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PERFORMANCE OF METAL MESHES AS A FUNCTION OF INCIDENCE ANGLE

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ABSTRACT

An inductive mesh was measured for transmission as a function of frequency, incidence angle and polarization. The experimental data agreed well with Chen's waveguide theory for meshes as long as an adequate number of modes were included in the calculation.

Introduction

Many applications of quasi-optical techniques in the millimeter or submillimeter wavelength region involve the use of metal meshes at non-perpendicular incidence angles. There is a large literature on both theory and experiment for the special case of normal incidence. The theoretical approaches and their comparison with experiment have been summarized recently by Durschlag and DeTemple [1]. Experimental results for 45° illumination have been reported [2] but the theoretical disccussion of these results is only qualitative. For many of the theoretical methods available the extension of the theory to non-normal incidence angles is not immediately obvious. However, the waveguide aperture theory of Chen [3] includes incidence angle and polarization effects from the outset. Since this theory gives the best results at normal incidence [1], we chose it for comparison with experimental measurements at other incidence angles.

Experimental

The mesh transmision was measured on a Nicolet 8000 Interferometer which is evacuated to exclude absorption by water. The beam in the sample area was collimated by a pair of concave TPX lenses. The dominant vertical polarization of the interferometer was selected using a commercial wire grid polarizer (Cambridge Physical Sciences). Transmission measurements at 118 micron wavelength were checked with a CO_2 pumped methanol laser.

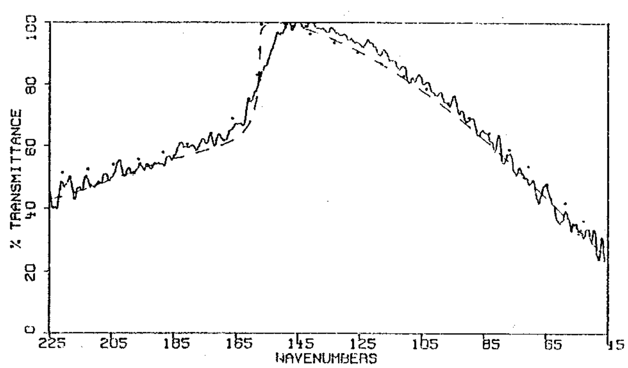
The meshes used were supplied by Buckbee-Mears, Inc. and were stretched on a 5.3 x 7.5 cm frame. The grid spacing and wire width were determined using a precision optical microscope. While the grid spaceing can be determined with good accuracy, the wire size is more uncertain because of etching irregularities. The grid spacing was 0.0636 ± 0.0002 mm and the opening size was 0.055 ± 0.002 mm and 0.052 ± 0.002 mm parallel and perpendicular to the plane of incidence, respectively. Because of uncertainties of wire dimension, the opening size was adjusted slightly to fit the theory. The resultant opening dimensions were 0.052 mm and 0.051 mm.

Theoretical

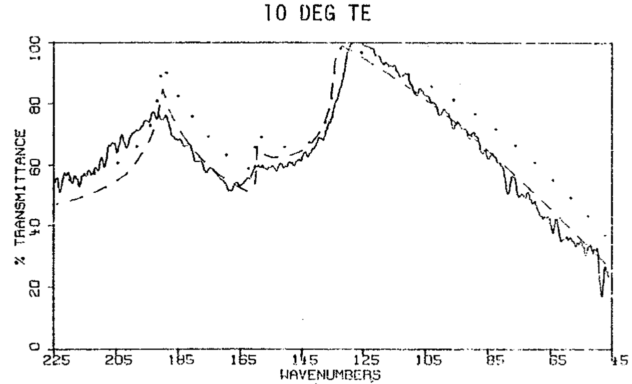
In Chen's theory, the fields in free space are perodic Floquet modes, and the aperture fields are expanded in waveguide modes. The solution for transmission and reflection involves finding the overlap between the Floquet modes and the waveguide modes and solving a set of complex linear equations for the amplitude of waveguide modes excited by the incident field. Like the waveguide modes, the Floquet modes are characterized by a cut-off frequency. Above this frequency the Floquet mode represents one of the Bragg diffraction orders, while below cut-off the Floquet mode is a surface wave. It is the surface waves which contribute the inductive character to the grid.

In principle, Chen's theory is exact if sufficient Floquet modes and waveguide modes are included and if the theory is reasonably insensitive to the differences between an ideal and real mesh geometry. Chen found that the solution converged for 200 Floquet modes and approximately 10 waveguide modes. Following a suggestin by McPhedran and Maystre [4], Durschlag and DeTemple found that good results for normal incidence can be obtained using only one waveguide mode. However, as Chen showed in two examples, use of one mode at high incidence angles is less likely to give satisfactory resullts. In our calculations we found that use of 200 Floquet modes was also adequate but that 14 waveguide modes were often required to give satisfactory agreement. This set of 14 waveguide modes includes all TE_{mn} and TM_{mn} modes such that $m + n \leq 3$. Use of more modes than this is not likely to be of practical utility since a mesh of finite thickness will be quite effective in quenching higher order modes.

