

Protecting Sensitive Conversations with Soundmasking

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Security professionals are rightly concerned about protecting corporate and government secrets. There is one aspect however, that does not get much attention: the protection of sensitive conversations. When it is given attention, very expensive solutions are used. There is a newer, better, and less widely known method called *soundmasking*. It not only permits the user to adjust and verify the degree of protection from most eavesdropping methods, but also affords very large cost reductions in both room construction and security maintenance. This method is universally accepted and used by the federal government.

The reason for concern is that most major strategic and tactical decisions are first made orally at meetings, and if eavesdroppers can obtain access, it gives them a distinct time advantage over written or computer documents.

Most building designs provide confidentiality of sensitive conversations in closed offices only from casual or accidental listeners. When the listener is a deliberate eavesdropper that makes use of sophisticated listening devices, normal building design is inadequate to provide protection. The normal way additional protection is provided is to create rooms that have high sound (speech) attenuation. For example, the government makes a room-within-a-room, a very expensive approach. Unfortunately, many facilities do not have the budget for such measures, particularly when one considers all the ways that audio access might be obtained.

Worse yet, rooms with high sound attenuation *do not* guarantee protection. There are **three factors that play a role in protecting conversations**: how loud the conversations are, how much those conversations are attenuated in route to a potential eavesdropping location, and how loud the background sound is at that location (which tends to mask the speech). The technical weaknesses of rooms with high sound attenuation are apparent. If a sound system is used to amplify speech (PA system, speaker phones), the room cannot be changed to accommodate the raised levels. When a room is constructed, there is no knowledge of the background sound level at locations where listening devices might be placed. A less obvious weakness is that modern listening devices can be placed in locations that building structure cannot protect against.

In the sections below, we discuss the various methods used to obtain access to a secure room, the standard costly solution, and the recommended solution using soundmasking. To do this it is necessary to examine the room perimeter. This, of course, excludes persons carrying listening devices. Any point on that perimeter may be usable to access the conversations inside. Potential problems occur at windows, walls, doors, ducts, conduit, piping, cable trays, raised floors, plenum ceilings and interior speakers.

Background

The American Society of Industrial Security and the U.S. Department of Commerce estimate the Fortune Five Hundred companies have lost more than \$45 Billion in 1999 due to the theft of proprietary information and estimates are that the amount rises every year. The Federal Bureau of Investigation brought back David Szady from retirement to head counterintelligence operations. An article in USA Today May 5, 2004, stated that many of our “friendly nations”, such as China, South Korea, India, France and Israel, do economic espionage on our defense, research, and high-tech firms. For obvious reasons, details about all the methods used to gain access to the information are not given.

Certainly, the information gathering methods described in the studies mentioned above are exceedingly important, but providing speech security is either overlooked or the solutions are misapplied. The federal government has been aware of this problem for many years and many government agencies, military bases and government contractors apply speech security techniques. As we shall see, sweeping rooms for electromagnetic emissions solves only one part of the eavesdropping link. Since not all listening equipment transmits.

Standards

The federal government has regulations on protecting sensitive conversations, but commercial standards organizations have not made use of them.

Defense Intelligence Agency Manual 50-3. Although this document is no longer the primary one related to physical security standards, the chapter on Audio Security addresses speech privacy in a general way. It notes the value of sound masking as a tool.

Director of Central Intelligence Directive 6/9. This document is now the primary unclassified document on physical security in Secure Compartmented Information Facilities (SCIF). Annex E of that document pertains to “Sound Masking Techniques”. It states “..systems are designed to protect SCI against being *inadvertently* overheard by the *casual* passerby, not to protect against deliberate interception of audio.” Experience with secure masking systems over twenty years has shown that military contractors and government agencies have been concerned the *deliberate listener*. It is likely that a publicly unavailable document exists that provides guidance for protecting against deliberate listeners. The directive does note that masking devices may be used on doors, windows, walls, and vents or ducts, where applicable. Unfortunately, the document *erroneously* permits music as the sole source of masking. Music only does not ensure protection, but below we show how it can be used effectively in conjunction with other sounds.

AFP 88-26. The United States Air Force has a document on the construction of secure conference rooms. It goes into great detail on the methods for creating sound attenuation around the room as well as control of communication devices. It states “The employment of sound masking in wall voids, doors, windows and overhead ducts may be a more economical technique to achieve acceptable transmission losses.”

Gramm Leach Bliley Act. In compliance with this law, all financial institutions must protect the confidentiality of customer information and guard against any threats to the security of it.

General Aspects of Security Masking

Categories of Surveillance

Two must be addressed. *Uncontrolled areas* are those where the persons attempting to protect themselves have little or no control over the environment. Generally, this includes all spaces outside the facility, such as other buildings, public spaces, and even locations within the property boundary where it is possible to gain access without detection. In the rental spaces of large commercial buildings, the offices of two companies may be immediately next to each other and the ceiling plenum above may be open, creating a serious protection problem. *Controlled areas* are those within a facility where there is some measure of control. The type of protection used depends critically on the category.

