CHARACTERISTICS OF SLOTTED IRISES

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Some preliminary measurements of slotted iris structures are reported in the minutes of the Conference on Proton Linear Accelerators at Yale University, October 21-25, 1963, p. 153.

Although the above measurements were made with sheet metal irises, the results were sufficiently encouraging to warrant further investigation.

Before embarking on a full-scale modeling program, it was decided that some additional measurements would be useful. The purpose of these measurements was, first, to measure such parameters as shunt impedance, bandwidth, etc., and, second, to gain some experience in setting up a full-scale modeling program.

The measurements to be discussed in this paper were made on a limited number of available cavities. With the limited amount of data available, some interpolation and extrapolation of the data was necessary.

A slotted iris model was constructed as shown in Fig. 1. Measurements were made with two different bore hole diameters of D = 1.625'' and D = 2.1'', four different drift tube lengths of ℓ = 1.0'', ℓ = 1.5'', ℓ = 2.0'' and ℓ = 2.5'', and two different cell lengths of L = 4.0'' and L = 6.0''. All measurements were made in the "π" mode.

Figures 2 and 3 are plots of frequency vs β for various drift tube lengths. Figures 4 and 5 are plots of shunt impedance vs β for various drift tube lengths. In all of the above plots, straight lines were used to join the measured data points. (Results generally obtained on various structures in the range of β = 0.5 to β = 0.8 show that the variation of frequency and shunt impedance do not vary appreciably from a straight line.) In Figures 2, 3, 4, and 5, we see that the actual measured points are grouped around β = 0.5 and β = 0.8, so that the conclusions, which will be drawn in the neighborhood of these values of β, should have about the same accuracy as the measured data.

From Figs. 4 and 5, by drawing lines at constant β's of 0.5, 0.6, 0.7, and 0.8, it is now possible to draw curves of shunt impedance vs drift tube length for constant β as shown on Fig. 6 for a bore hole of 1.625'' and Fig. 7 for a bore hole of 2.1''. In Fig. 7, the region between the drift tube lengths of 2.0'' to 2.5'' may be in error by as much as 10% due to the lack of data points in this region. A comparison of Figs. 6 and 7 reveals some interesting features. There is a considerable change

