WAVEGUIDE SYSTEMS FOR SHORT-MILLIMETRIC AND SUBMILLIMETRIC WAVELENGTHS

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ABSTRACT

Designs of H-guide and groove-guide for 100-1000 GHz use, with relatively low loss and single mode operation, are considered. Experimental measurements at 40 and 100 GHz show encouraging moding and attenuation characteristics.

Introduction

Short millimetric wavelengths, at present used for specialised applications, are inhibited for wider use by the absence of a convenient guiding system. Rectangular TE_{10} dominant mode guide presents difficulties because of high attenuation and minute transverse dimensions (e.g. 10dB/m and < 2mm at a wavelength of 2mm), whilst the low-loss circular guide mode is useful for transmission only and not signal manipulation.

An alternative waveguide system using H-guide or groove guide is described. The basic guide forms are shown in Fig. 1, with the corresponding field distributions. The electric field is mostly parallel to the conducting planes. The H-guide supports a hybrid mode, whilst the groove guide mode is transverse electric. Transverse field concentration in the H-guide is produced by the thin dielectric sheet, and in the groove guide by the longitudinal slot in the conducting planes. Field distributions for both guides have been analysed and published by several authors. Typical loss characteristics are given in Fig. 2. It is clear that for low loss the plane separations must be considerably greater than that for first order mode operation only. The dielectric thickness for H-guide must also be very small. Both guide types can be designed for single mode operation however, even with the wider plane separations.

H-guide Design

Support of the thin dielectric film, and higher mode suppression, can be achieved by the guide shown in Fig. 3. Suppression depends on the dimension d. The resonant spectrum of a section of guide at 8mm wavelength, short-circuited at both ends to form a resonant cavity, is shown in Fig. 4 for an optimum value of d. Careful measurements for variable d show that the first and higher order modes can be emphasised or suppressed. Optimum first order propagation occurs for the d value equal to one-quarter guide wavelength of the rectangular waveguide mode propagating into the slot, when the slot and main guide phase velocities are equal. Higher order modes are then suppressed. This technique has the disadvantage, however, of requiring a critical slot dimension d.

Groove-guide Design

The interesting property of groove-guide of allowing only single mode propagation even with a plane separation large compared with λ has been remarked by Nakahara and Kurauchi, although experimental verification of its validity at short millimetric wavelengths has not been reported by other workers. The moding spectrum at 8mm wavelength has been investigated by the resonance technique with variable groove depth, and a plane separation of 30mm, and the mode magnitude variations are shown in Fig. 5. With a groove depth of a quarter of the plane separation higher order modes are effectively suppressed. A simple Fourier analysis of fields at the groove-plane interface shows that there is then good coupling between a higher order mode in the groove region and the next odd but lower order mode between the planes. Consideration of the wave number equations show that this leads to a leaky mode in the planes and, hence, removal of the mode.

Measurements at 3cm wavelength confirm the adequacy of previous theoretical expressions, using only the first term of a series solution, for most applications.

Measurements at 3mm wavelength, using the guide cross-section of Fig. 6(a), gave the resonance spectrum of Fig. 6(b). The lossy material is to absorb leaky higher order modes. Even though having a plane separation of 10mm, first order mode resonances only were observed. The unloaded Q-factor was obtained from measurements on different length guides, and an equivalent guide attenuation of 0.6 dB/m calculated for the aluminium guide. This is a factor of 4 greater than the theoretical value, but a factor of 10 less than the attenuation of corresponding single-mode rectangular guide.

General Conclusions

Both H-guide and groove-guide of suitable design have the attractive features of convenient cross-sectional dimension, simple construction, single mode operation, and loss considerably less than the equivalent rectangular guide. Other potential advantages include low dispersion, the possibility of trading attenuation for degree of coupling to the guide with easy transitions from low-loss transmission sections to signal manipulation sections, simple connection due to the absence or low value of longitudinal currents, and the possibility of constructing components directly in the guide. Groove guide has the advantage over H-guide that no dimension is critical to a small fraction of a wavelength.

A complete system may be envisaged with generation, transmission and reception in groove or H-guide, or alternatively these guides may replace rectangular guide and may be used in conjunction with circular guide by development of a suitable transition.

