Modified F slot loaded CSRR inspired microstrip patch antenna for dual band WiMAX applications (3.5 GHz and 5.8 GHz)

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Abstract—In this paper, Modified F slot loaded Complimentary split ring resonator inspired microstrip patch antenna for dual band WiMAX applications (3.5 GHz and 5.8 GHz) is proposed. We introduced Modified F slot in ground plane for the reduction of physical size. And Complimentary split ring resonator inspired microstrip patch for dual band applications. The gap coupling feed is introduced for enhancing the bandwidth of resonance. This prototype antenna design was targeted for dual band for WiMAX applications at 3.5 GHz (3.4 to 3.6) and 5.8 GHz (5.25 to 5.825) GHz. Patch antenna size reduction, satisfactory Gain and Radiation pattern over these two bandwidths are also an important concern to be achieved in this work. Simulation of antenna is carried out using CST V9; with a substrate thickness of 1.524 mm and relative permittivity of 3.2.

Index Terms—Microstrip patch antenna (MSA), CSRR, Left handed metamaterials, WiMAX.

I. Introduction

There is a considerable amount of interest in the development of dual band microstrip patch antenna because of its versatile applications however antennas for handheld cellular phones are required to be small in dimension and light in weight. Moreover due to steady growth of wireless communication systems, most consideration has been focused on the necessities of providing more operational bandwidth [1]. Microstrip antennas (MSAs) have the attractive features of low profile, small dimension, economical, and conformability to mounting hosts which makes them excellent candidates for satisfying this design consideration. Recently, many novel planar antenna designs to satisfy the requirements of mobile cellular communication systems have been developed.

A. Microstrip patch antenna

A microstrip patch antenna consists of a metallic patch of any planar or non-planar geometry on one side of a dielectric substrate with a ground plane on the other side, the patch can be of several flexible shape such as rectangular, circular, triangular, square, semi-circular, sectoral and annular rings. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane in addition, the basic reason is the sinusoidal variation of field which cannot be vanish abruptly, while traversing from antenna to air therefore fringing occurs due to discontinuity.

For satisfactory antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since our purpose is to radiate the field so field should not be confined in the substrate region also this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a large antenna size. Radiation from the MSA can occur from the transverse nature of fringing fields between the periphery of the patch and the ground plane. The value of effective dielectric constant is slightly less than the dielectric constant of the substrate Because the fringing fields from the patch to the ground plane are not confined in the dielectric only, but also spread in the air so that the supported mode in this inhomogeneous medium is quasi TEM [1]. To enhance the fringing fields from the patch, which account for the radiation, the width of the patch is increased, while care should be taken of dominant mode of patch should not be disturbed.

B. Metamaterial

New advance to microwave and optical devices presented itself with the interesting breakthrough in the area of metamaterials. Metamaterial which exhibit negative permittivity and permeability (double negative or left-handed materials) show a phenomenon where the phase velocity is anti-parallel to the wave propagation direction. The History of Metamaterial started around 1967, Russian physicist Victor Veselago given the theoretical assumption of negative permittivity and permeability [2]. He called these substances Left Handed to show that they allow the propagation of electromagnetic waves with the electric, the magnetic field, and the phase constant vector forms a Left hand triad, compared to conventional materials (Right Handed triad). The past few years have been very eventful with respect to the progress in concept and implementations of 'left-handed materials (LHMs)'. After being inactive as an infeasible idea, for nearly three decades, this concept attracted attention when Shelby et al [3] confirmed experimental verification of the 'left-handed' behavior for some periodic structures in the microwave regime 'Metamaterial' are engineered to modify the bulk permeability and/or permittivity of the medium.

Metamaterials are artificially designed structures to exhibit electromagnetic properties not found in nature but by the shape and distribution of specific patterns included in them. The structure can be designed in many way, however the fundamental concept and theory of the structure and its properties is very important since it will determine the ability to produce the LHM behavior in the required frequency band.

A negative effective dielectric permittivity will appear in the substrate region of interest, near the CSRR's resonance and the propagation at this frequency is forbidden, it behaves like an LC resonant circuit that can be excited by axial electric field and it is the dual of SRR explained through Babinet principle [4]. SRR's have a negative permeability at its resonance frequency. In multichannel applications, the antenna is required to operate over a broad BW to cover all the channels, On the other hand, at any given time; it requires a small BW to cover a single channel. In this case, a tunable MSA is required. If the antenna is designed to operate at two far-away frequencies, then a dual-band MSA could be used. In general, all the methods described for increasing the BW of MSAs can be utilized to obtain dual-band characteristics. In the single-layer MSA, dual-band operation is achieved by using either slot or gap coupling or shorting pins or varactor or optically tuned diodes or by selecting the proper length of a stub [5-6]. In multilayered configurations, either electromagnetic or aperture coupling could be used for dual-frequency operation [7]. The separation between the two frequencies is obtained by adjusting the air gap between the two layers or by changing the dimensions of the patches; however the major drawback is bulky structure of the antenna.

