DESIGN AND FABRICATION OF MINIATURIZED METAMATERIAL ANTENNA FOR MOBILE AND WIRELESS APPLICATIONS

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ABSTRACT

Printed and multi-band antenna which is suitable for mobile or wireless applications is proposed and tested in this paper with the combination of composite right/left handed (CRLH) and SRR as central elements. The proposed antenna exhibits right handedness and left handedness with help of transmission lines on the printed circuit board (PCB) substrate which has epsilon value for RT Duriod 5880 LZ (εr=2.2). Resonance at various frequencies is due to driving of one cell to the other [1]. Cells are connected through contacts or via on the either side of the PCB. Through these two different units, antenna can have broad bandwidth which ranges from 1.9GHz to 2.7GHz and efficiencies of antenna at each frequency are over 76%. The proposed antenna operates at PCS (1850–1990 MHz), UMTS (1920–2170 MHz), WIBRO (2300–2390 MHz), Bluetooth (2.42–2.48 GHz), S-DMB (2.630–2.655 GHz) frequency bands. Total PCB size is 40×60 mm^2 with 0.762 mm thickness which is integrable in smart systems so it is very successful in RF applications. The proposed antenna has been designed within a volume that makes it suitable for ultra-thin mobile handsets or any wireless sets. Prototype is an electrically small, tunable has been fabricated and characterized for Reflection coefficient and radiation performances which are quite reasonable at all the frequency bands with good ability for tuning and large size reduction compared with a conventional planar antennas.

KEYWORDS: *Metamaterials, CRLH Transmission line, split ring resonators, system on chip.*

I. INTRODUCTION

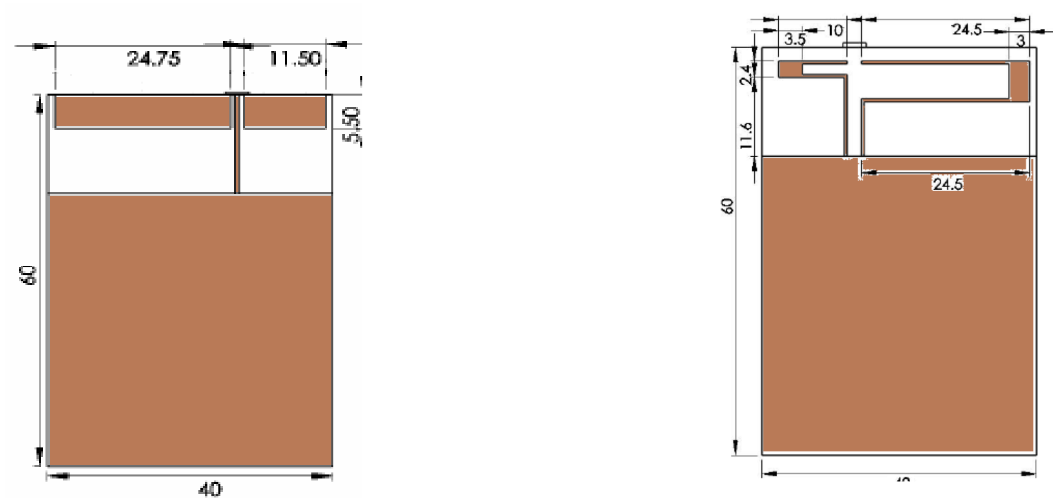
The microstrip antenna has recently come into vogue as a research topic and commercial application. The increase in interest is due to their low profile, which can easily be integrated flush against a surface for durability. Developing technology on personal mobile systems have been requiring that mobile handsets should have various integrated features with voice and data communication services. Some of the inherent difficulties have to do with its complicated fabrication process and possible limitation in component miniaturization for the antenna, power for multi-standard mobile phones. These mobile handsets are required to operate at different more frequency bands. Compact, slim, and multi-function handsets put difficult requirements on the antenna design. Physical size of the antenna is one of the greatest limitation for the wireless antenna set. The antenna proposed is printed double sided circuit and planar type. In order to accomplish the limiting antenna design parameters circumstance, a lot of antenna design guides have been introduced. For example, helical antenna, planar inverted F antenna (PIFA), and chip antenna. However, these common antenna designs still have a limitation that the size of antenna is proportional to its physical size and planar PCB embedded type. The proposed antenna is based on transmission lines on the PCB for reducing antenna volume such as height also cheaper. So, designing thin and slim handsets is possible without restricting antenna height but with reduction in weight. To be integrated within the system on chip the method is to make the antenna electrically small. Proposed antenna is based on (CRLH) metamaterial transmission lines for size reduction. This kind of metamaterial structure has been explored over the last years [1-3]. According to these papers, metamaterial is a novel structure which has unique electromagnetic properties such as supporting infinite wavelength wave at a specific non-zero frequency and left handed (LH) characteristics of wavelength proportional to frequency. It also implies the resonance frequency of a SRR depends on geometry of the structure, and it can be resonant at a frequency whose corresponding wavelength is much larger than the physical dimension of the SRR [4-5]. This makes a SRR structure a very promising design for an effective electrically small antenna. Here in this paper a planar double sided PCB antenna with RT Duriod as a substrate which exhibits metamaterial nature was presented. It is a meandered structure allowing large bandwidth of operation. The antenna was fed with coaxial cable and chemical etching fabrication process was employed. Testing and Characterization was done and it is suitable for mobile sets for wireless applications. The design dimensions on the either sided of the antenna was depicted in Fig. 1.

