A Zero-Index Metamaterial Unit-Cell for Antenna Gain Enhancement

Gijo Augustin, Bybi P. Chacko and Tayeb A. Denidni
Center for Energy, Materials and Telecommunications (EMT)
National Institute of Scientific Research (INRS)
University of Quebec, Montreal, Canada.
augustin@emt.inrs.ca

***Abstract*— A new metamaterial unit-cell with a zero refractive index (n) was developed, characterized and employed for the gain enhancement of a microstrip antenna operating at 5.2 GHz. The unique property of the metamaterial gathers the wave radiated from the antenna and collimates it towards the normal direction when used as a superstrate array. The proposed design provides a gain enhancement of 6.2 dB using a single layer superstrate, when suspended above a microstrip patch at 5.2 GHz.**

I. INTRODUCTION

The new paradigm of metamaterials creatively enhanced the capabilities of researchers around the globe to resolve many fundamental challenges in antenna engineering [1]. This leads to the development of various metamaterial unit cells with broad range of characteristics, including zero-index materials (ZIM) [2, 3]. Compared to various types of metamaterials, the ZIM materials impose a very small phase change when electromagnetic waves pass through them [4]. This results in the concentration of electromagnetic energy, normal to the metamaterial surface. This unique property of ZIM materials can be effectively used for the gain enhancement by loading an array of metamaterial superstrate structure above the conventional antennas such as a microstrip patch.

In this paper, we present a new unit-cell inspired from [5] based on an electric field coupled (ELC) resonator. An array of this unit cell was designed with an optimum periodicity and employed as a superstrate for the gain enhancement. Compared to the existing designs, the proposed configuration provides better gain enhancement in a single superstrate layer configuration.

II. METAMATERIAL UNIT CELL AND HIGH GAIN ANTENNA CONFIGURATION

The proposed antenna is shown in Fig.1. The basic building block of the metamaterial superstrate is the ZIM unit-cell operating at 5.2 GHz as displayed in Fig.1 (a) with geometrical parameters *l*, d and g. The superstrate is realized on Rogers® R04350B with dielectric constant 3.48 and thickness h2 = 0.762 mm. The unit-cells are arranged as shown in Fig.1 (b) with periodicity of 8 x 8 and spacing s = 2 mm. The perspective views of the proposed antenna are shown in Fig.1(c) and Fig.1 (d). The spacing from the radiator to the bottom layer of the ZIM superstrate is hs = 32mm. In this design, a probe fed microstrip patch antenna (MPA) with dimensions L x W = 12.6 mm x 16.5 mm operating at 5.2 GHz

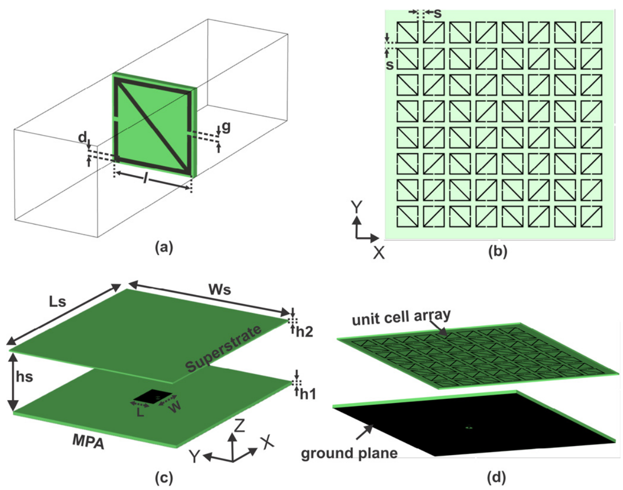

Figure 1.Geometry of the proposed antenna (a) Unit-cell, (b) bottom view of superstrate layer, (c-d) Perspective views. g = 0.5, d = 0.5, *l* = 9.5, s = 2, hs = 32, h1 = 1.6, h2 = 0.762, Ls = 100, Ws = 100. [Units = mm]

was designed on an FR4 substrate with relative permittivity 4.25 and thickness, h1=1.6 mm. As shown in Fig.1. (c), the superstrate and the antenna ground plane has dimensions of (Ls x Ws) = 100 mm x 100 mm and are aligned at the center.

III. RESULTS AND DISCUSSION

The unit cell is modeled using CST Microwave studio with unit cell boundary conditions. The scattering parameters were calculated over the band 1-8GHz and are shown in Fig.2.

