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AIRBORNE RADIO DIVISION - ENGINEERING TEST SECTION

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AIRBORNE RADIO - RESULTS OF ENGINEERING PERFORMANCE TESTS ON MODEL TS-329/U PHANTOM ANTENNA

By William J.J. Klemn, O. L. Wilkins.

-Report R-2965 -

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Dr. R. M. Page
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Airborne Radio Division

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Naval Research Laboratory

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ABSTRACT

1. Engineering tests were conducted on Model TS-329/U "Phantom Antenna" manufactured by General Industries Company, Contract No. NOas-5423, Serial N1045:CIG, in accordance with Reference (a) for satisfactory operation in the frequency range from 100 megacycles to 400 megacycles.

2. It was found that the instrument is not satisfactory in this frequency range for the following reasons:

a. Lack of electrostatic shielding permits radiation and causes erratic indications on the instrument.
b. Meter indications vary widely with frequency for a given power input.
c. The load presented by the instrument is neither constant nor is it similar to that presented by any V. H. F. antenna with which it was compared.
d. Power handling capability varies widely with frequency, from as low as 6.75 watts at 217 megacycles to a maximum of 12.5 watts. This is not adequate for present Naval Aircraft transmitters operating in this band.
e. The load presented and the meter reading changes with the temperature of the load resistors.

3. If the instrument is redesigned in accordance with the recommendations indicated in this report it will serve as a satisfactory relative power output indicator but will not be a true "phantom antenna". It will not be suitable for final tuning of the transmitter for operation but will be suitable as an indicator of the performance of a transmitter on the test bench.

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INTRODUCTION

4. The TS-329/U was originally designed as a "phantom antenna" and relative power output indicator for transmitters operating in the frequency range of 100 megacycles to 160 megacycles. It was desired to know how this device performed over a range of 100 megacycles to 400 megacycles.

5. Tt should be pointed out here that the TS-329/U is called a phantom antenna in Reference (c). It is in reality an indicating RF load for a transmitter. A true phantom antenna exactly simulates the impedance characteristics of a given antenna system and must be either designed especially for a particular antenna or be made with adjustable components so that it can be made to simulate the electrical characteristics of the antenna it was meant to represent. A great many factors effect the impedance characteristics of an aircraft antenna system as seen by the transmitter at the output connector. Some of these are, the length of coaxial line to the antenna, the location of the antenna on the airplane, the type of antenna used, and the degree of mismatch produced at connectors. This means that the antenna system on two identical aircraft using the same type of antenna system may not have exactly the same characteristics. It is therefore unlikely that a fixed component phantom antenna, such as the TS-329/U, can be built that will serve as a true "phantom antenna".

6. If a true "phantom antenna" were available for an aircraft antenna it would be possible to replace the true antenna by the phantom to tune up the transmitter and then replace the phantom by the true antenna for normal operation without retuning the transmitter. This cannot be done when using the TS-329/U since it does not simulate the true antenna.

7. The TS-329/U "Phantom Antenna" (see Plate 1) consists of a wooden box with a wooden base which is wider than the box and has four holes drilled in the extensions for mounting purposes. The top of the box is bakelite with a circular cut out in which a 500 milliampere R.F. thermocouple meter is mounted. A female "Selectar" fitting protrudes from the front, just above the base. The inner conductor of the "Selectar" fitting is connected to a silver plated ring approximately $1\frac{1}{2}$" in diameter. A similar ring is connected to one terminal of the meter by means of a broad flat metal strip of very short length. These rings are so aligned that twelve 620 ohm 1 watt composition resistors are connected between them forming a cylinder and permitting the use of extremely short resistor leads. The other terminal of the meter is connected by means of a 3/8" wide silver plated copper strip to the base of the "Selectar" fitting. The meter is shunted by a 50 ohm $\frac{1}{2}$ watt composition resistor. In this instrument there are many small lead inductances and distributed capacitances which will have a considerable effect on the impedance presented by it to very high frequencies. The exact value of these inductances and capacitances cannot be determined very easily and would be different, to some extent, for each particular instrument. An idea of the complexity of the impedance characteristic can be gained by examining the approximate equivalent circuit on Plate 2.

8. The circuit of the TS-329/U can be seen to be a complex circuit in which there are many parallel current paths. The meter therocouple is in only one of these parallel paths and so as the frequency changes the current in the therocouple circuit will vary with respect to the cufrent in the load resistor. This is basically the reason for the inconsistant meter readings at different frequencies with the same input power.

TESTS AND RESULTS

9. The impedance characteristics of the TS-329/U Phantom Antenna were obtained as follows:

a. Observations were made of the voltage standing wave ratio and the null position present on a precision slotted line when the TS-329/U was connected to one end of the line and a V.H.F. oscillator of suitable frequency range was connected to the other end of the line.

b. Observation was made of the voltage standing wave null position when the TS-329/U was replaced by a dead short at the end of the slotted line.

c. By making use of the value of voltage standing wave ratio and the direction and distance, in wave lengths, that the null position was shifted when the TS-329/U was replaced by a short circuit, the "R" and "jX" components of the TS-329/U were found with the aid of a transmission line calculator. (See Reference (B).

10. Impedance Characteristics. Tests and Results.

a. Plate 3, shows the variation of the resistive component, "R" and the reactive component, "jX" with frequency over the frequency range from 100 megacycles to 400 megacycles. It also shows the variation of the voltage standing wave ratio for a 50 ohm slotted line for the same range of frequencies. This test was made with the base of the TS-329/U removed to facilitate direct connection to the end of the precision slotted line. It can be seen from the "R" and "jX" curves of Plate 3 that the impedance variation is small over the range from 100 megacycles to 150 megacycles which is the approximate band for which the TS-329/U was originally intended. But the impedance presented at these frequencies is not approximately 50 ohms as stated in Reference (c). The voltage standing wave ratio on a 50 ohm line at 100 megacycles to 150 megacycles is less than 2 and is fairly constant. Above 150 megacycles the "R" and "jX" components of impedance and the standing wave ratio vary over a wide range of values. It was difficult to obtain accurate data here since the movement of the observers body near the unshielded TS-329/U caused changes in the readings of the instruments.

b. Plate 4, shows the same characteristic curves as Plate 3 except that in this case the TS-329/U was completely enclosed in a grounded sheet brass box. From these curves it can be seen that the "R" and "jX" components of impedance and the voltage standing wave ratio are no longer nearly constant from 100 megacycles to 150 megacycles but that the degree of

[redacted]

variation of these values over the rest of the band up to 400 megacycles is less than it was without shielding. The shielding also eliminated the variations in instrument readings due to movement of the observers body.

c. By comparing the curves of Plates 3 and 4 with the curves of Plates 5,6, and 7 (which are the characteristic curves for three commonly used v.h.f. aircraft antennas) it can be seen that there is no resemblance between the TS-329/U curves and any of these antenna curves. The TS-329/U cannot, therefore, be used as a substitute for a real antenna when tuning the transmitter antenna circuit for actual operation in an airplane.

