Hearing Assistance Induction Loops – A Brief Overview

BASIC INFORMATION
This section introduces Induction Loop technology and how it can be used for assistive listening. Please take some time to read and study this information which has been accumulated over many years of practical loop design and installation.

PURPOSE OF AUDIO INDUCTION LOOPS
Sound is normally transmitted from the source to the listener through the air by vibrations, which are received by the ear. All the sound in an area will be heard as the sum of signals whether they are the desired sound or not. The hard of hearing can find it more difficult to separate the sounds they want to hear from the others (known as background noise). A standard hearing aid will amplify all sounds in the area, and although this can assist in hearing anything at all, it does not help in an environment where there is significant background noise (some modern digital aids do try to shape the response to increase the clarity, but even this will be unlikely to work in noisy environments).
Audio induction loop systems are intended to help the hearing aid user by providing a clearer link from a sound source to the hearing aid than that provided by the normal acoustic transmission through the air. This is achieved by generating a magnetic field at audio frequency in the area where assistance is to be provided. In its simplest form, the magnetic field is generated by driving an audio frequency current through a loop of wire that surrounds the area in question.
The loop driver will normally take its signal input from a sound source via a microphone system (for voices or 'live' music) or from a sound reproduction system (e.g. a Public Address (pa) system, recorded announcements, etc.). It is therefore important to ensure that the signal input to the induction loop system is what the hearing aid user will want or need to hear. To do this, the system designer must correctly identify the sound sources that the hearing aid user will benefit from hearing. It is not sufficient to simply state that 'all sounds' in the room should be carried on the loop system.

What is an Audio Induction Loop?
An audio induction loop is a way of transmitting sound through a simple wire loop to a suitable receiver. They are used most frequently to help hearing aid users listen to a sound source more clearly where there is background noise in a room.

How does an Induction Loop work?
In a very basic form, an induction loop system consists of a loop of wire around the edge of an area connected to a special amplifier. The input of the amplifier is connected to the sound source that the hard of hearing users of the area want to hear more clearly.
The amplifier drives an audio current (not voltage) through the loop. This current generates a magnetic field in the area enclosed by the wire that a suitably fitted hearing aid can receive. more

Why use an induction loop?
People who suffer from hearing loss - the unseen disability - require more than just increasing the volume of sound into their ears.
The loss of hearing is generally associated with the neurological processing of information in the brain.
People with normal hearing require a signal to noise ratio of 6dB for a reasonable level of intelligibility. This represents quite a noisy background, which might be reverberation, air conditioning, ventilation systems or background noise such as a crowd of people.
When a person loses about 80% of their hearing, they generally need a signal to noise ratio of 15 to 20dB. This can be difficult to achieve unless the wanted signal is taken straight from the basic source and transmitted directly through the loop system, avoiding any reverberation or additional ambient noise.
Transient situations, such as ticket counters, information and help points, etc., are the worst areas for listening, though even in churches, theatres and lecture / conference rooms, there is often sufficient degradation of the signal to seriously affect intelligibility.
In most situations it is impractical to issue any form of separate receiver and the use of the individual' hearing aid is a major step to bringing people with hearing loss back into full contact with their environment. Only induction loop systems are capable of doing this.
Induction loop systems can be configured to reduce spill to surrounding areas and hence confidentiality is not an issue *if* designed and installed properly.

Do Induction Loops Interfere With Heart Pacemakers?
Under normal circumstances, a correctly installed induction loop system does not interfere with heart pacemakers. A minimum separation distance of 50mm (2") should be maintained between loop cable and pacemaker to remove any potential for interference.

