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A compact hybrid CPW fed planar monopole/dielectric resonator antenna

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Abstract

Design of hybrid antenna consisting of a coplanar waveguide (CPW) fed printed monopole and cylindrical dielectric resonator is presented in this paper. A CPW fed printed monopole acts as an effective radiator and excites the cylindrical dielectric resonator. A wide band width of the order of 51% is achieved with the hybrid antenna. The compact hybrid antenna with moderate gain and nearly omni directional radiation characteristics is highly suitable for wireless communication with broad bandwidth or multi band to support multiple services.

Keywords: Dielectric resonator; Planar monopole antenna

1. Introduction

Revolutionary progress in modern wireless communication has led to the invention of several low profile antennas. Dielectric resonator antennas are increasingly attractive for many applications in wireless communication due their attractive features like high efficiency, compact size, compatibility with MMICs, ability to obtain different radiation patterns by exciting different modes with simple and efficient coupling to most of the transmission lines. When the cylindrical dielectric resonator antenna (CDRA) is excited in the fundamental $HE_{11\delta}$ mode bandwidth is typically below 10%. Recently substantial efforts have been devoted to the bandwidth enhancement of dielectric resonator antennas by using geometry deforming,[1] stacking DRAs,[2] exciting two different modes with similar radiation characteristics,[3] etc. The concept of hybrid resonator antennas with two different radiators has attracted extensive interest with reference to dual band or wide band operations. An ultra wideband antenna proposed in Ref. 4 uses such a hybrid combination of monopole and dielectric resonator antenna. But the monopole mounted on the large ground plane increases the system complexity as the entire system is not planar. CPW fed planar monopole antennas are increasingly popular due to their low profile, wide bandwidth and nearly omni directional radiation characteristics.[5,6] This paper proposes a novel hybrid antenna configuration capable of achieving wide impedance bandwidth by combining the radiation properties of a CPW fed planar monopole and cylindrical dielectric resonator antenna (CDRA). The details of the antenna design and experimental results are presented and discussed.

2. Antenna design

Fig. 1 shows the geometry of the hybrid antenna. The antenna consists of a CPW fed printed strip monopole and cylindrical dielectric resonator antenna. The planar monopole acts as an effective radiator as well as a feed for cylindrical dielectric resonator. The CPW fed monopole antenna is printed on standard FR4 substrate of thickness $h = 1.6$ mm and relative permittivity $\varepsilon_r = 4.4$. A CPW transmission line with signal strip width $S = 3$ mm and gap width between the ground plane and signal strip $G = 0.3$ mm is used to feed the planar strip monopole antenna. Two finite ground planes with size $L_G \times W_G$ are situated symmetrically on each side of coplanar line. A cylindrical dielectric resonator of $Ca_5Ta_2TiO_{12}$ material synthesized by conventional solid state ceramic route with dimensions height $h_{dr} = 3.83$ mm, diameter $D_{dr} = 16.4$ mm and dielectric constant $\varepsilon_{dr} = 38$ is loaded on the CPW fed planar monopole antenna. The arrangement is a cascaded resonant circuit with two different resonant frequencies. The resonant length L_M of the monopole is approximately $\lambda_d/4$ at the first resonant frequency. When the width W_G of the ground plane is increased the resonant frequency decreases but overall dimensions of the antenna increases. Increase in monopole length increases the resonant

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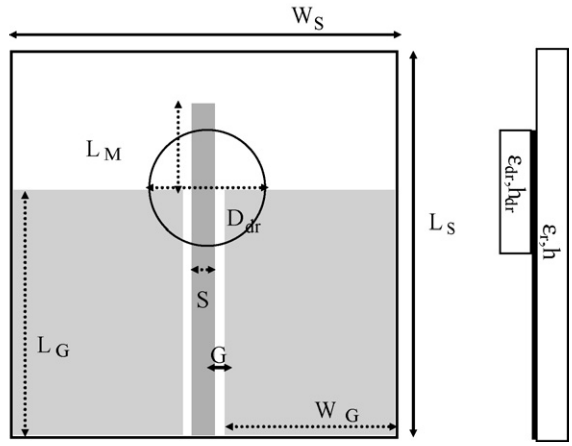

