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A WIDEBAND PLANAR DIPOLE ANTENNA WITH PARASITIC PATCHES

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Abstract—This paper presents a novel wideband planar dipole antenna with parasitic patches. Of which, acting primarily as directors, the parasitic elements aim to improve the radiation patterns in terms of gain especially at the higher frequencies. For verification, the proposed novel structure was fabricated and measured. The proposed antenna is well-matched with achieved VSWR < 2 and has a good radiation performance across the entire operating frequency range of 3–8 GHz.

1. INTRODUCTION

Antennas with wideband characteristics have found wide applications in modern communications systems. In the era of wireless communications, many buildings are installed with wireless networks consisting of numerous ceiling-mounted, indoor base station antennas. In many cases, antennas with wide impedance bandwidth (BW), low profile, and unidirectional radiation patterns become a necessary component in these systems. Several types of antennas are limited by their large dimensions for these applications. Patch antenna can provide unidirectional patterns and has major advantages of low profile, light weight and easy fabrication, but its impedance BW is not wide enough under the condition of stable unidirectional radiation patterns. For expanding the bandwidth, the arms of the dipole are usually designed with fat wire or planar. A series fed printed strip dipole with bandwidth greater than 30% for VSWR < 1.5 is proposed in [1]. A tapered-slot feeding structure, curve shaped dipole antenna with covering range from 3.1 GHz to 10.6 GHz for VSWR < 2 is presented in reference [2]. It has been reported that, with a shorting

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bridge connecting its two radiating arms for UWB applications [3], a printed planar dipole can achieve a wide impedance bandwidth of 118% with VSWR $\leq$ 2, covering the entire UWB band of 3.1–10.6 GHz. There are some other types of wideband printed dipoles, including square shape [4], bow-tie [5, 6], etc.) Reference [7] discusses a circular shape dipole antenna. The impedance BW of the proposed antenna with VSWR better than 2 covers a very wide frequency range from 3.0 GHz to 8.0 GHz, but the radiation pattern starts to deteriorate at 8 GHz. For the conventional compact dipole antennas, despite having a wide impedance bandwidth, it suffers from degradation in radiation patterns in terms of gain at maximum radiation directions at the high frequencies as the dipole becomes electrically large.

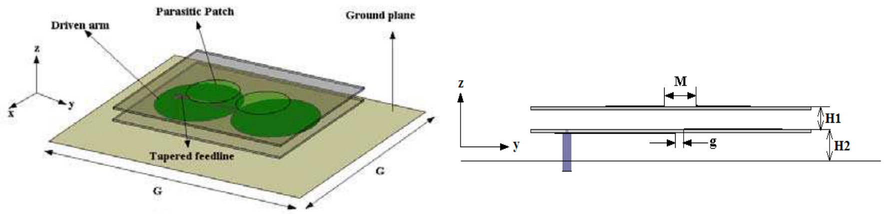
In this lettera concept, derived from the Yagi-Uda antenna, of using parasitic patches to enhance antenna gains was investigated. The proposed antenna is well-matched with achieved VSWR $<$ 2, covering the whole frequency range of 3–8 GHz. For comparison purposes, the radiation patterns of the proposed antenna with and without parasitic patches were also simulated. The experimental results indicate that the parasitic directors can enhance the gains and advance the radiation pattern characteristics especially at higher frequencies effectively.

2. ANTENNA DESIGN

From the 1930's on, antenna engineers have been searching for wideband antenna elements. Soon they discovered that, staring from a dipole or monopole antenna, thickening the arms resulted in increased bandwidths. The reason for this is that for a thick dipole or monopole antenna, the current distribution is-unlike for the thin dipole and monopole — not longer sinusoidal. While this hardly affects the radiation pattern of the antenna, it severely influences the input impendence, [8]. This band-widening effect is even more severe if the thick dipole is given the shape of a biconical antenna. A further evolution may be found in dipole and monopole antennas formed by spheres or ellipsoids, [9].

In reference [7], it discusses a circular shape dipole antenna to achieve BW range from 3–8 GHz. Being deduced from these above, an ellipse shape dipole antenna is presented in this paper. A concept, derived from the Yagi-Uda antenna, of using parasitic patches to enhance antenna gains was investigated.

