Cable locating principles and limitations

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Picture: Search with CB DiffAnt

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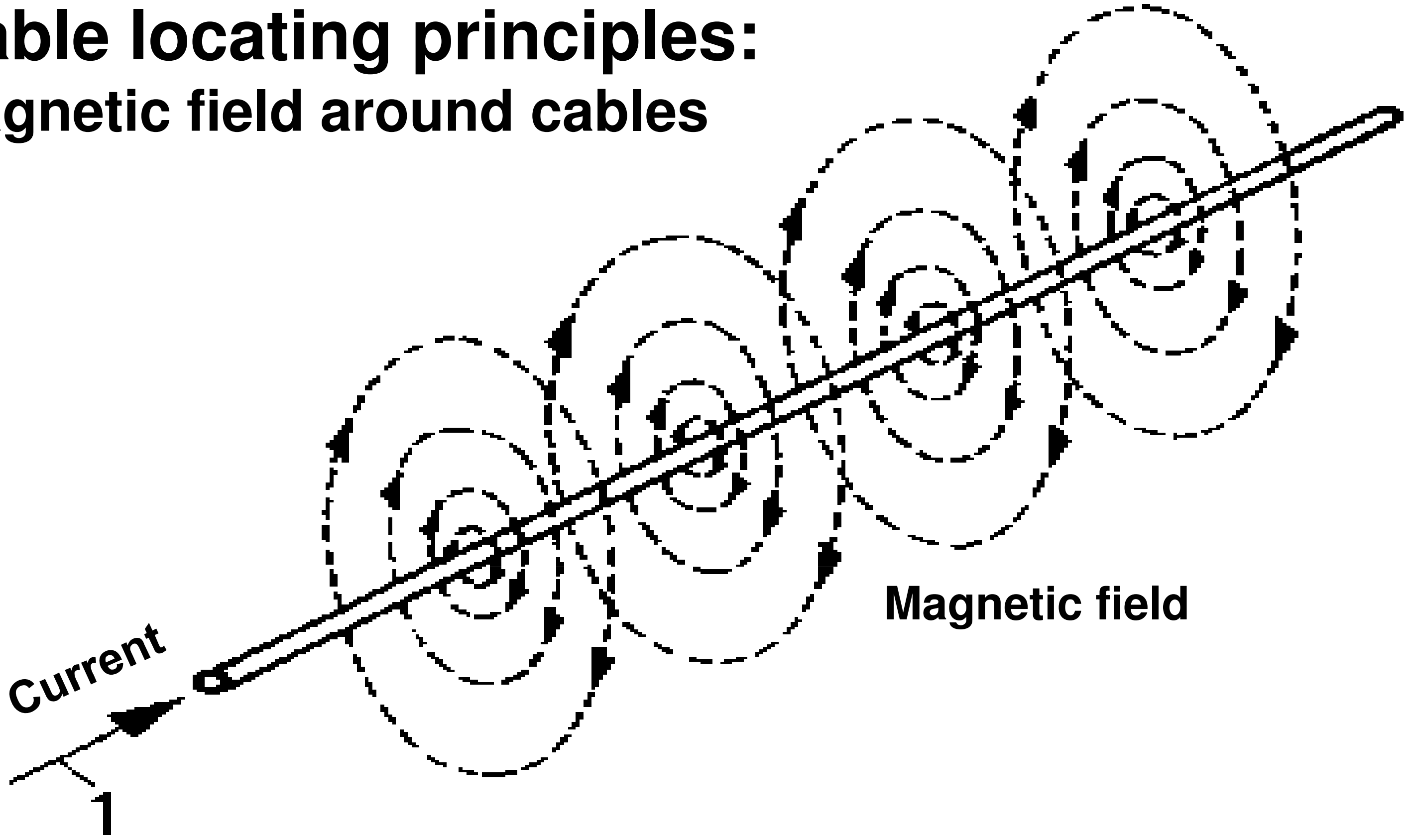
Scope of presentation

This presentation is not made for the expert, but for site managers and excavator drivers with emphasis on cable avoidance using passive search (exploiting "natural" signals).

Cable locating principles:

Magnetic field around cables



All cable locators are based on detecting magnetic AC fields from the cables to be located. The magnetic field that surrounds a cable penetrates well through rock, soil, ice and water, whereas the electric field is too strongly attenuated and distorted to be useful.

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Signal sources

The cable signals can be artificially induced by a sender (signal injector) or stem from power or telecom signals or pick up of radio signals and stray fields from neighbour cables.

Using a sender is called <u>active cable location</u>.

Depending on "natural" signals is called <u>passive cable location</u>.

An artificial signal can be introduced in three different ways:

1. **Direct, galvanic coupling. Inserting a signal generator between the cable and earth.**
2. **Placing a transformer clamp (split ring transformer) on the cable.**
3. **Sender with antenna coil (e.g. ferrite rod antenna) placed on the ground across the cable.**

Frequency range

Frequencies used for cable location vary from 50-60Hz to several hundred kHz.

<u>Low frequencies</u> give long tracking range and little "cross talk". They are best suited for tracking specific cables over long distances and normally require the use of a sender (with exception of 50-60Hz).

<u>High frequencies</u> (let us say: above 30kHz) are best suited for passive cable localizing and "cable avoidance". They suffer stronger attenu-ation over distance and are more exposed to crosstalk and pick up of foreign signals, giving "life" in the cables, than lower frequencies.

The frequency dependence is a function of wavelength. Lower frequency gives longer wavelength (= Vp / f). Vp is the propagation velocity in the cable (approx 2/3 x speed of light) and f is the frequency. 100kHz corre-spond to a wawelength of approx. 2km, whereas 10kHz corresponds to 20km. Coupling is a matter of distances measured in fractions of wavelengths.

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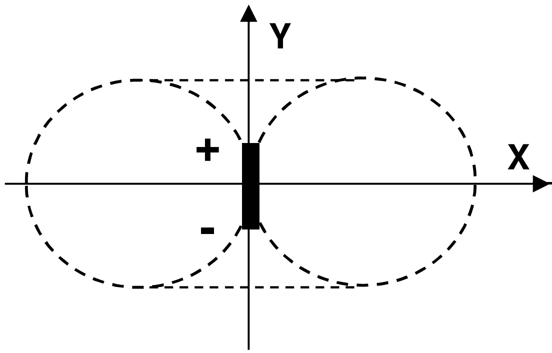
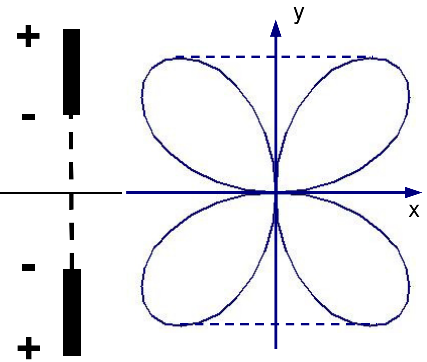
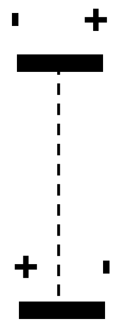
Basic antenna configurations

The antennas of a cable locator are pick up coils, normally with a ferrite core (concentrating the field) for reducing the necessary size of the coil.

A cable locator may have from a single to six antenna elements, depending on functionality.







Single antenna and sensitivity pattern

Axially stacked dual antenna and sensitivity pattern

Radially stacked dual antenna.

Allows making very small and handy instruments, but does not discriminate betwwen near field and far field and is sensitive to disturbances from foreign signals (e.g. radio signals).

Near field antennas. Unsensitive to direct radio signals, but pick them up indirectly via cables. (Cables act as antennas.) The axially stacked antenna has a sharp signal minimum, when pointing at the cable. The radially stacked one has a maximum with the coils oriented across the cable.

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Vertical or horizontal antenna orientation?

Horizontal antenna coils:

- **Best sensitivity. Maximum when positioned across a cable, null when pointing along the cable.**
- **Most true individual positions of parallel cables <u>with correlated signals</u>. The maximum is, however, rounded and quite unsharp.**

Vertical antenna coils:

- **3dB less sensitivity. Sharp minimum (deep notch) when pointing at a cable. Maxima at a approx. one cable depth on each side.**
- **More erratic indications of parallel cables with correlated signals, but <u>better than horizontal on uncorrelated signals</u> (independent random noise).**

The vertical configuration was preferred for CB DiffAnt due to the more distinct indication and more favorable shape (straight rod).

