Proceedings of the Institute of Acoustics

THE DEVELOPMENT OF AN ACTIVE NOISE CONTROL MICROPHONE

GE Warnaka, JA Kulikauskas, LM Hoover

Applied Acoustic Research, PO Box 10369, State College, Pennsylvania16805 USA

1. INTRODUCTION

There are many commercial and military applications for voice microphones in which the speaker is immersed in a noise field. As a result, both the spoken communication and the background noise are transmitted. This represents a classical problem in communication: understanding speech contained within noise.

The classical approach to the problem has been to use a noise-cancelling or pressure gradient microphone. In such a microphone, the front and rear of the microphone diaphragm are exposed to the external noise field. Since the noise acts with equal intensity on each side of the diaphragm, the external, or far-field, noise would cause each side of the microphone diaphragm to move in exactly opposite directions with an equal intensity. Hence, there would not be any motion of the diaphragm resulting from the far-field noise. That is, as sound is a pressure disturbance in a fluid medium, the pressure is equal in all directions, and so the pressure exerted on one side of the diaphragm is exactly counterbalanced by the opposite pressure on the other side. This discussion applied only as long as the dimensions of the microphone are very small compared to the wavelength of sound. Unfortunately, the microphone cannot be made small enough physically for all frequencies within the speech range. At the same time, various practical factors of materials, design, and manufacture limit the amount of cancelling that occurs, even at the lowest frequencies.

Improvements in noise cancelling microphones may be made by using second-order devices. However, the increased complexity, cost, size, and weight tend to offset any increase in performance.

Another disadvantage of the current noise-cancelling microphone is the necessity for "close talk." Since the pressure gradient microphone cancels noise that arrives from a distance, the microphone must be very close to the lips. Only in this way can a pressure gradient be established across the microphone so that the speech signals themselves are not cancelled.

Another undesirable feature of current, state-of-the-art noise-cancelling microphones is the hygiene problem caused by using a microphone that must be so close to the mouth. The microphone, with its mesh and cavity design, may harbor and encourage the growth of harmful bacteria.

THE DEVELOPMENT OF AN ACTIVE NOISE CONTROL MICROPHONE

This paper describes the development of an active noise cancelling microphone. The preliminary experiments showed the technical feasibility of producing a microphone with the technical features described [1]. The second set of experiments [2] showed that the improvements suggested in the earlier tests could be realized. The third set of experiments showed that the microphone could be made very compact and would produce superior results without the use of voice recognition or speech processing algorithms.

2. DISCUSSION OF PRELIMINARY EXPERIMENTS

This section describes a first attempt to produce a noise cancelling microphone that can be used far from the mouth of the talker. Two variations of the microphone were tried. In the first, the noise was cancelled at the face of the microphone by physical or acoustical means. That is, a loudspeaker was placed close to the microphone to cancel the external noise field at the microphone face. In the second case, the cancellation was accomplished by electronic means without the use of a cancelling microphone.

Figure 1 shows the performance of a typical noise cancelling microphone. Two curves are shown. For the curve marked "6.4mm Spacing," the microphone was mounted 6.4mm from the signal source. This very close spacing is, of course, typical for such a microphone which must be located nearly on the lips for proper operation. The second curve is marked "5cm Spacing," in this case, the microphone was moved 5cm from the signal source. Note that there is a marked degradation in performance of about 10dB in sensitivity at the lower frequencies. In fact, by moving the microphone two inches from the signal source, the performance falls to nearly that of the microphone's "far-field" response. This clearly indicates the necessity for percision placement of current noise cancelling microphones.

Figure 2 shows the configuration for all tests of the active noise cancelling microphone. Note that a loudspeaker, the "Interference Source," injected the background noise into a reverberant space. A reference microphone sampled the background noise. Another loudspeaker, the "Word List Source," presented various test signals, including word lists. The "Sensor Mic.," which was the microphone under test, was located 61cm from both the test signal source and the noise source. At such a distance from the signal source, conventional noise cancelling microphones would produce practically no intelligible output.

In the case of acoustic cancellation, a loudspeaker was placed near the sensor microphone to cancel the background noise at the microphone face. In the case where electrical cancellation was used, the hook-up was as shown in Figure 3.

Figure 4 shows the cancellation of an harmonic series. Note that there is cancellation of 20dB to 30dB of the harmonic peaks across the entire frequency range, the acoustic signature of turbo-prop aircraft helicopters.

Figure 5 shows the cancellation of the cockpit noise of a modern jet fighter. The noise is attenuated across the entire frequency band.