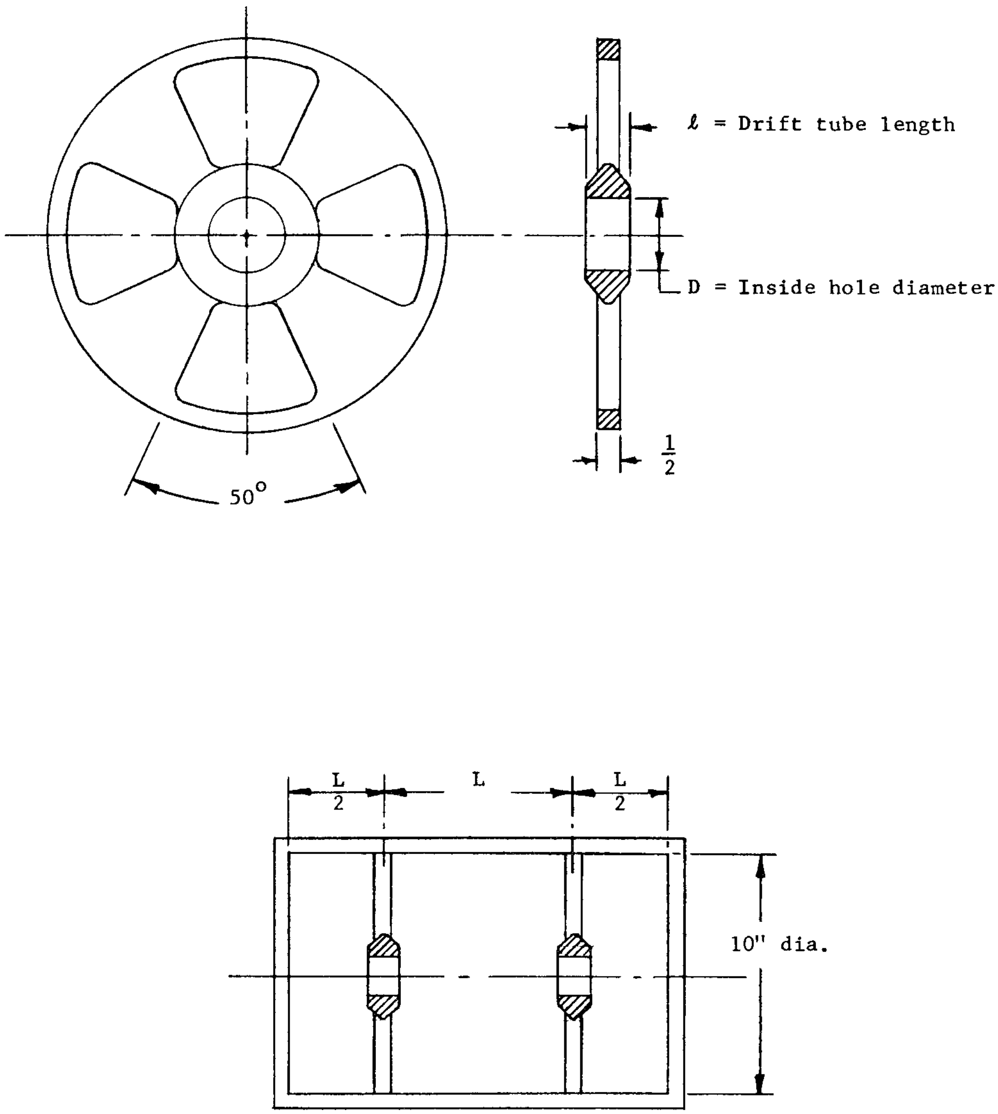


Fig. 1

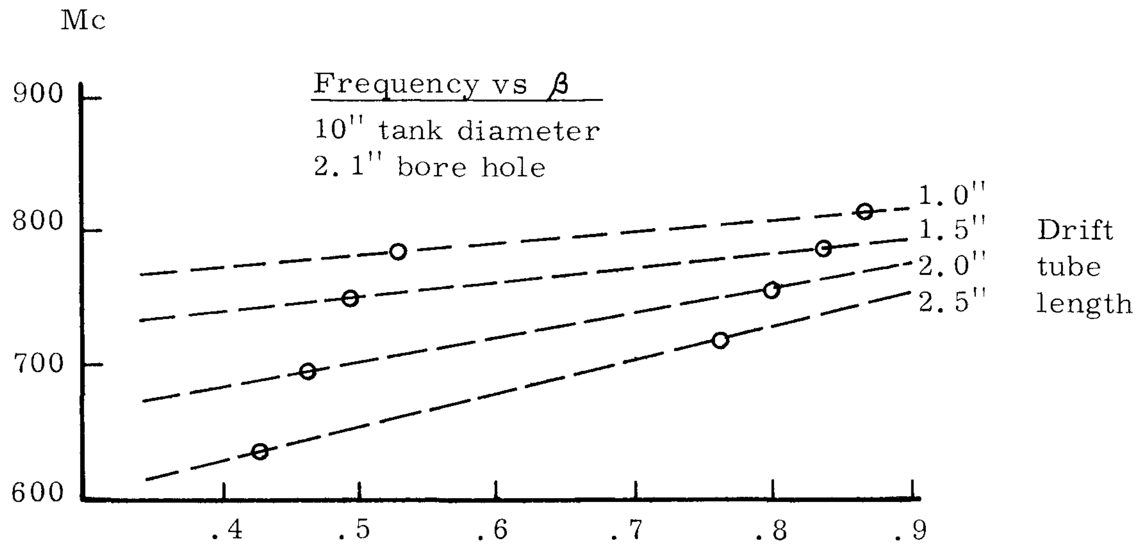
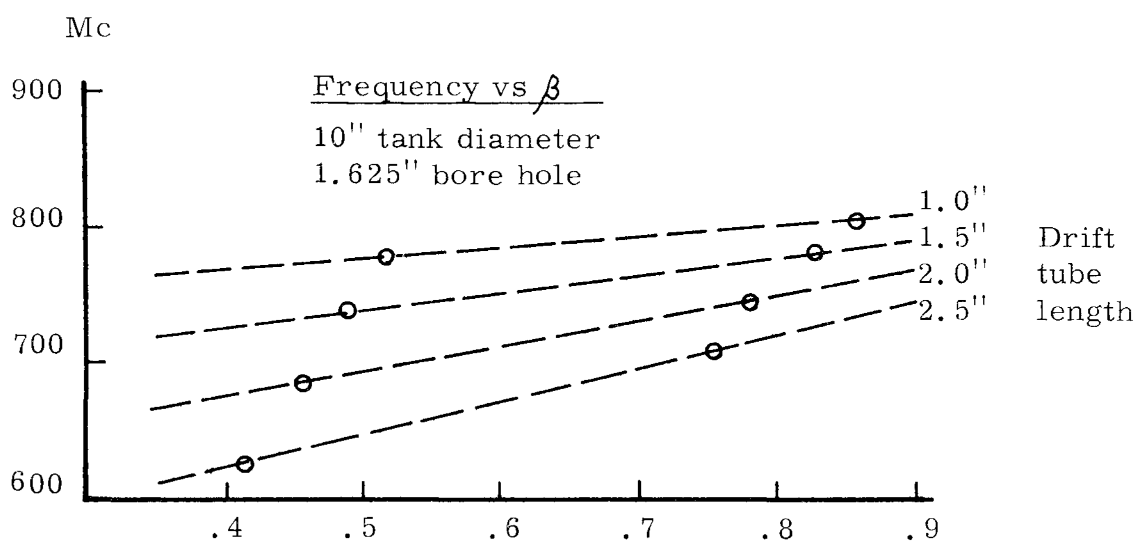

Mc
900
800
700
600
Frequency vs β
10'' tank diameter
2.1'' bore hole
1.0''
1.5''
2.0''
2.5''
Drift
tube
length
.4
.5
.6
.7
.8
.9

Fig. 2


Mc
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Frequency vs β
10'' tank diameter
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1.0''
1.5''
2.0''
2.5''
Drift
tube
length
.4
.5
.6
.7
.8
.9

Fig. 3

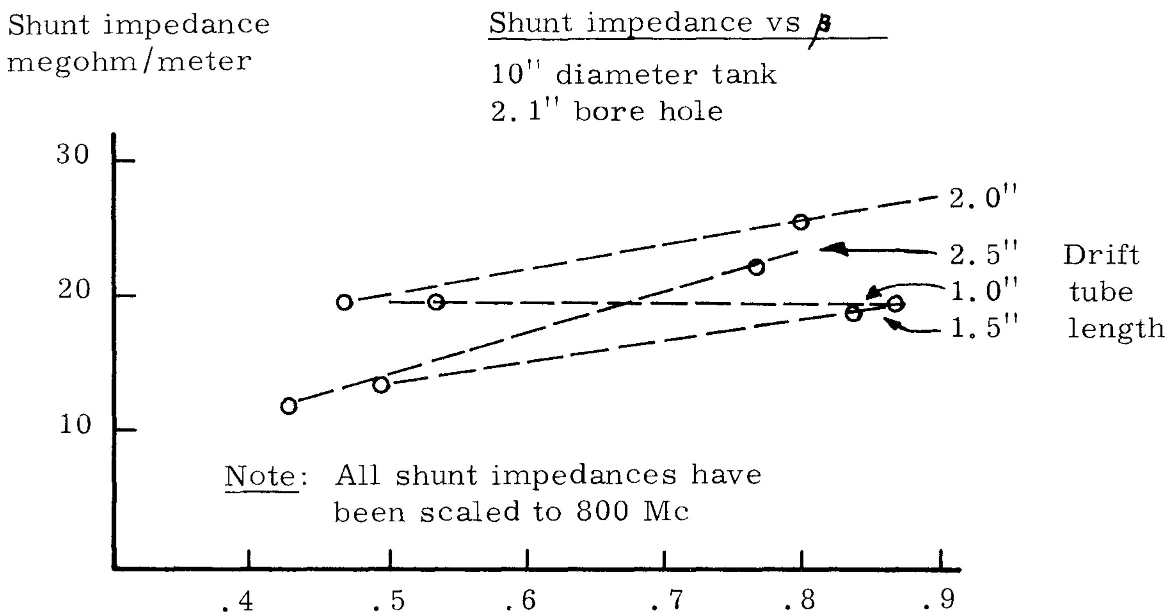

Shunt impedance
megohm/meter
Shunt impedance vs β
10" diameter tank
2.1" bore hole
30
20
10
2.0"
2.5"
1.0"
1.5"
Drift
tube
length
Note: All shunt impedances have
been scaled to 800 Mc
.4
.5
.6
.7
.8
.9

