PHASE CONTROL IN A TWO-ELEMENT FOLDED WAVEGUIDE ARRAY*

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ABSTRACT

A pair of folded waveguides have been used to determine the mutual coupling and to measure the field distributions for the magnetic field components for single units and for a pair. The phase difference controls the field distribution and the Fourier spectrum.

INTRODUCTION

The folded waveguide¹ FWG is an rf launching structure, particularly suitable for launching ion cyclotron range of frequency (ICRF) waves in the frequency range of about 80–500 MHz. A single 78-MHz FWG has been operated at 740 kW with plasma,² so the high-power performance of the FWG is well demonstrated. This paper addresses FWG performance as an element in an array of launchers. Specifically, adjacent FWGs are found to have very weak coupling. This weak coupling permits considerable control of the phase and amplitude of the fields produced by adjacent FWGs. The measurements described here have been with either one or a pair of models, one-fifth the size of the 78-MHz unit, operating at five times its frequency. Loop probes have been used to map out the field distributions, using an automated loop positioning system developed by F. W. Baity. Field polarizations corresponding to radial, poloidal, and toroidal field components have been measured. For the poloidal and toroidal components, a pair of measurements were made, with the probe orientation reversed between the two. The “true” signals are defined as those whose phase shifts by 180° when the probe is turned through 180°, and the “spurious” signals are the residual signals. The maximum value of the true signal is defined to be real and positive. The phase difference at other points determines the real and imaginary parts.

COUPLING

Two identical FWGs were used. The resonant frequency (f_{res}) of each was adjusted using a bolt through the back plate so that each FWG had precisely the same resonant frequency when isolated. The f_{res} of a pair of adjacent FWGs was determined for several values of the phase difference between the drive power for the two. When the phase difference was zero, the f_{res} was virtually unchanged from that for a single FWG. The f_{res} increased with increasing phase difference, of either sign. The fractional change in f_{res} reached a maximum of about 10^{-3} for a phase difference of 180°. This fractional change is taken to be equal to the mutual coupling between the two.

Fig. 1 Shift in Resonant Frequency for a pair of Folded Waveguides due to a Phase difference in the Power Feeds

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FIELD DISTRIBUTION FOR A SINGLE FWG

The spatial distributions of the various field components were measured when only one of the FWGs was excited. These field distributions, shown in Fig. 2, are very much like those for a loop antenna; the toroidal field component is a maximum at the center, falls to zero at the top and bottom, and becomes negative beyond the sides of the FWG. The radial field has its maximum positive value on one side, at the center, and its maximum negative value on the other side, at the center. The radial field values go to zero at the top and bottom. The poloidal field vanishes along the horizontal and vertical midlines, reversing sign across each of those lines. The maximum (positive or negative) values occur near the top and bottom at the sides. These field distributions can be compared with those calculated by Carter.³

Fig. 2 Magnetic Field Distribution 2.5 cm in Front of a Single Folded Waveguide

Since the coupling between two adjacent FWGs is so low, the field produced by each is determined solely by its driver power and is only weakly affected by the other FWG. The resultant field, for the two FWGs, is then simply the vector sum of the fields due to the two single FWGs.

FIELD DISTRIBUTION FOR A PAIR OF FWGs

Most of the measurements for a pair of FWGs have been for the toroidal component. The real and imaginary field distributions of the toroidal component are shown in Fig. 3. These were measured 5 cm from the face of the FWG pairs and along

Fig. 3 Real and Imaginary (Toroidal) Field Profiles and Fourier Spectra

the center line. For 0° and 184° phase difference the field is predominantly real. At $\pm 92^\circ$ the imaginary part is nearly equal to the real part and is a maximum where the real part is zero. The Fourier spectrum is also shown. For 0° or 184° the spectrum is symmetric, and for $\pm 92^\circ$ it is asymmetric, with the asymmetry reversing when the sign is reversed.

Similar measurements were made for the poloidal component, also 5 cm from the FWG face. The field distribution (shown in Fig. 4) along a line near the top or bottom of the FWG pair (near the maximum of the fields) shows behavior similar to that of the toroidal component.

Toroidal field distributions were measured 1 cm from the face for phase differences between 40° and 110° . The imaginary field was a maximum for a phase difference of 90° , and the Fourier spectra were asymmetric for all values of the phase difference. This behavior is consistent with that described above.

Toroidal field distributions were also measured 2.5 cm from the face, for phase differences from 0° to 90° . In this case, the ratio of imaginary to real fields did not vary as expected and as described above, nor did the Fourier spectra show the same asymmetry. It is unclear why this case differs from the others.

SUMMARY

The coupling between a pair of adjacent FWGs is observed to be 10^{-3} or less. The field distributions for the three components of the rf magnetic field are about the same as those for a loop antenna. Composite field distributions for a pair of FWGs have also been measured and show that the small value of the mutual coupling permits considerable control over the resultant distributions and of their Fourier spectra, in particular, by varying the phase difference between the two FWGs. For 0° or 180°

phase differences, the fields are primarily real. For other phase differences there are imaginary components, whose magnitude reaches a maximum for 90° . In most cases, the Fourier spectrum is asymmetric for 90° , and the asymmetry reverses for -90° phase difference.

These features make arrays of FWGs attractive for launching ICRF power in the frequency range above about 80 MHz. Spectral control, for either heating or current drive, should be readily possible.

¹T. L. Owens, IEEE Trans. Plasma Sci. **PS-14** (6), 934 (1986).

²F. W. Baity, T. S. Bigelow, M. D. Carter, W. L. Gardner, R. H. Goulding, G. R. Haste, D. J. Hoffman, D. O. Sparks, this conference.

³M. D. Carter, F. W. Baity, D. B. Batchelor, D. J. Hoffman, E. F. Jaeger, and D. W. Swain, this conference.

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