QUARTERLY REPORT NO. 3

PROJECT A-693

RADIO FREQUENCY COMPATIBILITY (RFC) ACCESSORY EQUIPMENT SET (U)

H. W. DENNY, W. R. FREE, AND J. R. WALSH, JR.

CONTRACT NO. DA 36-039 AMC-02223(E)
DEPARTMENT OF THE ARMY PROJECT: 1G620501D449

Placed by the
U. S. Army Electronics Research
and Development Laboratories
Fort Monmouth, New Jersey

15 October 1963 to 15 January 1964

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

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SIGNAL CORPS TECHNICAL REQUIREMENT
SCL-7687, dtd. 28 Sept. 1962

The object of this research is to prepare a Design Plan for a Radio Frequency Compatibility Accessory Set.

15 OCTOBER 1963 to 15 JANUARY 1964

PLACED BY THE U. S. ARMY
ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORIES
FORT MONMOUTH, NEW JERSEY

FOREWORD

This report was prepared at the Georgia Tech Engineering Experiment Station on Contract No. DA 36-039 AMC-02223(E). The report covers the activity and results of the third quarter's effort on a study project leading to the establishment of a Design Plan for accessory equipments to be used with Radio Interference Measuring Sets.

Respectfully Submitted:

J. R. Walsh, Jr.

J. R. Walsh, Jr.
Project Director

Approved:

D. W. Robertson

D. W. Robertson, Head
Communications Branch

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I. PURPOSE

The purpose of this project is to conduct a study leading to a Design Plan for accessory equipment to be used with Radio Interference Measuring Sets and signal generators. The accessory equipment includes the complementary devices necessary to determine radio frequency interference characteristics of U. S. Army electrical and electronic equipment in accordance with military specification MIL-I-11748. The frequency range of interest is 0.014 to 40,000 Mc. It is also the purpose of the project to investigate two items of equipment. These are a receiver input coupler and an audio susceptibility tester.

The areas of investigation on this project are divided into three tasks as follows:

I. Evaluation of state-of-the-art items and techniques from the viewpoint of modifying or extending them to fill the Design Plan requirements.

II. Investigation of new techniques and materials when the Design Plan requirements cannot be met by state-of-the-art items or techniques.

III. Verification of findings and conclusions by experimental work when necessary.

II. ABSTRACT

A discussion is presented of several of the items of equipment necessary in a radio frequency compatibility accessory equipment set designed for performing measurements as specified in military specification MIL-I-11748. Major items discussed are the frequency measurement system and a standard response indicator for both CW and pulse systems. The specifications for other accessory items such as directional couplers, isolators, attenuators, dummy loads, and filters are also reviewed.

Experimental work on the deposition of thin film alloys to obtain a film with a temperature coefficient of resistance which exhibits a minimum change of resistance over the temperature range of interest was conducted. Results of this work are shown.

A receiver input coupler which provides for coupling from 50 to 300 ohm transmission systems was designed and its characteristics are shown. The problems associated with the audio susceptibility tester are discussed.

Results of the evaluation of a rejection filter operating in the frequency range 100 to 400 Mc are presented.

III. PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

The Ninth TRI-SERVICE Conference on Electromagnetic Compatibility held in Chicago, Illinois, on 15-17 October 1963, was attended by Mr. J. R. Walsh, Jr.

Mr. H. W. Denny, Mr. W. R. Free, and Mr. J. R. Walsh, Jr. attended a conference held at USAELRDL, Fort Monmouth, New Jersey, 26 November 1963, to discuss details of the Design Plan and possible areas of needed developmental work.

Mr. Sidney Weitz and Mr. Guy Johnson visited Georgia Tech on 16 December 1963 to discuss project technical matters.

IV. FACTUAL DATA

A. Accessory set components

Development of the Design Plan continued with primary emphasis being placed on details of the accessory items. This resulted in the specification of the more important characteristics of these items deemed necessary for the Test Set. Generally the specifications conform to the present state-of-the-art. In some cases available components are not adequate and the specifications are those which are considered desirable for testing purposes.

1. Frequency measuring system

MIL-I-11748 does not require an extremely precise determination of frequency; however, in the interest of providing a test set that will be of maximum usefulness it is desirable to supply frequency measuring capabilities that will meet the requirements of MIL-STD-449A as far as possible. MIL-STD-449A requires the determination of frequency to an accuracy of one part in 10^6.

Using a transfer oscillator, accuracies of this degree can be obtained to 12 Gc. In the waveguide bands above 12 Gc frequency meters are generally accurate to one part in 10^3. Hewlett-Packard in one of their application notes[1] describes a frequency measuring system that provides much better accuracy in waveguide bands and is useful from dc to 40 Gc. This system uses a standard transfer oscillator to produce harmonics to 12.4 Gc which affords direct measurement to this frequency. An auxiliary output from the harmonic oscillator is amplified and subsequently applied again to other mixers to produce harmonics from 12.4 to 40 Gc. A minor problem exists in the use of the system in that the determination of the harmonic number of the signal supplying the beat note may be difficult for inexperienced personnel. Perhaps further investigation could develop a simplified method for readily determining the harmonic number.

2. Standard response indicators

In order to perform the majority of the receiver spectrum signature measurements described in MIL-I-11748 and MIL-STD-449A, it is necessary that an output monitoring device or standard response indicator be connected to the output video or audio terminals of a unit under test to determine the presence or absence of a desired signal-to-noise ratio under various interference conditions. Since instruments to satisfactorily accomplish this function have not been found to be readily available, the requirements and proposed configurations for such instruments or an integrated instrument are discussed in the following paragraphs.

a. Pulsed systems. A block diagram of a proposed standard response indicator for use with pulsed systems is shown in Figure 1. Two input signals are required for the instrument—a video input from the output of the receiver under test and a pulse repetition frequency (PRF) synchronizing signal from the modulator of the simulated radiator (the signal generator supplying the desired signal). The desired video, interfering signal, or signals, and noise are amplified in the video amplifier. The output from the video amplifier is split into two channels—a noise channel and a pulse channel. The noise gate samples the noise and interference immediately preceding each desired pulse. This noise sample is applied to a noise threshold amplifier which has an adjustable threshold which determines the noise and interference level which will be maintained at the output of the video amplifier. That portion of the noise and interference sample which exceeds the

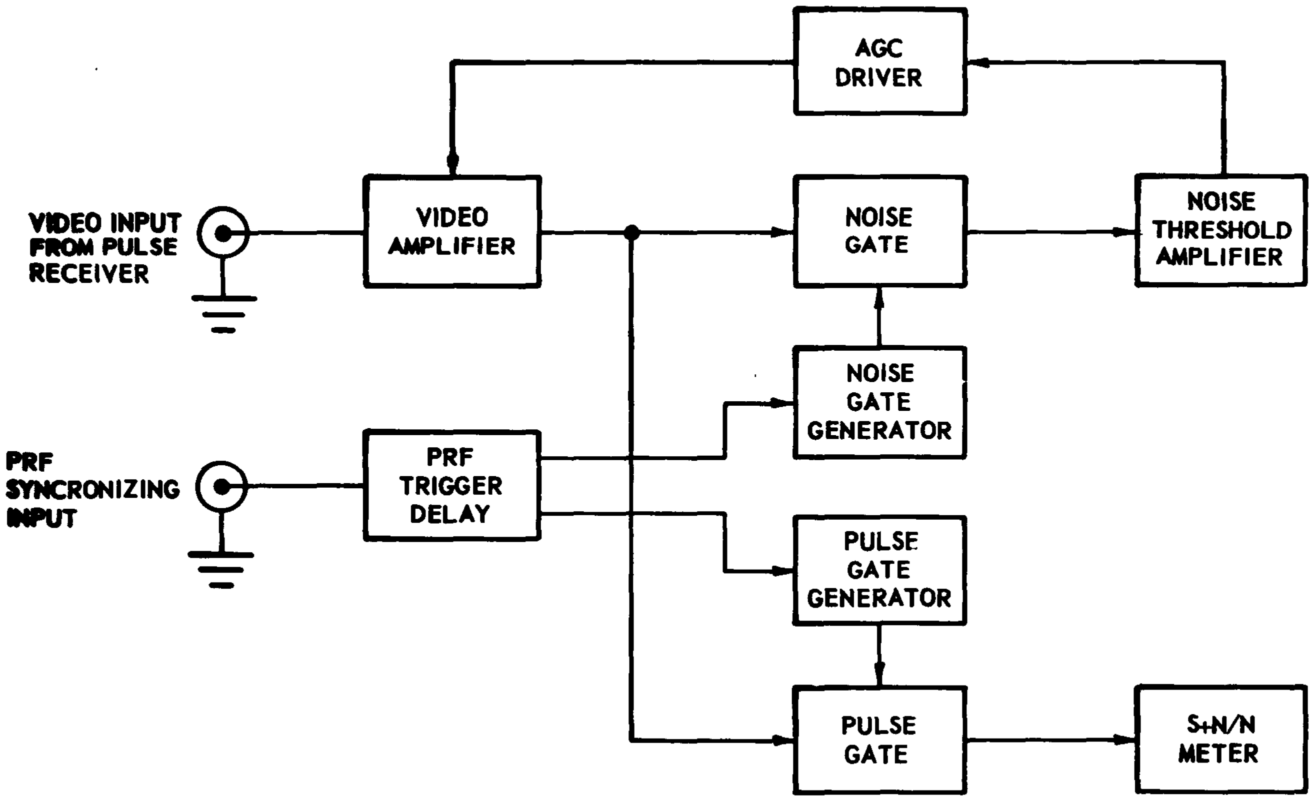


Figure 1. Block Diagram of a Standard Response Indicator for Pulsed Systems.

selected threshold level is amplified and applied to the automatic gain control (AGC) driver stage. The amplified noise samples are integrated and converted into a dc voltage in the AGC driver stage. This AGC voltage controls the gain of the input video amplifier to maintain the noise and interference level at the output of the video amplifier at a desired level, independent of the input level.

