AUDIO FREQUENCY INDUCTION LOOP DESIGN
"HEARING LOOPS"

TABLE OF CONTENTS

This text is intended as a reference for trained loop installers. This manual is not recommended as the sole source of information to install a hearing loop.

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CHAPTER 1 - BASIC INFORMATION

DEFINITIONS

IEC - **International Electrotechnical Commission** describes themselves as "the international standards and conformity assessment body for all fields of electrotechnology".

AFIL – Audio Frequency Induction Loop – hearing loop.

T-coil – a small coil of wire around a ferrite core that picks up the hearing loop signal for the hearing instrument.

Antenna – Flat, solid or stranded wire or foil used to create the loop signal.

Flat wire – Foil or wire with a flat profile. This style of antenna provides better frequency reproduction due to the large surface area.

Impedance - The effective resistance of an electric circuit or component to alternating current, arising from the combined effects of ohmic resistance and reactance.

Dynamic microphones – Microphones with similar construction to the T-coil that will pick up the hearing loop signal.

Overspill – The hearing loop signal that occurs outside the loop antenna.

mA/m - Milliamps per meter. The unit of measure for hearing loop strength.

dB – scale used in measuring milliamps per meter in a hearing loop field.

Field Strength Meter – A device that measure mA/m and converts it to dBmA.

Sine wave – A continuous wave with no variation.

Pink noise – each octave carries an equal amount of noise energy rather than volume.

Artificial speech – Artificial production of human speech.

Perimeter loop – A simple design with a single loop in a square or polygon shape.

Figure 8 loop – Two loops installed side by side.

Snowman loop – Three or more loop segments installed side by side.

Signal reducing loop – A two turn loop installed next to the the main loop. This design intends to reduce the signal along one side to provide privacy or limit overspill.

Phased array – A complicated design that produces a higher quality hearing loop with better frequency reproduction, greater power, privacy and less risk of feedback.

In-Phase – When the loop wire connection creates loops with a common rotation i.e. both loops clockwise

Out-of-Phase - When the loop wire connection creates loops with a opposite rotations i.e. one loop clockwise the adjacent loop counter-clockwise.

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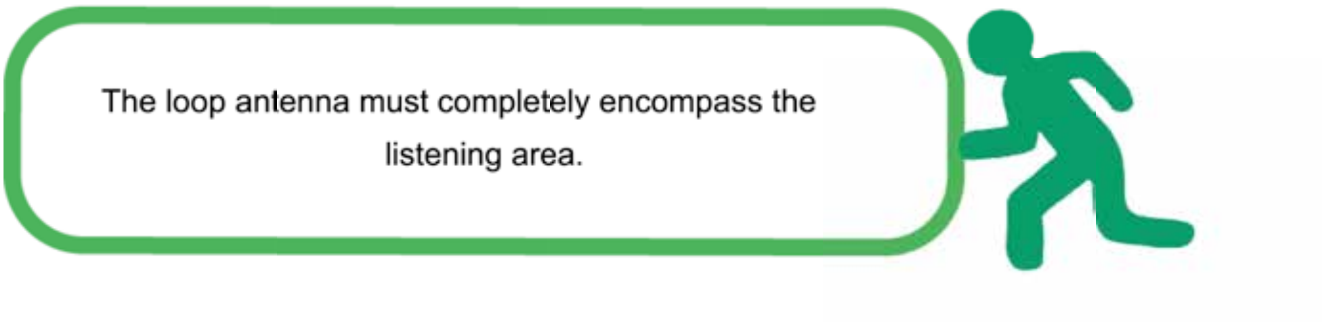
GUIDELINES

A test loop should always be installed prior to quoting or committing to a design.



The antenna should be consistently the same height throughout the installation if possible.

Metal in the structure will absorb the magnetic hearing loop field and distort the shape. The size of the loop segments may need to be reduced if the output is unacceptable to the users or does not meet the IEC standards. For the same reason, the antenna should not run parallel along metal structures like ductwork, metal pipes or steel framing. It can cross over these structures.

Unless metal content in the building is a significant factor, the loop signal will extend about 1/3 of the width around the outside of the wire. Smaller loop segments will reduce this overspill. See chapters 4, 5 and 6 for techniques to reduce overspill.

The space directly above or next to the antenna will be silent due to the orientation of the T-coil in the hearing instrument. Be careful to design the loop so the antenna is outside the planned listening area.

The antenna can be installed at floor level, and as much as 3' below the floor, depending on the size of the loop and the amount of metal in the structure.

The antenna can be installed between 7' and 12' above the floor, depending on the size of the loop and the amount of metal in the structure. Very narrow loops will limit the amount of distance the signal will extend up and down. The loop is basically a sphere with the top and bottom flattening as the width increases. Conversely height decreases as the width is reduced past the point that the sphere is round.

The antenna should not run parallel along metal structures like ductwork, metal pipes or steel framing. It can cross over these structures.

Dynamic microphones and some musical instruments will pick up the loop signal and create feedback. Plan the loop so it does not extend into band areas. See chapter 6 regarding phased array loops to eliminate this issue. The musical instruments can also be isolated from the loop system if there is a separate feed for the instruments on the sound board.

The higher frequencies in the loop signal will reduce more than the mid and low frequencies as the amount of metal in the building structure increases. If the treble boost control on the loop driver is not adequate to compensate for this frequency shift, an equalizer can be added between the sound source and loop amplifier to adjust the frequency output in the loop field. Smaller loop segments tend to reproduce the frequencies better than larger perimeter loops. See chapters 4, 5 and 6 for loop designs with smaller segments.