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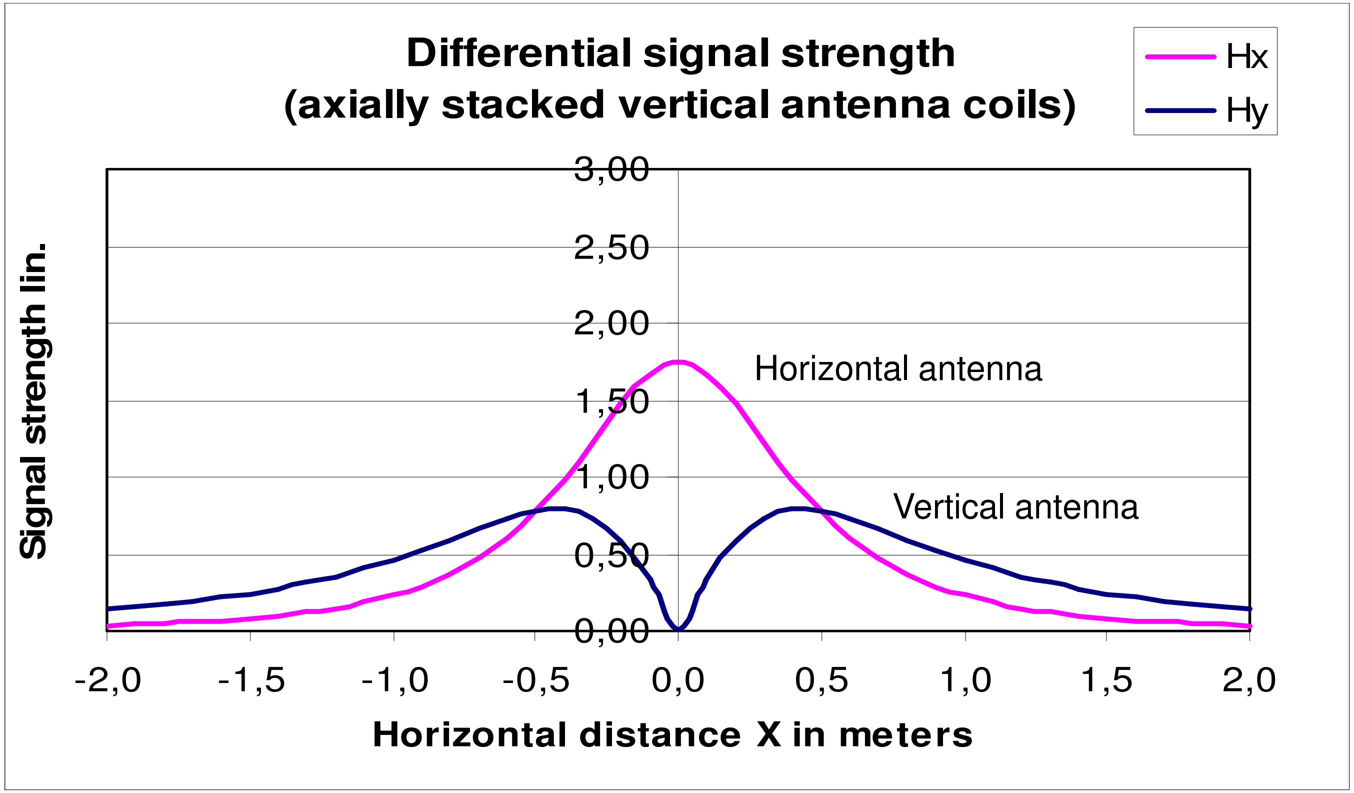
Response on single cable, lin.



Single cable at X=0 in 50cm depth, linear scale

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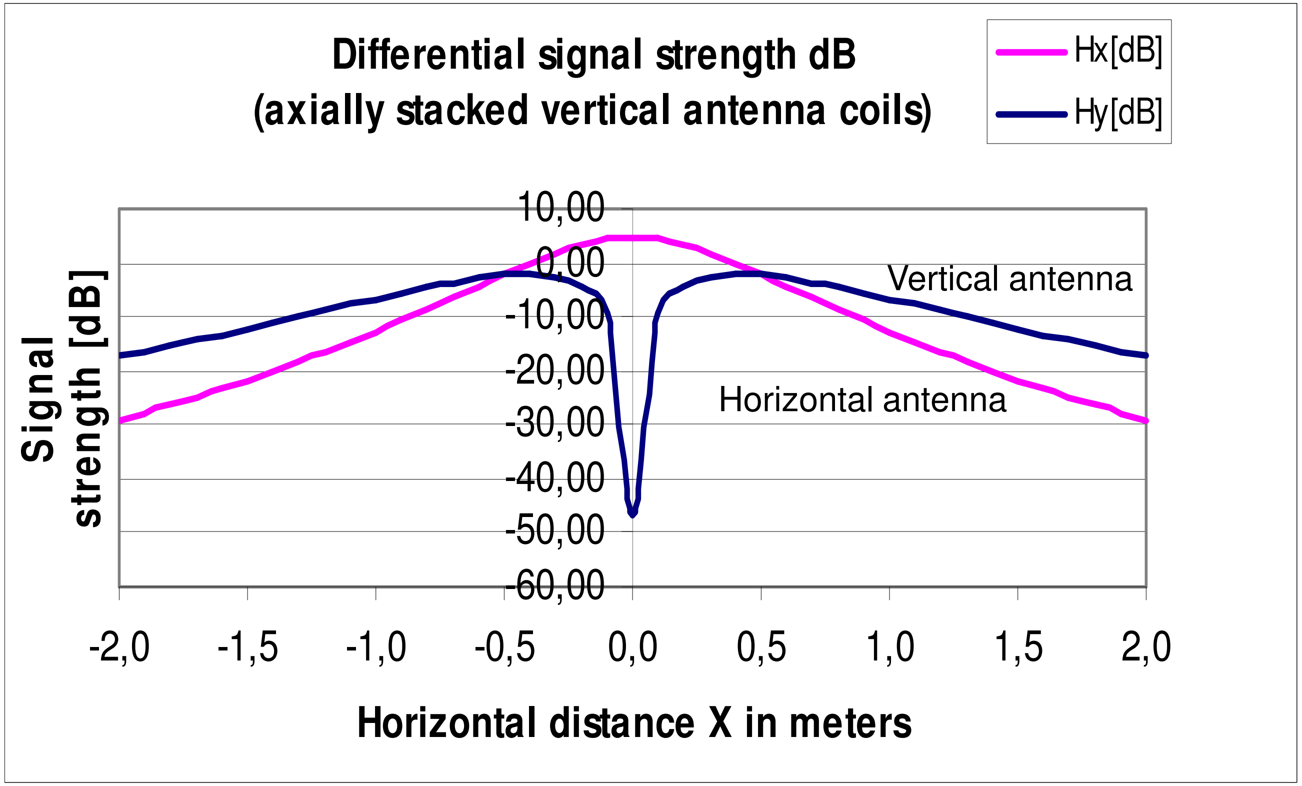
Response on single cable, dB



Single cable at X=0 in 50cm depth, logarithmic in dB

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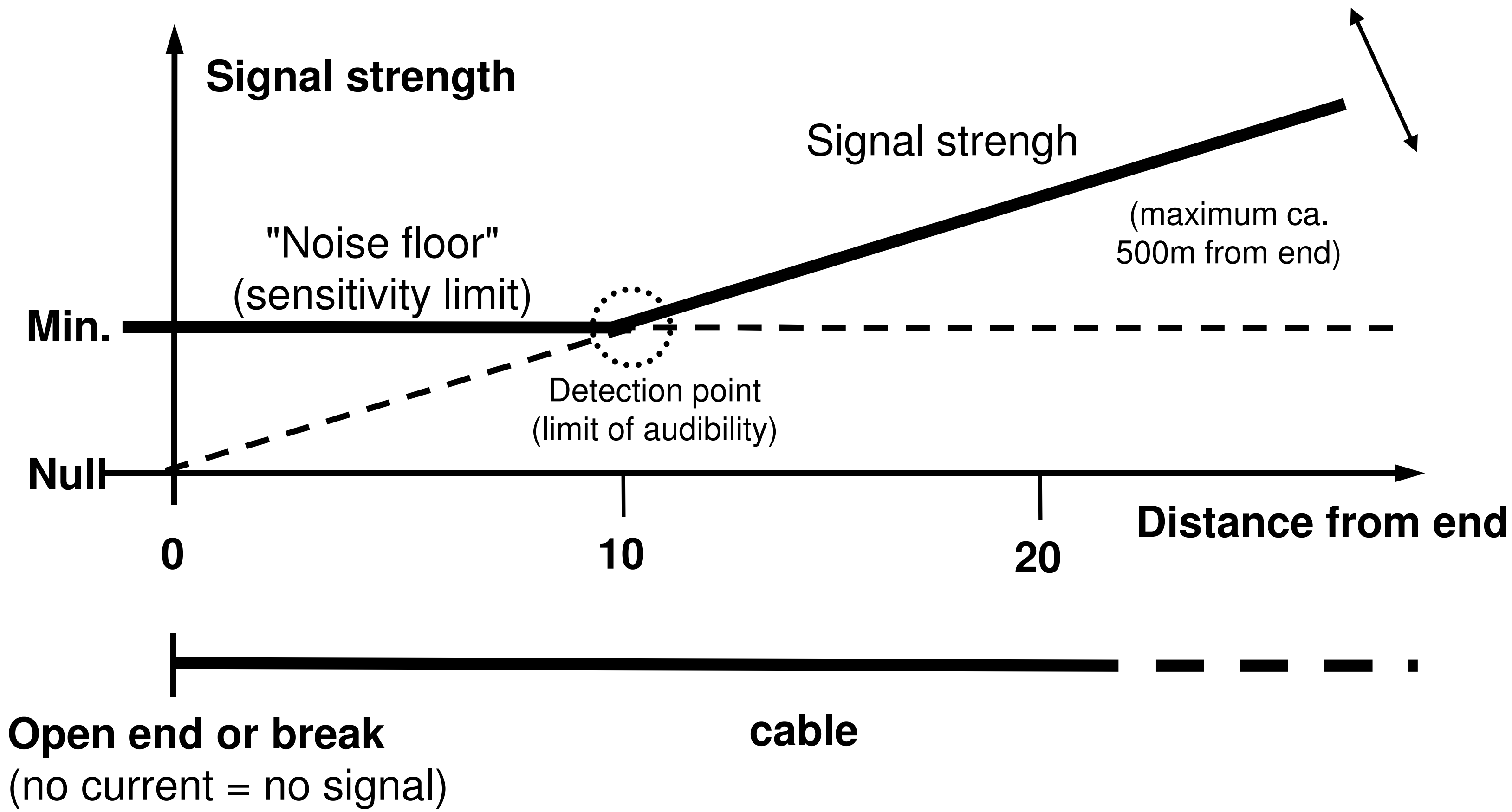
Error sources and limits

