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Design a 4G MIMO antenna over Wireless sensor Node Transmission for LTE Band

[1]M. Pachiyaannan and [2]G.K.D. Prasanna Venkatesan

[1]*Research scholar, Department of Information and Communication Engineering, Anna University Chennai, Tamilnadu, India*
[2]*Professor, Department of Electronics and communication Engineering, SNS College of Engineering, Coimbatore, Tamilnadu, India*

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ABSTRACT

A compact tri band antenna for long-term evolution (LTE) MIMO over Wireless sensor node transmission is presented in this paper. now days micro strip patch antenna has been commercially used in many applications such as satellite, mobile, global positioning system and medical services. Wireless sensor node communication systems and wireless computer networks are most commonly used and they are in need of antennas in different frequency bands. All kind services to obtain on single antenna is challenging at higher Frequency range which means that Ku-K-Ka band level. In this paper to study and investigate different rectangular shape and to achieve Ku-K-Ka band frequency with wider bandwidth. This Quad Arm shape antenna having a size of 45 mm x 45 mm used low-dielectric-constant substrates and dual-stacked patches with coaxial probe feeds to achieve the required wide bandwidth. The proposed antenna comprises different rectangular wavelength radiating strips and a slotted ground plane. This antenna design on different thickness and analyzed result of all thickness between 14GHz to 27GHz frequency, When the proposed antenna fabricated on a low-cost FR4 epoxy substrate with the thickness of 1.2 mm, relative dielectric constant of 4.4, and loss tangent of 0.008.The radiating strips and slots generate a impedance bandwidth (2:1 VSWR) achieved is the lower 14.8 GHz (Ku) band, Middle band 20 GHz ,23.2 GHz,(K- band) and 26.4GHz on the upper (Ka) band for future LTE Band. A novel isolation technique by placing a rectangular patch between the radiating strips is presented. The rectangular patch creates a dedicated current path for each radiating strip. This paper to study, investigate and simulated the results s using Ansoft HFSS. The Omni directional radiation pattern format, stable peak gain, small group delay and transfer function variation was observed on the whole Ku-K-Ka band frequency range. Its support data transmission over Wireless sensor node for Multiple Input Multiple Output systems with various LTE Band applications and also support for 4G Network applications.

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INTRODUCTION

1.1 Background and Motivations:

For many years base station antennas have been modified in one way or another to optimize the transmission or reception of signals. Multiple antenna elements may be used to shape beams and steer nulls in one direction or another. In the terminal, too, one may double the number of receive antennas to nearly double the received power and increase the SNR by nearly 3 dB.However, if we add antenna elements at both the base station and at the terminal, then we are able to introduce an important new capability of using multiple antennas to input signals into space and multiple antennas to output the signals. This is referred to as Multiple Input and Multiple Output (MIMO). MIMO schemes are characterized by the number of antennas transmitting into the air and the number of antennas receiving those same signals at the receiver, For Example the downlink may use 4 transmit antennas at the base station and two receive antennas in the terminal, which is referred to as 4x2 MIMO. The uplink might use one single transmit antenna in the terminal and 4 receive antennas at the base station, for 1x4 SIMO operation. The MxN refers to the number of antennas in each end of the link (downlink or uplink) and not to the number of antennas at just one end of the link. LTE is unique in requiring as a minimum that all terminals include a second receive antenna for receive diversity and downlink MIMO support With the E-UTRAN (LTE) 3GPP specifications, an extremely sophisticated suite of transmission modes was defined for taking advantage of a wide variety of

Corresponding Author: M. Pachiyaannan, Research Scholar, Department of Information and Communication Engineering, Anna University Chennai, Tamilnadu, India.
E-mail: pachiphd@gmail.com

MIMO antenna and channel situations. With LTE-Advanced, there are 10 different Transmission Modes (TMs) applicable to 1, 2, 4, or 8 base station transmit antennas and 2, 4 or 8 terminal receive antennas. If all antennas are co-polarized, in free space or in an anechoic chamber where there are no reflections, the rank collapses to 1 and no MIMO gains can be had, except for the added power received from multiple antennas. Polarization diversity increases the rank to the extent to which the channel sustains the independence of the signals transmitted on separate polarizations. For a SISO system this model can reduce the entire transmission environment to a single complex number. The system can then be represented using Equation (1),

$$y= hx + e \quad (1)$$

where h is the complex number representing the channel, x is the input signal, e is a complex number modeling the thermal noise at the receiver. The variables have the same meaning as for the SISO case, however instead of the scalar complex numbers in Equation (2), the variables are matrices of complex numbers.