Types of Masking Signals

Taking into account the capability of sophisticated listeners to recover speech buried in noise, it is advisable to use *layered* protection. Instead of just one type of masking signal, such as is used in commercial open offices, the generator creates and mixes several signals. For uncontrolled areas, non-stationary random noise must be the first layer; it covers the entire speech spectrum as is done with commercial sound masking, but its non-stationary characteristics inhibit signal recovery. For controlled areas, the less expensive stationary random noise generator is adequate. Music may be used as the second layer; it is buried below the random noise, so it is not actually audible to room occupants. This is a meaningful signal for recovery techniques to find should penetration of the noise be accomplished. Voice babble may be used as a third layer; it may be set at the same or lower level as the music signal. Babble is a semi-meaningful signal for recovery techniques to find. If equalized properly, the fourth layer, the actual voices to protect, will be sufficiently buried below the other layers.

Types of Masking Systems

There are two types of masking systems, the fixed and the portable. Most of the discussion below will concern the fixed system which is permanently installed a secure facility. However, there are situations where sensitive conversations must be conducted while traveling, such as in hotel/motel rooms. The portable system can be used for this situation. It provides coverage of windows, doors, walls and air vents in the room. Installation is quick; the maskers are attached temporarily and are removed when done. Evidence of attachment can be removed easily. This system does not have the refined capability of fixed system equipment, so levels are set higher than for fixed facilities in order to guarantee protection. As a practical control, all equipment and wiring should be contained within the secure room whenever possible.

Handling Amplified Speech

In some secure facilities, such as conference rooms, speech is amplified with a microphone or as part of a playback system. There are several aspects of such use that make eavesdropping simpler. These systems are almost always set too loud, but worse the level can be adjusted with the turn of a knob. Protection of speech requires precise

measurement, which can be completely undone with a turn of that knob. Worse yet, the adjustment of treble controls can enhance speech intelligibility just as is done with hearing aids and paging systems. To insure that protection schemes are effective in protecting speech confidentiality, audio systems should *not* be used. Unfortunately, some rooms, e.g., boardrooms, will have them. When this is the situation, controls need to be put on the equipment that limits the maximum level and the frequency spectrum. This requires sound measurement and modification of the equipment.

Locations for Protection

The locations, where acoustical access to a room can be obtained, are discussed in this section. The threat is first discussed, then the standard solution, followed by the sound masking solution.

Windows

Windows face uncontrolled areas so special measures need to be taken.

The Threat

A prerogative of high office has always been windows, both in offices and conference rooms. The word “eavesdropping” originated with listening at windows. It should go without saying that an open window is an open invitation to listening, so that aspect is not discussed. However, speech near a closed window causes a minute vibration of the window pane that appropriate sensors can detect. Since windows respond well at speech frequencies, the window easily carries intelligible speech in the form of vibration. There are three ways of eavesdropping.

First is the direct attachment of a *vibration detector* to the pane or the frame. Accelerometers or strain gauges are difficult to see, but can be discovered by inspection so are unlikely to be successful. These devices are commonly available,

Second is the *laser microphone*. The transmitter of this device sends an infrared beam that reflects from the window to a receiver. The minute vibrations of the window



modulate the base frequency that is later demodulated into speech. Theoretically, such a device can operate from any distance and, since the beam is invisible, is a potent detection device. It can be disguised easily because it is small (see the figure at left). Since the beam undergoes nearly specular reflection, very careful positioning is essential, which is time consuming and reduces the number of microphone locations and the number of windows that can be covered. Although manufactured in the United States, ordinary citizens are not permitted such devices. However, they are manufactured internationally. The widespread protection of windows in sensitive government facilities suggests these devices are in common use. Further, the Internet

has many web sites that suggest designs for such devices and remote vibration detection of machinery has been done for many years. Most of these devices use a red laser so the

beam is visible. Window vibration caused by high wind or high levels of traffic noise will act as masking and so will inhibit detection, but these factors are not under the control of the person attempting to protect the room.

Third is the *highly directional microphone* that detects the velocity fluctuations of the window (the radiated sound). The advantage of this device is that it can be at relatively arbitrary angles to the window. Not all such microphones have a large parabolic reflector that makes it easier to detect. These devices are commonly available, such as at sports events. Again window vibration caused by exterior noise sources will inhibit detection.

Standard Solutions.

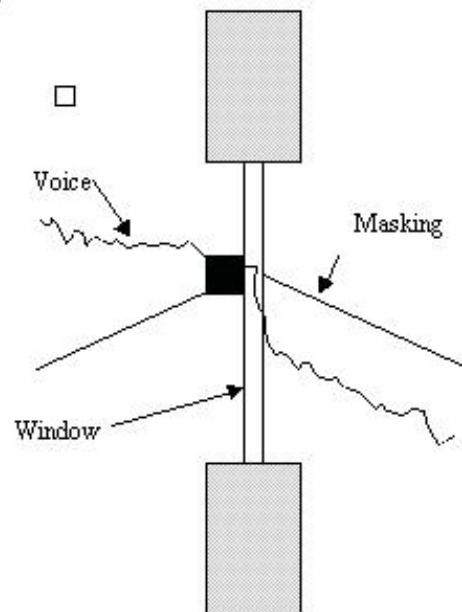
The most secure solution is to eliminate the windows entirely. Although it is the best solution, it is not always acceptable to occupants.

