Journal of Engineering and Applied Sciences 11 (6): 1417-1422, 2016
ISSN: 1816-949X

Strip Loaded Closed Loop Resonator Based Multiband Defected Ground Structured Antenna

T.V. Rama Krishna, B.T.P. Madhav, T. Sri Rama Krishna, K. Sravanthi and G. Dinesh Gopi
Department of ECE, KL University, Andhra Pradesh, India

Abstract: A defected ground structured circular monopole antenna is designed and presented in this research. The proposed antenna utilized closed loop resonator strips on both sides of the feed line. The overall dimension of the antenna is around 28×24×1.6 mm on FR-4 substrate with dielectric constant 4.4. The experimental results of the prototyped antenna on ZNB 20 vector network analyser are showing good agreement with simulated results on FEM based HFSS tool. A parametric analysis of the proposed antenna with respect to change in rate permittivity is also presented in this research.

Key words: Strip loading, closed loop resonator, defected ground structure, multiband antenna, FR4 substrat

INTRODUCTION

The study of microstrip patch antenna has made great progress in recent years. Compared with conventional antennas, microstrip patch antennas have more advantages and better prospects (Balanis, 1997; Randy, 2006; Johnson and Hess, 1975). Here we have designed an antenna of ultra wide band with tuneable band notched characteristics based on microstrip closed loop resonator at the central frequency of 5.1 GHz. As the name implies UWB, ultra wide band technology is a form of transmission that occupies a very wide bandwidth. Generally the band should work around 3.1-10.6 and it is this aspect that enables it to carry data rates of Gigabits per second. Some of the key benefits that UWB brings to wireless communications are ability to share the frequency spectrum, ability to work with low signal to noise ratios, Low probability of intercept and detection and resistance to jamming, etc. Designing antenna on different substrates is also one of the challenging tasks depending on the application (Madhav *et al*., 2010, 2011a, b, 2012, 2015a).

Designing of an antenna for wide band applications is a challenging issue and it should overcome the electromagnetic interference which is the major drawback for wireless communication. Different design methods of wide band antennas with band-rejection characteristic have been investigated and successfully implemented in the past. The most popular approaches are embedding different shaped slots in the radiating element or ground plane and loading diverse parasitic elements on the antenna. Once these antennas are fabricated, the notched bands are also fixed but radio signals have random nature of interference which varies from place to place and time to time. Therefore, it is more desirable to design a wideband antenna and this proposed antenna has flexibly with multiband to adapt to the changeable environment (Sundar *et al*., 2014; Madhav *et al*., 2015b, c; Bhavani *et al*., 2015). Usually consumer electronics applications prefer compact-size, low manufacturing cost and high quality. Here, we have taken different substrate materials duroid, FR4-epoxy and LCP where the usage will be varied according to applications.

We used FR4 as main substrate and studied all the characteristics. Generally, the high performance FR4 has good reliability characteristics. “FR” stands for flame retardant and denotes that safety of flammability of FR-4 is in compliance with the standard UL94V-0. Liquid crystals can be made into polymers also and can be used as substrates. Combining liquid crystal and polymer properties (the properties of plastics or rubbers) creates materials with unique characteristics. Two key examples of these types of materials are found in man-made and natural high yield strength polymers and in liquid crystal elastomers. Here, we have used lcp as one of the substrate. It works under different frequency bands. Duroid is the other substrate. RT/duroid 5880 high frequency laminates are PTFE composites reinforced with glass microfibers. Defected ground structured antenna are providing additional resonant frequencies in conjunction with patch on the surface (Nayak *et al*., 2015; Madhav *et al*., 2005; Ramkiran *et al*., 2015; Naik *et al*., 2015; Lakshmi *et al*., 2015; Madhav *et al*., 2016).

