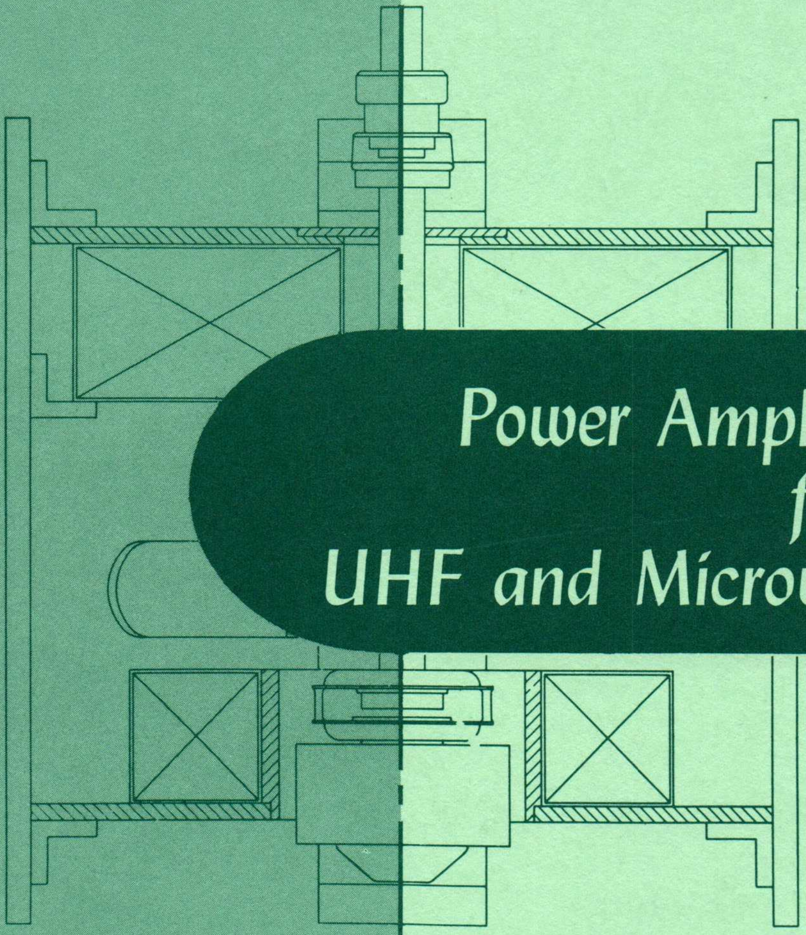
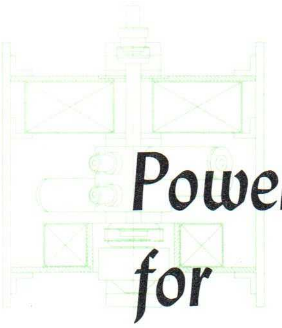


Power Amplifier Klystrons for UHF and Microwave Transmission

Eimac

EITEL-McCULLOUGH, INC.
San Bruno, California



Power Amplifier Klystrons for UHF and Microwave Transmission

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George Washington University

Figure 1
Outline drawing of typical Eimac external cavity klystron

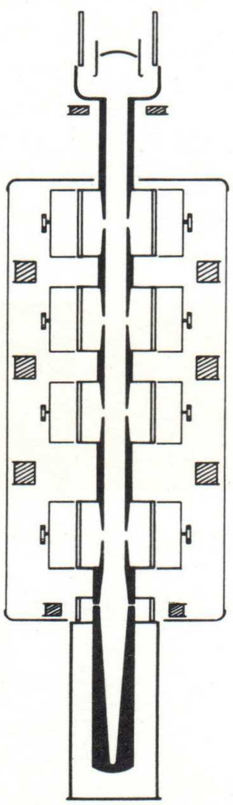

Figure 2
Outline drawing of typical Eimac external cavity klystron in amplifier assembly

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Power Amplifier Klystrons for UHF and Microwave Transmission

When one reviews the history of Scatter Communications, an important fact is immediately obvious; that is, a major development in communications techniques has occurred in a very short period of time. The evolution of reliable and economical Scatter systems has undoubtedly been expedited by the early development work of components manufacturers to meet UHF Television requirements. When considering the requirements for a high-power amplifier tube to be used in an effective Scatter system, we find several similarities to the UHF Television application. The following examples are given:

(a) Frequency
(b) RF Power Output
(c) Bandwidth
(d) Desirability of high power gain
(e) Adaptable to simple RF circuit techniques

We have developed and produced a rather complete line of density-modulated power tubes (such as the conventional negative-grid triodes and tetrodes) capable of meeting the requirements of VHF Scatter systems.

