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UNDERSTANDING THE PI METAL DETECTOR

BY REG SNIFF

PART TWO

The down side of PI's

All detectors are subject to external noise, but PI's are extremely temperamental in this regard. The reason PI's are more sensitive to noise is due to the design of the preamp or first amplifier stage. For a PI to work at optimum this amplifier has to be built to amplify a very wide range of frequencies to assure the decay signal isn't altered. This type of amplifier is commonly called a broadband amplifier.

On a VLF there normally is one specific operating frequency and the preamp or first amplifier is somewhat tuned to that frequency. Thus, other signals such as noise will not be amplified as much.

On a PI, all signals are basically amplified the same, thus all noise, especially electrical noise is amplified just like the signal from a nugget. This problem is compounded by the fact that the coil itself will generate a very small voltage as it is moved or swept above the ground.

This very small voltage is the result of the coil moving through the earth's magnetic field and this extremely small voltage is often referred to as the earth field effect (EFE) signal.

For a PI to be very sensitive, there has to be a lot of amplification of the sampled signal. As such, even the small voltage produced by the coil movement will create a signal large enough to be heard. To eliminate this EFE problem, a second sample is normally taken much later in time and this second sample is effectively subtracted from the first or main sample. Since the earth field effect is a very slow signal, taking the later sample will eliminate most of the earth field effect signal, thus it is normally not heard.

However, this subtraction process is seldom perfect and because the sample is taken at a different point in time, there will always be a very slight response, that just might cause a very slight increase or decrease in a target response. Most likely this will occur or be noticed on the targets just on the threshold of detection. However, if for some reason the subtraction process is not near perfect, then it is quite possible that there will be a noticeable increase in signal strength when passing over a target from one direction than when passed over on the opposite direction of the coil swing.

The earth field effect is one of the reasons there may be a slight response at

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responses mentioned should be considered normal.

One final noise problem is the noise generated within the detector itself. Just due to the nature of the circuitry used, a lot of noise is generated within the electronic circuitry .Much of this noise is "filtered" by the battery and aided by large capacitors and other filtering devices such as ferrite cores. However, no battery or capacitor is perfect so some noise always gets through.

The result of all the combined noises commonly creates a form of chatter or warble that can significantly reduce the sensitivity, especially to very small or deep objects producing very weak signals. In many cases, the noise may not even be really noticeable but be of sufficient amplitude to cause a reasonable depth loss.

Ground signals and Ground Balance

PI's are susceptible to many types of ground conditions, and, depending upon the type of ground, the sensitivity, and the delay, may generate a very strong signal due to the ground.

Terms like magnetic viscosity are used to explain just why certain types of ground can cause a strong response. Ground conditions having concentrations of maghemite will create very strong ground signals.

Areas having a clay base seem to produce strong ground responses also indicating that clay itself is part of the problem. Articles such as those written about geophysical research indicate that the clay problem can vary dramatically because of the type of clay as well as the moisture within the clay.

An article written by the Army Corps of Engineers indicates that clay will actually create a field that opposes the transmitted field of the PI and moisture enhances the ability for the clay to oppose the field due to the ionic behavior within the clay.

Coils, Coils, and more Coils

VLF's always have a transmit coil and a separate receive coil of wire in the search head. PI coils, however, can be produced in several variations. If the same coil is used for both the transmit and the receive signal, the coil is normally called a "MONO" coil.

If two sets of coil windings are used, and those coils are basically the same size and shape with one coil used as a transmit and the other the receive, and they overlap a small amount on one side, the coil is generally called a DD coil. The name DD generally refers to the design of the coils where they are sort of like D's with one D reversed and the backs of the D's overlapping slightly. This overlap area is the main detection zone and is the area where an object is under at least part of both coils at the same time. This detection zone is most noticeable on deeper objects.

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the DD electrical coil windings are smaller in size than the coil windings of a mono coil even they may have the same size coil housing.

One other key factor that is important is the fact to remember about a DD coil is the main detection zone is quite narrow. This narrow detection zone, normally at or near the overlap will create a very brief or narrow signal when compared to the signal on a mono coil. This situation makes the sweep speed of the search coil much more critical. Swinging the coil too fast can easily cause a very weak object to be missed simply because the signal is so short and the circuitry filtering used to eliminate the noise will also almost eliminate such a signal.

