A POLARIZING, REINFORCED, BROAD-BAND ANISOTROPIC PANEL

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INTRODUCTION

The panel to be described below, while not originally intended for radome use, might nevertheless be of interest in radomes for the following reasons:

a. The panel can be used in its present form to obtain circular polarization over a broad-band of frequencies.

b. The metallic sheets could serve as reinforcing for the panel.

c. The combination of anisotropic dielectric with the metallic sheets might, through modificaton of the present panel, effect an improvement in the transmission parameters of the panel.

The panel consists of an anisotropic dielectric with ϵ_y in the y direction greater than ϵ_x in the x direction, propagation through the panel being in the Z direction. At intervals along the y axis there are imbedded in the panel metallic sheets whose planes are parallel to the X-Z plane. A y oriented linearly polarized wave is not affected by the metallic sheets, its propagation constant in the panel being determined ϵ_y and ω. An X oriented linearly polarized wave has a propagation constant in the panel which is affected by the metallic sheets as well as by ϵ_x and ω. The X oriented wave, while in the panel, is in effect in a wave guide whose cut-off wave length is twice the electrical distance between metallic sheets. Because of this and because $\epsilon_y > \epsilon_x$ the curves of propagation constants vs frequency are very nearly parallel to each other over a broad band of frequencies. By properly choosing the panel thickness a differential phase shift of 90° can be obtained for the x and y oriented waves. If a wave linearly polarized at an angle of approximately 45° with respect to the y axis is incident normally upon the panel, a circularly polarized wave will be transmitted through the panel.

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ANALYSIS

Figure 1 shows the important dimensions of the panel and in addition shows a plane linearly polarized wave incident upon one face of the panel. This wave has electric field components E_x and E_y both being equal in magnitude and in time phase with each other. Ideally these two components should be transmitted with no attenuation, but with a 90° differential phase shift in time between the emerging fields.

