

## Protecting Secure Facilities with Sound Masking

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Most sound-masking systems are used to reduce distractions in open offices or provide confidentiality in closed offices (from a casual listener outside the office). There are many cases where a conversation is so sensitive that it must be protected from a deliberate eavesdropper who may make use of sophisticated listening devices to ensure speech intelligibility. Applications where sensitive conversations must be protected include offices at all levels of government; military facilities; commercial facilities such as boardrooms and research areas; and those of military or government contractors. Further, the application is worldwide. For such applications, normal methods of masking are not adequate and new techniques and equipment must be used.

The primary reason for concern is that most major strategic and tactical decisions are first made orally at meetings and, if an eavesdropper can obtain access, it gives him a distinct time advantage over written or computer documents. Therefore speech is the primary focus for this application.

To protect conversations, it has been normal practice to make rooms that have high sound (speech) attenuation. For example, the government has used a room-within-a-room, but that is very expensive. Many facilities, such as boardrooms and research areas, do not have the budget for such measures, particularly when one considers all the ways audio access might be obtained, nor are such measures necessary. Worse yet, rooms with high sound attenuation do not guarantee protection, since there are two other factors that play a role: how loud conversations are and how loud the background sound is at the listening location. Because the sound attenuation of the room cannot be changed to accommodate these two varying factors, sound masking, being a dynamic factor, has been used to handle them. A less obvious advantage of sound masking over sound attenuation lies in its ability to provide masking at the many possible eavesdropping locations. Not only does it permit the user to adjust and verify the degree of protection from most eavesdropping methods, but it also affords very large cost reductions in both room construction and security maintenance. The author has been involved with the use of sound-masking systems in secure facilities since the early 1980s. Although most have been permanently installed, there are portable systems for temporary use where sensitive conversations must be conducted while traveling, such as in hotel/motel rooms.



Figure 1

Most articles about the loss of proprietary and sensitive information concentrate on documents and computer data, however, the federal government has been well aware of the audio surveillance problem for many years. One need only cite the case of the American Embassy in Moscow. A standard protection method against "bugs" is to "sweep" a room, but this is not effective against all eavesdropping devices.

### STANDARDS

The federal government has several regulations for protecting sensitive conversations, but standards and commercial organizations have not made use of them. They apply mostly to Secure Compartmented Information Facilities (SCIF) and are:

1. **Defense Intelligence Agency Manual (DIAM) 50-3.** Although this document is no longer the primary one related to physical security standards, the chapter on audio security notes the value of sound masking as a tool, but is not specific. This is the earliest publicly available document on the subject.
2. **Air Force Pamphlet (AFP) 88-26, 1988.** This document goes into great detail on the methods for creating sound attenuation around a secure room. However, it also 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."
3. **Director of Central Intelligence Directive (DCID) 6/9 2002.** This document is now the primary unclassified document on physical security in SCIF. Annex E 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." The author's experience with secure masking systems suggests that the military and its contractors as well as other government agencies are more concerned about the deliberate listener. It is likely that a publicly unavailable document exists that provides guidance for this higher level of protection. The DCID document does note that sound-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 can be beneficial only when used in conjunction with sound masking.
4. **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 such information.

## LOCATIONS TO PROTECT

Consider the perimeter envelope of a room as the location for eavesdropping devices. Windows, walls, doors, ducting, piping, ceiling plenums, raised floor plenums, and loudspeakers are all potential penetration points. This consideration excludes the use of listening devices carried into the facility by occupants. Each are discussed separately below.

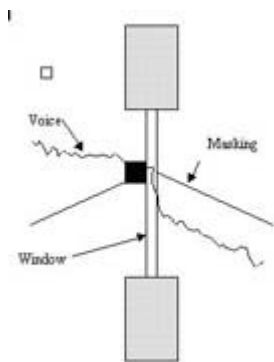


Figure 2

### Windows

Since windows, by their nature, face onto uncontrolled areas, they are good targets for audio surveillance, so having no windows is the best protection. Unfortunately, one prerogative of people holding high positions has always been windows, both in their offices and in conference rooms. The word "eavesdropping" originated with listening at windows. Open windows are open invitations to listening, so masking levels must be unacceptably loud to be effective. Speech near a closed window causes a minute vibration of the windowpane, which 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.