Cable detection is limited by:

- Signal strength
- Noise and interference
- Ambiguities (false maxima and minima) caused by reception of multiple signals.

See illustrations on the following pages.

Basic limitation:
Distance to nearest break or open end



The signal disappears gradually when approaching a break or a dead end. A stronger signal (e.g. from a sender) can be traced further towards the end of the cable.

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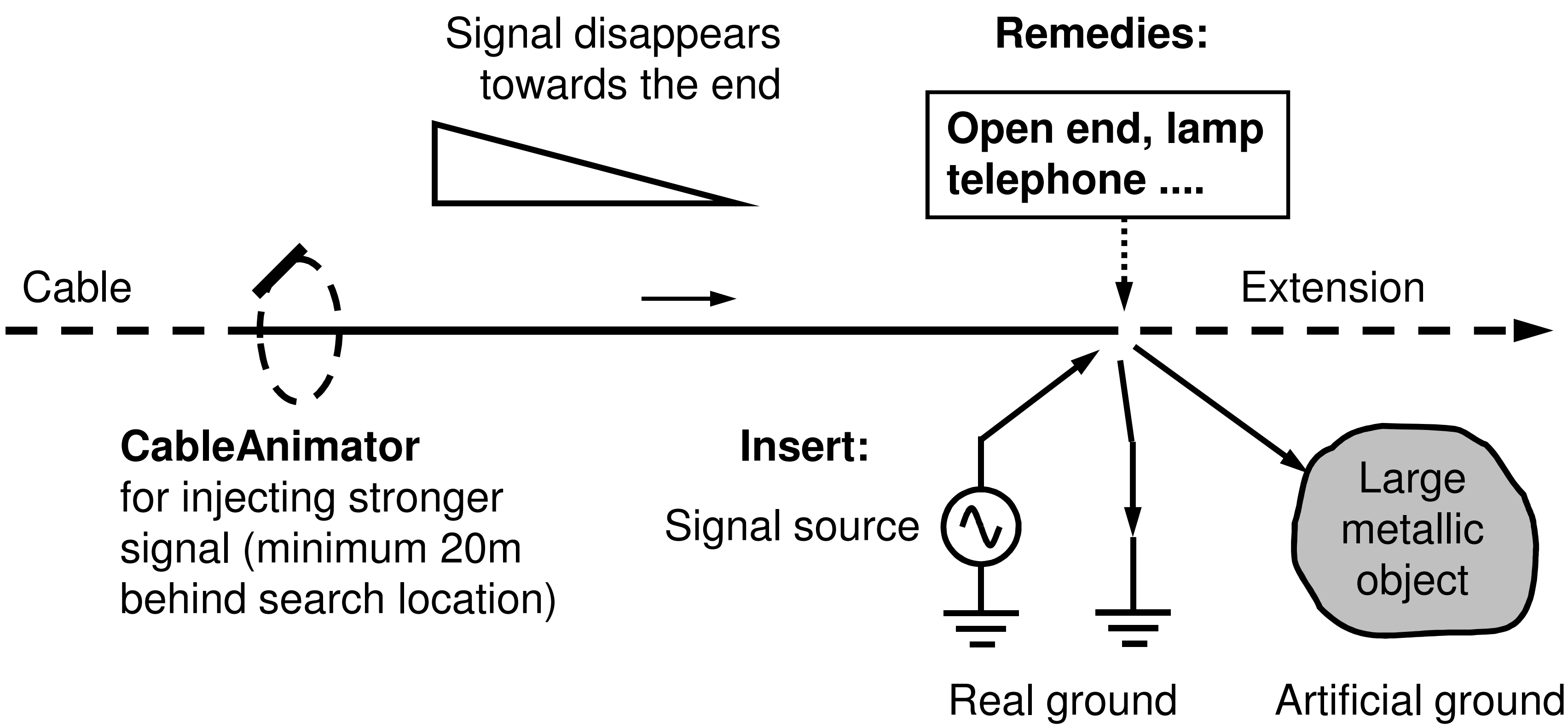
Short distance to dead end
what can you do?



End terminating possibilities

It may be a good idea to insert at power saving lamp and turn on the light, if the cable ends in a lamp holder. Power saving lamps are potent noise sources.

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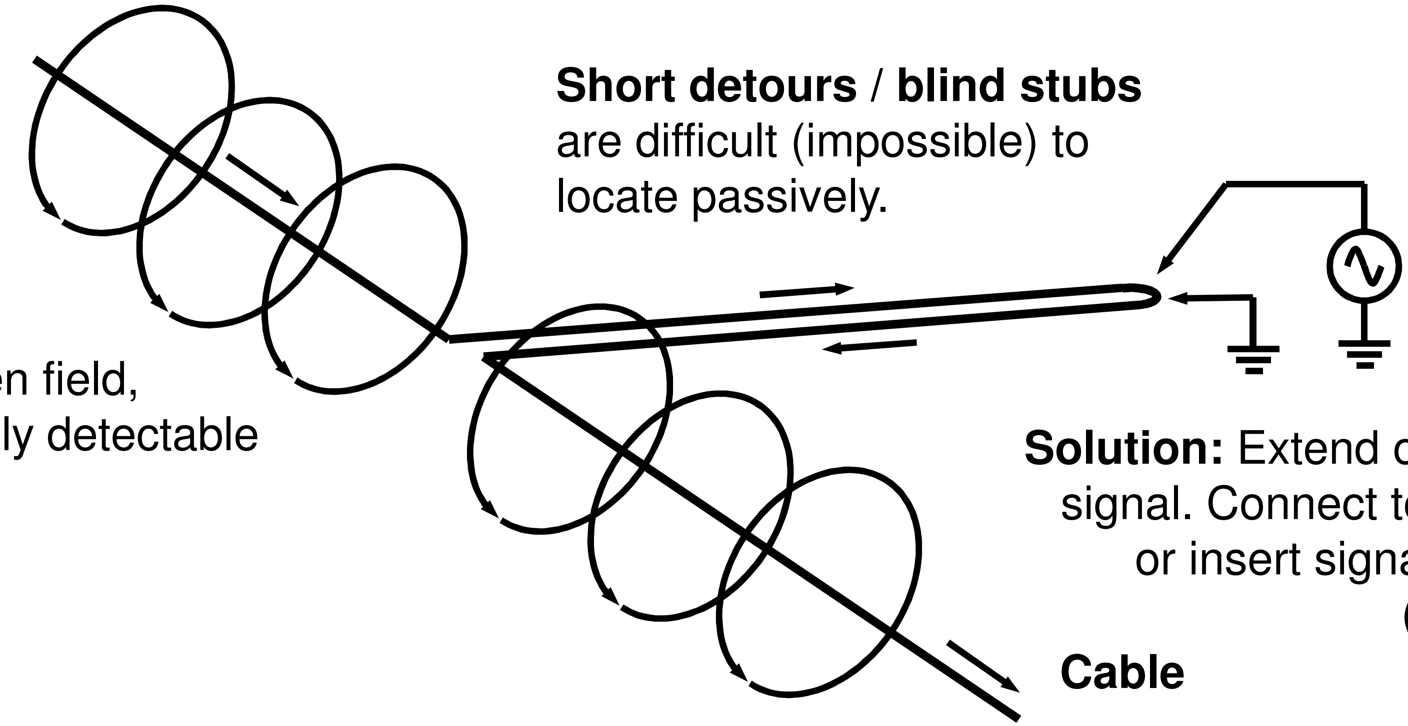
Short blind stub



Short detours / blind stubs are difficult (impossible) to locate passively.

