Design of a High-Gain Wideband Microstrip Antenna with a Stepped Slot Structure

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***Abstract*-This paper focuses on an antenna with a stepped slot structure. The paper analyzes the impedance and radiation characteristics of this type of antenna and designs a high-gain wideband antenna that operates in the L-band and S-band. The simulation results show that the antenna has a comparatively high gain, wide impedance bandwidth and beamwidth in the entire L-band and S-band, and can thus be used in the design of antenna arrays.**

Index Terms*-*Stepped slot structure, wideband, high-gain antenna.

I. INTRODUCTION

As a high-gain wideband traveling-wave slot antenna, the tapered slot antenna has been playing an important role in the research field of wideband antennas since it was put forward. Tapered slot antennas transmit energy through a microstrip slot structure and ultimately couples the energy to antenna patches for radiation.[1],[2]. The patch opening in a gradually widened horn shape constitutes the subject to radiate or receive energy, where different operating frequency points correspond to different 1/2 λ opening width values. Tapered slot antennas can realize highly wide frequency bands, good radiation pattern symmetry, high gains, high beamwidths and pretty low sidelobe levels.

This chapter deals with an antenna with a stepped slot structure, analyzes the impedance and radiation characteristics of the antenna in the S-band, and designs a linear polarized high-gain wideband microstrip antenna[3], [4],[5].

II. ANTENNA STRUCTURE

The structure of the stepped slot antenna described in this paper is shown in Fig. 1 below. The maximum opening width of antenna corresponds to minimum operating frequency of the antenna. The stepped slot structure determines that the antenna can achieve a very wide frequency band, good radiation pattern symmetry, and high gain. It is a linear polarized antenna. In the two main radiation planes, the antenna has a very high linear polarization purity, pretty low cross polarized levels, wide beamwidths and pretty low sidelobe levels.

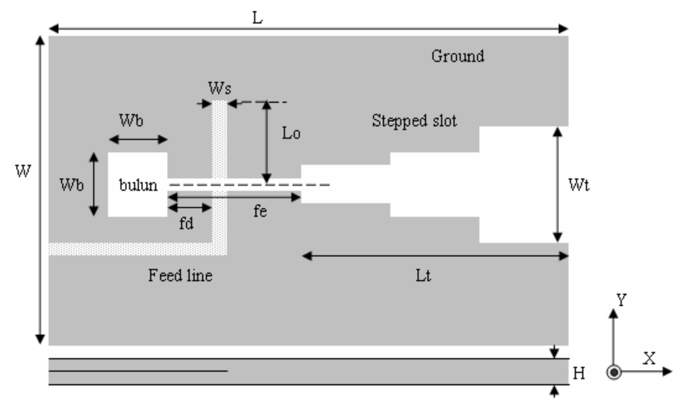

Fig. 1. Antenna with a stepped slot structure.

III. ANALYSIS OF ANTENNA CHARACTERISTICS

A. *Antenna structure*

The antenna in Fig. 1 is made up of strip lines. Stepped slots are made in mutually symmetric positions of the grounding plates at the top and base in order to radiate electromagnetic signals. The central conductor is a feed microstip line. The number of stepped slot lines depends on the antenna width. The more the number of stepped slot lines is, the wider the antenna width is. To improve antenna's impedance characteristics, cut out rectangular holes in the mutually symmetric positions at the feed end of both grounding plates at the top and base. The holes are used as Balun for feeding structure adjustment and has an important influence on the optimization of the antenna's impedance characteristics.

B. *Antenna performance*

The structure of the antenna in this paper is built using the finite element method for tetrahedral mesh generation. With this method, the electrical property of the stepped slot antenna can be worked out efficiently. Conventional slot antennas usually has a three-layer structure: metal radiation patches, dielectric substrate, and feeding structure. The tetrahedral mesh structure can accurately fit multi-layer metal patches and dielectric structure on the plane and fit small electrical structure in a highly accurate way through local uneven segmentation.

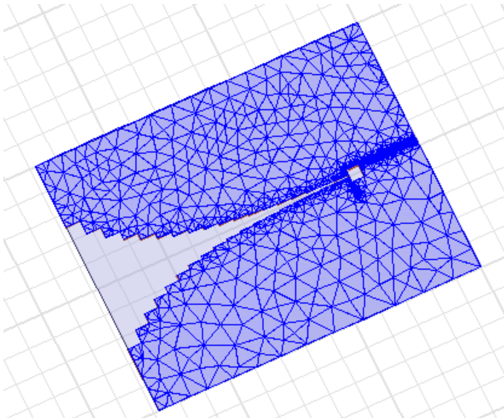

Fig. 2. Antenna segmentation with finite element method.

C. Antenna simulation

The paper designs an ultra-wide antenna which covers the L-band and S-band. The dielectric constant of the dielectric substrate of the strip line is 4.4 and the thickness of the substrate is 1.6 mm. Fig. 3 shows a screenshot of the antenna simulation.