II. PROTOTYPE ANTENNA GEOMETRY

Fig. 1 shows the geometry of the proposed metamaterial antenna. The overall dimension of the structure with a printed type on a substrate of RT Duroid 5880LZ (ε_r=2.2) is 40×60×0.762 mm^3, which is small enough to be built in mobile or wireless devices , and the space for antenna is 40×15 mm^2, which is PCB embedded type. PCB ground of front and rear side is connected through vias. Radiating patches are excited by feeding line through a small gap in between and lines are finally connected with rear side of ground. The proposed antenna has a two different unit cells. The size of each parts is shown in Fig. 1 (c) and (d). The width of via lines is 0.5 mm. The width of feeding line is also 0.5 mm. The gap between each unit cell and feeding line is 0.2 mm which is the distance between radiating patches and feeding line. The diameter of vias is 0.5 mm. This antenna is based on idea of metamaterials mentioned in [1-5]. This CRLH structure consists of series inductance, series capacitance, shunt inductance, and shunt capacitance. The characteristics of these inductances and capacitances are best illustrated in [6-7] the search for suitable substrates as a dielectric layer, it was desirable to use most suiting possible permittivity. Air, Styrofoam blocks, alumina, glass, sapphire, composite Duroid, silicon, ice, and liquid alcohol were all considered. Dictated by the availability of materials and desire to gain experience with the standard media, Duroid material was chosen.[11]

(a)

(b)



(c) (d)

Fig. 1. Front and rear views of the Proposed Antenna

III. DESIGN

The resonant frequency of a planar strip antenna can be designed using ANSOFT based on the width and length of the pattern, given the height and permittivity of the dielectric material between the conductive layer and ground plane. The substrate was proposed as possibilities for construction was RT/ Duroid 5880 high frequency laminate with ε_r=2.2 and a thickness of .762mm.

