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Basics of the GPZ 7000 Technology: Zero Voltage Transmission (ZVT)

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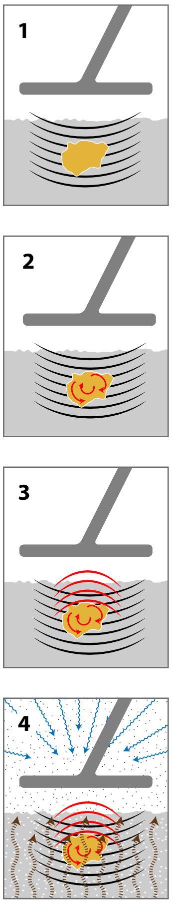
Basic Metal Detection Principles



Simplified representation of the basic principles of metal detection.

All metal detectors transmit (generate) changing magnetic fields from their coils (1).

When these changing fields interact with metal targets they cause electrical currents to flow in the targets called eddy currents (2).

These eddy currents then generate their own magnetic fields that are different to the magnetic field transmitted by the metal detector coil (3).

The transmitted field also causes soils to generate magnetic fields different to those transmitted by the metal detector and different to those from the target's eddy currents (4).

The metal detector coil senses (receives) the magnetic field from the target eddy currents, and also the magnetic field generated by the soils. The coil actually measures how fast the magnetic field changes rather than how strong the field is. For example, it will not respond to a fixed unvarying magnetic field even if it is strong.

The coil will also detect changing fields from the environment, such as electromagnetic interference from nearby mains electricity and even lightning from thousands of kilometres away (4).

The soil signals have predictable types of responses caused by the transmitted magnetic field, and thus can be recognised by the processing electronics and cancelled out; this is called ground balancing. Any received magnetic signals in response to the transmitted field that are different to those directly transmitted and also different to those from soils are assumed to be caused by a metal target and are reported to the operator.

Ground Balancing

The capability of metal detectors to effectively ground balance varies considerably between technologies and models. Many detectors only provide approximate ground balancing rather than true ground balancing.

Signals generated in soils by the transmitted magnetic field mostly consist of three different types:

Reactive Soil Component – By far the largest; a signal that is identical in form to the transmitted signal. This is called the Reactive Soil Component and often referred to as the X component.

Viscous Remanent Magnetism Component – Signals from microscopic magnetic particles, about a mere 30 millionths of a millimetre in size, produce a complex signal that can be described as being a 'delayed response' from the transmitted field and dependent on all of the past transmitted field, but much more related to the recent transmitted field than further back in time. This is called Viscous Remanent Magnetism (VRM). It is usually responsible for most of the ground signals that may not be completely ground balanced, if any.

Saline Component – Eddy currents in saline soils often cause most of the un-ground balanced ground signals in higher frequency VLF gold detectors (more so than VRM). However, in PI and ZVT detectors, the receive signal processing is designed so that signals from saline eddy currents are only noticeable from more highly saline soils. These eddy currents occupy a large volume of ground and can be determined if present because they cause un-ground balanced (audio) signals if the coil is moved up and down several feet above the soil surface (except if a Minelab GPX series or SDC 2300 gold detector is set to a 'salt cancelling' ground balancing mode).

Ground Balance Technology Comparison

The biggest problem is trying to cancel out the signals from the soil, which can be very large compared to the weak signals from deep metal targets.

Very Low Frequency (VLF) – VLF sinewave detectors have a major disadvantage in having to ground balance out all of the soil signals simultaneously (all three soil components above).

Pulse Induction (PI) – PI metal detectors have a major advantage of not even detecting the major soil signal; the X component, but only the saline components, but this is mostly insignificant, and the VRM component , which is just a very small percentage of the X component. This makes the capability of PI technology to ground balance far more accurate than VLF detectors. A disadvantage of PI is its lesser ability to detect very small nuggets compared to VLF detectors.