The configuration of the proposed antenna with parasitic patches is shown in Figure 1. It consists of two identical elliptical driven arms, a couple of parasitic elliptical patches, a tapered feed line, a coaxial cable and a rectangular ground plane. Two proposed elliptical driven



(a) (b)

Figure 1. Configuration of proposed antenna. (a) Three-dimension view. (b) Cross-section view.

arms, with the major radius R_1, the ratio of 0.75, are etched on the opposite plane of an inexpensive FR-4 substrate of 100 mm by 100 mm, permittivity (ε_r) of 2.65 and thickness of 1 mm. The planar arms lie in the x-y plane. There is a distance g between two driven arms in the side view. A tapered line varying from 50 Ω to 75 Ω, with the length of l, connects to the upper driven arm as the feed line. There is a coaxial cable which the inner conductor connects to the feed line, and the outer conductor connects to the opposite side driven arm. Two parasitic elliptical arms, with the major radius R_2, the ratio of 0.75, are printed on the same plane of the substrate having the same dimensions as one that the driven arms are etched on. A distance M exists between two parasitic patches. The length of one driven arm and one parasitic arm can be approximated evaluated by the following formula respectively:

$$L_d = \frac{C}{2 f_l} \tag{1}$$

$$L_p = \frac{C}{2 f_m} \tag{2}$$

where C velocity of light, L_d length of one driven arm, namely $2R_1$ by ratio, L_p length of one parasitic arm, namely $2R_2$ by ratio, f_l lower operating frequency, f_m medium operating frequency.

The optimized parameters are given as follows: $R_1 = 30$ mm, $R_2 = 18$ mm, $l = 37.5$ mm, $g = 0.8$ mm, $H_1 = 7$ mm, $H_2 = 10$ mm, $M = 2.8$ mm, $G = 150$ mm.

3. RESULTS AND DISCUSSION

Figure 2 shows the photograph of a prototype. The proposed antenna was simulated and optimized using EM software (HFSS.11) Obtained

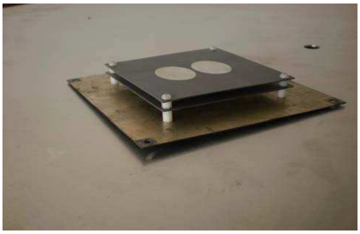


Figure 2. Photograph of proposed antenna.

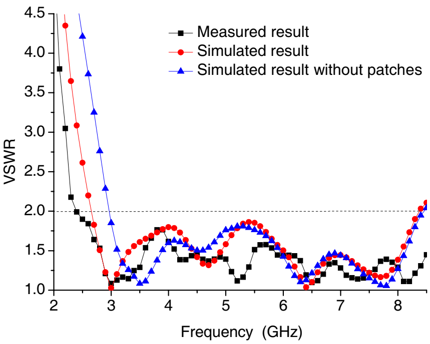


Figure 3. Measured and simulated VSWR of proposed antenna and simulated VSWR of antenna without patches.

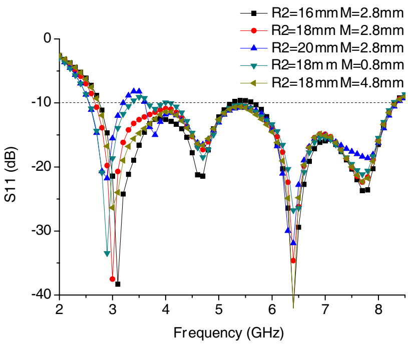


Figure 4. Variation of return loss with R_2 and M.

with Agilent E8363B vector network analyzer, the measured VSWR has been compared to the simulated one as shown in Figure 3. For VSWR ≤ 2, the simulated impedance bandwidth is about 107% (2600–8600 MHz) centered at 5.5 GHz and the measured one has a better result than that. The simulated VSWR of the proposed antenna without parasitic patches is also displayed in Figure 3. Note that the parasitic patches are insignificant to the impedance bandwidth characteristics.

At higher frequencies, one arm of the proposed antenna without parasitic patches is $> 1/2\lambda$ in length, which causes the radiation patterns to be changed. Furthermore, due to the higher order modes the currents along the two radiating arms are out of phase, which gives rise to the cancellation of radiation that eventually limits the achievable maximum gain. In order to advance the radiation pattern characteristics, a concept is to use an active antenna element a passive element called parasitic element and they act together to form an array. The input impendence of this array depends on selfimpedance of parasitic element and mutual impedance with driven element. For the proposed antenna, the variation of return loss with R_2 and M is illustrated in Figure 4 It indicates that the return loss (S_{11}) mostly fluctuates below 5 GHz. The lower bands are shifted to lower frequencies as R_2 increased and shifted to higher frequencies as M increased. By the proper selection of R_2 and M, better matching impedance will be reached over the wideband For comparison purposes, the simulated radiation patterns of the proposed antenna with and without parasitic patches at 3.5, 5.5, and 7.5 GHz are shown in Figure 5, respectively. Figure 6 presents the peak and boresight gains of the proposed antenna with and without parasitic patches in the operating bandwidth.

