Low Profile Three-Dimensional Orthogonally Polarized Antennas

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1. Introduction

In future wireless communication systems, high data-rate and reliability are compulsory requirements. But the system performances are often degraded due to the fading effect of channels. To improve the performance, diversity is commonly considered to be an effective method. There are basically three routes to realize diversity: space, polarization, and pattern. Given limited space and low profile of handheld devices, space and pattern diversity may not be the best choice. On the other side, it has been demonstrated that polarization diversity, basically dual polarization can be implemented in handheld devices with impressive performances [1-3]. The idea of three-dimensional (3D) polarization has recently been explored [4, 5]; it is suggested that the capacity of wireless systems can be increased by two to three folds. However, the physical dimensions of cubic structures may not be ideal to integrate with mobile devices easily [5].

In this article, we propose to utilize the low profile characteristic of half mode substrate integrated waveguide antennas (HMSIW) [6-8] and substrate integrated waveguide (SIW) [9, 10] to significantly reduce the thickness of the three-dimensional orthogonally polarized antennas. This low profile design will be a good candidate for embedding into most mobile devices. The three radiating elements are closely located and the design has been carefully considered matching with the nature of wave propagation in complex environments. Moreover, it is not necessary to insert any baluns before connecting to the backend RF circuits. The antennas are designed to operate around 3.5 GHz and have impedance bandwidth more than 150 MHz which can support 4G wireless networks, such as WiMAX. CST Microwave Studio has been used for the simulations.

2. Antenna Geometry

The geometry of the proposed three-dimensional orthogonally polarized antennas is shown in Fig. 1. The three-dimensional antenna consists of three radiating elements; Ant I and Ant II are basically thick-slot antennas, while Ant III is a HMSIWA. Coaxial probes are used for feeding all the three radiating elements. Ant I is responsible for the linear polarization in *x*-direction, and the polarization of Ant II is in *y*-direction, while *z*-directional polarized radiation is contributed by the HMSIW antenna – Ant III.

A half mode substrate integrated waveguide antenna basically is a quarter of a substrate filled circular parallel-plate waveguide with vertical walls on the two straight edges connecting the two parallel plates. The length of the arc is about half wavelength of the resonant frequency of the HMSIWA. Impedance matching can be achieved by adjusting the location of the feeding probe.

The dimension of the whole simulated model is $70 \times 70 \times 9$ mm^3 ($x \times y \times z$) which is based on the sizes of smart phones commonly used today. The thickness and dielectric constant of inserted substrate is 6.4 mm and 2.2 respectively. The size of the proposed antenna is about $38 \times 38 \times 9$ mm^3. Detailed dimensions of the antennas can be found in table 1.

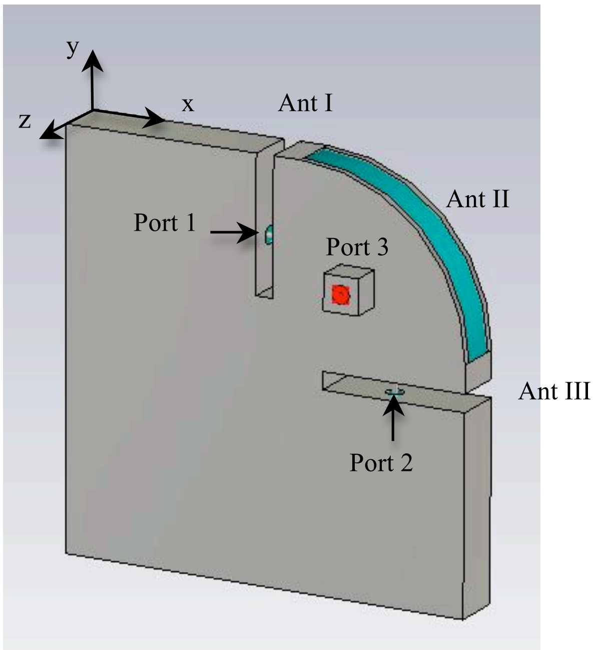


Figure 1: Geometry of the proposed low profile 3D orthogonally polarized antenna

Table 1: Dimensions of the proposed antenna (in mm)

	Ant I	Ant II			Ant III
width	3.0	3.0		radius	28.8
length	23.0	24.8		thickness	6.4
thickness	6.4	6.4		feed	10.0
feed	14.4	14.4			

3. Simulation Results and Discussions

3.1 S-parameters

In Fig. 2, we can see that the two slot antennas, Ant I and Ant II have wider impedance bandwidths ($|S_{ii}|$< -10 dB) of 800 MHz from about 3.1 to 3.9 GHz. The operating frequency band of the whole antenna is determined by the impedance bandwidth of the HMSIW antenna. The impedance bandwidth of the HMSIW antenna is approximately 160 MHz from 3.44 to 3.60 GHz. The isolation between port 1 and port 2 (S_{21}) is about -18 dB and better isolations of -45 dB are observed between port 3 and port 1 (S_{31}), and port 3 and port 2 (S_{32}).

3.2 Gain and Radiation Patterns

The gains and 3D radiation patterns of the antenna at 3.5 GHz have also been simulated and are illustrated in Fig. 3. The maximum gain of the two thick-slot radiating elements is about 2.5 dBi and the HMSIW antenna has a higher maximum gain of 3 dBi. Based on the simulated results, the three-dimensional orthogonally polarization can be achieved by exciting Ant I, II and III cooperatively. The variation of gain at different angles is less than 3 dB which is suitable for mobile communications.

The prototype was being fabricated when this article was submitted, experimental results and comparison with the simulated results will be provided in the presentation.