When considering the UHF Television requirement for 10KW-RF power at 400 Mcs. to 900 Mcs., our first choice, because of past experience, was the density-modulated type of electron tube. This was quickly discarded because of the manufacturing difficulties involved in producing a high-power tube with closely spaced elements. Close spacings are, of course, necessary for UHF operation of all density-modulated electron tubes, whether or not the tubes are of the beam-forming type. Other factors affecting our decision were ultimate product reliability, ease of operation, power gain, and the problems of RF circuit design. The best solution to all of these problems appeared to be the klystron tube; hence, we commenced work immediately on a klystron development program.

The result of this development program is the external cavity klystron described later herein, and this tube has proved to be a very satisfactory amplifier for the UHF Television application. The advent of Scatter Communications systems brought a new application for these tubes and we shall see that the klystron tube, properly designed and constructed, is extremely wellfitted for these applications at frequencies above 200 Mcs.

The general type of klystron to be described is the external cavity tube; that is, the RF cavities are completed outside the vacuum envelope. Figure 1 is an outline drawing of such a tube. The basic theory of the velocity modulated klystron tube is well known and the external cavity tube is no exception to the theory. An important feature of the external cavity tube is the employment of ceramic cylinders as both vacuum seals and RF windows. We need spend little time on why ceramics instead of glass—suffice it to say that we were never successful in getting 5KW-RF through a glass cylinder in the output cavity. The high alumina ceramics employed in these tubes possess excellent thermal conduction and mechanical strength characteristics. RF losses in the ceramics are negligible at frequencies below 3000 Mcs., as will be shown by the high efficiencies of these tubes.

The ceramic window permits several important advantages to be realized. The tuning mechanism can be removed from the vacuum envelope and, in most cases, physically separated from the tube, thus reducing tube production problems by permitting the processing of a simple vacuum structure. Tuning ranges of the klystrons can be made very broad with relatively flat efficiency over the band, and without use of vacuum bellows or other movable vacuum joints that limit tube life. The load coupling arrangement in the output cavity is also external to the vacuum system; hence, a wide range of coupling adjustment is possible and practical. This is a very important feature in the high CW power applications that are now commonplace.

Figure 2 shows the external cavity klystron amplifier assembly complete with tuning cavities and magnetic focusing system. The main magnetic field controls the electron beam through the RF section of the tube, which is designed in the usual manner excepting that particular attention is paid to minimizing secondary electrons and, thus, reducing random beam noise. Execution of the electron gun and anode section of the circuit is unique. The gun is a modification of the Pierce type with a separate focus electrode that can be biased nega-

