A NEW MEASUREMENT METHOD OF THE DELAY LINE LENGTH IN THE X-BAND DELAY LINE DISTRIBUTION SYSTEM (DLDS)

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Abstract

In order to control the driving RF phase at the input of the accelerating structure of X-band linear collider main linacs, it is necessary to measure the length of the long TE01 mode delay lines of 40-80m. A new measurement scheme by using the low frequency resonant mode of the TE01mode delay line was proposed. The delay lines have the tapered guide on its both ends, thus the low frequency resonant mode around 2GHz can be the measure of the delay line dimensions. The operational principle and the elementary characteristics of this measurement method such as, sensitivity, and other basic design parameters are presented.

1 INTORODUCTION

Delay Line Distribution System (DLDS) is an RF pulse compression equivalent sysyetm[1]. In DLDS, long circular wave guides are used as the part of RF power distribution systrem, and RF power must travel through these long delay lines to drive the accelerating structure where RF crest synchronize to the linac beam. In X-band linear collider, allowable RF phase deviation to the beam is about or even less than 1-degree to clear the energy spread of 0.2%. This limit is determined by the energy acceptance of the final focus system and also by the physics requirement [2,3,4]. This phase diviation limit correspond to the temperature change of 0.08 degree Celsius in case of TE01 mode 118.1mm circular Cu waveguide. Table 1 shows the thermal expansion coefficient and corresponding temperature change for TE01 mode in the guide. Even with Invar that is the typical low thermal expansion material, this temperature limit is 0.6 degree. Considering the size of the delay line and the scale of the linear collider, it is clear that some measurement of the delay line length and some phase control are necessary.

	$\alpha = \frac{1}{l_0}\frac{dl}{dT}$	Allowable ΔT (for 40m)
Cu	1.65×10^{-5}	0.08 deg.
Invar	2×10^{-6}	0.6 deg.

Table 1: Thermal expansion of material

2 MEASUREMENT PRINCIPLE AND BASIC PARAMETERS

2.1 *Measurement principle*

Delay lines have the tapered circular guide on their both ends that are connected to the mode convertor from rectangular TE10 to circular TE01. Thus, this delay line works as the resonant cavity for the lower frequency than the cut off of these tapered guide. This resonant mode parameters such as the resonant frequency, the phase change of the reflected wave etc., can be the measure of the dimension change of the delay line.

Figure 1. shows the conceptual illustration of this resonant mode measurement. Low frequency RF signal is fed into the delay line that works as a resonant cavity at this frequency. Observing the shift of the resonant mode frequency and/or the phase shift of the reflected wave from the delay line, change of the delay line length could be measured.

As the X-band high power mode in DLDS is expected to be an axial symmetric TE01 mode, TE11

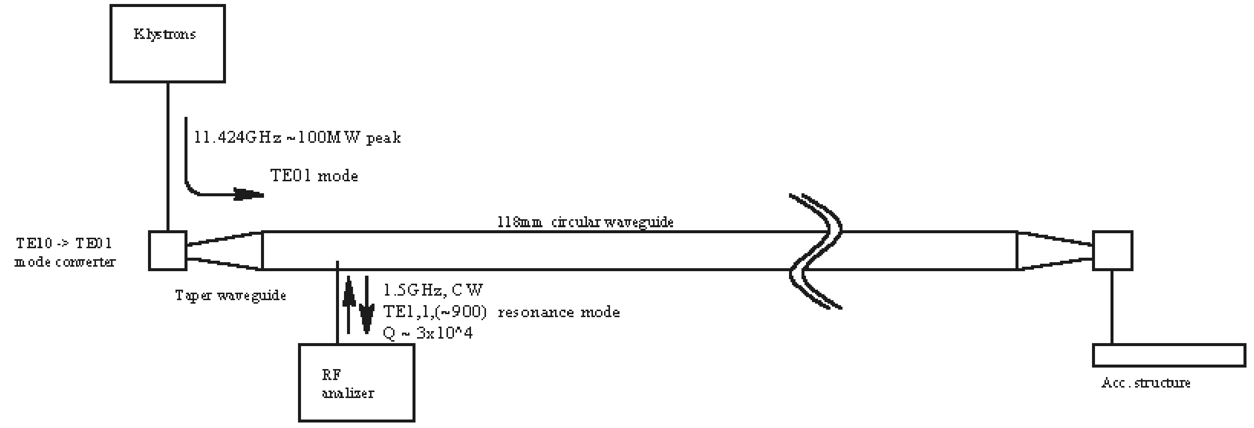

fig. 1: Conceptual diagram of measurement

dipole mode was chosen as the low frequency resonant mode of the delay line. Also, single mode operation by possible in using TE11 mode.

2.2 Parameters

Severtal parameters of the low frequency mode were calculated in case of 4/3 DLDS of JLC x-band main linac [4]. Two delay lines are 118.1mm circular waveguide of 80m and 40m respectively. For calculations, following points were assumed, (1) Tapered parts were ignored, ie. for the resonant mode calculation, both ends are assumed as being shorted. (2) temperature distribution along the delay line was assumed as uniform. (3) Dimension change of the line was also assumed as uniform and both ends were free for expansion.

For the 2.25GHz TE11,900 mode of 80m 118.1mm diameter circular delay line, Q_0 was calculated as ~ 40000. The conductivity of Cu was assumed as $\sigma = 5.6 \times 10^7$ mho per meter.

