Microstrip Monopole Antenna With Enhanced Bandwidth Using Defected Ground Structure

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***Abstract*—In this letter, a double U-shaped defected ground structure (DGS) is proposed to broaden impedance bandwidth of a microstrip-fed monopole antenna. The antenna structure consists of a simple trapezoid monopole with a DGS microstrip feedline for excitation and impedance bandwidth broadening. Measurement shows that the antenna has 10-dB return loss from 790 to 2060 MHz, yielding 112.4% impedance bandwidth improvement over that of traditional design.**

***Index Terms*—Defected ground structure (DGS), impedance bandwidth, monopole.**

I. Introduction

THE traditional monopole antenna is inherently a narrow-band structure. To enhance the impedance bandwidth, the monopole with different shapes is used [1]–[4]. According to the open literatures, the shape of conventional square monopole was changed to triangular- and disc-shaped so as to improve impedance bandwidth. When the microstrip-fed monopole antenna is considered, besides the change of patch shape, the impedance matching network can be easily incorporated with the microstrip feedline to realize wider impedance bandwidth. As reported in [5], a simple microstrip stub served as the impedance matching element and provided around 13% bandwidth enhancement when compared with the traditional design. To realize much wider bandwidth, additional stub could be added but the feedline becomes lengthy.

Recent development of Electromagnetic Bandgap (EBG) has led immense research interest of antenna performance improvements of size reduction [6], [7], gain enhancement [8] and radiation efficiency improvement [9] and so forth. A notable class of EBG structures named Defected Ground Structure (DGS) is recently introduced and it has a controllable finite transmission zero characteristic [10]. It was reported that an H-shaped DGS was used to suppress higher order harmonics of a microstrip patch antenna by more than 20 dB [11] and; a circular DGS reduced the cross-polarized (XP) radiation of a microstrip patch antenna by 8 dB [12]. As to the best of our knowledge, the usage of DGS in impedance bandwidth enhancement has not yet been addressed. To this end, we propose yet another technique that a single stub feedline etched with double U-shaped DGS is employed to enhance the impedance bandwidth of a microstrip-fed monopole antenna. Different from the traditional DGS, this U-shaped DGS offers dual bandgaps characteristic yielding a high order matching network for bandwidth enhancement [13]–[15]. In addition, the higher order modes of monopole are reduced due to the bandgap element. Etching this DGS underneath the simple microstrip feedline, impedance bandwidth broadening can be obtained. A prototype microstrip monopole antenna operated from 790 to 2060 MHz is presented and experimentally characterized. It is found that the measured 10-dB impedance bandwidth improvement is about 112.4% when compared with that of traditional monopole antenna.

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II. Monopole Antenna With DGS

The microstrip-fed monopole antenna printed on a grounded substrate with proposed DGS is shown in Fig. 1 and; it has a simple trapezoid patch that is optimized by full-wave electromagnetic solver—Zeland IE3D so as to operate at 1400 MHz [16]–[18]. The substrate is RO4003 with a dielectric constant of 3.38 and a thickness of 1.524 mm. The length and width of microstrip feedline is 26.2 and 2.6 mm, respectively. Different from the traditional microstrip feedline, a tuning stub with length $l_s = 12$ mm and width 4.1 mm is attached. This stub is placed $h_s = 15.6$ mm apart from the feeding port. Under this feedline, the DGS is strategically placed near the patch. Two distinct bandgaps at 2.5 and 5 GHz are designed with the inner and outer U-shaped patterns having different lengths but identical width $W_s = 1.6$ mm. The height of outer U-slot U_h is set at 15.7 mm.

The simulated input impedance ($\mathrm{Z_{in}}$) of trapezoid monopole using microstrip feedline alone and; the above DGS feedline is compared in Fig. 2. It can be seen that the DGS feedline reduced the purity of the higher order modes of monopole antenna compared with the traditional microstrip-fed arrangement. The impedance is thus closer to 50 Ω over a wider bandwidth.

III. Results and Discussion

The return loss characteristics of the proposed microstrip monopole with and without DGS have been studied in Fig. 3. Obviously, relatively narrow bandwidth of 41.9% is exhibited for a trapezoid monopole antenna without DGS. When the DGS is incorporated with the simple feedline, 10-dB impedance bandwidth is extended to 64.5%. The simulated 10-dB impedance bandwidth is increased to 90.4% when DGS is applied together with the tuning stub. The impedance bandwidth behavior of this DGS monopole antenna is also

