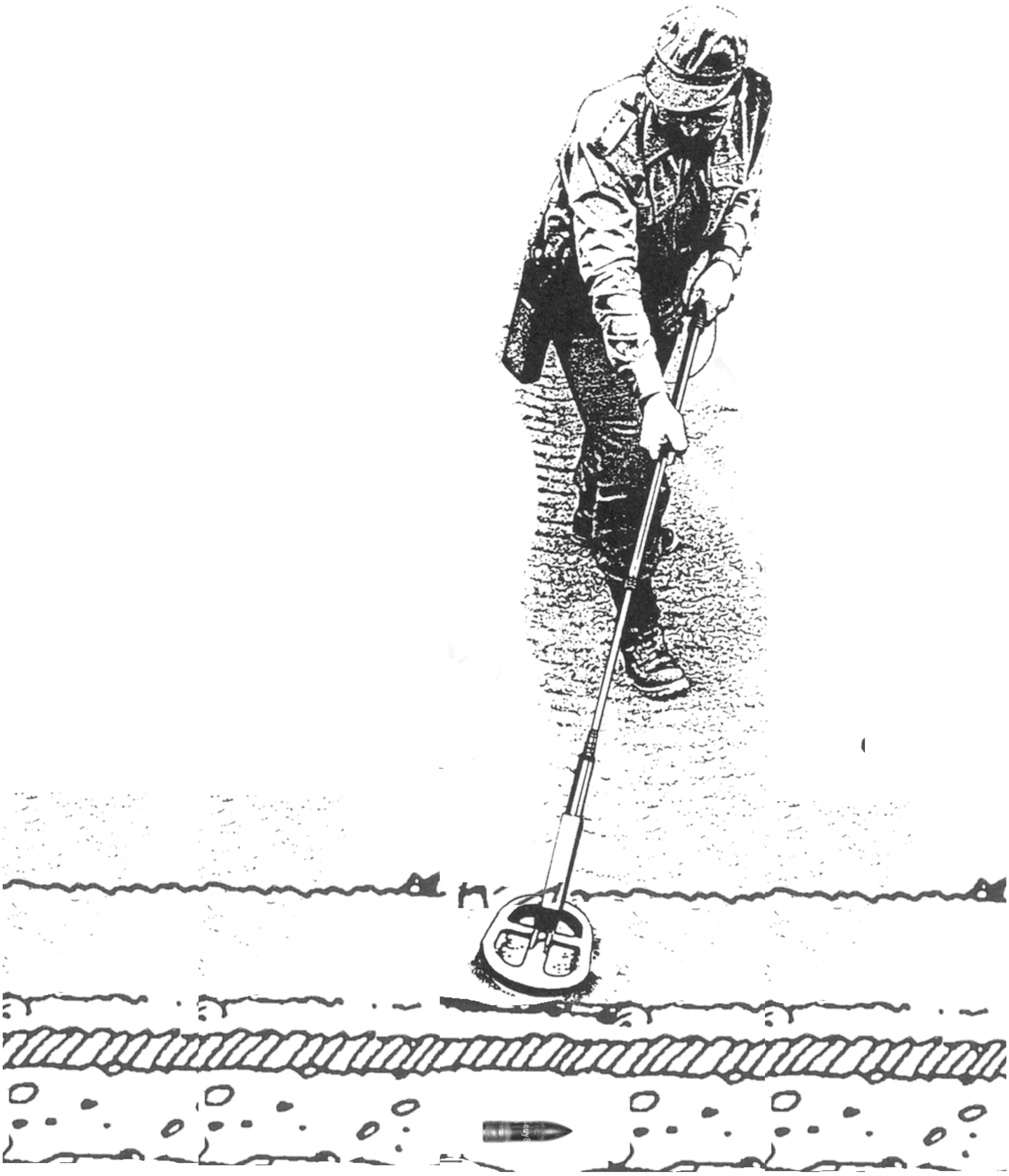
EBINGER – Detection technique

Inventions for the safety of people

Active Detection technique

Detection range indications for metal detectors



METAL DETECTORS – DETECTION RANGE INDICATIONS

Index

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1. General

Apart from a detector's ability to compensate non-cooperative soil the “maximum detection range” is the most important performance parameter. The detection ranges stated by producers or suppliers very often describe detection features which raise legal questions if this detector performance and the relevant specifications are unspecified or apparently exaggerated. In such case they are misleadingly the clientele. The user will normally compare the statements without realising the technical hurdles of a direct performance comparison.

We talk about vague claims such as “*depth over 10 meters*”, “treasures up to 12 m” or “coins up to 3m depth” which address potential buyers in an entirely unspecified way neglecting any technical background. At this point critical questions should be raised which will be discussed here after.

2. Maximum detection ranges

Maximum detection ranges can only by claimed for a measurement in air due to the large number of potential interferences which are described in the following. Randomly chosen metal target objects will hamper a comparison. Metal plates of defined material and dimensions are by far more helpful. Refer to figure 1.