$$Y= HX+E \quad (2)$$

Wong (2002) stated that in order to meet the miniaturization requirements of portable communication equipment, researchers have given much attention recently to develop compact micro strip antennas. Many significant advances in improving the inherent narrow operating bandwidth of micro strip antennas have been published in the open literature since 1997. In addition, for miniaturizing the wireless communication system, the antenna must also be small enough to be placed inside the system. Recently Several Micro strip patch antenna, which have the potential to meet such requirements and many systems operate across several frequency bands, requiring a band-notched or band-rejected function. David Brunnenmeyer *et al* (2012) reported that the Ku band is a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 11.7 to 12.7GHz. (downlink frequencies) and 14 to 14.5GHz (uplink frequencies) Ku-band,K band and Ka-band systems differ in many respects, including transponder bandwidth, beam size, transponder connectivity, topology (mesh vs. hub-spoke) and associated payload complexity and cost. Both Ku,K and Ka-band systems are used for multiple applications.

In evaluation of microstrip the several microstrip slot antennas Eldek *et al*(2005), Shams *et al*(2006) reported and various E-shaped Hoseini Izadi and Mehrparvar(2010)reported,C-shaped Kin-Lu Wong *et al*(2006) reported,C-shaped Padhi *et al*(2003) reported and U-shaped Guo *et al* (1998) reported and it have been designed. A number of antennas are also proposed for wireless applications Yi-Chieh Lee and Jwo-Shiun Sun (2009) reported like, WiMAX, WLAN, DCS, PCS, IMT, etc. The basic form of microstrip patch antenna includes a bottom ground plane, a dielectric substrate which has certain dielectric constant (εr) and finally patch reside on opposite to ground plane. Patch radiates only at the definite frequency band Ching-Fang Tseng and Cheng-Liang Huang (2009) reported .Many researchers have worked and presented the techniques for getting multiband operation using multistack patches Anguera *et al* (2003) reported. Using U-slot loaded patch stacked with H-shaped parasitic elements Ansari *et al* (2008) reported. Jhamb and Rambabu (2011) reported an annular ring patch is loaded with a slot, where the loaded slot makes the design capable for dual band operation.

In the Reference of Azim*et al* (2011) a 41 mm×14 mm slotted multiband antenna was designed which three frequency bands had centered at 0.9 GHz, 1.8 GHz and 5.2 GHz. In the Reference of Rao and Geyi(2009) A 38 mm×3 mm planar multiband antenna was proposed for GPS, DCS, and WLAN applications .In the Reference of Eldewiny *et al* (2010)a planar dual L shaped antenna 30.5mm×21.5 mm operating in the 1.569 GHz–1.585 GHz and 1.850 GHz–1.990 GHz bands has been pro-posed . In the Reference of Chen *et al* (2002) a 2.4 GHz and 5.8 GHz dual band antenna were proposed for the ISM band using a backed microstrip line 30mm×20 mm overall on an FR4 substrate and achieved a maximum gain of 4 dBi. However, the reported antennas were either larger, had a narrow bandwidth, low gain or were less efficient. There is still room to explore miniature antennas with wider bandwidth, and higher gain and efficiency. In the Reference of Samsuzzaman *et al* (2013) a new X shaped slotted multi band antenna was designed with a 1.905 mm high dielectric material substrate with bandwidths of 528 MHz (15.104 GHz–15.632 GHz) , 576 MHz (17.336 GHz– 17.912 GHz) and 804 MHz (18.476 GHz-19.280 GHz) and 4.80 dBi , 6.72 dBi and 3.91 dBi peak gain.

In the Reference of Islam *et al* (2013) a 20mm×20mm microstrip patch antenna was designed on a 1.575mm thick Duroid 5870 substrate for use in Ku- and K-band applications. A downlink frequency of 15.56GHz and an uplink frequency of 20.41GHz, with return losses of −32.56 dB and −31.13 dB, respectively, a peak gain of 3.90 dB, and 98.5% average efficiency were achieved.