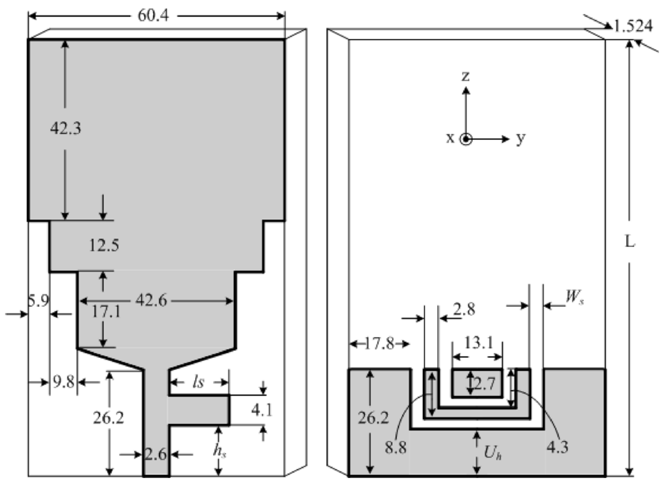

Fig. 1. Microstrip monopole antenna with double U-shaped DGS (unit: mm).

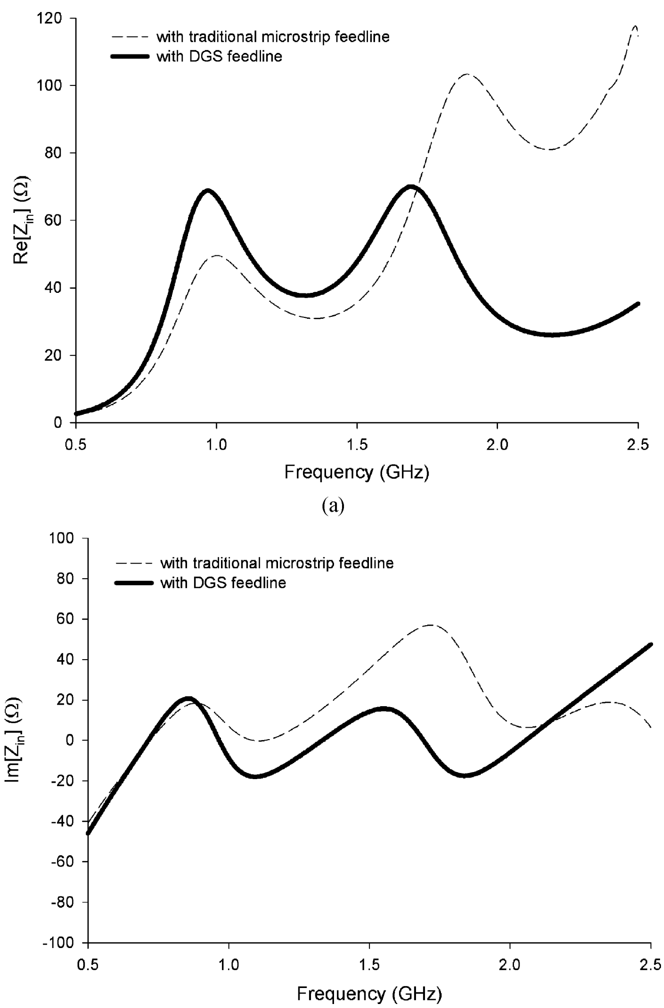

Fig. 2. Simulated (a) $\mathrm{Re}[Z_{in}]$ and (b) $\mathrm{Im}[Z_{in}]$ against frequency.

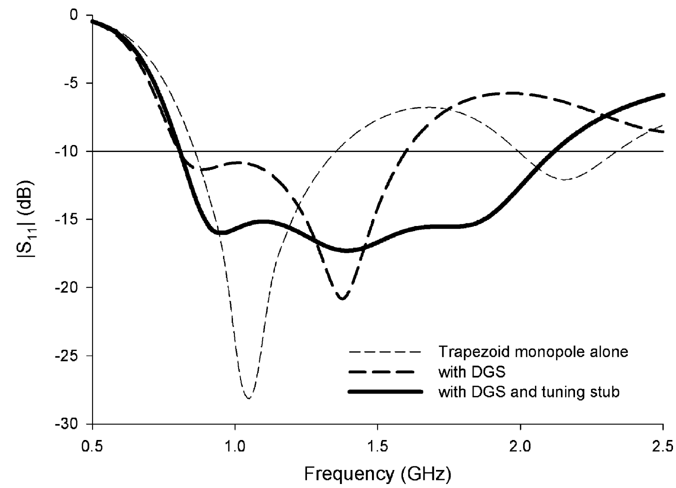

Fig. 3. Simulated return loss of microstrip monopole antenna.

