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DESIGN APPLICATION OF SERIES SLOTS

LOUIS A. KURTZ

Technical Memorandum No. 273

RESEARCH AND DEVELOPMENT
laboratories

Hughes

HUGHES AIRCRAFT COMPANY
CULVER CITY CALIFORNIA

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by

Louis A. Kurtz

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Introduction

Waveguide linear arrays of slots in which the radiated electric field is polarized transversely to the array axis have been built successfully using longitudinal slots[1] of both shunt and series types. The longitudinal shunt slots are described in Hughes Aircraft Company Technical Memorandum No. 261,[2] and the following is a description of the series slots and the manner in which they have been used in waveguide linear array design.

Series Slots

Measurements of resonant length and normalized resistance as a function of frequency have been made for 15°, 20°, and 30° resonant slots of the type shown in Figure 1 over a frequency range of 8600 to 9800 megacycles per second. The measurement techniques used are described in Technical Memorandum No. 262,[3] and the experimental data are shown in Figure 2. It can be seen that resistance and resonant length are very nearly linear functions of the frequency. The width of these slots was chosen for convenience to be one-sixteenth of an inch. A change in this value of slot width, for either power breakdown or other considerations, would cause a slight change in the resonant length and resistance but would not change appreciably their behavior as a function of the frequency.

In Figure 3, there is shown a comparison of the measured values of resistance with the theoretical values as given by Stevenson.[4] The measured values of resistance are lower than the calculated values due to the finite thickness of the waveguide wall. The variations in resonant frequency and resistance with varying wall thickness are shown in Figure 4 for a 30° slot. When the wall thickness of this slot is reduced from 0.050" to 0.013" and the length is varied to maintain resonance at 8700 megacycles per second, the change in resistance is +10 per cent as calculated from Figures 2 and 4. This per cent change applied to the measured values of resistance in Figure 3 brings them into agreement with the theoretical values of resistance. This agreement is based on the assumption that the resistance will not change appreciably when the wall is reduced from 0.013" to zero thickness.

The measurements have indicated that the resonant length remains nearly constant as the angle of inclination is changed, hence all slots have been cut to the lengths given in Figure 2.

A linear array of slots of the type shown in Figure 1 will radiate a longitudinal component of electric field in addition to the transverse component. In some applications it may be desirable to eliminate this cross-polarized component of electric field. In one instance this has been done by allowing the slots to radiate into a flared, parallel-plate horn similar to that shown in Figure 5. The plates are spaced such that the cross-polarized electric fields are suppressed, and the flare of the horn in Figure 5 is such that reflections from the throat and aperture very nearly cancel each other.[5] The horn can also be used to control the radiation pattern[6] in the transverse plane.

The addition of the parallel-plate horn produces an increase in both the resonant frequency and resistance of the series slots. Also any reflections from the throat or aperture of the horn will produce small variations in the resonant frequency and resistance. Reflections from the aperture, however, should become negligible compared with those from the throat when the E-plane aperture dimension is larger than about three-fourths of a wavelength.[7] Thus for a given flare angle there is a flare length beyond which any increase in flare length will produce a negligible change in slot characteristics. Reflections from the throat of the horn, on the other hand, will cause variations in slot characteristics, and these have a frequency sensitivity dependent upon the separation of the slots from the throat of the horn. It is important, therefore, that the electrical length from the slots to the throat of the horn be as small as possible consistent with effective suppression of the cross-polarized component of electric field, or that the reflections from the throat of the horn be matched out in some manner. The resonant length and resistance vs. frequency for a 20° slot with two different horns are shown in Figure 6. The slope of these curves is approximately the same as those of Figure 2; however, more data is necessary to establish the correspondence. The measured values of resistance for 15° and 20° slots with horns have been found to follow closely a $\sin^2 \theta$ curve, and it has been assumed that this will hold for angles less than 15°. That this is a reasonable assumption is evidenced by the radiation pattern of the linear array described below.

Linear Array Design Data

A design curve of resistance vs. angle of inclination can be obtained by measuring only two 15° slots with the desired horn configuration which are resonant at frequencies near the design frequency. The resonant length and resistance of these two slots are plotted as a function of frequency, and the values at the design frequency are obtained by interpolation. The resonant length remains nearly constant with changing angles of inclination, and the resistance can be obtained by passing a $\sin^2 \theta$ curve through the value of resistance of the 15° slot. If angles of inclination greater than about 20° are necessary, then additional slot measurements will be required.

Application

A linear array of series slots with a horn for suppression of cross-polarization and control of aperture distribution has been built using data obtained as described above. The horn was similar to number B in Figure 6 except that the flare length was increased to obtain increased directivity in the transverse plane. A Dolph distribution for the array excitation coefficients was used to obtain the design value of side-lobe level of -32 db. The array was center-fed by a resonant slot coupled series-T junction, and the dimensions of the resonant slot are shown in Figure 7. The radiation pattern of this array at the design frequency is shown in Figure 8. The dimensions of this array were scaled to L-band and the antenna shown in Figure 9 was then constructed. (Several of the slots in Figure 9 are covered by masking tape). The dotted curves of Figure 8 show the only deviations in the patterns of the two arrays down to a power level of -30 db. These deviations are believed to be due to the influence of the surroundings at the pattern measuring site.