Open field, easily detectable

Solution: Extend or feed in signal. Connect to ground or insert signal source (sender).

Cable

Detours to streetlight masts etc. are difficult to localize because the current goes back and forth in the same track, and the magnetic fields cancel out at a distance. In the case of street illumination it may help to turn on the light (noisy gas discharge lamps) in order to produce a stronger signal.

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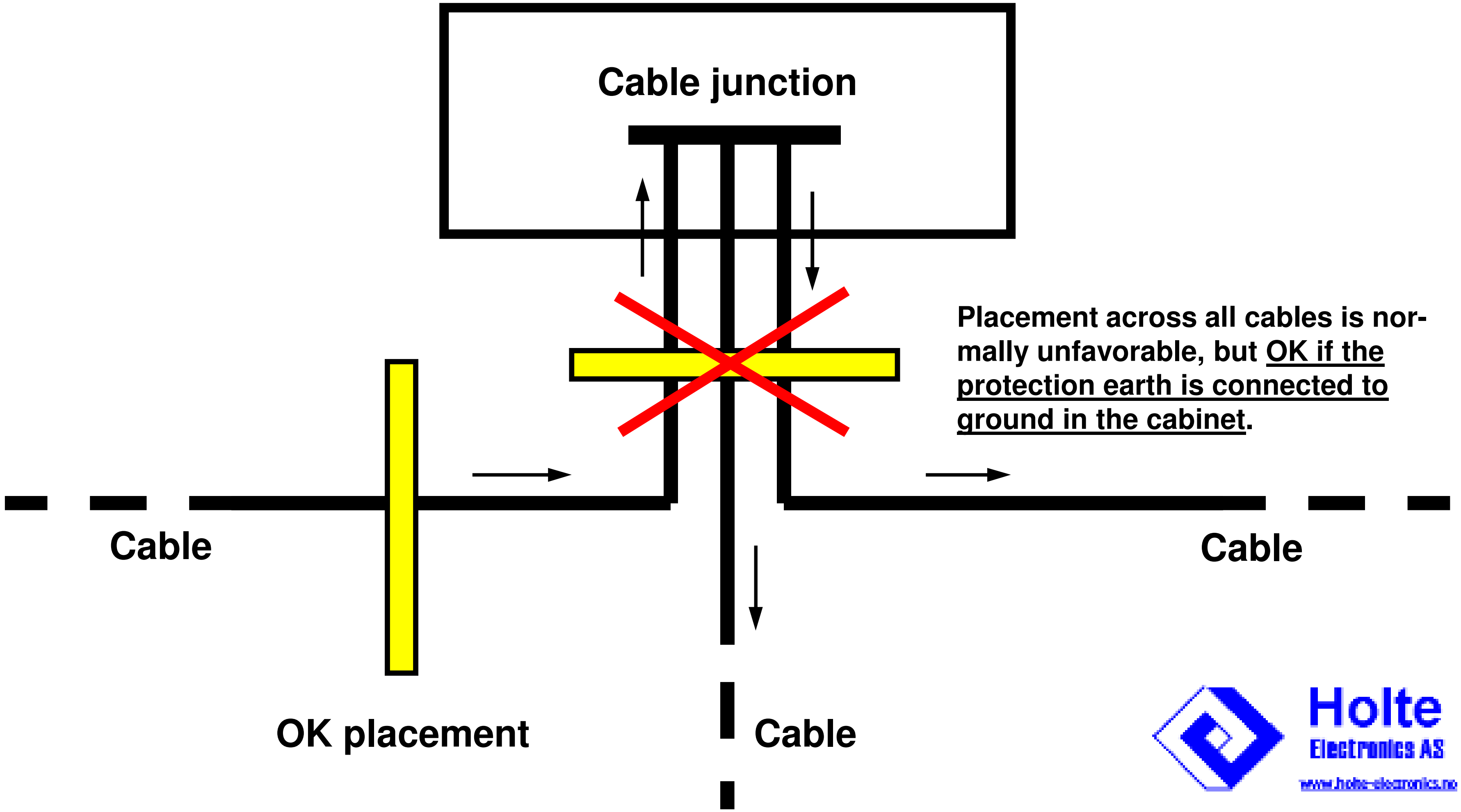
Junction cabinets

Avoid placing the CableAnimator across all the cables at a junction with no ground connection. (Ref. short detour).



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Signals from multiple sources

is a problem in congested areas.

A dominating signal can mask other signals and cause misleading field distortions. It is like with sound – the strongest sound wins!

I.e.: The signal from a noisy cable can prevent nearby cables from being detected. This is escpecially a problem for passive cable location which depends on "natural" signals.

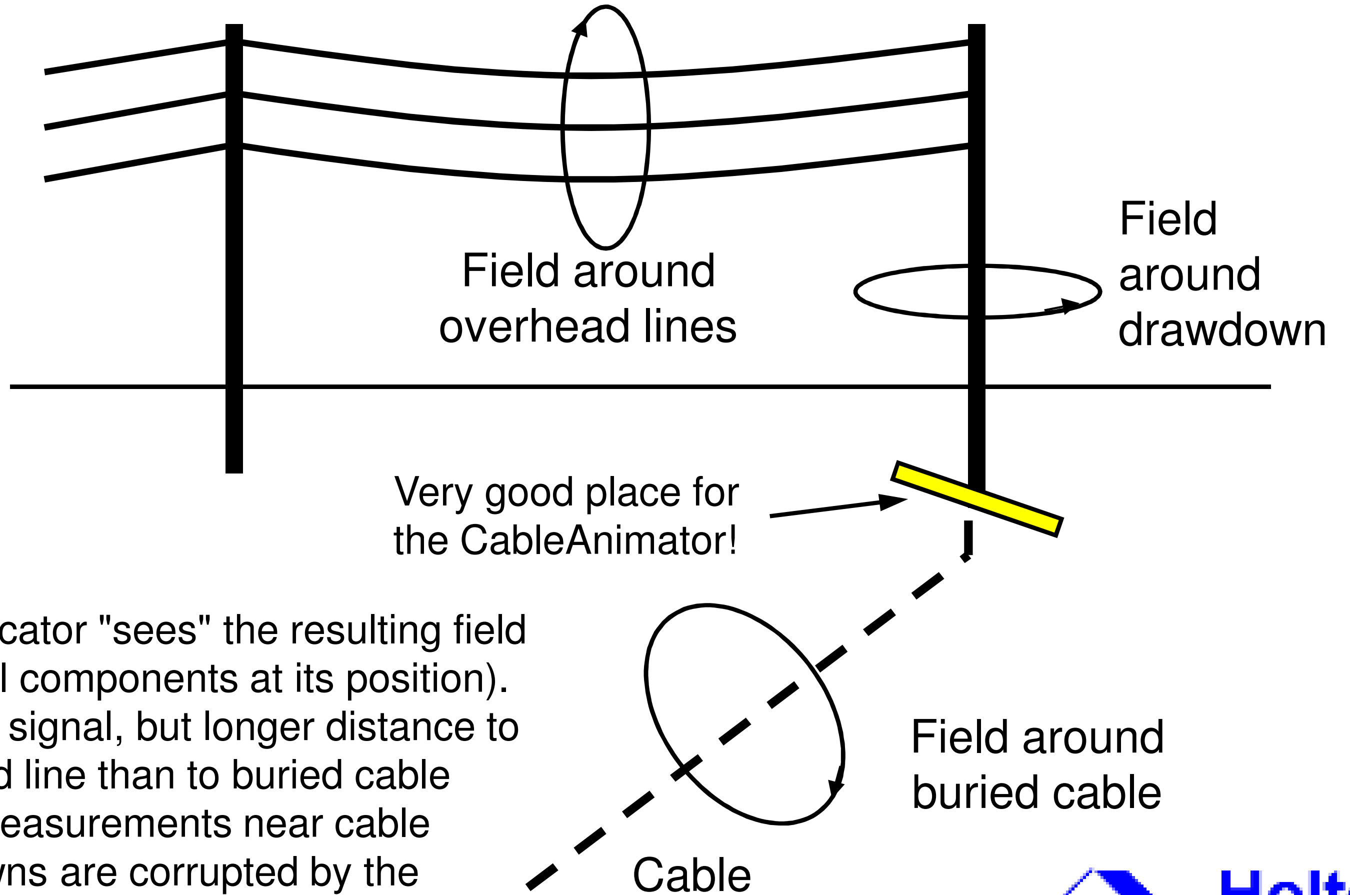
The signal strength differences can be formidable. 60dB corre-sponds to a factor of 1000. A 60dB stronger signal may suppress other signals within a range of 10 - 20 meters. 20dB is a factor of 10, enough to make neighbour cables undetectable. 10dB is a factor of 3, enough to cause erroneous measurements within a distance of some cable depths.