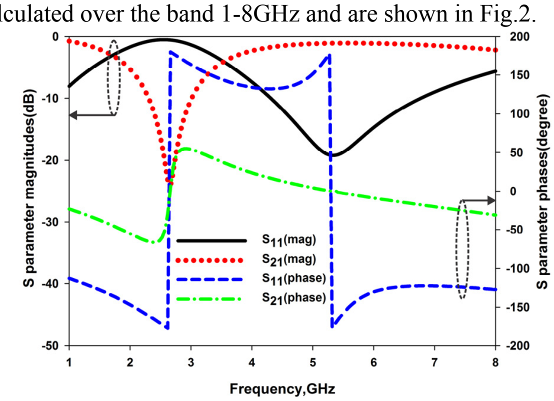

Figure 2. Scattering parameters of the metamaterial unit-cell

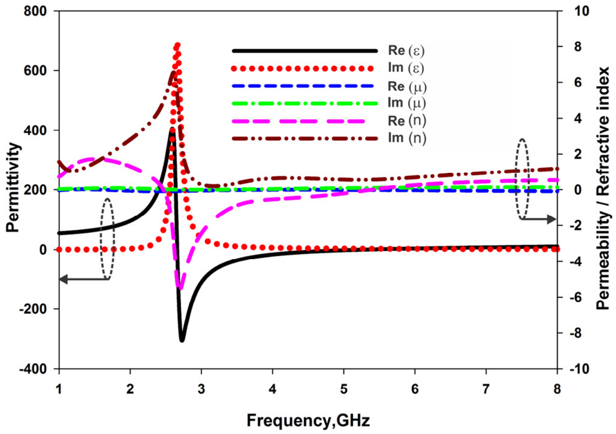

Figure 3. permittivity (ϵ), permeability (μ) and refractive index (n) of the metamaterial unit-cell.

The effective material parameters were extracted from the scattering parameters using the algorithm presented in [6]. At 5.2 GHz, the effective refractive index of the unit-cell is found to be -0.1+0.7i, which is very close to zero (Fig.3). It is observed from Fig.4 that, the resonance of the microstrip patch is slightly shifted to lower frequency region when loaded with the ZIM superstrate. The S11< -10 dB band of the proposed antenna is from 5.12 GHz to 5.36 GHz covering the IEEE 802.11a WLAN band.

The maximum gain of the proposed antenna is found to be 12.3 dB with a variation less than 2dB throughout the operating band. Compared to a microstrip patch antenna realized on the same FR4 laminate, the proposed design exhibits a gain enhancement of 6.2 dB with a single superstrate layer. The radiation pattern of the antenna is illustrated in Fig. 5. It is clear from the plot that by loading a microstrip antenna with the ZIM based superstrate focuses the beam and thereby enhances the directivity. The half power beam width of the antenna at 5.2 GHz is observed to be 33º and 40º in XZ and YZ plane, respectively.

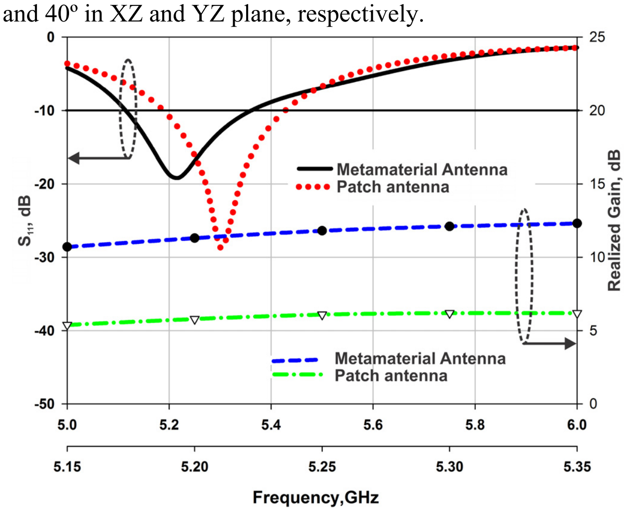

Figure 4. Reflection coefficient and gain of the microstrip antenna with and without metamaterial superstrate.

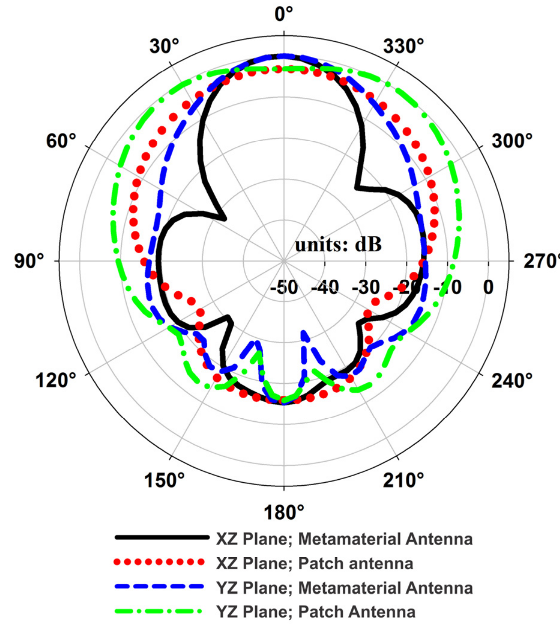

Figure 5. Radiation pattern of the proposed antenna and microstrip patch antenna at 5.2 GHz.

IV. CONCLUSIONS

We have proposed a high gain antenna based on new zero-index metamaterial unit-cell for WLAN applications. The extracted material properties of the ZIM unit-cell have indicated that, the refractive index is close to zero at 5.2 GHz. In order to verify the gain enhancement, the gain of the superstrate loaded antenna has been compared to a microstrip patch antenna resonating at same frequency. A gain enhancement up to 6.2 dB has been observed for the proposed design.

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