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Full Length Article

A cylindrical wideband slotted patch antenna loaded with Frequency Selective Surface for MRI applications

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ABSTRACT

A novel cylindrical antenna of a miniaturized printed circuitry is invented for Microwave Radiology Imaging (MRI) applications. Folded metamaterial structures based a Frequency Selective Surface (FSS) on a cylindrical profile is conducted in the design methodology. The combination of MRI systems with Ultra-Wide Band (UWB) radars for improving the functional diagnosis and imaging process has been proposed recently. Moreover, MRI systems call for a directive beam as much as narrow about 5 dBi with a fixed direction toward the broadside over the entire frequency range of interest to suit the mechanical steering principles. Therefore, a Slotted Triangular Flared (STF) patch excited with a 50 Ω exponential curved transmission line transformer centered between two matching circuit tuners is proposed. The patch structure is mounted on a Teflon substrate backed with a Partial Defected Ground (PDG) plane. An in-phase reflector array based on a cylindrical FSS is introduced to the antenna design to enhance the bandwidth and the front to back ratio. The antenna performance is examined using CST MWS commercial software package based on the Finite Integration Technique (FIT) in both Time Domain (TD) and Frequency Domain (FD) solvers. Moreover, the antenna dimensions are modified through a parametric study to arrive to the optimal performance in terms of antenna bandwidth with minimum size. The optimal antenna dimensions are realized to be 32 mm in height with a diameter of 20 mm. It is found the proposed antenna operates over the frequency range from 7.8 GHz up to 15 GHz with a bore-sight gain varies from 2 dBi up to 6 dBi. Finally, the obtained results are re-evaluated using Finite Element Method (FEM) based on HFSS formulation. An excellent matching is observed between the evaluated results from both software packages.

1. Introduction

The introduction to the microwave imaging technology and advance signal and data processing have reached a wide range of applications including breast cancer detection [1]. However, packing the entire systems and their terminals in a limited compact volume is still not considered yet. Cylindrical antennas show several desirable characteristics which are not offered by planar elements; such as, easy to install with high capability and enhanced angle of coverage [2]. Most cancer tumors can be imaged from the scattering response difference with respect to the unaffected zones; therefore, it became an attractive aspect by the microwave research societies [1]. This aspect is based on the difference in the electromagnetic properties of the human body bio-tissues [3]. These properties exhibit different electromagnetic responses with respect to the incident waves to create a microwave image [3]. In such systems, the transmitting antenna exposes the sample under test, then, the scattered wave is detected by a receiving antenna or with the same transmitting terminal [3]. Therefore, such antenna should be highly directive with excellent front to back ratio. Moreover, the antenna scanning angle must be directed efficiently to move transmitted and received signals in a broad frequency range to guarantee a high resolution with a good penetration.

Conformal antenna designs were proposed to provide high gain bandwidth products with focused radiation patterns [4]. Over the past decade, FSS structures have supported engineers with manipulating the material intrinsic parameters to control and utilize the propagation of electromagnetic waves in certain patterns. These structures improved the overall antenna performance including the antenna gain and the bandwidth [5]. Also, FSS structures can be used as reflectors placed underneath of the antenna patch at a

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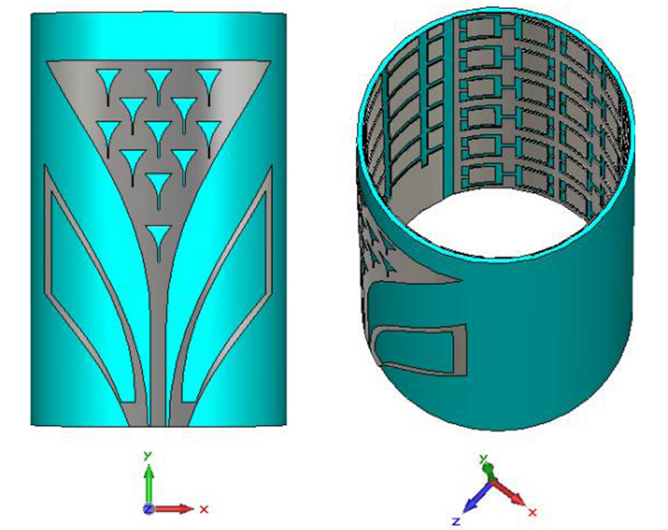

Fig. 1. Schematic of the proposed antenna with the FSS: (a) front view and (b) Enlarged cross view.

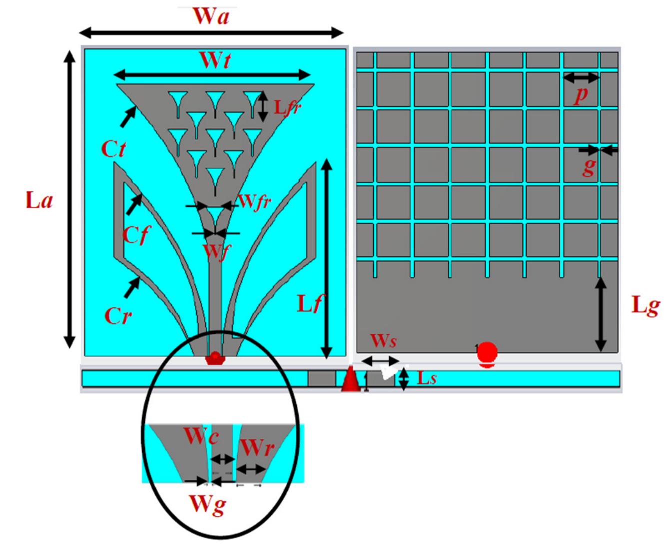

Fig. 2. Schematic of the planar antenna.

