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Prepared By: [redacted] 50X1
Project Engineer

Approved By: [redacted] 50X1
Chief Engineer

[redacted] 50X1

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INTRODUCTION

This is the fourth progress report submitted on the research and development Task IV. The report covers work done on a pulse time modulation system. More specifically it summarizes the results of tests performed to determine security of the equipment developed using this method of communication.

DISCUSSION

In this application of pulse communication systems, the problem of security is of particular interest. The term security refers to the inability of conventional AM and FM receivers to demodulate the pulse signal. Due to the wave shape of the transmitted signal, as contrasted to conventional amplitude and frequency modulation, it may well appear that only unique methods of detection could convert the pulse to intelligence. Nevertheless there are components in the modulation envelope that may result in detection with a conventional receiver.

Pulse time modulation results in an involved but important mathematical analysis of the modulation envelope. (see appendix). The deviation of the pulse leading edge is one factor in the envelope; the deviation of the lagging edge, if it is not identical, is another factor. Any amplitude variation of the pulse under modulation conditions, introduces a third factor.

Depending on the relative values of the three factors, there may be present three distinct types of modulation; amplitude, duration and phase. By careful use of clipping circuits in the design of the equipment, the amplitude variation under modulation conditions was eliminated. This avoided any amplitude modulation in the transmitted signal. The difference in deviation between leading and lagging pulse edges was made negligibly small by successive differentiation of the pulse. This in turn eliminated pulse duration modulation. Such duration modulation is converted to audio intelligence due to the restricted bandwidth of the audio amplifiers of the conventional communications receivers. Therefore, eliminating this factor is an important contribution toward security.

Phase modulation is the remaining component that accompanies pulse position or pulse time modulation. Phase modulation is a form of frequency modulation, as used in conventional F.M. transmitters. Thus it is to be expected that an F.M. receiver with sufficient bandwidth could convert a P.T.M. signal to audio intelligence. For these tests both an F.M. receiver and an A.M. receiver were used as detectors. All the tests were performed with strong signals. It was found that there was security with an A.M. receiver, and no security with an F.M. receiver that was designed with a 50 kilocycle bandwidth.

It would seem that if the first sideband of the transmitted pulse was wide enough to fall outside of the F.M. receiver bandwidth, security with P.T.M. could be accomplished. Since the sidebands are multiples of the pulse repetition rate, this would necessitate a pulse frequency on the order of 100 kilocycles. This choice, in turn, would result in the modification of the duty cycle or ratio of peak to average R.F. Power from its optimum value. It is the duty cycle that ultimately determines efficiency, size and/or range of the transmitter. Nevertheless it is important to consider the possibilities of attaining security by so simple a method.

TESTING AND EQUIPMENT

The following is a description of the tests performed and equipment designed for an investigation of a pulse time modulated system: Figure 1 is a block diagram of a pulse time modulation transmitter. This consists of two chassis. The first stage is a blocking oscillator operating at 12 kilocycles. This pulse triggers a one shot multivibrator. Also placed on the same multivibrator grid is the audio signal that provides the modulating intelligence.

The blocking oscillator determines the instant of initiation or triggering of the multivibrator, and as a result the instant of pulse leading edge remains virtually in dependent of modulating signal. However, once the tube is triggered, and the fast blocking oscillator pulse is over, the audio signal controls the current flow in the first section of the multivibrator. Since there is a common cathode resistor for the two halves, the audio signal thus determines the bias for the second half. The pulse duration which would normally be controlled by the R-C constant, which would determine the voltage on the grid of the second section, is thus modulated by the audio signal. This results in a pulse duration modulated signal.

The pulse is then passed through a differentiating network which converts it to two pulses of opposite polarity corresponding to the leading and lagging edges of the P.D.M. signal. This is pulse time modulation, where in the pulse corresponding to the lagging edge has its position varied relative to its unmodulated time of occurrence.

The transmitter was designed to accommodate single polarity pulses. This required that the P.T.M. pulses be converted to uni-direction pulses. The clippers and amplifier accomplished this. The second differentiator reshaped the reference pulse to make it more similar to the P.T.M. pulse both as to shape and size.

The signal leaves the modulator as a negative pulse, passes through two video amplifiers, Figure 3, on the transmitter chassis into a power amplifier that performs the modulating function. The R.F. section consists of a tuned plate tuned grid oscillator operating at 74 megacycles. This is a completely shielded stage. The oscillator is lightly coupled to a buffer amplifier which is fed to the R.F. power output stage. The plate of this stage is coupled to the modulator through a pulse transformer, utilizing plate modulation. However, there is no voltage on the R.F. stage plate except for the interval of pulse duration. This prevents R.F. output between pulses and insures a high ratio of peak to average power. The R.F. is loop coupled to a whip antenna.

