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PRECISELY MEASURING THE ELECTRICAL LENGTH OF COAX CABLES

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The Need

For the booster superdamper it was necessary to fabricate fast switched high quality delay lines to store beam bunch position information from the time it was detected until almost a turn later, then a deflection potential derived from the stored information acts to correct the position. The delay lines are switched out as the protons accelerate and are controlled by the booster RF oscillator. The overall tolerance on the delay system was less than 1 nsec, therefore, each of the 10 cables was cut to an accuracy of several hundredth nsec (± .02 nsec).

The Cable

Heliax air-dielectric cable (Andrew HJ5) was selected because of its low phase temperature coefficient. Also it was roughly positioned prior to final timing because of a noticed ~.1% effect (almost 1 nsec on the longer cables) caused by coiling the cable.

The Technique

The cable of unknown length(<1000 ft.)is terminated with a type N connector on the driving end, the far end is left open circuited. The cable is driven with a vector impedance meter* such as the H.P. 9815A whose frequency (period) is monitored by a counter such as the H.P. 5360 A. Starting at the low frequency end, note the frequency of:

1st Minimum Z i.e 1/4 λ Cable Resonance
1st Maximum Z i.e 1/2 λ Cable Resonance
2nd Minimum Z i.e 3/4 λ Cable Resonance
2nd Maximum Z i.e λ Cable Resonance

When the cable is resonant in the λ mode, the period reading is the transit time of the cable to that frequency. From this time must be subtracted the electrical length of the adapter from the probe to the coax line. We measured this by taking two sets of adapters back to back and using 1/2 this value as the length of the adapters. (Probe and N male adapter = 0.336 n sec, N Bullet and N Short = 0.193 nsec). We found that at low frequencies the cable appears longer by ~.1% than at frequencies above ~10 MHz, therefore, it is wise to excite the cable at the frequency of use. Keep track of the number of wavelets being used to excite the cable and multiply the indicated transit time period by this number. A short is more well defined in position than an open. When making a cable, it is wise to stay on the long side, terminate the far end with an N connector and short (then λ is to a low Z reading).

Comparison with Other Methods

A. Vector Voltmeter

This offers the best accuracy when the desire is to make cables alike. The H.P. 8405 A has a resolution of 0.1^0 at 1000 MHz (about 0.3×10^{-3} nsec). It is also possible to

*Suggested by Jim Griffin

make cables which are precisely η ($\lambda/2$) related to each other, but not to an absolute time delay!

B. Time Domain Reflectometry

This method offers sufficient accuracy for most laboratory situations. The H.P. 1815A/B provides 0.01 nsec/division resolution. This method provides the least ambiguous information on cable characteristics.

C. Vector Impedance Meter

The H.P. 4185A has a resolution of 1^0 at 100 MHz (about 3×10^{-2} nsec). In practice we found that the zero phase crossing gave a readability an order of magnitude better than this and was good enough for our purpose.