The loop field will change depending on the impedance in the loop antenna. The impedance increases as the loop antenna reduces in cross section, increases in length, or has too many sharp bends or connections. In high metal environments the impedance decreases dramatically as the loop signal is pulled into the structure. As the impedance increases the loop amplifier has to increase the voltage (signal pressure) and decrease amperage (signal volume). These changes will affect the frequency reproduction.

Flat wire or foil will produce better frequency reproduction than solid or stranded wire.

Isolating the grounds on the projector and the loop equipment will reduce interference with video feeds.

An unused microphone feed or wireless audio transmitter can be used if the audio signal source is too far from the area that is to be looped, or if there is a barrier.

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CHAPTER 2 – INSTALLATION STANDARDS

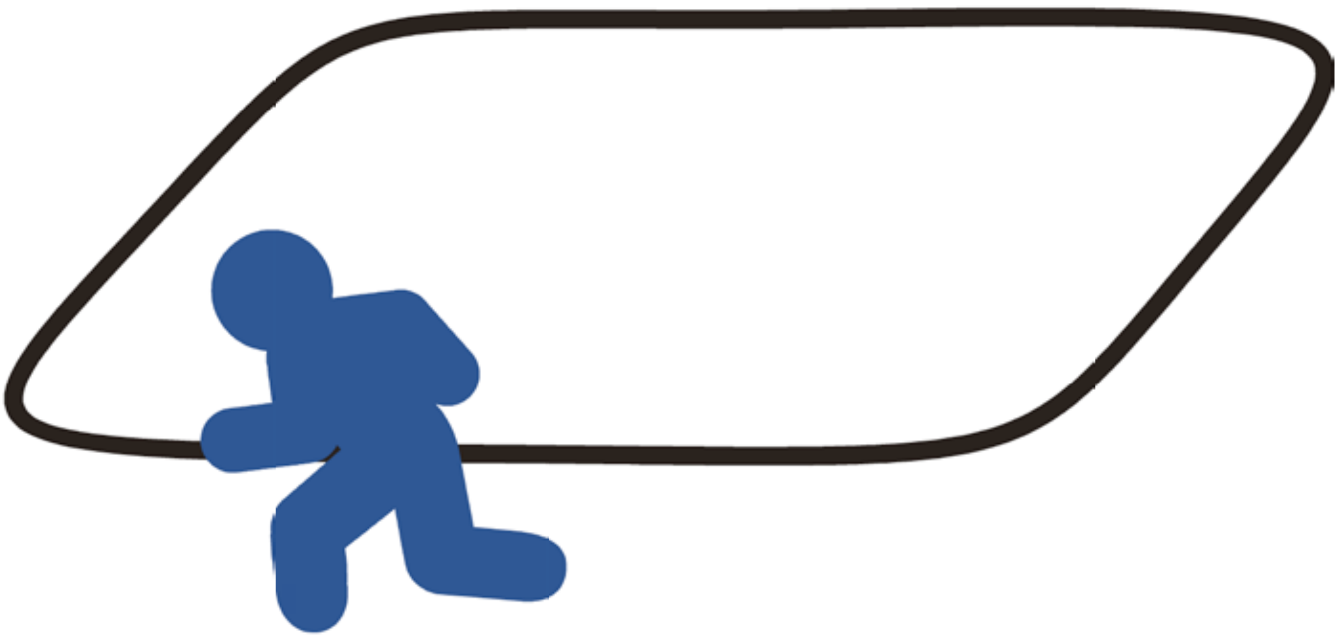
Unless the facility or local authorities have written standards, there are no governing bodies for many hearing loop installations. Best practices suggest compliance with the latest revision of IEC 60118-4. In most areas there is no code or law requiring adherence to the IEC standard, but most installers and experts regard it as the minimum standard for hearing loop installation. The standard is lengthy, filled with technical terms, and vague in some important areas. It is also not available without a contract with the IEC. Since the standard is aggressively protected by the IEC, it cannot be quoted or reproduced. Because of this it will be referred to in non-specific terms to provide the basic knowledge needed to design and install compliant loops. Anyone that is serious about installing high quality hearing loops should purchase and read the complete standard.

The standard uses mA/m (milliamps per meter) expressed in dB (decibels) as the measurement for the hearing loop field strength. This might be confusing, but the relationship between mA/m and dB is logarithmic rather than linear. In simpler term 1 plus 1 isn't usually 2. The number of mA/m double over each 6 dB increase. For example, 50 mA/m is -18 dB, 100 mA/m is -12 dB, 200 mA/m is -6 dB, 400 mA/m is 0 dB and 800 mA/m is 6dB, with the same progression in each direction. So there is a 50 mA/m difference between -18 and -12 dB and a 400 mA/m difference between 0 and 6 dB. In this case it makes sense to use the dB scale as a reference since we're concerned with the listening volume of the signal rather than the amount of power being generated in the loop field.

