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Azimuth and Elevation Direction Finder Techniques

Third Quarterly Report

1 January - 31 March 1968

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FOREWORD

This report was prepared by The University of Michigan Radiation Laboratory of the Department of Electrical Engineering under Contract No. DAAB07-67-C-0547. This contract was initiated under the United States Army Project 5A6 79191 D902-05-11 "Azimuth and Elevation Direction Finder Techniques". The work is administered under the direction of the Electronics Warfare Division, Advanced Techniques Branch at Fort Monmouth, New Jersey. Mr. S. Stiber is the Project Manager and Mr. E. Ivone is the Contract Monitor.

This report covers the period 1 January through 31 March 1968.

The material reported herein represents the results of the preliminary investigation into the study of techniques for designing a broadband circularly polarized azimuth and elevation direction finder system.

The authors wish to express their thanks to Messrs. A. Loudon and E. Bublitz for their efforts in the experimental work that has been performed during this reporting period.

ABSTRACT

During this reporting period all efforts have been directed toward the design and development of individual components. The components investigated have been the broadband, hybrids and phase shifter, to be employed with the quadrifilar spiral and the electromechanical switch. Typical experimental data is presented for engineering models of the above components. Since theoretical details were given in the Second Quarterly (ECOM-0547-2) they are not discussed here. Several of the electronic components (for the data processing equipment) have been received by the supplier of the data processing system. However, it appears that the peak reading detector (for data processing equipment) will be delivered approximately one month later than originally planned.

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I
INTRODUCTION

During this third quarter, much of our effort has been directed toward the design and fabrication of components required for the azimuth-elevation direction finder (DF) being developed by the Radiation Laboratory of The University of Michigan. The function of the azimuth-elevation DF system is to collect the relative signal levels from each of the antennas associated with the DF system. Employing this data and the pointing direction (associated with each antenna) the direction of the incoming signal is to be computed and optically displayed. As a design goal the accuracy of the system should be $\pm 2^{o}$ in azimuth and $\pm 5^{o}$ in elevation.

A thorough discussion of the theory of the DF system and the components associated with it have been presented in the first and second quarterly reports (ECOM-0547-1 and -2). Therefore, this report will be restricted to the experimental results that have been obtained during the reporting period.

Considerable effort has been expended on the development of the balun network required for a quadrifilar log conical antenna. The quadrifilar antenna has been selected because it exhibits the required pattern characteristics to ensure accurate directional predictions over the 5:1 frequency band (600 - 3000 MHz). The balun network will consist of three broadband hybrids and one broadband 90^{o} phase shifter. The development of these components will be discussed in Chapter II.

The design and development of a single pole 17-throw broadband electro-mechanical switch has also received considerable attention during this quarter. At present the switch is being designed to operate at rotational rates (10, 100 and 1000 rpm). In designing the switch, it is necessary also to provide a means by which the computer will know which antenna is being interrogated. The present status of the switch design is presented in Chapter III

Chapter IV discusses the status of the computer and its associated equipment which is being supplied by the S. Sterling Company.

II

A BALUN SYSTEM FOR ANTENNAS

Unexpected delays in the delivery of materials required for the balun network has hampered the development of this component. However, the necessary material (Rexolite 2200) has been received and several preliminary tests have been conducted on the prototype models of the 3 db hybrid coupler. The 3 db hybrid coupler is comprised of two 8.3 db couplers connected in tandem (as discussed in ECOM-0547-2) to minimize mechanical tolerances. Figures 1a and 1b illustrate the coupling response of a typical 8.3 db coupler over a 5:1 frequency band. This coupler was fabricated by cutting two conducting filaments from 1 mil brass shim stock and properly sandwitching the filaments between thin sheets of Rexolite dielectric material. The cutting accuracy was approximately $\pm$ 5 mils which is considered to be adequate for this technique.