It is apparent from the above discussion that the combination of the input video amplifier and the AGC loop results in a known, constant level of noise and interference being maintained at the input of the pulse channel, independent of the level of the noise and interference level at the input of the video amplifier. Since the amplitude of the desired pulse is changed proportionally to the input noise and interference level in the common video amplifier, it is only necessary to measure the pulse amplitude to establish the $\frac{S+N}{N}$ ratio of the input video signal.

The desired pulse is gated into the pulse channel by means of the pulse gate. The gated pulses are applied to a peak voltmeter which provides a continuous, direct reading of $\frac{S+N}{N}$ ratio in decibels on a front panel meter.

A PRF synchronizing waveform is required to maintain the proper timing of the various gating waveforms. The relative timing, position, and shape of the various waveforms required for the proper operation of this instrument are shown in Figure 2. The PRF trigger delay circuit generates a trigger in response to each PRF synchronizing pulse. This trigger is delayed from the leading edge of the PRF pulse which triggered its generation by the proper amount to position it 25 μsec before the next PRF pulse. The delay range over which the circuit must operate is determined by the PRF range over which it is desired to operate. Assuming a 100 to 20,000 pps PRF range, which appears adequate to cover the vast majority of systems presently in the

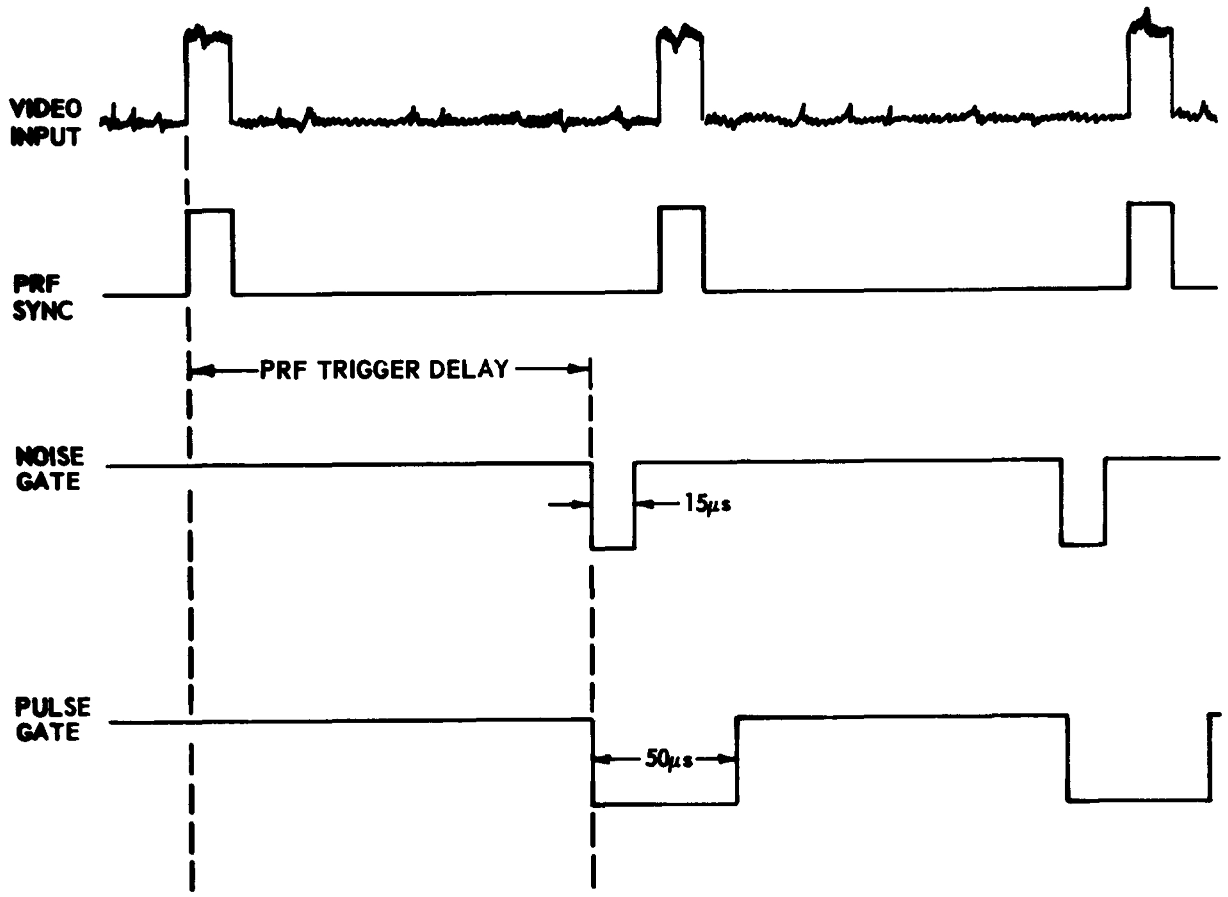


Figure 2. Waveforms for Standard Response Indicator.

field, the delay range required would be 25 μsec to 10 msec. A delay circuit capable of covering this range is readily obtainable. The delayed trigger from the PRF trigger delay circuit triggers the noise and pulse gate generators. The noise gate generator provides a 15 μsec noise gate starting 25 μsec before the next PRF pulse and ending 10 μsec before the pulse. The 15 μsec gate width is recommended on the basis that it is a sufficiently wide sample to drive the AGC driver and sufficiently narrow to be compatible with the minimum inter-pulse spacing at a PRF of 20,000 pps. The 10 μsec spacing between the trailing edge of the noise gate and the leading edge of the PRF pulse is felt sufficient to accommodate the gate turn-off time, the delay circuit jitter, and the PRF jitter. The pulse gate generator provides a 50 μsec pulse gate starting 25 μsec before the next PRF pulse and ending 25 μsec after the start of the PRF pulse. The 50 μsec pulse width is suggested on the assumption that all PRF pulses encountered will have a rise time of less than 25 μsec, and in addition, will reach their maximum amplitude during this period. On the other hand, the 50 μsec width is compatible with the minimum inter-pulse spacing at the maximum PRF. If all pulses will not reach their maximum applitude within 25 μsec, it will be necessary to make the pulse gate width variable. However, this will complicate the circuitry, controls, and operation and should be provided only if essential.

A more sophisticated, fully transistorized standard response indicator based on this same basic technique has been described in the literature.[2] The instrument described provides a Go/NoGo output signal in addition to the front panel meter reading. This feature would be necessary for radiated receiver measurements and, in some cases, for conducted measurements where the operator is required to be located at a point remote from the receiver-under-test. This instrument also includes a pulse position indicator circuit which makes it possible to accurately position the gates without an external oscilloscope or an extremely precise calibration of the delay dial (the delay must be positioned to an accuracy of approximately ±5 μsec over the range from 25 μsec to 10 msec). These features can be added to the system described without too much difficulty, and their inclusion in any system to be developed should be considered.

b. CW, AM, and FM systems. A block diagram of a proposed standard response indicator for use with CW, AM, and FM systems is shown in Figure 3. Only one signal input is required for this instrument—the audio output from the receiver under test. The desired audio, interfering signals, distortion components, and noise are amplified in the input audio amplifier. The output from the audio amplifier is split into two channels, a noise channel and a signal-plus-noise channel. The noise amplifier in the noise channel contains a tunable notch filter which notches out the desired audio signal (desired test tone) and amplifies all other components. The amplified noise-plus-interference-plus-distortion sample is routed to a noise threshold amplifier which has an adjustable threshold which determines the noise and interference level which will be maintained at the output of the input audio amplifier. That portion of the noise and interference sample which exceeds this threshold is amplified and routed to the AGC driver stage. This stage integrates and converts the input signal into a dc AGC voltage. This AGC voltage controls the gain of the input audio amplifier to maintain the noise-plus-interference-plus-distortion level at the output of the audio amplifier

