Transmission line and its components for ITER ECE diagnostic

Hitesh Kumar B. Pandya[1], Suman Danani[1] and Kaushal Patel[2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar-382 428 India*

[2]Charotar Institute of Technology, Changa, India

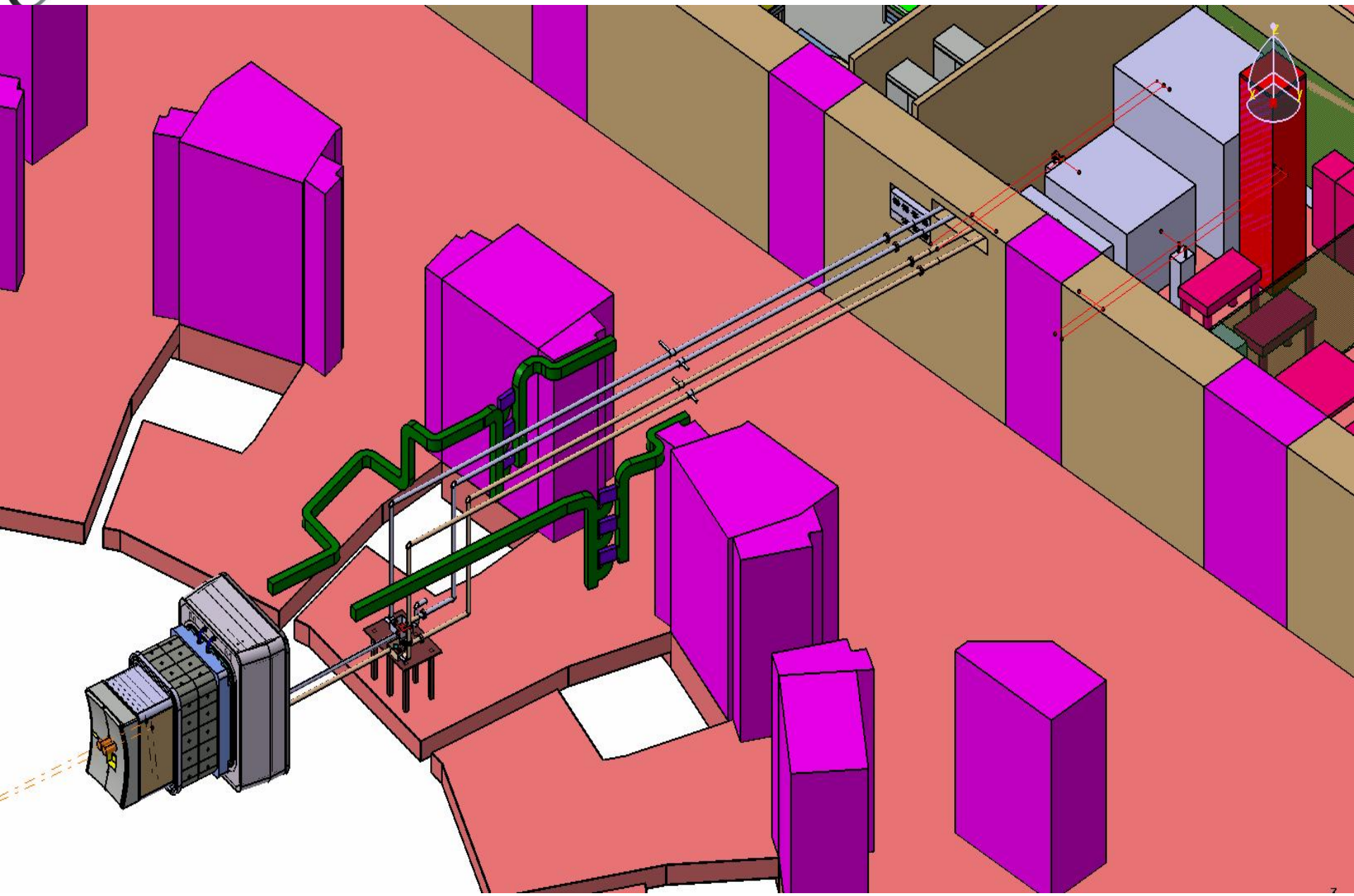
hitesh.pandya @iter-india.org

pandyahb@gmail.com

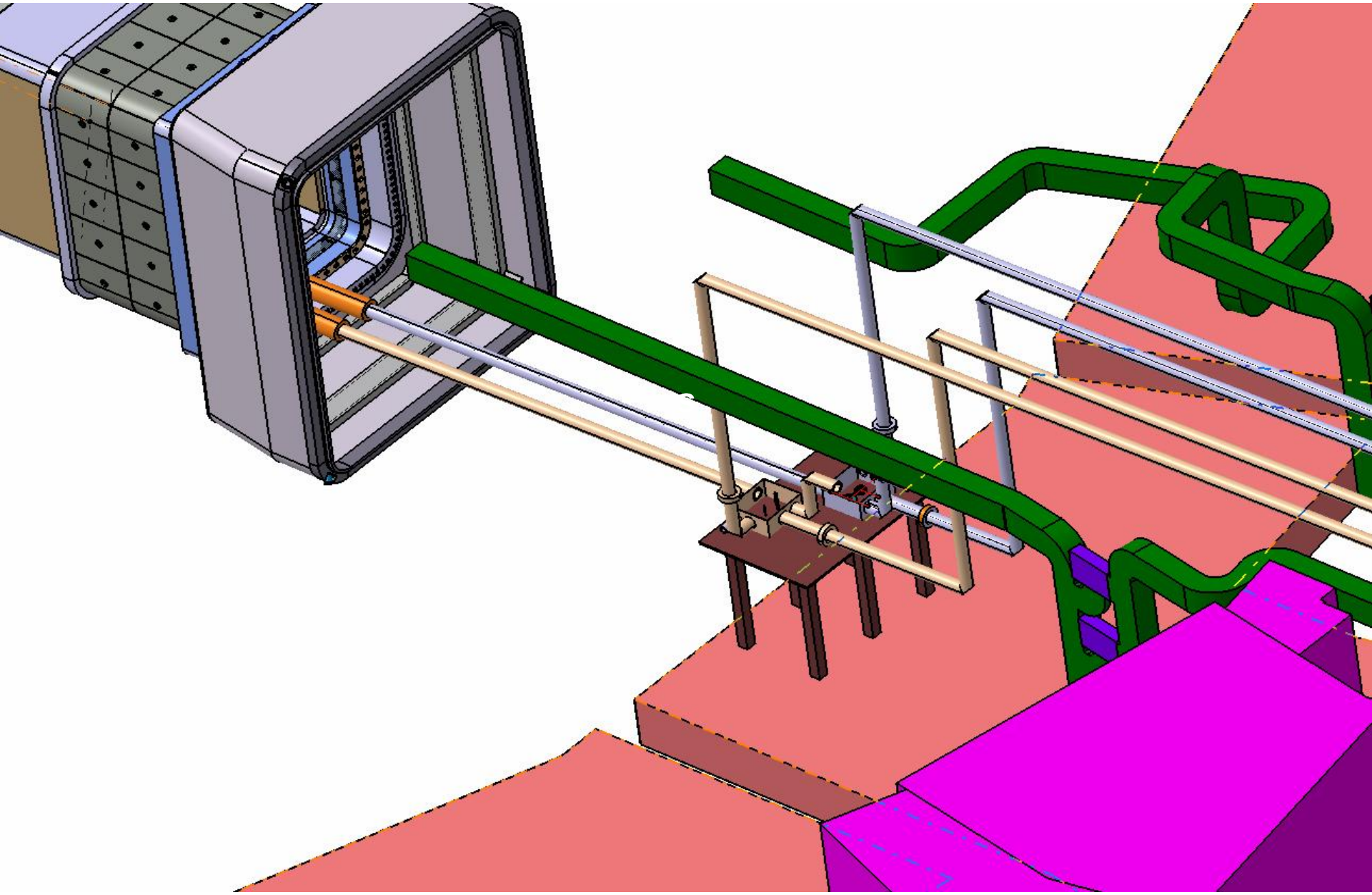
- A very low power (~ μW) ECE radiation of wide band frequency (70 to 1000 GHz) is needed to transmit a long distance
- Low loss Transmission line is required
- A circular corrugated waveguide in HE_{11} mode gives low transmission in wide band
- HE_{11} mode can be very efficiently coupled with other optical components.
- The closed waveguides help to avoid atmospheric line absorption.

