Frequency Agile Triple Band Microstrip Antenna for WLAN/WiMAX Application

Sudarshan Joshi, A. K. Gautam, and Rajesh Upadhyay

Abstract—**A frequency agile triple band microstrip antenna using defected ground structure for WLAN/WiMAX application is presented, in which frequency agility is electronically achieved by changing the bias voltage of varactor diode. A defected ground structure rectangular patch with dual inverted L-shaped fed with a cross shaped strip line is used to achieve multiple bands. Simulated results are validated by the experimental results and show a good agreement between simulated and experimental results. The proposed antenna has small size and operates 2-2.15 GHz, 2.75-3.5204 and 5.4-5.9 GHz. The lower and upper band remains almost constant while resonance frequency of the middle band is changing with the bias voltage of varactor diode and frequency agility of 768.4 MHz is achieved. Thus the proposed antenna is suitable to be used for WLAN and WiMAX applications.**

Index Terms—**Multiband antenna, defected ground structure, frequency agile microstrip antenna, triple band, wimax, wlan**.

I. INTRODUCTION

Multiband antennas perform exceptionally well in aggregating various communication standards in a single platform. Communication standards like wireless local area network (WLAN) and worldwide interoperability of microwave access (WiMAX) need antennas which possess compact size and multiband operations. Other structures have also been proposed by the researchers for reduction of size, bandwidth enhancement and resonance-mode increment [1]-[3]. Further, a solid ground plane is replaced by a recently invented defected ground structure [4]-[6]. The advantage of defected ground plane is reduction of size and excitation of additional resonance bands. L shaped strips are loaded to modify the radiating element and feeding with a cross shaped stripline. The reduction of size can prevent large surface wave loss so it can be used as an array element also [7]. However, the proposed antenna has various inherent advantages such as low profile, light weight, easy fabrication, and suitability of mass production. It has also been found suitable in integrating various communication standards. However, on reducing the size of an antenna makes the radiation efficiency low and it narrowed the bandwidth. Active microstrip antennas have become one of the mainstay components of modern communication system due to its frequency agility, simple structure and an efficient radiating element. Their relative compact structure, low cost and fast installation makes them an obvious choice for raises the mobility of the communication system [8]-[11]. Many different types of active antenna structure has been investigated and used in various communication applications.

In this paper, a frequency agile triple band microstrip antenna using defected ground structure for WLAN/WiMAX application is proposed. The radiating patch is loaded with protrudent strip and varactor diode and fed with a cross shaped strip line as shown in Fig. 1. To excite the triple resonant band, the ground is cut out by shaped slots as a result the defected ground structure is formed. Further, a varactor is loaded with the above structure to achieve frequency agility in the middle band while two other bands remain unaffected. As the bias voltage of the varactor diode changes, the capacitance introduced at the radiating edge is changed and resulting in change in the resonant frequency of the middle resonant band [12]. Thus, the resonance of the middle band of the micro strip antenna is electronically controlled by the reverse bias of varactor diode. Simulated results for the active microstrip antenna has been obtained and validated with the measured results, which shows a good agreement with the measured results. The proposed antenna can operate at two multiband wireless communication system such as the wireless local area network (WLAN) 2.4/5.2/5.8 GHz and the world wide interoperability for microwave access (WiMAX) 3.5/5.5 GHz. The detail of entire investigations is given in the following sections.

II. ANTENNA DESIGN AND SIMULATION

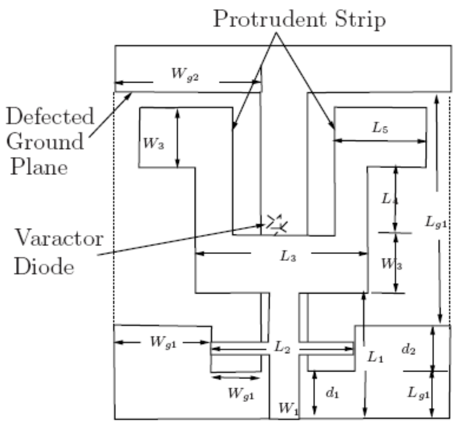

Fig. 1. Schematic configuration of frequency agile triple band microstrip antenna using defected ground structure.