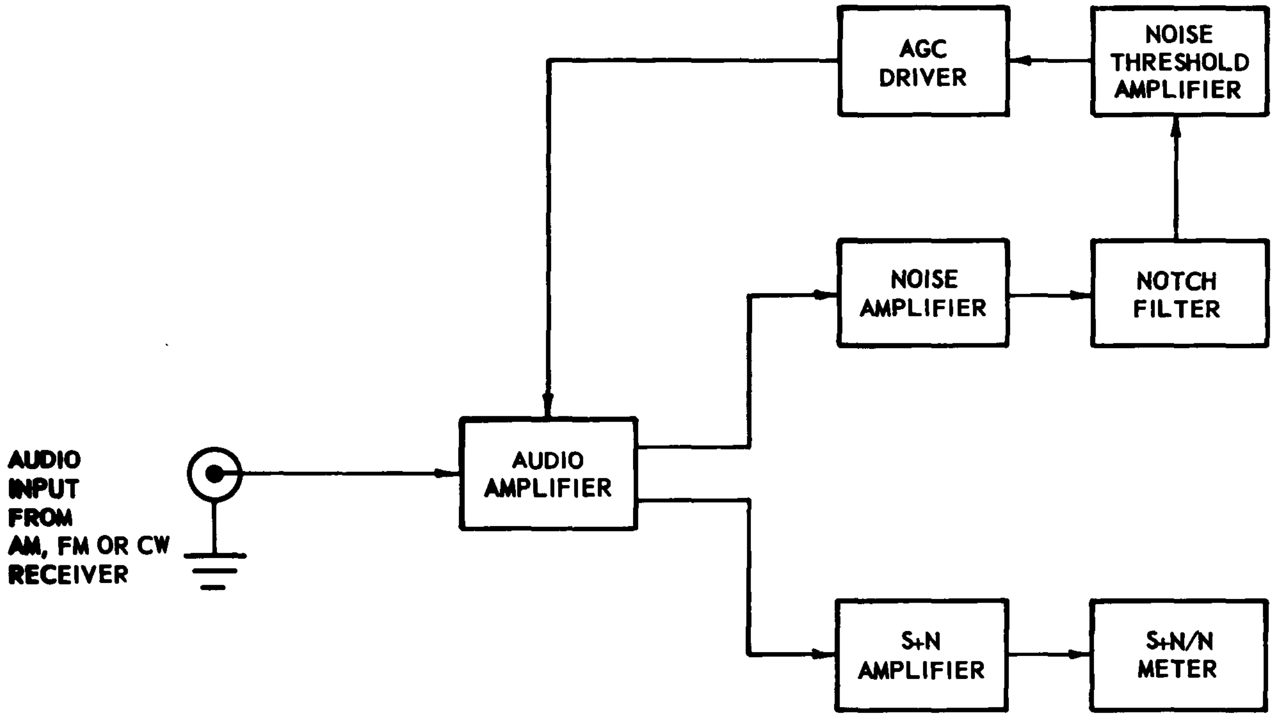


Figure 3. Block Diagram of a Standard Response Indicator for AM, FM, and CW Systems.

at a desired level, independent of the input level.

The noise-plus-interference-plus-distortion level at the input of the signal-plus-noise channel is a known, constant level, and hence, since the amplitude of the desired signal is changed proportionally to the noise level in the common input audio amplifier, it is only necessary to measure the amplitude of the composite signal to establish the $\frac{S+N}{N}$ ratio of the input audio signal. The total audio signal, including the desired signal, is amplified in the signal-plus-noise amplifier, and the output is applied to a voltmeter. The voltmeter provides a continuous, direct reading of $\frac{S+N}{N}$ ratio in decibels on a front panel meter.

This system utilizes the same basic technique that has been utilized in distortion analyzers for some time. However, providing two separate channels and the AGC loop makes it possible to obtain a continuous, direct reading of $\frac{S+N}{N}$ ratio without the inconvenience of switching from "notch in" to "notch out" positions, adjusting the input level, and determining the difference between two meter readings. In addition, a simple circuit to provide a Go/NoGo output signal to permit remote operation can be readily added to this system, but presents a real problem with the distortion analyzer. It would probably be desirable to add a two-pole switch to (1) open the AGC loop and (2) disconnect the S+N amplifier output from the voltmeter and connect the noise threshold amplifier output to the voltmeter during tuning of the notch filter. This would allow the notch filter to be tuned to the desired signal frequency by tuning for a dip on the meter.

It is apparent from the above discussions of the two proposed standard response indicators that two different techniques are required to operate with pulsed and CW, AM, and FM systems. Pulsed systems require a time division multiplex technique while CW, AM, and FM systems require a frequency division multiplex technique. However, in order to obtain a general purpose standard response indicator, the two techniques can be integrated into a single instrument as shown in Figure 4. Not only does this approach provide a general purpose instrument, but a significant amount of the circuitry (power supplies, output voltmeter, etc.) can be shared between the two functions.

Based on the information available[2] it appears that a fully transistorized, portable general purpose standard response indicator is quite feasible. It is anticipated that such an instrument will significantly improve the accuracy, repeatability, and correlation of spectrum signature measurements on pulse, CW, AM, and FM receivers since it will permit a given signal-to-noise ratio to be established more accurately, a given ratio to be reestablished any number of times over both short and long periods of time, and provide a common standard for various measurement teams operating at remote locations.

3. Directional couplers

A general discussion of the requirements of signal samplers was included in Quarterly Report No. 1. Directional couplers in particular seem to be the most useful sampling device at frequencies where they are usable.

Since couplers are needed to sample the transmitter output signal, their power handling capabilities are of prime importance. Ideally they should be capable of handling the rated power of the transmission system which is the case for waveguide narrow wall couplers. Narrow wall couplers also meet the 40 db coupling criterion as established in Quarterly Report No. 1 and are available commercially to cover waveguide bands through 40 Gc.

Commercial coaxial couplers are generally rated at 1,000 watts or less which is lower than the rating of the coaxial line. Octave bandwidths are available above 240 Mc.

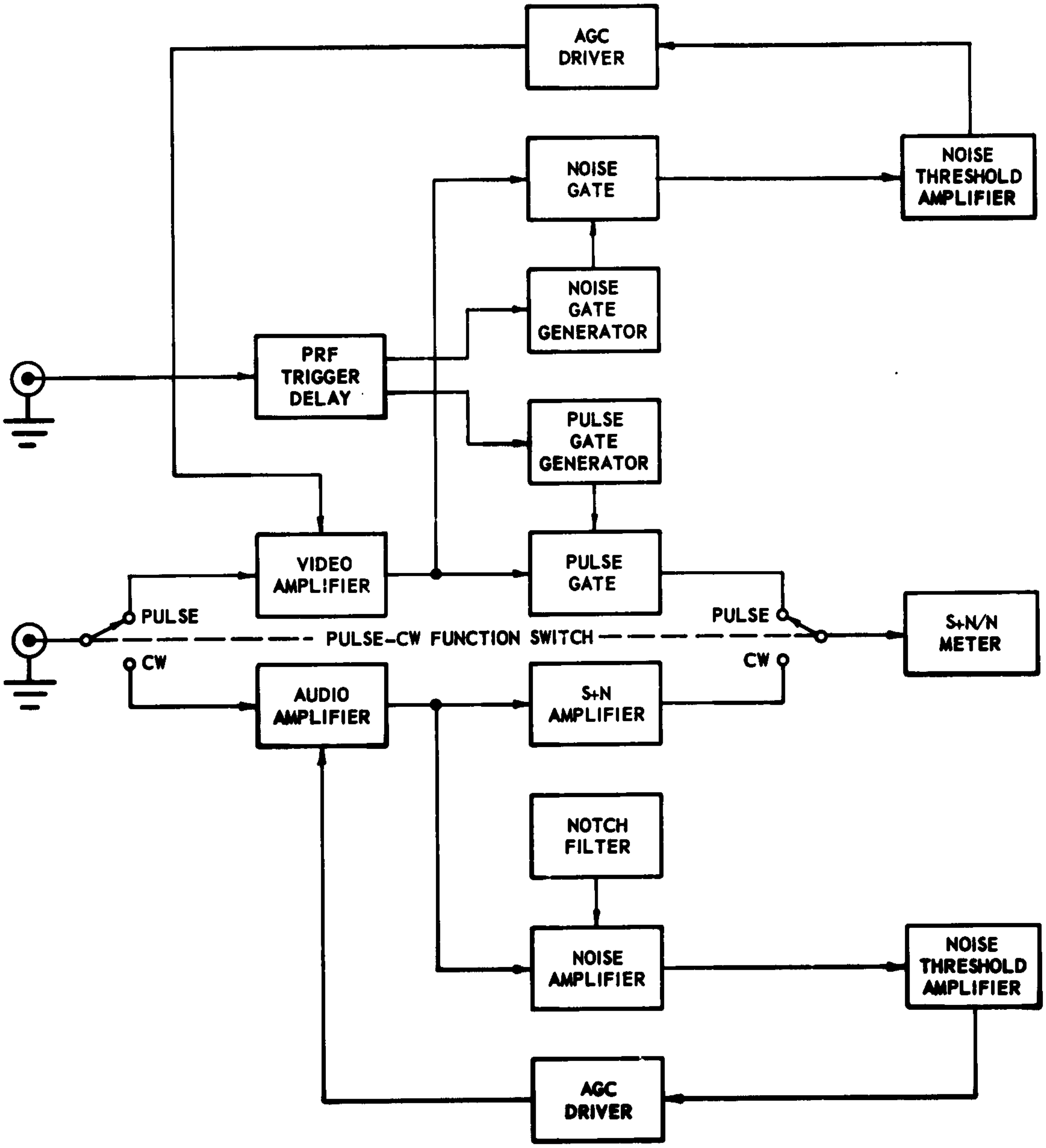


Figure 4. Block Diagram of an Integrated Pulse-CW Standard Response Indicator.

A variable probe coupler such as the General Radio Model 874 GAL coupler could be used from 100 to 240 Mc. This coupler possesses a power handling capability of approximately 1,000 watts at 100 Mc which decreases inversely as the square root of the frequency.

In Quarterly Report No. 2 the conclusion was reached that a high powered attenuator would be useful as a sampling device from 14 kc to 100 Mc. If space requirements or heat dissipation presents a problem as it might in a field setup, the resistive coupler referred to in Quarterly Report No. 1 would be more appropriate. Further evaluation of this resistive sampling technique needs to be done before selecting this method.

Merrimac Research and Development, Inc. advertises two models of an IF directional coupler that collectively will cover from 0.15 to 200 Mc with a nominal coupling of 15 db. The severest limitation on these couplers is the one watt power rating, but it is quite likely that the power rating can be raised and the coupling value increased.

