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United States Patent

Ravenscroft et al.

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[54] **DIELECTRIC WAVEGUIDES**

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[73] Assignee: **The Post Office,** London, England

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[30] **Foreign Application Priority Data**

Dec. 17, 1969 Great Britain.....61,589/69

[52] **U.S. Cl.**.....**333/95 S,** 333/98 M, 350/96

[51] **Int. Cl.**.....**H01p 3/16,** H01p 3/18

[58] **Field of Search**.....333/95, 95 S, 98, 98 M

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Assistant Examiner—Marvin Nussbaum
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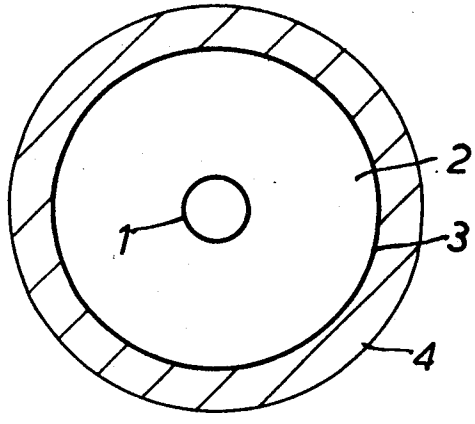
[57] **ABSTRACT**

A dielectric waveguide for millimetric wavelengths comprising a core of polymer material supported by a body of foamed polymeric material and enclosed in a protective jacket.

4 Claims, 7 Drawing Figures



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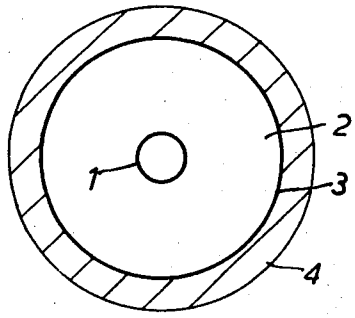

FIG. 1.

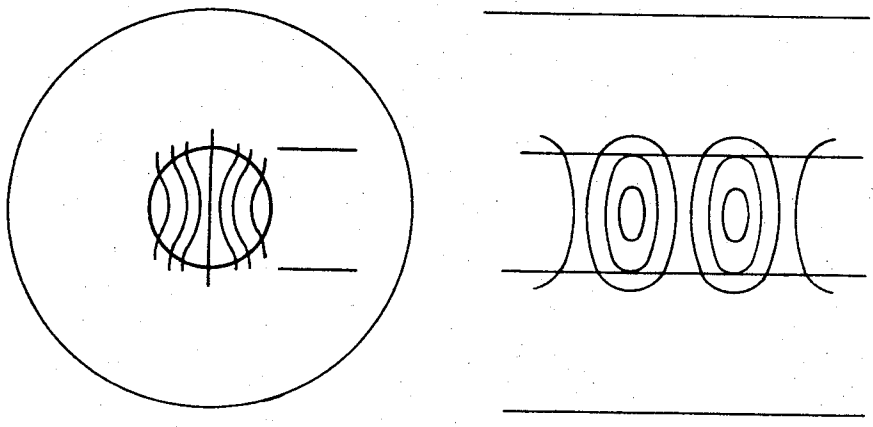

FIG. 2.