Early masking methods placed a loudspeaker facing down from the suspended ceiling. They were called *window washers* since the sound “washed” over the window causing random window vibrations. The level required at the window was loud enough to interfere with the speech to be protected, as well as to annoy the occupants. To converse, voices had to be raised, a self-defeating proposition.

Since more than acoustic emissions occur through windows, films have been applied to block any electromagnetic emissions. There have been claims that such films also will protect speech. A film *cannot* be used to sufficiently reduce the mechanical vibration of a window to protect conversations.

Masking Solution

Because windows will almost always face uncontrolled areas, care must be taken in protection. The non-stationary masking generator mentioned above is needed for this case. A vibration masker is attached to the window; it converts the generator signal to a broadband random vibration covering all speech frequencies. Because windows have many vibration modes, positioning of the masker can be important. A laser beam, particularly, can be aimed at any point on the window or frame. Measurements have shown that placement of one masker on normal sized windows will excite enough of the vibration modes to provide complete coverage at all points when the location and masking spectrum are set properly. The masker is located where it can drive the frequency modes that are most significant for intelligibility. The window masker is the same at that used for walls. Maskers on adjacent windows facing the same direction must not



be placed in exactly the same locations. If one window has no conversation then it contains only the masking vibration that an eavesdropper wishes to subtract from the signal on the window that has both speech and masker vibration.

For design purposes there are several categories of windows

Normal Windows. These windows have their largest dimension less than five feet so only one masker is required.

Large Windows. These windows have their largest dimension five feet or greater, so two maskers are required.

Multi-Pane Windows. Each pane will vibrate in response to speech. If the panel is heavy and small the vibration response is small and mostly above the speech frequencies so no masker is necessary, unless amplified speech is used. An expensive solution is to place one masker on each pane. A less costly solution is to use the older *window washer* masker to cover the window generally.

Double Pane Windows. Each pane is a partially independent vibrator; the interior pane response is higher than the outer pane. Double pane results in a Sound Transmission Class rating that is higher than a single pane, so the transmitted sound is attenuated, reducing the ability for a directional microphone system to detect speech, but does not preclude the effective use of laser microphones. As a result, double pane windows should be treated as if they were single pane.

Walls

The Threat

Again, there are two categories of walls, exterior walls facing uncontrolled areas and interior walls facing controlled areas.

Exterior walls can be constructed of many materials, not all of which require protection. This is discussed below. Because interior walls are most often constructed with studs and gypsum board to reduce weight, listening opportunities are better if access can be achieved. For example, standard construction may consist of one or two sheets of gypsum board on either side of a wooden or metal stud with an air cavity that may, or may not, be filled with fiberglass.

There are several ways speech can be detected through walls.

Remote from the wall. On all types of walls, listening can be done remotely from the far side, with microphone or ear. On exterior walls this method is greatly inhibited by the heavy wall structure and the fact that the outdoor background sound level is generally high enough to inhibit eavesdropping. However, on interior walls, with much lighter construction, such is not the case as persons in many closed offices can attest. This method of listening must be taken into account for both interior and exterior walls.

On the far side of the wall. Detection of wall vibration on the far surface can be accomplished with a remote laser microphone or by attachment of a vibration detector. On most, but not all, exterior walls, detection of this type is very difficult. On interior walls, with their lighter construction, vibration probes can be used quite effectively. This method of listening must be taken into account for both interior and exterior walls.

Within the wall cavity and on inner surfaces. Wall cavities can be hollow or filled with fiberglass batts for thermal insulation or for additional sound attenuation. Penetration of either exterior or interior walls that have cavities can be used to place acoustical devices in the cavity as well as to attach vibration devices on either of the inner surfaces of the cavity. There are two acoustical devices that can be used within the cavity. The first is the *normal microphone* that converts sound to an electrical voltage. Many are quite small. They may require a wire to carry the signal out, or have a transmitter to send it remotely. Detecting this device is mostly by visual inspection. The second is the less known *fiber optic microphone*. See picture on the right. It is an analog to the laser microphone used on windows, except that the beam is confined to a fiber optic cable. It has no metallic parts except for a thin aluminum diaphragm. It is very difficult to detect; is quite small and may be mistaken for a normal fiber optic cable if merged with others. This method of listening must be taken into account for both interior and exterior walls.



