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ELECTRONIC SPECIAL RESEARCH DIVISION
APPLICATION RESEARCH SECTION

7 January 1946

ELECTRONIC TRANSMITTING SWITCHES FOR THE 225 to 390 MEGACYCLE FREQUENCY RANGE

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Preliminary Pages ....a-c
Numbered Pages...........5
Plates...................4
Distribution.............d

BuShips Problem S1004R-C

(a)

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ABSTRACT

On board Navy ships many antennas must be located in places where the resulting field intensity patterns do not give adequate coverage in all directions. A system has been devised of using two antennas in parallel and switching the transmitter alternately from one antenna to the other at a super-audible rate, this giving an average effect of the patterns from the two antennas.

This report describes the development of and results obtained from such a system and it gives some results of an investigation of the interfering signals produced. The frequency range covered was 225 to 390 megacycles, and the switching rate used was 20 kilocycles. The results obtained from the transmitting switches developed were unsatisfactory, the power handling capacity being limited by available tubes to less than five watts per switch.

The switching action was accomplished through the use of a vacuum tube across a resonant tank. The plate resistance of the tube, varying with the dc current through the tube, was used to control the r-f transmission through this tank.

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INTRODUCTION

1. This work was requested by the Bureau of Ships and authorized by reference (1).

2. On board Navy ships, due to the large numbers of antennas used, it is necessary that some of the communication antennas be mounted in places where good coverage over 360 degrees in the horizontal plane is not possible. One possible method of improving the coverage of these antennas would be to use a pair of antennas with each transmitter. Each antenna would be mounted in a position such that in the direction in which radiation by one antenna would be low, the radiation by the other antenna would be high. Such a case would occur if the two antennas were mounted on opposite sides of the ship. The transmitter could then be switched from one antenna to the other at a super-audible rate and the patterns of the two antennas would in effect be averaged, thus giving more nearly uniform coverage.

3. The purpose of this project was to investigate and develop a method for the super-audible switching of the output of a 225 to 390 megacycle transmitter alternately between the two antennas, and to make an experimental determination of modulation components and bandwidth characteristics in the individual and composite radiation fields of the two antennas.

METHOD OF OBTAINING ELECTRONIC SWITCHING

4. The method used to produce the switching was essentially the same as that used in some TR systems in radar. A switching vacuum tube was used under the two operating conditions of conduction and non-conduction, r-f plate resistance being low during conduction and very high during non-conduction of the current through the tube. This tube was connected directly across the antenna transmission line, thereby alternately providing a low resistance short and an open circuit in parallel with the line, switching thus being obtained. Switching was at a 20 kilocycle frequency.

5. The plate resistance of most tubes is not low enough to provide a good short circuit across a 50-ohm line during conduction of the tube. Consequently, a resonant tank tuned by a parallel tuning stub was used to build up the voltage. (See Figure 1, Plate 1). The tank was made approximately a half wavelength at mid-frequency with the switching tube located at the center or high impedance point. This location permitted maximum effectiveness in switching.

6. The switch, as just described, would in one condition transmit the r-f energy and, in the second, provide a short past which the energy could not flow. For alternate switching of two antennas two of these units were required, each keyed 180 degrees out

of phase so that one switch would transmit energy during the time the other would not. When one switch would be shorted out its input impedance would be very low; therefore, quarter wavelength transmission lines were used between each switch and the common transmission line to the transmitter to transform this low impedance into a high impedance. This high impedance, being in parallel with the other branch, would not have much effect on the transmission of the energy from the other switch to the transmitter. This system is shown by Figure 2, Plate 1.

TRANSMITTING SWITCHES USING TRIODES

7. Some of the tubes tried for this transmitting switch were the 826, the 2C39, and 3C22 triodes, the best results being obtained with the 3C22. When triodes were used, the grids were bypassed to the plates so that with respect to the r-f voltage the tubes acted as diodes. A photograph of the switch using the 3C22 triode is shown by Plate 2. The graph of Plate 3 gives the performance of only a single switch measured with dc operating conditions rather than with 20-kilocycle keying. In this graph the switching efficiency is expressed as the ratio of the powers transmitted by the switch in the transmitting and non-transmitting conditions expressed in decibels.

