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High Performance Dual-band Printed Doublet Design Loaded with Split Resonator Structures

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Abstract:

This paper presents the design of new miniaturized double-sided printed (doublet) dipole antenna loaded with split resonator as metamaterial structure. Resonators placed close to the edge of the printed antenna cause the antenna to radiate at two different frequencies. It is shown that the proposed loaded dipole antenna is a dual band radiator with sufficient gain and return loss suitable for applications such as wireless communication. The main intention is to use this design in RFID tags for tracking and monitoring purposes. Design of miniaturized double resonant doublet is done and tested using the Advanced Design System (ADS) simulation tool.

Keywords: Advanced Design System, Doublet, Insertion Loss, Metamaterial, Return Loss, RFID-Radio Frequency Identification.

1. Introduction

There is an increasing demand for multi-function devices. The multi-frequency printed dipoles can be integrated into familiar devices such as laptop computers and mobile phones. Compact antennas are important for today's mobile communication systems. Ever-increasing demands for low profile multifunctional antennas have resulted in considerable interest by the electromagnetic research community in metamaterials. Due to unique electromagnetic properties, metamaterials have been widely considered in monopole and dipole antennas to improve their performance. It was revealed in [1-2] that an efficient and electrically small magnetic based antenna can be realized by adding a planar interdigitated CLL element to a rectangular semi loop antenna, which is coaxially-fed through a finite ground plane. The performance of a printed dipole antenna near a resonator changes and has been examined in this paper. Recently, TL-MTM is used to load antennas [3-4]. A miniaturized printed dipole loaded with left-handed transmission lines is proposed.

In this paper, we propose a new dual band printed dipole antenna in that resonators act as reactive loads and are placed close to the edge of the dipole. The losses associated with the resonators are very low in the frequency range of interest, resulting in both the acceptable gain, return loss and radiation pattern. The unloaded printed dipole antenna has only one resonance. When the resonators are incorporated the resonant behavior of the printed dipole antenna changes. As a result, a new resonance appears with the frequency determined by the resonator dimensions. The resonator is an LC resonant circuit in which the resonant frequency is mainly determined by the loop inductance and the capacitance. The proposed dual band resonator loaded dipole antenna radiates effectively at both resonant frequencies with good return losses and gains as well as acceptable omnidirectional radiation patterns. The Advanced Design System (ADS) simulator is adopted for the simulations.

2. Dual Band Printed Dipole Antenna

To test the proposed design, double-sided printed dipole antenna is loaded by resonators. Figure 1 shows the resonator-loaded printed dipole antenna together with the resonators. All the elements are printed on a FR4 substrate with a thickness of 0.8mm and a dielectric constant of 4.4 to reduce the cost of the antenna. Figure 2 shows the return loss of the proposed dual band printed dipole antenna as well as the unloaded dipole antenna. It is observed that when the resonators are added, two resonance frequencies become distinguishable from each other and thus two resonances are clearly observed in the return loss curve.

The unloaded dipole antenna resonates at around 1.8 GHz. In contrast, the resonator-loaded dipole resonates at 1.8 and 3.6 GHz, as shown in Figure 2.The lower resonant frequency corresponds to that of the original printed dipole while the higher resonant frequency is mainly determined due to the resonator loading. To further understand the performance of the printed dipole antenna close to the resonators, Figure 3 shows the magnitude of the S-parameters versus frequency for the resonator-based metamaterial. It is observed that the resonator element effectively resonates at around 3.6 GHz with small loss.

3. Design

The design of dipole antenna is based on the following general equations for transmission lines.

$$\frac{W}{d} = \frac{8e^{A}}{(e^{2A}-2)} \text{--(1)}$$

$$A = \left(\frac{Z_0}{60}\right)\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left(0.23 + \left(\frac{0.11}{\varepsilon_r}\right)\right) \text{-- (2)}$$

The width of the feed as well as the dipole antenna depends upon the value of A which in turn depends on the value of the characteristic impedance (Z_0).The impedance for the feed line is taken to be 50Ω and the power from feed is equally split into two parts to the dipole antenna. So the impedance for the antenna is taken as, $Z_0/\sqrt{2}$. In this case, W denotes the width of the transmission line and d denotes the thickness of the substrate. $\varepsilon_r$denotes the dielectric constant of the substrate.