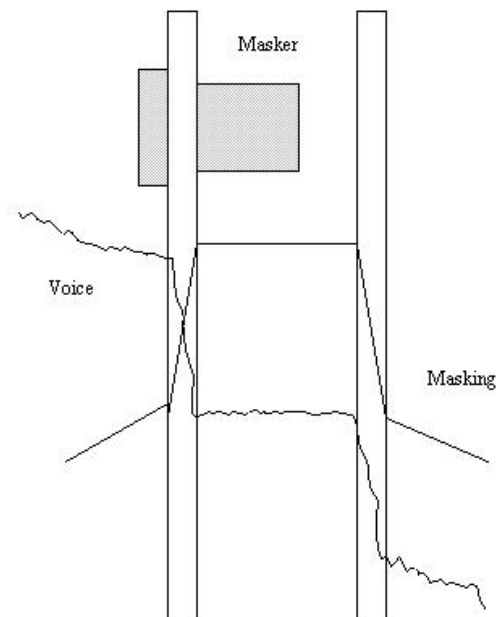
Standard Solutions.

The architectural solution has been to require walls with a high Sound Transmission Class (STC) rating; established methods die hard. Federal standards require walls with STC ratings of at least 45. As with all structural solutions, one may ask the question: Is the sound attenuation adequate to create speech privacy? The answer lies in knowing the background sound level on the far side of the wall (both the sound level and the wall vibration level). Unfortunately, STC has a number of weaknesses. It was not designed for speech, permits deficiencies in performance, field performance always is less than that determined in the laboratory, and does not address the other potential listening methods. The only good thing about an STC rating in this context is that the higher the number the better the sound attenuation.

Adding fiberglass batts to the wall cavity is used to enhance the STC rating. Unfortunately, this inhibits visual inspection, is only partially effective against listening beyond the wall and is not effective within or on the wall. Further, fiberglass batts inhibit the distribution of sound masking. The recommendation: Whenever ever possible, fill the wall with sound, not fiberglass.

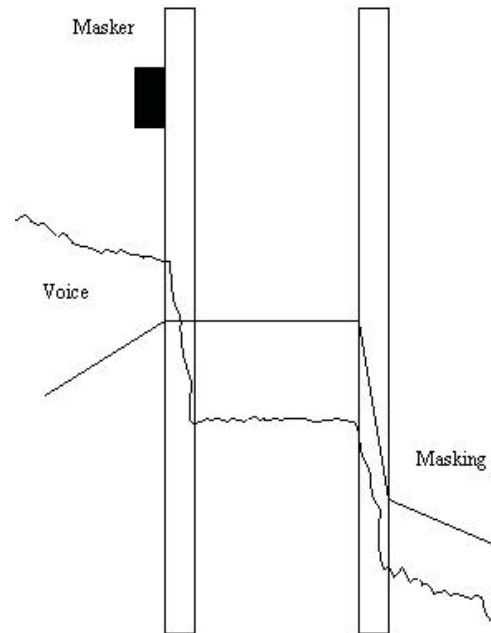
Masking Solution

One solution is to place a loudspeaker masker inside the wall cavity; it is mounted on the inside wall with an inspection plate. To keep secure room levels reasonable, no fiberglass should be in the cavity. The sound inside the cavity will fill it with masking. Also it will vibrate both layers of gypsum board, the



outer layer of which will radiate masking into the far side. Thus it covers *all* possible listening devices and locations when equalized properly. The best position on the wall is at standing height although other locations can be used. The sound level within the secure room caused by the masking is too low to create speech interference or annoyance. Since maskers at the best position are quite visible, they can be placed above the suspended ceiling, if that is available. That location requires somewhat more power, but the device is out of sight and generates lower sound levels in the secure room.

As a replacement for the speaker masker, a vibrator can be affixed to the inside surface of the wall. This newer method has certain advantages. It is simpler to install and inspect, does not require penetration of the gypsum board, wiring can be seen and inspected, and is just as effective as a loudspeaker. If the vibrator meets building codes, it can be placed above the suspended ceiling. Some older vibrators screw into the gypsum board. This method of attachment is known to cause the internal gypsum material to settle, reducing the vibration transferred to the wall and thus the masking. In newer techniques, the masker contacts the wall over a much larger area and so strongly reduces this effect.



There are two different categories of walls and they must be addressed differently.

Exterior Walls

Most secure rooms do not have walls facing the exterior of the building, but some do. Exterior exposure dictates that non-stationary noise be used as a masking source. There are several types:

Brick or Cinder Block Walls. These walls are relatively massive so transmitted speech is low. It is difficult to use remote sensing since the material is rough and has high vibratory damping. It is more difficult to penetrate the material or affix devices because of the rough texture. Generally these structures do not need sound masking.

Wood or Metal Stud Walls with Exterior Siding. These walls are less massive so speech is transmitted better. Although some walls of this type can be heavy, measurements suggest that they be protected.

Concrete Slab Walls. These walls are massive but are very stiff, transmitting speech relatively well in vibration form. If furred out on the interior, protection is not required, but otherwise protection is recommended.

Glass Block Walls. Although not common, such exterior walls occur. The masking solution noted above is not feasible, since most blocks are on the order of six inches on side, implying an excessive number of vibration maskers. In this case, *window washers* in the suspended ceiling above the wall are the recommended solution. The

masking level required for the protection of glass block walls is much less than that formerly used for normal windows, so speech interference is not a problem.