II. ANTENNA DESIGN

The proposed antenna structure is shown in Fig. 1. The metallic resonator structure is on a dielectric substrate with r=3.2, thickness of substrate is 3.048 mm with loss tangent 0.0024. The dimensions of patch taken are 30x44 mm^2 as shown in Fig. 2. Thickness of copper metal used in the design is 0.07 mm. Patch is resonating at 5.8 GHz with CSRR inner radius 2.2 mm having the given patch dimension. Gap coupling between microstrip line feed and patch is used for capacitive matching. The 'via' radius is 0.3 mm in the center of CSRR provides better capacitive matching.

III. RESULTS AND DISCUSSION

A Prototype of the proposed antenna was experimentally fabricated and measured to support the EM simulation. Simulated return loss at lower frequency range shows good bandwidth while at higher frequency of WiMAX it has reasonable required bandwidth. The values of S11 at 3.5 GHz are around -40 dB but it shows -50 dB at 5.57 GHz. As far as fabrication is considered these values are good candidate. It is seen from the Fig. 3 that the proposed antenna achieves dual resonant modes over the frequency ranges of 3.5 GHz and 5.8 GHz for reflection coefficient less than -10 dB, simultaneously covering the 3.5 and 5.8 WiMAX standards.

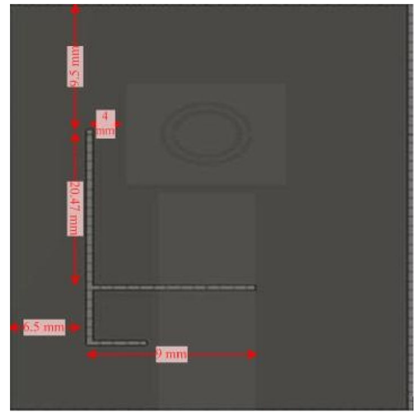


Fig. 1. Optimized dimensions of patch and slot for dual band operation

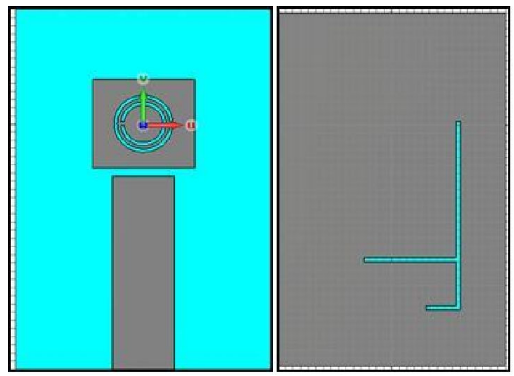


Fig. 2. Top and Bottom view of rectangular patch antenna taken CSRR center as origin

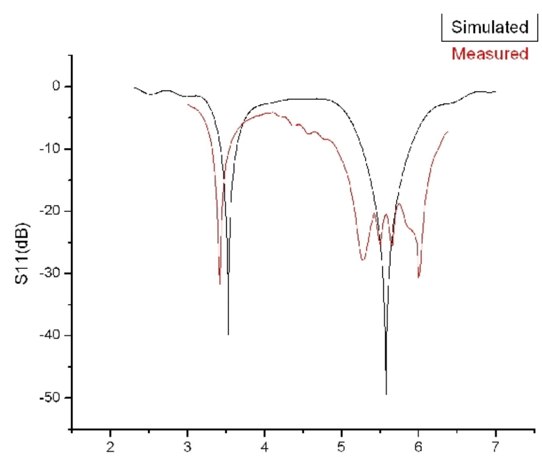
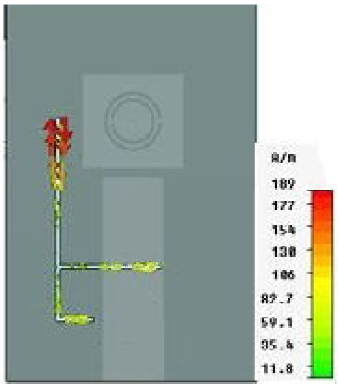


