

Hearing Loops

The Preferred Assistive Listening Technology

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This article discusses the benefits of hearing loops as an effective and user-friendly assistive listening technology and summarizes the current progress of adoption in the United States. Research shows that audio frequency induction loops are strongly preferred by hearing aid users over FM and IR systems and allow venues to provide their hard-of-hearing patrons with the optimal and most convenient listening experience.

BACKGROUND

Hearing loss is the third most prevalent chronic health condition facing older American adults and one of the most common disabilities. Many individuals with hearing loss find their communication needs unaddressed or ignored and experience frustration, uncertainty, and stress in everyday life as they struggle to hear.

Hearing loss has been described as having attenuating and distorting components. Attenuation, measured by a pure tone threshold test, is characterized by a need for sound to be louder in order to be audible. Distortion in the inner ear due to a variety of causes, such as aging, noise exposure, or ototoxic drugs, causes an otherwise audible and clear signal to be altered and perceived as muffled by the individual. A third problem, recruitment, is marked by an exaggerated increase in perceived loudness with only a slight increase in the actual intensity of a sound. In many cases, sounds are perceived as painfully loud, causing discomfort, and resulting in a narrowing of the listener's dynamic range.

Improved signal processing in digital

hearing instruments can help compensate for threshold loss or attenuation, and partially compensates for the minimized dynamic range that comes with nearly 90% of all hearing losses. However, these devices can typically only correct for half of the loss of audibility and cannot correct for auditory distortion. Research has demonstrated that hard-of-hearing listeners may require an increase in the signal-to-noise ratio of more than 10 dB, some as high as 25 dB, to achieve the same word recognition as a normal-hearing person in the same situation. The result is that users of even the most advanced digital hearing instruments or cochlear implant processors frequently report that they are able to hear but not fully comprehend spoken information. A decline in the signal-to-noise ratio results in an inability to effectively discern speech from what would be considered mild background noise to listeners with hearing within the normal range.

Hearing loops, also known as audio frequency induction loops, offer a practical and typically cost-effective solution to greatly improve the signal-to-noise ratio and

speech understanding. Furthermore, hearing loops reduce effort in hearing comprehension, enhance sound quality, increase perceived pleasantness and naturalness of sounds, and fulfill compliance requirements laid out by the Americans with Disabilities Act (ADA). A hearing loop system wirelessly transmits sound directly to an individual's hearing aid or cochlear implant without the need for any additional equipment, such as headphones or neck loops. The electromagnetic signal that is sent out by the system can be received directly by a telecoil (or t-coil)—a component that is already integrated into the vast majority of modern hearing devices. Additionally, individuals without personal hearing devices can benefit from hearing loops by accessing them via portable receivers and headphones or ear buds. This is similar to current infrared (IR) and frequency modulation (FM/RF) systems, which constitute the majority of assistive listening devices in the United States. The practical reality, however, is that receiver/headphone units that require initiative to locate, check out, wear, and return, are much less likely to get used than hearing

assistance that is directly and immediately hearing-instrument compatible.

This article aims to inform audio engineers about the benefits of hearing loop technology to the end user and to summarize the current progress of adoption of loop technology in the United States. Currently, many U.S. venues are still unaware of the existence of this technology, despite it being the preferred type of assistive listening system by hearing aid users.

HEARING LOSS PREVALENCE IN THE UNITED STATES AND HEARING AID ADOPTION RATE

According to the World Health Organization's definition of hearing loss, an estimated 22.1% (57.1 million individuals) of the U.S. population over the age of twelve years are subject to hearing loss in at least one ear, and 13.8% of these (35.5 million individuals) experience hearing loss in both ears. The prevalence of hearing loss increases with every age decade. Table 1 shows the prevalence and number of individuals in the United States with hearing loss by age group. The number of individuals in the United States with binaural hearing loss (in both ears) is expected to grow to over 41 million by 2025.

Within the group of people with binaural hearing loss, the hearing aid adoption rate rose from 20.4% in 1997 to 24.6% in 2008, with an estimated hearing aid adoption rate of 26.3% for the year 2014. However, significantly higher adoption rates can be found for individuals with more severe degrees of hearing loss.