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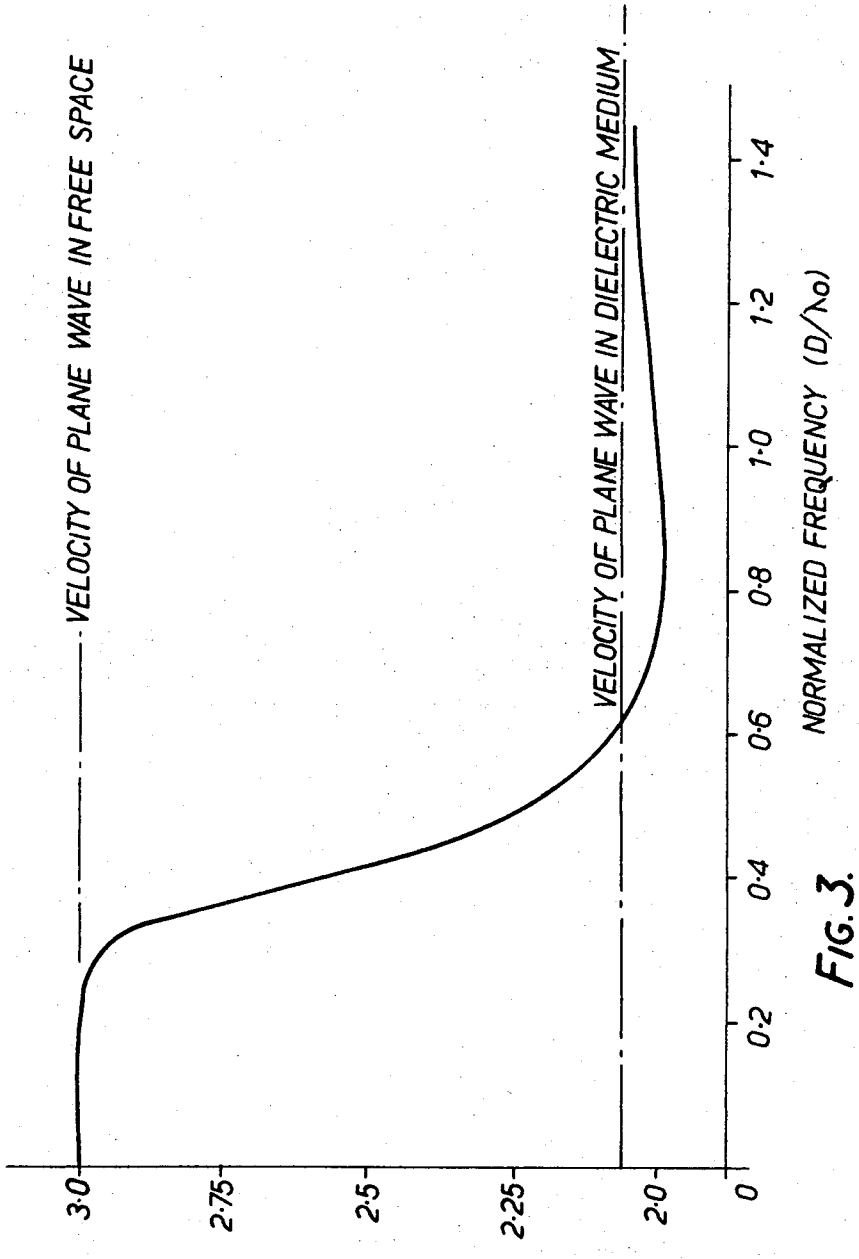

FIG. 3.