Interior Walls

These walls are generally within controlled areas, so less expensive masking generators can be used. There are a variety of materials used for the construction of interior walls:

Brick or Cinder Block Walls. These walls are relatively massive so transmitted speech is low. It is difficult to use remote sensing since the material has high vibratory damping. It is more difficult to penetrate the material or affix devices because of the rough texture. Generally these structures do not need sound masking.

Walls with Wood Studs. These walls are less massive than cinder block, so speech is transmitted better. If loudspeaker maskers are used in this construction, one speaker must be placed at each cavity, since the studs effectively block acoustical coupling between the cavities whether the cavity has fiberglass batts or not. Vibration maskers can be spaced at greater distances.

Walls with Metal Studs. These walls also are less massive than cinder block, so speech is transmitted better. If loudspeaker maskers are used in this construction, one speaker can be placed in every other cavity if there are no fiberglass batts, otherwise one must be placed on each cavity. Vibration maskers can be spaced at greater distances.

Demountable Partitions. These partitions are intended to be moved periodically, so are lighter than any of the other walls. Most are thinner than fixed wall construction and have STC ratings that are less. Since they are demountable, these ratings are further degraded by the fit at the suspended ceiling, the floor and between the panels. Most are composed of gypsum board, so that maskers can be affixed at four foot intervals.

Concrete Slab Walls. These walls are massive but are very stiff, transmitting speech relatively well in vibration form. If furred out on the interior, protection is not required, but otherwise protection is recommended. Most often the room length is greater than the slab width, requiring two slabs to butt together. Probe microphones, a device with a very small diameter, but long, extension has been known to be inserted in the filler between the two slabs. It is recommended that a plate be used to cover the joint.

Glass Panel Walls. Many conference rooms have glass-paneled walls that face an interior aisle way. Glass panels have considerably lower STC ratings than other wall construction. Each panel must be protected in the same way as windows.

Doors

The Threat

Doors are weak links in walls. Typical doors may be hollow core, solid core, metal or special. They can open to exterior, uncontrolled areas, or to internal controlled areas. Every door has a gap around its periphery. These gaps may, or may not, be gasketed. Because carpeting is often used, the gap at the bottom is generally larger. Listening at a hollow core door can result in clearly intelligible speech; and such doors are not recommended. Listening at an ungasketed gap also can result in clearly intelligible speech at reasonable distances from the door. For interior doors, eavesdropping with the ear is the most likely surveillance method, although it is unlikely

that a person will stand close for an extended period of time. It is also unlikely that detection devices will be attached to interior doors. This is not the case for doors opening to uncontrolled spaces (e.g. emergency exits, or seldom used adjoining doors). Remote sensing of exterior door vibration or sound radiation are potential threats. Attachment of vibration detectors to these doors or listening at gaps is also possibilities.

Standard Solution

The normal solution is an architectural one where a hollow core door is replaced with a solid core door internally or with a metal door externally. To provide more protection gasketing is applied at the gaps and a *floor wiper* is placed at the bottom. Although these solutions improve matters, and are recommended, they have the same limitations as all sound attenuating mechanisms: are they enough? Avoidance of exterior doors is the best solution, of course.

A more effective structural solution is to install doors with very high STC ratings. These doors are specially built to greatly improve sound attenuation; unfortunately, they still are sound attenuating devices. They have several drawbacks. They are very heavy, much more difficult to install and are very expensive compared to normal doors. Further, the wall framing has to be altered to accept the thicker frame, which generally means adding more gypsum board to match.

Masking Solutions

A vibration masker can be added to the secure side of a normal solid core door that has gasketing and a floor wiper. The masker is best placed at the upper, hinge side of the door to minimize visible wiring. The door masker is the same as that used for walls. The door vibration radiates into the door gap as well from the outer door surface. If regulations permit, a plenum masker should be added to the plenum immediately above the door. For interior solid core doors, this additional masker is needed only to make the sound spectrum outside the door more acceptable. In exterior doors, it can be used high on the exterior wall to further inhibit eavesdropping potential. .



There are several types of doors:

Metal Doors. These doors typically are single exterior doors. Metal panels accept sound masking very well. Gasketing around all gaps is mandatory.

Hollow Core Doors. These doors should never be used for secure facilities. Although speech can be secured with sound masking, the required level is much too high.

Solid Core Doors. These doors may be used for secure facilities. With a masking speech privacy can be obtained with reasonable levels of masking. For double doors, one masker must be applied to each, as well as a flange plate over the gap between the doors.

Very High STC Doors. In certain circumstances (high existing background levels) sound masking is not required.

Roll Up Doors. On occasion, doors to maintenance areas need protection. If the door is composed of flat panels, vibration maskers may be applied. If the door is segmented, it is necessary to use door washers, akin to window or wall washers that radiate masking from properly located loudspeakers.