Fig. 3. Simulated and Measured return loss of dual band MSA



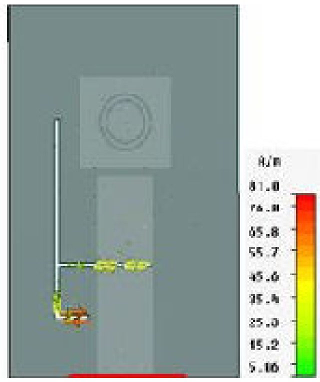


Fig. 4 Current density at 3.5 GHz Fig. 5 Current density at 5.57 GHz

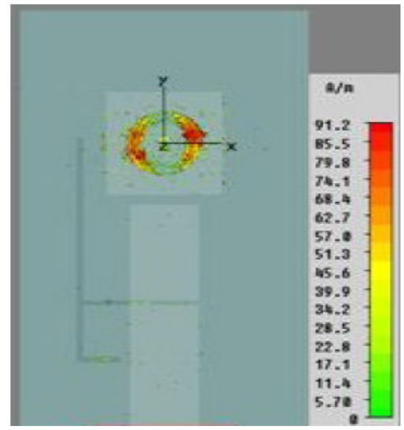


Fig. 6. Current density at 5.8 GHz

A. Current analysis of Antenna

Current density at 3.5 GHz shows whole F slot is resonating as shown in Fig. 4. While at 5.57 GHz two horizontal slots are resonating effectively as shown in Fig. 5 and [8] current density at 5.8 GHz shows complementary split ring resonators are resonating, as shown in Fig. 6.

B. Parametric analysis

Some variation of parameters has been shown, the parameters are defined taking CSRR center as origin, and compromised simulated results have been obtained. Variation of CSRRs radius effects the patch fundamental frequency for smaller radius shift occurs at higher frequency while for increasing it moves down are shown in Fig. 7. As the vertical F slots length increases lower resonant frequency decreases and vice-versa as shown in Fig. 8.Variation of d effects the capacitive matching of microstrip line and patch antenna is well shown at upper frequency as shown in Fig. 9. Upper horizontal F slot affects the lower frequency more effectively than upper frequency as shown in Fig. 10.