11. Operation in the frequency range from 100 megacycles to 400 megacycles:

a. A test was conducted, using the AN/ARC-13 (100 megacycles to 400 megacycles) and the AN/ARC-1 (100 megacycles to 156 megacycles) as sources of V.H.F. power, to determine the suitability of the TS-329/U as a means of comparing the power outputs of a transmitter at different frequencies in the range from 100 megacycles to 400 megacycles. For this test the TS-329/U was completely shielded by a brass box with a viewing hole in the top covered with wire mesh.

b. This test was carried out as follows:

(1) The reading of the TS-329/U meter with the antenna control of the transmitter adjusted for maximum reading of the TS-329/U meter was observed.

(2) The TS-329/U was replaced by a bolometer power measuring device which was then matched to the transmitter by means of matching device associated with the bolometer, so that maximum power was indicated in the bolometer.

(3) The RF-power in the bolometer was obtained by the "D.C. Power Substitution Method". The ratio of the R.F. power in the bolometer to the square of the current reading of the TS-329/U was calculated. The ratio was plotted against frequency on Plate 8.

c It can be seen from Plate 8 that the ratio of P/I_M^2 is not a constant over the band of frequencies from 100 megacyles to 400 megacycles and since the true power is $(P/I_M^2) \times I_M^2$ the reading for a given power output varies considerably with frequency. Therefore the TS-329/U cannot be used to compare the relative power outputs of a transmitter at different frequencies. It will, however, indicate maximum power output at any one frequency.

d. It was found that when the TS-329/U was used with the AN/ARC-1, bringing the hand near the TS-329/U caused its meter reading to change. When the TS-329/U is enclosed in a sheet metal box the readings are unaffected by the position of the observers hands.

e. It was found that when the TS-329/U was used with the AN/ARC-13 in the range from 200 megacycles to 400 megacycles without shielding, the meter readings were extremely critical as to the position of the TS-329/U and surrounding objects. A

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change in reading of half scale was noticed for a small change in the position of the TS 329/U. When the TS 329/U was enclosed in a metal box its readings were not affected by its position or by movements of the surrounding objects.

f. It was found that the length of the coaxial cable feeding the TS-329/U from AN/ARC-1 or AN/ARC-13 was changed, the Antenna circuit had to be retuned to obtain maximum indication of the TS-329/U meter. The maximum reading obtained with different lengths of cable was the same when the antenna circuit was retuned.

12. Power Handling capabilities.

a. The power handling capabilities of the TS-329/U may be limited by any one of three factors:
   (1) The allowable temperature rise of the load resistor.
   (2) The current carrying capacity of the meter thermocouple.
   (3) The RF power at which full scale deflection of the meter is reached.

b. As previously stated, the load resistor of the TS-329/U is a set of 12 one watt composition resistors connected in parallel. A temperature rise characteristics for the load resistor was obtained by using a 60 cycle power source to supply a rated and constant 12.5 watt power input while using a thermocouple attached to the load resistor to determine instantaneous temperatures. This was done with the base attached to the TS-329/U so as to have the same heat conduction and enclosure characteristics as would exist under normal operating conditions.

c. Plate 8 shows the variations of temperature in degrees centigrade with time as 12.5 watts are applied to the TS-329/U for a period of 90 minutes. From this plate it can be seen that 90 minutes are required for the temperature to rise to 92.3°C from an ambient temperature of 28°C, but the major portion of this rise takes place in the first 15 minutes and the temperature rise of the last 20 minutes is only 1.5°C or 2% of the total rise. The total temperature rise is 74.3°C which is not excessive.

d Examination of the resistors showed no apparent physical damage after the test. Continuous operation for a period of 90 minutes is not be to expected in the application of the TS-329/U to testing transmitters and so the load resistor can be considered capable of handling 12.5 watts.

e. It was noticed that as the temperature of the TS-329/U increased the reading of the TS-329/U meter decreased from 456 at 30°C to 415 at 92.3°C with constant 12.5 watts applied. The fact that the meter reading decreases with temperature rise is reasonable since the resistance increases with temperature and so for a given power input the current will be less since the power is equal to the resistance times the square of the current.

f. The resistance was measured at 30°C and at 78°C and found to be 56.1 ohms and 58.4 ohms respectively. The change in resistance therefore was 2.3 ohms for a change of 48°C or 2.3/48 = 0.0479 ohms per degree centigrade. This ghange of resistance

[redacted]

with temperature will cause the impedance to V.H.F. to change with temperature. This will cause the reading of the TS-329/U to change as it warms up during a test of a transmitter. Because of the complex nature of the TS-329/U circuit, at some frequencies the reading will increase and at other frequencies the reading will decrease as the temperature increases.

g. The thermocouple of the meter is operated close to the burn-out temperature when the meter reads full scale. Therefore, if the current in the external part of the thermocouple circuit is increased much beyond the value required for full scale deflection the thermocouple will burn out. This is the second limitation on the power that can be handled by the TS-329/U in the range from 100 megacycles to 400 megacycles.

h. When the TS-329/U meter reads off scale its reading cannot be used to indicate when the transmitter is tuned for maximum output and hence is of no value. Thus the third power limitation of the TS-329/U is the power level at which its meter is caused to read off scale.

i. Examination of Plate 8 shows that the actual power being dissipated in the TS-329/U load resistor will not be the same for a given reading of the TS-329/U at different frequencies. If we consider the extreme case at 190 megacycles where the ratio, $P/I_M^2 = 27$, the power represented by full scale deflection is $(0,5)^2 \times 27 = 6.75$ watts. Here the power that can be handled is limited to 6.75 watts by the usefulness of the Meter reading and by the current carrying capacity of the thermocouple. If we consider the other extreme case at 217 megacycles where the ratio, $P/I_M^2 = 72$ the power dissipated in the load resistor at full scale deflection is $0.25 \times 72 = 18$ watts. Here the power handling capability would be limited to 12.5 watts by the wattage rating of the load resistors. Thus it can be seen that the power handling capabilities vary with frequency.

