received from the coil is as low as is practical.

Voltage +/- 10V. Safe range without damage is approximately +/- 30V

Pre-amp operating range -20 to 50 degrees Celsius.

The pre-amp has a 50kHz low pass filter (variable) and damping often set at 330 ohms.

Amplification is variable but commonly set to 20x. For Wallaroo in-loop it is set at 1x.

Pre-Amp ‘delay’ of 8-9 uS and synchronization cable delay are corrected in the receiver or later processing. This may be considered as a delay or as a low-pass filter. It is more accurate to interpret it as a low pass filter.

AGTEM-WALLABY CORE RECEIVER

Air cored induction sensor

Bandwidth 50 kHz (pre-amp filter)

Equivalent area – main AgTEM-Wallaby mid-plane coil – either 10 or 20 x 2.06m^2 x pre-amp (up to 100x but 10x by default) => maximum 4120 m^2; typical 20.6 to 412 m^2

Dimensions: AgTEM-Wallaby (2 x 1 m in AgTEM-core midplane);

This receiver is positioned precisely to achieve null mutual inductive coupling with the both the main transmitter loop and the pair of small transmitter loops.

FRONT LOOP

An air cored loop of the size of the top of AgTEM-Wallaby core can be fitted to two booms fixed to a bull bar and suspended in front of towing vehicles at a height that clears fences and most vegetation. This highly maneuverable Slingram loop is quickly attached to and detached from the bulbar using quick release hitches. The loop is attached at its center of gravity so that it moves only in a stable manner.

Figure 130 Front loop on suspended booms and gimbal mount. Area is 1.000 x 1.600m x number of turns x Pre-amp. With 10 turns and 10.25x preamp this is 164

GIMBAL MOUNT RECEIVER

This is an air cored induction sensor used with AgTEM-Wallaby in a gimbal mount on a boom in front of the motorized vehicle towing the AgTEM-Wallaby or on a boom extending from the AgTEM-Wallaroo or AgTEM-Barrow or in a sled or hand carried at a fixed distance from the transmitter in any variant. A sled consists of either a rigid polycarbonate sheet with a tapered and bent up front or a flexible HDPE sheet (often made locally).

Separation is dependent on Synchronization or signal cable lengths. 15m is typical and gets far enough away to diminish most transmitter loop effects below deeper ground effects.

This receiver is also used suspended directly beneath AgTEM-Wallaroo for highly focused shallow survey.

AgTEM-Wallaroo small or Wallaby gimbal mount – 400 x 800 mm approximate; A 1m x 1.6m version also exists (see photo) and a collapsible 1.6m x 1.0m version is normally distributed with AgTEM-Wallaroo.

A Gimbal mount includes a gimbal, a telescopic boom, pivot socket and rigging. A second boom and mounting frame can be added for faster setup and packup.

Other specifications as per core receiver.

TOWED FLEXIBLE MAT RECEIVER

Air cored induction sensor

A low weight easy-to-pull mat that rolls up and has loop wires in seams.

Equivalent area: approximately 2.4m^2 x 7 turn x pre amplification.

Dimensions: Towed mat approximately 1.2 x 2.4m (roll up) with tapered nose.

Use with low cost replaceable 2mm HDPE under mats.

Other specifications as per core receiver.

AGTEM-WALLAROO ½ X 1M POLE MOUNTED OR SLED TOWED RECEIVER COILS

A small sled towed receiver can be made using a standard Wallaroo receiver coil, and a disposable piece of thick (1.6 to 2mm) plastic such as polyethylene. The 'nose' of the sheet is bound into a point and the towing tether enters through a hole underneath. The rear and front corners of the coil are fixed to upturned parts of the sheet via small holes and cable ties. This small coil, however, only produces low quality data, especially when close to the ground, because its loop area is small. It is a compromise between practicality and need to see deeply.

Flexible sled coils have been made up to 2m x 6m in size in various designs and shortcomings are well known. Anyone wanting to try again can ask for advice but must first be warned that they are seeking a high maintenance solution.

Figure 131 AgTEM-Wallaroo small towed receiver coil on a disposable mat. Foam distributes load to increase the life of the disposable sheet when dragged over gravel. The sheet is 1.6mm thick polyethylene.

RECEIVER ELECTRONICS

24 bit – resolution depends on gain. Minimum single point resolution 23nV

Input range +/- 200V (optional maximum with attenuator) measurable otherwise +/- 10V, 200V input protection.

Sampling frequency 156.25 KHz (6.4 uS bin size) default. The AgTEM Sigma-Delta type analogue to digital converters maximum possible sample rate is 625KHz for a single channel (due to data streaming issues) with 24bits each sample or 312.5 KHz with 24 bits for 3 channels simultaneously. In AgTEM the sample rate is set (by default) to 156.25 KHz to improve noise rejection on late time data while retaining as much early time data as the system is optimized to provide. This provides a minimum bin size of 6.4uS which is suitably small given the coil damping, pre-amp low-pass filters and coil self-responses set up in AgTEM by default. AgTEM is set up to transmit large magnetic moments and receive signal returning from a great depth. A change to faster sampling would compromise this ability and logically also require changes in numerous parameters. For studies of root zone heterogeneity, UXOs or blast pattern optimization these changes can be requested (if not already supplied). Additionally, dual transmitter and receiver options may be requested for simultaneous shallow and deep investigation – our instrument cases and wiring facilities are pre-designed to fit such dual transmission options).

Each channel has a distinct signal path and ADC to minimize cross coupling. All data channels are simultaneously sampled.

Windows – 200 gates max but predefined gates make easy operation.

Full waveform is not supplied by default but may be negotiable on a case by case basis.

Functions measured: Full transmitter Tx current waveform, Tx turn-on and turn-off, loop input voltage, tx resistance, temperatures, transient response, noise with same period as sounding + many more.

Stacking 1 to 65536 stacks

Gain 1 to 100

The receiver has an internal housing, onto which connectors are attached, and an external housing, incorporating batteries, forced air circulation pathways, and cable strain relief.

Electronics housing: Extruded aluminum finned heat sinking case with silicon impact absorbing corners and IP67 rating, breathing vent and internal air circulation fan.

External housing including batteries: molded plastic backpack able case with battery fixtures, cable protectors, strain reliefs, cable exit hole & Rough handling protection. An extra filtered intake vent and fan circulates air around the internal housing then out the cable access hole. The external housing is designed to be shippable as is and to mount on a back pack for Wallaroo usage.

Operating temperature - -20 to 40+ degrees Celsius. External venting may be required over 30 degrees for extended period operation. Internal parts may safely reach 80 degrees Celsius.

TRANSMITTER

Output current up to 50 Amps

Loop power voltages of 5V to 15V.

Synchronization via cable. (GPS and Crystal synchronization options are available suitable for use with AgTEM transmitters that rove independently to AgTEM receivers for purposes such as providing data for 3D modelling over mineral targets. Contact your AgTEM distributor for further information).

Waveform – bipolar 50% duty cycle

On-off time 1.25 to 20mS

Turnoff:

- Wallaby 1 turn @ 40 Amps (12V) = around 16uS at 40Amps
- Wallaby 2 turn @ 30 Amps (12V) = around 22 at 30Amps
- Wallaby 1 turn @ 20 Amps (5V) = around 8uS.
- Clamping voltage = 200V – this can be used to determine turnoff for other loops and currents. A faster clamping voltage was not selected to decrease turnoff as there are many trade-offs if clamping voltage increases including greater system response. Instead of increasing clamping voltage, use of in-ramp channels is recommended for very shallow investigation.

Load matching and Efficiency optimization: Loop resistances are designed to exactly load the transmitter at close to 50Amps using either 5V, 6.4V or 12V sources delivered either direct from batteries (such as in Wallaroo @ 6.4V) or via DC-DC converters with around 70% to 80% efficiency and permitting 24V to 48V power transmission from the motorized vehicle to AgTEM Wallaby to reduce line loss. Wire diameters are selected to balance system weight with battery weight, particularly for the AgTEM-Wallaroo system which is hand carried.

A 19-26V input DCDC converter with 5V <57Amp output is incorporated into the transmitter internally and liquid cooled to avoid dust ingress. This is because even with Wallaroo mode it is thought with airfreight requirements common use will involve 12V 7Amp hour batteries connected in series as a power source.

Repetition rate 200Hz to 0.125 Hz or 5mS to 8 seconds at 50Hz power line frequency. Repetition rate is <240Hz for 60 Hz power line frequency.

Transmitter loop size (effective area):

- AgTEM-Wallaby – 32.5m^2 equivalent to 5.7 x 5.7m with 1, 2, 3, 4, or 5 turns
- AgTEM-Wallaroo – rounded corner loop 29m^2 with 1 or 2 turns.
- AgTEM-Triple-Wallaroo – 48m^2 with 1 to 4 turns
- AgTEM-Barrow – adjustable - yet to be determined – 16 to 70m^2
- AgTEM-Wallaby core upper and lower opposing loops – 1.754m^2

A dual transmitter option is negotiable.

Cooling: Water cooling (regulated) and closed cell to open cell air cooling via finned heatsink are options. Air cooled option with regulated fan speed is possible. Cooling parts and case are designed to minimize inductive coupling with the system so the transmitter can be placed directly on the transmitter loop. Air-cooling results in a compact (230 x 320 x 100mm) lightweight transmitter while the water cooling is appropriate if the dual transmitter option is implemented.

Liquid cooling specifications: Copper radiator and fan 120mm. Cooling ramps up from idle at 35 degrees C using 0.35A at 12V Fan 800 rpm pump 150 rpm to 1.72A at 12V Fan 160 rpm pump 420 rpm. Orientation acceptable during operation include all apart from upside down.

Housing: Internal housing seals the electronics from dust and moisture while external housing provides rough handling protection, cable strain relief, battery housing, DCDC converter housing, effective cooling, secondary rain protection and backpack mounting facilitation.

Fly lead and battery lead length: The transmitter is mounted close to the loops, so fly lead length is only about 1.5m. This minimizes inductive load on the transmitter while still separating the transmitter suitably from the loop to avoid inductive pickup of metal cooling components. Batteries are either mounted in the transmitter case or a DCDC converter is mounted in the case and higher voltage leads supply battery power from the motorized vehicle.

Internal resistance: Batteries and the transmitter combined add around 0.1 Ohms of resistance to the system so it is barely practical to transmit 50 Amps using 5V. For deepest penetration 12V should drive the transmitter.

DUAL TRANSMITTERS

A dual transmitter option is in development. It will be suitable for dual moment operation and for two component transmitter operation. Both an 8mm^2 two turn loop and a 4mm^2 one turn loop are in the standard loop cable surrounding AgTEM-Wallaby in preparation for the dual transmitters (both of which can be housed in the transmitter case). The in-core upper and lower transmitter loop pair also could be driven by the second transmitter. A further option is driving of 2 x 50 Amps through respective double turns of the standard loop cable surrounding AgTEM-Wallaby using a 24V source to give a moment of 6500Am^2 (NIA). Another option is tensor TEM using vertical loops to make full use of 3D TEM modelling of complex orebodies. Full size orthogonal vertical transmitter loops are readily added to AgTEM-Wallaby using more booms and rigging.

AGTEM-WALLABY

WEIGHT

AgTEM-Wallaby Weight: 230kg excluding electronics.

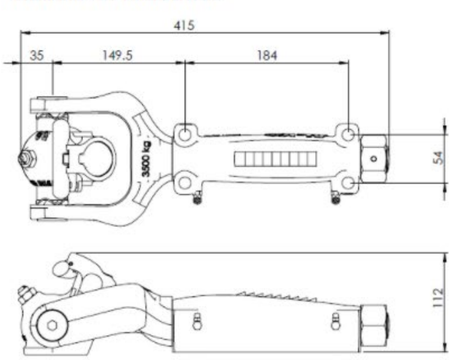
Each wheel bears 90kg (more when booms are extended backwards)

Towball download 50kg (less when booms are extended backwards)

CLEARANCES AND ARTICULATION

AgTEM-Wallaby is fitted with an 360 degree x 2 axis articulation hitch so it can be driven without problems through creeks, irrigation canals and over embankments. It is tested on both 50mm and 50.8mm (2”) tow balls. Should AgTEM-Wallaby only be towed with light all-terrain vehicles then a lighter hitch may be substituted. Specifications are:

50mm Ball - 3.5 T Fixed Electric



✔ EXTREME ARTICULATION

Extreme articulation (vertically and horizontally) suitable for extreme off road towing. Overcomes the articulation limitations of the traditional ball coupling.

✔ QUICK-HITCH AND LOCK

No difficult pin or hole alignment as is associated with most pin type off road couplings

✔ FITS TO A STANDARD 50MM TOW BALL

For ultimate convenience. Utilises standard tow vehicle setup.

✔ DURABLE DESIGN

Tough zinc plated metal components. Built for serious off-road use.

AgTEM-Wallaby has a ground clearance of 500mm. Its ramp-over angle between the towing vehicle and the cart is 22 degrees and rear ramp angle is 22 degrees. Similarly, side clearance ramps up from the wheels at 40 degrees at boom tips and is sufficient for clearing most gate posts without side boom folding.

SPECIFICATIONS

WEIGHT

AgTEM-Wallaby Weight: 230kg excluding electronics.

Each wheel bears 90kg (more when booms are extended backwards)

Towball download 50kg (less when booms are extended backwards)

LOOP AREAS

A comparison of loop areas is given in the table below:

The **main receiver loop** in the Wallaby center plain has a single turn loop area of **2.0648**m^2. Either 10 turns or 20 turns can be switched in so the area is either **20.648** m^2 or **41.296** m^2. With the standard gain pre-amp, nominally 10x but typically 10.25 these areas become **211.74** m^2 or **423.47** m^2.

Small 500mm x 1000mm coils sometimes used with AgTEM-Wallaroo, have single turn loop area of **0.409** m^2 or for 10 turns **4.09** m^2 or for 20 turns **8.180** m^2. With 10.25x preamps these come to 41.92 and 83.84. Due to a shipping box design change forced upon us, newer versions will be shorter so they fit the new shipping boxes and loop areas will need to change.

The Larger stand-alone coil typically used as the front loop on a pair of suspended booms in front of vehicles are slightly shorter (1.6m) than the 1.754m dimension of the upper and lower planes of the Wallaby core so their single turn loop area is 1.6m^2. With 10 turns this is 16m^2 and for 20 turns it is 32m^2. With 10.25x amplification effective loop areas are 164m^2 and 328m^2 respectively.

The 1.6m wide by 2.58m long (tapered) floppy mat receiver loop often towed behind AgTEM-Wallaroo has an area of 3.584m^2 and typically has 7 turns giving a pre-amplified area of 25.088m^2 .

Rx Loop	Area	Low Turns	High Turns	Low Area	High Area	LowArea x 10.25	HighArea x 10.25
Wallaby Mid-plane	2.0648	10	20	20.684	41.296	211.74	423.47
Wallaby Front Loop	1.600	10	20	16.000	32.000	164.00	328.00
Wallaroo Floppy Mat 7 turn	3.584	7	n.a.	25.088	n.a.	257.152	n.a.

Wallaroo Floppy Mat 20 turn	3.584	10	20	35.840	71.680	367.36	734.72
Wallaroo 480x1000	0.409	10	20	4.090	8.180	41.922	83.845
Wallaroo 480x950	0.387	10	20	3.870	7.740	39.667	79.335

The main **6m transmitter loop** area is:

32.527 m^2 **1 turn**

65.054 m^2 **2 turn**

97.581 m^2 **3 turn**

130.108 m^2 **4 turn**

162.635 m^2 **5 turn**

The upper and lower small transmitter loops in the core have only 1 turn each and **1.754** m^2 area each. With standard connection they will be connected with opposing polarity in series to reject deeper signal but keep shallow signal.

Large X and Y component Tx loops can be added using extra booms should they be useful if the cart is used as a transmitter within a network of static receivers for 3D modelled survey.

QUICK DEPLOYMENT FLOAT TRAILER

Figure 132 AgTEM quick deployment float trailer

The quick deployment float trailer for AgTEM Wallaby permits AgTEM-Wallaby to be simply winched on and off with minimal additional packing effort. It supports part of the cart above the towing vehicle to improve parking options when in transit.

Figure 133 AgTEM-Wallaby secured on the float trailer, with tailgate reattached behind. Rigging is packed in the bag and rear booms slide, with rigging still attached, down a long cylinder hidden by the bag. AgTEM slides up onto the trailer along skids.

SHIPPING ENCLOSURE

AgTEM Wallaby is designed for shipping in an aluminum enclosure of clam-shell design. Design to fit between wheel arches in pickup trucks, on standard Australian and USA double pallets for truck and ship freight and within unit load device dimensions on aircraft. It has space beneath for most forklift prongs.

Shipping details are as follows.

Three shipments typically are been prepared, each to be with its own consignment note:

1. AgTEM-Wallaby structure in a fork-liftable aluminum box,
2. Transmitter and Receiver in a plastic case, &

3. Batteries and Chargers in a cardboard box.

For ease of identification here are pictures of the three shipments.

Figure 134 AgTEM-Wallaby shipping box

Figure 135 AgTEM transmitter and receiver shipment

Figure 136 AgTEM battery and charger shipment - note the chargers fold up into the lid and the batteries are in the base of the case. The plastic case is placed in the cardboard box behind for shipping.

Contents of each box and value are listed below

BOX 1 – AGTEM-WALLABY

The AgTEM-Wallaby aluminium shipping box has dimensions:

Length: 223cm Width: 117cm Height: 149cm The box is 'contoured' top and bottom by 48cm to fit airfreight space better. Weight is 452kg.

AgTEM Wallaby contains the following:

Shipment	Item	Quantity
Box1	AgTEM-Wallaby	1
Box1	Tool case, Tools & Spares	1
Box1	Front Loop Booms Assembly	1
Box1	Front Loop	1
Box1	Instruction Manual - actually sent via internet	1
Box1	Overheads (Product liability insurance, Workers Compensation Insurance etc.)	1

BOX 2 – AGTEM TRANSMITTER AND RECEIVER

This plastic shipping case has dimensions:

Length: 121cm Width: 57cm Height: 39cm (add 14cm if adding a pallet beneath).

Weight is 48.8kg (add 3.1kg if adding a pallet beneath).

The AgTEM Transmitter and Receiver box contains:

Shipment	Item	Quantity
Box2	TxRxShippingBox	1
Box2	300x300mmTestLoops	1
Box2	Transmitter	1

Box2	Receiver Assembly	1
Box2	Receiver Core	1
Box2	Panasonic Toughpad integrated into installation (batteries removed)	1
Box2	Trimble AgTEM interface	1
Box2	iKey dock and dashmount kit	1

BOX 3 – BATTERIES AND CHARGERS

Box 3 contains batteries and as such is classified as dangerous goods so it is shipped separately. It is a plastic case encased in a fibreboard box. Batteries inside are of Lithium Ion type and weigh <10kg. They are all of <100WHrs each and are all isolated with connectors protected to prevent short circuit. The intended shipping method is UN3480 PI 965 IB and a shippers declaration is provided. I do not have 'Lithium Battery Test Summary' for some of the batteries but supply a Safety Data Sheet in substitution. The chargers are separated from the batteries by packaging to comply with packing instructions.

Dimensions are: Length: 52cm Width: 23cm Height: 44cm

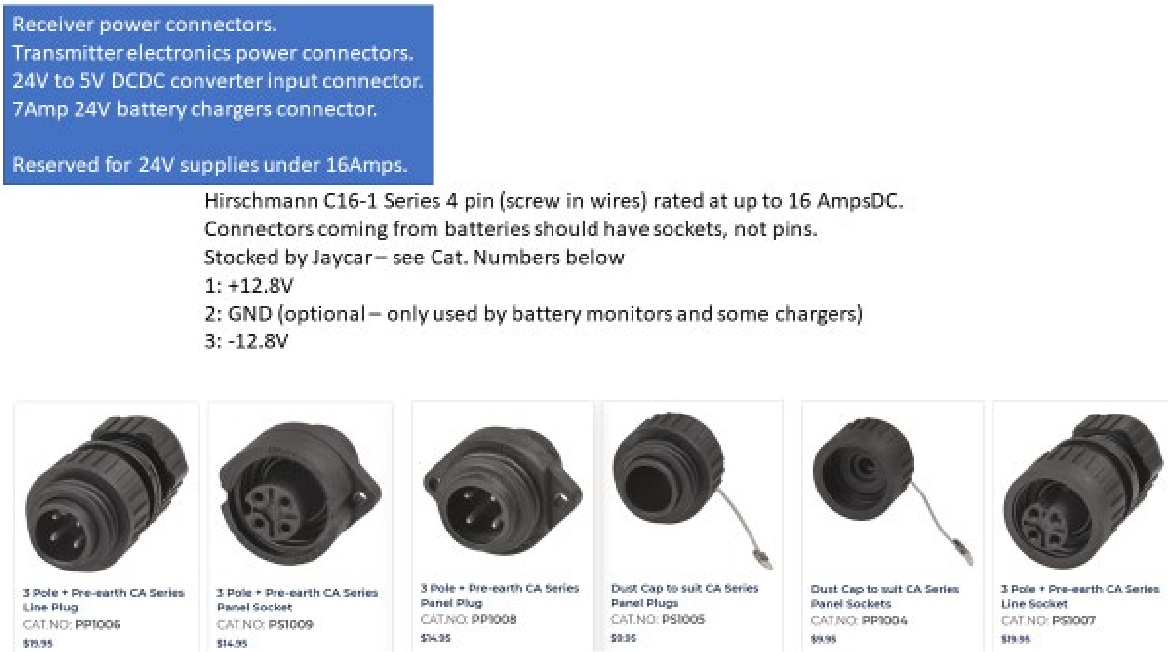
Weight is 17.8kg.

The Batteries and Chargers box contains:

Shipment	Item	Quantity
Box3	Set of six 7AHr 12.8V LiFePO4 chargers	1
Box3	7AHr battery accessories	8
Box3	Panasonic toughpad batteries (free here as overhead added to Toughpad in box2)	2
Box3	7AHr 12.8V batteries	8

WIRING DIAGRAMS AND FILE DESCRIPTORS

24V POWER CABLES – ALL DEVICES UNDER 16AMPS



12V POWER TO TRIMBLE GFX 350

Power is supplied from the Receiver External Enclosure for the Trimble GFX350, and, in-turn, the Trimble NAV500 antenna. The 24V battery power goes through a small DCDC converter to become 12V. It then is made available from an Amphenol LTW 2pin connector. Jaycar Part Number PP0542.

The mating cable is terminated with Jaycar part number PS0541 (Amphenol 0W1171).

Looking at the front of the in-line socket picture above the negative is clockwise (right) from the keyway and positive is anticlockwise (left) from the keyway.

At the GFX350 it passes into a Deutsch DT 6 socket connector (Jaycar part PP2148). Trimble do not make pin outs easy to find, allowing only dealers to get access. Deutsch connectors are stocked by most agricultural electrics agents. This one is from the waterproof range. Wires are ideally crimped – soldering tends to lead to flexure failures. Negative is pin 1 and positive is pin 2. Looking at the face (where the orange seal goes) pin 1 is clockwise from the spring-clip and pin 2 is next to it clockwise. Pin 1 is negative (gnd) and pin 2 is positive (+12V).

TRIMBLE GFX350 TO NAV500

This is a standard cable that comes with the Trimble equipment, terminated in M12 connectors. Procure from Trimble agents. It supplies power to the NAV500 antenna and communication to the display. It also supplies authorization signal to the antenna so do not expect to be able to use the antenna without it.