Since the coupling data of Figs. 1a and 1b was felt to be satisfactory an accurate drawing of the coupler was made and photographed to enable photo-etching of the necessary couplers. The etched coupler will be tested to observe the effect of employing tighter tolerances in the printing of the conducting filaments and assembly of the coupler. One should note that the shim stock coupler has a reasonably flat response at the center frequencies with an abrupt drop-off at the end frequencies. This type of response is due to inaccuracies inherent in the cutting and overlapping of the brass shim stock. It is hypothesized that the etched coupler will be more accurately constructed with the result that the coupling characteristics will be more uniform across the 5:1 frequency band. It is believed that one additional design iteration may be required to achieve the desired 8.3 db coupling factor.

For proper operation of the hybrids all ports must be terminated with their characteristic impedance. In the event the ports are improperly matched, reflected energy will be present. Since the hybrid is a reciprocal device, reflected energy will be coupled to various ports causing unwanted and possibly large variations in the forward coupling characteristics as a function of frequency.

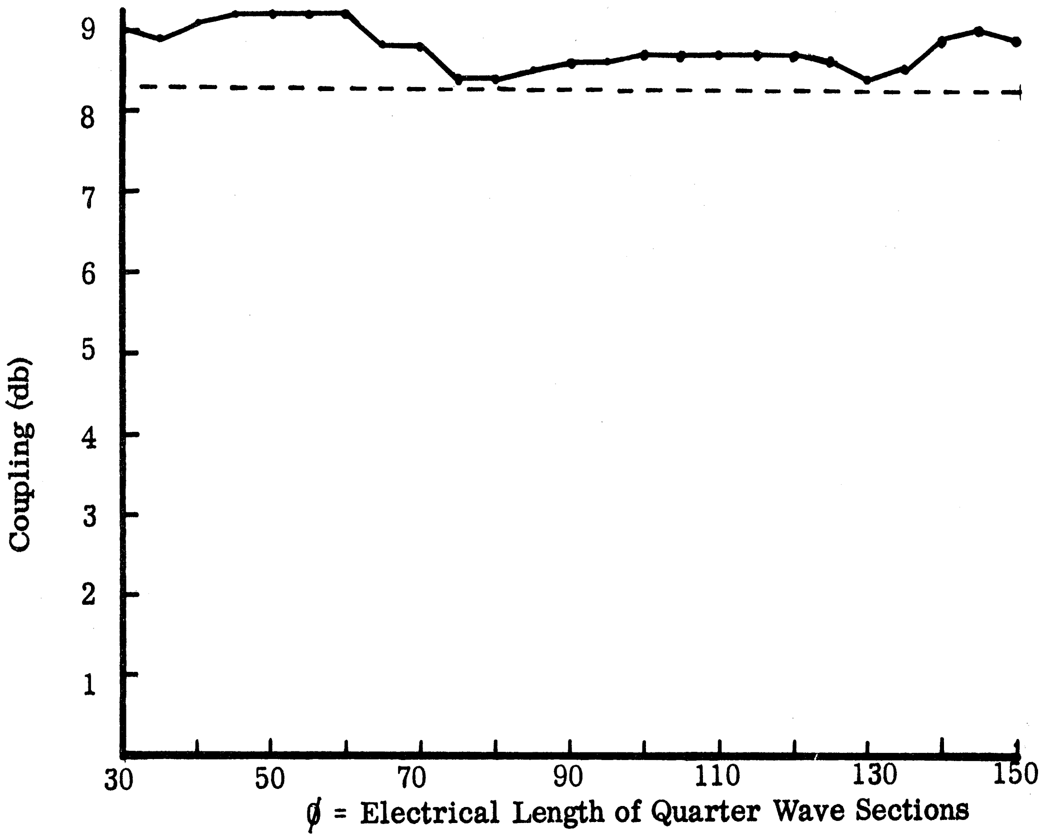

FIG. 1a: COUPLING OF 8.3 db COUPLER IN DB.

