Review of Reconfigurable Monopole Microstrip Patch Antenna Design for Wireless Applications for Handheld & Portable Devices

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Abstract— This paper depicts a review work on all about the monopole antenna, with come reconfigurable antenna used for handheld gadgets, such as, cell phone, tablet, portable PCs and so on. The LTE is (long-term evolution) that can give mobile broadband and multimedia services better than the GSM and UMTS systems. With the development of modern wireless communications, there is an increasing demand of compact, low profile, multiband monopole antennas. Recently, Wireless Local Area Networks (WLANs) and Worldwide Interoperability for Microwave Access (Wi-MAX) is extensively being used in commercial, medical and industrial sectors. In this paper comparative analysis of different monopole antennas on the basis of size, gain, bandwidth, VSWR and efficiency for different working bands such as LTE700/2300/2500, Wi-MAX (2.4/2.5/3.4-3.6/5/5.5/GHz) and WLAN (2.4/2.7/4.2/5-6GHz) etc. are presented. As well as we see that different techniques of switching using PIN diode or copper strip In this letter different techniques for improvement of bandwidth, gain, size and impedance of monopole antenna designs are discussed.

Key words: Monopole Microstrip, Wireless Applications

I. INTRODUCTION

He advances in the Wireless communications had been begun from the so-called second generation (2G) systems of the early 1990s, in this year digital cellular technology was introducing. Through the deployment of third generation (3G), the fourth generation technology being developed today with high-speed data networks. For 4G framework fewer models are being proposed than in past eras. Only two 4G candidates being actively developed today: 3GPP LTE-Advanced and IEEE 802.16m, which is evolution of the Wi-MAX standard known as Mobile Wi-MAX. The LTE project was started in 2004 with expectation on reduction in the cost per bit beside the adaptable utilization of new and existing bands, better user experience in lower cost, simplified network with open interface, reduced terminal complexity and lower power consumption etc [2]. The long-term evolution (LTE) framework with LTE700 (698-787 MHz), LTE2300 (2300-2400 MHz), and LTE2500 (2500-2690 MHz) operating bands are greatly used in 4G wireless wide area network (WWAN). Numerous planar interior mobile phone antennas (MAs) have been manufactured for LTE operation. However, there are limitations include a larger antenna measure for the MAs with a greater dimension and insufficient operating bandwidth [1]. Due to the rapid growth in communication technology, many Portable devices such as smart cell phones, tablets and laptops will have both the WWAN and the LTE functions. These handheld devices has used for real-time voice and real-time data transmission. For this antenna application a multiband antenna design will be a suitable technique. [3]. The IEEE standard was proposed in 1997 for Wireless Local Area Network (WLAN) applications. The bands for WLAN applications are 2.4 GHz (2.4 -2.484 GHz), 5.2GHz (5.150 - 5.350 GHz) and 5.8GHz (5.725 - 5.825 GHz) and for Wi-MAX applications are 2.5 GHz (2.5-2.69 GHz), 3.5 GHz (3.4 -3.69 GHz) and 5.5 GHz (5.25 -5.85 GHz) [30], [32] & [37]. Because of the advantages of low cost, easy integration, easy fabrication and omnidirectional radiation pattern, the printed monopole antenna has drawn much attention, and many shapes have been reported, such as F shape [1], T shape [3], U shape [10], L shape [6],[35], E shape [37], C shape [27], O shape [31], δ shape [19] and H shape [26], etc. [24]. In this paper various monopole antennas are discussed. The antenna designing techniques to get desired bands, improvement of bandwidth, impedance matching mechanisms are briefly stated in this letter. Different antennas designed for LTE, Wi-MAX and WLAN applications are compared. Reconfigurable antenna having different type like the frequency [], polarization [], radiation pattern[]. If we change the ground structure of antenna we got the major change in the efficiency, gain, etc that change can arrived by DGS [], EBG [] etc.

II. AMONOPOLE ANTENNA

The monopole antenna is half of the dipole antenna, there are a great deal of likenesses among dipole and monopole antennas, yet there are likewise a few contrasts. The most ideal approach to dissect the monopole is to use the image theory. The input current for both the dipole and monopole are same. Subsequently, the input impedance of the monopole antenna is half of dipole antenna. The monopole antenna has many preferences, for example, the size of monopole is half of the dipole; the directivity of monopole antenna doubles that of corresponding dipole antenna; the monopole's input impedance is half of dipole antenna etc. The effect of ground plane on monopoles are based on the assumption that there is an infinite perfect conducting ground plane. But in reality,

We normally do not have an infinite ground plane or the ground plane is not a perfect conductor (like earth). What are the effects on the monopole? All parameters of the monopole (radiation pattern, gain and input impedance are just some examples) may be affected by the ground plane. If the conducting ground plane is of limited size, the radiated power will leak to the lower half of the space, which means that the radiation pattern is changed. There may be side or even back lobes. The edge of the ground plane will diffract the waves, which results in many side lobes [18].