Be aware that you can have overlooked other cables near a very noisy one!

Overhead lines and cable drawdowns

Confusing, many error sources!

The cable locator may be confused by overhead lines and drawdowns!



A cable locator "sees" the resulting field (sum of all components at its position).

- Identical signal, but longer distance to overhead line than to buried cable
- Depth measurements near cable drawdowns are corrupted by the horisontal field from the drawdown.

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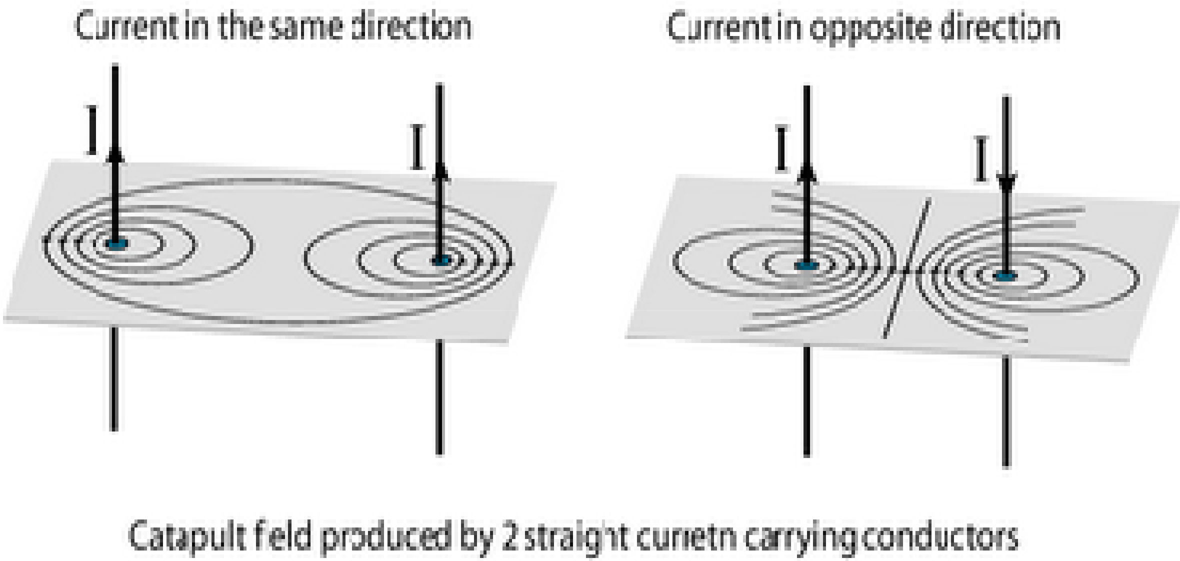
Parallel cables



Basic field distribution around parallel conductors

Signals from multiple cables

Signals from multiple cables can be very confusing.

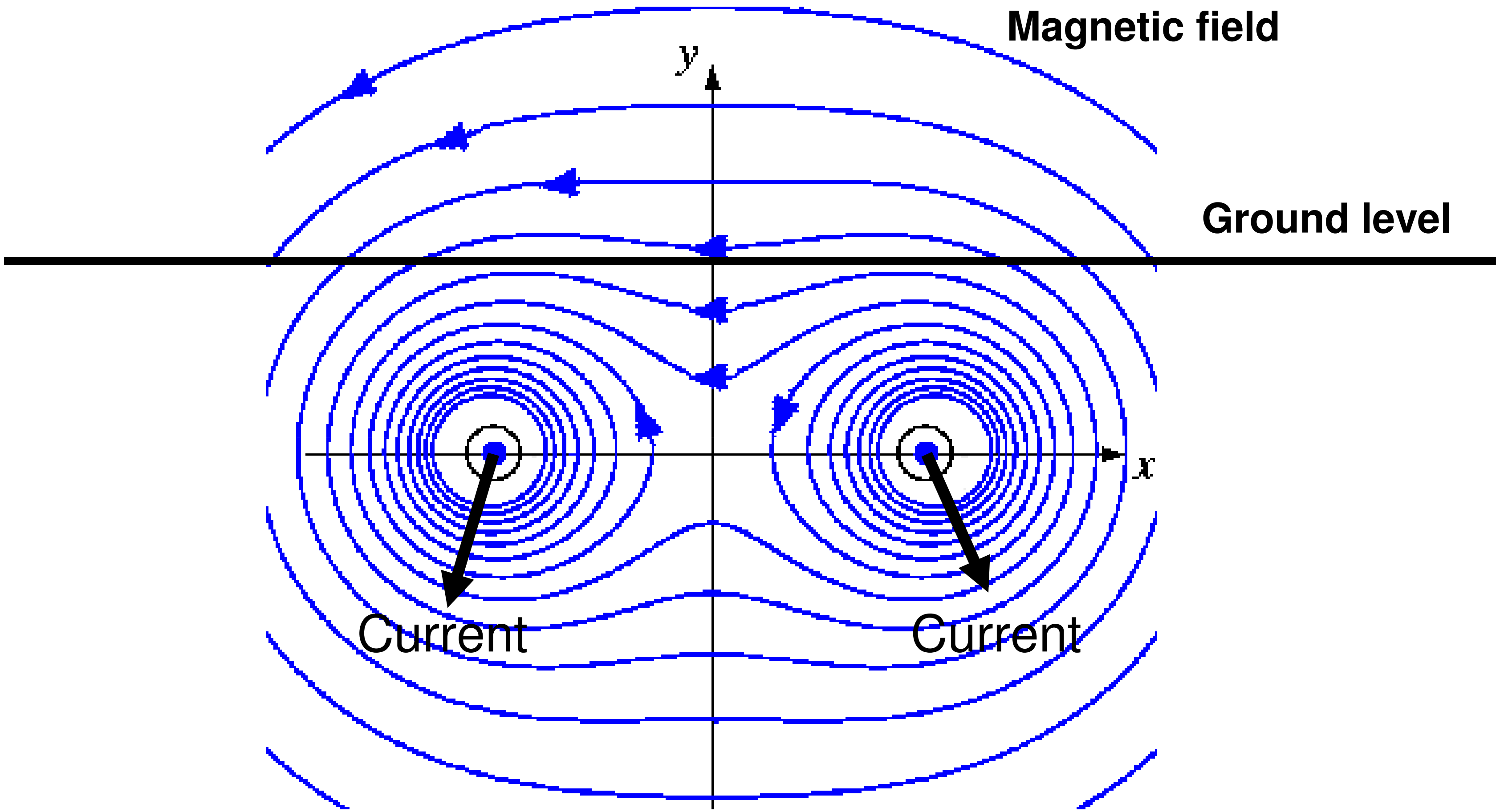
<u>Parallel cables give ambiguous results</u>

Assymetric depth measurements and weird (mostly assymetric) signal strength patterns across a cable path tell that you are receiving signals from more than one source

This can be very confusing, but:
<u>You will never be in doubt that there is something in the ground!</u>

