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PRINTED DIPOLE ANTENNA WITH BACK TO BACK ASYMMETRIC DUAL-C-SHAPE UNIFORM STRIPS FOR DTV APPLICATIONS

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Abstract—A printed dipole antenna with back to back asymmetric dual-C-shape uniform strips capable of generating a wide operating band for digital television (DTV) signal reception in the 470–862 MHz band is presented. This antenna is associated with C-shape strips and asymmetric structure, and it operates band in 455–865 MHz. By proper adjusting some parameters, it is possible to achieve a broadband response. Measured results have been compared with simulation and found in a good agreement. The antenna with back to back asymmetric dual-C-shape uniform strips can generate two adjacent resonant modes to form a wide operating band of larger than 62% in 2.5 : 1 VSWR bandwidth, which is much wider than that of the corresponding back to back symmetric dual-C-shape strips dipole antenna. The experimental results show that stable radiation pattern is similar to a dipole antenna. The measured peak gains are 3.2 dBi and 2.3 dBi, at 620 MHz and 780 MHz, respectively. The radiation efficiencies are all larger than 60% for an entire DTV band.

1. INTRODUCTION

In the last few years, more countries offer digital television (DTV) broadcasting services with video and audio. Broadcasters can transmit television with high-definition image and sound by using DTV system, and furthermore, DTV broadcasting also provides multimedia and

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interactive services. Today, DTV signals reception has thus become very attractive for applications in many devices such as notebooks, tablet PC and vehicles, etc. For this reason, a simple antenna as a transducer between the DTV transceiver and the propagating medium is much desirable if it could operate at DTV bands. Planar printed antennas include broadband dipole [1, 2] and broadband monopole antennas [3–5]. On account of horizontally polarized DTV signals, the horizontally oriented antenna is a very promising candidate for DTV signal reception, and desirable radiation patterns for devices are usually omni-directional, therefore, a dipole antenna could be expected.

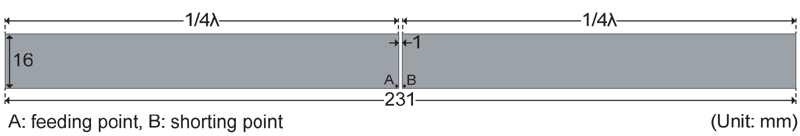
The half-wavelength dipole antenna is perhaps one of the most fundamental and commonly used antennas ever since the discovery of electromagnetic wave radiation. Generally, printed dipole antennas have significant advantages, such as low cost, light weight and ease of fabrication. However, conventional dipole antennas normally have a narrow bandwidth, which makes them difficult to cover all DTV bands. In order to enhance the bandwidth considerably, several techniques can be found in literature to achieve a wider bandwidth. For example, a double-printed U-shape antenna is proposed, with two U-shape dipole arms and fed by a micro strip line, and the antenna realized ultra-wideband character by multistage impedance conversion [6]. A dipole antenna composed of four micro strip dipoles with different lengths and widths to enlarge its bandwidth was reported in [7]. The antenna with an L-shaped feed gap could be excited to provide a wide bandwidth of larger than 50%. A wideband dipole antenna is proposed in [8], through investigating rectangle aperture with different sizes, an approximate 47.8% bandwidth is obtained. A wideband unidirectional patch antenna composed of a shorted bowtie dipole with Γ-shaped feed and an L-shaped electric dipole is designed [9]. It achieves an impedance bandwidth in the range 2.2–5.6 GHz. These antennas are ideal for design applications that require broad bandwidth. However, most methods are hard to offer antennas a feature of low-profile. Antennas with low-profile that can produce a broadband are highly desirable.

A single printed dipole antenna with back to back asymmetric dual-C-shape uniform strips for DTV bands is presented in this article. The purposed antenna can be easily integrated with commonly used printed circuit boards (PCB). The design procedure of the antenna is elaborated, and the simulated return loss and current distribution have been analyzed. To achieve the wideband characteristic, the parameter of g (distance of the gap between back to back dual-C-shape uniform strips) is controlled. Details of the antenna design are described and both simulated and measured results are shown in the following sections.

