A Compact Beam Steering Dielectric Resonator Antenna for Wireless Power Transfer

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***Abstract*—Design and simulation of a low profile and compact beam steering dielectric resonator antenna are discussed. A central feed primary monopole antenna is used to excite a DR, and another secondary monopole is used to achieve a unidirectional antenna. In order to have the desired direction, a fixed phase shift is added to all monopole antennas due to the physical distance. By switching between five monopole secondary antennas, a 60-degree 3-dB bandwidth pattern with the coverage of a half space is achieved.**

I. Introduction

The usage of wireless devices has significantly increased for the past decade [1],[2]. RF frequencies for wireless power transfer (WPT) have become an interesting and alternative way of charging consumer devices [3]. One of the main features of a WPT system is a high gain, high efficiency transmitter antenna with the ability of steering beam. The advantage of WPT using microwave frequencies over other methods is its application for longer distances with better directivities [4].

Numerous techniques have been proposed recently to implement a beam steering antenna transmitter [5],[6]. Near-field phase transformation is used in [4] to steer a high gain antenna. A beamforming technique is discussed in [5],[6] and much more literature that needs a complex circuit. In [7], a lens antenna is used to reduce hardware complexity. However, it still has a large size and relatively complex structure. A cost-efficient method to have high gain and efficiency antennas is designing Dielectric Resonator (DR) Antennas [8].

In this paper, a new beam steering antenna based on a unidirectional DRA is proposed. The proposed structure has a primary excitation in the middle of a DR cylinder and five secondary excitations around it. By switching between each of these secondary excitations, a beam steering antenna is achieved that can considerably cover half a space in the azimuth plane.

II. Design and Results

The configuration of the proposed dielectric resonator antenna (DRA) is shown in Fig. 1. The main structure is a DR cylinder of Rogers 6010 material with a dielectric constant of ε_r = 10.2. A central port as a primary excitation excites the DRA. The DR is located on a Rogers 4003 substrate with the dielectric constant of $\varepsilon_r = 3.55$. Five monopole antennas along the diameter of the DR cylinder are added as secondary excitations to achieve a unidirectional antenna system. The central monopole individually excites the DRA in its $HEM_{11\delta}$ mode. The

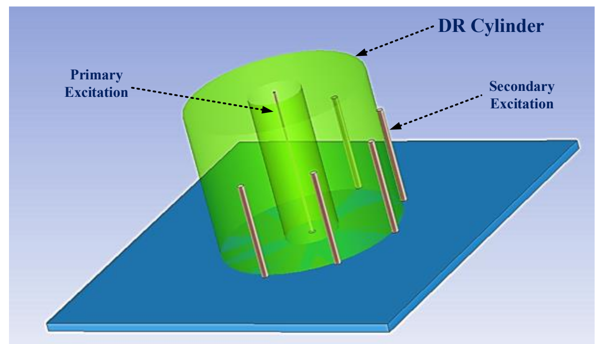


Fig. 1. Configuration of the proposed beam steering antenna by dielectric resonator antenna

parametric simulations show that by changing the size of the central monopole, the resonant frequency will slightly shift, but changing the height of the DR will significantly change the resonant frequency. As a result, one can conclude that it is the DR working, and its mode is $HEM_{11\delta}$ mode. In order to achieve a unidirectional antenna, a single monopole antenna is added to the structure. Final optimization is done for the antenna to operate at 2.45 GHz. Fig. 2 represents the radiation pattern of the DR, the monopole, and a super composition of these two antennas. Fig. 2 (c) confirms that a unidirectional pattern is achieved by this method.

