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The Effects of Ground Plane and Parasitic Layer on Linearly Tapered Slot Antenna

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Abatract : The effects of a large ground plane and an upper parasitic layer on a linearly tapered slot antenna has been experimentally investigated. Results indicate that the presence of a large ground plane causes the beam to steer by as much as 50° from the endfire direction in the H-plane. With the addition of a parasitic layer above the fed antenna, further beam scanning can be achieved when the spacing between the fed and parasitic layers is properly chosen.

Introduction : Linearly tapered slot antennas (LTSAs) of both coplanar or antipodal types have been demonstrated to have higher gain and broader bandwidth than microstrip antennas [1]. Because these antennas radiate in the endfire direction, they are very suitable for use in arrays of "brick" architecture [2]. Another important application for the LTSA is in mobile and wireless communications [3]. The LTSA can be mounted conformal or in close proximity to a metal surface, such as the body of a vehicle or an aircraft. These applications often require a radome to protect the antenna from extreme environmental conditions. Previous studies on LTSA treat the antenna as an isolated radiator without taking into consideration of the ground plane and radome effects. In practice in real antenna system designs, these effects impacts the antenna performance and must be taken into consideration. This paper reports for the first time an experimental investigation of the ground plane and radome effects on the performance of a planar LTSA. In the experiment, a parasitic layer is used as the radome.

Antenna configuration : Figures 1 (a) and (b) show the schematic of the LTSA used in the experiment. The LTSA with a length of L=6.6 cm and a taper angle of $2\alpha=11.2°$ is formed by gradually increasing the width of the slotline from its feed end to an open end of width H. The LTSA is excited with a finite coplanar waveguide (CPW) feed [1]. RF power is electromagnetically coupled to the antenna through the center conductor of the CPW feed which is extended to form a CPW-to-slotline transition with the LTSA. The slotline at the feed end has a circular bend to provide a smooth transition. The entire circuit is fabricated on 0.0508 cm thick RT/Duroid 5880 ($\epsilon_r=2.2$) substrate. In the experiment, an identical LTSA (without the CPW feed) was used as a parasitic layer, and foam spacers were used to separate the parasitic/fed antenna layers and the ground plane. To simplify the feed connection, the parasitic layer and the ground plane cover only the LTSA portion of the substrate as shown in Fig. 1(c).

Results and discussion : (a) LTSA with ground plane only : To study the ground plane effect, the LTSA shown in Figures 1 (a) and (b) was placed over a copper ground plane separated by form spacers. Results for the H-plane patterns are shown in Figure 2. With a ground plane placed immediately below the fed LTSA and with no spacer, the beam is scanned by about 50° in the H-plane. The amount of scan decreases from 50° to about 35° and to 25° as the spacings of separation is increased from zero to 0.3175 cm (0.116 λ_o) and to 0.635 cm (0.232 λ_o) respectively. In general, the effect of the ground plane diminishes as the distance between the antenna and the ground plane increases. For comparison purpose, radiation pattern of a LTSA without a ground plane was also measured. In the experiments with ground plane, no significant change was observed in the E-plane patterns except that the LTSA had to be tilted in the elevation to receive full power. In addition to beam scanning, approximately 2 dB higher directivity was observed with the LTSA having a ground plane. (b) LTSA with a ground plane and a parasitic layer : To study the parasitic effects, a parasitic layer with a 0.9525 cm foam spacer was superimposed on a LTSA which is arbitrarily chosen to be 0.3175 cm above a ground plane. Figure 3 shows the H-plane patterns for the LTSA with a ground plane only and that with a ground plane and a parasitic layer. Adding a parasitic layer to the LTSA with a ground plane improves the beam scan from about 35° to 42° in the H-plane, but often requires further impedance matching in order to optimize power reception.

Conclusion : The effects of a ground plane and a parasitic layer on a linearly tapered slot antenna was experimentally investigated. Results indicate that a 50° beam scan can be achieved by placing a LTSA closely over a ground plane. Further improvement in beam scanning is possible by superimposing a parasitic layer to the antenna. The multilayer LTSA has been demonstrated to have excellent radiation patterns and higher directivity compared to an isolated LTSA. Because of its low profile and its ability to scan, this antenna has high potential for mobile communication applications.

References :

(1) Lee, R.Q. and Simons, R.N., "Linearly Tapered Slot Antennas and Feed Network", **Proceeding of the 1993 Antenna Application Symposium**, September 1993.

