Metal Detector Description

A typical metal detector used for detecting buried coins, gold, or landmines consists of a circular horizontal coil assembly held just above the ground.

A pulsed or alternating current generates a time-varying magnetic field around the coil, as shown in figure 1. This field induces currents in a nearby metal object which, in turn, generate a time-varying magnetic field of their own. These fields induce a voltage in the receive coil which, when amplified, reveal the presence of the metal object or target.

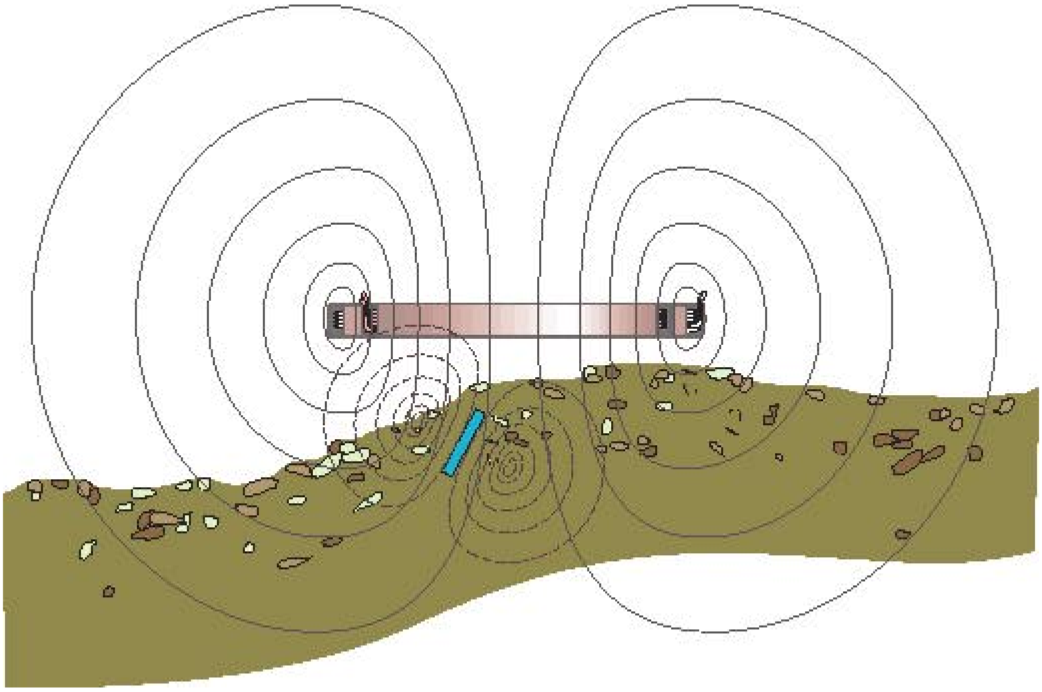


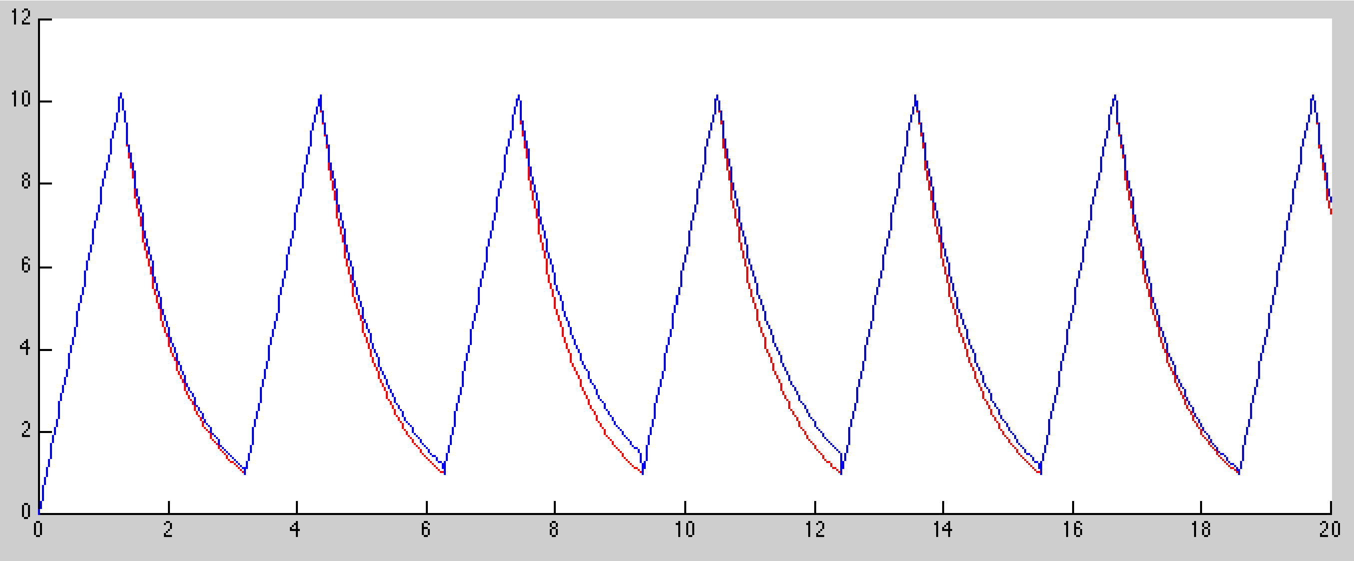
Figure 1: Twin coil detector - outer coil is receiver and inner coil is transmitter. Transmit coil field generates eddy currents in buried metal target which magnetically induce voltage in receiver coil.