Another disadvantage of PI is its capability at detecting very large nuggets compared to CW metal detectors, such as ZVT. CW means Continuous Wave and includes all technologies that do not have zero transmit periods (almost all technologies other than PI).

Zero Voltage Transmission (ZVT) – ZVT has the same major advantage as PI for ground balancing in not detecting the major soil component X, but has the same advantage of CW metal detector technologies compared to PI for detecting very large nuggets because ZVT is CW (unlike PI that is not CW), and also the same advantage as PI for being relatively insensitive to saline soils compared to VLF.

What is the ZVT transmitted field, and how does it differ to PI?

Both ZVT and PI measure a signal (receive signal) immediately after a very rapid change in magnetic field. During the receiving (measuring) period, PI does not transmit a magnetic field at all, whereas ZVT transmits an exceptionally constant magnetic field (until the next very rapid change in magnetic field occurs). The ZVT transmitted field alternates between transmitting very steadily in one direction; e.g. North Pole pointing into the ground; then rapidly switches to South Pole pointing steadily into the ground, then back to North and so on.

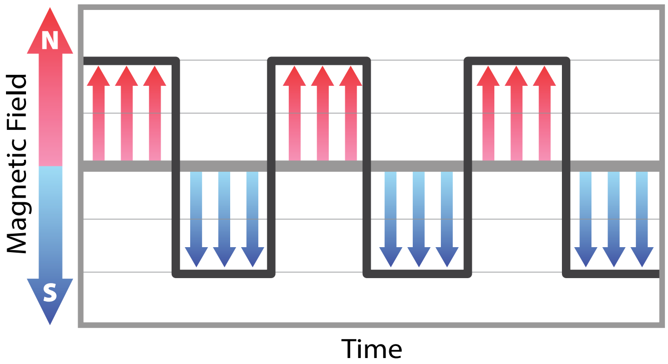


Figure 1. ZVT time varying transmitted field.

Why the term ZVT?

A more complete definition actually would be Zero Reactive Voltage Transmission. The transmit coil Reactive Voltage refers to voltage associated with the transmit coil winding that is proportional to changes in the transmitted magnetic field. Signals detected directly from the transmit coil are given the same name 'reactive' because they are directly proportional to the transmit coil reactive voltage.

The ZVT transmitted field is designed to be as constant (unchanging) as possible during the receive periods; this means that the transmit coil's reactive voltage must be zero during these constant field periods, and thus too is a receive signal directly from the transmit coil's field. Hence Zero Reactive Voltage Transmission (ZVT) refers to this ultra-stable transmitted magnetic field period during which receiving occurs.

Similarly, the signal from the soil reactive component, X (mostly soil 'ferrites'), also produces zero receive signal if the transmit coil reactive voltage is zero; just the same as during PI detector receive periods.

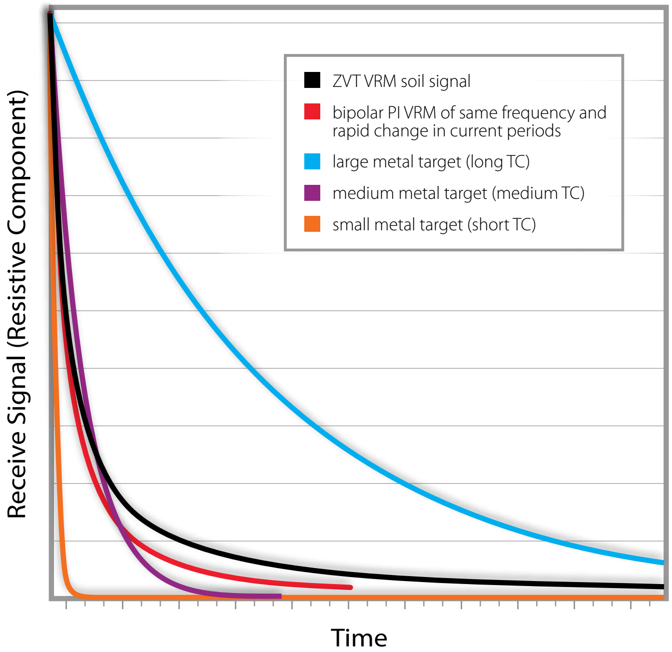


Figure 2. The receive signal from the sensing coil following a very rapid change in magnetic field, measured during the constant current period. The Time Constant or TC of a metal target is basically how quickly the eddy currents decay.

