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Design of Bragg Reflection Notch Filter for Microwave/Millimeter Wave Applications

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***Abstract* —A high power radiation of single millimeter wave frequency is used as axillary heating system on fusion research device. This source gives stray radiation and affects sensitive millimeter wave diagnostics components. Therefore, aband stop (notch) filter is required to remove the high power radiation from transmission line of the millimeter wave diagnostics system. A new type of notch filter of millimeter wave frequency is designed and developed. In this filter a Bragg reflection in circular corrugated waveguide is used as band stop in the transmission line. For this the corrugation period, depth and width for given diameter of the waveguide is determined by theoretical calculation and numerical simulation. The numerical simulation shall be done in COMSOL multi-physics RF module and CST microwave studio to validate the design parameter. The waveguide will be fabricated according to calculated dimensions. The fabricated waveguide will be tested for transmission characteristics.**

***Keywords*—Corrugated waveguide, Notch filter design.**

1. INTRODUCTION

Modern Electron Cyclotron Resonance Heating (ECRH) systems at thermonuclear fusion experiments operate at one or more frequencies in the millimeter wave range at power levels of several MWatts. The Gyrotron sources used on these experiments operate at a single frequency or at several frequencies using frequency step-tunable Gyrotrons. The current plan for ITER include 24 Gyrotrons source with 1 MW power and 170GHz frequency for electron cyclotron heating (ECH), current drive, control element and diagnostics[1]. Consequently there will be accidently significant stray radiation at frequency 170GHz and ITER diagnostics [2] with detectors having sensitive to this radiation will be adversely affected. Therefore it is necessary to be protected against ECRH stray radiation[3]. Diagnostics that operate at wide frequency range including 170GHz frequency such as Interferometer, Polari meter, Thermal bolometer, electron cyclotron emission (ECE) can be protected by Notch filters [4]. Diagnostics that operate at wide frequency range will require narrow band notch filters with stop bands wide enough to block multiple drifting Gyrotron frequencies [5] and at the same time have wide, low loss pass bands outside the notches.

2. CORRUGATED WAVEGUIDE

Simple smooth wall cylindrical waveguides are useful for low-power experiments, but when considering the transmission of power on the order of MWatts for 10th of meter length distances, traditional methods will be insufficient due to large attenuation, mode conversion, the possibility of electromagnetic breakdowns, and high heating which can lead to failure in the transmission system[6]. The HE_{11} mode is the fundamental mode for corrugated waveguides that has power concentrated in the center and small fields at the walls of the waveguide, whereas TE_{01} and TM_{11} the lowest loss modes for smooth wall waveguides, have power that is off-center and more susceptible to losses due to fields present at the walls.

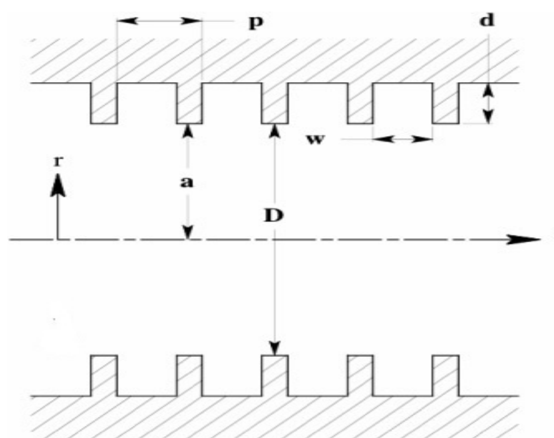

Figure.1. Schematicof corrugated waveguide geometry.

Attenuation is not considerably important factor for low frequency but when higher microwave frequencies come into picture, attenuation will become an increasingly significant feature while designing microwave components. Overmoded corrugated waveguide were first introduced for millimeter wave transmission because of their low attenuation for the fundamental mode. This attenuation was seen to be lower than the smooth-wall fundamental modes [7]. Clarricoat observed that the HE_{11} mode of a corrugated waveguide had a lower attenuation than that of the TE_{01} mode in smooth wall waveguide of comparable size. The equation of the attenuation coefficient is referred from the paper [6]. To calculate the attenuation in corrugated waveguide in MATLAB; the code require the value of frequency, the diameter *D*, and the corrugation geometry (period *p*, width *w*, and depth *d)*. In the millimeter-wave region, the surface resistance R_s is proportional to the square root of both the frequency f and the bulk resistivity $\rho$of the waveguide wall through the relation$Rs = \sqrt{\pi\mu\rho f}$, where$\mu$is the permeability. The surface resistance Rs is input in decibels as 8.686 Rs/Z_0, where $Z_0 = 377\ \Omega$is the impedance of free space. Finally the code required the value of the$v$, i.e. zeroes of the Bessel function for HE_{11} mode in the corrugated waveguide. The value of $v = 2.405$ is for the corrugated waveguide for the propagation of wave.The longitudinal propagation constant $k_z$is determined from the following:

$$k_z^2 = k^2 - k_T^2 = k^2 - (v^2/a^2)$$

Where k is the propagation constant of free space and$k_T = v/a$is the transverse wave number. Figure.2 shows the simulation result of the attenuation in dB/100m for the frequency range 100 GHz to 200 GHz. The simulation result are similar to that are present in the paper [8].