Fig. 1. Geometry of the hybrid CPW fed planar monopole/dielectric resonator antenna. $L_G = 25$ mm, $W_G = 10$ mm, $L_M = 18$ mm, $\varepsilon_r = 4.4$, $h = 1.6$ mm, $L_S = 50$ mm, $W_S = 30$ mm, $S = 3$ mm, $G = 0.3$ mm, $\varepsilon_{dr} = 38$, $h_{dr} = 3.83$ mm and $D_{dr} = 16.4$ mm.

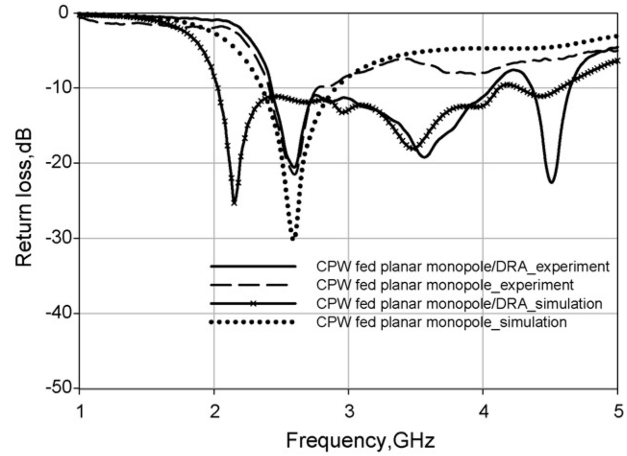

Fig. 2. Return loss characteristics of the hybrid CPW fed planar monopole/dielectric resonator antenna. $L_G = 25$ mm, $W_G = 10$ mm, $L_M = 18$ mm, $\varepsilon_r = 4.4$, $h = 1.6$ mm, $L_S = 50$ mm, $W_S = 30$ mm, $S = 3$ mm, $G = 0.3$ mm, $\varepsilon_{dr} = 38$, $h_{dr} = 3.83$ mm and $D_{dr} = 16.4$ mm.

length which results in a decrease of the resonant frequency. The dimensions of the CPW fed monopole are optimized for a maximum bandwidth with out affecting the compactness of the hybrid antenna configuration. The monopole is designed to resonate at the lower frequency and DRA at the higher resonant frequency. The fundamental $HE_{11\delta}$ resonant frequency of the cylindrical dielectric resonator is calculated using equation in Ref. 7 as

$$F_r = \frac{18.972 \times 10^8}{\pi D_{dr}\sqrt{\varepsilon_{dr}+2}}\left[0.27 + 0.36\left(\frac{D_{dr}}{4h_{dr}}\right) + 0.02\left(\frac{D_{dr}}{4h_{dr}}\right)^2\right] \tag{1}$$

The resonant frequency of the cylindrical DRA is selected approximately 1.5 times than that of planar monopole. The two frequencies are selected such as to maintain 10 dB return loss over the entire band. If the two resonant frequencies are spaced further apart the dual band operation will result with the hybrid configuration. The parameters that affect the overall performance of the hybrid antenna include the length of the planar monopole, permittivity of the DRA and size of the ground plane. The length and width of the ground plane of CPW fed monopole is optimized for maximum bandwidth operation of the planar monopole antenna. When the DR is loaded on the optimized planar monopole, the monopole excites the DR and it resonates at a frequency close to the resonant frequency of the monopole. The position of the CDRA on the planar monopole is adjusted to obtain maximum bandwidth.

3. Experimental results

Typical proposed antenna is characterized using HP8510C Vector Network Analyzer. The dimensions of the planar monopole antenna are optimized numerically with the aid of IE3D^{TM}. The return loss characteristics of non-loaded and CDRA loaded CPW fed printed monopole is presented in Fig. 2. Experimental results are confirmed using Ansoft HFSS.