The overall attenuations achieved at the microphone face were:

100Hz Tone	40dB to 60dB
500Hz Tone	40dB to 60dB
Broadband Harmonic Series	10dB to 25dB
Helicopter Noise	10dB to 20dB
Turbo-prop Noise	12dB to 20dB
Pink Noise	10dB to 17dB
Jet Fighter Noise	12dB to 20dB.

The range of values shown depends on whether the cancellation was by acoustic or electronic means. The electronic cancellation generally showed better results.

In all of the experiments described for the improved noise cancelling microphone, a simple, non-noise cancelling microphone was used. Rather primitive electronics, using only 32 taps, were employed. Considerable improvement over the results shown was considered to be possible with improved electronics.

The first set of experiments showed that the principles of physical (acoustic) and electronic active noise control can be successfully applied to produce noise cancelling microphones with improved characteristics. The advantages of the active noise cancelling microphone are:

1. The microphone placement relative to the mouth of the speaker is not critical. In fact, the microphone could be removed from the helmet position entirely and could be located in some other convenient location. This has the advantage of reducing the helmet weight in critical applications.
2. The microphone element can be a conventional single stage unit which is less complex and has less weight and volume.
3. With improvements, the system can provide more uniform performance as a function of frequency and greater attenuation.
4. The system can be combined with conventional noise cancelling microphones if desired.

3. DISCUSSION OF SECOND SET OF EXPERIMENTS

A second set of experiments similar to the first set was performed using a more sophisticated controller [3]. This controller is a specially designed development unit in which the response time and the size of the control function parameters can be varied in order to determine the control requirements for a given problem. The results for jet fighter cockpit noise is shown in Figure 6. In this figure the original unattenuated noise is shown along with the attenuation achieved with the more sophisticated controller. Note that the attenuation is very much improved over the first test results. The active system attacks the high amplitude portions of the noise curve first, reducing the amplitudes by as much as 30dB to 40dB. However, the system also has the capability to reduce the lower levels of noise (away from the peaks) by 20dB to 30dB over a bandwidth of at least 4kHz. Figure 6 shows the results of electronic cancellation. The acoustic cancellation microphone is still undergoing development as it may have advantages in certain applications.

The second set of experiments showed that the active noise control microphones can provide more uniform performance as a function of frequency as well as greater attenuation.

4. DISCUSSION OF A THIRD SET OF EXPERIMENTS

In a third set of experiments, the design of the microphone was altered to produce a single unitary microphone element. The microphone is small and compact and does not require any external sample of the external noise. The new microphone may still be located several feet from the speaker. The microphone can discriminate between the voice and noise without the use of voice recognition elements. A simple electronic control unit can be used to produce a commercially economical system. The performance of this new microphone is shown in Figure 7 where the rejection of automobile random road noise is illustrated. Further details of the microphone cannot be given, at this time, due to proprietary constraints.

5. REFERENCES

[1] LA POOLE & GE WARNAKA,"Improved Active Noise Cancelling Microphone," Proceedings, Noise-Con 87, pp. 377-382.
[2] GE WARNAKA,"An Active Noise Cancelling Microphone for Crew Communications, 3rd SAE/NASA Interior Noise Workshop, 11 and 12 April 1988.
[3] LA POOLE, GE WARNAKA & RC CUTTER,"The Implimentation of Digital Filters Using a Modified Widrow-Hoff Algorithm for the Adaptive Cancellation of Acoustic Noise," Proceedings, ICASSP 84, pp. 21.7.1-27.7.3.

6. ACKNOWLEDGEMENT

Applied Acoustic Research acknowledges the support of The Ben Franklin Partnership Fund of Pennsylvania and Oxford Speaker Company in the development of this microphone.

Note: Because of space limitations, the figures are not in numerical sequence.