Fig. 4

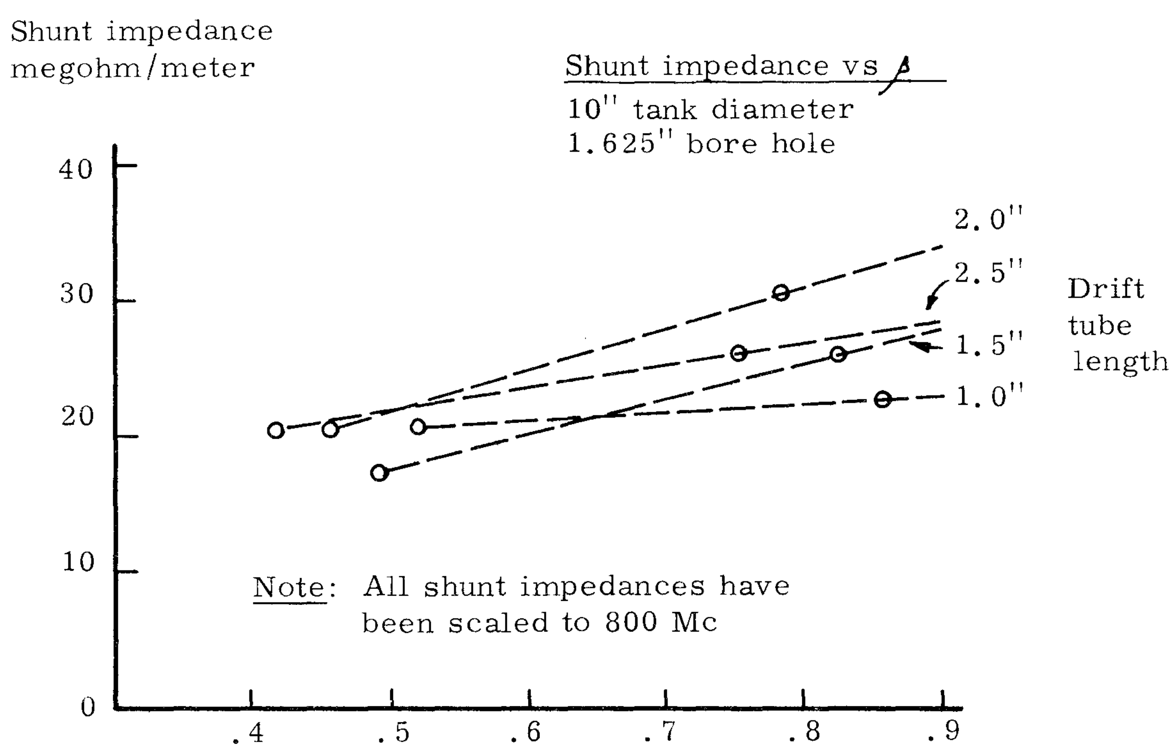

Shunt impedance
megohm/meter
Shunt impedance vs β
10" tank diameter
1.625" bore hole
40
30
20
10
0
2.0"
2.5"
1.5"
1.0"
Drift
tube
length
Note: All shunt impedances have
been scaled to 800 Mc
.4
.5
.6
.7
.8
.9

