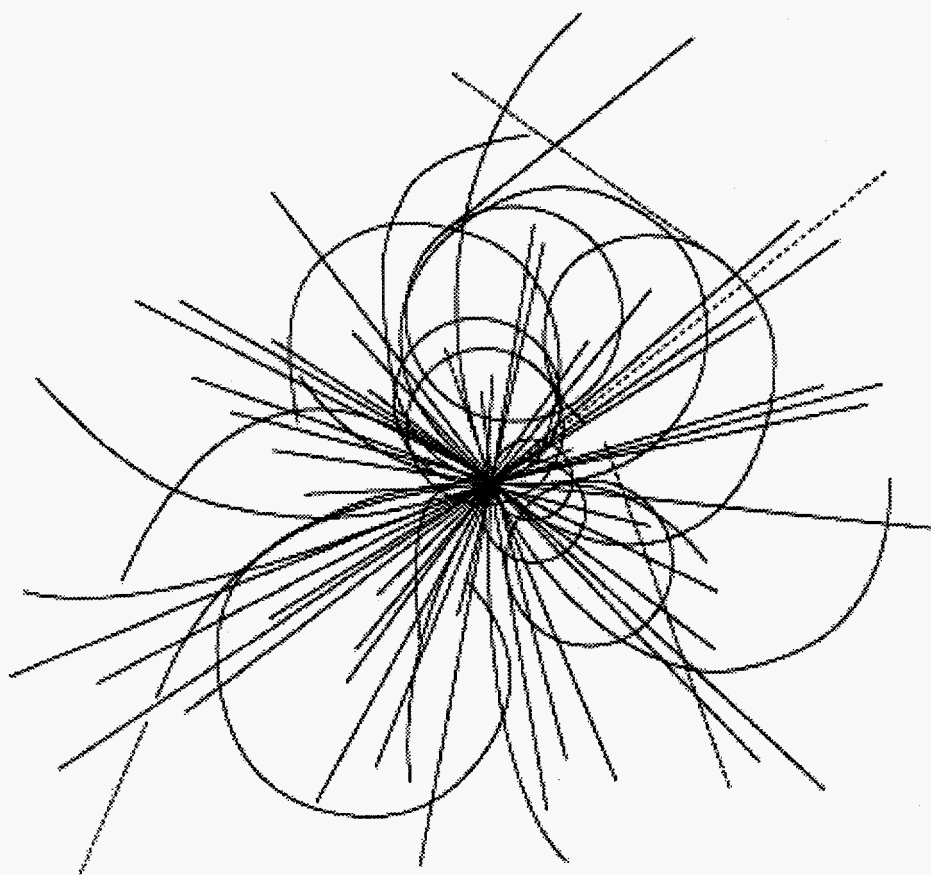


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L. Walling

# Impedance Measurements of the LEB Extraction Kicker Magnet



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LEB Extraction Kicker Magnet**

L. Walling

Superconducting Super Collider Laboratory\*  
2275 North Highway 77  
Waxahachie, TX 75165

October 1994

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## 1.0 INTRODUCTION

This report provides results of longitudinal and transverse impedance measurements of the Low Energy Booster (LEB) Extraction Kicker Magnet of the Superconducting Super Collider (SSC). The kicker magnet was designed to steer the beam upon extraction from the LEB into the septum magnets, requiring a vertical angular deflection of 1.5 mrad. This magnet would have been required to generate an integrated field of 0.06 T-m for 2  $\mu$ s, rising from 1% to 99% of peak in  $\leq$  80 ns. This magnet is described in detail in Reference 1. Figure 1 shows a cutaway view of the magnet, which is enclosed in a large tank approximately 1 m in length.

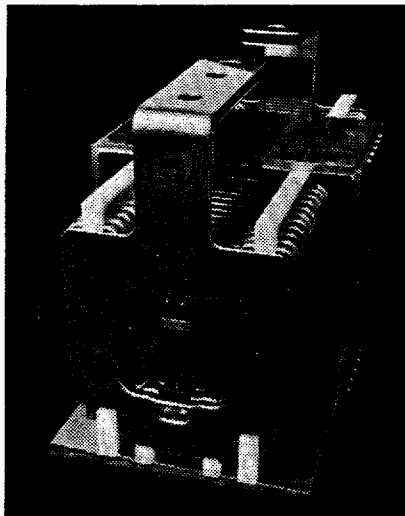


Figure 1. Cutaway view of the 28-cell LEB extraction traveling wave (TW) kicker magnet.

## 2.0 MEASUREMENT METHOD

The wire measurement method<sup>2-4</sup> was used to perform the measurements. The accuracy of these measurements is approximately 20–40%. The beam pipe diameter was 7.9 cm and the wire diameter 0.32 cm, and for the transverse measurement the distance between the two wires was 2.0 cm. This resulted in a line impedance of 193  $\Omega$  for the longitudinal and 290  $\Omega$  for the transverse measurement. Because of the extremely high inductance of this kicker, it was necessary to modify the analysis software in two ways. One was to include more terms in the expansion of the distributed impedance model, and the other was to keep track of non-resonant phase transitions in  $S_{21}$  from  $-180$  to  $+180$  and subtract  $2*\pi$  for each. Since it was necessary to break the measurements up into multiple runs with fairly narrow frequency ranges in order to have high enough resolution to calculate the impedances at resonances, it was then necessary to keep track of the cumulative phase from one frequency range set to the next and to correct the phase of the first point of each data run. The reactance is calculated from the phase as follows (see Eq. (11) in Reference 1):

$$\phi = -\frac{\omega l}{c} \left[ \sqrt{1 + \frac{cx}{\omega Z_c}} - 1 \right]$$

$$\text{Im } Z = lX = \frac{\omega l Z_c}{c} \left\{ \left[ 1 - \frac{c\phi}{\omega l} \right]^2 - 1 \right\}.$$