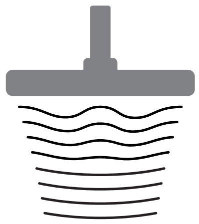
Figure 2 shows a comparison between the ZVT VRM soil signal and the nearest equivalent PI soil VRM signal; both transmitted magnetic signals being bi-polar, with the same fundamental frequency and same rapid change of magnetic field period. It should be noted that the PI receive period is half that of the ZVT period, because the PI system shown in figure 2 transmits for half the time and receives for the other half of the time, unlike ZVT that transmits and receives simultaneously just about all of the time. The important difference in the VRM signals is that the PI signal decays away substantially faster than the ZVT system. This indicates that the receive signal for PI is less sensitive to longer Time Constant (TC) components compared to shorter TC targets than ZVT, and this is one of the main reasons why ZVT technology is better at detecting large nuggets compared to PI; another main reason being from the double length receive period in ZVT compared to PI for the same fundamental frequency.

A significant technical achievement of GPZ 7000 ZVT technology was in creating the ultra-stable transmitted magnetic field during the receive period, to ensure that the large reactive component of the soil signal, X, is not detected, in the same way that it is not detected in PI.

The GPZ 7000 Super-D Coil

The GPZ 7000 coil must be symmetrical about the left-right axis because ZVT transmitted signals cause a type of signal to be produced from the ground which is absent during PI receiving periods. This ZVT receive signal is from something called soil magnetic hysteresis. If an asymmetrical (un-symmetric) coil like a Double-D is used by a ZVT detector (asymmetrical because the transmit coil is on one side and the receive coil on the other), a signal is produced which depends on the speed at which the coil is swept over the ground (and how close the coil is to the ground), and the audio tone will be higher going in one direction (for example left to right), and lower when sweeping in the other direction, which would clearly be unacceptable.

Two symmetric Double-D windings, with a central transmit winding.



Double audio response for shallow targets, single response for deeper targets.

To avoid this problem, the GPZ 7000 uses a coil consisting of two symmetric D-shaped receive coils, one on the left and one on the right of a central oval transmit winding. This Super-D coil winding geometry means that for targets close to the coil's surface, the targets produce a double audio response as the coil is swept over the target, the same response separately for each of the receive coils. For targets further from the coil's surface, the coil behaves more like a traditional coil, with the peak audio response occurring directly below the coils central axis.

The GPZ 7000 coils are specifically designed to have minimal response to scraping and knocks to the coil housing, which can cause annoying false signals when in use; e.g. some PI coils suffer from this. While this knock and scraping insensitivity feature increases the weight of the coil, it significantly improves performance through minimising false signals.

Performance advantage of the GPZ 7000

To measure the performance of any detector depends on many factors, such as: particular detector settings, coil size and configuration, ground type, mineralisation levels and type, electromagnetic interference, gold nugget size and composition, and of course, operator skill. Figure 3 shows the percentage increase in depth of a GPZ 7000 compared to the GPX 5000, using the same sized coils (14-inch). This data was obtained at several different soil locations and conditions in Australia.

For these measurements:

- A GPX 5000 using a Monoloop with Fine/Enhance timings is used when testing in (highly) mineralised soils.
- A GPX 5000 using a Double-D with either Normal or Sharp, whichever gives the best depth for each nugget tested (referred to as 'GPX 5000 Normal'), is compared to the GPZ 7000 Difficult + General in moderately mineralised soils.
- The GPZ 7000 General is compared to the GPX 5000 Sharp or Normal (again referred to as 'GPX 5000 Normal') using a monoloop in moderately mineralised soils.