III. LITERATURE SURVEY

The need for compactness along with multiple bands is the best way for the design of various types of antennas. Designing such a small size internal antenna is challenging because of limited space. Many numbers of antennas are designed for LTE, Wi-MAX and WLAN applications such as monopole antenna [1], loop type antenna [5], planar inverted F antenna (PIFA) [6], micro strip patch antenna [20], [30] and reconfigurable monopole antenna [39] etc. In order to avoid potential interference between nearby communication systems, antennas need to be designed that would work in only the desired frequency bands [27]. Many planar antennas have been reported in [4], [9-12], [22], [29] & [34] etc. The various types of substrates have been used for fabrication of antennas such as FR4, PCB [30], FR4-EPOXY [32], Taconic TLY 5 [27] etc. having different values of permittivity ε, loss tangents tan δ, conductivity σ and thickness of substrate.

A. Antenna Design Techniques and Comparative Analysis for LTE Applications

Jui-Han Lu and et al. has proposed a small printed antenna using a novel loop parasitic shorted strip and a C-molded framework ground to carry out an in cell phone antenna. A C-shaped ground plane is introduced to enhance the operating bandwidth of an antenna. To make antenna more promising for practical slim handset application, a battery is embedded into the square notch with the size of 40*40 mm² and connected to the ground plane of the C-shaped circuit board. By introducing a novel loop in the parasitic shorted strip, better impedance matching in the lower operating band can be easily obtained [1]. C.H. Ku and et al. [3] has designed a planar coupled-fed monopole antenna. By properly designing the T-shaped strip and coupled radiating structure, the antenna can give three resonance modes to make good LTE bands feature. T-shaped strip of the antenna can act as not only a driven strip but also a radiating monopole structure. If the length of the ground plane decreases, bandwidth reduction will be happened in both the lower and upper bands.

In [4] Cheng-Tse Lee and et al. has designed a planar monopole with a wide radiating plate excited by a coupling feed and short-circuited by an inductive metal strip to make small size yet wideband operation for applications in the mobile phone to cover the LTE bands. The antenna has printed on no ground portion. If the length of coupling strip has increased the upper LTE band will shift in lower frequencies. Hence by properly selecting the length of strip the band can be adjusted. If the width of strips decreased there will be change in bandwidth of upper LTE band. Kin-Lu Wong and et al. has planned a uniplanar printed antenna with small and wide band for LTE operation. This antenna comprises four effective radiators, including one loop-type antenna, one driven monopole for the antenna feed, and two stacked coupled-fed shorted strip monopoles, incorporated into a compact structure. With the adding of the two stacked strips, which are short circuited to the system ground of the shorted coupled section, the bandwidth of the proposed antenna can be greatly enhanced [5].

Chen zhi and et al. has proposed a coupled-fed eight band printed PIFA antenna for the mobile phone. The proposed antenna printed on the no-ground part directly, and a second folded strip which has printed on the reverse side. The impedance matching over the lower and upper bands can be controlled by adjusting gap g3 in the coupling feed [6]. Fang-Hsien Chu and et al. has proposed uniplanar printed mobile handset antenna. The antenna is a spiral monopole coupled with a long parasitic shorted strip. The spiral monopole is encircled by the shorted strip so that the antenna has a compact configuration to fit in a small no-ground portion of the main circuit board in the mobile handset. Through the capacitive coupling, good excitation of the parasitic shorted strip to generate its fundamental and higher-order resonant modes to enhance the bandwidth of the proposed antenna [7].

Z. Chen and et al. presented a new coupled-fed mobile phone antenna, using a slotted ground structure to improve the desired impedance matching bandwidth for LTE bands. The proposed design can be divided into four parts: a double-branch feeding strip, a long coupling strip (or called a parasitic strip) with two open-ended loops, a slotted ground structure formed by two monopole slots, and a chip inductor of 1.5 nH. The coupling gap between the feeding strip and coupling strip has selected to have a narrow width of 0.3 mm, which is helpful in obtaining wide bandwidths for the excited resonant modes, especially for the lower band.

