X-band H-Plane Sectoral Horn Antenna Designed with Two Balanced Screws for Tunable Bandwidth

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Abstract An X-band H-plane sectoral horn antenna with tunable bandwidth presented in this paper is designed based on a conventional horn structure applied with two balanced tuning screws. The proposed design method is for reducing the horn size which is smaller than a conventional pyramidal horn designed at the same frequency. The measured response of return loss S_{11} for the proposed antenna shows good agreements with the simulated result. Also, its operational bandwidth show dual band as larger than 1 GHz for both lower and higher bands. The radiation patterns of the antenna exhibit narrow beamwidth on H-plane orientation, which is suitably utilized with the modern wireless communication application for the frequency of 8.5 GHz and 11.5 GHz.

Keyword H-plane sectoral horn, tuning screws, pyramidal horn

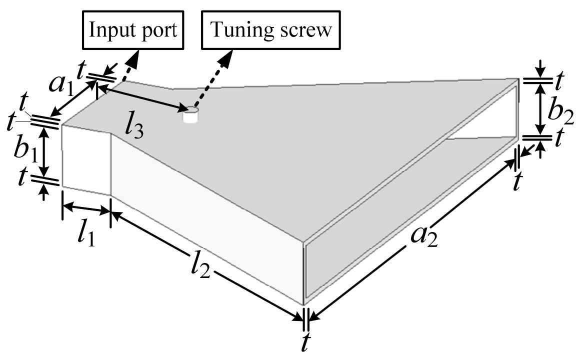
1. INTRODUCTION

Antennas are the crucial components and mainly utilized in the wireless communication systems. The main role of antennas is for transmitting/receiving EM waves depending on the distance. For the long-distance wireless communication, a high gain antenna with narrow beamwidth is required and need also to be small for the modern communication technology. Horn antennas are also matched for this requirement; however, the antenna sizes are not small for the high gain horn. Most antenna designers have attempted to redesign horns in order to reduce the size with high performance such a gain and a beamwidth. An H-plane sectoral horn is a favorite of reduced horn structure and is applied for different applications. Asymmetric H-plane horn structure made of aluminum presented in [1]. The proposed design can be controlling the beam direction based on its structure, but its size is large and heavy. The substrate integrated waveguide (SIW) is a most popular structure and can be applicable to design any compact passive device. It has been applied in the design of H-plane horns which were presented in [2] for reducing the size with large bandwidth, [3] integrated with a PTFE substrate for automotive radar application, [4] for improve directivity, [5] using array design technique, [6] using ridge structure to improve the bandwidth, and [7] with embedded metal-via arrays.

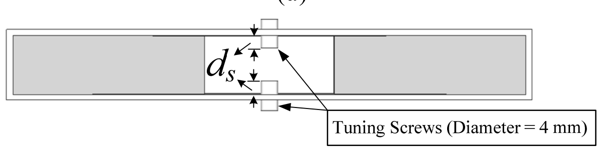
In this paper, H-plane sectoral horn are presented and designed at the X-band frequency (8 GHz – 12 GHz). The proposed antenna can also be tunable its bandwidth with the use of two balanced screws. This design aims to improve the horn size with high gain and narrower beamwidth for the H-plane orientation. Also, we have used the advantages of tuning screws for controlling the bandwidth resulted in dual bands. The design principle of horn and the simulated results will be discussed in Section 2. The fabrication and measurement are discussed in Section 4. The conclusion is given in Section 5.

2. DESIGN AND SIMULATION

An H-plane sectoral horn antenna shown in Fig. 1 is designed at the X-band frequency (8 GHz – 12 GHz). The stainless steel is selected as a material of the antenna body in this design. All the dimensions of the antenna structure are defined using the designed equations from [8] and are shown in Fig. 1(a). They are a_1 = 22.86 mm, a_2 = 87.79 mm, b_1 = b_2 = 10.16 mm, l_1 = 10 mm, l_2 = 64 mm, l_3 = 20 mm, t = 2 mm. For the screw depth (d_s) for Fig. 1(b), both screws can be adjusted together in order to tune the bandwidth of the response of return loss S_{11}. The H-plane sectoral horn antennas for this structure with tuning screws and without tuning screws are simulated for obtaining the responses of S_{11} with the use of the CST simulation software [9]. An example of two screw usage is defined for both d_s of 2 mm, the frequency response of S_{11} for this example is shown in Fig. 2 compared with the S_{11} response for the antenna without tuning screws. It can be seen that the response of S_{11} for the antenna with tuning screws for d_s of 2mm show the minimum return loss level of two frequency band as about 30 dB around the center frequency f_{01} of lower band as 8.5 GHz and the center frequency f_{02} of higher band as 11.5 GHz, whilst the S_{11} response for the antenna without tuning screws shows a single band with the minimum return loss level as about 15 dB.



