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TRANSMITTER IMPEDANCE CHARACTERISTICS FOR AIRBORNE SPECTRUM SIGNATURE

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ABSTRACT

A simple linear model of a transmitter-transmission line-antenna system has been proposed in previous reports. The work described in this report is concerned with evaluating the correspondence between the behavior of the model and a typical transmitter. To evaluate the applicability of the model to power output predictions, a new analytical tool is introduced. Power output contours as a function of the phase angle of the load are developed for the linear model. Also included are a number of such curves generated from experimental data taken from a typical transmitter for a variety of loads. The experimental and theoretical results are compared and discussed.

I. INTRODUCTION

The statement of problem as set forth in the contract which provides for the present investigation is as follows:

(1) A determination of the power delivered to the antenna for "spectrum signature" purposes will require a measurement of the antenna impedance, transmission line characteristics, transmitter maximum power output, and transmitter output impedance at the fundamental, spurious and harmonic frequencies. The transmitter output impedance at the spurious and harmonic frequencies is not well understood and, therefore, requires further study. The prime payoff in this study will be better "spectrum signatures" for more accurate predictions of interference between systems.

(2) There is a requirement to verify the results of the earlier successful program, Contract AF 33(615)-2606 "Simplified Modeling Techniques for Avionic Antenna Pattern Signatures", with a mock-up of an aircraft transmitter system.

(3) The stated objective of the contract is: To conclude the development of "simplified" techniques for determining the RF spectrum signatures of flight vehicle electronics systems. To establish the validity of the techniques by comparing the results of data obtained by the "simplified" techniques with data obtained from tests employing a typical transmitter system in a mock-up.

(4) The present phase of the contract is concerned with developing a technique

for the accurate prediction of the power output of a typical transmitter. The evaluation of this technique requires an investigation of the linearity of a typical transmitter not only at the fundamental but the harmonic and spurious frequencies as well.

II. SOURCE LINEARITY EVALUATION

The possibility of evaluating the power transfer in a given transmitter-transmission line-antenna system by modeling the system with linear idealized circuit elements has been introduced in previous reports. To evaluate the feasibility of the linear model approach, the study for the past several months has centered around the development of a convenient technique for the quantitative evaluation of the linear model parameters, where applicable, and the modification of the existing model in accordance with the deviation of the real transmitter behavior from that of the model.

2.1 Shortcomings of Rieke Diagram Approach

In the past, the major analytical tool employed for active source evaluation has been the Rieke diagram. This approach, while it does afford a graphic illustration of the transmitter's behavior has several serious disadvantages. It is difficult to experimentally obtain Rieke diagrams to the required precision, and the diagrams do not readily lend themselves to a quantitative evaluation of the model parameters. For these reasons the data format has been changed from load impedance contours at a constant power output (Rieke diagrams) to power output contours at a constant magnitude of load impedance.

2.2 Theoretical Power Output Contours as a Function of Transmission Line Length

It has been shown (DeHart, 1966) that the power transfer from an idealized source through a lossless transmission line to a linear passive load can be expressed as a function of the phase angle of the load impedance.

$$P = P_{max} \frac{1}{\alpha^2 \cos^2 \phi + \sin^2 \phi} \tag{2.1}$$

where

P_{max} = the maximum power transfer for a given load

α^2 = the ratio of the maximum to the minimum power transfer for a given load, P_{max}/P_{min}

ϕ = the phase angle (electrical degrees) of the load

Furthermore, α^2 can be expressed solely in terms of the source and load VSWR's.

$$\alpha^2 = \left(\frac{S_g S_1 + 1}{S_1 + S_g} \right)^2 \tag{2.2}$$

where

S_g = the source VSWR

S_1 = the load VSWR

Several plots of $P(\phi)$ for various values of α^2 appear in Figure 2-1.