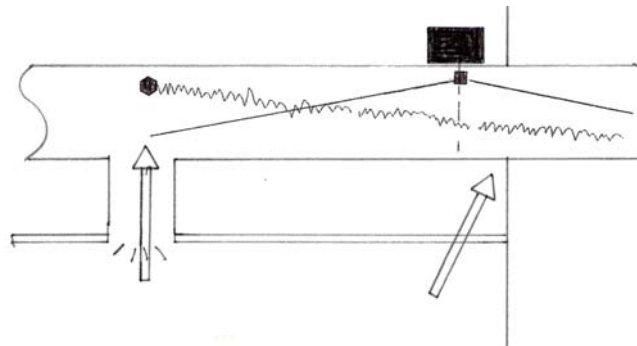
Ducts

The Threat

Listening through air ducts is a time honored source of intelligible speech since almost all rooms now have supply ducts, either round or rectangular, metallic or fiberglass, that connect to a multiplicity of rooms. Local ducts are typically metallic with no sound absorbing materials and therefore are decent speaking tubes. Speech within a room is attenuated as it passes through the duct grille and bend, but after that the decay rate is quite small. Fiberglass ducts transmit much less speech so if there is more than 10 feet between openings they usually are not a concern. In unsecured commercial facilities, listening can be done by ear, but for more difficult situations, a sophisticated listener can insert a microphone into the duct. It is also possible to place a vibration device on the duct wall near a room diffuser to detect speech. Since they are on or within the duct they cannot be swept, so detection must be by visual inspection or other means. There are cases where the duct connects to uncontrolled areas and non-stationary noise is needed.

Standard Solutions

Duct mufflers have been the traditional method of solution. They were added at each point where the ducts penetrate the room perimeter. For many secure rooms, this implies a number of mufflers. They are expensive, bulky, and require an adequate plenum height to fit and because of their weight are difficult to install. There are two other significant disadvantages in their use. They are just a sound attenuating device, and they add significant pressure drop to the air handling system which adds additional operating cost to the air handling system,



Masking Solutions

Speech that enters an air duct decays as it passes down the duct. Sound masking created within the duct can easily be set higher than the speech. Because it also decays as it passes down the duct, it generally is barely heard in the secure room. Maskers should be placed at each penetration of the duct to another room.

Earlier masking techniques used a loudspeaker that radiated sound into the duct. If the speaker were located within the duct, additional pressure drop is incurred. Other designs placed the speaker outside the duct with the speaker, suitably sealed to prevent leaks and excess pressure on the speaker, radiating sound into the duct through a penetration. This latter solution could only be applied to rectangular metallic ducts.

Current techniques use a vibrator on the exterior surface of the duct wall. The device is easy to install, requires no penetrations, can be inspected, has no impact on airflow and can be applied to both round and rectangular ducts.

There are several types of d

Rectangular Metal Ducts. Loudspeaker or vibration maskers can be applied. They should be located near the wall penetration.

Circular Metal Ducts. Only vibration maskers can be applied. They should be located near the wall penetration.

Circular Fiberglass Ducts. Normally the sound attenuation in these ducts is sufficient, that masking is not necessary. If required, however, special low pressure drop maskers can be inserted into the duct.

Stub Ducts. These ducts often are inserted into structure high walls around secure facilities to permit return airflow. Since they are penetrations they must be protected. See the section on ceiling plenums.

Piping

The Threat

Normal liquid filled pipes do not carry significant speech energy nor does conduit piping filled with wires. Whenever there is a power panel in the secure room, and not all conduit pipes leaving that panel are filled, there can be a loss of protection. As any sailor knows, unfilled pipes are excellent speaking tubes.

Standard Solution

Generally the threat has not been recognized, so a standard solution has not been available. When it has been, liquid filled pipes have had vibration breaks installed but empty conduits were ignored. Filling the conduit opening with a rubber plug on the secure side will provide adequate protection and masking is not required.

Masking Solution

Masking is only required if an empty conduit is not plugged or specifications require a protection on a liquid filled pipe. A vibration masker may be attached to the pipe at any convenient location within the room. It is similar to those used on ducts.

Raised Floors

The Threat

A raised access floor is used in some facilities. Cabling or ventilation air may be supplied to the room under it. Both imply penetrations of the perimeter that must be protected, but are seldom addressed. It is possible for *probe microphones* to be placed in the floor cavity, but because of the high sound attenuation of the floor, they would have difficulty detecting speech unless an open grille is located on the floor nearby. *Vibration detectors* may be attached to the underside of a floor plate. Since these plates are stiff to carry the floor load, they act more like a window in that they prefer to respond at speech frequencies, making such detectors effective.

Standard Solution

If the threat is recognized, a wire mesh grid is placed over each perimeter opening. The only weakness of this solution is that alterations in the cabling often compromise the integrity of the mesh.

Masking Solution

Maskers can be placed under the floor and can serve two functions. They can be placed only at perimeter penetrations to provide protection there. They can be placed uniformly under the floor, as is done in commercial facilities, to provide speech privacy within the room itself. If plenum masking is used, this latter solution is redundant.

