Self-Complementary Ring Planer Antenna of Very Wideband Operation

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Abstract

The principle of self-complementary is applied to develop the traditional planar monopole antenna into a dipole antenna with frequency range which exceeds UWB requirements. The proposed design has compact, planar, and simple shape arranged in self-complementary manner. The self-complementary structure reduced the imaginary part of the antenna impedance, resulting in wider bandwidth. The proposed antenna showed –10dB return loss bandwidth extending from 1.87 GHz up to 17.77 GHz.

Keywords : UWB Antennas; Self-Complementary Antennas; Circular Ring; Microstrip.

1. Introduction

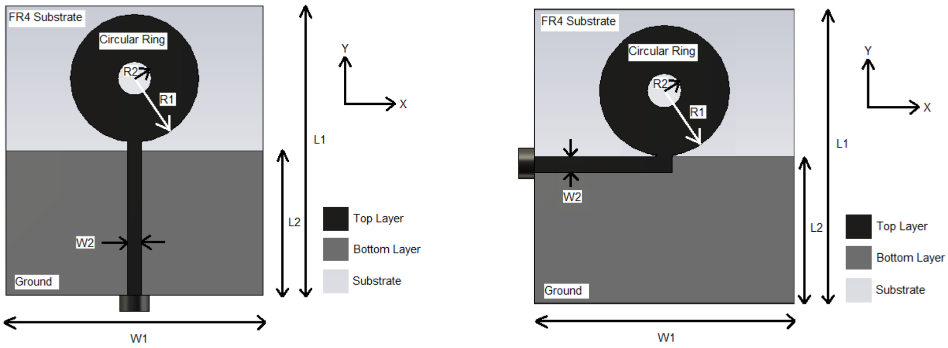
Significant research activities in the field of ultra wideband (UWB) antennas have appeared since its adoption by US-FCC in 2002 [1-6]. Among the presented types of antennas there were printed monopoles, dipoles, as well as modified microstrip patches. The proposed shapes deployed in these planar antennas, were volcano-smoke slot [1], square [2], rectangular [3], triangular [4], elliptical [5] and circular [6] monopoles. The fractal geometry has also been investigated for the UWB required characteristics [7]. Most of the adopted design methodologies were trial and error methods with the help of a simulation tool to get the desired UWB operation by tailoring corners, tips, slots, and parasitic parts. Some of the achieved designs have very complicated geometries that are sensitive to the manufacturing tolerances when implemented practically. However, some general design rules have also been presented [5, 6]. Nevertheless, there are some other methods that can be exploited to design efficient UWB antennas, but unfortunately, these methods are rarely used. One of these methods is the principle introduced in the 1940s to account for the self-complementary antennas [8]. These antennas are characterized by a self-complementary metallization, which means that metal patches can be replaced by dielectric substrates and vice versa. The behavior of self-complementary structures can be analyzed by applying Babinet's principle leading to an invariant input impedance of ($Z_{in} = Z_{F0} / 2 = 60\pi\ \Omega$) with Z_{F0} being the free-space impedance. While self-complementary structures only guarantee a constant input impedance, they do not necessarily guarantee constant radiation patterns independent from frequency [9]. There were some attempts to apply this technique for designing UWB antennas having a good impedance bandwidth, but the main goal was to perform miniaturization, rather than enhancing the impedance bandwidth [10].

In this contribution the above efforts is extended to use the self-complementary principle where the two arms of the dipole antenna are made in the form of circular ring and annular slot. The feed line of conventional circular ring monopole is modified to be suitable for the proposed self-complementary configuration. Validity of the proposed design method is confirmed by computer simulations using CST Microwave Studio™ package.

