A RIDGED WAVEGUIDE SLOTTED COUPLER FOR LARGE TOKAMAKS

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1 Introduction

A ridged waveguide was proposed to transfer the waves into the plasma through the small cross section for the ICRF heating experiments[1][2]. It can be fabricated compactly with all-metal, which is free from the damage of insulators in the coupler. In order to apply the ridged waveguide to the tokamak, this paper newly proposes the slotted coupler which can reduce the VSWR in the ridged waveguide.

2 The ridged waveguide slotted coupler

The maximum transmission power P_{tm} is the power in the case of no reflection from the load. However the load is not matched to the ridged waveguide, the maximum launching power to the load P_m is given as follows[1].

$$P_m = \frac{(1-|\Gamma|^2)P_{tm}}{(1+|\Gamma|)^2} = \frac{P_{tm}}{\rho} \qquad (1)$$

where Γ , ρ are the reflection coefficient from the load and the VSWR in the waveguide, respectively. Eq.(1) shows that the maximum launching power is inversely proportional to the VSWR in the waveguide. Then following experiments are devoted to reduce the VSWR in the ridged waveguide.

2-1 Simulated coupler geometry

A ridged waveguide slotted coupler has a short circuit in the mouth and a series of slots like a Faraday shield. Fig.1 shows the overall configuration. The frequency of ICRF heating in JT-60 is planned to be 110MHz-130MHz. The simulated coupler was about one-tenth of actual size, and the VSWR in the waveguide was measured around 1GHz. Design parameters of the coupler are shown in Fig.2. A polyethylene water tank (260mm x 260mm x 300mm) filled with 20 liter water is used as dielectric instead of the fusion plasma, where the thickness of the polyethylene is 3mm. In our experiments, there was not a large flange around the mouth for the simplicity of set up. Additionally, the distance to the water tank d could be varied in order to simulate the change in distance to the plasma.

The ridged waveguide consists of a rectangular waveguide of 4GHz band and a T-shaped aluminum ridge. Three kinds of gap spacing G, 2mm, 4mm and 6mm between the waveguide wall and the plane plate on the ridge were provided. Cutoff frequency for respective waveguide is calculated by the equivalent circuit method[2] as 0.47GHz, 0.66GHz and 0.81GHz. The slotted coupler (coupler II) is compared with the coupler I which has a simple open end. As an other parameter of the slotted coupler, gap spacing g at the mouth were varied for each waveguide.

The VSWR generally increases in the absence of water which corresponds to the plasma being away from the aperture. To overcome this difficulty, the simple matching is tried by inserting a quarter-wave matching section into the coupler as in Fig.2-(III). The coupler with matching section consists of two guides with the different gap spacings, G_1 and G_2. The detailed length l of matching section is determined through the experiment.

2-2 Measurement results

The dependence on the distance to the water tank is presented in Fig.3. In Fig.3(a), the VSWR of coupler II is always less than that of coupler I, and the increase of the former is more gradual than the latter. The VSWR of slotted coupler is less than half that of coupler I except for the large distance to water tank (d>6cm). This result indicates that the matching between the ridged waveguide and the water load can be improved by the slotted coupler. The VSWR of g=2.5mm is a little bit smaller than g=4mm in the range of d>3cm, while the VSWR varies considerably by the g for G=6mm in Fig.4(b). The VSWR curve of coupler I with G=6mm is smaller than that of slotted coupler with g=6.4mm for d>1cm. However the VSWR of coupler II is improved by the small g, for example, that of g=1.7mm is less than the half that of coupler I for d<4cm. The VSWR of the slotted coupler for water load with G=6mm is also improved, provided the gap spacing g at the mouth is smaller than the G.

Though the VSWR for air load is not improved by the slotted coupler, the matching section reduces it less than one-third. One typical result of the slotted coupler with matching section is contrasted with the couplers I and II. It is shown in Fig.4. The VSWR for air load is reduced from 20-30 less than 7 at the matching frequency. In this paper, we call the frequency of the minimum VSWR as the matching frequency. In addition, the effect of matching section is more obvious for water load. The matching section reduces its VSWR less than one-third of coupler II and less than one-fourth of coupler I at the matching frequency. The slotted coupler with matching section is proved to be very effective to reduce the VSWR even if the air load.

3 Discussion

For the estimation of the maximum power capability of the ICRF coupler, electric fields around the short circuit at the mouth should also be considered. However those electric fields are expected to be smaller than those in the waveguide, since a node of standing wave is located at the bottom of short circuit. At this stage, the maximum launching power of the slotted coupler by eq.(1) represents the maximum power capability of the ICRF coupler.

According to this procedure, we estimate the maximum launching power of the slotted coupler for water load using the measured VSWR in the waveguide. The maximum transmission power of the ridged waveguide with G=4mm as in Fig.3(a), for example, is 10MW[3]. Consequently, the maximum launching power is 3.4MW for d=5mm and 2MW for d=10mm by substituting the measured VSWR into eq.(1). This power capability is sufficient for the ICRF coupler to large tokamaks which need a few million watts incident power.

4 Conclusion

The ridged waveguide slotted coupler has lower VSWR for water load than that of the simple open ended coupler. The matching section reduces its VSWR to one-third of coupler I for air load and one-forth for water load. These results suggest that the ridged waveguide slotted coupler is very attractive for ICRF coupler. The applicability of this coupler to the plasma load together with its optimum design is left for future problem.

Acknowledgment

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References

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[3] Y.Yano, N.Goto and T.Nagashima, "An ICRF ridged waveguide coupler," ibid.