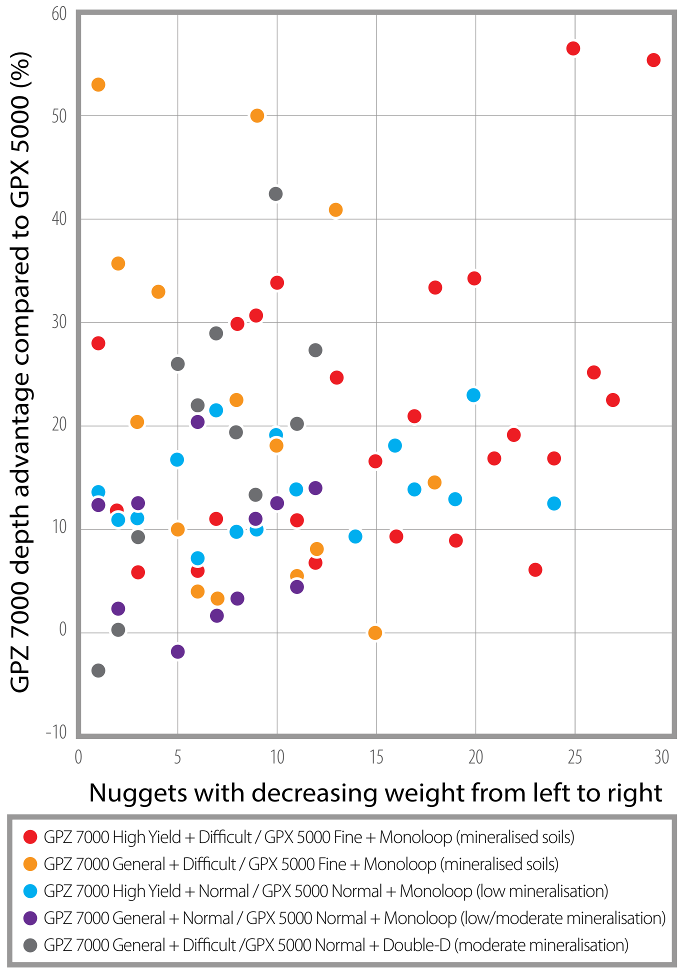


Figure 3. The percentage depth advantage of the GPZ 7000 versus the GPX 5000 for the same diameter coils.

Here the vertical Y-axis is the percent advantage, and the horizontal X-axis from left to right, is for a steadily decreasing mass of the nugget tested, going from number 1 being for a 20 ounce nugget, to number 30 for a 0.13 gram nugget.

The X-axis is not drawn to any scale, merely listing nuggets that were available for testing in decreasing weight order. The depth advantages of nugget numbers above 30, (30–35 being between 0.13 and 0.05g) are off scale; above 60%, and thus not shown on this graph.

The reason why the data is so scattered is because the two different technologies respond differently to how fast the eddy currents change; due to different Time Constants (TC). The Time Constants vary considerably between nuggets even if they have the same mass; that is, whilst the X-axis list decreasing nugget mass, this does not necessarily correspond to continually decreasing Time Constant. As can be seen, the depth advantage varies considerably from nugget to nugget, and setting to setting, but **the general advantage of ZVT is clear; mostly distributed between 0–40% improvement, and even more.**

It should be noted that the GPZ 7000's Normal Ground Type is not equivalent to the GPX 5000 Normal. Simplistically, the GPZ 7000 Normal behaves most similarly to a GPX 5000 Normal (or also Sharp) timing when using a monoloop coil but with the ground noise being typically less for the GPZ 7000 when using General Gold Mode than the GPX 5000 using a Monoloop. With the GPZ 7000 using the High Yield Gold Mode with the Normal Ground Type, the GPZ 7000 will have somewhat more ground noise than the GPX 5000 using a Monoloop and Normal.

