A Compact Beam Steering DRA Antenna for Wireless Power Transfer

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***Abstract*—Design and simulation of a compact beam steering antenna is discussed. A center feed monopole antenna is used to excite a DR and another dipole 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 5 monopole antennas a 60-degree 3-dB bandwidth pattern with the coverage of a half space is achieved.**

I. Introduction

The usage of the 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. One of the main features of a WPT system is a high gain, high efficiency transmitter with the ability of steering beam. The advantages of WPT using microwave frequencies over other methods are its application for longer distances with better directivities.

Numerous techniques have been proposed recently to implement a beam steering antenna transmitter [3]-[6]. Near-field phase transformation is used in [3] to steer a high gain antenna. A beam forming technique was discussed in [4]-[5] and many more literatures which needs a complex circuit. Or in [6] lens antenna were used to reduce the hardware complexity. However, it still has a large size and relative complex structure.

In this paper a new beam steering antenna based on a unidirectional DRA is proposed. The proposed structure has a primary excitation at the middle and 5 secondary excitation around a cylinder DRA. By switching each of this secondary excitation a beam steered antenna that can cover half a space in the azimuth plane can be achieved.

II. Design and Results

The configuration of the proposed array antenna is showed in Fig. 1. The structure have a cylinder DR with a dielectric constant of (e_r=10.2) which a center port excite the DR mode. The DR is mounted on a Rogers 4003 with the dielectric constant of (e_r=3.55). Five monopole antennas at the diameter of the DR is added to achieve a unidirectional antenna system. The center dipole excites the DRA in its HEM$_{11\delta}$ mode. The parametric simulations showed that by changing the center monopole size the resonant frequency will slightly changes while by changing the height of the DR the resonant frequency will significantly change. As a result one can conclude that it is the DR working and it is working at the HEM$_{11\delta}$ mode. In order to achieve a unidirectional antenna a monopole antenna were added to the structure. Fig. 2 represents the radiation pattern of DR, the monopole, and the super composition of the two antennas. As it is cleared from the fig. 2 (c) a unidirectional pattern is achieved by this method.

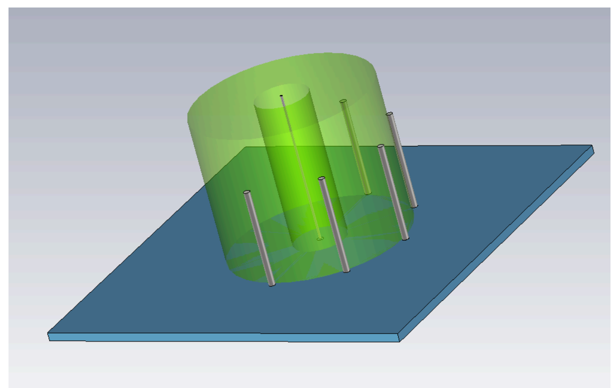


Fig. 1. Configuration of the proposed beam steering antenna by dielectric resonator antenna

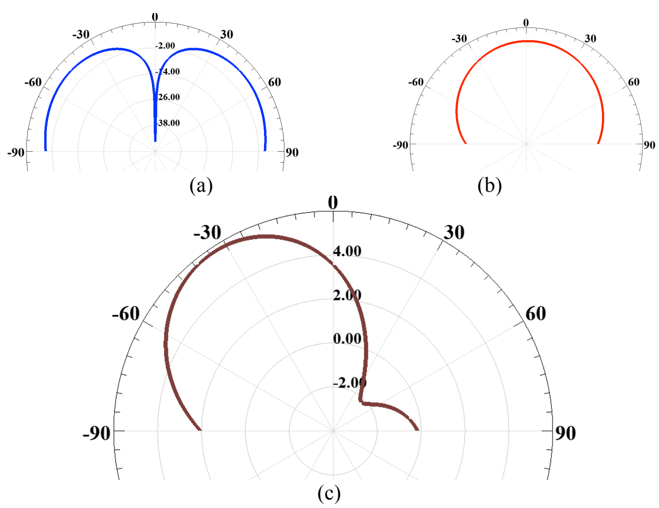
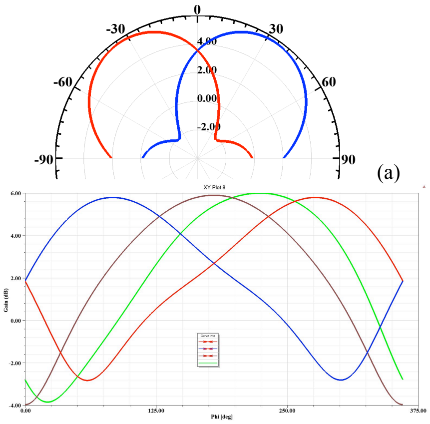