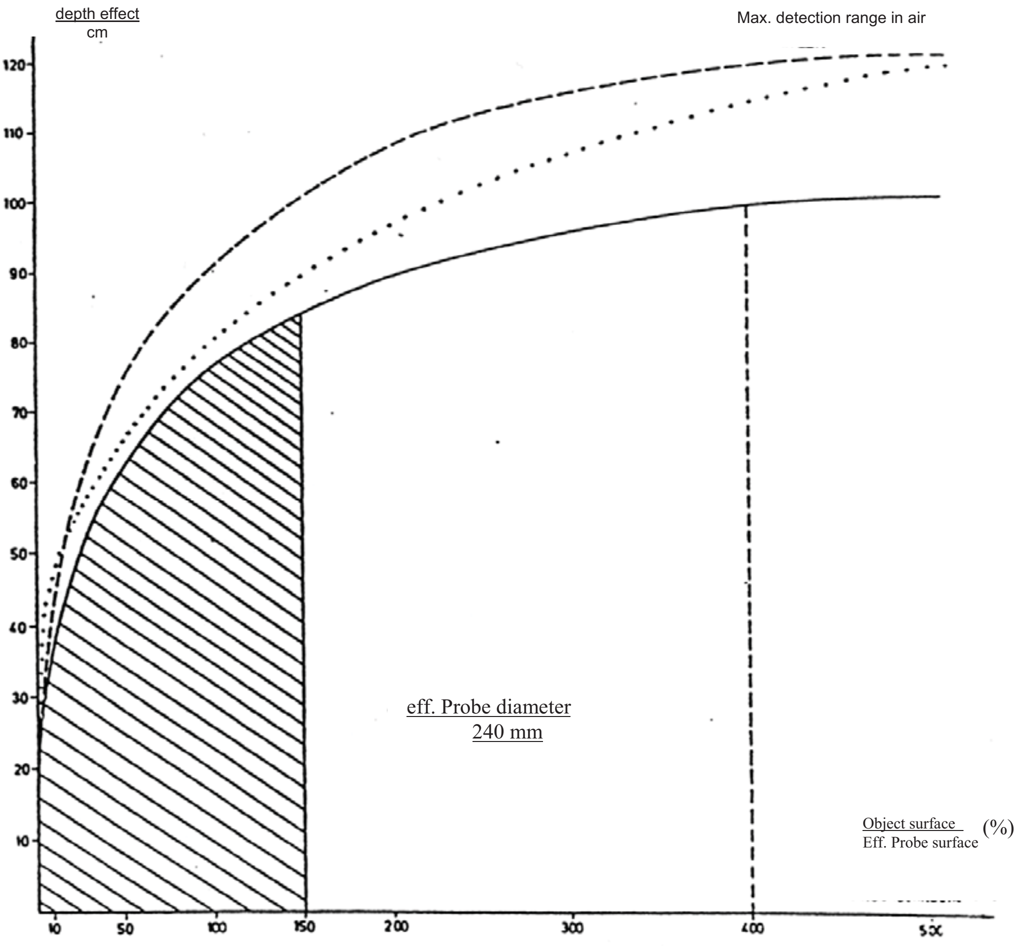


Fig 1 : Detection range chart: Detection ranges in correlation to the metal surface to be detected. The chart shows the theoretical performance of continuous wave metal detectors (dashed line) in comparison to pulse induction systems (dotted line). The continuous line symbolises the detection range which can be achieved in case of favourable search conditions.

Detection ranges in air are obviously dreamlike in case no 'electromagnetic interference' (EMI) was encountered during the tests. They cannot be expected to be reproducible in real fieldwork. Fig. 2 assists the detector operator with a picture on how detection sensitivity drops with increasing distance between search coil and target object.

