Wideband Linear and Dual-Polarized Antenna Based on Huygens' Source Principle

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Abstract

A Huygens source principle is used to design a wideband antenna. An electric dipole and a slot are located above a ground plane to have unidirectional broadside radiation with high front to back ratio. A symmetry radiation patterns are obtained. Linear and dual polarized antennas are designed and tested. The antennas achieve more than 50% bandwidth for both cases. The dually polarized antenna achieves around 30 dB isolation between the two ports.

1. Introduction

The concept of a complementary antenna, which is based on Huygens' source principal, is implemented by exciting an electric dipole and a magnetic dipole simultaneously, so as to have equal E- and H-planes radiation patterns as proposed by Clavin in 1954 [1]. It is well known that the radiation pattern for the electric dipole has a figure-8 shaped pattern in the E-plane and a figure-O shaped pattern in the H-plane; whereas the radiation pattern for the magnetic dipole has a figure-O shape in the E-plane and a figure-8 shape in the H-plane. With appropriate excitation of both the electric and magnetic dipoles, the complementary antenna can have a symmetric E- and H-planes radiation patterns. This idea was realized by Clavin again in 1974 [2]. Similar designs using a slot and dipole combination [3-6] are suggested, however, all of these designs [1-6] are either narrow bandwidth or bulky in structure. Recently, a wideband complementary antenna was proposed by Wong and Luk [7-8]. The wideband antenna element consists of a planar dipole and a shorted patch antenna backed by a common ground plane. Good electrical characteristics, such as low back radiation, stable antenna gain over the operating band, and symmetric E- and H-plane radiation patterns, were achieved. The planar dipole is adopted as an electric dipole and the wideband shorted patch antenna [7] is chosen as an equivalent to a magnetic dipole, respectively.

In this paper, a linearly and dually-polarized wideband complementary antenna is studied and proposed. The wideband complementary antenna element in [8] is adopted and extended to dual-polarized operation. Due to the enhanced channel capacity by reducing the side effects of multipath fading, the dual polarized antenna is more desired than the linearly polarized antenna in modern wireless communication systems. A similar approach for dual-polarization is reported in [10], but the bandwidth is reduced due to the dielectric materials between two vertical shorting walls. Here, the proposed antenna with shielded dielectric substrate has been proposed to avoid loading the radiating slot with dielectric and simplify the excitation mechanism. At the same time retain the excellent characteristics of the wideband complementary antenna element. In order to verify the performance of the proposed antenna, simulation analyses are compared with experimental measurements.

2. Linearly Polarized Huygen's Source Antenna

The design process started with the linearly polarized antenna designed at the central frequency of 2.5 GHz. As shown in Figure 1 a sketch of the antenna geometry with L= H_1 = 0.25 λ_0, W = 0.5 λ_0, and S = 0.11 λ_0 at 2.5 GHz. Here, a 50 Ω microstrip line exciting the antenna is placed in the back of the two parallel plates performing the slot. Such a form of excitation avoids the use of the microstrip line between the two parallel plates, which would requires using an air substrate for the microstrip line as used in [8], which makes it difficult to construct. The antenna parameters are studies and the final design is built and tested. The reflection coefficients are shown in Figure 2 for computed and measured results versus frequency. The -10dB reflection coefficients bandwidth is 53%. Sample radiation patterns are shown in Figure 3 for E-plane and H-plane radiation patterns at 2.5 GHz. The radiation patterns show excellent front to back ratio level with excellent symmetry in the main beam and low cross-polarization level (-25 dB) that makes this antenna an excellent prime focus feed for parabolic reflector. Another form of linearly polarized antenna is designed with two hocks probes exciting the slot. The antenna achieved 72% bandwidth. For brevity its results are omitted.