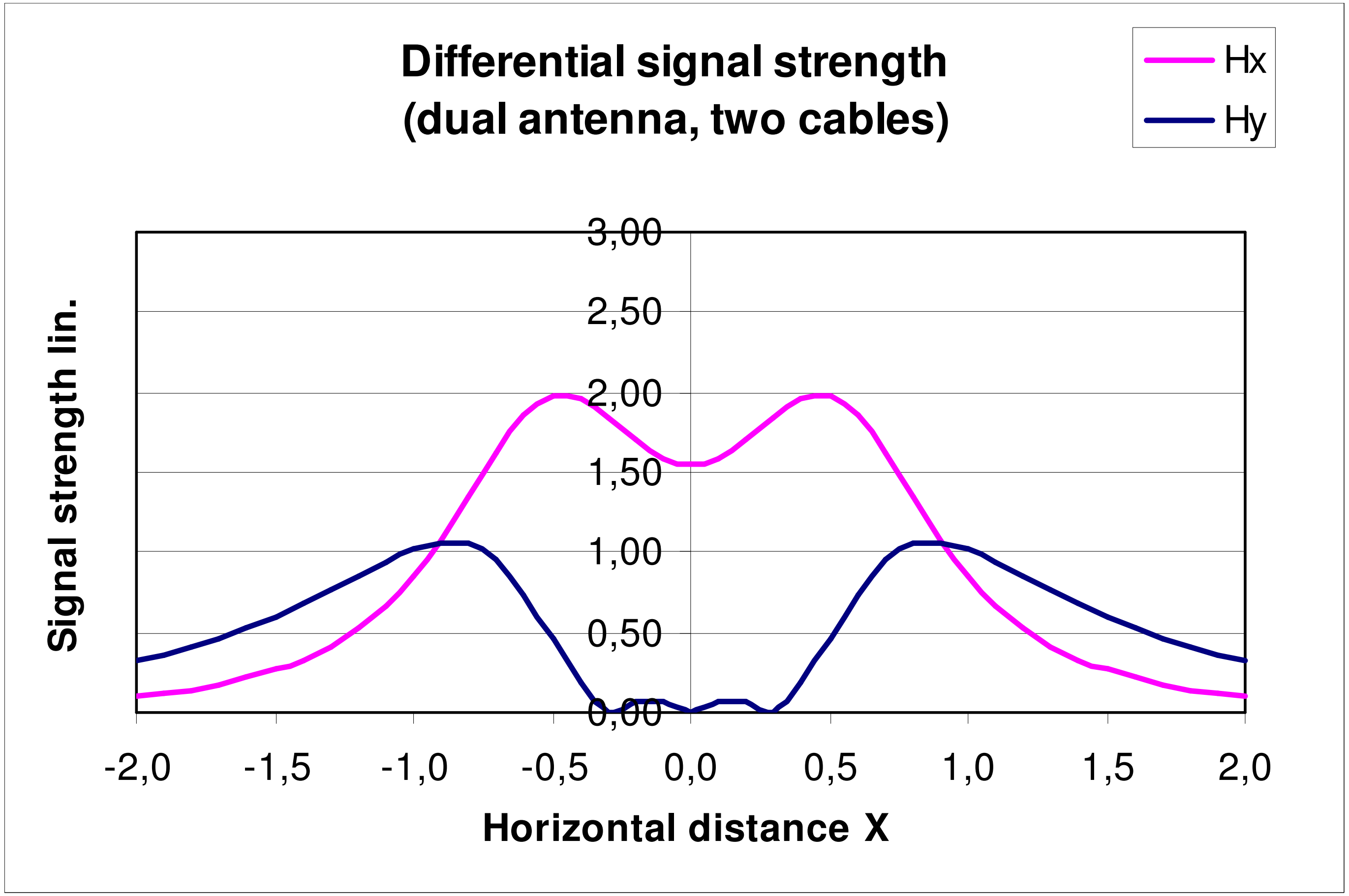
Use the smallest depth assessment with caution. Be aware that it can be too deep. **Dig cautiosly and check at short intervals!** The resolution improves as you get closer to the cables.

Parallel cables with same signal in SAME direction



Basic configuration

Differential signal strength 1. lin.



Two cables 1m apart with coherent signals and SAME current direction at 0,5m depth. (Linear scale)

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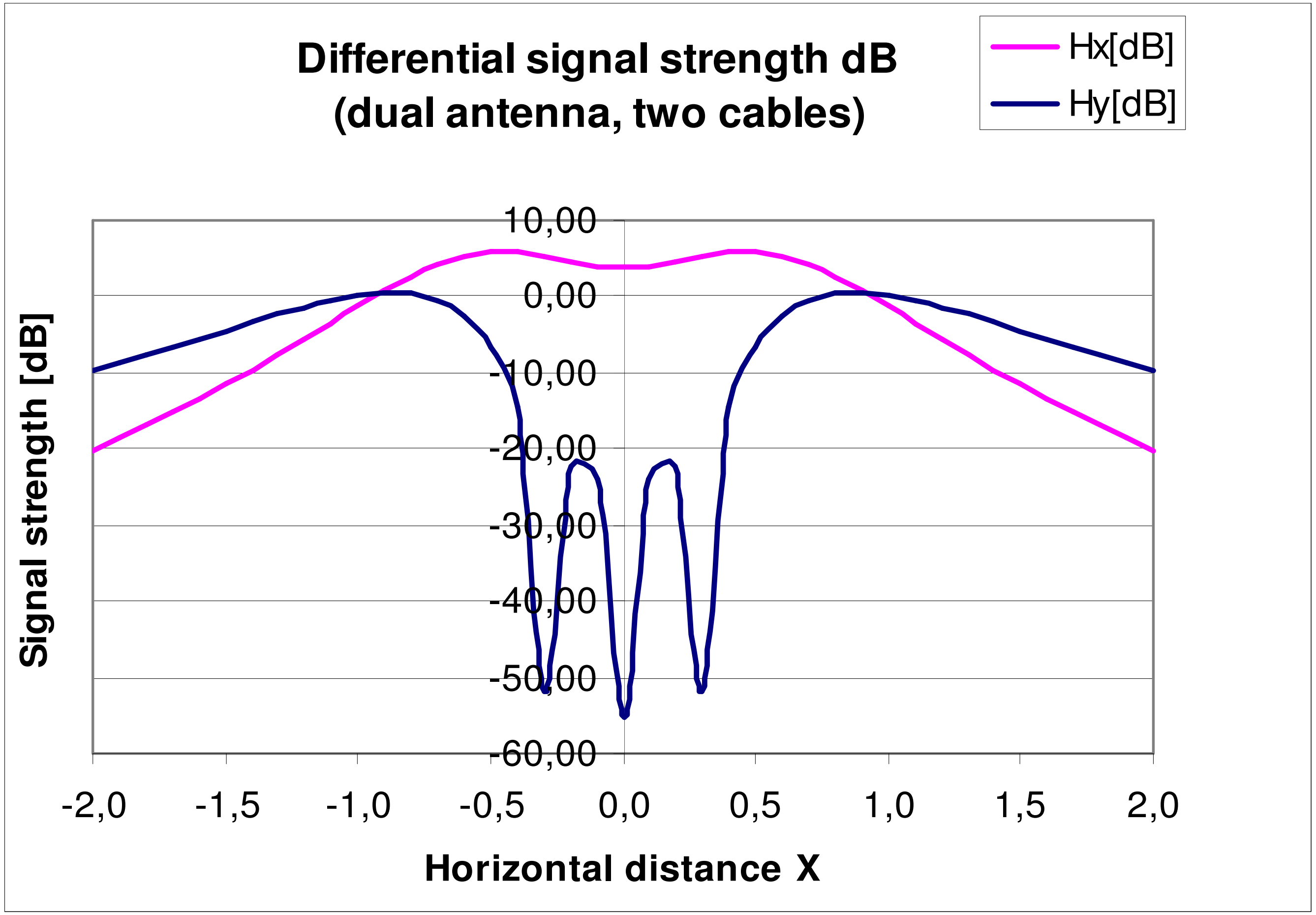
Differential signal strength 1. [dB]



Two cables 1m apart with coherent signals and SAME current direction at 0,5m depth. (Logarithmic scale)

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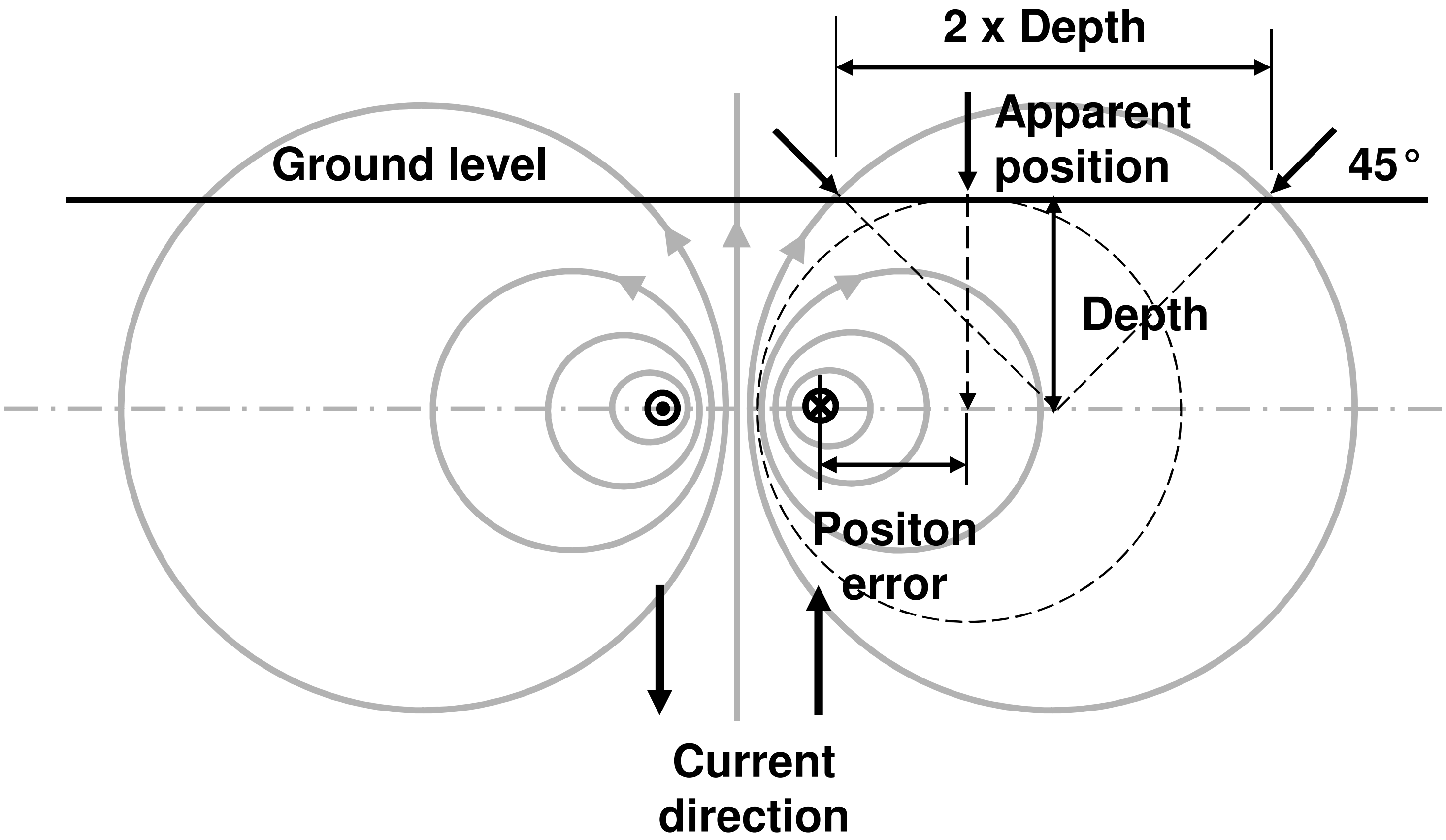
Parallel cables with same signal in OPPOSITE directions