8. The reflection curve is for the operating condition of non-conduction through the tube, or of transmission through the switch. At low power level the reflection of this switch was of the order of 15 percent and switching efficiency was about 25 decibels. When the power was raised to five watts the switching efficiency dropped to approximately 20 decibels, this switching efficiency varying over the frequency band. The reflection did not vary much as the power was raised, but due to experimental difficulties the data obtained at the higher power level was too erratic to be plotted. The source of power was the XAZ transmitter at the quarter-power tap position. The power output at this setting was not known accurately, but was probably between 5 and 10 watts.

9. The power capacity of this switch was limited by the permissible r-f voltage swing of the grid of the 3C22 tube. This can be explained with the aid of Plate 4, which shows the variation of the output from the switch expressed in percent of the power which would be transmitted without the switch, as a function of the grid voltage of the 3C22 triode, at a plate voltage of 600 volts and a frequency of 325 megacycles. During dc conduction through the tube and non-transmission through the switch the tube should be operated with grid voltage sufficient to give maximum rated plate current. The r-f voltage applied will swing the grid voltage around this operating point but the amplitude of this swing is limited to the region where the switch is well cut

off. In the non-conducting condition of the tube the dc bias must be far enough negative that no plate current will flow during any part of the r-f cycle super-imposed upon the dc bias on the grid. Upon the application of the largest permissible r-f signal to the switch, the grid of the 3C22 will swing on the positive peak of the r-f cycle from the point at which the tube just begins to conduct to a point of maximum inverse voltage for the grid of the tube on the negative peak of the r-f cycle. The drop of switching efficiency when 5 watts power was applied to this switch, as shown by the graph of Plate 3, is due to the fact that during dc conduction through the triode and non-transmission of the r-f energy through the switch the r-f voltage across the triode became too great. The plate resistance of the triode, varying with the current, becomes too great at the negative part of the r-f cycle, this giving poorer keying.

10. By measurement of the dc bias necessary for complete cut-off of the plate current of the tube both with and without application of the r-f power to the switch it was found that when the 3C22 was not conducting the r-f voltage across the 3C22 was approximately 15 times the flat 50-ohm line voltage. If the resonant tank should be designed to give lower r-f voltage across the tube during non-conduction the voltage across the tube during conduction would be higher, and vice versa.

PRODUCTION OF UNDESIRED MODULATION COMPONENTS AND CARRIER HARMONICS

11. This foregoing discussion assumes square-wave keying. If sine-wave keying should be used on the grid of the tube, the operating point with respect to the carrier frequency would move along the sloping part of the output vs. grid voltage curve of Plate 4 at a relatively slow rate. The r-f voltage would swing the grid potential above and below this operating point giving various degrees of transmission for different parts of the r-f cycle. This would be equivalent to the production of harmonics of the carrier frequency. Since the switch is rather sharp in tuning it would probably attenuate these harmonics to a considerable extent. If additional attenuation of these harmonics should be desired, filters could be placed between the switches and the antenna.

12. In addition to the harmonics of the carrier frequency, undesired signals are produced by the switching through interaction between the switching frequency and the original carrier sidebands. This occurs even when the signal amplitude is small enough that the transmission through the switch does not change appreciably over any part of the r-f cycle. The switching frequency acts as a modulation frequency in amplitude modulation, but it modulates both carrier and sideband frequencies rather than just the carrier. This creation of extraneous sideband components by the switching is discussed in reference (2) where it was shown that the frequencies present would be the carrier frequency, the

original sideband frequencies, the sideband frequencies produced by the modulating action of the switching on the carrier, and sideband frequencies containing the sums and differences of the frequencies of the switching and of the original sidebands.

13. As this switch was not suitable for switching appreciable amounts of power no keyer was built for it, and it was tested only under static conditions of bias. An experimental study of modulation bandwidths and of interfering harmonics was not made since this would probably be mainly dependent on the type of switch used.

TRANSMITTING SWITCHES USING GAS TUBES

14. Characteristics of gas tubes were investigated but no gas tubes suitable for use in the transmitting switches were found. Although gas tubes fulfill the requirements of low plate resistance, there are several obstacles to their use: namely,

(a) Gas tubes introduce the possibility of producing noise.

(b) To extinguish the arc in a gas tube, the peak anode voltage must fall below the extinction potential for the tube.