MATERIALS AND METHODS

Antenna design and geometry: The configuration of the proposed Closed Loop Resonator multi-band antenna is presented in Fig. 1. Figure 2 indicates the back view of the

Corresponding Author: T.V. Rama Krishna, Department of ECE, KL University, Andhara Pradesh (AP), India

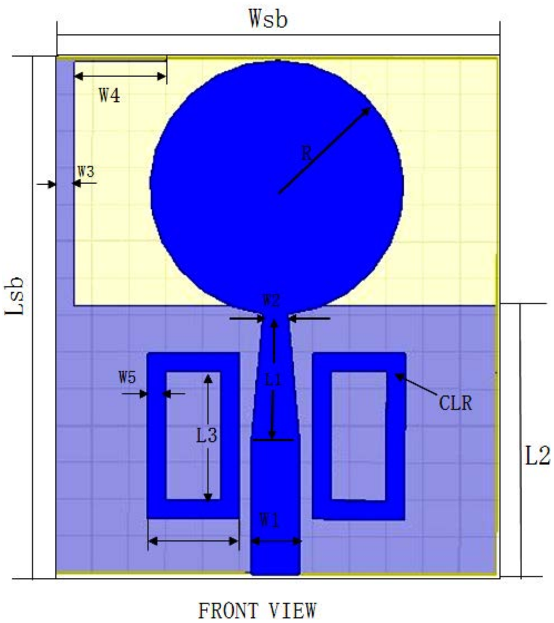

Fig. 1: Closed loop resonator antenna top view

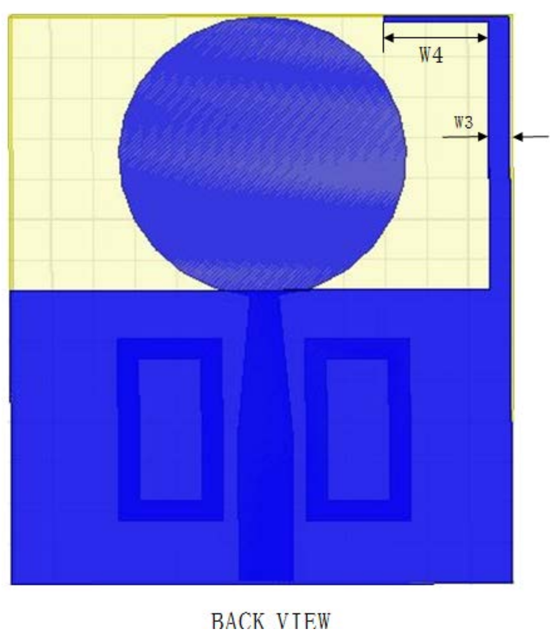

Fig. 2: Antenna back view

antenna with defected ground structure. The dimensional characteristics of the designed antenna are 28×24×1.6 mm on lossy FR4 substrate material with dielectric constant 4.4 (Table 1). Square shaped closed resonators are placed nearer to the feed line on both sides as shown in Fig. 1 to elevate additional resonant frequencies. The central resonant frequency is inversely proportional to the effective electrical length of the resonator.

Table 1: Antenna dimensions

Parameters	Dimensions
LSB	28 mm
Wsb	24 mm
L1	6.8 mm
L2	14.5 mm
L3	9 mm
W1	2.6 mm
W2	1.2 mm
W3	1 mm
W4	5 mm
W5	1 mm
W6	4 mm
R	6.9 mm
CLR	Closed loop resonator

RESULTS AND DISCUSSION

Figure 3 shows the reflection coefficient of the proposed antenna with change in permittivity of the substrate material. Three materials are considered in this research to analyse the performance characteristics of the proposed. Initially FR4 substrate is used in the design of the antenna by applying its dielectric characteristics in the simulation using HFSS. Two more materials are also used in the simulation along with FR4 substrate. Commercial RT-duroid 5880 with dielectric constant 2.2 and loss tangent 0.0009 is used as one of the material and a flexible and conformal substrate material liquid crystal polymer is also used with dielectric constant 2.9.

The S-parameters of the proposed antenna is examined with these materials and presented in the reflection co-efficient curve of Fig. 3. Figure 4 shows the VSWR characteristics of the proposed antenna with change in substrate permittivity. It is been observed that FR4 substrate material based antenna is resonating at quad-band with high Band Width at higher resonant frequency. RT-DUROID material based antenna is also resonating at quad-band with high band width at fundamental resonant frequency. The liquid crystal polymer based antenna is showing triple-band characteristics with narrow band width at middle-resonant frequencies. Even though, LCP based antenna is showing quad-band, reflection co-efficient is very poor at one of the resonant frequency. So, we considered only triple-band characteristics in this case.

