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Design and Simulation of Microstrip Antenna Using Composite Right/Left Handed Transmission Line (CRLH-TL) Technique for LTE and Radar Applications

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***Abstract*— A compact metamaterial inspired antenna operates at LTE and Radar applications is introduced in this paper. Control and manipulation of electromagnetic waves is at the heart of many industries from wireless communication, internet and optical data storage to imaging and displays. Progress in these technologies places challenging demands on material properties and therefore structured electromagnetic materials. Metamaterials are a special class of structured materials. Patterning on the sub-wavelength scale allows precise engineering of their electromagnetic properties over a range going far beyond natural media. In this paper, microstrip antenna consists of radiating patch and two parasitic elements (open-loop ring resonators) to serve coupling bridges with partial ground plane and composite right / left-handed transmission line (CRLH-TL) embedded in the patch antenna. The antenna topology possesses an area 26×37×1.27 mm^3.The analysis and design is simulated and optimized commercial software. The good agreement between the theoretical expectation and the simulation results is observed. Finally, the proposed optimum antenna design structure has been fabricated and the measured *S*-parameters, VSWR of the proposed structure can be analyzed with network analyzer to demonstrate the excellent performance and meet the requirements for LTE and Radar applications.**

Keywords*— *Microstrip antenna; CRLH-TL; LTE; Radar; Partial ground plane; Interdigital Capacitor; HFSS.

I. Introduction

In the present-time communication, antennas cover a wide range of applications in different areas, such as mobile communication, satellite navigation, internet services, automobiles and radars. Antennas are metallic structure which radiate and receive waves. Mobile phone handsets are generally required to be small in size. On mobile phone, current needed is more in terms of parameters such as shape, performances, qualities and its technology. There are various new technology arriving in wireless communication now a days that has brought a lot of devices which are portable in the future, such as a mobile phone that will possess function for fast data transmissions. LTE (Long Term Evolution) is the project related to high performance air interface for mobile telephony. LTE is the latest new technology that ensures competitive edge over existing standards: GSM, UMTS, etc. It improves user experience with full mobility. LTE minimizes the system and user-equipment complexities. LTE covers three bands, where the lower band includes frequency range of (698–966 MHz), middle band in the range of (1.427– 2.69 GHz) and higher band in the range of (3.4–3.8 GHz). Also, Radar has a wide range of applications in C-band (4-8 GHz) as well as X-band (8-12 GHz).

Metamaterials is a rapidly evolving field of research that covers a vast range of artificial structures and Electromagnetic properties. Resulting from this, there is no universally accepted definition of what is meant by a metamaterial [1-5]. It is generally agreed that metamaterials are artificial media with unusual properties not found in their constituent materials. In nature, the permittivity (ε) and the permeability (μ) of all the materials are positive. The Material with positive permittivity and permeability are referred as right-handed materials (RHMs). But the negative ε and μ can be achieved in some artificial materials, which are referred to as left-handed materials (LHMs). Metamaterials are periodic arrays of artificial structures with a pitch smaller than the wavelength of excitation. Due to their sub-wavelength periodicity, metamaterials do not diffract. Therefore, they appear homogeneous to an incident wave and can be described in terms of effective or averaged parameters that are controlled by the geometry of the metamaterial unit cell and its constituent materials. In analogy to natural materials, the elementary building block of a metamaterial, i.e. the metamaterial unit cell is often referred to as a metamolecule The CRLH metamaterials has been applied to some novel microwave devices [6-9]. The properties of the CRLH metamaterials can be analyzed by the transmission line theory.

The analysis and design of the proposed microstrip antenna supports multiband operations in much smaller size ($37\times26\times 1.27\ mm^3$). The structure of the antenna is very easy to fabricate. The proposed antenna has been successfully designed with Rogers RO3010 substrate by HFSS simulator [10]. An extensive analysis of the antenna parameters (reflection coefficient, gain, radiation pattern.) including surface current distribution is discussed in the following section. The good agreement between the simulation and measured results are observed and the radiation characteristics have been illustrated the performance. Finally, the proposed design structure has been fabricated and the measured *S*- parameters in dB versus frequency in GHz, of the proposed antenna array structure can be analyzed with network analyzer.