- we propose a possible scheme for the transmission line
- It includes many components like wire grid polarisers, straight jointed sections of waveguide, mitre bends and other optical components
- Each components has transmission loss
- The total loss of the transmission line can be determined

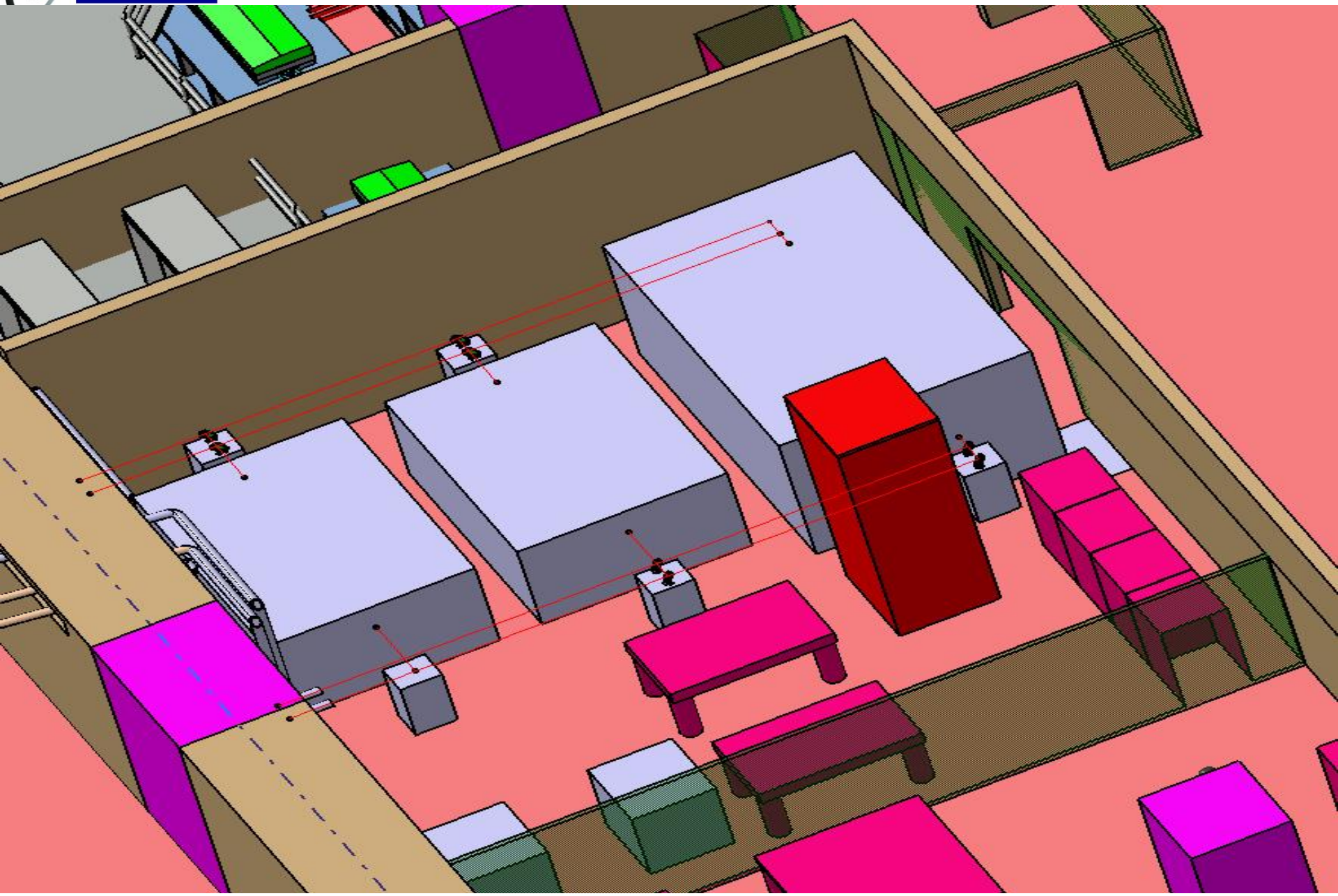
Proposed design



Proposed design (Cont.)