[8]. in [9] Fang-Hsien Chu and et al. has proposed a planar printed strip monopole with a firmly –coupled parasitic shorted strip suitable for LTE operation. This antenna can printed on the no-ground portion of board of mobile phone. Jui-Han Lu and et al. presented a bandwidth enhancement approach using a novel T-shaped parasitic shorted strip and the asymmetrically U-shaped driven monopole to achieve a small-size LTE bands for internal tablet computer antenna. [10]. A novel compact planar antenna design for tri band operation has proposed in [11]. The multi-resonator-loaded method, by using a pair of miniaturized edge resonators embedded into the edges of the monopole, and a T-shaped stub resonator extended from the ground, used for achieving a compact size. Jui-Han Lu and et al. has proposed a monopole antenna for the tablet computer. The proposed antenna comprises an inverted-L driven monopole and dual parasitic shorted strips. By insetting the L-shaped slit into in the ground plane, the impedance bandwidth for the lower operating band LTE700MHz can be improved [12].

Yong-Ling Ban and et al. clarified a novel low-profile printed antenna for LTE operation in the internal cell phone. By utilizing a printed nourishing strip(a chip inductor stacked) and a coupling shorting strip, which shape a parallel resonant (PR) structure to produce two wide working bands. A small radiating feeding plate which has used for fine-tuning the impedance matching of the excited resonant modes to form desired wide lower and upper bands. Chip inductor has added in feeding point to increase the bandwidth [13]. An author designed next small size printed antenna for LTE operation in the internal mobile phone. By utilizing a feeding strip and two emanating strips with two symmetrical printed circulated inductors. It was shown that the loading not only reduces the antenna size but also results in two resonant frequencies near 2.4 GHz for bandwidth enhancement [14]. In [15] a novel small-size wideband monopole with the distributed inductive shorted strip for LTE operation has proposed.

The result analysis of monopole antennas designed for LTE applications are shown in table 1. From the table 1 it is shown that the different techniques are used such as loop parasitic shorted strips, F shaped driven monopole [1], couple radiating structure [3], inductive strip [4], spiral monopole [7], slotted ground structure [8], T & U shaped monopoles [10], different feeding strips [13].[15] etc. to get the desired bands. By adjusting the monopole strips, gaps between coupling strips, addition of DGS, slots etc. there is improvement in bandwidth gain and efficiency of the antennas. From the analysis of results of monopole antennas it is clear that the gain for LTE 700MHz band varies between 0.3-2.9dBi., bandwidth is lower as compared to LTE higher bands. The efficiency for the lower LTE band i.e. LTE 700MHz is greater than 44%. Whereas for LTE higher bands LTE2300/2500 MHz the gain fluctuates between 0.4-5.4dBi., bandwidth is grater as compared to lower bands and efficiency is greater than 50%. The various antennas are designed using different substrates having different values of permittivity, loss tangent and thickness. The size of antenna designed in [12] is 45*15mm². It is the smallest antenna among the antennas stated in table 1.

B. Antenna Design Techniques and Comparative Analysis for WLAN and Wi-MAX Applications

D.B. Lin and et al. has proposed multiband monopole antenna using interdigital capacitor coupling technique for impedance matching, achieving stable radiation pattern and gain, good radiation efficiency and compact size for mobile phone [16]. In [17] author has designed 3 types of antennas. They achieved good impedance, gain and efficiency by changing the length and position of parasitic elements. The impedance matching and bandwidth of the proposed monopole antenna depends on the gap 'g' between radiating patch and ground plane width. Hence adjusting the values of 'g' author has achieved impedance matching in the antenna [19].

R. lothi Chitra and et al. proposed a coplanar Waveguide fed double L slot antenna array for multi-band operation for satisfying WLAN and Wi-MAX application. The proposed array antenna comprising two rectangular planar patch elements each embedded with two L shaped slots to improve the gain [20]. In [21] stable gain and good impedance matching achieved by changing the length L6 of parasitic element. S reddy and et al. [22] proposed a microstrip based monopole antenna for WLAN and Wi-MAX application. The antenna consists of two symmetrical twisted arms with each arm having two bended strips with the same width and lengths for good performance. By adjusting W2 values in [23] lower WLAN band can be achieved. CPW feeding and elliptical shape of antenna in [25] improves the bandwidth. Defected ground plan in [26] achieved good impedance matching. The C-shaped ground stub which has placed close to the feed line in [28] antenna acts like a resonator which helped in shaping the radiation patter and impedance bandwidth.