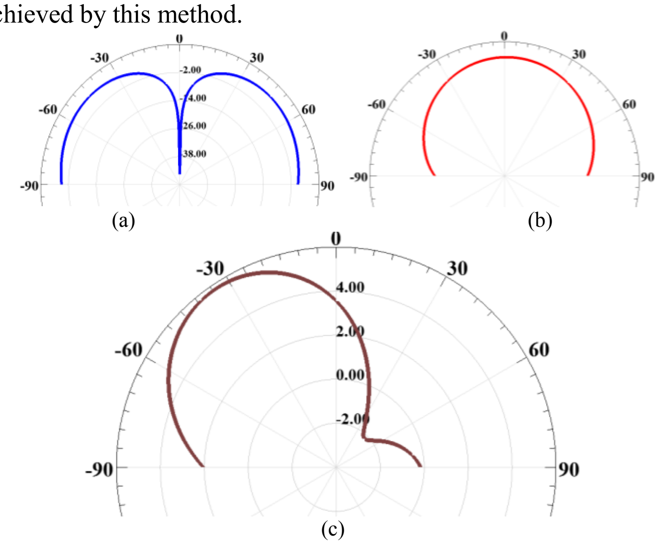
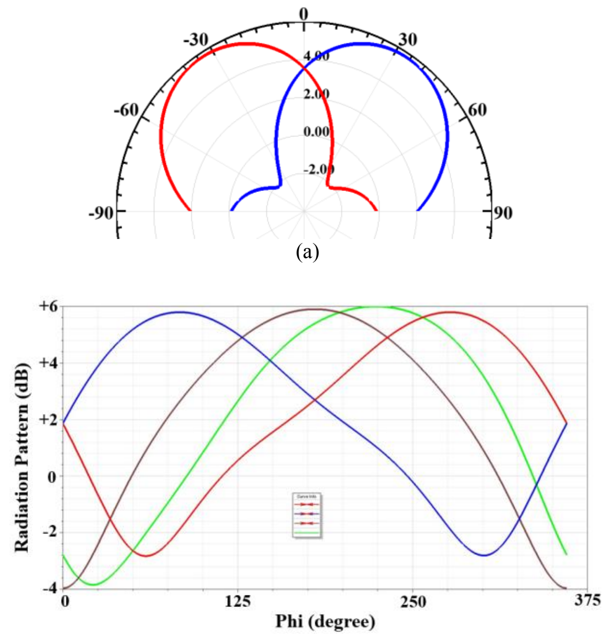


Fig. 2. (a) The radiation pattern of the DR at the $HEM_{11\delta}$ mode, (b) radiation pattern of a secondary excitation by using a monopole antenna, and (c) super composition of the two excitations.

To design a beam steering antenna, five of these single monopole antennas are located around the main DR. It should be noted that for operating both primary (central monopole antenna) and secondary (one of the monopole antennas) excitations at the same time and haveing a unidirectional antenna, it is needed to have both excitations at the same physical location. In order to decrease the physical distance of the secondary excitations, an electrical distance or a constant phase shift is added to all secondary excitations. The constant phase shift (θ) is calculated as follow:

$$\theta = \beta \times d, \ \& \ \beta = \frac{2\pi}{\lambda_g} \qquad (1)$$

where λ_g is the guided wavelength, and is calculated based on an average estimation of air and DR dielectric constant, and d is the physical distance between primary and secondary excitations. The calculated phase shift for this design is 150 degree.



(a)

(b)

Fig. 3. Radiation pattern for (a) polar plane with the same Phi-plane, and (b) rectangular plane with the constant Theta plane.

Figure 3 (a) depicts two different radiation patterns regarding two different secondary excitations. As it is cleared from the Figure, the maximum directivity is achieved at 32 degree. These two radiation patterns are at the $\varphi = 0^o$, and $\varphi = 180^o$. Figure 3 (b) shows the rectangular radiation patterns at the constant $\theta = 32^o$ with respect to the phi (φ) plane. It is cleared from the Figure that the maximum gain is almost flat for the whole coverage and it is about 6 dB.

Figure 4 shows the reflection coefficient of the primary and secondary excitations. Since the antenna has a symmetric structure, other reflections coefficients have not been shown in the Figure. It is clear from Figure 4 that the reflection coefficient is better than -15 dB, for both primary and secondary excitations at the operating frequency (2.45 GHz).

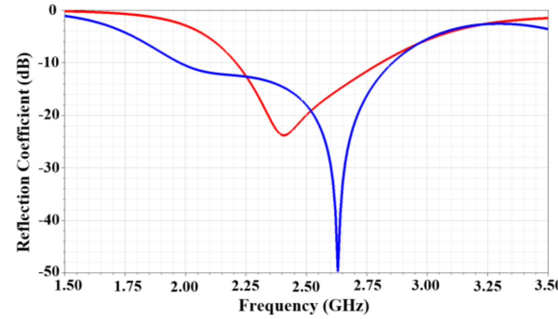


Fig. 4. Reflection coefficient of the primary (blue curve) and one of the secondary (red curve) antennas.

III. Conclusion

A novel compact beam steering antenna is proposed and discussed. By exciting a DR resonator and an electrical monopole at the same time, a unidirectional pattern is achieved. A central feed monopole antenna excites a cylinder DR at its $HEM_{11\delta}$ mode. The radiation pattern of a single DR has a donut shape which changed to one direction (unidirectional) pattern by exciting another monopole antenna at the same frequency. In order to decrease the physical distance between the two excitations, a fixed phase shift is added to the secondary excitations. The simulation results for radiation pattern shows a constant gain for the whole coverage space at the frequency of 2.45 GHz. By switching the excitation between the secondary monopole ports, a beam steering antenna is designed. The proposed structure has a compact size, low profile and complexity, and high efficiency that makes it an excellent candidate for wireless power transfer applications.

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