TRIMBLE NAV500 (OR NAV900) DATA OUTPUT CABLE

Serial data is available from the GFX350 with authorization from Trimble which we have not be able to obtain. Rather they supply us with NMEA0183 data direct from the NAV500 antenna. To access this data we plug a 12 socket Deutsch connector into the antenna and pass the signal to our acquisition computer via an RS232 convertor fixed to an USB hub on the rear. Only 2 wires are connected as communication is one way only.

ETHERNET CONNECTOR – RECEIVER TO COMPUTER

Jaycar Ethernet IP68 bayonet connector to standard RJ45 connector unprotected at computer. A standard Ethernet cable can substitute here but without the IP68 rating – this is useful when troubleshooting.

Ethernet to computer from Receiver

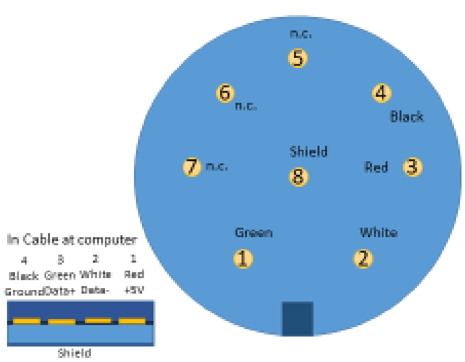
Jaycar

USB – COMPUTER TO RECEIVER

Some information may be sent via USB cable from the receiver to the computer – at least in early versions of AgTEM-electronics. The connection diagram for this facility is given below.

USB for computer connection Binder 8 pin

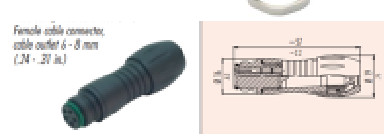
View outside (facing) receiver



Binder Pin	USB cable color	Purpose
1	Green	Signal + USB1
2	White	Signal – USB1
3	Red	+5V
4	Black	Ground
5		
6		
7		
8	Shield	Shield

BINDER - 99-9127-00-08 - PLUG, PANEL, 8WAY

Mates with In-line plug Binder 99-9126-00-08 or for thicker 6-8mm cable 99-9126-02-08



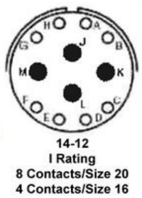
SYNCHRONIZATION CABLES

The standard synchronization cables have plugs with pin inserts at each end. Extension synchronization cables have pins at one end - such as one on AgTEM-Wallaby which has pins at the tow ball for facilitating quick disconnect of the towing vehicle wiring loom when disconnecting the Wallaby.

The Synchronization cables are terminated with Connectors MS3116F14-12P and fit into receptacles on the receiver and transmitter MS3112E14-12S. Amphenol brand details are given below but other brands are available at much greater cost, and risk of slight dimensional misalignment:

Element14: 1482278 MS3116F14-12P CONNECTOR, CIRCULAR, SIZE 14, 12WAY $173.79
Element14: 1476372 MS3112E14-12S CONNECTOR, CIRCULAR, SIZE 14, 12WAY $118.20

Synchronization Connector



Element 14:
2707197
Receptacle

MS3116F14-12P	Color
A	Brown/White
B	Brown
C	Blue/White
D	Blue
E	Green/White
F	Green
G	Orange/White
H	Orange
J	Not connected
K	Not connected
L	Not connected
M	Shield
Keeping twisted pairs together is important but otherwise if colors are the same both ends then pairs can be swapped.	

Element 14:
1601322
Plug

Element 14:
2112301
C10-101949-012
+ four 6mm long M3 Screws
threaded into enclosure

Panel Mount: AMPHENOL INDUSTRIAL - MS3112E-14-12S - CIRCULAR CONN, RCPT, SIZE 14, 12POS, BOX

Mates With: AMPHENOL INDUSTRIAL - MS3116F14-12P - CIRCULAR CONNECTOR PLUG SIZE 14, 12 POSITION, CABLE

The Standard Synchronization cable has the same gender at each end.
An Extension Synchronization cable such as from the tow hitch to transmitter on AgTEM Cart has opposite gender (pin/socket & plug/receptacle)on one end.

Synchronization cable is typically harsh environment DataTuff® Belden Cat5e high flex Ethernet cable.

It is terminated as follows:

MS3116F14-12P	Color	Purpose
A	Brown/White	RS232 Comms rmt power supply
B	Brown	RS232 Comms rmt power supply
C	Blue/White	Bipolar waveform drives remote Tx
D	Blue	Bipolar waveform drives remote Tx
E	Green/White	RS232 Comms rmt timer controller

F	Green	RS232 Comms rmt timer controller
G	Orange/White	Tx Current signal return to Rx
H	Orange	Tx current signal return to Rx
J	Not connected	
K	Not connected	
L	Not connected	
M	Shield	RS232 Comms etc. Ground
Keeping pairs together is important but otherwise if colors are the same both ends then pairs can be swapped.		RS232 comms is for remote power supply and remote timer controller.

6M^2 RECEIVER LOOP 16 CORE CONNECTORS TO PRE-AMP BOX

PIN	Wire Colour
A	Black
B	Red
C	Blue
D	Faint Pink
E	Grey
F	Yellow
G	Green
H	Brown
J	White
K	Grey Pink
L	Mauve
M	Green White
N	Blue Red
P	Yellow Brown
R	Yellow White
S	Green Brown
T	-seal
U	-seal
V	-seal

Souriau 19 pin TrimTrio

Souriau Circular Connector, 19 Contacts, Cable Mount, Socket, Male, IP68, IP69K, UTS Series

RS Stock No.: 190-807

Mfr. Part No.: UTS6JC1419P

RECEIVER LOOP CABLES

Receiver cables also are typically made of harsh environment DataTuff® Belden Cat5e high flex Ethernet cable. Three pairs of signal wires can lead to up to 3 receiver loops (eg. One three component sensor). Pre-Amp power wires pass through a fourth pair of wires and the shield acts as ground return.

Connectors on this cable are pins at the receiver electronics end and pins at the loop end (but on rare older front loop connectors were sockets on the loop end – this was changed for conformity with Monex conventions).

Termination at the receiver electronics end of the cable was with Mil-Spec style Amphenol-Industrial Kit PT06E-12-10P(SR) (as a kit – but see updated list below – preferred for precision conformity with Monex parts).

An in-line termination at the receiver electronics end or within an extension cord is

Connector	Amphenol	62GB-56T12-10PN
Connector clamp	Amphenol	62GB-585-12-10P
Rubber bushing for connector	Amphenol	9779-513-6

These are an update from Monex June 2022 and are preferred over similar parts listed below.

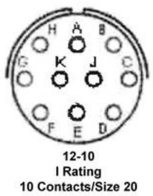
The old discontinued socket variant was Element14 part 3280549 PT01A-12-10S $83.28 CIRCULAR CONNECTOR RCPT SIZE 12, 10POS, CABLE. The socket variant was only used with the front loop as other devices were directly wired. Recommended backward compatibility with old front loop box connectors is to use an adaptor. This will allow conformity with Monex receiver loops going forward. Exposed power pins on the end of this cable are not considered problematic due to being current limited to a small current.

Termination is as follows:

Pin	Wire Color	Description
A	Brown/White	Rx1 (+ve)
B	Brown	Rx1 (-ve)
C	Blue/White	Rx2 (+ve)
D	Blue	Rx2 (-ve)
E	Green/White	Rx3 (+ve)
F	Green	Rx3 (-ve)
G	Orange/White	+15V Pwr OUT @ 200mA
H	Orange	-15V Pwr OUT @ 200mA
J – join to K	MonexShield	- Original cables had this not connected but for conformity with Monex cables this should be the shield – connecting to K will make both conventions work.
K – join to J	Shield	Power and signal ground and shield

		Signal wire pairs are rotated 2,3,1 and 3,1,2 should connection to receiver sockets 2 and 3 be made respectively.

Receiver Loops



Element 14: 2707840
Amphenol:PT02E-12-10S(025)

Element 14: 2015547
Amphenol:PT06E-12-10P(SR)

Monex prefer for precision conformity, this supplied as parts:
Connector Amphenol62GB -56T12-10PN
Connector clamp Amphenol62GB -585-12-10P
Rubber bushing for connector Amphenol9779 -513-6

Post 2022 cables have pins in plugs at both ends –power pins are exposed live but are current limited such that this is not a problem. This convention conforms with Monex receiver loops and as of 2023 with new Groundwater Imaging receiver loops. It does however mean that to join extension cables a receptacle -receptacle type joiner box will be required.

Old Cables have pins at the receiver end and sockets at the pre - amplifier & loop end. If conforming with old cables use panel mount with a back shell for loop end if inline connector is not easy to source.

To connect up to 3 coils optionally with preamps via Shielded Ethernet cable		Description
A	Brown/White	Rx1 (+ve)
B	Brown	Rx1 (-ve)
C	Blue/White	Rx2 (+ve)
D	Blue	Rx2 (-ve)
E	Green/White	Rx3 (+ve)
F	Green	Rx3 (-ve)
G	Orange/White	+15V Pwr OUT @ 200mA
H	Orange	-15V Pwr OUT @ 200mA
J – join to K	Shield	Power ground and shield
K – join to J	Shield	Signal ground and shield
		Signal wire pairs are rotated 2,3,1 and 3,1,2 should connection to receiver sockets 2 and 3 be made respectively.

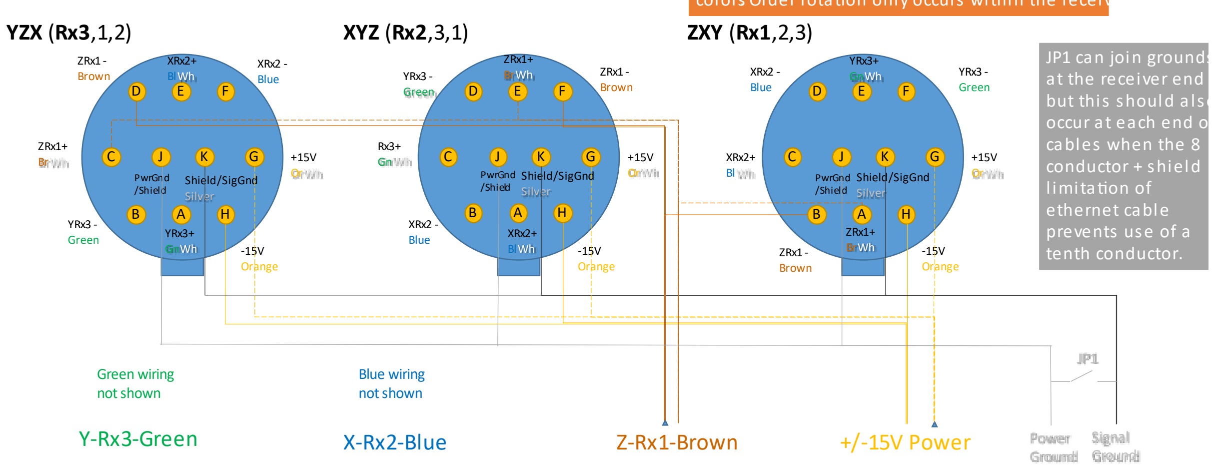
To connect a single loop directly (do not forget the damping resistor) via shielded microphone cable use the following table. A 4 core shielded microphone cable can similarly be used for a pre -amplified single loop by adding wires to pins G and H

Pin	Wire color	Description
A	Red	Rx1 (+ve)
B	Black	Rx1(-ve)
K & J joined	Shield	Shield and Ground

Receiver connectors– view from within the receiver

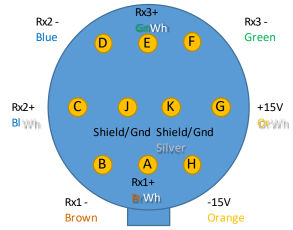
Signal wire pairs are rotated 2,3,1 and 3,1,2 should connection to receiver sockets 2 and 3 be made respectively.

External cables always have the same ZXY order and colors Order rotation only occurs within the recei



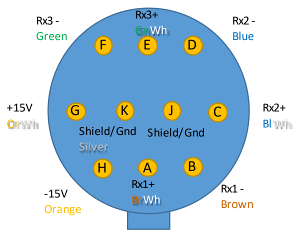
Receiver loops x 3

Inside ZXY Rx1 View



Panel Mount: AMPHENOL INDUSTRIAL - PT02E-12-10S(025) - CIRCULAR CONN, RCPT, 12-10, BOX MOUNT

Outside ZXY Rx1 View

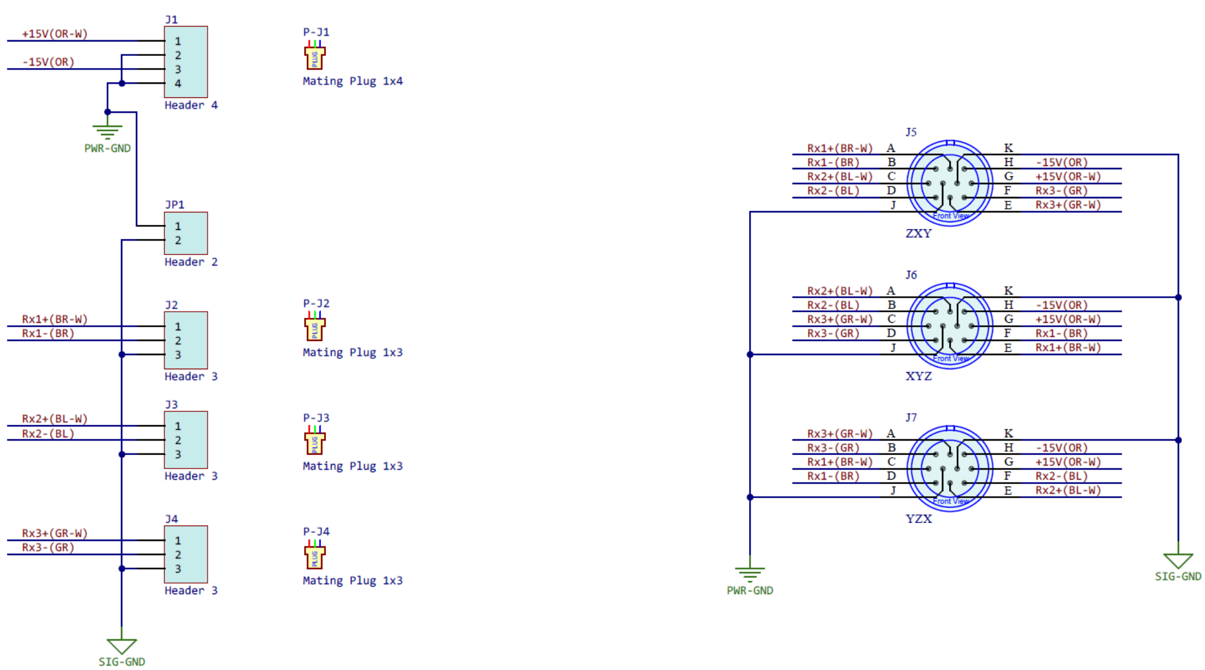


Mates with connector kit: AMPHENOL INDUSTRIAL - PT06E-12-10P(SR) - CIRCULAR CONNECTOR PLUG SIZE 12, 10 POSITION, CABLE

Monex prefer for precision conformity, this supplied as parts:

Connector	Amphenol	62GB-56T12-10PN
Connector clamp	Amphenol	62GB-585-12-10P
Rubber bushing for connector	Amphenol	9779-513-6

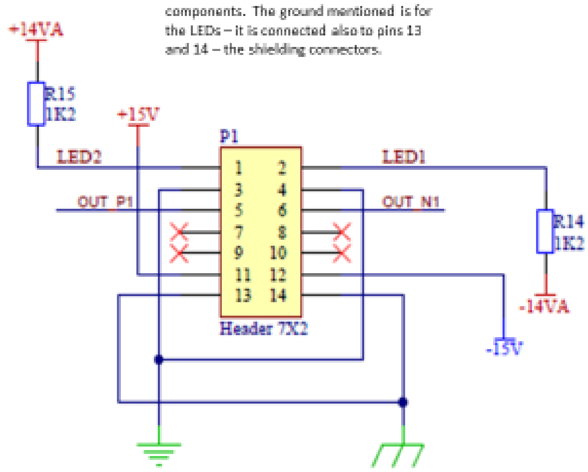
The receiver connectors on the electronics enclosure are connected to an MG214-V10 circuit board wired as per below:



RECEIVER CABLE TERMINATION HEADER TO PRE-AMP

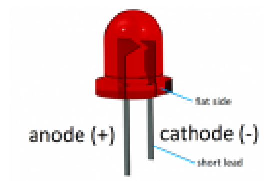
Pre-Amp wiring

Looking down onto the circuit board MG09 – some references are to on board components. The ground mentioned is for the LEDs – it is connected also to pins 13 and 14 – the shielding connectors.



MG09 P1	Description	Wire color
1	LED2 Anode (A)	
2	LED1 Cathode (K)	
3	LED2 (K)	
4	LED1 (A)	
5	Signal Pos	Brown/White
6	Signal Neg	Brown
11	Pwr Input +15V	Orange/White
12	Pwr Input -15V	Orange
13/14	Shield Pwr GND	Shield

Note that LED1 and LED2 are wired in opposite polarity with reference to ground

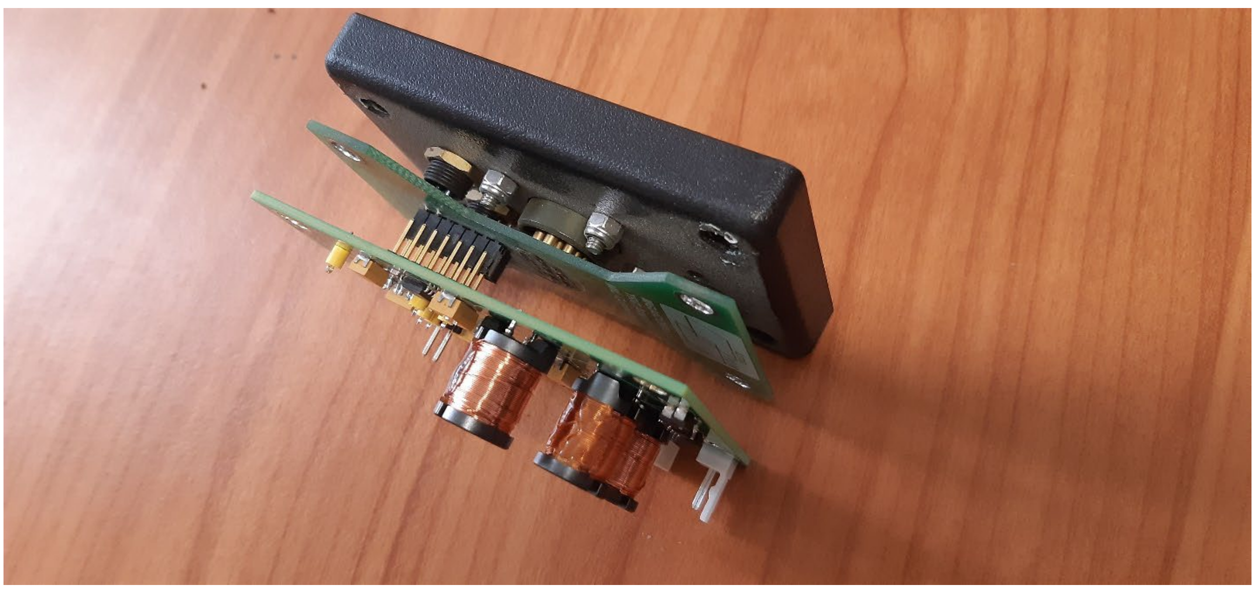


The connector on the outside of the box is:

PT02E12-10P. CIRCULAR CONN, PLUG, SIZE 12, 10POS, BOX Element-14 part 2016140

The connector at the end of the cable attaching is:

PT06E12-10S(SR) CIRCULAR CONNECTOR PLUG SIZE 12, 10 POSI Element-14 1434603



Connector parts for the preamp are:

The assembly will include the 14 pin header fitted to the MG09 (the pre-amp), which connects to the 14 pin connector socket on the MG04CONN (the PCB closer to the black plastic face plate). You can see these two parts connected together in the photo.

MG09 14 pin header: manufacturer p/n PH2-14-UA.

MG04CONN 14 pin connector socket: mfg p/n 803-87-014-10-001101

The two pin connector fitted to the MG09v11 version has been replaced by a three pin connector. MFG p/n 0436500327 (listed on RS Components and e14 as MFG p/n 43650-0327). This would mate with MFG p/n 0436450300.

For the LEDs, we fit LED MFG P/N QBL8IG60D to the MG04CONN board. There will be a LED housing fitted to the black plastic face plate.

The header to the pre-amp MG209V11 has 2 LEDs attached along with the receiver cable. It is possible to attach it to the pre-amp under normal operation but for diagnostics it can bypass the preamp and attach to pins provided on the rx loop turns connection board. This totally eliminates the pre-amp from the circuit so that confidence that the pre-amp is not causing unusual data can be gained.

Use the shield as the Power common so that the shield is connected at both ends.
As we did not have spare conductors we did not make an isolated power supply in the TRC instead utilizing filtering and common mode isolation in the power ground which is connected via an inductor to signal ground. The signals being driven differential up a twisted pair do not require a separate ground.
If you use a signal ground you will remove this and potentially make it noisier.
Pos 15V to P11
Neg 15V to P12
Shield to P13/P14

Sig +ve P5
Sig -ve P6

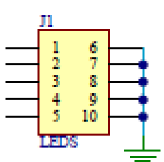
LED2 Anode P1
LED2 Cathode P3

LED1 Cathode P2
LED1 Anode P4

The schematic shows how P1 is wired on MG09 not what is to be connected to them.

REMOTE TX LED CONNECTIONS

All LEDs are replicated on the PCBs. See below for the connector numbers descriptions.



RemoteTx MG207 LEDs
The Tx LEDs will only flash when current exceeds approx 1Amp

MG207 J3	Description

1	Tx+ LED (K)
7	Tx+ LED (A)
2	Tx- LED (K)
8	Tx- LED (A)
3	Tx Error (K)
9	Tx Error (A)

Remote TX LED wiring colour conventions are:

Grey/Orange = TxError
Grey/Red = Tx+ (> 1 Amp)
Grey/Blue = Tx- (> 1 Amp)

Yellow/Blue = Ring around On/Off button - Software driven power on, tried to get it to flash in standby mode

Green/Red = From Pre-Driver board - Tx+ (Synch pulse from Rx)
Green/Blue = From Pre-Driver board - Tx- (Synch pulse from Rx)

REMOTE RX LED CONNECTIONS

RemoteTx MG205 LEDs

MG205 J1	Description
1	Tx+ SIG (A)
6	Tx+ SIG (K)
2	Tx- SIG (A)
7	Tx- SIG (K)

Receiver MG205 LEDs

MG205 J1	Description
1	Tx+ SIG (A)
6	Tx+ SIG (K)
2	Tx- SIG (A)
7	Tx- SIG (K)
3	RxTrig (A)
8	RxTrig (K)
4	iGPS 1PPS (A)
9	iGPS 1PPS (K)

Connectors for these LEDs are Molex Micro-Fit 3.0

Receptacle housing 43025-xx00 where xx is number of pins. Eg. 2x5row is 43025-1000 (Digikey:WM1787-ND); Crimps 043030-0007; crimp tool 638190000

PRE-AMP DAMPING AND AMPLIFICATION

Loop signal into the pre-amplifiers is damped and filtered at the board inputs.