All the techniques can achieve good band notch characteristics, but some of the notched band structures are complex and difficult to design. In the designing of triple or multiband notch antenna, it is difficult to adjust and to control the frequency centre of the notch bands in a limited space.As the Literature rectangular Microstrip antenna is its narrow bandwidth and lower gain. The bandwidth of Microstrip antenna may be increased using various techniques such as use of a thick or foam substrate, cutting slots or notches like W slot, E shaped, plus shaped patch antenna, introducing the parasitic elements either in coplanar or in stack configuration,

defected ground plane and modifying the shape of the radiator patch by introducing the slots .

To overcome the Narrow bandwidth and lower gain we were used Quad arm with rectangular slot Microstrip patch antenna in this paper. In order to design a compact Microstrip patch antenna, higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance.

1.2 Scope and Structure of the Paper:

With reference of above analysis the proposed antenna has achieved Ku-K-Ka band operation with wider bandwidth.The simulated result as follows:14.8GHz (Ku-band) an having return loss -20db and 20GHz ,23.2 GHz,(K- band) and 26.4GHz(Ka band) an having return loss-24.9db,-19.12db,-20.16db. The VSWR value of 14.8GHz is 3.10, 20GHz is 0.97, 23.2GHz is 1.92 and 26.4 GHz is 1.71. The Proposed antenna achieve total radiation efficiency over both bands are above >95.

This paper describes the design of Quad arm shape Patch antenna that have been linearly polarized and coaxial feeding techniques with rectangular slots. The effect of the size of the ground plane on both frequency bands was also investigated. Section II discusses Antenna Architecture and optimization issues. Section III discusses the results and discussion. Section IV concludes the paper.

II.Antenna Architecture and Optimization:

Fig.1 shows the geometry of the proposed quad arm shape Patch antenna. It shows the layout of a coaxial probe-fed slotted patch antenna.The proposed quad arm shape Patch antenna is located on the x–y-z plane. This antenna is fabricated on a low-cost FR4 epoxy substrate with the thickness of 1.2 mm, relative dielectric constant of 4.4, and loss tangent of 0.008. On the front surface of the substrate of each quad arm shape Patch antenna, fed by a microstrip line 50Ω with 1mm of width.The ground plane size is 60 mm× 60mm, and the distance between the radiating patch to the ground plane printed on the back surface substrate is 1mm.The Proposed antenna design parameters are WGnd=60mm, P1width=45mm, P1Length=45mm, PL0_L1=7.5mm, CLength=2mm, PUL_L1=3mm, PP_L1=2mm, PUR_L2=3mm, CP_H1=6mm, PL2=3mm, PWidth=6mm, P2Width=6mm,Tw2=2mm,Tw1=2mm,P1Inner=3mm and LN=3.8mm.

The proposed antenna exhibits tri-band characteristics. The two operating bands 17GHz (Ku-band)an having return loss-20db and 19GHz ,20.2GHz, 22.6GHz,23.4GHz(K band) an having return loss -15.6db,-27.7db,-16.3,-17.0 and 26.6GHz (Ka-band) frequency an having return loss -26.3db frequency bands. The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas.In this paper Coaxial feeding techniques were used. The inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.In this Proposed antenna when compared to the loss tangent and permittivity of substrate material the FR4 epoxy is having very less permittivity value i.e 4.4 and loss tangent value is 0.020.In below the tabular columns showing the different substrate material property value. The simulated voltage standing wave ratio (VSWR) of the reference antenna without band-rejected is presented in Fig 2.