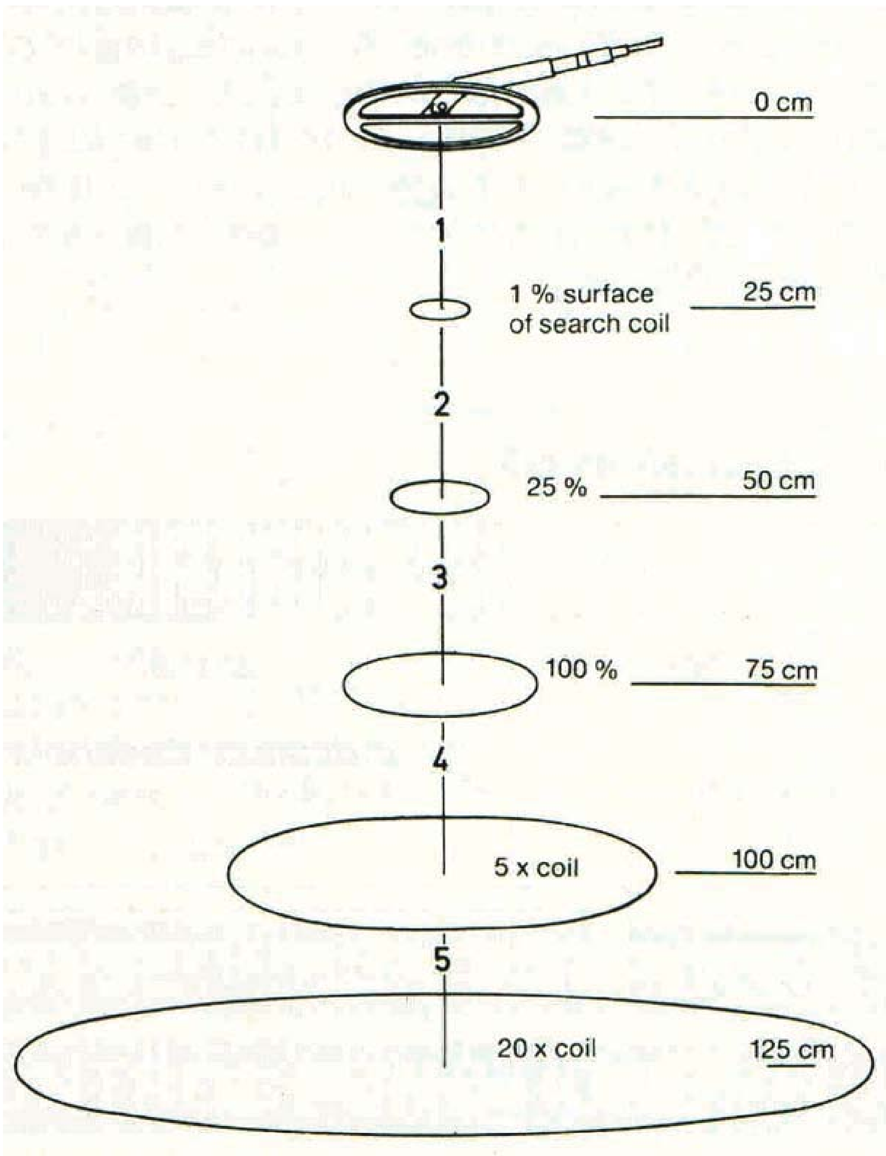


Fig. 2 Exemplary course of detection sensitivity in correlation to distance and surface of metal objects

The example clearly shows the loss of electromagnetic field strength between the primary (transmitter) and secondary effect (receiver):

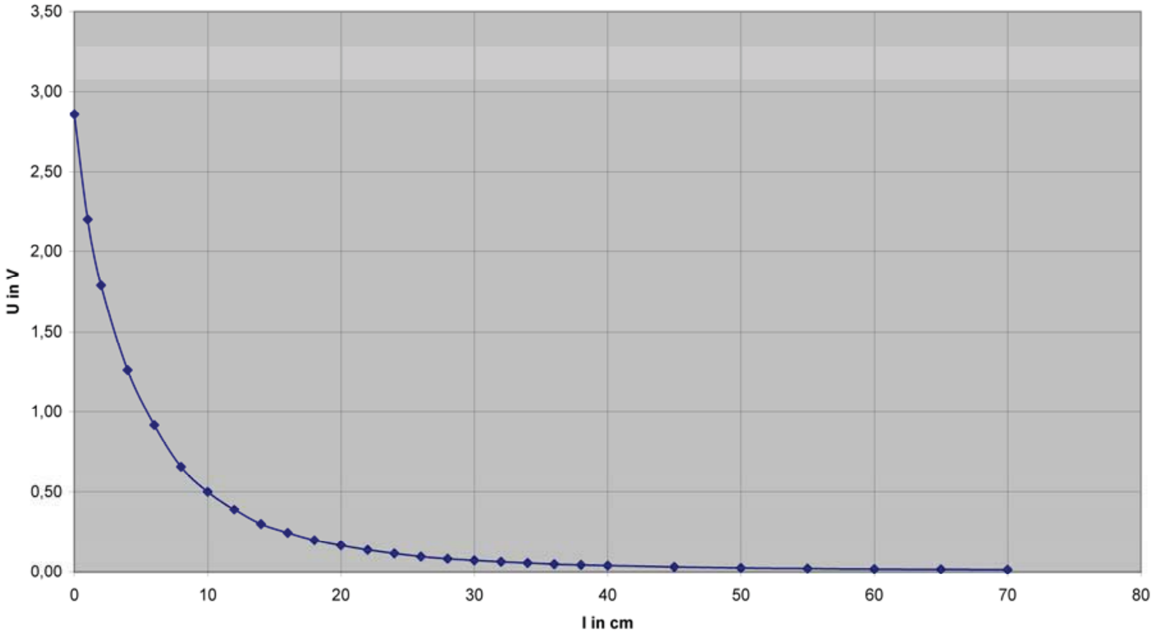


Fig. 3 A simple experiment: the graph shows the distance depending decrease of sensitivity resp. voltage in a receiver coil (uncompensated, approx. Ø 220 mm) which picks up the induced alternating field from an identically shaped transmitter coil.

3. Operation mode of active detectors

It is assumed that reader is aware of the fact that the all active detection principles require signals to travel the distance between antenna and target object twice: first from the antenna to the object inducing eddy currents which then cause a secondary field which travels back to the antenna to be processed and converted into a visual or audio indication.