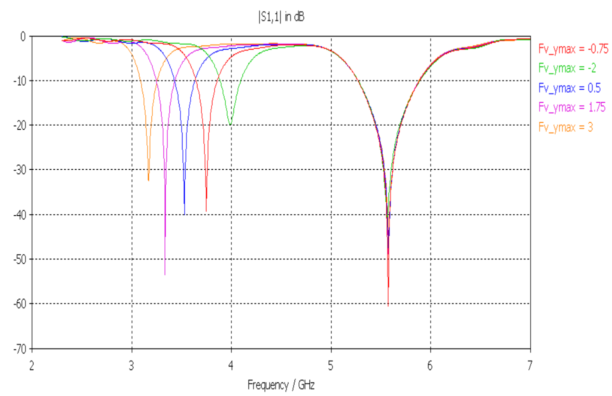


Fig. 8. Variation of Fv_ymax

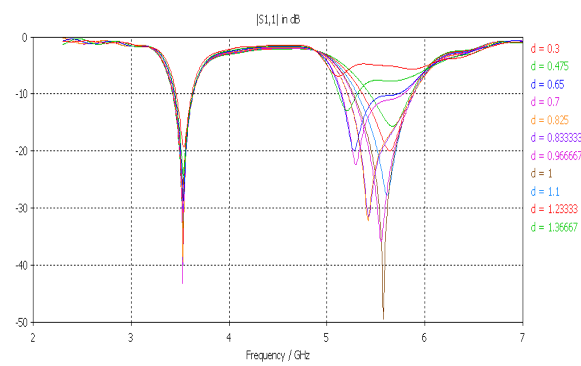


Fig. 9. Variation of d

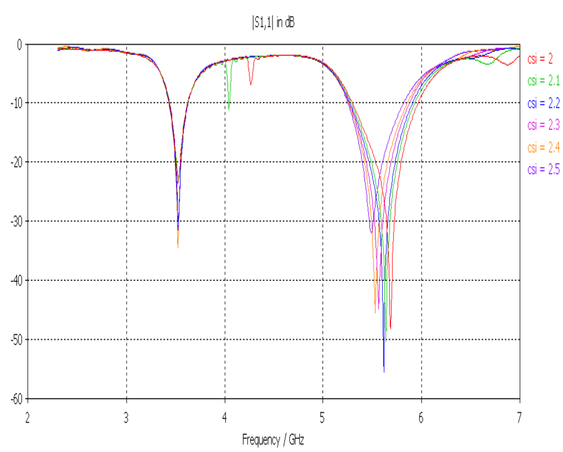


Fig. 7. Variation of csi

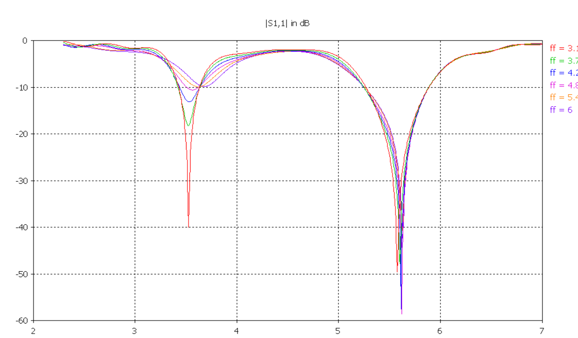


Fig. 10. Variation of ff

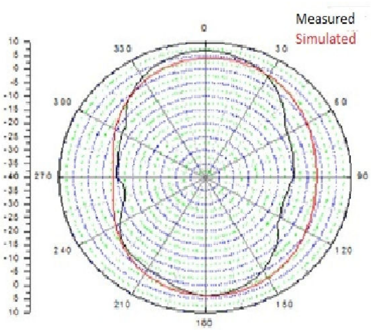


Fig. 11. E plane at 3.52 GHz

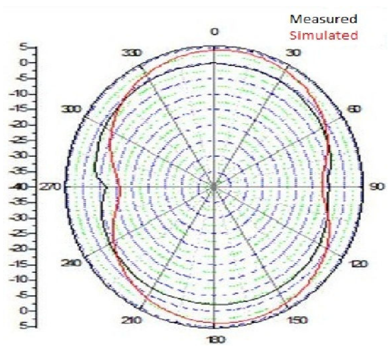


Fig. 12. H plane at 3.52 GHz

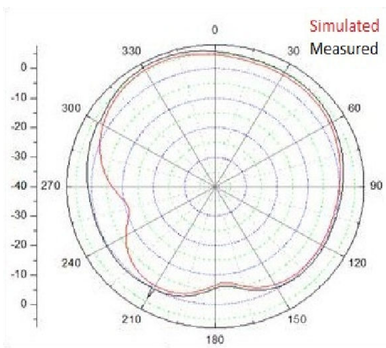


Fig. 13. E plane at 5.57 GHz

D. Measured and Simulated Radiation Pattern

The simulated and measured gain over WiMAX range are shown in Fig. 15

IV. CONCLUSION

The proposed antenna remarks dual band a size reduction of patch about 40% has been achieved; Moreover bandwidth around 1 GHz at upper band is obtained, the desirable performance of dual band microstrip patch antenna in respect of good gain, return loss, and satisfactory radiation pattern at the overall WiMAX band for 3.5 GHz and 5.8 GHz has been achieved.

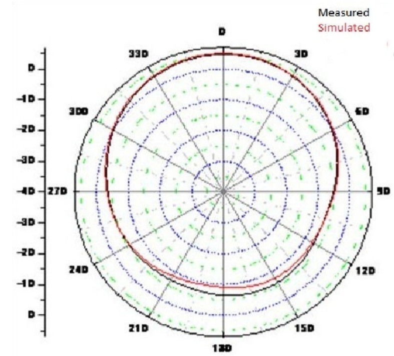


Fig. 14. H plane at 5.57 GHz

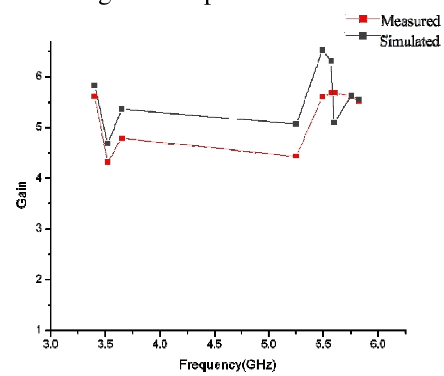


Fig. 15. Gain over WiMAX range

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REFERENCES

[1] Kumar G. and Ray K.P.,”broadband microstrip antennas”, Artech House, INC. London, U.K. 2003.
[2] Caloz C. and Itoh T.,”Electromagnetic Metamaterial Transmission Line Theory and Microwave Applications” New Jersey: John Wiley Sons, Inc.
[3] Shelby R. A., Smith D. R. and Schultz, S. ”Experimental verification of negative index of refraction”, Science, vol. 292, pp. 77-9, Apr. 2001
[4] Balanis C. A., Antenna Theory: Analysis and Design, 3rd ed. New York, John Wiley & Sons.
[5] James, J. R., and P. S. Hall, Handbook of Microstrip Antennas, Vol. 1, London: Peter Peregrinus Ltd., 1989.
[6] Ray, K. P., and G. Kumar, ”Tunable and dual-band circular microstrip antenna with stubs,” IEEE Trans. Antennas Propagation, Vol. 48, July 2000, pp. 1036-103
[7] Yazdi, M. L., M. Himdi, and J. P. Daniel, ”Aperture-Coupled Microstrip Antenna for Dual Frequency Operation,” ’Electronics Letters, Vol. 29, No. 17, 1993, pp. 1506-1508
[8] Goodwill Kumar, Kalaria Parth C., Patel Ramesh, Malik Jagannath, Patnaik A., Kartikeyan M. V., ”Dual band microstrip patch antenna for wireless applications at 5.2 GHz and 5.8 GHz using CSSRR, ’International Conference on Communications, Devices and Intelligent Systems (CODIS), 2012, pp. 228-230