2.3 Experimental Power Contours

The idealized source can now be compared with a physical transmitter by experimentally determining power output contours as a function of the phase angle of the load. This has been done with an RT-178/ARC-27 military transceiver and

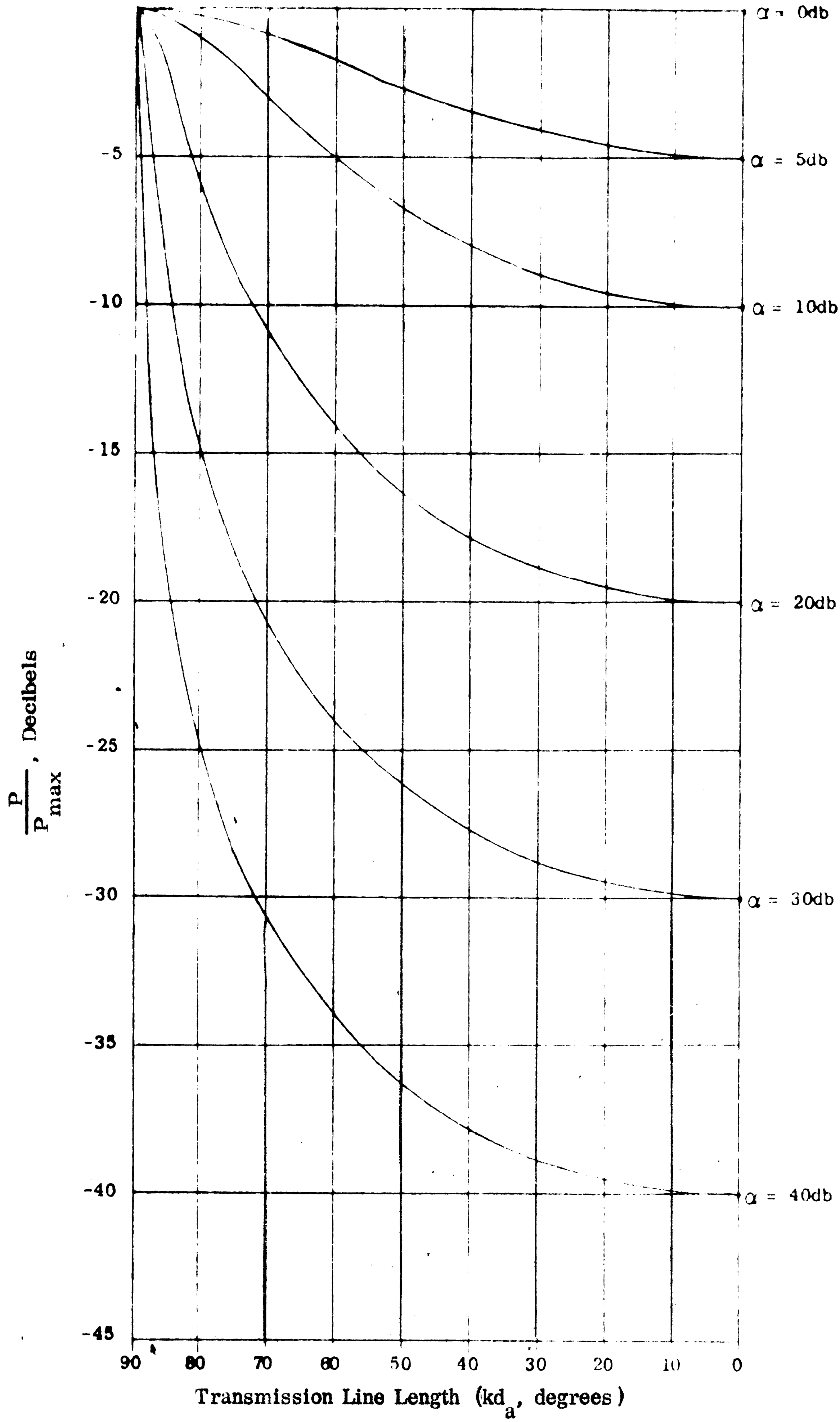


FIG. 2-1: POWER TRANSFER VERSUS TRANSMISSION LINE LENGTH

the results appear in Figs. 2-2 and 2-3. The equipment arrangement used to collect these data is diagramed in Fig. 2-4. Care was taken to preserve the match at the fundamental (300 MHz) while the load phase angle (transmission line length) was varied at the second (600 MHz) and third (900 MHz) harmonic frequencies. The lower curves represent relatively large values of load VSWR, however, the measured data is within $\pm$ 1.5db of the value predicted by the linear model.

Once α has been measured for a known load, it is possible to solve for the source VSWR.

$$S_g = \frac{\alpha S_1 - 1}{Sl - \alpha} \qquad (2.3)$$

Assuming that the source VSWR remains constant for a given frequency, α and thus the power transfer are specified at that frequency for a given load VSWR. Thus the source power output can be predicted for the RT-178/ARC-27 type of transmitter from a linear model provided that the fundamental is well matched.