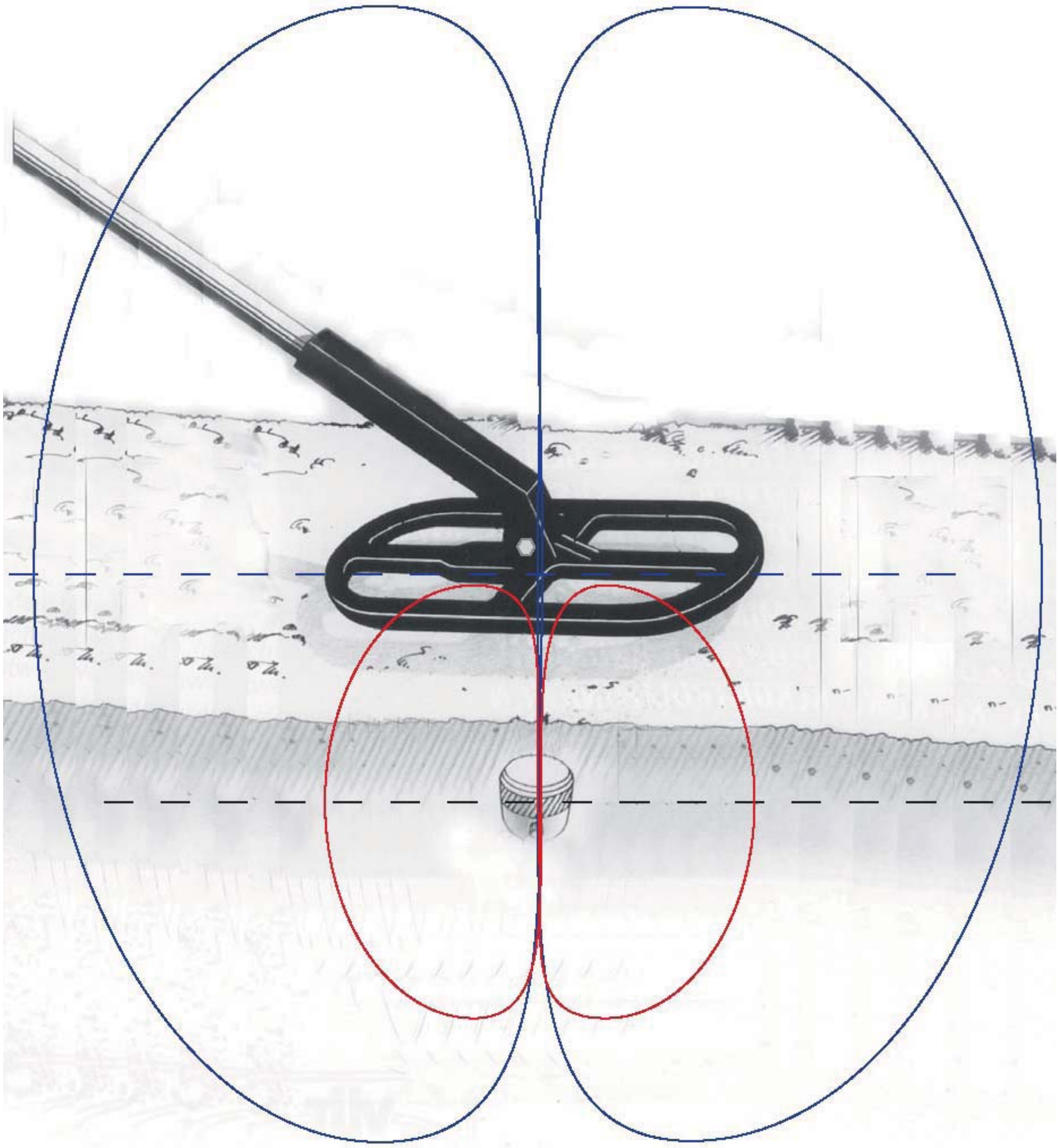


Fig. 4 Illustration of the primary field (blue) and the induced secondary field (red)

4. Concept of a close-, intermediate and far field

Figure 5 provides an idea on how the field strength of a metal detector signal can be classified for a practical understanding. The effective range of the *close field* represents the highest detection sensitivity as required for solving difficult detection tasks when minimum amounts of metal have to be located.