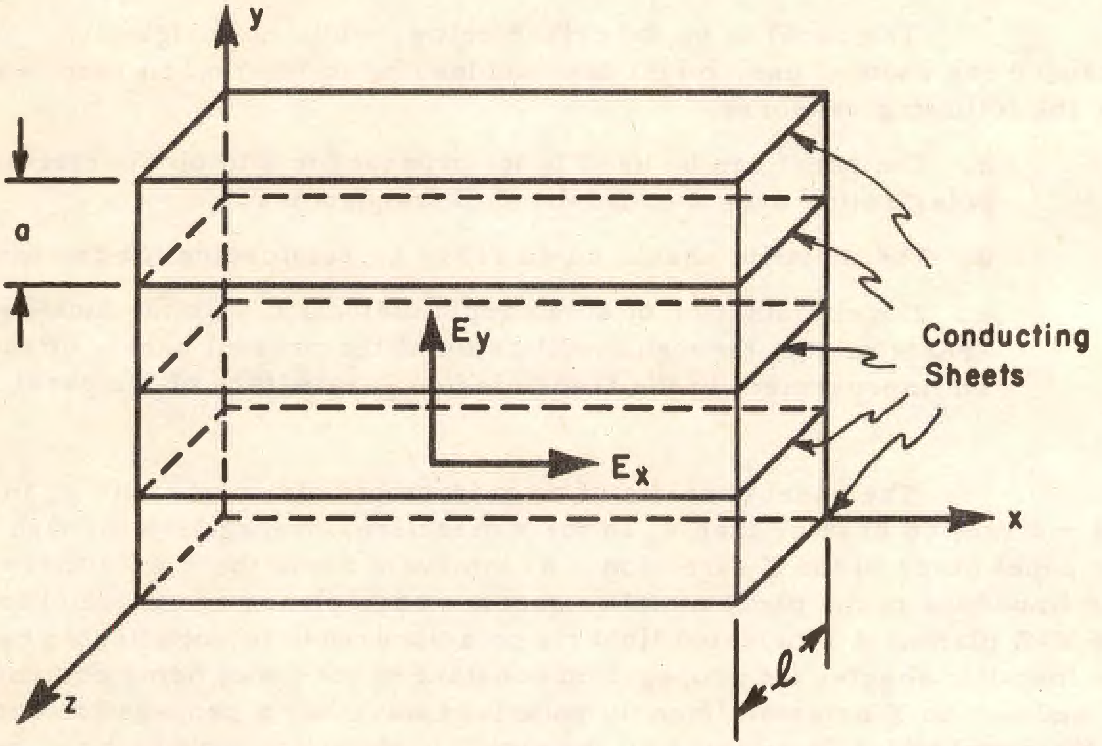


Fig. 1.

Figure 2 shows the phase constants for the x and y polarized waves. The frequency ω_o is that frequency at which the slopes of the two curves are equal. This is taken as the center of a frequency band over which the differential phase constant is very nearly constant. The phase constants are given by

$$\beta_y = \frac{2\pi}{\lambda} \sqrt{k_y} \tag{1}$$

$$\beta_x = \frac{2\pi}{\lambda} \sqrt{k_x - \left(\frac{\lambda}{2a}\right)^2} \tag{2}$$

where λ is the free space wave length of the wave. Letting λ_o denote the free space wavelength at the center frequency ω_o then,

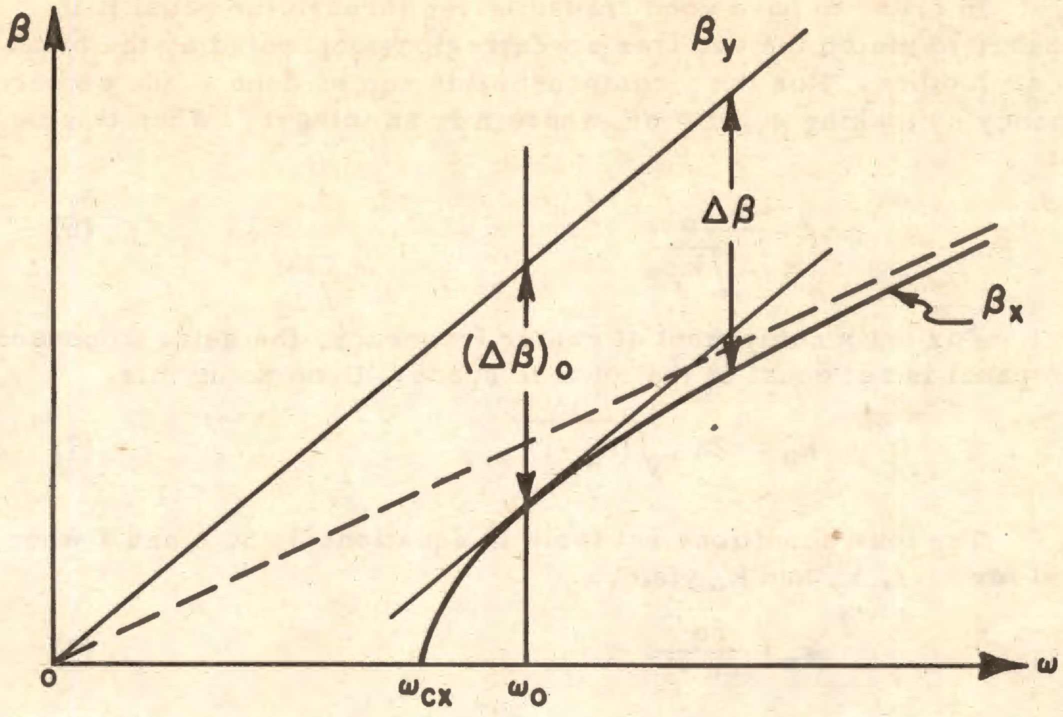


Fig. 2.

