Report on Research on EASYCHAIR

A. Technical Description

The passive modulator may be regarded in a broad sense, as a device which provides the following four functions:

1. Response to unmodulated R. F. energy.
2. Response to audio energy.
3. Modulation of the R F energy by the audio energy.
4. Radiation of the modulated R F energy.

When these devices are excited by R F energy at their resonant frequency, they radiate this energy in a manner similar to radar echo boxes and parasistic antenna elements. The energy radiated by the passive modulator is amplitude modulated by audio energy impinging on the device.

The contemporary type of passive modulator, shown diagramatically in Figure 1, consists of a resonant cavity of the reentrant type. The resonant frequency of the cavity is varied by the audio energy impinging on the unit. When used with a fixed frequency transmitter, this results in a variation of the reactive loading on the antenna, with consequent changes in the magnitude of the reflected wave.

R F energy is coupled into the cavity by means of an antenna rod, one end projecting into the cavity, and the other end extending a half wave length beyond the outside surface of the cavity. The cavity end of the rod is terminated in a capacitive probe which is tightly coupled to the mid-section of the reentrant rod.

To determine the resonant frequency of a cavity of the reentrant type, it is permissable to draw an analogy between the reentrant cavity and a simple LC circuit.[1] The C is formed by the backing plate and the diaphragm, and is of such magnitude that the over-all size of the cavity is small compared to the wave length. The equivalent lumped inductance may be calculated from the formula for inductance of a coaxial system.

(1) $$L = \frac{\mu l}{2\pi} \ln \frac{r_1}{r_2}$$

where:

μ = permeability for the dielectric

l = length of the cavity

r_2 = radius of the cavity

r_1 = radius of the reentrant rod

The resonant frequency is then given by:

(2) $$f = \frac{1}{2\pi \sqrt{LC}}$$

where:

L = equivalent lumped inductance of cavity

C = capacitance between backing plate and the diaphragm

The above relationships neglect the effect of the reactance reflected into the cavity by the tightly coupled antenna.

1 - Ramo and Whinnery, Fields and Waves in Modern Radio
Page 409, Wiley 1948.

When the resonant frequency of the cavity and antenna system is known, a closer approximation of the equivalent lumped inductance is found by solving eq. (2) for L.

B. Measurement Standards

In order to evaluate the relative merit of passive modulator designs developed during the course of this project, a comparative measurement system was established.

For the purpose of studying passive modulators designed to operate in the frequency range of 1000 megacycles, the microwave signal generator, frequency range 1000 to 1300 megacycles, was used as the fixed power level source of R. F. at the selected frequency. Audio excitation of the passive modulator at a fixed sound pressure level, was provided by a loudspeaker fixed to the jig in which the passive modulator was mounted. A calibrated high gain receiver was used to detect the amplitude modulated R F energy radiated by the passive modulator. A Ballantine A C vacuum tube voltmeter monitored the audio output level of this receiver. A block diagram of the set-up is shown in Figure 2.

C. Experimental Results

A detailed study of the performance and characteristics of the contemporary passive modulator was made. Physical and electrical characteristics were determined with a view to optimizing the present design. In this design, a conducting diaphragm is used as one plate of a variable capacitor which varies the resonant frequency of the passive modulator cavity at the impinging audio rate. Mechanically, this operation is analogous to the functioning of a condenser microphone. The contemporary passive modulator design suffers from a lack of audio sensitivity, as does a conventional condenser microphone. The displacement of the diaphragm, in both cases, due to the pressures exerted by the sound field, results in extremely minute variations in capacitance. In the case of the contemporary design, the low audio sensitivity results in a very low percentage modulation of the radiated R F energy. The present state of the art of condenser microphone design, however, indicates improvements which can be incorporated in the design of this type of passive modulator.

Measurements have been made of the sound pressure level, 8 to 10 feet distant from two persons speaking in normal conversational level. This sound pressure averaged 75 db. above the standard reference level of .0002 dynes per square centimeter, for a total of 3.95 milligrams average force acting over the 3.625 square centimeters of the passive modulator diaphragm area.

