Investigation of Antenna Structure Consisting of Crossed-Field Elements for Strong EM Radiation in the Near-Zone Communications

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Abstract **– We present a design of antenna structure consisting of two orthogonal elements to radiate strong EM field in the near-zone. The use of conjugate magnetic and electric elements not only provides a good mechanism of impedance matching, but also radiates orthogonally polarized fields to form the Poynting vector. The radiation efficiency can be enhanced and provides good communication quality for the near-field communications. Both numerical and experimental results based on exampled antenna design are presented to validate the concept.**

Index Terms **—Near-Field Communication, RFID, Reactive Field.**

I. INTRODUCTION

In this paper we present a design concept of minimized antenna structures consisting of two orthogonal antenna elements to radiate strong electromagnetic (EM) near-field. The antennas are very useful in the typical applications of classic near-field communications (NFC) [1] radio frequency identifications (RFID) [2], body area network (BAN) and wireless power transfer (wireless power charger) [3], and etc. Especially in many cases, the near zone is very close to the antenna for non-contact energy coupling such as in the application of wireless power charger, where a strong field distribution in the vicinity of antenna will be very beneficial to enhance the energy efficiency in terms of coupling [4].

The orthogonal antenna elements are magnetic and electric, respectively, which not only produce a conjugated pair of input impedance, i.e., inductive and capacitive for natural matching, but also produce orthogonal polarizations of magnetic and electric fields to form the Poynting vector as in the crossed-field radiation [5], which is beneficial to the power propagation. The concept is presented with the prototype of an example antenna for 2.45GHz RFID applications to demonstrate the feasibility.

II. BASIC CONCEPT

The design concept employs a pair of antenna elements, which are magnetic and electric such as slot and monopole antennas as demonstrated in the examples. The characteristics of these antenna pair are that their input impedances are conjugate in nature as shown in Fig. 1. In this case, a well selected power division will make the imaginary parts of the input impedances perfectly conjugated as required in the impedance matching. In this case, an impedance transformer is generally required to match with the characteristic impedance of 50Ω.

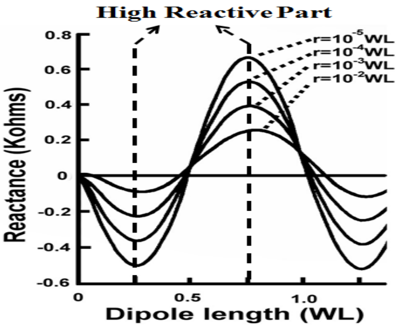

Fig. 1: The reactance of a dipole to show the inductive or capacitive input impedance. The idea selects a pair of elements with different imaginary parts.

Afterward, the strategy is to produce the electric and magnetic fields with orthogonal polarizations as illustrated in Fig. 2. This orthogonality of polarizations will form the Poynting vector to increase the propagating power by

$$\overline{W}_{tot} = \frac{1}{2}\left[\left(\overline{E}_e + \overline{E}_m\right)\times\left(\overline{H}_e + \overline{H}_m\right)^*\right] = \overline{W}_{ee} + \overline{W}_{mm} + \overline{W}_{em} + \overline{W}_{me}$$

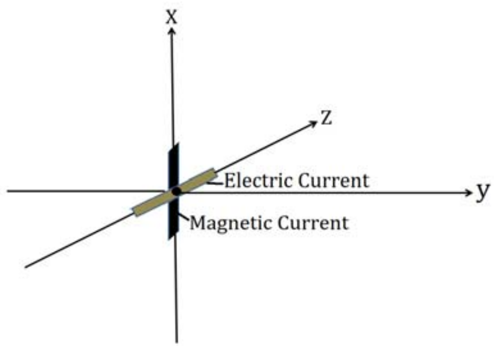

Fig. 2: The orthogonal pair of electric and magnetic currents.

In this case, the $\overline{W}_{mm} = \overline{W}_{ee}^{*}$ and the mutual coupling terms are entirely imaginary and will produce the energy propagation.

III. The Demonstration Examples

An example of implementing the concepts is presented using a slot and monopole element pair. The input impedance is shown in Fig. 3 where the reactance near the resonant frequency is nearly zero while the resistance is nearly 50ohm for the matching to the characteristic impedance of transmission line.

