1. 9 Development of Ceramic-free Antenna Feeder

S. Moriyama, H. Kimura, T. Fujii, M. Saigusa
Japan Atomic Energy Research Institute

H. Arai
Yokohama National University

Introduction

One of the major critical points of the IC antenna for next-generation tokamaks is a ceramic support of an internal conductor of a coaxial antenna feeder close to the plasma. Enhancement of dielectric loss tangent of ceramics due to neutron irradiation may limit antenna power injection capability significantly. We propose a ceramics-free antenna feeder line employing a ridged waveguide as a local support inside the cryostat which is applicable to a wide frequency range, e.g., 15-80 MHz (for ITER CDA parameters) and within constraints of ITER ports.

Figure 1 shows the schematic view of the antenna designed for ITER employing ceramics-free antenna feeder lines. Inner conductor of the coaxial line connected to the current strap of the antenna is mechanically supported by the all metal ridged waveguide section. This structure enables ceramic vacuum windows to place far from the plasma where neutron flux is small enough. The ridged waveguide section can be placed inside the cryostat because of its compact size.

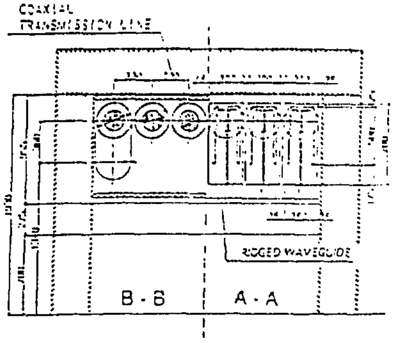

Fig. 1b Cross section of coax. and support section

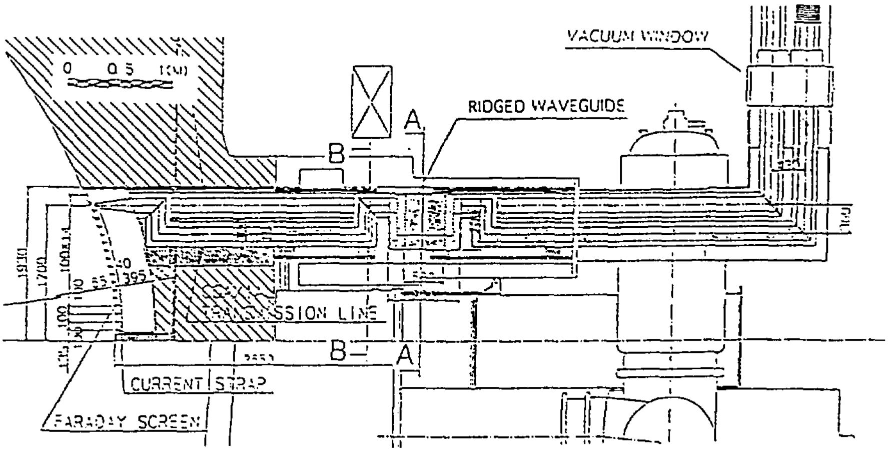

Fig. 1a Schematic view of the antenna designed for ITER employing ceramics free feeder line. Inner conductor is supported mechanically by ridged waveguide section.

Mock-up model and impedance calculation

One fourth mock-up model of the all metal waveguide designed for the ITER ICRF system is fabricated (Fig. 2). Analysis of the electrical characteristics of the ridged waveguide has already been done by a calculation with finite element method). However it is not easy to calculate the effect of the junction to a coaxial line because the structure is not simple. We intend to analyze the electrical characteristics of the all metal waveguide including the connection by means of measurements with the mock-up model. The model consists of a TEM waveguide supported mechanically by a T-shaped ridged waveguide, junctions to an coaxial line which is called "coax-waveguide converter", coaxial lines with the same impedance of the TEM waveguide, coaxial $\lambda/4$ impedance transformers and 50Ω coaxial lines for measurement. The cut-off frequency and the length of the ridged waveguide can be varied according to the choice of arms and supports of the waveguide. The length and the vertical position of the coax-waveguide converter can be varied as well.