To enable a direct measurement of the rest capacitance of the passive modulator cavity to be made, the construction of one of the contemporary cavities was modified. An annular sector of the reentrant wall was removed, and replaced with a sector made of polystyrene. In this manner, the reentrant portion of the cavity was insulated from the rest of the cavity. The spacing between the backing plate and the diaphragm measured before the alteration was .001 inches. The altered cavity was readjusted for this spacing and a capacity of 10 micromicrofarads was measured, using a Boonton Radio Corp. "Q" meter. Calculation of the capacitance, using the areas of the plates and their spacing, and neglecting fringe effects, resulted in a value of 12.2 micromicrofarads.

The displacement of the passive modulator diaphragm due to the force exerted by the sound field, results in a capacitance change in the order of .01 micromicrofarads. Since the change in capacitance varies the resonant frequency of the passive modulator cavity at the audio rate, the .01 micromicrofarad capacitance change represents a change in resonant frequency of approximately .8 megacycles. The "Q" of the passive modulator should be of the order of several thousand, in order to obtain an effective percentage modulation from this small change in resonant frequency. Preliminary measurements have been made to determine the order of magnitude of "Q" for the contemporary passive modulator design. An experimental measurement of passive modulator "Q" would best be made by measuring the response of the passive modulator as the frequency of the exciting R F energy was varied. The passive modulator would remain tuned to a fixed frequency and the exciting R F would be audio modulated to enable measurement at the receiver. Measurement by this method could not be made, however, since the audio modulated R F radiated by the passive modulator could not be distinguished from the audio modulated R F received directly from the transmitting unit. The order of magnitude of passive modulator "Q" was determined by means of the experiments discussed below.

Figure 3 is a plot of relative receiver output against separation of diaphragm and the backing plate of the passive modulator. The microwave signal generator, operating at a fixed frequency of 1002 megacycles, fed ten watts of R F power to a ten turn helical antenna. The antenna was directed to activate the passive modulator spaced 15 feet distant. A ten turn helical receiving antenna directed at the passive modulator, fed a Thompson Products Co. wavemeter used as a preselector and crystal detector for a high gain audio amplifier. A Ballantine A C vacuum tume voltmeter served to measure the audio output of this receiver. A loudspeaker operating at a fixed power level at a frequency of 2500 cps., supplied audio excitation of the passive modulator. This unit was placed in the jig used to support the passive modulator. The separation of diaphragm and backing plate, initially .00485 inches, was increased in .00008 inch increments, noting the receiver output for each increment, until receiver output had varied from noise level, through a peak and back to noise level.

The .00008 inch increments were determined by dividing the circumference of the adjustable rear section into 64 parts. The adjustable rear section has 48 threads per inch. Each division on the rear section then represents an advance of .000325 inches. Advance of the threaded section was always in the same direction to minimize backlash. By estimating the thread advance to one-fourth of a division, it was possible to measure an advance of .00008 inches. This curve, as a first order approximation, can be viewed as the response of a passive modulator set at some resonant frequency, not audio excited, plotted against the frequency of incident unmodulated R F energy. Figure 4 is a plot of relative audio output of the receiver against transmitter frequency. During this experiment the passive modulator remained at a fixed setting. The transmitter, passive modulator, and receiver set-up was identical to that used in the previous experiment, with the exception that the transmitter frequency was increased incrementally, starting with a frequency below cavity resonance, through resonance to a value above cavity resonance.

From the results shown graphically in Figure 4, the order of magnitude of passive modulator "Q" may be determined.

Using the relationship:

$$(3) \qquad Q = \frac{f_c}{\Delta f}$$

where:

f_c = resonance frequency

and:

Δf = bandwidth

and taking the bandwidth to be the frequency separation of the two peaks on the curve, 20 megacycles, and f_c = 1000 megacycles, "Q" is approximately equal to 50. This value of "Q" represents that of the loaded passive modulator system. Unloaded cavity "Q" is considerably reduced by the loading effect of the antenna on the passive modulator system.

D. CONCLUSIONS AND FUTURE WORK

Analysis and measurement of the contemporary passive modulator will be continued. Experimental evidence indicates that the operation of this passive modulator design can be improved. By redesign, the "Q" of the device will be increased and the diaphragm construction will be improved, so that increased deflection will result from a given variation in sound level. These improvements will increase the variation in reactive loading on the antenna of the passive modulator, with a consequent increase in the magnitude of change in the reflected wave.