It has been previously reported (7956-2-T) that there was evidence of a non-linear condition existing at the second harmonic with the fundamental terminated in a matched load. Figures 2-6, 2-7, and 2-8 in report 7956-2-T show an unexplained discrepancy between predicted and measured values of load impedance for a given power output. Later investigation revealed an equipment malfunction. The data

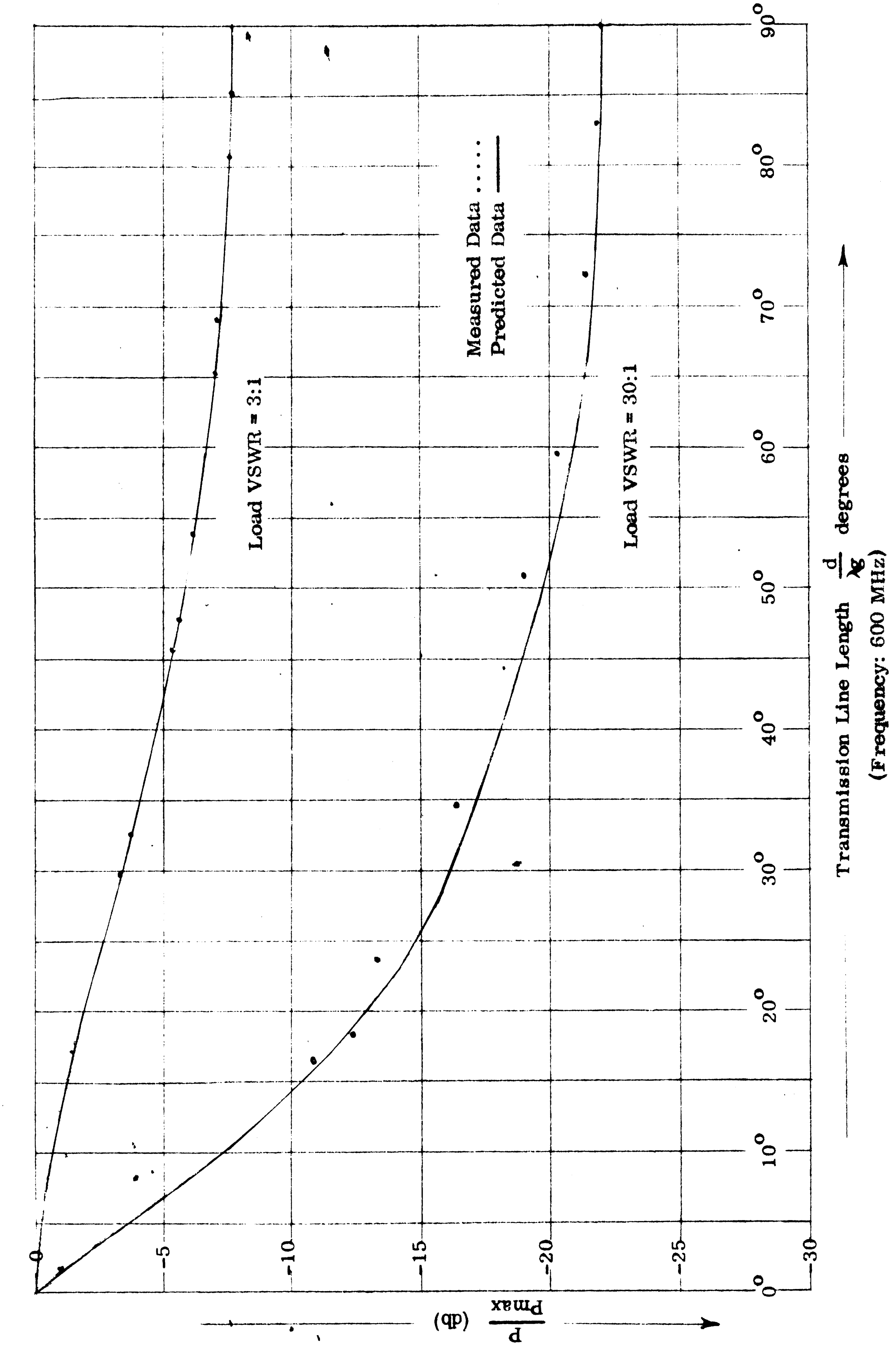
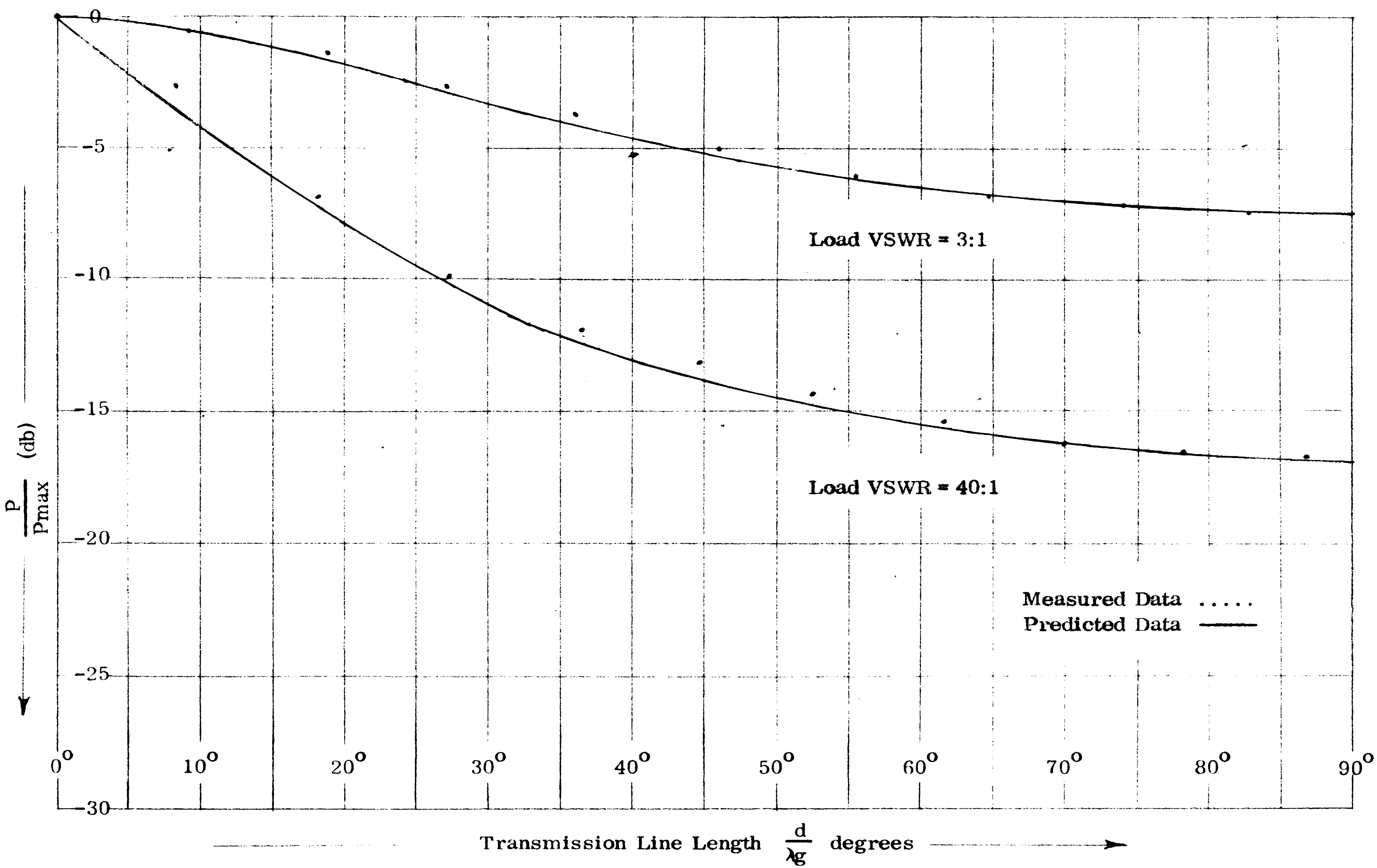


FIG. 2-2: POWER TRANSFER VERSUS TRANSMISSION LINE LENGTH



(Frequency: 900 MHz)