Desirable specifications for coupling devices are as follows:

a. Waveguide

Bandwidth: standard waveguide band
Power rating: rating of waveguide
Coupling: 40 db ± 3 db
Type: narrow wall
Directivity: 20 db
VSWR: 1.10:1
Insertion loss: 1 db
Secondary line VSWR: 1.3:1

b. Coaxial:

Bandwidth: octave coverage (minimum)

Power rating: 1000 watts

Coupling: 40 db

Directivity: 30 db (nominal)

VSWR, 1.3:1

Insertion loss: 1.0 db

Secondary line VSWR: 1.3:1

Impedance: 50 ohms

4. Isolators

In Quarterly Report No. 2 reference was made to the usage of isolators to reduce undesired reflections at the input of a receiver. An isolator could be used to reduce an excessive VSWR by attenuating the reflected wave. Isolators may be used effectively to minimize generator intermodulation that is a problem in conducting the receiver intermodulation test. The placement of an isolator in each signal path attenuates the interfering signal and reduces the possibility of product frequency generation in the signal generators.

Coaxial isolators are generally available in octave bandwidths or greater above 500 Mc. Waveguide models are available that cover a waveguide band.

Specifications:

a. Waveguide

Bandwidth: standard waveguide band

Isolation: 20 db

Insertion loss: 1 db

VSWR: 1.15:1

Power (avg): 10 watts

b. Coaxial

Bandwidth: octave (minimum)

Insertion loss: 1 db

VSWR: 1.25:1

Power (avg): 10 watts

Isolation: 20 db

Impedance: 50 ohms

5. Attenuators

Attenuators are useful in any measuring setup for extending the range of power measuring instruments. They may also be used to provide a reference impedance for insertion loss measurements and to reduce reflections occurring in a mismatched system.

Two basic techniques are used in building a coaxial attenuator that is broadband. The lower frequency type which is useful from dc to 4 kMc is a resistive T section network consisting of a disc resistor between two rod resistors in a coaxial line. The higher frequency model which is useful to 11 kMc is a distributed element attenuator conisiting of a matched resistive element in the center conductor of a coaxial line.

One type of waveguide attenuator utilizes a section of resistive material parallel to the electric field lines in a rectangular guide. The attenuation is adjusted by appropriate placement in the electric field region.

The power handling capabilities for a given size attenuator are generally determined by the temperature characteristics of the resistive material. Special construction techniques providing for better heat dissipation make possible higher powered attenuators. For the purpose of the Design Plan, 1 watt attenuators will probably be adequate since they will be used after the coupler or other signal sampler.

The data from some manufacturers indicate that closely matched attenuators are available that exhibit small variations from their nominal attenuation over limited frequency ranges. The typical characteristic curves indicate that the specifications on the variation of attenuation are relaxed in an attempt to extend the frequency coverage.

The typical VSWR specification is in the neighborhood of 1.5:1. More closely matched units are necessary to avoid exceeding the 1.3:1 specified for the Test Set. If the attenuator is to be used to correct mismatches, its residual VSWR must be low enough to permit correction to within the desired limits.

Desirable specifications for fixed attenuators are:

a. Waveguide

Frequency range: waveguide band
VSWR: 1.15:1
Attenuation: 10 db ± 1 db
Power (avg): 1 watt

b. Coaxial

Frequency range: 0 to 11 Gc
VSWR: 1.3:1
Attenuation: 6 db ± 0.5 db
Power (avg): 1 watt
Impedance: 50 ohms

6. Dummy Loads

The selection of a dummy load is influenced by a number of factors. Although a specification of the Design Plan is a 10 kw CW power handling capability, a termination of this capacity is not practical or necessary in most cases. The physical size alone would be incompatible with the rest of the accessory items. In addition, present state-of-the-art does not include such power handling capabilities above 1500 or 2000 Mc.

A review of the testing setups reveals that limitations of other accessory items make extremely large terminations unnecessary. The main line and secondary line power rating of coaxial directional couplers place an upper limit on power requirements for loads unless higher power couplers become available. For instance, a 1 kw main line rating on couplers would negate any higher power requirements on terminations. A higher powered transmitter would require that its output be radiated in order to perform spurious emissions tests and other tests involving the higher power transmitter output.

A problem is also encountered in transmitter intermodulation tests in that the amount of power that can be handled by the secondary line of a directional coupler is generally much less than the capacity of the main line. This is true for both coaxial and waveguide models. Coupling of higher powered transmitters must then be done by radiation, which removes the need for terminations. The power line tests and emissions tests on waveguide systems could be done as readily with the transmitter loaded with its associated antenna. The mainline power limitation of couplers for waveguide systems does not seem to be a problem since narrow wall directional couplers are capable of handling the rated power of the guide.

Dry loads, either air-cooled or liquid-cooled, are generally limited in their frequency coverage from dc to 10 Gc (or less) or to a waveguide band. Above 1 kw capacity they become rather large. Water loads are smaller in size, allow the greatest dissipation of power in the microwave region, and provide a wider useful frequency range. An adequate water supply is required which may not always be available in a field test setup. Water reservoirs and cooling units of a practical size limit the capacity of such loads to 2 kw in the absence of a large supply of water.

Thus, on the basis of the considerations of excessive physical size, limitations in state-of-the-art, and characteristics of the test setups a termination capable of handling 10 kw is neither necessary nor practical. A 1 kw load should be adequate for the Test Set. At the higher waveguide bands, transitions could be used to adapt the guide to lower band load. The frequency characteristics of the load must be compatible with the frequency of the signal to be absorbed.

Specifications:

Type: unspecified
Frequency: as wide as the state-of-the-art permits
VSWR: 1.1:1 (maximum)
Power: 1 kw

This nebulus frequency coverage specification is intended to encourage the selection of a load that will absorb as many harmonics of a signal as possible. Proper termination of a transmitter through at least its tenth or higher harmonic permits more accurate measurements to be made.

7. Filters

Quarterly Reports Nos. 1 and 2 discussed several considerations in the selection of filters along with some aspects of their commercial availability.

Although variable low-pass and high-pass filters are desirable, improved performance of fixed frequency filters may be the deciding factor in the final selection. Trade literature indicates a marked improvement in skirt characteristics as well as extended out-of-band performance. The number of fixed filters is of course larger than the number of variable filters to cover the same range. The consideration of fewer pieces of equipment is offset by the generally slower cutoff characteristics of the variable filters.

Band-pass and band-reject filters must be variable because of the impracticality of predetermining where in the testing range that the filters would be required. Trade literature does not permit a complete determination of the commercial availability of adequate filters.

Throughout the coaxial range low-pass and high-pass filters should be chosen with cutoff frequencies that will insure differentation between the fundamental and the second harmonic. If the cutoff frequency is chosen to be about 1.8 times the next lower cutoff frequency, sufficient overlap is provided. The skirt attenuation should rise rapidly enough to reach at least 60 db within 5 per cent of the cutoff frequency.

The following specifications are considered desirable, though not necessarily optimum, for filters to be used in test work:

a. Low-pass

Passband attenuation: 1 db

Stopband attenuation: 60 db

Skirt attenuation: 60 db within 5 per cent of f_c

Extent of stopband: 6 f_c

Spurious responses: none within stopband

Power rating: 2 watts

VSWR: 1.2:1 (see note)

b. High-pass

All specifications identical to those for low-pass filters except the passband should extend to 2 f_c.

c. Band-pass

Type. variable

Tuning range: octave or standard waveguide band

Bandwidth: 1 per cent of the tuned frequency

Out-of-band attenuation: 60 db within 1 per cent of f_c

Power rating: 2 watts

VSWR: 1.2:1 (see note)

d. Band-reject

Type: variable

Tuning range: octave or standard waveguide band

Bandwidth: 1 per cent of the tuned frequency

Skirt attenuation: maximum of 6 db within 1 per cent of f_c

Power rating: 2 watts

VSWR: 1.2:1 (see note)

The present state-of-the-art may be hard pressed to meet some of the specifications on the variable band-pass and band-reject filters. The specificiations were selected to be of maximum usefulness in a test program.

Note. Most filter specifications give the passband or tuned frequency characteristic impedance or maximum VSWR. For testing purposes it is desirable to know the out-of-band impedance or mismatch. A constant impedance filter would provide the most reliability in that its effect on out-of-band signals would be of a more predictable nature.

B. Experimental work

1. Thin film load

Increased effort was devoted to the thin film load this report period. Quarterly Report No. 2 presented a discussion of a possible configuration for a coaxial load. Before a final configuration can be selected and evaluated, characteristics of the power absorbing element must be known. Therefore, before directing additional effort toward the configuration, further evaluation of thin film resistors has proceeded.

A number of methods for producing a metal film on a substrate are known in the present-state-of-the-art. Firing, electroplating, evaporation, sputtering, and pyrolytic deposition are some of the well known techniques. Evaporation and sputtering have long been used for producing precise films over a small area; these processes can be used to deposit most metals and nonmetals. For the purposes of this effort, they are not easily applicable due to the requirement for a vacuum system capable of enclosing the substrate.

Pyrolytic deposition is an attractive technique because of its adaptability to larger surfaces. The only compounds available to the project were those of molybdenum and tungsten, both of which require an inert atmosphere during the process. Adequate information was not available on the quality control obtainable when applying the material to a large surface.

The firing process involves depositing the desired metal by applying a resinate solution to the substrate and then removing the carrier by heating. It is a simple process to use from an equipment requirements standpoint. Quality control is a matter of art in that it greatly depends upon the experience of the individual applying the film of resinate solution.

For the purposes of investigation to this point in the development, the firing process was chosen as being the most readily available, most easily applied, and least expensive to use. Using this technique, investigations of the temperature coefficient of resistance (TCR) of several samples of metal combinations were performed with a minimum of time.

