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Axial Corrugated Horn Antenna with an Elliptical Tapering Function

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ABSTRACT

An axially corrugated horn antenna with an elliptically shaped taper is proposed for satellite communication applications. This structure is a good candidate for the feed of reflectors and also for improving the electrical properties of reflector antennas. A tapering method is used to justify the horizontal location of the corrugation profile which improves the electrical performance of the presented antenna. The simulation results of a conventional axial corrugated horn antenna with a linear taper are compared to those of the proposed antenna. These results illustrate that the cross-polarization, side-lobe level and return loss of our antenna are improved by about 16dB, 4dB and 9dB, respectively. The axial corrugated horn antenna with an elliptical tapering function is simple and low-cost as compared to the other corrugated horn antennas such as scalar (vertically) corrugated horn and subsequently, it could be preferred in commercial applications.

1. Introduction

Horn antennas are very useful antennas in the microwave band (above & around 1 GHz) and are very suitable candidates for the feed of reflector and lens antennas [1]. The horn antennas can take many different types but conventional apertures are rectangular or circular shapes [2]. In Figure 1, conventional pyramidal and conical horn antennas are shown.

In some applications, the need for circularly polarized and dual polarized antennas, has made the circularly aperture horns to be used extensively. Meanwhile, the symmetrical radiation pattern, low spillover and very low cross polarization are the main reasons for the utilization of circularly aperture corrugated horns as feeds of reflector antennas [3].

In recent decades, vast development in satellite communications has made high-performance reflector antennas much more attractive. The main advantages of a corrugated (grooved) horn antenna as compared to a conventional design as a feed of a reflector antenna, are its low cross-polar level (XP) and low side-lobe level (SLL) over the operational bandwidth [4].

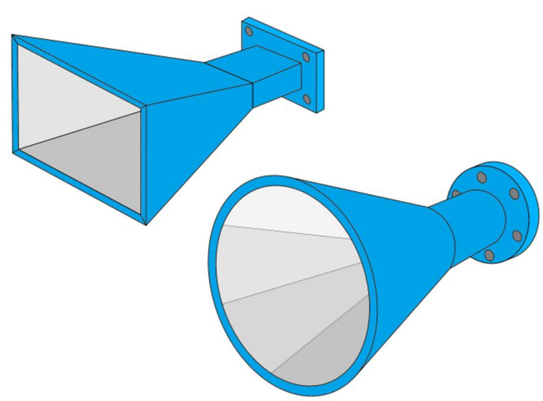

Figure 1: Conventional pyramidal and conical horn antennas.

As shown in Figure 2, the traditional corrugated profiles such as axial (horizontal) corrugation, scalar (vertical) corrugation and standard (normal) corrugation are used in horn antenna structures [5].

The electrical performance of a corrugated horn is strictly influenced by its dimensions and the method of corrugation. So, optimization approaches and tools are widely used to design corrugated horn antennas [6-9].

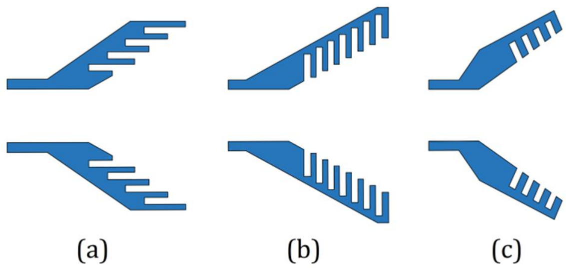

Figure 2: Common types of grooves in corrugated horn antenna. (a) Axial corrugation, (b) Scalar corrugation, (c) Standard (normal) corrugation.

Moreover utilizing a combined structure compromising of conventional corrugated profiles, the XP of the radiation patterns of a corrugated horn antenna is enhanced in [10] and [11].

In this paper by using the elliptical function, the effect of tapering shape of a corrugated horn antenna has been studied.

By comparing the performance of the proposed antenna with a conventional corrugated horn antenna, it is observed that some characteristic radiations, such as XP and SLL are improved. For this study, we have used the finite integration technique (FIT) in CST Microwave Studio (MWS) software.

2. Elliptical Function for Tapering Corrugated Horn Antenna

Figure 3 shows the cropped view of a conventional axial corrugated horn antenna. It depends on five main parameters such as the corrugations (grooves) depth, corrugations tooth thickness, corrugation width, aperture diameter and the location of each corrugation on the antenna.