To receive the signal from a hearing loop, the user's hearing aid, remote control, or wireless gateway device needs to feature an

inductor with an open magnetic circuit, known as a telecoil. In 2009 and 2010, 69% of all available hearing aid models had telecoils built in. This number increased to 71% in 2014 and exceeds 80% when excluding completely-in-the-canal (CIC) hearing aid models, which are typically only used by individuals with mild to moderate hearing loss. The prevalence of telecoils is generally higher in more powerful hearing aids, which are needed by individuals with more severe losses. Since the group with more severe hearing loss has a higher adoption rate, it can be estimated that at least 75% of hearing aid users have telecoil-equipped devices and can thus benefit from hearing loop systems. Furthermore, this figure can be increased in certain markets due to a high hearing loop adoption rate and local public awareness campaigns.

The number of telecoil-equipped devices is expected to increase as personal sound amplifier products (PSAPs) with telecoil functionality have recently entered the market.

LEGAL OBLIGATIONS AND ASSISTIVE LISTENING TECHNOLOGY OPTIONS

Public venues and commercial facilities are required by the Americans with Disabilities Act (ADA) and other government mandates to provide equal access to individuals with hearing loss. These requirements can be fulfilled by making assistive listening technology available to the public. Currently, there are three technology options for assistive listening systems (ALS): infrared (IR), frequency modulation (FM) / radio frequency (RF), and induction hearing loops.

IR systems use invisible light waves to transmit sound to the receiving device,

which is worn by the user. On the positive side, the signal of an IR system is localized, does not leak into adjacent rooms and is not susceptible to interference. However, a significant drawback of these systems is the requirement of a direct line of sight between the transmitter and the receiver. This causes difficulties with reception in peripheral areas of the room as well as when the detector of the receiving device is obscured in any way, such as by clothing or the user's hand. IR is currently the most commonly used assistive listening technology in theaters and places of worship.

FM/RF systems transmit sound to the receiving device via radio waves. Many hearing aids offer FM accessories to directly receive the sound signal with the hearing device. However, these devices are costly and significantly drain the hearing device's battery. In addition, FM systems are susceptible to outside interference, are not universal in their transmission modes, and use multiple frequencies, thus posing compatibility challenges between devices.

In general, for both IR and FM systems, the user is required to borrow a receiving device from the venue, which is either a headset or a body pack, where a user can plug in a headset or ear buds. ADA guidelines also require a percentage of the receivers to be hearing-aid compatible. This is ensured by providing neck loops that plug into the receiver and are worn around the user's neck to transmit a magnetic signal to the user's hearing device, utilizing its telecoil. Although the IEC 60118-4 standard also applies to the magnetic field strength neck loops create, consumers have reported to the authors that neck loops are frequently not provided by venues and, when available, may lack the ability to create a strong enough magnetic field strength (one reaching peak levels of 400 mA/m), thus resulting in an unsatisfactory listening experience for end users.

Nevertheless, many hearing aid users are reluctant to borrow equipment from a venue due to the additional time and effort it requires, the stigma associated with wearing a conspicuous listening device, and hygiene concerns over shared headphones or ear buds. In our experience, users frequently report staff members not being able to locate receiving devices, and headsets being discharged or nonfunctional. Hence, despite the clear benefits, many hearing aid wearers choose not to use the provided equipment, a trend that has also been confirmed by venues reporting infrequent use of their assistive listening devices. Hearing aid users may be deterred from attending such venues at all,

Age, years	Hearing Loss in at Least One Ear (Monaural & Binaural)		Hearing Loss in Both Ears (Binaural Only)	
	Overall Prevalence	Number (millions)	Overall Prevalence	Number (millions)
12-39	3.7%	4.2	0.8%	0.9
40-49	12.9%	5.5	6.5%	2.7
50-59	28.5%	12.2	13.1%	5.6
60-99	59.7%	35.2	44.6%	26.3
12-99	22.1%	57.1	13.8%	35.5

Table 1. Prevalence and number of individuals in the United States with hearing loss. 13.8% of the population over the age of 12 years experience hearing loss in both ears.

