

STUDY OF RF COMPONENTS FOR JLC 2×2 DLDS

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Abstract

We have studied a multi-mode Delay Line Distribution System (DLDS)[1][2] as the RF power distribution system from klystrons to RF structures for linear colliders. In particular, a 2×2 DLDS has been proposed and studied at KEK for Japan Linear Collider(JLC). It has been proved that the 2×2 DLDS is simple, but has good transmission efficiency. We have designed RF components of a basic unit of a DLDS using the High Frequency Structure Simulator (HFSS) code[3]. They include the TE₀₁ extractor, the TE₁₁ to TE₀₁ converter, and the TE₁₁ to TE₁₂ converter for TE₁₂ mode. HFSS calculation of the system, which consists of TE₀₁ extractor and TE₁₁ to TE₀₁ converter, shows that the transmission efficiency of each mode is better than 95%. The components, as well as the system are being studied experimentally. A low power test model for the mode stability experiment in 55m long wave guide in DLDS is also being developed..

1 INTRODUCTION

The Delay Line Distribution System (DLDS) invented by KEK has been considered for the compression and distribution of the RF power from klystrons to accelerator structures in the proposed projects of linear colliders, such as the Japan Linear Collider (JLC)[4] and Next Linear Collider (NLC)[5]. In DLDS, the long pulse of combined klystron output is subdivided into a train of shorter pulses and each subpulse is delivered to accelerating structures through a delay line distribution system. This system utilizes the delay of the electron beam in the accelerator structure of the linear collider to reduce the length of the waveguide assembly. A conceptual improvement is proposed by SLAC to further reduce the length of waveguide system by multiplexing several low-loss RF modes in a same waveguide. Thus, the subpulse in the distribution waveguide are carried by different waveguide modes so that they can be extracted at designated locations according to their mode patterns. Based on the SLAC multi-mode DLDS, a 2×2 DLDS [6] is proposed in KEK for JLC. The advantage of 2×2 DLDS is that it's simple and easy to be expended to accommodate combinations of more klystrons, and also it has good transmission efficiency.

In this paper the design of the main RF components of a basic unit of 2×2 DLDS is presented. The main

components include the mode launcher, the TE₀₁ extractor, and the TE₁₁ to TE₀₁ mode converter. A basic system of DLDS that consists of TE₀₁ mode extractor and the TE₁₁ to TE₀₁ mode converter is also studied. For long distance transmission, the low loss TE₁₂ mode is preferred, so a TE₁₁ to TE₁₂ mode converter and the low choked flange needed for connecting between waveguide is also designed. The High Frequency Structure Simulator (HFSS) code, which evaluates in frequency domain with 3D finite element method, is used for design and study.

2 BASIC UNIT OF 2×2 DLDS

A test unit is proposed and studied to verify the principle of multi-mode 2×2 DLDS. It includes the mode launcher, the TE₀₁ extractor and the TE₁₁ to TE₀₁ converter. Fig. 1 is the schematic layout of the unit.

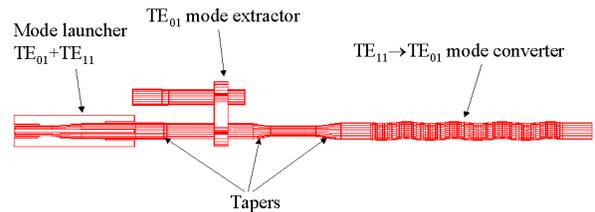


Figure 1: Schematic layout of 2×2 DLDS unit.

2.1 TE₀₁-TE₁₁ Multi-mode Launcher

The TE₀₁-TE₁₁ multi-mode launcher converts the power from four rectangular waveguides feeds to separate modes i.e. TE₀₁ and TE₁₁ modes, in a multi-moded circular guide through coupling slots. Here, we adopt the same design as that proposed by Zenghai Li, et al [7].

