*Broadband Coax-Waveguide Transitions**

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ABSTRACT

A broadband coax-waveguide transition for the high power test of the PEP-II RF cavity HOM waveguides has been studied. The design requirements are that it must have a VSWR less than 2 over the frequency range 714MHz to 2500MHz and transmit 10kW average power from a 250mm * 25.4mm rectangular waveguide to a 50 Ohm coaxial line. A double ridged waveguide section with the same cut-off frequency as the rectangular waveguide has been selected to keep its impedance near 50 Ohm over the frequency range. HFSS calculation results and design of the transition are reported.

1. INTRODUCTION

Single cell cavities for the PEP-II B-factory high energy ring (HER) and the low energy ring (LER) have three higher order mode (HOM) ports in the configuration of waveguide (250mm * 25.4mm) with cut-off lower than all the HOM's of the cavity except for the fundamental accelerating mode. The port terminates with a broadband load capable of dissipation up to 10kW.

For low-power and high-power tests of the HOM damper waveguide with a load, a broadband coax-waveguide transition has been studied. Since it must have small reflection at the same frequency range as the HOM damper and must be also capable to the transmission up to 10kW, it can be thought as a "spare" option in case this HOM damper might face any inconveniences. By using the transition with a broadband window, a broadband load can be put outside of vacuum and can be treated easier.

Though studies of a broadband coax-waveguide transition already began more than thirty years ago for low power, a kW-order high power transition study has been performed only at INFN (Istituto Nazionale di Fisica Nucleare) for DAΦNE damped cavities. It is for up to 1kW transition.

On this study, the requirement for power transition is severer. It is getting obvious that higher power needs a bigger coax and that it gives more limitations for its design, while HFSS calculations are performed.

2. DESIGN REQUIREMENTS

The design requirements of the broadband coax-waveguide transition are that it must have a VSWR less than 2:1 over the frequency range 714MHz to 2500MHz and transmit 10kW average power from a 250mm * 25.4mm rectangular waveguide to a 50 Ohm coaxial line. They are same as ones of the HOM damper.

In order to transmit up to 10kW over the range, the coaxial line is desired to be bigger than 3-1/8". If smaller, not only heating at inner conductor is too much, but also a broadband window design must be very difficult.

3. DESIGN OF TRANSITION

For such a broadband coax-waveguide transition, it is well known that applying a ridged waveguide is inevitable.

Because it has a flat impedance characteristics and also a higher cut-off frequencies of HOM's it's easier to make a match with a coaxial line and the effects of HOM's are very small.

Accordingly, it consists of two parts, which are a rectangular-ridged waveguide transition and a ridged waveguide-coax transformer.

3.1 Ridged Waveguide Design

To decide the ridged waveguide configuration is one of the most important parts of this study.

For the coax-waveguide transition parts, it is necessary to keep the cut-off frequency of any cross section same if it's for broadband. Therefore the ridged waveguide has the same cut-off of TE10 mode, 599.6MHz.

And also its cut-off of the next higher mode coupled to a coax, TE30 must be far higher than 2500MHz, which is the upper limit of the applied range. A rectangular waveguide with TE10 cut-off frequency of 600MHz has 1800MHz cut-off frequency of the TE30 mode. If it's ridged, cut-off of TE30 is higher up to more than twice of it, which is higher than 2500MHz. But if the design of the ridged waveguide is not suitable, it will be below 2500MHz.

Furthermore, its impedance must be not very far from 50 Ohm, one of the coaxial line, over the range 700 MHz to 2500 MHz.

If we suppose a simple impedance connection between 50 and Z Ohm, its S-parameter of reflection is $|Z-50|/(Z+50)$. It is desired to keep the reflection ratio below 0.25 over the range in order to obtain VSWR<2. Thus, $83.3>Z(\mathrm{Ohm})>30.0$ is required over the range.

A ridged waveguide shape is defined with four parameters, width and height of a rectangular waveguide, ridge width and ridge gap.

For good broadband matching, electric field distribution should be as uniform as possible at a junction of a coaxial line and a ridged waveguide. From this point of view, a smaller coax is preferable. At least, a coax outer electrode must be smaller than ridge width, and possibly far smaller. Nevertheless, as the coaxial line must transit 10kW, it cannot be too small. Insteadly, we should make ridge width wider or ridge gap shorter. But ridge width is limited by the cut-off of TE30 and ridge

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width is restricted by heating or multipactoring at the gap, though it is supposed to be suppressed with TiN coating.