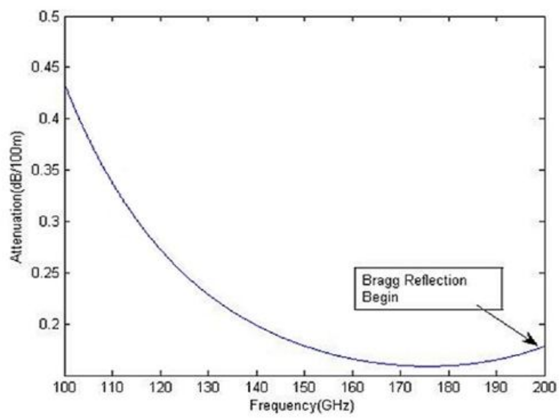

Figure.2. Attenuation in corrugated 31.75-mm aluminum waveguides with bulk resistivity$4.0\ \mu\Omega.cm$, $period = 0.76mm$, $width = 0.56mm$, $depth = 0.51mm$are corrugation geometries. This resistivity and a 30% increase in the attenuation due to surface roughness are assumed in this Figure.

3. DESIGN OF BRAGG REFLECTIONNOTCH FILTER

The stray radiation from the tokamak vessel is affecting the measuring diagnostic component. The Bragg reflection notch filter is used for the protection of diagnostic component. Therefore Bragg reflection notch Filter at 90 GHz is designed and developed. The current plan for the ITER requires the notch filter at 170 GHz but here we design the prototype of the filter at the 90 GHz. Simulation of the attenuation characteristic in the circular corrugated waveguide is performed in the MATLAB.

The attenuation is measured for the desired frequency range of W-band i.e. (75 GHz to 110 GHz). It is found that for $period = \lambda/2$, $width = \lambda/3$, $depth = \lambda/2$ we get the considerable increases in attenuation. Therefore for designing the Bragg reflection notch filters at any frequency the parameters of the corrugated waveguide are required to be extracted as discussed above.

4. DESIGN PARAMETERS

The diameter of the corrugated waveguide is kept as per the diameter of the transmission line which is 89.9mm. The other parameters of the corrugated waveguide are extracted for the frequency 90 GHz as discussed above. The simulation is done in MATLAB.

Parameter	value
Diameter	89.9 mm
Period	1.66 mm
width	1.33 mm
depth	1.66 m

5. SIMULATION RESULTS

Figure.3 shows the simulation result of the design parameters at 90 GHz with step size of 1 GHz. It is found that the attenuation is considerably increased nearly at the 90 GHz while it is nearly zero for all the other frequencies.

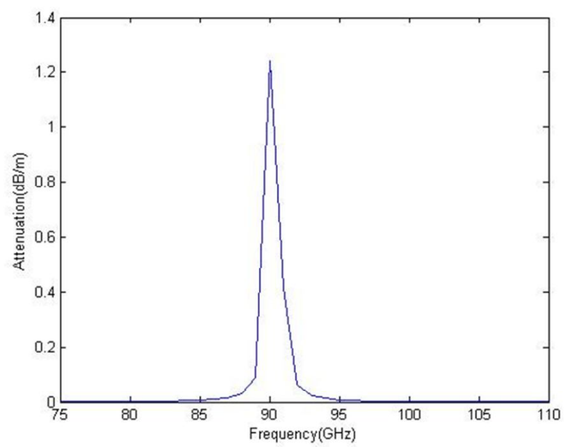

Figure.3. Attenuation in corrugated 89.9-mm aluminum waveguides with bulk resistivity $4.0\ \mu\Omega.cm$. This resistivity and a 30% increase in the attenuation due to surface roughness are assumed in this Figure.