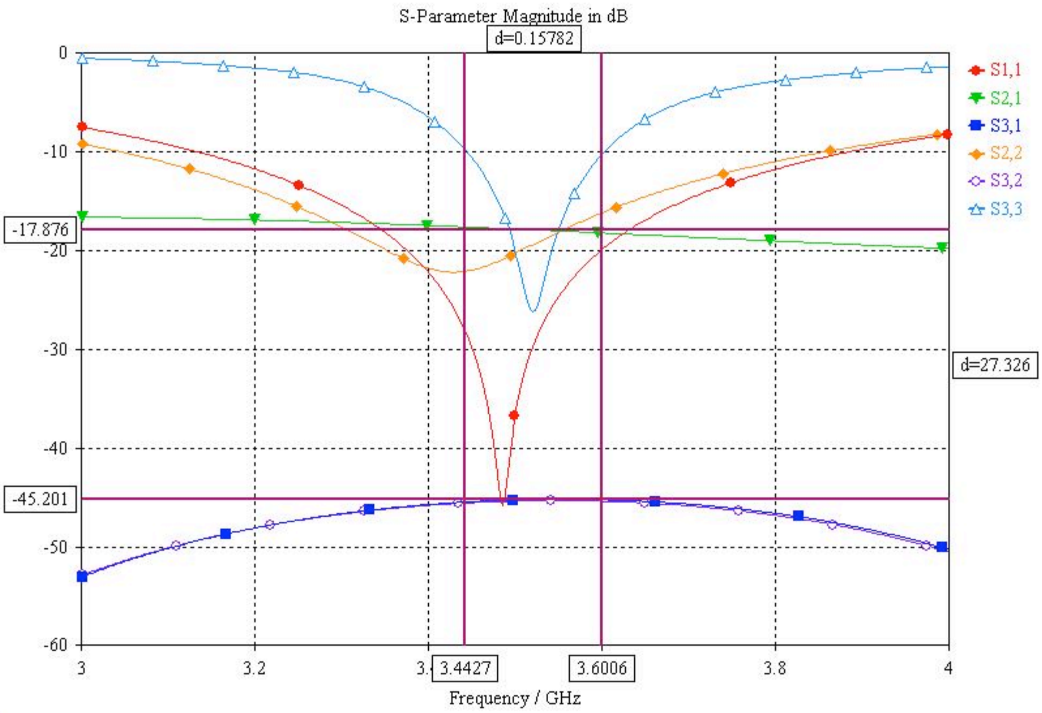
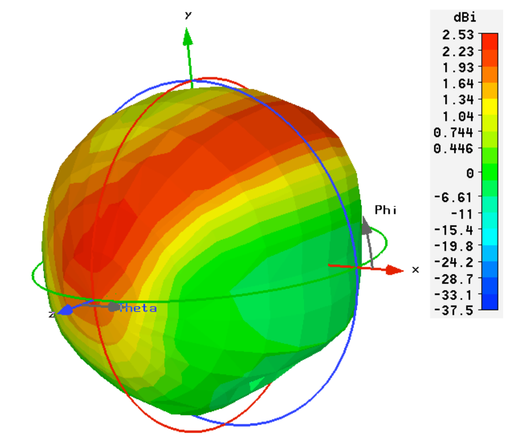
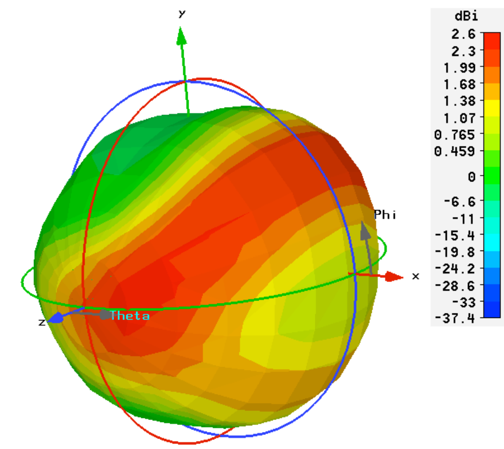


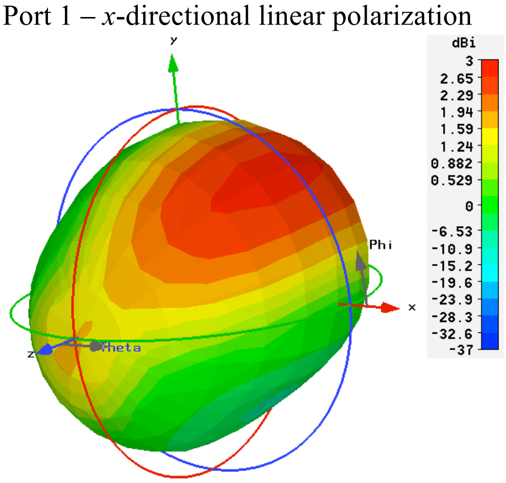
Figure 2: S-parameters of the proposed antennas.



(i) Port 1 – *x*-directional linear polarization



(ii) Port 2 – *y*-directional linear polarization



(iii) Port 3 – *z*-directional linear polarization

Figure 3: Gains and 3D radiation patterns of the proposed antenna at 3.5 GHz

4. Conclusion

The simulated performance of a low profile three-dimensional orthogonally polarization antenna has been demonstrated. Two thick-slot antennas are responsible for the two planar polarizations, while the third perpendicular polarization is contributed by an HMSIW antenna, moreover, the thickness of the antenna has shrunk by the inherent thin structure of HMSIW antennas. Reasonable impedance bandwidth and isolations between ports have been obtained.

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