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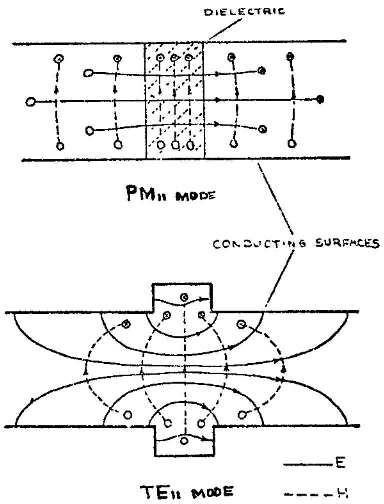

Fig 1 Cross-sections and transverse field distributions

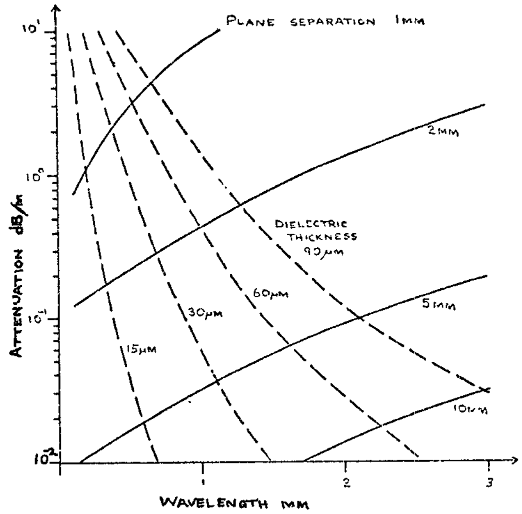

Fig 2(a) H-guide attenuation
— conductor loss ($\sigma_m = 5.8 \cdot 10^7\ Sm^{-1}$)
- - dielectric loss ($\varepsilon_r = 2.1$ $\tan\delta = 0.001$)

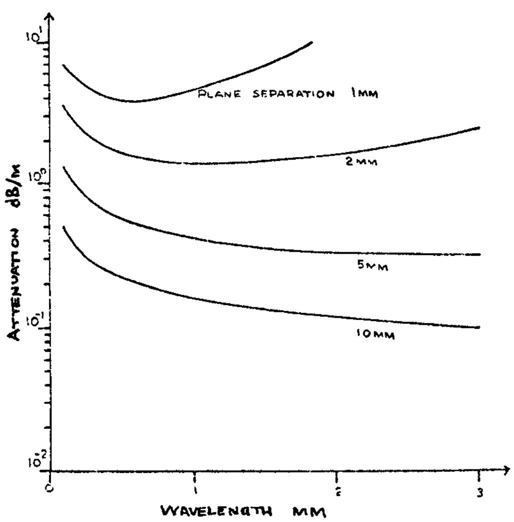

Fig 2 (b) Groove-guide attenuation

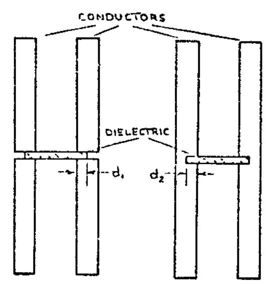

Fig 3 Modified H-guide

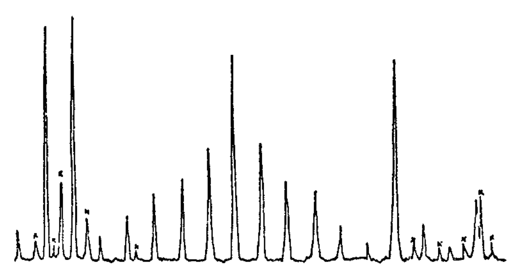

Fig 4 Modified H-guide spectrum
plane separation 35mm
optimum d_2 frequency 26-40 GHz
x higher order modes

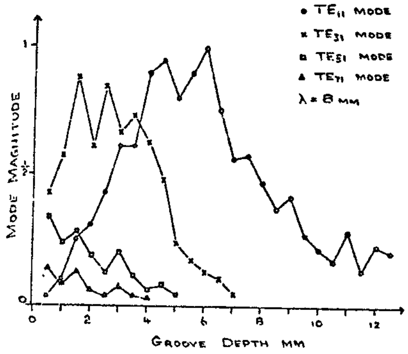

FIG 5 RELATIVE GROOVE-GUIDE MODE MAGNITUDES
PLANE SEPARATION 30MM

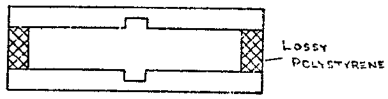

FIG 6(a) GUIDE CROSS-SECTION
PLANE SEPARATION 10MM
GROOVE 2·5 × 5 MM

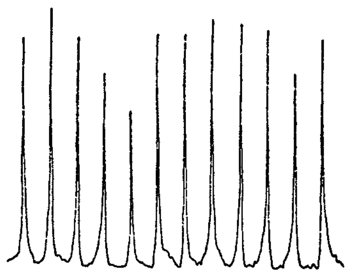

FIG 6(b) RESONANCE SPECTRUM
GUIDE LENGTH 95-115MM
FREQUENCY 95·8 GHz