$$\lambda_o = 2a\sqrt{k_x\left(1 - \frac{k_x}{k_y}\right)} \qquad (3)$$

At this wavelength the differential phase constant $(\Delta\beta)_o$ is,

$$(\Delta\beta)_o = \frac{\pi}{a}\sqrt{\frac{k_y - k_x}{k_x}} \qquad (4)$$

In order to achieve a 90° differential phase shift at the wave length λ_o it is necessary to choose ℓ so that $\ell\,(\Delta\beta)_o = \pi/2$. When this is done,

$$\ell = \frac{a\sqrt{k_x}}{2\sqrt{k_y - k_x}} \qquad (5)$$

In order to have good transmission through the panel it is necessary to match the two free space regions separated by the panel from each other. For the y component this can be done at the center frequency by making $\beta_{yo} \ell = n\pi$ where n is an integer. When this is done,

$$\ell = \frac{n \lambda_o}{2\sqrt{k_y}} \qquad (6)$$

For the x component at center frequency, the guide impedance in the panel is set equal to that of free space. Upon doing this,

$$\lambda_o = 2a \sqrt{(k_x - 1)} \qquad (7)$$

The four conditions set forth in equations 3, 5, 6 and 7 when solved for a, ℓ, k_x and k_y yield,

$$k_x = \frac{2n}{2n - 1} \qquad (8)$$

$$k_y = k_x^2 \qquad (9)$$

$$a = \frac{\lambda_o}{2\sqrt{k_x - 1}} \qquad (10)$$

$$\ell = \frac{n \lambda_o}{2 k_x} \qquad (11)$$

For example at $\lambda_o = 3.00$ cm if n = 3 there results,

$k_x = 1.20$ $\quad$ a = 3.35 cm, (= 1.32 inches)

$k_y = 1.44$ $\quad$ ℓ = 3.75 cm, (= 1.477 inches)

Figure 3 shows the calculated axial ratio for this panel over a band of frequencies from to mc.

EXPERIMENTAL RESULTS

Using polystyrene and polyfoam it was not possible to construct an artificial anisotropic dielectric with the above relative dielectric constants. Instead a panel was constructed using an anisotropic dielectric having the

