

DESIGN OF A LOW COST METAL DETECTOR FOR DEMINING PROJECT

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ABSTRACT

Designing of low cost metal detector within the framework of humanitarian demining research activities has been selected as our final year project. Broadly speaking, there are five main ways of detecting metal: BFO (Beat Frequency Oscillator), induction balance, Pulse induction, off resonance, and the magnetometer. The latter works by detecting small anomalies in the Earth's magnetic field strength.

1.0 Introduction

The BFO & off resonance types both operate by detecting the small change in the search coil inductance which occur when a metal object is present. Yet both methods suffer from poor sensitivity.

Pulse induction detectors are also available in the market though the ones with good sensitivity are very expensive relative to the BFO and VLF detectors.. They operate by exposing ground to powerful pulses of magnetism & listening between the pulses for signals due to eddy current set up in any metal object present in the field. Despite their sensitivity they have few important drawbacks. Their battery consumption is heavy due to the power required by the pulsed transmitter, and they are extremely sensitive to even tiny ferrous objects.

This leaves the induction balance types, which have become more or less the standard general-purpose detector. It has two coils in its search head, one of which is fed with a signal, which sets up an alternating field around it. The other coil is placed so that normally the field around it balances and it has no electrical output. A metal object approaching the coils will distort the field, resulting in an imbalance so the pickup coil will produce an output. This can be amplified and used to inform the operator of a "find" in a variety of ways.

'VLF' stands for "very low frequency". The ability to discriminate from phase information against thin section objects like foil depends on frequency. At higher frequencies, 'Skin effect' eddy current conduction makes such discrimination ineffective. Therefore manufacturers began using lower and lower frequencies, at least one machine actually worked at less than 2kHz. Most detectors nowadays operate somewhere between 10 and 20kHz. Where discrimination is still excellent but sensitivity and coil design problems do not arise.

2.0 Discrimination

In addition to the features discussed above, there are some other key issues one must address in designing a metal detector. One of these is the ability to discriminate among the landmines and unwanted debris such as bullet cases, metal parts from exploded mines etc, which are heavily available in a battlefield and Unexploded Ordnances. The other is some means of eliminating false signals due to "ground effect". Ground capacitance effects can easily be prevented by Faraday shielding around the coils, but most inland soils contain a proportion of iron oxide which gives a signal similar to a piece of ferrite.

Obviously some means of "tuning out" these effects will improve the detector considerably. Fortunately the signals from the search coil consist of more than just amplitude variations; they also contain information in the form of phase shifts, which differ markedly according to the type of object causing the signal. With a relatively simple phase sensitive detector therefore, a machine can be designed which will totally reject ground effects and can also, with practice on the part of the user, eliminate the majority of the rubbish detected without the necessity of having to dig it up.

3.0 Coil Arrangement

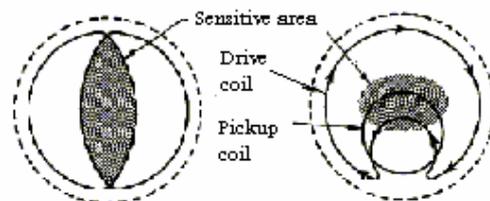


Fig 1

There are many possible coil arrangements, but most detectors available today use one of the two shown in Fig. 1. left shows a "widescan" coil, so called because its most sensitive area (shaded) extends right across the coils. Fig. 1 (right) shows a "pinpoint" type. It's noticeable that many of the best-imported American mine detectors use pinpoint coils.

4.0 Block Diagram

Fig. 2 shows a schematic of the detector. The drive oscillator sets up a field around the search coil, and the pickup coil is positioned so that it only gives an electrical output when a metal object distorts this field.

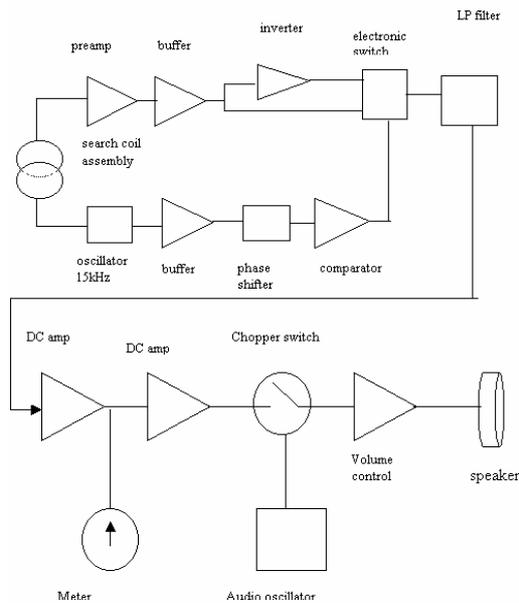


Fig 2 - schematic of the detector

The operating frequency of these stages is approximately 20kHz. Signals from the pickup coil are amplified, buffered and then inverted so that non-inverted and inverted versions of it are simultaneously available.

