A Triangular Antenna with Spiral Slot Arrays for Beidou Navigation

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Abstract— A dual-band triangular microstrip antenna is presented for Beidou navigation, applying spiral-slot arrays coupling technique. The antenna's radiation patch is designed on a single layer of medium loaded with 6-elements feed coupling slot arrays. Thus, the actual current path could be controlled and the size of the proposed antenna is reduced effectively. Dual-band radiation is realized by introducing two triangular vortex rings coupled with 6 meandering slots, covering 1.616 GHz and 2.492 GHz. The three meandering slots are introduced on the ground plane to improve the antenna performance further. The simulation results show that the 10 dB impedance working bandwidths are 17 MHz and 35 MHz respectively for lower and higher frequencies of Beidou navigation, with quite good radiation stability and high gain performances.

1. INTRODUCTION

Rapid development in the field of Beidou Navigation technology demands multiband and wideband antenna, primarily to achieve high data rate transmission function in CNSS (Compass navigation Satellite System). Rectangular and circular microstrip patches are widely applied in antenna design for low profile, simplification and light weight. In addition to the above advantages, triangular patch is a better choice for wideband radiation performance in dual-band antenna [1, 2]. For much higher gain and better directivity of an antenna, Y. S. H. Khraisat and M. M. Olaimat used a triangular patch antenna array to achieve better suppression for side lobe level compared with using a rectangular one [3]. By introducing some specific slots in antenna design, the corresponding resonant frequencies can be excited simultaneously [4, 5]. However, several slots introduced solely, that is equivalent to a load capacitance, are not sufficient to reach the desired frequency and also there would be a drawback of narrow bandwidth. Loading some modified slots or inverting the corresponding conductor on the ground plane of an antenna gives a simple tuning mechanism for the frequency bands and band spacing [6–9]. Furthermore, some improved structures were applied in multiband microstrip antennas, such as a spiral slot antenna [10–12]. A novel triangular split-ring resonator antenna was realized, measured and analyzed in Ref. [13].

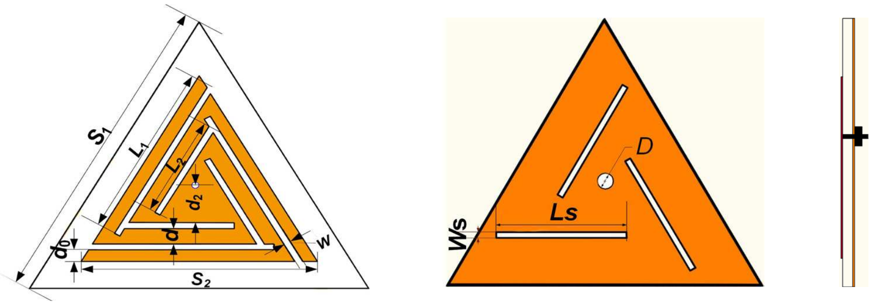
In this paper, a triangular antenna loading with a spiral slot array on the radiation patch and ground plane respectively is proposed. The coupled inner and outer spiral slots are nested with each other. Meanwhile, the folded structure can be introduced in the triangular surface while other slots are in the clipped area with a self-similarity of resonator. Thus, the multiband radiation is expected with a good matching performance and bandwidth.

2. ANTENNA DESIGN AND CONFIGURATION

The configuration of the proposed triangular antenna loading with spiral slot arrays is shown in Fig. 1. On the top layer, a triangular patch, a self-similar pair of triangular slots is introduced parallel to the patch sides and each other, to increase energy coupling and realize dual-band radiation. The substrate is a triangular CER-10 (Taconic), with thickness of 3 mm and dielectric permittivity ε_r of 10 respectively. The thickness h of the triangular radiating patch is 0.0035 mm, so the actual height of the antenna will be the summation of the patch thickness h and the substrate thickness. The ground plane is modified by introducing three meandering slots to tune the frequency bands and bandwidth on the bottom layer. As shown in the figure, the main optimal dimensions of the designed antenna are as follows

$S_1 = 49.6$ mm, $S_2 = 37.7$ mm, $L_1 = 26.8$ mm, $L_2 = 15.6$ mm, $W = 0.9$ mm, $d_0 = 1.8$ mm, $d = 2.5$ mm, $d_1 = 10.7$ mm, $D = 3$ mm, $L_\mathrm{s} = 15.5$ mm, $W_\mathrm{s} = 1.1$ mm.