Table 1
Antenna with EBG structure dimensions.

Description	Symbol	Value (mm)
Substrate width	Wa	28
Substrate length	L_a	32
Patch width	W_t	21
Flared length	C_t	$y_1 = 3.18e^{Rx} - 11.56$ $\frac{W_c}{2} \leqslant x \leqslant \frac{W_t}{2}$
Reflector length (Top side)	C_f	$y_2 = 3.06e^{Rx} - 19.56$ $\frac{W_c}{2} + W_g \leqslant x \leqslant \frac{W_t}{2}$
Reflector length (down side)	C_r	$y_3 = 1.64e^{Rx} - 18.52$ $\frac{W_c}{2} + W_g + W_r \leqslant x \leqslant \frac{W_t}{2}$
Reflector length	L_f	20
Feed-line width	W_c	1.2
Ground plane length	L_g	8
Gap width between taper-shaped and feed line	W_g	0.2
Reflector width-down	W_r	1.45
Fractal width-top	W_{fr}	2
Fractal width-down	W_f	0.1
Fractal length	L_{fr}	2.8
Shorting plate width	W_s	1.45
Shorting plate length	L_s	0.5
EBG unit cell width	p	3.6
Gap between two EBG neighboring cells	g	0.4

certain distance as in [5,6]. In addition, a 3D-FSS structure was demonstrated to provide frequency stability at different angle of incidence and polarizations [7].

FSS layers may be considered as a thin periodical structure to provide reflection, transmission or absorption properties around a certain frequency band. These periodic structures were used as radomes, spatial filters, electromagnetic bandgap, reflectors, and absorbers on the antenna structures [8,9]. The operation of the FSS layers depends on number of factors like operating frequency, principle of operation, and manufacturing techniques [8,9]. Different FSS configurations based ring, patch, square loops, strips and slots were designed and compared to each other in [10–12]. Fractal geometries were structured from different unit cells to contribute multiband operation as in [13,14]. In [15], two frequency bands were obtained from a Hilbert curve based unit cell. A bandpass FSS was presented in [16] based on a miniaturized periodic element of metallic loops with grid wires operating between 2 GHz up to 8 GHz to enhance the antenna performance; the proposed structure provided a stable response to with different polarizations and incident angles. Octagonal fractal structure was presented in [17] with bended edges to improve the unit cell miniaturization. In [18], a hexagonal fractal unit cell to design a compacted FSS

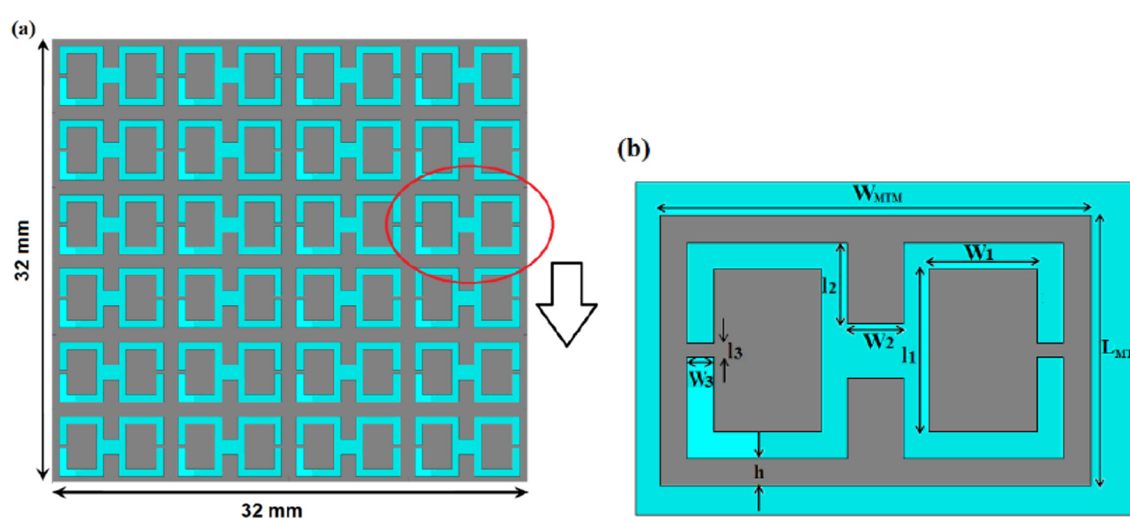

Fig. 3. The proposed FSS schematic: (a) Full structure (Front view), (b) Planar profile (Enlarge view).

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