(2) Yngvesson,K.S., Schaubert, D.H., Korzeniowski, E.L., Thungren, T. And Johansson, J.F., "Endfire Tapered Slot Antennas on Dielectric Substrates", **IEEE Trans. Antenna Propagation**, Vol. AP-33, No. 12, pp. 1392-1400, Dec. 1985.

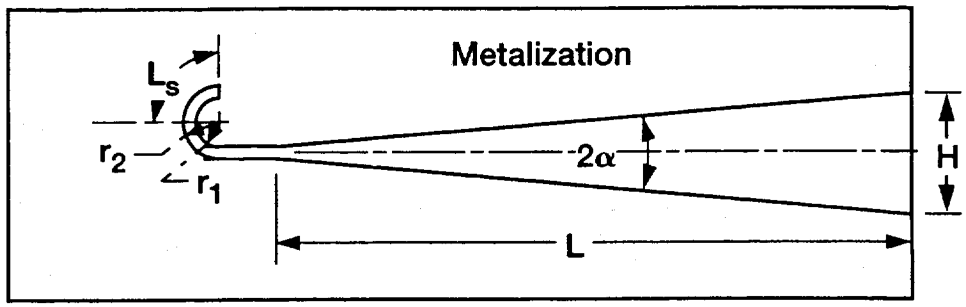
(3) Simons, R.N., Kelly, E., Lee, R.Q. and Taub, S.R., "Linearly Tapered Slot Antenna Circular Array for Mobile Communications", **International Conference on Millimeter and Submillimeter Waves and Applications**, Afsar, M.N., Editor, **Proc. SPIE 2250**, pp. 20-22, January 1994.

Figure Captions

Figure 1. Schematic for the LTSA and the CPW feed circuit: (a) Top metallization/antenna layer - r_1=2.171 mm, r_2=2.425 mm, L_s=3.43 mm, (b)Bottom metallization/feed layer- S=0.762 mm, W=0.254 mm, G=5.08 mm, L_w=2.951 mm, ϵ_r=2.2, and (c) side view of the multilayer LTSA structure: D_1=0.508 mm, D_2=0.254 mm.

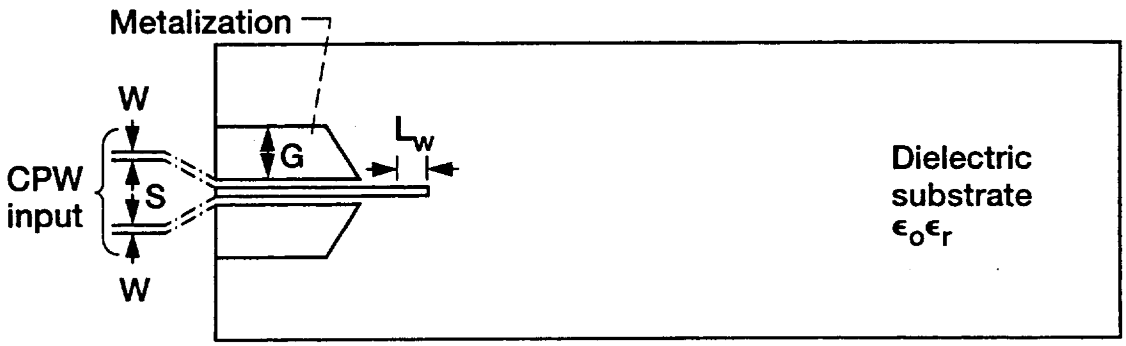
Figure 2. H-plane patterns for a LTSA over a ground plane having different spacings of separation at 11 GHz : – – – without a ground plane; ---- with a ground plane and no spacer; —— with a ground plane and a 0.3175 cm form spacer; —- - with a ground plane and a 0.635 cm form spacer.

Figure 3. H-plane patterns for a LTSA over a ground plane with and without a parasitic layer at 11 GHz: —— with a ground plane only; ------ with a ground plane and a parasitic layer.