2. Antenna Design

2.1 Circular Ring Monopole Antenna with Straight Microstrip Feed Line– Antenna-1.

The first configuration of the investigated UWB antennas is the circular ring monopole antenna shown in Fig.1-a. It may be difficult to identify the resonance modes of the antenna on the Smith chart in the traditional way, where a reactance equals to zero is the criterion. However, a dip in the return loss curve, can be regarded as the resonances of the antenna. The first resonant frequency occurs when the diameter of the ring is about 0.25 of the wavelength. The rest of resonances seem to be the harmonics of the first one as the current of other modes will arrange themselves in some fashion for resonances. Then proper overlapping of closely spaced multiple resonances leads to the wanted UWB features. For microstrip fed ring monopole, the copper radiator and the 50Ω feed line are printed on one side of the substrate, while the ground plane is printed on the other side as illustrated in Fig. 1-a. The geometry illustrated in Fig. 1-a was simulated assuming a dielectric FR4 substrate of 1.6 mm thickness, ε_r of 4.3, and dielectric loss tangent of 0.025**.** The design parameters and the resultant frequency characteristics are shown in the 1st row of Table I.



-a- **-b-**

Figure 1. Geometry of the circular ring monopole antennas;- **a-** Antenna-1 with straight feed line, **b-** Antenna-2 with bended feed line.

Fig. 2 shows the return loss curve, in red dotted line, obtained from simulation. As it can be seen from Fig. 2 and Table I, the obtained (VSWR< 2) frequency range extends from 1.63 to 12.23 GHz, which forms a 7.5 to 1 ratio. The input impedance is shown in the Smith chart of Fig. 3-a. The radiation patterns in the three principal planes are plotted in Fig. 4, for selected frequencies.

TBABLE I COMPARISON OF DESIGN PARAMETERS AND OBTAINED FREQUENCY CHARACTERISTICS OF THE 3 DESIGNED ANTENNAS

Antenna Type	*Parameter*									
	L_1 *[mm]*	L_2 *[mm]*	W_1 *[mm]*	W_2 *[mm]*	R_1 *[mm]*	R_2 *[mm]*	f_{min} *[GHz]*	f_{max} *[GHz]*	*BW [GHz]*	f_{max}/f_{min}
ANTENNA-1	*52*	*26*	*46*	*2.6*	*11.5*	*3*	*1.63*	*12.23*	*10.6*	*7.5:1*
ANTENNA-2	*52*	*26*	*46*	*2.8*	*11.5*	*3*	*4.87*	*11.6*	*6.73*	*2.38:1*
ANTENNA-3	*52*	*26*	*46*	*2.8*	*11.5*	*3*	*1.87*	*17.77*	*15.9*	*9.5:1*

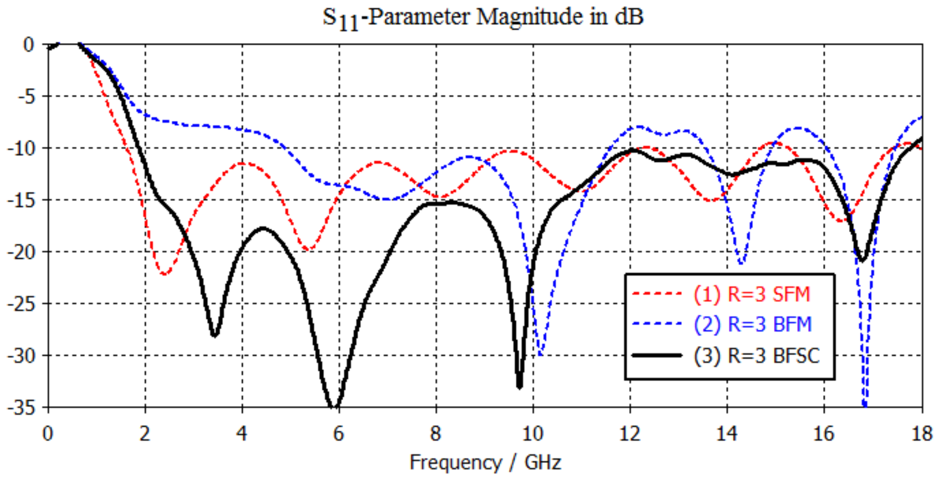


Figure. 2 Return loss curves for the three designed antennas. SFM: Straight Feed Monopole; BFM: Bended Feed Monopole; BFSC: Bended Feed Self-Complementary.

