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DESIGN OF ELC LOADED ULTRA WIDE BAND METAMATERIAL ANTENNA

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***Abstract*— A square shaped monopole antenna, loaded with Electric LC element (ELC) is proposed for Ultra WideBand (UWB) applications. This metamaterial antenna covers UWB frequency of about 1.47 GHz to 5.36 GHz with peak gain of 2.36 dBi. Directional radiation pattern is achieved at resonating frequency with return loss of -18.21 dB. The proposed antenna can be used for various UWB applications such as Microwave imaging, WiMAX, UWB Radar, and other wireless communication services.**

***Index Terms*— ELC element, Metamaterial, Monopole antenna, Ultra WideBand.**

I. Introduction

Today, Ultra wideband antennas are most widely used in portable communication devices due to its various merits such as compact small size, low transmission power, high penetration quality, low cost and less interference with existing narrowband systems [1]. These unique features are made use in numerous applications which include high resolution Radar, Medical imaging, positioning and tracking [2]. Mostly UWB technology is employed as it transmits information over short pulses at a speed in excess of 100 Mbps, consuming higher bandwidth of greater than 500 MHz or at least 20% of the center frequency with maximum allowed power spectral density of -41.3 dBm/MHz or 75 nanowatts/MHz [1]. Types of UWB signal pulses are Gaussian, Chirp, Wavelet and Hermite based short duration pulses, Gaussian Doublet and Rayleigh monocycles [3], [4]. Any modulation schemes can be used with UWB signals but the most widely used one is Pulse Position Modulation (PPM) and Pulse Amplitude Modulation (PAM) [5]. There exists a variety of UWB antennas such as planar monopole UWB antenna, Slotted UWB antenna, Tapered slot UWB antenna and fractal UWB antenna [6]. Different techniques are available to achieve UWB in low profile antennas such as increasing the thickness of the substrate [7] , using fractal designs either in patch or in ground[8], reducing the size of an antenna[9], modifying the ground or patch [10], loading the Electric LC circuit (ELC) or Electronic Band Gap (EBG) and use of any forms of Meta materials [11].To achieve negative electrical permittivity and negative permeability, three unit cells of Left Handed Materials is used, which resonates in UWB band[12]. Various metamaterials such as SRR, CSRR, omega structure, S shaped structure are used as an antenna substrate to study the effectiveness of directivity and S-parameters [13]. In this paper, an inset feed square shaped monopole antenna has been designed to achieve UWB bandwidth of about 1.71 GHz. An ELC element is loaded at the backside of square shaped monopole antenna which further enhances bandwidth to 3.74 GHz, operating in the frequency range of 1.48 GHz to 5.22 GHz. The designed antenna is simulated in Ansoft HFSS and various parameters such as return loss, VSWR, radiation pattern has been extracted, which shows its applicability in wireless communication devices.

II. Antenna Design

The proposed antenna design and its dimensions are shown in Fig.1 and Fig.2. The square shaped radiating element is designed with the FR-4 substrate having relative permittivity $\varepsilon_r = 4.4$ and dielectric loss tangent loss $\delta = 0.02$. The overall dimension of antenna is $35 \times 35 \times 1$ mm^3, having ground plane width of about 8.9 mm.

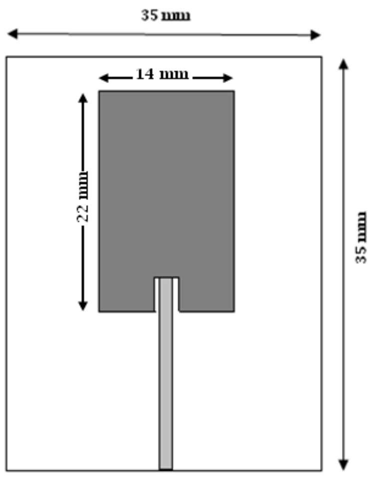

Fig.1. Front view of proposed antenna

The width of the rectangular shaped patch is calculated using [14]

$$W = (C0 / fr)\sqrt{2 / \varepsilon r + 1} \quad (1)$$

Where $C0$ denotes speed of light, fr is the resonating frequency. Similarly length of the patch has been brought from [14]

$$L = [C0/(fr\sqrt{\varepsilon reff})] - 2\Delta L$$
(2)

Where ΔL and $\varepsilon reff$ are effective parameters.

The radiating element is of dimension 22 × 14 mm. It is excited through 50 Ω microstrip transmission line of width 2 mm. To improve the bandwidth, a H- shape slotted rectangular ELC element is loaded at the bottom of the substrate having length 14 mm and width 17 mm as shown in Fig.2.

