MULTIBAND MONOPOLE ANTENNA WITH COMPLIMENTARY SPLIT RING RESONATOR FOR WLAN AND WIMAX APPLICATION

PRAVANJANA BEHERA[a1], AJEETA KAR[b], MONALISA SAMAL[c], SUBHRANSU SEKHAR PANDA[d] AND DURGA PRASAD MISHRA[e]

[abcde]Gandhi Institute For Technology, Bhubaneswar, Odisha, India

ABSTRACT

This paper presents a compact multi band monopole antenna with complimentary split ring resonator element for WLAN (2.4/5.8GHz), WIMAX(3.5) applications. The proposed complimentary split ring resonator antenna(CSRA) has novel design which provides 21.35%(2.42GHz), 38%(3.7GHz) and 13.8%(5.78GHz) impendence bandwidth at operational frequency bands. This antenna have good radiation pattern at resonant frequencies 2.42 GHz & 3.7 GHz,5.78GHz. The design and analysis of the proposed antenna have been carried out by means of Ansoft HFSS 14.0 based on finite difference time domain(FDTD) method . Electrical permittivity, permeability property of complimentary split ring resonators is measured using MATLAB also presented in this paper.

KEYWORDS: CSRR, WLAN, WIMAX, Monopole Antenna, Multiband

Antenna is a transducer which convert Electromagnetic wave to Electromagnetic radiation. Antennas which are working properly more than one frequency region either for transmitting or receiving purpose are known as multiband antennas [Balanis, 1996]. Such antennas are usually used for dual band, tri-band, penta-band , hepta-band Applications. Naturally multiband antennas are more complex than the single frequency resonating band. We will investigate compact multiband monopole antenna with complimentary split ring resonators for WLAN and WIMAX application .

Rapid development of various wireless local network(WLAN)**,** WIMAX applications have forced researchers to use novel antenna for mobile and base station called miniaturised multi band and wideband antenna . Today the most popular wide spread WLAN protocols have been IEEE 802.11 b/g, which is used the 2.4 GHz ISM band(2.4-2.484 GHz),IEEE 802.11y, which is used the 3.6 GHz band(3.6-3.7 GHz) and IEEE 802.11a which employs the 5 GHz U-NII band (5.725-5.850 GHz).The WIMAX licensed band (3.3-3.8 GHz).In this context preferably all those bands are achieved using a single antenna.

A monopole antenna is the best antenna for multiband and wideband application**.** Due to their appealing features of wide bandwidth, simple structures, ominidirectional patterns and ease of construction, planar metal-plate monopole antennas have been proposed for such applications [Choi et.al., 2005].

In this context a printed rectangular monopole antenna (PRMA), which is a rectangular microstrip antenna (RMSA) with etched ground plane. Complimentary split ring resonator provides negative permittivity & may negative permeability which has the ability to tuned the antenna at certain frequency.

Tuning a particular frequency can be achieved by taking the monople antenna length is equal with quarter wavelength. But due to complimentary split ring resonator the rectangular monopole antenna length further reduced and can be tuned to particular frequency according to the shape, size, structure of the split ring resonator. For improving impedance bandwidth various types of transition between the feed line and patch has been adopted. Such region is known as feed region .The feed regions include rectangular microstrip feed region.

DESIGN AND METHODOLOGY

The objective to study the behavior of complimentary split ring resonator & to design an antenna using this CSRR element.

Complimentary Split Ring Resonator

CSRR is an artificial metamaterial which does not depend upon crystal & lattice of an atom or molecule. It only depends on shape, size and structure. CSRR are excited by means of a dynamic electric field with a non-negligible component in the axial direction and these particles make the artificial line where they are inserted to behave as a negative permittivity [Nicolson and Ross, 1970] [Weir, 1974]. CSRR is known as a resonance particle. But resonance of this particle depends upon always shape and size. CSRR means etching of split ring resonator from the metal coated substrate. With this we have investigated the multi resonance behaviour of split ring resonator .And the optimum size of CSRR particle design is presented

[1]Corresponding author

here, which provides a resonance frequency at 2.42GHz, 3.5 GHz, 5.78GHz.