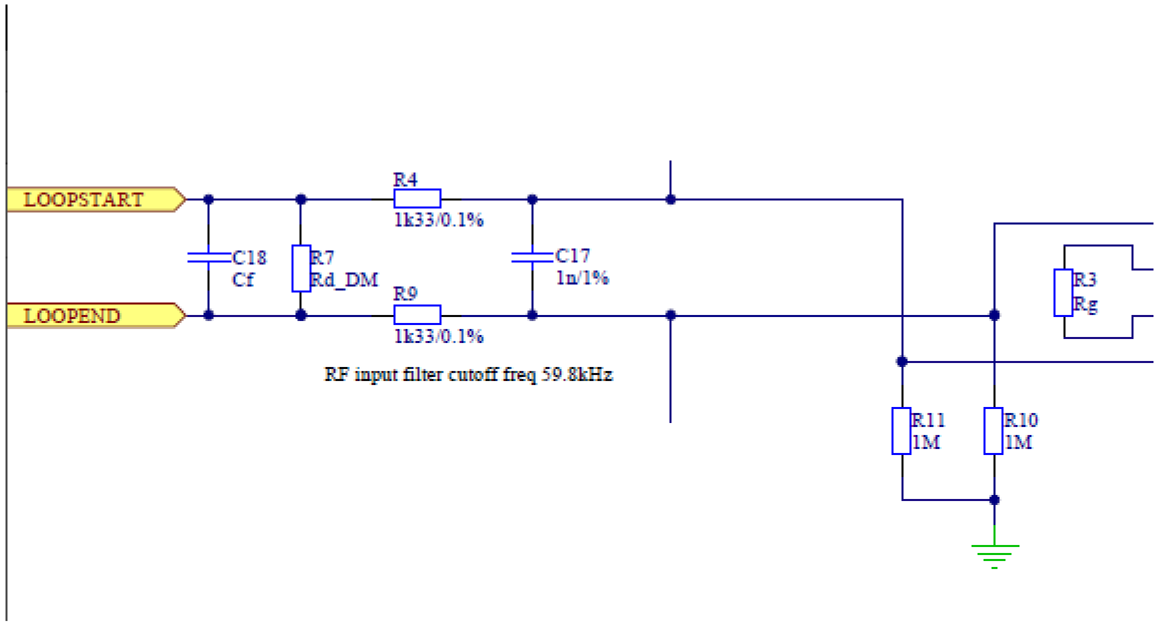


Figure 137 The passive front end of the MG09 Pre-amp set up for 59.8 kHz damping

The low pass damping filter frequency $F = \frac{1}{2\pi \times Resistance \times Capacitance}$.

The relevant components (R4 + R9) and C17 are marked on the circuit board – for experimentation, it is better to replicate externally. C18 is a legacy component no longer filled.

R3 is the amplification resistor with a value of 12KOhms shown in the photo below giving a calculated amplification (see below) of 5.11 times. Since preamp amplifies via a differential line driver the multiplication factor seen at the receiver will be 2 x 5.11 = 10.22. The amplification measured is 10.25x.

For resistor R3, Also called Rg , Gain = 1 + (49.4kΩ/Rg). Some examples if you leave it blank then it will be unity gain; 499Ω = 100; 5.49kΩ = 9.998

R7 is the loop oscillations damping resistor and the default (for lower frequency work) displays 4871 (4.87KOhms). Again this is often assisted or replaced by damping resistors external to this board.

RECEIVER LOOP CONNECTION

The receiver loops are made of ribbon cable. There is no electrostatic shield as such shields have been found to be of little benefit in this application. Ribbon cable is spiral-wrapped around foam core padding in order to keep vibrations damped while maintaining dimensional accuracy needed for null mutual induction with the transmitter loop.

The ribbon cables are attached to a simple circuit board which at present is still hand-cut. In order to make it useful for use with or without the pre-amp, an extra connector, equivalent to the pre-amp output connector is attached – this is very useful when troubleshooting as the preamp can be bypassed.

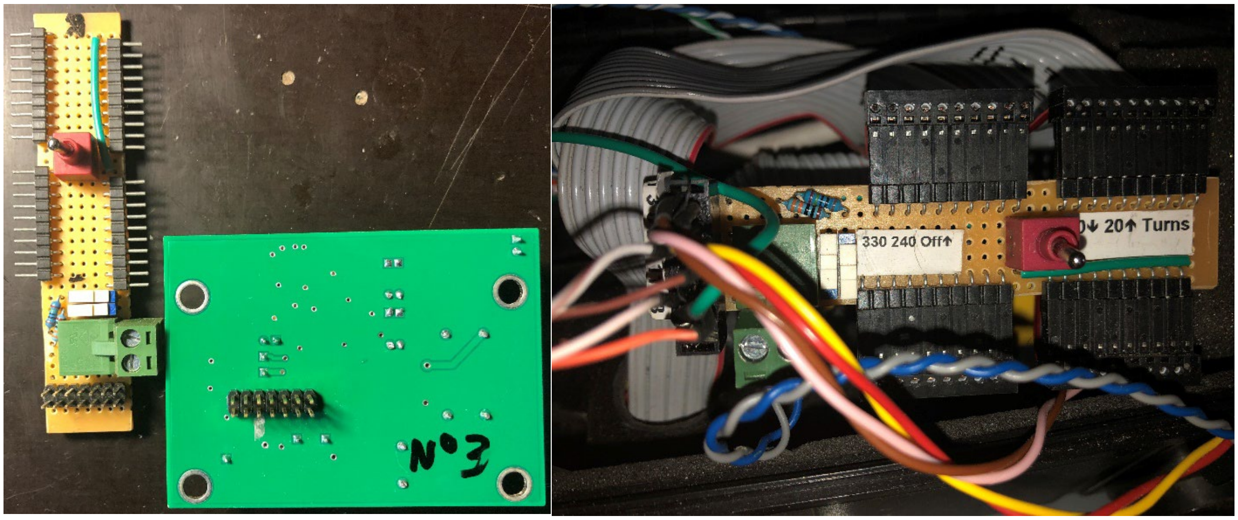


Figure 138 Left - Equivalent output connectors on both the loop connection board and the pre-amp. Standard connection with the preamp uses the green screw terminal connector instead. Right - a wired loop connection board. Note that as of 2025 the loop connector boards are largely replaced with newer bolt-on stackable boards that keep the ribbon away from inductive coupling with inductors on the pre-amp which previously caused a large source of system response oscillation and variation as ribbon cables bounced and moved in the box near the inductors – a very bad fault. If using the old style boards, then ensure this cannot happen!

The loop connection board has capacity for two ribbon cables (20 turns) and attention is required to ensure the correct turns are connected in the correct orientation. A switch allows choice of either 10 turns or 20 turns but for most situations it seems that 20 turns creates system response of too high a time constant.

Two damping resistors can be switched in but the pre-amp board also has such damping. Values are 330 and 240 ohms. If both are switched in then damping of 140 ohms is achieved and if both are removed then a horrible resonating response will be observed. Polarity can be changed with the screw terminals.

Twenty turns has generally been found to be excessive so in future it is likely that the switch will facilitate either 5 or 10 turns. A more refined version of this board is planned and installation will be a simple swap of boards.

The output connector on the pre-amp board has some LED outputs which are fixed to the case to indicate whether both the +15V and -15V power supplies are still operational.

ALTERNATIVE PREAMP

Temporary documentation during trial – this section is likely to be removed after trial. (January 2025 update - trial was dropped as limitation of this pre-amplifier were realized and supply of our normal amplifiers was replenished).

In February 2022 an alternative Chinese preamplifier was in testing. It is documented as follows (pre trial – yet to report the result). It is tested to see what magnitude of improvement there is in Monex preamps compared to off the shelf amplifiers.

Description

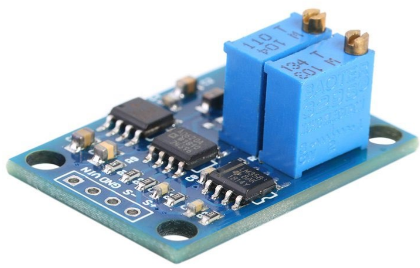
3-12V DC High Precision AD620 Microvolt mV Voltage Amplifier Module Small Signal Instrumentation Amplifier Board
Description:
Using AD620 as the main amplifier, can amplify uV, mV voltage. Magnification 1.5-10000 magnification, adjustable. High precision, low offset, better linearity. Adjustable zero to improve accuracy. Can be used for AC, DC signal amplification. A certain electronic basis is required for this module use.

Feature:
1. Wide supply voltage range: the AD620 amplification of this product can be amplified microvolts, millivolt, compared to LM358 amplification accuracy, better linearity, the maximum voltage output range of ± 10V.
2. Magnification range: magnification up to 1000 ti2mes, only through a potentiometer can be adjusted.
3. Adjustable zero through the zero potentiometer to adjust the zero, improve accuracy, there will be no zero drift phenomenon to meet customer needs.
4. A negative voltage output: the module uses 7660A chip output negative voltage (-Vin), can be provided to the customer to drive other dual power load.
5. Mini type: evenly distributed around the four 3mm positioning holes, both sides of the port 2.54mm standard pitch pinhole.

Specification:
Input voltage: 3-12V DC
magnification: 1.5-1000 times adjustable, zero adjustable
Signal input voltage: 100uV-300mV
Signal output range: ± (Vin-2V)
Negative voltage output: higher than -Vin. As the negative voltage chip output resistance problem, the actual output is higher than -Vin, the greater the load power, the greater the negative voltage drop
Offset voltage: 50μV
Input bias current: 1.0nA (max).
Common mode rejection ratio: 100 dB
Offset voltage drift: 0.6uV / ℃ (maximum)
Stability: 2uV / month maximum
Product size: 30*21*11/1.18*0.83*0.43"

Note:
1. There may be slight size deviations due to manual measurement, different measuring methods and tools.
2. The picture may not reflect the actual color of the item because of different photographing light, angle and display monitor.

1 X Small Signal Instrumentation Amplifier Module



https://www.cesdeals.com/products/ad620-uv-mv-voltage-amplifier-small-signal-instrumentation-amplifier-board?spm=..order.order_detail_1.1

AGTEM RECEIVER BOARD LAYOUT

Inside the AgTEM receiver case there is one small board and two stacks of full size boards as shown in the photo. From left to right:

- Quad Serial to USB board powered from the computer via the USB link. Adjacent is a fan extracting from below the base plate and bowing through the board stacks. Another fan between this board and the next stack extracts from all directions and blows through the board stacks.
- Stack 1:
  - On top, power supply for all pre-amps. Blue wire -15V; Black wire GND; Red Wire +15V
  - Beneath – MG209 - top of two boards that make up the inputs to the receiver and A/D converters (MG205 & MG206 ?). The connector at the picture bottom has Y, X, and Z component inputs within it in that order.
  - Beneath – MG206 – bottom of two boards as above
  - Beneath – receiver processor board
- Stack 2:
  - Power Supply board with piggyback control board.
  - Beneath is the Ethernet router board.

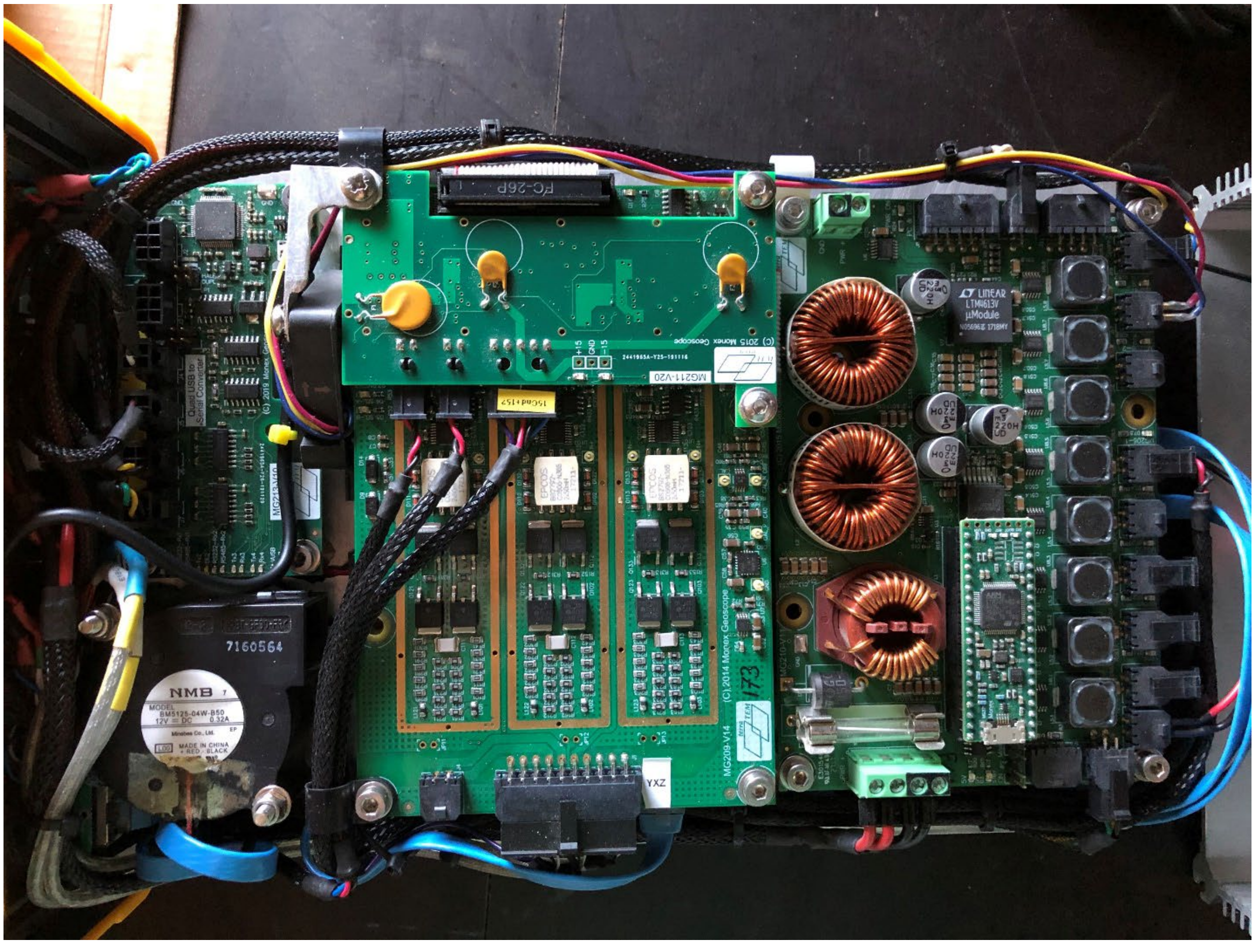


Figure 139 The receiver internal layout. All is slid out of the extruded case while attached to the connector end panel after removing the four yellow plugs and concealed corner screws in the corners.

TRANSMITTER BOARD LAYOUT AND WATER COOLING

Mosfets in the transmitter connect directly to a water block – specifications are at
http://ixapps.ixys.com/DataSheet/DS100135(IXFK-FX140N25T).pdf

Transmitter loop power input and output are either Red/Black or Blue/Yellow. Red or yellow being + and Black or Blue being – by convention. Red/black wire WH3062 and WH3060 8AWG from Jaycar is suitable.

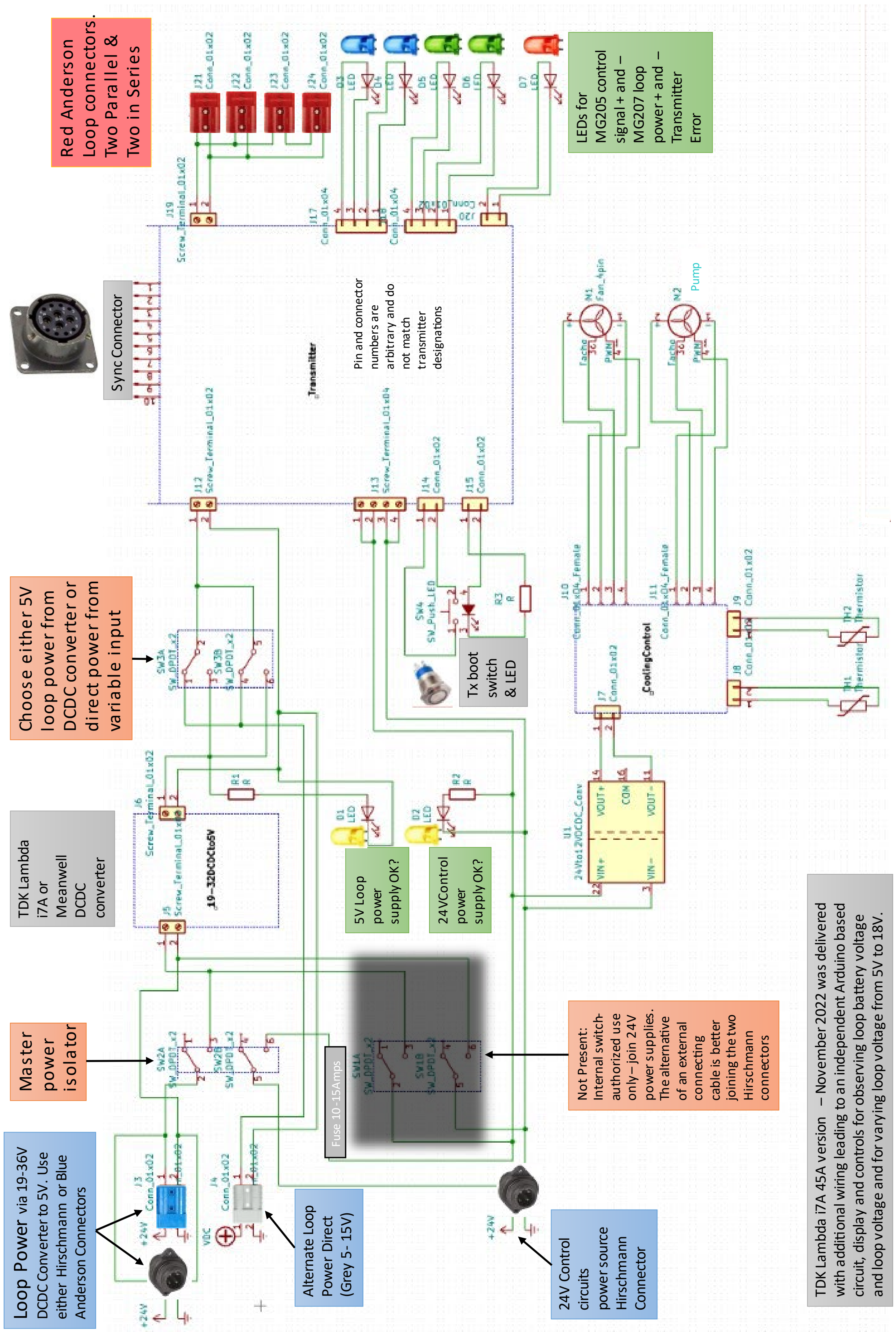


Figure 140 Transmitter case wiring (June 2021 prototype)

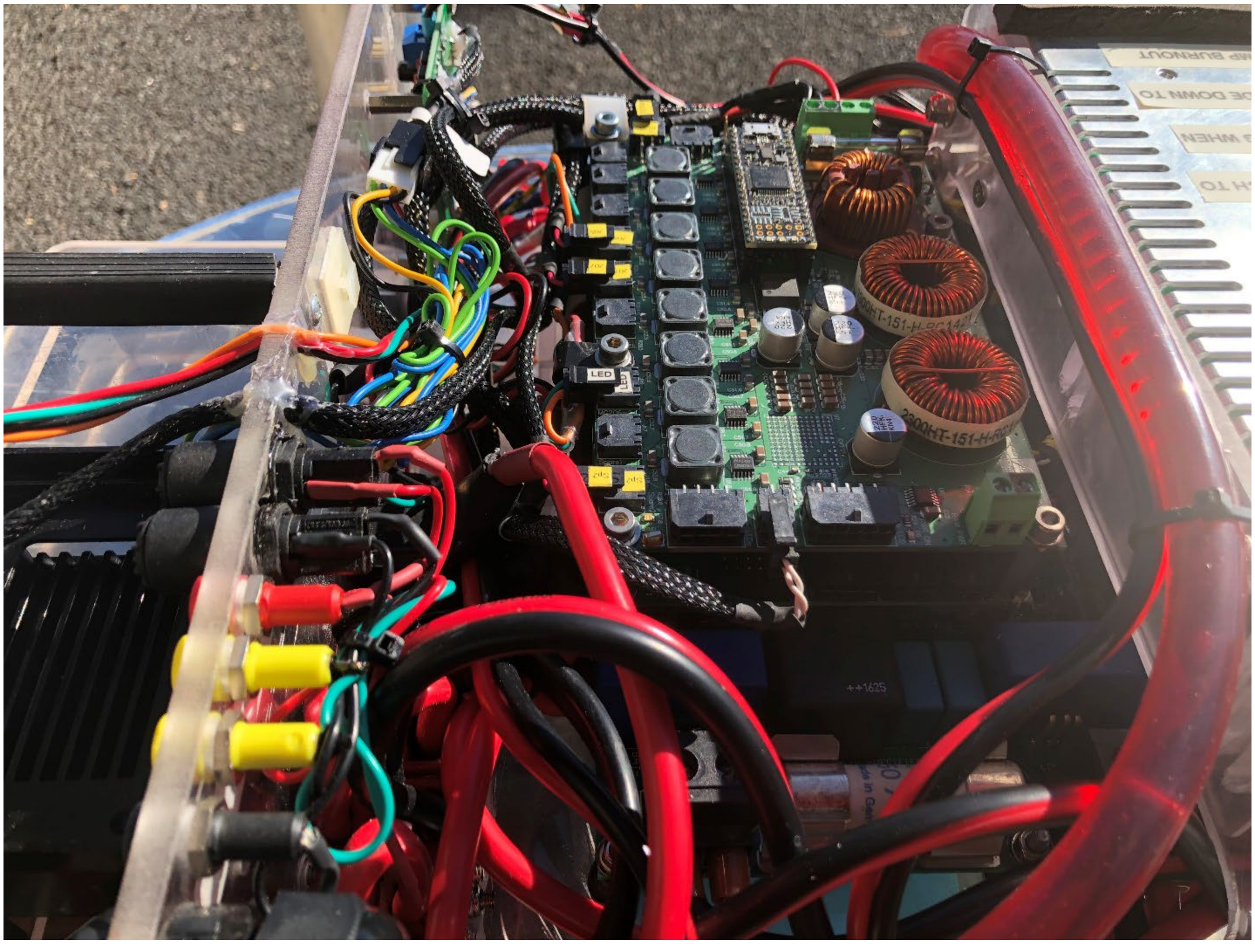


Figure 141 The Transmitter is opened simply by removing all the panel mount screws, lifting the entire contents out, and turning it upside down. Then to work on it there is a marked switch used to temporarily disable the cooling which could suck air if operated upside down (see the Troubleshooting section for its location). The board on the top as shown is the power supply board. The transmitting board is on the bottom. The 19-32V to 5V DCDC converter and cooling block are on the right. 4mm sockets and fuse holders in view are legacy diagnostic parts – not part of the standard product.

TDK LAMBDA I7A24045A033V-0C1-R 750W 18 TO 32V INPUT NON-ISOLATED STEP-DOWN DCDC CONVERTER AND LOOP SWITCHING RELAYS

The Meanwell DCDC converter has been replaced by the TDK i7A24045A033V-0C1-R DCDC converter so that variable loop voltage is possible with just one product. Loop voltage can now be varied between 3.3V and 18V (other limits in the transmitter may further limit range) Further, the i7A is more efficient, provides cleaner signal, has less inductive moment in its case (useful if near receiver and transmitter loops), and can be cooled compactly. Further, with addition of a MCP4725 DAC or MCP4728 (with internal voltage reference) it can be controlled digitally from software.