Platinum and gold resinate solutions were applied to alumina substrates in varying combinations and fired. Table I presents a summary of the results of nine samples. It is of interest to note that the alloys of metals exhibit

TABLE I

ELECTRICAL RESISTANCE DATA ON THIN FILM RESISTORS

Sample No.	Composition+	Substrate	Resistance++	TCR
1	1-0	Alumina+++	42.4	.00189
2	1-1	"	5.9	.00035
3	1-1	"	20.8	.00039
4	1-2	"	301.5	.00031
5	2-1	"	16.0	.00048
6	1-1.5	"	18.1	.00042
7	1-3	"	41.5	.00066
8	1-1	"	40.4	.00037
9	1-1	Fuzed Quartz	12.7	.00044

\+ This column gives the ratio of the volume of platinum resinate solution to gold resinate solution respectively. These resinate solutions are supplied by Engelhard Industries, Inc.

++ Resistance at room temperature after any annealing was done.

+++American Lava Company, AlSiMag 614.

a lower TCR than does the single-metal sample. The lowest TCR's are produced by approximately volumetrically-equal solutions of platinum and gold.

Sample 9 was fired on a fuzed quartz substrate. The slightly higher TCR is characteristic of films applied to smooth substrates as opposed to rough surfaces.

Figure 5 shows the resistance versus temperature behavior of five samples which demonstrate the typical behavior. The definitely greater temperature dependence of the single-metal resistance is shown by sample 1. Figure 6 shows the per cent change in resistance versus temperature for selected samples. Room temperature (25° C) is taken as the reference temperature. These curves are from data that were taken after annealing of the film.

Attempts were made to fire rhenium resinate but difficulties were encountered due to the absence of a firing procedure. Rhenium oxidizes at about 350° C and above this temperature an inert atmosphere must be supplied. Platinum-rhenium alloys produce very low TCR's and for this reason rhenium is being investigated.

Palladium has demonstrated a low TCR[3] for a pure metal. No reports of experiments with a platinum-palladium alloy have been found. Palladium is a relatively inert metal with a melting point near that of platinum, and it should be easier to fire than rhenium. In view of these characteristics, some palladium resinate solution has been ordered. Further examination of palladium and rhenium alloying with platinum will be conducted upon receipt of the resinate and required firing procedure for the rhenium.

Power dissipation tests were conducted on samples 3 and 9 by applying 60 cps power to the sample. A hot spot developed near the center of sample

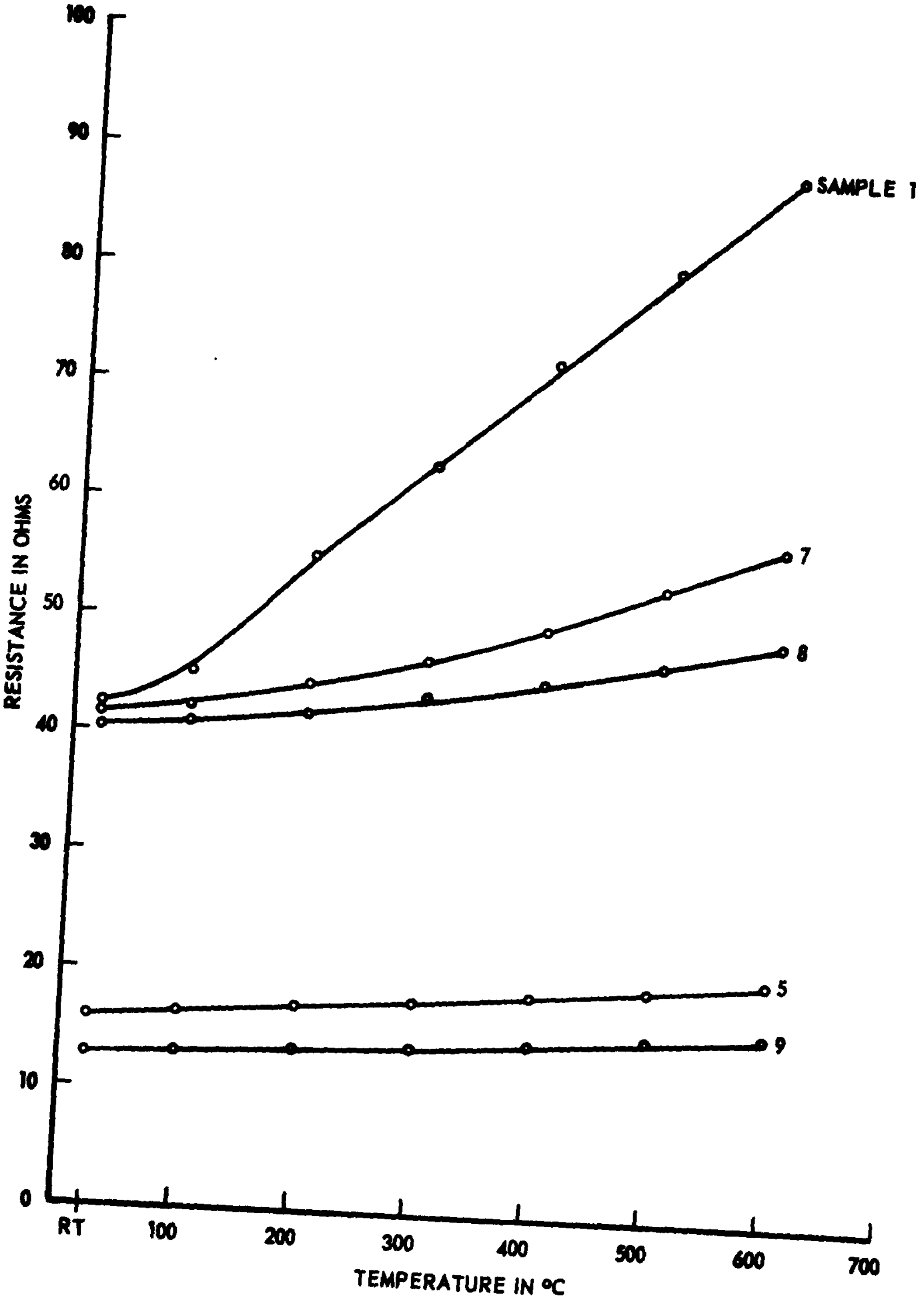


Figure 5. Resistance Versus Temperature Behavior for Five Fired Resistance Samples.

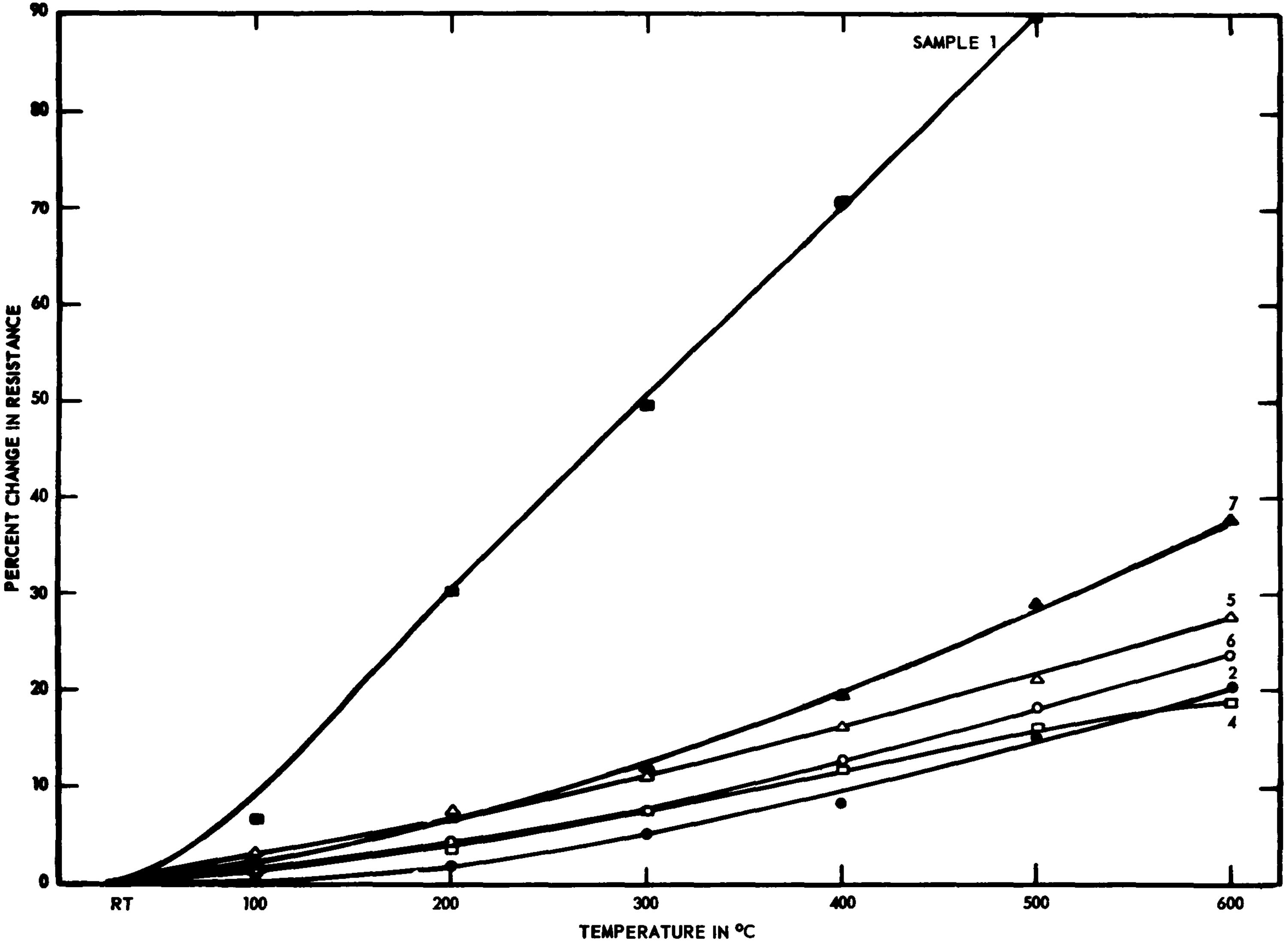


Figure 6. Per Cent Change in Resistance Versus Temperature for Six Fired Resistance Samples.

