Stripline Fed Tapered Slot Antenna

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Abstract— Development of a strip line fed linearly tapered slot antenna has been presented. The basic antenna is designed theoretically. The performance of the antenna has been optimized using commercially available finite element based simulation software HFSS. The antenna is then fabricated using dimensions optimized by simulation. 31 mil substrate of dielectric permittivity 2.2 has been used as the substrate material. Antenna performance is measured in a Compact Antenna Test Range. Measured results are also presented.

I. Introduction

Microstrip antennas are inherently narrowband. In spite of that microstrip antennas are popularly used for many applications due to its low profile characteristic. But the bandwidth enhancement has always been a subject of interest for the antenna engineers, especially over the last two decades. Number of techniques for the microstrip and printed antennas have been developed to achieve more than 50% bandwidth. Strip line fed tapered slot antenna has gained the importance because of its ability to produce large impedance bandwidth. A tapered slot antenna uses a flared slot line etched on a dielectric substrate to produce an end-fire pattern from a surface wave.

In this paper the development of a strip line fed tapered slot antenna has been presented. Relevant simulation and measurement results are also given.

II. Design of the Antenna

The basic strip line fed tapered slot antenna configuration is shown in Fig. 1. The antenna consists of three layers. The top and the bottom layer consist of metallization which is etched away in an identical manner on dielectric substrates. A linear slot is used as a feed to the tapered slot elements. The intermediate layer consists of the 50Ω strip line feed. The feed line protrudes between and past the feed slots. The values of the slot width and length are determined by simulation. The slot act as a transmission line matched to feed the strip line at the input. A circular open circuit of radius R is attached to the slot. The linear taper begins after this slot. The opening angle of this antenna ranges from 5° to 12°. The stripline feed terminates in a radial stub

The dielectric substrate slows the wave in the slot and increases gain. The effective dielectric thickness can be calculated using equation 1.

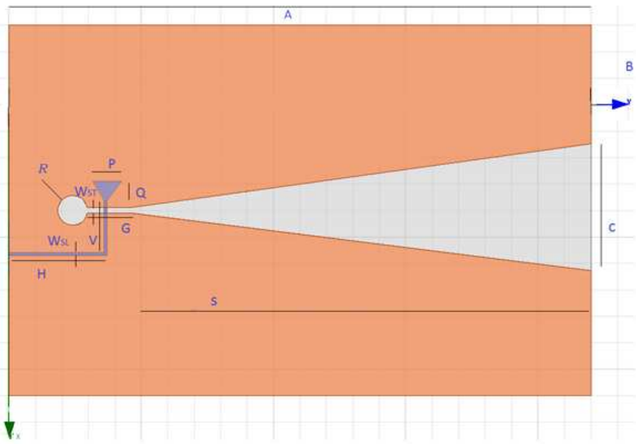

Fig. 1. Single surface lens with hyperbolic profile.

$$\frac{t_{eff}}{\lambda} = \left(\sqrt{\varepsilon_r} - 1\right)\frac{t}{\lambda}$$

Thinner substrates produce insufficient slowing and thicker substrate produce too much slowing, which brakes up the main beam. The optimum value of t_{eff} / λ is obtained by simulation. Lowering the dielectric permittivity produces broader beamwidth with decreased sidelobes.

III. Design of the Antenna

Extensive simulations have been carried out to optimize the performance of the antenna. The optimum dimensions of the antenna have been achieved after parametric investigations.

TABLE - I
Variation of Bandwidth, Beamwidth, Gain with Length of the Ground Plane

$h_1 = h_2 = 0.7874$ mm, $\varepsilon_1 = \varepsilon_2 = 2.2$, $W_G = 70$mm, $L_A = 86.8$mm, $W_A = 24$mm, $R = 2.82$mm

Ground Plane Length L_G (mm)	Bandwidth (GHz)	3dB beamwidth (deg)		Gain (dBi)
		E-plane	H-plane	
100	2.3-10.3	58	60	9.1
110	1.6-9.65	61	62	9.1
120	1.6-10.8	68	66	9.1
130	2.0-10.5	66	66	9.1
140	2.0-10.6	66	66	9.1

The variations of bandwidth, beamwidth, gain of the antenna with the length of the ground plane has been investigated and are given in Table-I. It is observed that maximum bandwidth is achieved at L_G=120mm.