The nickel foil diaphragm of one of the contemporary passive modulators has been replaced by a "Mylar" plastic diaphragm, .0007 inches thick, upon which an aluminum film has been evaporated. This diaphragm is able to withstand extreme physical abuse, with no adverse effects. Diaphragm materials of this type offer promise in passive modulator design. The performance of this passive modulator unit will be compared with one of the nickel foil type, using the measurement set-up discussed previously in this report. Experiments will be performed in an effort to optimize the method and degree of antenna coupling to the contemporary cavity during the next period. Experiments to determine the relative merits of magnetic loop coupling as compared to capacitive probe coupling into the cavity will be conducted.

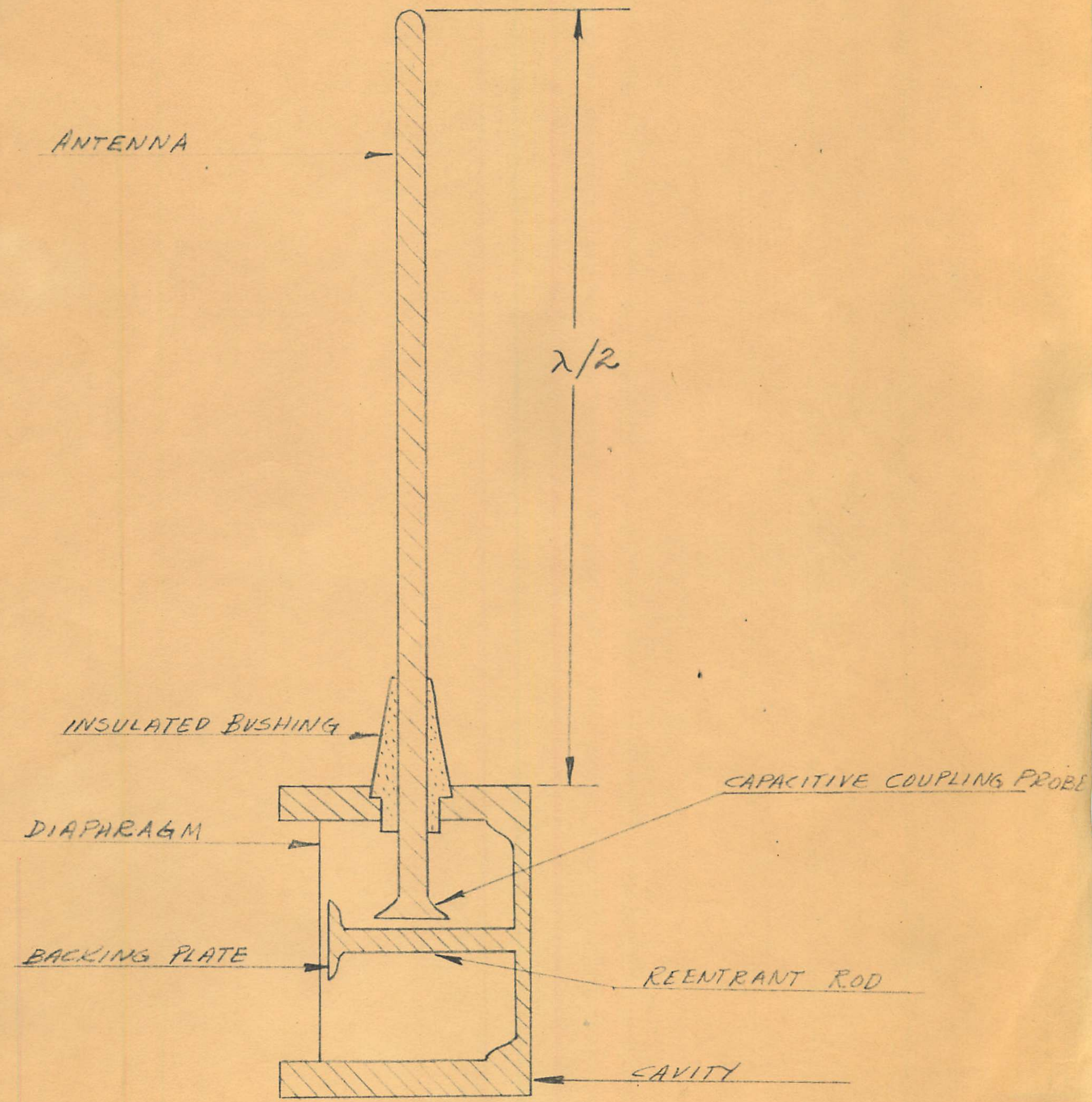

Fig. 1. PRESENT PASSIVE MODULATOR

