Design and Analysis of Tri-I Slotted Patch Antenna for Multiple Wireless Applications

Rajiv Yadav[1] Prof. Sneha Jain[2]
[1]M.Tech Scholar [2]Associate Professor
[1,2]Department of Electronics and Communication Engineering
[1,2]Radharaman Institute of Technology & Science, Bhopal, India

Abstract— There is a growing demand for a multiband terminal antenna that is capable of receiving multiple services introduced by different wireless technology networks. This paper introduces a novel rectangular tri-band patch antenna that is fabricated and measured for wireless communication systems. The introduced antenna is designed for WLAN and WiMAX applications. In this paper design and analysis of Tri-I slotted patch antenna for multiple wireless applications below 3GHz.

Keywords: Antenna, Tri-I, WLAN, WiMAX

I. Introduction

With the wide spread proliferation of wireless communication technology in recent years, the demand for compact, low profile and broadband antennas has increased significantly. To meet the requirement, the microstrip patch antenna has been proposed because of its low profile, light weight and low cost [1]. However, conventional microstrip patch antenna suffers from very narrow bandwidth, this poses a design challenge for the microstrip antenna designer to meet the broadband techniques [2, 3]. There are several well-known methods to increase the bandwidth of patch antennas, such as the use of thick substrate, cutting a resonant slot inside the patch, the use of a low dielectric substrate, multi-resonator stack configurations, the use of various impedance matching and feeding techniques, and the use of slot antenna geometry [4, 6]. A good amount of increment in the performance of the antenna structure is achieved by using these techniques but the application of these antenna structures are limited to be operated in single frequency band. In this paper a multi slotted rectangular shaped patch antenna structure is designed by cutting three slots in a rectangular microstrip patch antenna.

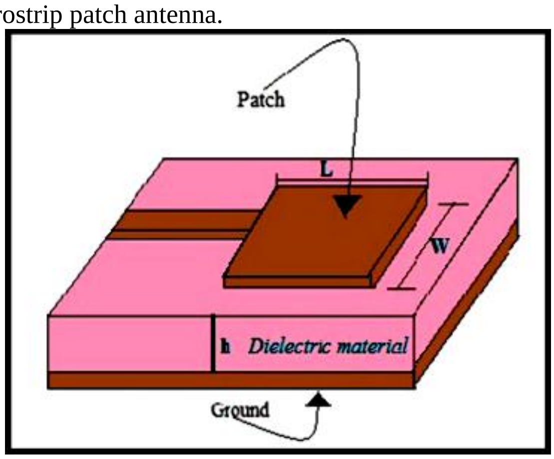

Fig. 1: Microstrip patch antenna

II. Background

From the inception of the patch antenna many more techniques has been used to enhance the antenna's characteristics. To design a multiband patch antenna is trending topic among researchers as it has wide application in the modern world of communication. For the designing of such antennas a much way of configuration are being used by the researchers. By introducing different type of structures (U- slot, L- slot, T- slot, rectangular slot, pi shaped slot etc.) on the patch and the ground. A double meander slot on the patch make a antenna resonate at dual frequency but a triple meander slots gives better return loss than the dual.[5]. The aim of cutting slots on the patch gives a new mode of frequency along with their fundamental band of operation , a half U-slot on the patch introduce a new mode and again a rectangular slot also gives a new mode and by changing geometry of these a triple mode antenna exists.[6]. Over one or two decade back a new geometry called fractal geometry are also introduced for designing of multiband patch antenna. As J.J. Huang, he had used fractal geometry for multiband antenna design and he found many bands between 0.5 GHz to 5 GHz, so this technique is also being frequently used by the researchers. [7]. Stacked patch also have an impact in designing of multifrequency RMSPA (Rectangular Microstrip Patch Antenna), in this design multi layers of patches and substrate are stacked to one another. Also stacked patch with slots on the patches are used for increasing the gain. [8]. Here we have presented a unique structure of the rectangular patch antenna by inserting triple rectangular slots into the patch to make it radiates at useful multiple frequencies (2.4 GHz and 3.6 GHz). The presented design of the patch antenna is easy to design and fabricate so these may be the major advantage for this designing.

In 2015, A. Khidre, F. Yang presented a new design approach for a microstrip patch antenna to achieve reconfigurable dual-band operation with tunable frequency ratio. The approach uses a lumped capacitor in the middle of a slotted patch antenna, which results in two resonant frequencies. To understand the dual-resonance behavior of the proposed antenna, an equivalent circuit model based on the transmission line theory of the antenna is established, considering the slot effect and the lumped capacitor. The results are verified with full wave simulation. Furthermore, measurements for fabricated antenna prototypes operating in 2–4.5 GHz are carried out for validation, and the performance shows a tunable frequency ratio from 1.45 to 1.93 with a capacitance range from 0.31 to 0.74 pF. It is worthwhile to point out that the radiation patterns are similar at both bands because both resonances are due to the fundamental TM01 mode.