(c) When the peak-to-peak r-f voltage swing becomes too great it will become impossible to extinguish the arc even with zero dc bias on the gas tube. This results because the voltage at the positive peak of the r-f cycle will become great enough to produce an arc in one direction and the negative peak will become great enough to produce an arc in the other direction, thus maintaining the ionization of the gas in the tube.

(d) Ionization and deionization time become factors to be considered at 20 kilocycles, this rapid keying not being possible with tubes containing some of the heavier gases.

15. Such tubes as the 1B23 and 702A, having been designed for pulse operation in TR systems, do not have the power dissipation necessary for continuous operation at currents large enough to reach the conditions of low r-f plate resistance.

CONCLUSIONS

16. The transmitting switch using the 3C22 triode is not suitable for switching more than about five watts power. If

an effort should be made to switch more power than this, the switching efficiency would be lowered, the peak inverse voltage on the grid of the 3C[illegible] triode would become excessively high and harmonics of the carrier frequency would be produced. At any power level additional sidebands resulting from the 20 kilocycle switching will be present.

ACKNOWLEDGEMENTS

17. Co-workers on this project were Mr. Sam K. Brown, Ens., USNR, and Mr. Henry F. Carlson, CRE, USN.

18. Mr. John H. Markell of NRL performed preliminary work on electronic switches under this project. His work was of value in the development of the switches presented in this report.

REFERENCES

1. BuShips ltr. Sec. 929 Ser. No. 71 of 30 December 1944 to Director, N.R.L. (SRPPB): Request for Assignment of Problem S1004R-C.

2. NRL Report R-2715, January 1946: Development of Electronic Receiving Switches for the 225 to 390 Megacycle Frequency Range.

