Cable locators and their application in power and telecommunication cables

by Eng. Eugen Jäckle

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Cable locators working with audio frequency have a most versatile applicability in telecommunication, pilot and power cables. The methods used are relatively uncomplicated, easy on the cable and do not disturb the service of a cable installation. The frequencies used lie in the range of audible frequency, i.e. between 480 Hz and 10 kHz. Occasionally, frequencies from 10 kHz to 300 kHz are applied. This essay will not deal with the legal regulations for the use of high frequencies. The output of the audio frequency generators lies between 0.5 Watts and 500 Watts. High-power instruments are normally not used for cable location, but for fault location in power cables.

The following is a description of the fundamentals of cable location and of some special audio frequency methods for use in telecommunication cables.

1. Methods used

1.1. Electromagnetic method

The measurement principle is based on the fact that an electromagnetic field is generated around a current-carrying conductor. The expansion and intensity of this field are determined by means of a search coil and a subsequent receiver.
The evaluation of the located electromagnetic field then serves for the determination of the cable trace, as well as for the detection of other phenomena leading e.g. to a cable identification, pinpoint location of cables faults, the location of pair transpositions in a telecommunication cable and to the location of joints or coil boxes.

1.2. Theory of Measurement

It can be assumed that in the free space the electromagnetic field expands strictly concentrically around the longitudinal axis of the current-carrying line. The field intensity "**H**" in the vicinity of a current-carrying conductor is mainly governed by the current value "**i**" and the distance between search coil and the centre of the conductor.

The electromagnetic field of a straight-lined current-carrying single conductor is shown in figure 1.

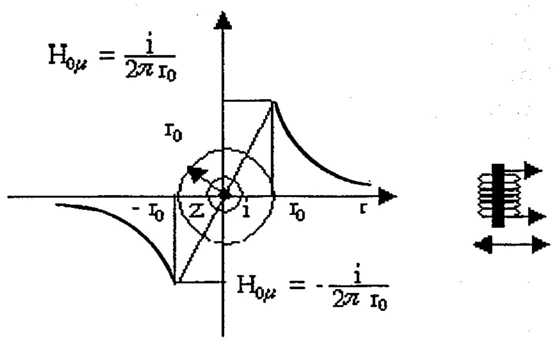

Figure 1: Magnetic field of a straight-lined, current-carrying single conductor with the radius „ro" in the Z-axis with current „i" in the positive Z-direction.

The magnetic field is concentric to the Z-axis and constant to the Z-coordinate.

When calculating the strength of the magnetic field "**H**" as a function of the radial distance, it has to be distinguished between two different situations :

$$(1) \qquad H_{(r)} = \frac{i \cdot r}{2 \cdot \pi \cdot r_0^2} \qquad |r| \le r_0$$

$$(2) \qquad H_{(r)} = \frac{i}{2 \cdot \pi \cdot r} \qquad |r| \ge r_0$$

For an infinitely thin single conductor "**ro**", the following formula is valid :

$$(3) \qquad H_{(r)} = \frac{i}{2 \cdot \pi \cdot r}$$

1.3. Maximum method

If a search coil in horizontal position is conducted across a current-carrying line, then a maximum voltage is induced when the search coil is directly over the line. This also applies, if the current flows on a cable screen or in the wall of a metallic pipe. Here also, a concentric electromagnetic field is obtained whose centre lies on the axis of the cable or pipe.

This maximum of induced voltage is to be traced back to the fact that the concentric flux lines are almost horizontal over the centre of the line and hence induce a maximum possible voltage into the windings of the search coil. The value of this induced voltage "E" (EMK) is determined by the following factors

a) Value of the test current (i)

b) Distance between coil and centre of the line (r)

c) Spatial position of the search coil in the electromagnetic field

d) Frequency (f)

e) Mutual inductance of nearby return conductors for the test current (M).

The interrelations are shown in the formula (4) :

(4) $$E = 2 \cdot \pi \cdot f \cdot M \cdot i$$

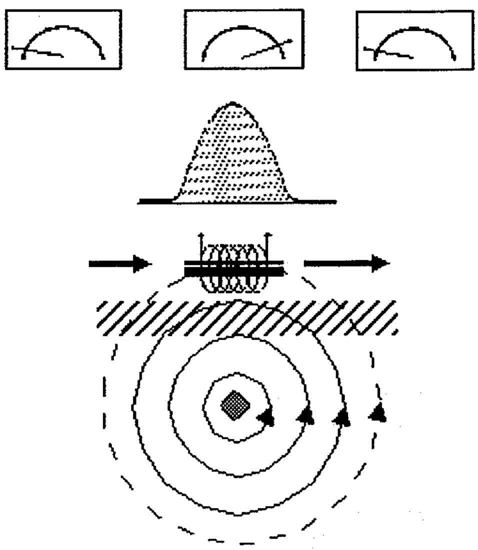

Figure 2: The maximum method

In the practical execution of a cable or pipe location, a maximum in test signal is obtained, when the search coil is exactly over the cable at an angle of 90°, as shown in figure 1.

1.4. Minimum method

If the flux lines flow tangentially through a coil in vertical position, a voltage cannot be induced if the axis of the coil lies in the direction of the conductor carrying the test current. This is the case if the flux lines pass through the search coil at an angle of 90° as shown in figure 3.

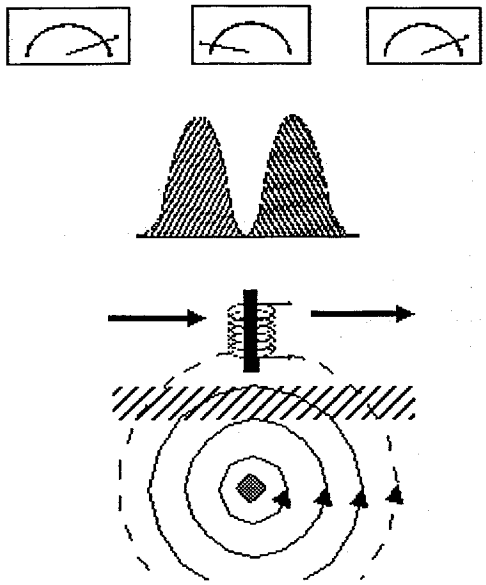

Figure 3: The minimum method

Here, a maximum is received at either side of the conductor which indicates that the flux lines pass through the search coil at an angle of less than 90°, thus inducing a voltage.