Acknowledgments

The assistance of J. R. Miller and E. Strumwasser in obtaining the slot data is gratefully acknowledged.

References

1. W. H. Watson, "Resonant Slots," Journal I.E.E., 1946, 93, p. 747.
2. R. J. Stegen, "Longitudinal Shunt Slot Characteristics," Hughes Aircraft Company Technical Memorandum No. 261.
3. R. J. Stegen, "Waveguide Slot Measurement Technique," Hughes Aircraft Company Technical Memorandum No. 262.
4. A. F. Stevenson, "Theory of Slots in Rectangular Waveguides," Journal of Applied Physics, 1948, vol. 19.
5. S. Silver, "Microwave Antenna Theory and Design," McGraw-Hill, 1949, p. 373.
6. Op. cit., p. 329.
7. Op. cit., p. 369.

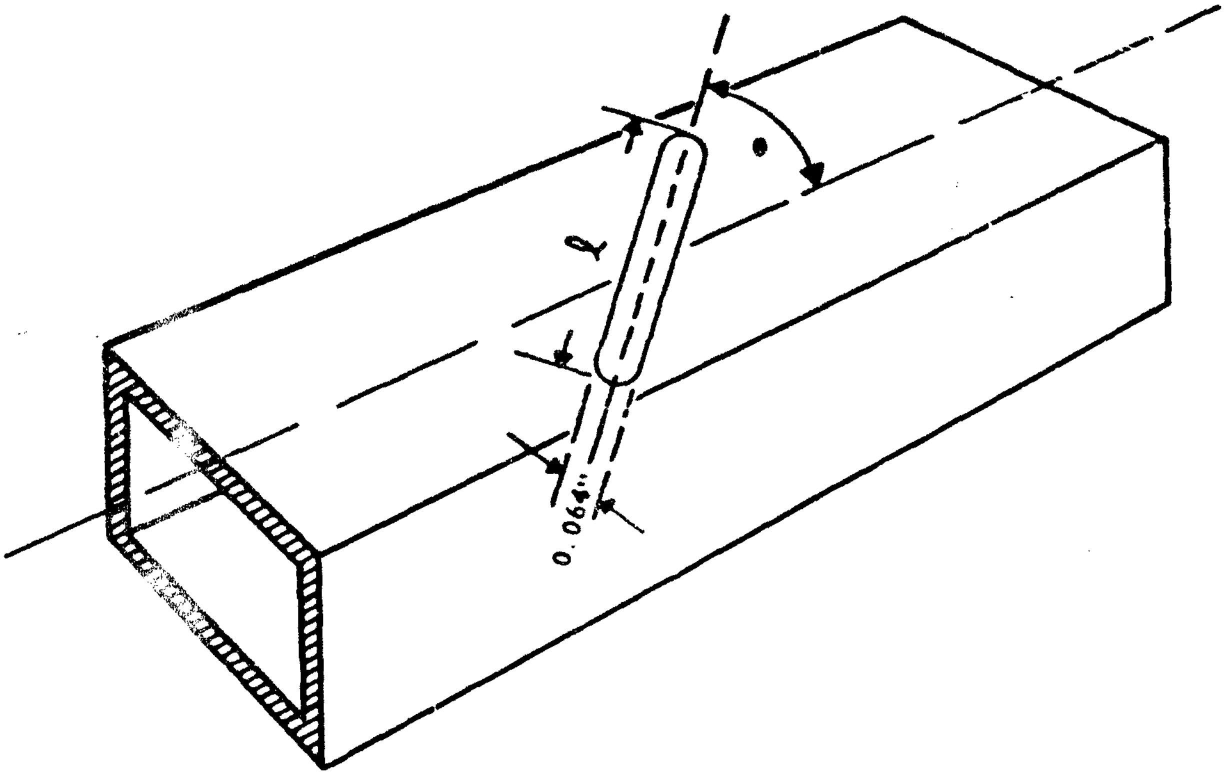

FIGURE 1. SERIES SLOT IN RECTANGULAR WAVEGUIDE

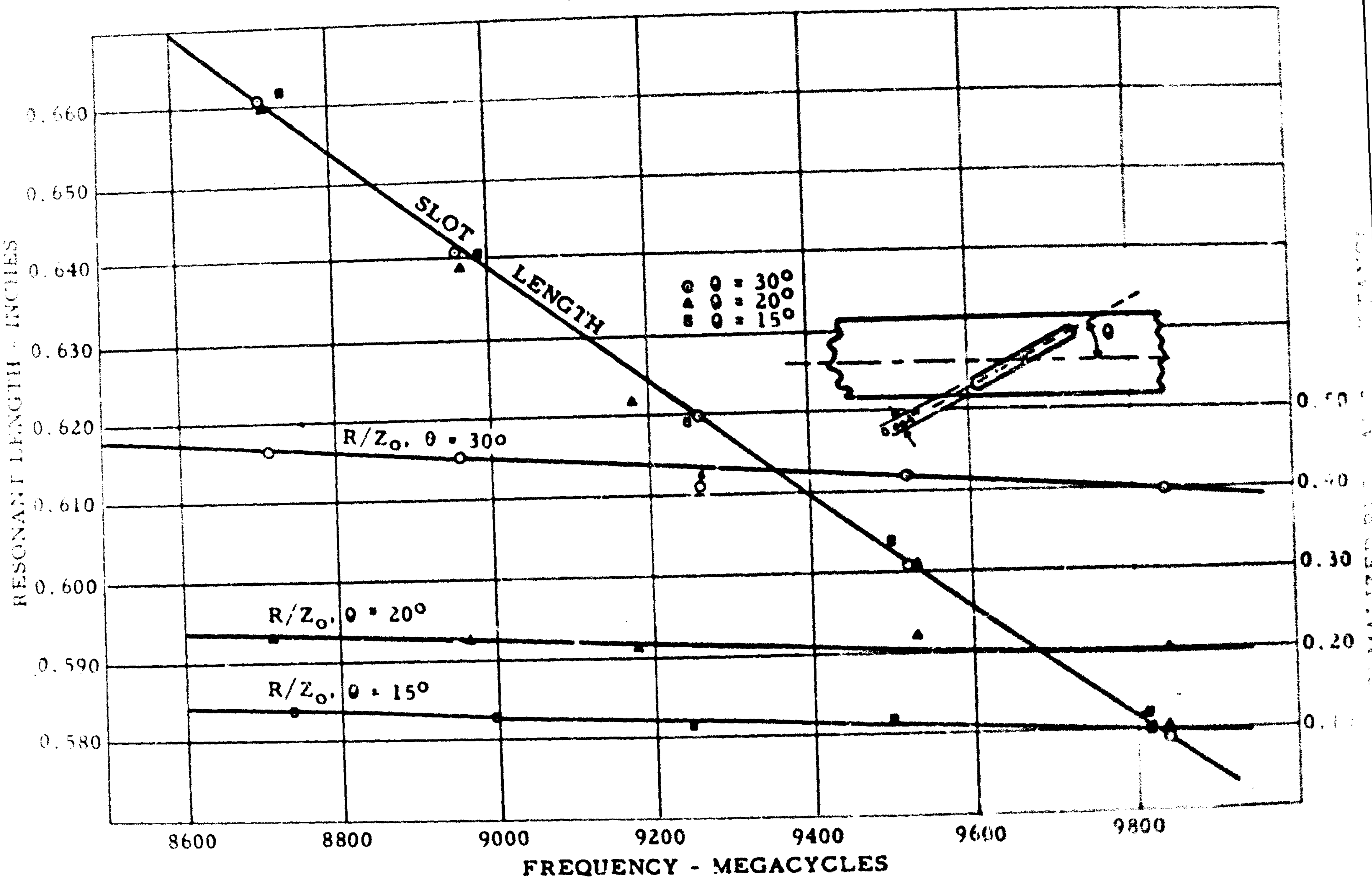

FIGURE 2. RESONANT LENGTH AND NORMALIZED RESISTANCE VS. FREQUENCY FOR SERIES INCLINED SLOT ON ℄ OF 0.400" x 0.900" ID WAVEGUIDE

