IV. Communications and Related Projects

A. Noise, Interference and Distortion in Pulse Modulation

Staff: Mr. W. G. Tuller

Experimental Work - A small gas tube pulser, capable of giving pulses with very steep rise and decay and with very flat tops, has been built. It has been used to modulate klystron amplifiers, and the resulting spectrum measured. Particular attention has been paid to far-out spectra, in an attempt to check the interference band width of a pulse modulated transmitter. Some small attempt has been made to check the effect of cavity resonator filters on pulse shape and spectrum, but this whole project needs much more design time spent on special pulse viewing equipment, since the presently available envelope viewers are inadequate in one way or another.

A pulse generator suitable for use in pulse communications research has been constructed and is in operation. This unit delivers, at a repetition frequency of 10 KC, a triple-pulse coded synchronizing pulse, a phase modulated pulse, and a width modulated pulse. The mean position of either the phase or width modulated pulse may be placed in any one of ten "channels" with respect to the synchronizing pulse, or one may be continuously varied anywhere in the cycle while the other remains fixed. The generator also delivers 100 KC, and 1 MC sinusoidal voltages, locked to the p.r.f., for time measurement purposes or high speed sweeps. Pulse output voltage from this unit is 30 volts; mean duration of pulses arbitrarily set at one microsecond but may be varied.

A high power video amplifier to amplify the output of the pulse generator described above has been bread-boarded and is awaiting delivery of the two output tubes for completion. It will deliver pulse voltages adequate for the modulation of c.w. magnetrons or other tubes needing more than 30 volts for modulation.

A pulse decoder, companion unit to the generator described above has been constructed and is now being debugged. This device takes the detected pulse output of a receiver receiving transmission modulated by the pulse generator and will, when completed, convert these pulse modulated signals into some sort of replica of the original modulating intelligence. Two methods of decoding pulse phase modulated signals will be tested. The one, on which amplitude and frequency distortion tests have been made, uses a variant of the radar automatic ranging circuit to give an output voltage proportional to the position of the center of gravity of the modulated pulse. The other method is the more conventional one of converting the phase modulated pulse into a wide width-modulated pulse, which is then decoded by integration. It is expected that the C. G. determination method, which is novel, will give 3 db. better signal-to-noise ratio than the conventional method.

Theoretical Work - A complete analysis of the distortion inherent in the Pound discriminator has been made. This analysis is also applicable to the Foster-Seeley discriminator, widely used in ordinary F. M. receivers but about which no distortion analysis has been published. A report is in process on this analysis.

Preliminary investigations of the Hartley law relating intelligence, band width, and time of transmission have shown this law to be a valuable tool in the analysis and synthesis of communication systems, and a few analytical conclusions have been drawn. The effect of noise on this law has been considered in a qualitative manner.

Some work has been done on an analysis of the automatic ranging circuit used as a pulse phase modulation detector. More needs to be done, but the results so far obtained check qualitatively with experiment.

Specifications have been drawn up for equipment useful in thorough communications research, in the hope that a staff adequate to design and construct this equipment will some day be available.

The effect of pulse length on signal to-noise ratio in pulse phase modulation has been briefly analyzed.

Coincidence detectors and integrators for improving signal-to-noise ratio of pulse phase modulated signals have been designed on paper.

A qualitative study of the effect of interference on pulse-phase modulated signals has been made.

IV. B. Stabilized Oscillator Problems

1. Modulation and Stabilization

Staff: Mr. F. P. Zaffarano

With minor exceptions, little in addition to repeating the experimental work done by R. V. Pound on stabilized oscillators has been accomplished during this period. Since the modulation of stabilized oscillators and not the actual stabilization is the eventual objective, more emphasis has been centered on the system video frequency characteristics than in Pound's experiments.