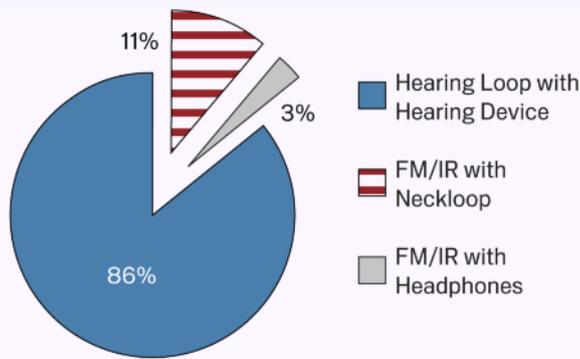


Fig. 1. Users' preferred assistive listening technology in large venues. 86% of hearing aid users prefer listening with a hearing loop and their own hearing device to other assistive listening systems.

resulting in the user being deprived of entertainment or information, and a loss of revenue for the business. In comparison to IR and FM systems, hearing loops offer numerous distinct advantages to both the venue and the patron.

HEARING LOOP TECHNOLOGY

As previously described, a hearing loop transfers sound directly to a user's existing hearing device without the need for any additional equipment. A hearing loop system consists of an amplifier of special design, which is connected to the venue's sound system or to its own microphones, as well as a wire, which—in the simplest case—surrounds the perimeter of a room or specified listening area. A current is driven through the wire, resulting in the generation of an electromagnetic field, which can be received by the telecoil in a user's hearing device. All that is required of the user is the push of a button on the hearing device to access the "hearing loop" or "telecoil" mode. For users without hearing devices, portable receivers with headphones are also available to be used with a hearing loop system. Additionally, hearing loops are the only assistive listening system that can be used in transient communication situations, such as box offices, service desks, or airports. Box office environments typically involve high levels of ambient noise and the additional barrier of staff being located behind a window. These scenarios already pose communication challenges to individuals with normal hearing, let alone individuals with hearing loss. Hearing loop systems at box office windows can facilitate communication between staff members and customers, and significantly enhance the customer's overall purchase experience, as they allow a clear speech signal to be transmitted directly from the staff member's microphone to the customer's hearing device.

Individuals with hearing loss typically have different hearing thresholds for different frequencies of sound, which are amplified by their hearing device accordingly. If the user is required to take off his or her hearing device to be able to use a headset or earbuds, the clarity provided by the hearing device is lost, resulting in the perception of distorted sounds at a higher volume. Since hearing loops utilize the user's

existing hearing device, which has been programmed for the wearer's specific degree and pattern of hearing loss, the perceived quality and clarity of sound are drastically improved when compared to using a headset.

To summarize, hearing loops are the following: simple and user-friendly for people of all ages to operate; convenient, as no additional equipment is required for the user; dignified, as they utilize the user's inconspicuous hearing device as a receiver; universal and directly compatible with any telecoil-equipped hearing device, independent of the manufacturer; cost-efficient for the venue, as they allow for an unlimited number of simultaneous users, while also reducing the number of receiver/headset units that must be purchased and maintained with fresh batteries; affordable for the user, as they do not require the purchase of any additional equipment; and energy-efficient, as they place no drain on the hearing device's battery.

Of the three ALS options, hearing loops are the most versatile and strongly preferred by users. When presented with three ALS options—hearing loop with hearing device, FM/IR with neck loop, or FM/IR with headset—86% of users chose a hearing loop system as their preferred ALS, as can be seen in Fig. 1.

In a recent university study by Magann Faivre et al., hearing aid users as well as individuals with normal hearing were presented with TV sitcom clips and asked to compare their experiences

with and without using a hearing loop. Ninety-nine percent of the subjects indicated a preference for listening with the hearing loop. Ninety-six percent of the subjects with hearing loss indicated that they were "likely" or "very likely" to use a hearing loop where it is provided. Surprisingly, 48% of the subjects without hearing loss indicated that they would use a hearing loop when available. The vast majority of subjects—hearing aid users and normal-hearing students not using hearing aids—showed significant improvements in speech understanding, reduced effort in hearing comprehension, enhanced sound quality, and increased perceived pleasantness and naturalness of sounds.

In another study by Kochkin et al., hearing loop users were asked to focus on a single looped venue that they attended, compare their listening experience with or without the hearing loop, and give a rating on a scale from 1 ("I heard nothing.") to 10 ("I heard every word."). When listening without the hearing loop, only 14% of respondents rated their experience at 8 or higher, whereas when listening with the hearing loop, 86% of respondents rated their experience at 8 or higher. The data are shown in Fig. 2.