The observation of the minimum is a better way of determining the track of a line than the maximum method, since here, at a lateral movement of the coil, the change in induced voltage is far more obvious than in the maximum method. Moreover, it is very difficult for the human ear to assess differences in volume.

On the other hand, the cessation of a noise is very well perceived. In the minimum method, the negative effect through a turning of the search coil is eliminated, since the directional effect is in the vertical direction.

1.5. Maximum - minimum - run

When a search coil is conducted in horizontal position in the vicinity of a current-carrying cable and is turned by 180°, then a maximum signal is received when the search coil makes an angle of 90° with the cable as shown in figure 4a. If the coil lies parallel to the cable, a minimum signal is obtained as shown in figure 4b.
With this simple orienting measurement, the track direction of the cable can be quickly located and thus the first search coordinate is determined.

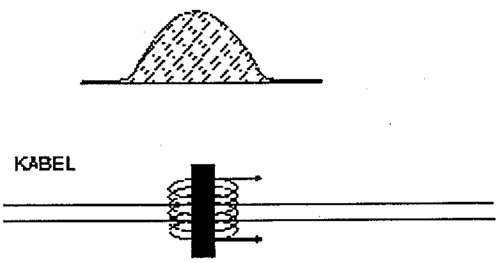

Figure 4a: Coil in horizontal position, fully turned. Maximum at coil position 90° (Top view of coil and cable).

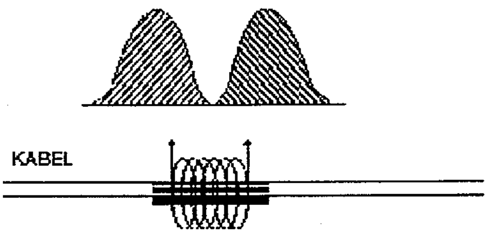

Figure 4b: Coil in horizontal position, fully turned. Minimum at coil position 180° (Top view of coil and cable).

1.6. Depth measurement

Provided that the magnetic field expands concentrically around the cable to be located, a minimum will be received if the search coil is conducted in a vertical position and vertically over the cable carrying the test current.
If the search coil is now swivelled by 45 ° about its axis and is conducted away from the cable at an angle of 90°, then a minimum will be received on either side of the cable (figure 5).
As per the trigonometrical relationships in the rectangular and isosceles triangle, the distances l_1 and l_2 correspond to the depth „**T**" of the cable to be located (figure 5.). The 45° position of the search coil is enabled through a click-stop device.

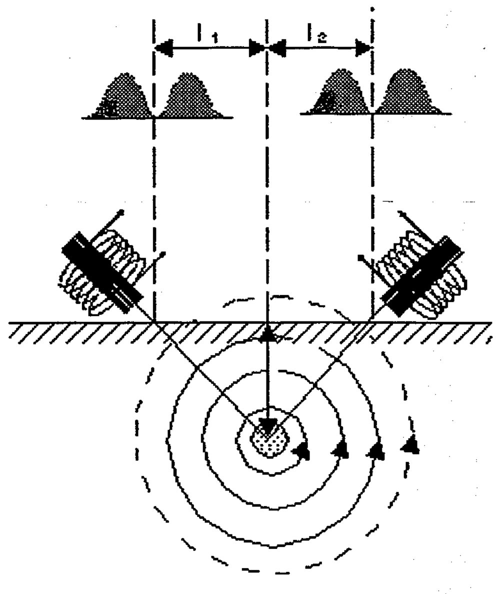

Figure 5: Depth measurement with coil in 45° position

2. Coupling methods

For the purpose of locating a cable or pipe, an audio frequency AC current has to be induced into the same. Erronerous measurements can be eliminated by avoiding as far as possible undesired and inadvertent coupling to neighbouring or intersecting cables.

Apart from the coupling method itself, the measuring frequencies are a decisive factor. Since these unintended couplings can be both capacitive and inductive, there is a frequency-dependent interrelation. Taking into consideration the formula (4), this unintended coupling decreases by the factor of the frequency ratio.

For this reason, nowadays multi-frequency generators with three frequencies are used. Typical frequencies are 0,48 - 1,45 and 9.82 kHz. If e.g. the frequencies of 0.48 and 9.82 kHz are put into proportion, then a factor of approx. 20 results, by which the undesired couplings are reduced when using the lower frequency of 0.48 kHz.

Since the coverage during a cable location also depends on the frequency used, it has to be examined from case to case, which frequency is to be applied.
The use of higher frequencies on cables in the open field for instance gives a larger coverage and measuring errors through neighbouring cables are considerably low in these areas. However, in the dense cable networks of a large city, the lowest frequency should be used in order to reduce an interaction.

2.1. Matching

For an optimum connection of the audio frequency generator to the test object and for an optimum transmission of audio frequency energy, the output impedance of the audio frequency generator has to be matched to the impedance of the measuring circuit. This is done either manually, whereby the correct matching value is determined by observing the battery current, or automatically. In the event of a mismatch of the audio frequency generator, especially at an under match, the sine shape of the output voltage is distorted and strong harmonics will result. These in turn can cause operating trouble in the cable system.

It is to be noted that each change in frequency on the audio frequency generator requires a fresh matching.

2.2. Direct coupling

The principle of direct or galvanic coupling is shown in figure 6. Here, the current generated by the audio frequency generator flows on a disconnected core to the earthed end of the cable and returns through the ground. Especially in areas with dense cable networks, the return current will not only flow through the ground, but also on the screen of the cable under test and on neighbouring cable screens.

If this coupling mode is used on cables which are only partly cut off, the service of neighbouring cores might be affected. Erroneous measurements mainly occur in areas with a dense cable network, since the return current can take any route.