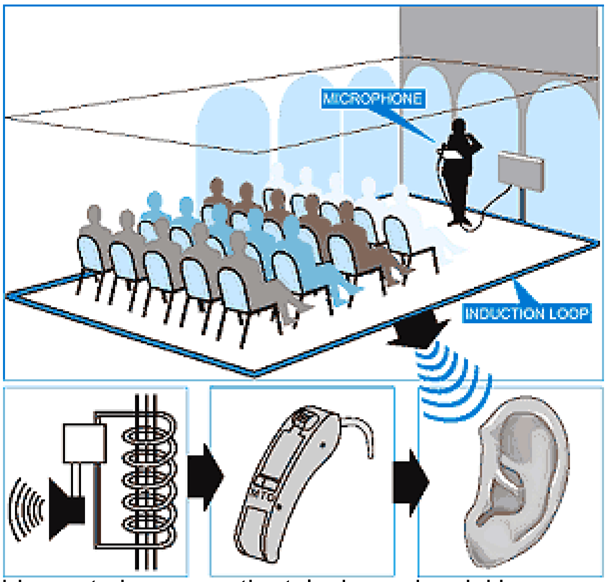
What are the alternatives to an Induction Loop System?
There are a number of other assistive listening technologies available. All rely on providing a transmission of the audio signal by some other method to a receiver carried by the listener. The principal systems are "Infra-Red" (IR) and FM carrier systems.
FM works by transmitting a normal radio signal carrying the audio that the user wants to hear. The FM system has to work with limited power and on a narrow unlicensed frequency band. It is therefore often susceptible to interference from other radio users (e.g. taxis) and general interference.
Infra-Red works by transmitting the audio signal on an Infra Red light beam and requires a line of sight (or reflected light) from the transmitter to the personal receiver unit.
With both these alternative technologies, the venue operator has to issue each user with a receiving unit (and get it back from the user afterwards!) The receiver unit often couples to the hearing aid using a small induction loop worn around the neck.
Note that, because each brand and variety of IR or FM system works differently, a different receiver is needed each time. Users cannot (and do not) carry around a receiver for FM or IR systems, although some will have direct audio input (DAI) leads to link the venue's receiver to their hearing aid.

Are all hearing aids compatible with Audio Induction Loops?
Sadly, not all hearing aids are fitted with the loop facility. In the UK, almost all NHS aids are equipped with a 'T' position, as are many privately sold aids. In the UK private sector, it is often the audiologist who decides whether to offer the loop reception facility, but generally they do offer aids with a 'T' setting. At present, about 95% of hearing aids in the UK are said to have the loop receiving function.
In the USA, audiologists do acknowledge the benefit of the 'T' facility, however some 40 to 60% of aids sold in the USA are without the loop facility.
The situation may vary in other parts of the world.

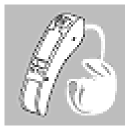
What about Digital hearing aids?
Digital hearing aids work in exactly the same way as ordinary analogue aids in terms of induction loop use but you must make sure that the digital hearing aid has a 'T' switch position. As far as we are aware, all digital hearing aids supplied by the NHS (National Health Service) in the UK have a 'T' coil facility. Privately dispensed digital aids may or may not have a 'T' coil. As policies over 'T' coil provision in hearing aids vary around the world - check with your audiologist about this *before* you buy, as it may affect what they offer to you.
Many digital hearing aids allow the option of setting the relative levels between microphone and 'T' coil inputs to be adjusted by the audiologist. If the loop signal is quiet / loud relative to normal microphone use, ask your audiologist to adjust it for you.
The international standard governing the use of induction loops (IEC60118-4) requires that the loop coil be vertically orientated to pick up the magnetic signal. Regrettably, IEC60118-1 which applies to hearing aids, does not define any orientation. Some hearing aids are available with a pick up coil adjusted for reception of horizontal magnetic fields and these may give poor results even when used in a correctly installed loop system unless you bow your head forwards to face the floor. Ampetronic are currently researching this effect and would welcome your comments if you have experienced this problem. Please let us know the hearing aid manufacturer, model number and date of purchase for our records together with a brief description of the exact circumstances under which the problem arose.
Always check with your audiologist BEFORE purchasing the hearing aid to ensure compatibility with induction loop systems.

Can I have a Digital Loop for use with my Digital Hearing Aid?
No - a digital loop would not be receivable by your hearing aid! Audio induction loops are a purely analogue technology, as is all sound. The way that the loop signal is transmitted to your aid is an analogue signal defined by international standards so that you can use any good loop system.
Digital audio products have to convert the analogue signal into the digital domain for processing then return the signal to analogue for us to hear it. There is no such thing as a digital headphone (unless you possess a pair of digital ears!).