3 which resulted in a crack developing around the unit. It appeared as though the localized heating caused an increase in resistance and the two effects cascaded to failure. The power test was run on sample 9 to observe the differences in the quartz and alumina substrates. More even heating occurred over the sample but this could have been due primarily to a more uniform film on the smooth surface. Film failure appeared to be in the nature of film agglomeration. Agglomeration has been found[3] to occur at about half the melting temperature. Probably agglomeration of the gold used in the film resulted in failure. This particular effect was the primary factor prompting the consideration of higher melting point metals such as rhenium and palladium as the alloying material for platinum.

The power dissipation tests resulted in a revaluation of the load configuration presented in Quarterly Report No. 2. The two samples tested failed at less than 300 watts applied power. The first configuration requires the heat developed in the resistor to be predominantly radiated to the shell and then removed by convection and radiation. At the temperature allowable, radiation is not an efficient mode of heat transfer. To provide a larger dissipating surface it may be necessary to plate the resistive element on the outer conductor and taper the inner conductor.

2. Receiver input coupler

Quarterly Report No. 2 reported the development of a minimum-loss resistive coupler that could be used to match a 50 ohm system to a 300 ohm system. This coupler exhibited an insertion loss rise up to 150 Mc which then leveled off at about 15 db.

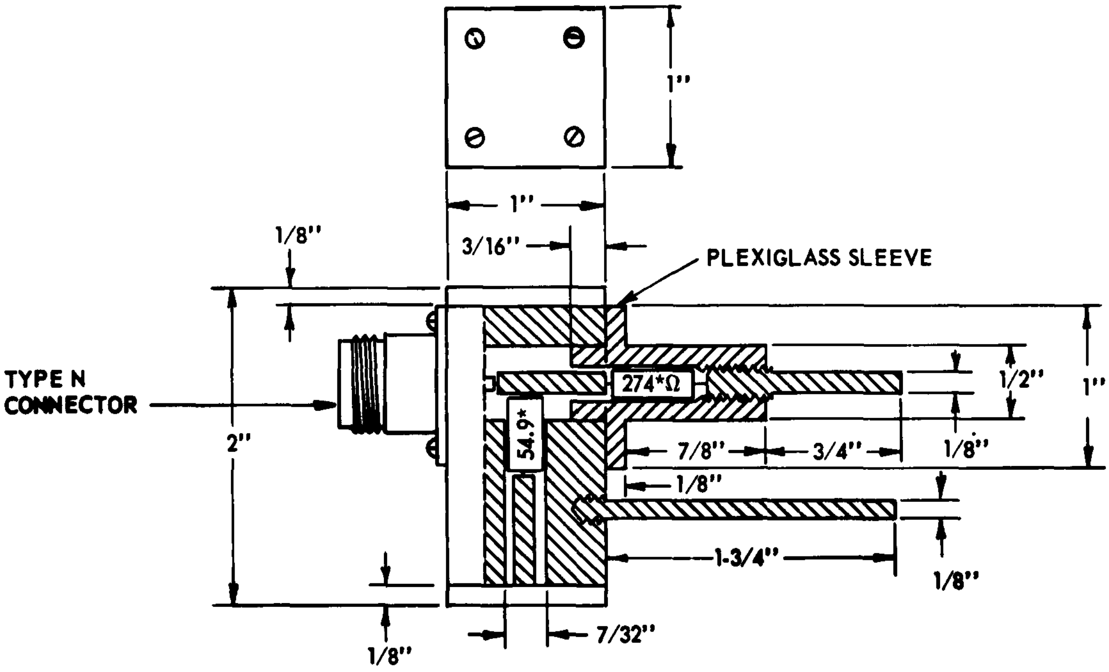
This quarter the holder was redesigned and precision resistors were purchased. International Resistance Company, Type MEB, 1 per cent tolerance, resistors were obtained.

Experimental investigations revealed that the 274 ohm resistor in series with the 300 ohm line must be placed exterior to the metal body to flatten the insertion loss characteristic. This was accomplished by placing the resistor inside a plexiglass sleeve support that affords adequate mechanical rigidity to the 300 ohm terminals. Figures 7 and 8 show more clearly the construction of the coupler.

Figure 9 shows how the insertion losses for two units in tandem and the input impedance for one unit vary with frequency. The total insertion loss for the two units is 26.5 db on the average from 14 kc to 400 Mc Attributing half of the total loss to each coupler, each unit has a 13.25 db insertion loss, which agrees favorably with the idealized figure of 13.42 db for a minimum loss resistive pad. The maximum input impedance shown on the curve represents a VSWR of 1.2 in a 50 ohm system.

3. Audio susceptibility tester

Work continued during the third quarter on the audio susceptibility amplifier and transformer. Several designs of transistorized power amplifiers to furnish the audio susceptibility testing voltage were considered. An amplifier was constructed and tests are presently underway on this unit. This amplifier consists of a driver and power output stage. The power output stage is a conventional arrangement of PNP power transistors in a bridge configuration, one half of the bridge being made up of a series connection of the power transistors and the other half of the bridge being the positive and negative power supplies. The load is connected between the midpoint of the power supplies and the power transistors in such a manner that the dc current can be balanced out of the load. Additional sets of power transistors may



COUPLER BODY & 300 OHM TERMINALS MADE OF BRASS

*IRC TYPE MEB RESISTORS

Figure 7. Partial Cutaway Drawing of Receiver Input Coupler.

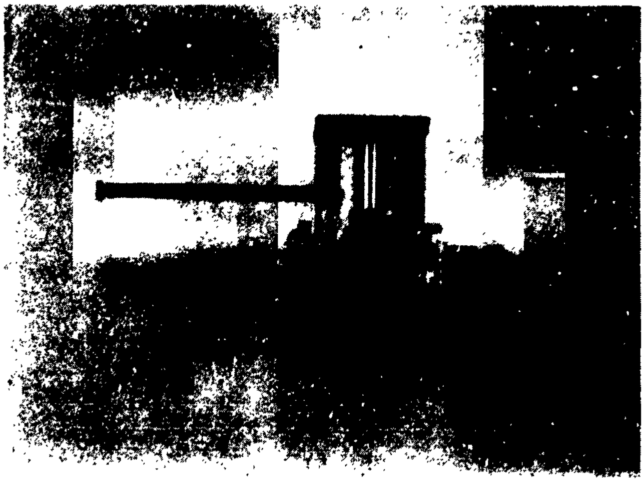


Figure 8. Photograph of One of the Receiver Input Couplers.