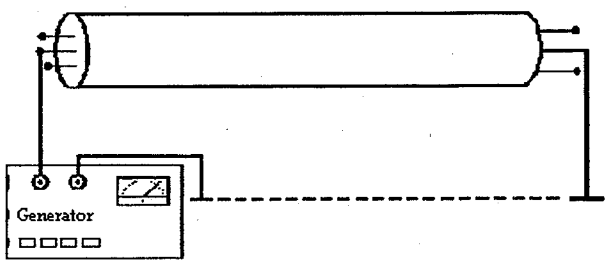

Figure 6: Galvanical (direct) coupling 1

Another, better way of galvanical coupling is shown in figure 7. Here, the return current flows on the screen or metallic sheath of the cable under test. Since an electromagnetic field is generated both around the core carrying the test current and around the screen, a differential field appears in the surroundings of this cable.

The intensity of this field is dependent on the current value and the distance between the two field centres. The closer the two field centres lie to each other, the smaller is the usable field. In the case of a concentric cable make-up, the two field centres coincide and the resulting fields have the same intensity, but opposed directions of flux, whereby the two fields totally compensate and are no longer measurable.

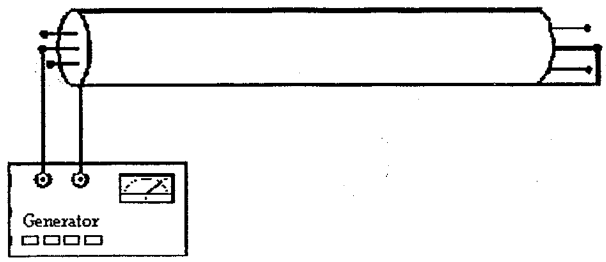

Figure 7: Galvanical coupling 2

Figure 8 shows a special variant of galvanical coupling. Here, the galvanical circuit inside the cable is interrupted and the test current flows via the capacitive servings. That's why this method is often wrongly called capacitive coupling. In this coupling mode, the intensity of the test current is governed by the capacitance of the two cores carrying the test current and by the measuring frequency.
The intensity variation of the resulting electromagnetic field is negatively logarithmic and hence does not allow a location upto the end of the cable.

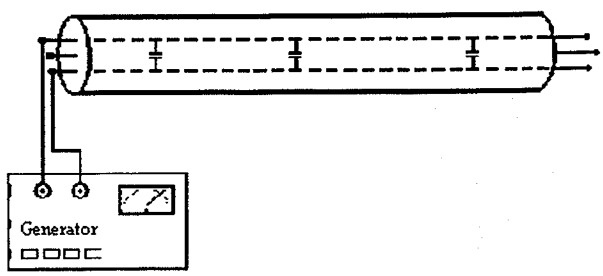

Figure 8: Galvanical coupling 3

2.3. Inductive coupling

The cable to be located is not always accessible, or it is in service and does not allow a galvanical coupling, be it to avoid damage to the audio frequency generator or an impairment or disturbance of the information flow. In these cases, the inductive coupling mode is of an advantage.

As per the law of induction an electromagnetic AC current field generates a secondary current in a line, provided it is in the correct coupling position to the same. With this, even telecommunication cables in service can be located, since on the basis of the symmetry of the cable, a coupling into an individual core.

2.3.1 Inductive coupling with transmitter coil.

In this coupling mode, the audio frequency generator excites an aerial coil- or ferrit antenna which is in resonance. The antenna in turn generates a voltage (EMK) in the cable which acts as a mutual inductance. This voltage produces a current in the coupled cable and establishes the pre-requisites for a location.

For an optimum coupling, the transmitter coil is positioned vertically and parallel to the cable to be located. The pre-requisite for this method is a closed current circuit of the cable under test, so that the induced voltage can generate a current flow. A buried cable for instance cannot be located, if the two ends of the screen have no ground connection and all cores are floating.

The presence of a voltage alone in the cable to be located is not sufficient, a current flow has to be generated. In the event of very long cables, a current flow is still possible and comes about through capacitive couplings between screen or cores and the ground. For the execution of the measurement itself it is of no consequence, whether the located magnetic field is generated by an active or reactive current.

When positioning the transmitter coil as shown in figure 9, care has to be taken to see that the indicated minimum distance between transmitter coil and search coil is observed. This minimum distance depends on the intensity of the transmitted signal and is approx. 10m.

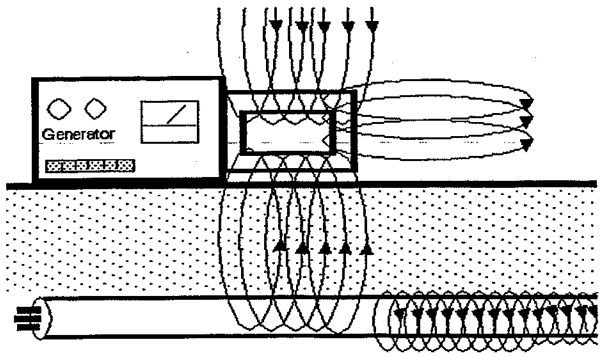

Figure 9: Inductive coupling with transmitter coil

If the distance between transmitter coil and search coil is too short, then the radiated horizontal field runs through the search coil, whereby the field of the induced cable cannot be identified anymore. Through a sideward shift of the transmitter coil by approx. 5°, the actual field position can be recognized by the fact that the minimum determined by the search coil also shifts aside. In this case, the minimum detected first originates from the transmitter coil and not from the cable underneath.

In order to preserve the resonance characteristics of the transmitter coil, it should not be positioned in direct vicinity of larger metallic objects like metal lattices or cable cover sheets.

2.3.2 Inductive coupling with transmitter tongs

Another variant of inductive coupling requires the use of a clip-on transmitter coil which is laid around the cable to be induced. This special coupling offers the possibility of applying a signal to cables without service interruption and with a good efficiency.

In order to avoid an influence on the signal circuit, the tongs have to be laid around the whole cable and not only a single core. The pole faces of the transmitter tongs have to be clean since a magnetic circuit which is not completely closed affects the efficiency considerably.

The action principle of this coupling mode is shown in figure 10. Here also, care should be taken to see that the current circuit is closed via the earthed ends of the screen. No shunts must exist which would practically short-circuit the induced current circuit and make a cable location impossible. Such a short-circuit loop is shown at the coupling point "B" in figure 10. A coupling at point "A gives" optimum coupling conditions.