CONCLUSIONS

13. The Model TS-329/U Phantom Antenna manufactured by General Industries Company is not considered satisfactory for use in the frequency range from 100 megacycles to 400 megacycles for the following reasons:

a. It is not electrostatically shielded to prevent radiation and as a consequence its impedance changes and its meter indication changes whenever the positions of nearby reflecting objects are changed.

b. It does not present a constant load to the transmitter independent of frequency, nor does it simulate the load presented to the transmitter by any V.H.F. antenna with which it was compared.

c. (1) When the TS-329/U is shielded the power output of a transmitter represented by a given meter reading varies over wide limits with frequency.

(2) In this connection the power handling capabilities also vary over wide limits with frequency.

d. The power handling capabilities are not sufficient for use with the AN/ARC-13 equipment, which operates in the 100 megacyles to 400 megacycles band.

e. The impedance and the meter reading change as the load resistor warms up.

RECOMMENDATIONS

14. Based on the results herein reported, it is recommended that the TS-329/U be re-designed along the following lines:

a. It be completely shielded against radiation.
b. It be modified so as to present a constant 50 ohms, purely resistance load, at all frequencies from 100 megacycles to 400 megacycles.
c. It be designed and constructed so that a given meter reading will represent the same power output at all frequencies from 100 megacycles to 400 megacycles.
d. It be designed so that the meter reading will not change as temperature changes for a given power input or so that the final temperature stability is quickly reached when power is applied.
e. It be capable of handling above 25 watts of V.H.F. power without excessive temperature rise and without driving the meter pointer off scale.
f. The device be designated as an indicating V.H.F. load; not a "phantom antenna".

REFERENCES

(a) BuAer ltr. AER-E-3T63-FCB NOas 5423 of 17 August 1945 to Dir. NRL (Secretary Radio Problem Priorities Board).
(b) "Transmission Line Calculator" by P.H. Smith, Bell Telephone Laboratories, January 1939 and "Electronics" January 1944. The Emeloid Co., Inc., Arlington, N.J.
(c) Maintenance Instructions for Model AN/ARC-1, Aircraft Radio Equipment, Section V, Paragraph 2a(13) dealing with the purpose of the TS-329/U.

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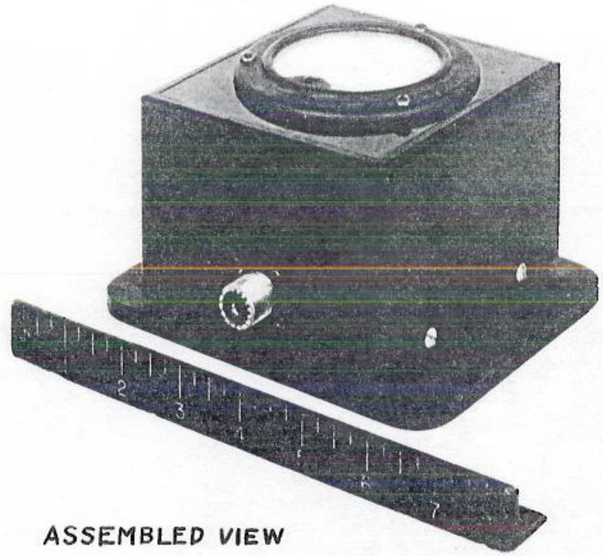
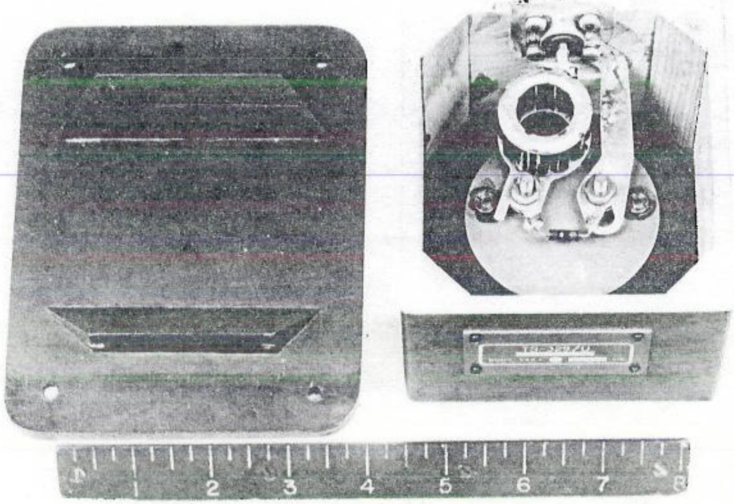
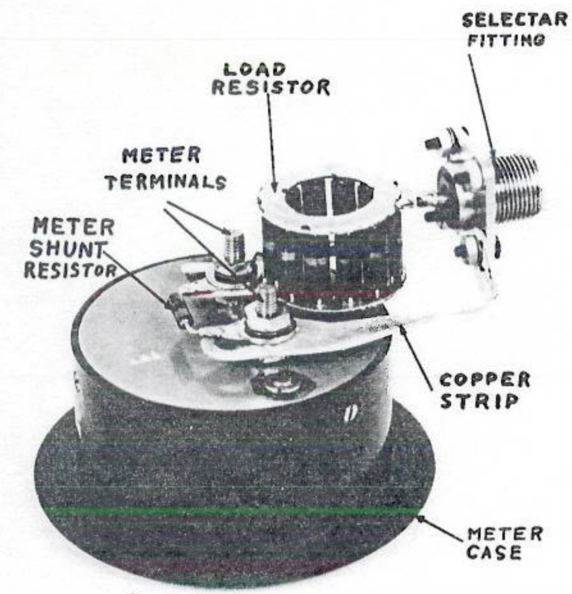