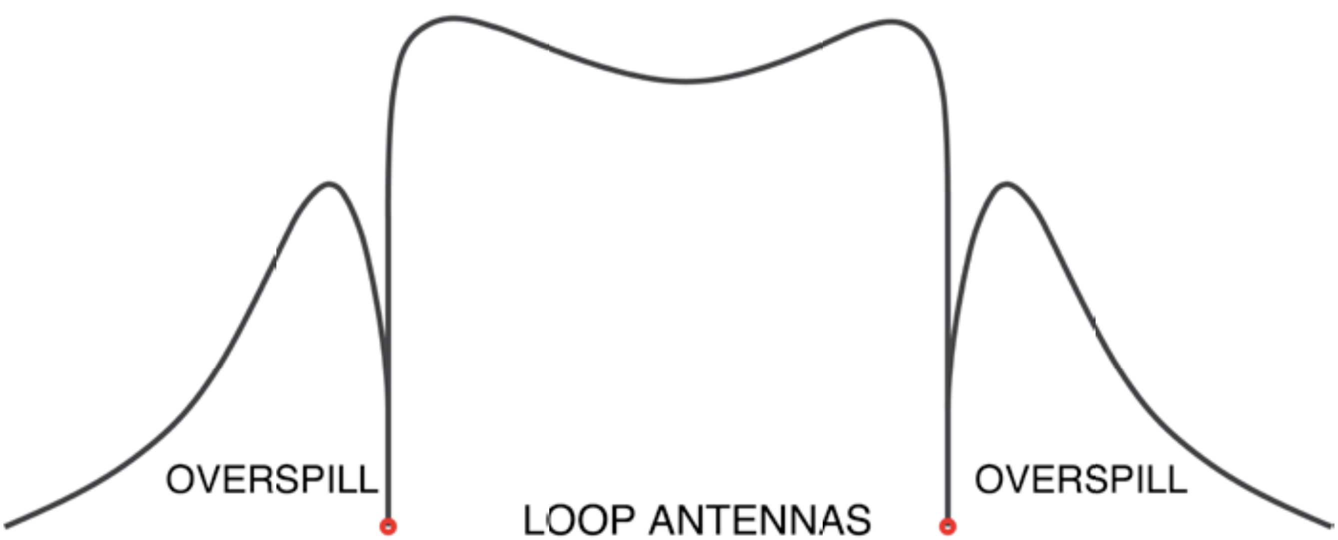
Any electronic background noise will be picked up by hearing devices in T-coil mode. This is usually the result of inefficient electric equipment or defects in the grounding of the building. This hum and static can be distracting if too loud, and can make a hearing loop impractical. Background noise in the loop signal range should be measured prior to considering a facility for a hearing loop. The standard suggests the background noise be at most -32 dB, with an ideal range less than -47 dB. It is acceptable to have as much as –22 dB in transient situations like teller windows where the user isn't subjected to the noise for a prolonged period of time. Hearing loops are not an option if higher levels of background noise are present. The “Background” noise setting on hearing loop Field Strength Meters give preference to the electric current in the loop field rather than volume at the ear. The energy required to reproduce frequencies has the same logarithmic relationship to loudness as mA/m do to dB. In other words the amount of power expended does not result in an equal increase in loudness with different frequencies in the loop field. The “Normal” setting on most hearing loop Field Strength Meters give preference to this difference in frequencies as they relate to volume at the ear rather than electric current in the loop field. Let's consider the different configurations of loops before we delve deeper into testing instructions.

CHAPTER 3 - PERIMETER LOOPS

A test loop should always be installed to prove the results before a design is finalized.



The easiest hearing loop to install is a perimeter loop. The antenna is simply installed in a single loop around the listening area. The advantage to this style is the low cost allowed by the ease of installation. The amount of variation across the loop field is sometime a deterrent depending on the width and amount of metal in the structure. Consider the alternative methods in chapters 4, 5 and 6 if there is too much variation.



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Installing the loop antenna can be done in a number of ways. If it is a wire, it can be tucked in between the wall and carpet, under trim, above the ceiling, under the floor or any other area that allows concealment. Foil or flat wire can be installed below most floor surfaces.

Care should be taken to insure the antenna is not cut during installation of the flooring material. If damage does occur, a wire tracker designed to find breaks in phone and data lines can be used to find the cuts. Foil can also be used directly on wall surfaces. It can be covered by decorative wall coverings or plaster.

Sometimes carpentry or flooring work is required. Grout can be cut between tiles and the wire grouted in between tiles. The concrete slab can be cut and the wire mortared into the floor. Care should be taken to use a wire that is rated to be directly enclosed in concrete. At this writing there are no wire manufacturers that will guarantee this type of installation due to the caustic nature of concrete. The best method to place the wire in a concrete slab is to bury conduit in the concrete during installation. The loop can be installed outside the building if underground and UV rated wire is used.

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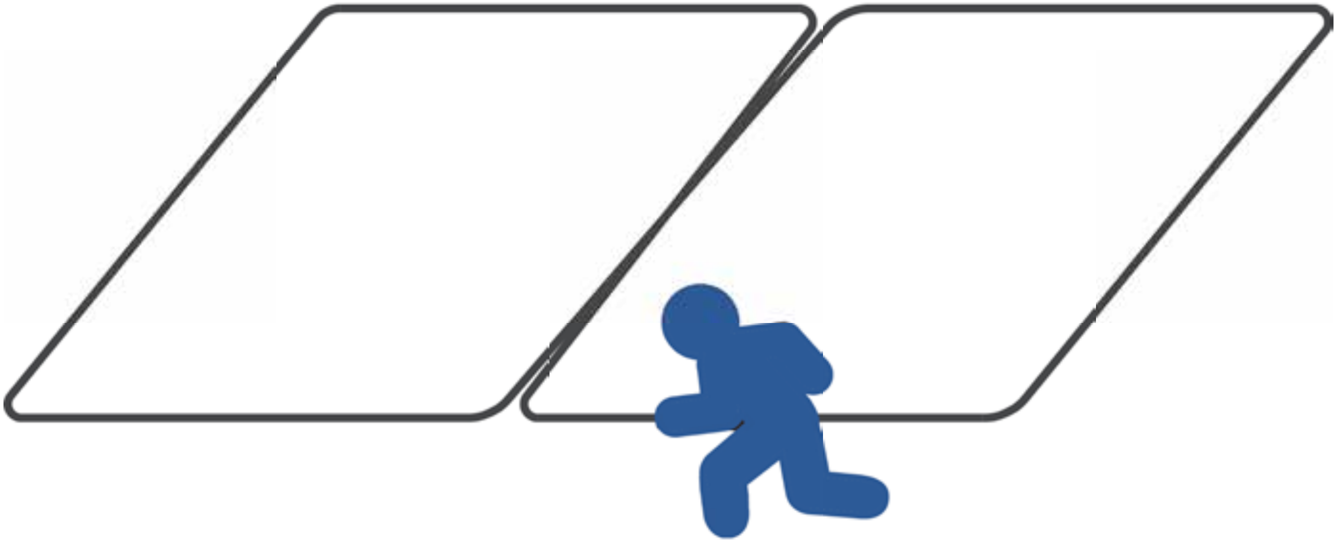
CHAPTER 4 – MULTIPLE SEGMENT LOOPS

Smaller, connected loop segments can be used if there is too much variation in the loop field of a simple perimeter loop. The number of segments is limited by the design of the room. Two segments side by side are referred to as a figure eight loop. Three or more are called snowman loops.