TABLE - II
VARIATION OF BANDWIDTH, BEAMWIDTH, GAIN WITH WIDTH OF THE GROUND PLANE

$h_1 = h_2 = 0.7874$ mm, $\varepsilon_1 = \varepsilon_2 = 2.2$, L_G =120mm, L_A=86.8mm, W_A=24mm, R=2.82mm

Ground Plane Width W_G (mm)	Bandwidth (GHz)	3dB beamwidth (deg)		Gain (dBi)
		E-plane	H-plane	
50	2.1-9.86	63	66	9.1
60	2.4-10.7	63	66	9.1
70	1.6-10.8	63	66	9.1
80	1.6-10.2	63	64	9.1
90	1.65-9.8	64	64	9.1

TABLE - III
VARIATION OF BANDWIDTH, BEAMWIDTH, GAIN WITH LENGTH OF THE TAPERED SLOT

$h_1 = h_2 = 0.7874$ mm, $\varepsilon_1 = \varepsilon_2 = 2.2$, W_A =24mm, L_G=120mm, W_G=70mm, R=2.82mm

Tapered Slot Length L_A (mm)	Bandwidth (GHz)	3dB beamwidth (deg)		Gain (dBi)
		E-plane	H-plane	
80	2.1-10.9	80	68	9.1
85	1.9-10.45	78	66	9.1
86.8	1.6-10.8	78	68	9.1
90	1.65-10.75	78	66	9.1
100	1.56-10.9	80	68	9.1

The variations of bandwidth, beamwidth, gain of the antenna with the width of the ground plane have been investigated and are given in Table-II. It is observed that maximum bandwidth is achieved at W_G=70mm.

TABLE - IV
VARIATION OF BANDWIDTH, BEAMWIDTH, GAIN WITH WIDTH OF THE TAPERED SLOT

$h_1 = h_2 = 0.7874$ mm, $\varepsilon_1 = \varepsilon_2 = 2.2$, L_A =86.8mm, L_G=120mm, W_G=70mm, R=2.82mm

Tapered Slot Width W_A (mm)	Bandwidth (GHz)	3dB beamwidth (deg)		Gain (dBi)
		E-plane	H-plane	
20	1.4-10.2	68	68	9.1
22	1.4-10.5	68	68	9.1
24	1.6-10.8	68	66	9.1
26	1.7-10.9	68	66	9.1
30	2.1-11.1	68	66	9.1

The variations of radiation parameters with the length of the tapered slot have been investigated and are given in Table-III. The maximum bandwidth is achieved at L_A=86.8mm. The parametric variations of radiation parameters with the width of the tapered slot have been investigated and are given in Table-IV. The maximum bandwidth results at W_A=24mm.

TABLE - V
VARIATION OF BANDWIDTH, BEAMWIDTH, GAIN WITH WIDTH OF THE TAPERED SLOT

$h_1 = h_2 = 0.7874$ mm, $\varepsilon_1 = \varepsilon_2 = 2.2$, L_A =86.8mm, L_G=120mm, W_G=70mm, W_A =24mm

Circular Cavity Radius R (mm)	Bandwidth (GHz)	3dB beamwidth (deg)		Gain (dBi)
		E-plane	H-plane	
2.70	1.5-10.4	65	65	9.1
2.75	1.7-10.6	66	66	9.1
2.82	1.6-10.8	66	66	9.1
3.00	1.5-10.6	66	66	9.1
3.20	1.5-10.55	65	65	9.1

The variations of radiation parameters with the radius of the circular cavity have also been investigated and are given in Table-V. The maximum bandwidth is achieved at R=2.82mm.

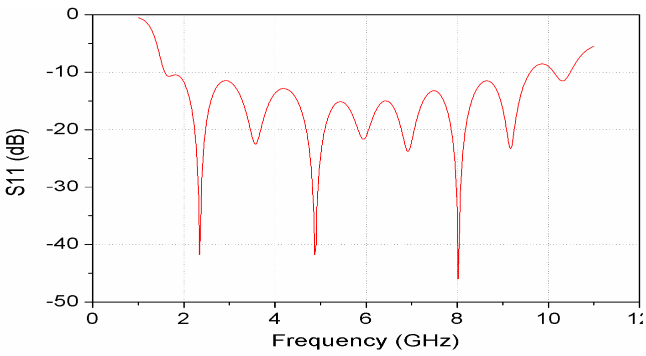

Fig. 2. Simulated S11 of the Linear Tapered Slot Antenna.

Simulated return loss of the antenna with the optimized dimensions is shown in Fig. 2. The return loss is less than -10dB over the frequency range 1.76GHz to 10.9GHz. The simulated elevation and azimuth plane radiation patterns are shown in Fig.3. and Fig.4. respectively. Simulated 3dB beamwidth in E-plane is 68° and in H-plane is 66°.