ASSEMBLED VIEW



BOTTOM VIEW BASE REMOVED



VIEW OF COMPONENTS ASSEMBLED

TS-329/U
PHANTOM ANTENNA

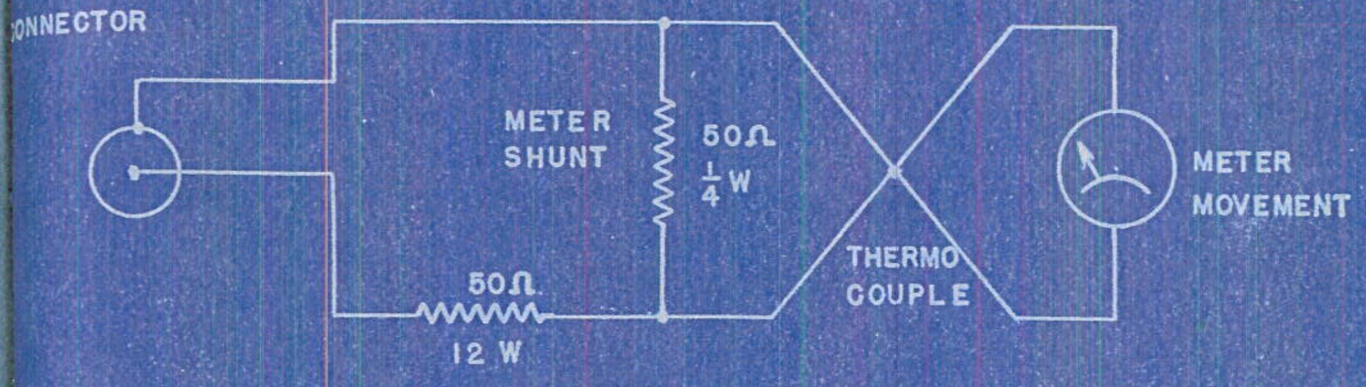
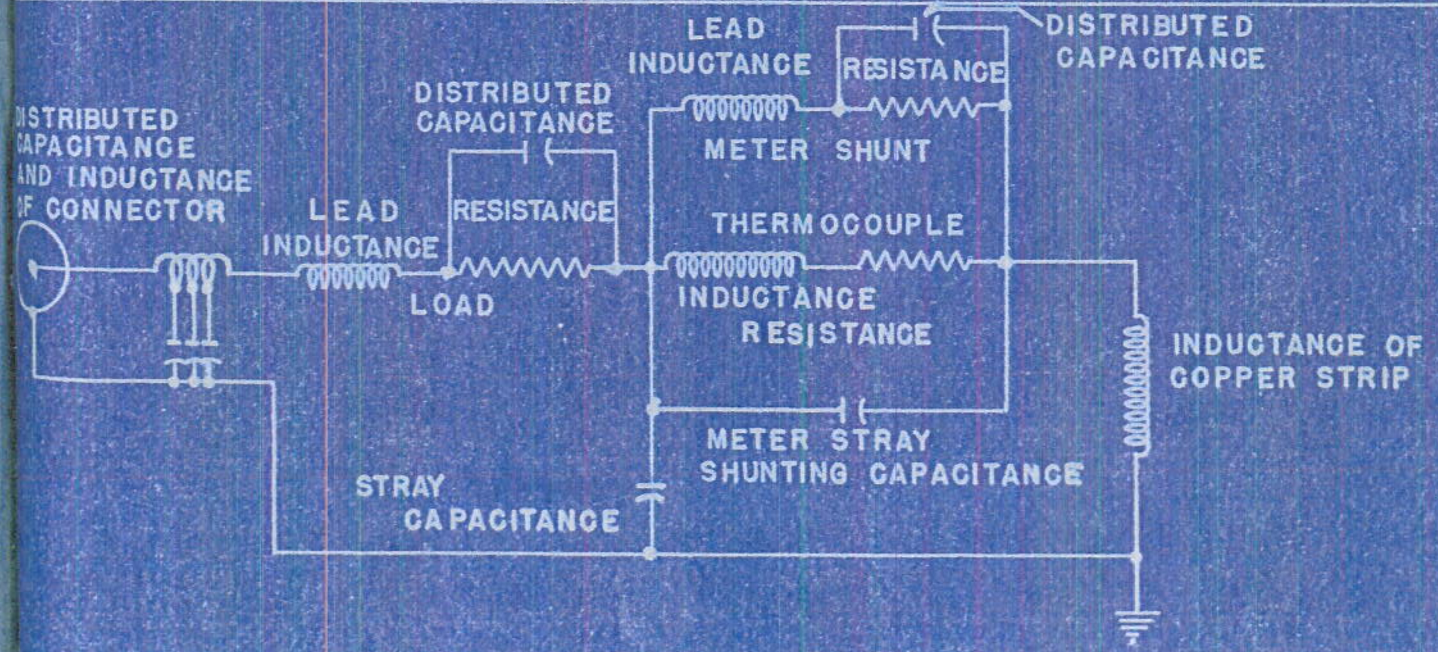