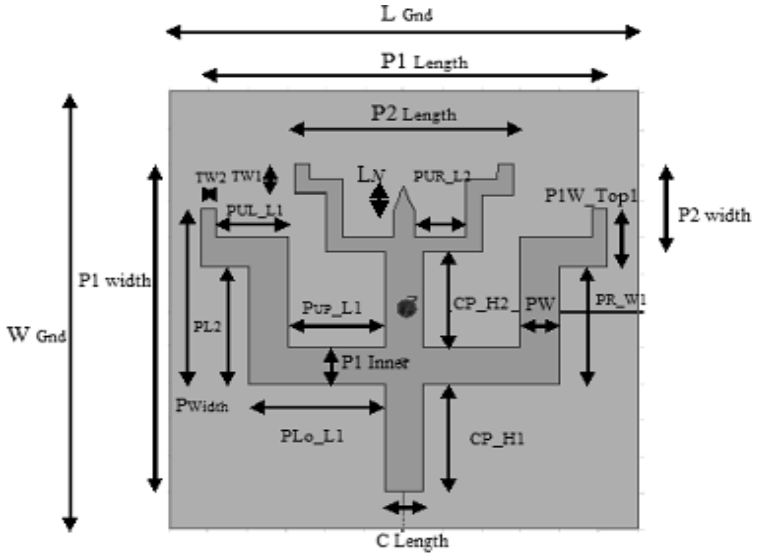

Fig. 1: Geometry of the proposed Quad arm shape Patch antenna.

The parameters of the reference antenna are optimized to get a VSWR that is less than 2 and to get stable radiation characteristics throughout the frequency band 16 GHz to upper than 30GHz.

The patch can also be fed with a probe through ground plane. The probe position can be inset for matching the patch impedance with the input impedance. This insetting minimizes probe radiation. The ease of insetting and low radiations is advantages of probe feeding as compared to microstrip line feeding. The dimensions of shaped patch shown in Fig.1 are these are designed at operating frequency 14.8GHz to 26.4GHz.

RESULTS AND DISCUSSION

The different characteristics of the proposed shape antenna are investigated and optimized by commercially available finite element based software HFSS (High Frequency Structured based Simulator). The proposed antenna with triple band characteristics has been fabricated and simulated. The photograph of the prototyped antenna front view for 2x2 MIMO Model is shown in Fig.3. The VSWR is a measure of the impedance mismatch between the transmitter and the antenna.

The higher the VSWR, the greater is the mismatch. The minimum VSWR which corresponds to a perfect match is unity. Fig 8 shows the measured and simulated voltage standing wave ratio (VSWR) results for the proposed antenna with bands characteristics, an excellent agreement between them is observed. The bandwidths for each of the band are very suitable to suppress the disturbances from Satellite and mobile systems. The simulated return loss of the proposed antenna is shown in Fig.3.The measured frequency range covers commercial application i.e.,14.8GHz (Ku-band)an having return loss -20db and 20GHz ,23.2 GHz,(K- band 26.4GHz(Ka band) an having return loss-24.9db,-19.12db,-20.16db. The simulated VSWR of the proposed antenna is shown in Fig.4. The standard value of VSWR is less than 2 for the operational bands of the microstrip patch antenna. The value of VSWR achieved is less than 2 in the desired operating bands.The Simulated result of VSWR value of 14.8GHz is 3.10, 20GHz is 0.97,23.2GHz is 1.92 and 26.4 GHz is 1.71.

Radiation Pattern of Proposed antenna is shown in Fig.5 its shows that the nearly omnidirectional radiation characteristic in the E-plane copolar radiation patterns over operating frequencies are roughly symmetric. Omnidirectional characteristics and radiation bandwidth can be improved if the ground plane length is approximately the same size as that of the radiating structure width. Also they can be further improved by using a thin substrate or a substrate with low dielectric constant. The Radiation Pattern of Gain in Phi and Theta is Shown in Fig.5(a) and 5(b) its shown that radiated all direction equally and its look like Omni directional radiation pattern.

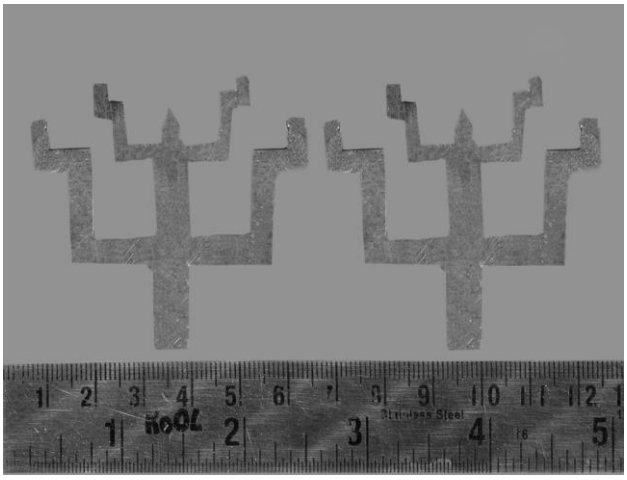

Fig. 2: Proposed Prototype Model for 2 X 2 MIMO Model.