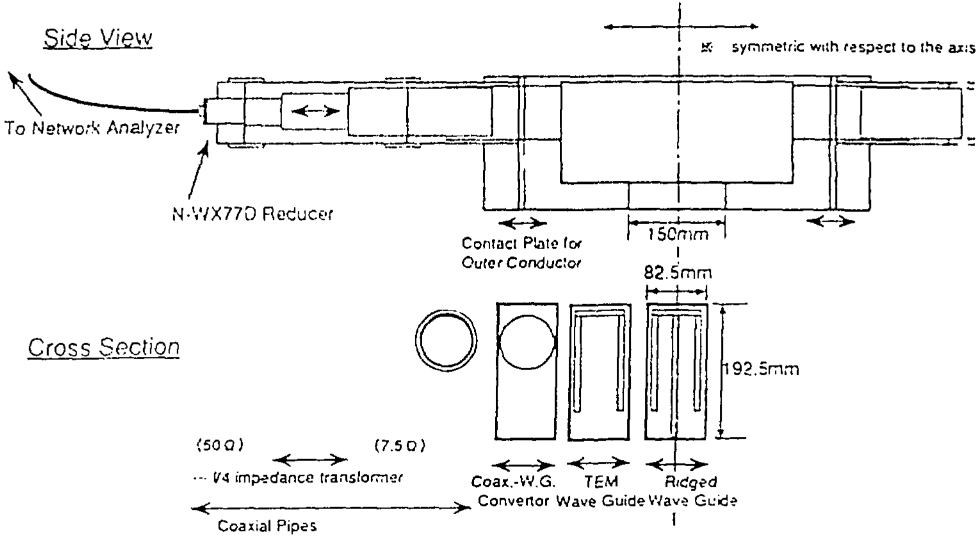

Fig. 2 Schematic view of the one-fourth mock-up model of the all metal waveguide designed for ITER ICRF system.

RF transmission properties of the model are measured in 54.5 - 291 MHz corresponding to 15 - 80 MHz with a network analyzer. Measured data is compared with calculation on the basis of the transmission line model (Fig. 3). The cut-off frequency and the characteristic impedance of the ridged waveguide were calculated by the finite element method.

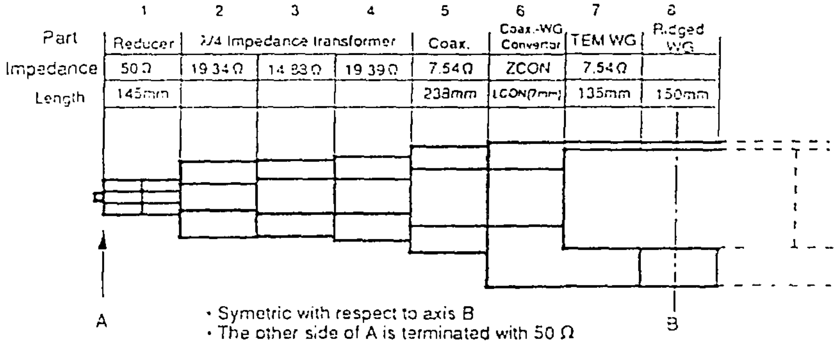

Fig. 3 Transmission line model for impedance calculation.

Measurement and analysis

Measured and calculated power reflection coefficient of the whole model is shown in Fig. 4. Relatively high reflection coefficient especially below the cut off frequency of 107 MHz or discontinuity comes from imperfect impedance transformer. The 1/4 impedance transformer has sliding part which has slightly different impedance from $(Z_1 x Z_2)^{1/2}$, moreover, because of wide frequency range, we use three impedance transformers which cover 1/3 of whole frequency range respectively. In the calculation which shows good agreement with the measurement, we assume the coax-waveguide converter as a very short TEM line whose characteristic impedance is estimated (~45Ω) referring to Fig. 5. In Fig. 5, frequency dependence of the measured reflection coefficient with fixed length of impedance transformer is compared with the calculation for some values of characteristic impedance of the coax-waveguide converter which is assumed as a TEM line. In the case of 45Ω, the calculation is most close to the measurement.

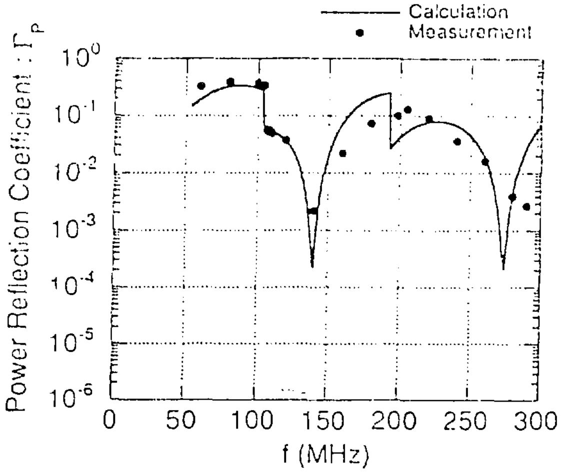

Fig. 4 Measured and calculated power reflection coefficient of the whole model with impedance transformers.