The MCP4725 is controlled by an Arduino with code that allows the system software to adjust loop voltage, set loop voltage in the MCP4725 EEPROM, switch between two preset loop voltages and to control a set of 60Amp automotive horn relays that facilitate loop switching. This means that dual moment operation is feasible (once AgTEM firmware also supports it) plus selection of if two output ports are serial or parallel.

Figure 142 TDK Lambda i7A 45A DCDC converters

In an interim measure, the i7A control electronics is fitted onto a prototype board and the Arduino is controlled by a potentiometer and momentary switch. The momentary switch allows the MCP4725 EEPROM to be programmed so that no problem occurs if the Arduino can be turned off. A toggle permits the 2nd (dual moment) voltage to be set in an EEPROM on the Arduino only. Centre position of the toggle leaves the Arduino off. This may be useful should transmission from the Arduino be found to be introducing noise.

As of January 2025 - Finding introduction of noise via the DAC is a problem, some implementation has involved just a remote potentiometer on the base of the transmitter panel and an adjacent voltage display and toggle for input/output volts display.

FILE DESCRIPTIONS

GPS.LOG: The GPS log is a simple list of NMEA0183 GGA strings and is useful for interpolating GPS data in post-processing to more accurately position fast sampled AgTEM data. To use this data, GPS and computer clocks need to be synchronized, their difference known and used for correction or determined by plotting lines passing over distinctive features and correcting the time difference successively until images of the features form a straight line. In real time AgTEM data is simply paired with the last good GPS record – this quick and easy practice is not adequate in some rare situations. The GPS log can also provide more detail for topography mapping. For documentation see generic notes on NMEA 0183 GGA strings.

***.BIN**: The data files are binary and the format is kept confidential by Monex Geoscope. A BIN to TXT file converter is provided to recover information from the receiver.

TROUBLESHOOTING

COMMON WIRING DIAGNOSTICS

Every AgTEM operator should attain skills in wiring diagnostics at least equivalent to auto-electrician proficiency. There are many cables and connectors and there is generic procedure for diagnosing faults with these. The wiring diagram chapter helps with choice of pins for testing. It is commonly difficult to isolate exact causes of problems in wiring however there are some procedures that help.

THOROUGH METHODICAL OBSERVATIONS

AgTEM is a system of some complexity so many faults will be challenging to diagnose. Nevertheless, procedures of substitution, isolation, duplication and comparison applied logically will isolate most problems. Intermittent and subtle problems generally require more work and often continuation of survey so that more thorough observation can occur. A chapter of this manual dedicated to real time observation is provided to help in this respect. Resting to take account and re-assess generally is very helpful.

BYPASSING THE PRE-AMPS

Pre-amps require +/-15V power which means extra wires and pins must connect. Further, they provide a delay and filtering which can complicate diagnosis. If one side of the power supply is interrupted then DC offsets can occur. Sockets are added on loop connection circuits so that the pre-amps can be bypassed – these connectors however can be plugged in inappropriately so that short circuits occur – avoid this. With a pre-amp bypassed, there will be a ringing developed in the shielded cable leading to the receiver but otherwise the signal will be simple and useable (minus the amplification). There is also damping supplied by the pre-amp board. Once removed, an alternative damping resistor on the loop connection board can be switched in to substitute.

CHECKING FOR BROCKEN RECEIVER LOOP CIRCUITS

When receiver loop circuits are broken, small weak decays are still observed but these are just from parasitic processes in the wiring. The strong consistent primary field response will be gone (yet this is not so clear in a system that is designed to null primary field). A multi-meter check on pins of connection cables is a typical first test. Then bypassing the pre-amp and/or multi-meter testing on the loop breakout board. Wire tracing here follows simple logic and is a finite task.

CHECKING FOR RESPONSE

If AgTEM is driven onto, or at least near, a metal object such as a pickup truck, silo, reinforced culvert or railway lines then a strong long-time-constant response must be observed or the system is broken. An easy way to get such a response anywhere is to use the extra turns in the transmitter loop in a short-circuit manner. This is achieved by a certain pattern of connection explained in the configurations chapter.

CHECKING THE RECEIVER ELECTRONICS

The receiver has three loop connection sockets. Each can accept 3 loops at once but with connections rotated round by one loop such that Z may become X, X become Y and Y become Z, or similar. You may use this feature, to test that there is not a problem within just one component of the receiver simply by plugging the same cable into a different connector and observing a different component in the receiver.

SYSTEM DRIFT

Wherever possible it is appropriate to conduct tie-lines across surveys to check for system drift. On a very cold morning expect the system to take a little time to warm up and stabilize. If there is a tie line then such drift can be observed and corrected in processing so that waiting for warm-up becomes less important.

Any change in the transmitter loop position close to the receiver loop will cause a system response shift. For this reason the part of the loop near the receiver loop is kept taught and/or rigid. Connectors are held out near boom tips as slack cable must accompany the connectors.

Booms are held in place using cable ties which are used as weak links. Always replace with tightened ties – do not allow booms to sag at different heights by replacing ties with loose ones.

BOOMS FALLEN

The driver must always keep alert of the plight of the booms on the receiver. They may brush against trees and weak-link cable ties may break leaving parts dragging on the ground. The first alert often is from observing sudden changes in the primary field part of the signal received. If the vehicle is not stopped quickly then breakages can compound.

COOLING OF THE AGTEM RECEIVER

The AgTEM receiver creates heat at a rate of around 70 watts. For high quality pre-amplification a lot of power is used specifically on board MG206. This is blown off heat sinks by two or more fans that recirculate air through the boards and then via return paths on the top or bottom of the aluminum case with heat sinks. In the external case a further fan takes outside air and blows it over the internal case such that a dual solar heat and weather protection system always exists.

If overheating is imminent then software shuts the system down.

If for some reason the external cooling flow is blocked or turned back on itself it will not be effective – trace the air flow and verify it is working as designed.

COOLING OF THE AGTEM TRANSMITTER

The transmitter is liquid cooled. There are issues with the liquid cooling system that require regular observation, attention every six months and potential yearly maintenance. EKWB recommends replacing the coolant every 12 months similarly to replacing coolant on car engines and for the same reasons. See the maintenance section for more details.

The swiveling elbows and other swivel joints in the EKWB water cooling system can leak when flexed and placed under bending strain. Tubing is fixed by cable ties to minimize this risk.

Changes of pressure such as in air freight or descent from high altitude or simply weather change stress the cooling system. Observation after such events is appropriate.

Coolant evaporated through the flexible tubing walls very slowly so refilling will inevitably be required. Refill via the refill port provided. Use coolant from EKWB or similar as it contains corrosion inhibitors.

The coolant is corrosive so galvanic current loops are set up between parts of different metals of very different nobility. For this to work there has to be both electrical connection between the metals and fluid connection between the different metals. The water block and connectors are aluminum but are not electrically connected to the pump and radiator. The pump and radiator are copper/brass products and connectors attached are best made of brass or nickel. If mixed up with Aluminum parts there is potential for rapid corrosion including pitting of the aluminum parts.

If the transmitter is left running upside down then the pump may collect air and burn out. Any other orientation is deemed by EKWB to be OK.

When the transmitter is out of its box one may want to run it for short times or at small loads while upside down. To facilitate this there is a switch as shown in the photo below provided to temporarily turn off the cooling system.

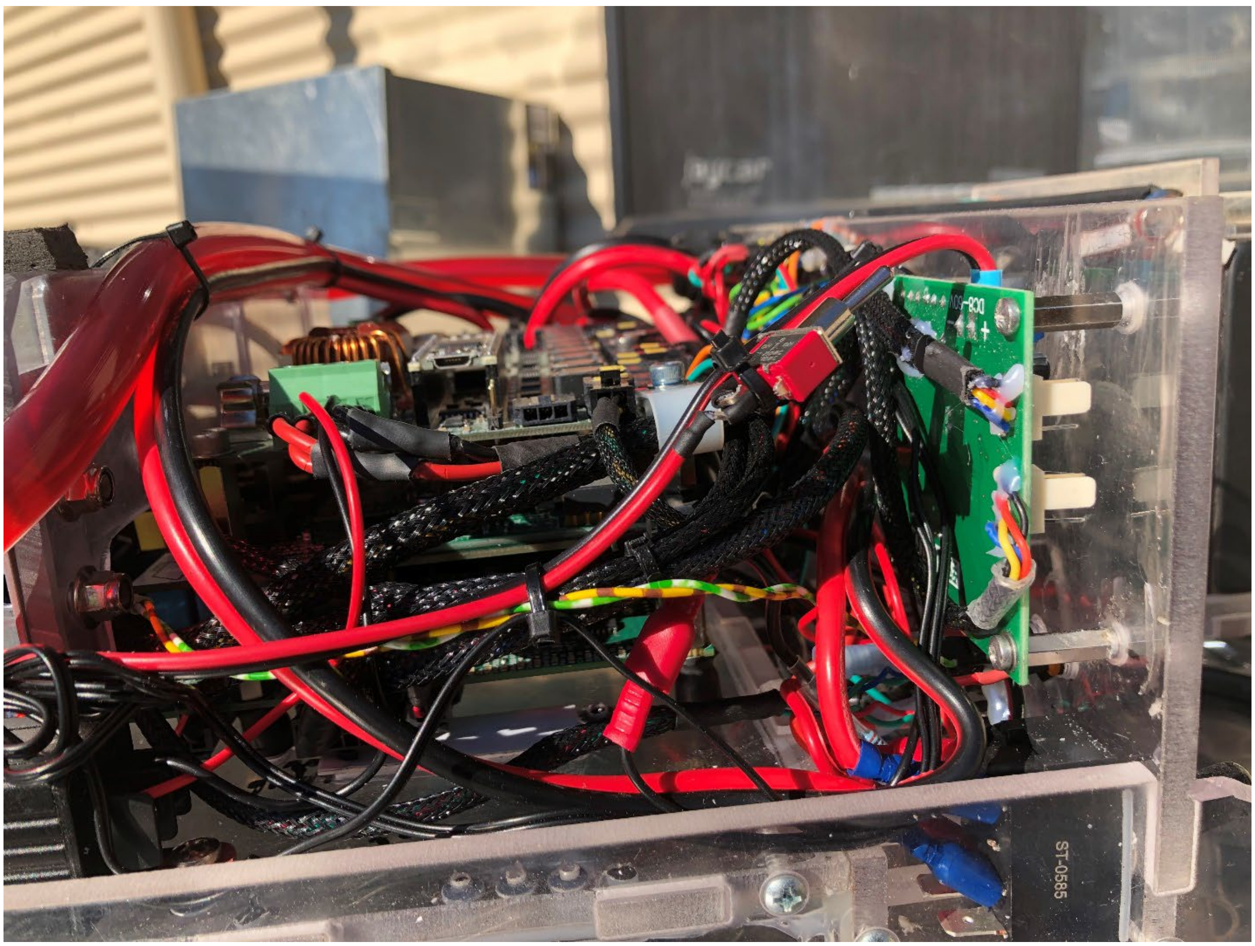


Figure 143 An inline switch provided for temporarily turning off the cooling system - remember to turn it back on again.

TOO MANY SERVICES RUNNING ON THE COMPUTER

If AgTEM.exe shuts down when transmitting high currents at 100 or 200 Hz then it is known this can be due to WiFi congestion should WiFi be turned on – perhaps due to EMI slowing down the WiFi signal which in turn times out AgTEM.exe. Some very demanding applications have however been run simultaneously with only occasional conflicts – applications successfully run include Picoscope 6 and Windows Remote Desktop.

It is most appropriate to keep the AgTEM computer dedicated and isolated from the internet except for manually managed software upgrades and security updates. The image below shows interruption that is unwanted.

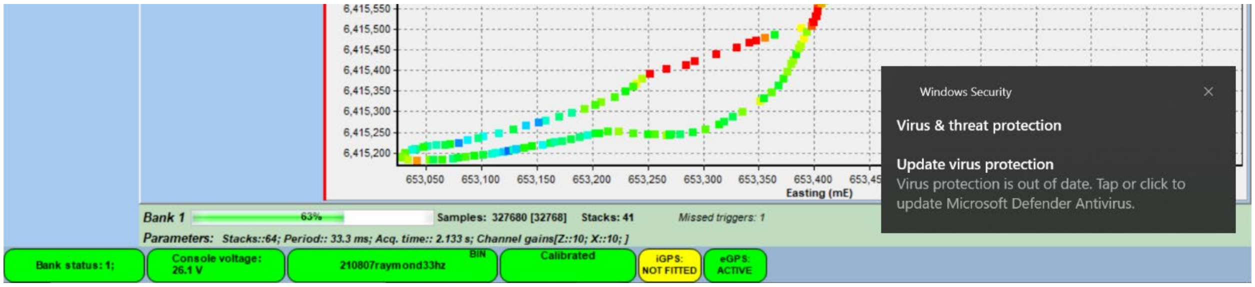


Figure 144 Having too many extra processes running can cause fast cycle-rate acquisition to stop, unwanted messages that confuse, and timeout error messages. Keep automated updates, WiFi and other extra processes turned off if they are not necessary, especially if you are encountering strange problems. Virus software need not run while the computer is not internet connected – only invoke it if and when you connect to the internet.

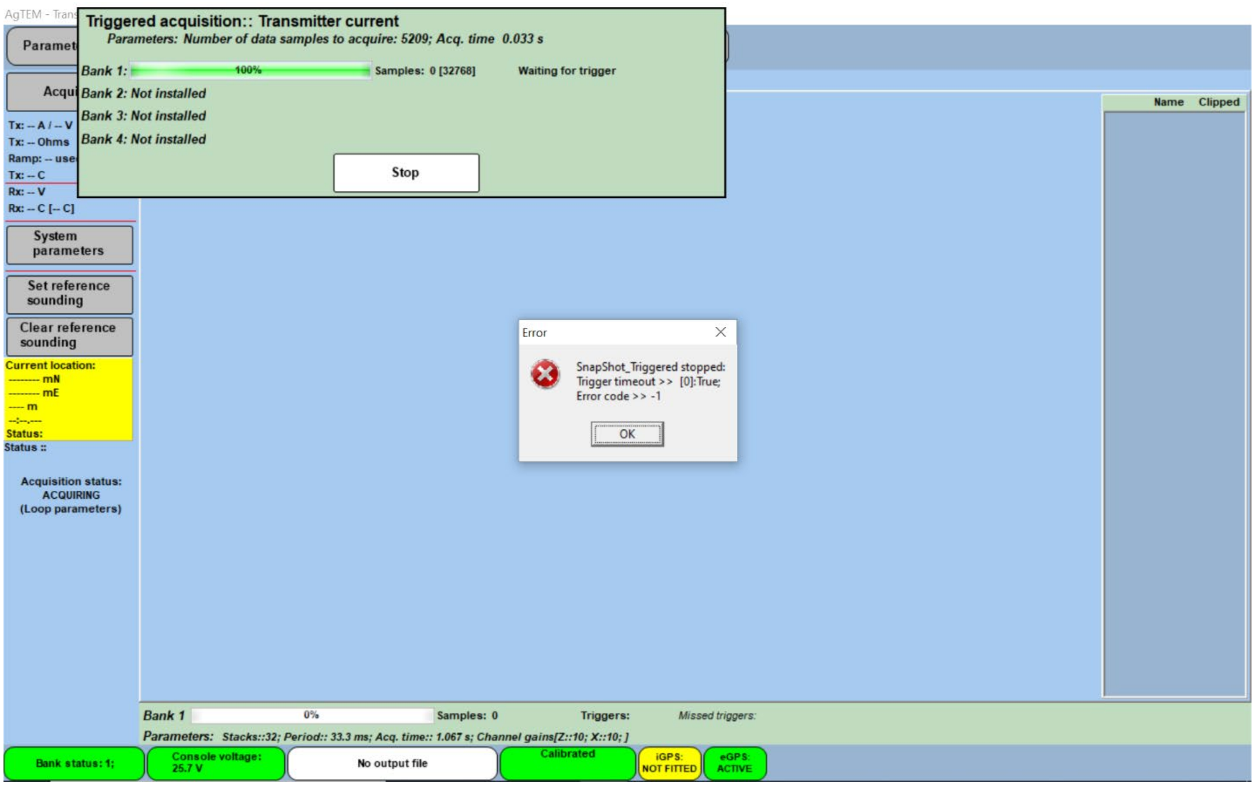


Figure 145 Trigger timeout errors can be from excessive slow, cleint added, background processes interfering with real time acquisition processes. Beware that they can also be from lost connection with components of the system.

AIR BAGS

The air bags have valves accessible beneath. Re-inflation is required after tubing tampering or when ground conditions require different suspension response. Do not exceed 20 psi or the bags will bulge. Dropping pressure very low will cause the bags to crumple and tilt, applying unwanted pressure sideways on the suspension system leading to twisting and rapid wear and tear of many parts. DO NOT DROP PRESSURE SO LOW THAT THE AIR BAGS

CRUMPLE. Be aware that the roughest impact on air bags can be sideways jolting while the Wallaby is being floated from site to site.

REPAIRS

WHEEL CHANGE

When used on rocky sideslopes the AgTEM wheels will have a short life. Solid tires do not puncture but this is at the expense of tread wear and tear. Eventually the tyre will disintegrate and typically jam in the wheel well. Careful observation by the driver can save a lot of cost here as wheels can be reused.

BEARING LIFE

The wheel bearings are of high quality and will last generally longer than the wheel. Never substitute them with common wheelbarrow wheel bearings as you will be lucky to get a day out of such substitutes. Instead, choose quality replacements – these still are common and readily available.

LIFTING THE WHEEL

AgTEM-Wallaby is light enough to lift without the assistance of a jack but a jack will be welcome.

CHANGING THE WHEEL

The axle is removed with 14 and 15mm sockets or spanners (9/16” and 5/8”). Bracing plates supplied have several holes – if one wears out then use another. Some options for 26” wheels also are provided.

ADDING YOUR OWN TYRES

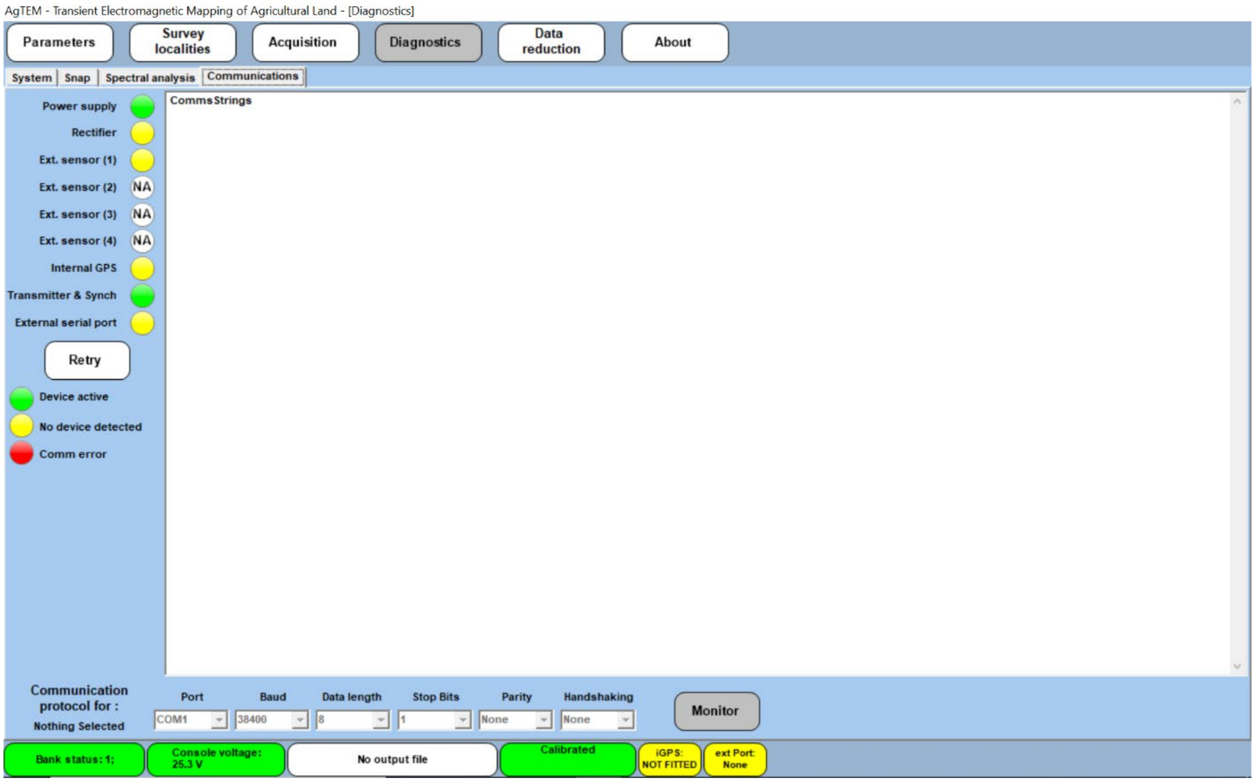
There is a serious induction problem with steel bead tires so we use Kevlar bead tires. These are available from bicycle stores and can be used with extra thick inflated tubes or with solid fill. Inflated tubes need to be inflated to at least 50 psi if they are to stay on the rims when traversing side slopes.

Figure 146 Changing an AgTEM-Wallaby tire with a high lift jack.

COM PORT ASSIGNMENT PROBLEMS

AgTEM will not start up nor run correctly if COM port assignments are incorrect. It expects its own four ports to be assigned COM ports 7,8,9 and 10, and the GPS to stream in on COM port 11.

Reading the manual Chapter 'Menu by Menu' diagnostics entry will reveal how it is possible to test internally in AgTEM.exe if the correct data is entering from the correct COM ports. A good start is simply to run the communications page test sequence (shown as a 'Retry' button below) in the diagnostics page as shown below. If all relevant circles turn green and only uninstalled ones stay yellow then all COM ports are assigned and connected correctly. You can check further using the Monitor button and watch to see if correct data is streaming in. Of course you will see nothing on ports where only outward communication occurs so they are not selectable.

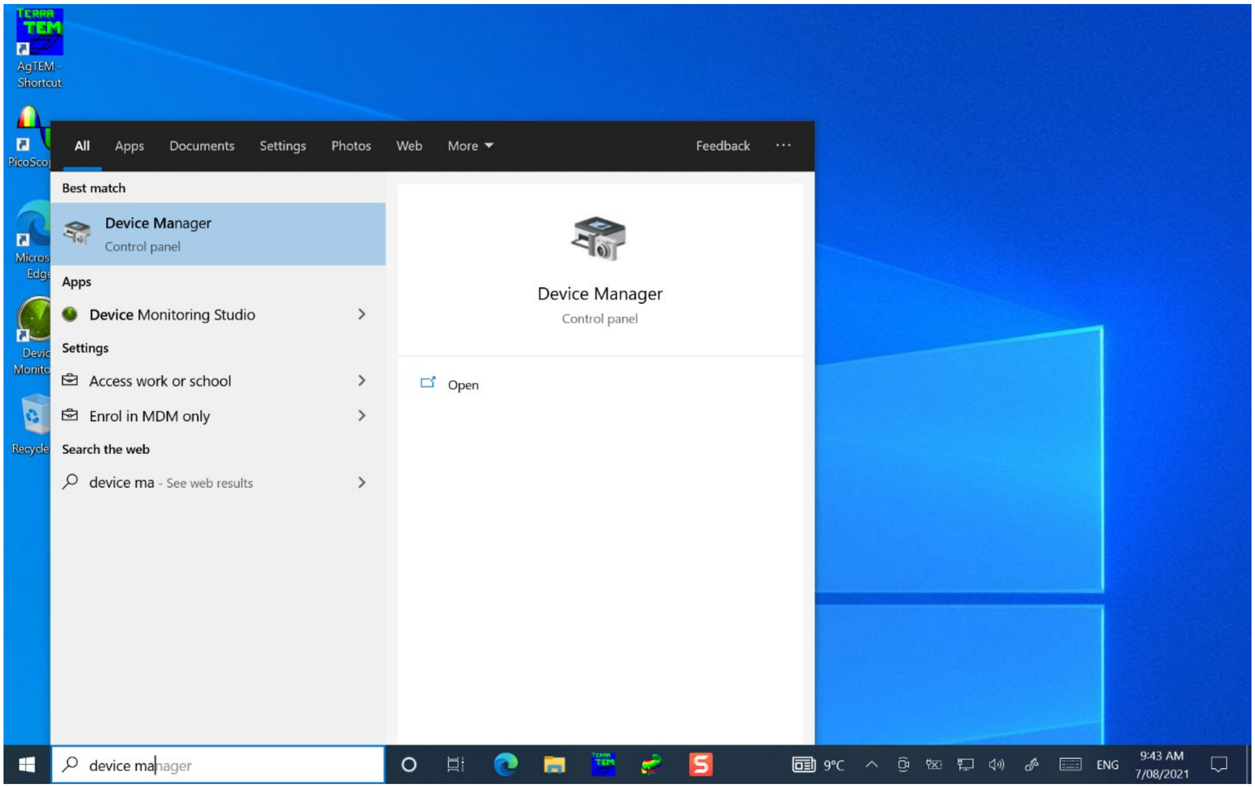


Of course, if the ports for some reason are not actually connected then that is a different problem but to change those port assignments the following procedure works.

