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Interim Development Report

for

DEVELOPMENT OF LOW-NOISE TRAVELING-WAVE TUBES

This report covers the period 1 June 1961 through 30 June 1961

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Navy Department Bureau of Ships, Electronics Division
Contract NObsr-81227, Index Number SS-021001/S. T. 21

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ILLUSTRATIONS

1. ABSTRACT

1.1 The helix impedance transformer has been designed, and calculations predict a very good match from 1 to 2.6 Gc.

1.2 The initial PPM-focusing considerations indicate that it will be possible to focus a tube with a helix voltage of 250 volts.

2. PART I: TECHNICAL REPORT

2.1 Purpose

2.1.1 Phase II of the contract is for the design and development of L-band low-noise TWT's and for delivery of four final design samples.

2.2 General Factual Data

2.2.1 Identification of Technicians

2.2.1.1 The names of various technical personnel involved in this contract and the man-hours worked are reported in the covering letter accompanying this report.

2.2.2 Patents

2.2.2.1 No patents have been issued during this report period.

2.2.3 References

2.2.3.1 No new references are applicable to this report.

2.3 Detailed Factual Data

2.3.1 Matching Transformer Design

2.3.1.1 The helix characteristic impedance was calculated, and the result is an impedance which varies from 500 to 200 ohms from 1 to 3 Gc, as shown in Fig. 1.

2.3.1.2 At the center frequency, the impedance reduction can be computed in terms of the pitch by

$$ZP = \text{Constant} \tag{1}$$

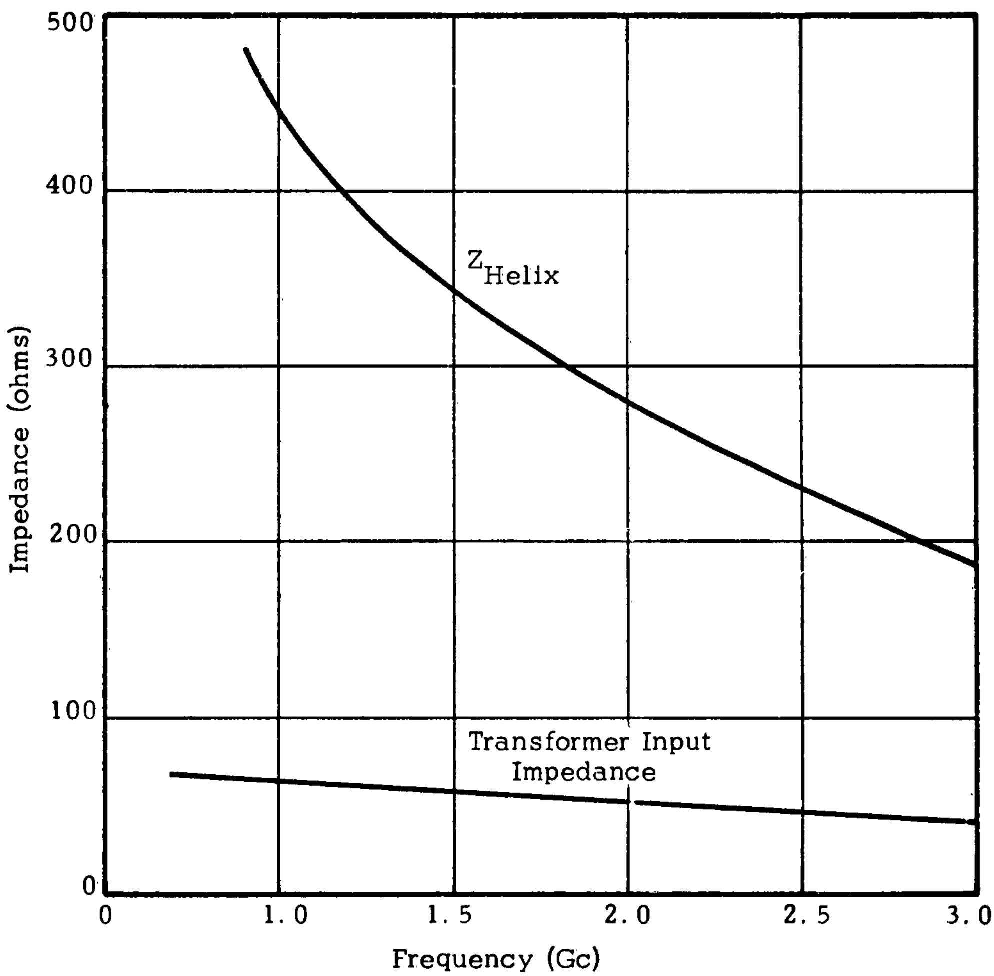

Fig. 1. Helix impedance and the transformed input impedance as a function of frequency.