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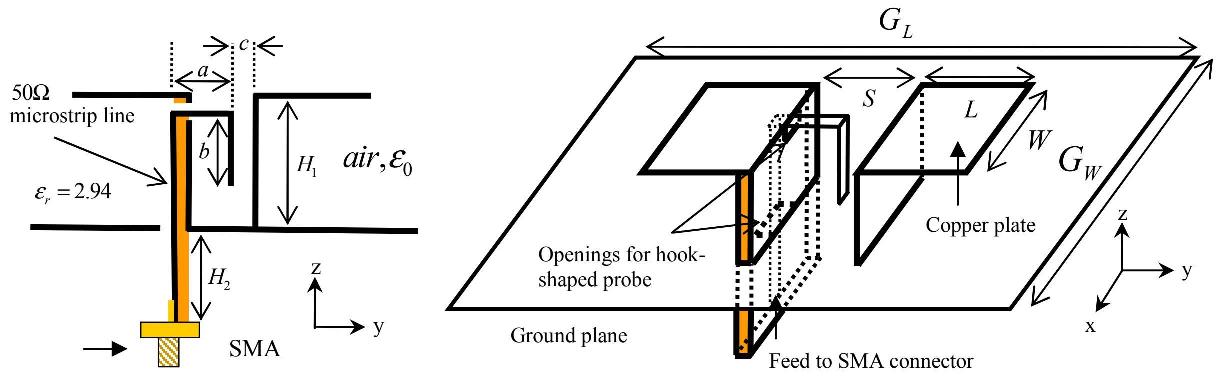


(a) Cross-section (b) 3D view graph

Figure 1 Geometry of linearly polarized Huygens source antenna

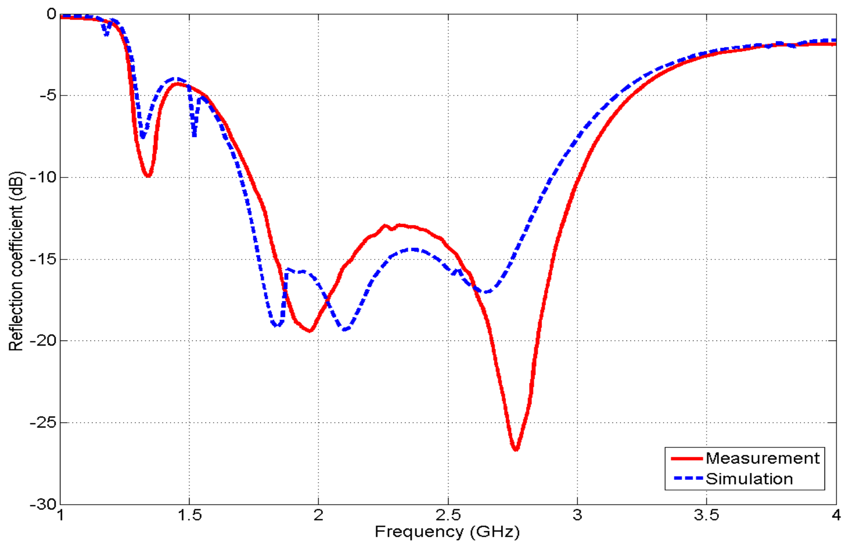


Figure 2 Computed and measured reflection coefficients of the linearly polarized antenna in Figure 1.

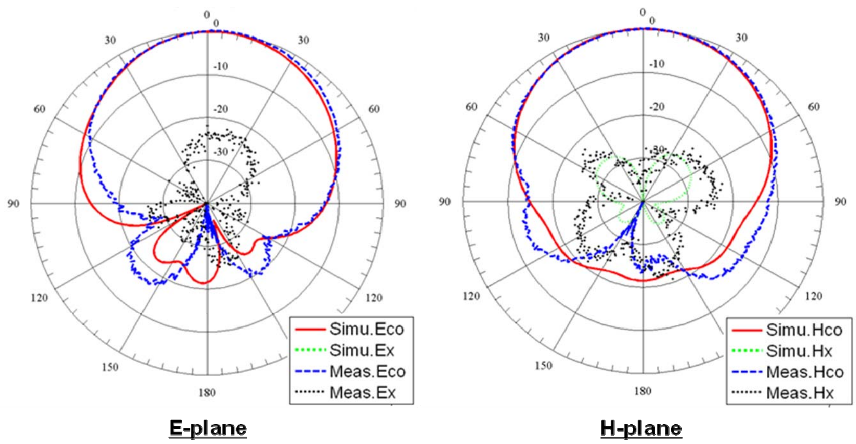


Figure 3 computed and measured radiation patterns at 2.5 GHz.