The resistive part of the impedance is then found (also from Eq. (11) in Reference 1):

$$|S_{21}| = e^{-\alpha}$$

$$\alpha = -\frac{l}{2Z_c} \left[ \frac{R + R_0}{1 + (cx / \omega Z_c)} - R_0 \right] = \ln |S_{21}|.$$

Thus,

$$\text{Re}(Z) = lR = (-2lZ_c \ln |S_{21}|) \left( 1 + \frac{cx}{\omega Z_c} \right).$$

Prior to performing the wire measurements, transmission through the cavity was measured by inserting antennas at both ends of the tank gap. This was necessary to determine the measurement frequency range and to provide insight into the validity of the final impedance measurements.

### 3.0 MEASUREMENT RESULTS

The preliminary measurements that were performed with antennas and no wires are shown in Figures 2 and 3. These show three major resonances: at 30, 88, and 485 MHz. This is useful for helping to determine the validity of the wire measurements, because if large resonances at frequencies other than these were to appear in the final results, this would imply that the presence of the wires was creating spurious resonances due to reflections from, say, the magnet end gaps, and would lend doubts as to the validity of the measurements in general. Happily, this did not occur, and these preliminary measurements lend credibility to the final wire measurement results.

The results of the longitudinal impedance measurements are shown in Figures 4–15, and the transverse impedance results are shown in Figures 16–19.

### 4.0 CONCLUSIONS

When these results are compared to the impedance budget of the Medium Energy Booster (MEB) for the SSC, both the longitudinal and transverse impedances of one kicker magnet exceed the calculated total kicker magnet budgets (15 magnets) by approximately one order of magnitude. Comparing to the budget for the LEB, one magnet's longitudinal impedance exceeds the calculated total kicker magnet budget (8 magnets) by approximately three orders of magnitude, and the transverse by one order of magnitude. Since the measurement value was for only one magnet, the total discrepancies are an additional order of magnitude larger than stated. Because of these large discrepancies, were the SSC to be built it would be necessary to calculate the magnet impedances using MAFIA in order to confirm (or hopefully, discredit) the measurement results.

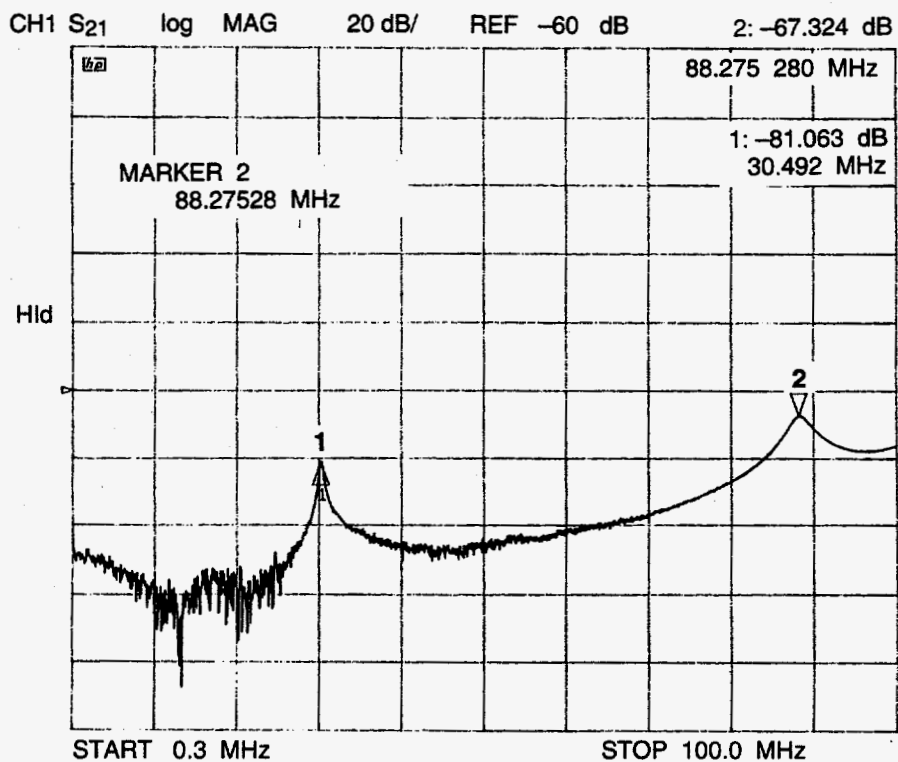


Figure 2. Transmission measurements of kicker magnet using antenna excitation and pickup.