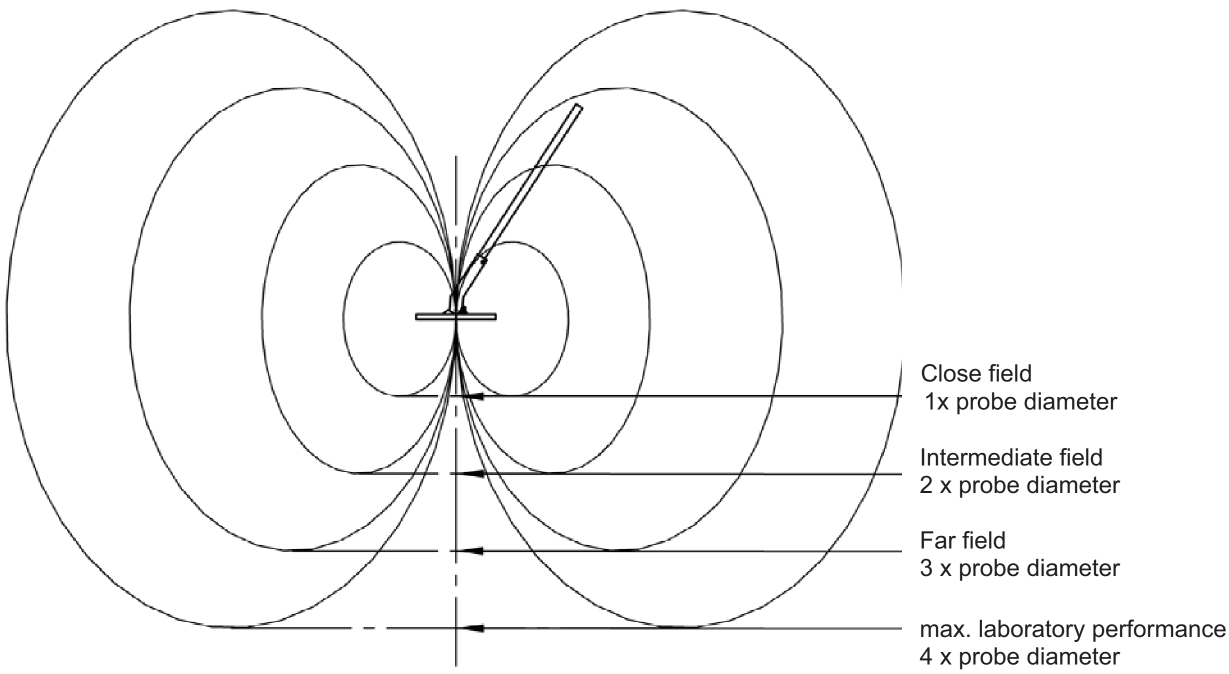


Fig. 5 close field, intermediate field and far field of a metal detector

5. Detection range factor

Detection conditions and scenarios can be quite different worldwide. In Humanitarian Mine Action minimum amounts of metal have to be detected. Equally in archaeology very small metal objects have to be located e.g. ancient coins in an area to be inspected. This requires a high detection sensitivity which is only available within the *close field* of the detector coil.

A new definition for the detection range factor for the *close field* is based on the metal surface required to allow a detection range which corresponds to the search coil diameter. Electrical short circuit rings are well suited to produce eddy current effects which correspond to those from non-ferrous objects showing the same face as the object imitation.

Reproducible detection ranges characterising the system sensitivity of a metal detector are normally measured in air. These values do not correspond to those experienced in real field operations. The bar chart in figure 6 shows the detection range on typical short circuit rings that were buried under magnetic floor casts. The detection range has been recorded in three detector sensitivity settings (1,2,3 = low, medium, high) in an environment with average electromagnetic interference (alternating fields, EMI).

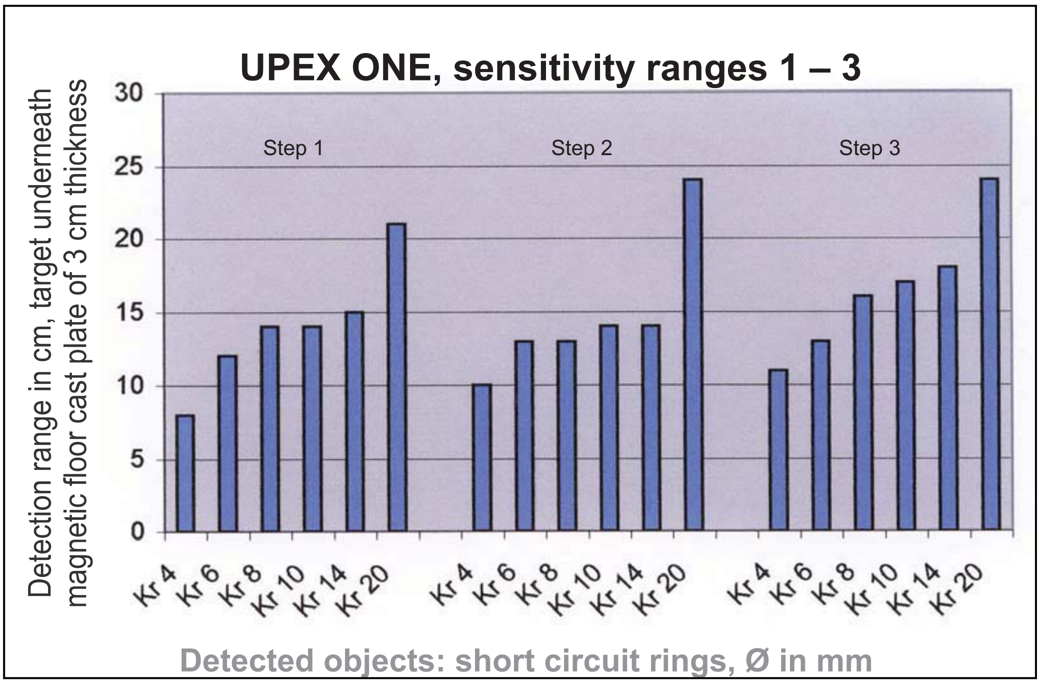


Fig 6. UPEX ONE detection range chart with standard coil 230 mm

If only large metal objects have to be located (e.g. in BAC) small metal fragments are a source of substantial interference. To verify the 'system sensitivity' of a “subsurface detector” metal plates as defined in fig. 1 are well suited.