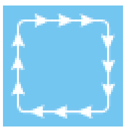
Induction Loops Explained by Ampetronic



Not all hearing-aid users and technicians / system installers can be expected to know the answer. Many have not heard of such things, and do not understand the great help an induction loop can be to users of hearing aids in compensating for their disability. So, the following explanation may be of some help in enabling non-technical persons to understand how an induction loop works. Most hearing aids nowadays have a switch marked M and T. Some even have M, MT and T. The M (microphone) position is for "normal" listening, that is receiving airborne sound via the microphone built in to the hearing aid. The T (telecoil) position is for receiving the sound via an induction coil which is built in to the hearing aid. For the induction coil to provide sound, a magnetic field is needed via which the sound is transmitted. This facility in hearing aids was introduced by a number of manufacturers many years ago and was then known as the "telephone" or "telecoil" position on the hearing aid switch. It was intended to make it easier for the hearing aid user to hear over the telephone, by picking up the sound via the magnetic field generated by the diaphragm coil in the receiver of the telephone. In many locations, telephone handsets now have this required capability. In recent years, however, induction loop systems have begun to be provided in public places such as churches, cinemas and theatres, bank, ticket and information counters and desks. It is even found in the home. In all these cases the T facility is used in to listen inductively, without the interference of airborne background sound. The MT position which is provided on some hearing aids allows listening simultaneously both to airborne sound via the microphone and to inductively transmitted sound via the telecoil.



It is well known that when an alternating current is passed through a wire, a magnetic field is generated around the wire. If a second wire is brought within this magnetic field, a corresponding alternating current is created within the second wire. In technical language, it is said that a current is "induced" in the second wire. Hence the term "induction". This particular magnetic principle is the basis on which electrical motors, electrical generators and transformers operate. An induction loop for hearing aid purposes also operates in the same way. An induction loop system consists of an amplifier and a loop. The amplifier can be connected to a sound source such as a TV or radio, a PA / sound reinforcement system or a dedicated microphone. The signal is amplified and fed into the loop cable, in the form of a strong alternating current. The loop itself consists of an insulated wire, one turn of which is placed around the perimeter of the room. When the alternating current from the amplifier flows through the loop, a magnetic field is created within the room. If a hearing aid user switches their hearing aid to the T position, the telecoil in the hearing aid picks up the fluctuations in the magnetic field and converts them into alternating currents once more. These are in turn amplified and converted by the hearing aid into sound. The magnetic field within the loop area is strong enough to allow the person with the hearing aid to move around freely within the room and still receive the sound at a good, comfortable listening level. The performance of these systems is specified in agreed international standards.



Some loop layouts are not simple single wire surrounding a room, but the above explanation covers the basic principles.

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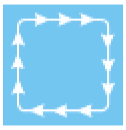
Loop Design by Ampetronic

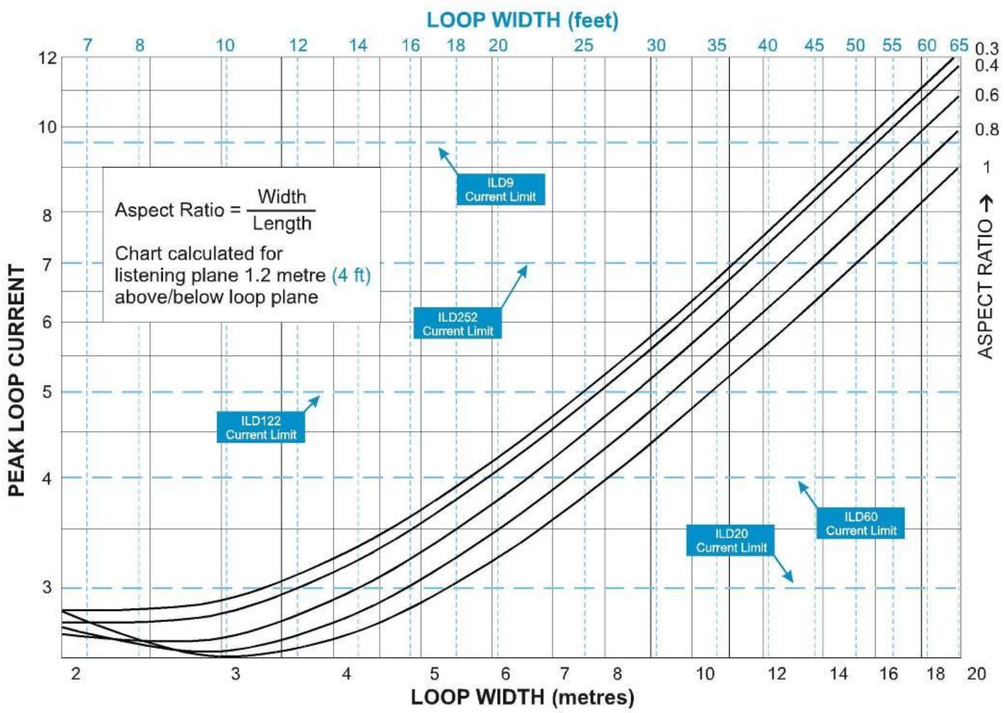
Full design data in pdf format Download (500K).