The geometry of a rectangular patch antenna loaded with two inverted L shaped strips, a cross shaped strip and defected ground plane is shown in Fig. 1. The conductor plane is etched on the upper side while the ground plane is on lower side of the PCB. The dielectric constant is 4.4 and substrate thickness is 1.6 mm. The radiator is a rectangular

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patch of dimension 10×6 mm loaded with two inverted L shaped strip from the patchs upper two sides. The dimensions of the L shaped strips having both horizontal and vertical strips are 5×5 mm and 5×2 mm, respectively. A cross-shaped stripline is used for feeding which comprises both the vertical and horizontal strips with dimensions of 9×2 mm and 8×1 mm and a distance of 5 mm between the horizontal strip and the feed point. The overall size of the ground plane is 20×30, and each of the embedded slots has a vertical section of 4×2 mm as well as a horizontal section of 18×8 mm. Meanwhile, the slot is etched with a distance of 4mm from the bottom of the ground and its vertical section has a distance of 6mm from the ground side edge. The varicap diode is loaded at the upper most edge of the rectangular radiator patch at point (a, b). The varactor diode when reverse biased is shown in Fig. 1, in which *Lp* and *Cp* represent parasitic inductance and capacitance associated with the mounting and packaging of the device. Rs is the spreading resistance associated with the finite thickness of the epitaxial layer as well as the ohmic contact of the diode and *CT* is the bias dependent capacitance which is used to obtain the tunable resonance frequency in microstrip antenna. The following relation can be used for calculating the range of transition capacitance that may be required for achieving a tunable frequency range [12].

$$C_T = C_0\left(1+\left|\frac{V_r}{V_T}\right|\right)^{-n}$$

where C_0 is the value of CT at zero bias voltage; *Vr* the value of DC reverse bias; VT the threshold voltage; $n = 1/(m+2)$; and m is a constant number depending upon the type of p-n junction doping. The Table I (tab) shows, the typical design parameters for varactor diode.

The investigation has been carried out using the electromagnetic simulator IE3D (Zeland software, USA) which is generally considered as an efficient and reliable tool for the simulation of various antenna configuration. Firstly the effect of loading microstrips of different dimensions with defected ground plane is studied and then varactor loaded structure is studied.

TABLE I: DESIGN PARAMETERS FOR VARACTOR DIODE USED WITH ANTENNA

Design Parameter	Value
Mount and packaging inductance, Lp	0.4 nH
Mount and packaging Capacitance, Cp	0.15pF
Spreading resistance, Rs	2.27 Ω
Threshold voltage for varactor diode, V_T	0.70 V
Type of doping profile	*m*=-0.5
Hyper abrupt junction	*n*=2
Transition capacitance of varactor, C_T	(2.4-0.4)pF
Reverse bias voltage, V_r	0 - -30V

III. RESULTS AND DISCUSSION

Various antenna structures were successfully implemented. The simulated results are validated with measured results and show a good agreement. The comparative study of different antenna structures with or without inverted L shaped strips, cross shaped strips and defected ground plane are carried out. It is observed that the best results were obtained for Wg1 = 2mm, Wg2 = 8mm, l2 = 8mm, and l5 = 5mm. Fig. 2 shows, the simulated and measured return loss for various frequency with above dimensions. From the figure, three resonant bands are observed at 2.1 GHz, 3.6 GHz and 5.2 GHz frequencies. It is found that the instantaneous bandwidths for three bands are about 190 MHz (2.00-2.19 GHz), 310 MHz (3.41-3.72 GHz) and 690 MHz (4.90-5.59 GHz), respectively. Further, it is also observed that loading of two inverted L shaped strips not only improves the impedance matching of the first and the third band but it can also excite an additional resonance at the second band. It is evidently clear from the Fig. 2 that the above results show good results for designing desired triple- frequency band antenna but still there is requirement to work on the instantaneous bandwidth of the these bands.

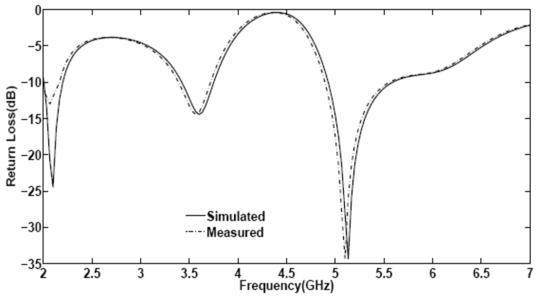

Fig. 2. Variation of the simulated and measured return losses for various frequency with Wg1= 2 mm, Wg2= 8 mm, l2=8 mm, l5=5 mm.

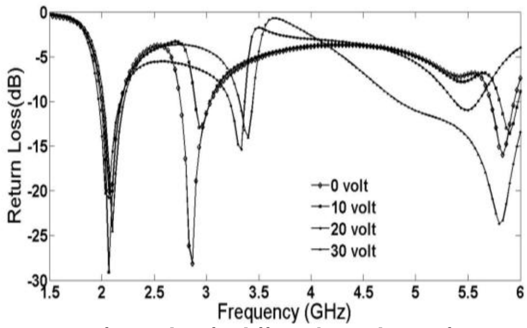

Fig. 3. Variation of return loss for different bias voltages of varactor diode.

