TRANSMISSION CHARACTERISTICS OF $H_{11}^0$
MULTI-MODE CIRCULAR BEND WAVEGUIDE

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Abstract

Recently, the influences of high order mode $E_{31}^0$ and transmission characteristics of $H_{11}^0$ multi-mode circular bend waveguide used in a high performance Cassegrainian microwave antenna, which utilized an offset excited horn-feeder, for the antenna and feed system of 4.5 and 6 GHz bands have been studied and analyzed by N. Nakajima, et al. But in their paper, the influence and effective method of treatment for another important high order mode $H_{21}^0$ have not been solved. In this paper, higher order modes coupling characteristics in $H_{11}^0$ circular bend waveguide are analyzed according to the coupled wave equations and coupling coefficients of $E_{31}^0$, $H_{21}^0$ modes and their amplitudes are computed. A broadband $H_{21}^0$, $E_{31}^0$ mode filter has thereby been proposed. Experimental results indicated that it performs well in practical application. Thus, the problems still confronting N. Nakajima et al. are capable of being solved thoroughly.

I. Introduction

In a large diameter $H_{11}^0$ circular waveguide system circular bend waveguides with various turn angles are always used. In such cases, if the diameter of the bend waveguide is selected the same as the main circular waveguide, some of the high order modes could be excited and transmitted along the system. In the past, in order to avoid the difficulties caused by high order modes in the bend waveguide, a smaller diameter bend waveguide or other design schemes were usually employed\cite{1, 2}. These methods will cause the system to be complicated in construction and the attenuation and reflecting characteristics of the main mode will be seriously deteriorated.

Recently, N. Nakajima et al. employed a large diameter multi-mode $H_{11}^0$ circular bend waveguide between a high performance Cassegrainian antenna and circular waveguide system in 4, 5 and 6 GHz bands\cite{3, 4}. In this paper, only the orthogonal characteristics caused by inhomogeneity of waveguides and the high order mode $E_{31}^0$ excited by a bend waveguide are analyzed and studied experimentally. But the influences of another important high order mode $H_{21}^0$ had not been discussed. In the present paper, the coupling characteristics of high order modes in multi-mode circular waveguide have been analyzed according to coupled wave equations of a bend waveguide and the computation of the amplitude of the high order mode $H_{21}^0$ has been emphasized. A wide-band mode filter is proposed. With experimental results given that when the mode filter is connected in series with the bend waveguide system, influences of high order modes excited by the bend waveguide can be well suppressed.
II. Mode Coupling Characteristics in $H_{11}^e$ Circular Waveguide

In order to solve the problems of coupling characteristics between various modes, in a multi-mode circular waveguide system, the solution in general may be obtained by means of transforming Maxwell equations into coupled wave equations in question by using the expansion method \[^6, 8^\] of orthogonal functions. The transmitting and coupling characteristics in a multi-mode circular bend waveguide were discussed by using the coupled wave Eqs. (8—75), (8—76) in [7].

![Circular bend waveguide coordinate system](image)

Now, according to the coupled wave equations given by [7], we may analyze the coupling characteristics between modes in a circular bend waveguide for the following several different cases. If an odd dominant mode $H_{11}^e$ is applied into a circular bend waveguide under the assumption that the polarizing direction of the electric field is parallel to the plane of bend waveguide, then from the coefficients $K_{(\pm)(\pm)}$ in the coupled wave equations it can easily be observed that magnetic waves could be coupled with the dominant mode. In this case, the following integral forms of angular functions in the coupled coefficients will be obtained.

$$\left[ \cos \varphi \sin \varphi \left\{ \frac{\sin m\varphi}{\cos m\varphi} \right\} - \cos^2 \varphi \left\{ \frac{\cos m\varphi}{\sin m\varphi} \right\} \right] d\varphi,$$

$$\left[ 2 \cos \varphi \sin m\varphi \left\{ \frac{\sin m\varphi}{\cos m\varphi} \right\} - \cos^2 \varphi \left\{ \frac{\cos m\varphi}{\sin m\varphi} \right\} \right] d\varphi.$$

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It is obvious from analysis of the above integrations that the dominant mode $H_{11}^e$ can only be coupled with high order modes $H_{2n}^e$.

If an even dominant mode $H_{11}^{e'}$ is transmitted in the circular bend waveguide it can easily be seen from the integral equations of coefficients $K_{(\pm)(\pm)}$ that the dominant mode can only be coupled with high order modes $H_{2n}^{e'}$ and $H_{2n}^{e''}$.

From the above analysis, it is not difficult to obtain the following conclusions: $H_{11}^{e'}$ can only be coupled with modes $E_{2n}^{e'}, E_{2n}^{e''}$ and cannot be coupled with modes $E_{2n}^{e'}$; the mode $H_{11}^{e'}$ can only be coupled with $E_{2n}^{e'}$ and cannot be coupled with modes $E_{2n}^{e''}$.

On the theoretical basis presented above, a series of high order modes $H_{2n}^e$, $H_{2n}^{e'}$, $E_{2n}^e$, and $E_{2n}^{e'}$ only can be excited in a $H_{11}^e$ multi-mode circular bend waveguide.