Unidirectional Antenna Composed of a Planar Dipole and a Shorted Patch

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Abstract—A wideband unidirectional antenna composed of a planar dipole and a shorted patch antenna is presented. The antenna is excited by a Γ-shaped strip feed line. A wide impedance bandwidth of 43.8% (SWR≤1.5) from the frequency of 1.85 to 2.89 GHz is achieved. Stable radiation pattern with low cross-polarization, low backlobe radiation, nearly identical E- and H-plane patterns and an antenna gain of ~8dBi is found across the entire operating bandwidth.

Index Terms—dipole, shorted patch, L-probe, wideband antenna, low cross-polarization, low back radiation

I. INTRODUCTION

Several studies have been focused on the development of wideband unidirectional antenna elements [1-3]. A unidirectional antenna can be realized by placing a dipole one quarter of a wavelength above a finite ground plane [1]. Since the height of this antenna [1] in terms of wavelength is frequency dependant, the antenna has drawback of the large variation in gain and beamwidth over the operating bandwidth. Another popular unidirectional antenna is the microstrip/patch [4-7] antenna. There are many articles on the design of wideband patch antennas using an L-probe feed [4], an aperture coupled feed [5], stacked patches [6] or a U-slot patch [7] etc. For SWR≤2, within 20% to 40%, can be achieved by these designs which are sufficient for many wireless communication systems. However, the radiation pattern changes substantially across the bandwidth of these designs [4-7]. High cross-polarization usually can be observed, especially in the upper frequency band. Although some techniques such as anti-phase cancellation [8], twin-L probes coupled feed [9], M-probe feed [10] etc, were suggested for suppressing the cross-polarization, these antennas still have the weaknesses in gain and beamwidth variations with frequency as well as different beamwidth in the E- and H-planes.

To achieve an equal E- and H-planes radiation pattern and a stable performance over frequency, the idea of complementary antenna consisting of an electric dipole and a magnetic dipole was revealed in 1954 by Clavin [11]. It is well known that an electric dipole has a figure-8 radiation pattern in its E-plane and a figure-O pattern in the H-plane; while a magnetic dipole has a figure-O pattern in the E-plane and a figure-8 in the H-plane. If both electric and magnetic dipoles can be excited simultaneously with appropriate amplitude and phase, a unidirectional radiation pattern with equal E- and H-planes can be obtained. A practical design was proposed by Clavin again in 1974 [12]. Another design, which consists of a passive dipole placing in front of a slot, was also reported by King [13]. Similarly, this idea was realized by other investigators, based on a slot-and-dipole combination [14,15]; however, all of these designs [11-15] are either narrow in bandwidth or bulky in structure.

In this paper, a new wideband complementary antenna with low cross polarization, low back radiation and symmetric E-and H-plane patterns is presented. The antenna comprises a vertical-oriented quarter-wave shorted patch and a planar dipole, which is equivalent to a combination of an electric dipole and a magnetic dipole. Experimental data are obtained to verify the theoretical prediction. Due to its excellent electrical characteristics, the proposed antenna finds applications in various wireless communication systems.
II. ANTENNA DESCRIPTION

The proposed design is based on the approach of combining an electric dipole antenna with a magnetic dipole antenna. Among many candidates of electric dipoles, a planar dipole antenna is chosen as shown in Fig. 1a; while a wideband short-circuited patch antenna is selected as the magnetic dipole as depicted in Fig. 1b. To combine these two antennas, the short-circuited patch is placed vertically and is connected to the planar dipole as illustrated in Fig. 1c. Based on this idea, a new wideband antenna is proposed and its geometry is shown in Fig. 2. After a detailed parametric study, an antenna operated at the center frequency of 2.5GHz is designed for demonstration. Each side of the planar dipole has a width $W=60\text{mm}$, a length $L=30\text{mm}$ (0.25 $\lambda$). The shorted patch antenna has a length $H=30\text{mm}$ (also close to 0.25 $\lambda$), where $\lambda=2\pi f$. For wideband operation, the separation of the two vertical plates, $S=17\text{mm}$, of the shorted patch antenna should be close to 0.14 $\lambda$ and the width of the dipole and the patch $W$ should be around 0.5 $\lambda$. The size of the ground plane can be used to adjust the back radiation. The optimum dimensions of the ground plane are $120\text{mm} \times 120\text{mm}$ (1 $\lambda$ by 1 $\lambda$).

![Fig. 1 Principle of operation of the antenna.](image)

To excite the antenna, a $\Gamma$-shaped probe feed is employed. This feed consists of three portions, which is made by folding a straight metallic strip of rectangular cross-section into a $\Gamma$-shape. The first portion which is vertically-oriented has one end connected to a coaxial launcher mounted below the ground plane. This portion together with one vertical plate of the shorted patch antenna acts as an air microstrip line with 50$\Omega$ characteristic impedance, which transmits the electrical signal from the coaxial launcher to the second portion of the feed. The second portion which is located horizontally is responsible to couple the electrical energy to the planar dipole and the shorted patch antenna. The input resistance of the antenna is controlled by the length of this portion. This portion is very inductive reactance which can make the antenna totally be mismatched. The third portion incorporated with the second vertical plate forms an open circuited transmission line. The equivalent circuit of this line is a capacitor. By selecting appropriate length for this portion, its capacitive reactance can be used to compensate the inductive reactance caused by the second portion.

III. EXPERIMENTAL VERIFICATION

To verify the simulated results, a prototype of the proposed antenna was built and tested. Dimensions of the antenna are listed in the table inserted in Fig. 2. and the picture of fabricated antenna is shown in Fig. 6. Experimental results of SWR was obtained by an HP8510C network analyzer and radiation patterns and the antenna gain were measured by a compact range with an HP85103C antenna measurement system. Fig. 3 shows a comparison of the measured and simulated SWRs of the proposed antenna. As seen from the SWR curves, the antenna has wide impedance bandwidth of 43.8% (SWR<1.5) from 1.85 to 2.89 GHz. Fig. 4 illustrates the measured and simulated gain curves of the antenna. It can be observed that the proposed antenna has an average gain of 8dBi approximately, varying from 7.5dBi to 8.2dBi across the operating bandwidth. Radiation pattern at frequencies of 1.75, 2.5 and 3 GHz were measured and shown in Fig. 5. For both E and H-planes, the broadside radiation pattern shapes are stable and symmetric across the operating bandwidth, and the beamwidth for the center frequency of 2.5GHz at the H-plane is 79°, which is slightly larger than the beamwidth at E-plane which is about 75°.
cross-polar radiation level as well as low back radiation are achieved across the entire operating bandwidth.

Fig. 3 SWR against Frequency

Fig. 4 Gain against Frequency

Fig. 5 Radiation Pattern
IV. CONCLUSION

A new wideband antenna composed of a planar dipole and a vertically-oriented quarter-wavelength patch is introduced. It is simply excited by a Γ-shaped strip line. More than 43.8% impedance bandwidth for SWR<1.5 and 8dBi maximum gain has been achieved. This new design antenna has many advantages, including simple structure, wide bandwidth, low cross polarization, symmetrical radiation pattern, and in particular, very low back radiation. Moreover, the gain and beam width of the antenna are almost constant over the operating band. The antenna will find many applications in modern wireless communications.

Fig. 6 Photo of the proposed antenna

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V. REFERENCES

[16] Zeeland IE3D version 10.0.