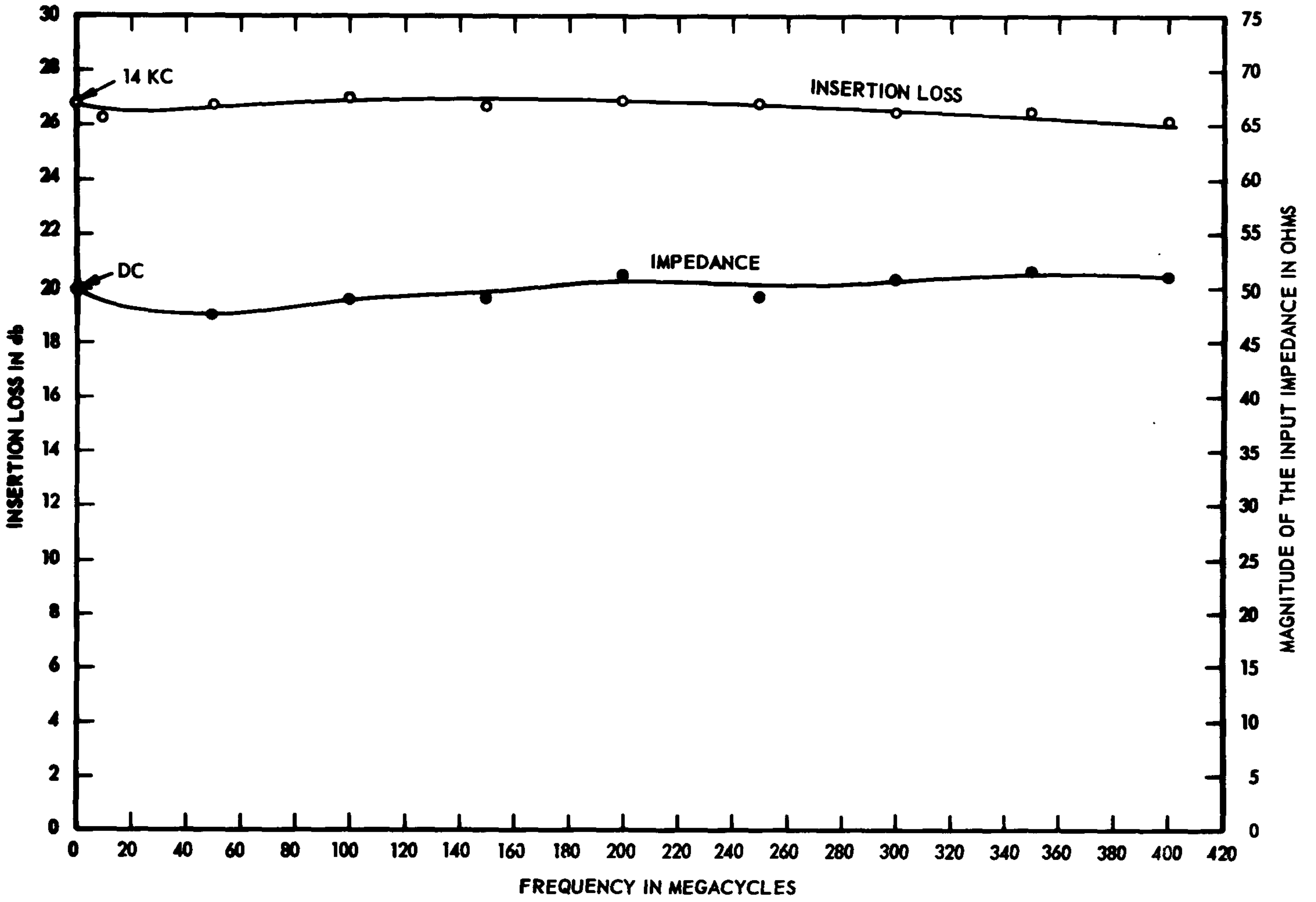


Figure 9. Insertion Loss and Input Impedance Variations with Frequency for the Receiver Input Coupler.

be paralleled with those in the power output stage to increase the power handling capababilities. A transformer was constructed to obtain the phase relationship of the driving signal required by the output stage because of the use of all PNP transistors. This amplifier has operated at a 30 watt level with what appears to be an adequate thermal margin.

Consideration is being given to the possible operation of the transistors in a series configuration of two transistors to replace one transistor to obtain a higher breakdown voltage. The problem of transients which may be passed back through the transformer and their effect on the amplifier has been considered. Several methods of possible protection of the amplifier include the use of zener diodes, or surge suppressing selenium rectifiers, to limit the voltage of transients on the primary of the coupling transformer. Protection of the amplifier in case of the loss of the low electronic output impedance must be considered also since it is this impedance which is depended upon to keep the power frequency voltage drop on the secondary of the coupling transformer within the specified limits. Loss of the low amplifier output impedance could result in a high voltage being applied to the amplifier.

A possible method which may be used to protect against the steady state situation under these conditions is to short circuit the transformer winding on the amplifier side with a set of relay contacts when the amplifier power source is lost. The methods depend on the transient suppressors to protect the amplifier until the relay can operate.

The audio susceptibility tester transformer is presently being constructed, procurement of materials for the present design having been completed. This design will yield a transformer with a maximum turns ratio of

10:1 and with low leakage reactance, the conductors being copper foil and the winding configuration being bifiliar.

C. Evaluation of EMCO rejection filter

In performing emissions tests on transmitters it is often necessary to attenuate the fundamental to allow measurements of adjacent signals which are much lower in amplitude. For this reason rejection filters are useful in extending the dynamic range of the measurement system and avoiding damage to sensitive measuring instruments. At the beginning of this contract two principal sources of rejection filter designs were available in the 14 kc to 1 kMc range. The Bureau of Standards developed a set of seventeen different filters to cover this frequency range.[4] Filters developed by the Electro-Mechanics Company, Austin, Texas, cover this range with three filter units using plug-in-coils. One of these units was purchased and evaluated for possible use in the Accessory Set.

The following are the published specifications:

Model: MF

Serial Number: 1105

Tuning range: 100 to 400 Mc

Number of bands: 3

Characteristic impedance: 50 ohms

Attenuation: 120 db or more at rejection frequency; 40 db or less at 10 per cent removed

Dimensions: 8-1/2" high
11-1/2" wide
11" deep

The insertion loss versus frequency characteristic for a tuned frequency at the center of each coil range was obtained and the results are shown in Figure 10. Two important features are to be noted on these curves. One is that the maximum rejection obtainable by project personnel adjusting the filter was less than 100 db at best and only about 81 db at one point. A possible contributor to this less-than-specified rejection could be a broad skirt to the spectrum of the output of the signal generator. If this signal extends beyond the bandwidth of the rejection filter and feeds into the IF of the measuring instrument the rejection figure will be degraded. In the opinion of project personnel, the primary problem lies in the precise adjustment required on the potentiometer and capacitor controls of the filter.

From 400 to 1000 Mc the attenuation begins to rise and develop peaks as high as 20 db in the neighborhood of 700 Mc. From the reoccurrence of these peaks with each coil they appear to be due to resonances in the body cavity of the filter enclosure.

A pseudo-sweep system was constructed by mechanically coupling a slow speed synchronous motor to the capcitor control. The motor was equipped with start-stop and reversing switches. Curve tracing was accomplished by recording the output of an Empire Devices Noise and Field Intensity Meter, Model NF105, while the filter was swept across its region of maximum rejection. In this manner the mechanical backlash in the controls was graphically displayed. From these graphs and recorded dial readings, Figure 11, which demonstrates the backlash in the capacitor adjustment, was constructed.

The chart recording shown in Figure 12 is a sample of the effects caused by jarring and by introducing additional capacitance into the body

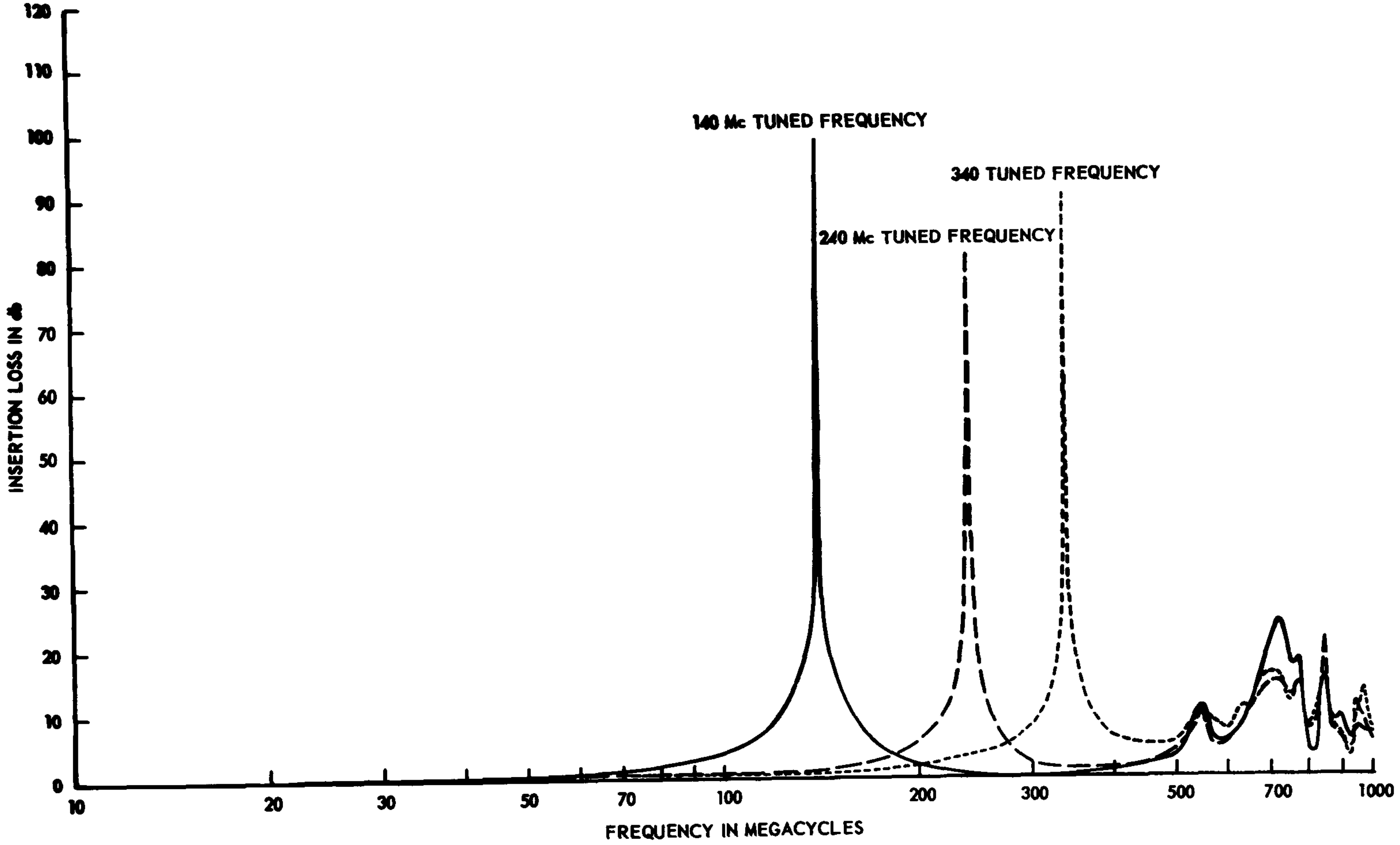


Figure 10. Insertion Loss Versus Frequency Characteristics of the EMCO Rejection Filter.