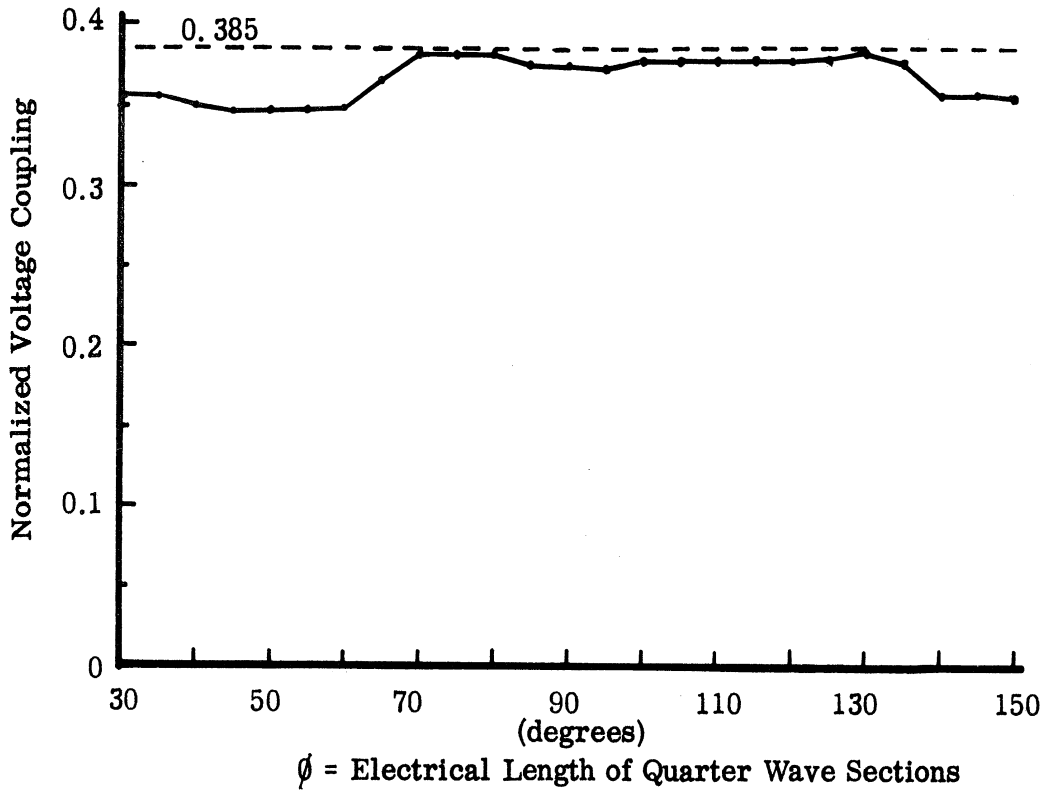

FIG. 1b: COUPLING OF 8. 3 db COUPLER IN TERMS OF VOLTAGE COUPLING.

Therefore, reflection from the antenna may detrimentally affect the performance balun network. At the present time we do not know the magnitude of the expected reflections and are unable to predict their effect on the balun. We will be able to make a more intelligent approach to this problem after we have obtained data employing the balun with an antenna.

In addition to the hybrid it has been necessary to design and develop a broadband 90° phase shifter. Figure 2 is a graph of phase shift vs frequency for a shifter fabricated of Rexoline S dielectric material. This material has been found to be unsatisfactory for mechanical reasons. It has been discarded the replaced with Rexolite 2200 as noted earlier.

The phase shift of a broadband phase shifter is achieved by maintaining a constant phase delay between a reference line of constant impedance (50 ohms for the present system) and a section of coupled lines. A further discussion of the broadband phase shifter was given in the Second Quarterly (ECOM-0547-2). The coupled section consists of a pair of phase shifters connected in tandem to minimize mechanical tolerances.

As noted earlier the balun network will consist of three broadband 3db hybrids and one 90° phase shifter. This network will have a single unbalanced input and four outputs equal in magnitude with relative phases of 0°, 90°, 180° and 270° . The center conductor of each of the four outputs will be connected to a separate filament of the quadrifilar spiral. The four shields of the output cable will be tied together to ensure that the output currents remain balanced.

