DEVELOPMENT OF KU-BAND WAVEGUIDE BREAK FOR ECR-3 ION SOURCE

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Abstract

This article describes the analytical design, simulation results, engineering design and testing of WR-62 waveguide break for ECR-3 ion source and it also emphasizes on the estimation of far-field radiation with the use of advanced 3D codes.

INTRODUCTION

The microwave circuit of an ECR ion source consists of a waveguide break which provides a dc isolation of typically 20 kV, necessary for the operation of ion source and allows the microwave energy to pass through. The finite discontinuity between the waveguides would allow a substantial microwave leakage unless a choke flange is used. The optimization of the choke flange depends on the permittivity ε_r of the dielectric used and also on its thickness d. The design was done in CST Microwave Studio for the dielectric thickness optimization and far-fields due to the discontinuity were estimated. The waveguide break was fabricated with silver polished walls to minimize the conduction loss. The high voltage test of waveguide break was carried upto 25kV and microwave test was done till 200W of microwave power at a frequency of 14.5 GHz. The overall performance of the waveguide break is in very good agreement with simulation results.

ANALYTICAL DESIGN

In Fig. 1, we show a sketch of the three transmission lines which form the dc break, where TL1 and TL2 are filled by insulator (Teflon) and the groove is air loaded, only power entering in line 2 can be (partly) radiated. The input impedance of TL1 line is the obstacle seen from the waveguide. Note that TL1 goes from the rectangular waveguide walls to the groove at $r=r_g$.

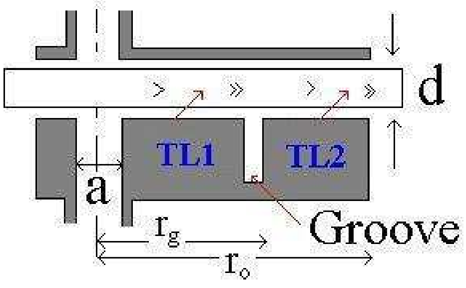


Figure 1: Waveguide break

The choke principle described in ref [1] allows suppression of radiation and reflection from a dc break by three combined actions. The impedance Z_g of the groove may be made large by choosing the phase length of the groove *π/2* according to equation (1).

$$Z_g^i = i * Z_g^0 * \tan\beta_g \quad (1)$$

Where Z_g^0 is the characteristic impedance of the groove The load end of the line TL2 is open and input impedance R of the radiating line TL2 may be made small by choosing its phase length; this implies a relation between the groove mean radius r_g and the outer radius r_o. The large impedance loading line TL1 (the series of Z_g^i and R) may be transformed to a null impedance at the line TL1 input by making its phase length $\beta_1 = \frac{\pi}{2}$ and characteristic impedance as small as possible.

For standard chokes used in the air, r_g may be chosen to achieve $\beta_1 = \frac{\pi}{2}$ on average. In our case, ε_r=2.1, the corresponding r_g=9.21 mm results to be inconsistent with the guide itself, so that we have to design r_g=10.5 mm and consequently r_o=29.6 mm. Moreover, the impedance is proportional to the constrained dielectric thickness of 1mm.

SIMULATION

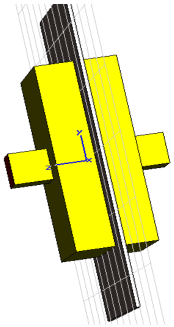


Figure 2: CST model of waveguide break

CST 3D code [2] was used for the optimization of the dielectric thickness, dimension of the waveguide flange, groove depth and far-field radiation pattern. We have achieved the reflection coefficient better than -25dB and transmission coefficient better than -0.3dB at 14.5 GHz. The reflection and transmission optimization is not sufficient for design of waveguide break, since microwave energy leaks from the gap between the waveguides and we need to optimize the groove height and depth for minimum leakage. Fig. 5 clearly illustrates the effect of choke on the transverse radiation from waveguide break; we have achieved a radiation efficiency of just 1 % which gives minimum leakage from the waveguide break.

