International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in

Vol.4., Issue.1., 2016
(Mar-Apr)

RESEARCH ARTICLE

ISSN: 2321-7758

DESIGN AND ANALYSIS OF ASYMMETRIC PILLBOX TYPE RF WINDOW FOR 6 MW PULSE POWER S- BAND KLYSTRON

O S LAMBA, V K SAXENA, L M JOSHI, D PAL, D KANT, A BANDHOPADHYAY
Microwave Tubes Area
Central Electronics Engineering Research Institute. Pilani
Email: osl@ceeri.ernet.in

O S LAMBA

ABSTRACT

The paper presents design, analysis and electromagnetic simulation of Asymmetric structure of pillbox type RF window for S-band high power applications. This study is motivated by 6 MW pulse peak and 24 kW average power S band klystron project. Asymmetrical pill box type RF window structure is a new approach for reduced wave guide in either side of the window. The simulated results are well matched to the analytical approach. The simulation is done using CST microwave studio code.

I. INTRODUCTION

Pillbox-type microwave windows are generally used for high power klystrons due to their high peak / average power handling capability and an operating bandwidth of the order of 30%. Its other functional advantages include easier impedance matching and broad frequency response just by adjusting the dimensions of the window. The studies on high power RF windows are motivated by the need for high peak power klystron 6 MW peak and 24 kW average power for linear accelerators.

Microwave windows are passive components used on the output of vacuum electron devices for the extraction of microwave power from vacuum to atmosphere. These windows protect the tube's vacuum from the outside atmosphere and function as a vacuum-vacuum or vacuum-pressure barrier that is essentially transparent to the flow of microwave energy. Therefore the windows are critical component of high power microwave tubes.

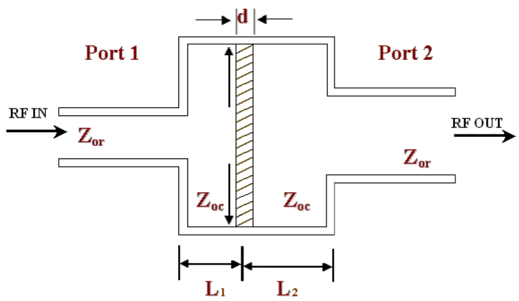

Fig1: Schematic diagram of Asymmetric pillbox type RF window.

Asymmetric pillbox type window shown in Fig.1 has been simulated with following dimensions.

Alumina ceramic disc diameter : 90mm.
Alumina disc thickness : 3mm.
Window diameter : 90mm.
Input side circular W/G length : 17 mm
Output side circular W/G length : 24 mm
Input W/G a = 72.14 mm, b = 20.6 mm ;
Output W/G a = 72.14 mm,b = 34.04 mm

II. WINDOW DESIGN

The RF output power of klystron transported from output cavity to load through RF window. Impedance matching of different components is essential in the waveguide line. The height of standard W/G WR 284 between window and RF cavity reduced from 34.04 mm to 20.6 mm However on the other end of window standard W/R 284 waveguide have to be used. The required dimensions of waveguide in input side of RF window are as follows:

Wide dimension: a_r = 7.214cm

Narrow dimension: b_r = 2.06 cm

Cut off frequency: f_c = 2.080GHz

In order to transfer maximum of microwave power from rectangular to circular and then vice-versa for downward transmission, it is required that at the junction, impedance of the rectangular waveguide should match with the impedance of circular waveguide both in the Input & output side.

The characteristic impedance for rectangular waveguide Z_{or} and circular waveguide Z_{oc} operating in dominant modes are given, respectively, by the following relations :

$Z_{or} = 377\ (\varepsilon_r / \mu_r)^{-1/2}\ (b_r / a_r)\ (\lambda_{gr} / \lambda_0)$(1)

And, $Z_{oc} = 377\ (\varepsilon_r / \mu_r)^{-1/2}\ (\lambda_{gc} / \lambda_0)$ (2)

where ε_r and μ_r are respectively, the relative permittivity and relative permeability of the dielectric medium. For non magnetic material μ_r is taken as 1.0, and thus equations (1) & (2) reduce in the form