Since outer diameter of a 3-1/8" coaxial line, which is enough capable for 10kW transition, is about 80mm, the ridge width should be more. At first, we tried with 128mm or 96mm ridge width. However, HFSS calculations never found a shape that satisfied all the criteria: TE10 cut-off about 600MHz, TE30 cut-off >> 2500MHz and an impedance which varied between 30(Ohm) and 83.3(Ohm) over the applied frequency region.

Then ones with 64mm ridge width were surveyed. Because it is smaller than the coax size of 3-1/8", a taper from a smaller coax, e.g. 1-5/8", at a junction to 3-1/8" is required at the transformer part. 1-5/8" coax is rather small for 10kW transmission, but cooling of inner conductor, as told later, is not difficult for this type of transformer.

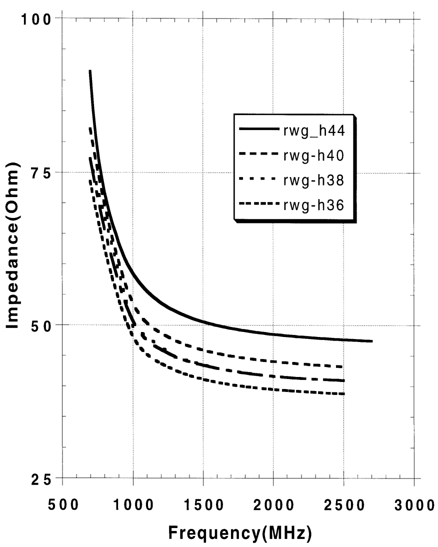

Figure 1 Ridged Waveguides Impedance Comparison

Figure 1 shows impedance calculation results with ridged waveguides with 64mm ridge width and 8mm ridge gap, whose cut-off of TE10 is about 600MHz. The best case is one with 36mm waveguide height and its cut-off of TE30 is more than 3GHz, high enough to think HOM effects are negligible.

All the calculations above have been performed for double ridged waveguides. Though single ridged waveguide might be possible, from the results so far, it is more difficult to obtain the good matching transformer to a coaxial line than with double ridged. Because, as shown later, where to stop ridges in the back cavity is one of the most important parameter for the part and in the best case, two ridges are stopped with different length.

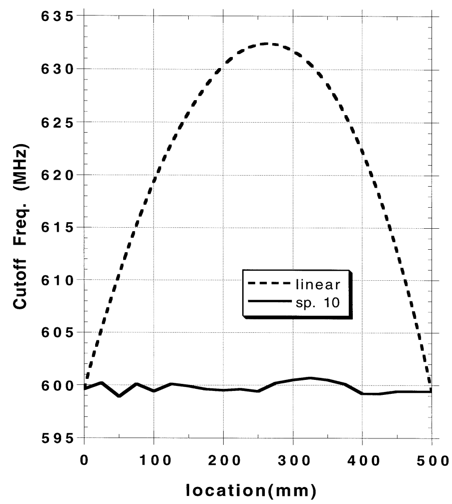

Figure 2 Cutoff Frequency Distribution

3.2 Rectangular - Ridged Waveguide Transmission

For a broadband transition, the cut-off frequency of any cross section must be kept as same. If the part consists of only linear tapers, cut-off distribution in the taper will be shown as a dotted line in Figure 2. (Assumed taper length is 500mm.) And S11 parameter will be calculated as a dotted line in Figure 3, which is not satisfactorily small because more reflection will be expected at the following transformer part. For lower reflection, the transmission part need to be separated into small pieces, all of whose cross section have almost 600MHz cut-off.

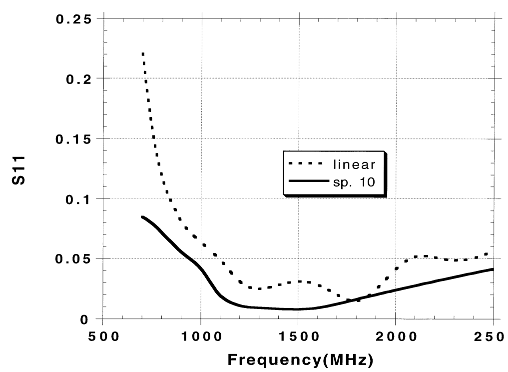

Figure 3 Effect of Taper Modification

HFSS calculations shows 10 pieces are enough to get the flat TE10 cutoff distribution within 599.8+0.9MHz and smaller reflection, which are shown as solid lines in Figure 2 and 3, respectively.

3.3 Ridged Waveguide - Coax Transformer

In a regular rectangular waveguide-coax transformer, as the impedance of the ordinal guide is much higher than that of the coax, the inner conductor of the coaxial line must stop short of the opposite wall of the guide or touch side walls to prevent mismatch. On the other hand, the impedances of the ridged waveguide and the coax are nearly matched, thus the inner conductor must touch the far wall of the guide or top of the ridge for matching.