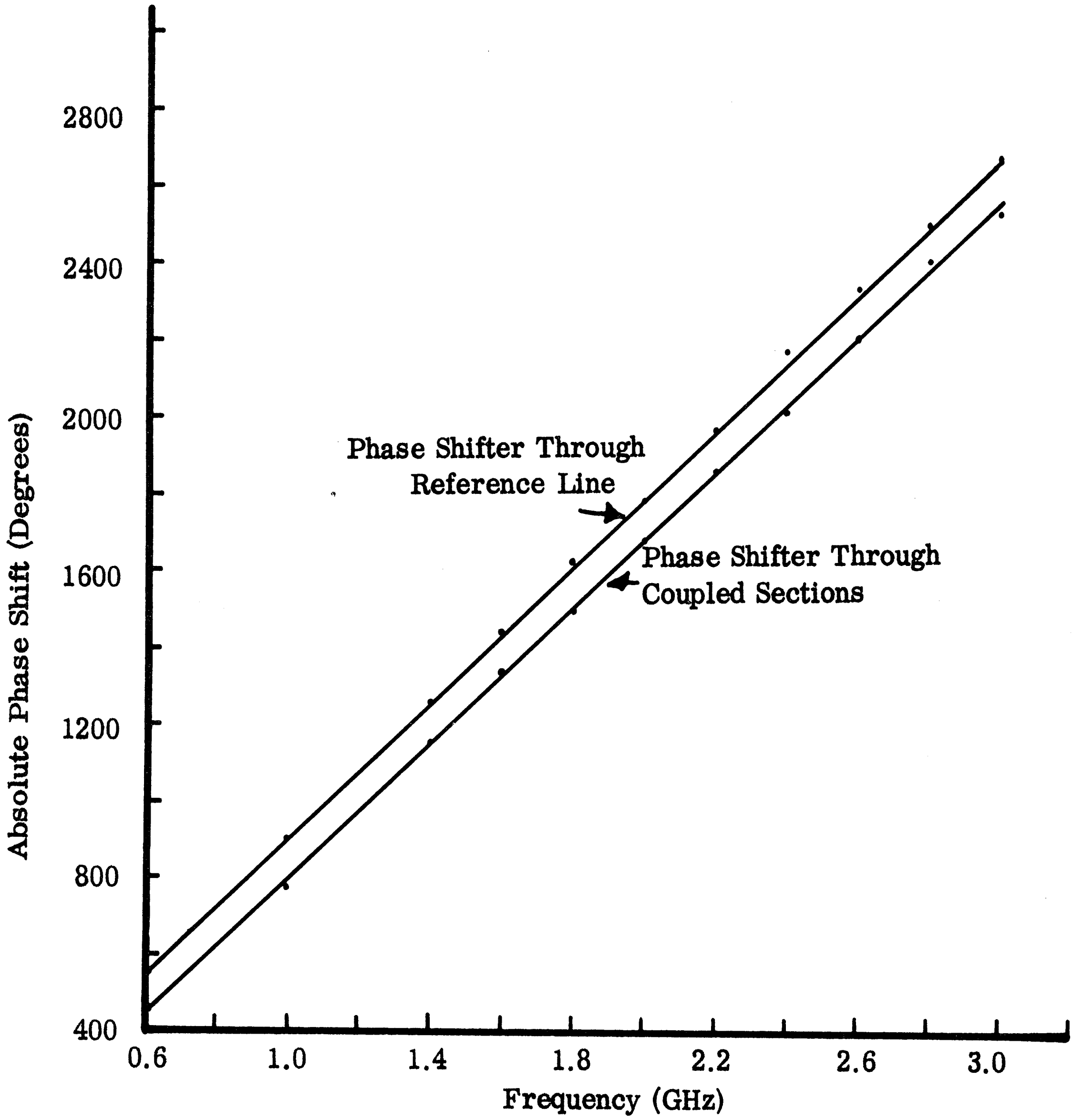

FIG. 2: PHASE SHIFTER PERFORMANCE AS A FUNCTION OF FREQUENCY.