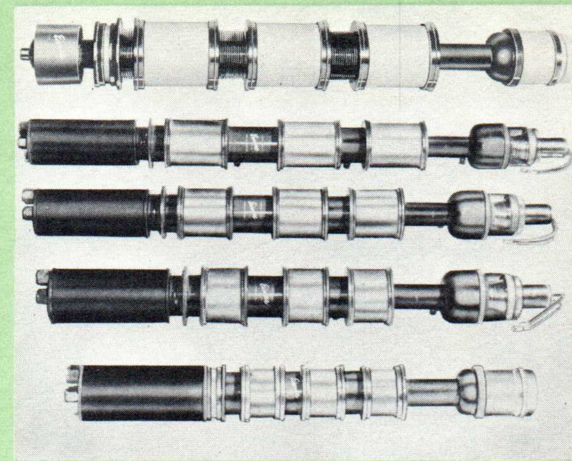

Figure 3
Five typical Eimac external cavity klystrons

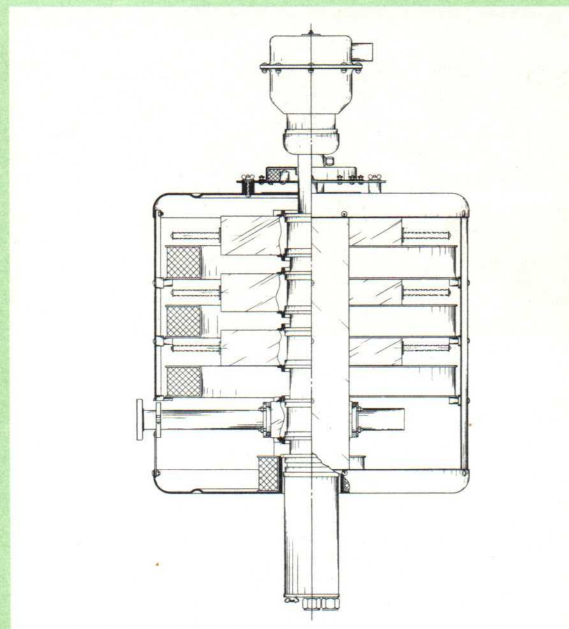

Figure 4
Complete 4K50,000LQ amplifier assembly

DATA COMPARISON OF 4K50,000LQ vs. 3K50,000LQ

ITEM	3K	4K
FREQUENCY	700-1000 Mc	700-1000 Mc
RF POWER OUTPUT	10 KW	10 KW
BEAM VOLTAGE	16 KV	16 KV
EFFICIENCY	42%	44%
POWER GAIN	30 db	40 db
BANDWIDTH, 3 db	2.5 Mc	+6 Mc

Figure 5
Data comparison of the Eimac 3K50,000LQ and 4K50,000LQ klystrons

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Figure 6
Tuning range and efficiency of Eimac's 4K50,000LQ amplifier klystron

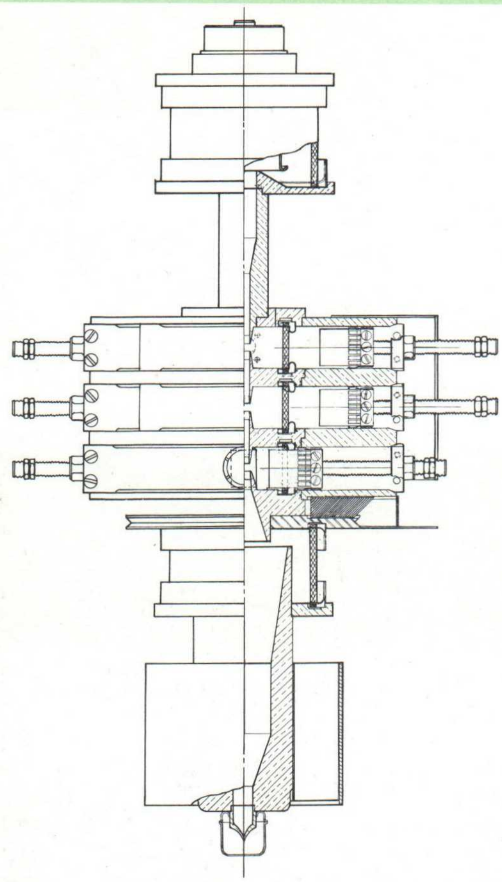

Figure 7
The Eimac X571 klystron

tively with respect to the cathode. This structure combined with the pre-focus coil (or neck coil) produces a well-shaped parallel electron beam before the beam enters the main magnetic focusing field. This combination of gun and pre-focus coil is partially responsible for the 40 to 50 percent efficiencies achieved in Eimac klystrons. The combination also permits great flexibility in gun design because the diameter of the electron beam emerging from the short magnetic lens supplied by the pre-focus coil can be different from the beam diameter entering the magnetic lens. For example, we have successfully used the same size cathode for klystrons having RF section drift tube diameters from 1/4 inch to 1 3/4 inches.

The collector is insulated from the RF section for D.C. This permits monitoring of the klystron body current while making adjustments or during normal operation. Since the inter-action gaps or drift tube tips are quite sharp (a radius of .010″ to .040″ is normal) in any well designed klystron, it is considered necessary to protect them against excessive electron bombardment due to maladjustment of the beam focusing system. The insulated collector permits use of suitable circuits for body current overload protection and thus helps prevent catastrophic tube failure.