Cables couples with transmitter tongs can be easily located over long distances (several kilometers).

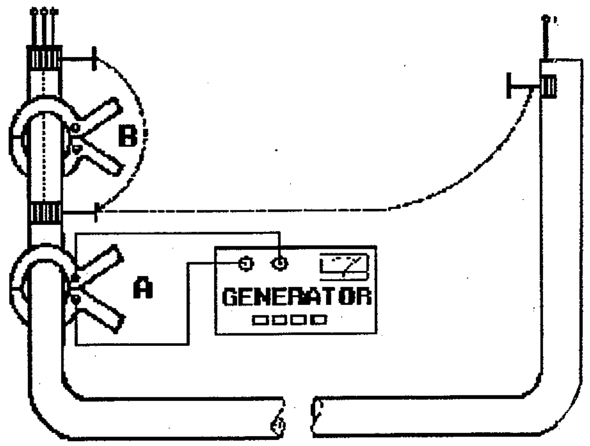

Figure 10:Inductive coupling with transmitter tongs

3. Deviations through field distortions

With an audio frequency coupling to an individual buried cable without neighbouring lines, one can proceed on the assumption that the electromagnetic field, created by the test current expands concentrically around the centre of the cable. Hence follows, that the geometrical centre point of this field lies on the axis of the cable. This also applies, if the test current flows on the screen of a cable. Only an exactly concentric field leads to an accurate cable location by the minimum or maximum method or to a depth determination.

In the event of congestions of cables or lines, multiple fields are generated by parallel test currents which can also flow in the opposed direction. These have to be regarded as distortions of the concentric field. Intensity and configuration of a differential field depend on the direction and value of the test current on the one hand and on the distance of the respective field centres on the other hand.

The ideal case where the forward current flows in a concentrated form only on the cable to be located and the return current on many small current paths through the ground, is practically only encountered in the open field. Here, a higher measurement accuracy can be expected. In urban areas however, one always has to reckon with parallel lines and cables which take over part of the return currents.

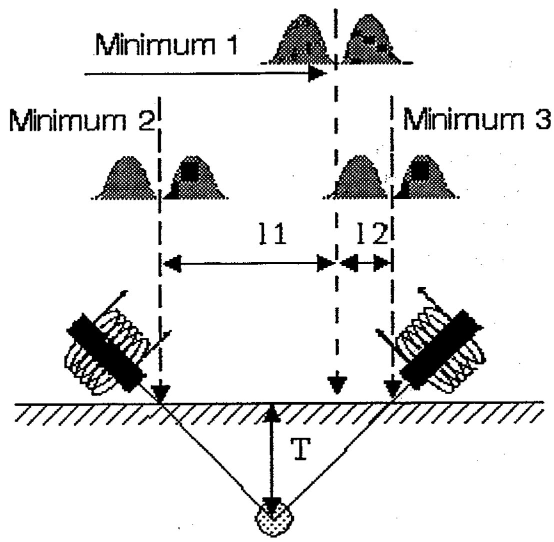

Figure 11:Measurement on elliptical fields

The hereby occuring field distortions can only be eliminated by forcing the return current to take a certain path. However, field distortions can also occur in cases where neighbouring cables or lines are unintentionally coupled. In most cases, this is an inductive coupling, whereby the degree of coupling is given in formula (4).

Since apart from the current intensity "i" and the frequency "f" all values are invariable, the possibility exists of reducing the coupling through the use of lower frequencies. At a frequency of 480 Hz for instance, the test current coupled to the parallel cable is 20 times lower than at a frequency of 10 kHz.

Erroneous measurements caused by field distortions can be traced back to the fact that e.g. an elliptical field develops as shown in figure 10 whereby the horizontal field lines are shifted aside. A lateral displacement is encountered where the minimum is measured, i.e. at the point where the field lines cut the coil axis at an angle of 90°. If a depth measurement is carried out at this point, the values l_1 and l_2 will differ, since the minima are indicated where the lines of force pass the search coil at an angle of 90°.

Hence, the depth measurement also serves for verifying a cable location, since with a constant distance of l_1 and l_2 to the minimum of the track of the cable, the measured track corresponds to the actual track.
The depth of a cable with differing values at both sides is calculated by the formula (5) as follows :

(5) $$T = \frac{l_1 + l_2}{2}$$

A correction factor for an exact location of the track cannot be determined from the differing lengths l_1 and l_2, since the dip of the two elliptical field configurations is not known. It can only be taken for granted, that the actual track of the cable is between the minimum and the longer one of the two sections l_1 and l_2.

Club-shaped field distortions which also lead to erroneous measurements can be recognized through a vertical movement of the search coil. With a concentric field, the minimum over the marked point is retained which is not the case with a distorted field. Here, the minimum can only be measured after a lateral movement (figure 12).

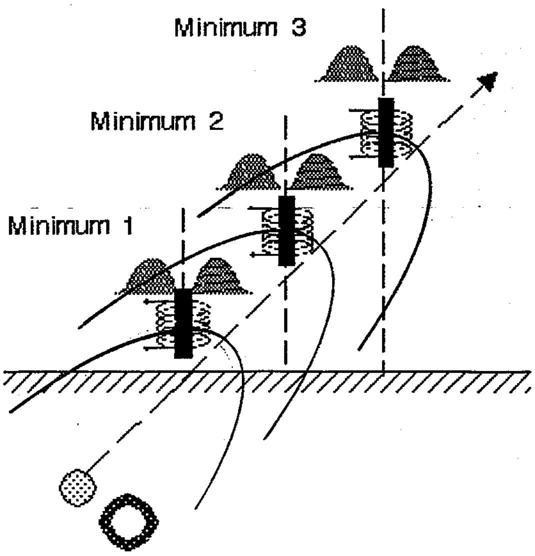

Figure 12:Location with a club-shaped field.

As shown in figure 12, the lateral deviation from the actual track of the cable increases the higher the search coil is conducted over the ground. Through a ficticious extension of the minimas, the track of the cable can be determined with sufficient accuracy.

During the plan reconstruction of a cable network, the actual track of the cable has to be repeatedly verified through a depth measurement. Areas where the lateral lengths l_1 and l_2 differ should be marked in the plan in order to indicate a deviation or that a cable section could not be accurately located.