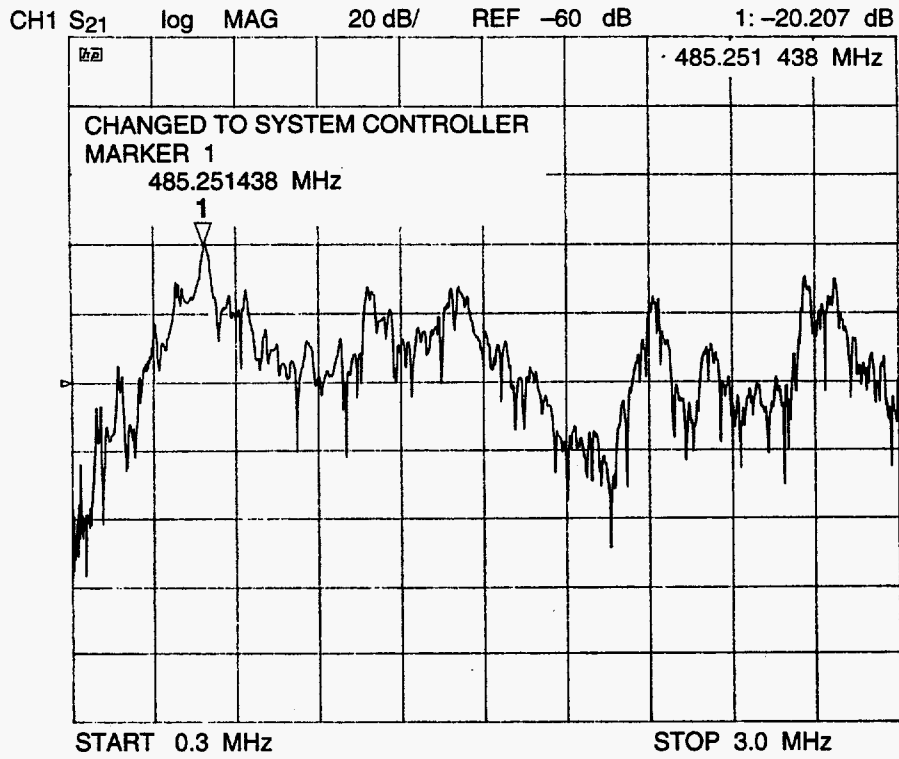


Figure 3. Transmission measurements of kicker magnet using antenna excitation and pickup.

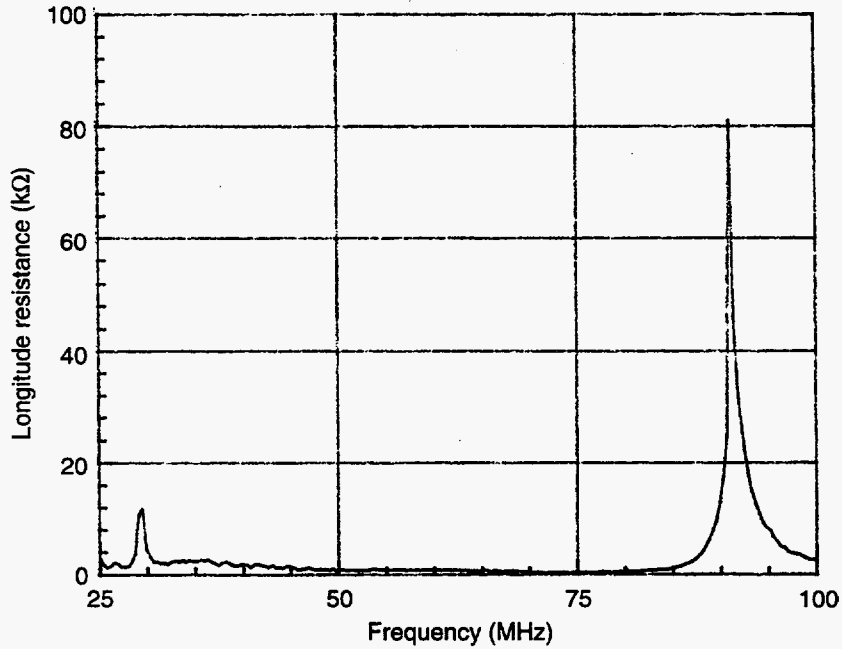


Figure 4. Kicker magnet longitudinal resistive impedance, 25-100 MHz.



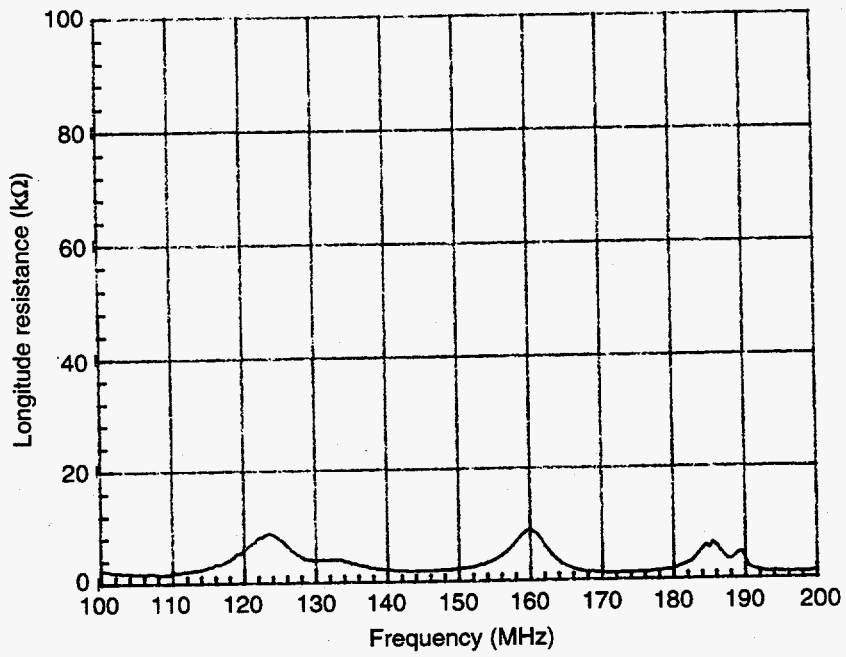


Figure 5. Kicker magnet longitudinal resistive impedance, 100–200 MHz.