Plenum Ceilings

The Threat

Secure rooms often have a suspended ceiling with a plenum above to accommodate air ducts and cable runs. The walls defining the room may extend to the structural ceiling to create a closed plenum, or they may not, to create a continuous open plenum. The plenum space is normally used for non-ducted return air (if return air ducts are used, see the section on ducts). If the room has walls to the structural ceiling, there must be an opening in the wall above the ceiling to permit the air to return to the fan and it is normally not in view for inspection. Cable trays often will penetrate the walls creating the same weakness. If the walls extend only to the suspended ceiling, the plenum is accessible to all other rooms. In each of these situations, listening devices, such as microphones, can be inserted.

Standard Solution

For return air penetrations in structure high walls, duct mufflers have been added (See the section on ducts for more details about mufflers). For return air in open plenums an exceedingly ineffective solution has been to lay fiberglass batts on the suspended ceiling. Cable trays have been either ignored or each cable penetration has been individually sealed, adding expense.

Masking Solution

For walls to the structure with a return air opening, a stub duct must be added with sufficient length to apply a duct masker. Either a loudspeaker or vibration masker can be attached to the duct. For walls to the structure with cable tray penetrations, a plenum (loudspeaker) masker should be placed just inside the opening.

For open plenum spaces, it is prudent to distribute plenum maskers throughout the secure room. One additional benefit, not normally contemplated, is that such masking provides speech privacy between individuals *within* the room. The levels within the room can be set as with commercial facilities without compromising the protection afforded in the plenum space.

Internal Loudspeakers

The Threat

Many codes require the presence of speakers in a secure room for emergency announcements. Although speakers are intended for creating sound, the speaker cone responds to external sound and the coil generates a minute voltage characteristic of that sound. By proper sensing, that voltage can be converted to speech

Standard Solution

. An optical isolator permits a signal to go to the speaker, but prevents any signal to pass back from the speaker. This is the recommended solution; such devices are commercially available.

Masking Solution

If an optical isolator is not available, a masker should be placed next to the speaker. The required levels are sufficiently low as not to cause distraction within the secure room.

Equipment

Only for very small or portable systems is the equipment not mounted in a rack cabinet, so all the equipment described below are rack mountable.

Generators

In some applications two types of masking generators may be needed. To keep costs down, the more restrictive generator may be used as the source.

Non-Stationary Random Noise. These generators are the most restrictive and expensive; their use and description are discussed above. They should have two channels of 1/3 octave band equalization to accommodate the different masking spectra required; otherwise two generators of this type are required. They should have at least one auxiliary input for mixing other signals with the masking. Any advanced features, such as slow ramp up, automatic level control, or remote addressing; should be bypassed. They are recommended for secure areas where there is exposure to uncontrolled spaces, and as a minimum:

1. All light weight exterior walls; *not* those made of concrete or cinder block.
2. All exterior windows.
3. All exterior doors

Stationary Random Noise. These are the most common commercially available generators. They may be either analog or digital. Again, they should have two channels of 1/3 octave band equalization to accommodate the different masking spectra required. An auxiliary input is useful. DSP based generators are best since they are equalized through software, and the computer is removed after equalization. They are recommended for secure areas where there is no exposure to uncontrolled spaces.

Amplifiers

Two channel, or greater, amplifiers are recommended to accommodate masking signals with different equalizations. Single channel amplifiers can be used when there is only one channel needed (See below). Single channel amps on larger systems add considerable weight and cost to a project. Further, amplifiers are the most likely part of the system to fail, so even if only one channel is used, having a two channel amplifier supplies a ready back up. Analog level controls (rotating knobs) should be on the rear panel to discourage occupants from adjusting the system even when the cabinet is locked. Adjustment of an analog control will destroy the work in equalizing the system. 70.7 V outputs are on commercial power amplifiers and most maskers are designed for this type of input.

Mixers

A mixer/preamplifier should be added if more than one signal is to be added to the masking and the generator has only one auxiliary input (which is generally the case). Almost all commercial mixers have analog controls (rotating knobs) on the front panel. Although these added signals may not be critical, they should always be placed in a locked cabinet.

Zone Controls

Zone controls permit fine level adjustments for each particular type of masker and each particular application. For example, vibration duct maskers may be used on air supply ducts and also on stub ducts. They can have the same masking spectrum, but will need different levels. The recommended controls have a number of features that are important for secure facilities.

They must be detented so that any change in position can be undone without destroying the equalization.

They should have small steps in level, such as 1.5 dB, not 3 dB as found in many controls. A 3 dB change in level represents too large change in speech privacy, and is unacceptable for secure facilities.

They should have a sufficient number of steps to permit gross changes in level without resorting to rotation of the analog control on the power amplifier.

Speakers

There are several types of maskers used in secure facilities.

Masking Loudspeakers. These maskers are used in commercial applications. Their application to secure facilities is for ceiling plenum masking or under floor masking. No modifications to them are required for these applications. If the plenum cavities are small, special speakers are available.