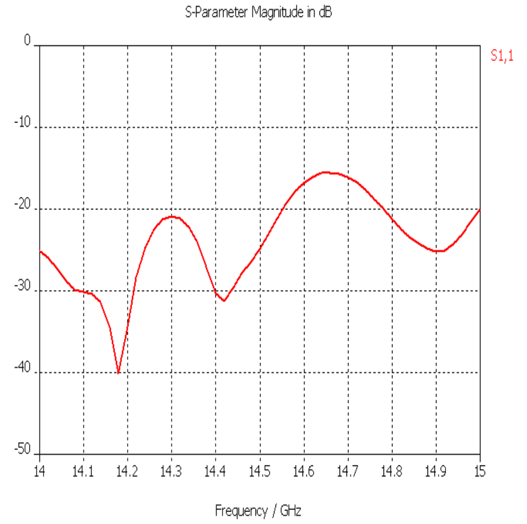


Figure 3: Reflection coefficient graph for waveguide break

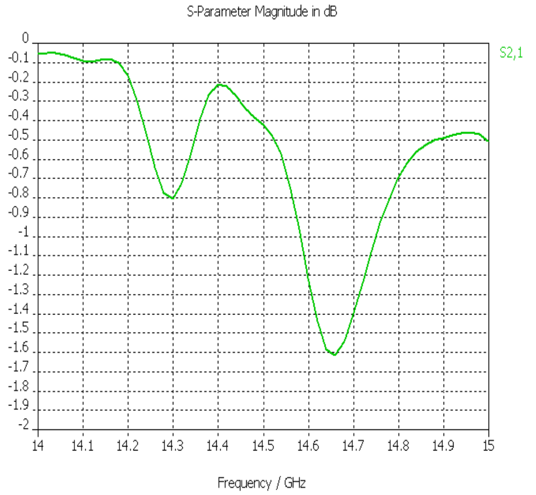
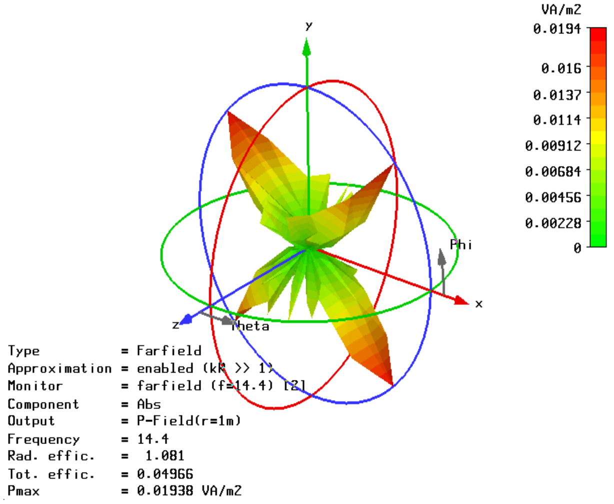


Figure 4: Transmission coefficient graph for waveguide break

EXPERIMENTAL RESULTS

The waveguide break was fabricated as shown in Fig. 6. Waveguides were silver polished to reduce conduction loss due to surface currents. The two flanges were clamped with a glass epoxy base plate with a 1mm Teflon sheet in between for high voltage isolation. During High voltage test leakage current in high voltage power supply was observed, high voltage was slowly varied from 100V to 25kV at a rate 100V/5 min. Sparks was not observed during the high voltage test and leakage current was always between 10-20 nA. Microwave test was performed by installing the waveguide break assembly at the output of microwave generator and terminating one end of the break with 200W dummy load.



```
Type          = Farfield
Approximation = enabled (kR >> 1)
Monitor       = farfield (f=14.4) [2]
Component     = Abs
Output        = P-Field(r=1m)
Frequency     = 14.4
Rad. effic.   =  1.081
Tot. effic.   = 0.04966
Pmax          = 0.01938 VA/m2
```

Figure 5: Far-field radiation pattern of the simulated waveguide break

Figure 6: Choke and cover flange of waveguide break

Microwave power was varied in steps of 10W and reflected power was within 1W for 200W transmitted power.

CONCLUSIONS

The high voltage and microwave testing of the waveguide break has given satisfactory results, experimental and simulated values of reflection coefficient of waveguide break are -25 and -23 dB respectively, which are in close agreement.

REFERENCES

[1] G.L.Ragan, Microwave Transmission Circuits, McGraw-Hill, New York, 1948.

Computer Simulation Technology website, http://www.cst.com.