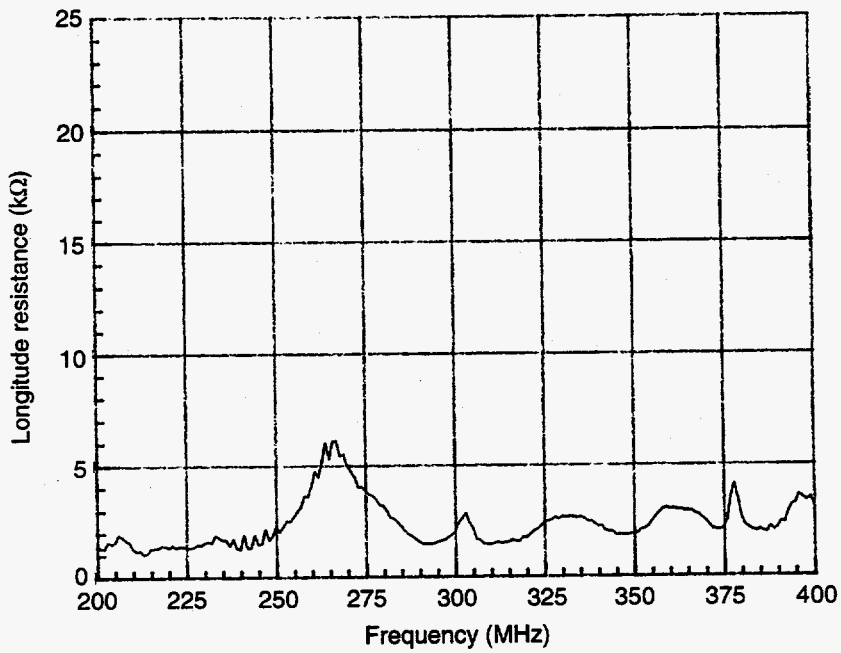
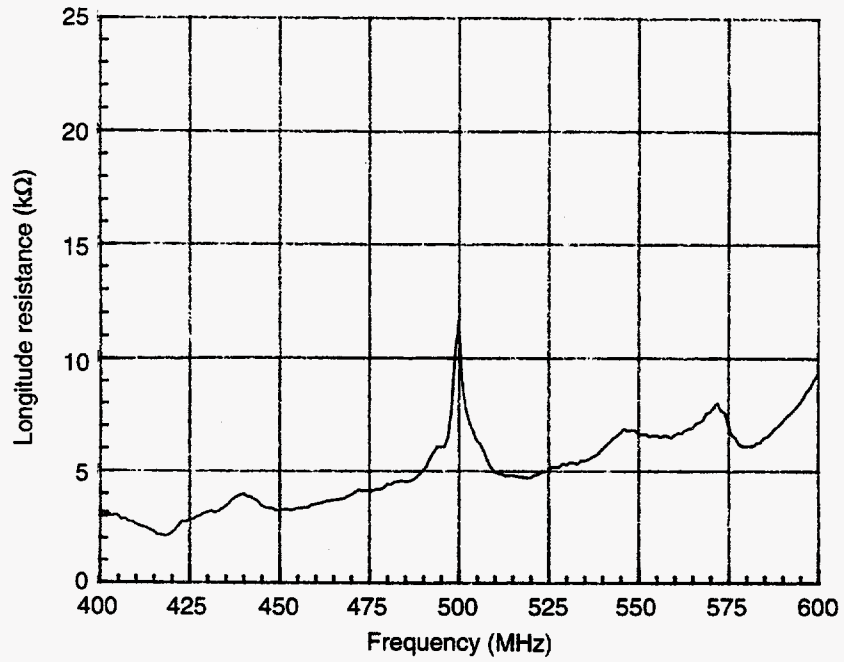
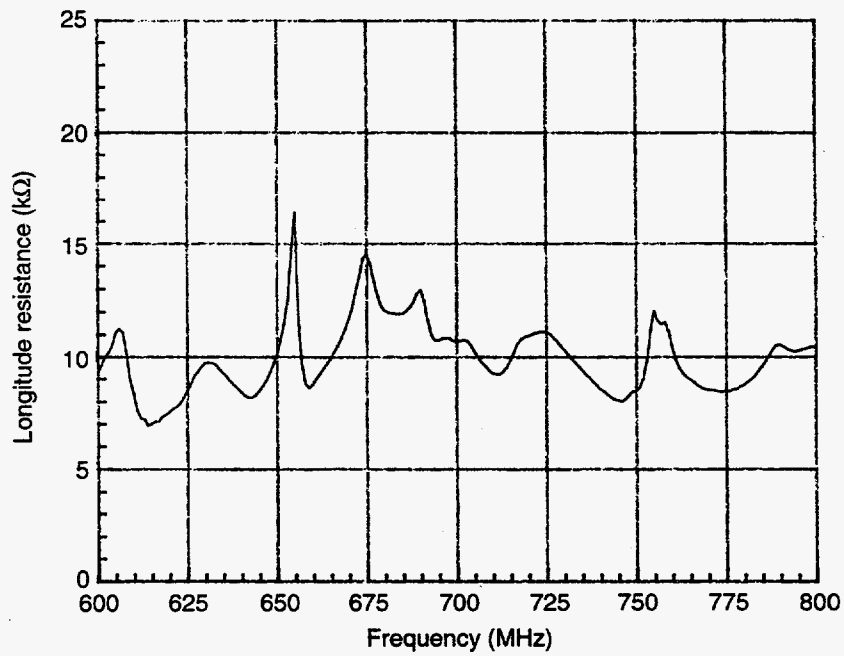


Figure 6. Kicker magnet longitudinal resistive impedance, 200–400 MHz.