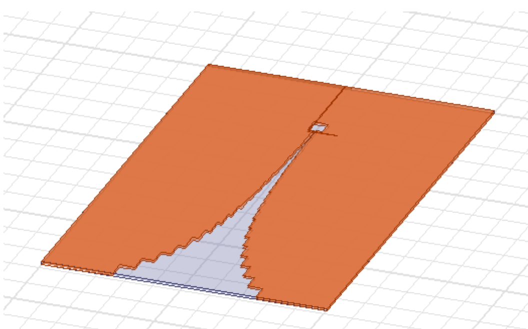

Fig. 3. Screenshot of the antenna electromagnetic characteristics simulation.

The impedance and radiation characteristic curves of the antenna as well as its geometry are given in the table below, which are obtained through the antenna optimization and simulation analyses:

(unit: mm)

W	L	Wb	Ws	fd	fe	Wt	Lt
100	200	10	0.7	5	15.8	100	200

D. Antenna radiation characteristics

Fig. 4 shows the 3D beam direction pattern of the antenna. The data column to the left shows antenna gains. The maximum antenna gain is 9.8 dB. The 3D beam direction pattern is to the right of the pattern, where the maximum radiation direction lies in the X axis which has a better radiation symmetry and thus serves as the radiating elements of the antenna array. Thanks to the strip line structure, the antenna has a high linear polarization purity, pretty low cross polarized level, wide beamwidth, and pretty low sidelobe level, all of which makes the antenna ideal for the application of antenna arrays. See Fig. 5 below.

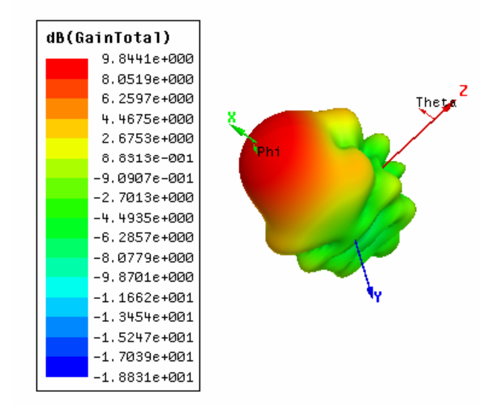

Fig. 4. Antenna 3D direction pattern.

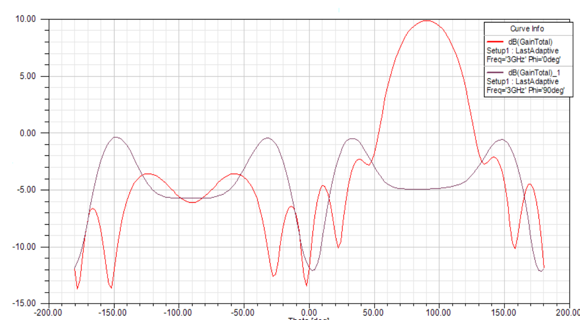

Fig. 5. Antenna 2D direction pattern.

E. Antenna return loss characteristics

Fig. 6 shows the return loss characteristics of the antennal. It can be seen that when the antenna operates in the L-band and S-band, if the antenna return loss is less than 10 dB, then the antenna bandwidth can reach 1800 MHz or so, and the relative bandwidth is about 60%. The frequeny band is very wide.

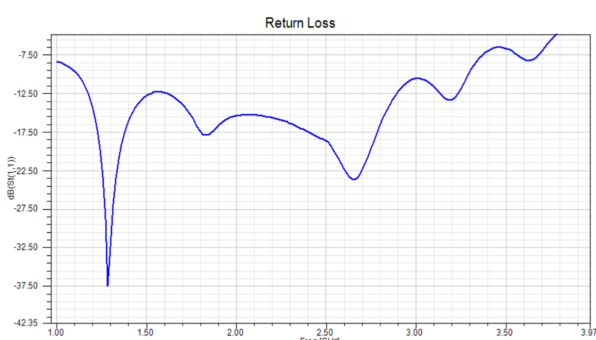

Fig. 6. Antenna return losses.

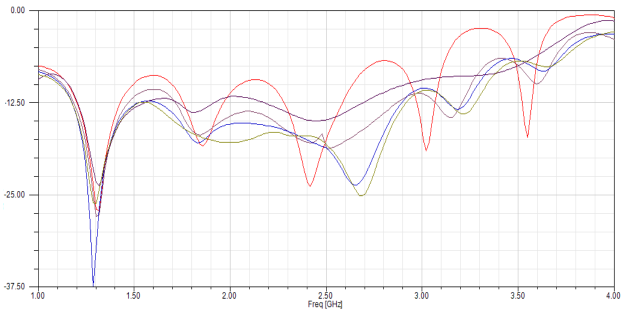

Fig. 7. Influence of the number of stepped slots on return losses.

It can be seen from Fig. 7 that the number of stepped slots of the antenna has a certain influence on the impedance and radiation of the antenna. The impedance width increases with the increase of stepped slots.

IV. CONLUSION

One can make a conclusion from above analyses that the antenna with a stepped slot structure has a higher gain of up to 10 dB, impedance bandwidth of 60%, low sidelobe levels, extremely small cross polarization component, and good radiation characteristics and bandwidth performance, which

make the antenna ideal for the applications of antenna arrays. This type of antenna has a marked advantage compared with conventional microstrip antennas; nevertheless, the type of antenna has a comparatively complex structure and more parameters to adjust. In particular, any slight deviation in the feeding structure of the antenna may result in performance deterioration, which may cause certain difficulty in antenna manufacturing.

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