$Z_{or} = 377\ (\varepsilon_r)^{-1/2}\ (b_r / a_r)\ (\lambda_{gr} / \lambda_0)$ (3)

And $Z_{oc} = 377\ (\varepsilon_r)^{-1/2}\ (\lambda_{gc} / \lambda_0)$ (4)

λ_{gr} and λ_{gc} are guide wavelengths for rectangular and circular waveguides respectively and can be obtained from the following relation:

$\lambda_g = \lambda_0 / (\varepsilon_r - (\lambda_0 / \lambda_c)^2)^{1/2}$ (5)

Here λ_0 and λ_c are free space and cutoff wavelengths respectively. Now from the two equations (3) and (4) it can be easily seen that:

$Z_{oc} / Z_{or} = (a_r / b_r)\ (\lambda_{gc} / \lambda_{gr})$ (6)

But, in this case of pillbox-type window, circular waveguide is partially filled with a dielectric (alumina). This may be treated as equivalent to the circular waveguide filled uniformly with a dielectric having effective relative permittivity (ε_r') .. Then eqn (6) becomes,

$Z_{oc} / Z_{or} = (\lambda_{gc} / \lambda_{gr})\ (\varepsilon_r')^{-1/2}\ (a_r / b_r)$ (7)

For most of the high power pillbox-type windows the value of ε_r' will vary between 1.0 and 2.0. A value of 1.5 is reasonable for ε_r'. Then above equation becomes,

$Z_{oc} / Z_{or} = (\lambda_{gc} / \lambda_{gr})\ (0.816)\ (a_r / b_r)$ (8)

For impedance matching of rectangular and circular waveguide we have

$\lambda_{gc} / \lambda_{gr} = b_r / (0.816\ a_r)$ (9)

Input side circular waveguide length determination:

Putting the value of a_r ,b_r and λ_{gr} in the above equation we get the guided wavelength of circular waveguide as

λ_{gc1} =(2.06* 15.33) / (0.816*7.216) = 5.36 cm.

As we know from Transmission line theory that for maximum power transmission we match through λ/4 section, so the input side of RF window length of the Circular wave guide L_1 can be written as

$L_1 = \lambda_{gc}/4$ =5.36/4 = 13.4 mm.

Output side circular waveguide length determination:

We can find the output side circular waveguide length from the same calculation L_2. So we need guided wave length for output side as

λ_{gc2} =(3.404* 15.33) / (0.816*7.216) = 8.86 cm

$L_2 = \lambda_{gc}/4$ = 8.86/4 = 2.215 cm.

In 3D design window look like as figure below:

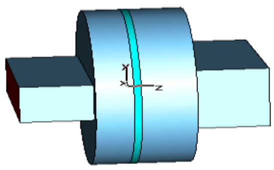

Fig2: 3D view of Asymmetric pillbox type RF window

III. SIMULATION AND DISCUSSIONS

The asymmetric pillbox type RF window is designed for S-band high power klystron where input side waveguide is reduced and the input output impedance is not matched. As described above the input, output cylindrical waveguide length is different; we found in simulation the analytical dimensions have small variation with simulated results. But the approach to change the length of the circular waveguide on the both side of dielectric disc well followed

Table:2 Analytical and simulated window length

Circular waveguide length L_1 (mm)		Circular waveguide length L_2 (mm)	
Analytical Result	Simulated Result	Analytical Result	Simulated Result
13.44	17	22.15	24

From software simulation, we get the return loss is –41.3 dB and insertion loss –0.014dB at 2856 MHz frequency as shown in figure below:

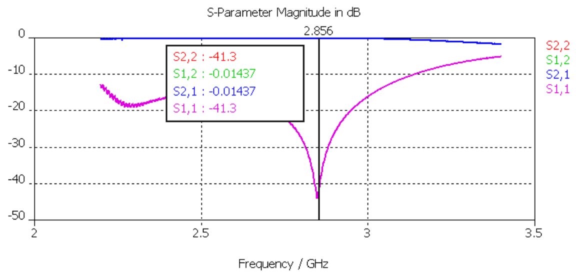

Fig 3: Simulated Return loss and Insertion loss

Table:3 Window performance with dielectric constant variation

Serial No.	Dielectric Constant	Return loss (dB) at 2.856 GHz	Insertion loss (dB) at 2.856 GHz	Window length	
				L_1 (mm)	L_2 (mm)
1	9.2	-50.38	-0.055	17.2	24.2
2	9.4	-41.3	-0.014	17	24
3	9.6	-34.68	-0.012	16.8	23.8