Here the substrate is FR4 epoxy with dielectric constant ε_r=4.4, having tangent loss tanδ=.0018. The substrate is of length l3=22 mm & width w=20 mm. Fig 1 (a) shows a rectangular substrate with metal coating, from which a split ring resonator is etched. And becomes a complimentary split ring resonator. Here l1=12mm, l2=4.5mm, w1=10mm.Fig 1(b) shows a microstrip line withl4=12mm,w2=14mm, l5=5mm ,w3=4mm. The air box having dimension 20 x 22 x 11.67 $(mm)^3$. The excitation is the wave port given to the CSRR & microstrip ground plane to two ports. The port to port distance is 20mm.

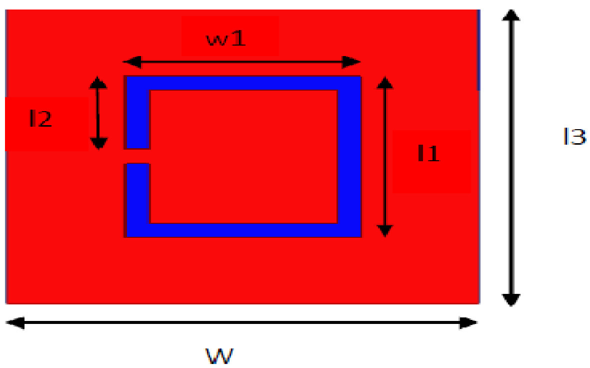

Figure 1(a): CSRR top view

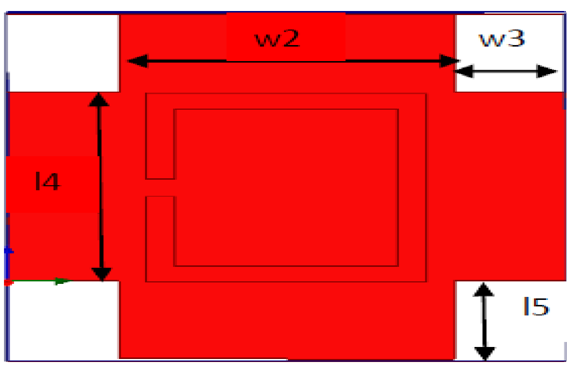

Figure 1(b): CSRR bottom view

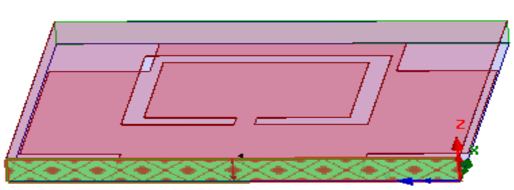

Figure 1(c): Waveport applied in YZ Plane

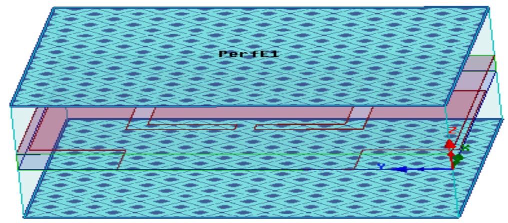

Figure 1(d): PEC boundary applied at z=-5.035, 6.635 plane & PMC in ZX plane.

The air box XY plane applied as PEC & ZX plane as PMC.

SIMULATION AND RESULT

The above design is simulated in ANSOFT HFSS 14 which is developed by using finite difference time domain method.

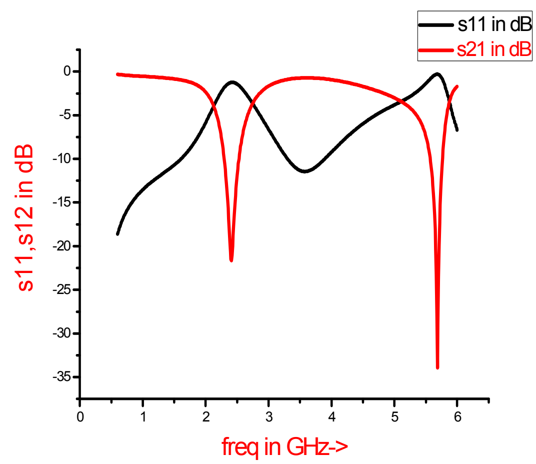

Figure 2(a): Reflection and transmission coefficient vs. frequency.