Axial Ratio is the ratio of peak value in the major lobe to peak value in the minor Lobe direction. Axial ratio which is the ratio of the major axis to the minor axis of the polarization ellipse where the resulting pattern is an oscillating pattern is obtained as in Fig.6. The Current distribution of E-field and H- field is shown in Fig.7.Its shows that the E and H-field radiated all direction equally, which means that perpendicular to each other. The polarization of the EM field describes the time variations of the field vectors at a given point.

In other words, it describes the way the direction and magnitude the field vectors change in time. The electric field vector is perpendicular to both the direction of travel and the magnetic field vector. If the field travels in counter clockwise direction and out of screen, it would be right hand elliptically polarized. If the E-field vector is rotating in opposite direction, the field would be left hand elliptically polarized.

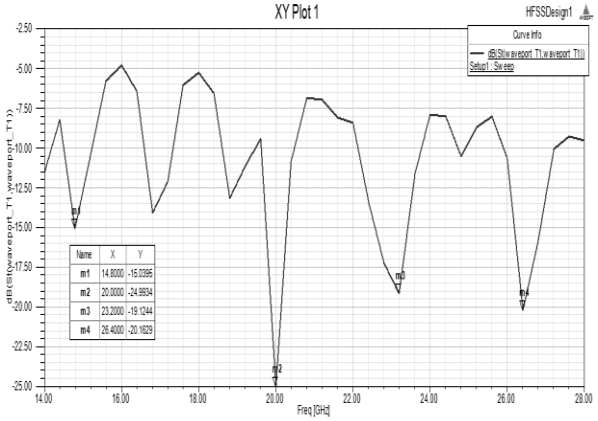

Fig. 3: Return loss VS Frequency of proposed antenna.

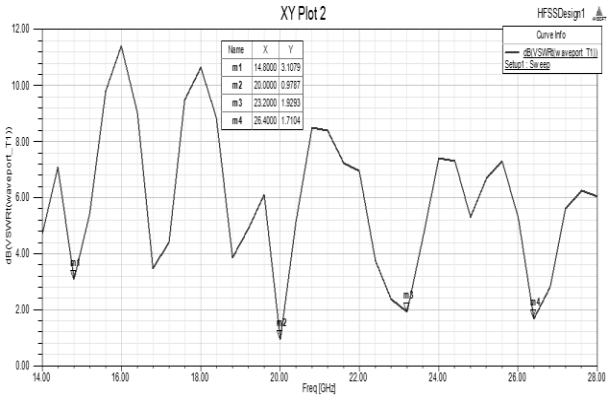

Fig. 4: VSWR VS Frequency of proposed antenna.

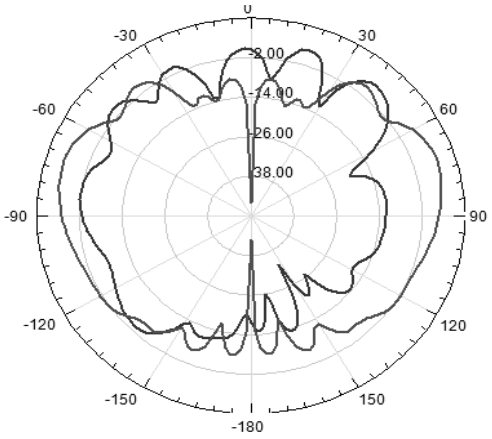

Fig. 5: Radiation pattern of total gain of proposed antenna.

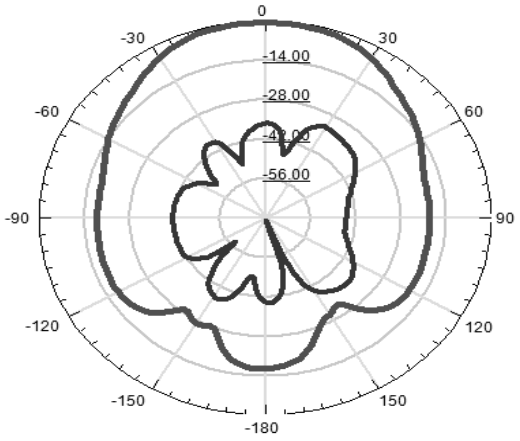

Fig. 5(a): Radiation pattern of Gain in phi.