6. SIMULATION RESULTS OF CORRUGATEDWAVEGUIDEIN CST MICROWAVE STUDIO

The Computer Simulation Technology (CST) is most accurate and efficient computational solution for electromagnetic designs. For the validation of design parameters the simulation of the extracted parameters is done in CST. CST allows us to quickly and accurately predict electromagnetic field distributions; transmission, reflection and power dissipation in a proposed design.CST microwave studio does not provide the facility to give the equation or option to excite the hybrid mode directly in the design geometry. Therefore Mode Converter which converts dominant circular mode (i.e. TE11) to dominant Hybrid Mode (i.e. HE_{11}) is required to design. Figure.4 shows the geometry of mode converter.

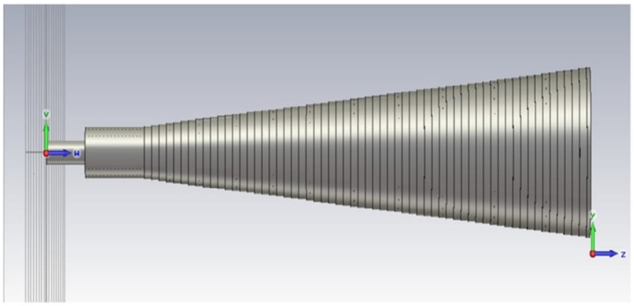

Figure.4.Geometry of Mode Converter

Figure.5 shows the field monitor at the input side which is TE_{11} mode. TE_{11} mode is the dominant mode in circular waveguide and has attenuation which is larger than HE_{11} mode in the corrugated waveguide.

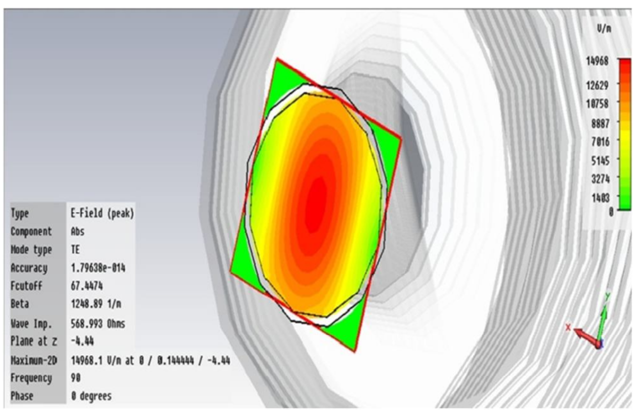

Figure.5. Field monitor at Input side of Mode converter

Figure.6 shows the field monitor at output side which is HE_{11} Hybrid mode. It has been shown that the field intensity is highly concentrated at the centre of the waveguide and hence it has the lowest attenuation than any other mode in waveguide.

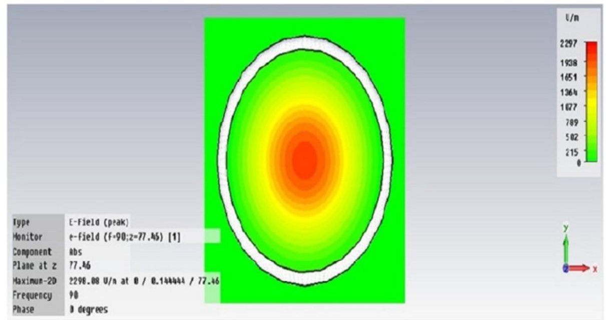

Figure.6. Field monitor at Output side of Mode converter

Figure.7. shows the geometry of mode converter with the Bragg Reflection Notch Filter. The parameters for the Notch Filter is p=1.66 mm, w=1.11 mm, d=1.66 mm and diameter=89.9 mm. However a non linearity is produces in the structure because of mismatch in outer diameter of Mode converter and input diameter of Notch Filter. In practical set-up the outer diameter of mode converter is increased by putting lens which is used to collimate the E.M. beam at the larger diameter.

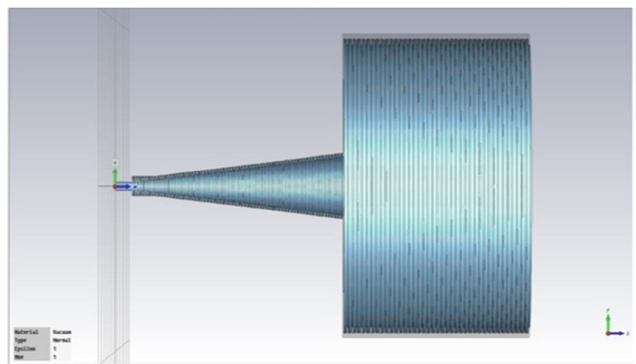

Figure.7. Geometry of Mode Converter with Notch Filter

Figure.8. shows the field monitor at output of the Notch Filter for 80 GHz and 90 GHz frequency. It can be concluded from the Figure, that the field monitor give the exact Hybrid mode at 80 GHz because of transmission of EM Wave at this frequency, while the field monitor of hybrid mode get disfigured because of the reflection of wave at 90 GHz. The field monitors at 90 GHz give the validation of the design parameters that the E.M. wave gets reflected back at the 90 GHz. The actual idea of the validation of the design parameters for Bragg Reflection Notch Filter is obtained from the S-parameter plot which gives the transmission coefficient as well as reflection coefficient.