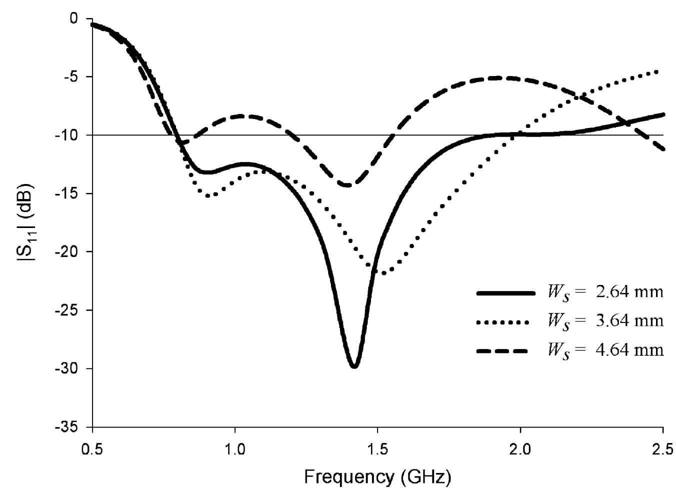

Fig. 4. Width W_s variation against $|S_{11}|$.

explored as follows. Two parameters of the DGS monopole antenna (i.e., width W_s, height of outer U-slot U_h) and two parameters of tuning stub (i.e., length l_s, position of stub h_s) are thus studied respectively. Fig. 4 shows the variation of return loss of the monopole when only parameter W_s of the above double U-shaped DGS is varied from 2.64 mm to 4.64 mm. It is apparent that a narrow width W_s, a wider impedance bandwidth. In fact, the bandwidth varies from 34% to 82% for the above width change. As U_h is varied from 12.74 mm to 14.74 mm, the impedance bandwidth is increased accordingly as in Fig. 5. In this plot, it is observed that better matching can be achieved at 900 MHz and 1800 MHz. The variation of U_h yields the 10-dB impedance bandwidth changed from 83% to 88%. The length l_s of the stub and its distance from the feeding port h_s are also studied as in Fig. 6. The variations of these parameters l_s and h_s are plotted against impedance bandwidth. It is observed that the bandwidth change is about 17.5% as l_s varies from 9 mm to 12 mm. On the other hand, the parameter h_s varies from 12.6 mm to 15.6 mm, the impedance bandwidth changes from 78% to 90.4%. Different from the bandwidth change due to the DGS, the variation of stub alone results narrow bandwidth as recorded.

Fig. 7 shows simulated and measured return loss characteristics of the DGS antenna. Good agreement was observed. The prototype antenna reported the 10-dB return loss bandwidth from 790 to 2060 MHz leading to 112.4% improvement over that of the trapezoid monopole antenna without DGS. Measured radiation patterns at 800, 1480, and 2000 MHz were also

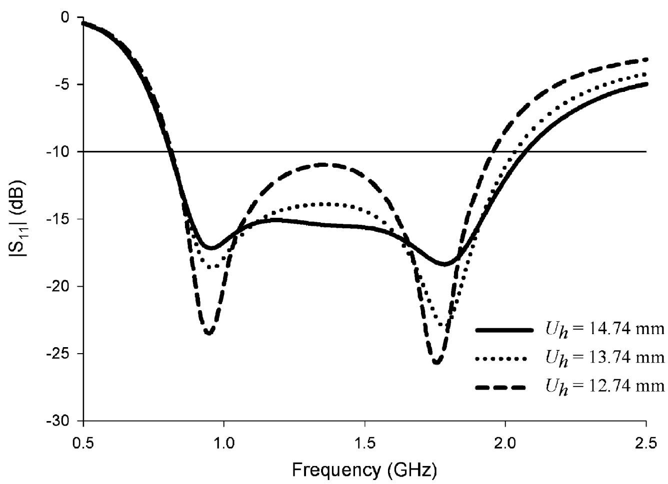

Fig. 5. Height U_h variation against $|S_{11}|$.

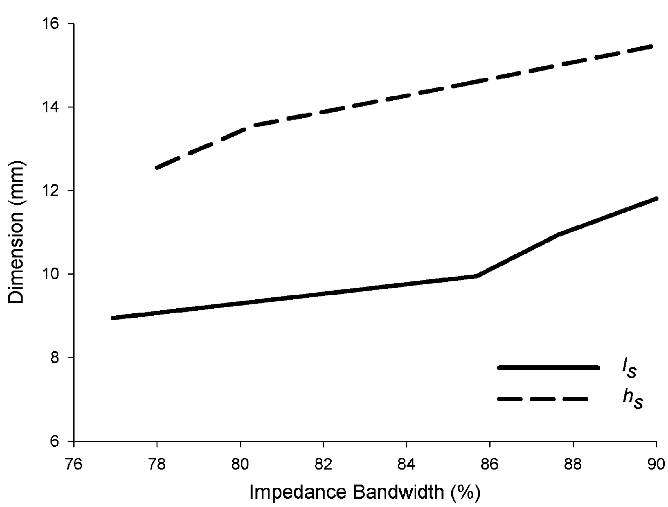

Fig. 6. Impedance bandwidth variation against parameters of stub.