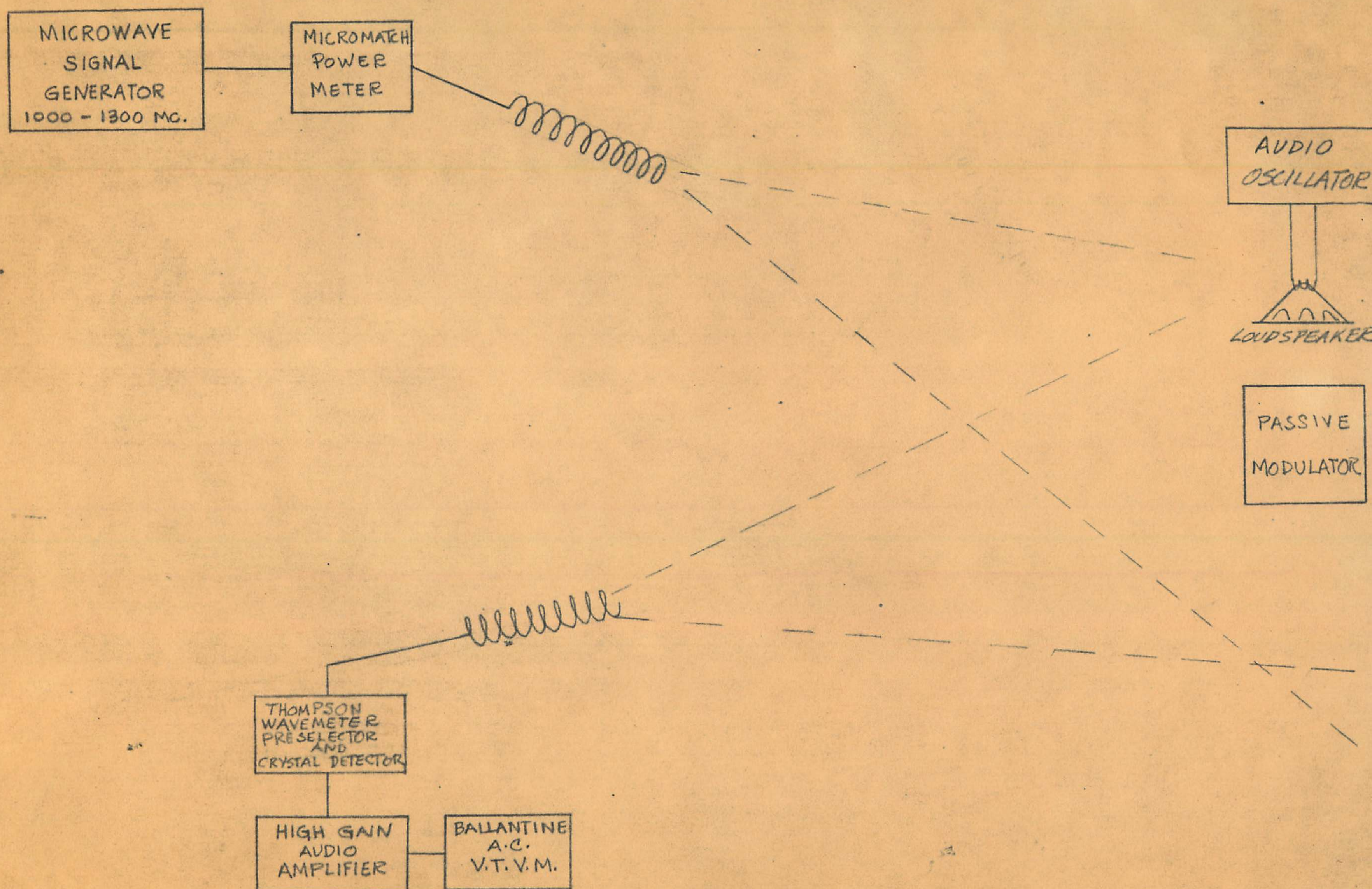

FIGURE 2. BLOCK DIAGRAM OF MEASUREMENT SET UP

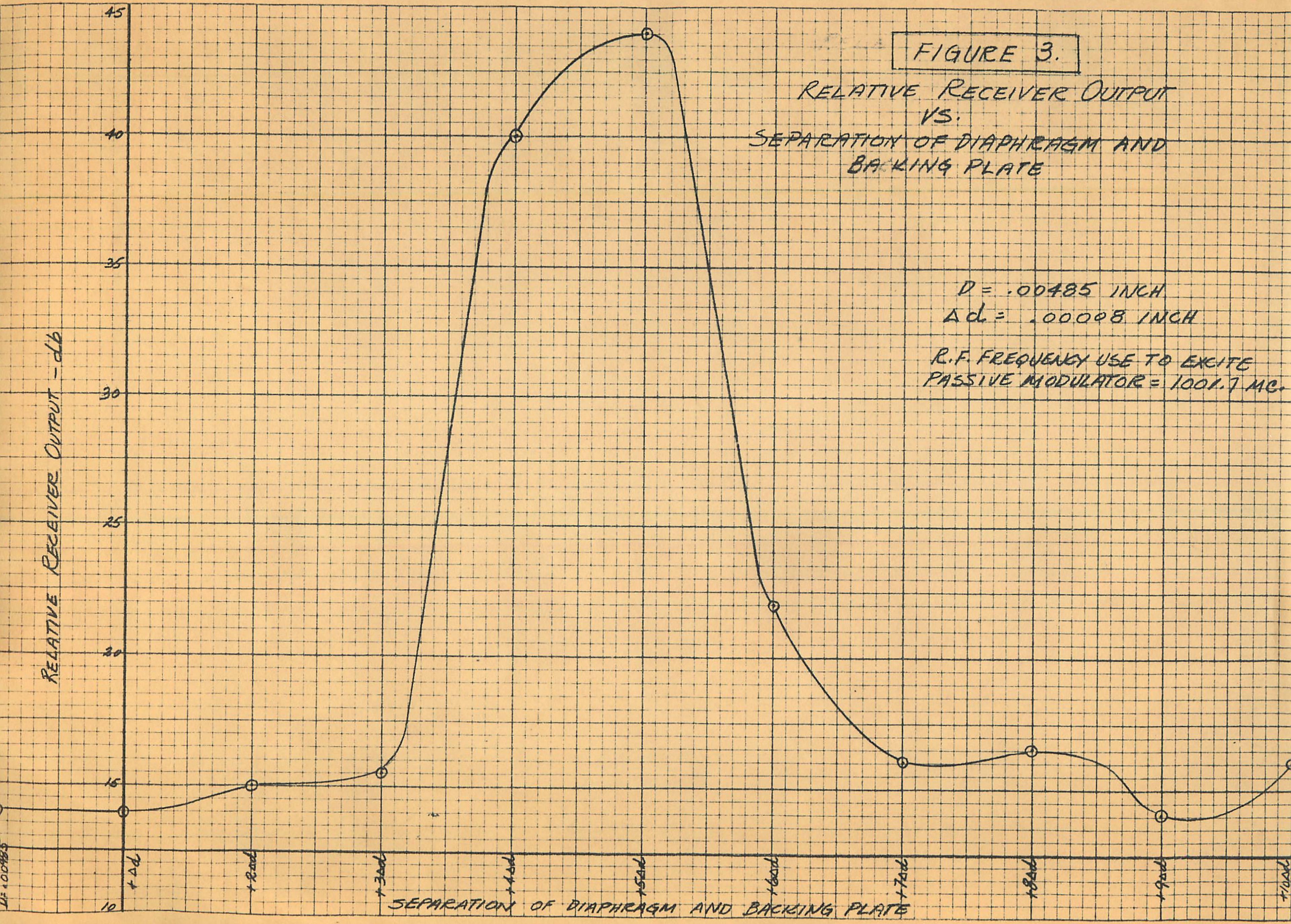
FIGURE 3.
RELATIVE RECEIVER OUTPUT
VS.
SEPARATION OF DIAPHRAGM AND
BACKING PLATE
D = .00485 INCH
Δd = .00098 INCH
R.F. FREQUENCY USE TO EXCITE
PASSIVE MODULATOR = 1001.7 MC.
RELATIVE RECEIVER OUTPUT - db
45
40
35
30
25
20
15
10
D=.00485
+Δd
+2Δd
+3Δd
+4Δd
+5Δd
+6Δd
+7Δd
+8Δd
+9Δd
+10Δd
SEPARATION OF DIAPHRAGM AND BACKING PLATE