The challenges for multiple segment loops is hiding the center wires and the distortion that happens over this connection. This sort of loop is only practical for an area that has fixed aisles where the wire connection can be placed. Otherwise a T-coil user will experience a distorted signal if they sit directly over the connection between segments. If a perimeter loop will not work, and the distortion over the wire is not acceptable, the only option is a phased array loop. It will provide a smooth, consistent signal with very little variation between the loops segments. Phased array loops have minimum overspill because of the small segment size, reduced variation between frequencies, and less variation to the hearing device regardless of the orientation to the loop field (head shift). However phased array loops are the most difficult to install and requires a special loop amplifier. See chapter 6 for more about phased array loops.

There are also overlapping loops where a single perimeter loop is installed in the center of a figure 8 loop. This helps smooth the transition between the segments, but adds a level of complexity to the installation.

There are two ways to orient the wire direction. In-phase refers to multiple segment loops that all run in the same direction i.e. clockwise OR counter-clockwise. Out-of-phase refers to alternating directions. i.e. the first loop is clockwise, the second loop is counter-clockwise, third loop is clockwise, etc.

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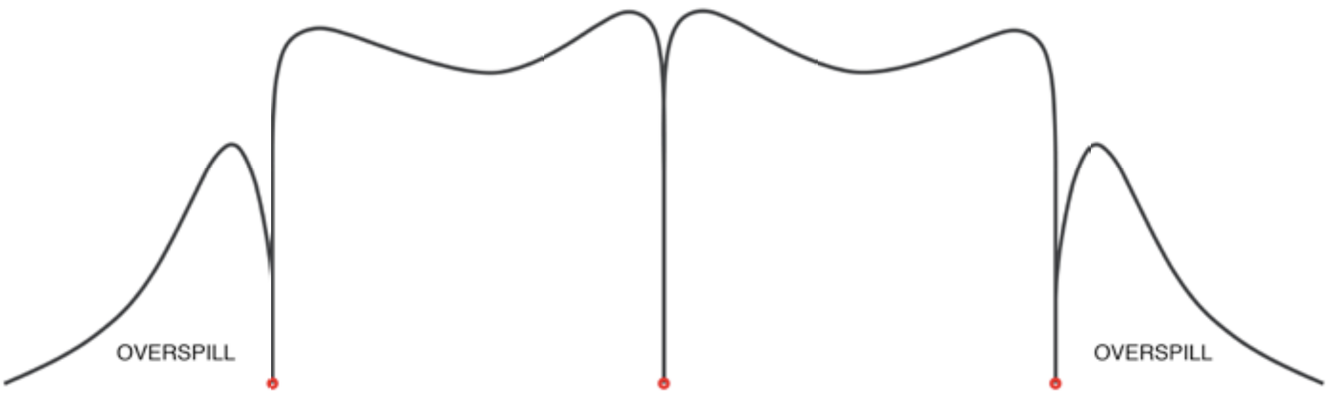
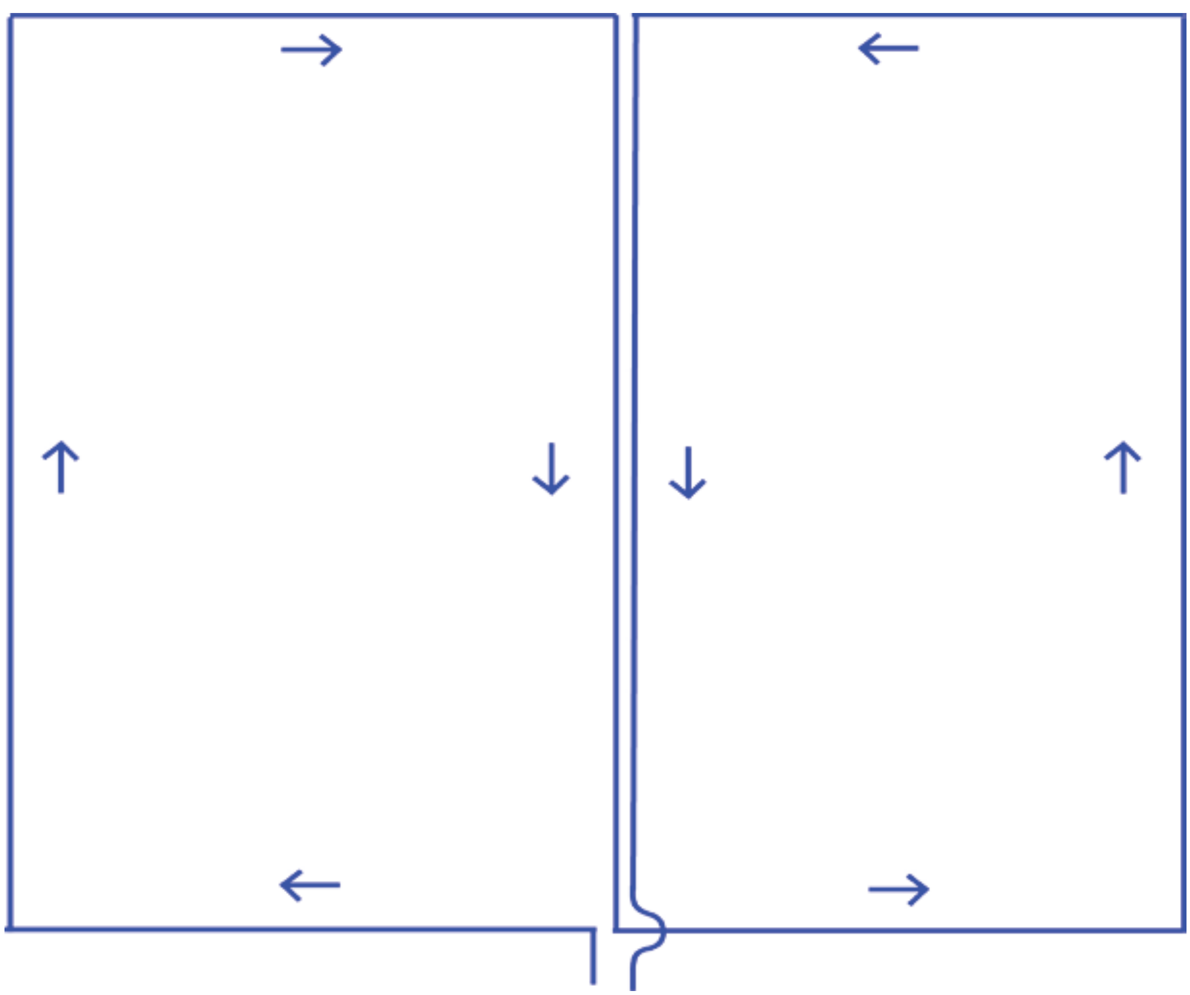
Out-of-phase loops have more variation between segments, but produce a higher field strength with less power demand.