III

ELECTROMECHANICAL SWITCH

Several engineering configurations of the electromechanical switch have been tested during this third quarter. It is envisioned that the switch will consist of two capacitively coupled junctions. One will function as a rotary joint and the second as the switched port. Efforts were first directed toward the development of each junction separately. The final engineering models have VSWR characteristics typical of those shown in Figs. 3a and 3b. A graphical analysis of the final configuration showed that shunt capacitance was excessive thus contributing to the high VSWR in the low frequency range (600 - 1000 MHz). Efforts are now being made to reduce the shunt capacitance.

A prototype model of the rotary switch has been built. In this model the RF energy is transferred from the switched port to the rotary port, through a strip-line of the proper impedance characteristics. VSWR data that has been collected for the prototype model has been high because of the VSWR characteristics of the individual ports. However, it is felt that the VSWR can be significantly improved by reducing the shunt capacitance as noted below.

To ensure that the rotor of the switch has a uniform and true rotation without vibration, a Gilimin spindle (Model 1875N-1m) is to be used. A prime reason for selecting this spindle is that its specifications show it to have a maximum run out of 2 mils. In addition, its length is variable (micrometer type adjustment) thus enabling adjustment between stator and rotor of the switch. The output of the spindle is to be suitably connected to a Geartronics transmission (Model 2400 or 2600). These units have ten-speed reduction rotors (1:1, 2:1, 5:1, 10:1, 20:1, 50:1, 100:1, 100:1, 200:1, 500:1 and 1000:1). Although the number of reduction rates is greater than the DF requirements, it is felt that its availability and low cost precludes us from designing and developing one of our own.

