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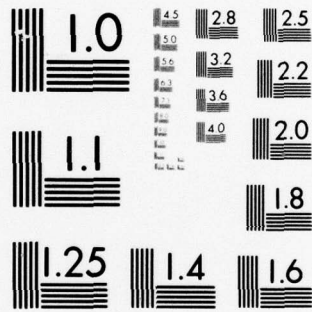
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ADAPTIVE ARRAYS FOR AM AND FM SIGNALS

R. T. Compton, Jr.

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The Ohio State University  
**ElectroScience Laboratory**

Department of Electrical Engineering  
Columbus, Ohio 43212

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This report describes progress under Naval Air Systems Command Contract N00019-77-C-0156 during the first quarterly period. Research on the problem of integrating adaptive arrays into conventional modulation systems is summarized.

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## INTRODUCTION

This report describes progress under NASC Contract N00019-77-C-0156 during the first quarterly period. There are three areas of work under this contract. The first involves experimental tasks with an adaptive array in an AM communication system. The second involves array experiments with an FM communication system. The third consists of theoretical studies of methods of integrating adaptive arrays into other types of conventional communication systems such as single sideband and frequency shift keying.

The AM and FM communication systems involve the addition of a binary phase switching modulation on conventional AM and FM signals. The purpose of this phase switching is to allow the array to distinguish between the desired signal and interference. Implementation of the system with this phase switching requires the construction of an IF delay lock loop for the AM system and a Costas loop and baseband delay lock loop for the FM system, in addition to other peripheral circuitry.

## PROGRESS

During the first quarter of this program, work has been done in three areas as discussed below.

### (1) Implementation of the Array System

Implementation of an adaptive array and the associated signal processing circuitry for the AM system has been started.

A four element LMS adaptive array processor built under a previous contract (DAAG39-72-C-0169) is available at the Ohio State University ElectroScience Laboratory and is being modified for use under the present contract. This array system originally operated over a frequency band of 162-174 MHz. The signals received in this frequency band were mixed down to a 70 MHz IF, where the actual array processing with the LMS weights was done. Under the current contract, we are using the basic 70 MHz processor portion of the array system. This processor includes all necessary circuitry to accept four signals and combine them adaptively according to the LMS algorithm. The preamplifiers, mixers, etc., used to receive the 162-174 MHz signals and downconvert them to 70 MHz are not needed.

To use this processor for the current program, it was first necessary to convert the processing units to a lower frequency, because the bandwidths in the AM and FM systems are too narrow to obtain suitable filters at 70 MHz. We chose to convert the processor to 10.7 MHz, a common IF where such components are available. Changing the processor to 10.7 MHz required changing several hybrids, phase shifters, etc., in the units. These changes have now been completed. Some repairs of damaged components have also been made, and we are now in the process of realigning the

multipliers and integrators. This is a somewhat lengthy procedure that is necessary to get the processor working properly with adequate interference nulling.

## (2) Tests with Biphase Modulation

The second area of work involves the effects of biphase modulation on the audio quality in an AM system. The AM system under study requires a PN coded biphase modulation to be added to the conventional AM signal. As discussed in an earlier report [1], this type of modulation causes envelope distortion when the signal is bandlimited. The distortion results because, with finite bandwidth, the signal takes a finite amount of time to reverse phase. During this interval, the envelope drops to zero and a spike appears in the output of the envelope detector.

Tests have been performed to determine whether the envelope distortion caused by the biphase modulation is objectionable. An AM signal was phase switched by multiplying it with a squarewave voltage and then the resulting signal was envelope demodulated with a conventional AM receiver, as shown in Figure 1. The bandlimiting was provided by the receiver itself, which had a bandwidth of 6 kHz. The resulting receiver audio output was listened to as the frequency of the squarewave was varied.