For optimum evenness of magnetic field, it is advisable that the loop plane should be displaced from the normal hearing (listening) plane by some 12–16% of the smallest dimension of the loop (width). Thus for a room 10 metre wide (30 ft), the optimum loop position is from floor level to 0.4 metre (22”) below, or some 2.4–2.8 metres (8 – 9 ft) above floor level. With some degradation, the figures can be 8% to 25%, and this should cater for all most installations.

If the displacement is large, then consult the graph on this page, which gives the field distribution against loop elevation in %, and offers a guide to the extra power needed to achieve correct field strength. Often, a ceiling mounted loop may simplify the installation to an extent that the extra power needed is actually economical.

The position and size of the loop can also be affected by the position of the listening area (often much less than the full room size), the position of the microphones and other equipment that might be affected by the magnetic field of the loop (such as electric guitars without humbucker coils).



Click here to see a larger version of this graph.

If dynamic microphones are used, they should preferably be used outside the loop, or if this is not possible, the actual loop cable should be kept as far away as possible from the microphone to prevent feedback due to magnetic coupling. (a distance of at least 1 metre / 3½ ft is advisable). Some dynamic microphones have better shielding than others, but this can only be established by practical assessment. The use of capacitor / electret microphones often reduces this problem, but does not always remove it.

Microphone connections should always be via good quality balanced and screened cable to reduce pick-up. They should not run parallel with the loop cable when in close proximity. Wiring inside Junction and splitter boxes is very important, as open loops are very susceptible to magnetic pickup.

For information about choosing the right size of wire (perimeter loops) see here.

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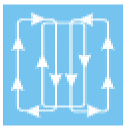
Induction Loop Planning and Design



This section explains how to take the basic loop information and use it to plan full systems. Unlike the Support section, this part of the website explains in detail the underlying principles behind loop design in an easy to understand manner.

WARNING You *cannot* ignore the following questions and issues if you want to install induction loop systems that meet internationally agreed standards.

The design of a complete loop system depends on a number of different factors, each of which may influence the final choice of loop design and equipment, but they must be considered in the correct order:

1. *Are there any existing loop systems nearby?* These could be a counter system or any other loop system installed in adjacent rooms either horizontally or vertically. If there are, we need to consider using low spill phased arrays. If the existing loop is a perimeter loop, it may need to be re-engineered to prevent spill into the new proposed loop system.
2. *Are there any issues of spill or confidentiality?* If so, we must use a low spill phased array. Areas such as a council chamber, courtroom or conference room with dividing partition(s) are examples of this type of installation.
3. *How much metal is contained within the proposed loop area?* If none and there are no issues of pre-existing loops, spill or confidentiality, then a simple perimeter loop will suffice. However, if there are metal structures - reinforced concrete floor, metal ceiling grid, metal ceiling tiles, raised drop in metal floor tiles etc., then we MUST use a phased array to overcome energy losses.
4. If a counter loop or local loop is being installed, then provided there are no metal structures (or metal counter), installation is likely to be straight forwards.
5. Any other considerations not mentioned above - contact us.

Answers to these questions will determine the exact type of loop necessary. For more complex installations Ampetronic provide solutions derived from custom CAD and simulation software - Contact us for more assistance. If the questions above are answered correctly - there should be no guesswork involved!

All installations fall into one of the following five categories:

1. **Local Loop** - Used where limited loop coverage is required. A counter system, help point or just one part of a room can be described as a local loop. Note this application is the only use of a multi turn vertical loop coil.
2. **Perimeter Loop** - A single turn of wire which is fitted around the perimeter of the room at a particular height. Used for rooms where spill is not an issue, or where loss due to metalwork is very small or for very small rooms (less than 5m wide) containing some metalwork. Cathedrals, churches, old community halls (with wooden floor) or domestic properties might fall into this category.
3. **Cancellation Loop** - A cancellation loop is a variation of a perimeter loop and is used for limited control of spill, usually in a single direction. It normally consists of a perimeter loop in a fig 8 configuration but needs careful design to avoid null points falling within the required coverage area. This type of loop has size limitations.
4. **Low Spill Phased Array** - Consists of two completely separate loop arrays arranged in a precise overlapping manner. Each array consists of typically two to six (or more) loops all connected in series which are installed to cross the room in a number of places. It is the precise overlap and spacing of the loops that achieves cancellation of the magnetic field outside of the loop area. With this design, spill can be reduced to 2m or less. An additional benefit of a low spill design is that by its nature it tends to overcome losses due to metal structures.
5. **Low Loss Phased Array** - Is exactly the same as a low spill array but with wider gaps between wires to increase the magnetic field strength for a given size of amplifier.