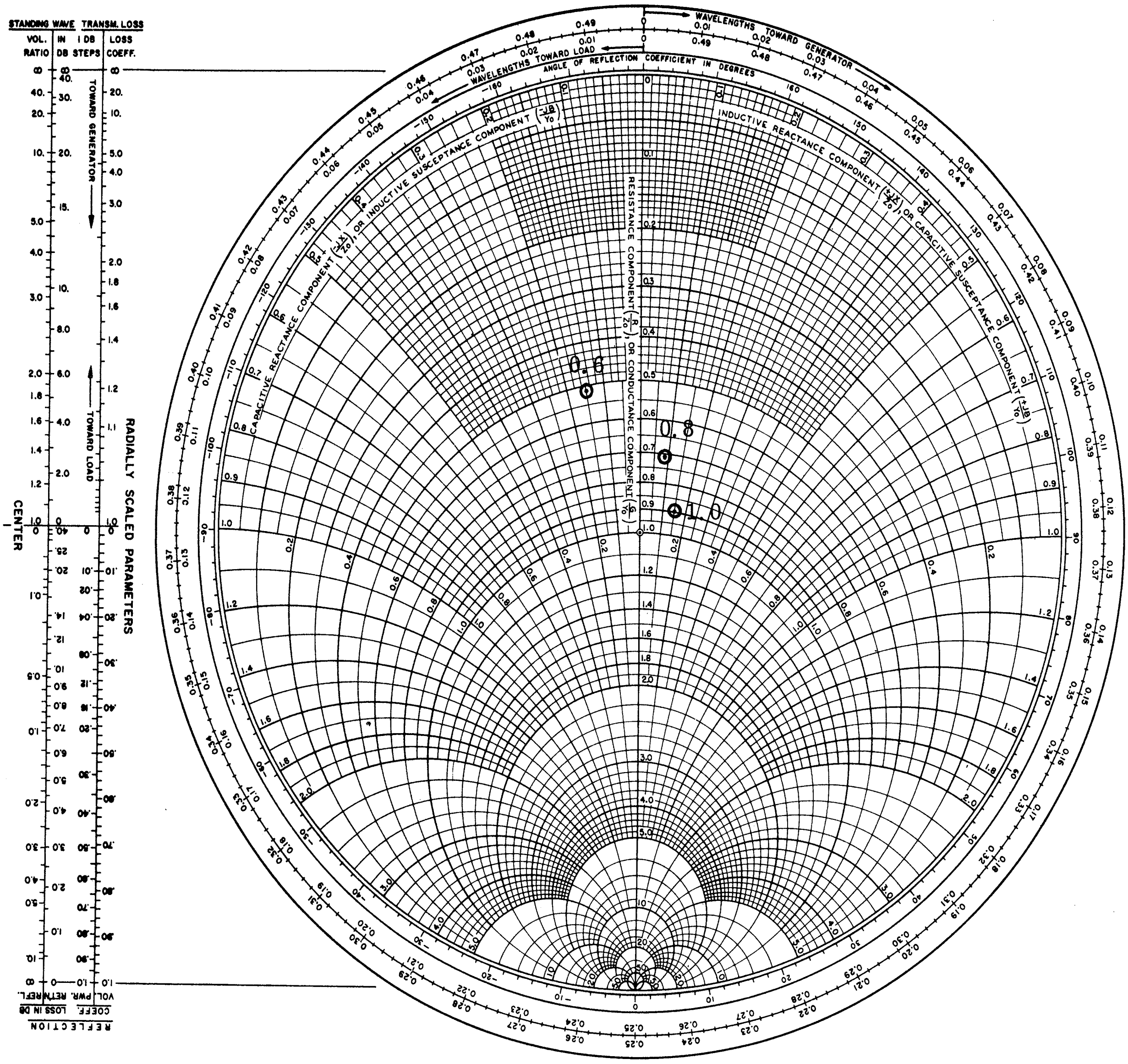

FIG. 3a: IMPEDANCE OF ONE CAPACITIVE JUNCTION OF THE MICROWAVE SWITCH. F = 0.6 - 1.0 GHz (Frequency in GHz).