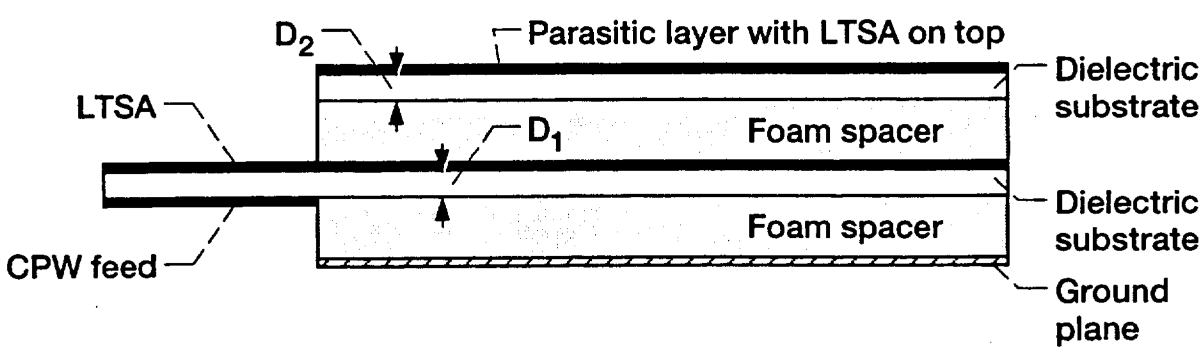
Metalization
L_s
r_2
r_1
2α
H
L

(a)



Metalization
W
CPW
input
S
W
G
L_w
Dielectric
substrate
$\epsilon_o\epsilon_r$

(b)



D_2
Parasitic layer with LTSA on top
Dielectric
substrate
LTSA
D_1
Foam spacer
Foam spacer
Dielectric
substrate
CPW feed
Ground
plane

(c)