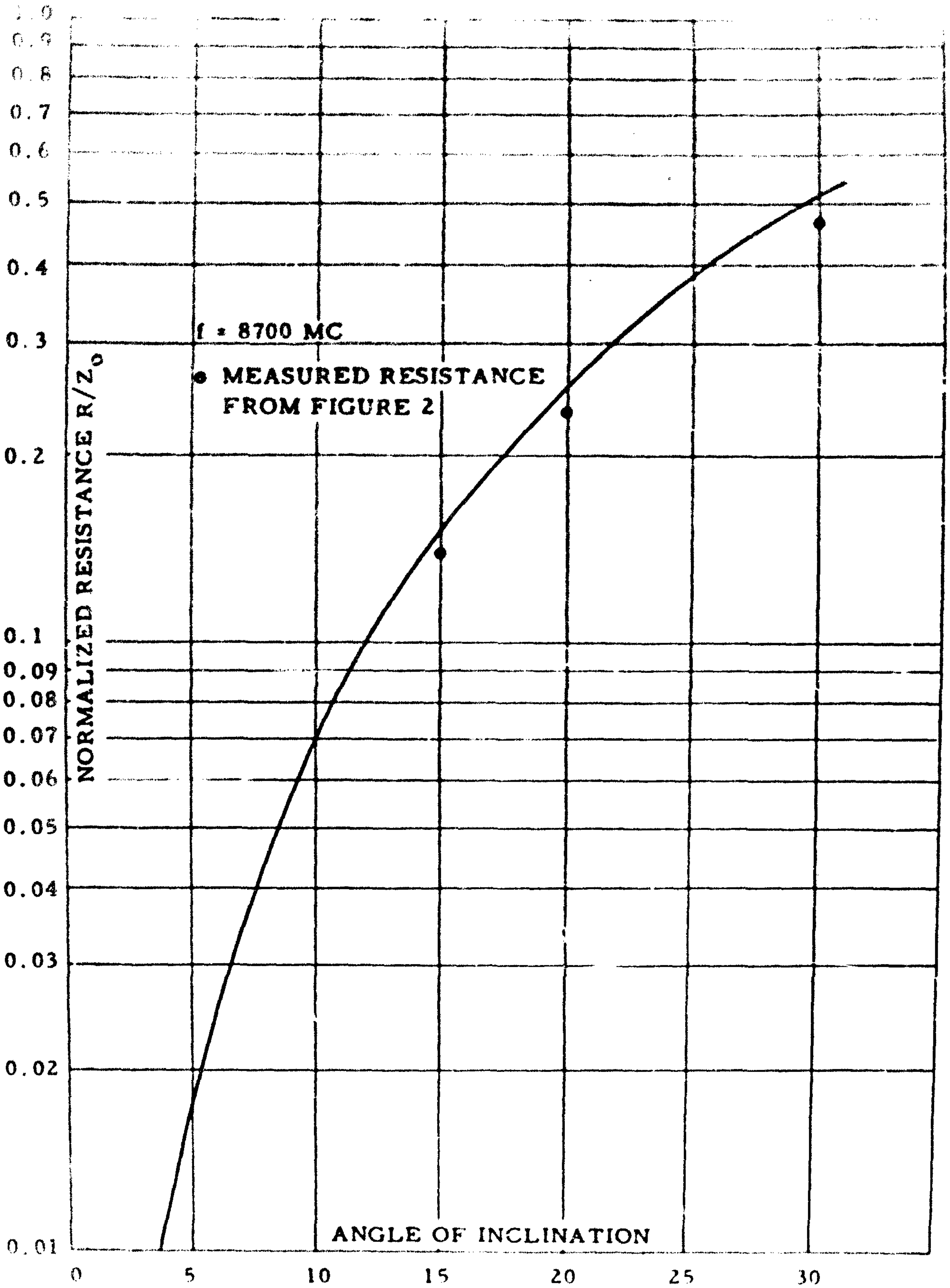

FIGURE 3. COMPARISON OF MEASURED RESISTANCE WITH THEORETICAL CURVE CALCULATED FROM STEVENSON'S EQUATION

