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File P185

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August 16, 1957

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Subject: Contract RD-94
Task Order No. 2

In accordance with Article 2 of the basic contract, there are forwarded herewith two (2) copies of the Monthly Progress Report for July, 1957 on Task Order No. 2 of RD-94. This report is UNCLASSIFIED. An additional copy is being held in by the project engineer for the use of your personnel while at this location. 25X1

In connection with this monthly progress report, the following information is submitted:

Total expenditures to 6-30-57	$37,649
Outstanding commitments as of 6-30-57	65
Funds remaining as of 6-30-57	$22,602

You will note that the figures given above are the same as those reported for 5-31-57. The figures shown for 5-31-57 in our letter of July 17, 1957, should have read:

Total expenditures to 5-31-57	$33,413
Outstanding commitments as of 5-31-57	None
Funds remaining as of 5-31-57	$26,903

Very truly yours,

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Manager
Government Contract Administration

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Monthly Progress Report
July 1957

Task Order No. 2
Contract No. RD-94

Audio Noise Reduction Circuits

The object of this project is to develop a noise reduction circuit suitable for use in separating speech intelligence from a signal containing speech and noise when the speech intelligence is masked by the noise. The proposed method involves a principle which has been used successfully to improve the signal-to-noise ratio in music reproducing or transmission systems.[1] The system used for music contains bandpass filters which pass frequencies over a range of an octave or less. These filters are used at the input and output of a non-linear element. The output of the non-linear elements contain the fundamental, and also harmonics and subharmonics of the fundamental. However, since the pass band of the input and output bandpass filters is no greater than an octave, the harmonics and subharmonics are not transmitted by the system. The function of the non-linear element is to reject all noise signals below a given amplitude or threshold level. The threshold levels of the non-linear devices in each channel can be adjusted so that, in the absence of desired signal, the noise is rejected. When the desired signal is greater than the threshold level, the non-linear elements allow the composite signal to pass. Thus, for passages of recorded music, when the music signal is below the noise level in a given frequency channel, the channel is inoperative, and its output is eliminated from the total output. Since the contribution of this channel to the total output would have been only noise, the over-all noise level is reduced. When the

1. H.F. Olson, "Electronics," Dec. 1947.

music signal in a given channel is greater than the noise, the channel conducts and allows the composite signal to pass. Thus, a channel conducts only when the desired signal is greater than the noise, and rejects when noise alone is present.

In order to apply this method of noise reduction to speech, when the wide band speech signal-to-noise ratio is very low, it was believed necessary to find frequency regions in which the speech amplitude is greater than the noise. Although the long time average spectrum of speech is continuous, and similar in shape to the spectrum of room noise,[2] the short time spectrum of various speech sounds contains regions of maximum energy called speech formants.[3] The assumption that this method of noise reduction should be utilized for speech was based upon the belief that it would be possible to find frequency regions in which the amplitude of the speech formants would be greater than the noise a substantial part of the time.

A study has been made to determine what bandwidths are required in order to obtain speech formant amplitudes above the noise when a wide band speech sample is just intelligible in noise. It is known that for noises with a continuous spectrum it is the noise components in the immediate frequency region of the masked tone which contribute to the masking.[4] When a very narrow band of noise is used to mask a pure tone, the masking increases as the bandwidth is increased until a certain bandwidth is reached. After this, as the bandwidth is increased, the amount of masking remains constant. This bandwidth at which the masking reaches a fixed value is termed the critical

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2. H. Fletcher, "Speech and Hearing on Communication," Van Nostrand Co., Inc., New York, 1953 (see Figures 61 and 70).

3. Op.cit. chap. 1.

4. L.L. Beranek, "The Design of Speech Communication Systems," Proc. IRE, Vol. 35, pp. 882, Sept. 1947.

bandwidth.[5] Measurements have been made using filters which were both narrower and wider than the critical bandwidth. Both pure tones and speech mixed with continuous spectrum type noises have been studied. The results of this study show that, for the narrowest permissible bands which can be used to pass speech formants, the number of times the speech formant amplitude in a given band exceeds the noise is small. Also, in these bands, the speech amplitude is never considerably greater than the noise. Since very narrow bandwidths are required to reduce the noise below the signal, the number of bands required to cover the speech spectrum is quite large. There was no satisfactory way of evaluating the effect upon speech intelligence of small contributions from many narrow bands without building a many channeled circuit and evaluating it.

In view of this fact a complete multi-channel system has been developed in order to determine the effectiveness of this method of improving speech intelligibility in noise. The multi-channel system developed contains 80 channels covering the frequency range from 700 to 3200 cps. The bandwidth of each channel is adjustable and each has been set so that it is one half that of the critical band when the signal is 3 db above the threshold level. A schedule of the band centers and their bandwidths is contained in the progress report for January 1957. A preliminary evaluation of the circuit has been performed.

During July evaluation of the noise reduction circuit was continued. A series of tape recordings were made of the noise reducer output for various test conditions. These recordings will provide a permanent record of the effectiveness of the noise reduction circuit. Tests were made for signals

5. N.R. French and J.C. Steinberg, "Factors Governing the Intelligibility of Speech Sounds," Jour. Acoust. Soc. Amer., Vol. 19, Jan. 1947 (See Figure 7).

consisting of speech in noise at various levels above the threshold in 5 db steps. Both flat or white noise and simulated room noise were mixed with speech so that the speech was judged to be just intelligible in the noise before it was passed through the noise reduction circuit. The thresholds of the noise reducer were set either flat, i.e., all equal; or varied as a function of frequency so that they followed the shape of the room noise spectrum. The results of these tests indicate that the signal to noise ratio of the noise reducer output as viewed on a scope is greatly improved, but the improvement of the intelligibility of speech is marginal.

It has previously been found that the peak amplitude of a speech signal must be about 15 to 20 db above the threshold of the noise reducer. Originally the bandwidths of all channels were adjusted for the desired bandwidth when the signal was 3 db above threshold. The bandwidths of the channels are a function of amplitude so it is conceivable that a narrower bandwidth would be more effective for signals 20 db above threshold. In view of this the bandwidths of all channels have been made narrower. Tests for this condition have not yet been made.

During July thirty additional channels were delivered by the model shop. These channels have been tuned and adjusted and are now ready to be added to the low frequency end of the noise reducer. With the addition of these channels the noise reducer will have 110 channels covering the frequency range from 170 to 5200 cps. Evaluation of the complete system is being continued.

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August 7, 1957