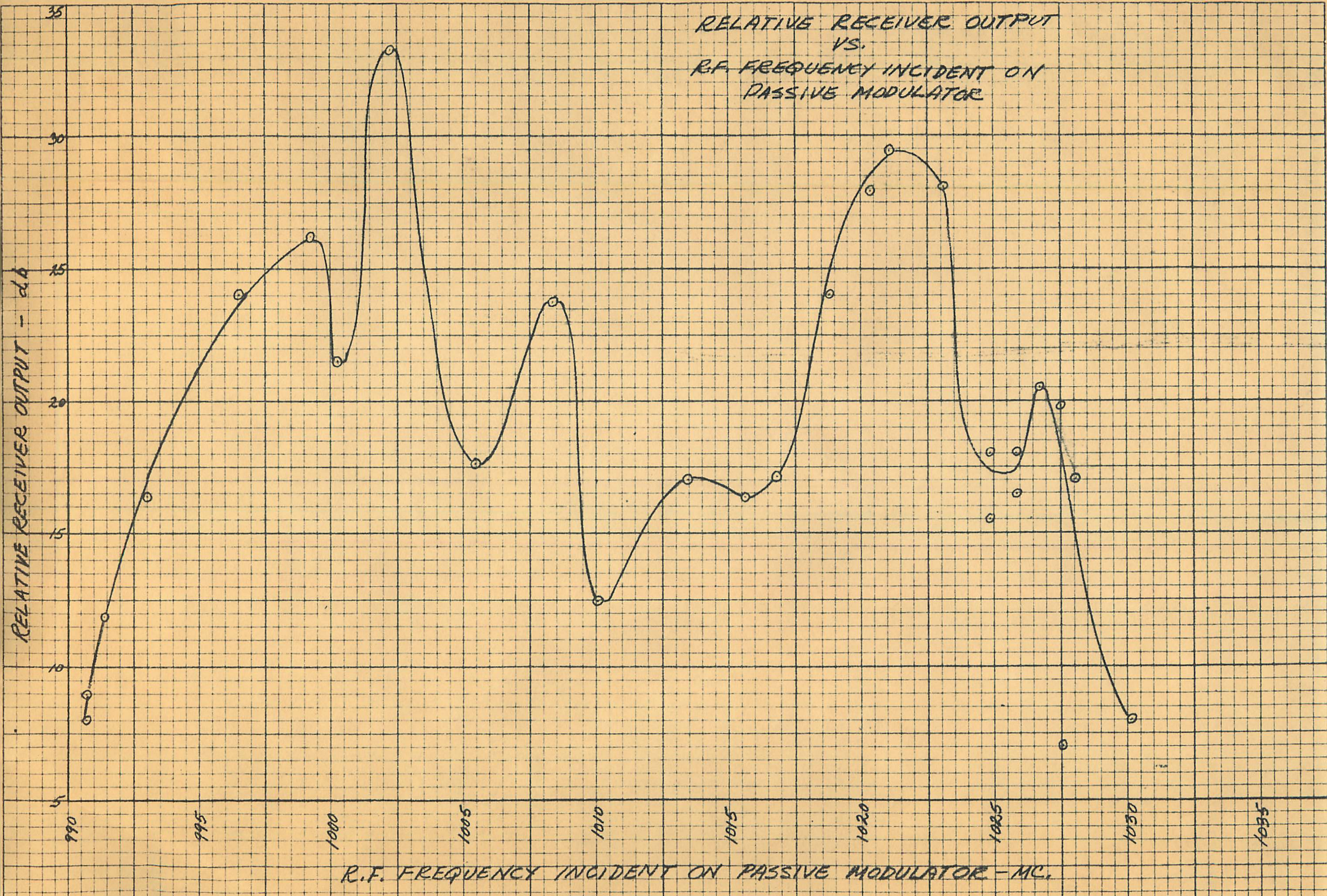
RELATIVE RECEIVER OUTPUT
VS.
R.F. FREQUENCY INCIDENT ON
PASSIVE MODULATOR
RELATIVE RECEIVER OUTPUT - db
35
30
25
20
15
10
5
990
995
1000
1005
1010
1015
1020
1025
1030
1035
R.F. FREQUENCY INCIDENT ON PASSIVE MODULATOR - MC.

FIGURE 4.