The planar monopole resonating at 2.6 GHz offers a bandwidth of 375 MHz (2.40–2.775 GHz). When cylindrical dielectric resonator is loaded on the planar monopole the hybrid antenna shows a wide band width with merging of two resonant frequencies. The first resonant frequency is due to the planar monopole and the second resonance is close to the calculated value of $HE_{11\delta}$ mode resonant frequency of the loaded cylindrical dielectric resonator. Using this cascaded arrangement a wide bandwidth of the order of 1650 MHz (2.425–4.075 GHz) can be achieved.

The position of DRA on the monopole plays a significant role in determining the bandwidth of operation. The variation of reflection characteristics for different position of DRA is summarized in Table 1.

In the table P1 corresponds to the position where the center of the CDRA is on the open end of the CPW feed line (refer Fig. 3). At this position the resonant mode of planar monopole and $HE_{11\delta}$ mode of CDRA merge together resulting in wide impedance bandwidth. At position P2 the CDRA is on the monopole but with out touching the ground plane. At this position the CPW excited planar monopole energizes the CDRA

Table 1
Variation of reflection characteristics with position of dielectric resonator

Position (x, y) (mm)	Band (GHz)	Bandwidth (MHz)	%BW
P1(11.8, 22.4)	2.425–4.075	1650	51
Single frequency			
P2 (11.8, 40.4)	2.1625–2.4125	250	10
Dual frequency	4.3875–4.875	487.5	10.6
P3 (15.21, 21.4)	2.4625–3.1125	650	22.7
Dual frequency	4.2625–4.625	362.5	8
P4 (15.21, 38.4)	2.2375–2.4125	175	7.6
Dual frequency	3.7125–4.2375	525	13

$L_G = 25$ mm, $W_G = 10$ mm, $L_M = 18$ mm, $\varepsilon_r = 4.4$, $h = 1.6$ mm, $L_S = 50$ mm, $W_S = 30$ mm, $S = 3$ mm, $G = 0.3$ mm, $\varepsilon_{dr} = 38$, $h_{dr} = 3.83$ mm, and $D_{dr} = 16.4$ mm.

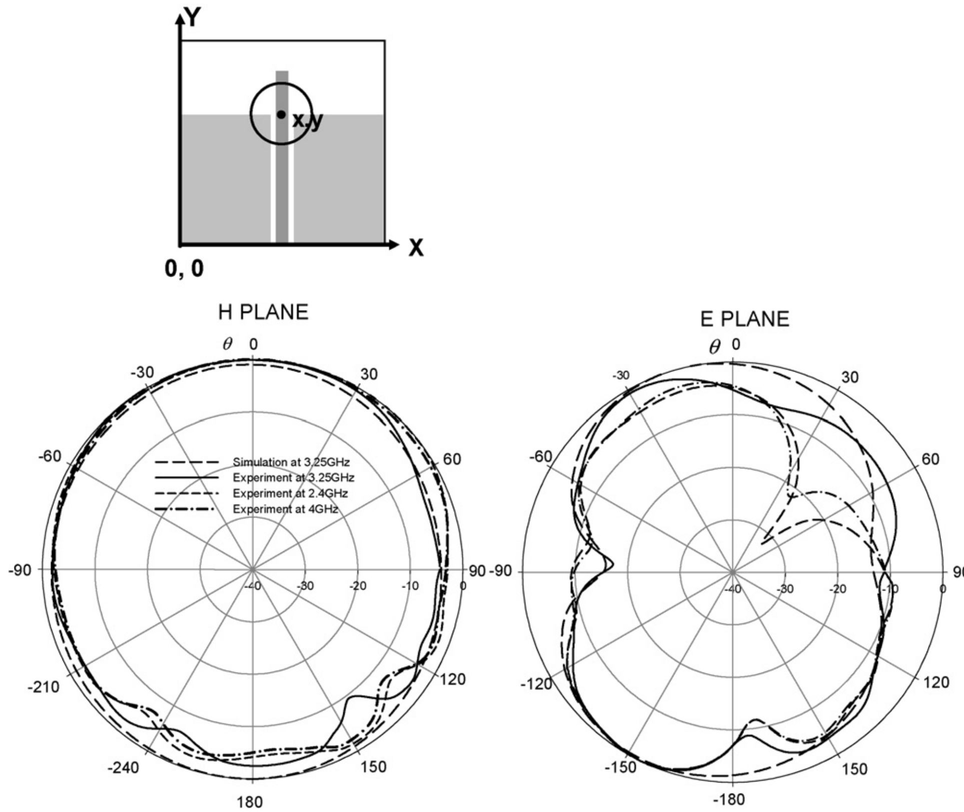

Fig. 3. Radiation characteristics of the hybrid CPW fed planar monopole/dielectric resonator antenna.