Figure 5 shows the impedance characteristics of the proposed antenna model with three dielectric materials. Liquid Crystal Polymer based antenna is showing superior impedance characteristics over the operating band when compared with other materials. Figure 6 shows the radiation patterns of the proposed antenna for three materials that we considered the study. The RT-DUROID material based antenna is showing Quasi-Omni directional radiation pattern in H-plane and bean shaped pattern in E-plane. A directive gain of 2.1 dB is obtained from

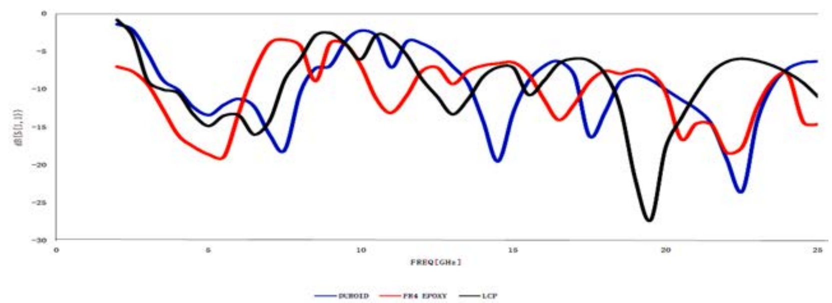

Fig. 3: Return loss vs frequency

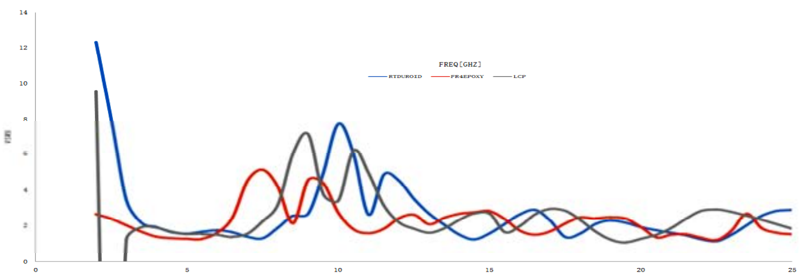

Fig. 4: VSWR vs frequency

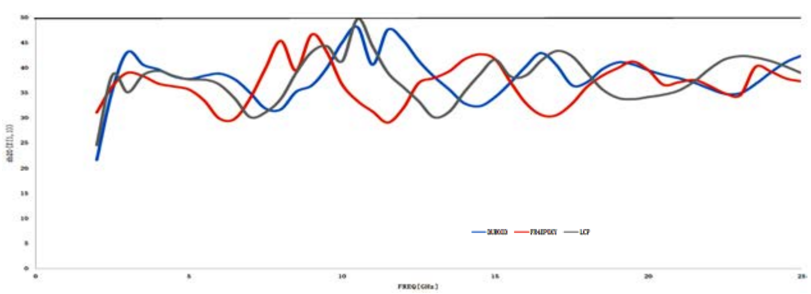

Fig. 5: Impedance vs frequency

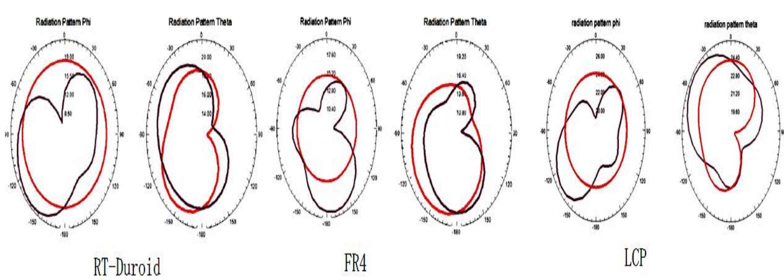

Fig. 6: Radiation pattern of antenna on three materials in E and H plane

Figure 7 of three-dimensional radiation characteristics. The FR4 substrate material based antenna is showing low cross polarization in H-plane and directive radiation pattern in the E-plane gain of 2dB is attained with FR4 substrate material based antenna. Surprisingly, liquid crystal polymer based antenna is showing better radiation characteristics and gain. A peak realized gain of 2.75 dB is attained from this case.

The surface current distributions of the proposed model on three-dielectric materials are presented in Fig. 8.

