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METHOD FOR PROTECTING SPEECH INFORMATION

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Methods for protecting speech information from leaking via acoustic channels are analyzed. A method for protecting speech information using a combination of masking signals consisting of «white» noise and speech-like signals is proposed.

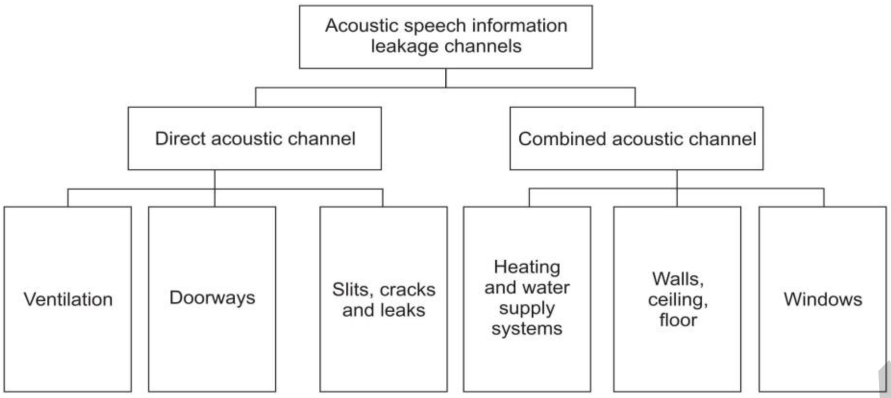
Key words: speech information protection, acoustic leakage channels, active protecting method, masking signals, speech-like signals.

Introduction

Speech information protection is relevant for a long time, since the speech itself appeared. In the course of human activity, including thinking, a man becomes the owner of certain information that may be confidential. With specific information, a person has a need to share it with a selected number of persons. At the same time, as it often happens, the first type of such information is the voice information. In this context, the issues raised in this article are very important. Speech information protection feature is that it is closely connected with the source of speech as acoustic sound waves. Acoustic wave transmits speech information from the source to the receiver, and simultaneously effects on the elements of the walling premises. This gives rise to walling elements vibration which, spreading throughout structure of the building, transfers it and thus creates voice data acoustic leakage channels. High quality protection of the speech information circulating in acoustic form in the protected area is primarily determined by the right choice of protection means and modes of their work.

Voice data leakage channels

Voice data acoustic leakage channels are channels formed through the acoustic waves propagation through the medium between the source and receiver acoustic waves. Voice data acoustic leakage channels can be divided into two types: direct acoustic channel for air and combined acoustic channel, including the propagation of acoustic waves in a gas, solid and liquid media or various combinations thereof [1, 2]. Combined acoustic channel leakage of voice information in a number of references [2] is also called vibroacoustic channel. Such definition from the point of view of the acoustic waves propagation physics is not entirely correct since we are talking about the propagation of acoustic waves instead of vibrating processes in the sense that there is a source of vibration. Based on the analysis of the literature [2] voice data acoustic leakage channels can be classified into groups as shown in figure.



Classification of voice data acoustic leakage channels

Direct voice information acoustic channel leakage has three main types: channel leakage ventilation systems; channel leakage through doorways and gapping the doors to the boxes; channel leakage through cracks in the enclosing structural elements and the gap in the channel electro-telecommunications, heating and water supply. Voice information in such channels can be intercepted using microphones or by direct listening. The greatest dangers are the air ventilation ducts and channels of communication that are acoustic waveguide. Acoustic waves carrying voice information, while passing through the ventilation ducts are weakened due to wall absorption and the changes in direction of propagation. In this case, due to multiple reflections from the walls of the duct acoustic wave energy is not dissipated into the environment, so the range of acoustic wave propagation in waveguides is significantly greater than the propagation of acoustic waves in the open space. Attenuation of acoustic waves in direct metal waveguide is 0.15 dB / m, and in waveguides embedded in protecting structural elements (such as air ducts in brick or concrete structures) is 0.2–0.3 dB/m. On the air pipe bends at an angle of 90 degrees attenuation of the acoustic wave is 3–7 dB at one bend. When changing the duct section the damping of acoustic waves is about 1–3 dB, and at the transition into the open space of the waveguide (e.g. room) attenuation is 10–16 dB.