(a)



(b)

Fig. 1 The structure of a tunable H-plane horn. (a) 3D view. (b) Front view.

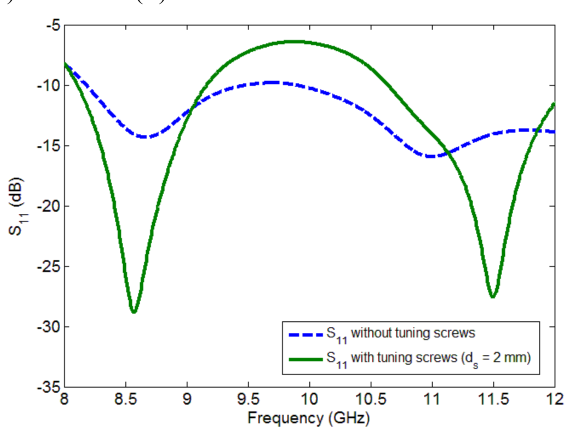
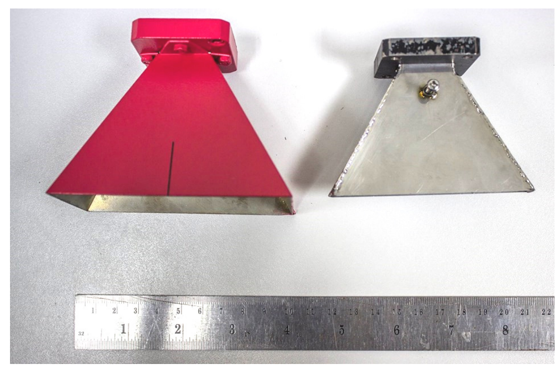


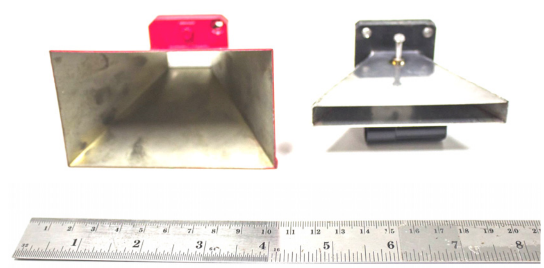
Fig. 2 Simulated frequency responses of S_{11} of the proposed antenna without tuning screws and with tuning screws.

3. Fabrication and Measurement

The H-plane sectoral horn is made from the stainless steel sheet with the thickness of 2 mm. In addition, the antenna has been fabricated using a laser cutting machine to make every body parts followed the dimension details as described in Section 2. After that, the entire cut sheet will be assembled using an electric welding machine. The photographs of the realized proposed horn compared with a conventional pyramidal horn for the top and front views are shown in Fig. 3. It is clearly seen that the proposed horn antenna is smaller than a conventional horn as about one of five times as compared on the horizontal plane.



(a)



(b)

Fig. 3 Photographs of a fabricated antenna compared (on the right) with a conventional pyramidal horn (on the left). (a) Top view. (b) Front view.

The fabricated antenna with tuning screws for the d_s of 2mm has been measured the response of return loss S_{11} using a network analyzer, Agilent N5230A setting up to measure the operational frequency of the realized horn from 8 GHz to 12 GHz. The measured results show very good agreement with the simulated results, as shown in Fig. 4. The bandwidth measured under -10 dB of each bands are larger than 1 GHz for both simulation and measurement.