II. THE CRLH-TL UNIT CELL

The proposed CRLH-TL unit cells structure have been designed using Rogers duroid 6010 substrate with (ε_r= 10.2, $tan\delta$ = 0.0023) and thickness of 1.27 mm. The interdigital capacitor and stub inductor provide the LH and also the RH contributions [11]-[12]. The top view of the proposed unit cells and its mechanical parameters in mm are shown in Fig.1. The characteristics of the proposed structure, such as simulated S_{11} in dB and the surface current density, J_{sur} , are obtained and analyzed for three different number of fingers, N = 7, 8 and 9 pair These analyses were done using HFSS simulator.

From Fig. 2, it was found that the RH capacitance is attributed to the capacitance between the trace and ground plane, and the RH inductance is caused by the magnetic flux generated by the current flow in the digits of the interdigital, capacitor [6]. The proposed CRLH-TL unit cell structures have been achieved $S11 \leq$ -6 or -10 dB with multiband / wideband operational frequencies.

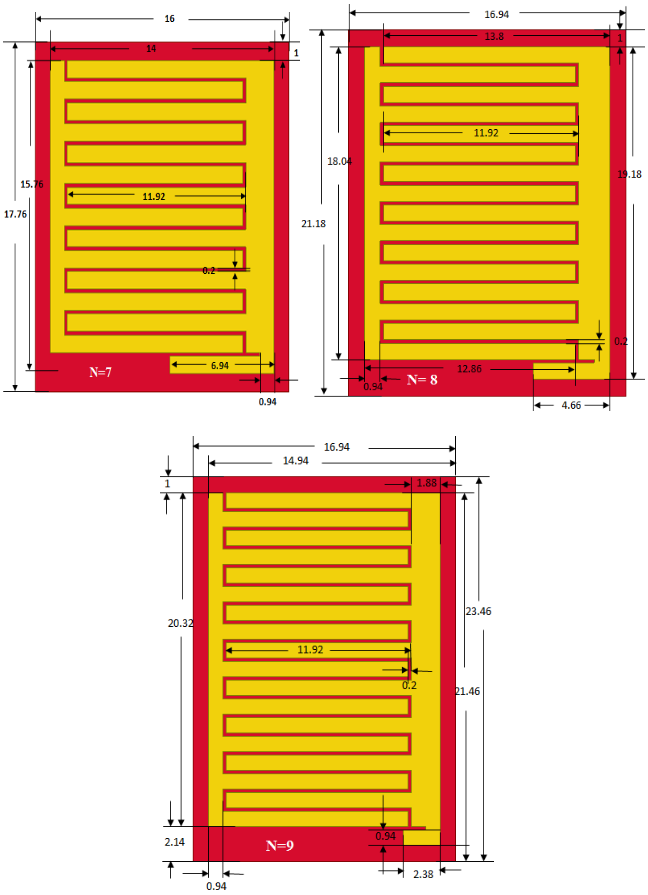


Fig. 1. The proposed CRLH-TL unit cells structure for N =7, 8 and 9 fingers.

