I-8 OVERSIZED RECTANGULAR WAVE-GUIDE COMPONENTS FOR MM WAVES

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Introduction

For mm- and sub-mm waves, standard-size rectangular waveguide has several drawbacks, which are more or less overcome by the use of oversized waveguide. The latter has the following advantages: 1) The broadband property (possibly one frequency decade) which is shared by the greater part of the components discussed in this paper. Also simultaneous transmission of several frequencies with large separations (multiplex) is possible. Other broadband transmission lines, e. g. coaxial- or strip line deserve no consideration due to their high losses.
2) The comparatively low value of the attenuation.
3) The large physical dimensions.
The last two points are important especially for sub-mm waves and high-power applications.

Oversized circular waveguide, operating in the H_{o1} mode, has been investigated extensively. Notwithstanding its higher losses, the oversized rectangular waveguide, operating in the H_{1o} mode (assumed to be the dominant one) has the following advantages:
1) As the standard-size waveguide is a rectangular one, operating in the H_{1o} mode, a simple transition (taper) is sufficient instead of a complicated mode-transducer.
2) Some components such as mode filters can be designed more easily due to the simple electromagnetic field pattern.
3) The mode stability is better (the H_{o1} mode in the circular guide is easily transformed into the E_{11} mode).

In this paper some new components for oversized rectangular waveguide are described. Experiments have been performed with standard X-band guide (0.4 x 0.9" I.D.) and a swept-frequency oscillator (f = 75 ± 1.5 GHz). The primary aim of the investigations was the development of precision measuring equipment. Furthermore short-distance transmission applications have been studied (Radar antenna feeding). In contrast with investigations done by other [1 - 4] for the purpose of high power transmission and physical applications, special care had to be taken of the higher order modes. For this purpose detectors for the H_{2o} and H_{3o} modes have been developed, which have an extremely high mode discrimination (> 50 dB). Moreover some components have been theoretically analyzed with respect to their mode conversion properties.

COMPONENTS FOR OVERSIZED WAVEGUIDES

The transitions (tapers) have to be designed carefully in view of mode purity. The H_{3o} mode turns out to be the most disturbing one, so that the taper profile has to be optimized with respect to minimum mode conversion $T_{1o,3o}$. A theoretical analysis [5] yields a wineglass form (Fig. 1) for the dependence of the width a upon the axial coordinate z. The height variation b(z) can be chosen linear, since this excites essentially H_{1n} and E_{1n} (n = 2,4,...) modes which can be easily attenuated by means of the mode filters described below. Measurements have yielded a mode conversion $T_{1o,3o}$ of 40 dB.

Mode-filters attenuate the unwanted modes, which can be classified into a) the H_{mn} and E_{mn} modes with $n \neq 0$, b) the H_{mo} modes with $m \neq 1$. Mode filters of a simple construction for the first type of modes consist of resistive sheets perpendicular to the electric field of the $H1_o$ mode. The surface impedance can be optimized with respect to certain modes [6].

An H_{mo} mode filter (Fig. 2) makes use of directional coupling. Two auxiliary guides are loosely coupled to the main guide by means of dielectric sheets. The $H3_o$ mode in the main guide has the same propagation constant as the $H1_o$ mode in the auxiliary guide, so that these modes are mutually coupled. With carefully chosen dimensions all power of the $H3_o$ mode is extracted from the main guide and dissipated in the loads. This device has almost ideal mode filtering properties but is inherently small-band and it cannot absorb more than one mode at the time.

Another device, which is broadband and attenuates all higher order modes simultaneously, consists of a waveguide with resistive side walls. The attenuation of the H_{mo} modes varies proportional to m^2; i. e. $\alpha H3_o = 9\ \alpha\ H1_o$. Obviously this construction is no ideal mode filter, but a mode selective attenuator.