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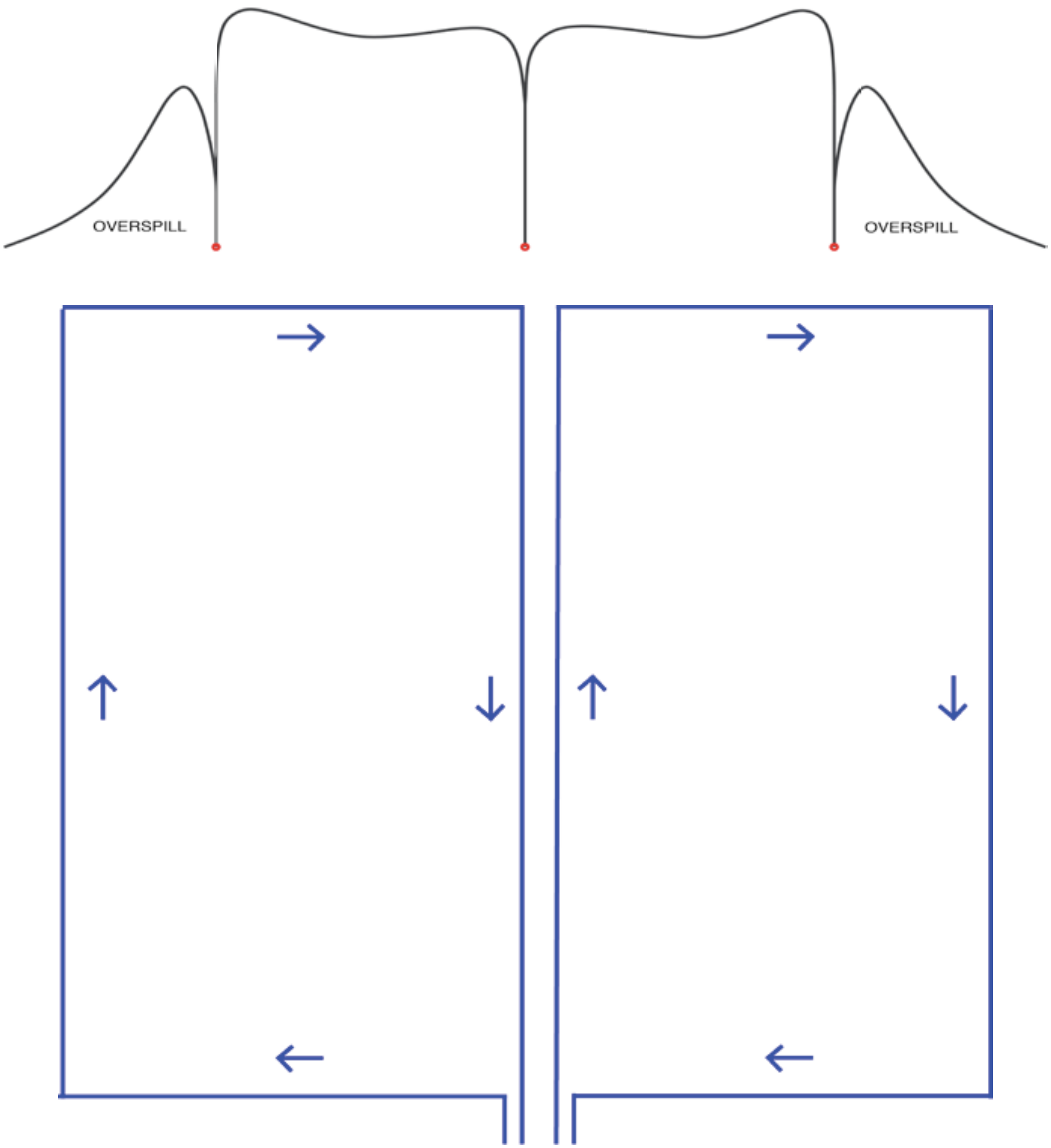
In-phase loops have less variation between segments, but produce a slightly weaker signal requiring more power.