As an example, for a multiplex movie theater with an average seating capacity of 225 seats per screen, the typical cost of installing a hearing loop system is approximately \$10,000 per screen. While this upfront cost might be higher than for an IR or FM system, more individuals will make use of the system, resulting in a lower per-user cost, as well as increased revenue for the venue after a one-time investment. Hearing loop systems are virtually maintenance free,

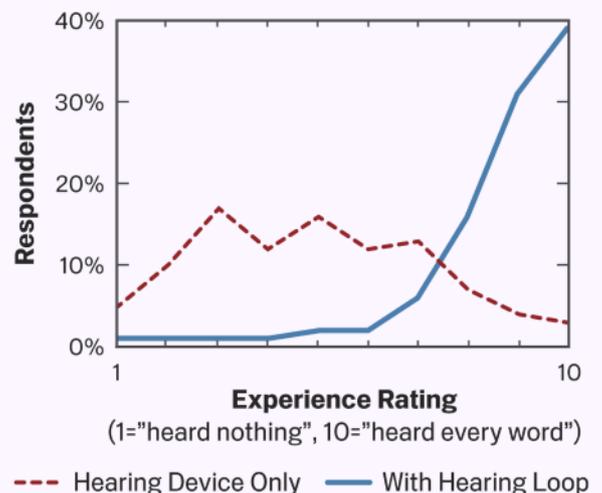


Fig. 2. Users' experience rating with and without a hearing loop in a large venue. When using their hearing devices only, 14% of users rate their experience at 8/10 or above. When using a hearing loop, 86% of users report an experience rating of 8/10 or above.

and given that most users will utilize their existing hearing devices as receivers, costs associated with handling and upkeep of existing headset receivers will be minimized.

The performance of a hearing loop system is largely dependent on its design and skillful installation. Special precaution needs to be taken when designing a hearing loop system for any large venue, especially when the building structure contains metal, and when multiple hearing loops are to be set up in close proximity, such as in multiplex theater settings. With an appropriate loop design, spillover into adjacent rooms can be eliminated. The International Electrotechnical Commission (IEC) specifies strict requirements and performance standards for hearing loop systems to ensure optimal sound quality and guarantee positive experiences for the user. The performance of hearing loop systems is specified in IEC 60118-4, while the performance of the system components is covered in IEC 62489-1. In order to achieve satisfactory results, both the design of the system and its installation should be entrusted only to qualified and trained personnel experienced in large theater installations. Training courses are offered by equipment manufacturers and independently by the Institute of Sound and Communications Engineers (ISCE) in

Europe. The major equipment manufacturers also offer support with system design.

Some venues pose an additional challenge to hearing loop installations due to electromagnetic interference (EMI), causing the hearing loop user to hear a buzzing sound. In most cases, EMI is caused by neutral-to-earth faults, defective water heaters or air-conditioning equipment, or electrical wiring that is not in compliance with the National Electrical Code (NEC). These issues are more common in older buildings and can typically be rectified by an experienced electrician with relative ease. If the guidelines of the NEC are observed—which is the case for basically every new building—and/or if ground fault interrupters (GFIs) are installed, EMI is almost never present to the extent that it compromises hearing loop performance. Furthermore, an important consideration is that EMI is not only an issue for room loops, but for any assistive listening system that utilizes the telecoil in a user's hearing device. EMI affects telecoil performance on the user's end and not hearing loop performance per se. Thus, neck loops used with IR or FM systems are equally affected by EMI. Therefore, it is important to ensure that a venue's EMI levels are adequate prior to installing any of the three ALS options.

Hearing loop systems are venue specific

and always require a site visit prior to providing an accurate installation cost estimate. Although some designs can be modeled on a computer, a simulation cannot determine whether EMI is present or whether the building composition may have negative effects on the loop signal. While computer modeling can be a good starting point, a hearing loop system should never be installed purely based on this simulation. The installer should be able to explain the on-site test results and what type of loop design (perimeter, multisegment, or phased array) will be needed in the facility to meet the IEC standard and what is will be required to hide the loop wire aesthetically.

THE FUTURE OF HEARING LOOPS

In October 2013, the 3rd International Hearing Loop Conference in the United Kingdom was attended by more than 200 hearing loop advocates and industry experts, mainly from the United States, Australia, and Europe. The concluding statement of the conference was that currently, no new technology is on the horizon that is as cost-efficient and universal and creates equal access for individuals with hearing loss with such simplicity as hearing loop technology.