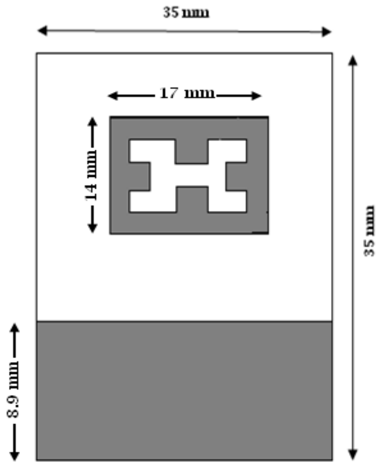

Fig.2. Back view of proposed antenna

Usually the dimension of the slot is referred to guided wavelength which is given as [15]

$$\lambda g = \frac{c/f}{\sqrt{\varepsilon reff}} \quad (3)$$

Where

$$\varepsilon reff \approx \frac{\varepsilon r + 1}{2}$$
(4)

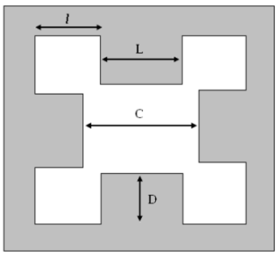

Fig.3. Structure of an ELC element

An ELC element structure with its dimensions is shown in Fig.3 and Table I respectively. The total dimension of H shape slot is of about 10.1×13.6 mm. Conventional monopole antenna radiates only dual bands at 1.54 GHz to 3.25 GHz and 4.36 GHz to 4.88 GHz. To cover UWB, this novel ELC element is loaded under the patch.

Table I Dimensions of an ELC element

PARAMETER	VALUE
L	4 mm
C	7.6 mm
D	3 mm
l	4.8 mm

III. Results and Discussions

The prototype of proposed monopole antenna is simulated with and without ELC element using Ansoft HFSS tool and parametric studies have been carried out. The parameters such as Return Loss, VSWR, and radiation pattern were extracted. Fig.4. shows the return loss of both conventional monopole and proposed metamaterial antenna.

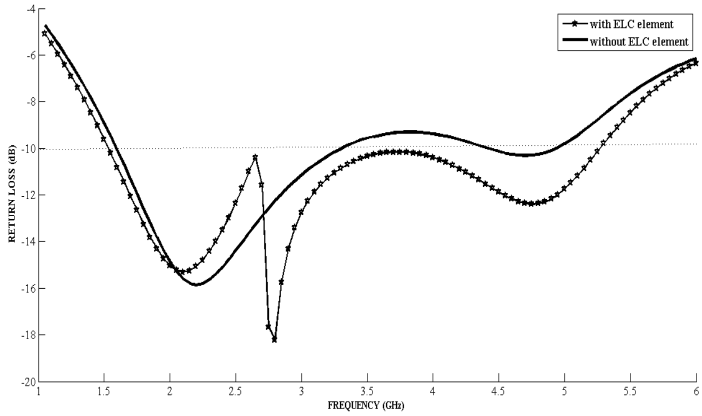

Fig.4. Comparison of Return loss performance

From Fig.4, it is observed that the conventional monopole antenna operates at 1.54 GHz to 3.25 GHz and 4.36 GHz to 4.88 GHz having notch at 3.25 GHz to 4.36 GHz. By loading an ELC element, the monopole antenna improves its bandwidth achieving UWB at frequency 1.48 GHz to 5.22 GHz having resonant frequency at 2.75 GHz with maximum return loss of about -18.21 dB.

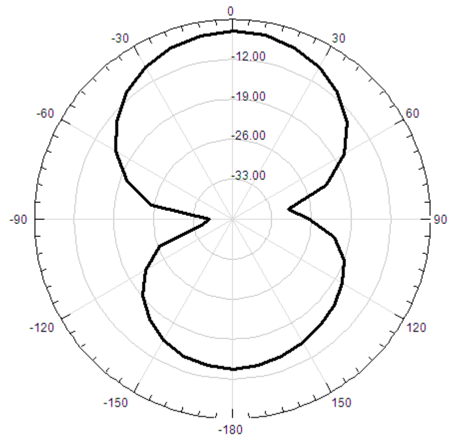

Fig.5. E-plane Radiation pattern

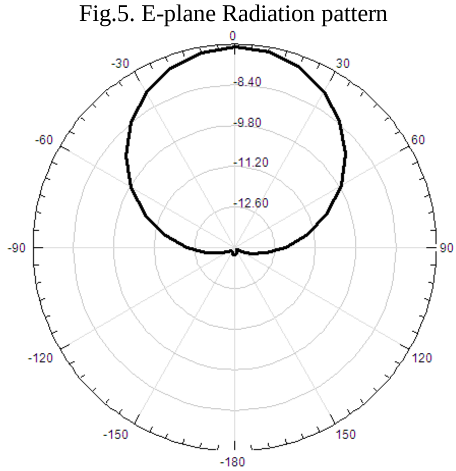

Fig.6. H-plane Radiation pattern

The radiation pattern for resonant frequency 2.75 GHz is extracted and is shown in Fig.5 and Fig.6. ELC loaded monopole antenna exhibits bidirectional pattern at E-plane and unidirectional pattern at H-plane at resonating frequency 2.75 GHz. It achieves a peak gain of 2.36 dBi at 5.45 GHz frequency in contrast to 1.94 dBi at 5.1 GHz frequency for conventional monopole antenna. An increase in peak gain of about 21.6% by loading an ELC element is achieved. Fig.7. depicts that VSWR $\leq$ 2 is achieved for operating UWB frequency. The maximum value of VSWR at 3.7 GHz frequency is 1.9006, which lies in the acceptable range.