The fact that DD coils have smaller diameter windings for the transmit and receive coil, when compared to a mono coil using the same size housing, has some advantages. Generally, the smaller receive coil is not as good of an antenna as a larger mono coil, thus less noise is detected and amplified. As a result, the detector can be much quieter when using a DD coil. In many cases the reduction in noise can outweigh the depth loss due to the size difference.

One other major asset of a DD coil is the fact the receive coil is isolated from the transmit coil. This helps in the fact that any low level noise that is generated by the transmit circuitry during the sampling time is isolated from the receive circuitry. This isolation therefore reduces the combined noise that can negatively affect a target response.

One final advantage of a DD coil is, by nature, a DD coil partially cancels the ground signal. If the coils are properly aligned or positioned, most ground signal in the receive coil is eliminated. This results in a detector that has very little ground response, yet still responds with a strong signal from a buried object.

Another type of coil that is made for PI's is called the figure 8 or "Salt" coil. In this design, there is a large transmitting coil and two receive coils that are wired such that the receive coils are opposite of each other, meaning that one coil will produce a positive signal and the other a negative signal. On this type of coil, it is quite common to build a larger receive coil, elongate it, pinch the center of the elongation and then twist one half of the receive coil one half turn to create two coils, much like a figure 8. As mentioned before, this type of receive coil is also called a "figure 8 coil" just due to how it is constructed.

One advantage of a "salt" coil having a large transmit coil and two smaller receive coils is the design is both ground canceling and noise canceling. The ground canceling relies on the principle that both receive coils are equally spaced from the ground for maximum ground signal elimination.

The disadvantage of the Salt or figure 8 coil is there is a depth loss that occurs when compared to a similar sized mono coil or even a similar sized DD coil. Part of the reason for the depth loss is the fact the two receive coil signals basically oppose each other since one will produce a positive receive signal and

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Because the signals from two receive coils have a tendency to cancel each other, any noise detected by the two coils basically is also canceled. This cancellation process has one other advantage and that is, it will eliminate the earth field effect.

A little different figure 8 coil can be built where there is only one coil used as both the transmit coil and the receive coil. This coil is again, elongated, pinched, and one half of the coil is twisted over so half of the coil is transmitting up when the other coil is transmitting down. This type of coil eliminates or cancels external noise extremely well but does not ground cancel. Since the two xmit coils are much smaller, there is also some depth loss on this type of coil because of the size of the coils as well as the signal from the two halves of the coil have a tendency to cancel each other. As such, the signal from a buried object will be the greatest when it is centered or near centered under either of the two coils and the weakest when the object is right at the crossover point of the two coils.

One of the most common coils found on a VLF is something called a concentric coil. In this case there generally is a large transmit coil and a smaller receive coil basically centered in the large coil. For this type of coil to really work correctly on a VLF, there will be an additional transmit coil wound directly on the smaller receive coil, but will wound opposite to the main transmit coil. The purpose of the smaller transmit coil is to cancel any signal in the receive coil caused by the larger transmit coil A concentric coil design can be used for a PI, but it is rare to find one..

Of course, there can be variations of the above coils, meaning they can be rectangular, round, oval, or any other shape a person should desire. Also, the windings can be changed or possibly additional windings can be incorporated to produce the desired results. So, the ultimate design of a search coil is left to the imagination of the designer.

Finally, some mention has to be made regarding coil size. The coil size of most PI's normally ranges from an 8" diameter coil to greater than 3 feet in diameter. It is quite common to hear of a person using an 18" diameter coil, but the most popular sizes range from 11" to about 14".

Recently, Eric Foster posted some interesting findings regarding the general detection ranges of different sized coils versus target or object size. This information can be viewed on the PI forum and displayed on September 16, 2002. Several discussions occurred during that time pertaining to the depth verses coil diameter, versus target size.

As one might expect, the larger the coil, the deeper one may find objects. However, it is quite possible a smaller coil will find an object deeper than a large coil, especially if the object is small. Contrary to the some of the discussion that resulted on the above mentioned forum, there is a more direct relationship between the size of the coil, size of the object and the ideal maximum depth such an object can be detected. An error in calculations led to

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generally theoretical and as such is subject to some distortion in the real world. However, as a rule, the general principle is quite accurate.