4. Limitations of cable location

Since for the location of a cable the electromagnetic field of the test current flowing on or in the cable is used, field distortions or deviations always affect the measurement accuracy. Field distortions are also encountered at narrow bends or tees of a cable. For instance, in the event of a 90° bend in a cable where the electromagnetic field is distorted, the track of the cable is determined as shown in figure 13. Here, an extrapolation of the two sections A and B would lead to more accurate results.

Problems are also to be reckoned with in the event of tees or vertical sections of a cable. The supply leads in the vicinity of the coupling point of the audio frequency also cause interferences, so that a location is not possible in this area.

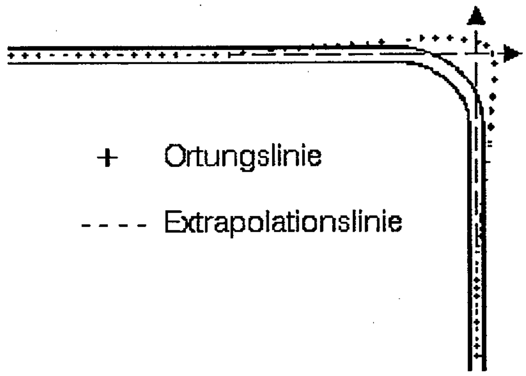

Figure 13:Location line at cable bends

Interfering influences and a heterodyning of the test signal can also lead to erroneous or inaccurate measurements. These are encountered if currents of the same frequency or with a high harmonic content flow in the area of measurement. In this case, receivers with a high selectivity have to be used in order to improve the ratio of useful and interfering voltage. This can to a limited extent also be achieved by increasing the generator output. However, the bounds are reached soon due to the quadratic interrelation between output and test current as shown in formula (6).

(6) $$i = \sqrt{\frac{P}{R}}$$

As per this formula, the output has to be increased by the factor 100 in order to obtain ten times the test current. Hence follows, that a comparison of generators with regard to their coverage and efficiency only makes sense, if a considerably higher test current can be achieved.

If the measurement is not made against ground, the measuring circuit is loaded with an inductance. This offers the possibility of increasing the test current by selecting a low frequency. The use of a low frequency of e.g. 480 Hz reduces the inductive resistance by the factor 20 as against a measuring frequency of 10 kHz.

In the event of interferences through AC currents of the same or a similar frequency, the output signal can be emitted as a pulsed tone. With this, it can be easily identified from interfering noise and a cable location can be carried out. An evaluation of the magnitude on the meter however is not possible. Here, a measurement can practically only be carried out as per the minimum method.

5. Step voltage method

Apart from the electromagnetic inductive method for cable tracing, cable identification and cable fault location, audio frequency units can also be used in the step voltage mode. For this purpose, the audio frequency receiver is equipped with a galvanical input through which the audio frequency voltage fed. In order to neutralize the capacitance of the operator or his contact resistance to the ground, this audio frequency voltage has to be balanced to ground. The audio frequency voltage normally appears as a step voltage potential on the ground surface and is picked up directly with contact points, or non-contacting via capacitive plates. The result is obtained by evaluating the maximum and minimum methods.

6. Practical measurements

6.1. Cable tracing

The cable to be located is connected either directly (galvanically) or inductively. In the galvanical coupling mode, the output impedance of the audio frequency generator has to be matched to the impedance of the measuring circuit in order to obtain a maximum possible audio frequency current on the one hand and to avoid harmonics through mismatches on the other hand. This adjustment is superfluous if the audio frequency generator has an automatic matching and the output current retains its sine shape. In the inductive coupling mode, the impedances of the transmitter coil and the transmitter tongs are given.

If the frequency is changed, the impedance of the measuring circuit changes and a new matching has to be carried out.

With an inductive coupling, the test current achieved is always lower than with a galvanical coupling which affects the measuring range. The actual location is carried out by the minimum method, whereby care has to be taken to see that the search coil is always in a vertical position and does not swing. The two maxima received on both sides of the minimum have to be observed in respect of a uniform magnitude.

Unequal maxima or sudden increases or decreases in the measured values indicate declinations, tees, narrow cable bends or intersections. A change in the laying depth of the cable also causes a distinct variation in the measured value.

A cable location is especially difficult if the cables are laid in rings as is often the case at cable boxes or transformer stations.

6.2. Cable identification

A reliable identification of a certain cable from a bunch is not possible with a conventional cable location, since the direction of flow of the audio frequency current is not recognizeable. This also applies for the safe determination of a quad in a multi-pair telecommunication cable.

For the identification of a telecommunication cable, a pair of a quad is to be used which should as far as possible lie in the centre of the cable. The pair is shorted at the far end of the cable and the audio frequency is fed to the start end as shown in figure 15.

The two currents flowing in opposed directions, generate a field in the form of an 8 as per figure 14, whereby the cross-overs lie between the two cores. If a small cable identification coil is conducted around the cable with the coil axis always pointing towards the axis of the cable, then over the cross-overs a maximum signal each, and at an angle of 90° a minimum signal is measured. If this measurement has to be carried out at a pair of a bunch lying at the inner edge of the cable, the resulting asymmetry has to be taken into consideration.

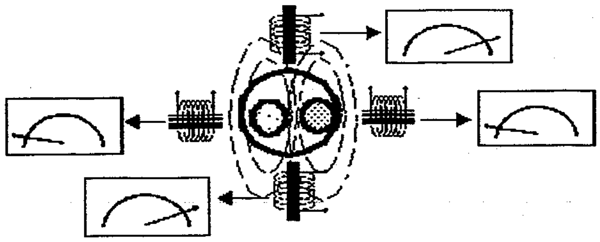

Figure 14: Cable identification with the coil conducted around the cable.

If the possibility does not exist of conducting the cable identification coil around the cable, then it has to be led directly along the same as shown in figure 15. Now, at the intervals of the twist of the cable, a periodical succession of maxima and minima is received.