The 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.

The 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, it is a potent eavesdropping device. It can be disguised easily because it is small (Figure 1 above). Since the beam undergoes 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 Europe and the United States, such devices cannot be purchased by ordinary citizens. The present widespread use of window protection in secure facilities suggests that these devices are actually in common use. Further, the Internet has many websites that suggest designs for such devices. 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 would make it easier to detect. These devices are commonly available, such as for sports events. Again, window vibration caused by exterior noise sources will inhibit detection.

As an early application to sound masking of windows, a loudspeaker was placed in the suspended ceiling, facing down. These were called window washers since the sound "washed" over the window. Unfortunately, the level required at the window was loud enough to interfere with conversations and resulted in raised voice levels, a self-defeating proposition.

A better solution is to attach a vibration masker to the windowpane: It converts the masking signal into a masking vibration. 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 as that used for walls. Maskers on adjacent windows facing the same direction must not be placed in exactly the same locations. If one window contains only the masking vibration and no conversation, the eavesdropper can subtract that signal from the one in which both masking and conversation vibration exist.

As shown in Figure 2, the masking level will be lower than conversations within the room, but higher than conversational levels beyond the room, and higher than the speech caused vibration levels at the window.

If one linear dimension of the window is greater than 5ft., two maskers are recommended.

There are several ways that conversations transmitted through walls can be eavesdropped:

1. **Remote from the wall.** On many types of walls, listening can be done remotely from the far side, with a microphone or the 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 further inhibit eavesdropping.

However, on interior walls with much lighter construction, such is not the case, as persons in many closed offices can attest.

2. **On the far side of the wall.** Detection of wall vibration on the far surface can be accomplished with the attachment of a vibration detector or listening by ear. On most, but not all, exterior walls, detection of this type is very difficult, but on interior walls, with their lighter construction, vibration probes can be used quite effectively.
3. **Within the wall cavity and on the interior surfaces.** Most walls have cavities that are either empty or filled with fiberglass. Penetration of either exterior or interior walls that have cavities can be used to place acoustical devices within the cavity or attach vibration devices to the inner surfaces of the cavity.



Figure 3

There are several devices that can be used to detect speech at walls. The laser microphone, highly directional microphone, or even the ear, can be used at locations remote from the wall. These apply mainly to exterior walls and, depending on the wall structure, may or may not, be successfully applied. Vibration detection devices can be applied directly to either of the wall surfaces, the best location being the interior surfaces of walls with cavities. Concrete or cinderblock walls, despite their greater mass, are not immune from eavesdropping. On most walls, speech vibration will propagate laterally, so localized eavesdropping is not required. There are several methods of surface eavesdropping. Devices that detect vibration normal to the surface, such as vibration probes and microphones in contact with the wall surface are used. Devices that detect lateral vibration, such as strain gauges, may also be used. These devices may have a transmitter or a wire to convey the information, so they are susceptible to discovery.

Within wall cavities, speech intelligibility can be high, so normal microphones placed there can be very effective. Again, sweeping for transmitters or physical inspection for wires is required. There is a little-known microphone called the fiber-optic microphone. (Figure 3) It is an analog to the laser microphone, 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; it is quite small, and may be mistaken for a normal fiber-optic cable if merged with data transmission cables. These devices are not available on the open market.

With all these ways of eavesdropping, it is little wonder that highly sound-attenuating walls (high Sound Transmission Class) are totally ineffective against deliberate audio surveillance. Unfortunately, established methods die hard and federal standards still require walls with STC ratings of at least 45. It is clear that high-STC walls might be effective only for remote eavesdropping, but because of limitations in the rating itself (not speech-weighted, permits deficiencies), even that is problematic. This is where sound masking has distinct value; it can provide a solution to all the eavesdropping possibilities.