Fig. 5

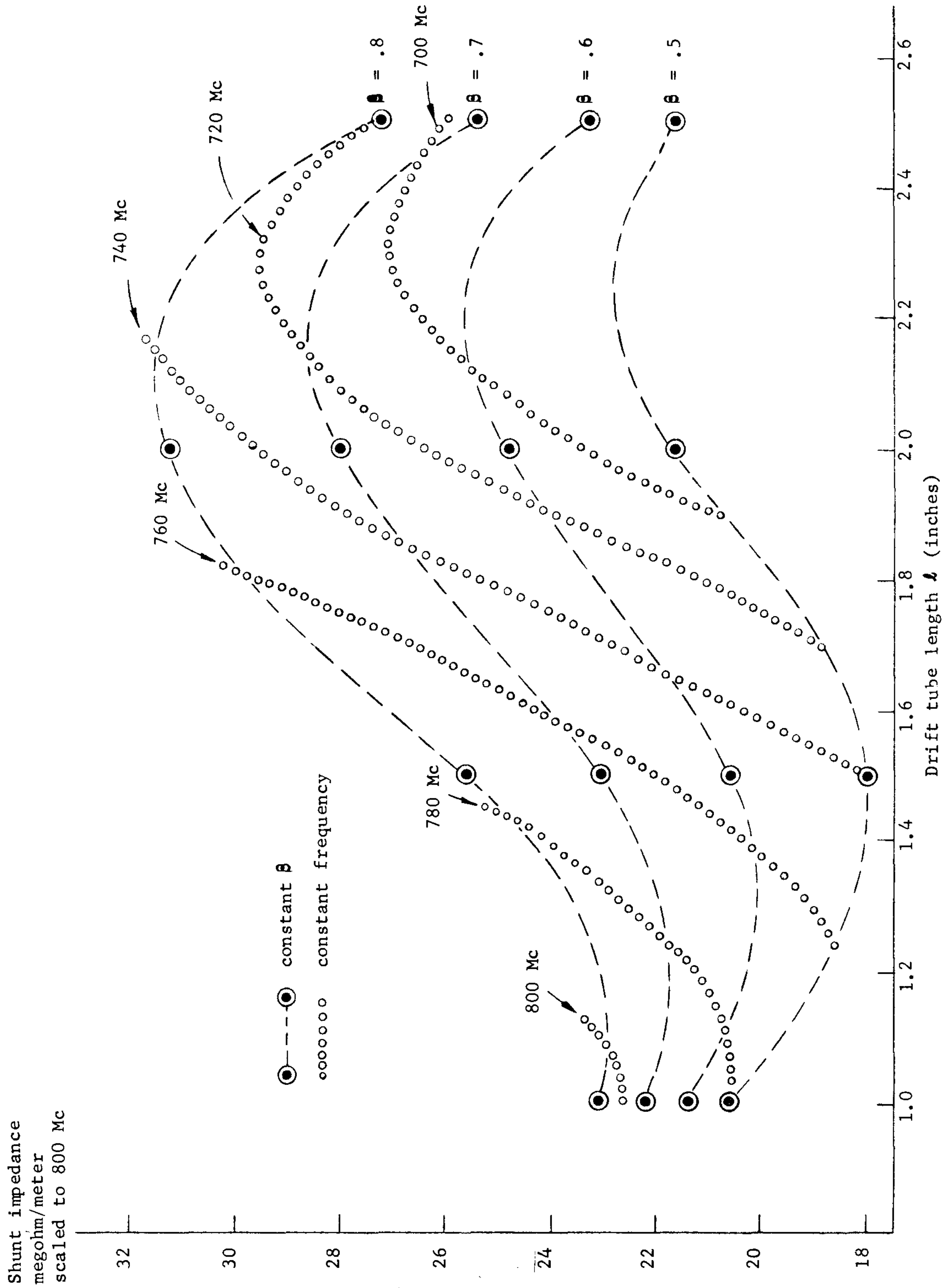


Fig. 6 Shunt impedance vs drift tube length for 50° slotted iris (1.625" bore hole) (curves of constant frequency and β)

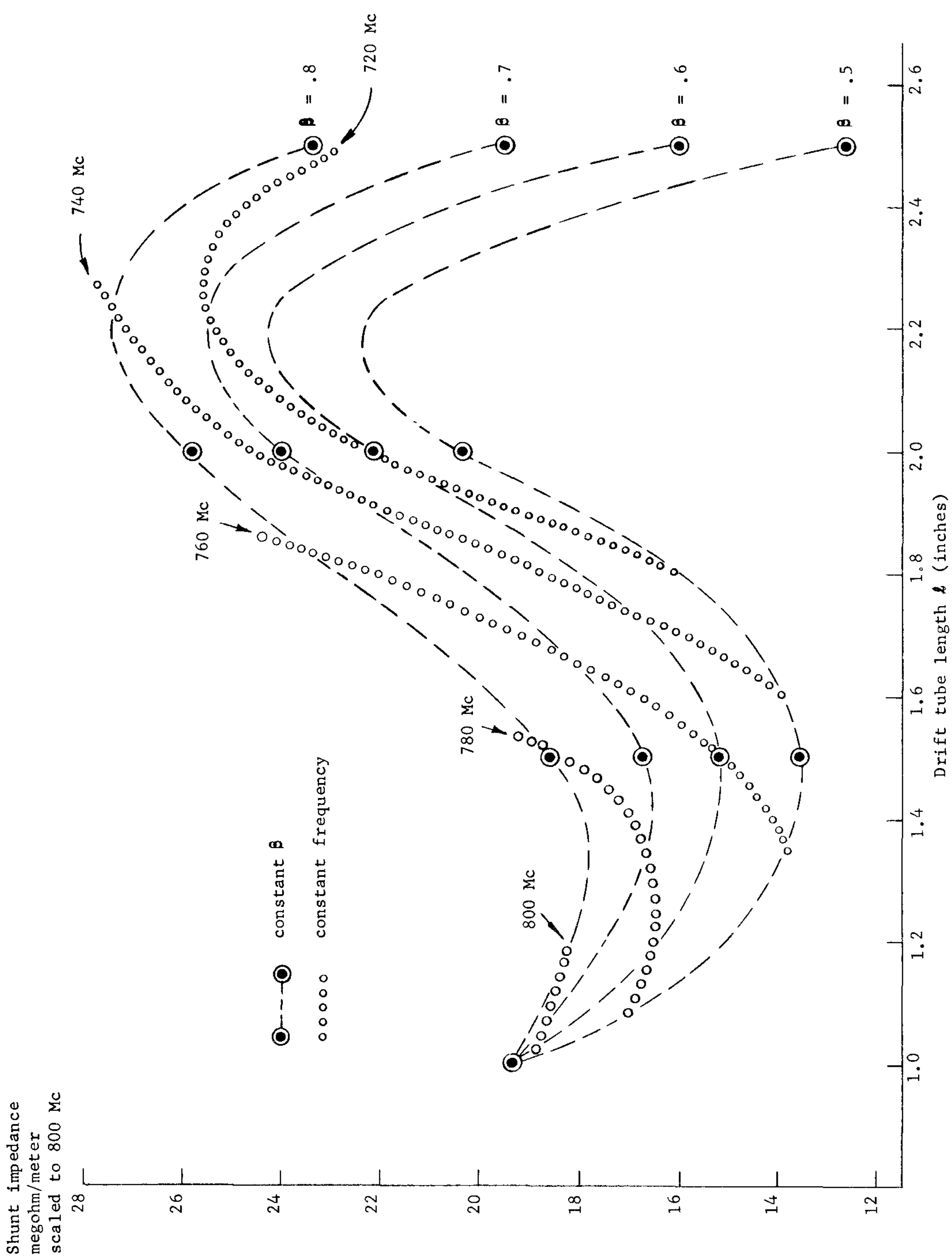
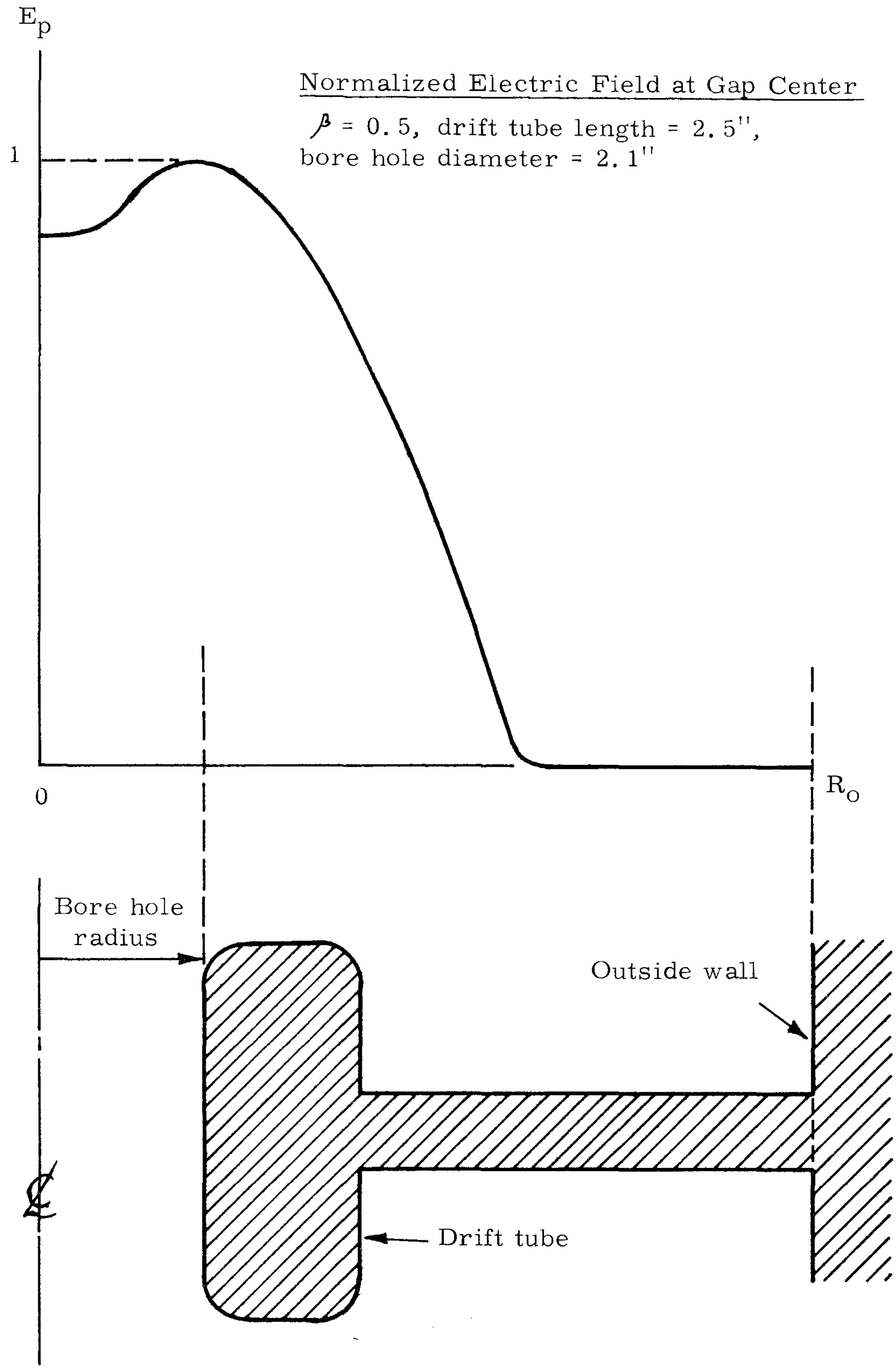