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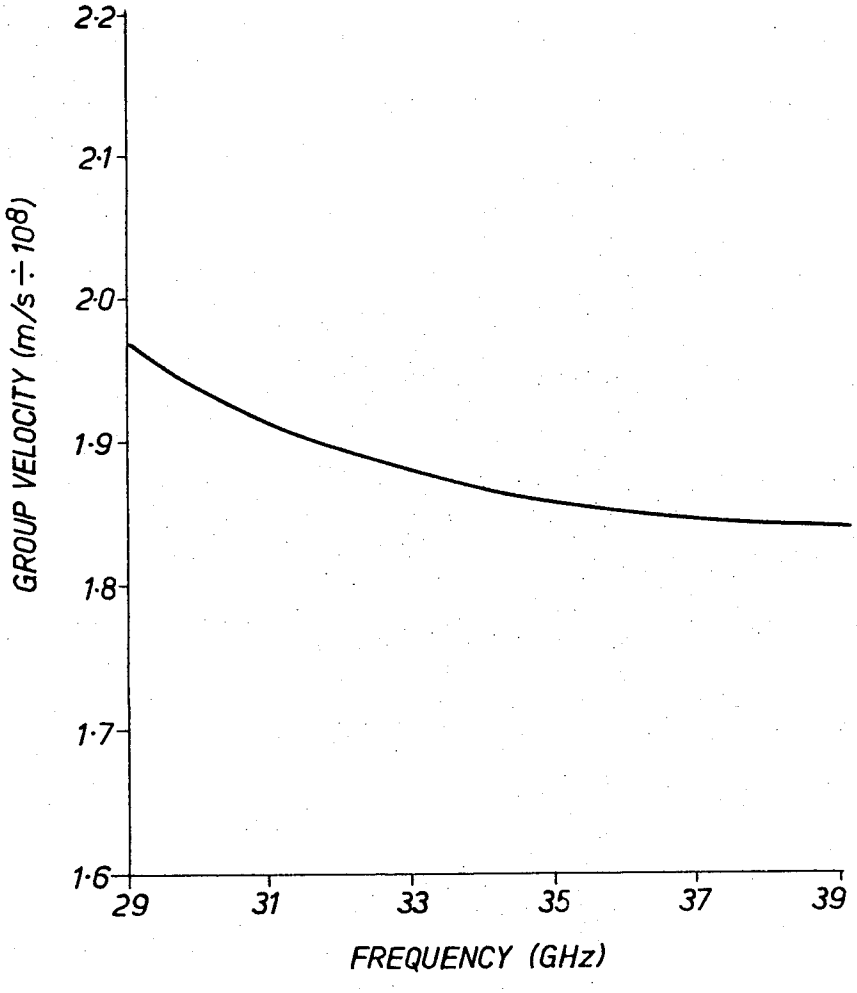

FIG. 4.

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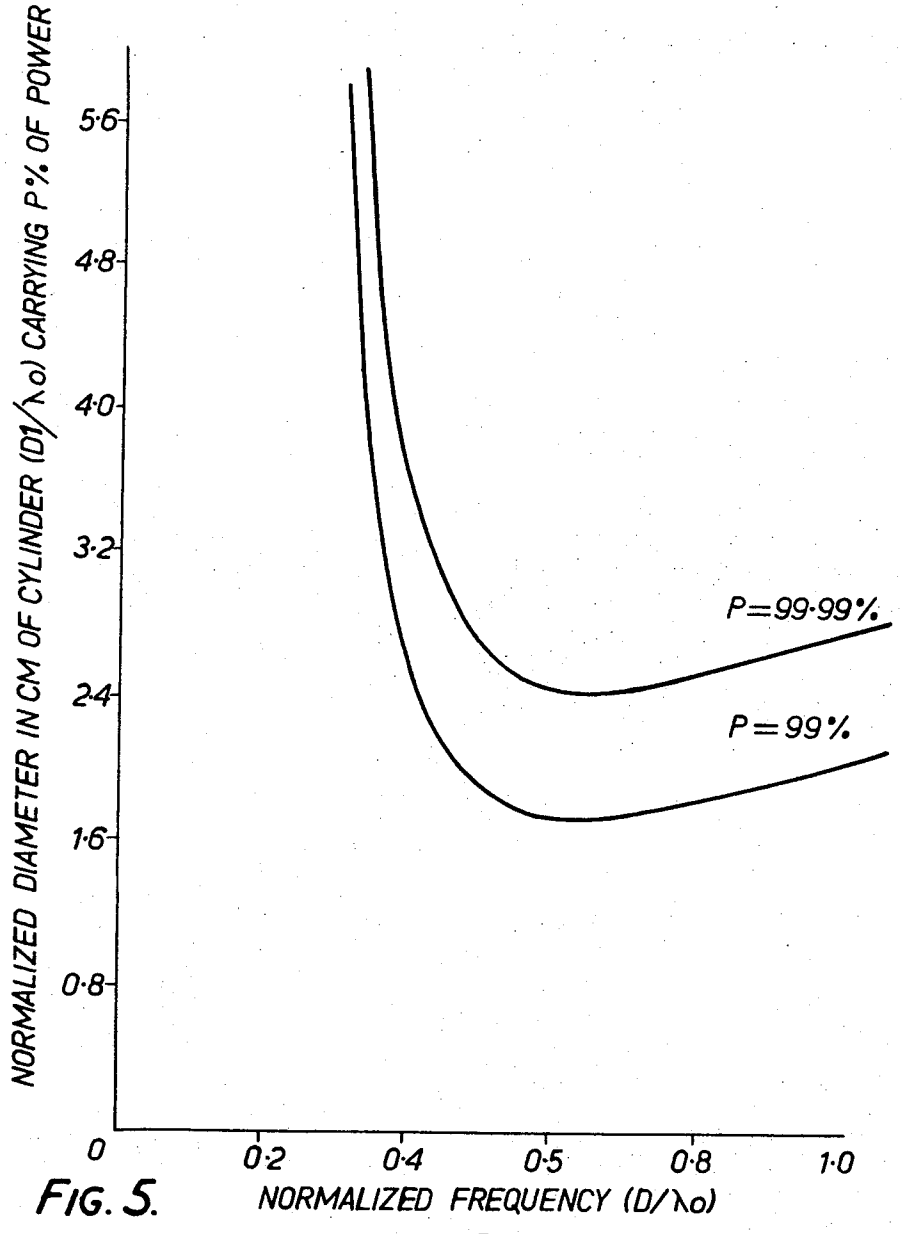