Per Kokholm Sorensen, director of research & development for Widex, one of the largest hearing aid manufacturers worldwide, discussed future technologies that could replace inductive hearing loops. He concluded that “loop systems as we know them today will stay around for many years to come.” His views were also confirmed by German hearing loop engineer Hannes Seidler.

The goal of a current project in the radio-communication sector of the International Telecommunication Union (ITU-R) is to develop a world-wide radio system specifically for communication with hearing aids, taking into account that battery life must not be seriously reduced. Such a system could eventually replace telecoils and hearing loops. Today's Bluetooth offers complimentary short-range, private connections, such as between smart phones and hearing instruments.

However, psychology professor and hearing loop advocate David Myers stated that “the challenge for hearing technologists is to make any future alternative technology similarly simple for people of all ages to operate, affordable, as telecoils are virtually free, available with nearly all hearing instruments, energy-efficient, scalable, with applications in public spaces from ticket windows and taxis to airports and arenas, and universal, with the same signal serving everyone, no matter their location or hearing instrument manufacturer.”

Furthermore, Cynthia Compton-Conley, former audiology professor and one of the leading authorities on assistive listening technology in the United States, also expressed her doubts that a new technology would soon replace inductive hearing loops, mainly because of the affordability for the user and the negligible battery drain caused by using a hearing loop system.

CONCLUSION

Hearing loops are the preferred assistive listening technology by hearing aid users and provide means to enhance the listen-