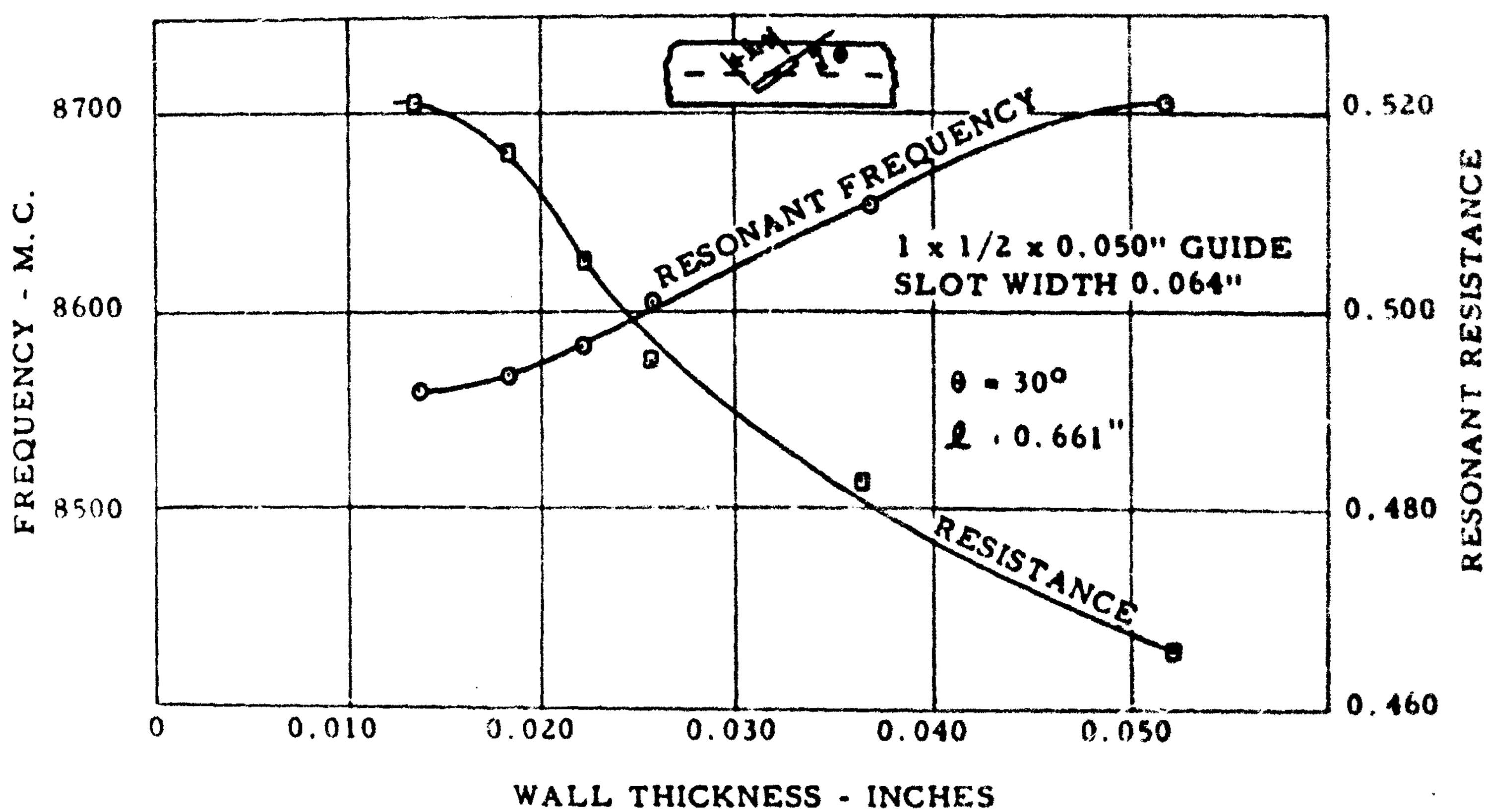

FIGURE 4. RESISTANCE AND RESONANT FREQUENCY VS. WALL THICKNESS FOR A SERIES SLOT

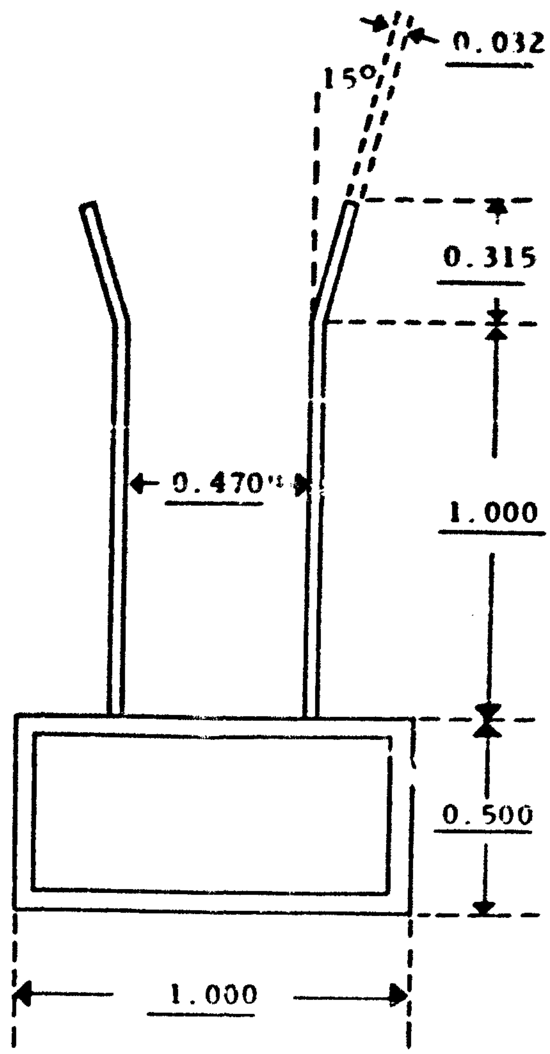

FIGURE 5