In 2015, B. Rana& S.K. Parui designed a cylindrical dielectric resonator antenna (CDRA) fed by nonresonant microstrip patch excites mode for efficient radiation. An antenna array with such an antenna element is designed at the center frequency of 9.04 GHz for obtaining higher directive gain. A prototype has been fabricated with FR-4 substrate, and experimental measurements have been carried out. The array offers an impedance bandwidth of 2.9% and a maximum gain of 14.8 dBi at the operating frequency.

In 2015, P. S. Bakariya, S. Dwari et al. proposed a new design of a multiband microstrip antenna with a proximity-coupled feed for operating in the LTE2300 (2300–2400 MHz), Bluetooth (2400–2485 MHz), WiMAX (3.3–3.7 GHz), and WLAN (5.15–5.35 GHz, 5.725–5.825 GHz) bands. In addition, it also covers 6-dB impedance bandwidth across the UMTS (1920–2170 MHz) band. The proposed antenna consists of a corner-truncated rectangular patch with a rectangular slot, meandered microstrip feed, and defected ground plane. The antenna is fabricated using 0.8-mm-thick FR4 substrate with a dielectric constant of 4.4 and has a small size of only 27 × 24 〖mm〗^2 . The antenna shows a stable gain over the operating bands and good radiation characteristics.

In 2015, B. R. S. Reddy & D Vakula designed a compact zigzag-shaped-slit rectangular microstrip patch antenna with circular defected ground structure (DGS) for wireless applications. The probe-fed antenna consisting of a zigzag-shaped slit, dual T-shaped slits on either sides of a rectangular patch, and circular dumbbell- shaped defected ground plane is optimized. The antenna was able to generate three separate resonances to cover both the 2.45/5.28-GHz WLAN bands and the 3.5-GHz WiMAX bands while maintaining a small overall size of 40 × 28 × 3.175 〖mm〗^3 .The return-loss impedance bandwidth values are enhanced significantly for three resonant frequencies. The designed antenna is characterized with better radiation patterns and potentially stable gain around 4–6 dBi over the working bands.

In 2015, Z. H. Zarghani & Z. Atlasbaf proposeda center-fed single-layer, dual-band reflect array antenna. Each element in this reflect array antenna consists of a square ring and a patch, with slots on it. The proposed antenna operates in two bands (X and Ku), and it uses only one horn antenna as feed, in a fixed position. By varying the size of elements, the required phase shifts in X- and Ku-bands are obtained. Measurements show a maximum gain of 23.4 dB at 8.2 GHz with 33%, 3-dB bandwidth and 17%, 1-dB bandwidth and a maximum gain of 25.7 dB at 13.2 GHz with 30%, 3-dB bandwidth and 14%, 1-dB bandwidth.

In 2014, S Liu et al. proposed asingle-layer single-patch four-band U-slot patch antenna, with linear polarization, for WiMAX and WLAN systems. Using this antenna, impedance bandwidths (dB) of 2.1%, 3.3%, 7.1% and 5.0% were achieved at central frequencies 3.35 GHz, 3.70 GHz, 5.20 GHz and 5.80 GHz, with gains of 7.6 dBi, 8.6 dBi, 8.5 dBi and 9.0 dBi, respectively. This antenna was made by cutting four asymmetrical U-slots in the patch. This structure has the following advantages: (1) the feed is simple, (2) the antenna has single-layer, (3) the structure of the antenna is simple, (4) the asymmetry of the U-slot arm provides one more degree of freedom in the design and (5) the antenna is inexpensive.

In 2016, Z. Wu, L. Li & et al. designed a new wideband circularly polarized antenna using metasurface superstrate for C-band satellite communication application. The proposed antenna consists of a planar slot coupling antenna with an array of metallic rectangular patches that can be viewed as a polarization-dependent metasurface superstrate. The metasurface is utilized to adjust axial ratio (AR) for wideband circular polarization. Furthermore, the proposed antenna has a compact structure with a low profile of .07λ_0(λ_0 stands for the free-space wavelength at 5.25 GHz) and ground size of 34.5 × 28 〖mm〗^2. Measured results show that the 10-dB impedance bandwidth for the proposed antenna is 33.7% from 4.2 to 5.9 GHz, and 3-dB AR bandwidth is 16.5% from 4.9 to 5.9 GHz with an average gain of 5.8 dBi. The simulated and measured results are in good agreement to verify the good performance of the proposed antenna.

III. SIMULATION RESULT

In order to realize multiband antenna, a wide variety of antenna types, which uses different multiband techniques, is used. The most widely used technique for obtaining multiband antenna system is the usage of multiple resonant structures. The multiple resonant structure method is also often used in mobile communication systems to achieve multiband mobile antennas.