There are two broad types of metal detector, classified by the type of magnetic field generated by the transmit coil.

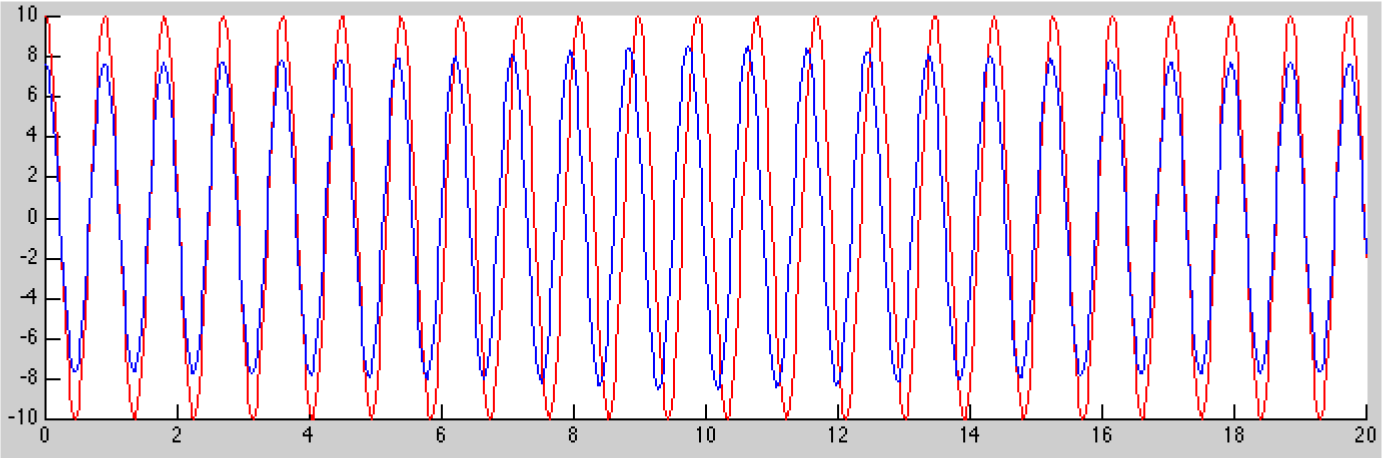
a. Pulse induction (PI) detectors typically generate a transmitter current which is turned on for a time, and is then suddenly turned off. The collapsing field generates pulsed eddy currents in the target, which are then detected by analysing the decay of the pulse induced in the receiver coil.
b. Continuous wave (CW) detectors generate a transmitter coil current which alternates at a fixed frequency and amplitude. Small changes in the phase and amplitude of the receiver voltage reveal the presence of metal targets.