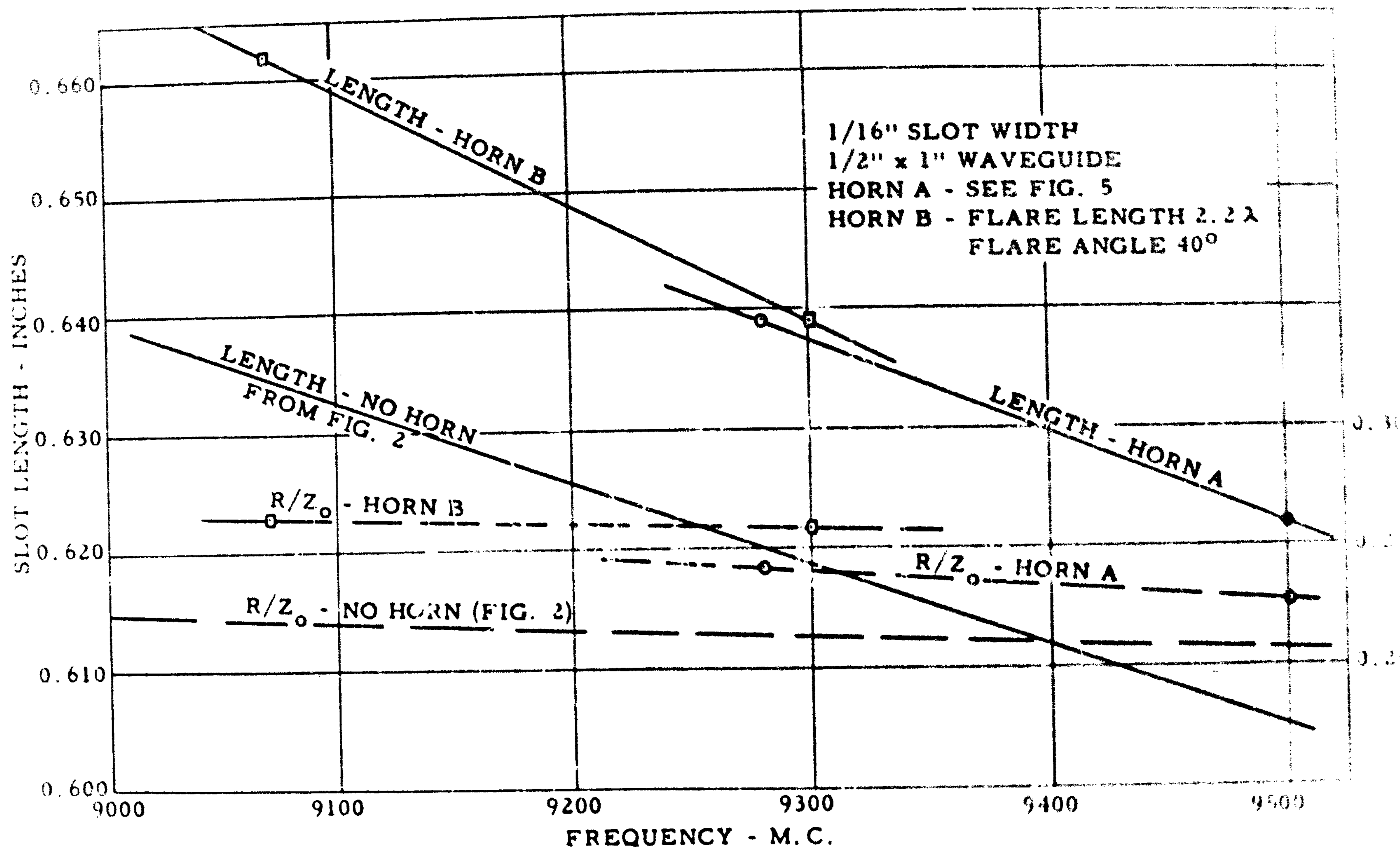

FIGURE 6. INCREASE IN RESONANT LENGTH AND NORMALIZED RESISTANCE WITH ADDITION OF HORN TO 20° SERIES SLOTS

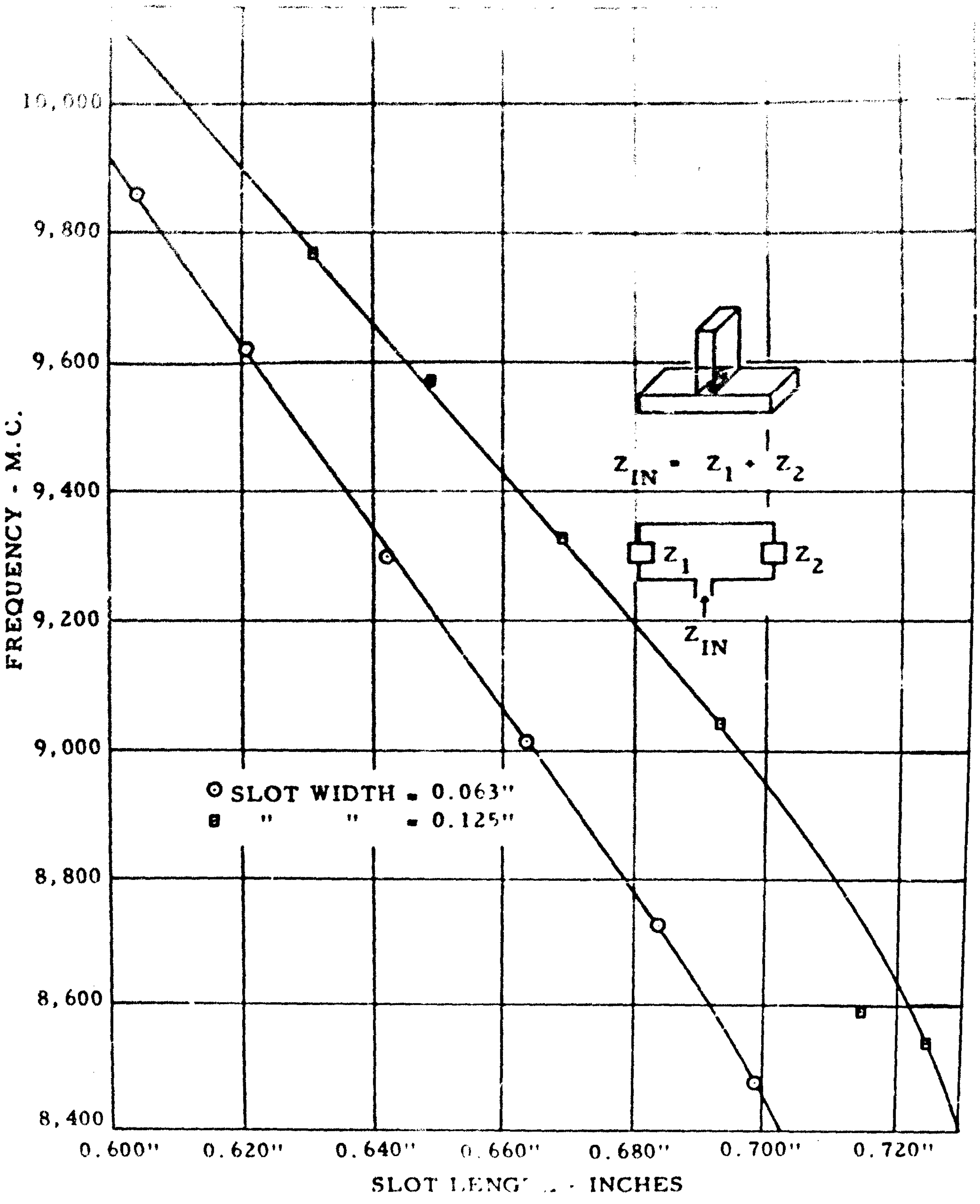