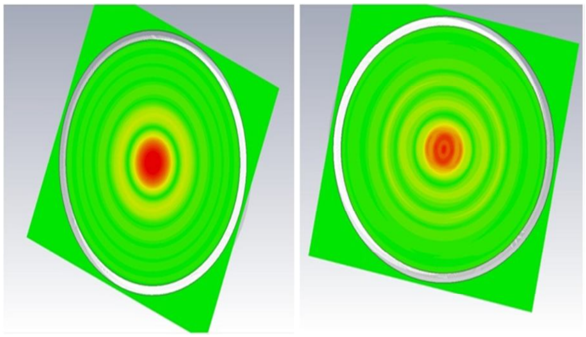

Figure.8. Field monitor at Output of Notch Filter at 80 GHz and 90 GHz respectively.

Figure.9. shows the S-parameter response for the structure of Mode converter with Notch filter. The S11 parameter is shown in the Figureure which shows rise of up to -6 dB near 90 GHz. From the simulation result we can say that the 35% power get reflected back at near 90 GHz. Ideally 100% powers should be reflected back at 90 GHz because of the non-linearity produce in the structure at the input diameter of Notch filter we get 35% power reflected back.

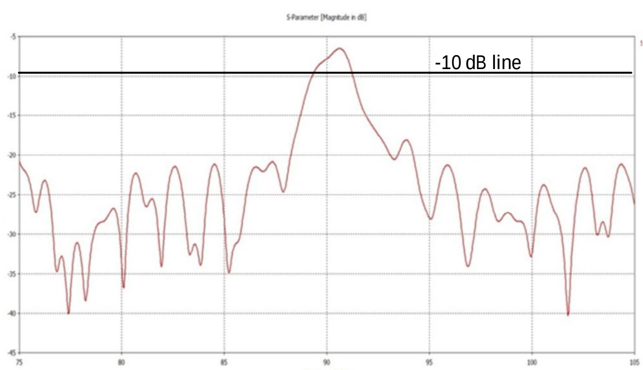

Figure.9. S11 parameter response of Notch Filter at 90GHz frequency

7. CONCLUSION

We can conclude from the simulation of attenuation characteristic in MATLAB that for the period=1.66 mm, width=1.11 mm and depth=1.66 mm we get the considerably increase in attenuation at 90 GHz. Therefore designing the Bragg reflection notch filter by corrugating the waveguide the parameters of the corrugated waveguide is$period = \lambda/2$, $dth = \lambda/3$, $depth = \lambda/2$.The proposed filter is designed using CST microwave studio. Results support the successful operation of mode converter and notch filter at 90 GHz frequency. This device is highly useful for RF Diagnosis in thermonuclear Nuclear Fusion Reactor.

REFERENCES

[1] G.Bosia,Proceedings of the 12th Joint Workshop on,"Electron Cyclotron EmissionandElectron Cyclotron Heating,"*World Scientific*,Singapore(2003)571.

[2] A.J.H.Donn et al, "Nuclear Fusion," 47,(2007) S337-S384.

[3] P.Woskov, "Notch Filter Options for ITER Stray Gyrotron Radiation,"*Proceedings 49th Annual Meeting of the Division of Plasma Physics*,Orlando, Florida, 52, No.11, NP8.00111, 2007.

[4] C.Winnewisser, IEEE Trans. "Microwave Theory and Technology," 48, (2000)744.

[5] P.Woskovet al, "Rev. Science Instrumentation,"77, (2006) 10E524.

[6] P. J. Clarricoats and A. D. Olver., "Corrugated horns for Microwave antennas," *volume 18 of IEEE electromagnetic wave series*. Peter Peregrinus, Ltd., London, UK, 1984.

[7] P. J. Clarricoats and P. K. Saha., "Attenuation in Corrugated Circular Waveguides," *Electronics Lett*.,6(12):370372, 1970.

[8] J. L. DOANE, "Design of Circular Corrugated Waveguides To Transmit Millimeter Waves at ITER," *General Atomics*, P.O. Box 85608, San Diego, California 92186-5608.