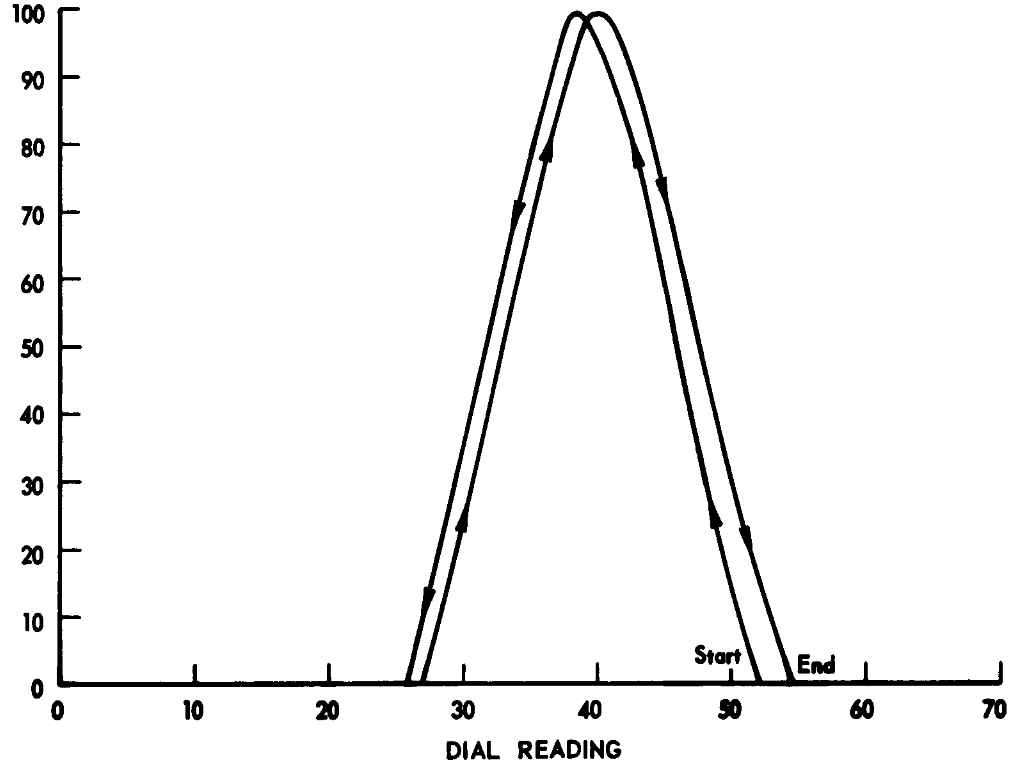


Figure 11. Backlash Behavior of the Capacitor Tuning Control.

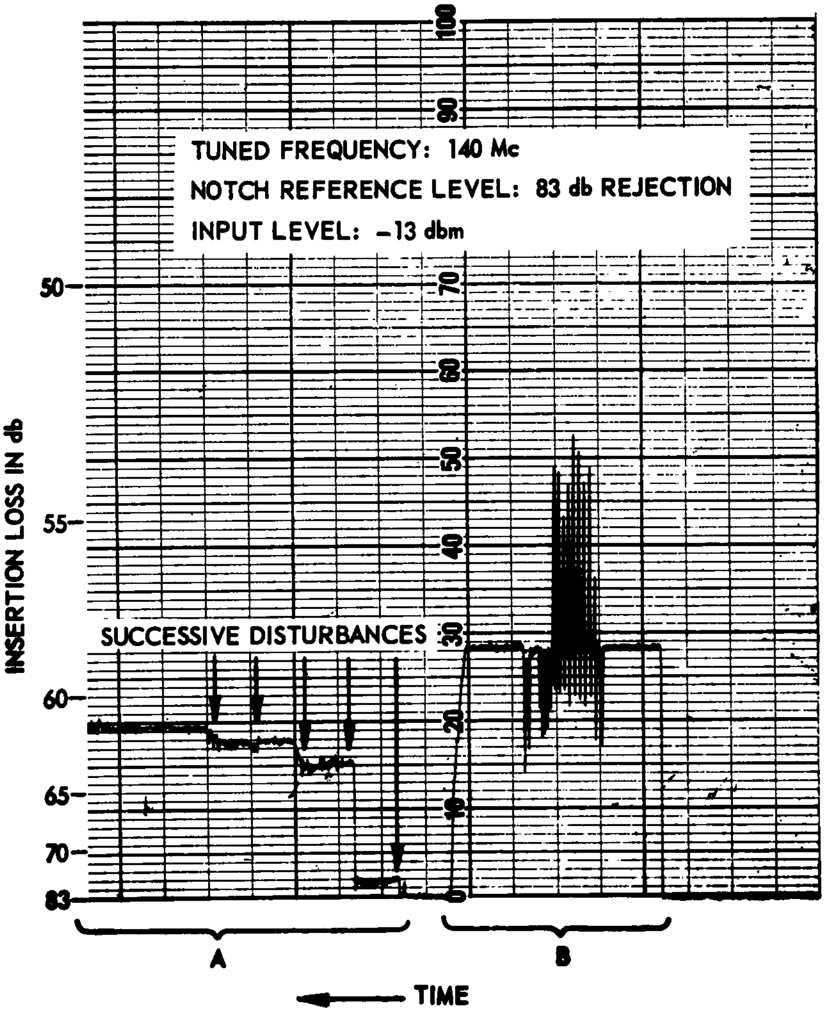


Figure 12. Chart Recording Showing the Effects of Jarring the Filter and Adding Capacitance to the Body Cavity.

cavity. The tuning did not return to its original position after being jarred off. Region A shows the effect on the output caused by jarring the filter. Note that a change in the rejection of more than 20 db was caused by disturbing the filter in this manner. Region B shows the necessity for always maintaining the coil holder on the filter because changes inside the cavity cause several decibels of variation in the rejection. The 25 db change in rejection was caused by the removal of the coil holder.

In conclusion, it appears that this filter is not entirely satisfactory for this Design Plan because (1) extreme care is required to obtain rejection of 80 db or more; (2) mechanical backlash in the tuning controls render tuning even more difficult; and (3) skirt attenuation is too broad for measurement of adjacent signals.

V. CONCLUSIONS

Several items of accessory equipment can be designated at present as fulfilling requirements for the final accessory set or that should be developed for use in the accessory set. A frequency measurement system meeting accuracy requirements suitable for most spurious response identification purposes and general frequency measurement requirements of MIL-I-11748 is presently available. Such a system is described in Hewlett-Packard Application Note No. 2 and is suitable for measurement of frequencies throughout the range of interest for the accessory set. Some work needs to be done to perfect simple operating procedures for this system. Another item of equipment which would provide a faster and more repeatable measurement of a standard response at the output of a receiver is the pulse and CW standard response indicator. This system would remove much of the labor of making measurements as well as improve their accuracy by removing operator judgement from the measurement. Several other items of accessory equipment for which the specifications can be outlined at present were discussed.

Films of gold and platinum alloys do not appear capable of withstanding the desired operating temperatures. Additionally, the resistance change over the temperature range is too great for the intended use. Further investigation into other materials and plating techniques will be required to lower the TCR and increase the temperature range of operation.

A receiver input coupler was constructed which allows matching 300 to 50 ohm systems by use of a minimum loss pad. Tests on this pad indicate that its characteristics are within the specifications imposed by the technical requirements.

A transistorized audio susceptibility amplifier has been operated at a 30 watt level with good thermal characteristics. The problem of protection of this amplifier against transients was considered from several viewpoints.

An EMCO rejection filter was evaluated. It appears that this filter is not entirely satisfactory for the purposes of the accessory set because of the tuning difficulties encountered to obtain a rejection of 80 db or more, mechanical backlash in the tuning mechanism, and attenuation of the filter near its rejection frequency being too high.

VI. PROGRAM FOR NEXT INTERVAL

During the next quarter work on the design plan will be continued so that it can be finalized.

Work on the audio susceptibility tester will continue.

Additional alloys and techniques of deposition of thin films will proceed as time permits.

VII. IDENTIFICATION OF KEY TECHNICAL PERSONNEL

Name	Title	Approximate Hours
Hugh W. Denny	Research Assistant	456
William R. Free	Research Engineer	47
Neil T. Huddleston	Graduate Research Assistant	344
D. W. Robertson	Head, Communications Branch	47
Joseph B. Walsh, Jr.	Project Director	311
W. Bruce Warren	Research Engineer	3
E. Wendell Wood	Assistant Research Engineer	60

Mr. Free joined the project in November 1963. He received a B.S. degree in Electrical Engineering in 1954 and a M.S. degree in Electrical Engineering in 1959, both from the Georgia Institute of Technology. His previous experience includes 3 years as an Electronic Engineer with Sperry Gyroscope Company at Great Neck, New York; 3 years as an Assistant Research Engineer with the Engineering Experiment Station, Georgia Tech; and 4-1/2 years as a Senior Staff Engineer with Sperry Microwave Electronics Company at Clearwater, Florida. Mr. Free's experience has been in the fields of Communications, RFI, and Pulse Circuit Design.

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4. "Instruction Manual for Filters, Tunable Rejection," National Bureau of Standards, BuShips Contract 1700R-629-59.

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Quarterly Report No. 4, 15 October 1963 to 15 January 1964, 44 pages, 15 illus. (Contract No. DA 36-039 AMC-02224(E), Department of the Army Project: 1P620501D449), UNCLASSIFIED REPORT.

A discussion is presented of several of the items of equipment necessary in a radio frequency compatibility accessory equipment set designed for performing measurements as specified in military specification MIL-I-11748B. Major items discussed are the frequency measurement system and a standard response indicator for both CW and pulse systems. The specifications for other accessory items such as directional couplers, isolators, attenuators, dummy loads, and filters are also reviewed.

Experimental work on the deposition of thin film alloys to obtain a film with a temperature coefficient of resistance which exhibits a minimum change of resistance over the temperature range of interest was conducted. Results of this work are shown.

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