**Figure 7. Kicker magnet longitudinal resistive impedance, 400–600 MHz.**



**Figure 8. Kicker magnet longitudinal resistive impedance, 600–800 MHz.**

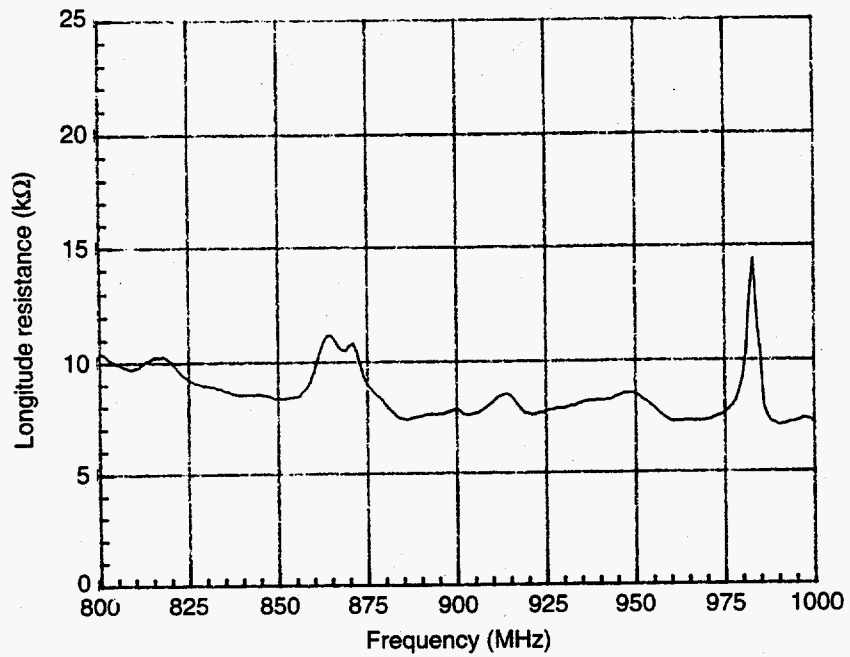


Figure 9. Kicker magnet longitudinal resistive impedance, 800–1000 MHz.

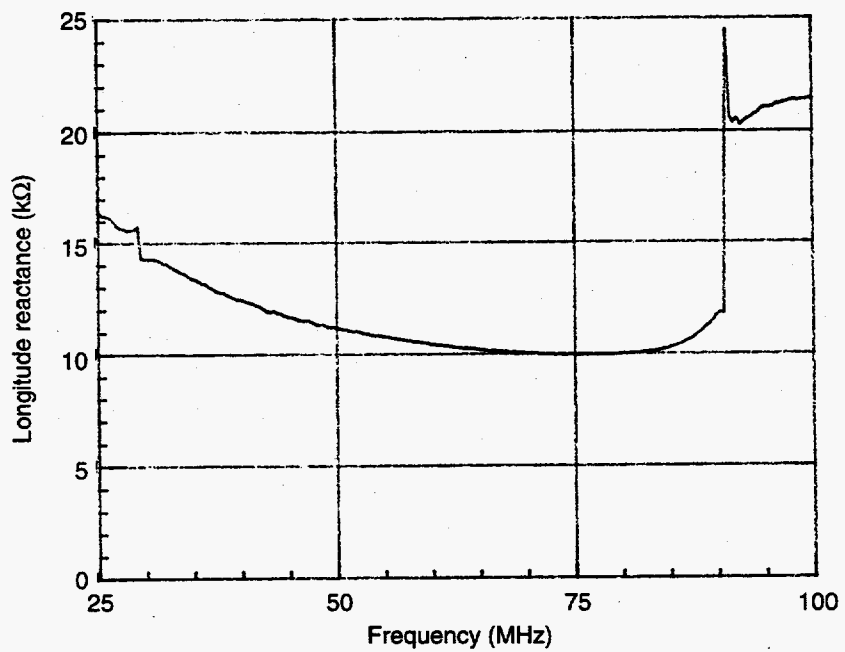


Figure 10. Kicker magnet longitudinal reactive impedance, 25–100 MHz.