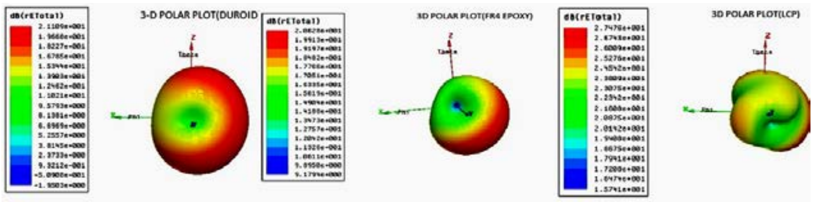

Fig. 7: Three dimensional radiation pattern of antenna on three materials

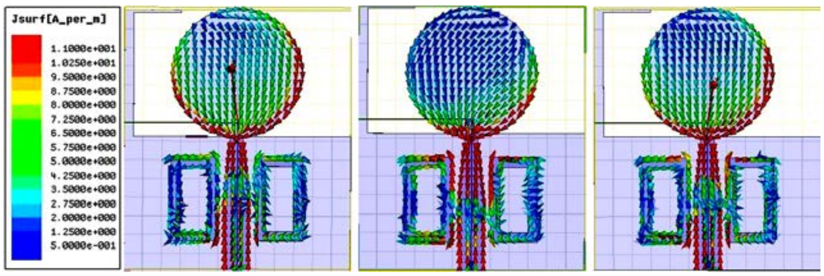

Fig. 8: Surface current distribution of the antenna on three dielectric materials

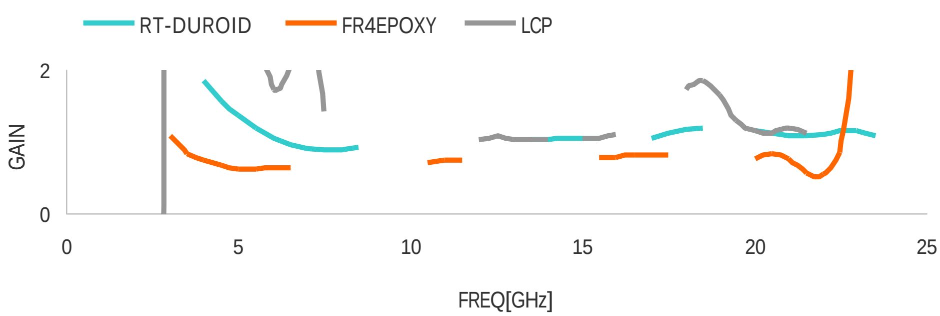

Fig. 9: Frequency vs gain

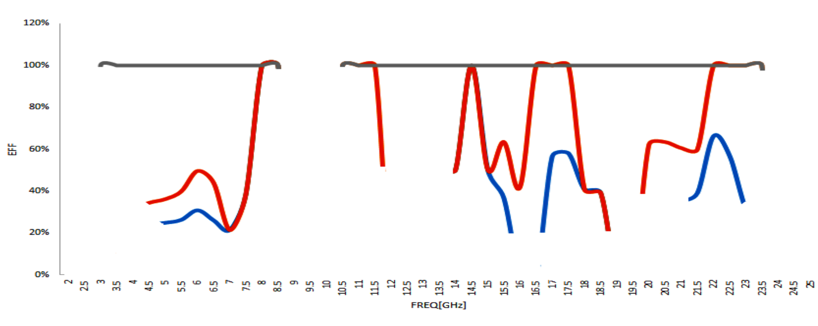

Fig. 10: Frequency vs efficiency

For RT-DUROID based antenna most of the radiation is from feed line and outer boundary surface the circular patch. For FR4 substrate material based antenna the same type of distribution can be observed. LCP based antenna is showing current density at lower part of the feed line and lower semi circle of the radiating element. Figure 9 shows the gain characteristics of the antenna for different substrate materials LCP based antenna is giving peak realized gain 2.75 dB and the remaining models have not reached to that mark. Efficiency wise also LCP material based antenna is showing almost 98% at the operating bands form Fig. 10. The RT-DUROID material based