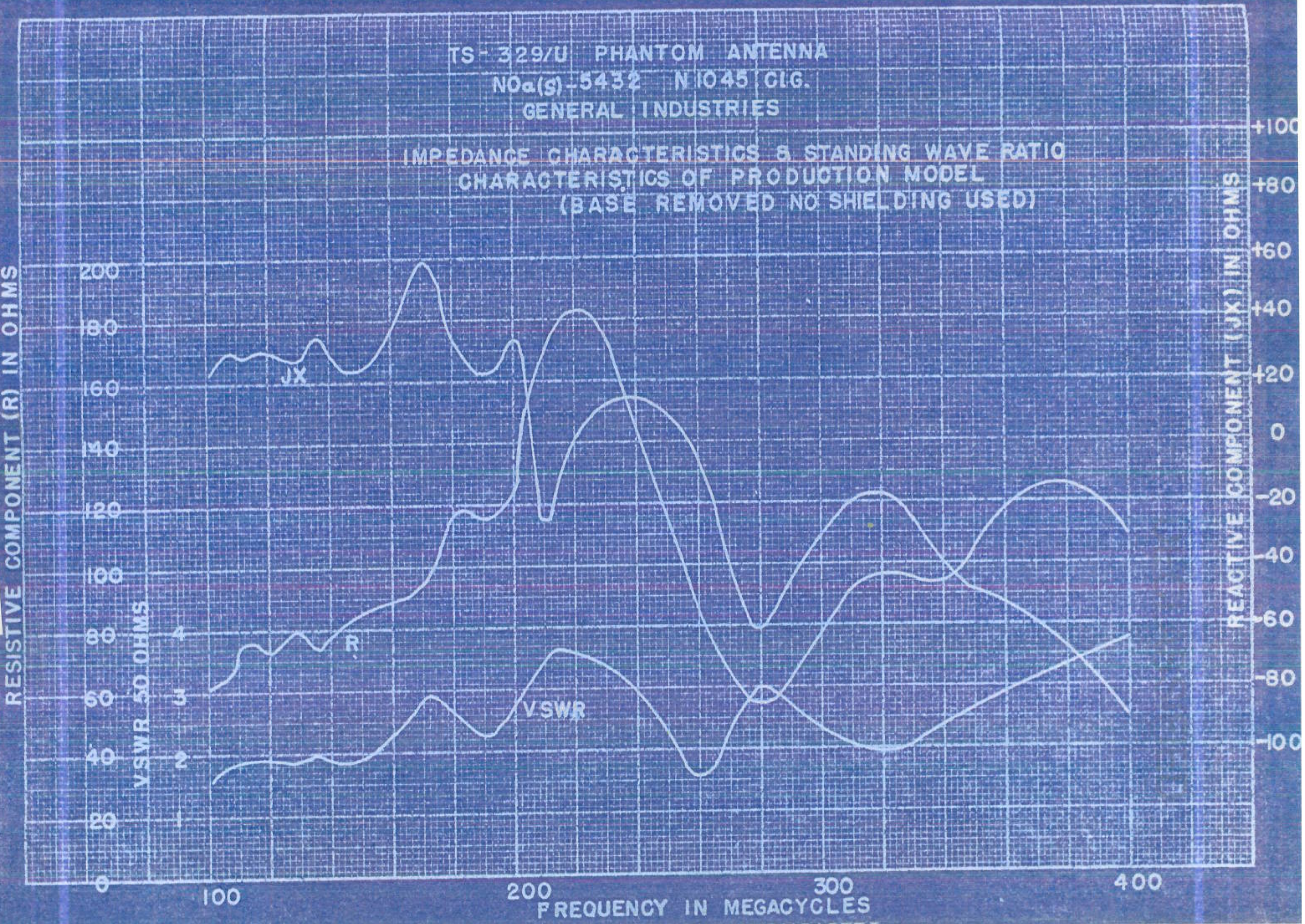
FIG. I

CIRCUIT DIAGRAM OF TS-329/U PHANTOM ANTENNA



APPROXIMATE EQUIVALENT ELECTRICAL CIRCUIT OF TS-329/U PHANTOM ANTENNA AT V.H.F.

FIG. 2


TS-329/U PHANTOM ANTENNA
NOa(s)-5432 N1045 CIG.
GENERAL INDUSTRIES
IMPEDANCE CHARACTERISTICS & STANDING WAVE RATIO
CHARACTERISTICS OF PRODUCTION MODEL
(BASE REMOVED NO SHIELDING USED)
JX
R
VSWR
RESISTIVE COMPONENT (R) IN OHMS
VSWR 50 OHMS
REACTIVE COMPONENT (JX) IN OHMS
FREQUENCY IN MEGACYCLES
0
20
40
60
80
100
120
140
160
180
200
1
2
3
4
+100
+80
+60
+40
+20
0
-20
-40
-60
-80
-100
100
200
300
400

