Beam-Switchable Magneto-Electric Antenna Array based on Composite Right/Left-Handed (CRLH) Structures

***Shulabh Gupta*, and Li Jun Jiang**

Department of Electrical and Electronic Engineering, The University of Hong Kong (SAR), China.
Email: shulabh@hku.hk

Abstract

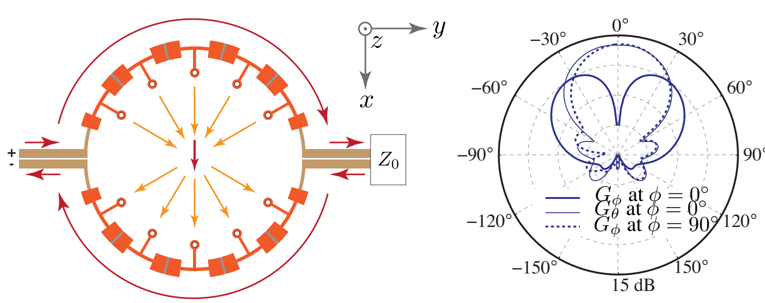
The beam-switching characteristics of Magneto-Electric (ME) dipole antenna array is presented based on differentially exciting the two ports of the array with different polarities. The proposed principle is demonstrated using full-wave simulations that the depending on the polarity of the two excitations, either a magnetic-dipole or an electric-dipole radiation can be selectively achieved.

1. Introduction

The concept of collocated magnetic and electric dipole radiators (M- and E-dipoles) has recently attracted a considerable attention due to the increased demand for multi-functionality and switchable characteristics in modern communication systems [1]. Applications include anti-collisions systems for vehicular transport and MIMO systems for high-speed communication, for instance. Recently a new magneto-electric dipole antenna array was proposed in [2] based on Composite Right/Left-Handed (CRLH) transmission lines [3]. This ME-dipole antenna structure was proposed in a planar configuration based on CRLH transmission lines, where the electric and magnetic radiators are excited simultaneously using a single differential feed. This structure acts as two distinct antennas in one structure with their individual radiation characteristics. Furthermore, compared to conventional resonant-type ME antennas, the proposed antenna is travelling-wave in nature, which makes it suitable for forming simple high-gain ME-dipole antenna arrays. In this work, its beam-switching characteristics is proposed where the two differential ports of the array structure is simultaneously excited to selectively radiate either a magnetic or an electric-dipole type radiation.

2.2 ME-Dipole Antenna Array

Consider the structure of Fig. 1(a) based on a Composite Right/Left-Handed (CRLH) transmission lines, implemented in Metal-Insulator-Metal (MIM) Technology. The series components of a CRLH structure forms a magnetic loop and the shunt components act as Electric-dipole radiators. When such a structure is fed using differential excitation, both electric and magnetic parts contribute to far-field radiation, simultaneously. Henceforth, such a combined radiator is referred to as a ME dipole antenna.



(a) (b)

Figure 1: A planar magneto-electric (ME) antenna. a) Proposed ME dipole antenna based on CRLH transmission lines operated in the infinite wavelength regime, where the size of the ring, in principle, can made arbitrarily large to enhance the gain. b) Typical radiation patterns computed using FEM-HFSS.

It is well-known that the gain of a magnetic loop dipole can be practically increased by exploiting the infinite-wavelength regime property of CRLH transmission line structure operated in its infinite-wavelength regime [3]. The

978-1-4673-5225-3/14/$31.00 ©2014 IEEE

CRLH transmission line consists of a series capacitance C_L and a shunt inductance L_L in addition to a series inductance L_R and shunt capacitance C_R. Depending on the relative values of the LH and RH contributions, such a CRLH TL can balanced, i.e. exhibiting a gapless transition between the LH and RH bands. The frequency, where the dispersion curve passes from the LH band to the RH band, $\beta = 2\pi/\lambda_g = 0$, is referred to as the transition frequency so that the phase is essentially uniform along the transmission line structure. The typical radiation characteristics of a single unit cell consisting of 5 CRLH unit cells is shown Fig. 1(b), where the magnetic and electric-dipole contributions is clearly seen.

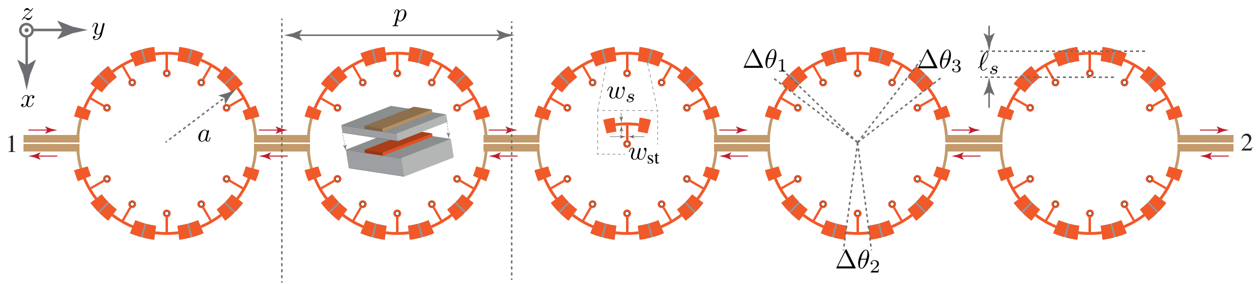


Figure 2: ME-dipole antenna array consisting of 5 rings.