Default Settings

A significant improvement of the GPZ 7000 compared to the GPX 5000 for most prospectors will probably be using the default settings of High Yield plus Difficult compared to the GPX 5000 most commonly used settings in average (Australian) mineralisation soils, namely, Fine plus a monoloop. These are shown as red circles in figure 3.

GPZ 7000 Gold Mode and Ground Type

Gold Mode

High Yield

High Yield is better for medium or small nuggets. The transmitted field switches pole direction (N–S or S–N) three times more often than in General mode.

General

General is better for detecting large or medium nuggets, however some very small shallow targets may be missed.

Extra Deep

Extra Deep is better for detecting in highly mineralised soils (soils that produce more audio signals than average). However, it is not as sensitive to very small nuggets as General or High Yield.

Ground Type

Normal

The Normal setting should only be used in less mineralised soils. This gives the best depth, but at the cost of significantly more ground noise. Normal plus High Yield is suitable only for low mineralisation ground types, but finds small/medium nuggets deepest of all.

See 'Saturable Soils' tip.

Difficult

Difficult is best for average (Australian) mineralised soils. This plus High Yield will most likely produce the most nuggets for average mineralisation and is the default setting.

Severe

Severe is ideal for the most mineralised soils (where the audio signals from the soil in other settings are impractical to use). This setting is not recommended for seeking very large deep nuggets.

Saturable Soils

In any of the above settings, it pays to swing the coil an inch or so above the soil surface if the soils are considered saturable (VRM). Saturable means that a detector ground balances well if the coil is raised and lowered down to about a few centimetres above the soil surface, and for the worst saturation, down to several centimetres, but not if the coil is swung up and down to a height lower than these saturation 'height thresholds' (e.g. down to the soil surface.) This is discussed in further detail below.

Searching and Ground Balancing

The Instruction Manual tells you how to do this, but here is some insight into what is happening.

After the detector is switched on, it calibrates itself to the ground within several seconds upon moving the coil near the ground (see important tip below) and pressing the Quick-Trak trigger button. This initial fast calibration involves several different aspects of the detector being calibrated, not just the usual ground balance.

Upon further searching, the ground balance continually tracks or 'updates' the ground balance moderately quickly, but the other parameters calibrated during the initial ground balancing are far more slowly updated. Thus, if you happen to initially ground balance on an atypical location (e.g. too close to a metal target or over an unusual patch of soil), the initial calibration may end up being inaccurate, and this will cause extra audio signals when detecting. This is because the slowly updating calibration is taking a longer time to become more accurate to the typical conditions (rather than the initial atypical conditions).

Ground Balancing - VERY IMPORTANT

The best way to ground balance initially after switch on with the Quick-Trak trigger depressed, is to sweep the coil in a typical side-to-side search mode at the expected operating height above the soil surface, e.g. 2–3 cm or whatever the soil saturation or terrain will allow, but at the same time move forward at slightly faster than normal walking speed, so as to cover as much different ground as possible in the first 10 to 12 seconds. The idea during this initial period after turn on, is to expose the detector to as much different soil data as reasonably possible to improve the initial calibration.

IMPORTANT! DO NOT ground balance using a coil up and down motion (like one would do using a PI detector) initially after turn on with the Quick-Trak trigger depressed. This does not give the initial calibration enough different soil information to calibrate optimally. If ground balance is required again sometime later (but without turning the detector off), ONLY THEN is the usual (PI type of) ground balancing up-and-down coil motion OK.

> **Ground Balance Reset**
>
> If you think the detector is producing an unexpected level of soil signals, switch the detector off, then on again, and re-ground balance. Usually this time your detector will be correctly calibrated from the restart.
>
> If your detector is still producing an unexpected level of soil signals, select Quick Start on the Detect page, and then select Reset Audio and Detector settings when prompted. The guide will then prompt you to perform a ground balance again.