There are always voice data leakage channels in the protected area. They are: doorways and doors gap pings to the boxes. Its parameters are determined by the acoustic characteristics of the room, doors, gaps and looseness between the door leaf and frame, the presence of the vestibule. Acoustic characteristics, such as reverberation time and absorption determine the audibility and intelligibility in the room. At very low reverberation time (less than 0.2 sec.) acoustic wave decays rapidly and has a small number of reflections due to the high absorption properties of enclosing structural elements. In this case, audibility and intelligibility with distance from the source decreases sharply, also changes the timbre of speech due to rapid attenuation of high-frequency components of speech (1000 Hz). This room will have sufficient protection against leakage of voice information on the direct acoustic channel even in the presence of leaks in the adjoining leaf to the door frame. For the most typical space the reverberation time is in the range of (0.2–0.6 sec.) This provides a good audibility and intelligibility. Therefore, for such premises one should pay particular attention to soundproofing doorways, use seals, door sills, door vestibules.

Voice information leakage channel through the cracks in the enclosing structural elements and cracks in the channels of telecommunications and electric heating systems and water supply is very dangerous. Such channels are characterized by low aspect ratio of the formed acoustic waveguide wavelength. Attenuation of acoustic waves in the channels is very considerable and ranges from 1 to 20 dB/m. It is primarily determined by the dimensions of the waveguide (the cross-section of the formed channel), the channel walls roughness and its configuration. For example, for the wall thickness of 0.5m with an opening of only 5 mm^2 soundproofing on the direct acoustic channel at the exit hole on the other side of the wall is 18 dB, although the sound insulation of the wall without a hole is 65 dB. On the other hand, find a point source of sound is not an easy task. This is due to the fact that the sound energy quickly dissipates from a point source in space. Considering the attenuation in the acoustic waveguide of 20 dB plus the losses in the waveguide transition to an open space plus

16 dB attenuation in the propagation indoors for 2–3 m 17 dB gives us total attenuation of the acoustic channel at the level of 53 dB. It is only 12 dB lower compared to the wall without a hole.

Thus, under the influence of acoustic waves with a sound pressure level of 70 dB brick wall thickness of 0.5 m makes vibration with acceleration of $3 \cdot 10^{-5}$ g [2]. However, it does not indicate the exposure frequency of the acoustic wave and the possible short-range mode of natural oscillations of the wall. At that this re- emitted acoustic wave from the reverse side walls will have a sound pressure of less than 10 dB, which is not possible to register by and listen. However, the pickup of the speech information in such channel is possible through the application of highly sensitive accelerometers, mounted on the back of the wall. Modern building materials and construction, joints and connections which are made with high quality and have a high hardness, have a very low rate of damping of flexural waves. These are constructions of reinforced concrete, precast concrete structures. Rates of attenuation are slightly higher in the construction of walls made of brick. For structures made of reinforced concrete there is a real danger of the spread of the speech information in the form of acoustic waves through 2 floors.

For heating systems pipes as well as water supply pipes voice data in the form of acoustic waves may be transmitted through buildings' several floors (2–4), although sound insulation is very high through direct acoustic channel.

Leakage channel through the window openings is not due to the process of passing a sound wave through the glazing and the formation of secondary acoustic wave, yet by pickup voice data directly from the vibrating elements (glass).

Methods for protecting speech information

Speech information protection from leaking via acoustic channels can be organized in two ways: passive and active ones. The first method is passive and is in use in the construction of buildings enclosing structural elements with high soundproofing properties. This type of protection began to be widely used in a number of countries, when it is in the construction requirements for high degree of insulation of separate rooms were introduced in the project documentation.

In the speech information passive method of protecting range of design and construction activities are aimed at completion of the following systems: walling elements (walls, floor, ceiling, windows, doors) premises' engineering systems (ventilation, heating, air conditioning), wired systems for various purposes. The above work permit to achieve appropriate levels of noise and vibration control and lower levels of dangerous signals generated due to acoustic-electrical conversions.

The acoustic characteristics for the audio frequency are determined for octave bands with center frequencies with the following values of 63, 125, 250, 500, 1000, 2000, 4000, 8000 Hz [2]. This makes it easy to compare the characteristics of sound insulation for various materials and a design insulation devices.

