Metamaterial Inspired Wearable Antenna for Medical Applications

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ABSTRACT: A compact wideband antenna with a metamaterial inspired patch designed for wearable medical application is presented in this communication. The microstrip patch is designed to be the replica of a single metamaterial unit cell.The antenna has wide measured bandwidth of 300 MHZ and peak gain 3.69 dB in the band of 1.5to3.5GHZ. The positive aspects of the antenna is are compared with the existing metamaterial unit cell patch design. The patch dimension of the measured design is 2.4x2.6mm^2.The antenna is fabricated on a jeans material to enable wearable applications. The antenna is operated in the frequency spectra of IEEE 802.11, WiMAX 2.3GHZ and GSM 1800MHZ bands.

KEYWORDS: Metamaterial unit cell; Wideband Antenna; Wearable; Medical Applications..

I. INTRODUCTION

The concept of incorporating the communication system in the wearable material is important in the case of medical applications where the regular observation is required. It helps in the continuous monitoring of the patients with health irregularities and other complication. The microstrip patch is substituted by the structure of a metamaterial unit cell. This unique structure is capable of bending, blocking, enhancing and manipulating the electromagnetic waves so as to achieve the desire output. The main purpose of this work is to design a metamaterial inspired wearable antenna for medical applications. The metamaterial unit cell structure brings about the miniaturization of the antenna, which is substantial in the case of medical applications. The antenna structure is designed and analysed using the simulator Ansys HFSS.

In [1], implements the co-existence of microwave and millimeter wave technologies. (i)They are supposed to cover two frequency bands. (ii)Therefore a signal routing approach is used to send the signals to the specific elements. (iii)This dual band antenna supports 5.8and 30GHZ simultaneously. (iv)The wave bands are designed with high flexibility In [2], designed a co-planer waveguide fed textile antenna for wearable applications. (i) Jean is used as the substrate with the dielectric constant 1.6. (ii)The antenna has the return loss of -19dB. (iii) It is flexible in design and shape and has excellent performance at different angles. In [3], it is based on a fully textile integrated antenna on a slotted short circuit microstrip line. (i) The antenna has the working frequency of 5.9GHZ. (ii)The antenna is manufactured using an industrial loom and a laser prototyping machine. In [4], the active integrated wearable antenna in the 2.45GHZ ISM Band. (i) The low noise amplifier is integrated in a hybrid textile substrate. It is located exactly underneath the wearable patch antenna. (ii) Gain of 12 dB and a noise figure of 13 dB are observed. In [5], a single layer wearable MIMO antenna is designed .MIMO antenna has the ground plane as the main radiator. (i) The antenna is designed on the substrate with permittivity of 1.2 and wide bandwidth of 20%. In [6], a circularly polarized wearable textile antenna is designed. (i) The design consists of a U-shaped radiating patch. (ii) A peak gain of 5.19dBi is measured. (iii) This antenna was to be fabricated and tested using a vector network analyzer. (iv)The impedance bandwidth of the antenna is observed to be 60.86% between 4.8 and 9 GHZ. In [7], a wearable antenna is designed to be operated at 2.4GHZ. (i) The antenna size is 75% smaller than the normal conventional antenna. (ii) The antenna performance is observed to be sustainable under deformation. (iii)The antenna exhibits an impedance bandwidth of 15% and efficiency of 79%. [8] For 2.4/5.2-GHz WLAN applications, A dual-band, wearable metamaterial loaded antenna is proposed. [9] A pattern reconfigurable metamaterial structure has been implemented in the antenna for wearable applications. [10] An antenna which consist of a compact split ring resonator that operates at 2.45GHZ is widely used in WBAN application. [11] E-textile METAMATERIAL transmission line are manufactured by utilizing common fabrics for signal transmission in UHF band. [12] A compact planar monopole antenna has been used for wireless communication. (i) It consists of an additional narrowband for Wi-Fi communication. [13] An antenna consisting of a metamaterial superstrate place an important role in gain enhancement. (i) It has highly enhanced gain and directivity. [14] An antenna that is low profile and meta-surface enabled is proposed for wearable medical applications. [15] For WLAN \ WiMAX/ITU applications, a compact metamaterial multiband antenna is proposed. patch is designed to be the replica of a single metamaterial unit cell.