The fields repel each other and cancel each other at some distance. Highest field density is between the cables. The position error increases with the depth, but average depth (measured from left and right) may still be acceptable.

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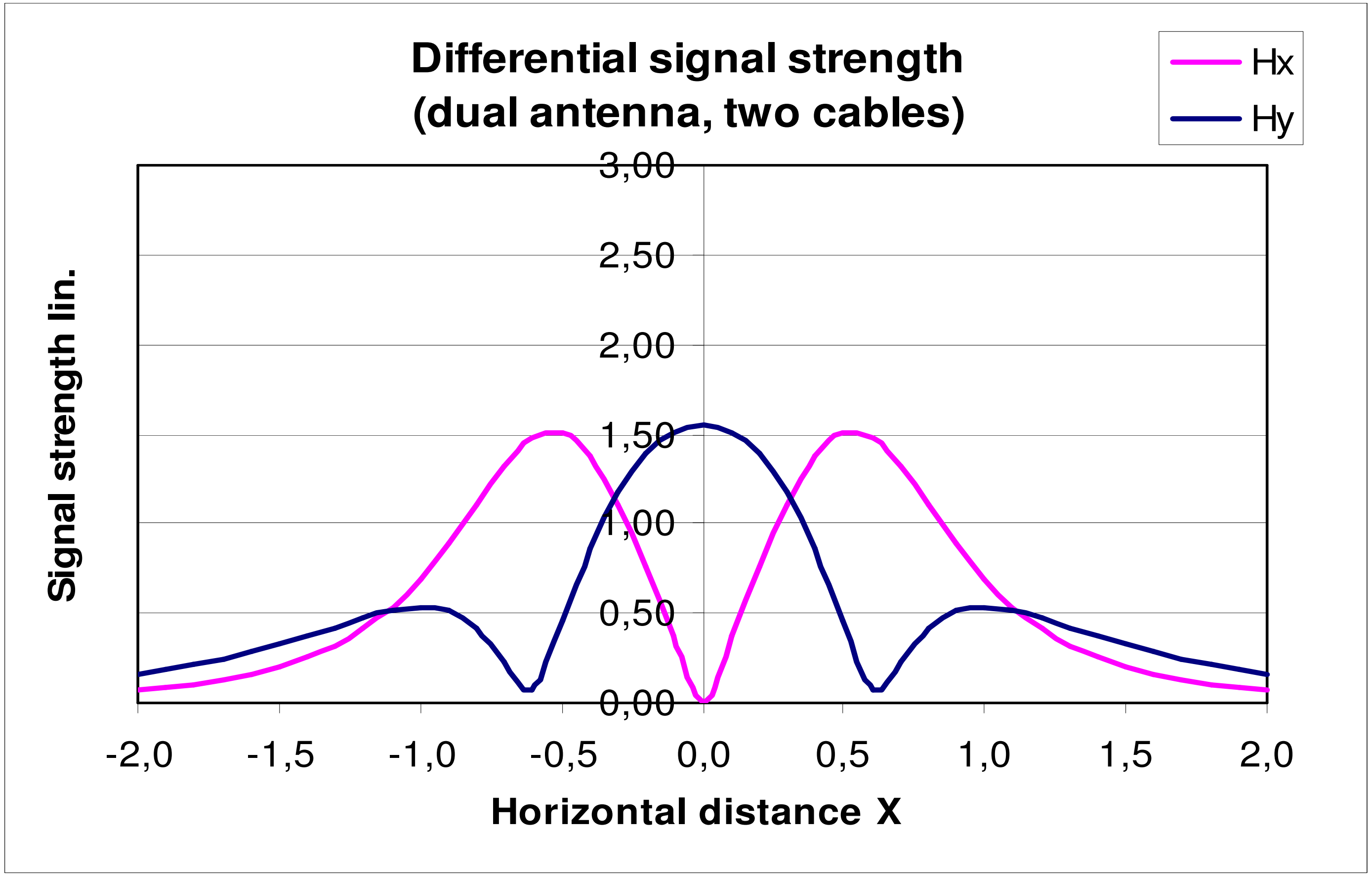
Differential signal strength 2. lin.



Two cables 1m apart with coherent signals and OPPOSITE current directions at 0,5m depth.

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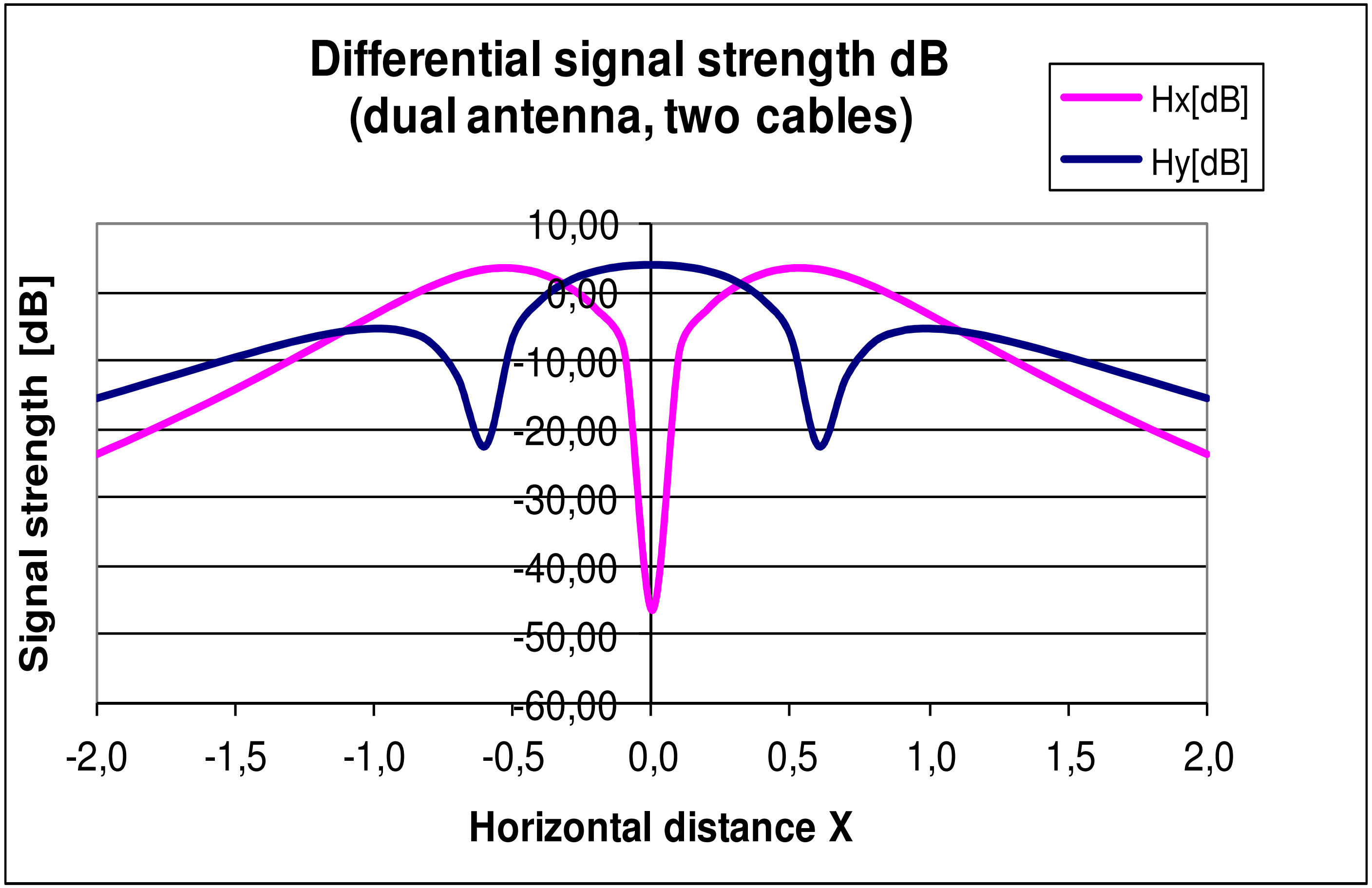
Differential signal strength 2. [dB]