Fig 1

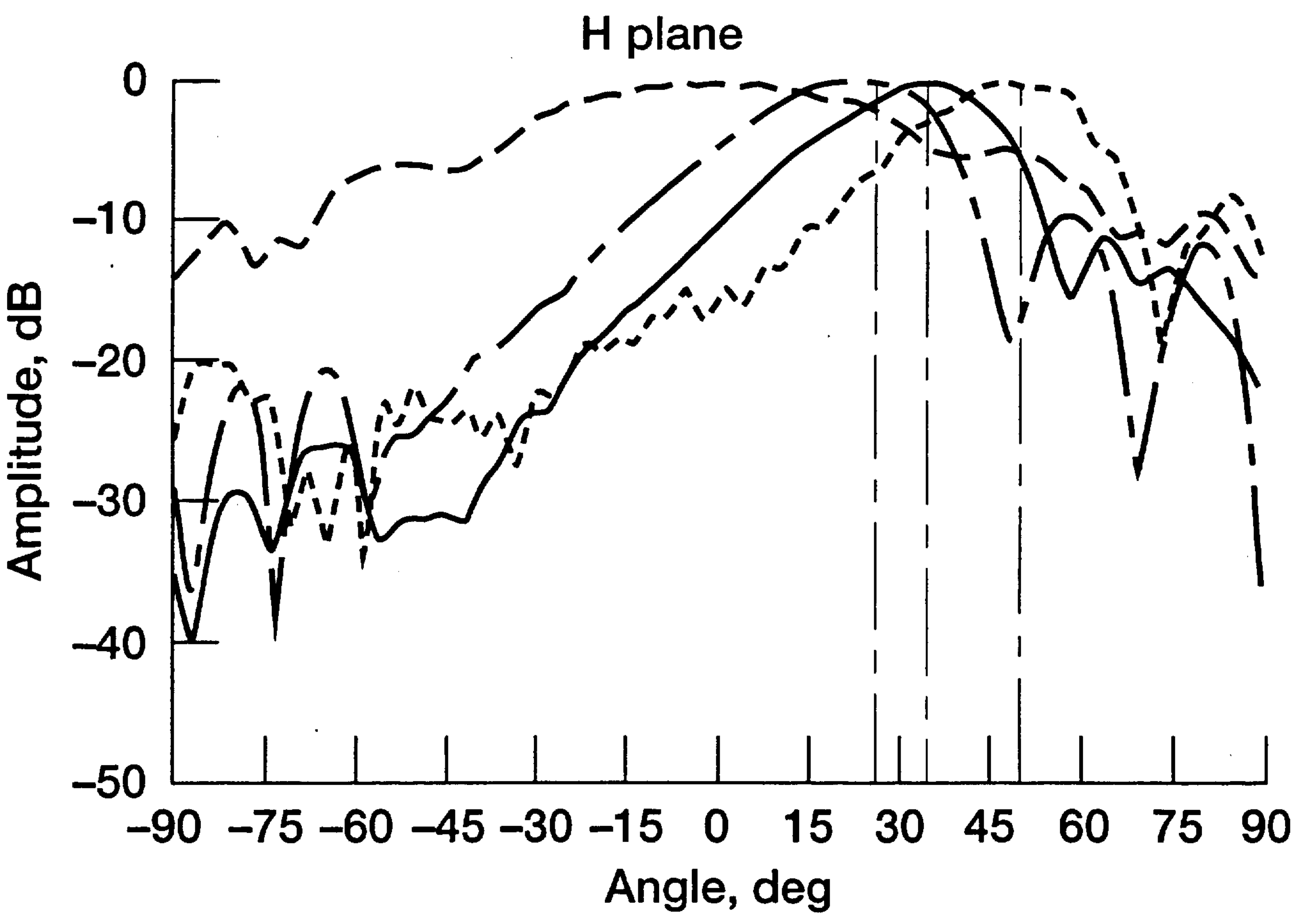
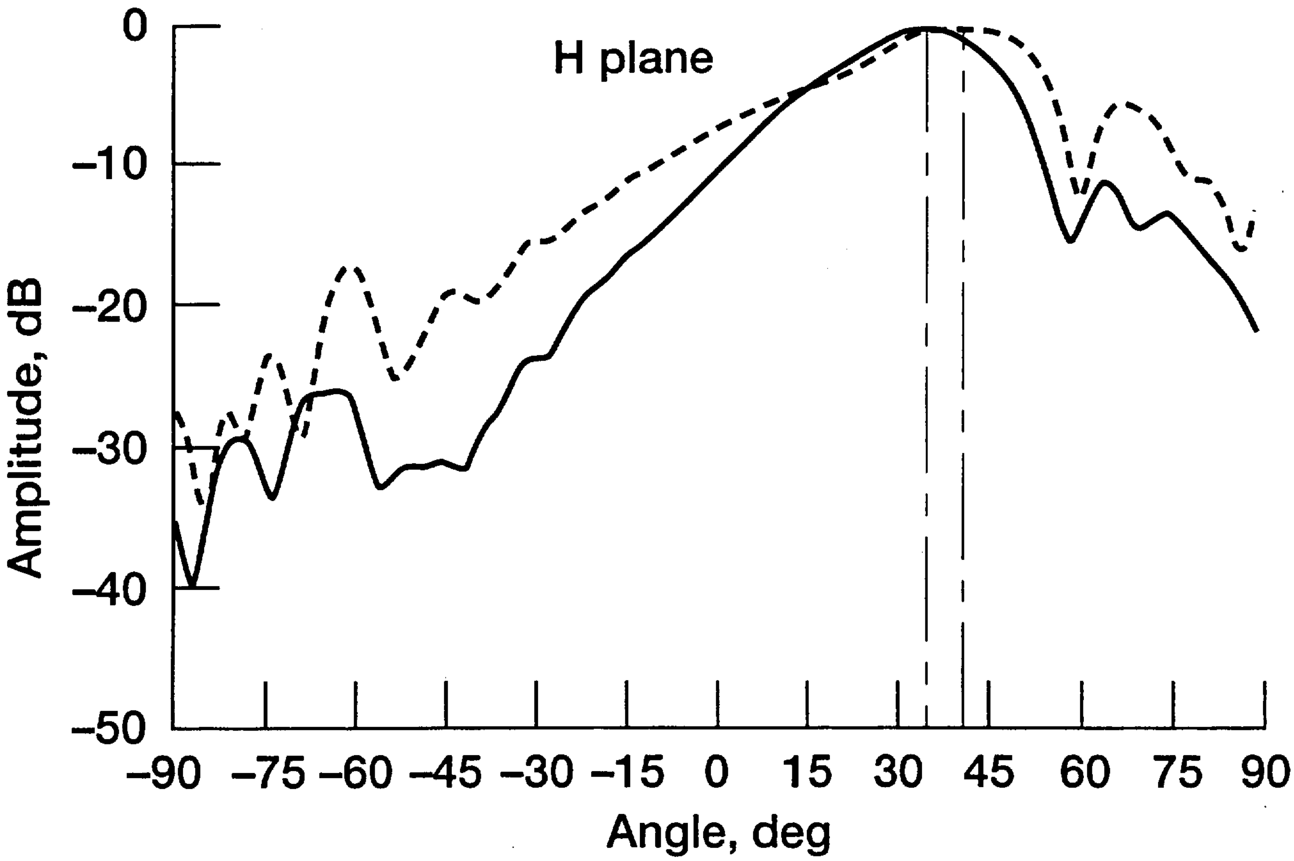

H plane
0
–10
–20
–30
–40
–50
Amplitude, dB
–90 –75 –60 –45 –30 –15 0 15 30 45 60 75 90
Angle, deg

Fig. 3


H plane
0
−10
−20
−30
−40
−50
Amplitude, dB
−90
−75
−60
−45
−30
−15
0
15
30
45
60
75
90
Angle, deg