It provides a convenience to cool the inner conductor and the reason why a smaller coaxial line than 3-1/8" can be applied at the inner conductor short position on the far wall. An 1-5/8" coaxial line was selected. For a broadband window, however, a taper to 3-1/8" must be necessary.

This transformer design is not very easy because there are too many parameters. In order to make it simple, firstly only three parameter were surveyed. They are back cavity length (short length) and length of two ridges, which means where these two ridges stop in the back cavity. And after that, a taper of the inner conductor at its short position was optimized. Shape of the back cavity might be (and should be) optimized, but it would be very complicated and need a great number of calculations. Since the configuration satisfies the requirement has been obtained as Figure 4, the back cavity shape survey has not been done.

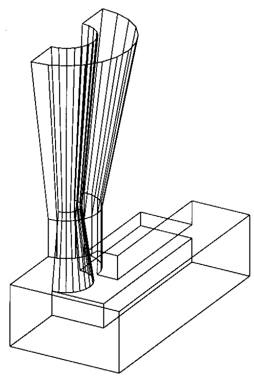

Figure 4 Optimized Configuration of the Ridged-Waveguide-Coax Transformer(1/2 symmetric model)

In the configuration in Figure 4, the ridged waveguide is transformed into 1-5/8" coax and changed to 3-1/8" by a 100mm taper with 50 Ohm. The upper ridge stops at the axis position of the coaxial line while the lower ridge stops at the end of the inner conductor taper. Figure 5 shows the HFSS results of reflection parameter S11 spectrum. The effect of the inner conductor taper is obvious when the solid line is compared with the dotted one for no taper.

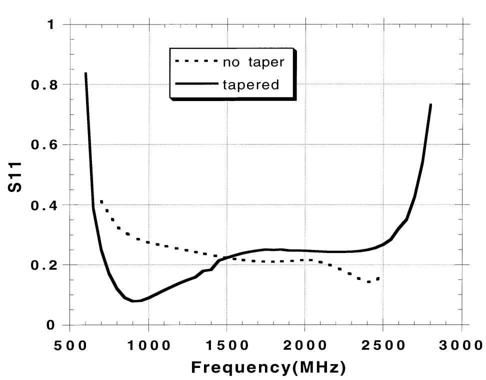

Figure 5 S11 Curves of the Transformer Part (Ridged Waveguide-Coax Trans., with and without Taper on Coax Inner Cond.)

3.4 Calculation Results Of Whole System

The whole system of the broadband coax-waveguide transition together with the transition and the transformer is shown in Figure 6, whose length is 640mm and height is 158mm. Figure 7 gives the HFSS calculation results of this configuration, showing VSWR<1.74 over the frequency range 714MHz to 2500MHz which satisfies the requirements.

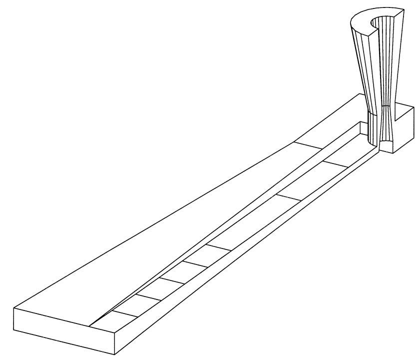

Figure 6 Broadband Waveguide-Coax Transition (1/2 symmetric model)

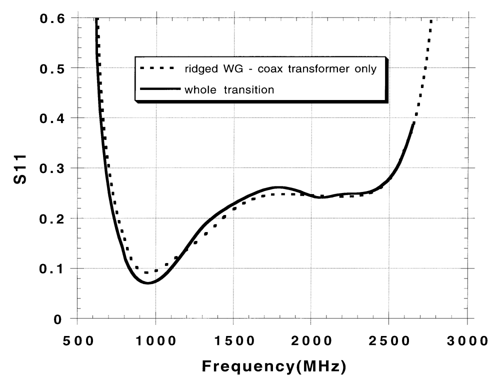

Figure 7 S11 Curves of the Optimized Configulation

4. CONCLUSION

A broadband coax-waveguide transition for the high power test of the PEP-II RF cavity HOM waveguides has been designed in order to fulfill that VSWR<2 at 714MHz to 2500MHz. Although such a broadband transition for up to 10kW average power has never been operated, the results indicate such a design could be used for broadband RF power tests.

5. ACKNOWLEDGEMENT

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6.REFERENCES

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