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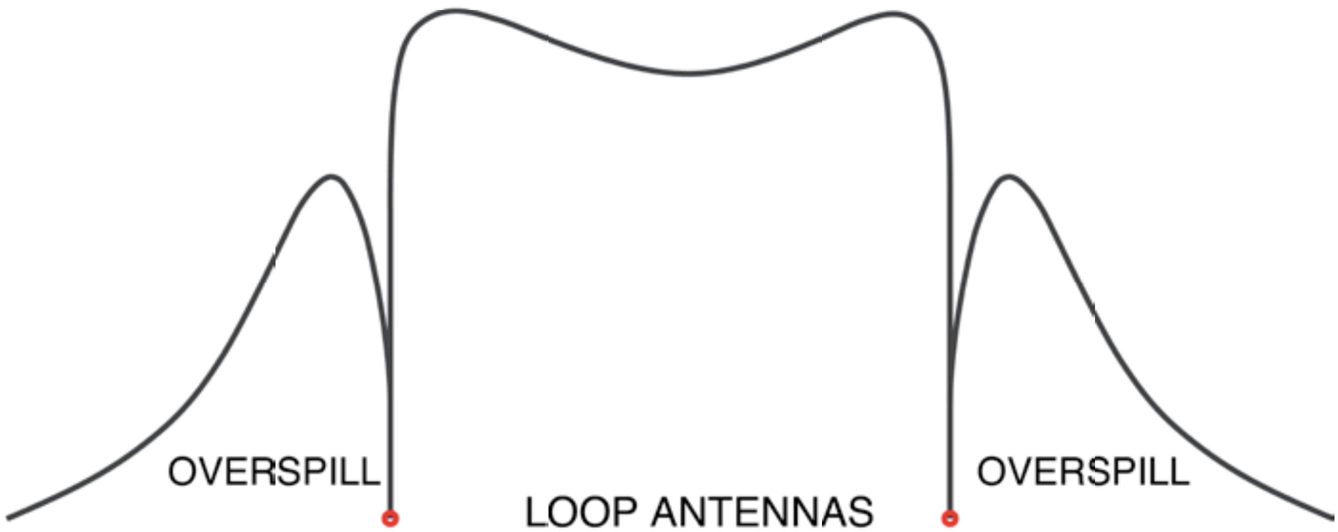
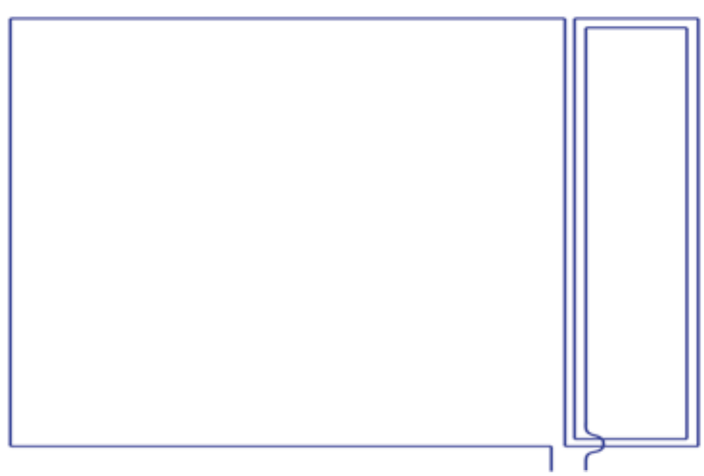
CHAPTER 5 - SIGNAL REDUCING LOOPS

Loop signals are not confined inside the loop perimeter. They typically extend 1/3 of the width of the loop in buildings with little metal in the structure. For example, a 30' wide loop will usually have 10' of spill, and a 60' loop will have 20'. The strength of the signal in the area of the overspill diminishes to nothing along the outside edge but it can create issues in the louder areas close to the loop antenna.



It is sometimes necessary to reduce the signal spill to provide privacy, reduce interference between loops or control feedback. A technique that has questionable results, is to reduce the spill by creating a signal reducing barrier along one or more sides of the loop. Simply reduce the size to construct a smaller but stronger loop along the outside edge of the primary loop. There are two factors that affect the amount of spill. First, the width of the main loop is reduced by the width of the smaller loop. Not only is the spill reduced by the smaller loop, the border is moved away from the barrier proportionately. Second, a two or three turn loop increases the signal strength in the looped area.

This technique utilizes these components to construct a smaller two turn loop along the outside edge of the primary loop.