Thus, it is decided to integrate a varactor diode with above antenna and it is found that the resonance of middle band can be controlled by varying the reverse bias voltage of varactor diode without affecting other bands. Variation of resonance frequency for varactor loaded active microstrip antenna is shown in Fig. 3. The range of frequency achievable for operation is 730 MHz for the second resonating mode. Since, the microstrip antenna is a parallel tuned circuit and when varactor is loaded with the antenna, the equivalent circuit of the varactor will be parallel with microstrip antenna. The fringing capacitance introduced at the radiating edge is changed with the change in the bias voltage, resulting in a change in the electrical length of the patch and thus its resonant frequency. So, the resonance of the microstrip antenna is electronically controlled by the reverse bias of varactor diode. It is evidently clear that the frequency agile active microstrip antenna can be operate with varying tuning capability at microwave range by controlling the bias voltage of suitable device integrated with the patch. Fig. 4 shows the directivity of the antenna with and without loading of the varactor diode. It is observed that the loading of varactor diode improved the directivity of the active antenna. The radiation efficiency of the antenna with and without loading of the varactor diode is shown in Fig. 5 in which the radiation efficiency is decreases with loading of the varactor. Radiation pattern of the antenna is shown in Fig. 6. Radiation pattern of the antenna is invariant with the bias voltage. Therefore, it is expected that the antenna performance will remain satisfactory for the entire tuning range.

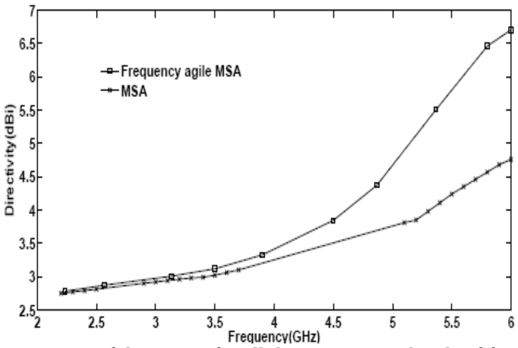

Fig. 4. Variation of directivity for all three resonance bands of frequency agile active microstrip antenna using defected ground structure.

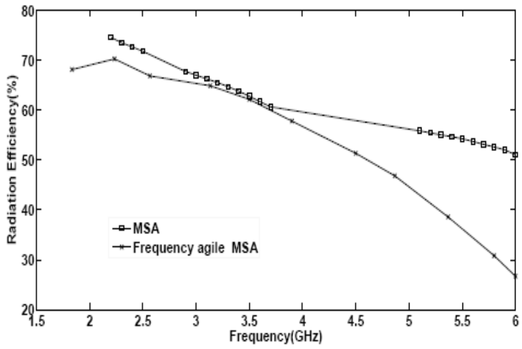

Fig. 5. Variation of radiation efficiency for all three resonance bands of frequency agile active microstrip antenna using defected ground structure.

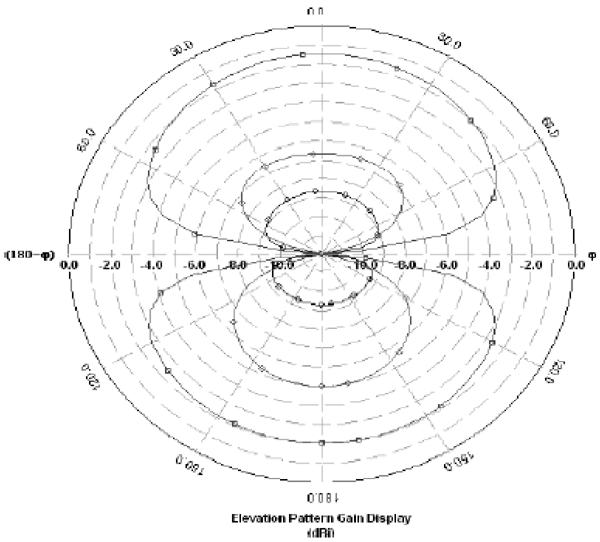

Fig. 6. Radiation pattern of frequency agile active microstrip antenna using defected ground structure.

IV. Conclusion

A frequency agile triple band microstrip antenna using defected ground structure for WLAN/WiMAX application is successfully implemented. By loading an active device we can enhance the frequency agility. The frequency agile active microstrip antenna can be operated with varying tuning capabilities at microwave range by controlling the bias voltage of varactor diode integrated with patch. The proposed antenna has small size and operates 2-2.15 GHz, 2.75-3.5204 and 5.4-5.9 GHz. The lower and upper band remains almost constant while resonance frequency of the middle band is changing with the bias voltage of varactor diode and frequency agility of 768.4 MHz is achieved. Thus the proposed antenna is suitable to be used for WLAN and WiMAX applications. The directivity of the frequency agile active microstrip antenna using defected ground structure is improved.

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