Fig. 2. (a) radiation pattern of the DR at the HEM$_{11\delta}$ mode. (b) radiation pattern of a secondary excitation by using a monopole antenna. (c) super composition of the two excitations



(a)

(b)

Fig. 3. Radiation patter for (a) polar with the same phi-plane and (b) rectangular with the constant theta plane

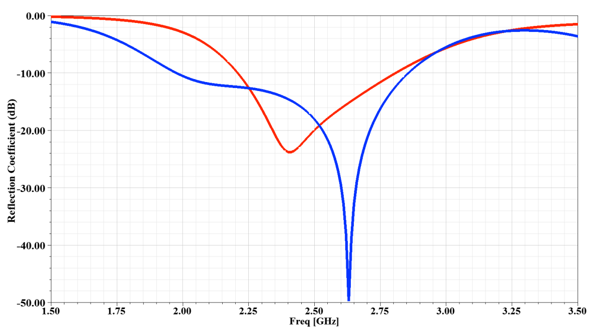


Fig. 4. Reflection coefficient of the primary (blue curve) and secondary (red curve) antenna

It should be noted that, in order to have both primary and secondary excitations work at the same time to have a unidirectional antenna we need to have both excitations at the same physical location. In order to mitigate 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 is calculated as follow:

$$Theta = \beta \times d, \beta = \frac{2\pi}{\lambda_g} \quad (1)$$

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 excitation. The calculated phase shift is 150 degree.

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

Figure 4 shows the reflection coefficient of the primary and secondary excitations. Since the antenna has a symmetry structure, other reflections coefficients haven't shown in the figure. As it is cleared from figure 4 the reflection coefficient is better than -15 dB for both primary and secondary excitations.

III. Conclusion

A novel compact beam steering antenna were proposed and discussed. By exciting a DR resonator and an electrical monopole at the same time an unidirectional pattern were achieved. A center 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 a one direction (unidirectional) pattern by using another monopole antenna at the same frequency. In order to mitigate the physical distance between the two excitations a fixed phase shift has 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 achieved. The proposed structure has a compact size and low complexity that makes it a good candidate for wireless power transfer applications.

References

[1] R. Karimian, M. Soleimani, and S. Hashemi, "Tri-band four elements mimo antenna system for WLAN and WiMAX application," *Journal of Electromagnetic Waves and Applications*, vol. 26, no. 17-18, pp. 2348–2357, 2012.

[2] R. Karimian, A. Kesavan, M. Nedil, and T. A. Denidni, "Low-mutual-coupling 60-GHz mimo antenna system with frequency selective surface wall," *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 373–376, 2017.

[3] M. U. Afzal and K. P. Esselle, "Steering the Beam of Medium-to-High Gain Antennas Using Near-Field Phase Transformation," in IEEE Transactions on Antennas and Propagation, vol. 65, no. 4, pp. 1680-1690, April 2017.

[4] C. Jun Ahn, "An applicable 5.8 GHz wireless power transmission system with rough beamforming to project Loon", ICT Express, Vol.2 , Iss. 2, pp. 87-90.

[5] J. Lopezf, J. Tsay, B. A. Guzman, J. Mayeda and D. Y. C. Lie, "Phased arrays in wireless power transfer," 2017 IEEE 60th International Midwest Symposium on Circuits and Systems (MWSCAS), Boston, MA, 2017, pp. 5-8.

[6] X. Zhao *et al.*, "All-Metal Beam Steering Lens Antenna for High Power Microwave Applications," in *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 12, pp. 7340-7344, Dec. 2017.

[7] K. Tekkouk, J. Hirokawa, R. Sauleau and M. Ando, "Wideband and Large Coverage Continuous Beam Steering Antenna in the 60-GHz Band," in IEEE Transactions on Antennas and Propagation, vol. 65, no. 9, pp. 4418-4426, Sept. 2017.