Two d.c. stabilizing units have been located, repaired, and put into operation using the production type double magic tee assemblies available. A variation of this plumbing assembly to give better stabilizing characteristics for large changes in oscillator power was used successfully. Although several desirable changes in these units were considered, it was decided to go directly to the i.f. type stabilizer which had the advantage of having several additional parameters which could be varied for modulation purposes while simultaneously providing better stabilization.

Rapid alignment of the 30 and 10,000 mc phase adjustments of the two i.f. type stabilizers built has been facilitated by using a sawtooth sweep and oscilloscope to plot the discriminator characteristic continuously.

Both the d.c. and i.f. stabilizers in the form described by R. V. Pound in Reports 815 and 837 have upper half power frequency limits at approximately 20 kilocycles. This is due to the capacity intentionally placed across the reflector circuit to prevent oscillation of the system which occurs as a result of phase reversal of the feedback (the oscillation takes place at approximately 1.2 mc). Increasing the usable frequency response of the stabilizing elements to the order of 2 - 10 megacycles is the present problem at hand.

Data on the following items have been obtained in widely varying degrees of completeness:

a. D.C. versus I.F. stabilizer

(1) Overall gain at d.c.

(2) Frequency-amplitude characteristic

(3) Phase-frequency characteristic

(4) Stabilization - frequency characteristic

(5) Optimum adjustment of variables.

b. Frequency Modulation of Systems

(1) Crystal bias modulation

(2) Modulation of standard cavity

(a) Mechanically

(b) With electron beam

(3) Direct reflector voltage modulation

(a) With low frequency stabilization only

(b) With linearizing stabilization

(4) Modulation of source of I.F. frequency

(a) I-F phase

(b) I-F amplitude

(c) I-F frequency

(5) Modulation with separate crystal in waveguide circuit

The phase detector (lock-in mixer) of the i.f. type stabilizer is the present limiting factor in video response. The "Brute Force" attack using higher r.f. levels and small plate load resistances, would seem to be the most promising. It may be possible, however, to bridge the present phase detector with another detector using a video amplifier. By arranging the cut-off frequencies of each detector the combined phase response may be made to remain essentially constant up to the desired high frequency limit. Both attacks will be tried.

2. D.C. Amplifier Problems

Staff: Prof. T. S. Gray

Study of the stability problems in d.c. amplifiers for use in measurement and control applications and for improvement of microwave discriminators is proposed. In particular, attention will be given to the series-balanced circuit proposed by Artzt,* and a study made of its suitability and practical limits of amplification for use in a cathode ray oscillograph, and in the discriminator work described above.

IV. C. Circuit Problems

1. Study of Waveguides With Dissipative Walls

Staff: Mr. R. M. Fano

Waveguides with highly dissipative walls have been used successfully in the design of broad band high-power loads. It was found in this connection that, if a rectangular guide with highly dissipative walls is joined to a non-dissipative guide of the same internal dimensions, there is always a frequency at which a perfect match is obtained. Experiments showed that this frequency satisfies the equation:

* M. Artzt, Electronics 18 (Aug. 1945), 112-118

$$\frac{f}{f_{co}} = \sqrt{1 + \frac{2b}{a}}$$

where b and a are the narrow and wide dimensions of the guide, respectively. It should be possible to justify the above equation theoretically, at least in the case of relatively small dissipation. Furthermore, it would be useful to know the reflection which takes place at other frequencies as a function of the guide attenuation. Such knowledge would permit the design of matched loads and pads with specified characteristics. This question is presently being investigated.

2. The Broadbanding of Microwave Networks

Staff: Mr. R. M. Fano

The first question to be investigated in this connection is the existence of theoretical limitations on the bandwidth when the maximum VSWR is specified. A solution of this problem will facilitate later the development of practical broadbanding techniques. Work along these lines will begin very soon, using as a starting point the work done on microwave filters during the war.