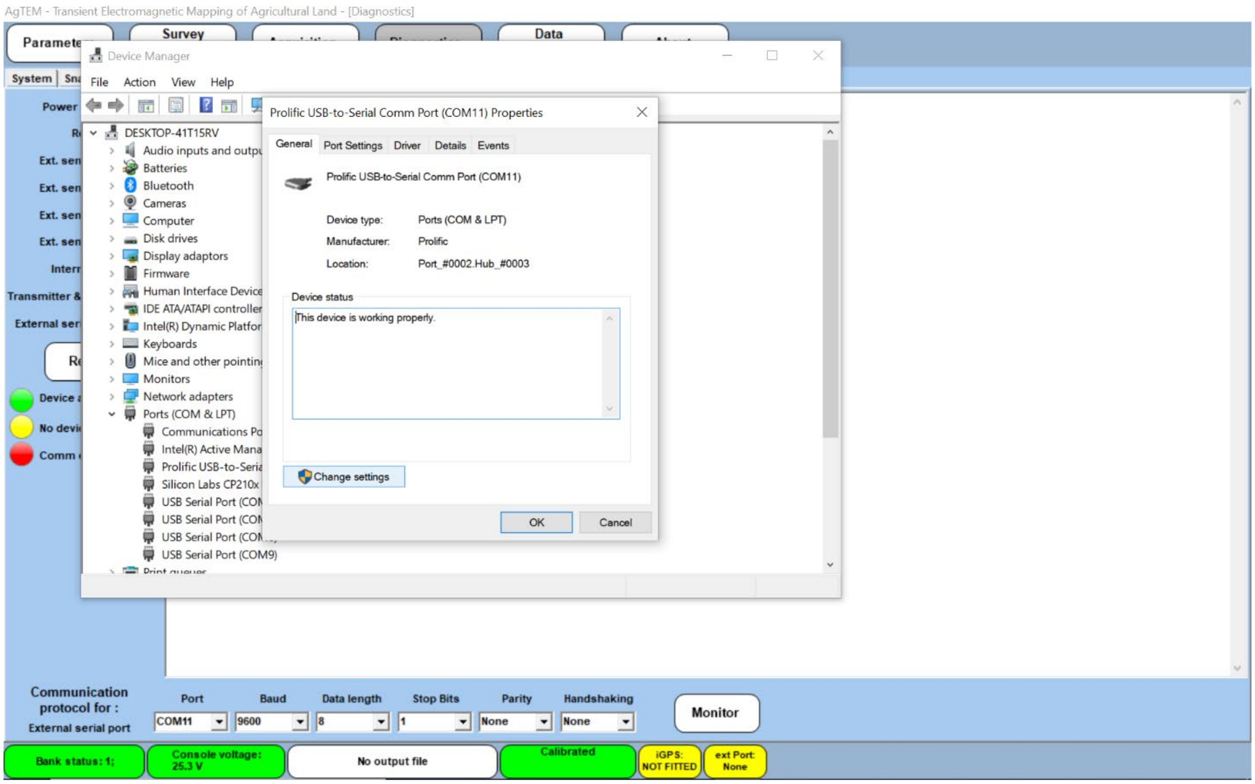
CHANGING COM PORT ASSIGNMENTS

In this example we are swapping the Trimble GPS with the Transystem GPS and need to change the transystem GPS port to COM11.

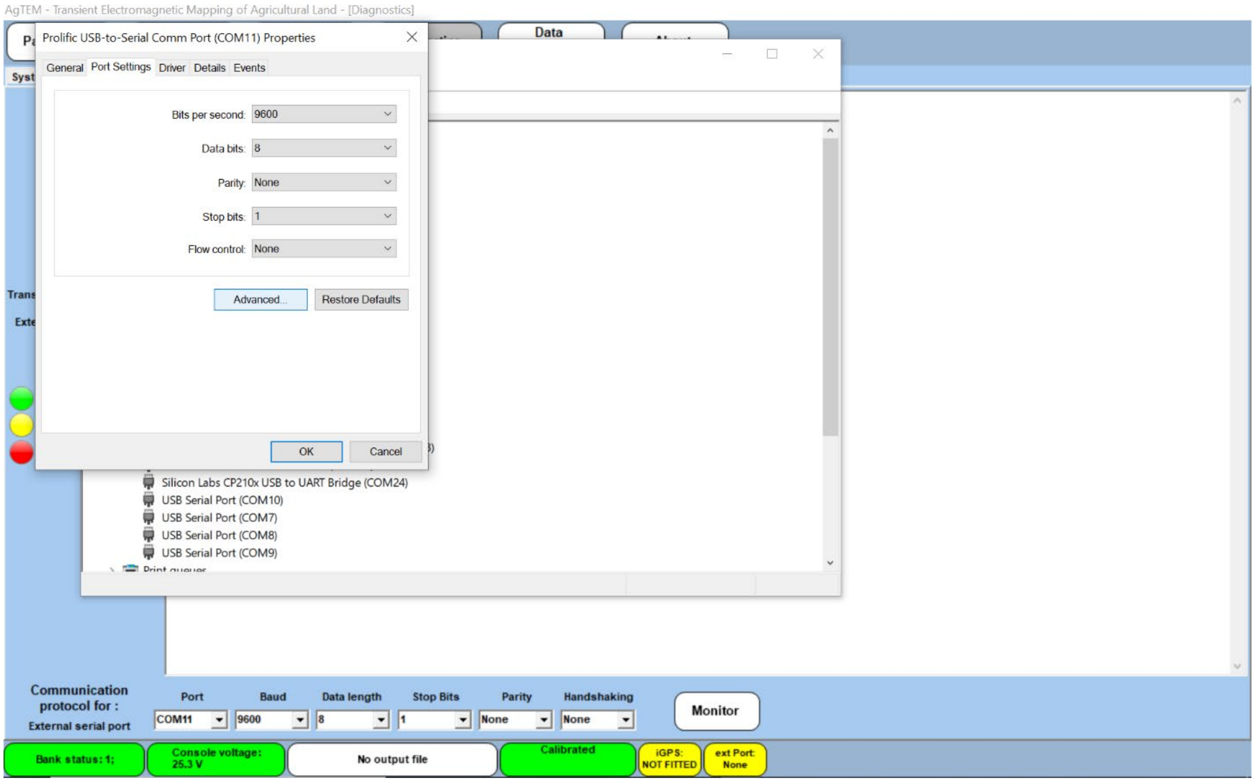
Press the lower left corner of the windows task bar – if off the screen it will appear even if you are presently on the AgTEM startup screen or if AgTEM.exe is running. In the figure below it is shown being accessed with just the Windows desktop in the background. Press on the search magnifier glass icon and start to type in 'Device manager' until it appears in a match list above. Select it.



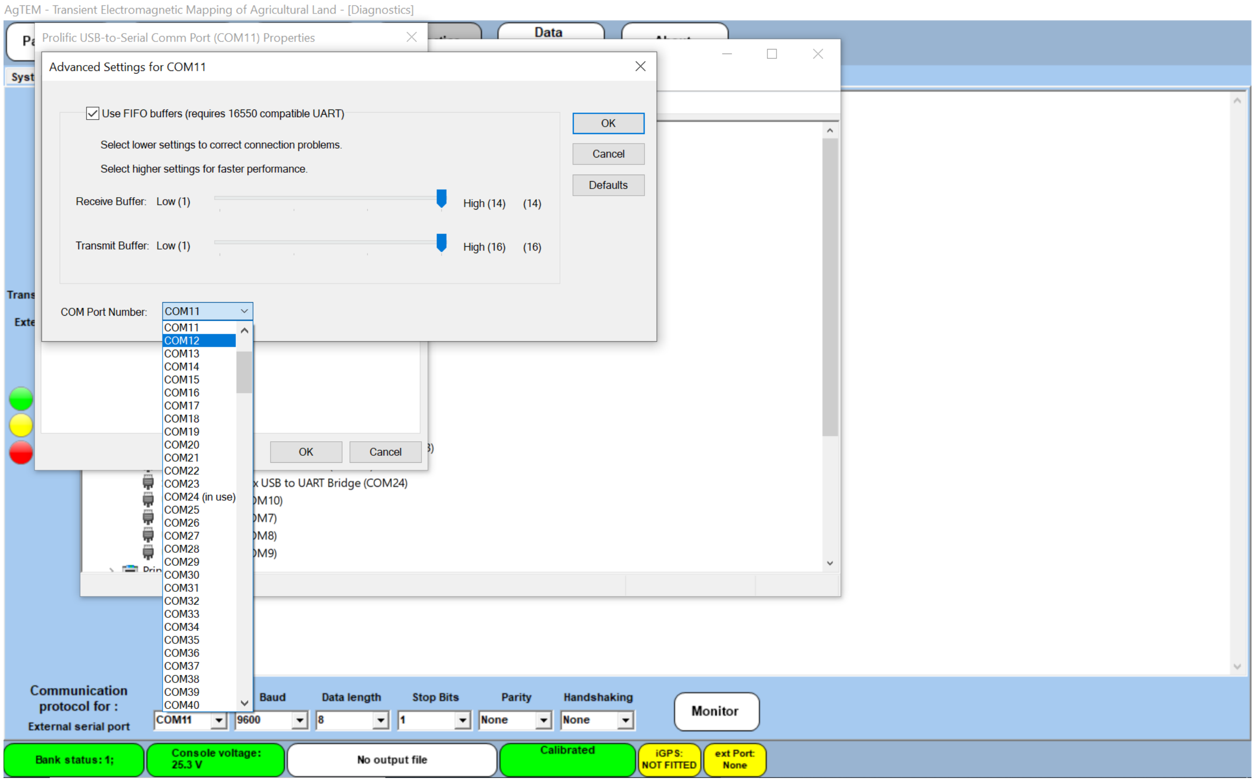
In device manager, find the part that reveals 'Ports (COM & LPT)' and expand it as shown below. You can see then bank of AgTEM port in the four port hub that exists within the AgTEM receiver. You can see COM11 is currently 'Prolific USB to Serial COM Port' which is the converter that was attached to the Trimble GPS previously. In the image below it has been double-clicked to open a window about it. Pressing 'Change Settings' with administrator privileges (hold down the shift button when pressing the button) opens basically the same window again but this time giving ability to make changes.



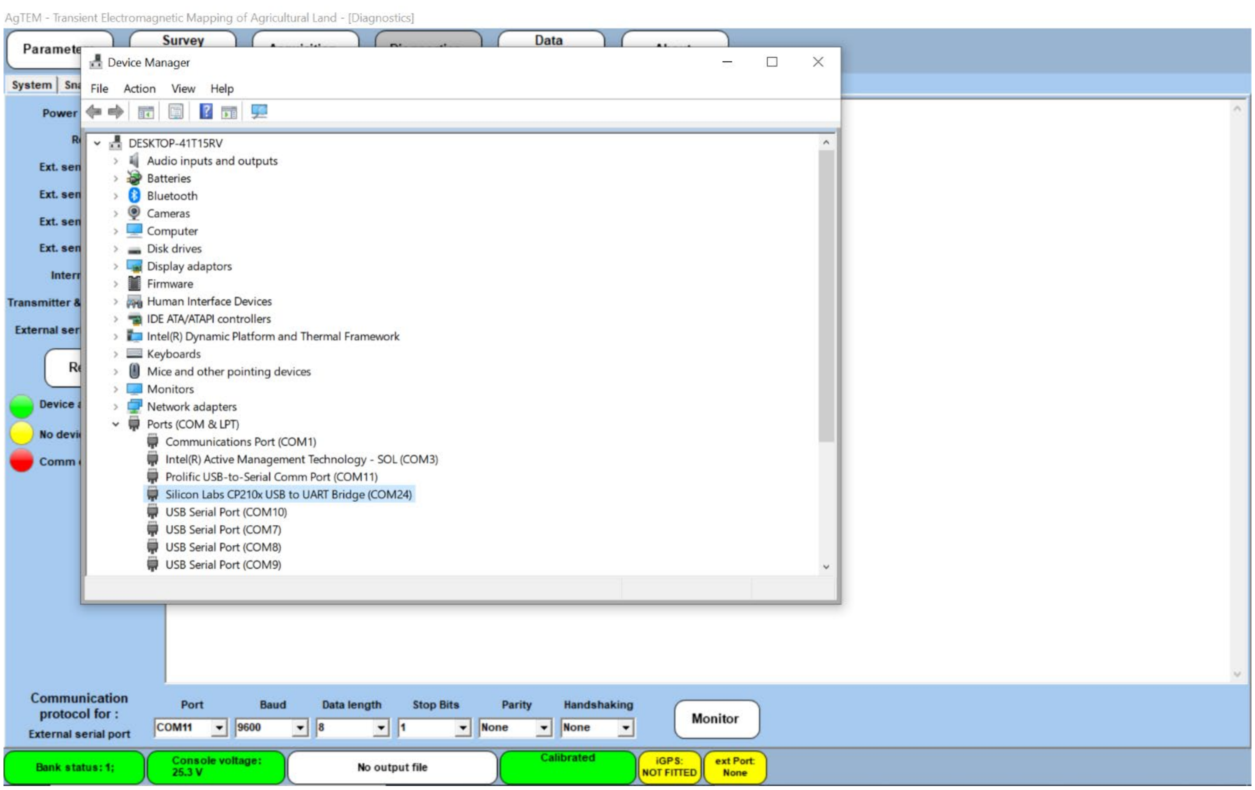
Press ‘Change settings’ and select the ‘Port Settings’ tab to reveal the display shown below. To access the port assignment press the ‘Advanced’ button as shown in the next image.



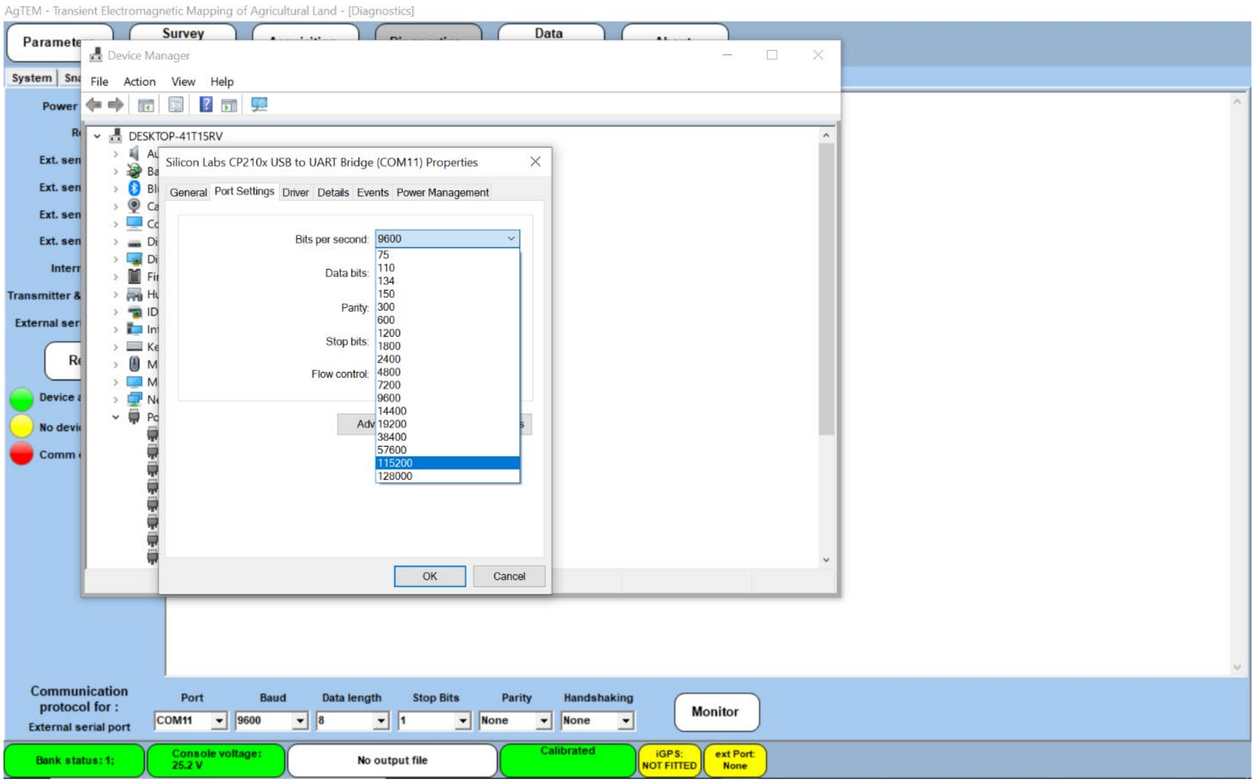
You now see some fine print at the bottom of the next form that lets you change COM port. We are now going to change this Trimble port to COM12 so we do not get conflict when we reassign the Transystem port, currently shown in the image above as 'Silicon Labs CP210x USB to UART Bridge (COM24), to COM11.



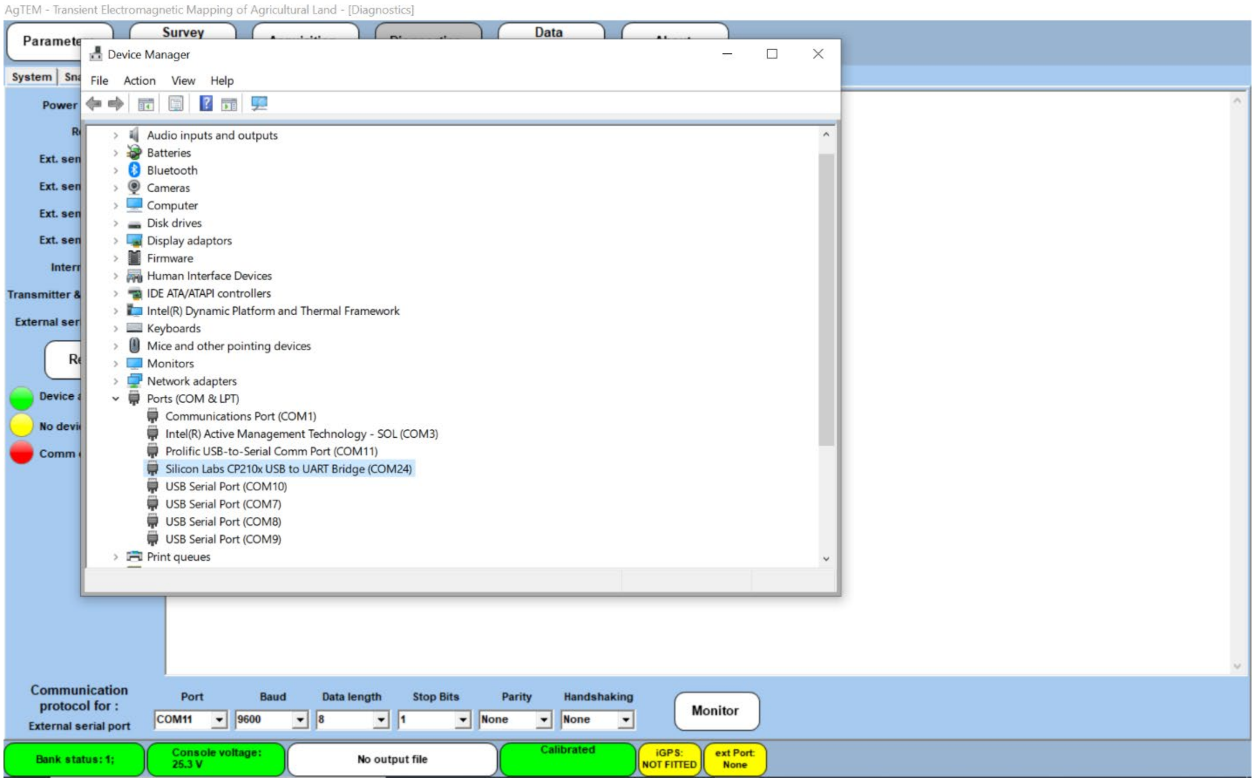
Pressing OK on forms to back out again we have made the change and now can do the same to change the Transystems GPS shown as COM24 below.



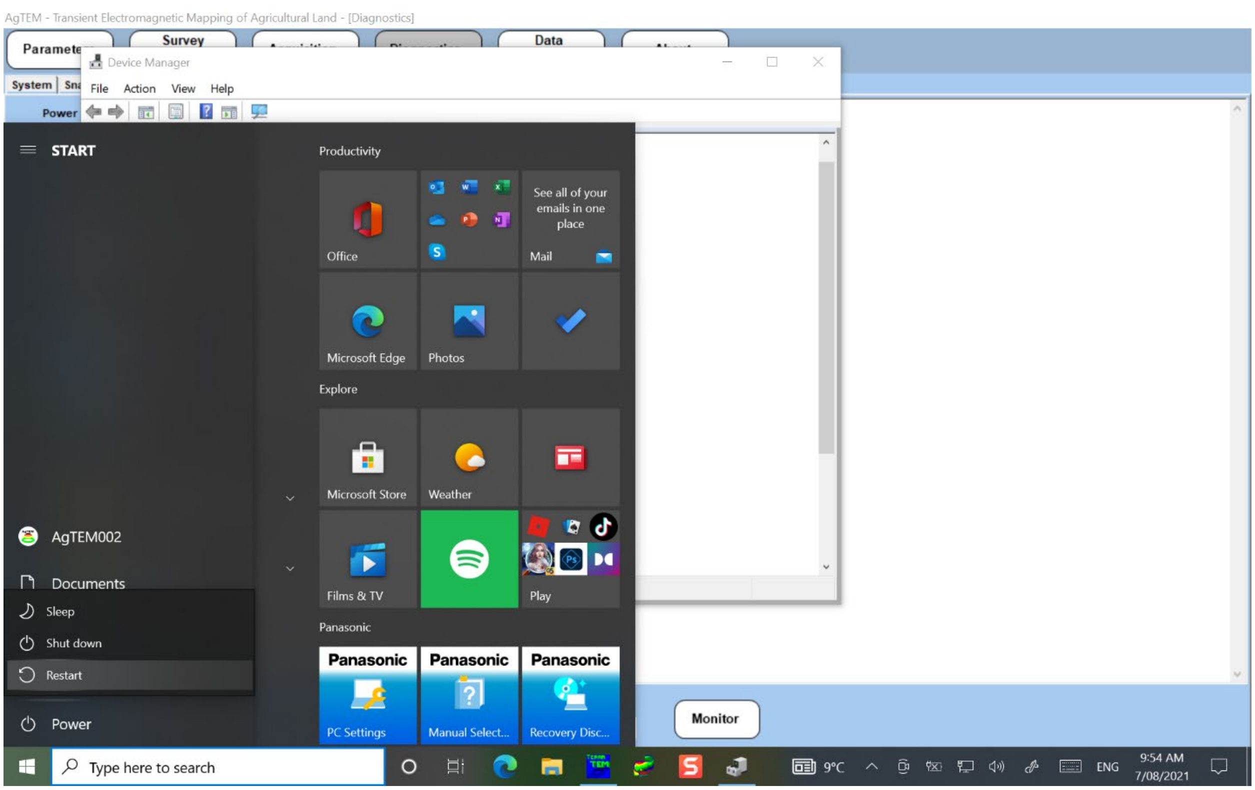
This GPS only runs at 115200 baud so select that in Port settings. You will have to select the right baud rate also in AgTEM.exe diagnostics screen later.