Original data recorded in NRL Log Book 5367

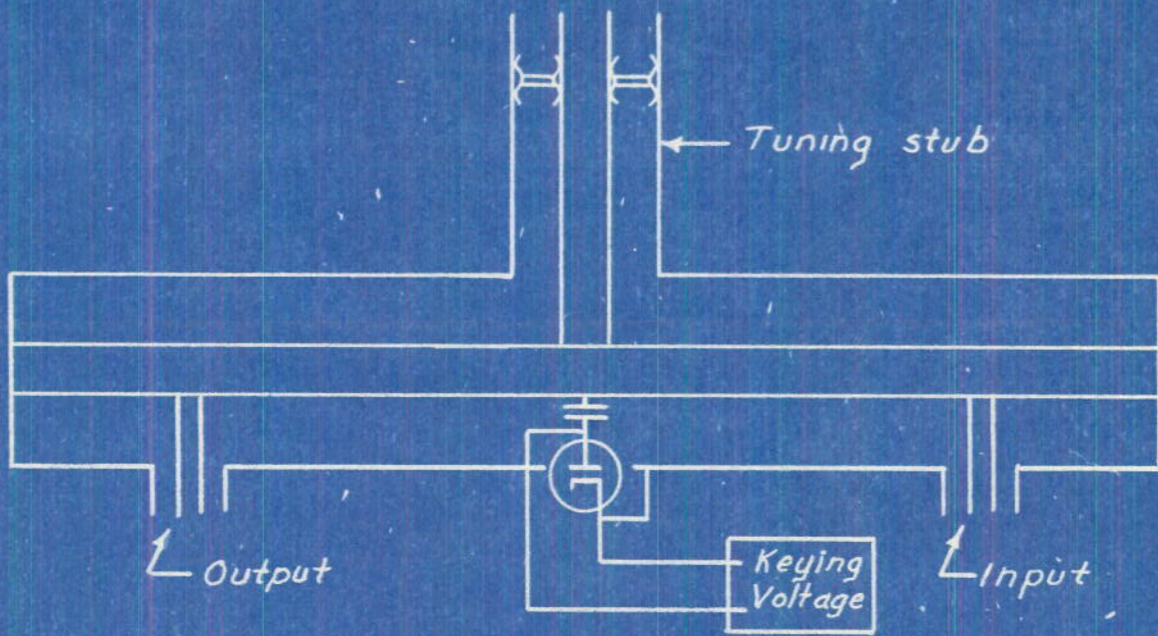

Fig. 1

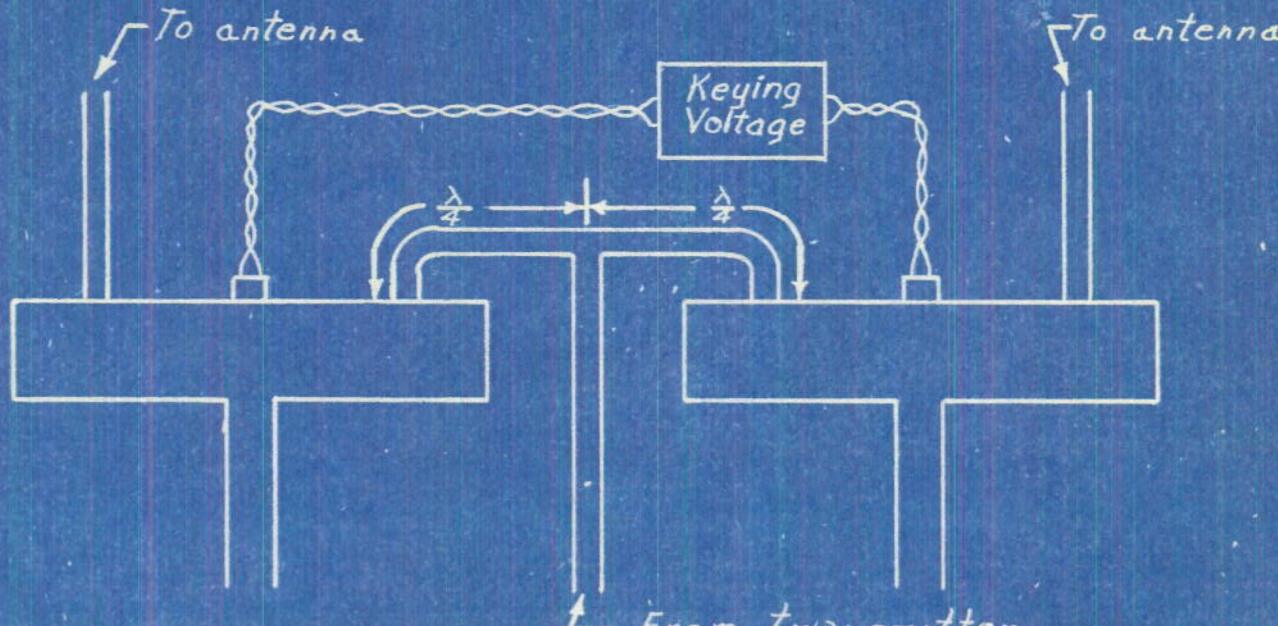

Fig. 2

SKETCHES SHOWING METHOD OF OPERATION OF ELECTRONIC SWITCHES

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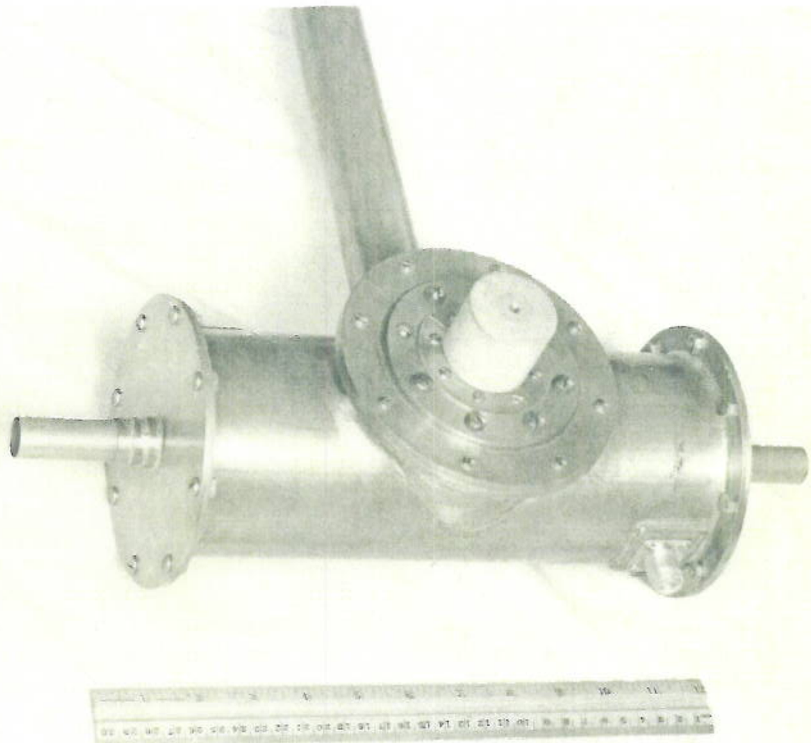
PLATE 1