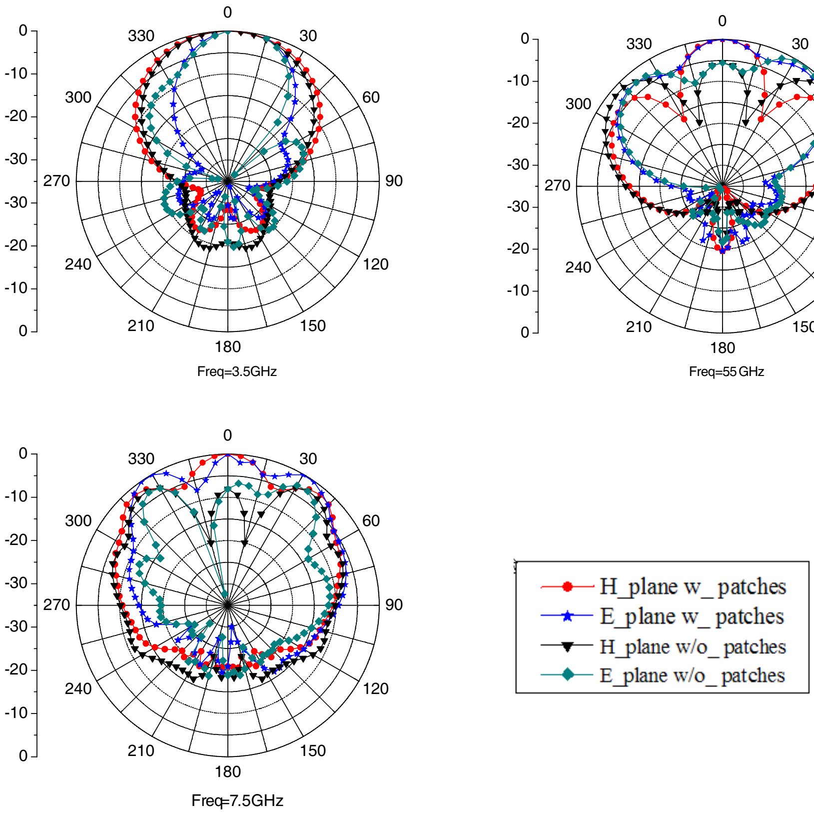


Figure 5. Simulated radiation patterns for antenna with and without parasitic patches at 3.5, 5.5 and 7.5 GHz.

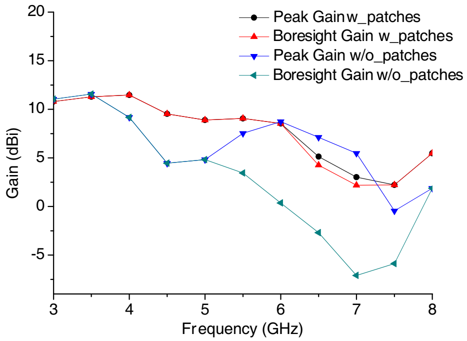


Figure 6. Peak and boresight gain of the proposed antenna with and without the parasitic patches.

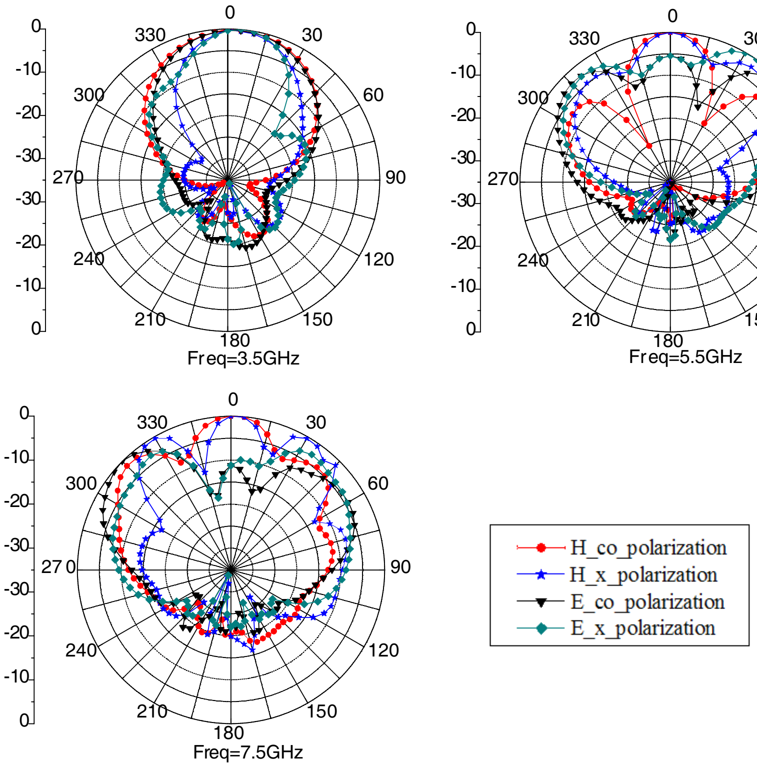


Figure 7. Measured radiation patterns for antenna with and without parasitic patches at 3.5, 5.5 and 7.5 GHz.

