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PERCEPTION OF SPEECH IN A SIMULATED TUNNEL USING A SUPER-DIRECTIVITY LOUDSPEAKER

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1. INTRODUCTION

A simulation research about speech transmission using a super-directivity loudspeaker in special environments surrounded by the wall which has high reflective coefficient was investigated.

In those surrounded environment, as sound waves usually accompany with many echo components due to multiple reflections, the speech intelligibility of recieved speech is generally extremly degraded.

It is easy to think of long highway tunnels and subways , so on as such special environments. In case of fire in suchlike special environments, it is very desirable to give a crowd of people under panic some pertinent informations about refuge.

In such circumstances, public addressing by loudspeakers is one of the best way to transmit the speech message. However, as already mentioned above, It seems that the pablic addressing by loudspeaker is not able to be used practically becouse of poor speech intelligibility due to the multiple reflections in those environments.

Generally, there are two causes for the degradation of the speech intelligibility. One is interfering noise and the other is delay distortion based on the multiple reflections. In this paper, the effect of the interfering noise is ignored and only the delay distortion is considered as the cause of the degradation of the speech intelligibility. Because, it depends on the fact that it is possible to ignore the degradation of speech intelligibility due to the interfering noise if signal to noise ratio is over 19dB,[1] and we assume the signal to noise ratio to be satisfied the above condition.

On the other hand, the delay distortion due to the multiple reflections is much influenced by some factors concerning loudspeaker, namely setting position, radiation direction, directivity pattern and so on.[2)]

In our research, a long highway tunnel was selected as a typical example of the special environments.

As result of computer simulations, a remarkable improvement of the speech intelligibility could be accomplished by using a nonlinear parametric loudspeaker having super-directivity. By using this type of loudspeaker, it is possible to reduce the reverberation greatly.

2. NONLINEAR PARAMETRIC LOUDSPEAKER : SOUND SPOTLIGHT[3)]

In this section, an outline of the nonlinear parametric loudspeaker is simply explained.

This type of loudspeaker has a quite different sound generating mechanism compared with traditional loudspeaker. In such loudspeaker, audible sound is not produced by vibrating diaphragm, but by the effect of nonlinear interraction of ultrasound waves in air.

At first, a finite amplitude ultrasound wave modulated in AM mode by any voice signal is radiated from a transducer array into air as the primary wave.

If the ralation between the transducer array diameter and wavelength of ultrasound is arranged suitably,the primary wave has a long near field region and the radiated ultrasound goes straight as a beam in its region.

Then, self-demodulation effect is occurred by the nonlinear interaction of sound wave, and virtual sound sources of the voice signal which is the modulation signal are produced in the primary wave beam as longitudinal array.

Therefore, the produced voice sound has very sharp directivity equal to main robe of the primary wave.

3. SIMULATION PROCEDURE FOR ESTIMATION OF SOUND ARTICULATION

In this section, simulation procedure is explained. At first, some parameters such as internal shape of tunnel, tunnel's size, setting position of the nonlinear parametric loudspeaker in the tunnel and listening position are assumed as shown in Fig.1.

As the simulation procedure.

(1) Calculation for squared impulse response of multiple pass way from the loudspeaker to the listening point, by the ray tracing method.[4)]

In order to calculated this value, besides the parameters shown in Fig.1, it is necessary to use directivity pattern of the loudspeaker and reflective coefficient of tunnel wall.

(2) Computation of MTF(Modulation Transfer Function) by doing FFT of the squared impulse response.

(3) Transformation of MTF to STI(Speech Transmission Index).[5)]

(4) Predicting Japanese sound articulation from STI.[1)]

4. SOUND ARTICULATION IMPROVEMENT BY NONLINEAR PARAMETRIC LOUDSPEAKER (SIMULATION RESULT)

Computer simulation was performed by using two kinds of sound sources. One was the nonlinear parametric loudspeaker described in section 2 and the other was a usual trampet type horn loudspeaker. The directivity patterns of each loudspeaker at 0.5KHz,1KHz,2KHz,4KHz are shown in Fig.2 and Fig.3.