Then, owing to the infinite-wavelength behaviour of the CRLH transmission line at the transition frequency, the size of the ring can be made arbitrarily large without altering the current phase or wave-propagation direction. The M-dipole gain can be progressively increased by increasing the size of the current loop with a larger number of unit cells while maintaining infinite-wavelength propagation at the design frequency. Considering that the CRLH structure, when open to free-space, operates as a leaky-wave antenna, the proposed structure maybe designed as an efficient radiator [3]. Furthermore, to increase the gain further, the structure can be converted into an array as shown in Fig. 2.

2.3 Proposed Beam-switching Method

The ME-dipole antenna array consists of two ports, which can be fed differentially either one at a time or simultaneously. In the case of simultaneous feeding, two scenarios are possible, as shown in Fig. 3. When both ports are fed with the *same polarity*, the antenna rings are deactivated and only E-dipole radiation exists. On the other hand, when the two ports are excited with a *opposite polarities*, all the E-dipole are deactivated and only the M-dipole radiates. This represents two states of the system which can be exploited to create switchable radiation system, where the M- and E-dipoles can be isolated and used individually.

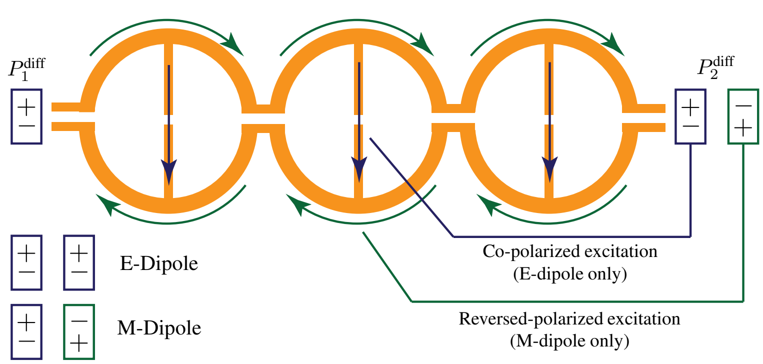


Figure 3: M- and E-dipole pattern switching using excitation from both ends of the ME-dipole array.

To confirm the beam-switching characteristics of the proposed ME-dipole array antenna, the 5 ring array structure of Fig. 2 is simulated using FEM-HFSS. The structure is excited from both sides, first with the same polarity and then with an opposite polarity. Fig. 4(a) shows the radiation pattern for the same-polarity excitation where the E-dipole contribution is clearly seen for the transition frequency corresponding to a maxima in the broadside direction.

Similarly, fig. 4(b) shows the radiation patterns for oppositely polarized ports, corresponding to M-radiation. This case leads to a null at broadside with typical M-dipole characteristics. This thus verifies the proposed beam-switching method.

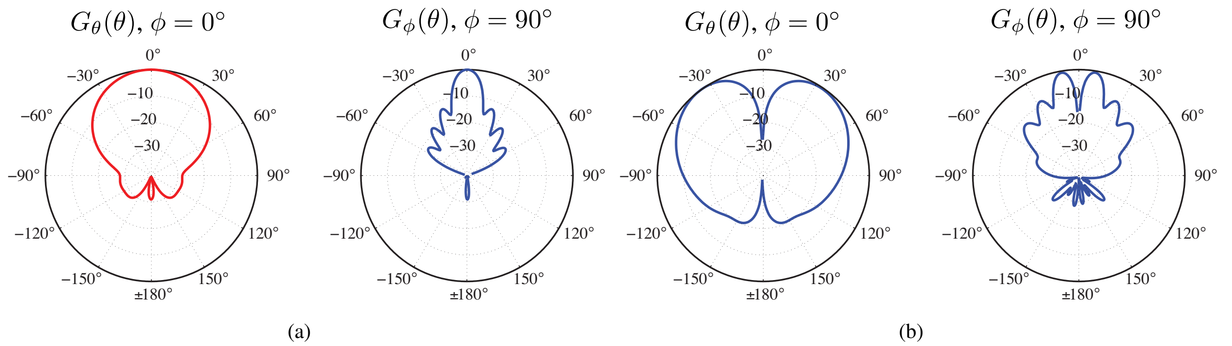


Figure 4: FEM-HFSS simulated radiation patterns corresponding to the structure of Fig. 2 when differentially excited from both ports with a) same polarity and b) opposite polarity.

Acknowledgments

This work was supported in part by HK ITP/026/11LP, HK GRF 711511, HK GRF 713011, HK GRF 712612, and NSFC 61271158.

References

[1] K. M. Luk and B. Wu, *The magnetoelectric dipole, a wideband antenna for base stations in mobile communications,* Proceeding of the IEEE, vol. 100, no. 7, pp. 22972307, Jul. 2012.

[2] S. Gupta, L . J. Jiang and C. Caloz, *Magneto-Electric Dipole Antenna Array,* IEEE Trans. Antennas Propagat., under review.

[3] C. Caloz and T. Itoh, *Electromagnetic metamaterials, transmission line theory and microwave applications*, Wiley & IEEE Press, 2005.