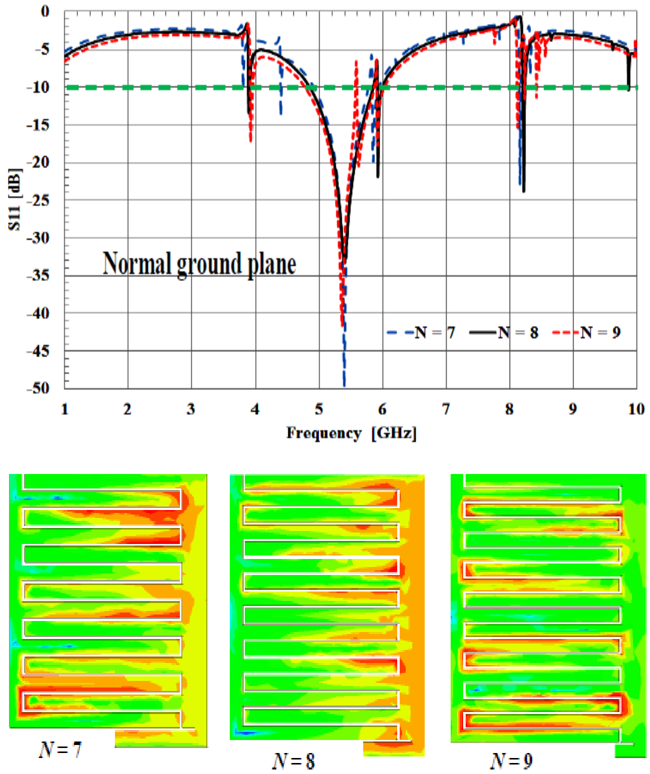
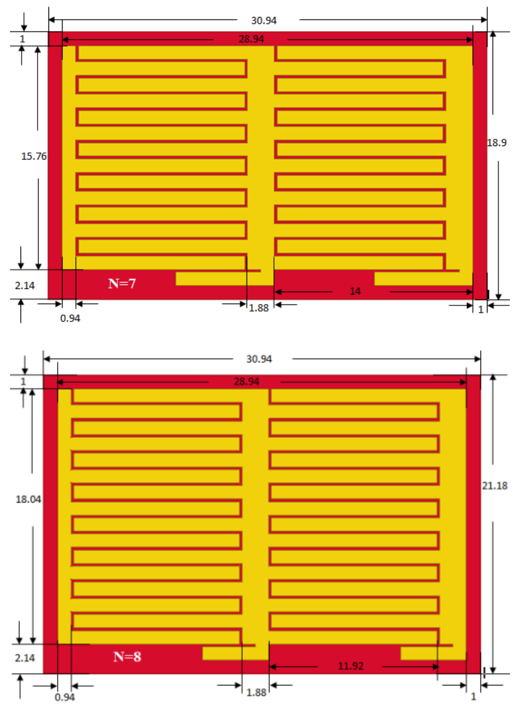


Fig. 2. The characteristics of the embedded proposed CRLH-TL Unit cell structures for N = 7, 8 and 9 fingers.

III. TWO UNIT CELL CRLH-TL

The proposed CRLH-TL with two unit cell elements array structure has been designed using Rogers duroid 6010 substrate. The top view of the proposed arrays structure and its mechanical parameters in mm are shown in Fig.3. The proposed CRLH-TL array structures have been achieved multiband/wideband operational frequencies with $S11 \leq$ -10 dB.



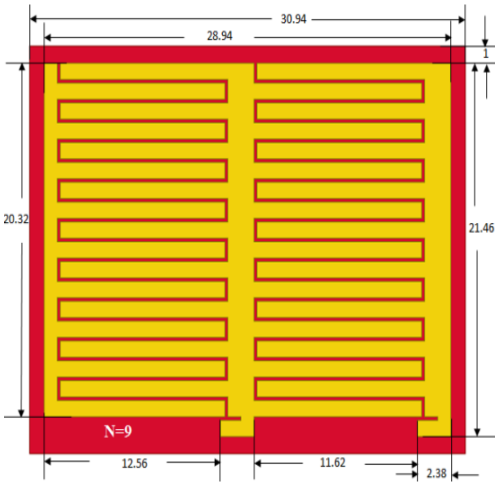


Fig. 3. The proposed CRLH-TL array structure for N = 7, 8 and 9 fingers.