Now considering the length of the antenna and feed, we are in need of wavelength. Once the frequency is known the wavelength can be calculated using the following relation.

Λ= c/f– (3)

In above mentioned formula, λ is the wavelength, c is the velocity of light and f is the desired frequency of operation. Similar proceedings are followed for the design of resonators. The only change is that the frequency of operation is f= 3.6 GHz.

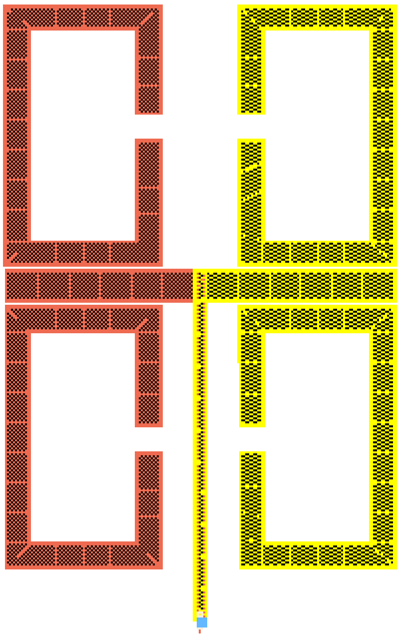

Fig. 1.Resonator-loaded printed dipole antenna

4. Results And Discussion

The return loss and insertion loss characteristics of the resonator -loaded printed dipole are given in figure 2 and 3 respectively.

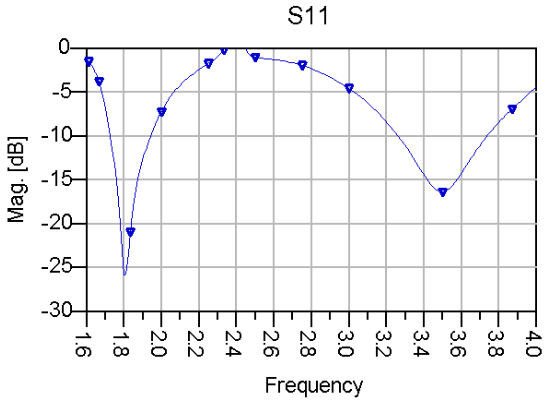

Fig. 2. Return loss of loaded printed dipole antenna.

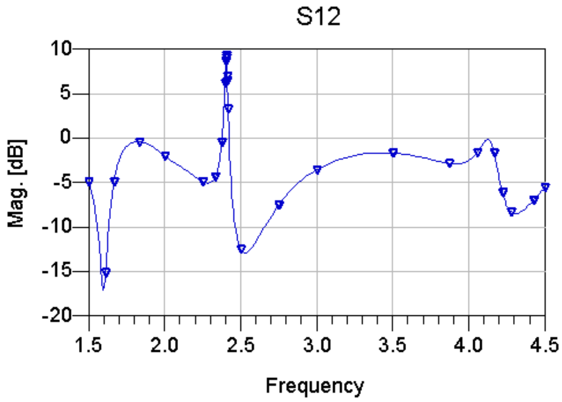

Fig. 3.Insertion loss of loaded printed dipole antenna.

Figure 4 and 5 shows the simulated radiation patterns at first and second resonant frequencies. Based on simulated results, the losses introduced by the resonator elements are significantly low in the frequency range. In the other words, the proposed dual band dipole antenna has acceptable performance in both gain and radiation pattern.