2.2 Circular Ring Monopole Antenna with Bended Microstrip Feed Line –Antenna -2.

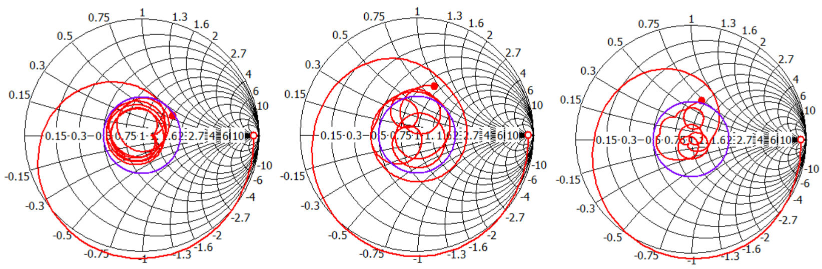
The feed line of the previous monopole was then bended to be in the geometry shown in Fig. 1-b. In this configuration the feed line runs parallel with the edge of the ground plane. The design parameters and obtained frequency characteristics are also listed in the 2nd row of Table I. Fig. 2 shows the obtained return loss curve, in blue dashed line, compared to that of the straight feed line monopole. The obtained (VSWR<2) frequency range extends from 4.87 to 11.6 GHz, having a 2.38 to 1 ratio, thus some part of the lower UWB range has been lost. The variation of input impedance is shown on the Smith chart of Fig. 3-b. No further optimization was made on this design as this arrangement is prepared for the other design which will be discussed in the next section 2.3. The radiation patterns in the three principal planes are plotted in Fig. 5. The pattern in XY-plane (E-plane) shows some changes, the XZ-plane (H-plane) pattern is still nearly omnidirectional and almost not affected, while the YZ-plane (E-plane) shows some improvement towards being nearly omnidirectional.

2.3 Self-Complementary Ring Dipole Antenna with Bended Microstrip Line Feed – Antenna-3.

With the self-complementary principle in mind, the proposed antenna configuration was developed by the procedure depicted in Fig. 6. In this configuration, the rectangular copper plane works as ground plane for the ring dipole arm, the slot arm, as well as for the microstrip feed line. Direct connection to one arm and aperture coupling to the slot arm are provided by this arrangement. Figure 7 shows detailed design and parameters of the proposed self-complementary dipole antenna. The parameters of the designed antenna are listed in the 3rd row of Table I. The simulated return loss curve is plotted in Fig. 2, where it can be seen that it is better than those of the previous monopoles. The (VSWR<2) bandwidth extends from 1.87 to 17.77 GHz giving a ratio of 9.5:1. The input impedance performance is shown in Fig. 3-c. The radiation patterns in the three principal planes are plotted in Fig. 8. This antenna shows very wideband operation, which covers and exceeds the UWB range, as well as good radiation pattern approaching omnidirectional shape.

3. Conclusions

It has been demonstrated that self-complementary principle can be used in designing UWB dipole antennas. Simulation results have shown that bending of the conventional microstrip line feed of the printed monopole, has a little impact on the radiation patterns, while some reduction in the bandwidth was noticed. The proposed dipole antenna showed return loss performance better that those of the conventional and bended feed line monopoles, and wider bandwidth performance.



-a- -b- -c-

Figure 3. Smith chart for; **a-** Antenna-1, **b-** Antenna-2, **c-** Antenna-3.

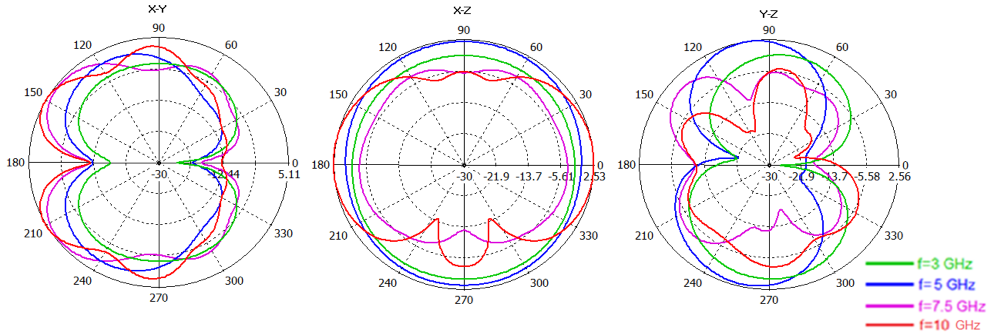


Figure 4. Radiation pattern in the three principal planes for Antenna-1.