Figure 3 shows photographs of 5 typical external cavity klystrons now in production at Eimac. A total of 11 types, including these 5, are actually now in production in varying quantities and are being generally used in Scatter systems. These 11 are the following:

3K3,000LA	3KM3,000LA	3K3,000LQ
3K20,000LA	3K20,000LF	3K20,000LK
3K50,000LA	3K50,000LF	3K50,000LK
3K50,000LQ	4K50,000LQ.	

Figure 4 is a drawing of the complete 4K50,000LQ amplifier assembly and represents one of our latest tube types. This tube produces 10KW-CW and covers the frequency range of 700 to 1000 Mcs. Its efficiency is slightly higher (2 to 3 percent) than the equivalent 3-cavity tube and this is to be expected. The important advantage of the 4-cavity tube is not higher efficiency but greater power gain and bandwidth.

Figure 5 gives comparison data for the 3K50,000LQ and 4K50,000LQ. It should be noted that the important differences are in gain and bandwidth. If the 4K50,-000LQ were not detuned for the wider bandwidth its gain would approximate 60 db.

Figure 6 shows one of the major advantages of the external cavity klystron; that is, broad tuning range and relatively flat efficiency over the range. This curve was taken with constant beam voltage and RF drive power. This can be considered as typical performance of an external cavity klystron.

Figure 7 shows the X571 klystron tube. The tuning cavities are external to the vacuum system and ceramic windows are employed. Due to the small size of the RF structure, it was necessary to use common walls for the RF cavities and make these a part of the tube. This design change produced a rigid mechanical structure that has excellent heat dissipation characteristics, an important point if the tube is to be stable during operation.

Figure 8 shows the same X571 klystron complete with tuning doors and magnetic focusing circuits. This assembly is air-cooled and produces 1KW-CW over the frequency range of 1700 to 2400 Mcs. It is interesting to note that this tube, equipped with a water cooled collector, has produced 5.3KW-CW at 2100 Mcs. and over 40 percent efficiency.

Figure 9 shows a recent addition to the external cavity tube line; that is, the X590D klystron. This unit tunes from 225 Mcs. to 400 Mcs. without changing components and produces 20KW-CW or FM. The klystron is equipped with a modulating anode for amplitude modulation applications or pulsing and will produce a 10KW carrier with 100 percent A.M.; thus, 40KW peak power. This tube uses a recently developed oxide cathode that requires 50 watts heater power and no bombarding power.

Figure 10 shows a working view of the tuning cavity for the X590. It can be seen that there are four doors in this tuning cavity, thus permitting the very broad tuning range of 56 percent of center frequency.

Figure 11 shows a plot of RF conversion efficiency vs. tuning range for the X590 klystron. Again, it should be noted that the beam voltage and RF driving power

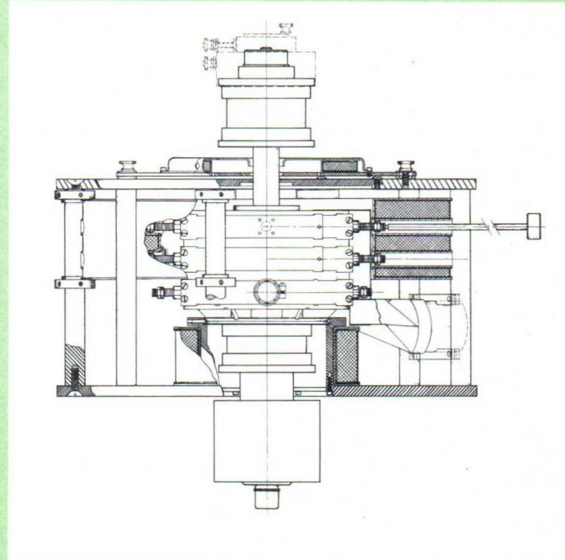

Figure 8
The X571 klystron with tuning doors and magnetic focusing circuits

Figure 9
Eimac X590D amplifier klystron and circuit components

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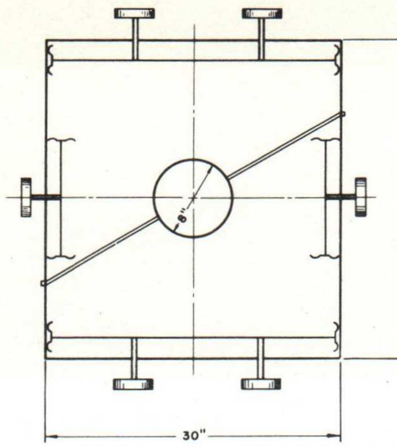