THE DEVELOPMENT OF AN ACTIVE NOISE CONTROL MICROPHONE

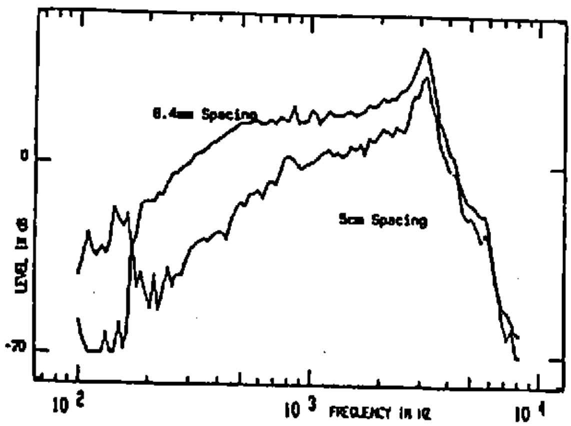
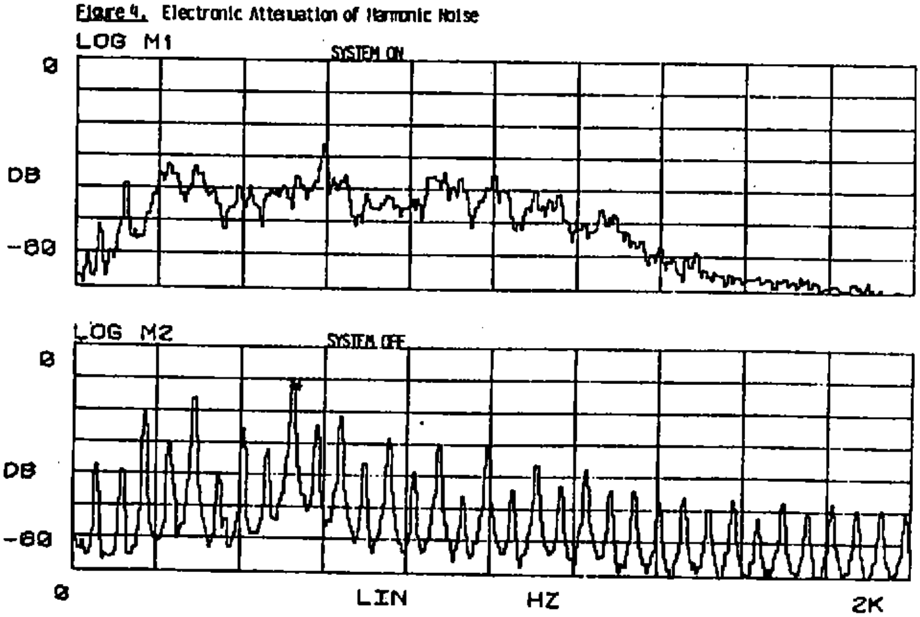


Figure 1. Response of Conventional Noise Cancelling Microphone.

Figure 4. Electronic Attenuation of Harmonic Noise



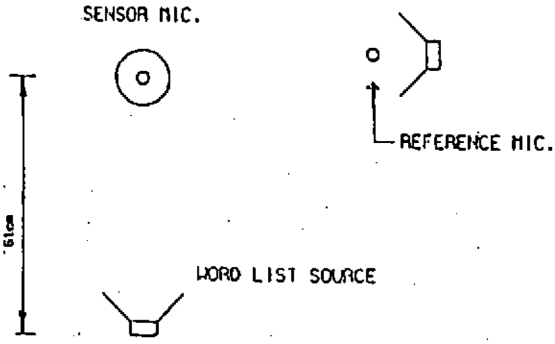
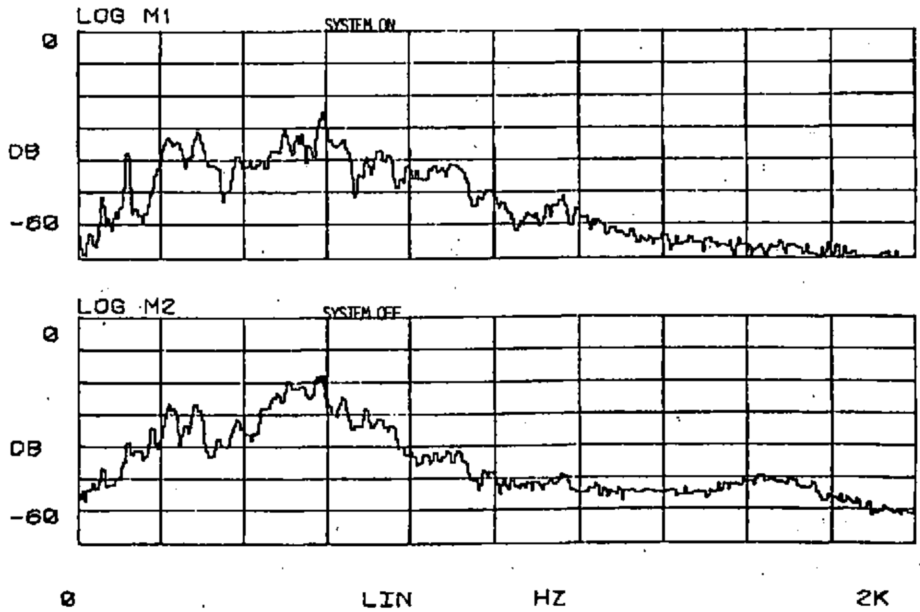


Figure 2. Test Configuration.