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FURTHER READING

- J. G. Collins, "Prevalence of Selected Chronic Conditions: United States, 1990–1992," *Vital and Health Statistics*, vol. 10, no. 194 (1997).
- D. Myers, "Progress Toward the Looping of America – and Doubled Hearing Aid Functionality," *The Hearing Review*, vol. 17, no. 2, pp. 10–17 (2010).
- R. Plomp, "A Signal-to-Noise Ratio Model for the Speech-Reception Threshold of the Hearing Impaired," *Journal of Speech and Hearing Research*, vol. 29, no. 2, pp. 146–154 (1986).
- R. Carhart and J. F. Jerger, "Preferred Method for Clinical Determination of Pure-Tone Thresholds," *Journal of Speech and Hearing Disorders*, vol. 24, pp. 330–345 (1959).
- M. C. Killion, P. A. Niquette, G. I. Gudmundsen, L. J. Revit, S. Banerjee, "Development of a Quick Speech-in-Noise Test for Measuring Signal-to-Noise Ratio Loss in Normal-Hearing and Hearing-Impaired Listeners," *Journal of the Acoustical Society of America*, vol. 116, no. 4, part 1, pp. 2395–2405 (2004).
- D. D. Dirks, D. E. Morgan, J. R. Dubno, "A Procedure for Quantifying the Effects of Noise on Speech Recognition," *Journal of Speech and Hearing Disorders*, vol. 47, pp. 114–123 (1982).
- R. Magann Faivre, F. Ismail, J. Sterkens, T. Thunder, K. Chung, "The Effects of Hearing Loop Systems on Speech Understanding and Sound Quality in Real World Listening Environments," *Poster session presented at Northern Illinois University Audiology Clinic, NIU Speech and Hearing Clinic, May 9, 2013*.
- U.S. Department of Justice. *ADA Standards for Accessible Design* (2010 September).
- S. Kochkin, J. Sterkens, C. Compton-Conley, D. L. Beck, B. Taylor, P. Kricos, M. Caccavo, A. Holmes, T. A. Powers, "Consumer Perceptions of the Impact of Inductively Looped Venues on the Utility of Their Hearing Devices," *The Hearing Review*, vol. 35, no. 5, pp. 16–26 (2014).
- C. Meyers, "Infrared, Frequency/Digital Modulation, and Induction Hearing Loops, A Comparison of Assisted Listening System Technologies," *Technologies for Worship Magazine*. Available at: <http://tfwm.com/infrared-frequencydigital-modulation-and-induction-loops/>
- World Health Organization, *Prevention of Blindness and Deafness Program. Grades of Hearing Impairment*. Available at: http://who.int/pbd/deafness/hearing_impairment_grades/
- U.S. Census Bureau, *Current Population Survey. Annual Social and Economic Supplement, 2012*.
- F. R. Lin, J. K. Niparko, L. Ferrucci, "Hearing Loss Prevalence in the United States," *Archives of Internal Medicine*, vol. 171, no. 20, pp. 1851–1852 (2011).
- A. M. Amlany, B. Taylor, "Three Known Factors That Impede Hearing Aid Adoption Rates," *The Hearing Review*, vol. 19, no. 5, pp. 28–37 (2012).
- S. Kochkin, "MarkeTrak VIII: 25-Year Trends in the Hearing Health Market," *The Hearing Review*, vol. 16, no. 11, pp. 12–31 (2009).
- J. Sheehan, "Understanding Hearing Loops," *Audiology Online* (December 2011). Available at: <http://www.audiologyonline.com/articles/understanding-hearing-loops-794>
- Etymotic Research, Inc., *The BEAN Quiet Sound Amplifier*. Available at: <http://www.qsabean.com/>
- California Building Standards Commission, *2013 California Building Code, California Code of Regulations, Title 24, Part 2, Volume 1 and 2* (2013 July).
- International Electrotechnical Commission, *IEC 60118-4 ed 3.0 Electroacoustics - Hearing Aids - Part 4: Induction Loop System for Hearing Aid Purposes – Magnetic Field Strength* (2014 December).
- International Electrotechnical Commission. *IEC 62489-1 ed 1.1 Electroacoustics - Audio-Frequency Induction Loop Systems for Assisted Hearing - Part 1: Methods of Measuring and Specifying the Performance of System Components* (2014 December).
- National Fire Protection Association, *NFPA 70: National Electrical Code, 2014*.
- S. Karg, "Gemeinsames Ziel: Weltweites Induktives Hören," *Spektrum Hören*, pp. 50–51 (2013).
- P. Kokholm Sorensen, "A Possible 'Successor' to Loop Systems," *Proceedings of 3rd International Hearing Loop Conference, Eastbourne, UK* (2013 October).
- H. Seidler, "Near Future of Induction Loop Systems," *Proceedings of 3rd International Hearing Loop Conference, Eastbourne, UK* (2013 October).
- International Telecommunication Union, Radiocommunication Sector, *Question 254/5: Operation of Short-Range Radiocommunication Public Access System Supporting Hearing Aid Systems*. Available at: <http://www.itu.int/pub/R-QUE-SG05.254-2014>
- D. Kirkwood, "As Hearing Industry Seeks New Wireless Standard, t-coil Advocates Say Not so Fast" (2014 May 19). Available at: <http://hearinghealthmatters.org/hearingnewswatch/2014/hearing-industry-seeks-new-wireless-standard-hearing-aids-t-coil-advocates-say-fast/>

ing experience for individuals with and without hearing loss. Concerns, such as overspill into adjacent rooms, electromagnetic interference, and inhomogeneous fields can be entirely eliminated by experienced and specialized installers. Despite the higher up-front cost, a hearing loop installation may result in a lower per-user cost, as the number of users grows over time due to the dramatic benefits hearing loops provide over FM or IR systems. Hearing loops allow public venue operators to provide their hard-of-hearing patrons with the best possible listening experience, and represent a cost-efficient and future-proof technology.

ABOUT THE AUTHORS

Thomas Kaufmann, founder and CEO of California-based hearing loop technology company Otojoy (www.otojoy.com), holds postgraduate degrees in physics and chemistry, and was recently honored with the Santa Barbara Mayor's Award for Outstanding Effort for providing civic leadership in the Loop Santa Barbara non-profit public awareness campaign (www.loopsantabarbara.org).



Juliette Sterkens, AuD, is an audiologist recently retired after 30 years in private practice in Oshkosh, Wisconsin. She is heavily involved in the grassroots advocacy campaign for wider use of hearing loop technology in North America and is a consultant to the Hearing Loss Association of America (HLAA).



John Woodgate was awarded the Bachelor of Science (Engineering) degree of London University. He is a Chartered Engineer and a Fellow of the Audio Engineering Society. He has made major contributions to important international standards including IEC 60118-4, IEC 62489-1 and IEC 62489-2, all concerning hearing loop equipment and systems.