II.PROPOSED METHODOLOGY

A .METAMATERIAL UNIT CELL DESIGN

The metamaterial unit cell is an artificial structure that drives its electrical properties from the structure and not the material that is made up of mathematically; it can be proved that the refractive index becomes negative in a double negative media (DNG media).

$$\sqrt{\ } = \sqrt{\ _r\ _0 - j'} \approx -j(|\ _r\ _0|^{0.5} + j\frac{'}{2|\ _r\ _0|^{0.5}})$$ ---(1)

$$\sqrt{\ } = \sqrt{\ _r\ _0} \approx -j(|\ _r\ _0|^{0.5} + j\frac{'}{|\ _r\ _0|^{0.5}})$$ ---(2)

Therefore, the refractive index will be,

$$n = \frac{kc}{w}$$

$$= \sqrt{\frac{\ }{\ _0}}\sqrt{\frac{\ }{\ _0}}$$

$$=-\left[\left((|\ _r||\ _r| - \frac{'}{\ _0}\frac{'}{\ _0}\right) + j\left(\frac{'|\ _r|}{\ _0} + \frac{'|\ _r|}{\ _0}\right)\right]$$ ^0.5

where $_r$ is the relative permittivity, $_0$ the permittivity of free space, $_0$ the relative permeability, $_0$ the vacuum permeability, ε″ the imaginary part of the permittivity, and μ″ the imaginary part of the permeability. The metamaterial unit cell structure is to be designed and fabricated on the jeans substrate whose dielectric permittivity is 1.6 and loss tangent is 0.02. The refractive index become negative which can be theoretically proved.

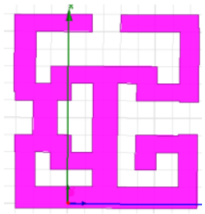

Fig.1 Metamaterial unit cell.

B .ANTENNA DESIGN

The compact wide band antenna is designed on the wearable jeans substrate, which has dielectric permittivity of 1.6 and a loss tangent of 0.02.The patch dimension is2.4x2.6mm^2.The microstrip patch is composed of the metamaterial unit cell structure. This metamaterial unit cell structure is directly used as a radiator of the wearable antenna.The design parameters of the unit cell are, L1=2.5mm, L2=0.7mm, L3=0.8mm, L4=1.2mm, L5=0.6mm, L6=0.6, G=0.3mm, H=0.7mm.

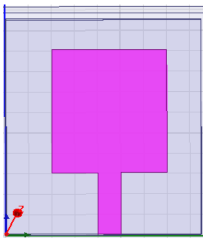
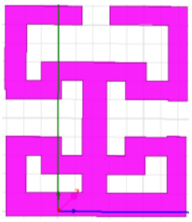
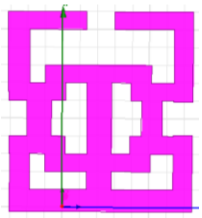
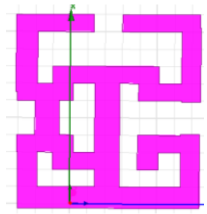

Fig.2 Microstrip Patch. Fig.2.1 Evolutionary design 1. Fig 2.2Evolutionary design 2 Fig.2.3 Prop.antenna

Fig.2 represents the structure of the single microstip patch antenna. In the proposed methodology, the microstrip patch is substituted by a single metamaterial unit cell structure. Fig.2.1and Fig.2.2 consists of unit cell structures that possesses bilateral symmetry. Both the structures are observed to be symmetrical about the vertical axis.Fig.2.2 consists of the patch of the proposed antenna, which is the replica of a metamaterial unit cell. It is observed to be an asymmetric structure

Table 1 Proposed Antenna Design Specifications

Parameters of prop.antenna	Dimension
L1	2.5
L2	0.7
L3	0.8
L4	1.2
L5	0.6
L6	0.6
G	0.3
H	0.7

III.RESULT AND DISCUSSION

The metamaterial inspired wearable antenna has been designed in the Ansys HFSS software. It is simulated so as to analyze the various antenna parameters. In this proposed antenna, the unit cell structure of Fig 2.1 produces a return loss of 4.8dB for 2.08GHz. Fig 2.2 the unit cell structure produces the return loss of 0.138dB for 2.1 GHz. The patch of the proposed antenna structure in Fig.2.3 produces a return loss of 2 dB for 2.40 GHz. Thus, the return loss of the proposed antenna in Fig 2.3 is considered to be more efficient than the previous one. It is because the least amount of reflection occurs at 2.40 GHz which is very close to the designed frequency. The plot of Fig.4, shows the scatter parameter s11 for our antenna. The antenna is to be simulated for the frequency of 2.45 GHz. The S_{11} parameter conveys the amount of input reflection at feed point. Ideally, the amount of reflection should be minimum for the antenna design frequency (2.45GHZ). It can be observed from the illustration that the least amount of reflections occurs at approximately 2.40GHz which is very close to the design frequency. The designed antenna has 29dB return loss. Fig.5, illustrates the bandwidth of the antenna refers to the range of frequencies over which the antenna can operate correctly. The bandwidth is observed to be 300MHZ.