The shaded section under the curve indicates the useful detection range of a standard metal detector when applied in favourable search conditions. **The detection range factor 3 of a detector is established by detection of a metal plate, which is of the same size as the detector coil's surface.** The coil has a diameter of 250 mm and the detection range is approx. 75 cm, which corresponds to three times of the coil diameter.

Depending on the detector operation principle a detection factor of 4 (=1m) might be achievable in laboratory conditions. Unfortunately this value is only useful for promotion but meaningless for field operations!

6. Factors of common influence

Typical factors of influence which can considerably reduce detection ranges achieved in air are:

- **Electromagnetic interaction – air – ground – water:**
  These impact factors can be characterized as NOISE that can superimpose to the detection signal. The ground and its mineral content show electric conductivity (salt water will do also) which will influence the transmitter and the receiver signal. Volcanic rock, lava ashes, laterite and fertilised soil are just a few of possible origins for ground interference.

- **Environment, electromagnetic alternating fields, radio signals, earth field induction, electric discharge in the air:**
  EMI is a collective term for the electromagnetic interference which deteriorates the receiver signal (or in worst case cover it). The presence of man-made scrap metal or remnants of war, such as for example on UXO demolition areas, is a crucial factor to success.

- **Dielectric effects:**
  These effects can be released by wet ground or vegetation. The “grass effect” modulates the detection signal and is a proof for the electrical component of the transmitted AC field. It's interference shows that a sensor has been insufficiently shielded against such capacitive effects. To check on such effects the “wet cloth test“ can be carried out. Touch or wipe the coil with a wet cloth while the detector operates at maximum sensitivity. The basic detector signal should change only little or not at all!

- **Electro mechanic sensor capacity:**
  relates to the mechanical stability of the search coil which can be misadjusted or change its electric parameters if subject to pressure or knocks. Halo search heads of decoupled VLF-TR systems are particularly sensitive to this.

- **Electric stability:**
  The stability results from the interaction of all electric/electronic and electro - mechanic parameters of the search arrangement. Thermal effects have to be mentioned in particular when looking at possible reasons for electric drifts or a reduced long-term stability during detector operation in static detection mode.

High standards have to be set to the search head, as it is the sensing part of the devices! On one hand it should sense extremely weak secondary signals, on the other hand it should be of lightweight, sturdy and suppress interference.

7. Various probe designs

Fig. 7

8. Ground effects

This topic is crucial to successful detection and discussed here after:

The electromagnetic character of the ground i.e. its electrical conductivity and magnetic susceptibility are generally determined by its chemical composition (content of metallic compounds), the level of decomposition resp. level of oxidation (grain size) and its content of humidity (amount of ionic solutions). These parameters can show strong frequency dependence such as i.e. resonance but may also support soil-compensating measures in the detector design. The ground can also be magnetised, notably by pulsed magnetic fields, which causes interfering retroactivity.

Before said has a direct effect on the distribution of the primary electromagnetic fields of the metal detector and on the secondary fields from the detected object. It is circumstantial if the detector applies continuous or pulsating alternating fields. In the worst case it would only lead to a slight damping of the primary and secondary fields reducing the achievable detection ranges. By far more complex processes will happen in volcanic ground or in laterite areas near the equator. They cause a strong interference to conventional detection technology. The non-cooperative soil can cause strong detection signals which cover any wanted detection signal entirely.

In a field operation the intensity of such ground response can be determined by approaching the search head of a well-calibrated detector from 1 m height to the ground while measuring the ground response signal. Depending on the character of the underground this response signal will be positive or negative (increasing or decreasing). The distance from where the ground response is noticeable is a measure for the intensity of the interference.

Mild ground effects can be suppressed by an appropriate selection of the alarm threshold value of the metal detector or by applying a dynamic search mode. If the ground effects are of substantial strength the sensitivity has to be reduced resp. increased. An experienced operated will succeed to ignore ground effects within limits when using a combination of all possible adjustments (sensitivity/amplification) and threshold values. **Obviously this will reduce the detection range.**

Due to the various techniques and search head designs the numerous commercial metal detectors respond in quite a different way to the described interference. There are detection principles that inherently react less sensitive to the ground effects. So for example the EBINGER continuous wave system that took hold in the field of battle area clearance and is still applied today with good success.

9. Ground compensation

A special technique for effective ground compensation is required when minimum amounts of metal (i.e. metal components in plastic mines) have to be detected in mineralised, laterite soil.

This technique is based on the combination of various procedures and steps of signal processing which can be consulted in some national and international patent applications. EBINGER pioneered also in this field which led to some additional patents and to new locators. Innovation and the creation of trend-setting technique are the prime task of the company.