3. Dually Polarized Antenna

Based on the two probes for the linearly polarized antenna a dually polarized version is designed. The concept is passed on creating a cross slot that at the same time forms the gaps exciting two dipoles that one would think of them as two overlapping flat dipoles. The two dipoles can also be seen as a square patch that is supporting two orthogonal modes. The geometry is shown in Figure 4. Half of each slot is excited by a probe connected to a microstrip arm of a power divider with its input represent the port excitation. The antenna electrical dimensions are similar to the linearly polarized antenna with L= H_1 = 0.25 λ_0, and S = 0.11 λ_0 at 2.5 GHz. Notice that the antenna width increases by S from the dimensions of the linearly polarized antenna because of the insertion of the orthogonal slot. Again, the present design is different from the one in [9] due to the use of the printed microstrip lines outside the parallel plate region. This design helps in achieving wider bandwidth for the dually polarized antenna with an excellent isolation between the two polarizations. The major part of the band achieves isolation better than 30 dB. The S-parameters of the antenna versus frequency are shown in Figure 5. This figure indicated a bandwidth of over 60%. A sample of the measured radiation patterns are shown in Figure 6 at 2.7 GHz in two planes for both polarizations. It can be seen the symmetry between the radiation patterns in both planes from the two ports. The antenna achieved a maximum gain of 10 dB.

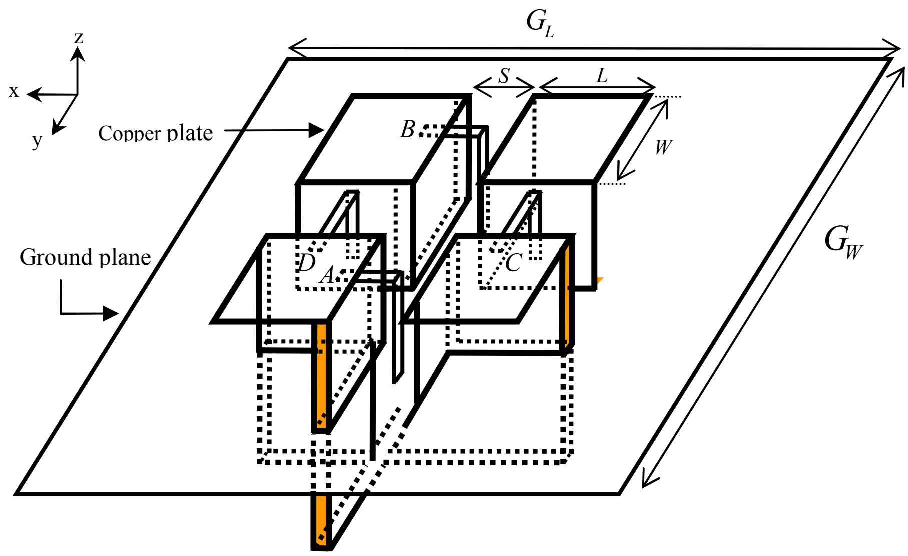


Figure 4 Geometry of dually polarized Huygens source antenna.