Figure 10
Working view of X590 tuning cavity showing the four doors

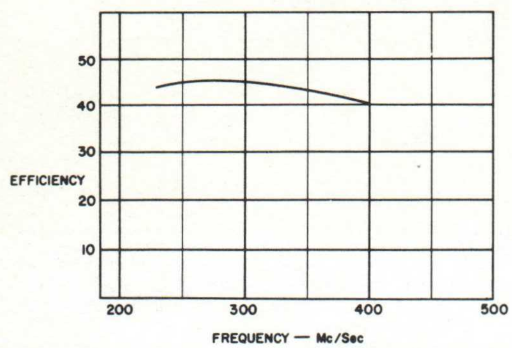

Figure 11
Tuning range and efficiency of the Eimac X590 klystron

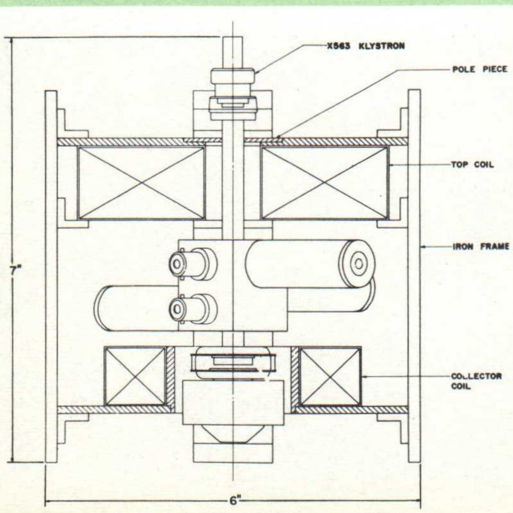

Figure 12
Eimac X563 amplifier klystron mounted in magnetic circuit

were constant and that the efficiency curve is reasonably flat over the tuning range of 225 to 400 Mcs.

Figure 12 shows our X563E klystron assembly. This unit has produced over 100 watts RF output through the tuning range of 5875 to 6425 Mcs. The X563E is a 4-cavity tube having a gain of 40 db with a bandwidth of 8 Mcs. to the -3 db points and a conversion efficiency of over 20 percent under these conditions. The tube has only recently been made available to equipment manufacturers.

Figure 13 is a chart of RF power output vs. frequency range of Eimac CW klystrons that are currently available. It is obvious that we are working to produce higher powers in the UHF range and, at the same time, broaden the frequency coverage of the tube line. We might point out that most of the current development programs are based on Scatter Communications systems requirements. The external cavity klystron is ideally adapted to Scatter requirements and offers us great flexibility in our design approach. An example of this flexibility is the X600. This tube will produce 10KW-RF output at 40 percent conversion efficiency. The tube uses ceramic RF windows in our usual fashion and is designed to tune from 1700 to 2400 Mcs.

Another recent but important development at Eimac concerns cathodes. The 3K3,000 series of tubes is now in production and these tubes all have oxide cathodes. A cathode for these tubes has now been on life test for 5,344 hours at 1.5 amperes steady D.C. emission at 15,000 volts with no deterioration. This power level is much greater than that used in the klystron. An early production model of the 3K3,000LQ klystron has been on life test for 3,006 hours at 2320 watts RF output with 49.2 percent efficiency at 800 Mcs. without change in emission or efficiency. Further notice of the achievement of reliable, long life oxide cathodes is given by the use of such a cathode in the X590D klystron at 20KW-CW output. One major reason that these cathodes can be used at such a high CW power level is that we achieve a good vacuum (the order of 10^{-7} mm. of Hg or better) in the tubes during and after processing; hence, the importance of a simple and chemically stable vacuum envelope such as is provided by the ceramic windows in the external cavity klystron.