The location of each corrugation is dependent on the antenna tapering shape. For instance, Figure 3 shows linear tapering (dashed, blue). In [12] and [13], a tapering corrugated horn by using the results of optimization methods is presented. Optimization methods lead to increase the complexity of the design, construction and increased manufacturing cost.

In this paper, axial corrugated horn antenna with elliptical tapering function (Figure 4) has been designed for 10.7-12.75 GHz. The red line illustrates the tapering shapes of the horn, which is based on an elliptical function.

The dimensions of the three proposed antennas and a conventional axial corrugated horn antenna are listed in Table 1. For all antennas, the diameter of the excitation circular waveguides are the same and is equal to din = 18 mm.

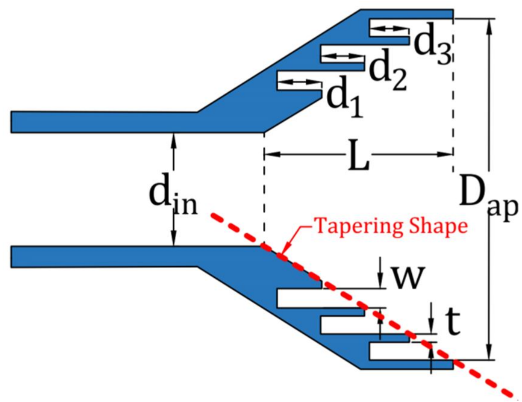

Figure 3: Side view of a conventional axially corrugated horn antenna.

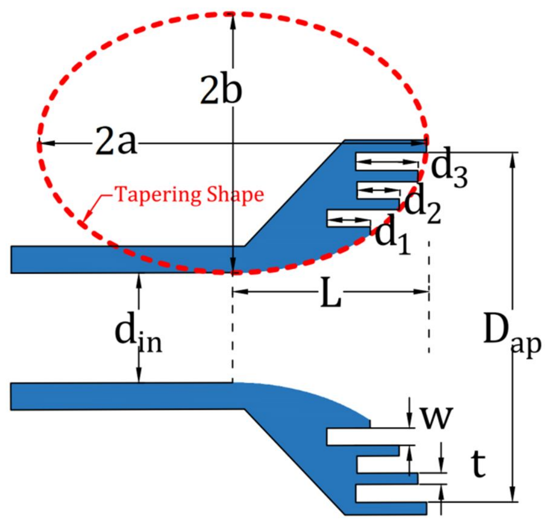

Figure 4: Side view of axially corrugated horn antenna with the proposed aperture taper based on an elliptical function.

Table 1
Dimensions of the Three Proposed Antennas and a Conventional Axial Corrugated Horn Antenna [In MM]

	a	b	d_1	d_2	d3	w	t	L	D_{ap}
Conventional	-	-	5.8	5.3	5.2	2.5	1	30	48
Elliptical1	35	15	5.5	5.5	8	2.5	1	35	48
Elliptical2	25	15	5.5	6	8.5	2.5	1	25	48
Elliptical3	30	15	5.5	6	7.5	2.5	1	30	48

3. Simulation Results

For studying the proposed corrugated horn antenna with elliptical tapering functions, simulation results for various dimensions and a conventional axial corrugated horn antenna in CST Microwave Studio software are presented. As shown in Figures 5-10. In the proposed structure, the aperture diameter is assumed to be equal to the conventional structure. Antennas return losses are illustrated in Figure 5. In nearly all the bandwidth concerned, the elliptical tapering structures compared to the conventional design are improved. This is due to the grooves performance in the antenna structure that reduces the diffracted rays back into the inner structure of the antenna.

The antenna gain is shown in Figure 6. In the proposed antennas, the gain is slightly lower as compared to that of the conventional structure. This is due to reduction of the electromagnetic field distribution on the edges of the antenna aperture. Furthermore, this field distribution reduction would lead to lower side-lobe levels and lower cross-polar levels.