TRANSMITTING SWITCH USING 3C22 TRIODE

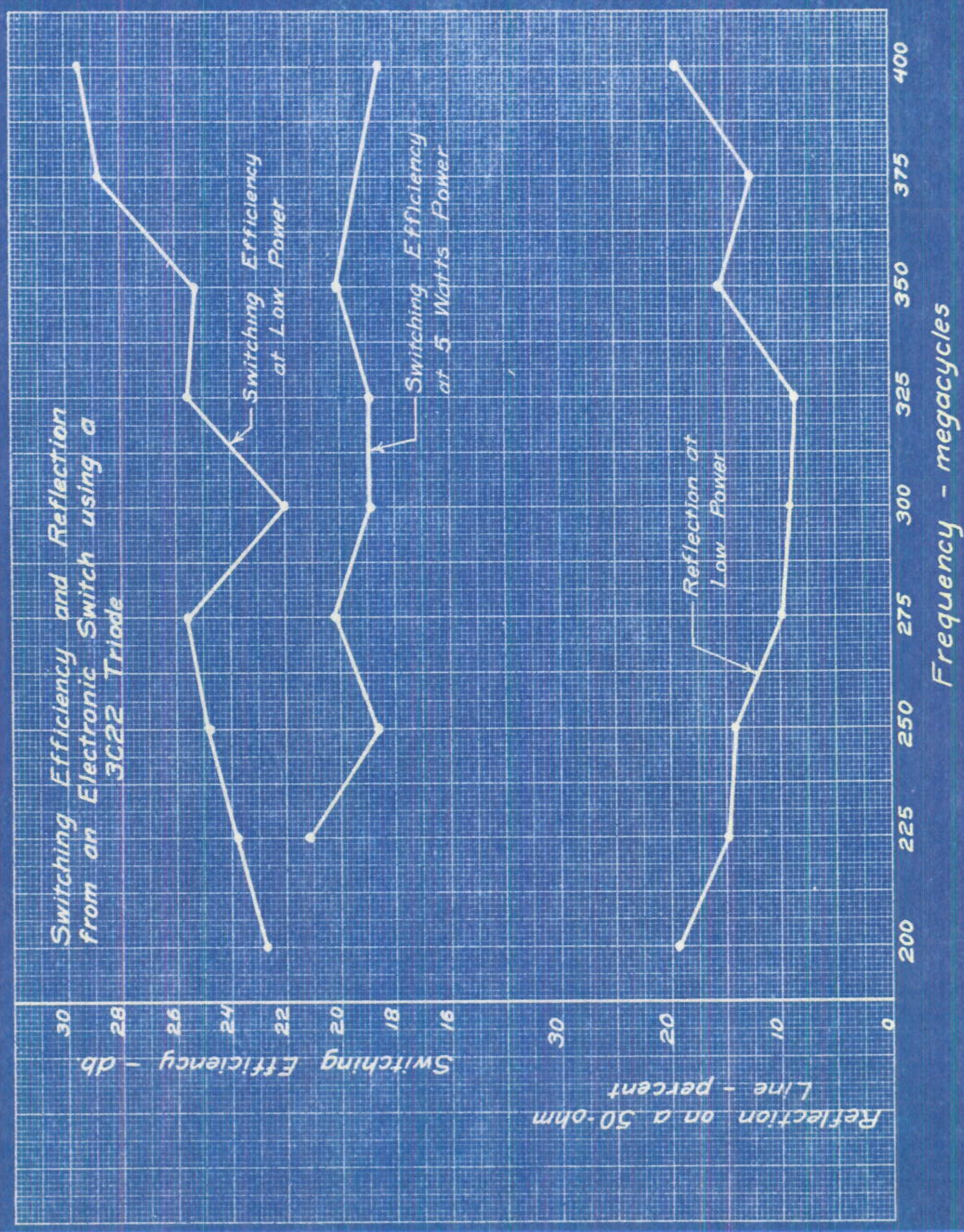


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PLATE 