along the transformer. Therefore, the last pitch of the transformer is given by

$$P_{last} = P_{typ} \frac{Z_{out}}{Z_o} = 5 P_{typ}. \quad (2)$$

The length of the transformer should be greater than a quarter-wavelength at any frequency, and the number of turns can be computed from the following relations. The effective length of the transformer is

$$L_{eff} = \frac{2\pi na}{DLF}, \quad (3)$$

and

$$L_{eff} \geq \frac{\lambda}{4} = \frac{11.8}{4f_{Gc}}; \quad (4)$$

therefore,

$$n = \frac{(L_{eff})(DLF)}{2\pi a}. \quad (5)$$

The value of n computes to slightly less than eight turns.

2.3.1.3 The computed input impedance to the helix is also shown in Fig. 1. The transformer not only reduced the impedance, but it also reduced the variation to approximately 20 per cent. This is a drastic improvement of somewhat greater than 250 per cent over the helix characteristic impedance variation.

2.3.1.4 The use of a linear taper in pitch yields an impedance variation similar to an exponental transformer. The normalized pitch of the transformer and the impedance variation are given in Fig. 2 as a function of distance along the transformer.

2.3.2 PPM-Focusing Considerations

2.3.2.1 As a result of PPM focusing of other MEC low-noise tubes, a focusing structure has been developed which uses a high magnetic field over the low-noise gun and a much reduced field over the

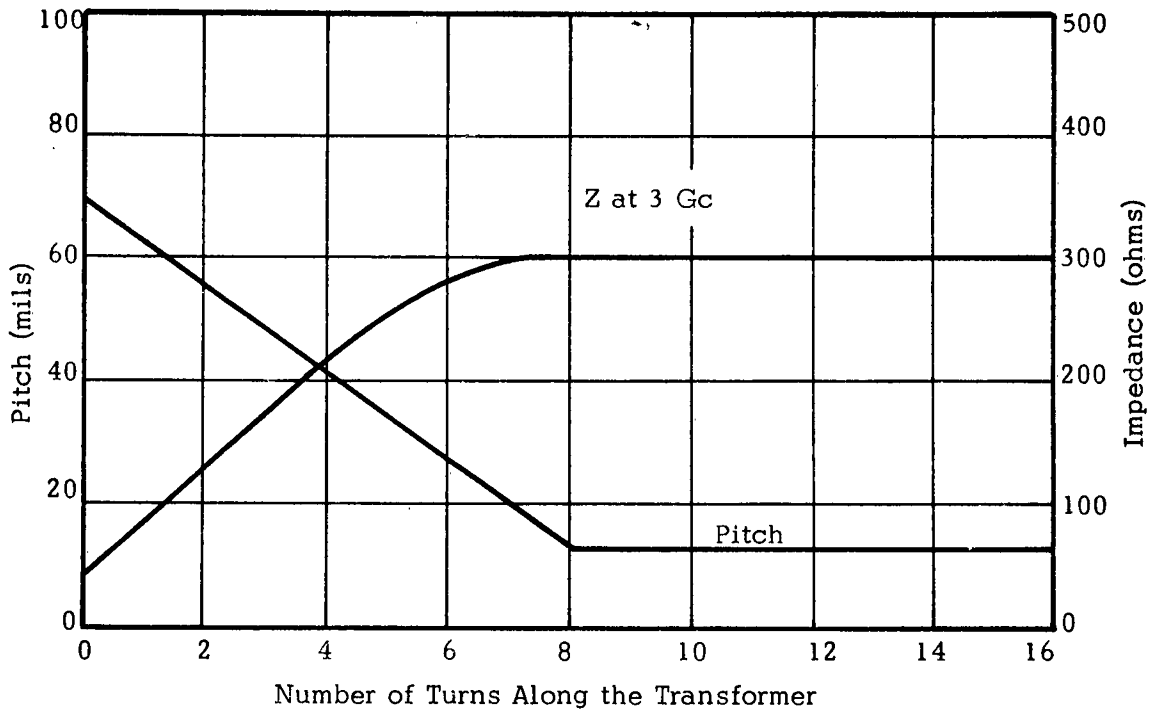

Fig. 2. The pitch and impedance as a function of distance along the helix transformer.

helix. The high field over the gun allows a degree of potential profile shaping independent of focusing, while the reduced helix field gives a beam radius consistent with broadband RF performance. This focusing structure is one of two possible for use with the L-band tube. The other structure is long-field focusing. The difference between the two is shown in Fig. 3.