FIGURE 7. RESONANT FREQUENCY VS. SLOT LENGTH FOR SERIES T-JUNCTION IN STANDARD X-BAND WAVEGUIDE

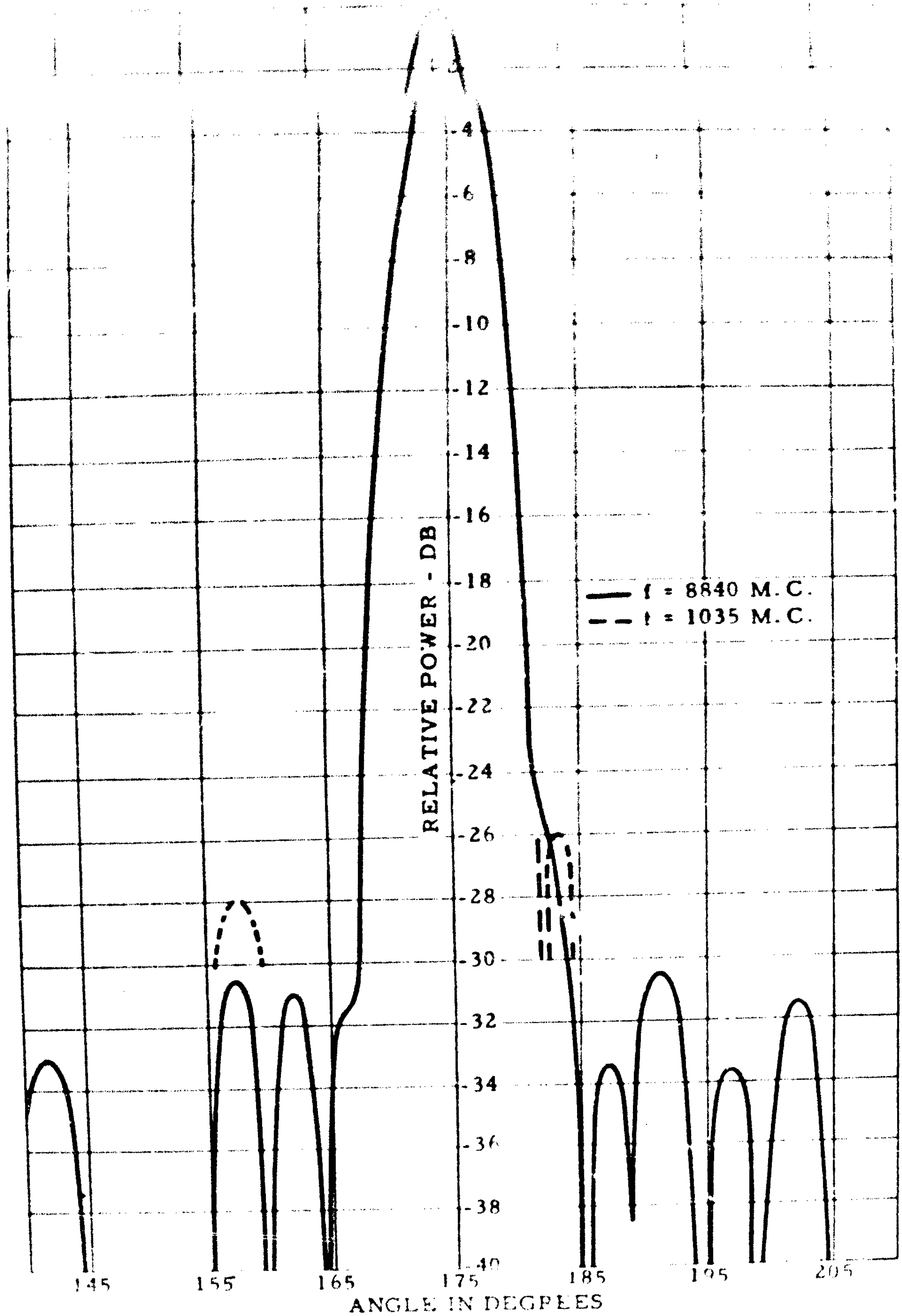

