Ceramics-less Transmission Line System for Fusion Plasma Heating

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1 Introduction

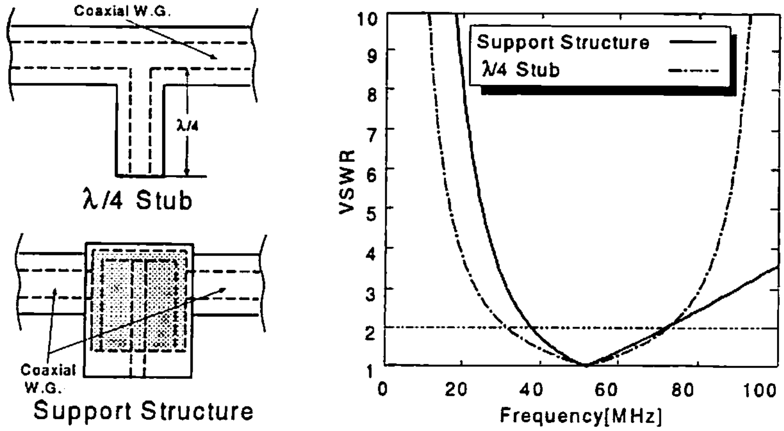
The electro-magnetic wave, from 15 MHz to 80 MHz, has been planed for ICRF(Ion Cyclotron Range of Frequencies) heating of ITER because it can heat plasma most efficiently in low frequency range. A metal waveguide has little loss for transmitting, however, the cross section per waveguide limited less than 35cm × 50cm increases its cut-off frequency. An inner conductor of coaxial waveguide with no cut-off frequency, must be supported mechanically, such as the ceramic ring. High energy particles from plasma deteriorate the electrical characteristics of ceramics, and we can't use it for supporting inner conductor near plasma. Then, we need all-metal support structure.

In this paper, we present new mechanical support structure for inner conductor of the coaxial waveguide and show the VSWR characteristics calculated by FDTD method. Furthermore, we show the characteristics including the antenna in front of the plasma.

2 Analysis of the support structure

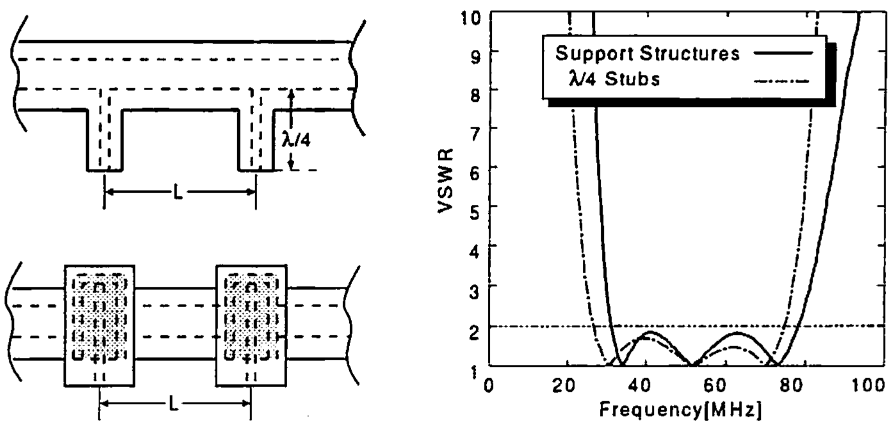
To support inner conductor of a coaxial waveguide, the usage of $\lambda/4$ stub has been proposed. It is useful in high frequency, however, the length becomes the problem in low frequency. For example, the length of $\lambda/4$ at 60MHz(which is also the height of the stub) is 1.25m and its size is much larger than the cross section determined for ITER. Hence, $\lambda/4$ stub is not suitable for ICRF transmission line system. Therefore we have to reduce the cross section of the support part.

Fig.1(a) shows a new support structure for ceramics-less transmission line. A metal post supports a concave shaped box which is connected to the inner conductor of coaxial waveguide with its characteristic impedance is 30 Ω. We calculate the VSWR characteristics of the concave capped stub(CCS) with FDTD method and compared that of $\lambda/4$ stub. The bandwidth of VSWR less than 2.0, is 65% for the CCS. According to Fig.1(b), the bandwidth of $\lambda/4$ stub is 79 %. The bandwidth of the CCS is a little bit narrower than that of $\lambda/4$ stub, however, it is wide enough for transmission line.