Most metal detectors amplify the differences in the receiver coil voltage caused by nearby metal targets and generate a sound signal audible to the operator (aural display) when a target is detected.

The following plots illustrate the different concepts by showing graphs of received signals with time on the horizontal axis. The scales are notional as the intention is to illustrate the principles of the two different kinds of detector.



Signal received by PI detector (blue) has change in decay rate compared to reference signal (red) when passing over a target at about 10 on the horizontal scale.



Signal received by CW detector (blue) has change in phase and amplitude relative to transmitted signal (red) when passing over target at about 10 on horizontal scale.

The main practical issues in designing a useful metal detector are as follows:

Sensitivity and detection depth

The changes caused by the target are small, so sensitive electronic circuits are needed to detect the changes which occur when a target is present. The transmitter coil requires considerable power and the nature of the transmitted signal must be controlled precisely to detect small changes in the receiver coil output due to nearby targets.

Closely related to sensitivity is the detection depth. It is desirable to be able to locate targets deep under the ground. Usually the diameter of the coil is the major determinant of detection depth.

Robustness and reliability

Metal detectors are often used far from support and repair facilities. Therefore reliability is vital, and self-calibration is needed as afar as possible to avoid complex adjustments in field use. The controls need to be well protected from accidental damage or actuation, waterproof (if possible), and resistant to UV in sunlight.

The electronics unit needs to be an integral part of the detector if it is to be set down on the ground and picked up often. This means that it must be very light, with batteries. A body-mounted electronics unit must be easily dis-connectable if used.

External wiring is a major vulnerability and needs to be eliminated if possible.

Endurance

The transmitted power must be as small as possible to enable the detector to be used for as long as possible on a given battery. Recharging from a car or truck is an essential part of a re-chargeable battery design. Demining agencies often prefer dry cell battery designs because re-chargable batteries require careful handling. Careless charging (over-charging, leaving them uncharged for a long time) can damge older types of batteries. However, modern Li-Ion designs have overcome most of these deficiencies.

Immunity to electro-magnetic interference

The detector should be disturbed as little as possible by electromagnetic fields generated by nearby detectors, nearby power lines, radios etc.

Ground effect

The soil will affect the receiver coil output. Some kinds of soil, particularly those containing a high iron content (often known as mineralised soil), affect the output strongly enough to indicate the presence of a metal target with certain kinds of detector. Most detectors provide a means for compensating the output for the ground effect. This usually requires the operator to position the detector near the ground (but not near a metal target) and adjust a control until the target signal disappears.

There are several different techniques for compensating the detector for ground effects.

Ground noise

Small variations in the soil characteristics and stones (particularly those containing iron compounds) can cause small changes in the detector output. Often these changes cause small target-like signals, often known as 'ground noise'. These can confuse the operator as they sound like small targets, but the target signals cannot usually be associated with a ground location.

Target localisation

It must be possible to find the location of a target. Buried targets have to be checked by subsequent probing through the ground or, more commonly, excavation to expose the target for visual inspection. The operator must be able to locate the target accurately enough to avoid unnecessary digging effort.