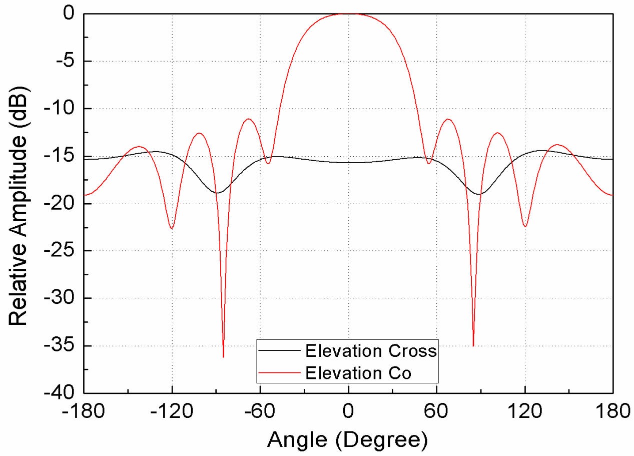

Fig. 3. Simulated elevation plane radiation pattern at 5 GHz of the Linear Tapered Slot Antenna.

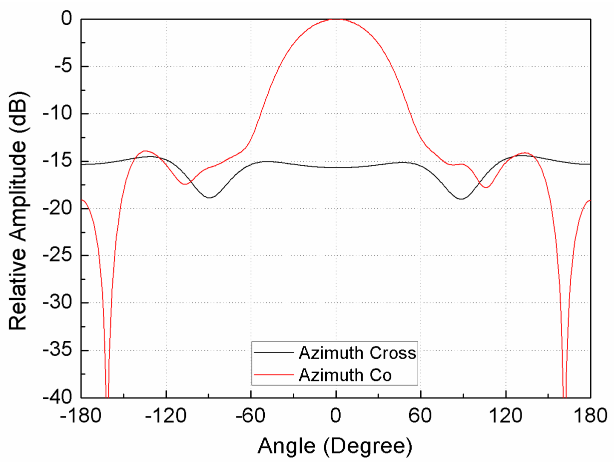

Fig. 4. Simulated azimuth plane radiation pattern at 5 GHz of the Linear Tapered Slot Antenna.

IV. MEASURED RESULTS

The antenna is fabricated with the theoretically obtained dimensions on 31mil thick dielectric substrate of permittivity 2.2. The fabricated antenna is shown in Fig.5. Antenna performance is measured in a Compact Antenna Test Range (CATR). Measured reflection coefficient is shown in Fig.6. The plot shows -10dB reflection coefficient bandwidth of about 6GHz (from 5.5GHz to 11.6 GHz). The antenna also has two discrete band around 3GHz (bandwidth ≈1.4GHz) and 4.5 GHz (bandwidth ≈0.4GHz).

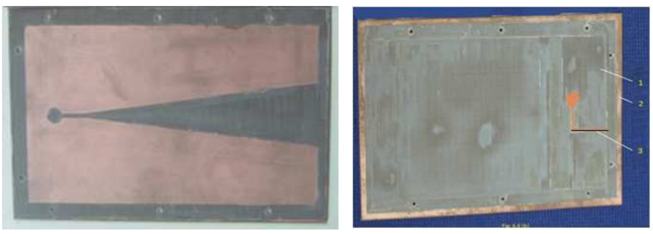

Fig. 5. Fabricated Linear Tapered Slot Antenna, Tapered Slot (left) and stripline feed (right) .

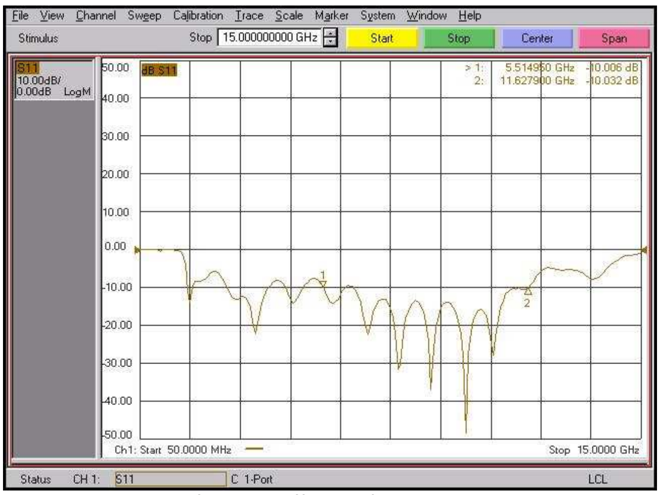

Fig. 6. Measured reflection coefficient of the Linear Tapered Slot Antenna.