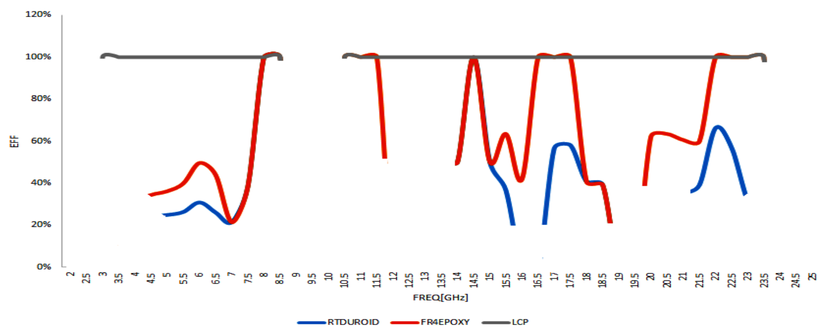

Fig. 11: Frequency vs directivity

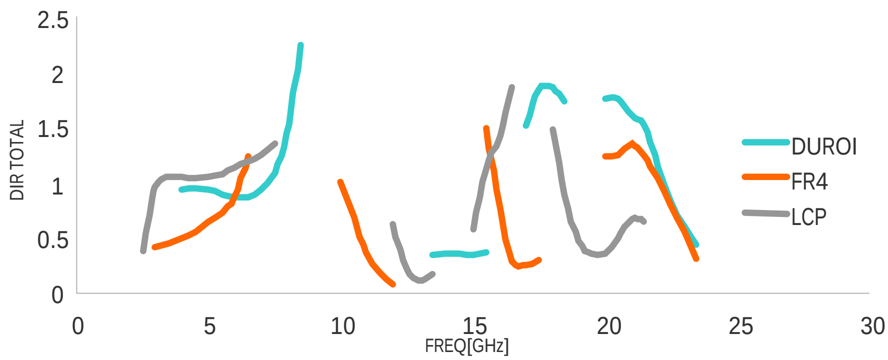

Fig. 12: Fabricated antenna top side and bottom side

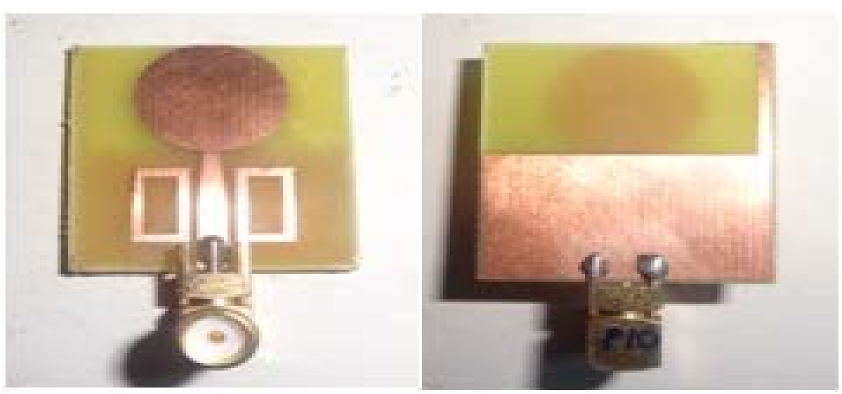

Fig. 13: Measured Return Loss on ZNB 20 VNA

antenna is showing peak directivity of 2.4 dB and LCP based antenna is showing 1.8 dB. The FR4 substrate material is showing maximum peak directivity of 1.5 dB from Fig. 11.

Figure 12 shows the fabricated antenna on FR4 substrate. The top side is loaded with strips on either side of the feed line and bottom side is showing the defected part in the ground. The measured results of the S11 are shown in Fig. 13 on ZNB 20 vector network analyzer. The measured and simulation results are in good agreement with each other.

CONCLUSION

Strip loaded closed loop resonator based multiband antenna is designed and analyzed in this research. The circular monopole and strips on both sides of the feed line are providing additional resonating frequencies in this design. the prototyped antenna on FR4 substrate with defected ground structure is giving good agreement with the simulated results from HFSS tool. The proposed antenna is covering microwave communication bands with moderate gain. Different substrate materials are examined in this research and found that duroid material based model is giving better directivity and liquid crystal polymer based antenna is providing excellent efficiency characteristics.

ACKNOWLEDGEMENTS

Research like to express their gratitude towards the department of ECE and management of K L University for their support and encouragement during this research. Further Madhav likes to express his gratitude to DST through FIST grant SR/FST/ETI-316/2012.

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