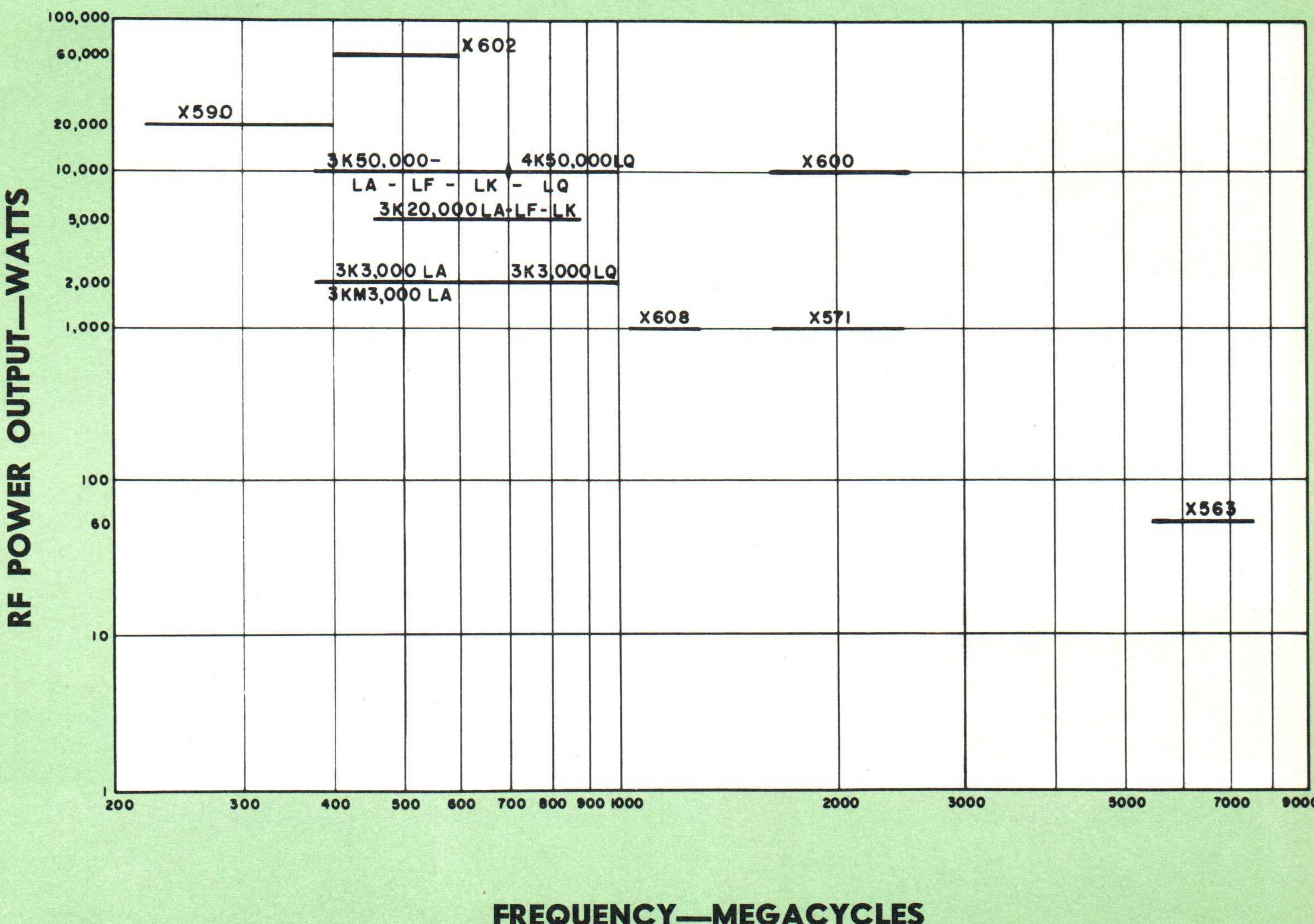

Figure 13—Power output vs. frequency range of currently available Eimac CW klystrons

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