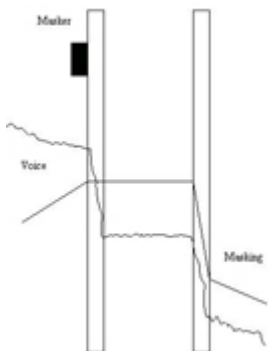


Figure 4

A vibration masker is attached to the outer surface of the wall on the secure side, as shown in Figure 4. It will generate random vibration of the interior wallboard that then radiates into the wall cavity, which in turn vibrates the further wallboard and creates a sound field beyond the wall. In this way, it covers all possible eavesdropping locations when installed properly. The best vertical position on the wall is at standing height, although many users have found that placing them above the suspended ceiling, out of sight, works as well. Experiments on walls with cavities have suggested that they may be placed as far as 8ft. apart laterally, since the vibration will carry around studs to create sound in more remote cavities. The sound spectrum and overall level must be determined from measurements. The required masking levels will cause sound within the secure room that can be heard but does not create speech interference or annoyance.

Vibration maskers have other advantages beyond performance. Because they are affixed to the wall surface inside the secure room, they are simpler to install. They do not penetrate the wall, so wiring can be readily inspected, and operation can be verified by listening. Since these maskers can be the same as those affixed to windows, they can be used for glass plate interior walls as well.

Doors are weak points in walls. For secure rooms, hollow-core doors are not recommended for two reasons: The required sound masking has to be unacceptably loud and the door has a cavity into which devices may be inserted. The sound-attenuation solution method is to install a specially built, high-STC door. These doors perform much better than standard doors, but are very expensive and require special frame construction. Another expensive structural solution has been to create a vestibule with two doors. Doors to uncontrolled areas, such as emergency exits, should not be in secure rooms. Eavesdropping devices attached to interior doors can be detected easily, so the listener can generally be presumed to be away from the door.

It has been found that a solid core door with gasketing and a "floor wiper" and a vibration masker on the secure side will provide confidentiality. The masker is best placed at the upper, hinge side of the door to minimize visible wiring. The door masker can be the same as that used for walls. The door vibration radiates into the door gap as well from the door's outer surface. If permitted, a loudspeaker masker should be added immediately outside the door. For interior doors, this added masker is needed only to make the sound spectrum outside the door more acceptable. For exterior doors, it can be placed high on the exterior wall to further inhibit eavesdropping.

Listening through air ducts is a time-honored source of intelligible speech. Almost all modern rooms have supply ducts—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 10ft. 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. Finding such devices must be by visual inspection or by a search for wires.

Duct mufflers have been the traditional sound attenuation solution. They were added at each point where the ducts penetrated the room perimeter. For many secure rooms, this implied a large number of mufflers. They are expensive, bulky, require a high plenum height, and, because of their weight, they are difficult to install. They suffer the weaknesses of sound attenuating devices, and add a significant pressure drop to the air handling system, which increases operating costs.

Again, sound masking can be used effectively here. Early designs placed a loudspeaker within the duct. Other designs placed the speaker outside the duct with the speaker radiating sound into the duct through a sealed penetration. The latter solution could only be applied to rectangular metallic ducts.

Current techniques use a vibrator on the exterior surface of the duct wall as shown in Figure 5. The device is easy to install, requires no penetrations, can be inspected, and has no impact on airflow. It can be applied to both round and rectangular ducts. The level in the duct is sufficient to block speech while the level in the secure room has no influence on conversational levels.

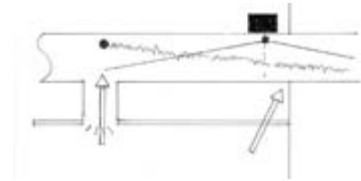


Figure 5

When the ceiling plenum is used for return air, and the room walls extend to the structural ceiling, a stub duct is required (as opposed to a hole in the wall). The duct length must be sufficient to attach a duct masker.

Normal liquid-filled pipes, or conduits filled with wires, do not carry significant speech energy. However, if there is a power panel in the secure room, and not all conduit pipes are filled, they become excellent speaking tubes, as any sailor knows.

The simplest solution is to use a rubber plug at the conduit opening. There have been cases, however, where a user wishes all pipes, and even structural columns, to be protected. A vibration masker, such as shown in Figure 8 below, can be attached to them.

With raised floors, cabling or ventilation penetrations will occur and must be protected. Loudspeaker maskers located at penetration points are effective solutions. If there are requirements for privacy within the room (such as a research office suite), the maskers can be placed uniformly under the floor, as is done in commercial facilities, to provide speech privacy within the room itself.