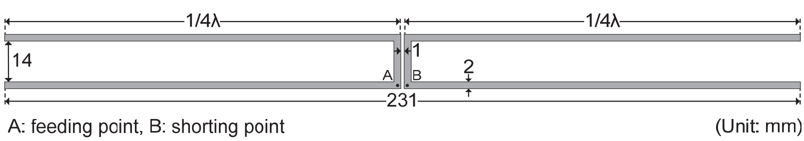
2. ANTENNA STRUCTURE AND DESIGN

A symmetric dual-rectangular patches dipole antenna and a symmetric back to back dual-C-shape uniform strips dipole antenna are shown in Figures 1(a) and 1(b) respectively. In general, a conventional symmetric dual-rectangular patches dipole antenna or symmetric back to back dual-C-shape uniform strips dipole antenna is hard to reach a broadband response. The back to back symmetric dual-C-shape uniform strips dipole antenna is constructed by etching off a smaller rectangle section from either patch, the strips profile could be adjusted to width and length conveniently for impedance and reactance in fine tune. Therefore the back to back dual-C-shape uniform strips dipole antenna is adopted. Figure 2 shows simulated return loss for symmetric dual-patch and symmetric back to back dual-C-shape uniform strips dipole antennas, have a bandwidth of 96 MHz (522 $\sim$ 618 MHz in 2.5 : 1 VSWR), the performances of the two dipole antennas are compared and results are similar obviously.

In this thesis, an antenna transforms from the back to back dual-C-shape uniform strips dipole antenna with symmetric structure to with asymmetric structure was provided. A dipole antenna with asymmetric configuration is able to generate two resonant modes, it could be exhibited a much wider bandwidth than a conventional symmetric dipole to cover the DTV signal reception within 470–



(a)



(b)

Figure 1. (a) Configuration of general two-rectangular patches dipole antenna, (b) back to back symmetric dual-C-shape uniform strips dipole antenna.

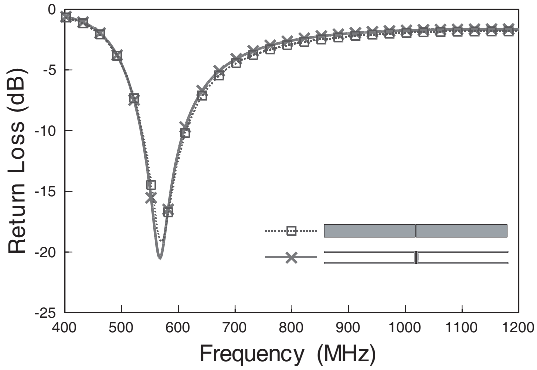
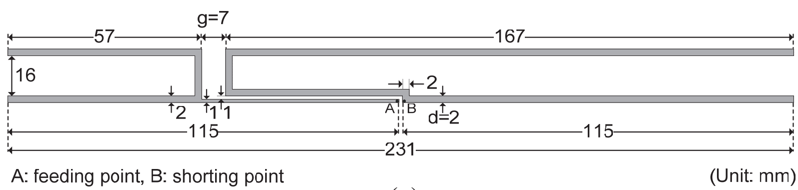


Figure 2. Comparison of the simulated return loss between the two-rectangular patches dipole antenna and the back-to-back symmetric dual-C-shape uniform strips dipole antenna.



(a)

(b)

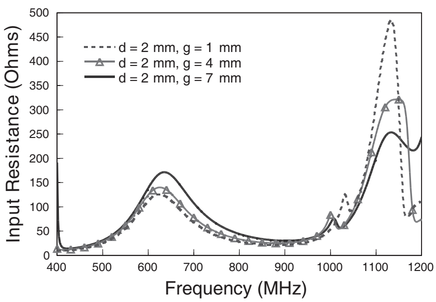
Figure 3. (a) Configuration of the printed dipole antenna with back to back asymmetric dual-C-shape uniform strips for DTV applications. (b) Photograph of fabricated antenna with SMA.