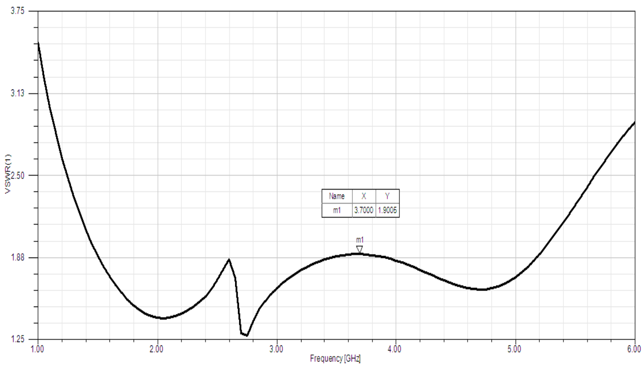

Fig.7. VSWR performance of proposed antenna

At resonating frequency, the minimum VSWR of about 1.2801 is achieved. With 1W incident power, this antenna radiates 77.27% power thus producing 81.6% radiation efficiency and zero decay factor. To provide impedance matching, feed is positioned at center of the substrate with the wave port. From the above shown results, it is clear that proposed ELC loaded monopole antenna characteristics are acceptable within the bandwidth and it shows the better performance at resonating frequency. This can be implemented as a miniaturized UWB antenna for wireless communication applications.

Table II Performance results of proposed antenna

PARAMETERS	VALUE
Frequency range	1.48 GHz to 5.22 GHz
Bandwidth	3.74 GHz
Return loss	-18.21 dB
Radiation pattern	Bidirectional (E-Plane) Unidirectional(H-Plane)
VSWR	Less than 2
Peak gain	2.36 dBi

IV. CONCLUSION

A miniaturized UWB metamaterial monopole antenna for wireless applications is proposed. To achieve wide bandwidth, ELC element is loaded to the monopole antenna, radiates in 1.48 GHz to 5.22 GHz. This antenna resonates at 2.75 GHz, covering WiMAX, Wireless LAN (WLAN), Wireless-Fidelity (Wi-Fi), Universal Mobile Telecommunication System (UMTS), Personal Communication Service(PCS) frequency band with directional radiation pattern and high gain of about 2.36 dBi. It has a simple prototype thus possessing a light weight and low power consumption.

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Design of Wideband Leaky Wave Antenna using Sinusoidally Modulated Impedance Surface Based on The Holography Theory. Article. Full-text available.Â In this paper, we propose a technique to improve the gain of ultra wide-band (UWB) planar antennas by using low profile reflectors based on frequency selective surfaces (FSS). This technique not only enhances the gain of the planar UWB antennas but also guarantees a constant gain with weak variation across the entire UWB while keeping their attractive merits such as planar structure and easy Design of ELC loaded ultra wide band metamaterial antenna. Jan 2015. B Saravanya. R Rajeswari. B. Saravanya and R. Rajeswari, "Design of ELC loaded ultra wide band metamaterial antenna," Int. J. Emerg. Technol.Â In this paper, a metamaterial-inspired dual-band antenna with modified complimentary split ring resonator and electromagnetic band gap loading is proposed. The newly proposed modified CSRR brings 11.4% miniaturization in area of antenna as compared to conventional CSRR. The proposed antenna has an electrical size of 0.175Î» 0 Ã— 0.218Î» 0 Ã— 0.014Î» 0 and shows dual-band characteristics. My Favorite Multi-Band Antenna. By G. E. "Buck" Rogers Sr; K4ABT. In September of 1949, I was tired of climbing poles and trees to move, remove, add, or change my single-band HF antenna's. In those younger years of my HAM radio hobby, I had used single band dipoles and doublets for almost every HF Amateur band.Â It is much easier to handle than open wire feeder yet retains its ultra low loss feature. And trust me...Â The antenna can be employed on 80, 40, 20 and 10m with considerable, though acceptable levels of VSWR. What became perhaps the most popular multiband Windom design of all, was the German-made Fritzel FD4 antenna, described by the late Dr. Fritz Spillner1, DJ2KY, in 1971. Subsequently, the design of several metamaterial-based antennas for passive UHF RFID tags will be summarized followed by a section on the conclusion and future applications of metamaterial-based antennas to RFID systems. 2. An introduction to passive UHF RFID systems using the Friis transmission equation.Â One such method is to incorporate metamaterial concepts into the design of the antenna on the RFID tag (Braaten et al., 2009a).Â 4.3 Meander-line antenna periodically loaded with right/left-handed CPW-LC loads There are other methods to introduce inductance or capacitance to the equivalent circuit of each meander-line section. One method is to periodically load each meander-line section.