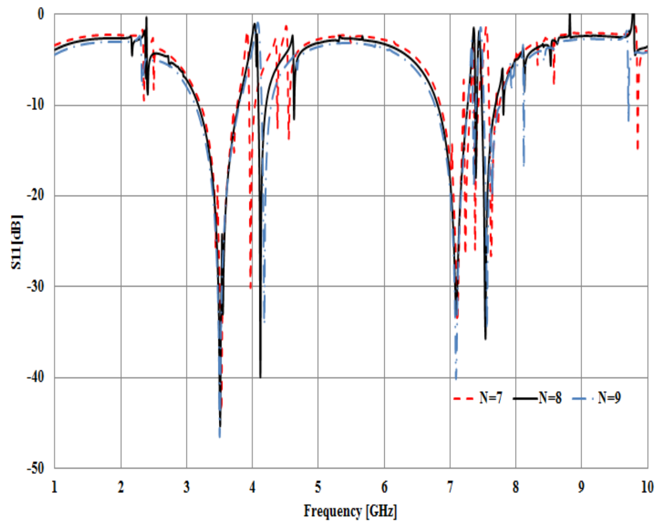


Fig. 4. The characteristics of the proposed CRLH-TL array structure with resonance frequency.

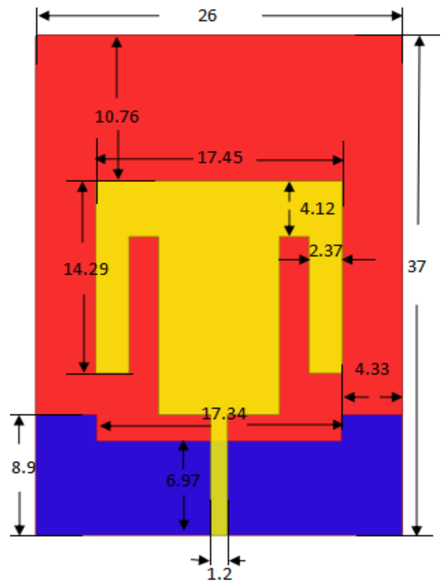


Fig. 5. Geometry of the proposed antenna structure.

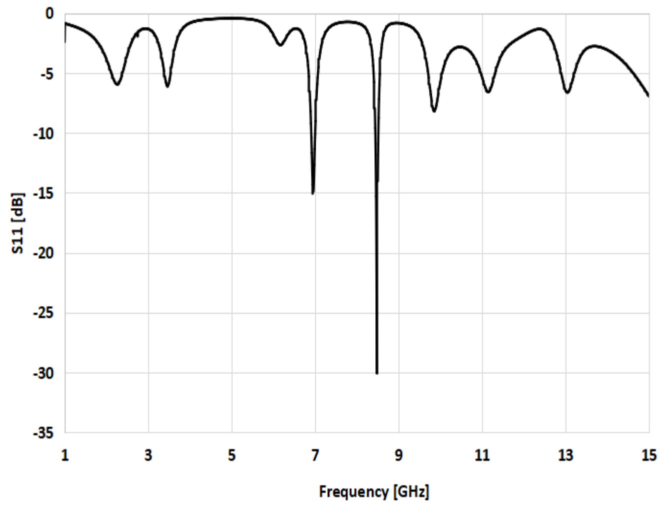


Fig. 6. The simulated S_{11}[dB] of the proposed antenna without CRLH-TL ground plane.

IV. MICROSTRIP ANTENNA DESIGN

A. Antenna Element without CRLH-TL Ground Plane

The structure of the proposed monopole multi-band antenna is shown in Fig.5. The design consists of a quasi-modified rectangular radiating patch with a partial ground plane [13]. The proposed rectangular antenna is fed by a 50 ohm microstrip line of width 1.2 mm and length 8.9 mm. The proposed monopole antenna is printed on a Rogers RO3010 substrate of thickness 1.27 mm, permittivity 10.2, and loss tangent $\tan \delta = 0.0035$. The overall dimension of the proposed antenna is only $37 \times 26 \times 1.27\ mm^3$. A small partial ground plane slot has an area of only $8.9 \times 26\ mm^2$ is etched from the ground plane to achieve multiband operation in compact dimension. The investigated antenna is connected to a 50 Ω-standard SMA connector to feed the microstrip line for RF signal input. All the parameters of the proposed antenna are finalized by parametric study through a number of simulations using HFSS software [10]. The simulated S_{11} in dB versus the frequency band 1-15 GHz and the surface current density have been shown in Fig.6 and Fig.7 respectively.