862 MHz. The Ansoft commercial program high frequency structure simulator (HFSS) [10] based on the finite-element method (FEM) is used for analyzing the behavior of proposed model and determining suitable values of parameters. Detailed dimensions of the proposed antenna are shown in Figure 3(a). In this study, a 0.8-mm thick FR4 substrate of relative permittivity (ε_r) 4.4 and size $231 \times 16\,\text{mm}^2$ is used. The proposed printed dipole has a simple structure and mainly consists of back to back asymmetric dual-C-shape uniform strips (including a radiating strip and a ground strip), and the width of uniform strips is 2 mm. The dimensions shown in the figure are the preferred design

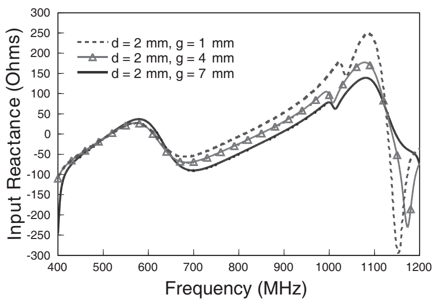
dimensions. With the proposed feed-gap arrangement, the antenna is separated into two asymmetric radiating portions of right C-shaped strip (length 167 mm or about 0.375λ) and left reverse-C-shaped strip (length 115 mm or about 0.25λ). By choosing a proper length of back to back dual-C-shape uniform strips, two resonant modes can be excited at about 530 and 830 MHz for the proposed antenna, thereby leading to a wide operating band. Figure 3(b) shows a photograph of the practical antenna, which is connected with SMA connector for measurement.

3. RESULTS AND DISCUSSIONS

In order to provide good matching characteristics, variations of the gap distance g between back to back asymmetric dual-C-shape strips and the width d of the strips were also studied. Figures 4(a) and 4(b)



(a)



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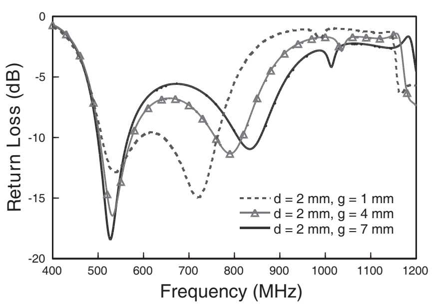


(c)

Figure 4. Simulated the variation of g of the gap between back to back asymmetric dual-C-shape strips ($d = 2$ mm). (a) Resistance of the proposed antenna for variation in g. (b) Reactance of the proposed antenna for variation in g. (c) Simulated return loss as a function of distance g. Other dimensions are the same as given in Figure 3.

simulate the input impedance characteristics of the proposed antenna with various the gap distance g between back to back asymmetric dual-C-shape strips. The effects of parameters g and d on the return loss are simulated and shown in Figures 4(c) and 5(c) respectively. The results for the gap distance g varied from 1 to 7 mm are shown in Figure 4; other dimensions of the antenna are the same as given in Figure 3. There are two resonant modes excited at about 530 MHz and 830 MHz for the proposed antenna. The antenna's second resonant mode is strongly affected by the gap distance g. With an increase in g, the second resonant mode is quickly shifted to higher frequencies leave from the first resonant mode. This result is expected, since the length of right-C-shape strip of connecting short point decreases as g increases, and so is the total effective length ($0.625\lambda{-}g$ mm) of dual-C-shape strips. Results also indicate that, with g chosen to be 7 mm, the antenna's two excited resonant modes can be formed