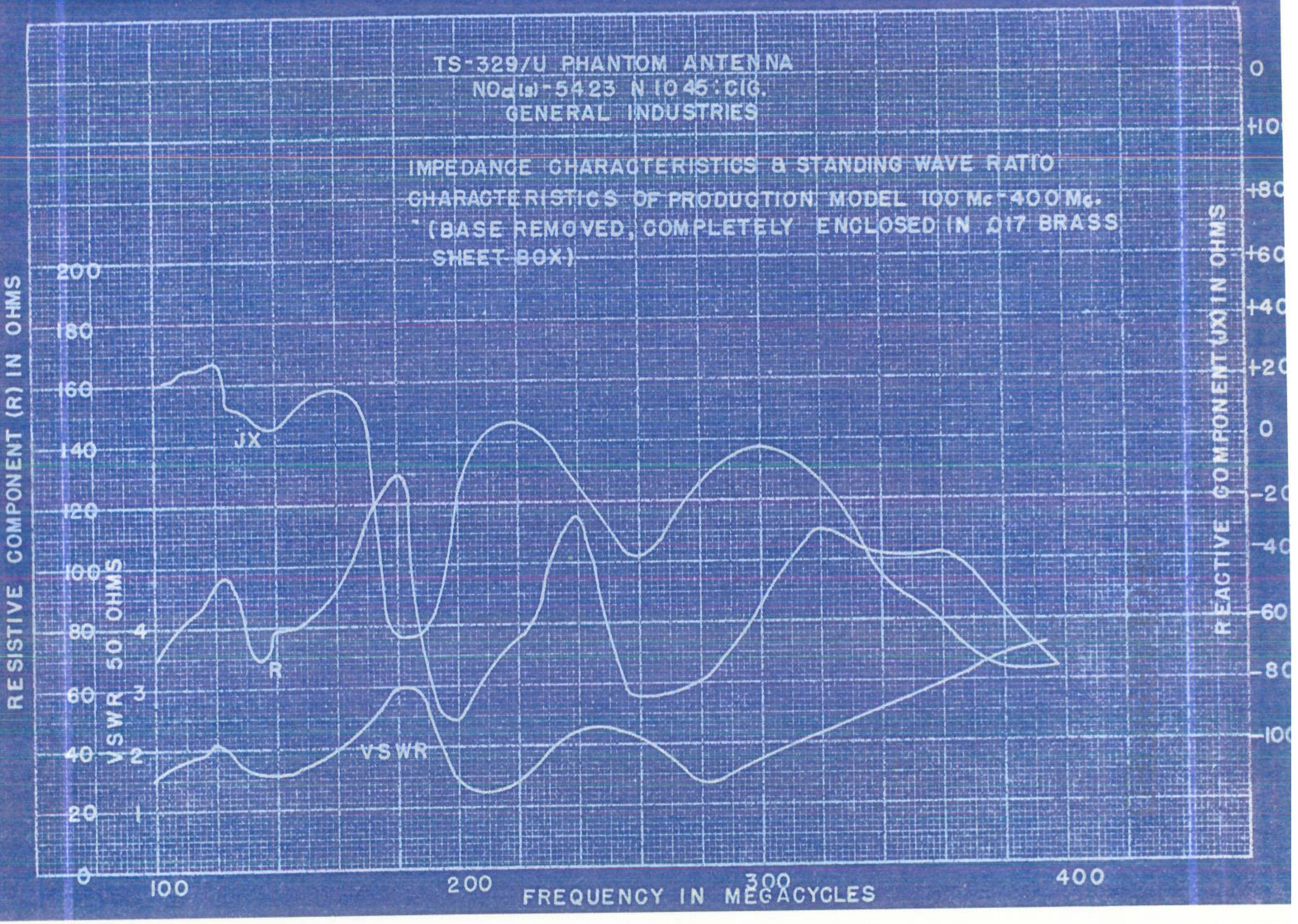


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PLATE 4

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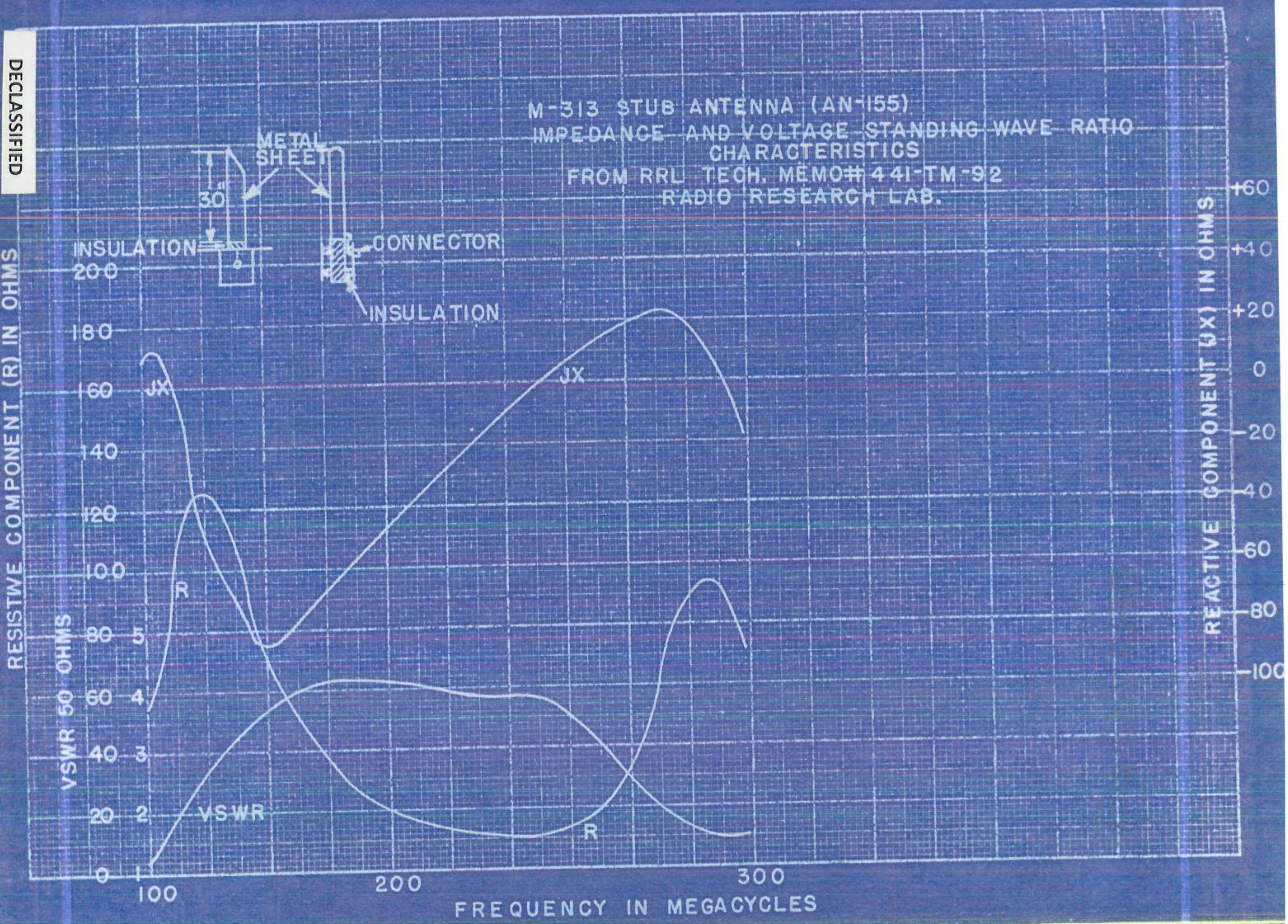

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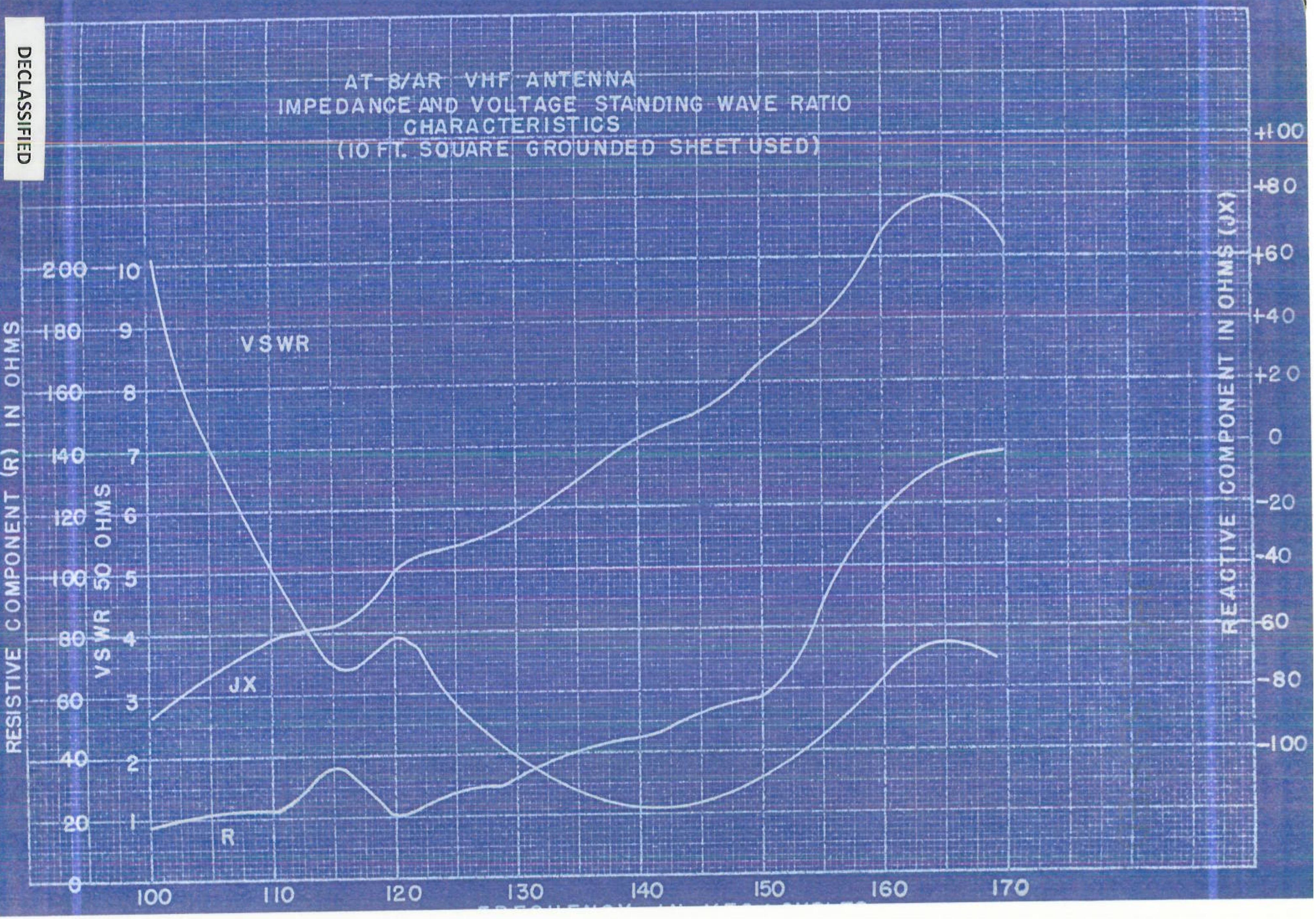
PLATE 5