Target discrimination

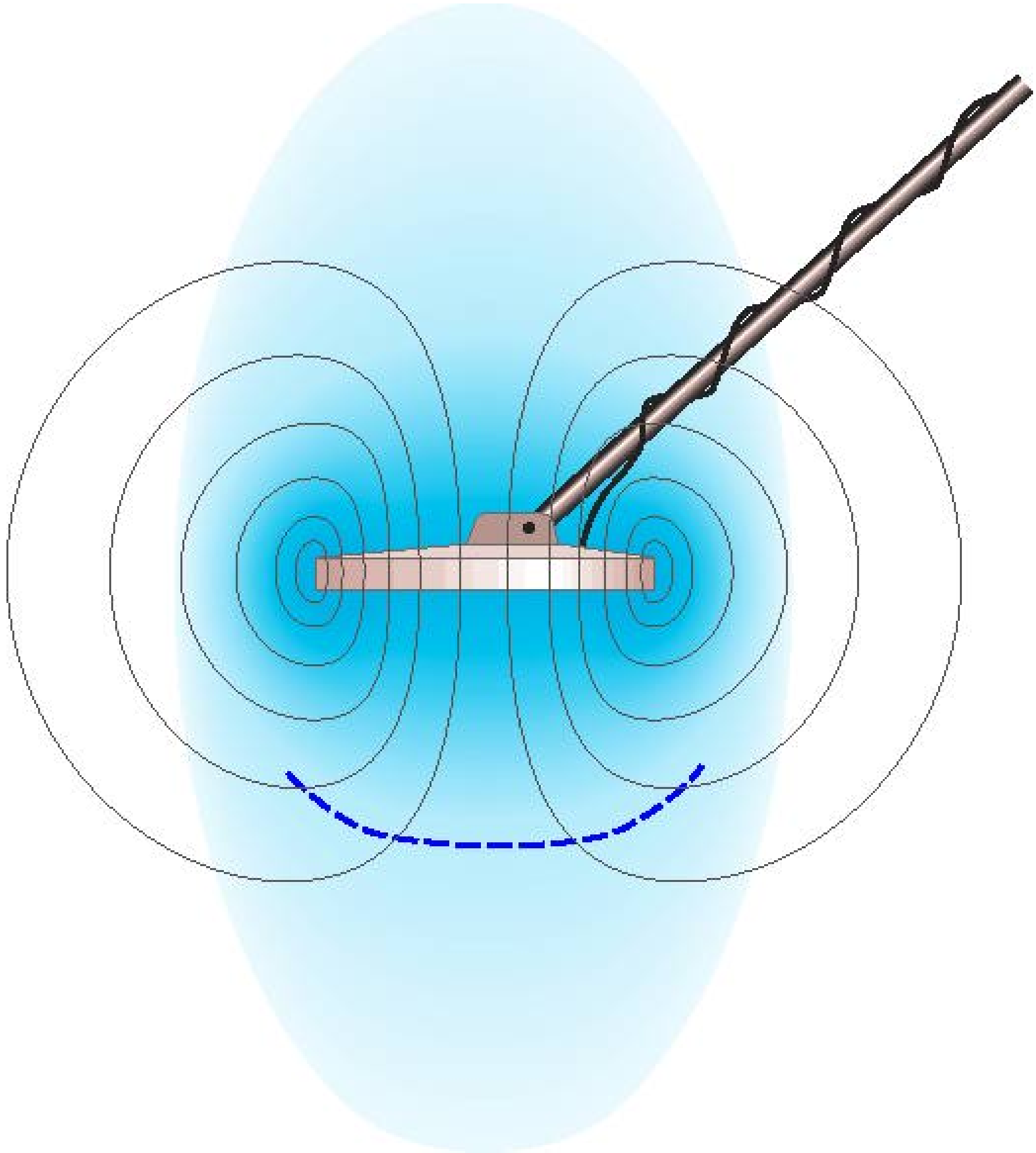
It is desirable to enable the operator to detect a different sound when the target is shallow or deep, when the target is large or small, or if the target is a particular kind of metal. This has great practical significance for a gold prospector who would like to ignore all metal targets other than gold.