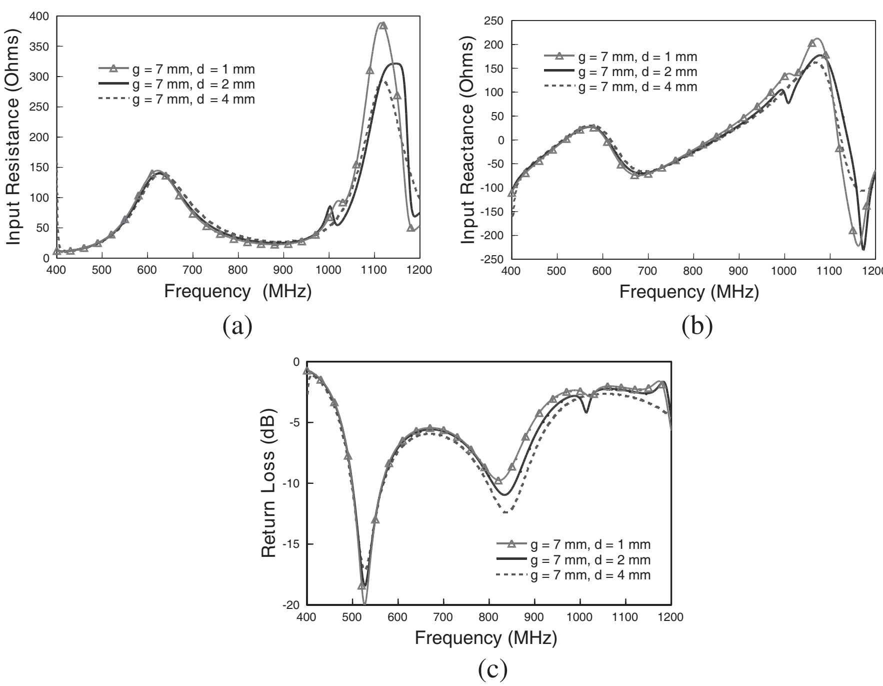


Figure 5. Simulated the variation of the proposed antenna with various strips width d ($g = 7$ mm). (a) Resistance of the proposed antenna for variation in d. (b) Reactance of the proposed antenna for variation in d. (c) Simulated return loss for the proposed antenna with various strips width d other parameters are the same as Figure 3.

into a wide operating band, with good impedance matching achieved for frequencies over the whole DTV band of 470–862 MHz. The gap distance g parameter mainly influences the impedance at higher frequencies, as shown in Figures 4(a) and 4(b). Figures 5(a)–(c) show that the uniform strips width d acts as an impedance matching element especially at higher frequencies. The impedance matching for frequencies in the upper band can be adjusted by varying the uniform strips width d, and the preferred uniform strips width d is chosen to be 2 mm in this study. This behavior can be seen more clearly from the simulated input impedance versus frequency for the proposed antenna, as shown in Figures 4 and 5.

Figure 6 shows the simulated excited surface currents distribution at 530 and 830 MHz (about center frequencies of the excited 0.5- and 1.0-wavelegth modes). At 530 MHz, the excited surface currents on right C-shaped and left reverse-C-shaped strips are in the same direction and very similar to those on the two equal C-shaped strips of the conventional center-fed dipole antenna excited at the first (0.5-wavelength) mode. For the excited surface currents at 830 MHz, there are a null current on right C-shaped and left reverse-C-shaped strips along the C-shaped feed gap, and the surface currents on right C-shaped and left reverse-C-shaped strips are in the opposite direction. This behavior is similar to that of the conventional dipole antenna excited at the second resonant mode (1.0-wavelength mode). In addition, it is seen that right C-shaped strip has a much longer length than left reverse-C-shaped strip, and the surface currents on right C-

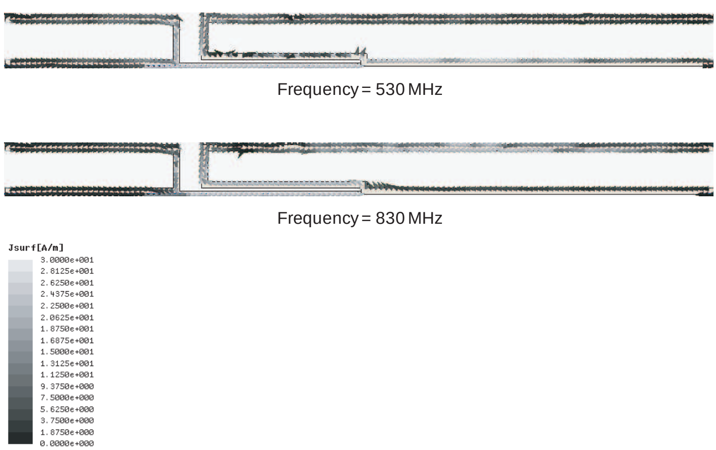


Figure 6. Simulated excited surface currents distribution of the resonant mode at (a) 530 MHz, (b) 830 MHz.