> **Shallow Soils**
>
> When searching in previously well-detected shallow soils that have been previously detected with a GPX 5000, it is likely all of the larger gold nuggets have been found because it is easily detectable at shallow depths, and only the smaller pieces remain. Hence in these locations, only operate the GPZ 7000 using High Yield, and do not use Extra Deep because this does not detect small gold well.
>
> To find deeper larger nuggets, you need to seek out deeper soils. Generally, many of the most well known gold fields that have often been detected with the GPX 5000 tend to be shallow (but by no means all), whereas the deeper fields are generally not so well-known because overall fewer nuggets (mostly fewer small/medium nuggets) have been found in these fields.
>
> **Saline Soils**
>
> Whilst the GPZ 7000 does not have a dedicated 'salt' detection setting (saline soils), the best Gold Mode setting for salt soils is Extra Deep.

What is the technical difference between Difficult or Severe Ground Types, and Normal?

Difficult and Severe are considerably less sensitive to spatial differences in ground balance conditions compared to Normal; that is, the optimal ground balance setting does not change from meter to meter as one passes the coil over different soils using Difficult or Severe, whereas the optimal ground balance setting varies considerably more using Normal for different soil locations, even as little as centimetres apart. In addition, the degree of (VRM) soil saturation is considerably less for Difficult or Severe than Normal.

Minelab has patents for the Difficult and Severe ground balance method. Simplistically, the standard ground balance methods and the scientific literature assumes that the VLF (sinewave) soil VRM received signal that is different to the transmitted signal, called the 'resistive' signal, has the same relative magnitude for all transmitted frequencies. The GPZ 7000 Normal ground balance method, and all PI ground balance methods in detectors prior to the GPX 4000, assumed that all soils behaved as such. However, the reality is that soils do not have resistive VRM signals that are the same for different VLF transmitted frequencies: Rather, if the resistive VRM component is measured and plotted on a graph with (linear) resistive signal magnitude on the Y-axis, versus the logarithm of frequency for the X-axis, the graph is an almost horizontal straight line, but slightly tilted away from the horizontal. Graphs with tilted straight lines plotted with a linear Y-axis versus a logarithm scale of a variable for the X-axis are referred to as 'log-linear.' The relative slope of tilt varies for each different soil location, sometimes considerably over even short distances, sometimes hardly at all even over longish distances. Hot rocks have different slope tilts compared to the soil matrix in which they are buried; this is why they are detectable.

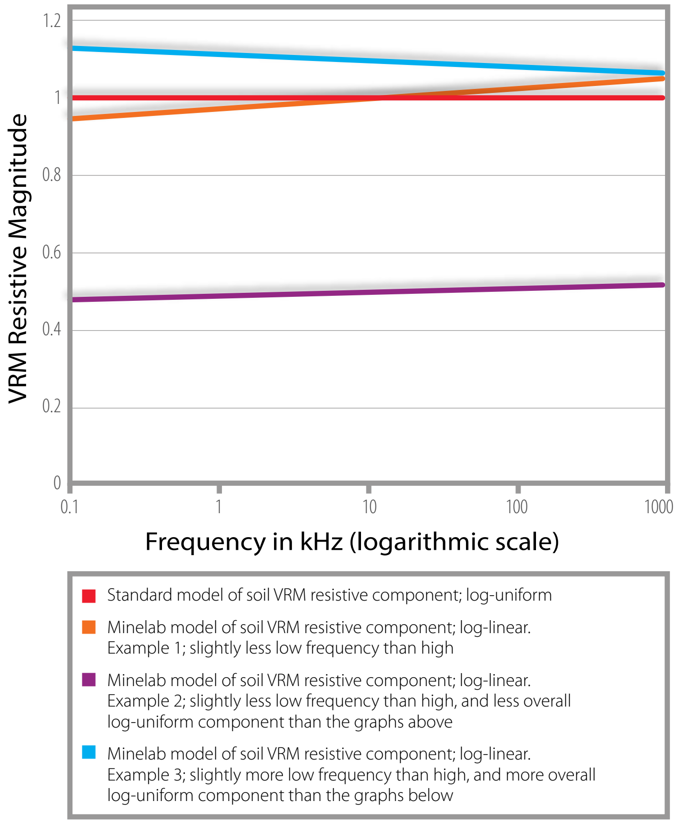


Figure 4. Different resistive VRM soils.