FIG. 5.

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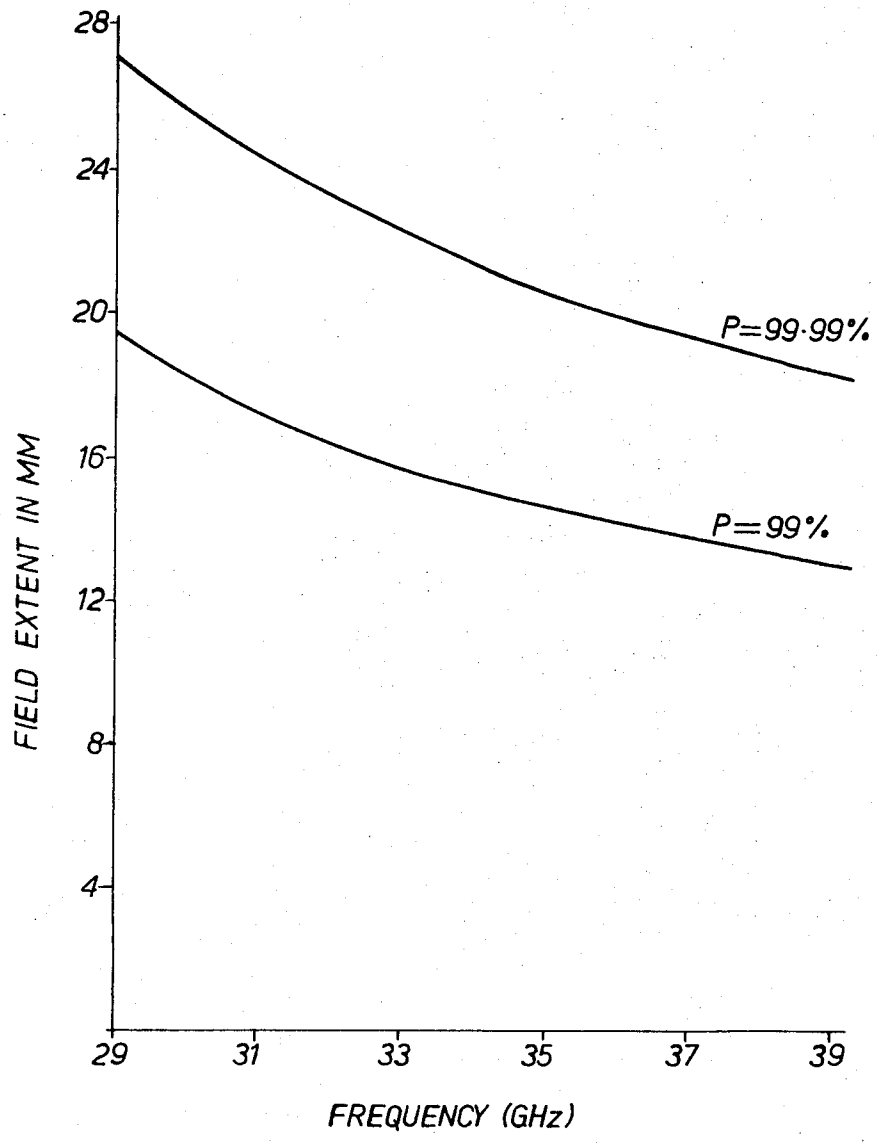