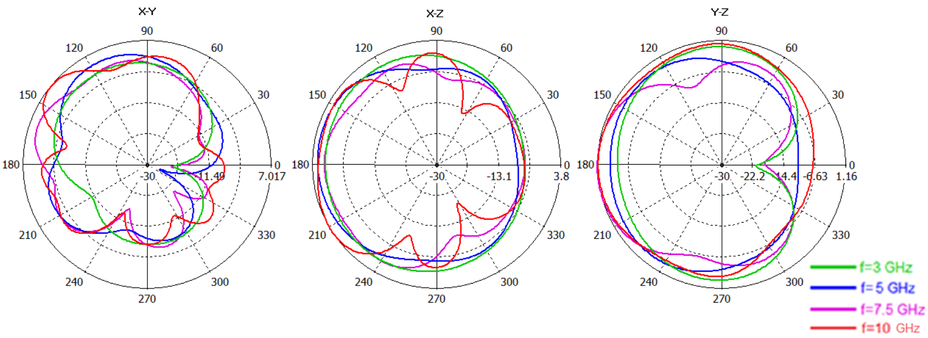


Figure 5. Radiation pattern in the three principal planes for Antenna-2.

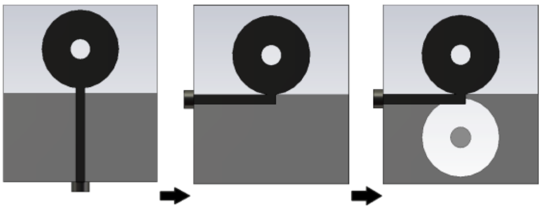


Figure 6. Development procedure for the microstrip self-complementary bend fed dipole antenna.

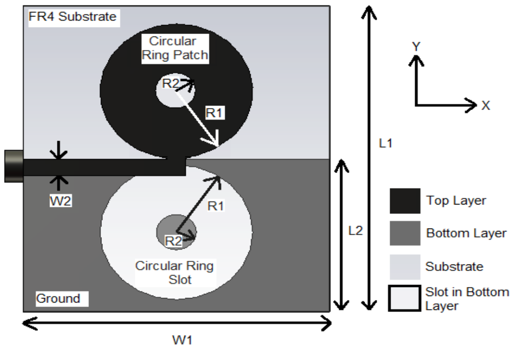


Figure 7. Geometry of the proposed self-complementary dipole antenna-3.

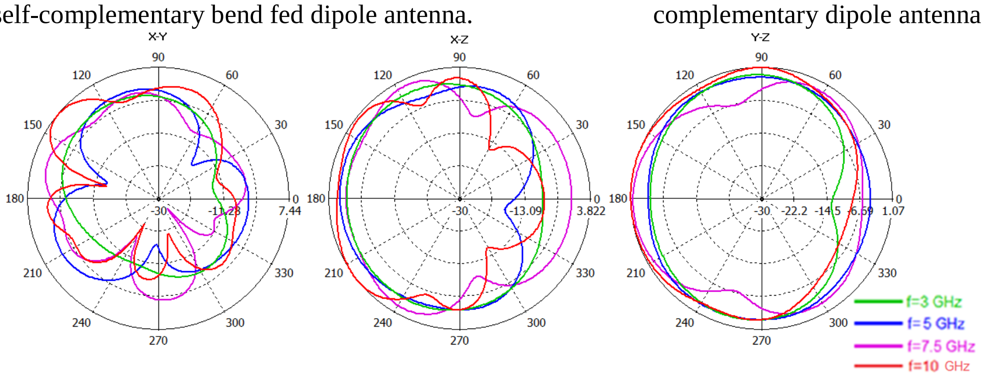


Figure 8. Radiation pattern in the three principal planes for Antenna-3.

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