(a) Analysis Model (b) VSWR characteristics

Figure 1: Analysis models and VSWR characteristics

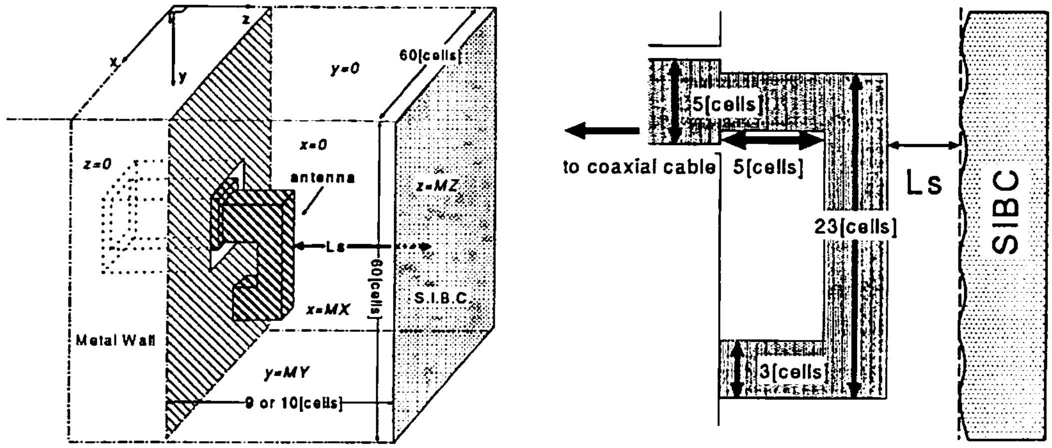


(a) Analysis Model (b) VSWR characteristics

Figure 2: Analysis Model and VSWR characteristics in case of support at 2 points

To increase mechanical strength of the transmission system, double support structure showed by Fig.2(a) will be used for ITER system.

We calculated VSWR characteristics of this transmission line with S-matrix and the results of single stub. Fig.2(b) shows the calculated VSWR characteristics. The distance L between the CCS is 4.85m, and the distance L between $\lambda/4$ stubs is 3.0m. Bandwidth is 91.3 % and 93.3 %, respectively. Then, the double support structures increase the frequency bandwidth.



(a) Analysis Region(cell size = $0.1^3 m^3$)

(b) Analysis Model of Antenna

Figure 3: Analysis Model of $\lambda/2$ Antenna

3 Analysis of antenna and the characteristics of whole transmission line

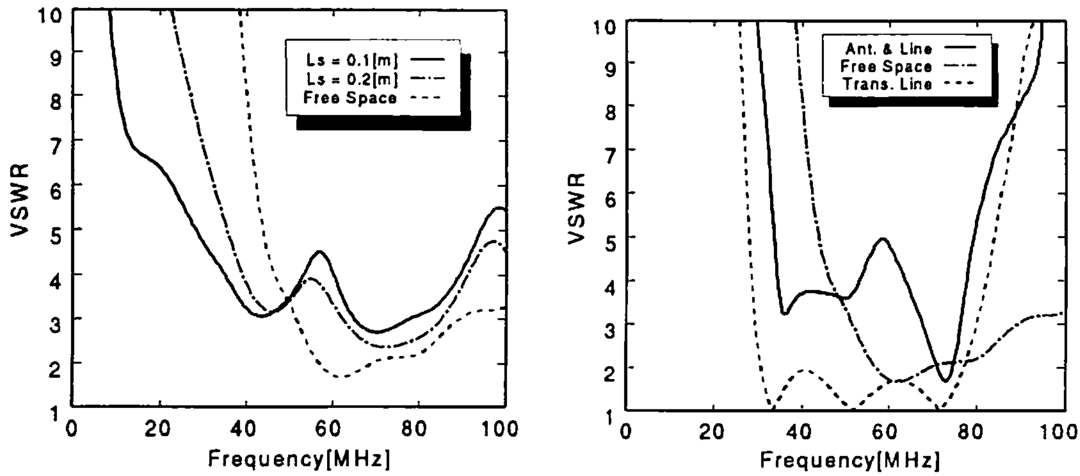
A $\lambda/2$ loop antenna has been planed to be used for radiating RF power to plasma by ITER. We also calculated the antenna input characteristics with FDTD method. Fig.3 shows an analysis model of $\lambda/2$ loop antenna. We assumed the boundary condition at z = MZ is SIBC(Surface Impedance Boundary Condition), at $z = 0$ is Mur's 1st order ORBC(Outer Radiation Boundary Condition), and other surfaces are Mur's 2nd order ORBC[4]. We defined surface impedance Z_{sibc} based on the following equation[2].

$$Z_{sibc} \cong 3.117(\omega\mu_0 x_0)$$

We determined that ω = 60.0MHz and x_0 = 0.1m, 0.2m. Therefore, distance Ls(between antenna and SIBC) is 1cell(10.0cm) or 2cells(20.0cm). The result is showed in Fig.4(a). The VSWR of the antenna increases around 60MHz and shifts low frequencies because SIBC is near to the antenna. Therefore, the VSWR of the transmission line including the antenna shown in Fig.4(b) increases. Then we have to optimize antenna parameters for plasma heating considering the effect of plasma.

4 Conclusion

We proposed a new ceramics-less transmission line system using concave capped stub and calculated the VSWR characteristic of the transmission line supported by the structure. The



(a) VSWR characteristics of $\lambda/2$ loop antenna

(b) VSWR characteristics of transmission line terminated to antenna with plasma load

Figure 4: VSWR characteristics of Antenna and whole transmission line

result shows that we can use the transmission line supported by them for transmitting power. The support structure has as wide bandwidth as $\lambda/4$ stub in spite of its small cross section. Furthermore, we calculated a $\lambda/2$ loop antenna in the region which has a Surface Impedance Boundary and showed Surface Impedance Boundary affects the VSWR characteristics of the antenna.

References

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