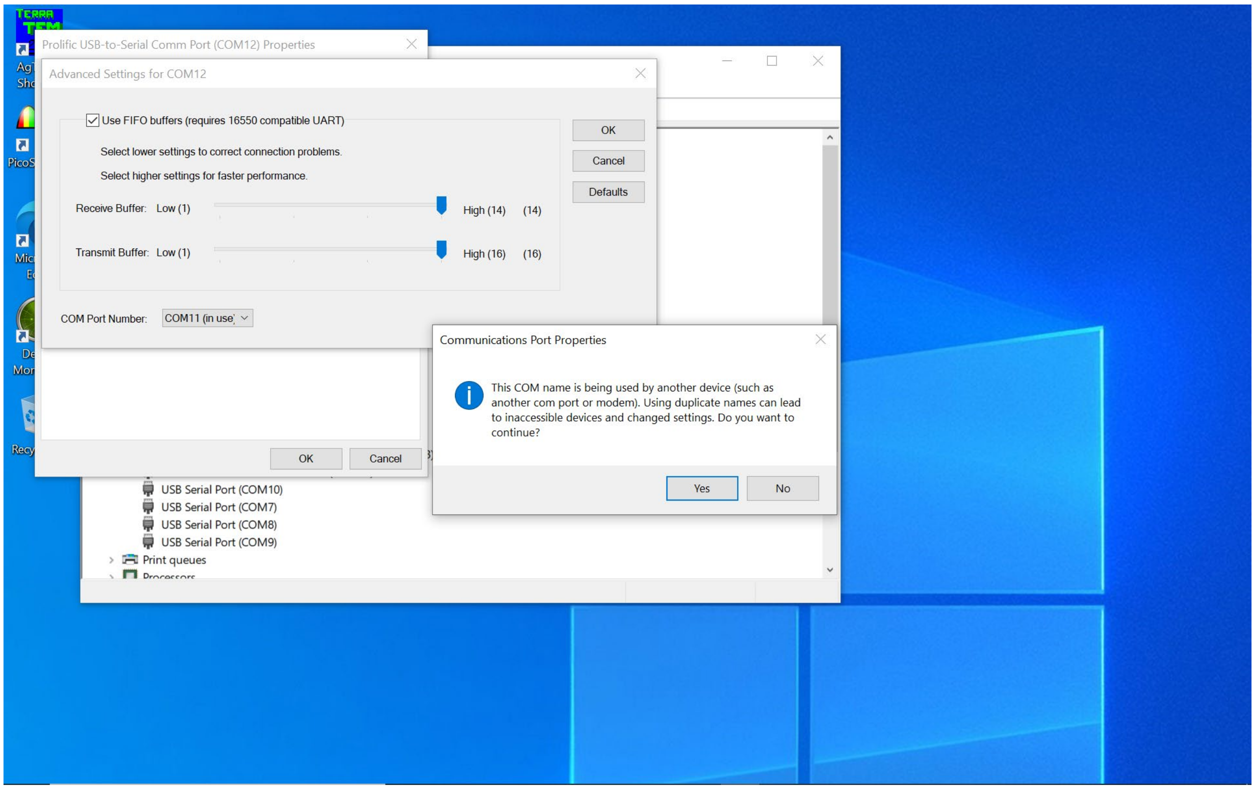
Now go to change COM24 port assignment to COM11 as was done before and you will see as in the display below that the change to the Trimble COM12 is not recognized and it remains assigned to COM11 so changing would cause a conflict. Frustrating – read on.



Reboot the computer as shown below (just a strong reminder image to help you remember).



The change of COM11 to COM12 will now have taken place and you are now able to change COM24 to COM11 using the procedure as before. Yet, as in the image shown below, you will see that COM 11 is considered to be 'In Use'. A message comes up and warns you against possible perils of making a change to COM11. In this case we know the conflict and have manually removed it so we can click 'Yes' without concern. Now another computer restart will be necessary then in AgTEM.exe a change of baud rate in the diagnostics display (Hint: in the list on the left of the diagnostics screen tap on the text 'Ext. Serial Port' in order to activate and direct the baud rate change control at the bottom of the screen to COM11). Selecting to 'Monitor now in the diagnostics display can reveal GPS data streaming in.



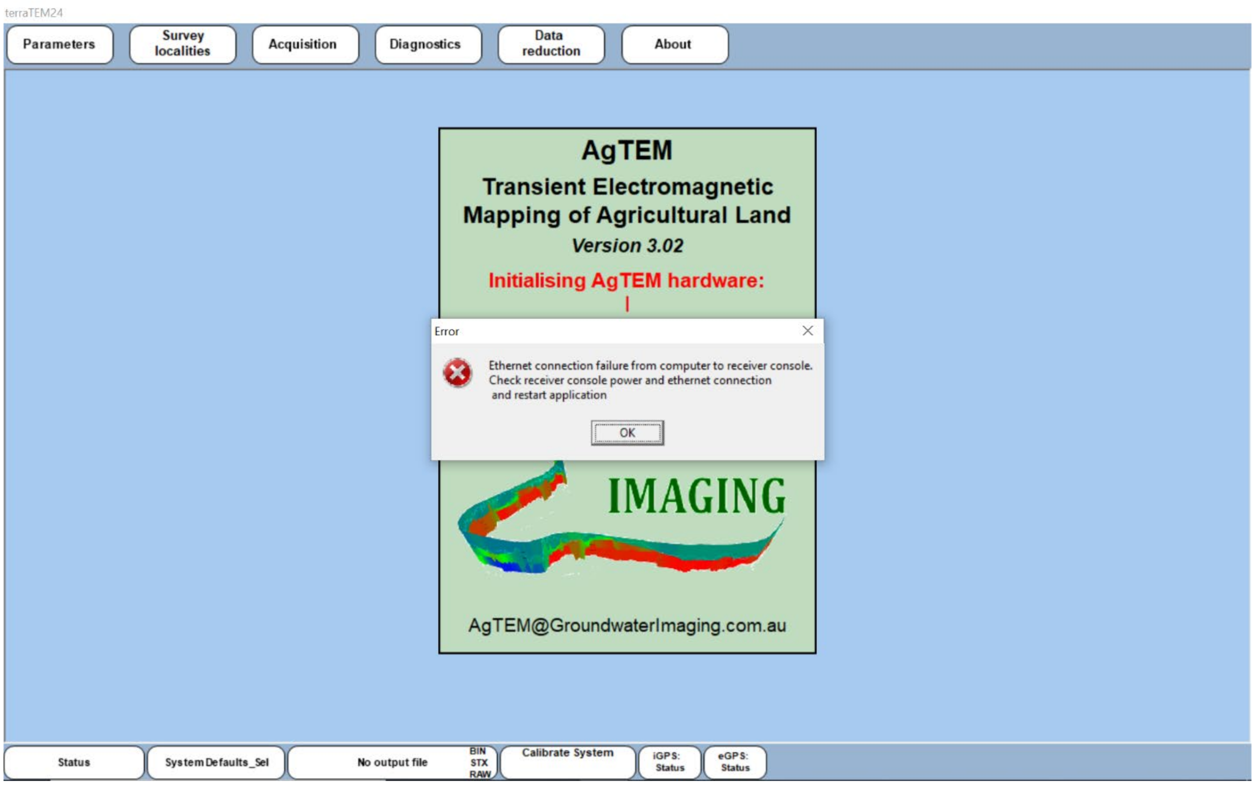
SHUFFLING COM PORTS 7 TO 10

Should com ports 7 to 10 be in the wrong order, use the AgTEM diagnostics or an external serial port monitor to view what is coming in from each port. Tell the transmitter and receiver power supply port data apart by observing their temperatures or voltages specific to each. You may need to assign one port outside the 1 to 10 range temporarily, to avoid assigning 2 to the same number, temporarily so you cannot then separate them.

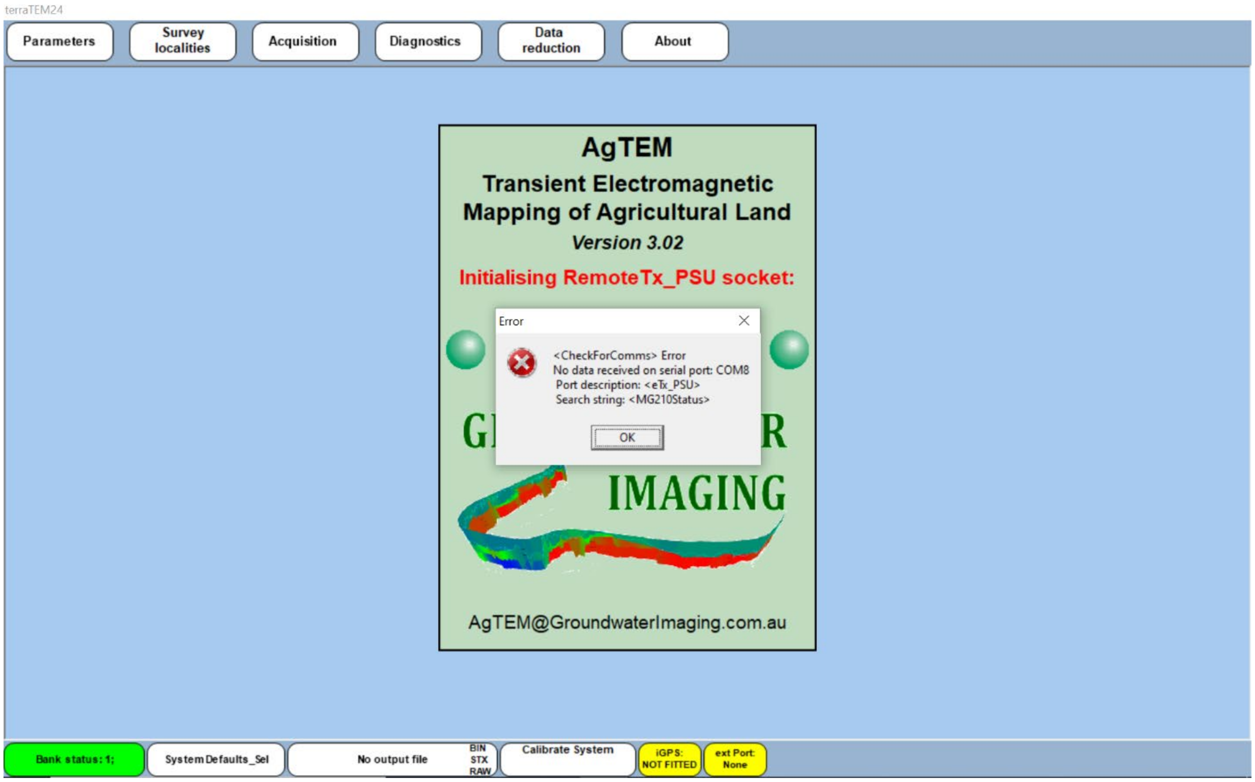
STARTUP WITHOUT ALL PARTS OPERATIONAL

The most common problem encountered with AgTEM is presently frustrating startup where parts are not all connected and started in the right order and with suitable delays between each. At August 2021, this is considered to be a bug that could be drastically improved with little programming effort – expect this eventually to be improved.

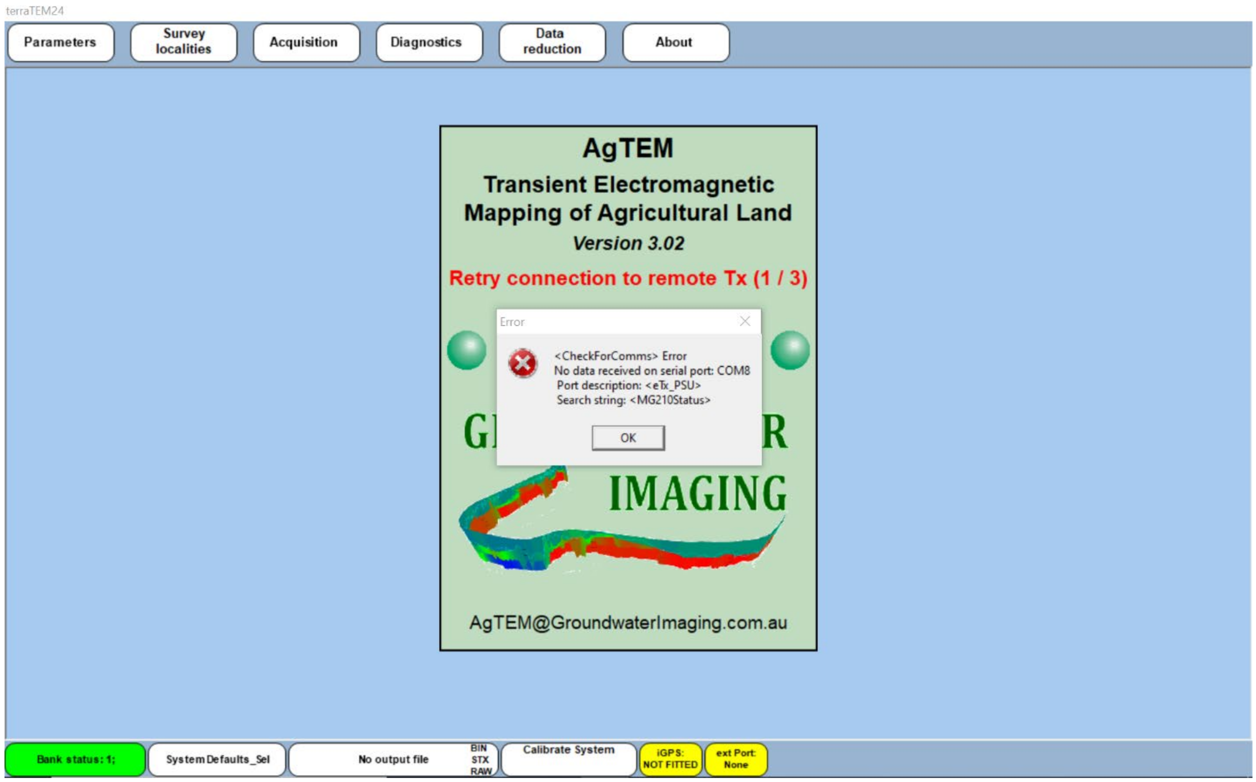
The first failure usually is to either activate AgTEM.exe before the receiver has booted completely (takes a long time and then you hear two beeps in quick succession) or to activate AgTEM.exe neglecting to first turn and boot on the receiver at all. The situation is further confounded by the tendency for AgTEM.exe to remotely shut down the receiver silently and subtly as it itself is shut down or should something go wrong so one thinks it is running but it no longer is. Of course there is also a possibility of the Ethernet cable not being connected yet this is not a common problem. The message below is not caused by failure to connect the USB cable. When any of the above occur the message shown below is displayed. When you press OK AgTEM.exe shuts down and if the receiver has managed to boot by that time the receiver is shut down shortly afterwards and needs restarting and running through the boot sequence again before AgTEM.exe should be started if you do not want to see the error message again.



The next problem encountered in startup is likely to be with the Transmitter. Like with the receiver, it must be powered up, and booted with the Synchronization cable to the receiver connected and the USB cable from the receiver to the computer connected and the COM ports assigned correctly otherwise the message below will display once the startup sequence reaches 'Initializing Remote Tx_PSU socket:' 'eTx_PSU' stands for External transmitter power supply unit.



You are given three attempts at getting the transmitter connected and running – the startup sequence will display 'Retry connection to remote Tx (1/3)' as shown below – in this case we failed to fix the problem and the same error appeared again a second time. Check all your cables, turn off the master power supply isolator on the transmitter and then back on again and if a remote boot instigation is not sent from the receiver, should it be turned on, then reboot it. This is because it is possible for AgTEM.exe to have shut some functionality of the transmitter down (such as by triggering non-cancelled error flags) so that the only way to start again is a reboot of it. The transmitter boots quickly. When AgTEM.exe manages to initialize connection you will hear a relay in the transmitter click and the AgTEM initialization will move on to the GPS connection.



Now startup will attempt to find GPS data streaming in failure with this is not fatal – if it does not come or had failed last time AgTEM was run then box 6 on the lower taskbar will display yellow with 'ext Port: none'. If access is just switched off then pressing here and reselecting the GPS will fix the problem but if there is a problem you will be told so – check your GPS is actually coming in. See the section above on COM port assignment problems for more information on accessing GPS data and the section below on Trimble GFX350 to see more on getting the NAV500 to actually send data.

TRIMBLE NAV500 OR NAV900 WILL NOT SEND GPS DATA

The Trimble NAV500 and NAV900 antennae can send data out a 12 pin connector if they are suitably setup with a GFX350 display with the right firmware version and authorization. The GFX350 also has a serial out port in the standard breakout cable supplied but this is for an autopilot and it seems you have to pay Trimble a lot of money to get them to authorize data output from this connector – by default it sends nothing. Further, early versions of firmware for the GFX350 never let any data out from anywhere. Once the firmware and authorization are suitable, one still has to go in and manually activate streaming out of data and tell it which port to send it out through. Considerable payment to Trimble is needed to get technical support and the documentation otherwise provided is inadequate as of August 2021.

Important: the Trimble data comes out a d-sub 9 pin connector. There is always a problem with these where for some situations pins 2 and 3 need switching over so they are not transmitting to a transmitter and receiving from a receiver. The swap-over device is called a null modem. This can be an additional problem with getting data out of any serial GPS product.

MISSING GPS PORT AND DATA WITH POSSIBLE CHAOS WITH FLICKERING CURSOR ONCE WINDOWS STARTS WITH GPS DATA COMING IN

GPS data streaming into a Windows computer via a COM port while windows is starting up will generally throw windows into chaos or at least lead to lack of access to the GPS data. The problem is that Windows still recognizes such data as coming from a serial mouse and reassigns it as mouse data which may cause chaotic mouse cursor movement and clicking which can in turn cause much more chaos. We have conducted special changes to the registry to prevent this chaos but a change of COM port or computer may provide you the same problem again.

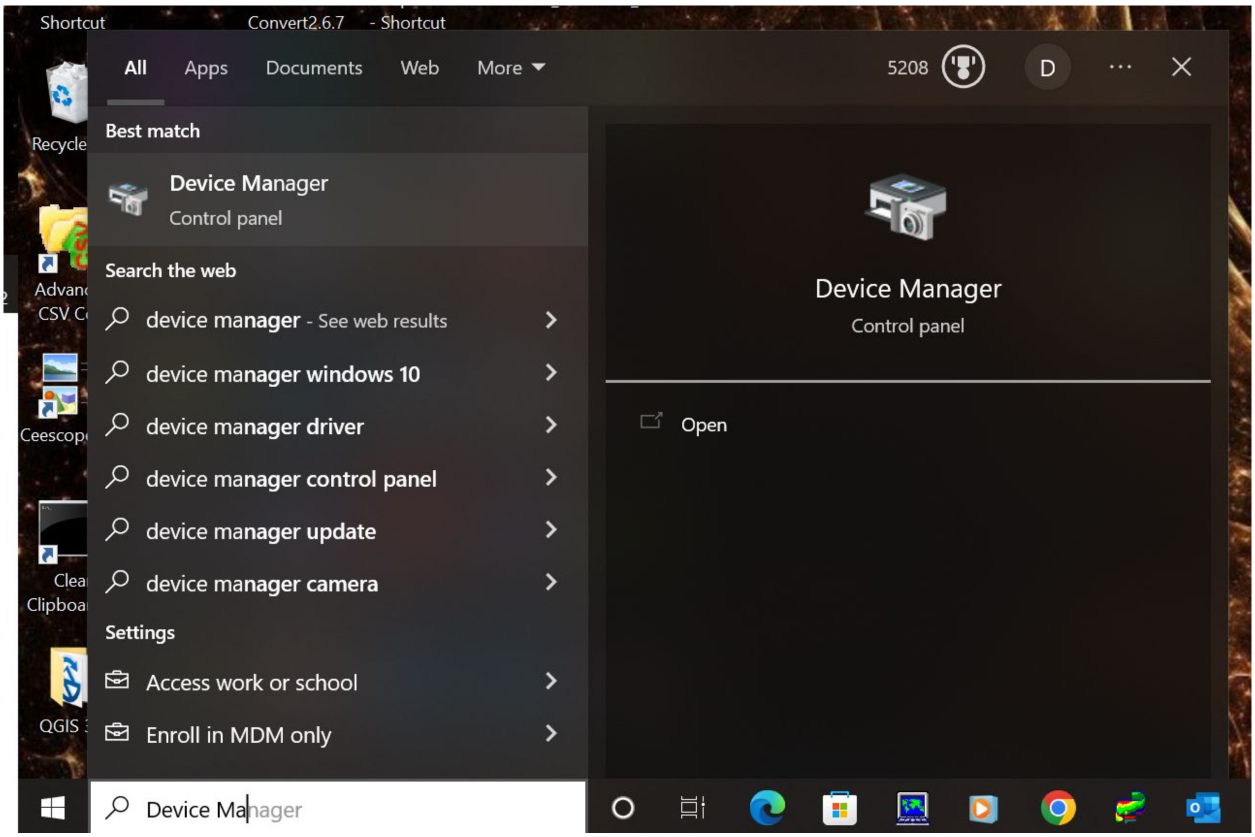
A temporary work around is to turn off or disconnect the GPS for every time you start up the computer and then re-enable once booting is well completed.