The original design is modeled with MAFIA [8], so HFSS is used to check the performance of the same geometry as the MAFIA model. But the result got by HFSS is not so good as that predicted by MAFIA: though the power transmission efficiency from the rectangular waveguide to circular waveguide for TE₀₁ mode in the can be 97.4%, the efficiency for TE₁₁ mode is only about 90%. We think that the deviation may be caused by the different mesh method between MAFIA and HFSS. By perturbation study [9], we found that it's possible to improve the HFSS result either by increasing the length of the coupling slot on the circular waveguide for 0.35mm or

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adjusting both short positions in the rectangular and circular waveguide for 0.35mm from the original MAFIA geometry. Then the requirement for high efficiency and low surface field can be satisfied [10]. This suggests that the prototype of the launcher should have the short position tunable. Present measurement has confirmed the above feature of the mode launcher.

2.2 TE_{01} Mode Extractor

The design TE_{01} extractor is based on the so call wrap-around converter [2]. When TE_{01} and TE_{11} modes pass through the extractor, the TE_{01} is extracted into another parallel waveguide, while the TE_{11} mode is not affected. The circular waveguide is tapered down to cutoff the TE_{01} mode while allowing the TE_{11} to go through, and the parallel one was shorted at one end to control the direction of TE_{01} mode transmission. Fig. 2 is the HFSS solid model. The rectangular waveguide is warped around the circular waveguide as shown. There are 6 coupling holes spaced 60° apart in the azimuthal direction around the circular wave guide. The size of the coupling hole is the same as the cross section of the rectangular waveguide. The distance between the center of every two holes is near the wavelength of the TE_{10} mode in the rectangular waveguide, so that the azimuthal resonant coupling between the two waveguides can be achieved. Thus the TE_{01} mode in the circular waveguide can be extracted efficiently into the wrap-around rectangular waveguide. Due to reciprocity, the extracted power in the rectangular waveguide can be converted back to TE_{01} mode in the parallel circular waveguide. The symmetry of the structure prevents the TE_{11} mode in the circular waveguide being affected.

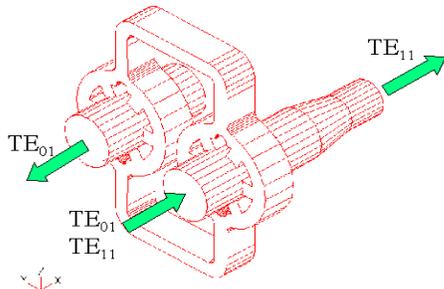


Figure 2: Solid model of TE_{01} mode extractor.

The geometrical structure is optimized with HFSS [10]. Simulation of present design shows that about 99.4% of the power of TE_{01} mode can be extracted, 97.2% of TE_{11} mode goes through without perturbation, while 2.3% converted to TM_{01} mode. The peak electric surface field at 600MW is around 80MV/m, which locates in the bifurcation area in the rectangular waveguide. Improvement of the design aiming to decrease the peak electric field at high power, and increase the transparency to TE_{11} mode is underway.

2.3 TE_{11} to TE_{01} Mode Converter

In DLDS, the TE_{11} mode has to be converted back to TE_{01} mode so that it can be extracted efficiently. The "Serpentine" style structure is adopted [11]. The radius of the circular waveguide keeps constant, but the axis of the propagation is deformed as a sinusoidal. The diameter of the waveguide is 20mm, the amplitude of the sinusoidal deformation is 2.33m, and the one periodical length is 80.4mm. The conversion efficiency can be better than 99.5% when four periods cascaded together. Here, We reproduced the SLAC design [12]. A novel idea has been proposed which can simplify the manufacture, that to cut the waveguide slantingly and then weld them in a right way, as shown in Fig. 3. With the slant angle chosen properly, the TE_{11} to TE_{01} conversion efficiency can be better than 99%. That can be a hopeful candidate in 2×2 DLDS scheme. A primary design has been confirmed by HFSS. Efforts are still continuing for further improvement in the performance.

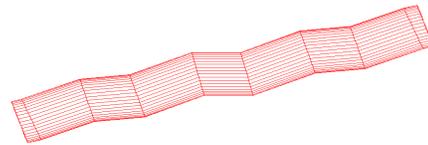


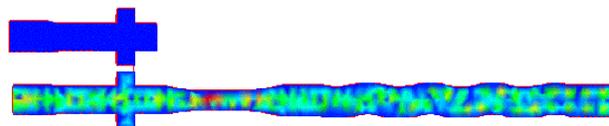
Figure 3: Solid model of TE_{11} to TE_{01} mode converter.