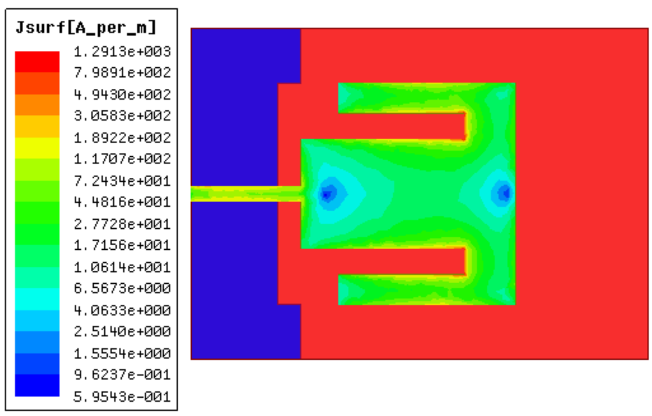


Fig. 7. Surface current density, *J*sur, of the proposed antenna.

B. Antenna Element with CRLH-TL Ground Plane

The proposed microstrip antenna with CRLH-TL structure embedded in the patch antenna at N=6 as an example has been introduced and analyzed. The proposed antenna is designed and fabricated on Rogers RO3010 substrate. The final top view of the proposed antenna is shown in Fig. 8. For the new performance of the final proposed antenna to achieve multiband operational frequencies, the position effect of the CRLH-TL structure has been understood compared with conventional antenna (without CRLH-TL array structure).

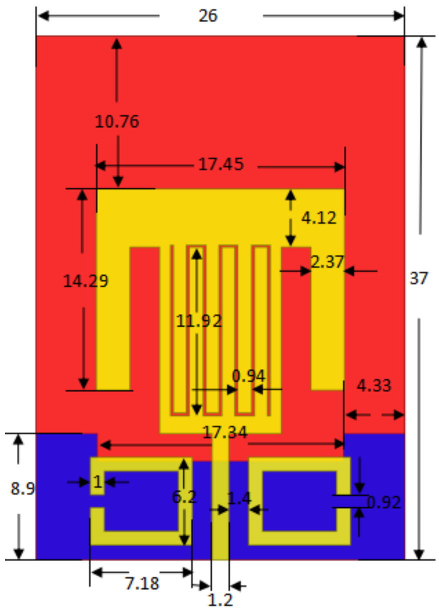


Fig. 8 The top, bottom views and mechanical parameters of the proposed antenna element with CRLH-TL on the top view.

V. SIMULATION RESULTS AND DISCUSSION

The simulated reflection coefficient curve of the proposed antenna is shown in Fig. 9. The simulated results indicate that the designed antenna achieves multiband operation with resonant frequencies.

It is observed from Fig. 10 that for operation, the surface current is mainly concentrated around the open loop ring resonators and thus increases the current path. So, the resonant frequencies are excited, generated and controlled by the parasitic open-loop resonators. The surface current distribution of the proposed antenna changes due to the presence of the open loop ring resonators that changes the resonance characteristics of the antenna. This is due to the fact that the distribution of electric and magnetic fields changes due to the lengthening of the surface current around the open loop resonators.

The simulated radiation patterns of the proposed monopole microstrip antenna with CRLH-TL is presented in Fig. 11. The proposed antenna shows almost stable radiation patterns with acceptable 3dB beam-widths.