The receiver, Figure 4, was a television receiver, modified for this specific application. This choice was made for a number of reasons. It provides complete coverage for the frequencies under consideration, 50 M.C. to 216 M.C., it is sufficiently sensitive, and contains a minimum bandwidth of 4 M. C. throughout the video or A.M. channel. In order to pass the pulse without mis-shaping or otherwise distorting, a minimum bandwidth of 2 M.C. is required. In addition the receiver can be readily adapted to work into a P.T.M. detector.

The sound section of the receiver functions as a narrow band frequency modulation detector, with an I.F. bandwidth of 50 KC. The audio amplifiers were re-arranged to be switched to either the F.M. sound stages or the A.M. video stages. This enabled a simple means of testing the P.T.M. signal for security on both A.M. and F.M. channels.

CONCLUSIONS AND FUTURE PLANS

A pulse time modulated transmitter was designed and tested. Checks were made for security in communication using an F.M. - A.M. receiver. Theory was confirmed in that security was obtained with an A.M. receiver, and found lacking in an F.M. detector.

It is planned to investigate further the possibility of accomplishing security with a P.T.M. system, against an F.M. receiver. The P.T.M. demodulator will be completed and the unit will be tested on a system basis. It will be compared to the previously tested pulse amplitude modulated system. Further testing will be done to compare the signal reception of this system to an F.M. receiver, under weak signal conditions.