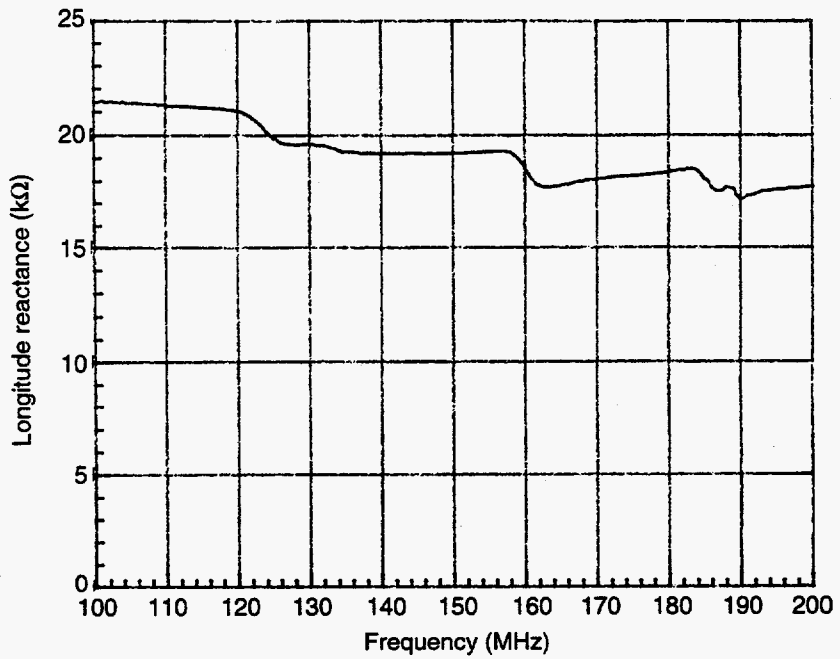


Figure 11. Kicker magnet longitudinal reactive impedance, 100–200 MHz.

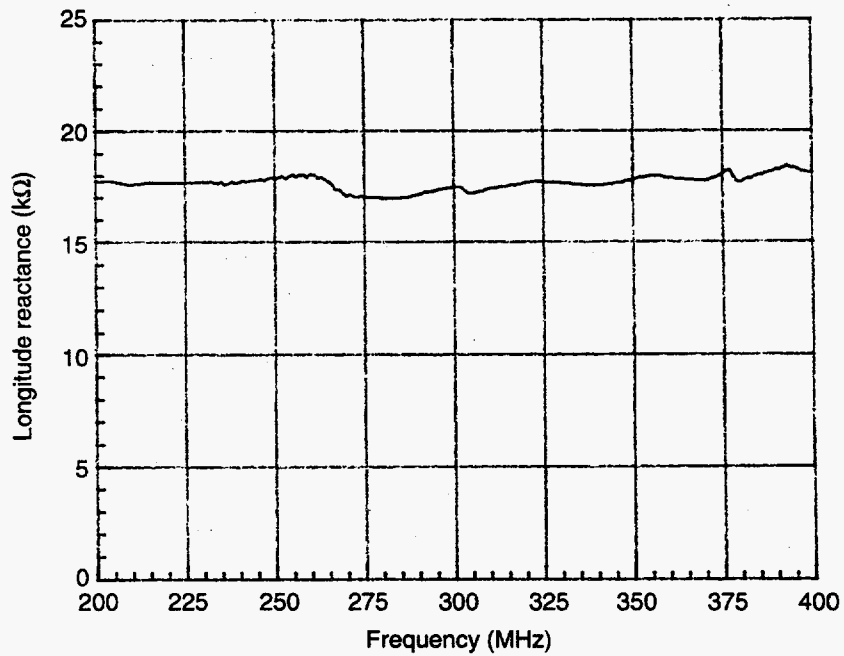


Figure 12. Kicker magnet longitudinal reactive impedance, 200–400 MHz.

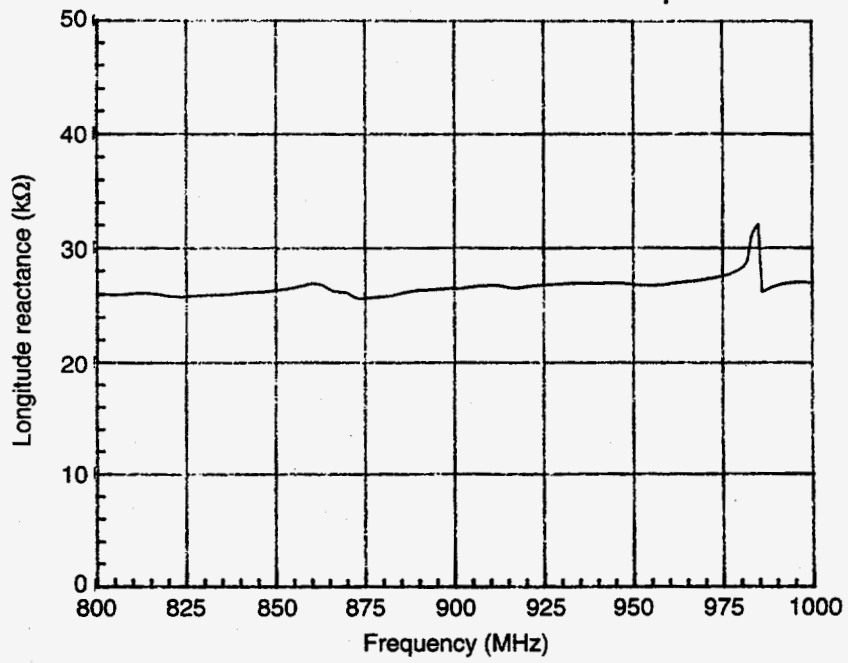


Figure 15. Kicker magnet longitudinal reactive impedance, 800–1000 MHz.