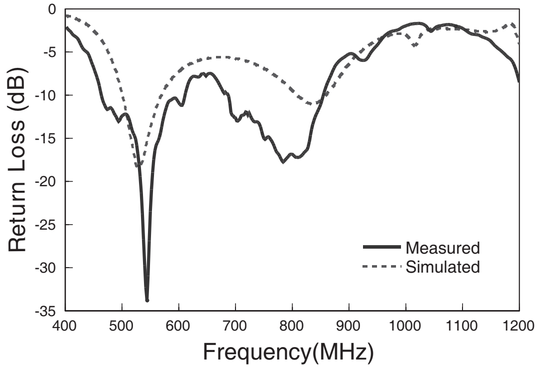


Figure 7. Simulated and measured return loss for the proposed.

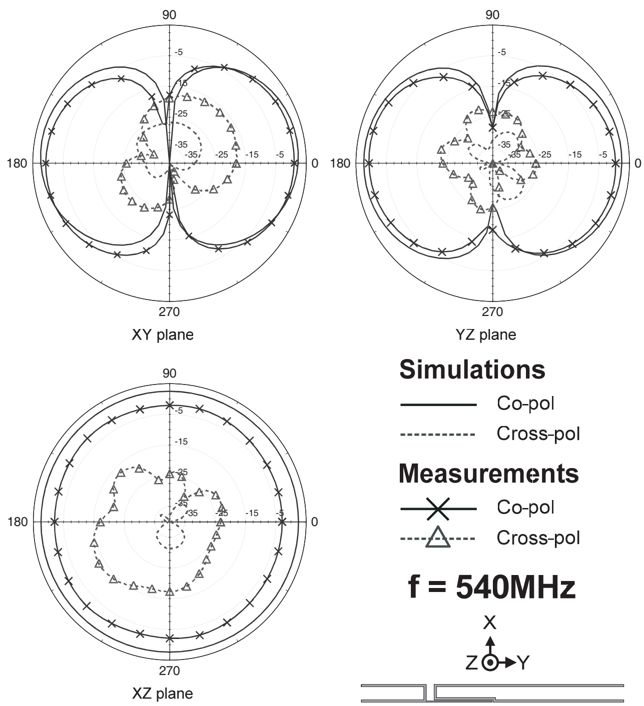
shaped strip are generally stronger than those on left reverse-C-shaped strip. In this case, it is expected that the radiation characteristics of the antenna at the second (1.0-wavelength) resonant mode will be dominated mainly by right C-shaped strip and similar to those of the antenna excited at the first (0.5-wavelength) resonant mode. That is, stable radiation characteristics and omnidirectional radiation in the plane orthogonal to the antenna are expected to be obtained over the wide operating band formed by the two excited resonant modes.

Figure 7 shows the simulated and measured return loss results of the proposed antenna. The fabricated antenna was measured on network analyzer HP8720C. The simulated results are obtained using Ansoft HFSS, and a good agreement is obtained between the simulation and measurement. The measured impedance bandwidth, defined by 2.5 : 1 VSWR, reaches 410 MHz (455–865 MHz), which is about 62% centered frequency at about 675 MHz. The obtained bandwidth makes the proposed antenna very promising to cover the whole DTV band (range of 470–862 MHz). Also note that the bandwidth definition of 2.5 : 1 VSWR is generally acceptable for DTV signal reception in practical applications.