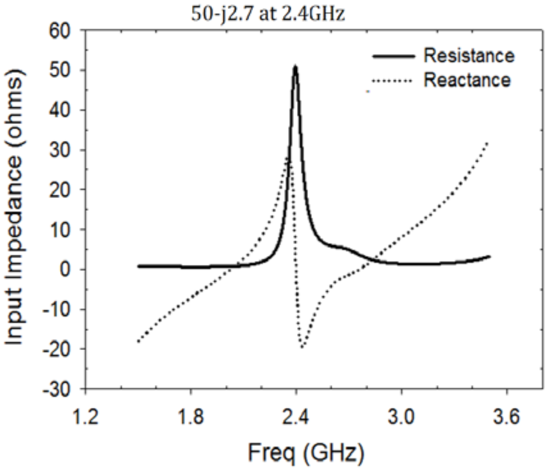

Fig. 3: The real and imaginary parts of input impedance measured from the prototype of the integrated structure.

The field distribution along the propagation radial direction is shown in Fig. 4, where both electric and magnetic fields are both shown as well as their ratio. This ratio of electric field over the magnetic field corresponds to the characteristic impedance in free space, which is 377 ohm (or nearly 50dB). As shown in the figure, this ratio is nearly constant as close by 10mm to the antenna (remain nearly 40dB or 100ohm). This characteristic allows the use of arbitrary receiving antenna type of either magnetic or electric antennas in the vicinity of the transmitting antenna. The near field contoured pattern at 25mm away from the antenna is shown in Fig. 5.

The radiation efficiency is roughly 52% obatined from the measurement. The antenna size is one tenth of wavelength, which is considered to be very small in comparison with ordinary dipole antennas. The bandwidth is roughly 2.5%.

IV. Conclusion

The antenna design concept presented in this paper is capable of minimize the antenna size while creating the strong near-field with uniform free space impedance. It is very useful for the near-field communications such as the wireless power charger, which requires strong near-fields.

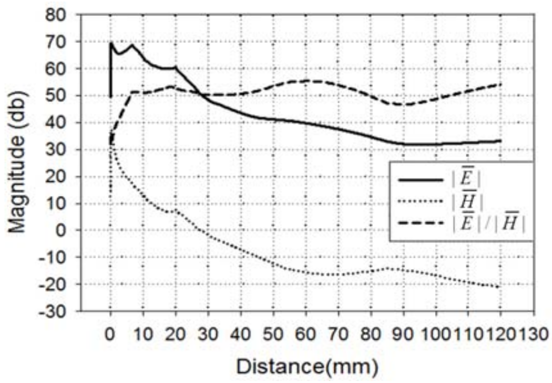

Fig. 4: Electric and magnetic field distributions along the radial propagation path.

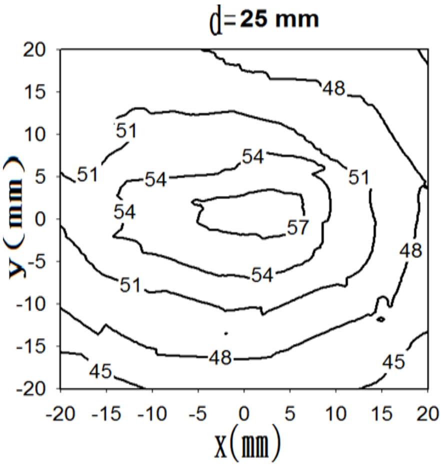

Fig. 5: The contoured radiation pattern at 25mm away from the antenna.

Acknowledgment

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References

[1]. Warnick, K.F.; Gottula, R.B.; Shrestha, S.; Smith, J., "Optimizing Power Transfer Efficiency and Bandwidth for Near Field Communication Systems," *Antennas and Propagation, IEEE Transactions on* , vol.61, no.2, pp.927,933, Feb. 2013

[2]. Michahelles, F.; Thiesse, Frederic; Schmidt, A.; Williams, J.R., "Pervasive RFID and Near Field Communication Technology," *Pervasive Computing, IEEE* , vol.6, no.3, pp.94,96, c3, July-Sept. 2007.,

[3]. Dan Dai; Jing Liu, "Human powered wireless charger for low-power mobile electronic devices," *Consumer Electronics, IEEE Transactions on* , vol.58, no.3, pp.767,774, August 2012

[4]. Smith, G.S.; Petersson, L.E.R., "On the use of evanescent electromagnetic waves in the detection and identification of objects buried in lossy soil," *Antennas and Propagation, IEEE Transactions on* , vol.48, no.9, pp.1295,1300, Sep 2000

[5]. Belrose, J.S., "Characteristics of the crossed field antenna obtained by numerical and experimental modelling," *Antennas and Propagation Society International Symposium, 2005 IEEE* , vol.1B, no., pp.21,24 vol. 1B, 2005