Measured azimuth and elevation plane radiation patterns along with cross polarization pattern at 5.6GHz are shown in Fig.7. Measured 3dB beamwidth of the antenna is 50.4° in the azimuth plane and 63.6° in the elevation plane. 1st side lobe is about 10 dB below the main beam peak in both azimuth and elevation plane. Measured cross polarization is better than -38dB.

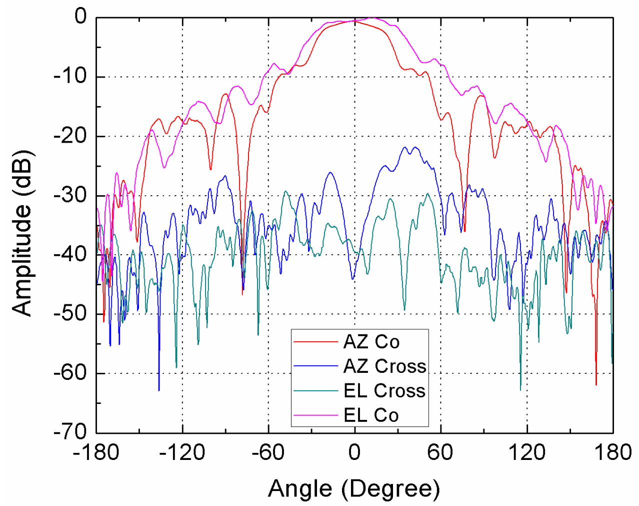

Fig. 7. Measured azimuth and elevation plane radiation pattern at 5.6GHz.

Measured azimuth and elevation plane radiation patterns along with cross polarization pattern at 8GHz are shown in Fig.8. Measured 3dB beamwidth of the antenna is 30.9° in the azimuth plane and 36.2° in the elevation plane. In the azimuth plane pattern, the 1st side lobe is 12.7dB below the main beam peak. Measured cross polarization is better than -32dB.

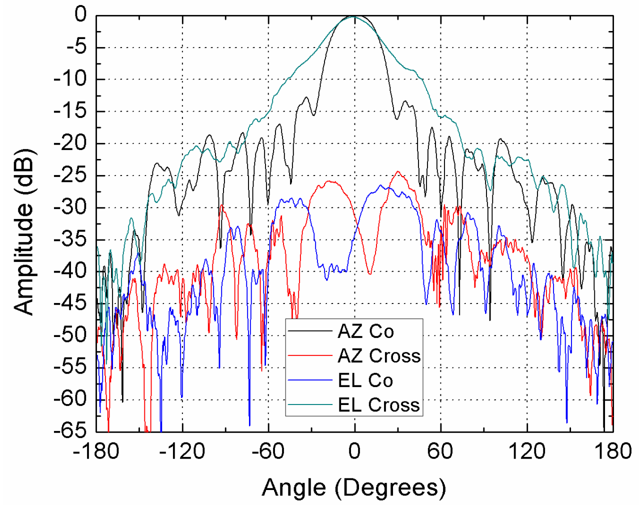

Fig. 8. Measured azimuth and elevation plane radiation pattern at 8GHz

Measured azimuth and elevation plane radiation patterns at 11GHz are shown in Fig.9. along with cross polarization pattern. Measured 3dB beamwidth of the antenna is 21.9° and 32.4° respectively in the azimuth and elevation plane. In the azimuth plane pattern, the 1st side lobe is 13.4dB below the main beam peak and cross polarization is better than -30dB.

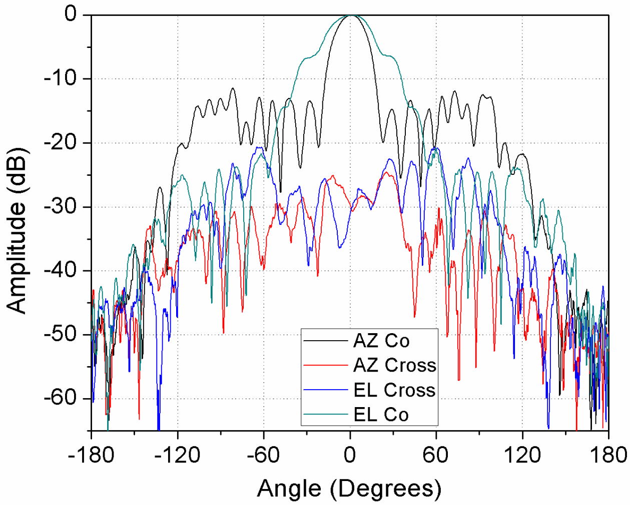

Fig.9. Measured azimuth and elevation plane radiation pattern at 11GHz.

IV. CONCLUSION

The paper describes the development of broadband strip line fed tapered slot antenna which can be useful for many communication application.

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