FIG. 2-3: POWER TRANSFER VERSUS TRANSMISSION LINE LENGTH

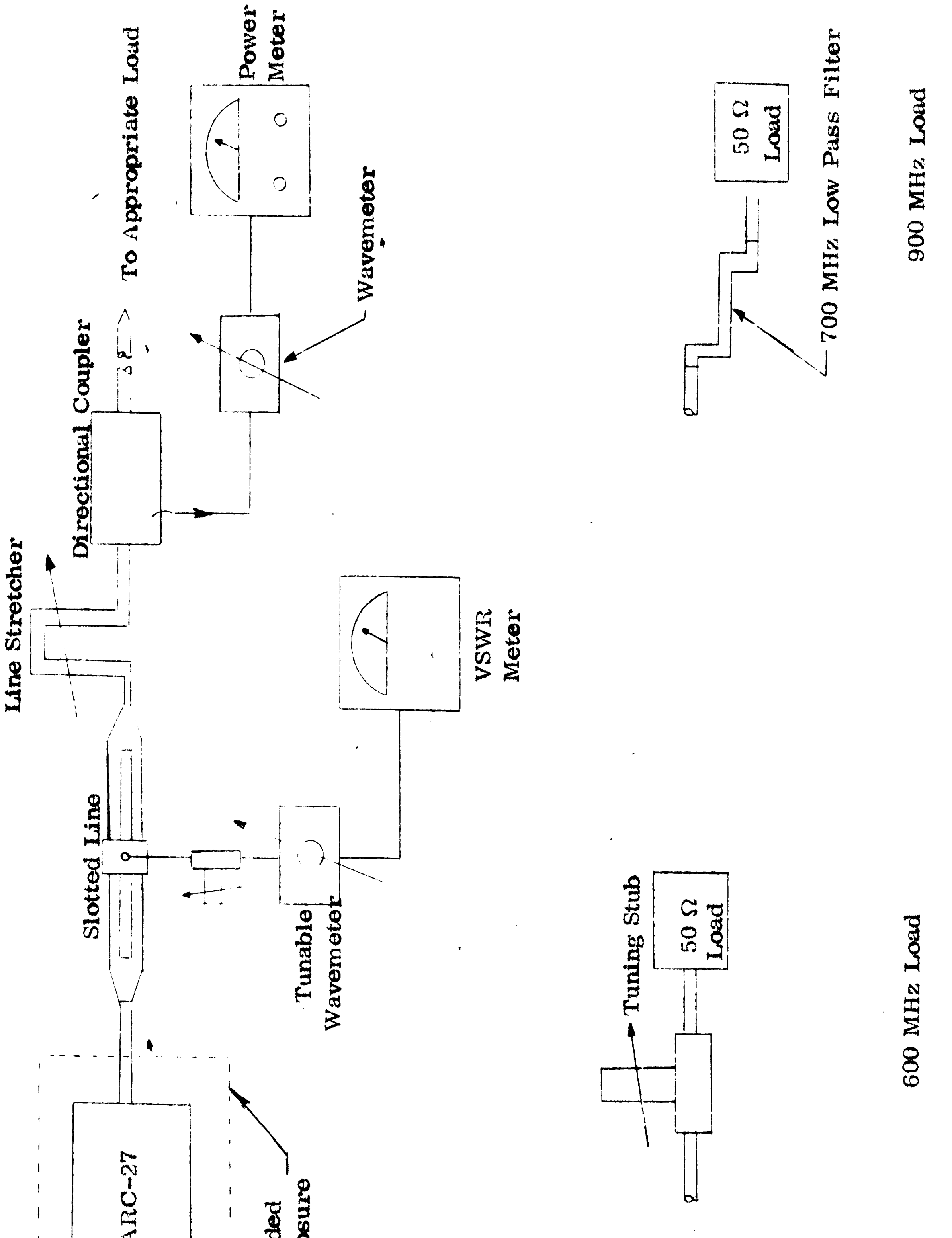


FIG. 2-4: EXPERIMENTAL EQUIPMENT ARRANGEMENT

presented here in Figures 2-2 and 2-3 demonstrate the extremely linear behavior of the second harmonic for a matched termination at the fundamental.

Figures 2-5, 2-6, and 2-7 are plots of the power delivered to an antenna by an ARC-27 transmitter as a function of transmission line length at the fundamental, second and third harmonic outputs. Also included are the values (smooth curves) predicted by a linear model assumption. Although the power output at the fundamental frequency agrees well with the predicted values, there is a large discrepancy at the harmonic frequencies that did not exist when the fundamental component was terminated in a matched load. Although it is not apparent from these data, the deviations from the expected values have a period corresponding with the wavelength at the fundamental frequency. What is apparent is that the discrepancy is sufficiently large to require modification of the proposed linear model.