Proposed design (Cont.)



Components

❖ List of required components for proposed transmission line

Components Name	Qnt./line	Total
1.Corrugated waveguide	34 miter	136 miter
2.Mitre bends	6/5 No.	21 No.
3.Polarizer splitter box	1 No.	2 No.
4.Vacuum windows	2 No.	8 No.
5.Pump out units	2/1 No.	6 No.

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Table 1 Experimental measurements of the insertion loss of the corrugated waveguide

Corrugated waveguide dimension		Frequency (GHz)	insertion loss (dB/meter)	Reference number	Remark
Diameter (mm)	Corrugation period (mm)				
63.5	0.254	60/140	0.08/<<0.035	5	
88.9	1.7	84	0.002	6	
63.5	0.45	100 to 300	0.0002	7	For 24 m W/G
63.5	0.66	50 to 220	30% for 80meter	8	Include mitre bends
31.75		110	0.003	9	

Table 2. The mitre bend insertion losses calculated and measured for HE_{11} mode

Waveguide diameter (mm)	Frequency (GHz)	Calculated loss (dB)	Measured loss (dB)	References
12.7	140	0.17	0.22 /0.3 ±0.1	11
63.5	170	0.011	0.05±0.02	11
63.5	100 - 300	0.025 – 0.0047	0.06	7
63.5	100 to 350	0.025 – 0.0038	0.25	12

- Theoretical insertion loss in the mitre bend can be calculated by following equation

$$HE_{11}\ loss\ in\ a\ mitre\ bend \cong 2.4\left(\lambda/D\right)^{1.5}\ dB$$

❖ Estimated transmission line loss

Component name	Quantities	Loss (dB)
Corrugated waveguide (φ = 88.9 mm)	34 meter	0.068
Mitre bend	5/6	1.1/1.32
Pump out unit	1	0.22
Polarizer splitter unit	1	0.175
	Total loss	**1.783 (~ 33%)**

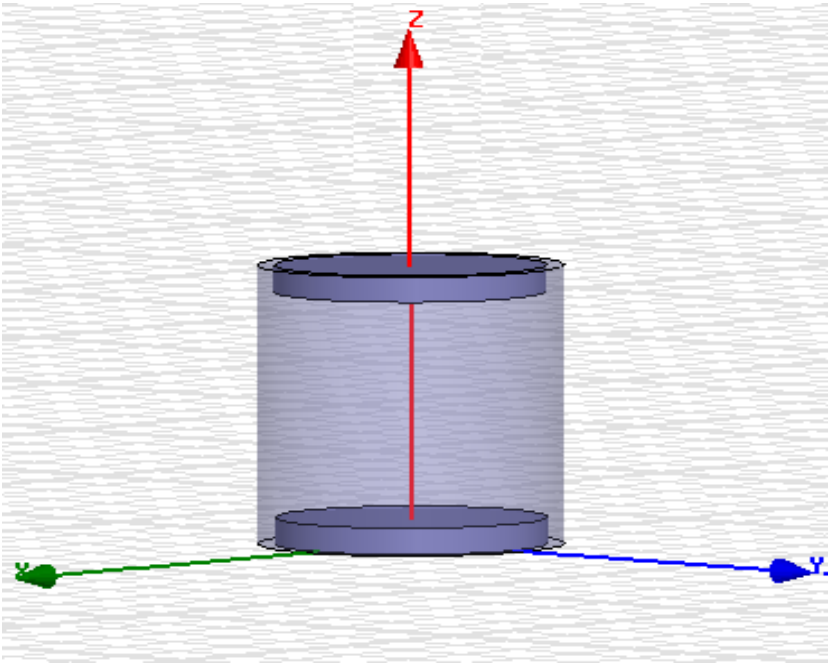
❖ It seems that the insertion loss of the mitre bend is higher than all other components