Table:4 Window performance with circular waveguide length variation

Serial No.	Dielectric Constant	Window length		Return loss (dB) at 2.856 GHz	Insertion loss (dB) at 2.856 GHz
		L_1 (mm)	L_2 (mm)		
1	9.4	16.5	23.5	-27.4	-0.05
2	9.4	16.5	24	-26.8	-0.01
3	9.4	16.5	24.5	-26.4	-0.014
4	9.4	17.0	24	-41.3	-0.014
5.	9.4	17.0	24.5	-29.23	-0.01

Table 5: Window performance with disc thickness variation

Serial No.	Dielectric Constant	Ceramic Disk Thickness (mm)	Return loss (dB) at 2.856 GHz	Insertion loss (dB) at 2.856 GHz
1	9.4	2.9	-23.74	-0.065
2	9.4	3.0	-41.3	-0.014
3	9.4	3.1	-35.8	-0.02
4	9.4	3.2	-25.49	-0.017

Table 6 : Window performance with disc diameter variation

Serial No.	Dielectric Constant	Ceramic Disc Diameter (mm)	Return loss (dB) at 2.856 GHz	Insertion loss (dB) at 2.856 GHz
1	9.4	89	-29.84	-0.04
2	9.4	89.5	-30.76	-0.04
3	9.4	90	-41.3	-0.014
4	9.4	90.5	-33.02	-0.055

Table:7 Window performance with disc and Circular diameter variation

Serial No.	Dielectric Constant	Ceramic Disc Diameter (mm)	Return loss (dB) at 2.856 GHz	Insertion loss (dB) at 2.856 GHz	Window length	
					L_1 (mm)	L_2 (mm)
1	9.4	88	-38.79	-0.026	17.1	24.1
2	9.4	89	-31.13	-0.025		
3	9.4	89.5	-28.66	-0.036	17	24
4	9.4	90	-41.3	-0.014	17	24
5	9.4	92	-44.51	-0.048	17.1	24.2
6	9.4	94	-43.46	-0.051	17.2	24.3

IV.CONCLUSION

- The Asymmetric pillbox RF windows performance has been found better than the symmetrical RF windows.
- The Asymmetric pillbox type 1 window RL –41.3 dB and IL -.014 dB and for type 11 RL –30.7dB and IL -.0013dB have been achieved.
- These RF windows have been planned to use in design and development of 6 MW peak and 24 kW average power S-band klystron. The performance of the RF window checked for variation of ±0.2 mm in ceramic disc thickness and variation of dielectric constant 9 to 10. It is acceptable for range of dielectric constant 9.2 to 9.6.
- Performance of RF window remains in acceptable range even after ± 0.5 mm variation in length and diameter from nominal value.

V. ACKNOWLEDGEMENT

The authors are thankful to the Head, MWT Area for his encouragement and Dr. Chandra Shekhar, Director, CEERI for permission to publish the paper.

V1 REFERENCES

[1]. P A Rizzi, Microwave Engineering (Passive Circuits), Prentice Hall International, Inc , USA, 1988.

[2]. O S Lamba, A Sharma, L M Joshi, Rashmi Singh, S C Nangru, V V P singh, “Electromagnetic Simulation of RF Window for 2856 MHz High Pulse Power Klystron “ proceeding of National Conference on Microwaves and Optoelectronics edited by Dr. M D Shirsat, Marathwada University H.Matsumoto, DEVELOPMENT OF A

[3]. HIGH POWER RF-WINDOW AT S-BAND,KEK, High Energy Accelerator Research Organization. Japan

[4]. O.S.Lamba, “ Electromagnetic Simulation of RF Window for 2856 MHz High Pulse Power Klystron”, 2004 Asia Pacific Microwave Conference – APMC’ 04