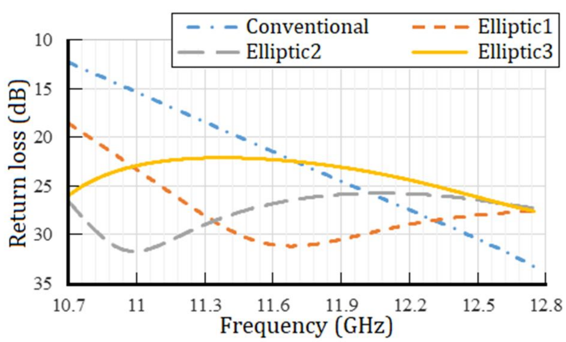

Figure 5: Comparison of the return loss of the proposed antenna with the conventional axial corrugated horn antenna.

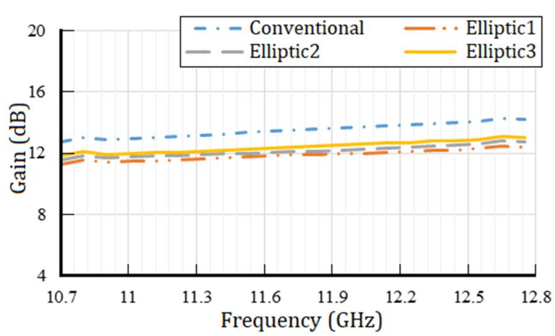

Figure 6: Comparison of the gain of the proposed antenna with the conventional axial corrugated horn antennas.

Figure 7 shows the comparison of the cross-polar levels of the proposed antenna with the conventional axial corrugated horn antennas at 70º beamwidth.

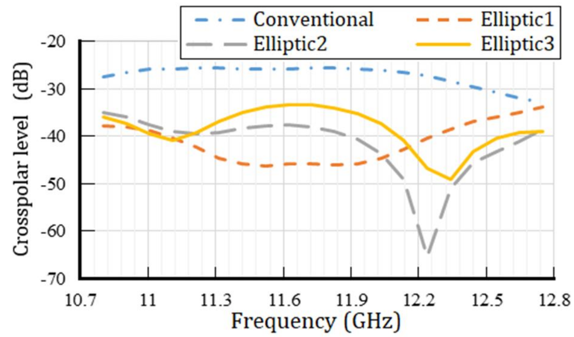

Figure 7: Comparison of the cross-polar levels of the proposed antenna with the conventional axial corrugated horn antennas at 70º beamwidth.

It is important to note that the cross-polar level (XP) in front of the corrugated horn antenna, on the axis of the antenna structure (on the maximum of the radiation pattern main lobe) is very low. Hence sampling the XP is not important for this location of the radiation pattern. But, XP for taper beam, an instance of -10dB beamwidth is necessary. Therefore, in Figure 7 results of the maximum cross-polar level for 70º beamwidth is shown.

For the better view of the regions where the cross-polar level is more sensitive, Figure 8 shows the cross-polar level versus Theta and Phi angles at 11.7 GHz frequency for the three proposed and conventional axial corrugated horn antennas. It should be noted that the maximum cross-polar levels appear at 45, 135, 225, and 315 degrees of Phi angle.

As shown in Figure 8, the proposed elliptical1 corrugated horn antenna has the lowest and the conventional corrugated horn antenna has the highest cross-polar levels.

Side-lobe levels are shown in Figure 9. In the proposed antennas, side-lobe levels are lower as compared to that of the conventional structure. E-plane far-field radiation patterns of the three proposed antennas and the conventional antenna are also shown in Figure 10.

4. Conclusion

Three axial corrugated horn antennas in the frequency range of 10.7 - 12.75 GHz with an elliptical tapering function are proposed. Low cross-polar levels, low side-lobe levels and low return loss have been achieved. The above characteristics of the proposed antennas are less than those of a conventional axial corrugated horn antenna. The above mentioned parameters for our proposed antennas as compared with the conventional counterpart, are improved by 16dB, 4dB, and 9dB, respectively.