3. The Extension of the Methods and Procedures of the Circuit Synthesis to Active Networks Involving Vacuum Tubes

Staff: Mr. M. V. Cerrillo

This problem was suggested by Professor Guillemin, because not much constructive and general work has been done in this connection. Most of the solutions are given for very specific and particular cases. Mathematical difficulties are the causes of these restricted solutions.

The way in which the investigation will be conducted to obtain more general solutions is as follows:

An active system will be looked upon as an extended passive one in which the variables must satisfy a specific set of constraints. In this fashion, vacuum tubes will be easily introduced. For a passive system, the currents are such as to keep a minimum the power dissipated in the network. Then, the Calculus of Variations, and to be more specific, the problem of Lagrange will be used as the fundamental mathematical tool in this investigation.

4. Transients in Waveguides

Staff: Mr. M. V. Cerrillo

Preliminary work has been started to investigate the transient phenomena in waveguides. Because of the variable phase constant as a function of frequency, the waveguides act like a dispersive medium. The formulation of the problem is straightforward, consisting of setting up the proper

Fourier Integral. It is expected to obtain the solution in series form. This problem was suggested by Dr. Chu.

5. Miscellaneous Waveguide Problems

Staff: Mr. R. M. Redheffer

The following problems have been studied.

a. Brief investigation of the air-guide equivalences, with regard to the fact that phase is measured perpendicular to the interface in one case, usually, but perpendicular to the wave front in the other.

(b) Brief study of the limiting error from probe reflection as the load reflection approaches unity.

(c) Investigation of the effect of impurity of the frequency on apparent reflection of a short circuit as measured by two methods.

(d) Derivation of a simple but exact free-space relation, and of approximate waveguide relations, for dielectric constant and loss in terms of interface reflection.

(e) Note on the possibility of obtaining a probe with high pick-up but zero probe-error by using a tuner which moves with the probe.

(f) Investigation of the effect of temperature change on the bridge method of dielectric measurement.

(g) Development of a new method of cancelling error due to direct pick-up between antennas when reflection is measured at arbitrary incidence in free space.

(h) Investigation of means for finding loss from interface reflection or from transmission of a sheet at Brewster's angle in free space.

6. Impedance of Magic Tees

Staff: Mr. C. W. Zabel
Mr. E. Gilbert

There are two general types of ring circuit magic tees (colloquially referred to as "rat races"): (1) The type employing a ring whose circumference is an even number of wavelengths long, and (2) the type whose circumference is a wavelength plus an odd number of half wavelengths long. The rat race used in the balanced duplexers is of the second type and has been successful at 3.3 cm. A similar design at 10 cm. was not entirely satisfactory.

A program was started to find out which of the two types of magic tees would be least frequency-sensitive and what design considerations must be made to be able to construct a satisfactory rat race for various frequencies and guide sizes.

Mr. E. Gilbert calculated the frequency sensitivity of both constructions and found the first type to be much more frequency sensitive than the second. For a 12% band at 3.3 cm. the SWVR for the first type was ≤ 1.5, while for the second type the corresponding figure was 1.16. The entire VSWR vs wavelength curve calculated for the second type agreed only roughly with the measured curves for the duplexer rat race. An unsuccessful attempt to explain this disagreement was made by assuming the E-plane T in the rat race to have an equivalent circuit of a simple shunt capacitance.

It was found that no theoretical data existed for the equivalent circuits of the E-plane T of the dimensions used in rat race. An X-band bench was set up and the equivalent circuit measured in two different ways. Due to an unfortunate choice in dimensions of the apparatus the precision of the experiments was not good enough to determine all the parameters of the equivalent circuit.

Mr. N. Marcuvitz was consulted as to the possibility of extending the range of dimensions in the theoretical solution of the E-plane tee. This extension will be available within the next few weeks. Assuming this information available, and by using the eigenvalue method of Dr. R. H. Dicke, simple relations were found to exist between the various parameters of the rat race in order to result in a magic tee. These have been determined only for the rat race of Type 1.