Categories 3-5 MUST be analysed and designed by Ampetronic for predictable results to be achieved

Choosing the right cable

The table below helps you select the correct gauge of wire for your loop amplifier. The type of wire is not too important, though experience has shown that a stranded cable with tri-rated insulation is probably the easiest to install and most robust in use. So for example, an ILD252 amplifier when using a 1.5mm^2 loop cable, will work with a minimum length down to 26m and a maximum length of up to 117m. Any length in-between these two values will work fine.

Cable / Wire Data				ILD20 - ILD60		ILD122		ILD252		ILD9	
				Length (m)		Length (m)		Length (m)		Length (m)	
Wire gauge mm^2	Resistance		|Z| @	Min	Max	Min	Max	Min	Max	Min	Max
	Ω per		1.6 KHz	DC	1.6 KHz	DC	1.6 KHz	DC	1.6 KHz	DC	1.6 KHz
	100ft	100m	Ω/m	0.3Ω	1.5Ω	0.2Ω	2Ω	0.3Ω	2.72Ω	0.4Ω	3.75Ω
0.5	1.051	3.448	0.0399	6	38	6	50	9	68	12	94
0.75	0.701	2.299	0.0305	9	49	9	65	13	89	17	123
1.0	0.526	1.724	0.0265	12	57	12	76	17	103	23	142
1.5	0.35	1.149	0.0232	17	65	17	86	26	117	35	162
2.5	0.21	0.69	0.0213	29	71	29	94	44	128	58	176
4.0	0.131	0.431	0.0206	46	73	46	97	70	132	93	182
FB 1.8*	0.292	0.958	0.015	21	100	21	133	31	181	42	250
AWG wire			Ω/100ft	Length (ft)		Length (ft)		Length (ft)		Length (ft)	
22 7x30	1.474	4.837	1.593	14	94	14	126	20	171	27	235
20 7x28	0.927	3.042	1.106	22	136	22	181	32	240	43	339
18 16x30	0.645	2.116	0.883	31	170	31	226	47	308	62	425
16 26x30	0.397	1.302	0.722	50	208	50	277	76	377	101	519
14 41x30	0.252	0.826	0.654	79	230	79	306	119	416	159	574
12 65x30	0.159	0.521	0.624	126	240	126	321	189	436	252	601
10 65x28	0.1	0.328	0.611	200	245	200	327	300	445	401	613

* FB 1.8 is Flat Copper Tape

Table Notes

The table above gives comprehensive information on the minimum and maximum length of cable of a particular wire gauge that can be used with specific Ampetronic loop drivers. Each driver has a specified minimum resistance and maximum impedance at 1.6KHz which can be driven at full current.
This is very important because the energy distribution in speech reaches a maximum at that frequency. To meet the frequency response requirements of IEC118-4, without driver output clipping (which causes the equipment to fail EMC requirement), full current is needed at this frequency, where the cable is inductive. The impedance at 1.6KHz for different cables is given above. This is based on 2uH/m (0.6uH/ft) for normal wire and 1.15uH/m (0.35uH/ft) for flat copper tape. Often, metal in a building may increase these figures. All Ampetronic drivers are designed for SINGLE turn loops (N=1). For multi-turn loops, inductance increases by N^2 and therefore, with a 3-turn loop, this increases by a factor of 9. As inductance is the dominant component at 1.6KHz, the maximum loop perimeter length that can be used is reduced by a factor of 9!

Feeder Cable

The values given in the table ignore the resistance of the feeder cable which is normally very low. If the situation is marginal, or where very long feeder cables are involved, additional design must be done to compensate. Feeder cable should always be tightly twisted to ensure that the reactive component is very low resulting in a low magnetic field near to the equipment. Use of shielded cable has no real advantages as magnetic radiation is not affected. Parallel wire cable (eg Fig 8) as used by some loudspeaker manufacturers is not recommended. Very often, the wire gauge of the feeder will be similar to the actual

loop cable.
The actual feeder length is double the physical length for resistance (send and return). This is important when calculating the total resistance of the system.