FIG. 6.

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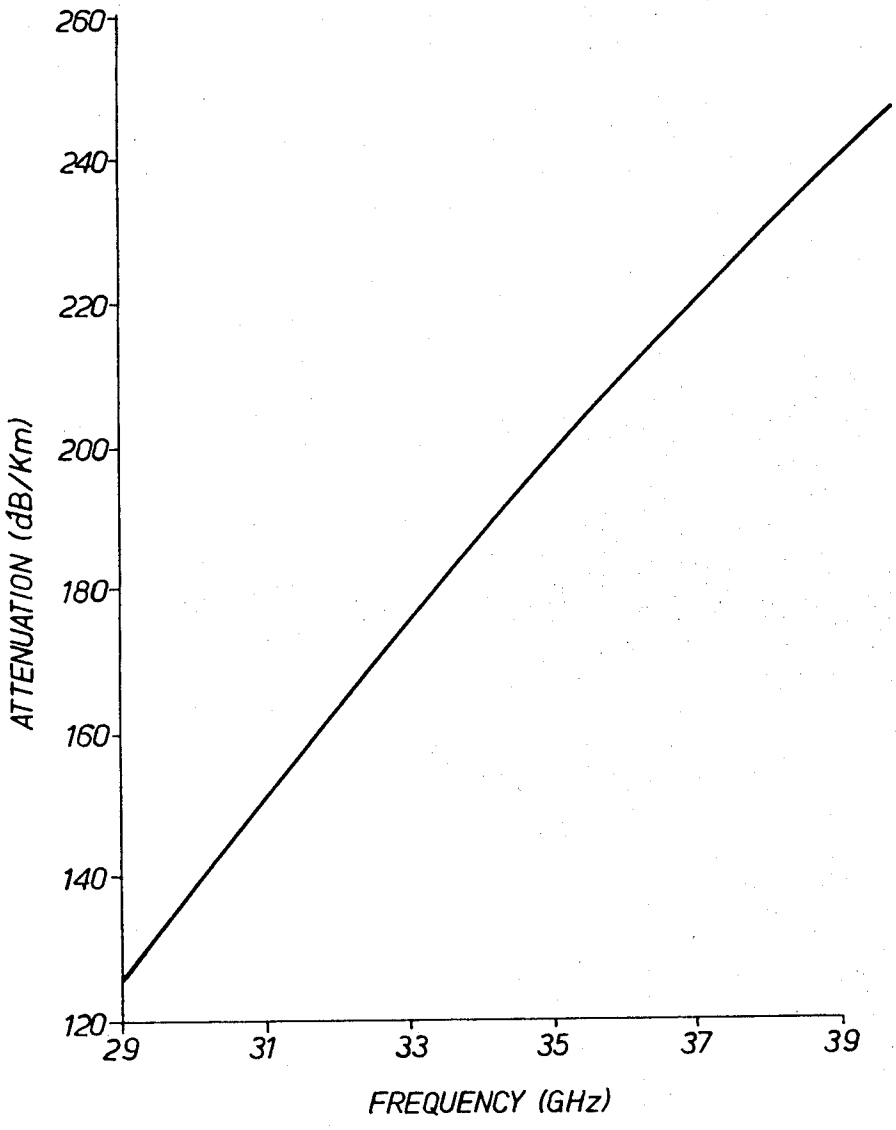

FIG. 7.