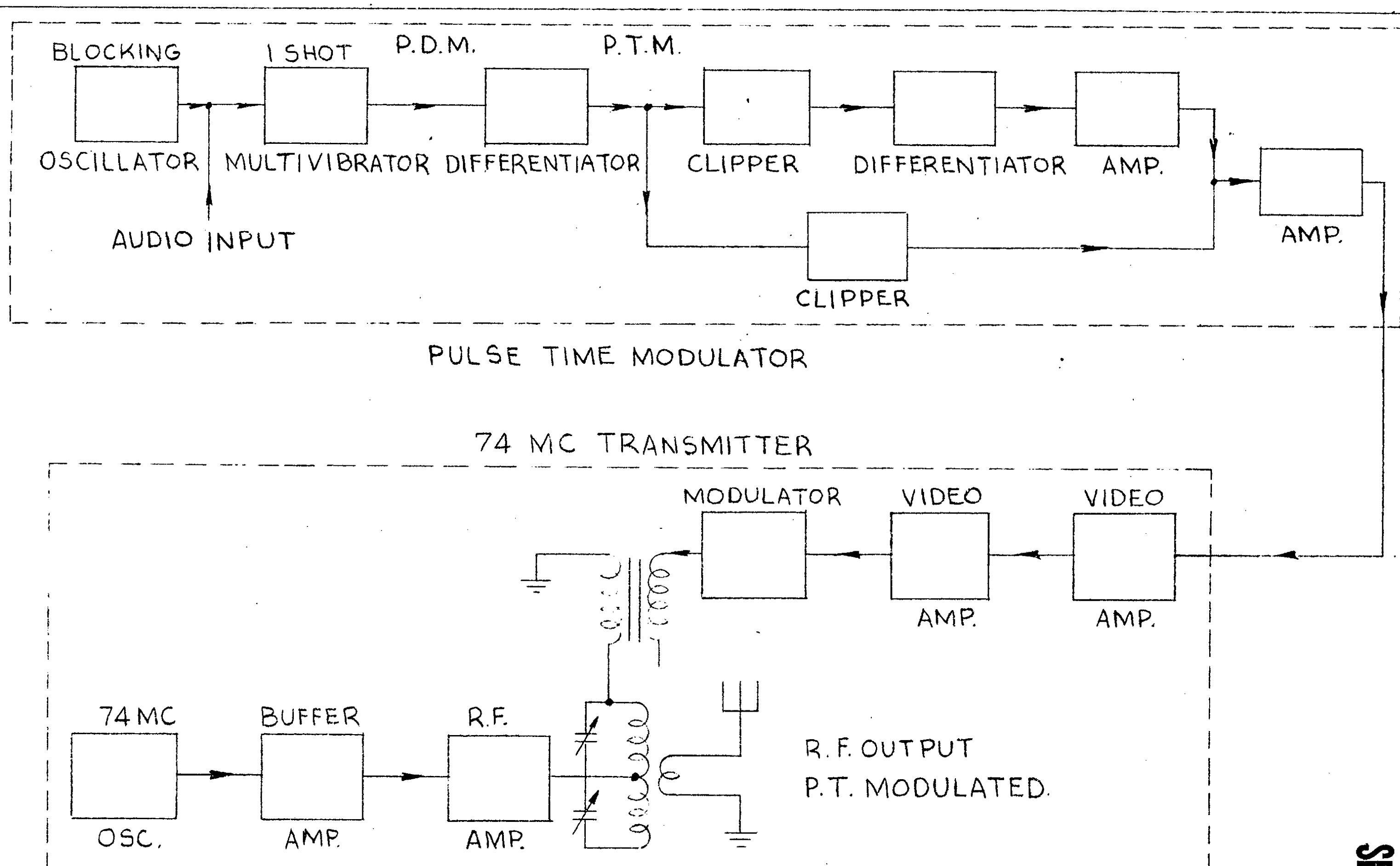

FIG. 1 - PULSE TIME MODULATED TRANSMITTER

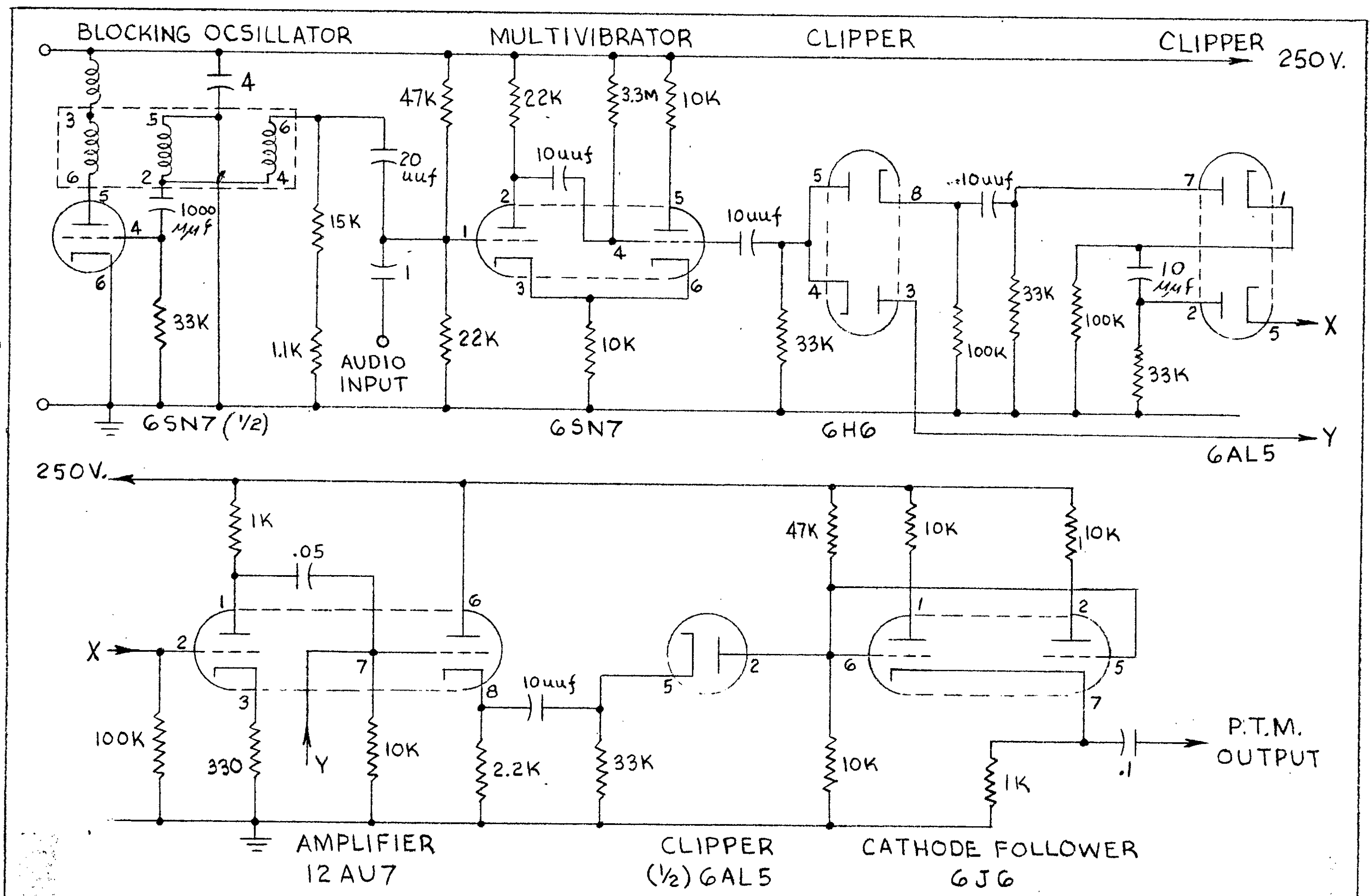

FIG. 2 PULSE TIME MODULATOR

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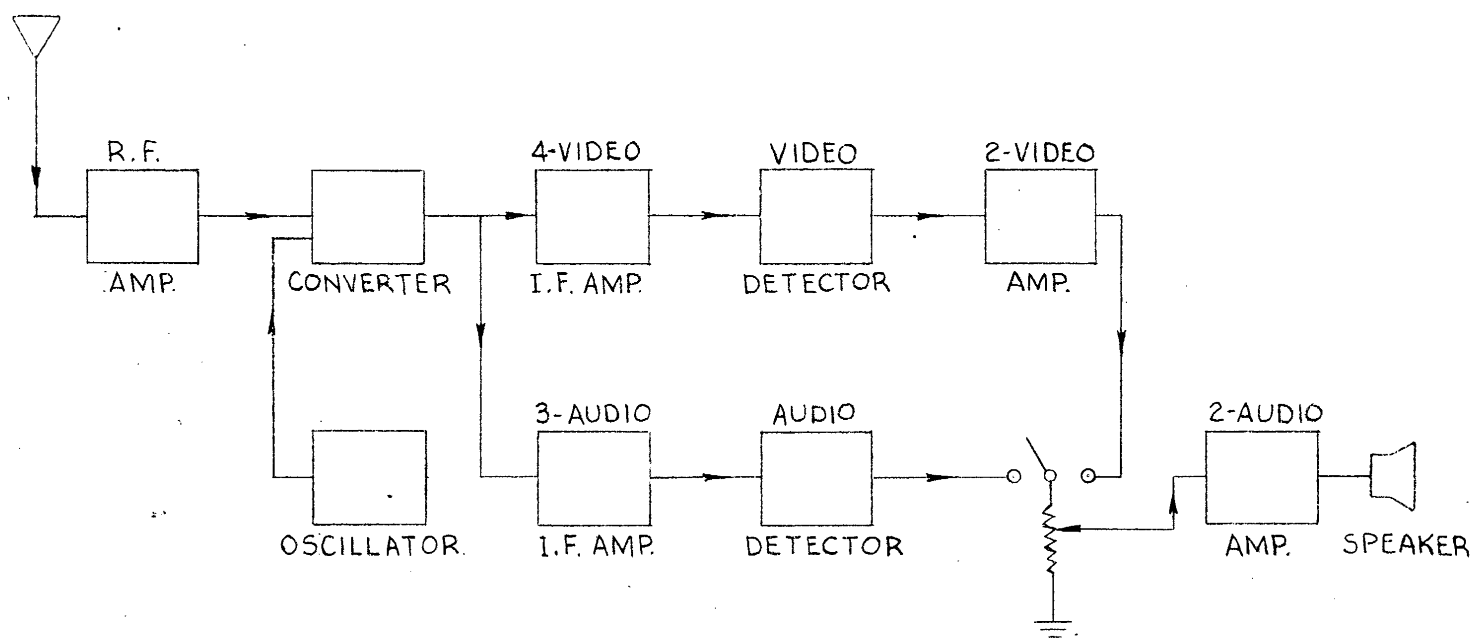

FIG. 4 F. M. - A.M. RECEIVER

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APPENDIX

The following is the spectrum of the modulated pulse position wave.

$$M(t) = \frac{t_o}{T} + \frac{K_2 - K_1 + K_3 t_o}{T} V(T_n) + K_3 (K_2 - K_1) V^2(T_n)$$

$$+ \sum_{m=1}^{\infty} 2 \left[\frac{1 + K_3 V(T_n)}{m \pi} \right] \sin m \omega_c \left[\frac{t_o}{2} + \frac{K_2 - K_1}{2} V(T_n) \right.$$

$$\left(\cos \left[m \omega_c t - m \omega_c \frac{K_1 + K_2}{2} V(t_n) \right] \right)$$

M (t) - Modulated Wave

to - Pulse Duration

T - Interval between pulses without modulation

K_1 - Modulation factor modulating leading edge

K_2 - " " " trailing "

K_3 - " " " amplitude

$V(T_n)$ - n^{th} period that modulating wave (V) was sampled.

W_c - Pulse carrier radian frequency = $\frac{2\pi}{T}$

K_3 and $(K_2 - K_1)$ contribute amplitude modulation only.

$(K_1 \neq K_2)$ contributes phase modulation only.

For $K_1 = K_2$ and $K_3 = 0$, only PPM is present

For $K_1 = K_2$ and $K_3 \neq 0$, both PPM and PAM are present.

Reference: Modulation Theory
By H. S. Black (P. 284)