From the above figure we observe that this complimentary split ring resonator tuned to three resonance frequencies around 2.42,3.6,5.7 GHz. 2.4 Ghz, 5.78 GHz provides band stop resonating frequency & 3.6 GHz provides band pass resonating frequency.

CSRR MEDIUM PARAMETER STUDY

To find out whether on those resonant frequency ε & μ negative or not S-parameters retrieval technique is useful in obtaining the material parameters, when analytical techniques become increasingly difficult to apply (e.g. Scattering object has complex geometry). This procedure extracts the effective permittivity, effective permeability, index of refraction by inverting the reflection–transmission results considering the metamaterial as a homogeneous effective medium. S-parameters retrieval provides complete information on the material parameters of the sample in a direct manner. S-parameters measurement and retrieval can form the basis of a semi automated metamaterial characterization procedure. To extract effective medium parameter from the normal incidence scattering parameter data, the Nicolson-Ross-Weir (NRW) approach [Kadaba, 1984] and the corrections were implemented. The NRW approach begins by introducing the composite terms.

v1=s21+s11..........................(1)

v2=s21-s11...........................(2)

s11=res11+j*ims11.............(3)

s21=res21+j*ims21.............(4)

$\mu = \frac{2}{jk_0 d}\frac{1-v_2}{1+v_2}$........................(5)

$\varepsilon = \frac{2}{jk_0 d}\frac{1-v_1}{1+v_1}$........................(6)

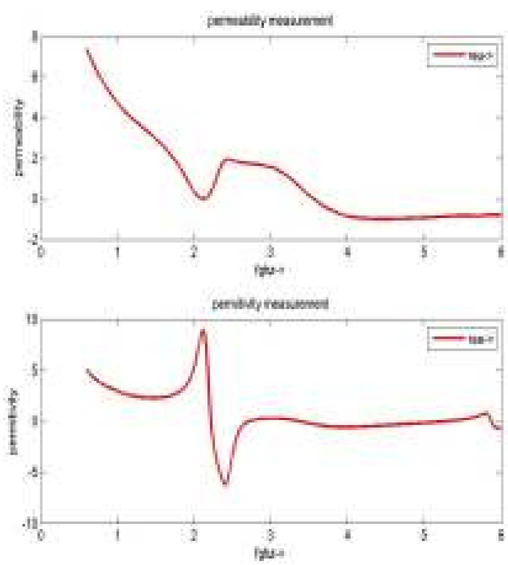

Figure 2(b): CSRR Permeability and permittivity curve with respect to frequency.

Using above formula a MATLAB program had been developed. We observed that electrical permittivity is negative around 2.45 GHz and 5.7GHz, thus giving two resonant frequencies . The electrical permeability is also negative around 3.5 GHz, that provides another resonance frequency.

Summary:-From the above study we observed that a Complimentary split ring resonator has dynamic multi frequency tunable capability, which depends upon the CSRR size, shape & structure. This unit can be embedded in any radiator which provides WLAN, WIMAX resonant frequency. So length of antenna only depends upon this resonating CSRR element. So antenna length can be reduced less than quarter wavelength.

MONOPOLE ANTENNA WITH COMPLIMENTARY SPLIT RING RESONATOR

A monopole antenna is mainly used for its appealing features, such as wide impedance bandwidth, ominidirectional, ease of construction. The antenna consists of three parts feed line, feed region and radiating patch. A feed region is introduced between 50 Ω feed line and the main patch to smooth the current path thus providing wider impedance bandwidth. In monopole antenna the length of the ground is important . Generally we take partial ground. To achieve the lower cut-off frequency at 2.4 GHz the radiating patch is a rectangular microstrip with a complimentary split ring resonator. The antenna is fabricated in a standard 1.6 mm FR4 epoxy substrate material with dielectric constant ε_r=4.4 at 2.42 GHz. The width of the monopole antenna is 26mm. The effective dielectric constant ε_{re} is calculated from the equation

$\varepsilon_{re} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+12\frac{h}{w}\right]^{-0.5}$...........................(7)

ε_{re} =3.989

The wave guide wavelength (λ_g) can be calculated from free space wavelength (λ_o), as