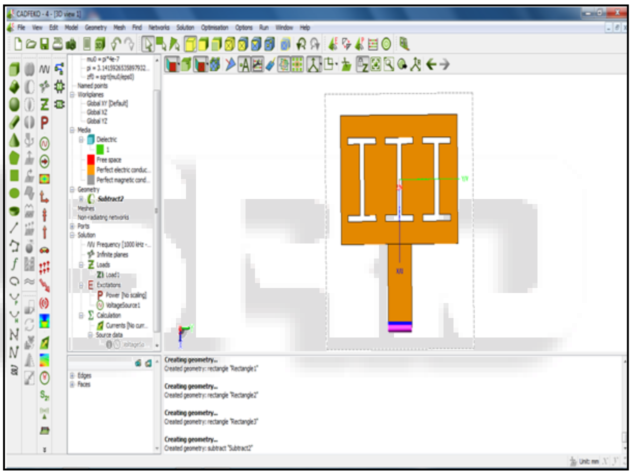

Fig 2: Geometry of I slotted antenna without mesh

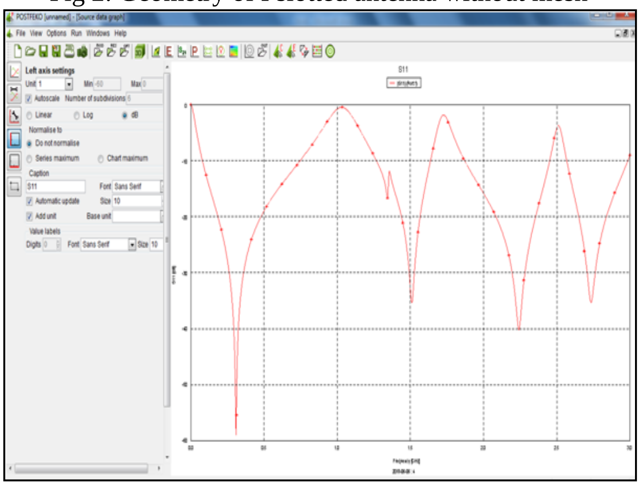

Fig. 3: S11 Vs Frequency of I slotted antenna

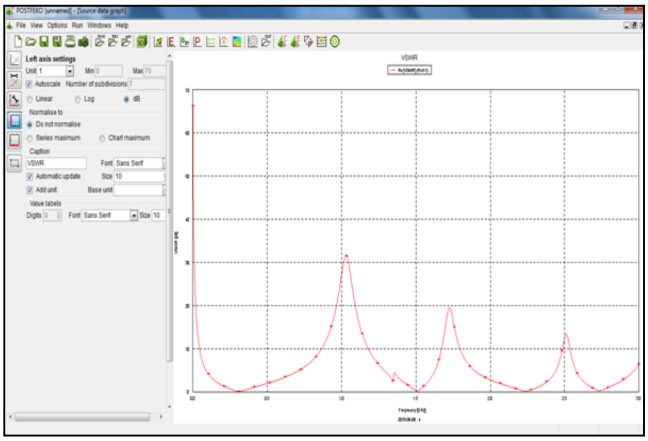

Fig. 4: VSWR Vs Frequency of I slotted antenna

Frequency → ↓ Parameter	F1(0.3G Hz)	F2(1.5G Hz)	F2(2.2G Hz)	F2(2.75G Hz)
S11(RET URN LOSS)	-58dB	-35dB	-40dB	-35dB
VSWR	Less Than Two	Less Than Two	Less Than Two	Less Than Two
BANDWI DTH	750MH z	700MH z	900MH z	850MHz

Table 1: Comparative analysis of Resonant Frequency, Return Loss, VSWR for I slotted antenna

IV. CONCLUSION

A quad band, triple I- slot rectangular patch antenna is designed and simulated using FEKO simulation software. The simulation results are presented and discussed. Structure of proposed antenna is simple and compact in size of 40×40 ×1.6 〖mm〗^3. The compact size of designed antenna makes it easy to be incorporated in small devices. Results show that the frequency bandwidth covers 700MHz, at centre frequencies 0.3 GHz, 400MHz at centre frequency 1.5GHz, 600MHz at centre frequency 2.2GHz and 400MHz at centre frequency 2.75GHz. There VSWR are less than 2, and S11 less than -10 dB. In above explained operating band it shows good impedance matching and bidirectional radiation patterns. Various parametric results of antenna are achieved and analysed by seeing the optimized result of different parameters. These parameters cover the S- parameter, VSWR, E-field and H- field gain and directivity. Thus, proposed antenna is a good applicant for wireless communication applications which includes long distance radio telecommunications like cordless telephones, some Wi-Fi devices, weather radar systems, direct broadcast satellite.

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