The top layer of the designed antenna is supported by six meandering slots, comprising internal and external triangular ring respectively. The two triangular rings have similar geometric structures and are coupled to be as vortex slot ring arrays. A lower frequency band is realized through three large meandering slots, which are coupled to be an external triangular ring with each other arranged according to 60 degrees. While three small meandering slots are inserted into the external slots by 60 degrees and coupled to be an internal triangular ring, through which a higher resonant frequency band is generated. As depicted in Fig. 1, the two coupled triangular slot rings are obviously self-similar in structure so that the coupling effect of electromagnetic fields can be also enhanced after



(a) (b) (c)

Figure 1: Configuration of the proposed antenna. (a) Top view. (b) Bottom view. (c) Side view.

optimization for the distribution feeding match. Both the bandwidth and return loss level of the antenna are improved significantly. Due to the loading of spiral slot arrays, further miniaturization would be expected.

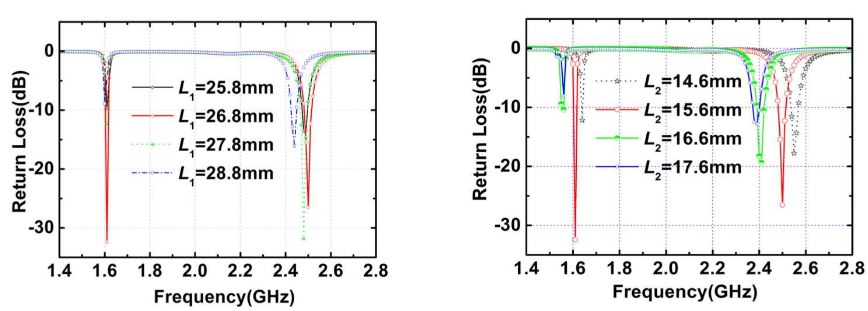
However, conventional slot patch antenna usually has no good matching impedance in the return loss curve with narrow bandwidth. Based on ground plane technique, some modified slots are considered for improving the performance of antenna. For instance, when three meandering slots are mutually staggered on the ground plane, the resonant frequency band with good matching condition will be achieved and thus the bandwidth and the return loss curve can be improved.

3. RESULTS AND DISCUSSIONS

As in Fig. 2, the variation of the return loss S_{11} values at dual-bands with the lengths of the external spiral slots and internal spiral slots are illustrated. As expected, the desired frequencies are reached by introducing the triangular spiral slot arrays. It is also clear from the figure that the dual frequency bands decrease with the length of the spiral slot increasing. Furthermore, the slot lengths corresponding to the best return loss curves are $L_1 = 26.8\,\text{mm}$ at the lower band and $L_2 = 15.6\,\text{mm}$ at the higher band separately.

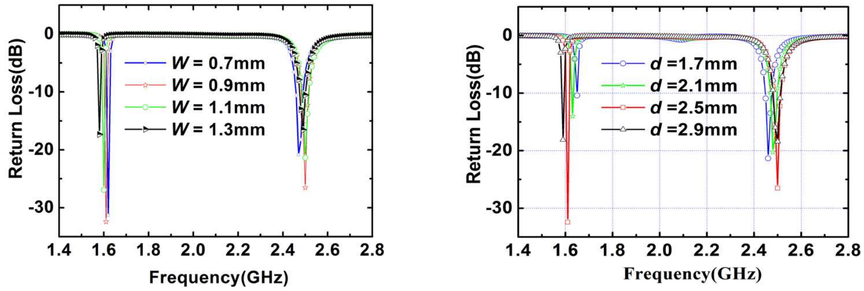
Considering the influence of the slot ring width and the distance between the external and internal slots at dual-bands on the performance of the antenna, Fig. 3 illustrates the variation of the return loss. Through the contrast of Fig. 3 with Fig. 2, it is obvious that the effect of the slot length is more than that of the slot ring width and distance. As the width and distance of the spiral slots increase, the relative current path at the edge of the triangular antenna patch will be reduced so that the lower frequency band will shift to the much lower. However, the distance from the internal spiral slot ring to the patch center is decreased in contrast so that the current path at the higher band decreases. Consequently, the higher frequency band increases with the width of the spiral slot as shown in the figure.

According to the analysis as above, it can be concluded that the designed antenna realize dual frequency bands with good matching condition. Furthermore, the simulated radiation patterns on XZ-plane and YZ-plane at 1.616 GHz and 2.492 GHz present all-direction radiation, as shown in Figs. 4(a) and (b) respectively. In addition, according to the formula for the bandwidth BW as



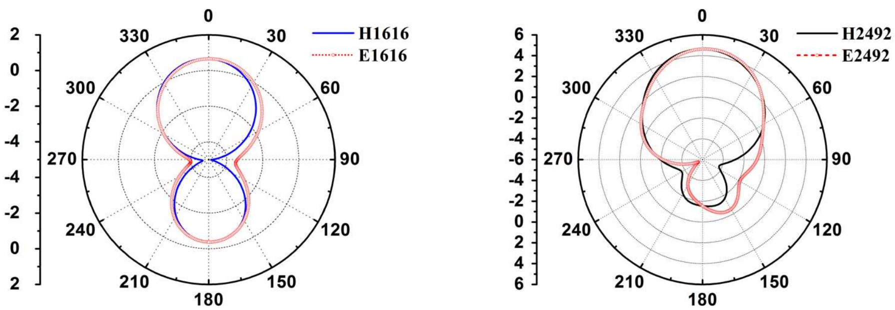
(a) (b)

Figure 2: Profile optimization analyses: effects of the slot lengths on the return loss of the designed antenna. (a) The external spiral slot at lower band. (b) The internal spiral slot at higher band.