Level of ground interference

search head and ground clearance

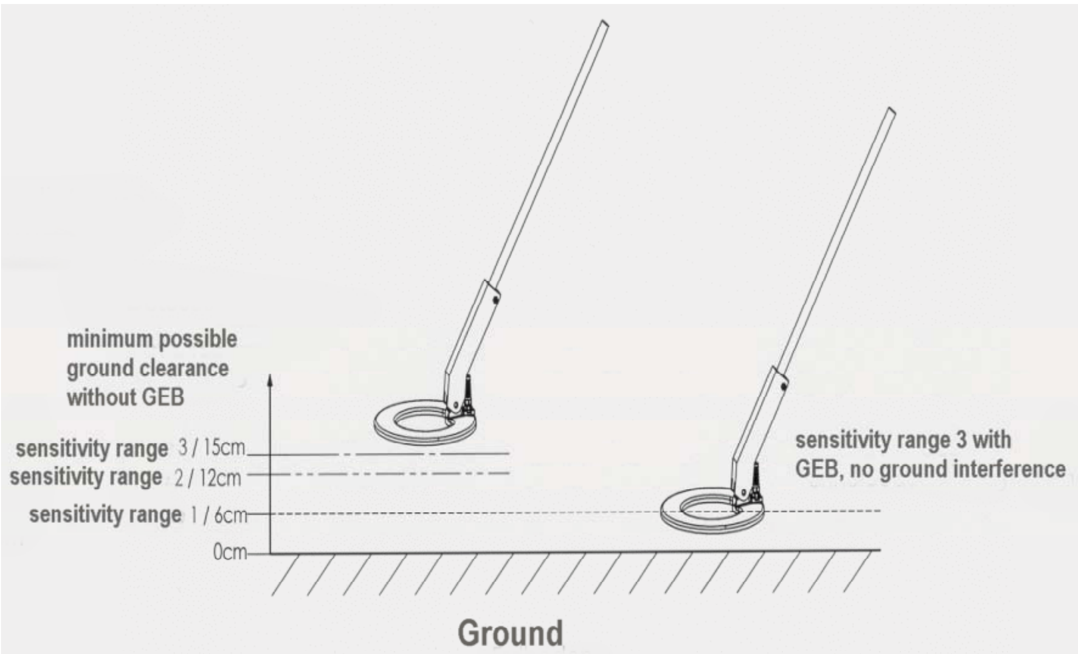


Fig. 8 Level of ground interference with and without GEB (Ground compensation)

10. Various detection techniques

Essentially we distinguish active systems between CW and TD systems:

- **CW systems:**
  CW is the abbreviation for Continuous Wave and relates to the continuous wave detection principle applying alternating electromagnetic fields.

- **TD systems:**
  TD stands for Time Domain – time operated detection systems applying short magnetic pulses according to the Pulse Induction principle.

11. Conventional Metal Mine detectors

During World War II various metal mine detectors were developed. All known detectors were based on the CW system applying alternating electromagnetic fields of high or low frequency to inspect the underground for metal objects. It would carry matters too far to list them all here. After the war the US mine detector SCR 625 was introduced into German BAC. It was updated and “transistorised” by EBINGER in the early 60ies (fig. 9).

Fig. 9 SCR 625 in the original and in transistorised version

Further R&D led to the design of the so-called *'hockey stick',* respectively the *KÖLN 661* detector, which appeared in 1966 and was mass-produced in the following years. In those days the CW systems suffered from considerable disadvantages as they were strongly interfered by mineralised soil and did not work well on volcanic ground.

Fig. 10 detector Köln 661

12. The EB continuous wave system

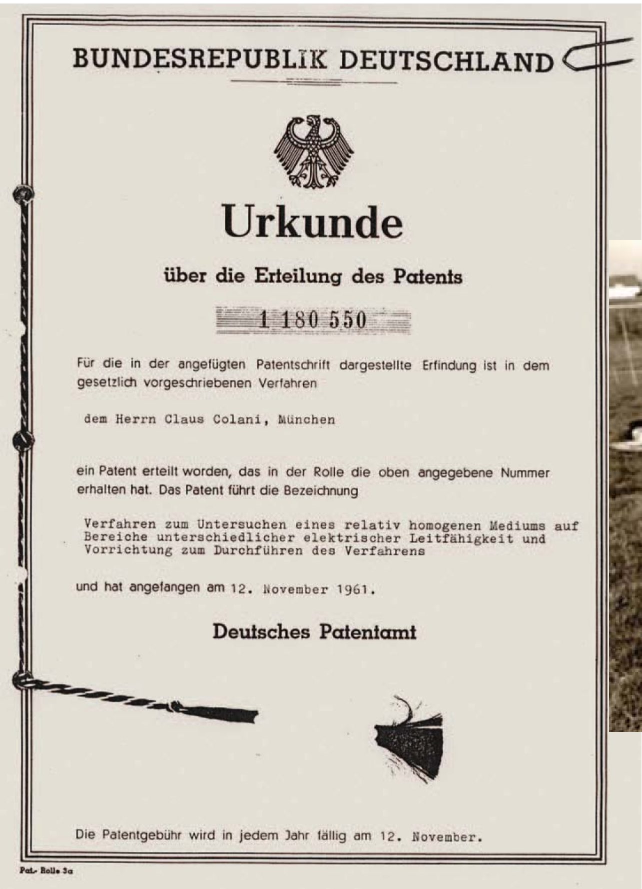
In 1968 EBINGER discovered the so-called damping system where the amplitude of a free-swinging oscillator was affected when metal objects came within the effective range of the detector search coil. At the time this EB system was considered to be a breakthrough, which changed the metal mine detector technology applied in BAC.