AT-8/AR VHF ANTENNA
IMPEDANCE AND VOLTAGE STANDING WAVE RATIO
CHARACTERISTICS
(10 FT. SQUARE GROUNDED SHEET USED)
VSWR
JX
R
RESISTIVE COMPONENT (R) IN OHMS
0
20
40
60
80
100
120
140
160
180
200
VSWR 50 OHMS
1
2
3
4
5
6
7
8
9
10
REACTIVE COMPONENT IN OHMS (JX)
+100
+80
+60
+40
+20
0
-20
-40
-60
-80
-100
100
110
120
130
140
150
160
170

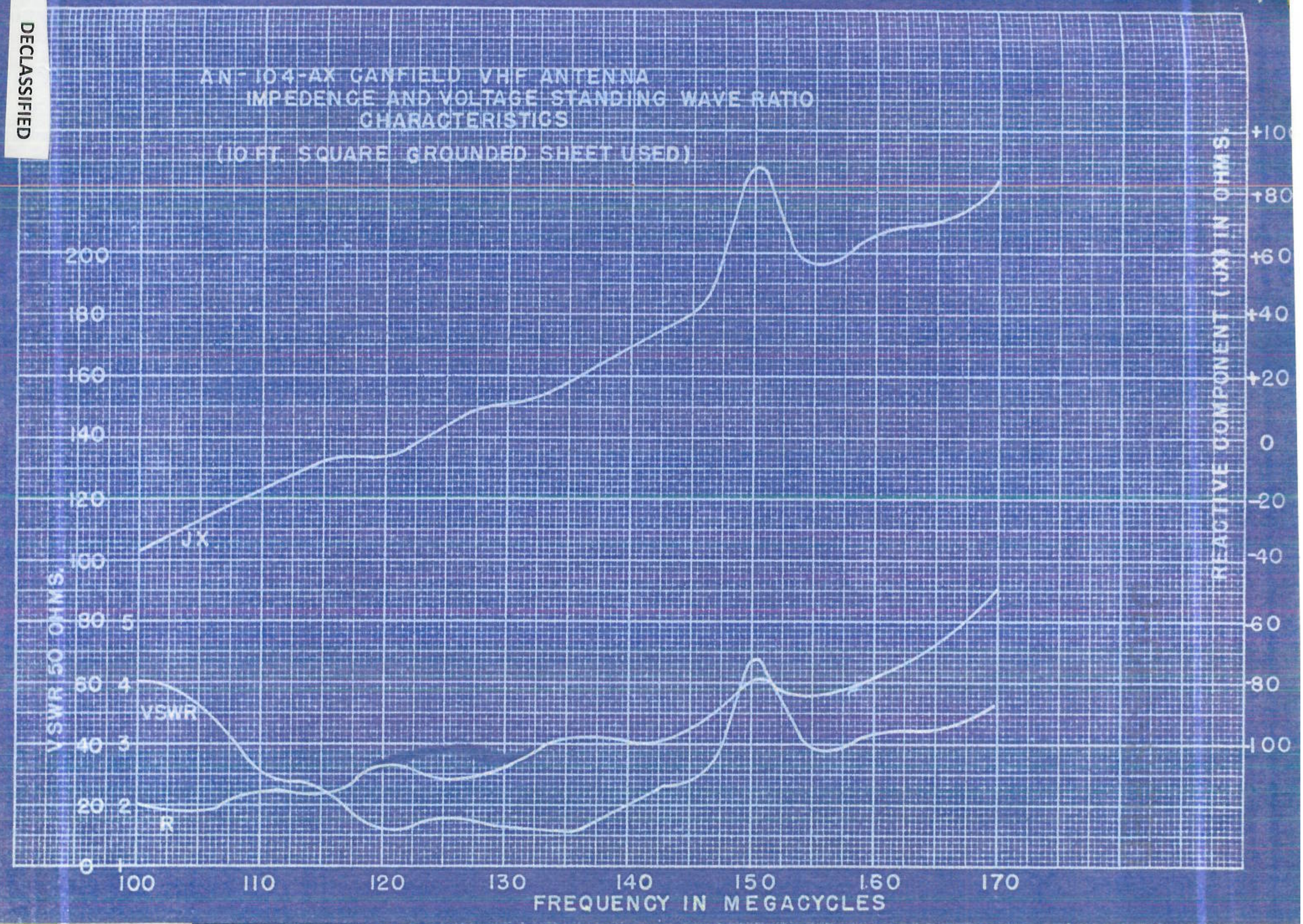


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PLATE 7