2.3.2.2 The long field approach, since it very clearly approximates solenoid focusing and, as a result, does not limit the maximum usable field to the low-value required by PPM focusing, will be necessary for focusing tubes which require high solenoid fields. The contract results on the S-band low-noise tube indicate that maximum broadband noise figures of less than 10 db can be obtained with low field focusing.

2.3.2.3 Considering these facts, the initial designs will include both focusing structures.

2.3.2.4 The ripple induced in a PPM structure has been studied by perturbation theory, which includes the following points.

2.3.2.4.1 As the beam moves from the gun field into the PPM stack, the equilibrium radius changes approximately as the square root of the ratio of the rms stack field to the cathode field.

2.3.2.4.2 The alpha-parameter cannot exceed 0.25 for confined flow.

2.3.2.4.3 Under proper entrance conditions to the PPM stack, cyclotron ripple can be cancelled. (Of course, the degree of difficulty in achieving this cancellation is greatly reduced if the ripple is originally small.)

2.3.2.5 The parameter of the PPM-focusing theory that determines the beam rippling is α, which is proportional to the field strength

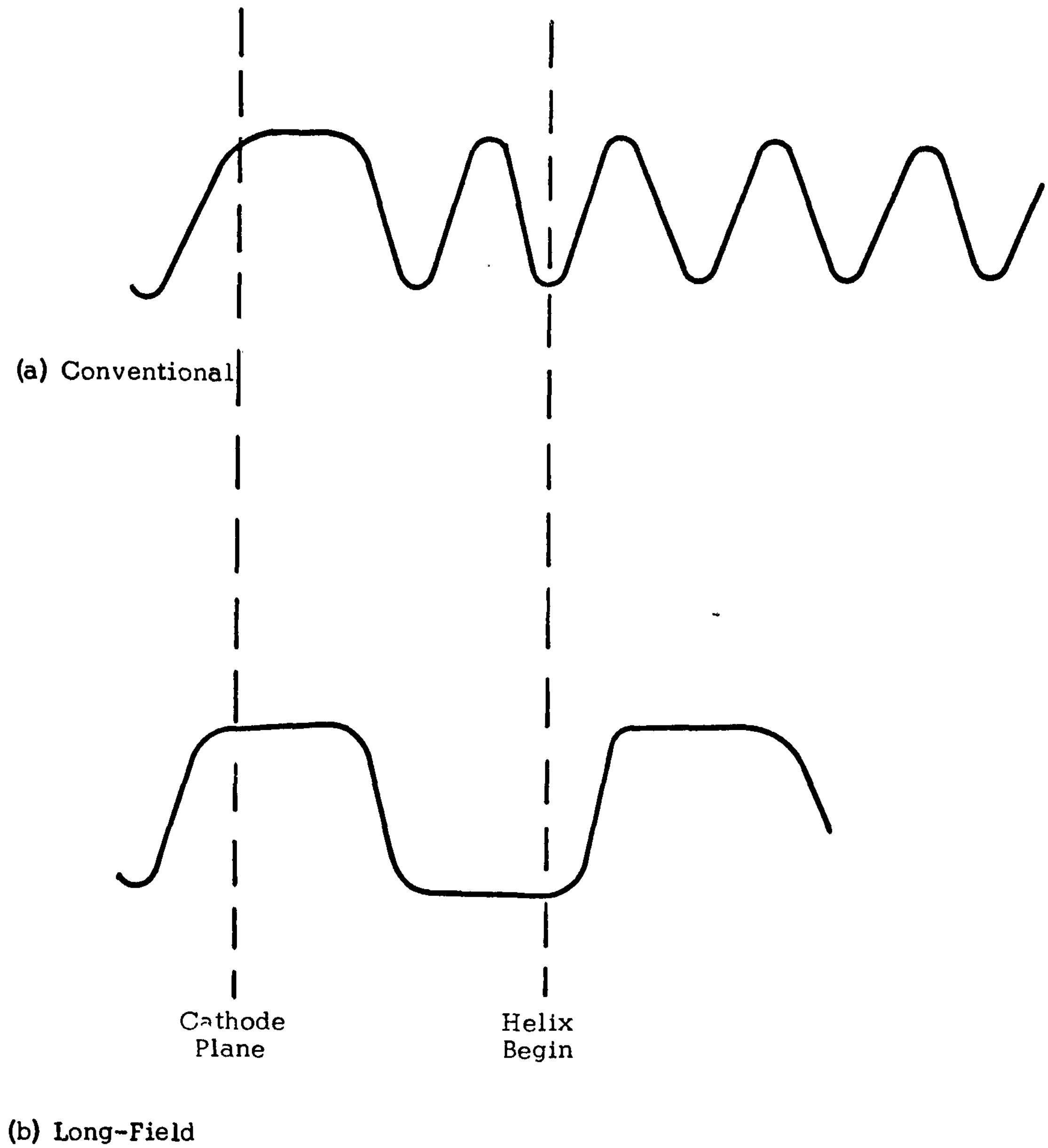

Fig. 3. Comparison of conventional and long-field PPM-focusing configurations.