### Suspended Ceilings

Secure rooms often have a suspended ceiling with a plenum above to accommodate air ducts and cable runs. The air ducts are addressed separately. If the surrounding walls do not extend to the structural ceiling, the open plenum extends above adjacent rooms. As those in closed commercial offices know, intelligible speech can be carried through that plenum. As with raised floors, loudspeaker maskers can be placed around the periphery of the room, or if interior privacy is desired also, the maskers can be placed uniformly above the room.

### Internal Loudspeakers

Many building codes require the presence of speakers in a room for emergency announcements. Most loudspeakers can act also as microphones; the minute voltages created can be converted to speech. Although a low-level masker can be placed in front of the speaker, an optical isolator is recommended. This device acts as an acoustical diode; it permits signals to flow only to the speaker, but not from it. Optical isolators are commercially available.

The primary advantage of a sound-masking system is that it can be altered in spectrum contour and overall level at any time and in any place, to suit the changing requirements of a facility, but there are others also.



### The Sound-Masking Signal

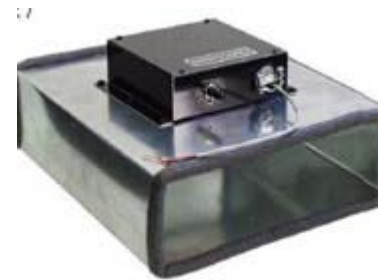
Taking into account the capability of sophisticated listeners to recover speech buried in noise, layered protection is recommended. The masking generator creates a normal masking signal but other several signals are mixed with it. The random noise must be the first and prominent layer; it covers the entire speech spectrum as is done with commercial sound masking. Music may be used as the second layer; it is buried below the random noise, so it is not actually audible to room occupants. Voice babble may be used as a third layer; it should be set at the same or lower level as the music signal. If the masking spectrum is set properly, the fourth layer, the actual voices to be protected, will be sufficiently buried below the other layers to inhibit recovery of conversations.

### The Front End

For high degrees of protection against audio surveillance from uncontrolled areas, a non-stationary random noise generator is recommended. This generator creates a masking spectrum that randomly shifts in level and spectrum so the statistics of the noise are continuously varying. For other cases, normal masking generators are adequate. In most cases two channels of equalization are enough; the equalization should be in 1/3-octave bands. For layering purposes, a mixer is needed. Some products have a mixer built into the generator cabinet. Multi-channel amplifiers are recommended to accommodate both the requirements for separate masking spectra as well as to set levels independently. If multi-channel amplifiers are not available, separate zone controls must be used. If zone controls are needed, they should be auto-transformers with detented knobs and 1dB or 1.5dB steps; 3dB steps are too large.

### The Speakers

Commonly available sound-masking speakers, such as those used in commercial applications, can be used for secure facilities. Their application to secure facilities primarily is for ceiling plenum masking or under floor masking. No modifications to them are required for these applications.



There are several vibration maskers available. Figure 6 shows two vibration maskers that are commercially available for application to windows, doors, and walls. One has an optional volume control for special situations and operates on a 70.7V system while the other operates on an 8Ω system. The adhesives used must be sufficiently flexible to accommodate large changes in temperature, such as at windows, without separation of the masker.

These maskers can be applied easily to rectangular metal ducts, but not to circular ducts or piping. Figure 7 shows a rectangular duct masker that is screwed to the duct. This particular masker has flanges that permit it to be screwed to circular ducts as well. Figure 8 shows this masker attached to a pipe. These maskers have optional volume controls and operate on a 70.7V system.



### Equalization

For most applications, the author has used the Privacy Index as the criterion for performance. Although the Privacy Index has been standardized only recently, it has been in use for more than 20 years as a criterion for the performance of secure masking systems. The index must be determined in both acoustical and vibration form. Each of the above masker locations requires individually set levels. Generally only two masking spectra are needed, so a 2-channel masking generator can be used to advantage. One channel should be used for loudspeakers, such as plenum and under floor maskers while the other channel should be used for vibration maskers, such as for windows, doors, walls, ducts, or pipes. The spectrum for the latter two applications is not critical.

Although the specifics of equalization are beyond the scope of this article, it should be noted that sufficient information is available in insure successful counter-surveillance.

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