Table 2 Bandwidth Measurement for different Materials

Ref.no	Material	Frequency	Gain	Bandwidth
4	Fabric material	2.45GHZ	12dB	-
7	Jeans	2.45GHZ	2.6dB	200MHZ
Prop.antenna	jeans	2.45GHZ	3.69dB	300MHZ

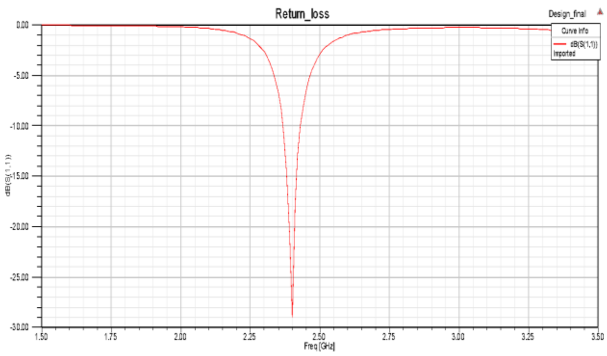

Fig.4 Return loss of the antenna

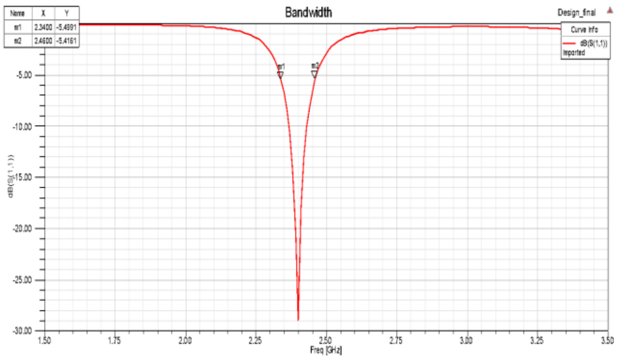

Fig.5 Bandwidth of the antenna.

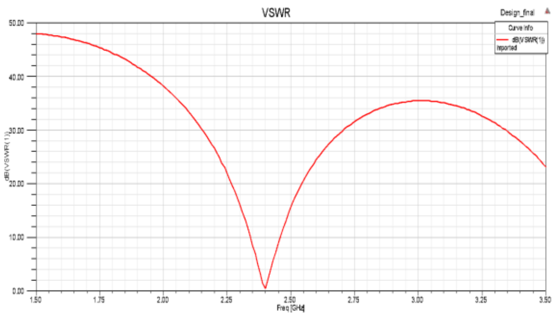

Fig.6 VSWR of the antenna.

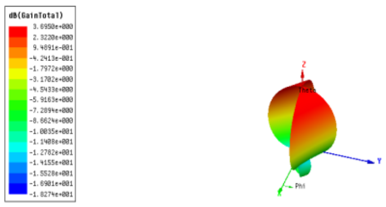

Fig.7 Gain of the antenna.

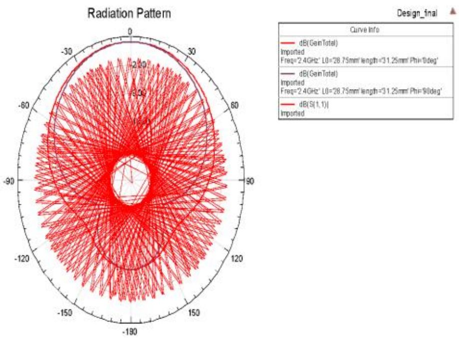

Fig.8 Radiation pattern of the antenna

Fig.6 illustrates the Voltage Standing Wave Rati of the antenna design. It is an indication of the amount of mismatch between an antenna and the feedline connecting to it. The VSWR is observed to be 0.9dB. A VSWR of under 2 is considered suitable for most of the antenna applications. Fig.7 illustrates the gain representation of the antenna. The term antenna gain describes the amount of power transmitted in the direction of the peak radiation to that of an isotropic source. The peak gain of the antenna is observed to be 3.69db at 2.45GHz. Fig.8 illustrates the radiation pattern of the antenna. A radiation pattern is defined as the variation of power radiated by an antenna as a function towards the desired direction.

IV CONCLUTION AND FUTURE WORKS

A compact wideband antenna with a metamaterial inspired patch designed for wearable medical application is presented in this communication .The antenna exhibits a wide measured bandwidth of 300MHz in the band 1.5GHz to 3.5GHz. The measured peak gain of the antenna is 3.69 dB at 2.45GHz. The measured peak gain of the antenna is 3.69dB at 2.45GHz. The proposed antenna covers the application bandwidths of IEEE 802.11, WiMAX 2.3GHz and GSM 1800MHz bands. In future, the dimensions of the patch could be altered and the results could be compared .Further, the microstrip patch could be designed to be the replica of a different metamaterial structure. Therefore, the different design alternatives could be analyzed and compared.

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