An oversized E-plane bend of constant cross-section excites $E1_n$ and $H1_n$ modes. If, however, the guide is sufficiently flat, these modes cannot propagate, The E-plane bend described here consists of a bending part in a flat guide tapered towards oversized waveguides (see Fig. 3).

The same construction can be used also for the H-plane bend, naturally leading to a narrow band component. A more broadband device is the well-known mirror construction, based on optical principles [7]. However, as with the crossing (treated below) some higher order H_{mo} modes,are excited, especially at certain (resonance) frequencies.

A well-known directional coupler in oversized waveguide consists of an H-plane cross-junction of two waveguides, with a dielectric sheet placed in the diagonal plane of the crossing. This sheet acts as a semi-transparent mirror and provides directional coupling following optical principles (interferometer). However, without any sheet, excitation of the main arm sets up some fundamental and also higher modes in the side arms due to diffraction. A theoretical treatment is given in detail somewhere else [8]. The diffraction phenomena give rise to certain errors of the directional coupler, especially for less oversized waveguides and in the vicinity of certain resonance frequencies.

An almost ideal as well as broadband directional coupler is based on a different principle illustrated by Fig. 4. The coupler consists of a septated power divider, where the common metallic wall changes into a semi-transparent resistive one. Power, incident from the left (port 1) is divided between waveguides 2 and 3 according to the ratio of their heights, thereby determining the coupling factor. A wave incident from port 2 does not couple to port 3 on account of the well-known directional coupling through homogeneous sheets. The higher order modes, excited by the resistive wall, are attenuated by the mode filter at port 1. A 3 dB-coupler with a directivity of almost 40 dB has been realized.

A frequency-independent variable attenuator, obeying a simple law, consists of a combination of two of the above-mentioned directional couplers with built-in loads (see Fig. 5). The attenuation depends on the postion of the septum accourding to $a = -20 \log y/b$ dB.

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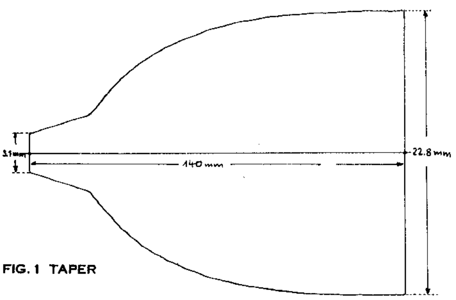

FIG. 1 TAPER

The a and z scales are different !

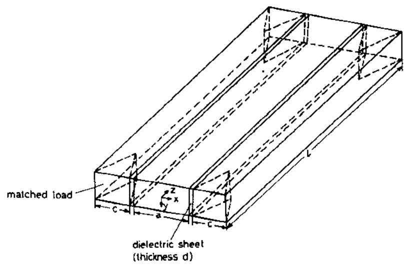

FIG. 2

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Microwave and Electronic Test Equipment and
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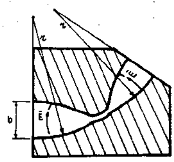

FIG. 3 E-PLANE BEND

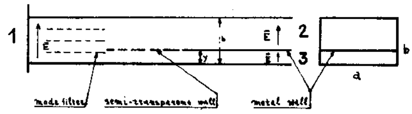

FIG. 4 DIRECTIONAL COUPLER

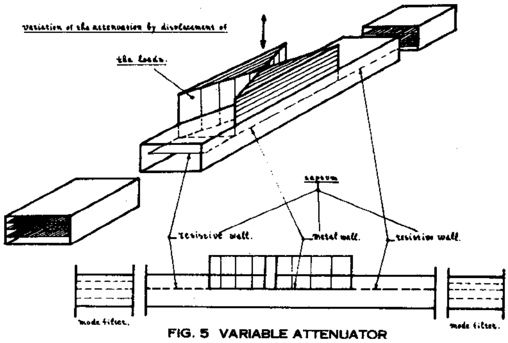

FIG. 5 VARIABLE ATTENUATOR