MR 386

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DATE: 1972

TITLE: A waveguide TEM mode exposure chamber (for the study of biological effects of microwaves).

SOURCE: J of MIcrowave Power 7(4):381-83

MAIN SUBJECT HEADING:

AN	HU	AT	IH	M
ANALYTICS	HUMAN EFFECTS	ANIMAL TOXICITY	WORKPLACE PRACTICES-ENGINEERING CONTROLS	MISCELLANEOUS

SECONDARY SUBJECT HEADINGS: AN HU AT IH M

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Methods of Analysis

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A Waveguide TEM Mode Exposure Chamber*

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ABSTRACT

A waveguide structure which allows simulation in finite dimensions of a TEM wave propagating in free space is examined theoretically.

Introduction

In the study of biological effects of microwaves and other aspects of microwave power it is often desired to simulate a uniform plane electromagnetic wave in a chamber of finite dimensions. The purpose of this note is to point out the existence of such a chamber and to examine the maximum chamber dimensions for only TEM mode propagation.

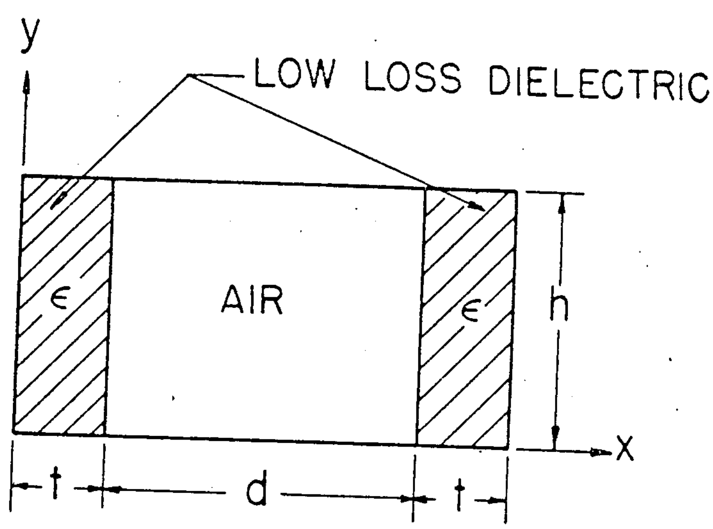

Fig. 1 Geometry of the chamber.

The possibility of TEM mode propagation in the inhomogeneously filled waveguide of Figure 1 has been demonstrated[1,2]. Figure 1 depicts a rectangular waveguide partially filled with slabs of low loss dielectric of relative dielectric constant ϵ. If the dielectric slab thickness $t = 0$, the waveguide supports propagation with a phase velocity greater than c, the velocity of propagation in free space. When the dielectric completely fills the waveguide, propagation with a phase

* Manuscript received August 14, 1972, in revised form October 12, 1972.
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velocity less than c is possible. It is thus not surprising that, at a given frequency, t can be chosen such that the waveguide supports propagation at a phase velocity c. In this case, the fields in the air region are those of a TEM wave. The electric field E has only a y component, the magnetic field H has only an x component, $E = 120\pi H$, and the fields are uniform over the air filled region of the waveguide. The appropriate dielectric thickness t is given by[1]

$$t\sqrt{\epsilon - 1} = \lambda/4$$

where λ is the free space wavelength at the desired operating frequency. Dispersion relations, power flow, and departures of field distributions from uniform as a function of frequency have been examined[1, 2]. In the more general situation considered by Hudson[1], the regions $0<x<t$ and $t + d<x<2t + d$ are filled with dielectric of relative permittivity ϵ_2 and the region $t<x<d$ with dielectric of relative permittivity ϵ_1. The above equation also applies in this case provided $\epsilon = \epsilon_1/\epsilon_2$ and λ is the wavelength of a plane wave propagating in an unbounded region of relative permittivity ϵ_1.

Maximum Chamber Dimensions

The waveguide of Figure 1 is capable of supporting the TEM mode described above for arbitrarily large values of d and h. However, if d or h exceed certain values, the waveguide is also capable of supporting higher order modes which are neither TEM nor uniform. If such an oversize waveguide is used, care must be exercised to excite only the desired uniform mode. It thus would appear useful to examine the maximum chamber dimensions possible for only TEM mode propagation.