Fig.4 shows the result of calculation of MTF, and Fig.5 shows the result of STI and the sound articulation. According to Fig.5, about 14% improvement of the sound articulation could be obtained using nonlinear parametric loudspeaker as a sound source.

As the conclusion, it become clear that a very sharp directivity sound sources is very effective to improve the sound articulation in the reverbrent space such as tunnels of concrete wall.

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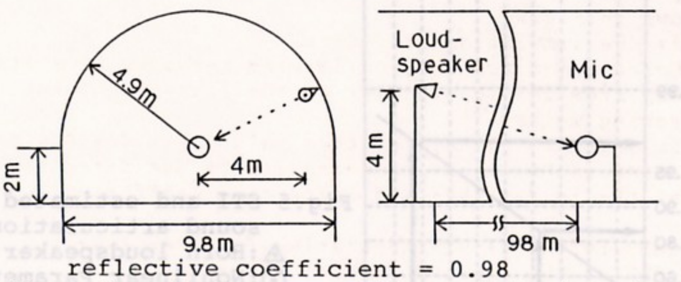


reflective coefficient = 0.98

Fig.1 Tunnel shape, positions of loudspeaker and listener in computer simulation

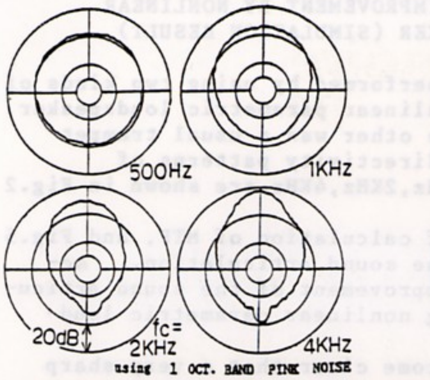


Fig.2 Directivity pattern of Horn loudspeaker

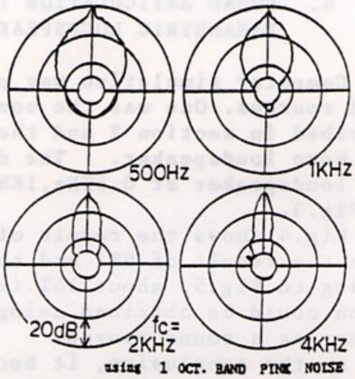
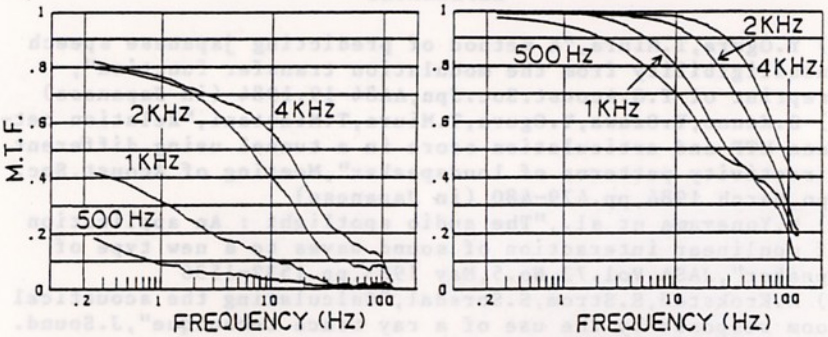


Fig.3 Directivity pattern of Nonlinear Parametric loudspeaker



a) Horn loudspeaker b) Nonlinear Parametric loudspeaker

Fig.4 MTF for 1 octave bands centered at .5 to 4KHz

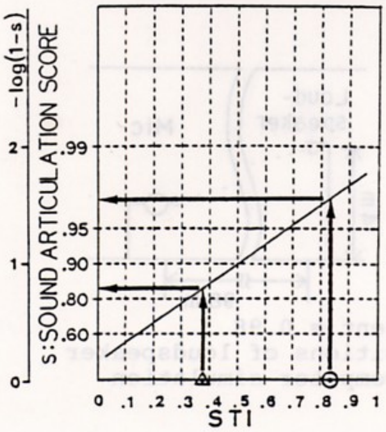


Fig.5 STI and estimated sound articulation

△:Horn loudspeaker

⊙:Nonlinear Parametric loudspeaker