This problem can be permanently fixed. Instructions are given at:

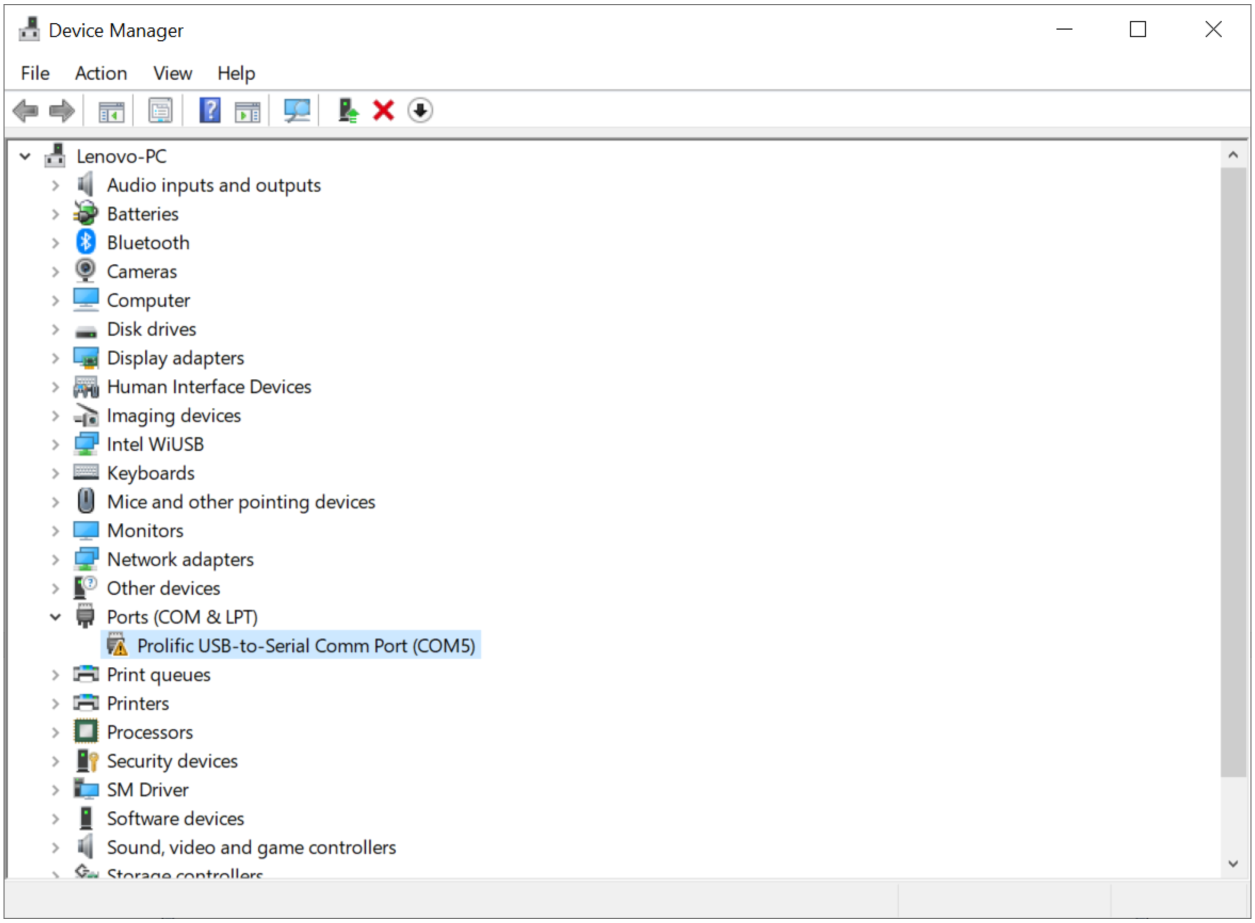
https://www.sealevel.com/support/how-to-fix-crazy-mouse-syndrome-with-usb-serial-adapters/

As 'Crazy Mouse' occurs when GPS is plugged in at boot up, you should start the computer without it connected then apply the following or you may get 'Crazy mouse'!

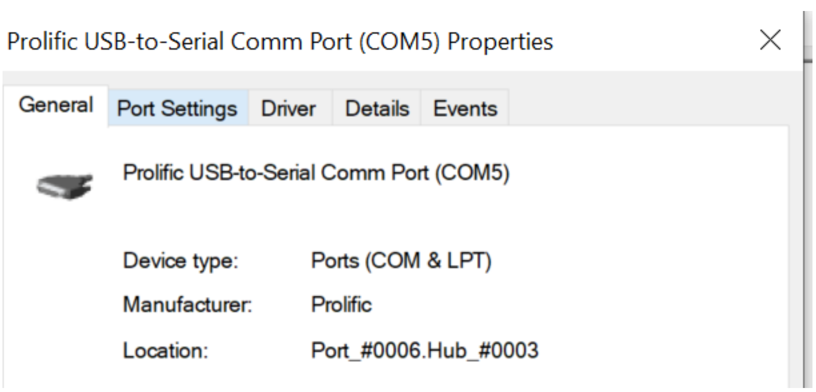
Start by running device manager, starting typing it in the search bar until it appears.

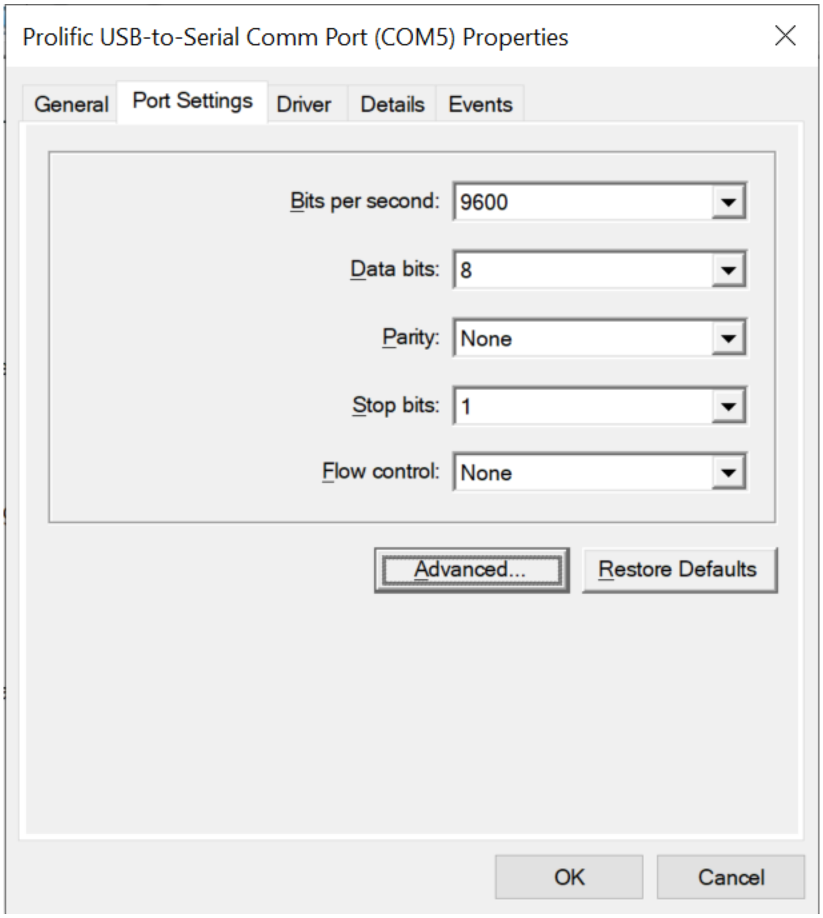


Assuming you have some RS232 devices pugged in, select and open the tree entry for COM ports.



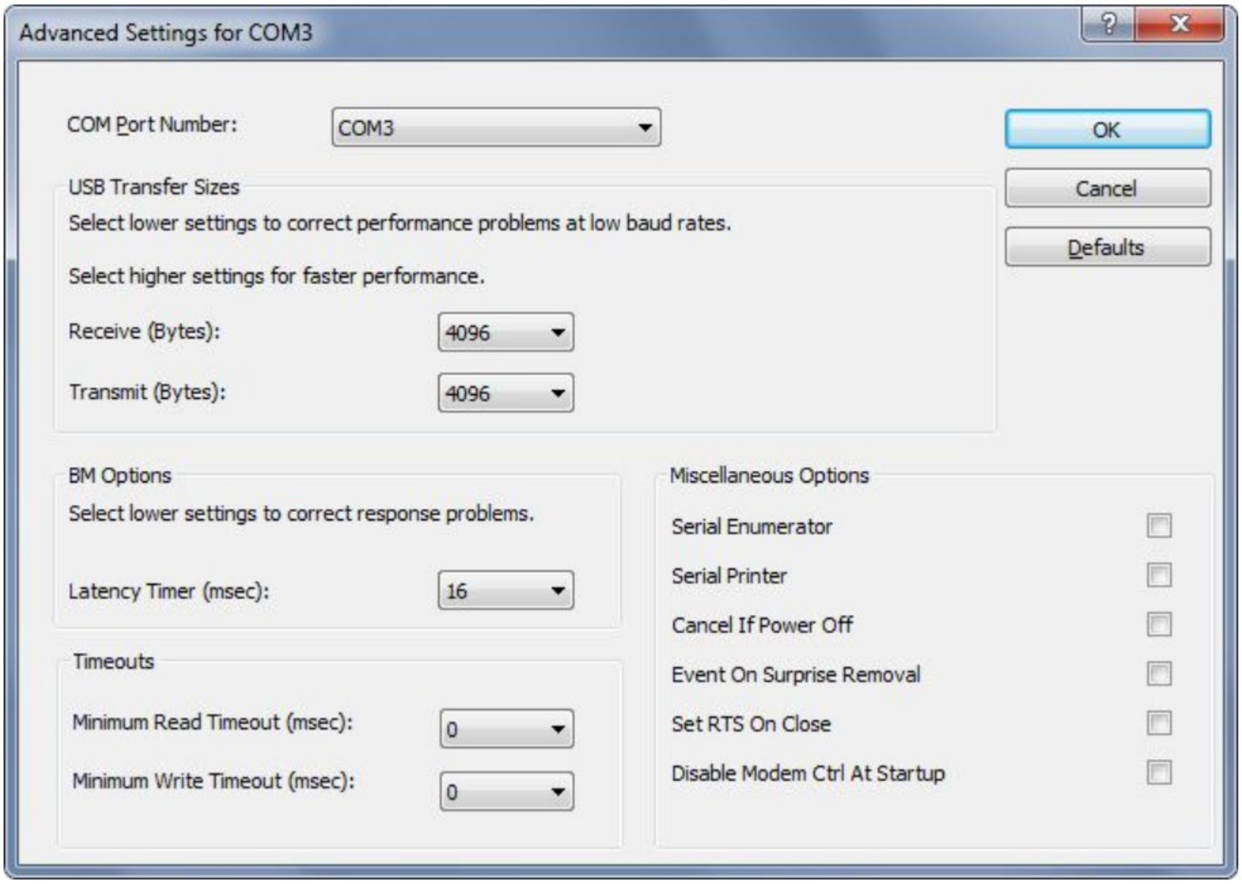
Double click the GPS port you want to address, like if you were changing port number assignments, and select the 'Port Settings' tab.



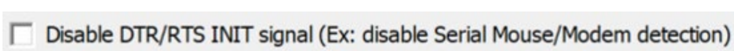


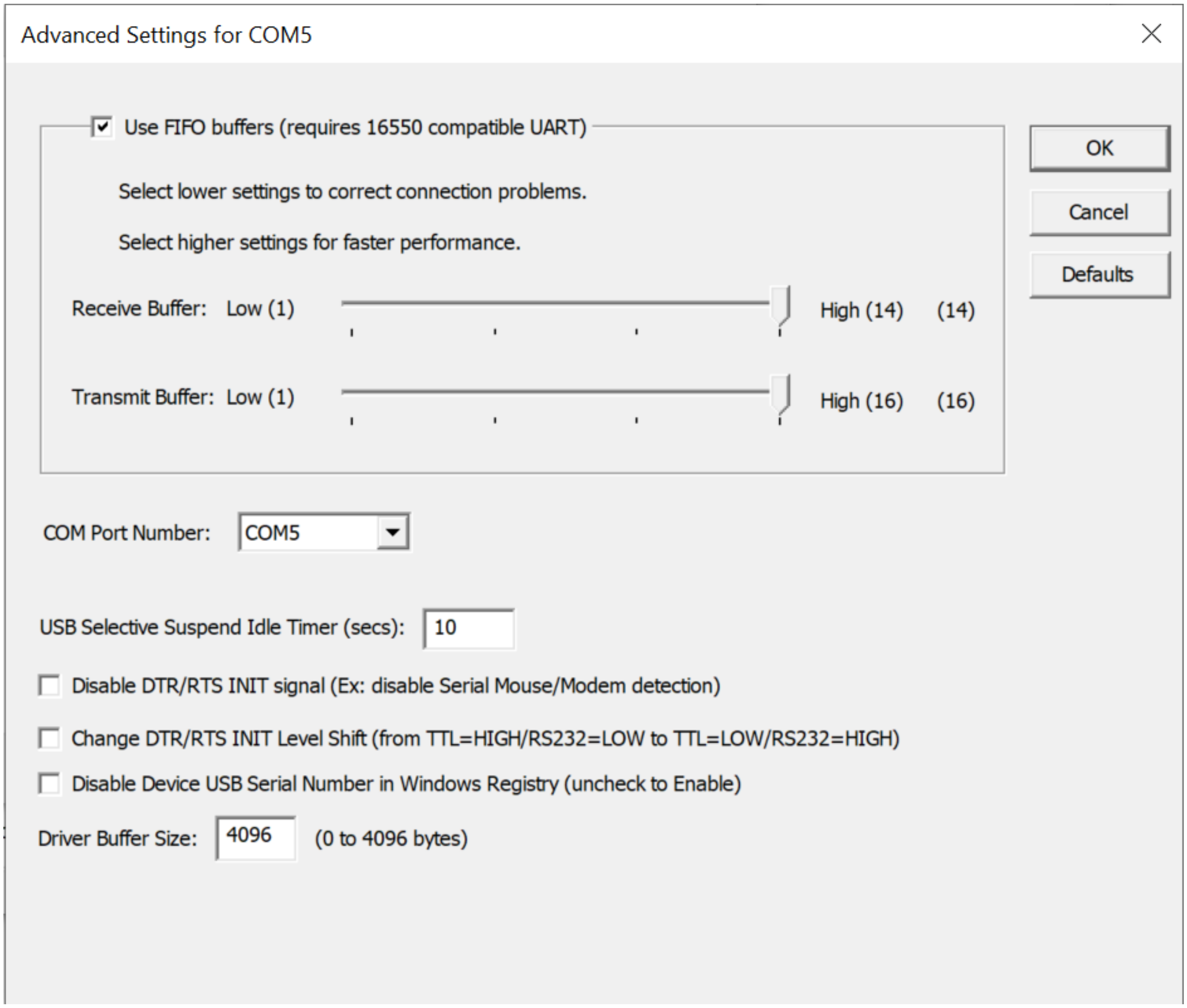
Click any 'Change settings' option if present, holding down shift key as you do to get administrative privileges so hidden controls appear, and the same with the 'Advanced' button.

Screens vary for different device drivers as suppliers recognize the problem and write slightly different shortcut fixes for the problem but here is the key screen – disable serial enumerator on this port.



I have encountered drivers that give you no option to Disable 'Serial Enumeration' leaving only registry related options as fixes. On another device as shown below the option to disable was:





There are also permanent fixes for particular COM port numbers possible by editing the Windows Registry. Microsoft have removed the documentation provided for these fixes.

ERROR DETECTING SERIAL PORT – TEMPORARY ERROR NOVEMBER 2022

Error detecting serial Port:

If not done already, I must mention the receiver will immediately, when AgTEM.exe is started, bring up an obtuse message if GPS is not plugged in and set up to communicate. It is displayed below.

Why is this? GPS is not set up or plugged in at startup.

November 2022 - this error message managed to get a hold again in late stage debugging, and it was not feasible to ask for another round of debugging and delays – the equipment needed shipping and the error only affects first impressions for new users. I expect it is easy to fix in the next round of debugging.

What should be done with this message? PRESS OK. Then if GNSS is not set up, once start-up has occurred, go into Diagnositics>Communication and set-up the com port for the GNSS receiver. If all that is wrong is that you did not have the GNSS plugged in when you started up then all you may need to do is plug in your GNSS.

There is a small box for GPS status at the bottom of the screen. The 'external GPS' box is meant to be green. This means that an available GPS source is assigned to supply coordinates during acquisition. If not green it may supply regardless but the intention is that it should need to be green – click and assign the external GPS to get it green if not already so.

Settings WILL BE REMEMBERED over shutdown/startup so when GNSS setup is completed and GNSS is plugged in this message will never bother you.

AGTEM PROTOTYPE TRANSMITTER NUMBER 2 – LOOP VOLTAGE MANAGEMENT

Prototype Transmitter No. 2 has had some interim loop voltage control added to provide this solution before the full dual moment transmitter is ready. As an interim measure, the new controls are concealed right down at the base of the connector compartment where they could be temporarily added and are unlikely to be bumped.

Prototype AgTEM transmitter No. 2 has a TDK Lambda i7A DCDC converter controlling loop power. It takes 19 to 32V input and ouputs constant voltage user controlled between 3.6V and 18V.

You can set this voltage and monitor input and output using on-off controls at the very base of the transmitter control panel once you turn on loop power. (The main transmitter controller does not need to be powered as the on-off controls are powered by the loop power).

The one-off controls include:

- a 4 digit display,
- a toggle switch,

- a momentary push button (redundant), and
- a knob.

Toggle the switch to display either **Loop Battery Voltage** (helpful in case you want to check if they are nearly flat), or **Output voltage**.

Output voltage is adjusted by rotating the knob. This arrangement is for constant voltage operation of the transmitter – constant current operation, that adjusts for loop resistance changes as the transmitter loop warms up, is only to be feasible in the future dual moment transmitter.

There are no checks to verify selected output voltage is suitable and will not cause overcurrent. Toggle the display to 'Output Voltage' and rotate the knob anticlockwise to bring voltage down to 5V (5V is the minimum with the 50K logarithmic potentiometer attached) then bring it up in voltage as far as you feel will be suitable. Attempt to transmit into the loop by selecting 'Acquisition Parameters' in AgTEM.exe and see what current you get. Keep doing this to optimize current by successive approximation. Allow a 15% margin as loop current will decrease as the loop warms up, or increase if started again on a colder morning. Avoid bumbing the concealed knob during acquisition.

MESSY AND LARGE SYSTEM REPSONSE

System response can be a mess when receiver loop components are unthoughtfully assembled. If not rigidly held in place, then system response varies as bumps are hit during survey. Prime problems are:

- 2 wire connector to pre-amp – although these can look fine, slight changes in contact resistance at the contacts can cause havoc.
- Any loop wiring passing near the ends of inductors on the pre-amp – This situation creates resonant oscillation in signal and high initial magnitude long time constant decay.

Putting too many turns in a receiver loop will overwhelm early time response – circuits used to switch in and out turns while leaving those turns in place have been found to be trouble free.

DUMB THINGS YOU SHOULD NEVER DO

This section is to be used for making Job Safety Analyses, Safe Work Method Statements, and other similar liability shifting documents. **It might also happen to help with safety**.

AgTEM survey is best achieved in a slow and steady manner. Remember the parable of the Hare and the Tortoise. Most disasters in cross country driving are averted by extremely slow driving so showing up early and slowly survey for long hours each day is the way to go even if almost everything else is done while driving.

Here is a list of dumb things you should never do:

1. **Get smacked in the head by an elastically restrained boom:** AgTEM-Wallaby booms are elastically held in place. If they are being dragged past a tree trunk or similar obstacle, or if someone is holding them back, and then they are released, then, if you get your head or other part of you in the path of the recovering boom then you can get smacked in the head.
2. **Shorting out the Anderson connector Y-leads:** Anderson connectors work in two directions – that is the plug is also the receptacle but + can only connect to + and – only to -. This may sound fool proof but it is not. AgTEM runs on 24V and often this is supplied by 12V batteries connected in series using Anderson connector wiring looms. Additional connectors may be added in Y-leads for battery charging. Series connection involve connecting + and – terminals and if Y-leads and series connections are sufficiently confused it is possible to short circuit the batteries via 8-Guage wire. It is best to bolt together charging leads or label clearly to prevent them being confused. We have adopted Blue Anderson connectors for 24V DC to reduce confusion leaving the common grey ones for 12V.
3. **Losing the winch handles:** The AgTEM-Wallaby and Float trailer have winches with removable handles. When used they can be left on so they fall off when travelling down the highway. When you get them out, devise a plan to help you to remember to remove and pack them when finished.
4. **Using powerful heavy towing vehicles:** Poor attention while driving AgTEM-Wallaby will end up with a destroyed Wallaby. This is especially so with heavy powerful towing vehicles like larger American pickup trucks. Avoid using large powerful vehicles for towing AgTEM. Wheels and wheel bearings eventually wear out and if left unchecked can result in a dragged Wallaby – the high friction forces adding to strains which may go undetected if the driver cannot feel the added dragging Wallaby. Further trouble occurs when reversing – AgTEM-Wallaby cannot tolerate large reversing forces – it is easy to fold the drawbar upwards with a powerful vehicle.
5. **Driving across steep side slopes:** where AgTEM-Wallaby may drift sideways down onto steeper slopes will result in the Wallaby overturning. This happens on roadside drain crossings and, sharp corners on reservoir walls. Once the Wallaby drifts down the wall it may be difficult to get it to stop skidding sideways.
6. **Sleep driving:** Driving AgTEM-Wallaby often involves 10 hours or more of non-stop driving when aiming at high productivity. This is a wide vehicle and there are plenty of obstacles to watch out for and react to at a second’s notice so it is a very tiring driving experience. Know limits and get a good night of sleep.

Figure 147 AgTEM driving can seem so easy you could do it while asleep but any off road driving can involve sudden and catastrophic encounter of obstacles that are hard to notice.

7. **Driving without watching all clearances:** The AgTEM-Wallaby front loop protrudes 6m in front of the towing vehicle. When turning sharp corners it swings very rapidly sideways. Managing this alone at corners with lots of obstacles just requires concentration but forgetting there is a 6m wide cart behind that also needs managing will result in one or the other getting damaged. The front loop may not survive a head on collision with a power pole or similar obstacle while you check your rear view mirror to watch Wallaby booms brush against trees.
8. **Drive fast in long grass:** It is common for long grass to hide tree stumps that can impact between protection bars and wheels, taking out steering apparatus in the process, even when idling in first gear in low range. Avoid long grass by surveying at a different time of year or after burning off or having tracks slashed if possible. Other perils in long grass include: logs, star pickets, fallen tree branches, fencing wire, rocks, erosion trenches and animal burrows.

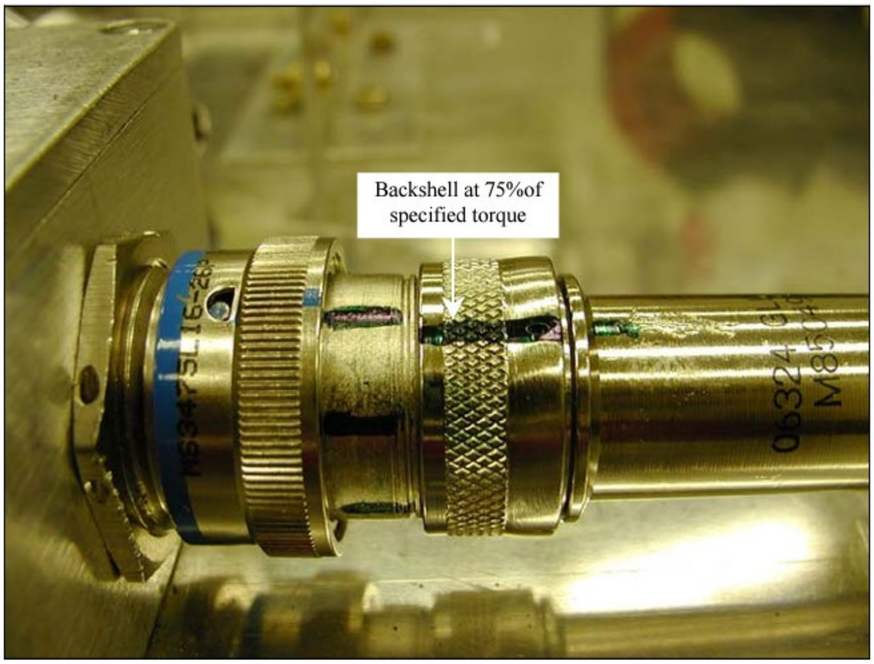
Figure 148 A great example of what you WILL hit if you drive in long grass. This hidden stump was hit in 2nd gear low range. It cost US$700 to repair the steering arm and bash bar damage. It hung up the vehicle – this photo is after winching and reversing.