resulting in two distinct resonant modes. Here the resonant frequency of the planar monopole is shifted to the low frequency regime due to the loading of CDRA. It can be inferred from the table that positions P3 and P4 where the CDRA is on the right or left side of the planar monopole the hybrid configuration yields dual frequency operation. Fig. 3 illustrates the measured and simulated radiation patterns of the hybrid antenna at the centre and two edges of the matching band. The hybrid antenna is linearly polarized along *Y* direction in the entire band. With the proposed arrangement DRA is expected to resonate at the fundamental $HE_{11\delta}$ mode that has broad side radiation patterns and planar monopole with similar radiation behavior. Thus stable radiation characteristics are observed with in the entire operating band. Antenna exhibits nearly omni directional radiation characteristics. The cross polar radiation studies shows a cross polar discrimination better than 25 dB in both the planes.

The conjecture made from experimental and simulated studies is further confirmed from the electric field pattern in the antenna structure at the resonant frequencies as shown in Fig. 4. The electric field distribution in the CDRA is very similar to that of $HE_{11\delta}$ occurring at its resonant frequency near 3.95 GHz.

Fig. 5 represents the gain of the antenna with in the operating bandwidth. Antenna exhibits an average gain of 5 dBi in the operating band. Gain variations are less than 1 dBi with in the operating bandwidth.

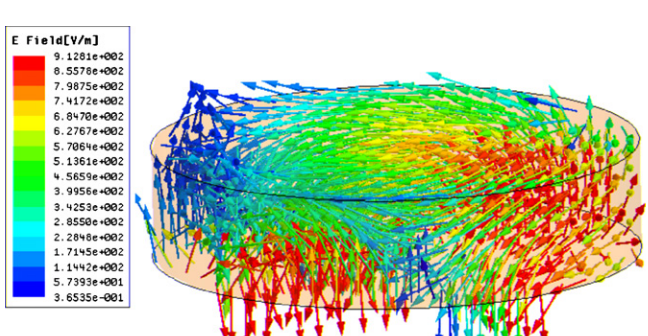

Fig. 4. Simulated electric field distribution inside CDRA at 3.95 GHz.

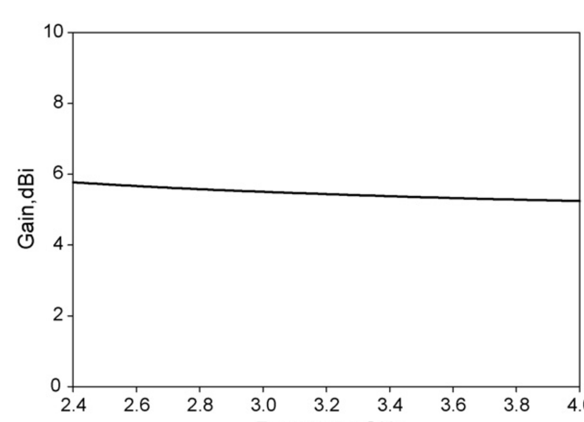

Fig. 5. Gain characteristics of the hybrid CPW fed planar monopole/dielectric resonator antenna.

4. Conclusion

A novel design of hybrid antenna with a CPW fed planar monopole and cylindrical dielectric resonator is proposed. CPW fed monopole is demonstrated as an effective radiator as well as feeding technique for cylindrical dielectric resonator antenna. The wide band planar hybrid antenna with moderate gain and nearly omni directional radiation characteristics reflects it as potential candidate for mobile and wireless communication applications.

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