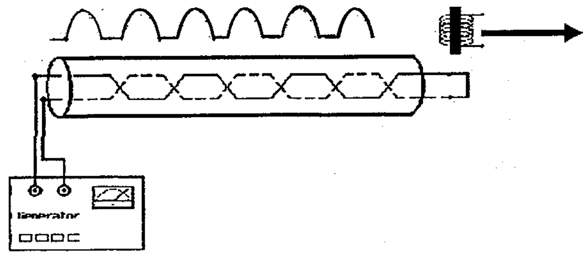

Figure 15: Cable identification with the coil conducted lengthwise.

6.3. Location of joints

The instrument requirement and coupling mode are similar to the cable identification measurement. Here however, the method can be improved by paralleling the cores of a quad lying at the outer edge of the cable and by interconnecting them (floating) at the far end of the cable.

Since in the joint, the distance between the two quads carrying the test current is larger than on the normal track of the cable, a change in the electromagnetic field results which, at a normal laying depth, can be detected at the ground surface as shown in figure 6.

If the two current carrying quads in the joint are in a vertical position to the direction of search, then this effect will not appear. This can be helped by transferring the coupling within the bunch by approx. 90°.

Prior to a joint location, a cable location has to determine the position and track of the cable, since it is not possible to carry out both measurements with a single coupling in one working process.

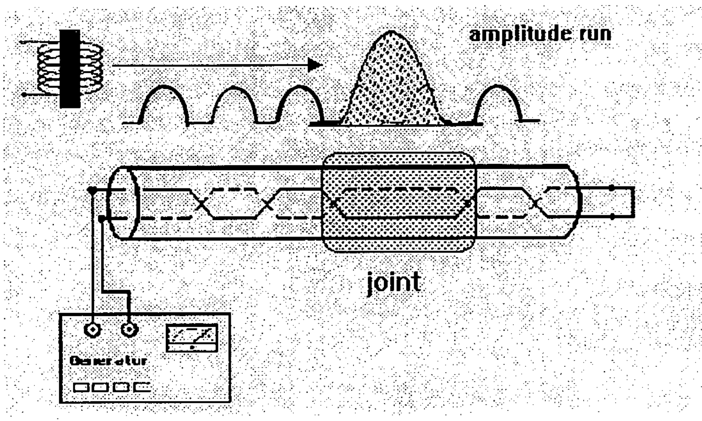

Figure 16:Joint location with audio frequency

6.4. Location of loading coil boxes

The location of loading coil boxes in the open field often fails due to the fact that fixed points in the network plans are concealed or no longer existent. Metal detectors are applicable for this purpose to a limited extent only, since they will indicate all metal objects in the ground which often leads to erronerous excavation.

Here also, the use of a cable tracer can solve the problem. The test method consists in feeding an audio frequency between the metallic outer sheath of the cable and an earth spike. The resulting audio frequency current will then return to the earth spike both via the cable sheath and the metal housing of the loading coil.

The audio frequency step voltage potential over the cable is measured on the ground surface. Since the surface per unit of length of the loading coil box is greater than that of the cable, the earth contact resistance is lower.

Thus here, a larger portion of the audio frequency current will return. The voltage drop at the earth resistance will therefore be much more intensive over the loading coil. The step voltage potential can be determined both with galvanic and capacitive probes as shown in figure 17.

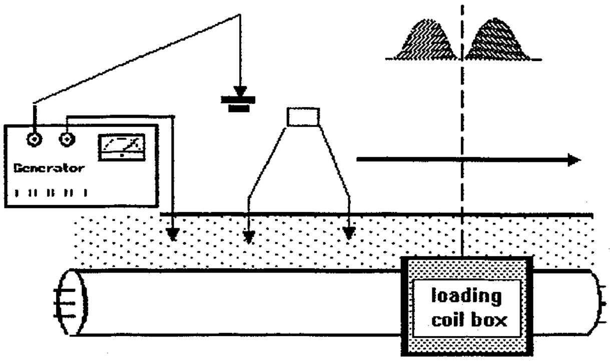

Figure 17:Location of loading coils with audio frequency

The audio frequency voltage drop (step voltage) expands circularly over the loading coil box. This also allows the measurement to be carried out with the step voltage probe conducted diagonally to the track of the cable at an angle of 90°. This gives a second coordinate, thus enabling a pinpoint location.

This measurement is carried out in the open field without disconnecting the cable - the ends of the cable are not connected. For the purpose of an effective coupling, the track of the cable in the area of the loading coil box has to be accurately located and marked. Over the cable - in the vicinity of the loading coil box, an earth spike is driven into the ground. A preceding depth location will protect the cable from being damaged by the earth spike. A second earth spike is to be positioned at a right angle to the first spike over the cable at a distance of 50 to 100 metres. The audio frequency is fed in between the two earth spikes.

Caution ! In this connection, dangerous voltages may be present at the two earth spikes. Hence, the audio frequency generator must only be switched on after the two earth spikes have been reliably earthed. If necessary, sentries have to be posted at the coupling point.

For the measurement, the highest possible audio frequency current should be fed. If the matching resistance is higher than 100 Ohm, a better earthing point for the second earth spikes should be looked for. The use of a third earth spike -positioned opposite the second spike - brings the desired result.

6.5. Location of a core transposition

The volumetric expansion of the electromagnetic fields of two cores carrying oppositely directed currents is primarily dependent on the distance of the two current carrying conductors. Since telecommunication cables are made up symmetrically, no electromagnetic field will appear in the surrounding of the cable. However, in the event of a core transposition, the symmetry of the cable is disturbed over the whole section of transposition and, depending on the coupling and connection mode, an audio frequency field is generated in the direct vicinity of the cable.

In the coupling mode shown in figure 18 in which the audio frequency current is fed into two pairs which are short-circuited at the end, a clearly measurable electromagnetic field emerges. For the location, it is sufficient to look out for the presence of a field short before and after the point of a possible transposition.

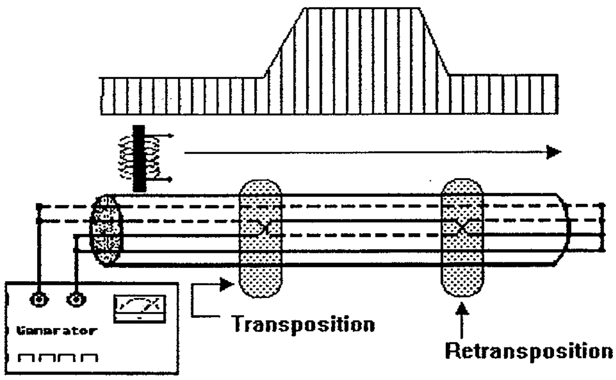

Figure 18:Location of a point of transposition with asymmetry over the section.