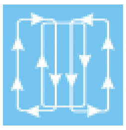
Star Quad Feeder Cables
For very long feeder cables, the recommendation is to use a 4-core round cable in a "star quad" configuration. Optimum cable size is 1.5mm² / 2.5mm² (14AWG / 16AWG). The opposing cores are connected together, providing a very low resistance and inductance with little magnetic radiation. This style of cable is often used for 3-phase + earth power connection of machinery.
UK style is 3184Y, harmonised H05VV-F. Similar UL approved cable is SV-3, UL recognised 4097. Total resistance of 100m of 3184Y cable, 2.5mm² per core is 0.69Ω (4-core 14AWG cable is 0.252Ω/100ft). This is well inside the capabilities of the Ampetronic loop drivers.

Calculation of Feeder Cable + Loop Cable Impedance

The chart helps you check that the loop inductance / loop plus feeder cable resistance will work with the chosen loop drive amplifier. The calculated impedance MUST be inside the driver limit envelope. The magnitude of loop reactive impedance is calculated as follows: Loop length (m) (or feet x 0.305) x 0.02 (for wire) or x 0.01156 (FC1.8 Copper Tape). Total resistance is actual loop resistance plus feeder cable resistance. The resistance figures given in the table above (ie Ω per 100m / ft) permit this calculation.	Click here to see a larger version of this graph.

Metal - Its impact on Induction Loops

Overview



The importance of designing Induction Loop systems to cope with losses due to metal structures within the fabric of buildings cannot be over-emphasised. It is absolutely critical to allow for signal loss caused by metal structures during the system planning phase of any installation. If this is NOT done, the installed loop system is most likely to suffer from a range of problems - insufficient signal strength, uneven signal strength - loud in places and inaudible in others, lack of high frequency detail / clarity or other problems. Metal loss problems can be overcome, but only by proper design and attention to detail.

Principles

- The magnetic field generated by an induction loop system, induces a current in any closed path of a metal structure placed in the vicinity of the induction loop. more.
- These induced currents tend to weaken the magnetic field and cause loss. This loss is dependant on the type and thickness of metal and its position in relation to the induction loop.

Examples of Metal Structures

- Reinforced concrete floors - Mesh within.
- Lightweight floor construction with a (usually profiled) metal sheet under a thin reinforced concrete slab.
- Metal floor tiles - System floors.
- Suspended ceiling grid - 600mm x 600mm (2' x 2') or 1200mm x 600mm (4' x 2') metal grids with acoustic or metal tiles.
- Foil backed plasterboard - Vapour barrier.
- Girders, beams, constructional metalwork.
- Metal cladding, walls and roofs.
- Metal counters - Whole or part metal.
- Metal box construction - Elevators / lifts.

Effects of Metal Structures on Inductive Loop Performance

1. Degrades magnetic field strength.
2. Produces uneven magnetic field strength across the loop plane.
3. Frequency dependant losses. High frequencies (ie intelligeability) are attenuated more than low frequencies. The effect is for the audio received through the loop to sound is as though you had placed a thick blanket across your hi-fi speakers - muffled and indistinct.

The main consideration is the amount of metal structures containing closed paths within the area covered by the loop. Any metal structures that do not form an electrically closed path within the loop can usually be ignored. This means that heating pipes, radiators, metal windows and isolated reinforcement bars within concrete tend not to cause problems.

A common misconception is that only ferrous metals create a problem. This is not true as both copper and aluminium cause signal loss. Since these materials have a lower resistivity, the loss would be greater. In short it is the conductivity of the metal, not it's magnetic properties, that is relevant here. Losses are usually up to 3dB/Octave with a lower corner frequency typically between 0.1Hz and 100Hz. As the losses increase with frequency, a metal loss corrector will be needed to flatten the response. The standard covering induction loops (IEC118-4) requires a flat frequency response between 100Hz and 5kHz.

When metal is found, the losses incurred are often so great that simply using a larger amplifier will not suffice. (Losses of more than 25dB @ 1kHz have been known!) In such cases a simple perimeter loop cannot achieve acceptable performance, so special loop design (eg phased array) and equipment are needed. Given the construction details, Ampetronic can estimate the required equipment and suggest a suitable loop design approach. For larger projects, a site visit may be advisable to measure the loss experienced in practice. Please contact Ampetronic for assistance in all these situations.

To illustrate why simply using more current is not an effective solution, consider the following example. It is not unusual for a reinforced concrete floor to suffer more than 15dB (@ 1kHz) of loss in the centre of a perimeter loop! Imagine such a loop required 8A peak without loss; you would need to use a loop current of 45 Amps to reach the target field strength! Even if it was this was feasible it would still not be possible to make the field adequately even across the loop as the loss would vary across the area.