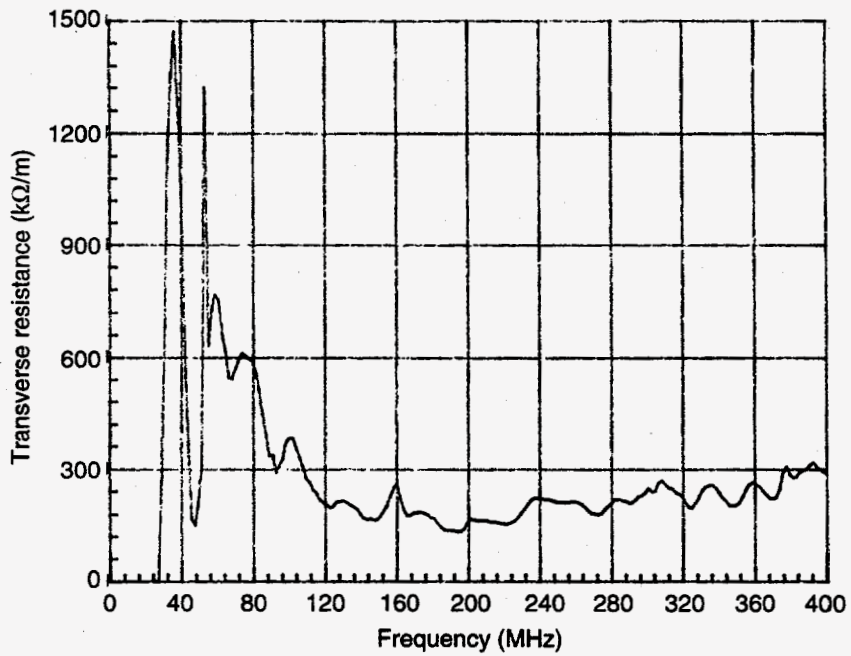
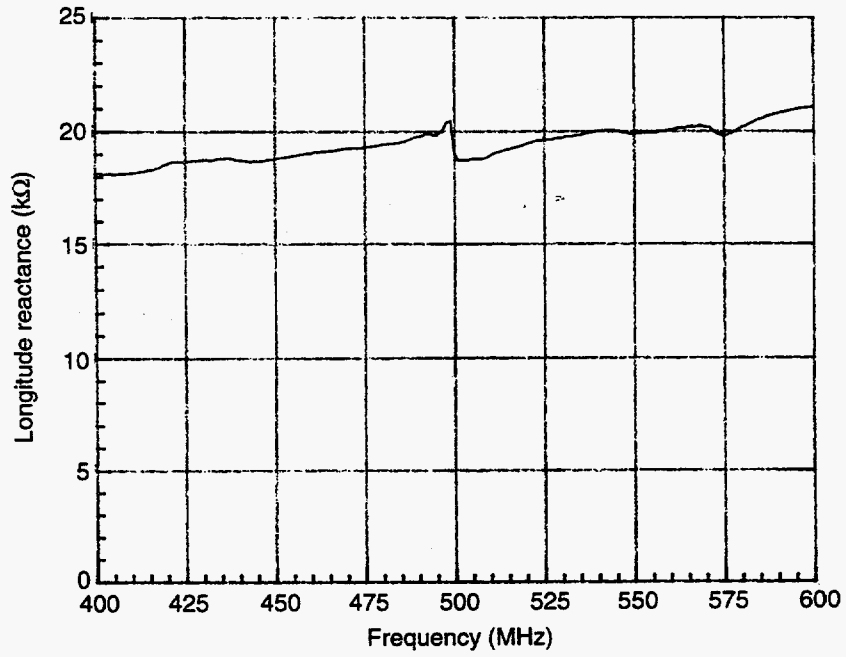
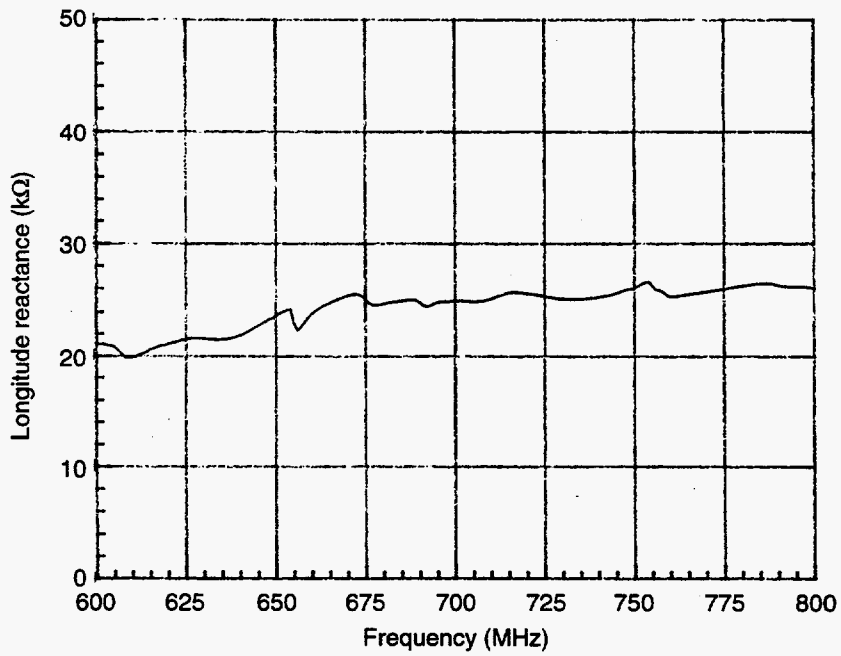


Figure 16. Kicker magnet transverse resistive impedance, 25–400 MHz.