Fig. 7 Shunt impedance vs drift tube length for 50° slotted iris (2.1" bore hole)
(curves of constant frequency and β)



E_p
Normalized Electric Field at Gap Center
β = 0.5, drift tube length = 2.5'',
bore hole diameter = 2.1''
1
0
R_o
Bore hole radius
Outside wall
Drift tube

Fig. 8

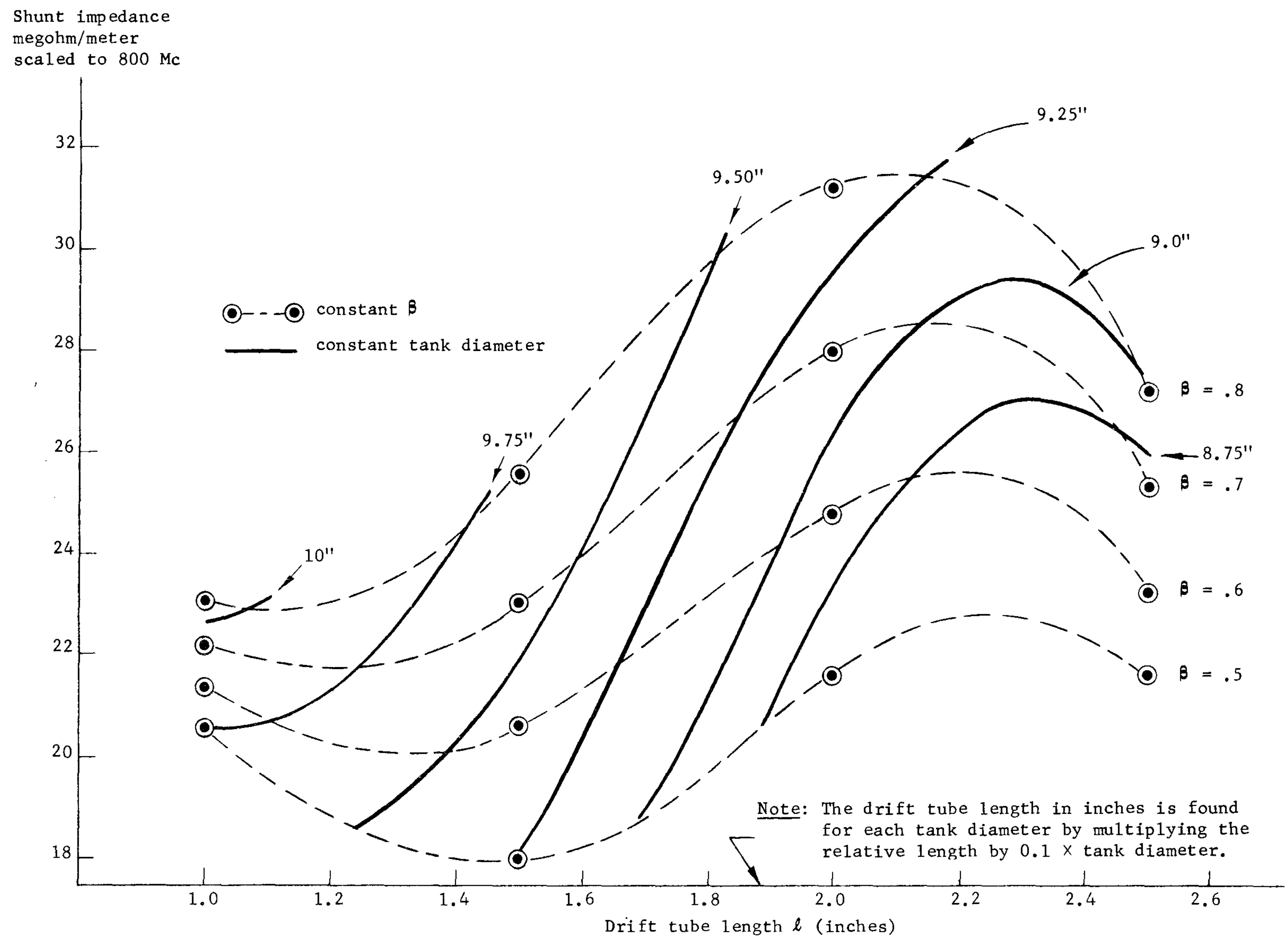


Fig. 9 Shunt impedance vs. drift tube length for 50° slotted iris (bore hole corresponding to 10" tank is 1.625") (curves of constant tank diameter and constant β) at 800 Mc