The mode spectrum of the waveguide of Figure 1 can be determined by standard techniques[3]. It can readily be shown that higher order mode propagation is possible if h exceeds $\lambda/2$. In this case, propagation in a mode with an x component of electric field which varies as $\sin(\pi y/h)$ is possible. The width of the air region d must also be restricted to cut off the first higher order LSE (Longitudinal Section Electric) mode. This mode[3] is asymmetric about $x = t + d/2$ with $E_y = 0$ on this plane. The maximum value of d,d′, which still excludes this mode is found from the dispersion relation to be given by

$$\sqrt{\epsilon}\,\tan\left(\frac{\pi}{2}\sqrt{\frac{\epsilon}{\epsilon - 1}}\right) = -\tan\left(\frac{\pi d'}{\lambda}\right)$$

Figure 2 shows d'/λ as a function of ϵ.

When the waveguide is fed symmetrically about $x = t + d/2$ and any objects introduced in the chamber are also symmetric about this plane, the first higher order asymmetric LSE mode is not excited and d is limited by the possible presence of the second higher order LSE mode. This mode is symmetric about $x = t + d/2$ and has two nulls of E_y in the air filled region. For exclusion of this mode, d cannot exceed the value d″ determined by

$$\sqrt{\epsilon}\,\tan\left(\frac{\pi}{2}\sqrt{\frac{\epsilon}{\epsilon - 1}}\right) = \cot\left(\frac{\pi d''}{\lambda}\right)$$

Figure 2 also shows d''/λ as a function of ϵ.

It should be noted that d′ and d″ are those values of d which yield cutoff frequencies for the respective higher order modes equal to the operating frequency. Consequently, maximum values of d employed should be perhaps 10% less than d′ and d″ to sufficiently attenuate these undesired modes.

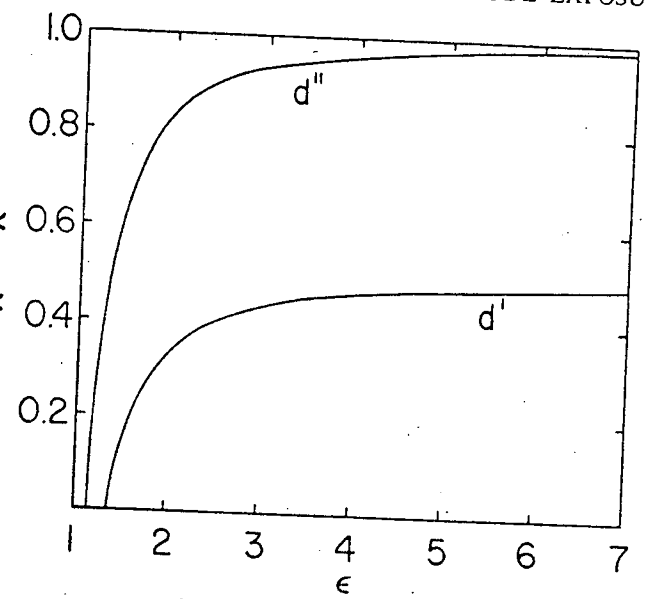

Fig. 2 Maximum chamber width for exclusion of higher order-modes.

It should be noted that the distribution of power absorbed in an object introduced in the chamber is not identical to that absorbed when the object is illuminated by a TEM wave in free space. One would expect, however, that the absorbed power distribution in the chamber described would more closely resemble the free space distribution than that realized in a chamber which does not provide TEM incident power.

In the special case in which a low loss sample of relative permittivity ϵ_1, completely fills the waveguide, the slab thickness t can be chosen to yield a TEM mode in the sample as shown by Hudson[1]. In this case, Figure 2 still applies provided λ is the TEM mode wavelength in the sample.

Figure 2 reveals that the maximum dimensions of the chamber cross-section are roughly $0.5\lambda \times 0.5\lambda$ or $\lambda \times 0.5\lambda$ if asymmetric modes are excluded. Such chambers thus are only of value in frequency ranges which yield chamber dimensions acceptable for the type of sample under consideration.

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