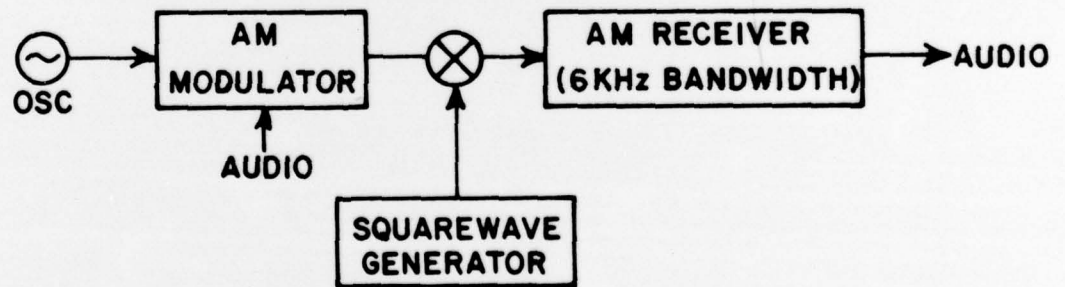


Figure 1. Envelope distortion test setup.

The results showed that the envelope distortion is not objectionable as long as the switching frequency is low enough. Typically, a switching frequency near the low end of the audio band, at 100 Hz or less, is required to make the envelope distortion unobjectionable. The sound produced by the switching when the switching frequency is higher is similar to that produced by ignition noise in an AM receiver.

The problem of envelope distortion can be substantially reduced by using quadriphase modulation in which the phase jumps are constrained not to exceed  $\pi/2$ , rather than biphase modulation. However, quadriphase is more complicated to implement than biphase. For this reason, we have chosen to implement the system initially with biphase modulation. It is believed that array performance will be the same for either type.

### (3) Research on Other Types of Modulation

During this period, research has been done on the use of AM signals with other types of phase modulation besides biphase switching. The goal of this work is to evaluate alternative methods of phase modulation that can be used to provide decorrelation between the desired signal and interference.

Voelcker [2,3] has shown that any bandlimited signal which has a given periodic envelope modulation is one member of a so-called common envelope set of signals. The common envelope set consists of a finite number of signals, all of which have identical envelope modulation and bandwidth, but which have different phase modulations. The conventional AM signal, which has no phase modulation, is one member of this set. The other members of the set, which do have phase modulation, all have the same envelope and bandwidth as the conventional AM signal.

This theory is relevant to the current research problem because it shows how phase modulation can be added to an AM signal so no increase in bandwidth results. With no increase in bandwidth, no envelope distortion will result when the signal is bandlimited. However, the presence of the phase modulation on the signal permits the array to differentiate between this signal and interference. Moreover, the phase modulated signal can also be intermixed with conventional AM signals in a communication net, because it can be demodulated with a simple envelope detector, which will not sense the phase modulation.

To test the usefulness of this idea, some simulations have been done of a 2-element adaptive array in which the desired signal and the reference signal are a phase modulated AM signal. It is assumed that the proper envelope-phase coupling is imposed on the desired signal at the transmitter. Also, it is assumed that interference incident on the array does not have the proper envelope-phase coupling. The purpose of the simulations was to determine whether there is sufficient decorrelation between the interference and the reference signal as a result of this phase modulation to enable the array to null the interference. The preliminary results show that this technique does work, at least when the reference signal is ideal. The results of this study are described in a technical report currently in preparation.

PLANS FOR NEXT QUARTER

During the next quarter, we plan to continue with the development of the circuitry required to operate the adaptive array with biphas modulated AM communication signals. Also, studies on modulation techniques allowing an adaptive array to be used with other conventional signals, such as single sideband and frequency shift keying, will be continued.

## REFERENCES

- [1] L. C. Chan and R. T. Compton, Jr., "An Adaptive Array Technique for AM Signals," Report 4326-3, January 1977, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract N00019-76-C-0195 for Naval Air Systems Command.
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- [3] H. Voelcker, "Toward a Unified Theory of Modulation - Part II: Zero Manipulation," Proc. IEEE, 54, 5 (May 1966), 735.