Important Characteristics for Mine Detectors

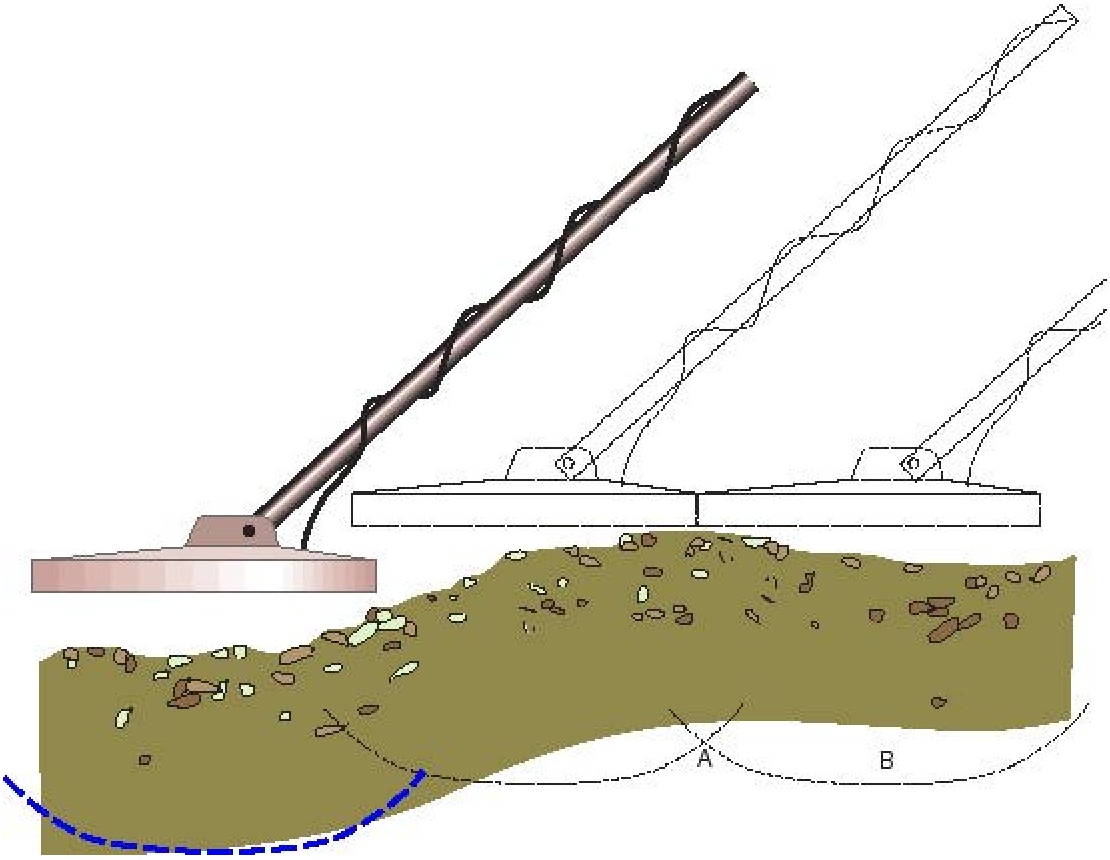
Detection depth

Apart from optimising sensitivity and endurance, mine detectors require a well-known detection depth. Mines are usually placed at a depth of 20 to 50 mm below the surface, but subsequent movement of soil (or the mine) can increase the depth. Deminers would like a detection depth to exceed 200 mm for minimum metal content mines, but in practice have to be content with a depth of 10-13 cm. The depth capability must extend across the width of the detector head, preferably with little change in depth across the head. This reduces the chance of missing targets, or finding targets in a subsequent quality control check.

If the detector is too sensitive (i.e. detection limit is too deep), then more small targets may be detected. Since each may have to be checked, this can greatly increase the work required.



Metal detector coil generates a magnetic field (field direction lines shown). Detection sensitivity for a particular target decreases rapidly with distance away from the coil (shown in shades of blue-green). The detection limit for a particular target has been illustrated by the blue dashed line below the coil.