IV. EXPERIMENTAL PROCEDURE

Designs should be simulated before fabrication, if possible to gain agreement with specification. Ansoft HFSS was used to simulate the performance and functionality of the antenna. The layout suite supports microstrip lines, user specified dielectric, and conductive layers. For antenna fabrication it is necessary to reduce the copper clad on either side of the dielectric to form the desired antenna, while leaving the rest of area intact to function as a ground plane. Two techniques of fabrication were tested as suitable methods, a metal lift-off, and a metal etch. Copper PCB etchant was selected over milling due to unavailability of a mill and the tediousness involved in milling by hand with a rotary tool. It is possible to mask off the un-etched portion with marker or to selectively remove the protective plastic coating from the laminate. Later method was selected for ease of measurement of dimensions and homogeneity of the resultant metallic pattern. Negative masks of the antenna were made by laser printing on overhead transparency. The negative mask is needed for the lift-off. In a lift-off, 3 photoresist is left under the unwanted metal so that a solvent may undercut and lift off the areas where metal is not desired. Cleaned and spin-dried in order to drive the solvent out of the polymer. The wafers were exposed to UV light through the negative mask for 15s at a dose of 14mW/cm2 in a. This is a higher than typical dose adjusted for the facts that the plastic mask is expected to absorb a significant portion of the UV, the negative mask is darkfield. After the metallization, the etched wafers proceeded to photolithography. This process was successful in creating the desired metallic pattern patch on substrate. The exposed copper metal layer was then wet etched in a ferric chloric acid and surfactant solution for 20mins at 40ºC. The remaining photoresist was then stripped of with n methyl pyrrolidone. The feed point was chosen to be in the edge of the PCB for impedance match. An SMA connecter was soldered into place, taking care not too short to patches on antenna surface, allowing for more compact planar antennas for a given wavelength.[9] A crippling setback to the investigation of the Duroid substrate was the difficulty involved in attaching a feed point. Possible solutions to this problem include the use of a proper wire bonder, probe station, or clamping devices.

V. RESULTS AND DISCUSSION

5.1 Analysis and Efficiency

The measurement reflection coefficient of proposed antenna is presented in Fig. 2. The antenna covers four bands which are DCS, PCS, WCDMA, and WIBRO. Especially, the resonant frequency of 2.4GHz has a good impedance matching value. Efficiency of each commercial band is over 60%. At 2.4 MHz, its efficiency is almost 90%. Measured radiation patterns at each frequency are plotted in Fig.3. These patterns are measured at 1700 M Hz, 2500 M Hz, Fig. 4 shows total radiation power efficiency of frequency range from 1500 M Hz to 2600 M Hz. This result is measured in an anechoic chamber. Fig 4. also shows current distributions at various points on antenna. Through these current distributions, operating mechanism at the resonant frequency can be verified. At varying frequencies the antenna has different current distributions. Verification of current distribution, which is simulated using Ansoft HFSS [8], can also be useful method for antenna tuning. Since the proposed antenna is printed on the PCB, tuning the resonant frequency is convenient [10]. It means that variation of transmission lines' dimensions can change the effective impedance of the antenna structure. First, the length and width of transmission lines affect both the inductance and capacitance of the antenna. The length of transmission line is, proportional to inductance. Similarly the width transmission line is more, inductance is low. Secondly, the gap between transmission lines affects the capacitance of the antenna. If the closer the transmission lines are closer, the capacitance is high. Moreover, how much area transmission lines are overlapped can also decide the capacitance value.