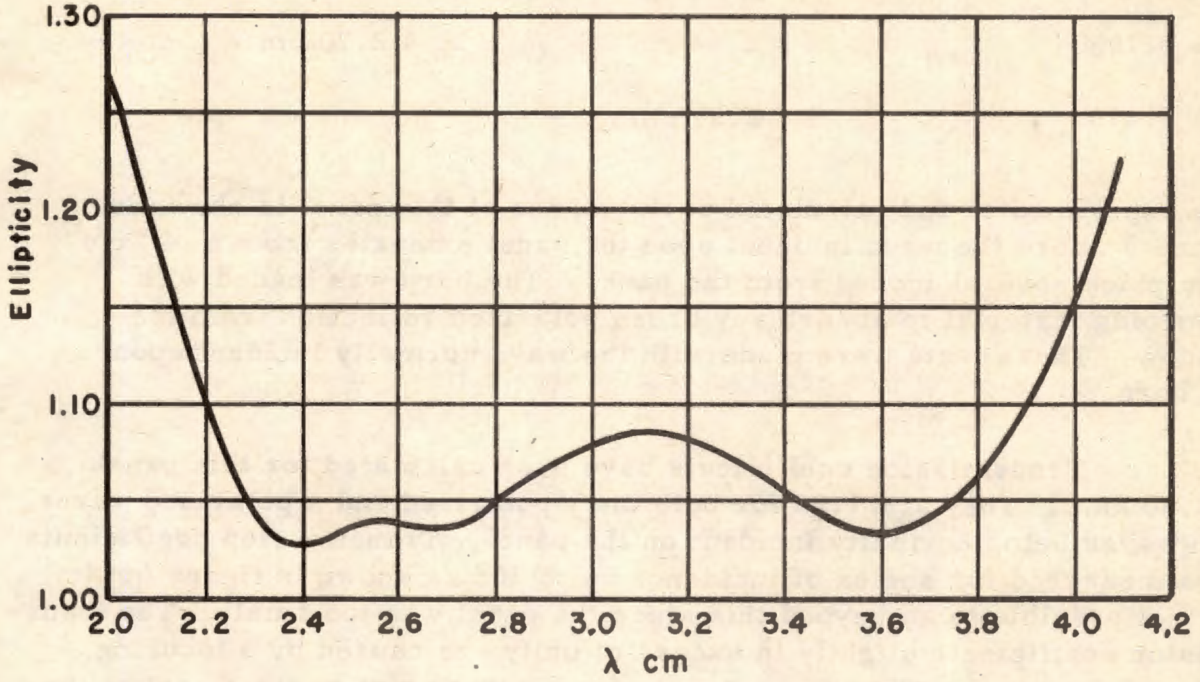

1.30
1.20
1.10
1.00
Ellipticity
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
λ cm

Figure 3

maximum ratio k_y/k_x obtainable from polystyrene and polyfoam. This panel, the dimensions of which are tabulated in Table I, is shown in figure 4.

Table I

Dimensions of Experimental Panel

$k_y = 1.795$	$a = 2.64$ cm	$\lambda_o = 2.70$ cm
$k_x = 1.470$	$\ell = 2.59$ cm	

The experimental and calculated performance of this panel is shown in figure 5 where the wave incident upon the panel emanates from a 4" x 4" horn place several inches from the panel. The horn was loaded with absorbing material to absorb any cross polarized reflection from the window. These tests were made with the wave normally incident upon the horn.

Transmission coefficients have been calculated for this panel at 8.80 kmc. They are 1.00 for both the y polarized and x polarized waves, both waves being normally incident on the panel. Transmission coefficients were measured for angles of incidence up to 30° as shown in figure 6. It was not possible to go beyond this since the panel was too small. The transmission coefficients slightly in excess of unity are caused by a focusing effect of the panel. The rays emanate from some point on the throat of the horn and are refracted toward the normal in the panel. After emerging from the panel, they appear to emanate from a "virtual" source somewhat closer to the panel than the actual source.

CONCLUSIONS

This panel, which contains metallic sheets as an integral part of the panel, offers some interesting possibilities for possible radome use. Further analysis and experimental work will have to be done in order to achieve those transmission properties which are desirable for radomes.