and the period:

$$\alpha \propto \frac{(L_M B)^2}{V} \qquad (6)$$

2.3.2.6 For practical designs, L_M is on the order of 0.3 inch minimum. Using this limit and the practical helix voltage, Fig. 4 was constructed. Figure 4 gives the beam radius and minimum ripple for various values of both rms stack field and cathode field.

2.3.2.7 One can immediately see that, for confined flow ($r_e \approx v_c$), the cathode and rms stack field must be equal. Also, the focusing instability occurs above about 300 gauss.

2.3.2.8 It has been possible to obtain low-noise figures in the S-band PPM-focused tube below 300 gauss cathode field, which implies that, by keeping the relative beam size constant, it is also possible to PPM-focus the L-band tube at a helix voltage of 250 volts. Usable fields are between 200 and 300 gauss. From Fig. 4, it can be seen that a cathode field of 300 gauss is well into the stable beam focusing region for B_{rms} = 250 g. This still gives a fairly low change in equilibrium radius, less than 10 per cent, and the cyclotron ripple through the gun itself is small.

2.3.3 Conclusions

2.3.3.1 The matching calculations indicate satisfactory performance over the total bandwidth, with the transformer designed on the basis of a linearly tapered pitch.

2.3.3.2 The PPM-focusing calculations indicate the possibility of low-voltage focusing. A 250-volt tube can be focused with 300 gauss over the cathode.

2.3.3.3 See Fig. 5 for the Project Performance and Schedule Chart.

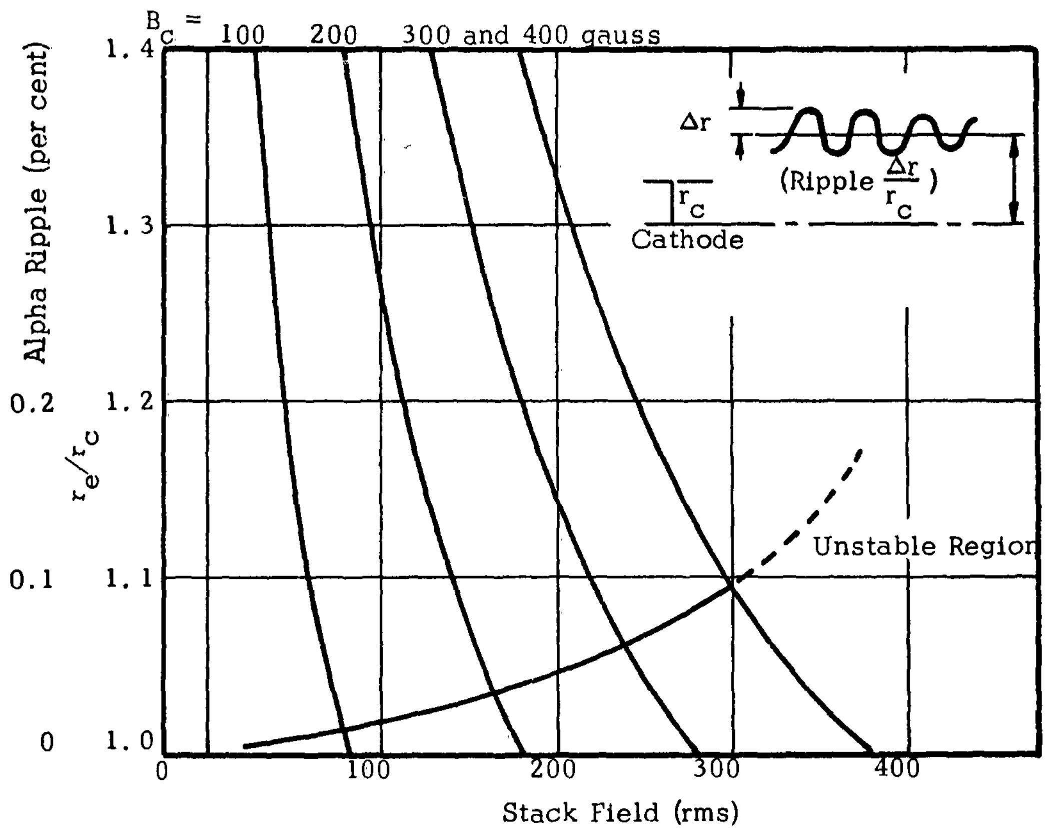

Fig. 4. The change in equilibrium radius as the cathode field is changed for values of rms stack field. Also alpha ripple versus rms stack field for V = 250 volts, and L_m = 0.300 inch. Note the unstable region above B_{rms} = 330 gauss.