In confined spaces sound waves repeatedly reflected from the enclosing structural elements, resulting in a complex pattern of the sound field. The absorption of sound energy is not just protecting designs premises, but also the air. The energy losses are due to air viscosity, thermal conductivity of air as well as molecular absorption.

The most frequent voice data leakage channels are generated through the vents, windows and doors. It is desirable to make window glass vibration-isolated from the frame by setting the rubber gaskets. It is recommended to use at least two double-glasses, and to install sound absorbers made of glass wool felt or install absorbers on the walls of ventilation ducts using artificial obstacles to change the direction of air flow in vents. Doors preferably should be performed with a vestibule and a snug fit of the door leaf to the door frame.

Active methods for protecting speech information

Active methods of speech information protection are based on the establishment of additional noise at a possible voice data leakage channels so is to hide the signal carrying voice data. "White" or "pink" noise are widely used as masking signals with a frequency range from 100 to 10000 Hz. Combined masking signals consisting of "white" or "pink" noise and so-called speech-like signals recently started to be applied. The best speech information protection results can be obtained using masking signals close to the spectral composition of signals to be protected, and having the structure of the voice message.

Voice information active protection devices typically consists of a masking signals generator and a set of electrical to acoustic signals (e.g. electrodynamic loudspeakers) transducer or electrical to mechanical motion signals transducer. When installing these transducers on protecting structural elements in in the place of equipment mounting you should create a force impact on the structural elements enclosing space causing them to vibrate.

As vibration transducers piezoelectric and electromagnetic transducers are widely used. The disadvantage is the complexity of the electromagnetic transducer design for operation at high frequencies (from 2000 to 8000 Hz). Piezoelectric transducers do not develop the necessary force to excite vibrations enclosing structural elements in the frequency range from 100 Hz to 500 Hz. Transducers mounted on the walls, floor, ceiling, window glass emit acoustic noise, creating uncomfortable conditions in the protected area. Therefore, it is proposed to close them with soundproofed caps and to use automatic level masking signals control depending on the sound pressure level of the protected speech.

The effectiveness of technical speech information protection depends on the proper placement of transducers on protecting structural elements. In [2] it is recommended that if the building is made of precast concrete, acoustic protection systems transducers must be placed on each element of the building structure. The need for such requirements is dictated by the lack of stability of the acoustic impedances on the joints in the operation of buildings. It is indicated that the installation of transducers must be performed in the geometric center of the building. However, neither theoretical studies nor the results of experimental tests are given.

An important requirement for masking signals is the requirement that they are formed at random, i.e. "white" noise must be formed due to the thermal noise of semiconductor or other natural physical noise. This requirement stems from the need to avoid any possibility of intercepted acoustic signals noise reduction. The use of digitally generated noise instead of "white" noise creates a risk that there is the possibility of applying noise reduction. On the other hand, and speech-like signals are generated using a random number generator should be based on the thermal noise in semiconductor devices and not on pseudorandom sequences generated digital devices.

Speech information security devices efficiency is enhanced when they use speech-like signals generated on the basis of allophones in view of the likelihood of continued words, long sentences and probabilities of phonemes of a speech protected. This solution is applied to the device for protecting speech information "Priboi-R". When the speech-like signals are formed on the basis of allophones of persons working in the protected area, it is very difficult to separate speech formant and speech-like signals pitch frequency of the signal intercepted and protected speech. Active and passive protection of speech information must be so arranged and carried out so as to prevent the propagation of acoustic vibrations, carrying voice data outside the protected area.

The development of new security systems should be put in such a way that as soon as the prerequisites for the creation of new means of violating the protection of information appear, we must begin develop measures to counter them. These developments should not begin when new means of violating information security are already created, but much earlier (when there are only prerequisites for the establishment of such means). Only under such conditions, information protection system can be considered as effective.

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References

1. *Kazumasa Yamamoto, Seiichi Nakagawa.* // Privacy Protection for Speech Information. Journal of information Assurance and Security. 2010. № 5. P. 284–292.
2. *Zheleznyak V.K.* Zashita informacii ot utechki po tehnicheskim kanalam. SPb, 2006.