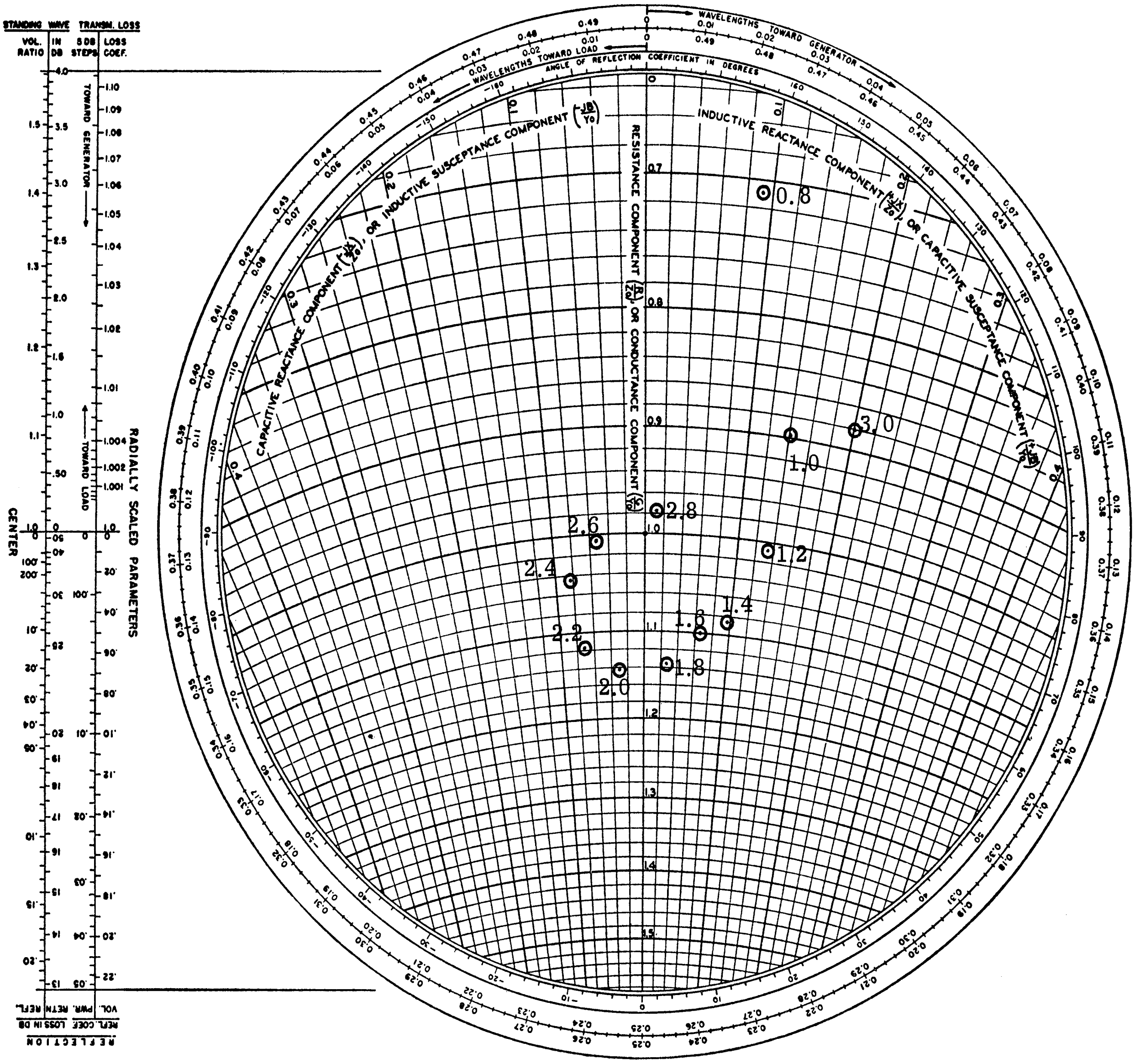

FIG. 3b: IMPEDANCE OF ONE CAPACITIVE JUNCTION OF THE MICROWAVE SWITCH. F = 1.0 - 3.0 GHz (Frequency in GHz).

IV

COMPUTER AND PERIPHERAL EQUIPMENT

The computer has been received by the S. Sterling Company and they have checked its performance. The interfacing has been designed and some of it is being wired into the computer at the present time. However, it appears there will be about one month's delay in the delivery of a major component in the computer detection system (the peak reading voltmeter). The delay of this item will in turn delay the delivery of the computer system. Currently, it appears the computer system will not be delivered before the end of May. Manuals for the computer have been received and the computer programmer is writing a simple program for the Data Machine 620 I.

During the next reporting period, considerable time will be spent with the contracting company discussing the interfacing and cabinet mounting of the computer components .

The delay in the delivery of the computer will complicate, and severely limit, the testing of the final configuration due to the reduced time available.

V

CONCLUSIONS

The design of the 90° phase shifter for the antenna balun of the DF study has been completed. The 3 db hybrid coupler requires additional work to ensure the proper coupling and phase shift over the 5 : 1 frequency band required for the balun assembly. A final engineering model of the electromechanical switch is now being fabricated. In addition the necessary electromechanical parts required for the rotation of the switch are being ordered and materials colletected together to aid in the fabrication of the rotary switch. It is anticipated that the switch will have a maximum rotation of 1000 rpm and several intermediate steps between 100 and 10 rpm. The impedance characteristics of individual switching ports appear to be quite promising for the 5 : 1 frequency band.

Insofar as the computer and peripheral equipment is concerned, the subcontractor (S. Sterling Company) has received several of the items, but difficulty has been encountered in obtaining a key item, the peak reading voltmeter. It is expected that this item will be received late in May making it necessary for them to delay delivery of the data processing equipment until mid-June.

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13. ABSTRACT

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