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DIELECTRIC WAVEGUIDES

BACKGROUND OF THE INVENTION

It has been proposed to employ a rod of dielectric material as a waveguide but in the past low loss transmission has been achieved only with rods of diameter small in relation to wavelength. Dielectric rods of such small diameter do not possess adequate "guiding" properties and therefore have to be employed in straight lengths which limits their usefulness.

It is an object of the present invention to provide an improved dielectric rod waveguide.

SUMMARY OF THE INVENTION

According to the present invention a dielectric rod waveguide comprises a core of a polymeric material of a loss angle about 50 microradians or less and of a diameter from about 0.5 λ_o to about 0.85 λ_o where λ_o is the free space wavelength of the electromagnetic energy to be transmitted along the waveguide, the core being supported by a body of polymeric material in foamed form, having an effective dielectric constant substantially equal to unity and of a size such that the overall diameter of the core and support body is of a value from about 1.6 λ_o to about 5.0 λ_o, the whole lying within a jacket providing protection against mechanical stresses, the ingress of moisture and providing electrical screening.

The core may be composed of polypropylene, a particularly suitable form of which is that known as PXC 3391 manufactured by Imperial Chemical Industries Limited.

The polymeric material in foamed form supporting the core may be the same material as that of which the core is composed.

Preferably, the loss angle should be below 5 microradians.

The core may be in the form of a solid rod or it may consist of a number of strands of the dielectric material or it may be a rod of foamed dielectric material. Both these alternative forms have a lower density than the solid rod and both have a lower effective dielectric constant and lower effective loss angle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an enlarged cross-section of the waveguide,

FIG. 2 shows on a different scale from FIG. 1 and in diagrammatic form the field configuration of the HE_{11} mode in the waveguide of FIG. 1, and,

FIGS. 3, 4, 5, 6 and 7 are graphs illustrating various relationships.

DESCRIPTION OF PREFERRED EMBODIMENTS

The waveguide shown in FIG. 1 consists of a core 1 comprising a solid rod of polypropylene of electrical grade having a dielectric constant $\epsilon_r = 2.26$ of a loss angles equal to 50 microradians. The diameter of the core 1 is 5.3 mm and it is covered by a sheath 2 of low-loss foamed polypropylene preferably of the same grade as that from which the core is made. The overall diameter of the core 1 and sheath 2 is 28 mm. The outer surface of the sheath is covered with a layer 3 of a "lossy" foam having the same effective dielectric constant as the low loss foam. The final covering of the waveguide is a protective jacket 4 of a suitable polymer. The jacket 4 provides protection against mechanical stresses and electrical screening. Embedded in or otherwise forming part of the jacket is a water barrier providing adequate protection against ingress of moisture.

The waveguide supports the HE_{11} mode and operates over the frequency range 29–39 GHz. The field configuration of the HE_{11} mode is indicated in FIG. 2.

The core 1 may be formed by extrusion, care being taken to maintain the diameter of the core 1 to within very close tolerances — about ± 1 percent — and to ensure that the core is totally homogeneous and of a high quality surface finish. The core 1 may be extruded by a method in which molten material is extruded through a nozzle along whose length the rate of cooling of material passing through it is varied in such manner as to permit the application to the molten material of an extra or "back-up" pressure which substantially prevents the appearance of voids. The nozzle has a bore which has an extremely smooth surface thereby ensuring the requisite high quality surface finish for the core.

The sheath 2 may be made by conventional foaming techniques and may be applied to the core during extrusion of the latter or after. The core 1 may be passed into a chamber inside which the core is held at a temperature below the softening of the material from which the core is made, sheathing material being fed to the chamber and therein bonded to the core. The sheathing material may be allowed to foam or be foamed after entry into the chamber or the sheathing material may be fed in foamed form into the chamber.

Application of the "lossy" material comprising the layer 3 may be effected by the introduction of a substance having a high loss angle, for example carbon, into the outer regions of the foamed sheath 2, or alternatively, the "lossy" material may be introduced as part of a separately extruded layer.