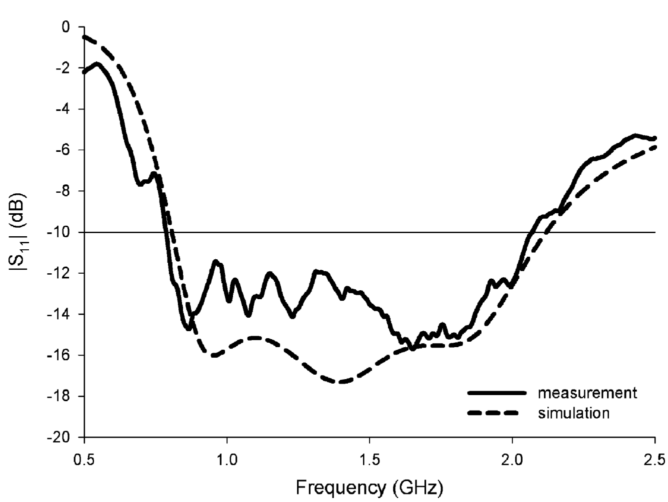

Fig. 7. Simulated and measured return loss of DGS monopole antenna.

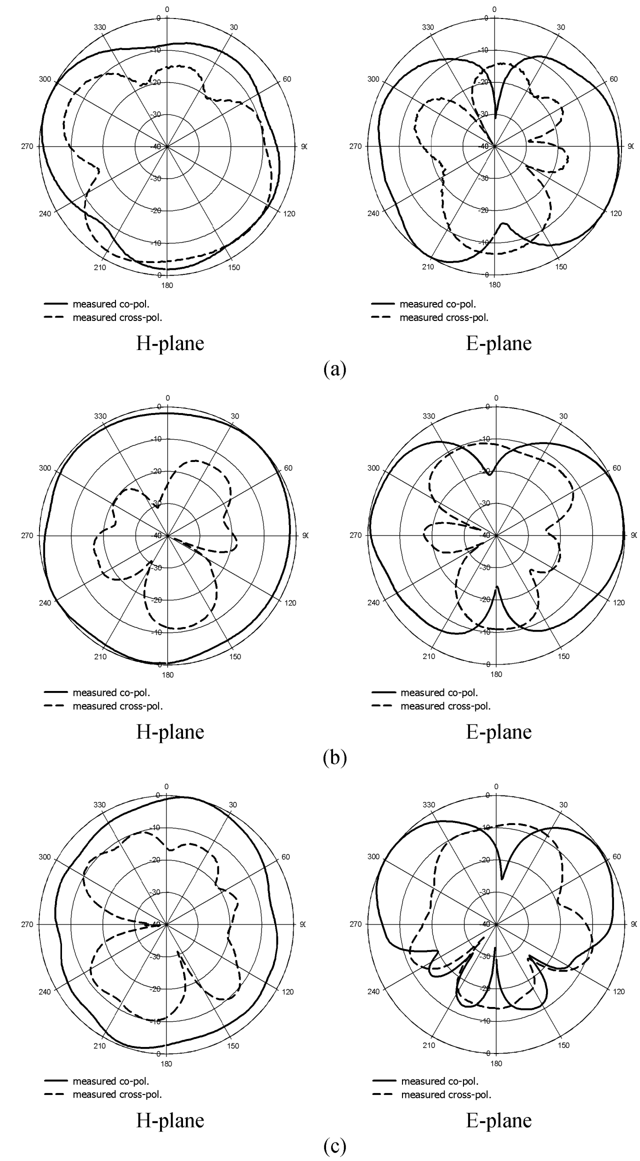

Fig. 8. Measured radiation patterns at (a) 800 MHz; (b) 1480 MHz; and (c) 2 000 MHz.

obtained in a far field anechoic chamber as shown in Fig. 8. These radiation patterns presented in the H- and E- plane were indeed similar to those of typical microstrip monopole antenna.

IV. Conclusion

A double U-shaped DGS is used to broaden the impedance bandwidth of a conventional microstrip-fed monopole antenna. By this new impedance bandwidth enhancement method, the prototype antenna obtains the 10-dB return loss from 790 MHz to 2060 MHz; yielding 112.4% enhancement when compared with that of the traditional design. An overall good monopole-like radiation patterns are also reported.

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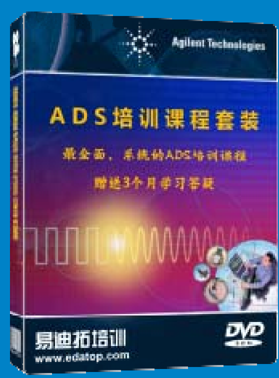

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