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Project Performance and Schedule
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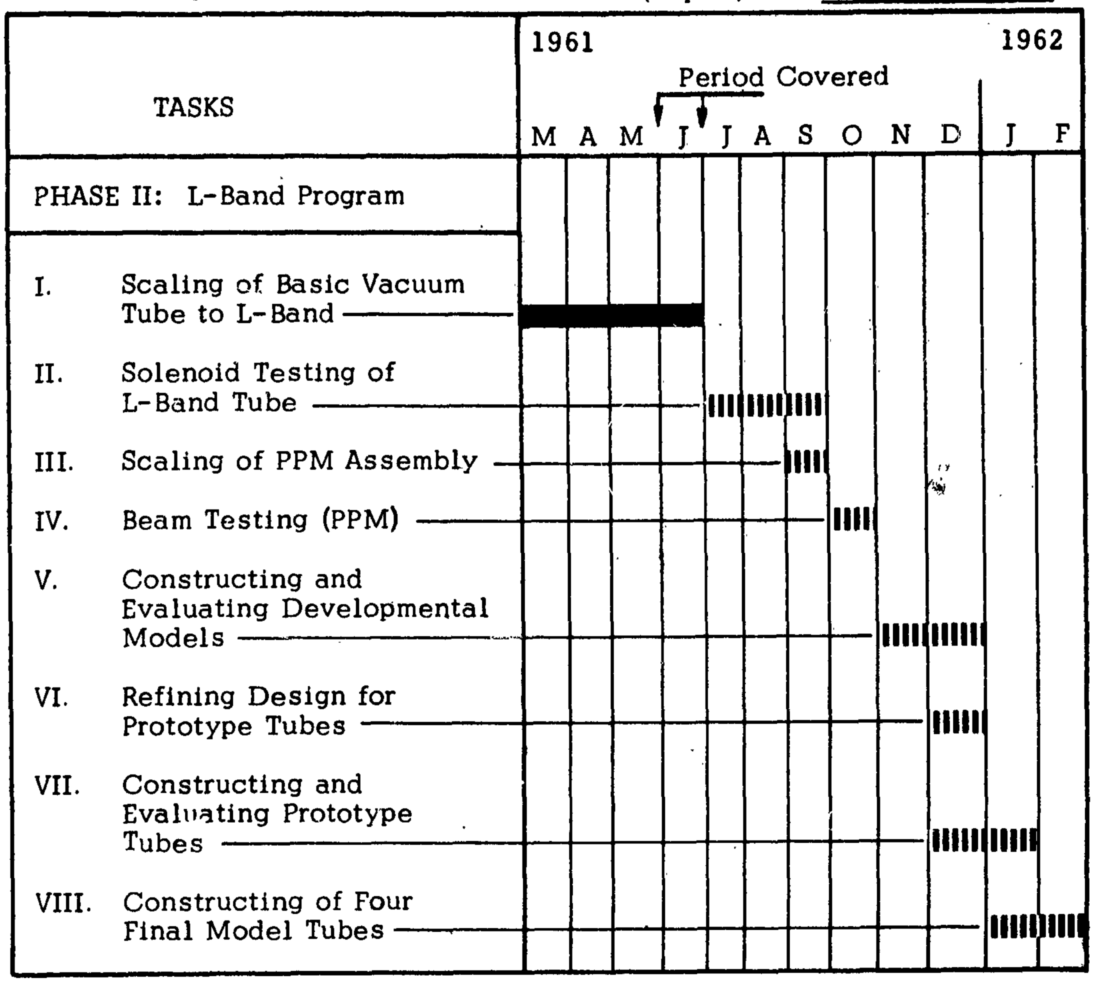

Fig. 5. Project performance and schedule chart.

3. PART II: PROGRAM FOR NEXT INTERVAL

3.1 The next month of work will include the following tasks:

- completion of the helix design, and
- helix assembly, fabrication, and cold testing for both phase velocity and matching.