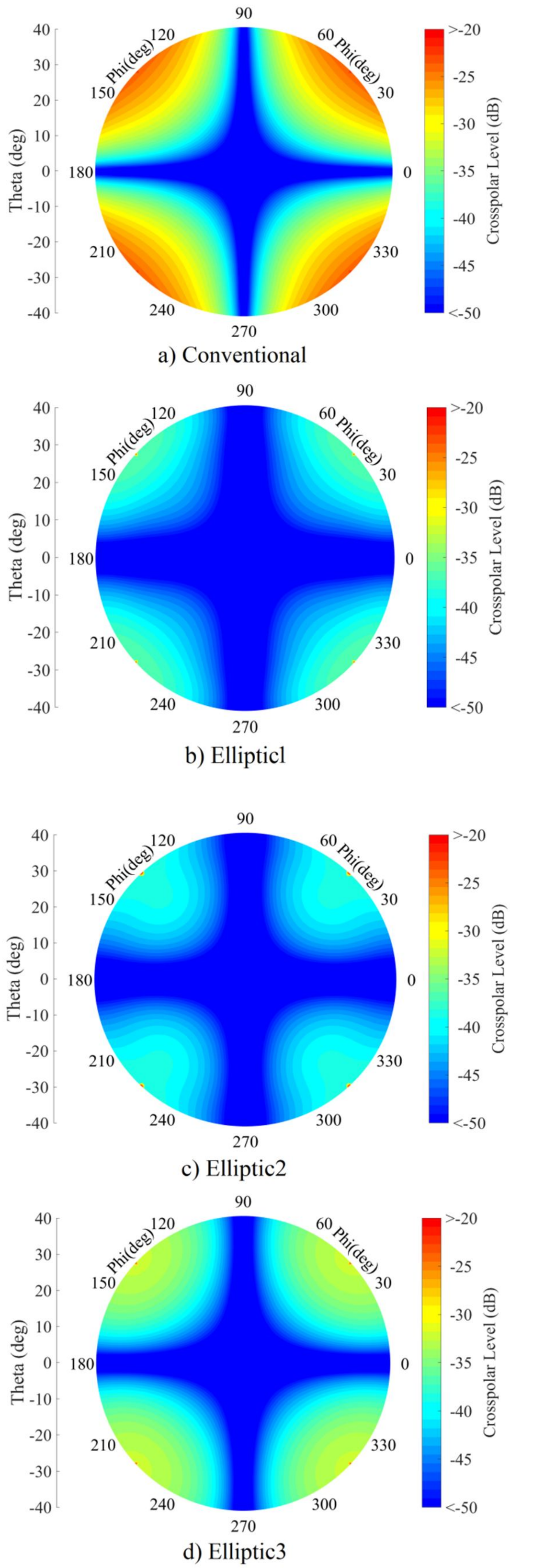

Figure 8: The cross-polar level versus Theta and Phi angles at 11.7 GHz. a) Conventional antenna, b) Proposed elliptical1 antenna, c) Proposed elliptical2 antenna and d) Proposed elliptical3 antenna.

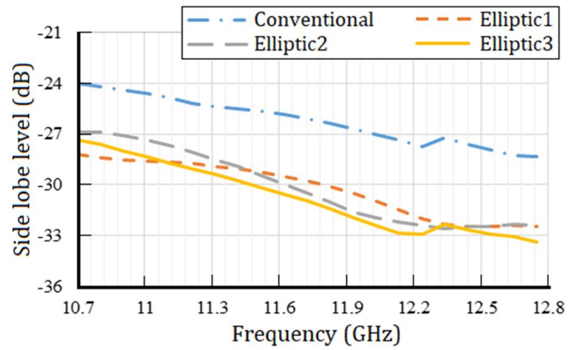

Figure 9: Comparison of the side-lobe levels of the proposed antenna with the conventional axial corrugated horn antenna.

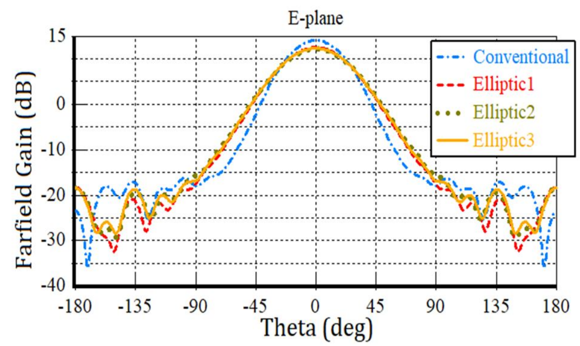

Figure 10: Optimized E-plane far-field radiation patterns for the proposed and the conventional axial corrugated horn antennas.

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BIOGRAPHIES

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