9. **Turning corners in long grass:** AgTEM will follow the towing vehicle exactly if travelling in a straight line, and be protected as any obstacle will hit the towing vehicle protective bash plates however if you turn in long grass it will potentially hit a hidden tree stump or log with the full force of the towing vehicle pulling. Always seek an area of sparser or lower vegetation in which to turn around.
10. **Belligerent attitude to booms brushing obstacles**: Wallaby booms will brush past many obstacles but there are some that will catch them. These include: tall gate posts with barbed wire dags sticking upwards, broken-off branch stubs on tree trunks and branches of plants such as box-thorns that have right angle joins. It is best to either watch very carefully, being prepared to suddenly stop, when brushing past such obstacles, or tie booms back then drive past, or get an assistant to walk behind and pull rigging backwards to fold booms when passing numerous obstacles. The method of an assistant pulling is most efficient.
11. **Swinging front boom into traffic:** The front boom extends 6m in front of the towing vehicle and can be swung sideways very rapidly. When working on the sides of trafficked roads a sharp turn can subtly swing the front loop into the path of passing traffic.
12. **Wallaby collapse on very steep slopes:** When descending steep slopes, in excess of about 40 degrees, the AgTEM-Wallaby rear booms will fall across the back of the cart. To descend such slopes, attach a weight to the tip of the centre rear boom or have an assistant walk behind to hold the centre rear boom down.
13. **Using vehicle lights while surveying:** Warning lights use while surveying adds noise. Modern LED lights run with DCDC power converters that generate electromagnetic interference – lots of it. Other circuits in vehicles may transmit noise up the lights wiring loom even when the lights are not in use. Always keep the

lights wiring loom disconnected when not needed. Ideally just use warning lights when transiting across and along trafficked roads. If it must be used while surveying then test with and without the loom attached and lights going and watch what difference it makes to the data.

14. **Oblivious survey ignoring real time data:** Inattention to data will result in expensive repeat surveying and often also equipment damage. Typically the first alarm that a boom has been torn off the cart or similar will be a sudden change in the real-time data display. When driving, constantly and diligently cycle through numerous observations including real time decay curve monitoring. Blindly surveying on and on with a faulty or broken system will just create a lot of pointless cost. Many cable and connector flaws can occur, especially with the rigors of off-road driving, and some only become relevant once condensing humidity develops in cables and connectors – usually the morning after wet weather. Read all the notes on sources of noise and never continue with a survey once unwanted noise is detected without a plan of action. In worst cases the plan may be to continue with the noise to allow it to develop more and to create a bigger mess to help with diagnosis. In most cases, stopping, and chasing the problem with a multimeter, and trial-and-error type tests will be most appropriate.
15. **Replace weak links with strong ones:** All the AgTEM rigging is held in place by cable ties, which snap at a designed stress and booms are held in their sockets by elastic restraints so they can pop out if caught and pulled inappropriately. It is easy for a fool to tie rigging directly to booms or to other rigging – if they do this and something gets caught during survey then costly damage occurs instead of a simple cable tie failure.
16. **Putting Loctite near polycarbonate:** Loctite type anaerobic thread-locker and polycarbonate are not compatible. Loctite will make the polycarbonate brittle and it will craze and fracture. All the panels in the AgTEM transmitter and receiver cases and many panels on the structures are made of polycarbonate. If you need to stop a screw coming loose then either be very careful to apply Loctite just to metal parts, use a Nylock nut, or use 'liquid electrical tape' i.e. PVC pipe glue as a substitute.
17. **Galling stainless screws:** There are many stainless steel screws in AgTEM electronics and other parts. Failure to use anti-seize compound on these parts will cause them to gall (basically welding the nut to the bolt). Even with the lubricant there is risk of galling if wrench speed is fast or screws are tightened considerably.
18. **Failing to configure a survey appropriately:** Success or failure of a survey is largely determined by suitable configuration when first reaching a site. Knowledge of anticipated resistivities and testing at the site using various configurations until one is found to give decay curves covering features of interest is very important. It is no use masking off all shallow response by going for maximum power or all deep response by using low current and only one loop turn on the transmitter and few loop turns in the receiver.
19. **Abusing the liquid cooling:** The liquid cooling system in the transmitter has swivel joins – if a sidewards force is applied to them then some types of them leak until that force is removed. If too much coolant escapes then the pump runs dry, especially if turned upside down. Transmitters with the 12mm diameter transparent tubing easily allow viewing of bubbles in the line but coolant gradually evaporates through the walls of these tubes. Diligence is required in refilling the coolant.
20. **Running too many other services on the AgTEM computer:** We have found that quite demanding programs such as high speed USB oscilloscope can run on the computer while AgTEM.exe is running but trouble free AgTEM.exe operation cannot be guaranteed under such competition for resources. It is known that running Wi-Fi links in the background can stop AgTEM.exe when transmitting at 100Hz or 200Hz repetition at high amperage. Similarly – use of anti-virus software should be considered only with reservation – keeping the AgTEM computer stand-alone off the internet during survey is most appropriate. An exception may occur when using TeamViewer or similar to get technical support but consideration of alternatives such as mobile phone camera should be considered.

21. **Forgetting to tie survey together using tie lines:** Drift can occur due to unintentional and unavoidable reasons and for this tie lines are important. They reveal drift and allow correction to occur. Drift may happen if the cart gets suddenly deformed, if connectors or condensation cause problems, if a very cold start results in thermal drift until the system warms up, or for a myriad of subtle reasons that are as yet unidentified. Most surveys will tolerate typical drift but a dense grid survey over a subtle or deep feature will not.
22. **Neglecting to measure system response at a resistive site:** There are many ways of configuring AgTEM and if a system response for the configuration used is not obtained then processing will be affected. System response should be obtained periodically because of two reasons: 1. No site is purely resistive so modelling with the most resistive response from one site may cause artefacts at another that is more resistive, and 2. Structural and wiring deformation can slightly change system response over time.
23. **Allowing slack on ropes holding the front booms:** Mutual inductance nulling of AgTEM Wallaby is highly susceptible to position of the wire leading out to the front boom tips. During survey this wire must remain taught as must the 'stop' rope that extends backwards from the tips. Loop connectors are elastically held out near the boom tips for this reason – if this was not so then system response would change all the time. Similarly, the elastic cords holding the booms forward must always be able to keep the 'stop' ropes taught.
24. **Not documenting configuration:** Tinkering with damping resistors, amplification, cut off filters, DCDC converter fine adjustment, receiver or transmitter loop turns, repetition frequency, Nyquist filter or any other critical parameter without documenting and repeat of measurement of system response will lead to data that cannot be accurately modelled.
25. **Rotate the back shell of connectors:** Milspec connectors, Binder connectors and Hirschmann connectors have some durability but also a bad design flaw. If you rotate the back shell while trying to connect the bayonet connectors then you risk shearing off all the fragile wires inside. This at best will lead to intermittent and confusing equipment behaviour. If a back shell does become loose then screw the bayonet connector to a mating connector and get a wrench or strong pliers and screw the back shell very tight again and take note and/or label for future reference in case intermittent problems have developed. The back shell may be fixed on with Locktite to prevent the hazard but then it becomes difficult or impossible to both test and maintain next time cable damage occurs at the back of the strain relief, as it tends to do. Note that on the receiver, where three loop cables can be connected, a short generated in one cable can destroy the data coming in through other cables. Locktite use is recommended even though the MilSpec specifications, which were written before Locktite was invented, do not mention this requirement.



26. **Calling for help without double checking a diagnosis:** We can all be prone to lacking self-confidence in our ability to solve technical problems. A quick check through rudimentary fundamental tools we understand may lead to solutions that are needed. Further it is common for tests to accidentally mislead as electrical testing is generally done in an ad-hoc way to save time. Repeating cable continuity tests, cable swaps and the like often resolves problems, or at least leads to confidence in change of focus of investigation. Almost all AgTEM faults that occur turn out to be very simple retrospectively.
27. **Leaving the equipment in storage out in the weather:** This is expensive plastic equipment that, despite measures to the contrary, will degrade when left out in weather, especially intense sunlight.
28. **Reversing without care using a powerful vehicle:** AgTEM-Wallaby is designed to glance over obstacles going forward but wheel wells will catch on obstacles when reversing. Further, reversing applies tensile forces to the top ropes of the drawbar assembly which are applied at an acute angle which becomes more acute as reverse force is applied – up to the point where they apply infinite force and something gives then the cart tilts upward. **REVERSE ONLY WITH LIGHT FORCE TO AVOID CRUMPLING THE CART.**

Here is a list of more generic mistakes made on AgTEM surveys:

1. **Half hitching a trailer:** When hooking up a float trailer, DO NOT GET DISTRACTED. The task must be finished and the hitch fully clamped over the tow ball, jockey wheel removed and stored, safety chains connected, and electrical connection made.
2. **Forgetting the shovel and jack:** Surveying alone means that often vehicle recovery alone is necessary. A shovel and high lift jack are the usual tools that result in effective recovery.
3. **Spinning yourself into a hole:** Remember that regardless of how powerful your vehicle is, boggy ground is weak and can only be treated with gentle care if you want to get out of a bog. Abort or reduce application of power as soon as spinning wheels start to dig a hole. A rocking motion may then result in escape or a vehicle lift and ground preparation may be necessary prior to driving away AND MUCH EASIER THAN IF A WHEEL HAS SPUN A HOLE IN THE GROUND.
4. **Driving in sand without deflating tyres:** Sand driving is very affected by tyre pressure. Deflate to around 20psi if bogging is occurring.

5. **Neglecting 4wd:** A very common foolish reason for vehicle bogging is forgetting to engage 4wd or free-wheeling hubs (both of them). Many embarrassed drivers can attest to this.
6. **Vehicle recovery by halves:** Vehicle recovery is exhausting and many try to take a short cut by not preparing sufficiently. Then spinning wheels they increase the problem. If the vehicle will not move at first application of power then preparation was insufficient.
7. **Ignoring fencing wire that catches under a vehicle:** Fencing wire typically winds around drive shafts and axles once caught – destroying brake lines and rubber seals. Stop immediately when fencing wire left in long grass catches on the underbody and fully remove it.
8. **Turning corners over fallen timber:** When in wooded country the ends of fallen logs pose a hazard to tyre sidewalls and it is common for rear wheel sidewalls to get slashed on hard timber as the vehicle is turned regardless of how many plies the tread has. This generally requires expensive complete tyre replacement. Old style ‘rag’ tyres did not have this problem. Hard eucalyptus timber is particularly problematic.
9. **Surveying without scheduled communication with a responsible person:** It is easy to get stuck without help when surveying remotely. Scheduled communication with a responsible person will result in help arriving should communication later be impossible when in trouble.
10. **Ignoring uneven ground on slopes:** A rabbit burrow or other uneven ground in long grass on a side slope can be encountered such that a vehicle tips and rolls over. Always be conservative on side slopes in long grass.
11. **Starting late and working into dusk when tired:** Daylight and wakefulness are both critical to safe operation and vehicle recovery. Keep risky and difficult driving early in the day and start early to avoid a vehicle recovery situation extending into dusk and night.

MAINTENANCE

Various maintenance tasks recommended include:

1. Transmitter liquid coolant refill/change.
2. Periodic battery charging when the system is not in use.
3. Visual check – rivets and bolts.
4. Chaffed rope replacement.
5. Wheel replacement.
6. Supplies replenishment.
7. UV and weather damage.

TRANSMITTER LIQUID COOLANT REFILL/CHANGE

EKWB recommends changing coolant every 12 months.

Coolant top-up will be required regularly to prevent air in pump or airlocks in pipes from burning out the pump. Coolant evaporates slowly through tubing walls and may leak if swivelling joins are flexed.

There is a fill up port provided. Make up coolant (EKWB coolant recommended) and pour it in.

If in the field you may want to top up with water but this will dilute the coolant and corrosion inhibitors so make sure that more coolant is promptly ordered and the diluted coolant is replaced soon after.

PERIODIC BATTERY CHARGING

LiFePO4 batteries do not leaks internally at a fast rate like lead acid batteries but charging every few months still is important. LiFePO4 batteries are best left stored at partial (30-50%) charge. Once over-discharged they may not recover well. BMS systems will gradually discharge the batteries.

VISUAL CHECK – RIVETS AND BOLTS

Every week of survey a visual check of rivets and bolts is appropriate – some may fail under harsh use but the system is designed so that strains will then be taken up by other parts of the structure. Do not then continue to use it harshly without changing the broken parts as then there will remain no contingency.

CHAFFED ROPE REPLACEMENT

Over years, ropes will chafe in clutches and other wear points.

WHEEL REPLACEMENT

Wheels will not last forever even when solid filled. Bearings may fail or the tyre wear away – especially on side-slope survey.

Wheels in Australia are a Starfire Rim

There is an almost identical mould in the USA owned by https://skywaywheels.com/index.htm and they also make closed cell urethane tyres and flanged hubs both of which we find essential

Tyres must be Kevlar bead

Schwalbe Rocket Ron 24 x
2.10 Addix Performance Line

BikeBox code TROCRON50754FP A$29.95 Each

Schwalbe Tube AV10 20
Schrader; 24" x 1.5 - 2.5

(40 to 62 - 507) 165g

If Tannus Armour inserts are used then inflatable tubes can be added with significant weight reduction. Use 600% thicker tubes with anti-flat sealant inside. Avoid using in areas with Box Thorns or similar inch long woody thorns that flatten pickup truck tyres too. With Tannus Armour it is appropriate to use larger tubes that can run at lower pressure – Schwalbe Fat Albert 24 x 2.40 (62-507).

WHEEL BEARINGS

Wheel bearings can wear out although some have been known to last over 500 kilometres and are still going. If substituted with cheap wheelbarrow bearings then expect failure within a few hours.

Appropriate replacement bearings are Brand:NSK Identifier:6202DDUCM. The last two letters 'CM' seem to be optional. Other markings on the bearing packaging are (1307 or 1410 not sure what that number means) NS7S8

15mm I.D. 35mm O.D.

SUPPLIES REPLENSISHMENT

Probably most important is replacement of supply of wheels, cable ties and electrical tape. Cable ties are used as weak joins. Electrical tape is used to fix cables in position during transit between jobs. Wheels wear out periodically and a replacement supply is very important.

UV AND WEATHER PROTECTION

Keep the equipment out of intense sun whenever not in survey. Most parts have some form of UV protection, but being plastics none of these are perfect. Eventually elasticisers will evaporate and polymer chains break down to powder. The Kevlar ropes have a UV resistant sheath that is effective. Fibreglass bolts will discolour. Tubing will fade and lose strength eventually.

Keep the equipment out of intense daily temperature cycles as condensing humidity will build up and work into cable sheaths and connectors. Action of expansion of ice in cracks and pores in fibreglass can gradually break it up.

KEEP AIRBAGS INFLATED LIGHTLY

The airbags will try to expand gradually over time if inflated to high pressure. If pressure is too low they will crease and crumple and this forms weakness and bags may then burst as shown below. Sleeves are available for stopping the gradual expansion and should be fitted.

Figure 149 An airbag that burst after being left crumpled at low pressure.

The inflation tube insertion point is prone to leakage if forces are put on the tube – take care to prevent deflection especially when left at low pressure.

Deflated airbags will lead to a second problem in that sidewards slumping of the cart will occur – within the slack and play of joins – this further exacerbates airbag crumpling problems.

MISCELLANEOUS APPENDICES

TIME GATES

The default time gate file used by AgTEM is TerraTEM24_Inter.chn. Other files are useable but may not be supported by some post processing software – beware. Other time gate files can be viewed in a text editor or MS Excel – accessed in the 'C:\AgTEM\Channel Files' directory.

The gates in TerraTEM24_Inter.chn are listed below. Notice that only the first 73 are likely to be used in AgTEM surveys.

Note also that the AgTEM system uses a 625 KHz Sigma-Delta 24 bit A/D converter. This means that earlier and narrower gates are possible. To improve resolution the default operation is at 156.25Hz with gate width of 6.4uS. A different set of time gates is needed for 312.5 Hz or 625 Hz operation. Facilitation of 312.5 Hz operation is planned for shallow projects.

terraTEM24_Inter

NUMTIMES=198

GATE	DELAY	WIDTH	GATE	DELAY	WIDTH	GATE	DELAY	WIDTH
1	0.0036	0.0064	31	0.8324	0.0896	61	13.722	1.2288
2	0.01	0.0064	32	0.9252	0.096	62	15.002	1.3312
3	0.0164	0.0064	33	1.0244	0.1024	63	16.3844	1.4336
4	0.0228	0.0064	34	1.1332	0.1152	64	17.8692	1.536
5	0.0292	0.0064	35	1.2548	0.128	65	19.4564	1.6384
6	0.0356	0.0064	36	1.3892	0.1408	66	21.1972	1.8432
7	0.042	0.0064	37	1.5364	0.1536	67	23.1428	2.048
8	0.0484	0.0064	38	1.6964	0.1664	68	25.2932	2.2528
9	0.058	0.0128	39	1.8692	0.1792	69	27.6484	2.4576
10	0.0708	0.0128	40	2.0548	0.192	70	30.2084	2.6624
11	0.0836	0.0128	41	2.2532	0.2048	71	32.9732	2.8672
12	0.0964	0.0128	42	2.4708	0.2304	72	35.9428	3.072
13	0.1092	0.0128	43	2.714	0.256	73	39.1172	3.2768
14	0.122	0.0128	44	2.9828	0.2816	74	42.5988	3.6864
15	0.1348	0.0128	45	3.2772	0.3072	75	46.49	4.096
16	0.1476	0.0128	46	3.5972	0.3328	76	50.7908	4.5056
17	0.1636	0.0192	47	3.9428	0.3584	77	55.5012	4.9152
18	0.1828	0.0192	48	4.314	0.384	78	60.6212	5.3248
19	0.2052	0.0256	49	4.7108	0.4096	79	66.1508	5.7344
20	0.2308	0.0256	50	5.146	0.4608	80	72.09	6.144
21	0.2596	0.032	51	5.6324	0.512	81	78.4388	6.5536
22	0.2916	0.032	52	6.17	0.5632	82	85.402	7.3728
23	0.3268	0.0384	53	6.7588	0.6144	83	93.1844	8.192
24	0.3652	0.0384	54	7.3988	0.6656	84	101.786	9.0112
25	0.41	0.0512	55	8.09	0.7168	85	111.2068	9.8304
26	0.4644	0.0576	56	8.8324	0.768	86	121.4468	10.6496
27	0.5252	0.064	57	9.626	0.8192	87	132.506	11.4688
28	0.5924	0.0704	58	10.4964	0.9216	88	144.3844	12.288
29	0.666	0.0768	59	11.4692	1.024	89	157.082	13.1072
30	0.746	0.0832	60	12.5444	1.1264	90	171.0084	14.7456

GATE	DELAY	WIDTH	GATE	DELAY	WIDTH	GATE	DELAY	WIDTH	GATE	DELAY	WIDTH
91	186.5732	16.384	121	2516.378	209.7152	151	33973.66	2936.013	181	456340.1	40265.32
92	203.7764	18.0224	122	2739.2	235.9296	152	37014.53	3145.728	182	498283.1	43620.76
93	222.618	19.6608	123	2988.237	262.144	153	40265.11	3355.443	183	543581.6	46976.2
94	243.098	21.2992	124	3263.488	288.3584	154	43830.27	3774.874	184	592235.5	50331.65
95	265.2164	22.9376	125	3564.954	314.5728	155	47814.86	4194.304	185	644244.9	53687.09
96	288.9732	24.576	126	3892.634	340.7872	156	52218.88	4613.734	186	701287.4	60397.98
97	314.3684	26.2144	127	4246.528	367.0016	157	57042.33	5033.165	187	765040.8	67108.86
98	342.2212	29.4912	128	4626.637	393.216	158	62285.21	5452.595	188	835505.2	73819.75
99	373.3508	32.768	129	5032.96	419.4304	159	67947.52	5872.026	189	912680.3	80530.64
100	407.7572	36.0448	130	5478.605	471.8592	160	74029.26	6291.456	190	996566.4	87241.52
101	445.4404	39.3216	131	5976.679	524.288	161	80530.43	6710.886	191	1087163	93952.41
102	486.4004	42.5984	132	6527.181	576.7168	162	87660.75	7549.747	192	1184471	100663.3
103	530.6372	45.8752	133	7130.112	629.1456	163	95629.93	8388.608	193	1288490	107374.2
104	578.1508	49.152	134	7785.472	681.5744	164	104438	9227.469	194	1402575	120796
105	628.9412	52.4288	135	8493.261	734.0032	165	114084.9	10066.33	195	1530082	134217.7
106	684.6468	58.9824	136	9253.479	786.432	166	124570.6	10905.19	196	1671011	147639.5
107	746.906	65.536	137	10066.13	838.8608	167	135895.2	11744.05	197	1825361	161061.3
108	815.7188	72.0896	138	10957.41	943.7184	168	148058.7	12582.91	198	1993133	174483
109	891.0852	78.6432	139	11953.56	1048.576	169	161061.1	13421.77			
110	973.0052	85.1968	140	13054.57	1153.434	170	175321.7	15099.49			
111	1061.479	91.7504	141	14260.43	1258.291	171	191260.1	16777.22			
112	1156.506	98.304	142	15571.15	1363.149	172	208876.1	18454.94			
113	1258.087	104.8576	143	16986.73	1468.006	173	228169.9	20132.66			
114	1369.498	117.9648	144	18507.16	1572.864	174	249141.5	21810.38			
115	1494.016	131.072	145	20132.45	1677.722	175	271790.7	23488.1			
116	1631.642	144.1792	146	21915.03	1887.437	176	296117.7	25165.82			
117	1782.375	157.2864	147	23907.33	2097.152	177	322122.3	26843.55			
118	1946.215	170.3936	148	26109.34	2306.867	178	350643.6	30198.99			
119	2123.162	183.5008	149	28521.06	2516.582	179	382520.3	33554.43			
120	2313.216	196.608	150	31142.5	2726.298	180	417752.5	36909.88			

TOWING OPTION

AgTEM towing options can make or break jobs' viability.

Compare:

Walk Wallaroo Need 2, or preferably 3 persons – not the fastest approach for long hours of operation.

AgTEM-Tractor 50kg Similar to CyberClydesdale but lighter – can walk in front regulating speed by walking speed. Good for Wallaroo on small jobs and/or difficult terrain. Slow and uses lots of batteries for AgTEM.

CyberClydedale 100kg Carry in dual cab ute ¼ of load space along with other freight. Do not need 4wd ute for mobilizing – just a small ute or van will do with Wallaroo on roofrack. https://curlysag.com/cyber-clydesdale-electric-two-wheel-tractor/#top

Argo 6x6 500kg Needs dedicated trailer or single cab ute. Causes electrical interference – yet to solve? Safety and compliance at mines is feasible but can be time consuming.

Quadbike 500cc petrol 500kg Needs dedicated trailer or single cab ute. May cause electrical interference?

Quadbike diesel 600kg no petrol allowed on Australian mines. No quadbikes allowed on mines. Needs dedicated trailer or single cab ute – no other freight space – need bigger ute engine to cart.

ATV diesel 1000kg no petrol allowed on mines and all diesel models are the bigger premium models. Need dedicated towing trailer and big ute engine and lots of fuel to mobilize.

Swincar 250kg and excellent bumpy ground traversing. Charging problems. Carry in a van.

Tow with ute zero extra weight but modern 4wd compliance means huge off-road restrictions, wear-and-tear costs and grass fire risk with anti-pollution gear. Cannot use ute as 2nd vehicle with 2nd person, nor as contingency emergency vehicle when have 2 man crew. Careless driving of bigger more powerful utes can easily destroy AgTEM without the driver noticing anything happened.