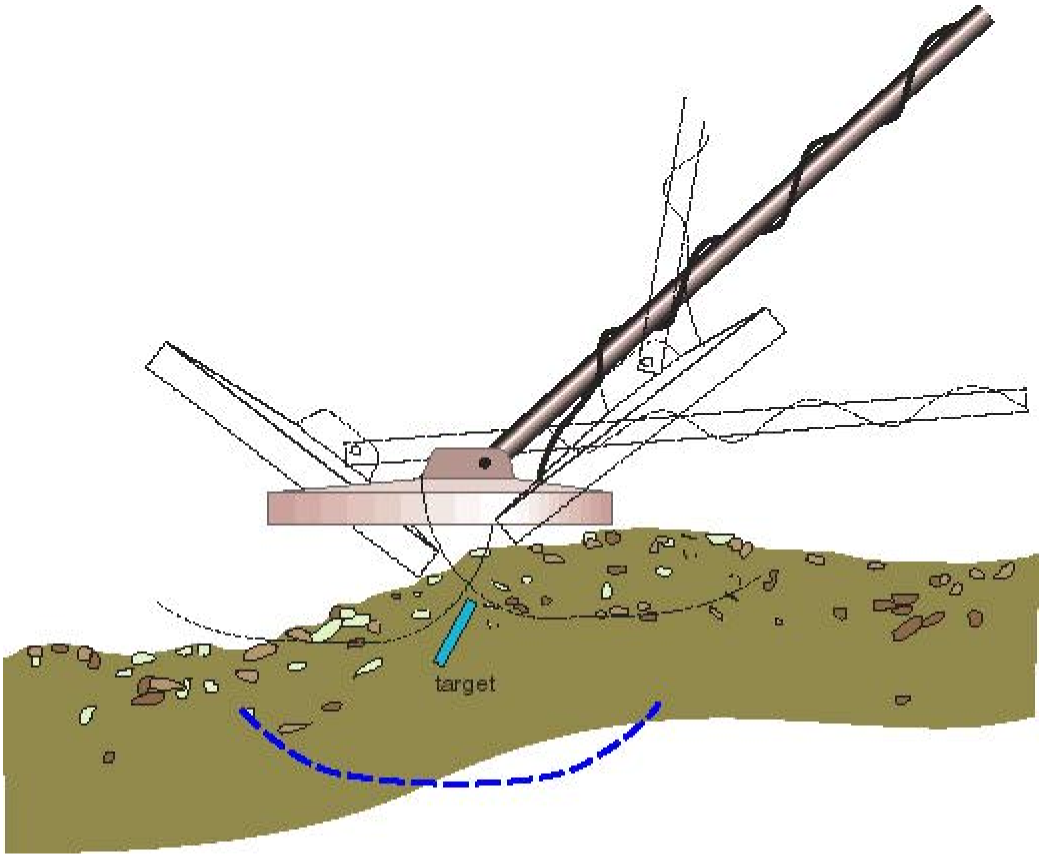
As a deminer sweeps the ground with the detector from side to side, he may assume that by moving ahead one coil width on each sweep he has not missed targets. The diagram shows that if the target was at position 'A' it would have been missed. If the detection limit is relatively flat across the coil width, this does not matter much.

If the detection limit varies considerably across the coil, this may cause problems for deminers, even if the minimum depth meets the required performance standard. After manual clearance, a quality control check requires that part of the minefield be checked with another metal detector. If there is a chance that targets will be detected, even though they are below the specified depth, this can cause unnecessary work in investigating the targets and possibly repeating the manual clearance task.

Localising capability

Deminers like to use the detector to localise the target as precisely as possible.