Study of the waveguide gap and mitre bend through gap theory and simulation

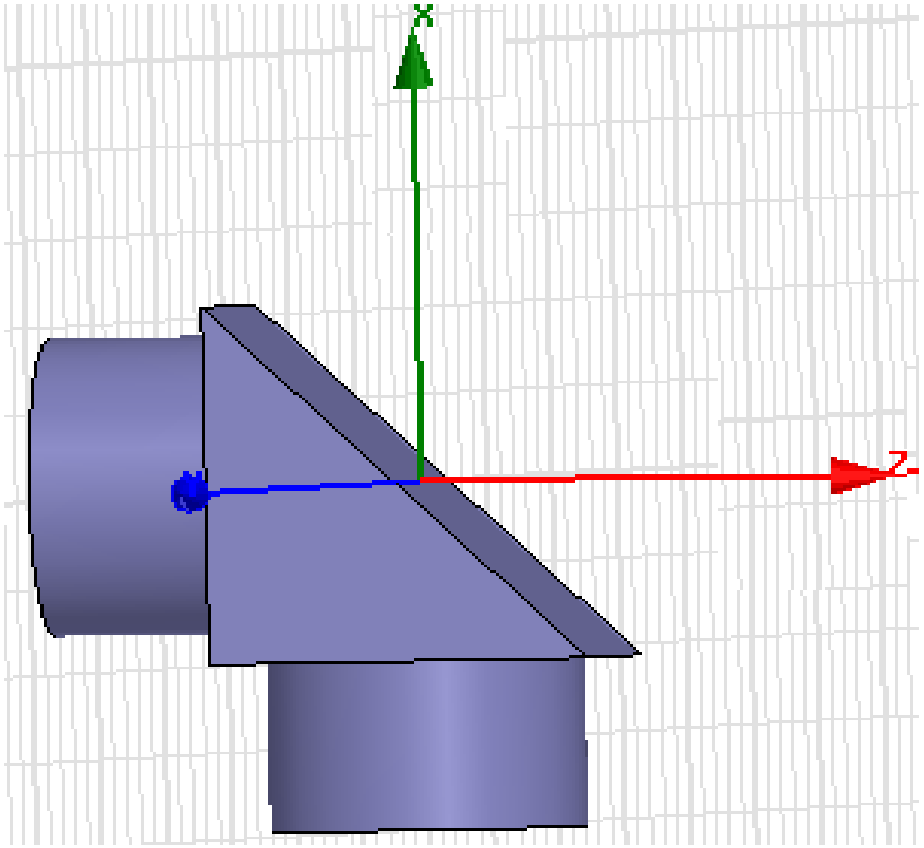
- The loss in the mitre bend can be determined by using mode matching technique[11]
- The numerical simulation can also be used
- The mitre bend loss is consider as the insertion loss due to gap in the waveguide