Figure 5. Electronic Attenuation of Jet Fighter Cockpit Noise



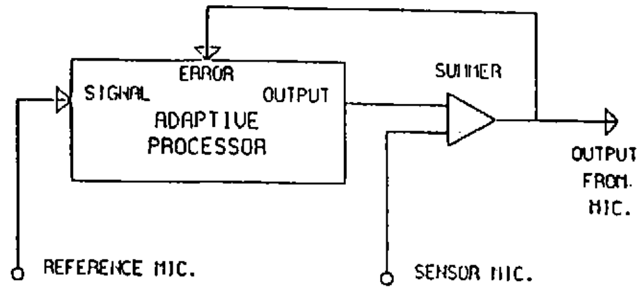
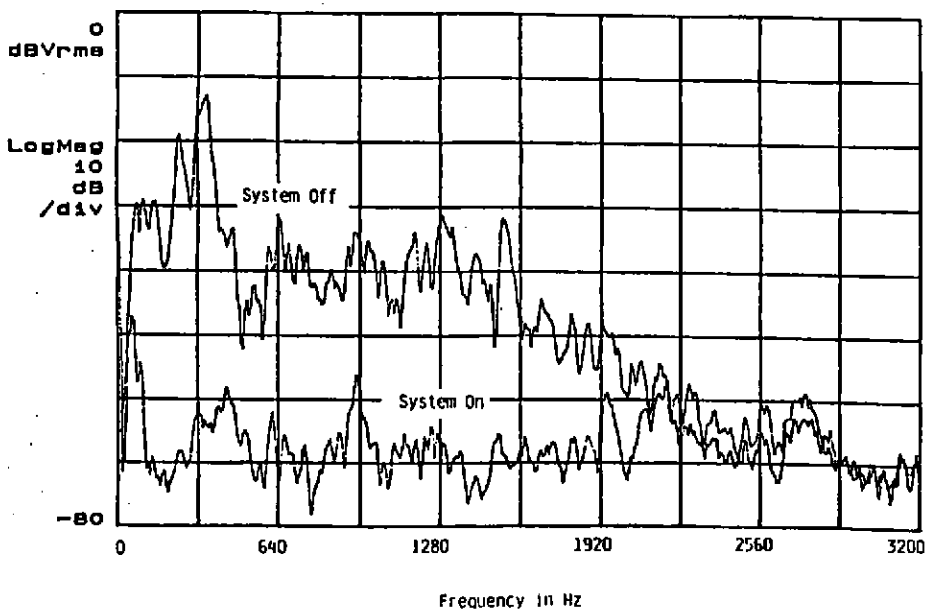


Figure 3. Configuration for Electronic Cancellation.

Figure 7. Attenuation Automobile Road Noise.



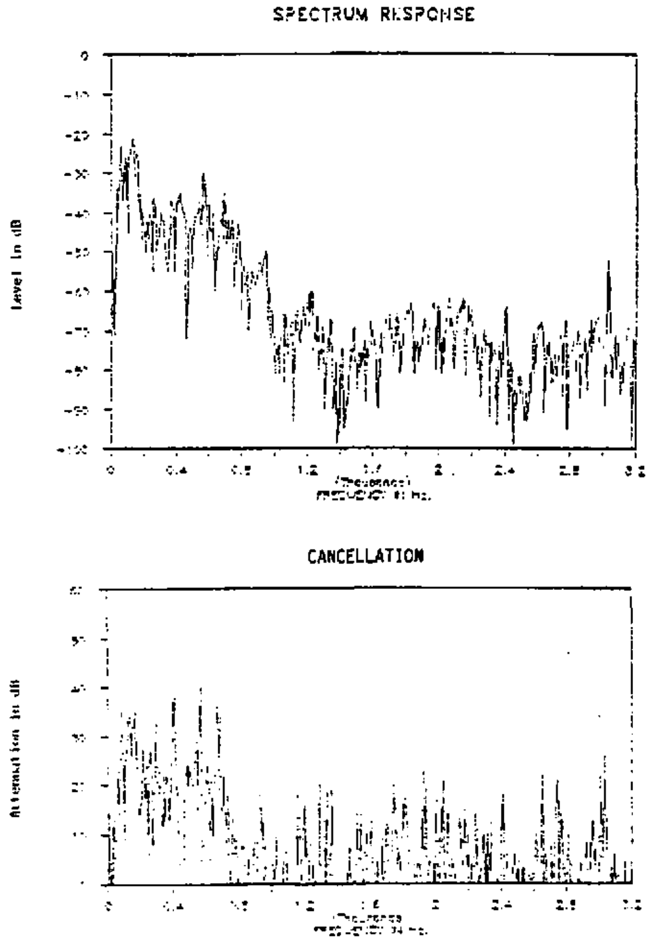


Figure 6. ATTENUATION OF JET FIGHTER COCKPIT NOISE.