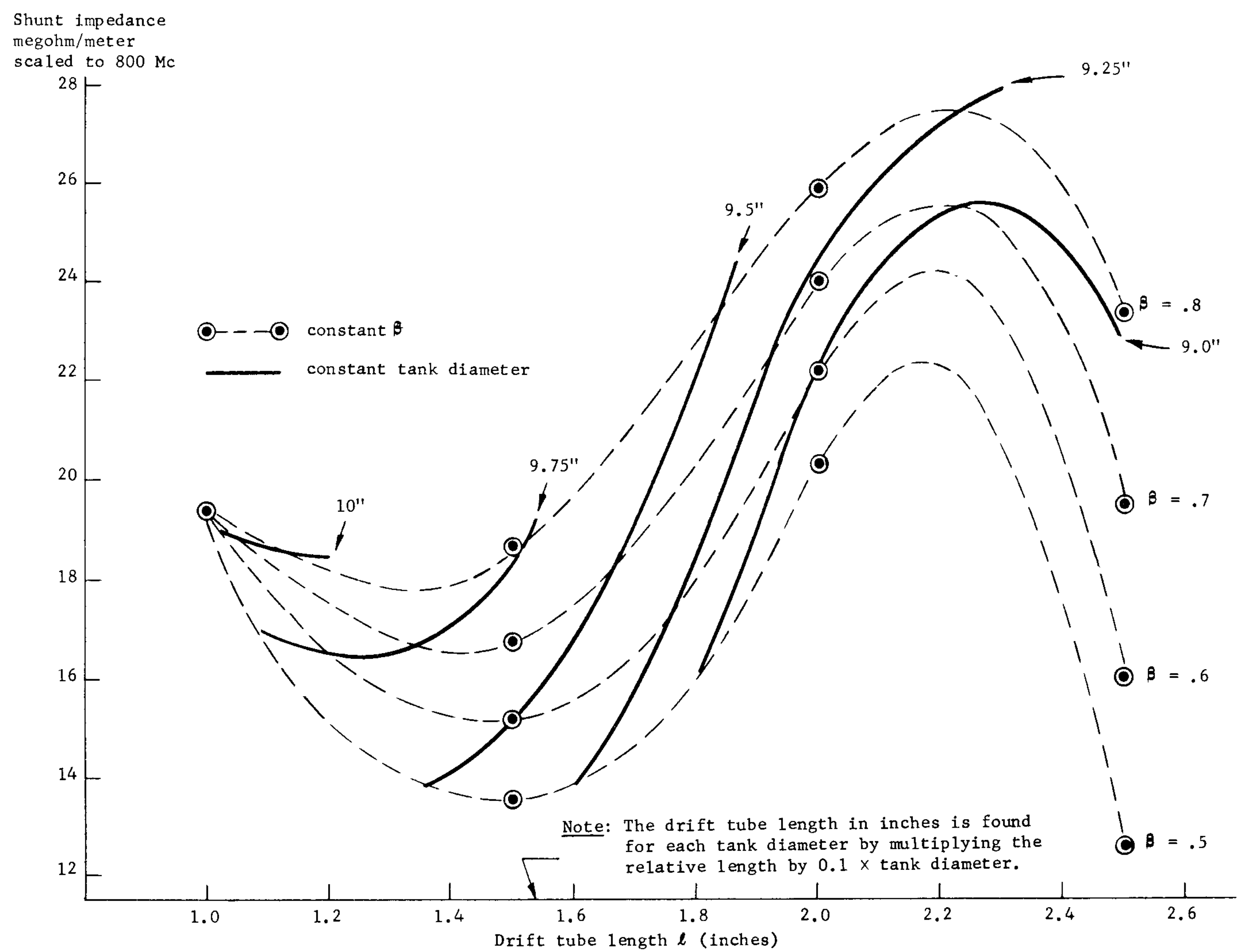


Fig. 10 Shunt impedance vs. drift tube length for 50° slotted iris (bore hole corresponding to 10" tank is 2.1") (curves of constant tank diameter and constant β) at 800 Mc