In another coupling mode shown in figure 19, symmetrical conditions are obtained on the transposed section. Due to the special coupling mode, the non-transposed sections show an asymmetry which also leads to the point of transposition.

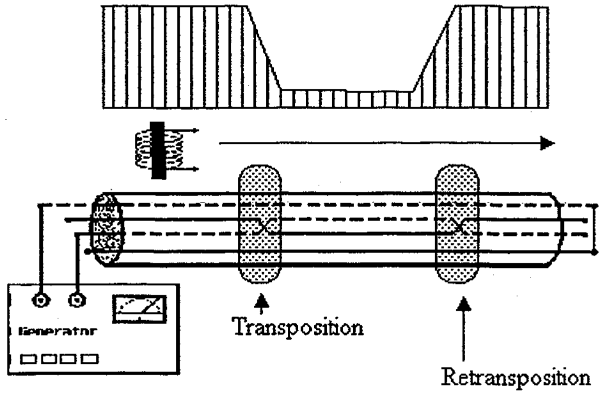

Figure 19:Location of a transposition with symmetrical section

Both these coupling modes require a careful matching of the audio frequency generator to the measuring circuit, since in the event of a mismatch, the sine shape of the audio frequency current will be distorted to meanders. This gives rise to harmonics which disturb or affect neighbouring signal-carrying cores. This is not the case in the event of audio frequency generators with automatic matching.

The measurement itself should not be made directly over a splice joint, since here also, non-homogeneities of the electromagnetic field will occur due to the larger distance of the cores. It is recommended to carry out the measurement approx. 1 m before or after the splice joint. Before and after the splice joint, care should be taken to see that the identification coil is always conducted in the centre of the cable.

6.6. Cable fault location with audio frequency

The pinpoint location of cable faults with audio frequency is another field of application of the versatile audio frequency units. The chances of success in telecommunication cables are considerably less (with the exception of a few special types of faults) than in power cables and are limited to very low resistance faults and a location on exposed cables.

Nevertheless, these methods shall be described herein, because there are no other methods for pinpoint location that are easier on the cable.

6.6.1. Low resistance faults between cores

A pinpoint location of low resistance faults between cores in telecommunication cables can only be carried out on an exposed cable. The method is however best suited for the location of the fault direction, so that the point where the cable has to be cut can be most accurately determined and only one repair joint has to be inserted.

In this location mode, the audio frequency generator has to be connected to both faulty cores and the highest possible current has to be set. In the case of long telecommunication cables with a high series inductance, this can be achieved through the use of a very low frequency. Very long cables with loading coils complicate the application of this method.

Here, like with cable identification, a very low resistance fault (< 10 Ohm) produces a field of twist which extends up to the point of fault (figure 20). This field disappears after the fault.
If the distance between the lays or lengths of twist is larger than the laying depth of the cable, then the field of twist can even be perceived on the ground surface.

This applies to almost all power cables, since their lengths of twist are considerably larger. As shown in figure 20, the measurement is carried out with the search coil in a vertical as well as in a horizontal position.

The pinpoint location should always be preceded by a prelocation either by means of a bridge tester or a pulse reflection instrument. It is also essential to locate and mark the track of the cable in the prelocation area.

On an exposed cable, however, this method is used for the determination of the fault direction. Here also, low frequencies like 1 kHz have proved to be very successful.

6.6.2. Location of a fault between core and screen

Depending on the position of the junction of a low resistance contact between a core and the screen, this fault can be located by means of the minimum turbidity method.

The audio frequency generator is connected to the faulty core and to the screen which has to be connected through over the total length of the cable. The actual fault location is carried out in the prelocated area where the track of the cable has been marked. For this purpose, the search coil is conducted in a horizontal position and parallel over the cable. Before and after the fault, a minimum is received when the search coil is turned by 180° and it´s axis is parallel to the cable. A maximum is received if the coil is turned by 90° to the cable axis.

At the fault position however, the situation changes completely. For instance, the minimum can be received when the search coil is at an angle of 90° to the cable as shown in figure 1.

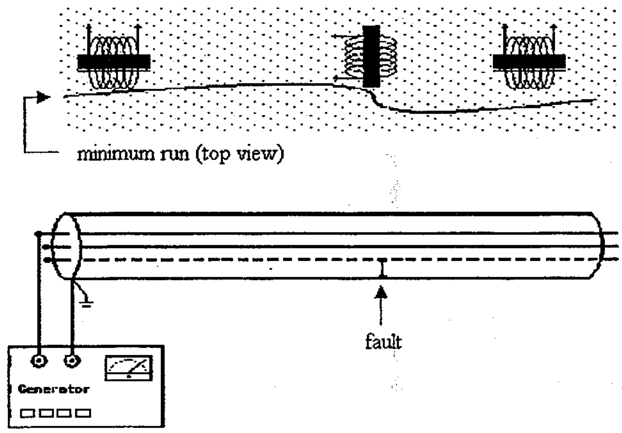

Figure 21:Minimum turbidity method.

Each deviation from the minimum run while the search coil is conducted parallel to the cable should be carefully examined

If no such deviation is detected in the prelocated area, then the possibility exists of locating the fault using another core if the fault transition takes on a different position. Figure 22 shows fault transitions at various positions of the pointer.