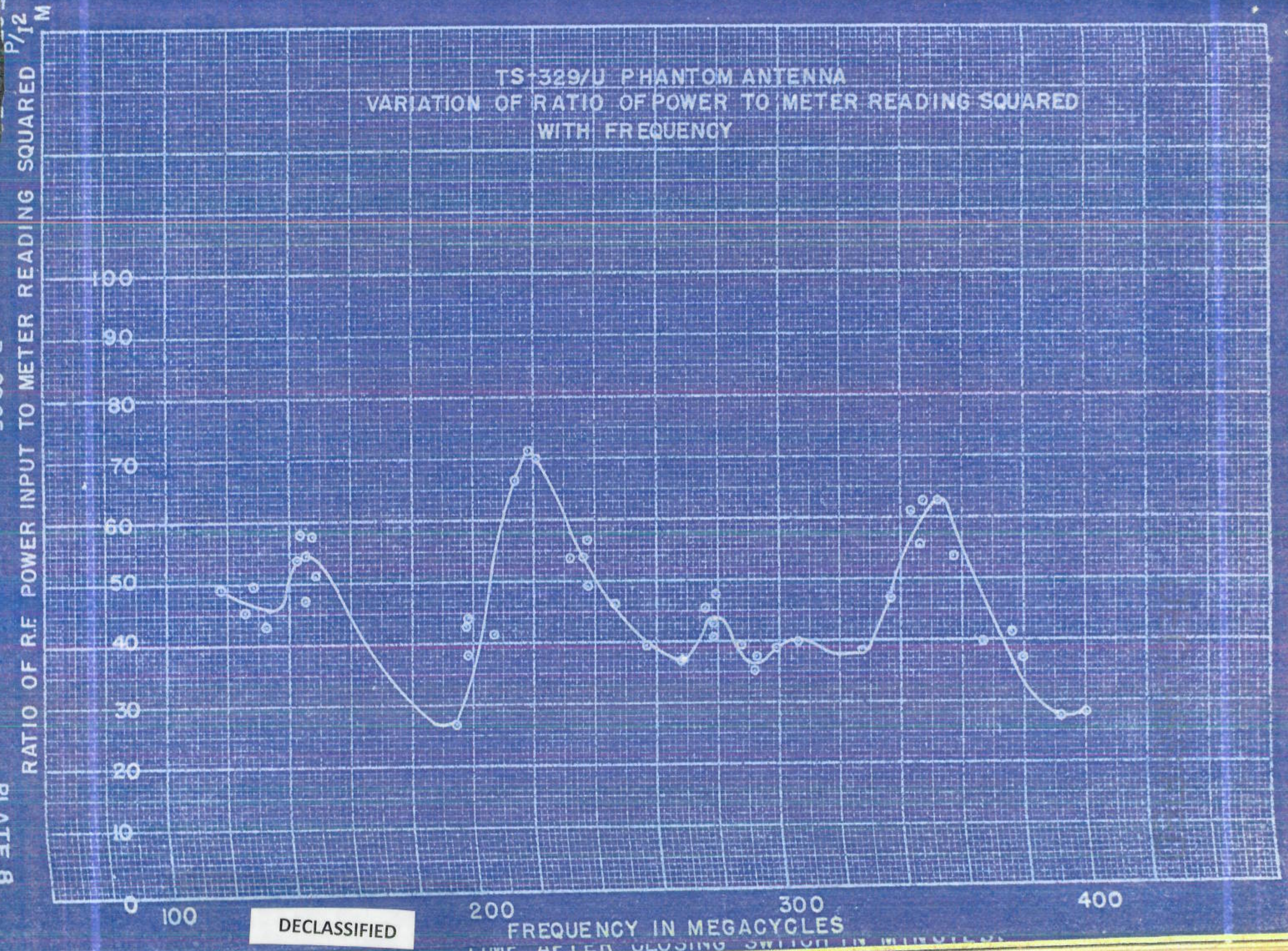

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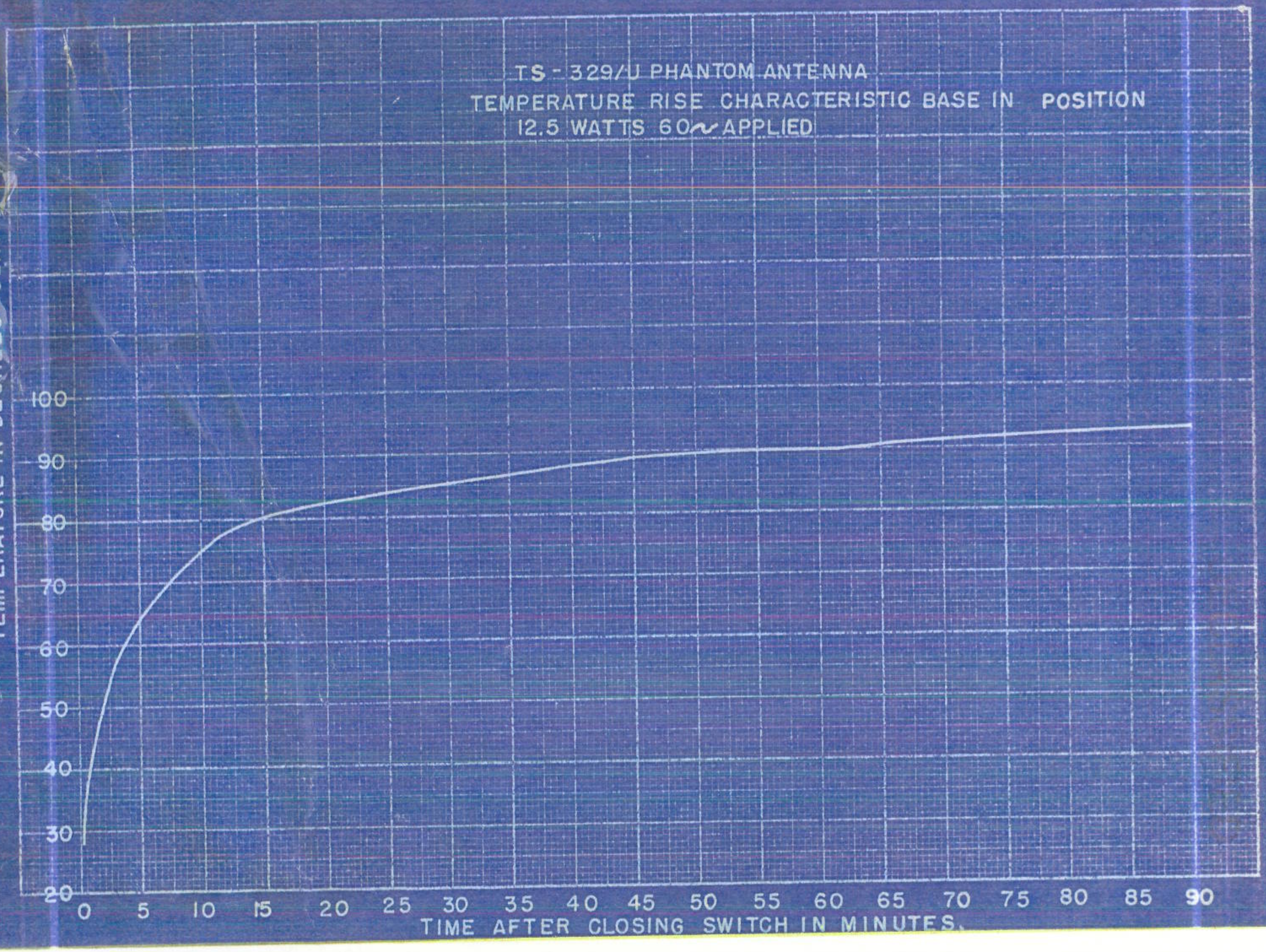
PLATE 8


TS - 329/U PHANTOM ANTENNA
TEMPERATURE RISE CHARACTERISTIC BASE IN POSITION
12.5 WATTS 60~ APPLIED
TEMPERATURE IN DEGREES CENTIGRADE
100
90
80
70
60
50
40
30
20
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
TIME AFTER CLOSING SWITCH IN MINUTES.