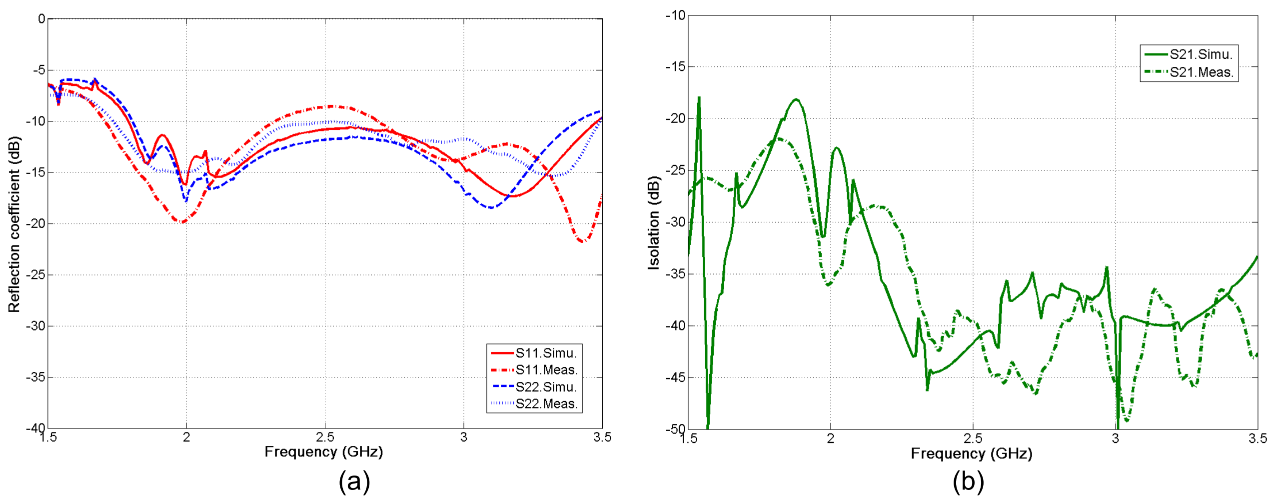
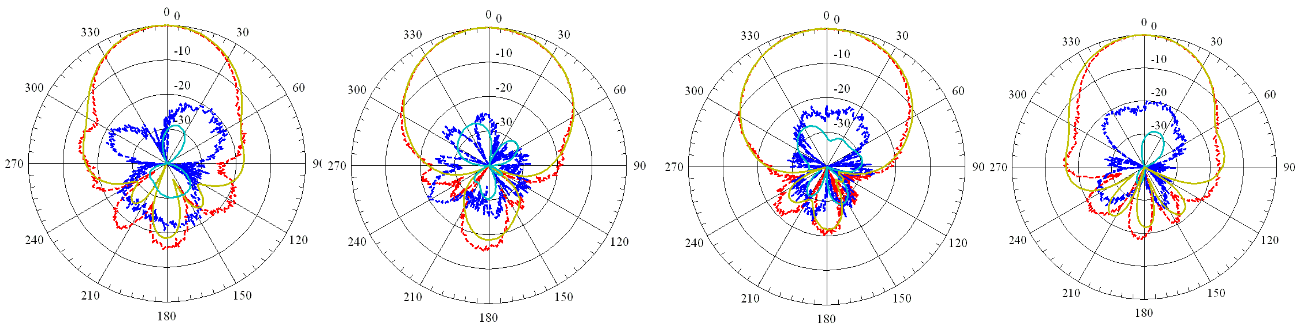


Figure 5 Computed and measured s-parameters of the dually polarized antenna.



(a)xz-plane, port 1 (b) yz-plane, port 1 (c) xz-plane, port 1 (d) yz-plane, port 2

Figure 6 Measured radiation patterns in the xz-plane and yz-plane at port 1 and port 2 of the antenna at 2.7 GHz. Solid line computed and dashed line measured.

4. Conclusion

Huygens source principle was used to design linear and dual polarized antennas. Wideband linear and dual-polarized antennas were designed and tested. Excellent characteristics such as symmetric E- and H-plane radiation pattern, low cross-polarization and stable gain over the operating frequency at 2.5GHz were achieved. To increase the bandwidth of the antenna, the dielectric substrate was shielded from the radiating region and twin hook-shaped probe feeds were implemented. From the measurement results, the dual-polarized antenna has about 67% ($S_{11} \le -10dB$) impedance bandwidth from 1.74 GHz to 3.50 GHz. The measured isolation level below 30dB within the common impedance bandwidth is about 44.8% from 2.22 GHz to 3.50 GHz. Symmetric radiation patterns for E- and H-planes were observed within the operating frequency. The maximum cross-polarization level in measurement is around -17dB.

5. References.

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