Fig. 11 Detector EB 710 (sine wave system in operation)

13. Pulse Induction principle

The German graduated engineer Claus Colani, Munich, invented the modern Pulse Induction principle. His “pulse patent” is mainly based on the so-called 'step function'.

Metal objects are “activated” by a sequence of primary magnetic pulses to become pulsating transmitters. Colani discovered the phenomenon that relatively short magnetic pulses cause long response signals in the metal objects resp. electromagnetic response signals with an extended decay time. These can be detected as a kind of echo and then transformed into an audio signal.



BUNDESREPUBLIK DEUTSCHLAND

Urkunde

über die Erteilung des Patents

1 180 550

Für die in der angefügten Patentschrift dargestellte Erfindung ist in dem gesetzlich vorgeschriebenen Verfahren

dem Herrn Claus Colani, München

ein Patent erteilt worden, das in der Rolle die oben angegebene Nummer erhalten hat. Das Patent führt die Bezeichnung

Verfahren zum Untersuchen eines relativ homogenen Mediums auf Bereiche unterschiedlicher elektrischer Leitfähigkeit und Vorrichtung zum Durchführen des Verfahrens

und hat angefangen am 12. November 1961.

Deutsches Patentamt

Die Patentgebühr wird in jedem Jahr fällig am 12. November.

Pat.-Rolle 3a

Fig 12 Colani's patent certificate 1180550 and a wheeled PI system with data output applied in archaeology, - Colani was well ahead of his time.

EBINGER became the first manufacturer of pulse induction metal detectors in Germany after it had purchased the Colani patents in 1973. In the meantime the pulse induction principle has been circulated worldwide. Compared to the CW system it has specific advantages which are explained on our website.

14. Summary

Detection ranges measured in air can serve only as a kind of reference for the “system sensitivity” of a metal detector. Due to different operational conditions they cannot or only partly be transferred to real field operations. Only the real detector performance in the field or on mineralized ground is of importance to the user. Detection ranges in air allow no conclusions about the performance of a metal detector in field use as they may considerably be impeded by interference which have been already been described. We as the manufacturer of metal detectors strive for clarification about this issue. Due to the lack of standards a performance description for active detection systems is still rather complex.

15. Patent specifications

Colani Patent 1 180 550 (PI primal patent)

PI literature: magazine FREQUENZ 22 (1968) 10

Ebinger:
DE 25 49 329 C2/1976: circuit arrangement bomb detector
DE 36 19 308 C1/1986: Probe for a metal detector
DE 41 12 363 C2/1992: Metal detector
DE 195 06 339 A1/1995: Technique/Circuit, object detection
EP 0 816 870 A2/1997: Metal detector/technique
DE 197 30 952 A1:1997: Technique/Detection device
DE 101 64 303 A1/2001: Technique and Detector device

(19) BUNDESREPUBLIK DEUTSCHLAND

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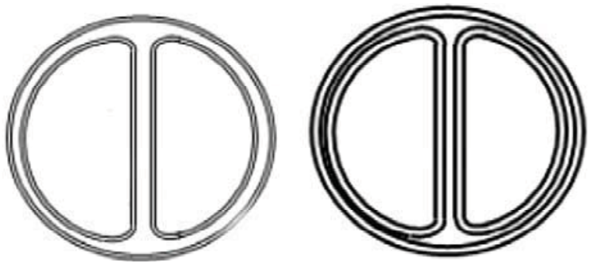
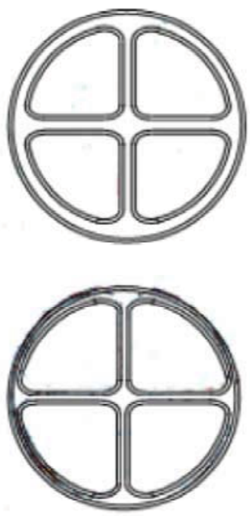
NICHTS-ERMITTELT



(54) Sonde für ein Metallsuchgerät

Ein als Differenzmesser arbeitendes Metallsuchgerät enthält als wesentliche Elemente einen Oszillator, eine an diesen angeschlossene Senderspule, mindestens zwei Empfängerspulen und eine an diese angeschlossene Anzeigevorrichtung. Die Spulen sind gemeinsam in einem tellerförmigen Gehäuse, der Sonde, angeordnet. Die Empfängerspulen sind elektrisch gegeneinander geschaltet. Das Problem liegt darin, die die Spulen enthaltende Sonde möglichst leicht und mit wenig Volumen und Fläche auszubilden. Zur Lösung dieses Problems ist die Empfängerspule gemäß der Erfindung innerhalb der Senderspule angeordnet. Bei Verwendung von mehr als einer Empfängerspule wird das die Sonde bildende Gehäuse durch Stege unterteilt. In die dadurch entstehenden Mulden werden die verschiedenen Empfängerspulen innerhalb der Senderspule angeordnet.



DE 3619308 C1

Fig. 13 A lot of experts argued over this patent which finally found varied interested parties

Technikzentrum Wiesbaum

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Wiesbaum Area of responsibilities:

- Sales for Germany / Benelux
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- Analogue/digital test procedurs (R&D)
- Test of underwater systems
- Instructions and training

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