Modeling of the smooth waveguide gap and mitre bend with TE_{01} mode

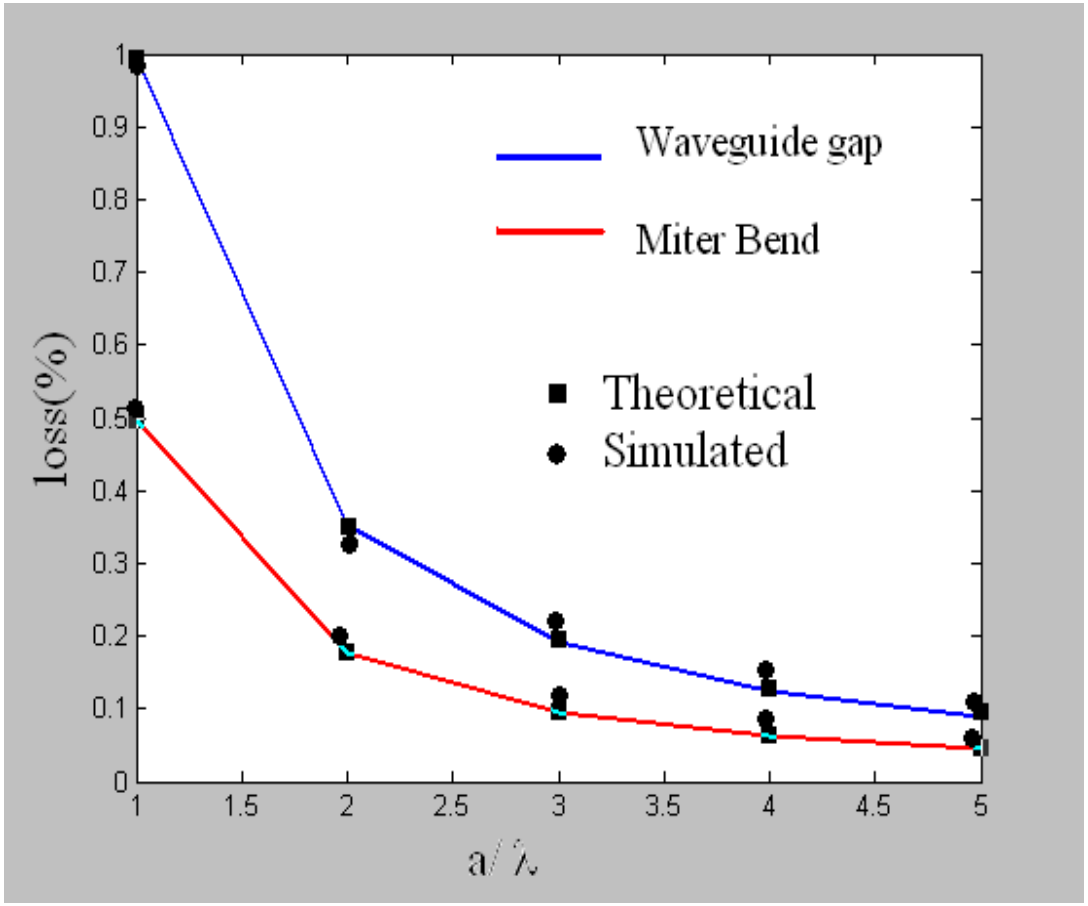
- The numerical solver HFSS does not able to solve hybrid HE_{11} mode
- A smooth waveguide propagating TE_{01} mode is used instead
- Since the gap theory is equally valid for TE_{01} mode