2.4 Conclusions

The data collected from the ARC-27 transmitter correspond well with the data generated from the linear model provided that the fundamental component of the transmitter's output is properly terminated in a matched load. There are wide discrepancies in the data collected at harmonic frequencies when the fundamental is not well matched. Due to the magnitude of the deviations, and the likelihood of a mismatch at the fundamental for most systems of practical significance, the simple linear model is not adequate for accurate power output prediction without some modification.

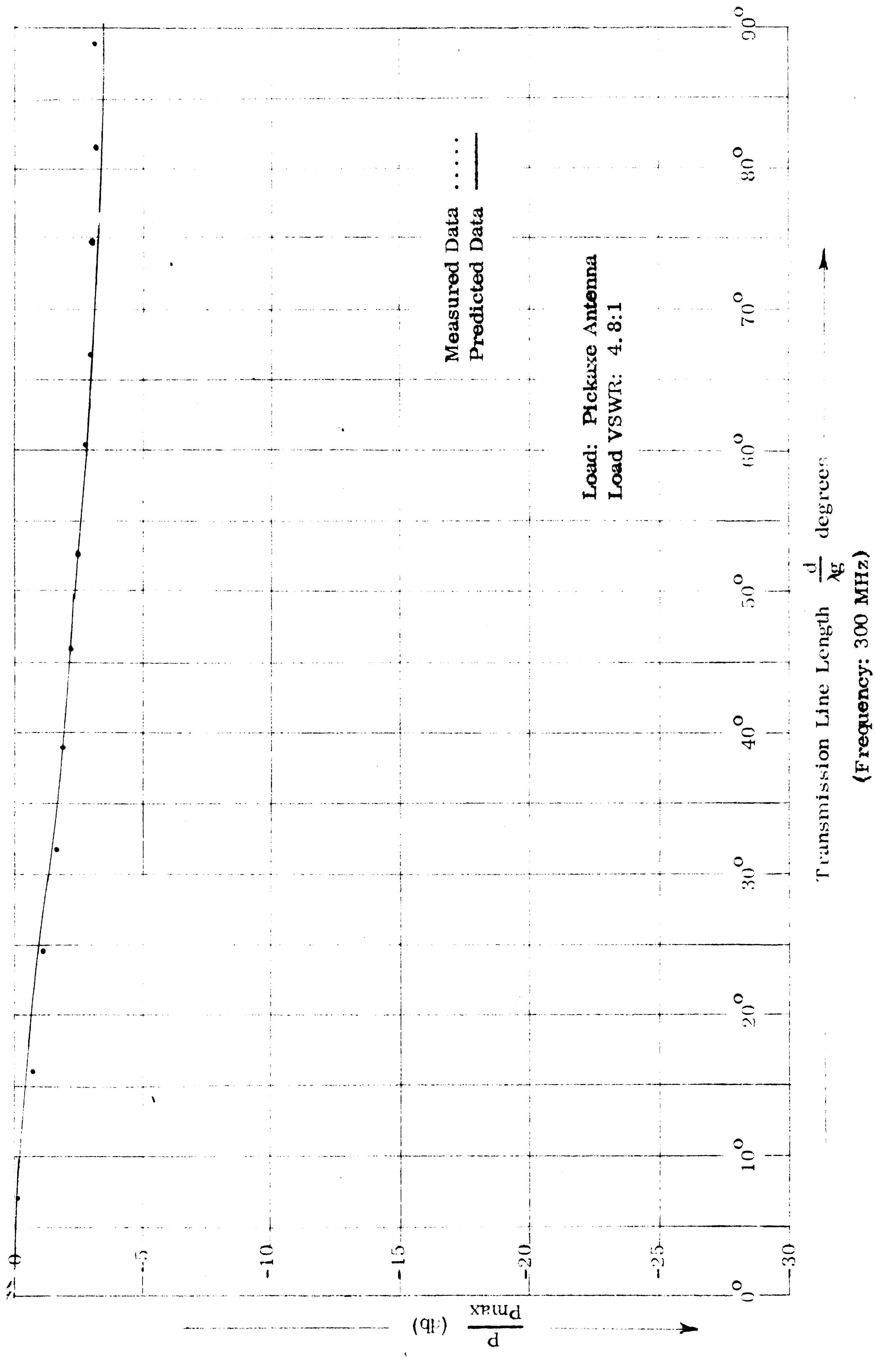


FIG. 2-5: POWER TRANSFER VERSUS TRANSMISSION LINE LENGTH

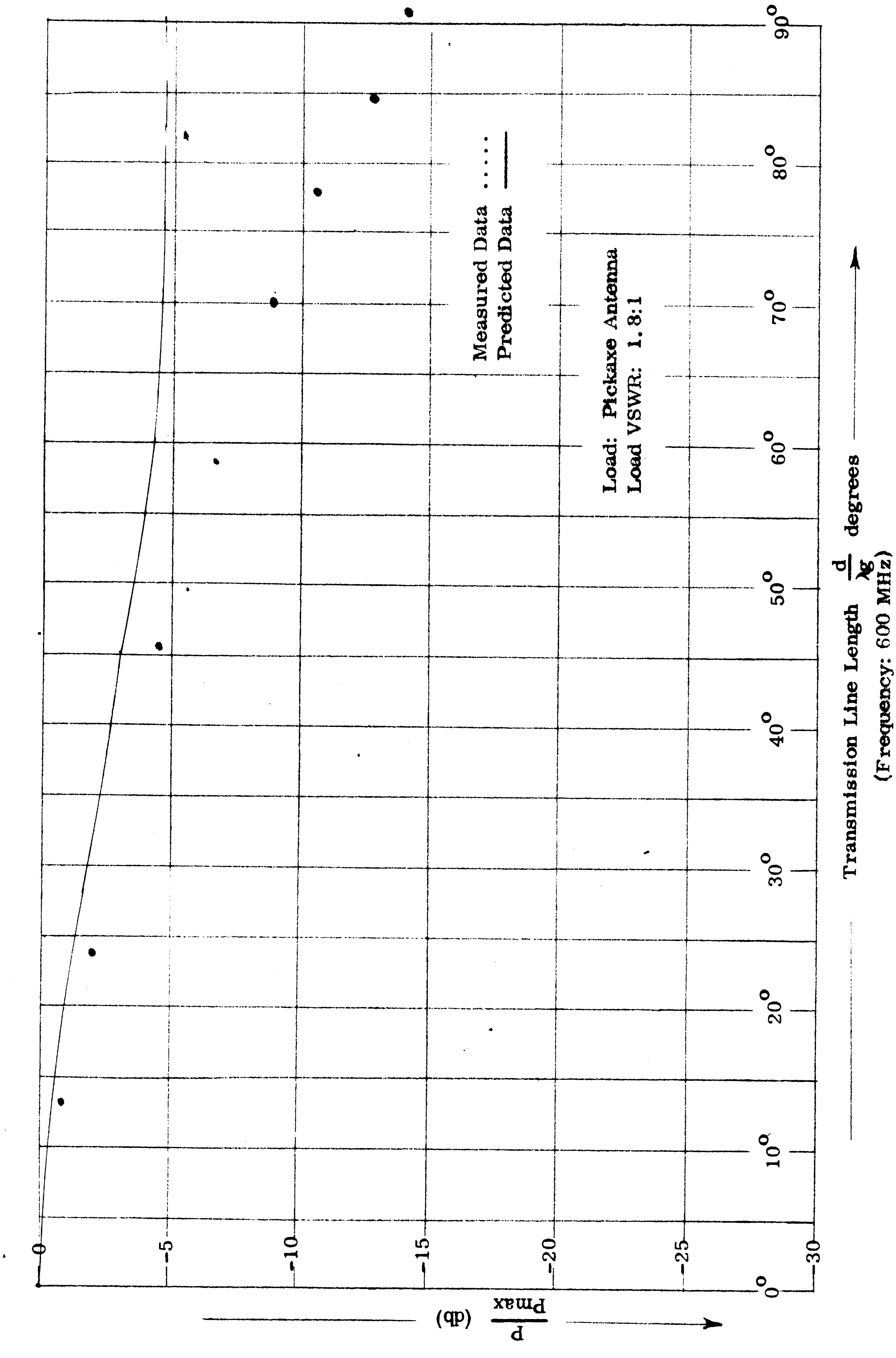