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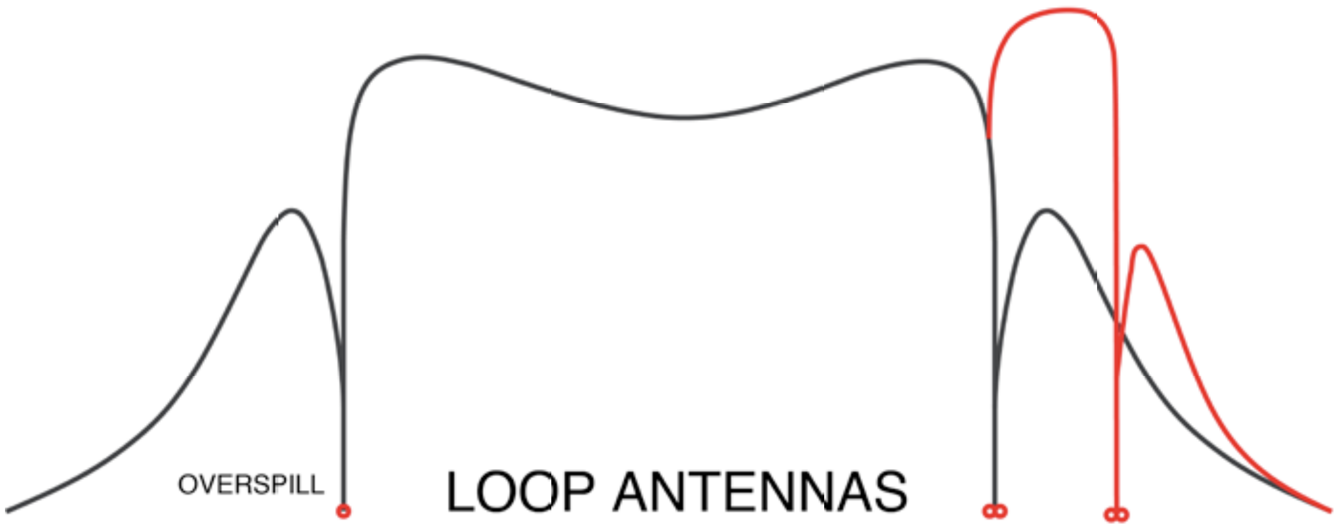
The smaller size of the primary creates a little less spill, and the spill is moved away from the edge to accommodate the small two turn loop. The stronger two turn loop along the edge creates the illusion of a partition as illustrated in the image below.



The functional reality of this configuration has less appeal than the reality. The signal is distorted by creating a second loop along the edge. It will be difficult to use a T-coil in this area. The useable area would not be affected by eliminating the small two turn loop, so this solution has very little functional application. It is just as effective to reduce the size of the main loop without adding the two turn loop along the edge.

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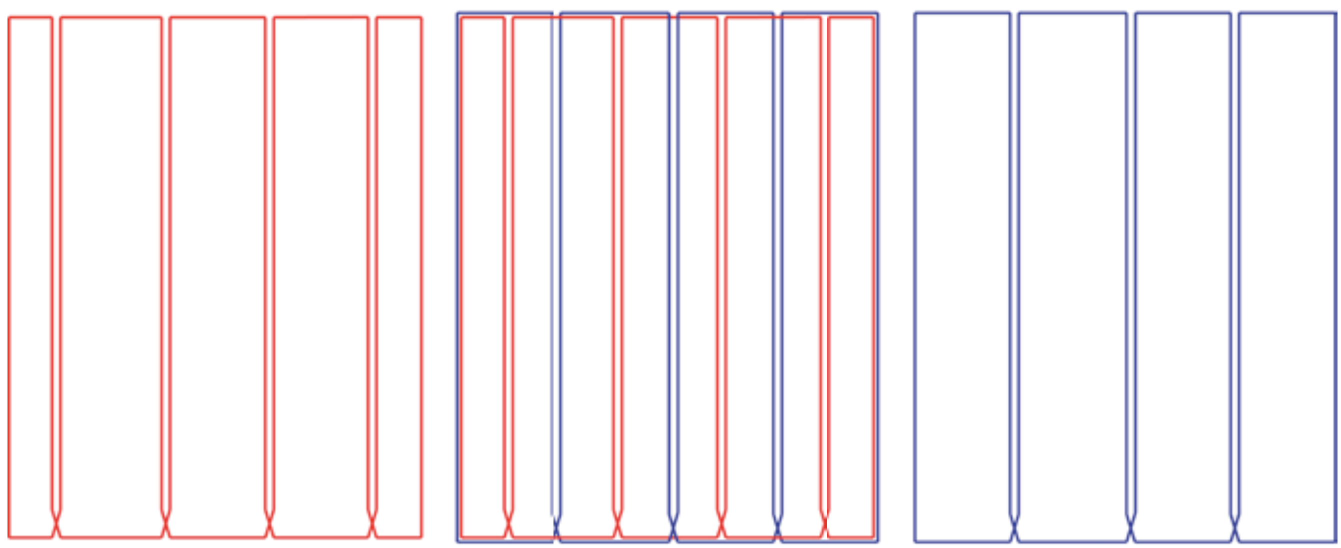
CHAPTER 6 - PHASED ARRAY LOOPS

Phased array loops are the most difficult to install and require a special loop amplifier, however they provide a smooth, consistent signal with very little variation between the loops segments. Phased array loops have the least amount of variation between frequencies and have minimum overspill because of the small segment size. They eliminate head shift which is the volume difference experienced when the orientation of the hearing device changes relative to the loop field.

This style of loop consist of a primary loop made completely with full segments, and a secondary loop that can have half segments on the edges if needed. The primary and secondary loops consist of snowman style loops, staggered so the center lines of one group are aligned with the connecting lines of the other loop group.



A phased array loop driver consists of two amplifiers with a phase shifter that orients the signals ninety degrees apart. This allows the two separate groups to blend into one smoother signal that is picked up by the T-coil in a hearing device regardless of orientation. Single amplifier loop drivers without phase shifters have a disadvantage referred to as “head shift”. Head shift is when the loop signal weakens when a user bows their head or changes orientation to the loop field. Phased array loops with the dual amplifiers and ninety degree phase shift eliminate this situation.

Smaller segments will generate better frequency response with less power expended. They will also limit the height above and below the loop antenna. This is necessary for stacked installations where there are loops on multiple floors. The size of the segments are limited on the smaller end by the functional height required for the loop. Very narrow loops will limit the amount of distance the signal will extend up and down. This is because the loop is basically a

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sphere with the top and bottom flattening as the width increases. Conversely, height decreases as the width is reduced past the point that the sphere is round. If the segments are smaller than three or four feet they will not extend high enough to create a useable loop field.

The loop segments can be larger without much detrimental impact until they cause too much variation in the signal. The amount of spill can also be a factor in determining the maximum segment size. This is critical when it's necessary for privacy or to keep the loop signal away from a performance area with musical instruments and/or dynamic microphones.