These are fed to the two inputs of an electronic changeover switch, operated by a reference signal derived from the drive oscillator. This reference signal has first been passed through a phase shifting network, which can be adjusted as required by the user. The output from the switch is passed through a 3rd order low-pass active filter with a cut-off point set at 40Hz, which removes practically all of the 20 kHz signal, leaving only the average d.c. Level. Any given signal producing object causes changes in both magnitude and phase of the received signal, so by adjusting the phase shift network correctly a point can be found where these changes either cancel out or cause a net fall in the d.c. Level, enabling unwanted signals from ground, foil, iron etc., to be eliminated. Incidentally, most similar designs to date have used either pulse sampling phase detectors, or have selected only half-cycles of the input signal.

Then the d.c. Signal is amplified. It is only changes in the signal that are of interest, so a means of “tuning out” the initial standing d.c. Level is required. In simple machines this is a manual control, but the need for readjustment after each operation of the phase controls - say switching from “ground” to “discriminate” - makes some form of automatic tuning desirable. On most commercial machines a “tune” button resets the output to zero every time it is pressed, but these are notoriously prone to drift.

Attempts to use continuously resetting systems have been made, but this tends to lower the overall sensitivity as most manufacturers use rather crude filtering, resulting in considerable delay in the response to a detected object. In effect the auto tune tries to reset the output to zero at the same time as the detected object is trying to cause it to rise!

The highly efficient filtering used in this design ensures an instant response to a signal, so a continuously resetting tuning system can be used. This does away with all the drift problems, and allows the machine to be used continuously at maximum sensitivity if required. A “freeze” button is provided to stop the tuning action whilst pinpointing the exact position of finds or discriminating. After the auto tune and amplifier stage the signal is fed to a center-zero meter; in “discriminate” this indicates positive for “good” finds and negative for “bad” ones. Then it goes to a further amplifier with a control, which sets the point at which the audio output is to start. The output from this is of course still d.c., so it is chopped up by an audio oscillator, providing a signal which only needs a power output stage to drive the loudspeaker.

5.0 Pulse Induction metal detector

The pulse induction method of detection works by subjecting objects to a rapidly changing electromagnetic field. The field is produced by building up a current in a simple multi-turn search coil, and then forcing the current to fall very rapidly by switching off the supply. As the electromagnetic field decays it induces a voltage back into the coil, and also into objects near the coil.

Poor or non-conductive objects are unaffected, but in conductive items a current is induced, producing a small magnetic field, which opposes the decay of the original field. This opposing field means that when near metal, the magnetic field around the search coil decays in a different way, and so the voltage induced in the search coil also differs. This is the principle used by Pulse induction metal detectors. Conventional Pulse induction detectors identify the presence of a metal by integrating the decaying part of the transmitted signal.

We have also designed a Pulse induction metal detector using a micro controller. The use of a micro controller has allowed all of the vital pulse timing to be optimized. It was set in software during development.

6.0 Conclusion

Broadly speaking there are five main ways of detecting metal: BFO (Beat Frequency Oscillator), induction balance, Pulse induction, off resonance, and the magnetometer.

Among those ways we have studied & designed metal detectors considering BFO technology, pulse induction technology, and VLF technology.

Under BFO technology we have designed simple circuit and tested it for different objects in different depths. While using a BFO technology main practical disadvantage that we had to face was low sensitivity for the small objects. This detector was sensitive for large type of objects but for small depths. In addition metal discrimination is little difficult using this technology.

The pulse induction (P.I.) method of metal detection relies on the electrical conductivity of buried objects. The biggest advantage of pulse induction is that it is virtually free of "Ground Effect". The only real disadvantage of this type of detector is that it detects ferrous and non-ferrous metals alike - and cannot discriminate between different types of metal.

The very low frequency method of metal detection was very successful among our experiments and main advantage of this detector is it can discriminate ferrous and non-ferrous metals. Also it has very high sensitivity.

7.0 ACKNOWLEDGEMENT

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