FIG. 2-6: POWER TRANSFER VERSUS TRANSMISSION LINE LENGTH

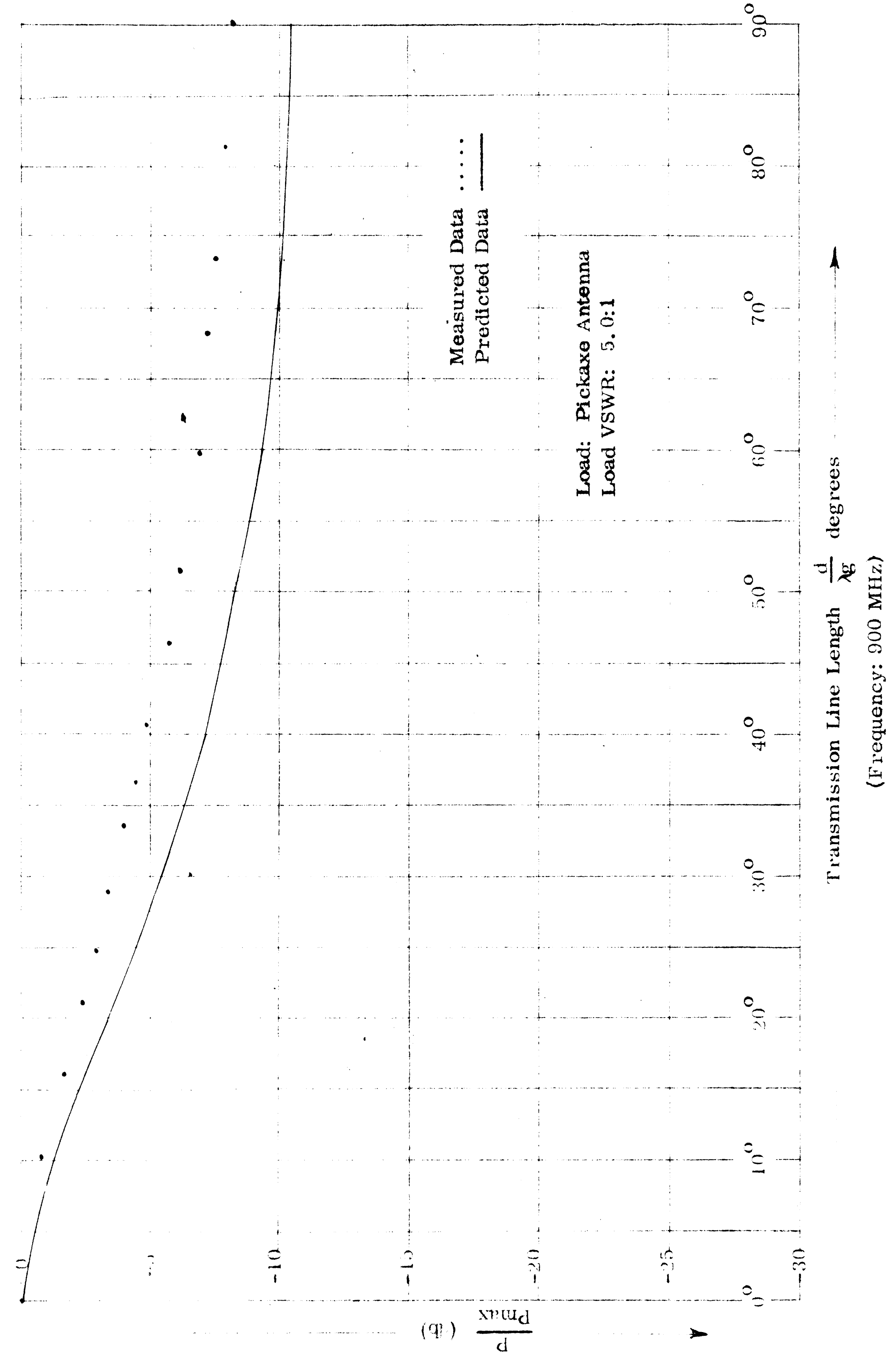


FIG. 2-7: POWER TRANSFER VERSUS TRANSMISSION LINE LENGTH

REFERENCES

DeHart, W. R., (1966) "Transmitter-To-Antenna Power Transfer Under Unmatched Conditions", IEEE Trans. EMC-8, No. 2, pp. 74-80, (June).

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