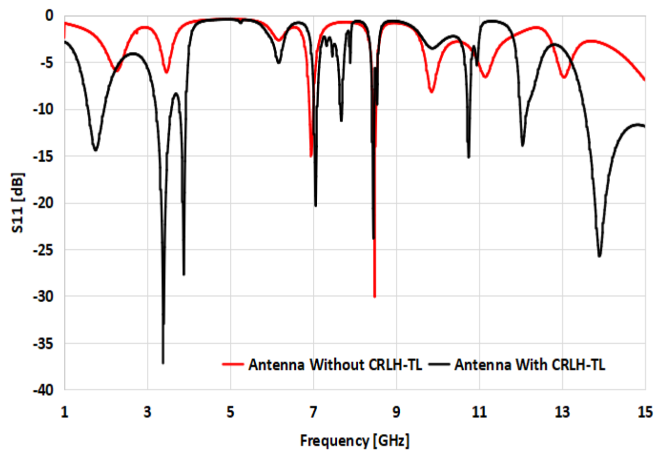


Fig. 9. The simulated S_{11}[dB] of the proposed antenna with CRLH-TL ground plane.

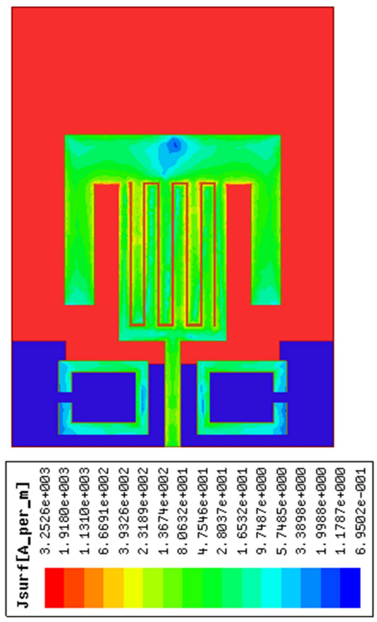
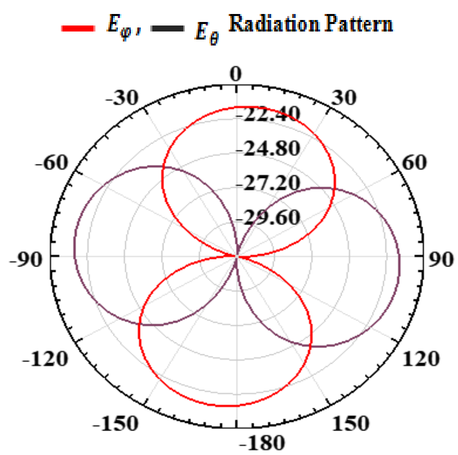


Fig. 10. Surface current density, *J*sur, of the proposed antenna with CRLH-TL ground plane.



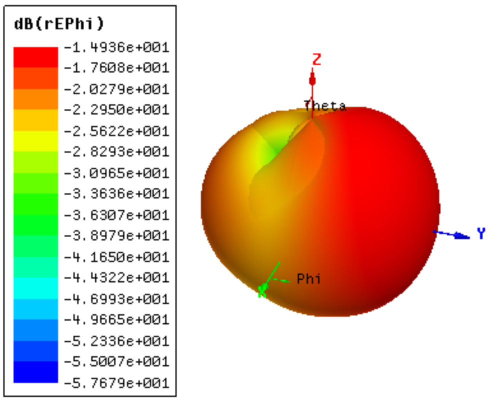


Fig. 11 Simulated 2D radiation patterns of proposed antenna and 3D radiation pattern at 3.5 GHz.

VI. FABRICATION AND MEASUREMENT RESULTS

After the optimization of the proposed antenna parameters, an experimental prototype of the proposed design was fabricated using printed circuit technology and tested. A photograph of the fabricated antenna using printed circuit technology at antenna laboratory as shown in Fig. 12.