3

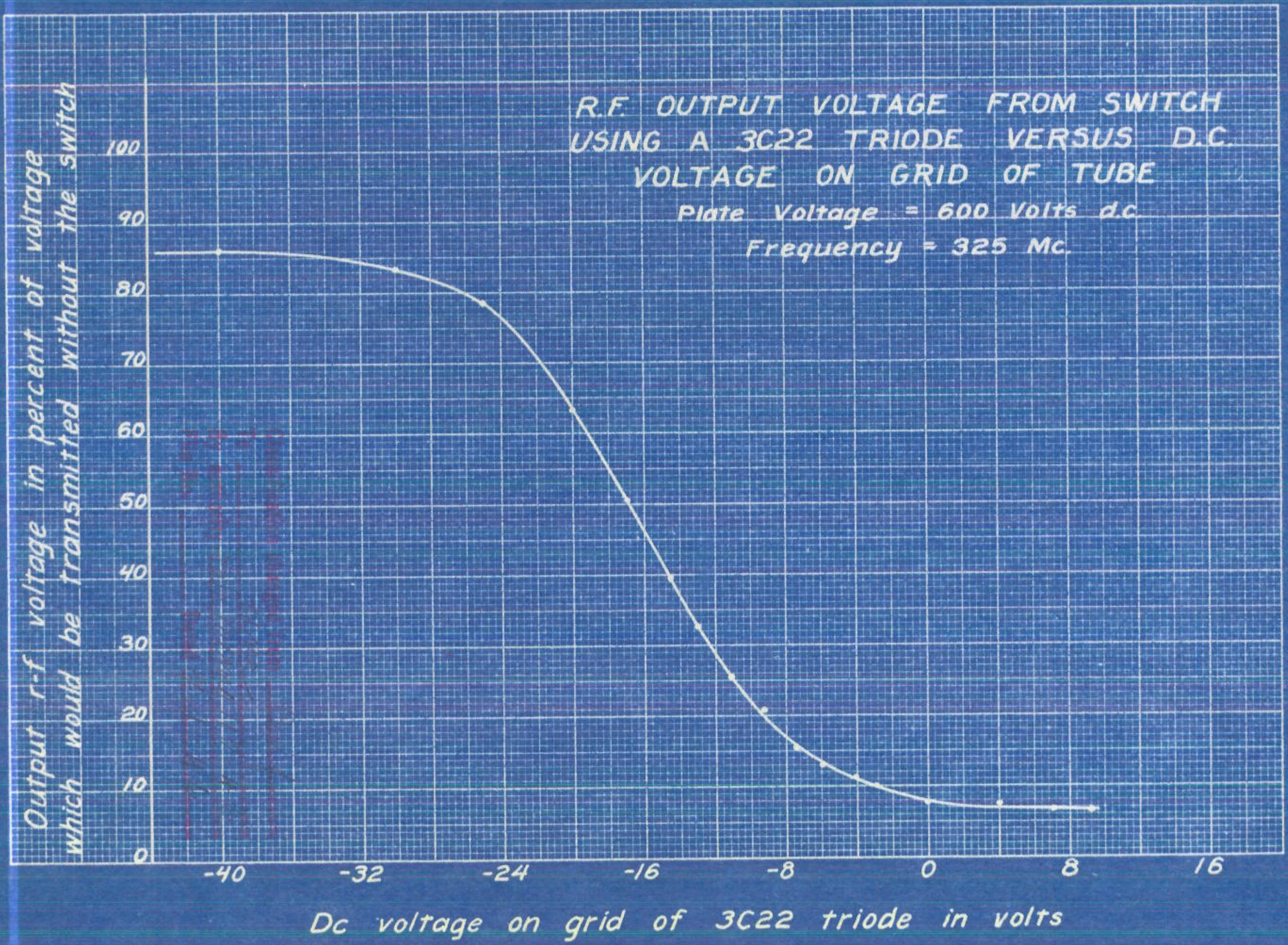

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PLATE 4