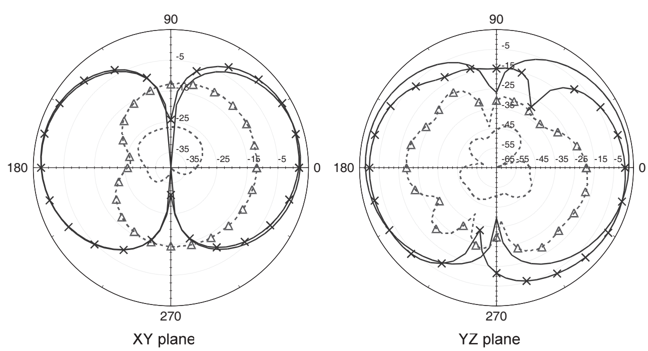
The radiation patterns are measured in a far-field anechoic chamber. Figure 8 plots the simulated and measured 2-D radiation patterns at 540 and 780 MHz for the proposed antenna. As expected, this pattern characteristics are similar to those observed for the conventional dipole for DTV operations, dipole-like radiation patterns for the frequencies are seen, the radiation patterns with good omnidirectional radiation in the azimuthal plane (x-z plane). The observed radiation patterns also show no special distinctions as compared to those of the conventional internal DTV antennas at the 540 and

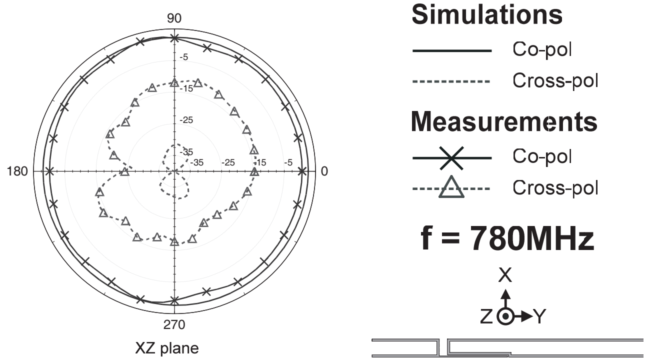
780 MHz bands.

Figure 9 presents the simulated and measured antenna gains and radiation efficiencies for the proposed DTV antenna 470–862 MHz operations, and the antenna gains vary from about −1 dBi to 3.2 dBi, while the radiation efficiencies range from about 38% to 97%.



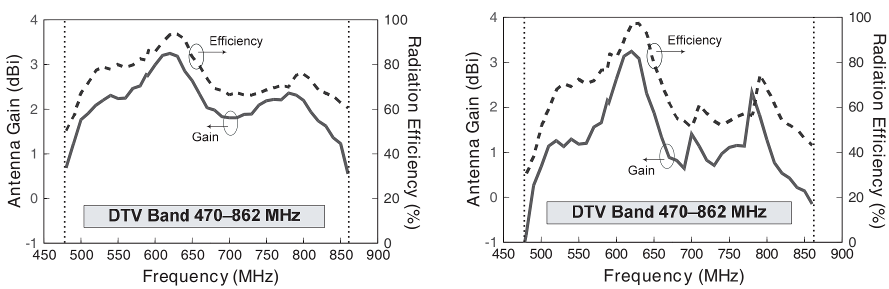
(a)





(b)

Figure 8. Simulated and measured radiation patterns of the proposed antenna in the x-y, y-z and x-z planes at (a) 540 MHz, (b) 780 MHz.



(a) (b)

Figure 9. Antenna gain and radiation efficiency for the proposed antenna, (a) Simulated. (b) Measured.

4. CONCLUSION

A printed dipole antenna with back to back asymmetric dual-C-shape uniform strips for DTV applications in the 470–862 MHz band has been studied and fabricated. The proposed printed DTV dipole antenna is easily printed on the PCB at low cost. The width and length of the back to back dual-C-shape strips with asymmetric structure could be adjusted conveniently for impedance and reactance in fine tune. At last, the impedance bandwidth of the proposed antenna occupies the entire band of the DTV system. The proposed dipole antenna shows good omni-directional radiation performances and high gain in the horizontal plane, which is due to the same current direction on radiation element and ground plane. The experimental results indicate that the design has the advantages of low-profile, easy fabrication, broadband performances, and stable radiation characteristics.

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