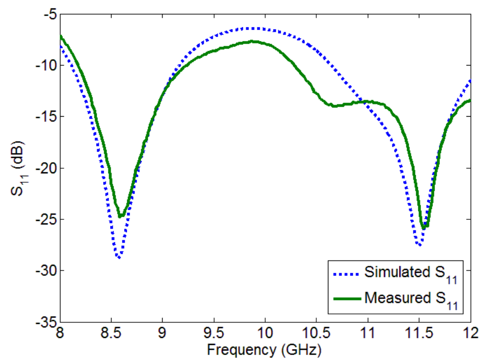


Fig. 4 The measured frequency responses of S_{11} of the antenna for screw depth (d_s) of 2 mm compared with the simulated result.

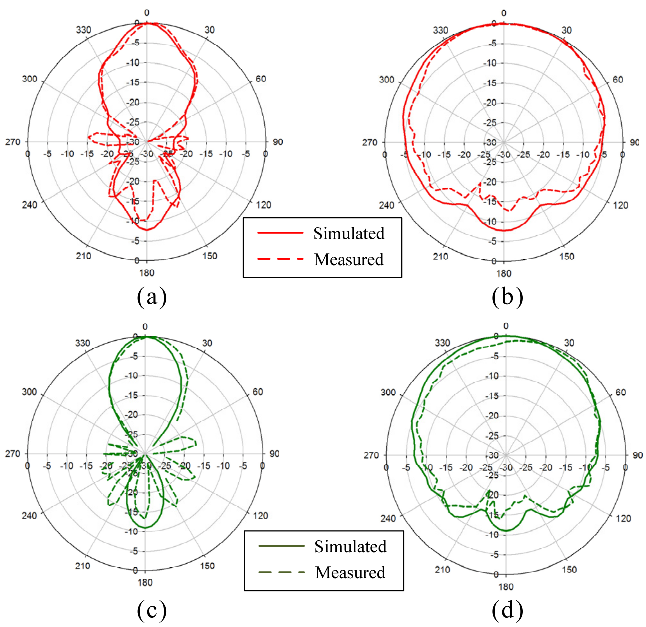


Fig. 5 The radiation patterns of H-plane sectoral horn with both screw depth of 2 mm. measured at 8.5 GHz for (a) H-plane (b) E-plane and at 11.5 GHz for (c) H-plane (d) E-plane.

The fabricated antenna has been measured in the inside an anechoic chamber of the wireless communication research group, KMUTNB to obtain the radiation patterns for the center frequencies for the lower band (f_{01} = 8.5 GHz) and the higher band (f_{02} = 11.5 GHz). The measured radiation patterns are plotted to compare with the simulated results, as shown in Fig. 5. It can be seen that the H-plane horn exhibits good agreement in terms of radiation pattern in H and E plane orientation. The performance of the H-plane horn is summarized for both H and E planes and presented in Table 1. The antenna shows a good performance for the 3 dB beamwidth of H-plane that is smaller than E-plane as about 73 degrees in simulations and 70 degrees in measurements. It is due to the large aperture size on H-plane which is related to the radiation performance. The cross polarization levels in H-plane are average larger than E-plane as around 30 dBi in the simulation and measurement shown in Table 1.

Table 1 Summary of the H-plane horn performance.

Orientation plane	*f* (GHz)	3 dB Beamwidth (deg.)		Side lobe level(dB)		Cross-Pol. level (dB)	
		Sim.	Mea.	Sim.	Mea.	Sim.	Mea.
H-plane	8.5	26.0	25	-7.8	-10	-77.1	-73
	10	26.2	27	-9.6	-14	-80.6	-75
	11.5	27.6	32	-11	-13.2	-78.3	-76
E-plane	8.5	123.5	125	-7.8	-7.75	-101	-98
	10	114.3	112	-7.5	-9.59	-106	-96
	11.5	100.7	102	-7	-10.9	-108	-97

4. CONCLUSION

This proposed antenna has been completely designed for having compact size with good radiation performance. The structure is easier fabricated to have light weight using stainless steel sheet. The experimental results of the antenna exhibited very good agreement with simulated results. It can also be adjusted the bandwidth using two balanced tuning screws. The antenna has a good radiation on H-plane and compact size for suitably use in the modern wireless communication systems.

5. ACKNOWLEDGMENT

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