**Figure 13. Kicker magnet longitudinal reactive impedance, 400–600 MHz.**



**Figure 14. Kicker magnet longitudinal reactive impedance, 600–800 MHz.**

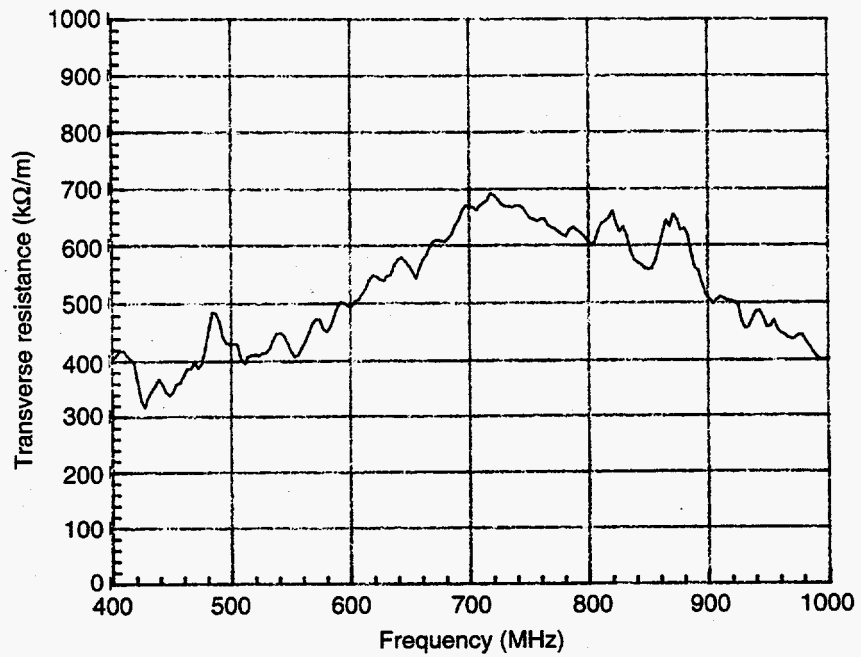


Figure 17. Kicker magnet transverse resistive impedance, 400–1000 MHz.

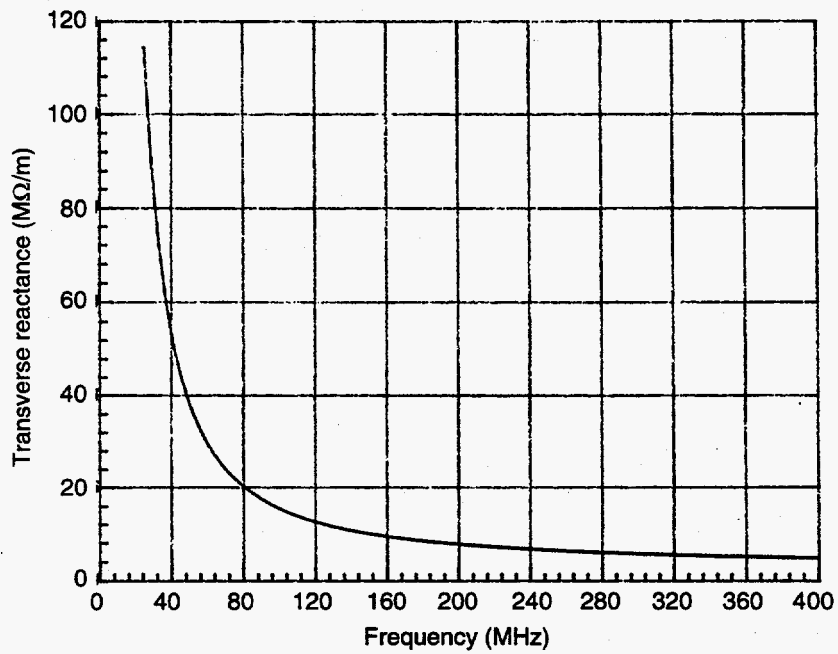


Figure 18. Kicker magnet transverse reactive impedance, 25–400 MHz.

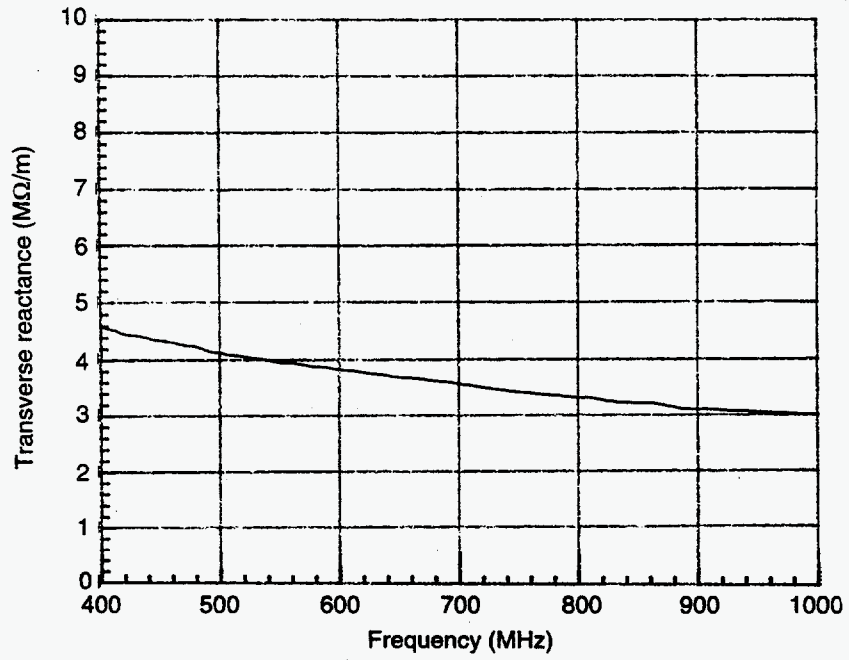


Figure 19. Kicker magnet transverse reactive impedance, 400–1000 MHz.



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