Figure 2 shows the X-band phase deviation (dimension change ofthe line) vs. phase change of the reflected resonance mode frequency. The sensitivity and the amplitude of the reflected wave strongly depend on the coupling coefficiet β, and reach zero and infinity respectively at the critical coupling, $\beta = 1.0$. Figure 3 shows the coupling coefficient vs. reflected power ratio. Considering the reflected power and the sensitivity, $\beta = 0.5$ was chosen as the operating point of this method. At this point, 10% reflected power is expected. And sensitivity, which is defined as $\left|\Delta\phi_{reflected} / \Delta\phi_{X-band}\right|$, is sufficient (about 8) at this point.

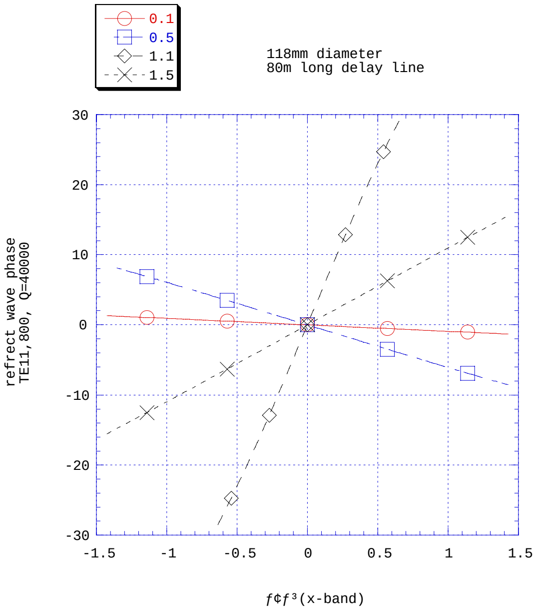

fig. 2: Phase deviation of X-band pulse vs. phase change of reflected wave. 1 degree of X-band corresponds to 70 micro meter lengh change.

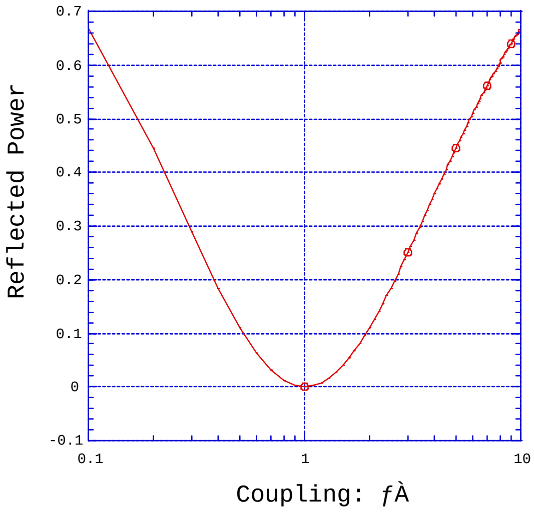

fig. 3: Coupling vs. reflected power

3 SIMULATION AND PRELIMINARY MEASUREMENT

Low power measurement set up with the 40m long and 69mm diameter circular wave guide system with two tapered guide and mode convertor is under preperation. The coupling slot of the TE11 resonant mode of the line must be seperated from the TE01 X-band mode. Figure 4 shows the HFSS model of the coupling slot.

SLED II theory shows the the coupling coefficient of the long line is represented by the reflection coefficient of the coupling S, as follows [5],

$$\beta = \frac{Q_0}{Q_{ex}} = \frac{-\ln s}{2\tau}$$

where:

$$Q_0 = \frac{\omega D}{4\tau},$$

$$Q_{ex} = -\frac{\omega D}{2\ln s},$$

τ: Attenuation of wave running guide between both ends.

s: Reflection coefficient into macthed circular wave guide.

D: Time that run pulse between both ends.

From this, coupling coefficient of 0.5 corresponds to the s=0.92 for the coupling slot to the matched circular waveguide.

Preliminary calculation by HFSS showed that this coupling slot in Figure 4 has only small effect to the TE01 X-band mode in propagating in the circular guide. This problem must be surveyed more carefully.

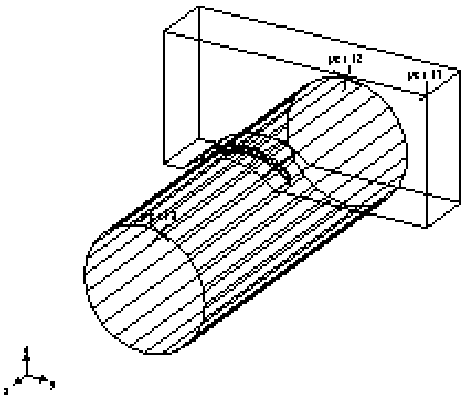

fig. 4: Monitor coupler design

4 DISCUSSIONS

As long as the preliminary calculation showed, this new measurement method has sufficient sensitivity and possible in principle. Several problems are to be considered as follows.

1) TE11 mode has dipole symmetry, therefore the probable rotation of its symmetry plane due to the deformation of the circular waveguide should be surveyed. This problem could be important especially in the very long resonator like this case.
2) Signal seperation from X-band TE01mode high power pulse. The preliminary calculation showed the posiibility that the design choice of the coupling slot can achieved this seperation. Also gating the X-band driving pulse could block the unnecessary X-band signal. X-band high power pulse has 500nsec width and 150Hz reptation rate, so we can spend about 5msec for this measurement. Time constant of the delay line resonator is about 4micro sec, so 5msec is enough to this measurement in principle.
3) High power related matters, such as a discharge around the coupling slot for TE11 mode, Mode purity degradation of the TE01 X-band mode and resulting loss of the power are to be surveyed.

5 ACKNOWLEDGEMENTS

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