2.4 Simulation of Test Unit

Due to the computer memory limit, we only simulate the performance of the system consisting of the TE_{01} extractor, the TE_{11} to TE_{01} converter, and the tapers between them. Fig. 4 shows the electric field pattern propagating in the system.



(a) TE_{01} mode input from left.



(b) TE_{11} mode input from left.

Figure 4: Electrical field patterns in the test unit.

The power of TE_{01} mode is extracted to a parallel waveguide with efficiency better than 96% as shown in Fig. 4(a), while the power of TE_{01} mode goes through the extractor directly and then is converted to again to TE_{01} as shown in Fig. 4(b). The transmission efficiency is better than 95%. With the wall loss taken into account, it's expected that the transmission efficiency in DLDS can be better than 90%. All the above components are being manufactured. The low power test will be done soon.

3 MODE STABILITY EXPERIMENT

In order to reduce the resistive loss in long distance transmission, the low loss TE_{12} mode is considered in the circular waveguide. The experiment to test the stability of TE_{12} mode propagating for long distance i.e. its sensitivity to all kinds of perturbations is being planned. The main purpose is to measure the purity of TE_{12} mode in a 55m long waveguide whose diameter is 4.75 inches. The experiment needs a TE_{11} launcher, a TE_{11} - TE_{12} converter, and the flange to connect waveguides.

3.1 TE_{11} Mode launcher

TE_{11} mode in circular waveguide can be converted from TE_{10} mode in rectangular waveguide. The converter, whose main part is the smooth taper from the 22.86×10.16 mm rectangular waveguide to the $\phi 50.2$ mm circular waveguide, is designed by HFSS. The conversion efficiency is better than 99.2%.

3.2 TE_{11} to TE_{12} Mode Converter

The structure with rippled diameters [13] has adopted. The radius of the waveguide varies longitudinally as sinusoidal wave. To avoid the conversion between TE_{01} and TE_{02} , the diameter of the waveguide is chosen to vary from 50.2mm to 57.8mm. Nine ripples are needed. Optimization is done on the periodic length of one ripple. We found that when the periodic length is 64mm, the converter has the highest efficiency. The whole structure is modeled with HFSS, it's confirmed that more than 99.6% of the power of TE_{11} mode will be converted to TE_{12} mode after it goes through the converter.

3.3 Choke flange

The 55 meters long waveguide is composed of 11 5-meter long sections, so choke flanges are needed to connect them in order to avoid the possible distortion to the transmission of TE_{12} mode. The geometry of the flange is proposed and designed by S. Tantawi. We used HFSS to verify its performance and tolerance to the manufacture errors. The transmission efficiency of TE_{12} mode is better than 99.9%, and the tolerance is acceptable to manufacture. The solid model of flange used in HFSS is shown as Fig 5.

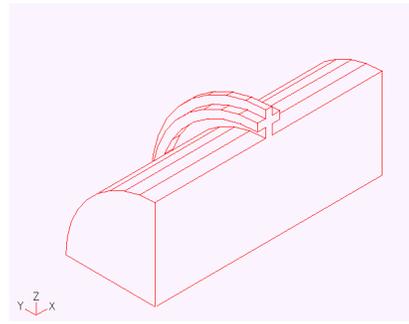


Figure 5: 1/4 solid model of the choke flange.

4 CONCLUSION

The main components have been designed using HFSS code. According to HFSS result, the power transmission efficiency in the components can at least meet the requirement of DLDS at low power, so the DLDS principle can work. A low power test facility is being setup in KEK, and the components are being manufactured. The performance of the components as well as the principle of the DLDS will be tested experimentally in near future. Meantime, the experiment to study the mode stability after long distance microwave transmission in DLDS is being developed. Improvement on the design of components of DLDS for high power test, or practical use is continuing.

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