(a) (b)

Figure 3: Effects and optimization on the return loss (S_{11}) for the proposed antenna at dual bands. (a) Optimization analyses of slot width. (b) Optimization analyses of the distance between slots.



(a) (b)

Figure 4: Simulated radiation patterns of the proposed antenna, (a) in lower band, (b) in higher band.

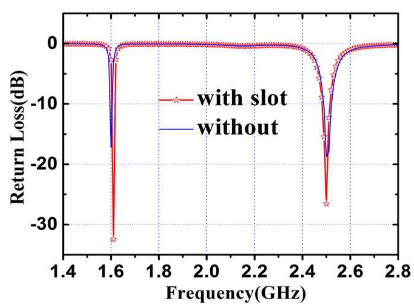


Figure 5: Simulated return losses of the proposed antenna with slots and without any slot.

follows

$$BW = (S-1) \Big/ Q_T\sqrt{S} \tag{1}$$

where S and Q_T are the standing wave ratio and quality factor respectively. The bandwidth of dual-band can be effectively improved by introducing modified slots on the ground plane. As illustrated in Fig. 5, if there is no slot in the ground plane, the return loss of the antenna without any slot introduced is more than -20 dB in the range from 1.6 GHz to 2.4 GHz. On the contrary, the dual frequency bands of the antenna with some suitable slots employed on the ground plane have a good performance in the return loss curve, due to the good matching condition achieved.

A fabricated model of the proposed antenna is shown in Fig. 6(a), and also the measured and simulated return losses of the proposed antenna are illustrated in Fig. 6(b). It can be observed that the measured results agree quite well with the simulated results. The measured 10 dB impedance working bandwidths are 17 MHz and 35 MHz respectively for the lower and higher frequencies, corresponding to the fractional bandwidth of 2.75% and 1.40% respectively. The major reason for the deviation in the higher frequency band is that the dimension of the fabricated antenna is small so as to generate carving errors during the processing.

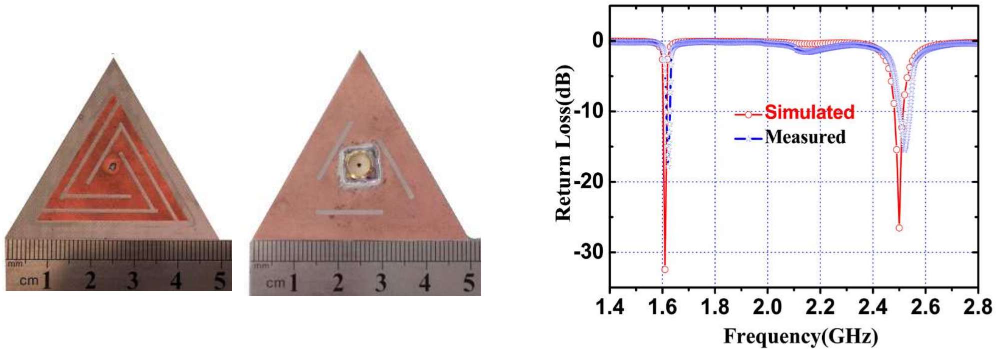


Figure 6: The outlook and properties of the fabricated prototype of the designed antenna. (a) Top & bottom view. (b) Comparison of simulated and measured return losses.

4. CONCLUSION

A triangular antenna loaded by spiral slot arrays with distribution feeding match to realize dual frequency bands is presented for Beidou navigation applications in this letter. Compared with the antennas with conventional slots, the frequency ratios of the proposed antenna can be effectively controlled through two self-similar spiral slot ring coupled strongly. By properly folding the spiral slots and tuning the coupled location, the multiband radiation can be achieved with the miniaturization of the antenna. Furthermore, the spiral slots on the ground plane are modified to enhance the bandwidth in dual frequency bands for the performance improvement of the designed antenna. The proposed antenna is easy to be fabricated for its simple configuration, and the measured results agree well with the simulated results.

ACKNOWLEDGMENT

This work is supported by Fujian Provincial Key Sci-Tech Project (2013HZ0002-1) of China. We thank the staff members of Microwave Library for helpful supports.

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