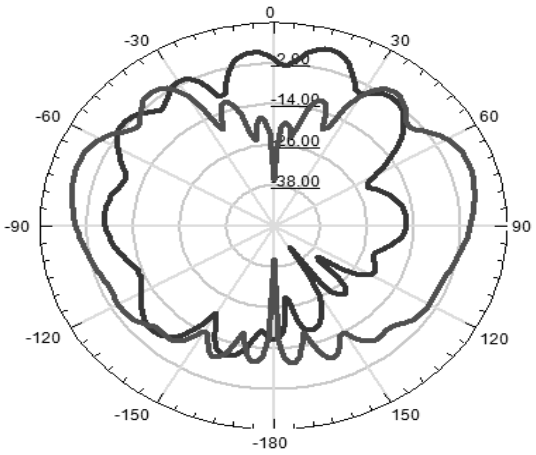

Fig. 5(b): Radiation pattern of Gain in Theta.

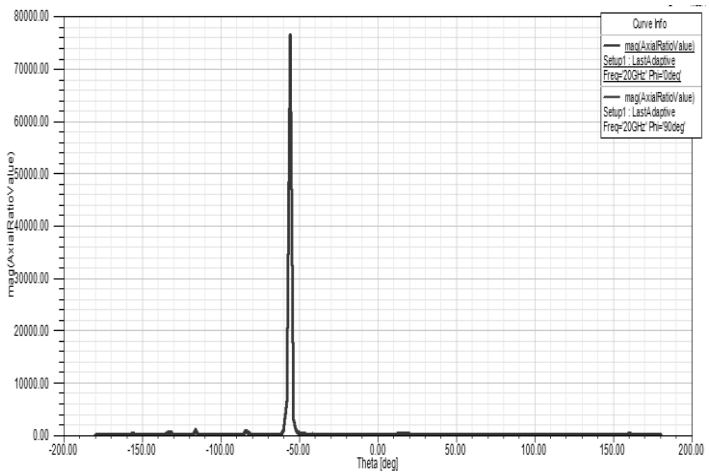

Fig. 6: Axial Ratio of proposed Antenna.

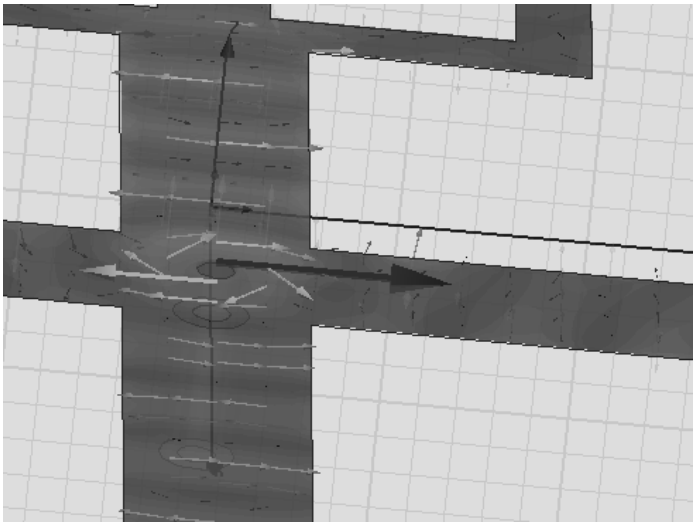

Fig. 7: E-Field and H-Field current distribution of proposed Antenna.

IV .Conclusion:

A compact low profile Tri-band antenna designed and analyzed for Ku/K/Ka band application over wireless sensor Node transmission.The proposed antenna can be integrated with wireless devices operate from 14.8 GHz to 26.4 GHz frequency band. The Return loss, VSWR, Gain, radiation pattern and radiation efficiency of the proposed antenna are analyzed and optimized by using finite element method based High Frequency Structured based Simulator.The proposed antenna can be a competitive solution for the current needs to be adopted with small multi technology wireless devices compare to other available wideband antennas.The simulated antenna has 4.7GHz bandwidth at VSWR < 2. Peak gain is 4.12dB and peak directivity is 8.40dB. The performance properties are analyzed for the optimized dimensions and the proposed antenna works well at the required MIMO systems and 4G Network applications.

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