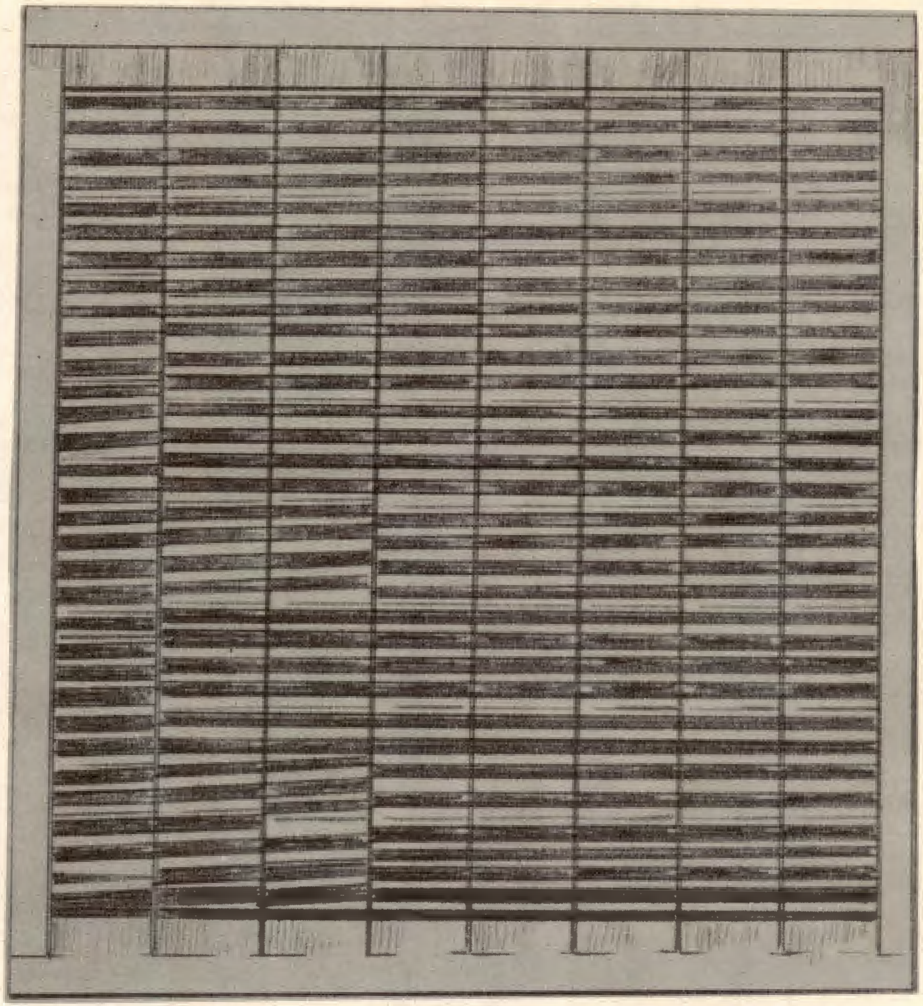


Figure 4

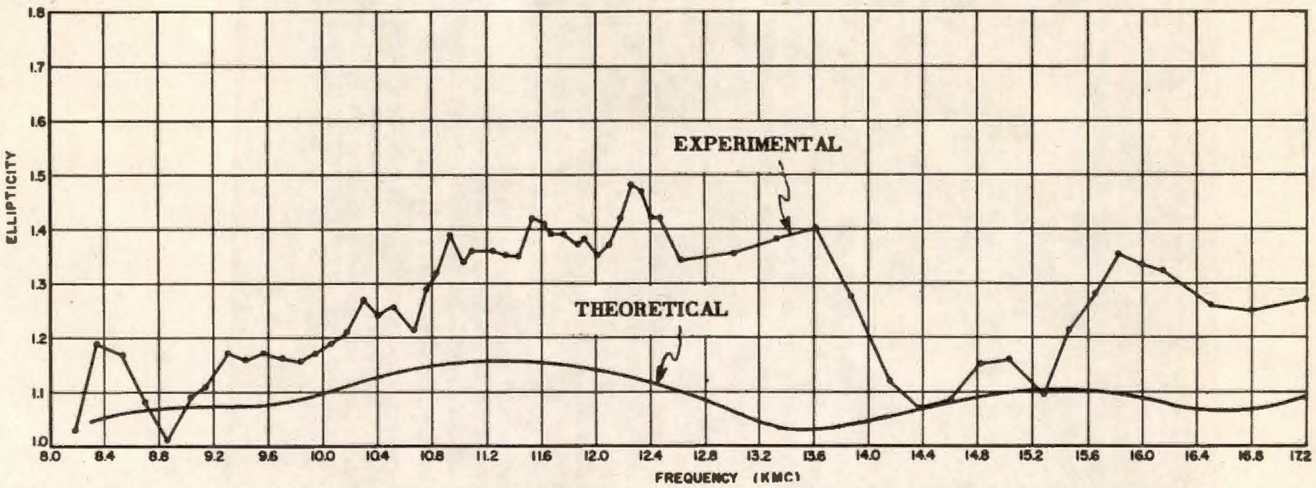
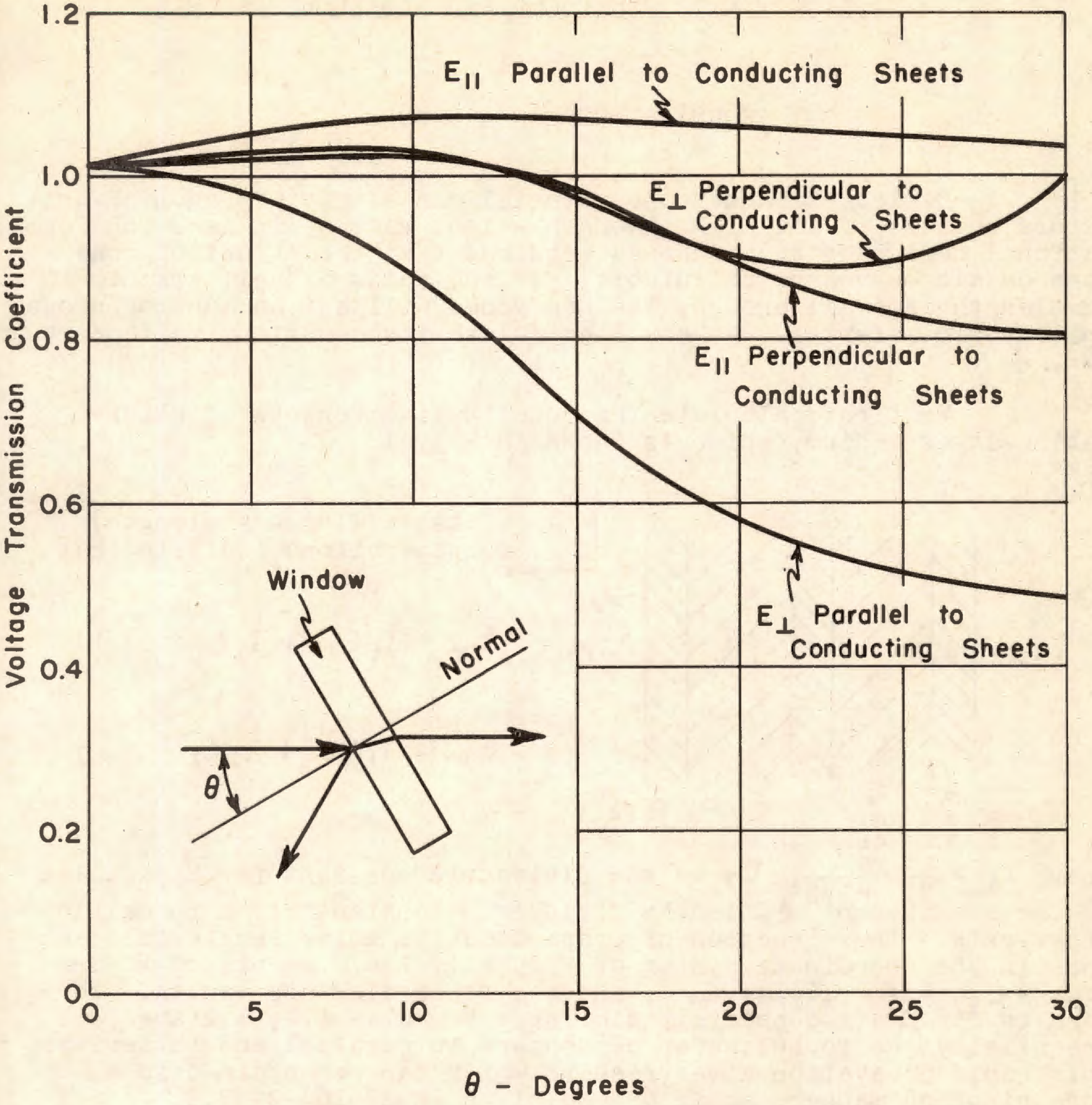

ELLIPTICITY
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
EXPERIMENTAL
THEORETICAL
8.0
8.4
8.8
9.2
9.6
10.0
10.4
10.8
11.2
11.6
12.0
12.4
12.8
13.2
13.6
14.0
14.4
14.8
15.2
15.6
16.0
16.4
16.8
17.2
FREQUENCY (KMC)

Fig. 5



1.2
1.0
0.8
0.6
0.4
0.2
0
Voltage Transmission Coefficient
$E_{\parallel}$ Parallel to Conducting Sheets
$E_{\perp}$ Perpendicular to Conducting Sheets
$E_{\parallel}$ Perpendicular to Conducting Sheets
$E_{\perp}$ Parallel to Conducting Sheets
Window
Normal
θ
0
5
10
15
20
25
30
θ - Degrees

Figure 6