The group velocity of the HE_{11} mode depends to a large extent on the diameter in wavelengths of the core 1, and varies between limits obtained by propagation in free space, when the core diameter tends to zero, and by propagation entirely through the material of the core. FIG. 3 shows, for material of dielectric constant $\epsilon_r = 2.26$, the relationship between group velocity and normalized frequency (core diameter D/free space wavelength) obtained by numerical methods. If dispersion is to be kept at acceptably low values, rod diameters below about 0.3 λ_o and from about 0.5 λ_o and above must be used, say from about 0.5 λ_o to 0.85 λ_o, the upper limit being reasonably close to the cut-off point for higher modes of operation of the waveguide.

The relationship between group velocity and frequency for the core 1 of the waveguide of FIG. 1 is shown in FIG. 4.

Since the core 1 must be supported in some suitable manner, practical values for the extent of the radial field of the HE_{11} mode must be ascertained. To indicate the extent of the radial field, the graph of FIG. 5 has been prepared showing the diameter of $D1/\lambda_o$ of the concentric cylinder through which 99 percent and 99.99 percent of the total power in the propagated wave flows. This indicates that the variation of the diameter of percentage power flow with frequency is fairly uniform over the range $D \times 0.5\ \lambda_o$ and $0.72\ \lambda_o$.

FIG. 5 also shows that 99 percent of the total power is transmitted through a cylinder of a diameter $D1$ of

about 1.6 λ_o over the range of D just mentioned whilst 99.9 percent of the total power is transmitted through a cylinder of a diameter $D1$ of about 1.4 λ_o. However, if the latter value is increased to about 5.0 λ_o a downward extension of transmitted bandwidth is possible.

FIG. 6 shows the relationship between extent of radial field and frequency of operation for the core 1 of the waveguide of FIG. 1. FIG. 6 shows that the overall diameter of the cylinder containing 99.99 percent of the energy is within 28 mm over the frequency range 29–39 GHz.

The attenuation of the HE_{11} mode is given approximately by the equation

$$\alpha \doteq \frac{\pi\delta}{\lambda_0}\sqrt{\epsilon}\frac{N_\epsilon}{N} \text{ nepers/metre}$$

where

λ_o = free space wavelength in meters
ϵ = dielectric constant of core 1 to sheath 2
γ = loss angle of core 1 in radians
N_ϵ/N = millimetric of power inside rod to the total power transmitted.

FIG. 7 shows the variation of the attenuation of the waveguide of FIG. 1 with frequency over the range 29–39 GHz.

Thus, by minimizing losses in the material, attenuation, for a given set of operating parameters, is reduced. The dielectric loss may also be reduced by adopting a core of foamed or standard form.

We claim:

1. A dielectric rod waveguide for the transmission of electromagnetic energy at frequencies in the millimetric waveband, the waveguide comprising in combination a core through which a proportion but not all of said electromagnetic energy is transmitted, said core having a diameter lying within the range from about 0.5 λ_o to about 0.85 λ_o where λ_o is the free space wavelength of the electromagnetic energy to be transmitted and being of a polymeric material with a loss angle not greater than about 50 microradians, a core support body round the core through which substantially the balance of said electromagnetic energy is transmitted, the support body comprising a tubular body of polymeric material in foamed form and having a dielectric constant of substantially equal to unity and of a size such that the overall diameter of core and support body lies within the range from about 1.6 λ_o to about 5.0 λ_o, lossy material associated with said support body to absorb electromagnetic energy incident upon it, and, surrounding the core support, a jacket providing protection against mechanical stresses, the ingress of moisture and electrical screening.

2. A dielectric rod waveguide as claimed in claim 1 in which the core is of stranded form.

3. A dielectric rod waveguide as claimed in claim 1 in which the core is of foamed form.

4. A dielectric rod waveguide as claimed in claim 1 in which the polymeric material of which the core is formed is the same as that of which the core support is formed.

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