Phased array loop systems are sometimes the only configuration that works in buildings with a high amount of metal. The smaller segment sizes allow the power to be utilized more effectively, and the variation across the loop field is minimized by the segment size.

Phased arrays have much less spill than perimeter loops so they are the preferred method for loops that require privacy. The smaller the segment size, the less spill is generated. However, when creating a private signal, the other factor to consider is the amount of connected metal in the structure. The signal is pulled into the adjacent areas of the building if the metal is connected. There is no way to know if this is a problem without installing a test loop and checking the signal strength outside the antenna.

Some installers insist phased arrays are the only acceptable way to create a hearing loop, but sometimes the expense makes the loop unaffordable. It is without argument the best loop. It requires less power, has better frequency reproduction with minimum spill and head shift. It would be prudent to quote both versions and make sure the customer understands the value of both options. It is wise to document the decision in a way that protects the facility and installer from future embarrassment if an outsider criticizes the design without the benefit of the reasoning that determined the configuration.

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CHAPTER 7 - TESTING

Once the installation is completed, the energy levels in the hearing loop should be checked and recorded with the Field Strength Meter suggested by the hearing loop amplifier manufacturer. Measurements should be made at a height of 47” for seated audiences, like a theater, and 67” for standing listeners.

The consistency of the energy in the hearing loop field is the main consideration. An approved audio signal should be broadcast into the looped area. This can be in the form of continuous sine waves at different frequencies, pink noise or artificial speech. Take readings of the loop signal within the listening area. The listening area does not have to be the entire looped area, just the designated listening area. Connect an adequate sound generator to the loop amplifier. Follow the loop amplifier manufacturer's instructions to adjust the volume to -12 dB at 1kHz in the midrange of the listening area. This is not the center. The center will usually be the quietest area in the looped area with the outside edge being the loudest. The midrange is halfway from the center to the outside. Measure the entire listening area. There should be a maximum of +/- 3 dB variation to be compliant with the IEC standard. Do not exceed -12 dB of volume at this stage of testing; louder volumes will put too much stress on the loop amplifier. If a -12 dB signal can not be achieved, the loop amplifier is not large enough for this configuration and size. A series of smaller loops or larger loop driver will provide a better response. Test and record the field strength at 100, 1000 and 5000 hertz in various areas of the listening area, as well as any other frequencies you deem necessary. Each manufacturer should provide a blank Certificate of Compliance (See Appendix A) that allows entry of of these values. Fill it out and leave a copy with the facility. There is a fair amount of disagreement concerning the necessity to maintain a +/- 3 dB variation between frequencies as well as across the loop field. Some experts say this is a requirement of the IEC standard, and others read it differently. Most of the people participating in the debate have not read the actual standard. This is one vague area that creates a great deal of division in the industry. The functional result is speech is diminished somewhat in a perfectly flat loop signal. Some people believe a curved response centering on the speech frequencies creates a more understandable hearing loop signal. Each installer should buy a copy of the standard, read it and decide for themselves.

After the consistency of the loop is confirmed, connect the sound system to the loop amplifier and adjust the volume to peak at 0 dB using live or recorded speech as the basis. 0 dB peaks in a speech signal equal the same amount of energy as -12 dB in a continuous sine wave. Because of the peaks and valleys in speech, 0 dB in a fluctuating signal averages the same amount of energy as -12 dB of a flat signal. The final and most important adjustment needs to be made with the input of actual hearing device users in the hearing loop field. However, the programming of the users hearing devices needs to be verified prior to this step.

Sound system adjustments and technology is outside the scope of this video. If the installer does not have experience with sound systems, and the facility doesn't have their own expert, it is prudent to make arrangements with a reputable sound technician to help connect the first few installations.

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APPENDIX A CERTIFICATE OF COMPLIANCE

IEC 60118-4:2014 for Hearing Loops

(A) All measurements must be made with an inLOOP Field Strength Meter in the upright position. The location of test points should be randomly distributed throughout the proposed listening area, but should be taken at a height of 47” for seated, and 67” for standing T-coil equipped hearing aid users. Seating arrangement, physical layout of the looped area and potential influence from metal and interfering signals should also be taken into account.

(B) BACKGROUND NOISE – Field Strength Meter set to Background – also known as A Weighted

The magnetic background noise level shall be measured at a sufficient number of points as referenced in (A). -32 dB is accepted by the IEC standard for background noise. For limited conversation areas like information desks, the background noise ceiling can be as high as -22 dB. Make note of noise levels above the accepted IEC ceiling. If the noise distribution is uneven it is suggested to specify the numbers on a map of the looped area.

Background noise: _____ dB   Noise level as measured on the Normal setting: _____ dB

(C) FIELD STRENGTH VARIATION

Broadcast a 1 kHz tone into the loop field. Adjust the field strength at the center to approximately -12 dB using the Normal scale. The field strength across the looped area should be within ± 3 dB. Check the field strength again with 100Hz and 5kHz tones without adjusting the volume of the loop driver. Draw a map of the looped field on graph paper, record the levels from the FSM and attach it to this report, or describe the results in text format below.

____

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(D) MAXIMUM FIELD STRENGTH LEVEL

Apply an artificial speech signal, or a comparable recording and measure for the highest peak. The loudest sounds should peak at the 0dB level.

(E) FINAL ADJUSTMENT

Connect the loop amplifier to the sound system that will be providing the audio signal under normal operating conditions. Adjust the volume with the existing sound system microphone(s) and input devices. A few hearing-aid users should be present when a system is set up to insure the actual results are consistent with the measurements. The hearing aids worn by the test subjects should be checked and adjusted in advance to work properly in a looped environment.

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