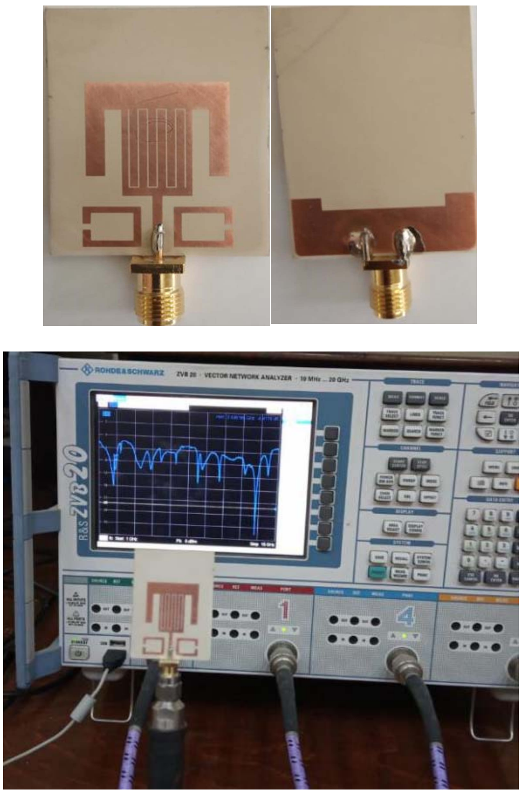


Fig.12. Fabricated prototype of the proposed antenna using VNA.

The measured S_{11} in dB of the proposed structure can be analyzed with network analyzer HP8719ES over a relatively wide frequency range from 1−15 GHz as shown in Fig. 13. The measured VSWR of the proposed antenna is shown in Fig. 14. The measured values of the voltage standing wave ratios of the proposed antenna lie within 2:1 for all of the operating resonant frequencies, which indicates less reflected power and better impedance matching.

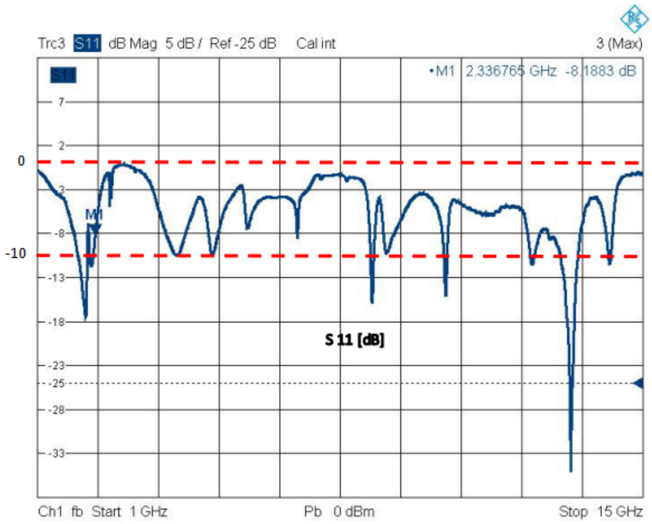


Fig. 13. The measured reflection coefficient of the proposed antenna.

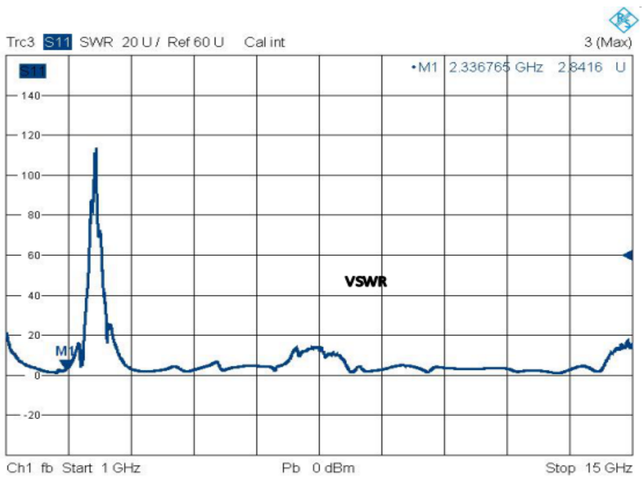


Fig.14. The measured VSWR of the proposed antenna

VII. CONCLUSION

An advanced and cost-effective multiband antenna for LTE, Radar, applications is designed, fabricated and tested. Antenna miniaturization is obtained by introducing CRLH-TL structure over the RO 3010 substrate which provokes multiband frequency characteristics by increasing the number of resonant frequencies without modifying the dimensions of the square patch antenna. The proposed antenna design has simple structure and can be used in multiband communication systems.

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