Reference [7] proposes a wideband circular shape compact size dipole antenna, with a small circle cut for each radiation circular arm, covering the band range of 3–8 GHz for VSWR < 2. However, the radiation pattern starts to deteriorate at 8 GHz, and the good radiation characteristics can be obtained from 3–7 GHz. The operating bandwidth is between 3 and 7.5 GHz.

In Reference [3], a compact planar dipole antenna with Ultra-Wide band performance is designed. For the improvement of deteriorating radiation patterns at higher frequencies, a shorting bridges, connecting two radiation arms, is introduced to increase the maximum gain of dipole.

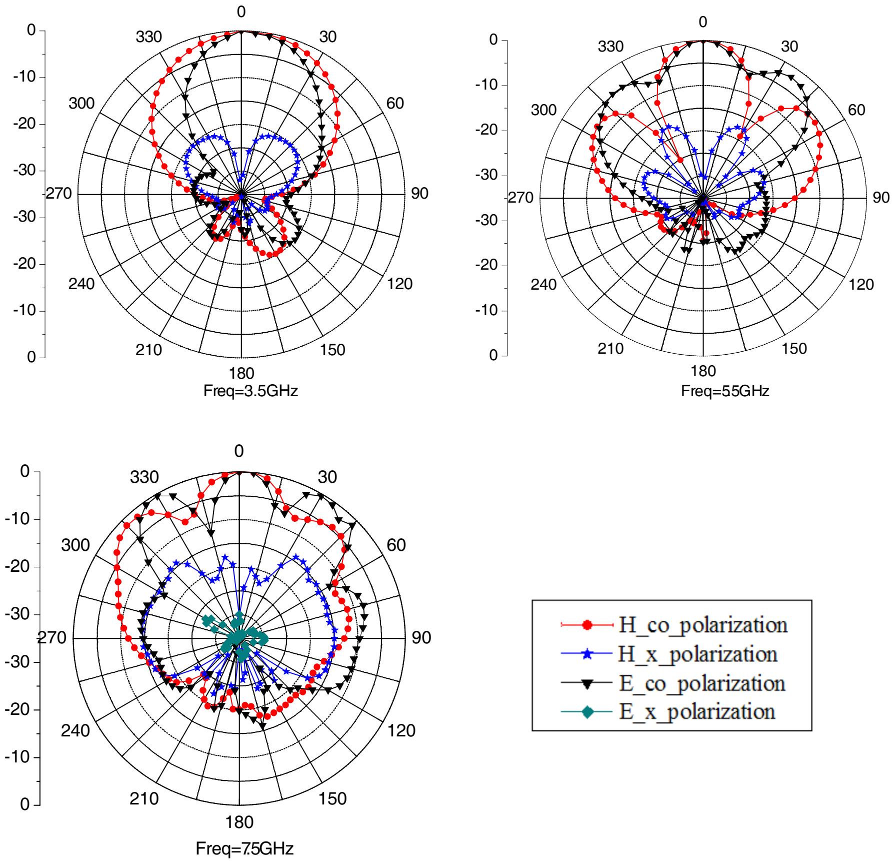


Figure 8. Radiation patterns of proposed antenna at 3.5, 5.5, 7.5 GHz in E- and H-planes.

For this antenna design, according to the results shown in Figures 5 and 6, it is evidently observed that, with additional parasitic patches, further improvement for radiation patterns and great increase in boresight gains especially at higher frequencies are possible. The good radiation patterns can be obtained over the whole operating band.

The measured radiation patterns for antenna with and without parasitic patches at 3.5, 5.5 and 7.5 GHz respectively are also given in Figure 7 to prove that the radiation patterns are improved indeed by using the parasitic patches. Figure 8 plots the radiation patterns of the designed antenna in the E- and H- planes at 3.5, 5.5, and 7.5 GHz, respectively. For the entire operating bandwidth, it can be observed that it has a maximum cross-polarization level of about -30 dB of the E planes and about -15 dB of the H-planes and the Front-Back Ration is about 20 dB. The proposed antenna gain has an average value of 7 dBi.

4. CONCLUSION

A printed dipole antenna with parasitic patches has been implemented and studied in this letter. The proposed antenna indicates not only a broad impedance bandwidth but also a good radiation performance across the whole operating bandwidth. As compared to the conventional printed dipole antenna, an extra layer of substrate with printed parasitic patches is added to prevent radiation patterns from deteriorating in terms of boresight gain at the higher frequencies. It features a relative bandwidth of about 91% for VSWR < 2 in the operating bandwidth of the antenna from 3 GHz to 8 GHz. It is expected that the antenna has appropriate properties for recent wireless communications.

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