Vibration Maskers. These maskers can be affixed in several ways either with adhesive or clamping in permanent facilities. The



requirement for adhesives is that they be sufficiently flexible so that large changes in temperature, such as at windows, do not cause separation. On vertical surfaces, they should be taped until the adhesive is set. Since a number of these devices may be applied in the same zone, they should be part of a 70.7V system with an internal stepdown transformer. Eight ohm maskers, without transformer, are more complex to install.

An example of the vibration masker that is attached to windows, doors or walls is shown in the figure. It is relatively small, if part of a 70.7. Volt system and has a stepped attenuator for local level control.

For application to ducts and pipes, the vibration masker is of another type. It can be clamped to a pipe or screwed to the duct surface as shown in the figures below



Wall Maskers. In certain cases, loudspeakers, in lieu of vibration maskers, are used for masking walls. These maskers are made specifically to inject sound directly into the wall cavity. One limitation on their use is that the cavity should have a 3 ½ inch deep stud; smaller cavities, such as on demountable partitions, preclude their use.

Wall and Window Washer Maskers. Plenum maskers in the ceiling plenum above the wall or window to be protected is not adequate, so special maskers are required. These are affixed to the suspended ceiling grid and hang below the ceiling. They have support brackets that can point the speaker axis in the desired direction. This type of speaker is commercially available. See the section on walls for their application.



Equalization

The specific settings of spectrum shape and level vary not only for each masker, but also for each installation. Thus, it is beyond the scope of this document to provide specific instructions on this process.

Although the Privacy Index has been standardized only recently, we have used it for over twenty years to establish the performance of secure masking systems. The Privacy Index is composed of the three key factors: voice spectrum level, sound attenuation spectrum level, and masking spectrum level. These factors can be determined in many applications, but not all. For example, the so-called “sound attenuation” at a window is actually a transduction of speech sound to speech vibration, and the “masking spectrum” there is actually a vibration spectrum. Further, it is impractical to make measurements within air ducts or on pipes. To handle the equalization for these cases, one must resort to guidelines that have been developed from detailed measurements previously made. For example, the Privacy Index on a window is determined by measuring the vibration spectrum of speech and the vibration-masking spectrum on the window. For duct situations, a recommended voltage is given, based on the specific masker used and the specific application.

Masking Spectra

The masking spectrum is set within the generator. For some applications the particular spectrum is very important while in others it is not. Since it is important to keep the amount of equipment limited, a division of spectra into two types has been developed. Within each division is a hierarchy of importance. The importance is set by the critical nature on the application, and the acceptability of the masking sound to room occupants. Those locations lower on the importance list are handled by adjustments of level with the zone control, so there is no compromise in performance.

Note that for walls, three types of maskers can be used: in wall loudspeakers, on wall vibrators, and wall washers for glass block walls.

The recommended hierarchy is listed below

Non-Stationary Noise Generator

This generator is recommended for perimeter surfaces that face on uncontrolled areas.

Channel 1

- Exterior Wall - Wall Washer Maskers
- Exterior Wall Loudspeaker Maskers
- Exterior Duct Maskers

Channel 2

- Window Maskers
- Exterior Wall Vibration Maskers
- Exterior Door Maskers

Stationary Noise Generator

This generator is recommended for perimeter surfaces that face on controlled areas.

Channel 1

Plenum Maskers

Raised Floor Maskers

Interior Wall Loudspeaker Maskers

Channel 2

This channel is used for vibration devices that are attached to stiff materials. The following maskers are set in the order of preference, i.e., the spectrum is set based on the highest installed item on the list below.

Interior Wall Vibration Maskers

Interior Door Maskers

Rectangular Duct Maskers

APPENDIX

Articulation Index (AI)

This metric takes into account all factors that relate to speech privacy. It is standardized in American National Standards Institute S3.5-1969. The equation for it is

$$AIS_i = (VS_i - TL_i - BS_i) * WF_i$$

If $AIS_i < 0$ then $AIS_i = 0$
If $AIS_i > 30 * WF_i$ then $AIS_i = 30 * WF_i$

$$AI = \sum_{i=200}^{5000} AIS_i * WF_i$$

The Articulation Index spectrum (AIS_i) is composed of the voice level (VS_i) measured at the standard distance and data for normal speech levels are given in American Society for Testing and Materials (ASTM) Standard Test method E1130-02. The sound attenuation spectrum (TL_i) is the loss of speech from talker to listener, and background or masking spectrum (BS_i) is the sound at the listener that masks the received speech. Note that the usual and recommended practice is to use 1/3-octave band center frequencies 200 to 5000 Hz. The weighting factors (WF_i) are given in the ASTM document. This task is made relatively simple with appropriate real time analyzers and computer software.

Privacy Index

This metric was developed to allow non-technical persons to more readily appreciate the meaning and the non-linear aspects of speech privacy. The equation for it is

$$PI = 100 * (1 - AI)$$

For protection of sensitive conversations, PI must be 100.