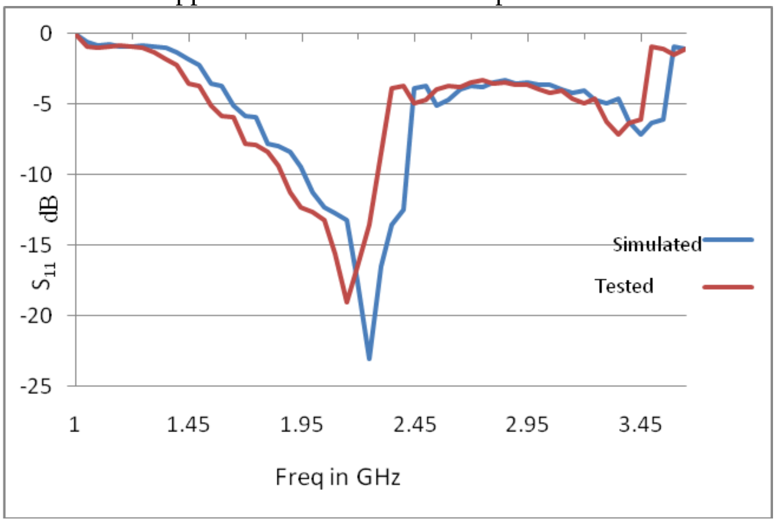


Figure 2 Reflection coefficient

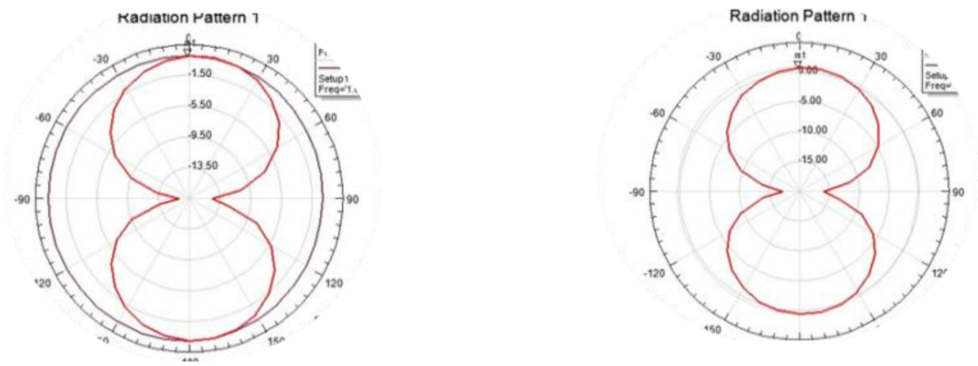


Figure 3 Radiation pattern at 10 dB Bandwidth

The primarily factors concerning the choice and design of this prototype to enable double sided PCB highly integrable in systems. In this study, the classic approach to antenna design is followed through its entirety. A printed circuit antenna for operation at 2400MHz is successfully designed, fabricated, and ultimately tested in the real world. Invaluable experience and insight into antenna engineering can only be realized by a complete design sequence exercise.

5.2 Antenna Characterization

The patch antenna was connected by RF coaxial cable to an Agilent Technologies E5071B Network Analyzer. Prior to antenna connection, the network analyzer was calibrated to open, short and 50 ohm load at the length of cable to normalize the measurements of the cable length so that the antenna alone would be characterized. The network analyzer is set to output sinusoidal signals at a range of frequencies while measuring the reflected amplitude. Thus the resonant frequency of the patch can be determined. Showing many interesting resonant modes over a large frequency. The antenna was measured to have the very good response of -5.69dB at 1960MHz, 60MHz deviation from the design goal band width of 900MHz.

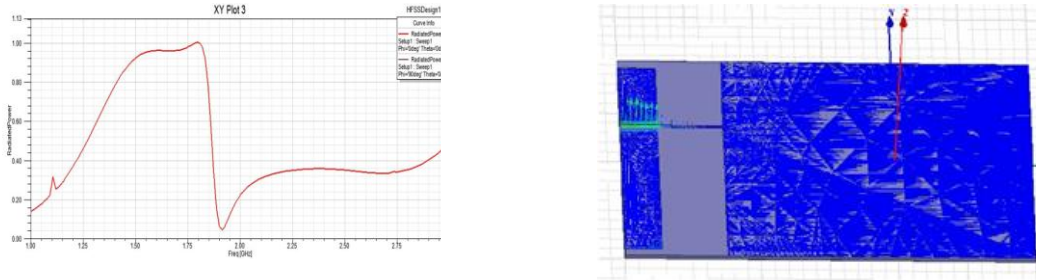


Figure 4 Radiated power and current distribution

VI. CONCLUSIONS

A new type of double sided miniaturized wideband antenna, basically designed with idea of Metamaterial structure was presented for mobile and wireless devices. Antenna performances such as bandwidth and efficiency was improved by meandered two different unit cells. Since the proposed antenna is implemented on PCB, it can be integrated with other systems in a compact package for smart systems. The testing results are in good agreement with that of simulation. The antenna on Duroid substrate has a resonance bandwidth of 900MHzcovering the commercial bands.

VII. FUTURE WORK

Further research could include optimization of the location of the feed point. By introducing varying sizes of radiating patches the power of radiation is increased due to the effect in overall structure. Wireless sets and slim mobile handset

ACKNOWLEDGMENTS

Author wishes to acknowledge the invaluable help of Mr. ANOOP SAGAR who helped greatly offering the fabrication support and facilities to process the antenna with the testing of the antenna and the ANSOFT software package.

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