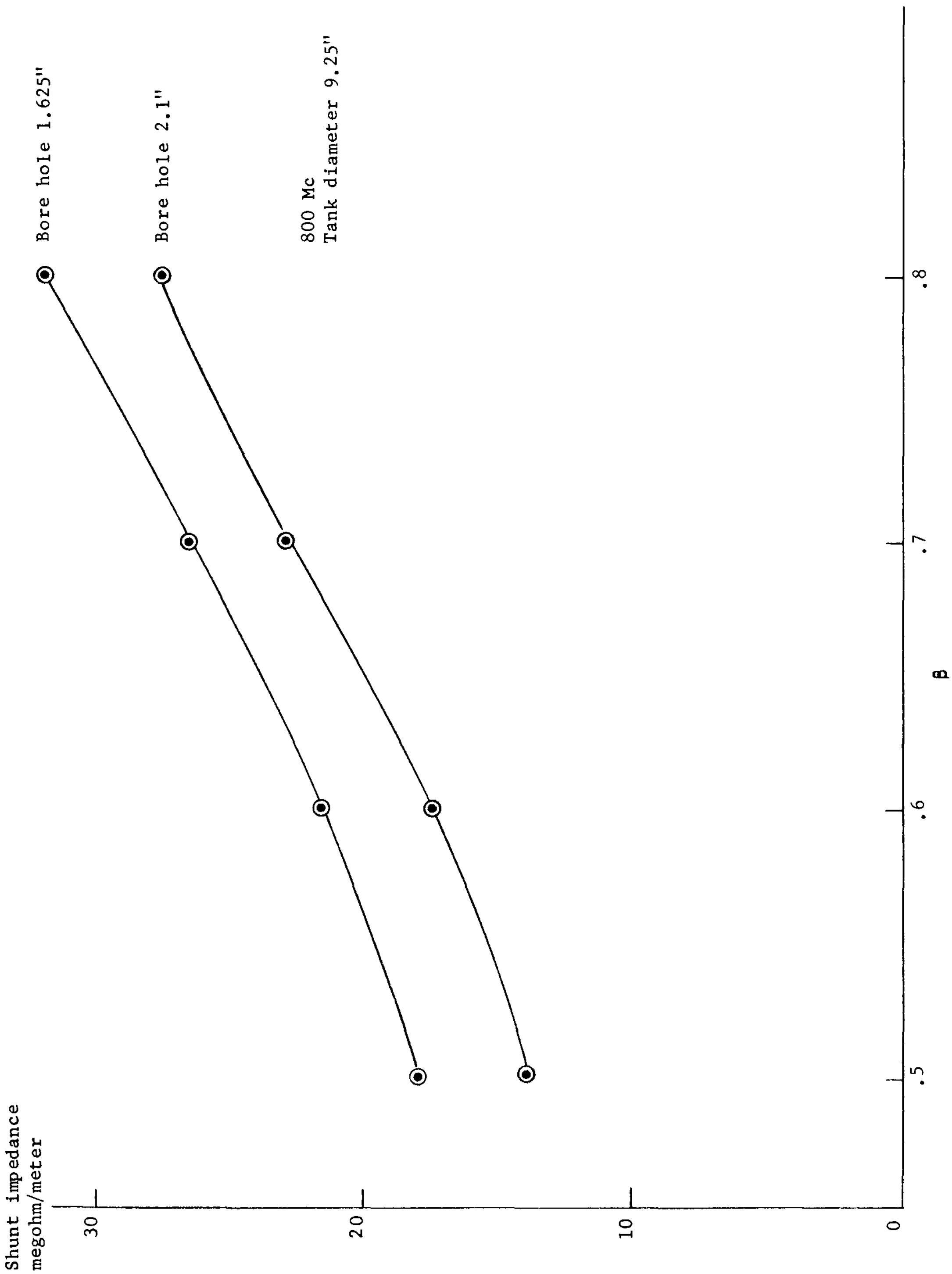


Fig. 11 Shunt impedance vs β for 50° slotted iris

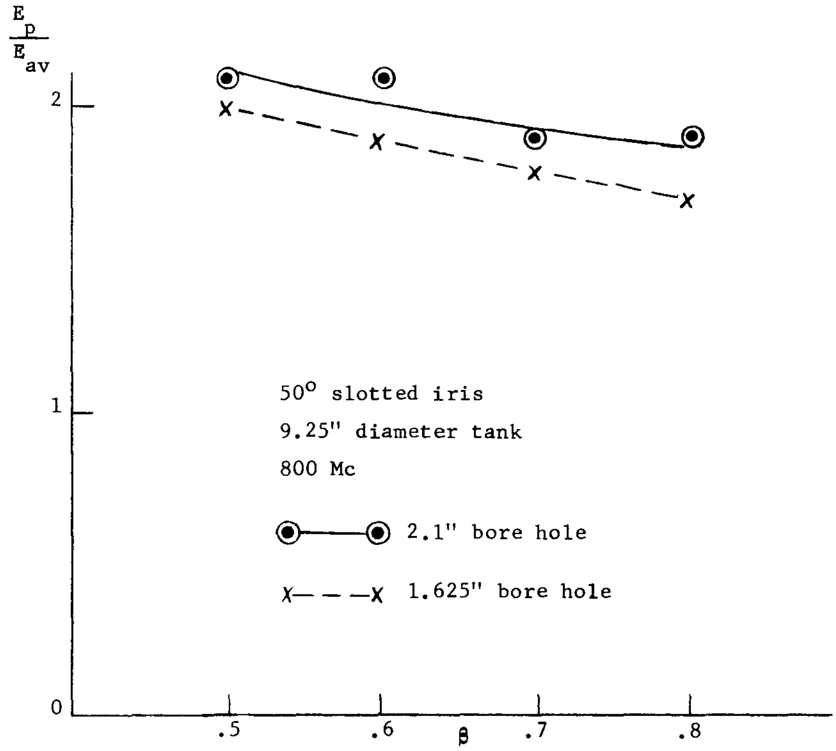


Fig. 12 Ratio of peak field to average field vs β for the 50° slotted iris

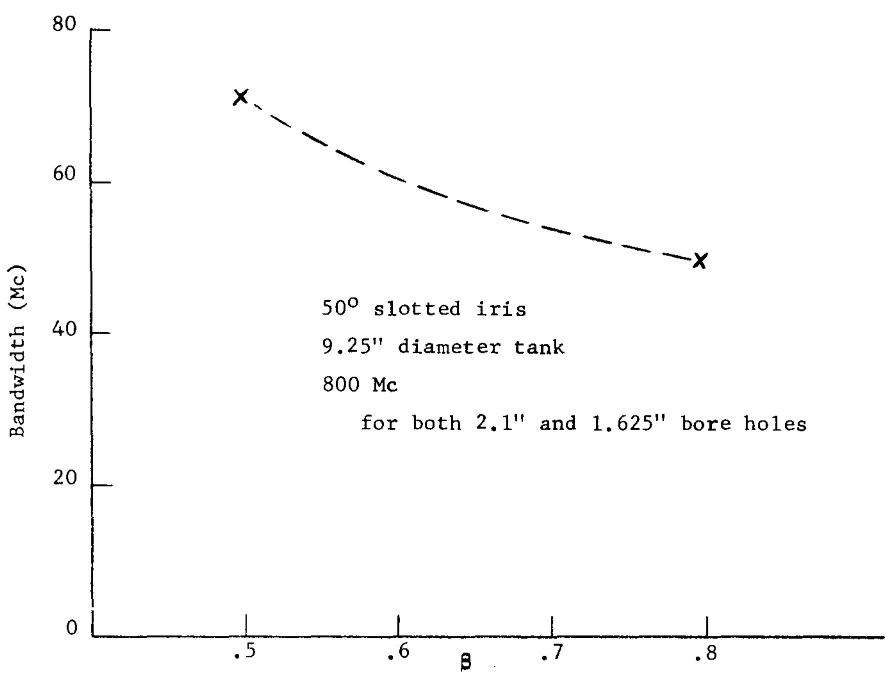


Fig. 13 Bandwidth vs β for the 50° slotted iris

in shunt impedance between the 1.625'' bore hole and the 2.1'' bore hole. Another interesting point is the rapid fall-off of shunt impedance with longer drift tubes. At $\beta = 0.5$ and a drift tube length of 2.5'', we see that, with increasing drift tube length, fall-off of shunt impedance for the 1.625'' bore hole is small as compared to the 2.1'' bore hole. One reason for fall of shunt impedance can be seen in Fig. 8, which is a radial plot of the electric field at the center of a cell and shows a dip of 11% in the electric field on the axis for the larger bore hole.