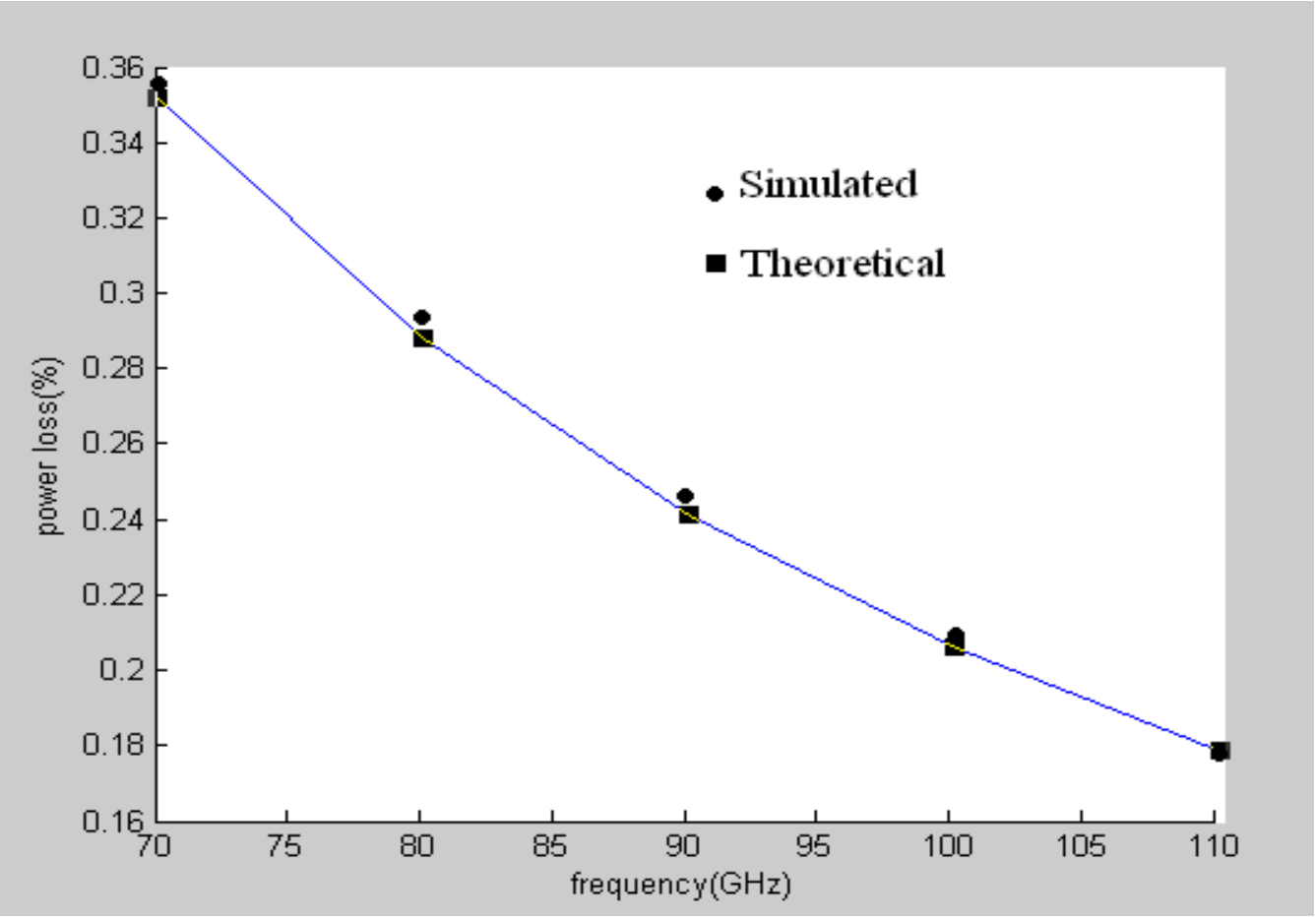
Model used to simulate TE_{01} mode in smooth waveguide gap



The model used to simulate the TE_{10} mode in mitre bend



Comparison of the loss in waveguide gap and the mitre bend



Power losses (%) for Waveguide gap for the radius of 8.56mm

Summary

- We proposed a transmission line for ITER ECE radiation
- Indentified required components
- We estimated insertion loss on basis of past measurements
- We deduced that the mitre bend has higher loss than other components
- We studied the mitre bend in more detail by numerical simulation
- We inferred that the insertion loss in the mitre bend is half of the loss in the waveguide gap
- The W/G gap theory can be used to determine the loss in the mitre bend and the pump-out unit or other gap in the transmission line

References :

1) DDD_55f_microwave_1.4

2) M.E. Austin, R.F. Ellis, A.E. Hubbard, P.E. Phillips, W.L. Rowan, "*Receiver front-end optics and performance assessment for ITER ECE system,*" S006937-F ITER ECE Report (U. Texas). pdf, February 2007,

3) David S. Tex, "Mode conversion losses in overmoded millimeter wave transmission lines", M.S. Thesis, MIT-2008

4) J. L. Doane, Fusion Scie. Technology, **53**, 159 (2008)

5) A. Cavallo, J. Doane and R. Cutler, Rev. Sci. Instrum., **61**, 2396 (1990)

6) K. Ohkubo, S. Kubo et al. Int. J. Infrared Millim. Waves, **15**, 1507 (1994)

7) N. Isei, A. Isayama et al. Fusion Eng. and Design, **53**, 213 (2001)

8) Nagayama Yoshio, Kawahata Kazuo et al. J. Plasma Fusion Res., **78**, 601 (2003)

9) Shinichi Moriyama∗, Masami Seki et al. Fusion Eng. and Design, **74**, 343 (2005)

10) J. L. Doane and C. P. Moeller, Int. J. Electron., **77**, 489 (1994)

11) S. T. Han, E. N. Comfoltey et al. Int. J. Infrared Millim. Waves, **29**, 1011 (2008)

12) Max Austin, Private communication

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Q/As