When searching for information about depth or size of objects that can be found with different size coils, extreme cases always show up. For example, many people have found extremely small nuggets ranging in the few grain range with an 18" coil. Normally such a large coil will not be able to see such a small target at any depth, or even in the middle of the coil if the nugget is small enough. However, this small nugget can produce a signal if it is very near the coil windings themselves.

One final point that I am sure will cause controversy and that is a smaller coil will not show as dramatic increase to sensitivity to small gold on a PI like it does on a VLF. The reason, again, lies in the fact that the sensitivity to small gold on a PI, is much more dependent upon the delay before sampling than it is on the coil itself.

Ground Balance Differences There is a world of difference in ground balancing techniques between a VLF and a PI. On a VLF, a sample can be taken such that the signal from the ground appears to be eliminated. Actually, it is still there, but by the sampling at the right time half of the signal is positive and the other half negative, so the net effect is 0.

On a PI, no such condition can exist because of the fact the transmit time is separate from the receive time. So, another method has to be used. One common method is to take advantage of the fact the ground signal lasts for a long time. So, if the initial sample is taken to look for a target and then a later sample is taken that still contains ground signals and this later sample is amplified, and then subtracted from the first or main sample, the ground signal can be minimized, thus leaving the target signal.

Unfortunately, any subtraction process also reduces the signals of targets also having a long decay. As it turns out, some gold signals will be very similar to the ground signal, so this subtraction process can effectively reduce the response from some gold objects.

In the case of larger gold objects, the subtraction process can actually cause the signal to change from an increasing response to a decreasing response, meaning a piece of gold would create a negative signal. This negative signal can easily be "rectified" much like the rectifier in any other circuit. The rectification process will then make the large gold also respond with a positive signal, rather than a negative signal.

However, as mentioned before, some gold will respond much like the ground so there will be some gold objects that will be cancelled much like the ground signal To overcome this problem, different length pulses can be used and multiple subtraction processes incorporated.

If a longer pulse is also used, the longer pulse alters the ground signal

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eliminated by only using a short pulse will produce a strong signal when using a long pulse, and visa versa. The result is most gold will be detected quite strongly if pulses of different duration are used. However, in all cases, many of the larger nuggets that have a decay lasting longer than the time when the ground signal sample is taken will also be reduced in signal strength.

Another technique can be used for ground balance but it is generally used with a DD coil. In this case, a sample is done during the pulse on time as well as the pulse off time. The two different samples produce different signals, which then can be combined to minimized the ground response. This type of sampling can also be used to produce a better form of discrimination which would be much more accurate.

One technique that can be used is a variation of the first ground balance technique. This method just minimizes the ground response using the subtract method. By doing this, the ground signal is minimized significantly but gold responses are not eliminated. Some nugget responses are, however, reduced in signal strength and as such, there is some depth loss. This normally occurs with nuggets greater than 2 gram or so.

Finally, Discrimination on a PI

Due to the nature of the signals caused by different objects, it is extremely difficult, or put another way, almost impossible to build a good discriminating PI.

Since the time it takes for a target signal to decay can vary because of the size, shape, and chemical makeup of the object, then any type of later sampling will not produce a reliable form of discrimination.

Many PI's rely on the ability of an adjustable delay whereby the operator can simply adjust the delay longer to see if an object is a piece of gold or not. If the delay is increased and the signal from an object disappears, then the operator can assume the object is made of a lower conductive material such as gold. This is acceptable for those hunting something like gold rings, but does not work well on gold nuggets. larger gold nuggets can produce a much longer delay, so any attempt to use this delay technique will result in one thinking a large gold nugget to be junk.

Another concept used on a PI for discrimination is to sample during the "on" time of the pulse. Any target will produce a slight change in the signal seen at that time as well as a change when the normal target sample is taken.

If the analysis is done correctly, then one can use both the "pulse on" and "pulse off" signals and get a better analysis of a target. This type of design can lead to a better form of discrimination. However, few if any PI's are actually using this technique.

Regardless of the technique used, no form of discrimination is perfect, and,

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