From Figs. 2 and 3, by drawing lines of constant frequency at 800 Mc, 780 Mc, 760 Mc, 720 Mc, and 700 Mc, and by interpolating between the various drift tube lengths at β's of 0.5, 0.6, 0.7, and 0.8, we may sketch in the contours of constant frequency in Figs. 6 and 7. The data in Figs. 6 and 7 were made on a 10'' diameter tank. It is interesting to note that the constant frequency contours in Figs. 6 and 7 can be made to represent constant tank diameters at some other frequency. If, for example, we select 800 Mc/sec as an operating frequency, and if we scale the dimensions of the original 10'' diameter tank (used for the measurements in Figs. 6 and 7) by $\frac{780}{800}$, we get a tank whose diameter is 9.75'', and the constant frequency contours of 780 Mc in Figs. 6 and 7 become constant tank diameter contours of 9.75'' at an operating frequency of 800 Mc. We may now draw Figs. 9 and 10, noting that the drift tube length is scaled proportionately.

If an operating frequency of 800 Mc is selected, we see that a tank diameter of 9.25'' would be a good choice. If one is willing to change tank diameters, some over-all improvement in the average shunt impedance can be gained. Figure 11 shows the shunt impedance as a function of β for a 9.25'' diameter tank at 800 Mc. There may be as much as a $\pm$ 15% error in shunt impedance due to the original measurements of "Q".

It can be shown that

$$\frac{E_p}{E_{av}} = \frac{1}{f} \sqrt{\left(\frac{L\,N}{2\,\pi^2\,\epsilon_o\,r_o^3}\right) \times \left(\frac{Q\,\Delta f}{R_s}\right)}\ ,$$

where E_p is the peak electric field at the center of a cavity, E_{av} is the average electric field as seen by a synchronous particle, f is the operating frequency, L is the length of the cavity in meters, r_o is the radius in meters of a small metal sphere placed at the center of the cavity, Δf is the frequency perturbation due to the metal sphere placed at the center of the cavity, and N is the number of cells. Figure 12 is a plot of

E_p/E_{av} scaled to a 9.25'' diameter tank. Figure 13 is a plot of bandwidth vs β at 800 Mc/sec.

From the results of the above measurements, a new series of test cavities is being built, having a tank diameter of 9.25''. Measurements will be made on four sets of irises with slots, subtending angles of 35°, 40°, 45°, and 50°, as shown in Fig. 1.

JOHNSTON: Was this a zero-mode structure?

GIORDANO: No, all these measurements were made in the π mode. It should be pointed out that the shaped iris cavity is a forward wave structure, and the slotted iris cavity is a backward wave structure.

CARNE: You gave us shunt impedance measurements at 800 Mc. What were the η/Q and the Q values?

GIORDANO: The Q values, as I recall, were around 14,000 at $\beta \cong 0.5$ and about 16,000 at $\beta \cong 0.9$.

NAGLE: What were the actual measurement frequencies? As I recall, they were about 700 Mc?

GIORDANO: For these particular measurements, the tank diameter was kept constant, and the only thing I varied was the drift tube length. The measured data points ran from about 625 Mc up to about 825 Mc.

NAGLE: Over what frequencies were the extrapolations made?

GIORDANO: In extrapolating from a 10-inch diameter tank to a 9-1/4 inch diameter tank, my actual frequency extrapolation was from 740 Mc to 800 Mc.

NAGLE: Were these models constructed with spring-ring contacts?

GIORDANO: Yes.

HUBBARD: I wanted to say that at Berkeley we have made some preliminary measurements on an 800 Mc slotted iris structure similar to one described by Giordano. I will put the numbers on the board:

β	R_{sh}
0.38	27 M Ω/meter
0.77	39 M Ω/meter

These values of R_{sh} are based on measured values of Q.

NAGLE: Does that have a transit time factor in it?

HUBBARD: Yes, I would also like to point out that our measured Q's are almost the same as yours. We did a fair amount of optimizing of the slot shape, but very little optimizing of the drift tubes.

GIORDANO: What was the bore hole size?

HUBBARD: That was for a 1.5-inch diameter hole.

GIORDANO: There should be very little difference in comparing the shunt impedance for your 1.5-inch diameter bore hole and my 1.625-inch diameter bore hole. I selected 50° slots and optimized the shunt impedance by varying the drift tube lengths. You (Hubbard) selected a fixed drift tube length and varied the slot angle to optimize the shunt impedance. Both our results are in good agreement.

LOEW: Do you know what happens if you alternate the angles of the slots of the cavities, like the colverleaf?

GIORDANO: Very little. Actually for the particular model I have, which is terminated in half cells, the irises have to be alternated in pairs with the exception of the first and last iris. This is necessary to match the boundary conditions at the ends. I was hoping to change the shape of the dispersion curve, but found there was very little change.

LOEW: It remains backward?

GIORDANO: Yes.

HAGERMAN: Did you ever look for any azimuthal asymmetries in this? Since you seem to be taking the energy density stored on the axis by varying the slot width, you might wonder whether these things are azimuthally symmetric.

GIORDANO: Perturbation measurements of the azimuthal field were made. These measurements were made at $\beta \approx 0.5$, slot angles of 35° and 50°, with a drift tube length of one inch. The field was measured at the center of a cell at a radius approximately 0.75 inch. I could not detect any appreciable azimuthal asymmetries.

LOEW: I just wanted to mention something that might be useful to some of these studies. There was a man by the name of Mike Allen who wrote his Ph. D. thesis on something very similar for a traveling wave tube a few years ago (he was a student of Chodorow), and he has a lot of curves put into it.

LEISS: Could you please tell me roughly what is the magnitude of the transit time correction in either one of the two cases described?

HUBBARD: About 85%.

LEISS: So about 15% is in other modes?

GIORDANO: The actual measurement of shunt impedance was made by the perturbation method, and numerically integrated.

LEISS: I'm asking for reasons of beam loading.

GIORDANO: Well, you actually have to compare the shape of the field here to the average field.