$\lambda_g = \lambda_0(\varepsilon_{re}.)^{-0.5}$......................................(8)

λ_g=62.1mm

Now quarter wavelength become 15.5 mm. So to resonate at 2.42 GHz the quarter monopole antenna patch length should be 15.5mm. But due to complimentary split ring resonator the length of the patch had taken 14mm to resonate at 14 GHz. The substrate dimension is 39x30mm.The microstrip feed line width w1=3mm is kept fixed at to achieve 50Ω impedance. A microstrip feed region of 3.5x1mm^2 is introduced between 50Ω feed line and radiating patch for smooth current flow .The radiating patch was composed of two side by side CSRR that covers an area 26x14 mm^2.On the other face of the substrate a ground plane of 22.2x30mm^2 was etched .The final dimension of the antenna was recorded as: L=3, k=22.2, w=30,w1=26, l1=22, l2=14, l3=10, w1=26, w2=8(all dimensions are in mm).

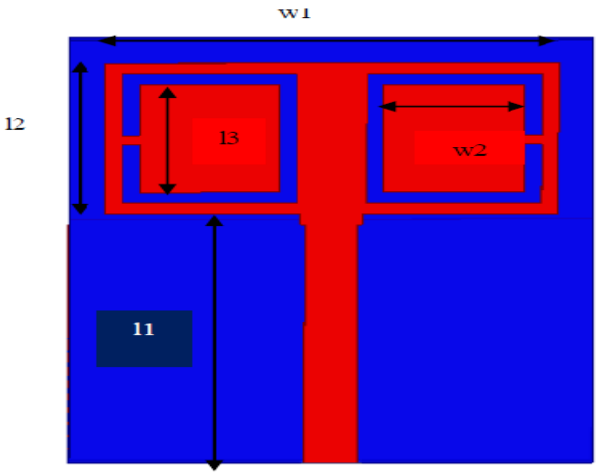

Figure 3(a): Top view of the proposed antenna

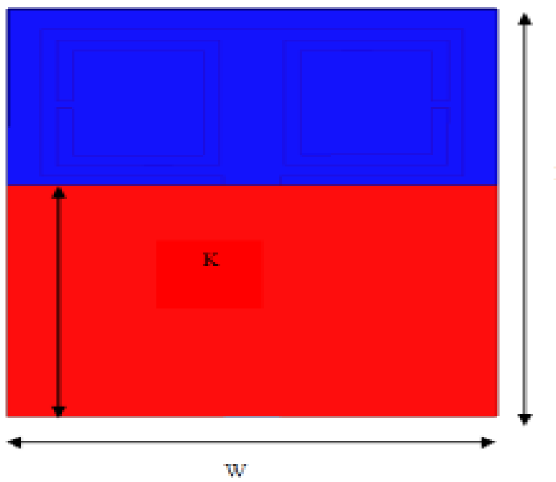

Figure 3(b): Bottom view of the proposed antenna

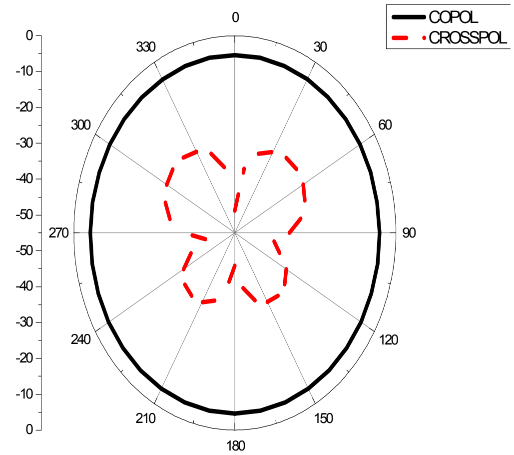

Figure 3(c): H-plane at phi=0°

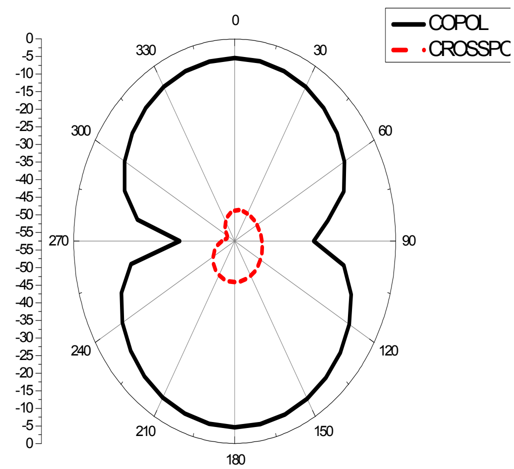

Figure 3(d): E-plane at phi=90°

SIMULATION AND RESULT

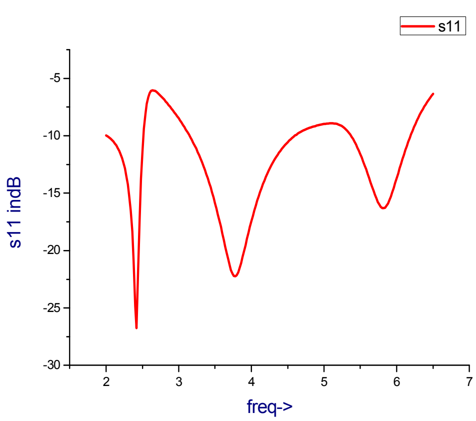

Figure 3(b): Return loss vs. frequency curve

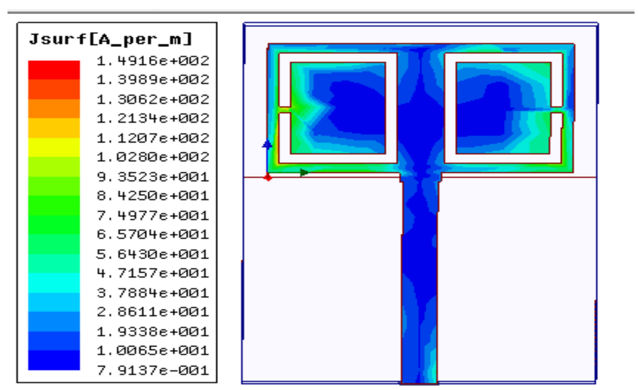

Figure 3(e): Magnitude of surface current density(J_{surf} in A/m)

Based on the designed parameter the simulated results are shown. Here our desired resonant frequency are 2.42 GHz with 21.35%, 3.7GHz with 38% bandwidth & 5.78 GHz with 13.8% bandwidth respectively. Hence the proposed antenna almost covers all WLAN band and WIMAX band. Radiation Patterns of the proposed antenna design also computed and the corresponding polar plots of 2.42 GHz are displayed.