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Correlated and uncorrelated signals

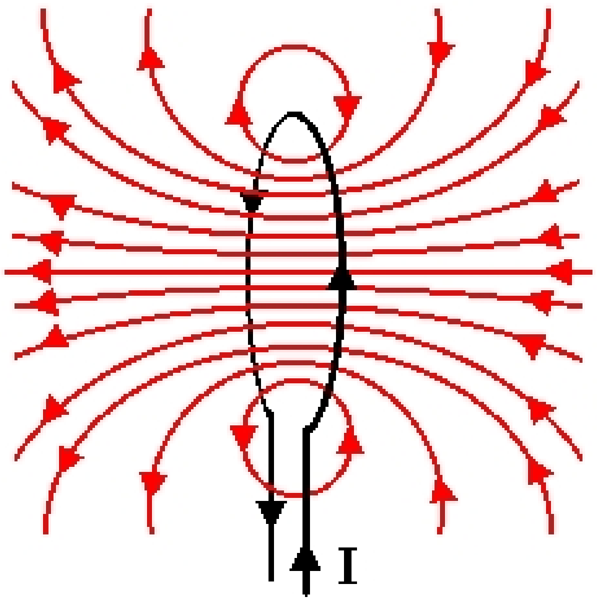
The effects of multiple signals depend on wheter the signals are correlated or uncorrelated, and on the mutual phase of correlated signals.

Correlated signals mean synchronized signals. They add vectorially and may enhance or cancel each other depending on their mutual phase. Two opposite signals with the same amplitude will produce a false null.

Uncorrelated signals are random. Polarity has no influence. They add linearly and do not produce false minima.

Purely correlated or uncorrelated signals are rare, normally there will be a complex mix. The effect of multiple signals is difficult (impossible) to predict.

Corners, loops and curves



This picture is clipped from the internet.

It shows the magnetic field of a narrow loop. The field lines (repelling each other) are sque-ezed together in the loop and spreading out outside the loop like the field of two parallel conductors carrying opposite currents, but more pronounced as they are squeezed from all sides. The strongest field is along the axis of the loop (vertical in the case of a buried loop). Position measurements will yield positions outside the loop.

A bend is a fraction of a loop, and the cable position will be errounously indicated outside the bend, whereas the strongest signal will be mea-sured inside the bend. The error increases with the depth.
(The above statements refer to vertical pick up coils.)

How to estimate errors caused by curvature?

It has been shown that curves (bends and loops) are distorting the magnetic field by forcing the field lines outwards. I.e. you have an assymmetric response and find an apparent cable position (horizontal magnetic field) outside the curve and the strongest signal (highest field strength) inside the curve. Despite the assymmetry and wrong position, the average depth estimate (left and right of the apparent position) can still be good.

<u>The error increases with the distance from the cable.</u> You can estimate it by lifting the cable locator from the ground, and you will see the zero crossing wandering off along an arc originating in the underground cable. You can estimate the true position by extrapolating the arc down to the measured or assumed depth.

Keep in mind that you must hold the cable locator vertically (not slanting) in order to achieve correct results.

False indications and phantom effects 1.

Most cable locators have a differential antenna consisting of two separated antenna elements balancing each other in order to neutralize direct signals from far away sources. The fine balance is easily disturbed, causing unwanted far field (radio) signals to come partially through (”ghost” signals). The same signals are useful when received indirectly via cables.

False indications and phantom effects may be caused by extended metallic objects (other than cables) in the ground and lossy dielectric media like water and wet soil upsetting the delicate balance between the antenna elements.

Metallic surfaces carry induced eddycurrents locally distorting the magnetic signal field, and they tend to ”short circuit” the lower antenna coil of the cable locator, making it less efficient and causing the upper antenna to be dominant.

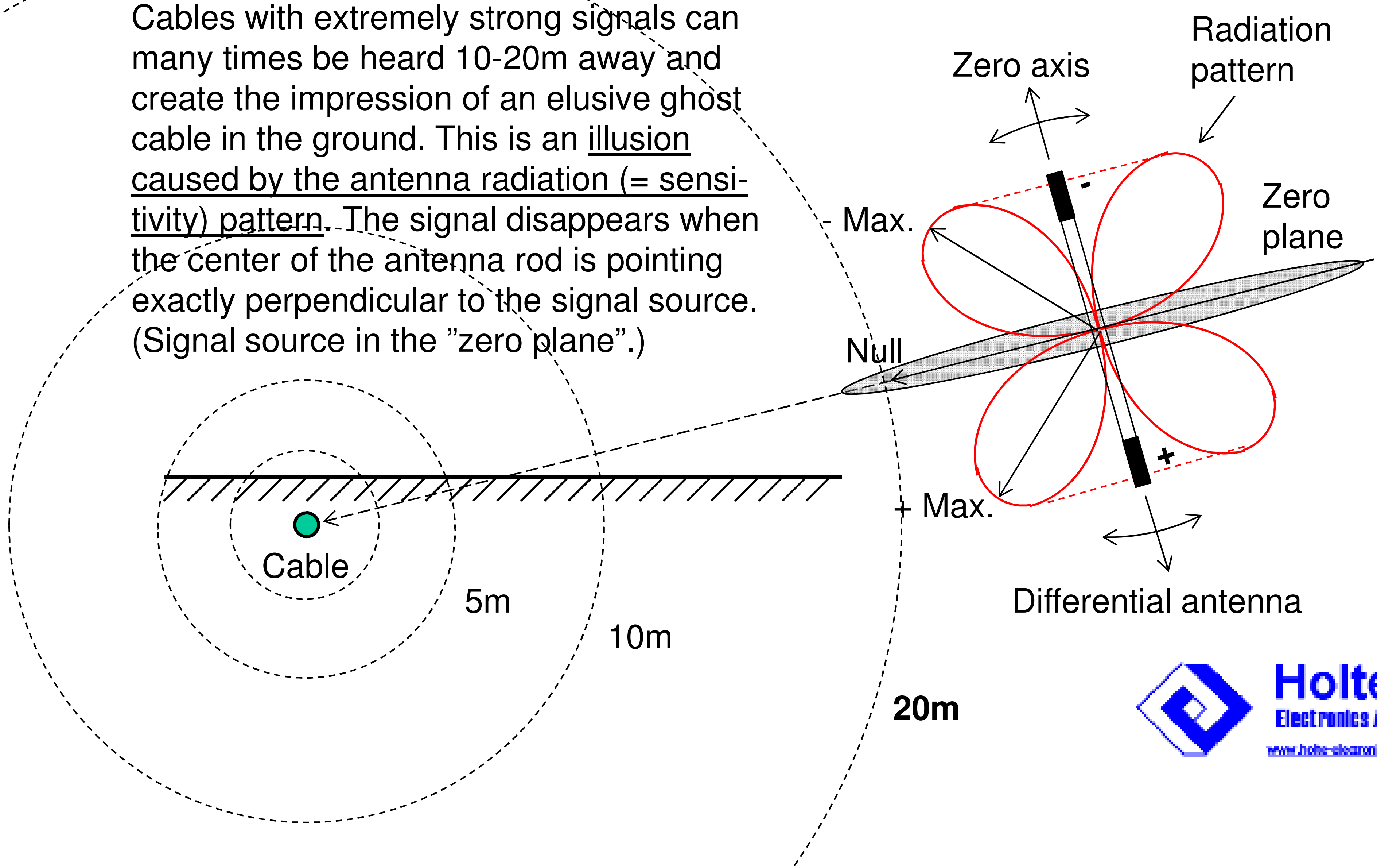
Water and soaked soil (and also body tissue) are lossy materials with a very high dielectric constant (”electric density”) which are disturbing (loading and detuning) antennas in their immedieate proximity.

<u>Test:</u> Lift the cable locator from the ground and see if the ”ghost” signal disappears.

False indications and phantom effects 2.

Geometric effects:

Cables with extremely strong signals can many times be heard 10-20m away and create the impression of an elusive ghost cable in the ground. This is an <u>illusion caused by the antenna radiation (= sensi-tivity) pattern</u>. The signal disappears when the center of the antenna rod is pointing exactly perpendicular to the signal source. (Signal source in the ”zero plane”.)



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