In figure 4, the X-axis is frequency in kilohertz drawn as a logarithmic scale. The Y-axis is the magnitude of the VRM resistive component measured using a VLF metal detector with variable transmit frequency. The standard (old) model is a horizontal line with zero slope and is called 'log-uniform', whereas in reality, soils exhibit log-linear resistive VRM responses. The examples shown are exaggerated for illustrative purposes.

The relative variations in the slope of the log-linear resistive soil components cause the VRM signal decay signals following the rapid change in transmitted field direction to vary. This is shown in figure 5.

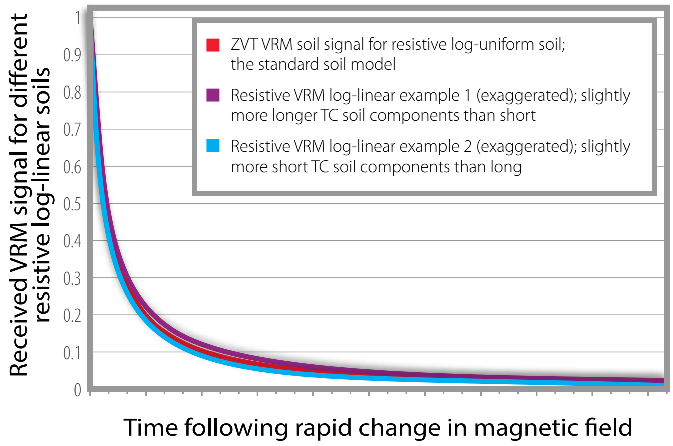


Figure 5. GPZ 7000 VRM receive signal decay signals

In figure 5, the standard model of Log-uniform resistive decay is shown as the red curve. The purple curve is the response for a negative slope tilt for figure 4; more low frequency than high, or, in other words, relative more long time constant signals than short, whereas the blue curve example is the opposite. The examples shown are exaggerated for illustrative purposes.

The Normal ground balance method in both the GPZ 7000 and GPX 5000, and all ground balanced methods prior to the GPX 4000 did not balance out these log-linear resistive signal relative tilt variations simultaneously, whereas, the Difficult and Severe GPZ 7000 ground balance settings, and Fine, Enhance and Smooth for the GPX 4000, 4500, and 5000, and SDC 2300 do balance out these log linear relative tilt variations simultaneously. If for example, Normal is ground balanced to any one of the soils exhibiting the decay curves of figure 5, then it will not be ground balanced to either of the other two; rather, it will require re-ground balancing. But Difficult or Severe will be simultaneously ground balanced to all three soil types in figure 5, without any re-ground balancing required. Hence Difficult and Severe (and Fine, Enhance and Smooth) typically produce far less ground noise than the Normal type of ground balance modes.

As the metal detector coil is moved towards a soil, the transmitted magnetic field in the soil gets stronger. This causes a (very) small degree of VRM signal 'saturation' that happens to cause the resistive signal relative slope of the tilt to change. This is why the amount of VRM soil saturation is far less for Difficult and Severe than Normal. Soil saturation often requires the user to operate the coil several centimetres above the soil surface for best results *(see 'Saturable Soils' tip)*.

However, whilst soils do have resistive signal that are very accurately log-linear, unfortunately this is not perfectly accurate for some soils, and, because the GPZ 7000 has such very high sensitivity, even miniscule deviations in the straightness of the line of the log-linear resistive signal will cause ground noise signals. Severe is less sensitive to these miniscule deviations than Difficult.