NORMAL



10 DEG TE



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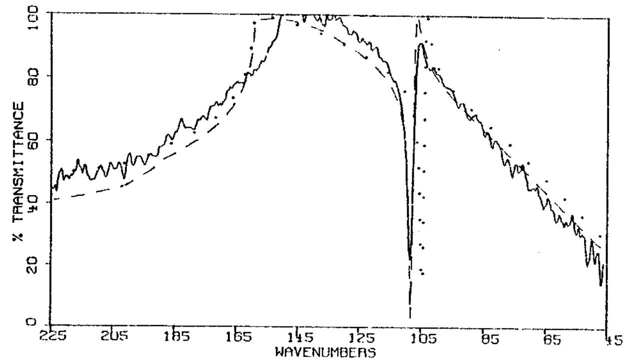

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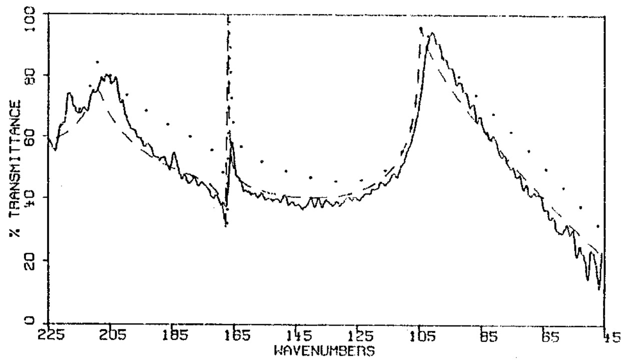

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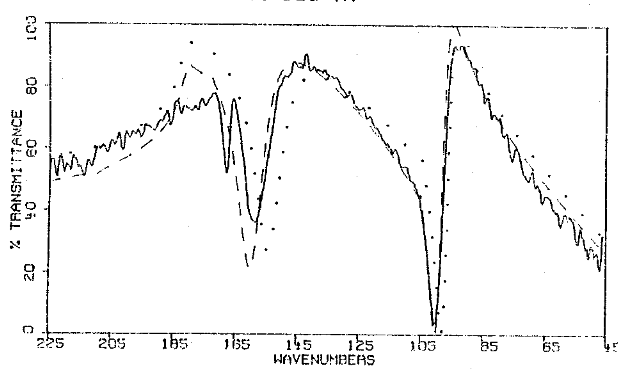

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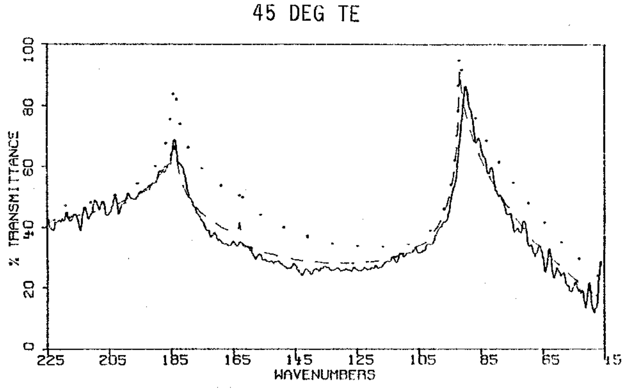

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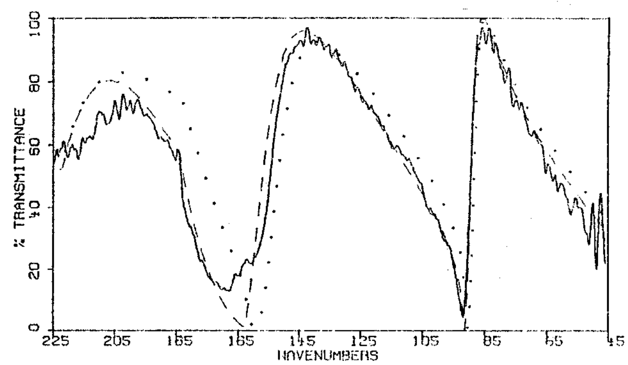

Results

Measurements were made at incidence angles of 0°, 10°, 30° and 45° for both polarizations. Following Chen, we label polarization with the E field perpendicular to the plane of incidence as a TE mode and polarization with the E field parallel to the plane of incidence as a TM mode. For all measurements the grid wires were parallel to the plane of incidence. In the figures the solid line is experiment, the dots are the theory with measured opening sizes, and the dashed are theory with adjusted opening sizes. As can be seen from the figures, agreement is excellent with the multimode theory. The agreement is very poor with the single mode theory and indeed the longest wavelength resonance for TM is not even predicted by the single mode theory. This resonance is not directly related to the onset of diffraction but is rather due to an interaction between the TE_{01} mode and a mixture of higher order modes dominated by the TE_{11} mode. We conclude that the theory developed by Chen can be condfidently used to predict a priori how a mesh will perform in a quasi-optical device for all incidence angles. It appears that the theory is insensitive to details of the mesh geometry, provided that enough modes are used in the expansion.

Acknowledgement

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References

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