FIGURE 8. RADIATION PATTERN OF SERIES SLOT ARRAYS WITH HORNS

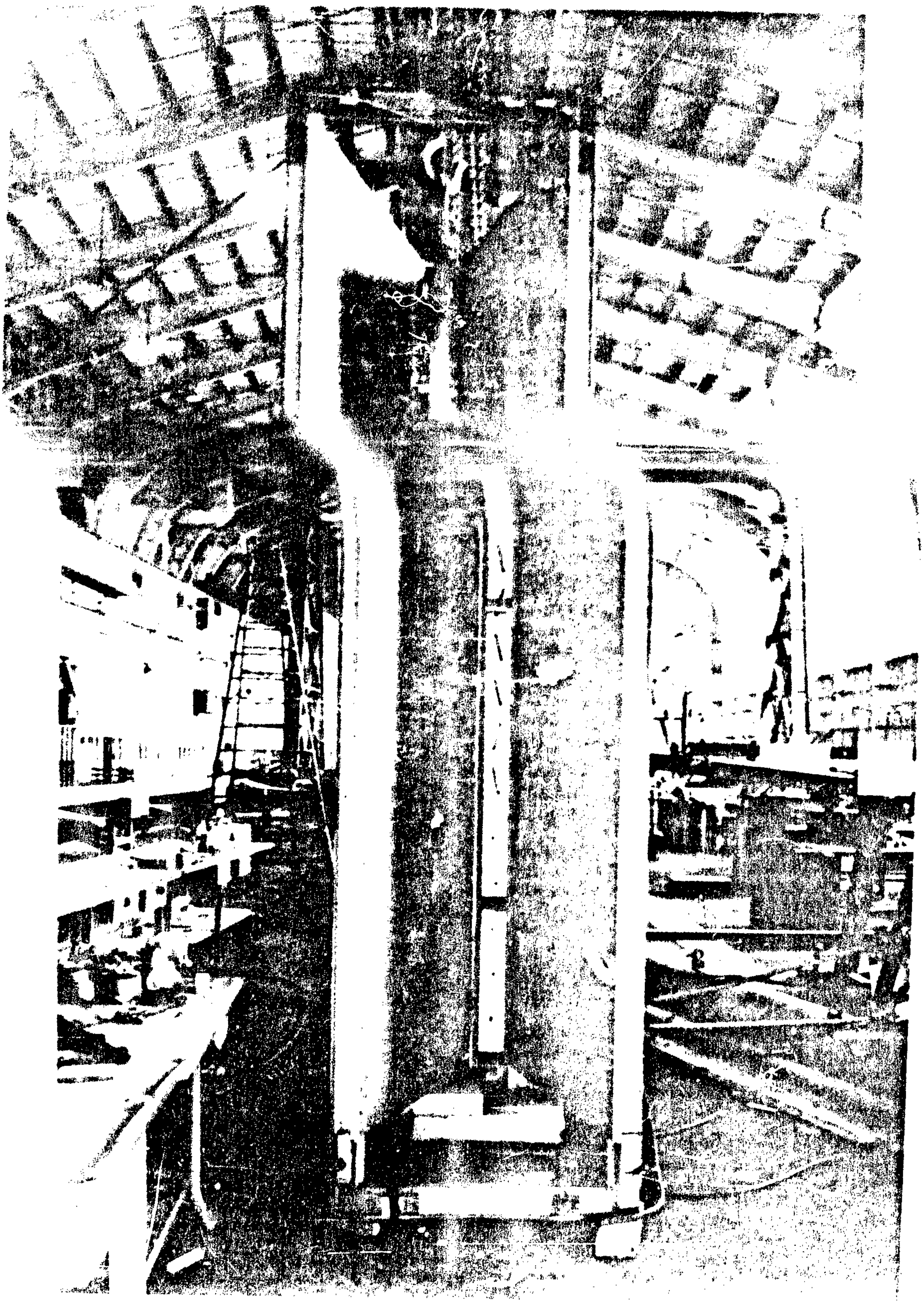

FIGURE [illegible]

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