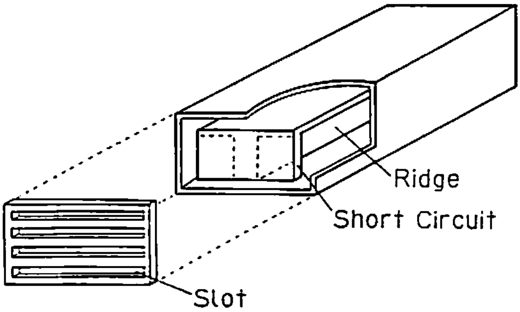


Fig.1 Outlook of ridged waveguide slotted coupler

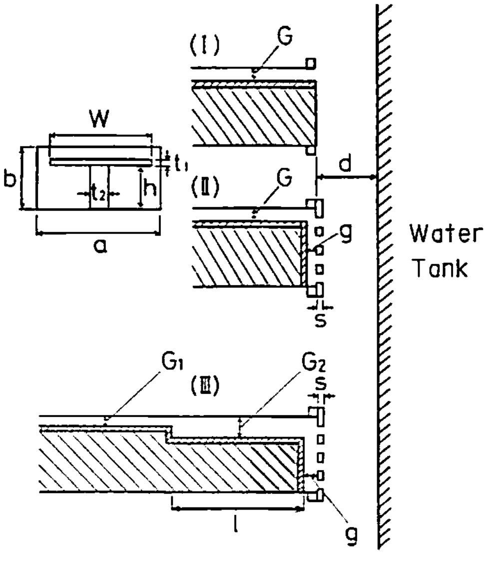
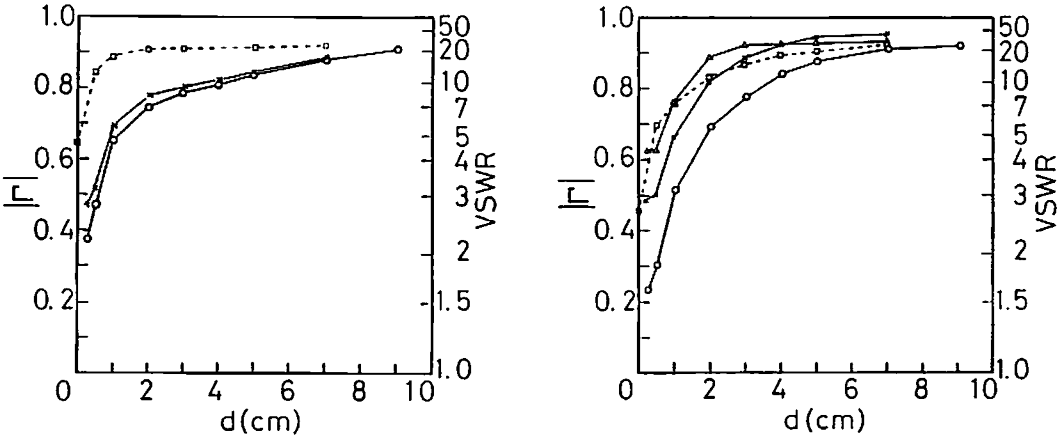


Fig.2 Geometry of simulated coupler



(a) (b)

Fig.3 VSWR versus distance to water tank (f=1.2GHz)
a=58mm, b=29mm, w=50mm, t_1=3mm, t_2=10mm, s=1.6mm
dashed line, coupler I: solid line, coupler II
(a) G=4mm, x-x g=4.0mm, o-o g=2.5mm
(b) G=6mm, Δ-Δ g=6.4mm, x-x g=3.7mm, o-o g=1.7mm
slot width 3mm, spacing 3mm, length 58mm, number of slot 5

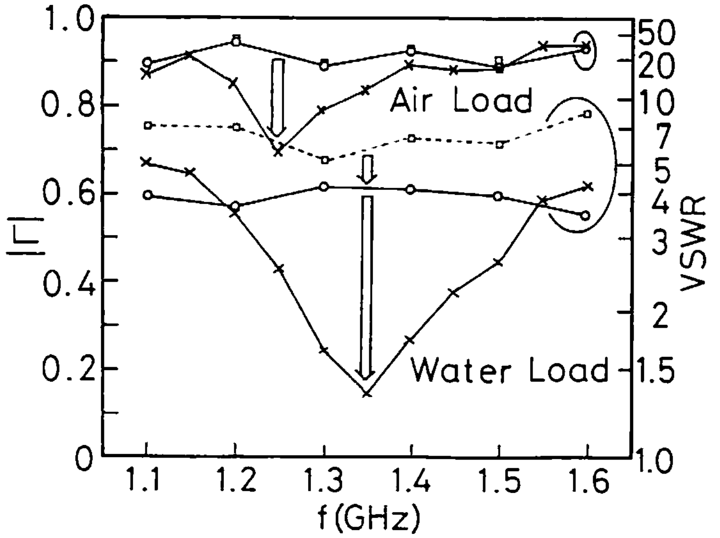


Fig.4 VSWR as a function of frequency
a=58mm, b=29mm, w=50mm, t_1=3mm, t_2=10mm, s=1.6mm
G=G_1=2mm, G_2=7.5mm, g=2.5mm
(□-□ coupler I, o-o coupler II, x-x coupler with matching section l=102.5mm)
d=0mm for coupler I, d=2.5mm for others
slot width 3mm, spacing 3mm, length 58mm, number of slot 5