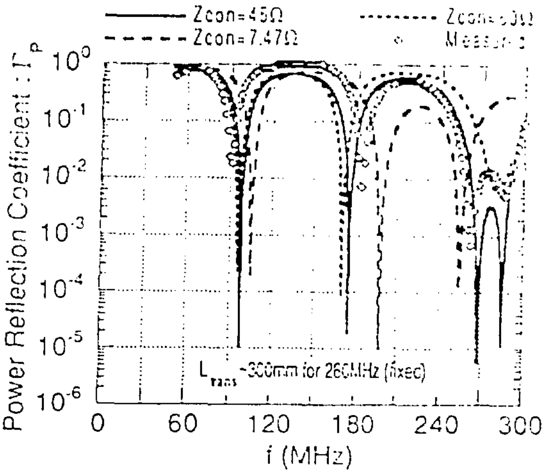

Fig. 5 Calculation for various values of impedance of the coax-waveguide converter which assumed as a very short TEM line. In the case of 45Ω, the calculation is most close to the measurement.

We obtain the power reflection coefficient of the model excluding the impedance transformer by means of assuming a perfect impedance transformer (Fig. 6). Power reflection coefficient of the model including the coax-waveguide converter to the input coaxial line is estimated less than 15% below the cut-off frequency of 107 MHz and less than 3 % above the cut-off frequency. The reflection coefficient is low enough for the antenna support which will be located at relatively high VSWR section between the matching circuit and the antenna. Power reflection coefficient of the model without coax-waveguide converter is shown as a dotted line as a reference.

Near cut-off frequency of the ridged waveguide, the reflection coefficient is close to 1.0 in the calculation as shown in Fig. 7. We cannot find such a high reflection coefficient in careful measurements, however it is better to avoid the frequency band near the cut-off frequency.

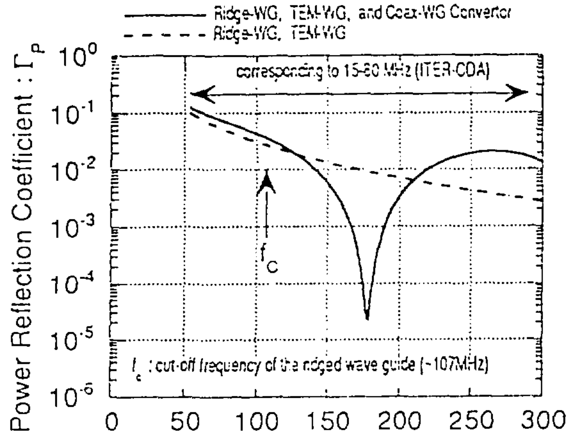

Fig. 6 Power reflection coefficient of the mock-up model of the ceramics-free antenna support with coax.-waveguide converter. Effect of the imperfect impedance transformer is removed by calculation. The reflection coefficient is low enough for a antenna support even below the cut off frequency of the ridged waveguide.

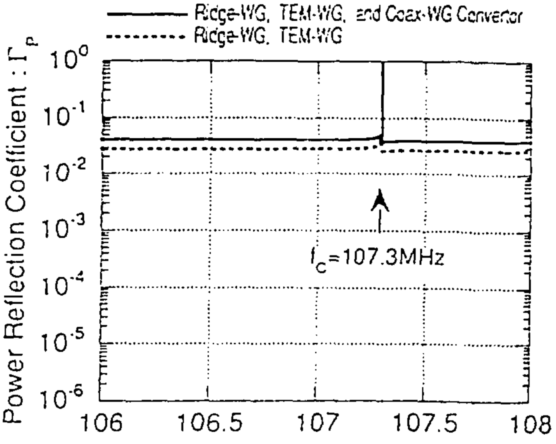

Fig. 7 Enlargement near the cut-off frequency of the ridged waveguide. In calculation, the reflection coefficient is ~1.0 near the cut-off frequency.

Summary

We have proposed a ceramics-free antenna feeder line employing a ridged waveguide as a local support for IC antenna of next-generation tokamaks. One fourth mock-up model of the all metal waveguide designed for the ITER ICRF system is fabricated and electrical characteristics of the model including the coaxial line - waveguide converter are measured. Power reflection coefficient of the model including the coax-waveguide converter to the input coaxial line is estimated to be less than 15% below the cut-off frequency of 107 MHz and less than 3 % above the cut-off frequency. It is found that this ceramics-free antenna support employing a ridged waveguide is quite available for IC antenna of next-generation tokamaks.

Reference

1) H. Arai, H. Kimura, T. Fujii, M. Saigusa, and S. Moriyama, "A Ceramics-Free Waveguide for ITER Ion Cyclotron Wave System," IEEE Trans. Plasma Sci., vol. 21, pp. 265-270, June, 1993.