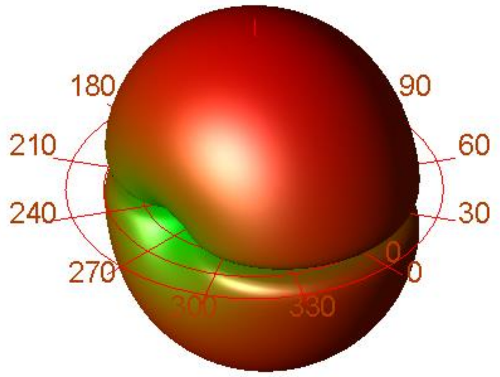

Fig. 4. 3-D simulated radiation patterns of the loaded printed dipole antenna for 1.8 GHz

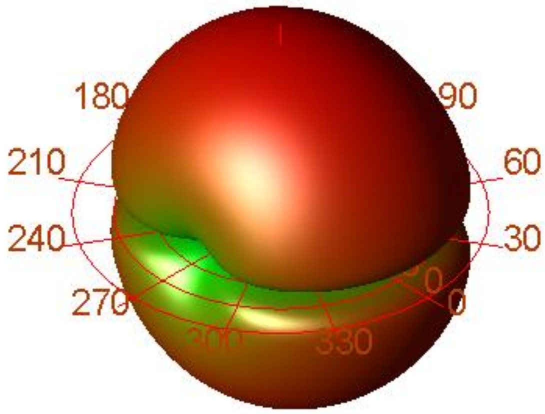

Fig. 5. 3-D simulated radiation patterns of the loaded printed dipole antenna for 3.6 GHz.

In order to meet the specification, the resonator-loaded printed dipole antenna should radiate linearly polarized waves at 1.8GHz and 3.6GHz. The size reduction can be achieved if it would be feasible to fabricate a proper metamaterial element that has a negative permeability at a frequency lower than the natural resonance frequency of the corresponding unloaded dipole antenna.

As can be seen, the resonant frequencies of the proposed miniaturized resonator-loaded printed dipole are lower than the main resonant frequency of the unloaded dipole antenna. It should be pointed out that the antenna radiation patterns at both resonant frequencies are quite similar to that of a half wavelength dipole, as shown in Figure 4. The frequency response of the unloaded dipole antenna is given in figure 5. Also the VSWR and smith chart response is given for the parameter S11 is given in figure 6 and 7 respectively.

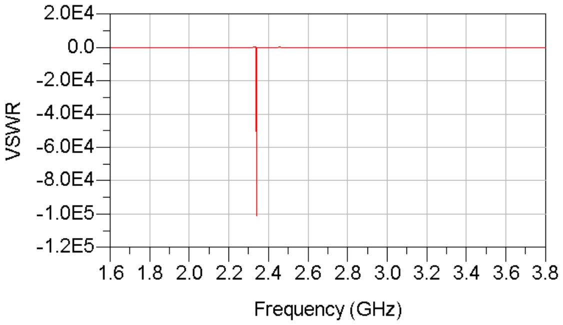

Fig. 6. VSWR Curve for S11

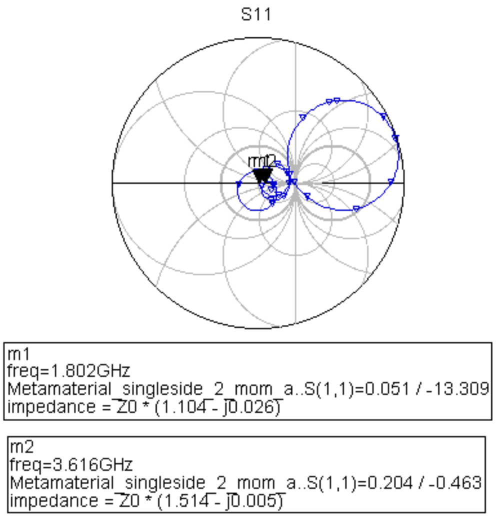

Fig. 7. Smith Chart Response for S11.

5. Conclusion

In this paper, the behavior of a double-sided printed dipole antenna loaded with resonator elements is examined. It is revealed that placing resonator elements in close proximity of a printed dipole antenna creates a double resonant antenna, the response of which is a function of resonator dimensions as well as of relative spacing between the antenna and resonators.

An important advantage of the proposed dual-band printed dipole antenna is its capability to resonate Omni-directional radiation pattern at both resonant frequencies. In addition, the antenna gain at the both resonant frequencies are high and found to be 3.53 dB for 1.8 GHz and 3.3 dB at 3.6 GHz.. A good agreement between the theoretical and simulated results is obtained.

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