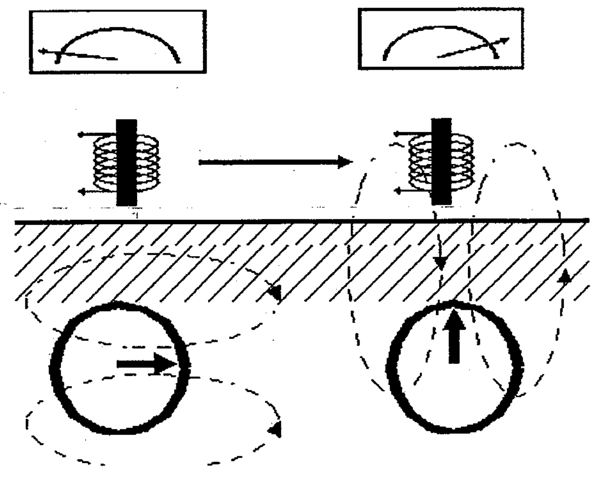

Figure 22: Pointer positions of fault transitions

The minimum turbidity can even be determined, when, as for conventional cable location, the search coil is conducted in a vertical position first at the left and then at the right of the track of the cable.

On a short section over the fault the minimum disappears or gets very feeble. The two maxima at both sides also differ largely in value, e.g. five scale divisions on the left and eight scale divisions on the right.

In principle, each irregularity in the structure of the audio frequency field can indicate a non-homogeneity in the cable or its periphery, e.g. cable crossings or sudden changes in the laying depth of the cable.

6.6.3. Location of earth faults

Earth faults of individual cores in a plastic insulated, unarmoured cable are located as per the step voltage method which generally gives very accurate results. For this purpose, the audio frequency generator is connected to the faulty core and to a good earth. At the point of contact between core and earth -here the fault resistance can be in the range of some 10 kOhms -an audio frequency voltage drop is generated, which can be measured both galvanically by means of earth spikes, or capacitively with capacitor plates.

When using the capacitive probe, the frequency applied should be as high as possible (> 1 kHz). Contact with blades of grass or other plants should be avoided since at these points, a sudden galvanical contact takes place leading to considerably higher voltage potentials which cannot be attributed to the voltage drop.

6.7. Pig - transmitter - location

Cable tubes without cables can get inaccessible by sagging or silting up, thus making it difficult or impossible to draw a cable in. In order to locate these points of obstruction, a pig-transmitter is inserted into the tube by means of a fibre glass spiral up to the obstacle.

Calibration pigs fitted with a pig transmitter which have got stuck, can be detected by the same method.

The electromagnetic field generated by the pig transmitter can be picked up by means of a receiver. Figure 23 shows this location method with the search coil in a vertical position. In this method, a distinct minimum is received directly over the pig transmitter. The advantage of a location with the search coil in a vertical position lies in the fact that the horizontal axis of the coil cannot be distorted.

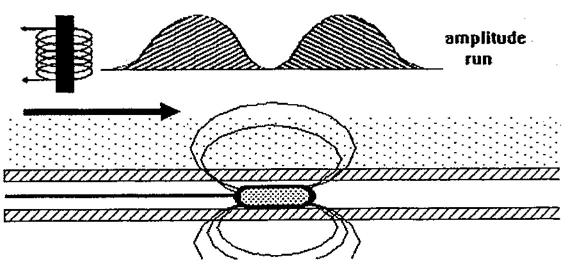

Figure 23: Location of a pig transmitter with vertical search coil

When conducting the search coil in a horizontal position as shown in figure 24, care has to be taken to see that the coil is parallel to the cable. In this case, a maximum is received over the pig transmitter, when the axis of the coil is parallel to the axis of the pig transmitter.

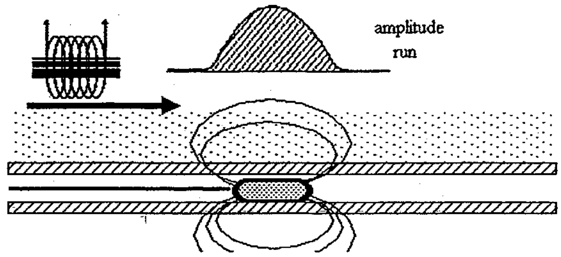

Figure 24:Location of a pig transmitter with horizontal search coil.

A measurement of the depth of the pig by the known 45° method is not possible. Nevertheless, the measurement itself is carried out by this method, i.e. first, the exact position is determined and marked with the coil in a vertical position.
Now, the search coil is set to 45° and is conducted along the track of the cable, until another minimum is received (fig. 25).

The following tables shows the depth of a pig as a function of the measured distance.

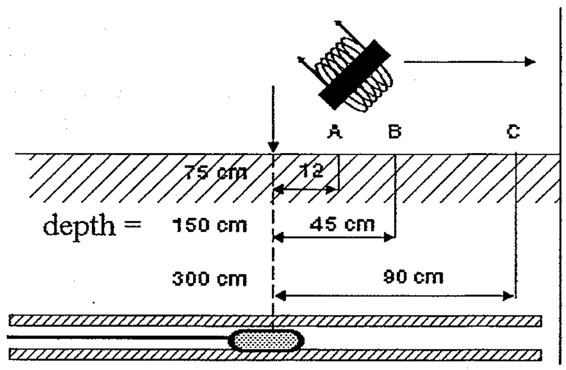

Figure 25:Determination of the depth of a pig transmitter

6.8. Ground survey

If, for instance, a building site is to be surveyed for the presence of unknown underground cables, then this can be done by means of the audio frequency method. For this purpose, the search coil is positioned in the center of the area under survey (approx. 100 to 200 qm) and the audio frequency transmitter is conducted in a circle around the search coil at a distance of 10 to 15 m.

Thereby, the transmitter frame has always to point to the search coil. When the transmitter frame crosses a cable, (e.g. position XX in figure 26), an audio frequency current is fed into the cable, generating an audio frequency field in the range of reception of the search coil which is used to locate the cable. The exact track is then measured with the methods described before.

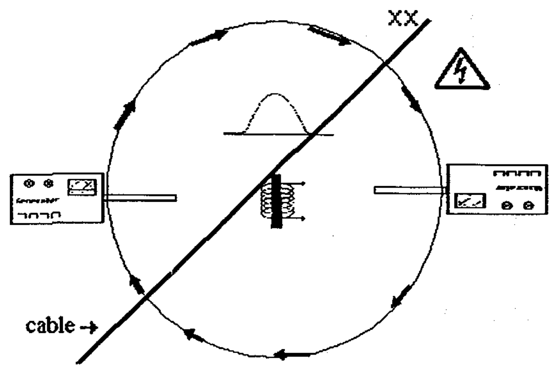

Figure 26:Ground survey