CONCLUSION

In this paper a multiband resonating frequencies are achieved by using complimentary split ring resonators monopole antenna for WLAN WIMAX applications is presented. The proposed antenna is compact and dynamically tuned to different frequencies which only depends upon the shape and size of resonating structure. It is simulated and observed it can cover almost all WLAN, WIMAX operation bandwidth. And at 2.42 resonant frequency the planar monopole antenna has preserved ominidirectional property . So it can fully meet the requirements of ISM band.

REFERENCES

Balanis C. A., 1996. "Antenna Theory: Analysis and Design, "John Wiley & Sons, 3rd Edition.

Choi W., Jung J., Chung K. and Choi J., 2005. "Compact Wideband Printed Monopole Antenna with Frequency Band- Stop Characteristic," IEEE Antennas and Propagation Society International Symposium, **3**A:606- 609.

Nicolson A. M. and Ross G. F., 1970. "Measurement of the Intrinsic Properties of Materials by Time Domain Tech-niques," IEEE Transactions on Instrumentation and Measurement, **19**(4):377-382. doi:10.1109/TIM.1970.4313932.

Weir W. B., 1974. "Automatic Measurement of Complex Dielectric Constant and permeability at Microwave Frequencies," Proceedings of the IEEE, **62**(1):33-36. doi:10.1109/PROC.1974. 9382.

Kadaba P. K., 1984. "Simultaneous Measurement of Complex Permittivity and Permeability at Microwave Frequencies," IEEE Transaction on Instrumentation and Measurement, **33**(4):336-340. doi:10.1109/TIM.1984.4315236.