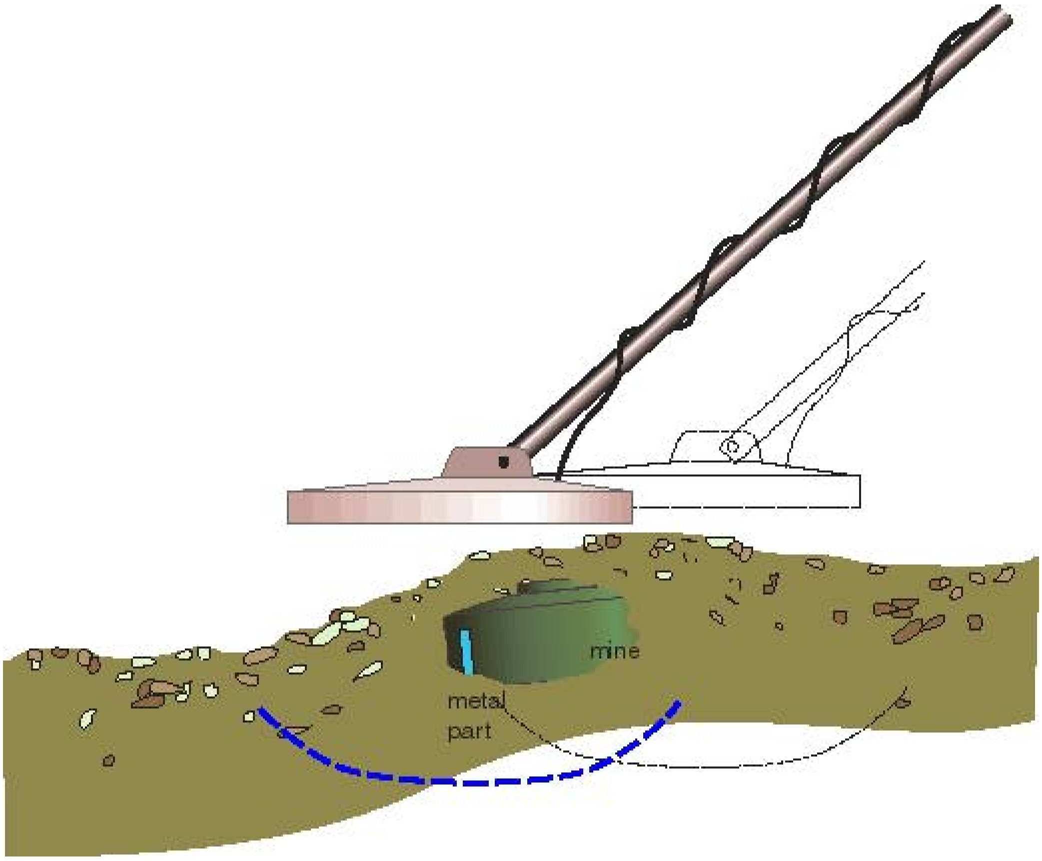
Having found a target with the coil horizontal, they may use the coil tilted at an angle, exploiting the much reduced width of the detection limit at an angle.



The detector may function in one of two ways:

a. The deminer moves the detector until the strongest continuous sound is heard - the sound continues while the detector is held still (The most common, almost universal with demining detectors).
b. The deminer has to keep the detector moving to hear a sound. If the detector remains still, the sound dies away. This type of detector compensates for ground effects by averaging the signal over 1 - 3 seconds. Any change lasting a short time is assumed to be a target and causes a sound. Holding the detector still causes the averaging circuit to assume that the target signal is part of the ground and the sound dies away.

Localising the target requires the deminer (in typical operating procedures) to mark the point where the detector sound is loudest, and mark another point on the near side of the target where the sound can just be heard. A further point may be marked 15 cm on the near side of this point where it is safe to start excavating the target. The detector may be responding to metal on the *far side* of the mine, so excavating the point where the sound is minimal may be dangerous.



Some kinds of metal detectors may have a non-circular detection limit when viewed from above. The sensitivity is concentrated in a narrow zone either side of the centreline