A new technique of using a combination of slots and slits in the radiating patch and the ground plane has been employed to achieve the multiband performance of the antenna [29]. A novel O shaped ACS fed dual band antenna has presented in [31] for omnidirectional radiation patter, small size and improved gain. In [32] antenna design the slot has used to introduce two different resonant modes. The additional resonant mode has excited by protruding an inverted L-shaped branch from the ground plane. For achieving good impedance bandwidth an impedance matching circuit has introduced in the design of antenna shown in [33]. It consists of three lumped elements, one chip capacitor and two inductors. The major function of rectangular structure patch loaded with a slit and branch strip used in [34] to achieve the dual-band operation for WLAN applications. The monopole design in [35] is a modified symmetrical U-shaped printed structure, and a parasitic Element has attached behind this printed monopole. Good Impedance matching has attained by loading two dissimilar notches separately into the two CPW ground planes. P. singsura and et al. planned a multiband monopole antenna with double square slots and capacitive CPW (CCPW) feed for applications in LTE, Wi-MAX and WLAN systems. In addition, matching between the capacitive feed and the antenna

C. Tables of Antenna Design Techniques and Comparative Analysis for LTE Applications & Antenna Design Techniques and Comparative Analysis for WLAN and Wi-MAX Applications &

Paper No.	Techniques	Bands	Gain	Efficiency	Bandwidth	size	Substrate& parameters
[1]	Loop parasitic shorted strip	LTE 700 MHz	2.2dBi	76%	277MHz	115*60 mm²	FR4 substrate
	F-shaped driven monopole	LTE2300/2500 MHz	3.1dBi	82%	1176MHz		
[3]	T-shaped strip	LTE700MHz	0.95-1.62 dBi	48-59%	315MHz	50*15 mm²	FR4, εr=4.4, tan δ=0.02, 0.4 mm thickness
	Couple radiating structure	LTE2300/2500 MHz	2.26-3.67 dBi	51-70%	1197MHz		
[4]	inductive shorting strip	LTE700MHz	0.8-0.9dBi	52 to 78%	490MHz	40*120 mm²	FR4, εr=3.0, tan δ=0.02, 0.8 mm

	coupling feed	LTE2300/2500 MHz	1.9-3.8dBi	68 to 92%	1220MHz		thickness
[5]	driven monopole, coupled section	LTE700MHz	0.3-0.8dBi	50-70%	660MHz	115*40 mm²	FR4, εr=3.0, tan δ=0.02
	driven monopole	LTE2300/2500 MHz	1.2-4.9dBi	50-82%	1300MHz		
[6]	Strip 1 and strip 2	LTE700MHz	…	45-85%	262MHz	115*60 mm²	FR4, εr=4.4, tan δ=0.02, 0.8 mm thickness
	Strip 1 and T monopole	LTE2300/2500 MHz	…	55-88%	980MHz		
[7]	parasitic shorted strip	LTE700MHz	…	50-80%	262MHz	115*60 mm²	FR4, εr=4.4, tan δ=0.02, 0.8 mm thickness
	parasitic shorted strip and spiral monopole	LTE2300/2500 MHz	…	50 to 70%	980MHz		
[8]	loop and slotted ground structure	LTE700MHz	0.5-1.3dBi	58-76%	262MHz	50*120 mm²	FR4, εr=4.4, tan δ=0.02, 0.8 mm thickness
	open ended monopole slot	LTE2300/2500 MHz	1.8-3.9dBi	60%	980MHz		
[9]	driven strip monopole	LTE700MHz	0.4-1.1dBi	53-76%	305MHz	115*60 mm²	FR4, εr=3, tan δ=0.02, 0.8 mm thickness
	closely coupled parasitic shorted strip	LTE2300/2500 MHz	2.7-4.4dBi	52-75%	1210MHz		
[10]	T-shaped parasitic shorted strip	LTE700MHz	2.9dBi	72%	281MHz	50*15 mm²	FR4, 0.2 mm thickness
	Asymmetrically U-shaped driven monopole	LTE2300/2500 MHz	5.4dBi	80%	1088MHz		
[11]	Parasitic shorted strip	LTE700MHz	0.88-2.81dBi	50-79%	262MHz	40*15 mm²	FR4, εr=4.3, tan δ=0.02, 0.8 mm thickness
	T-shaped driven monopole	LTE2300/2500 MHz	2.33-4.97dBi	61-87%	1610MHz		
[12]	dual parasitic shorted strip	LTE700MHz	2.5dBi	85%	255MHz	45*15 mm²	FR4, εr=4.3, tan δ=0.02, 0.2 mm thickness
	inverted L-shaped driven monopole	LTE2300/2500 MHz	3.6dBi	84%	980MHz		
[13]	shorter feeding strip with inductor of 20nH	LTE700MHz	0.9-0.6dBi	larger than 45%	256MHz	120*60 mm²	FR4, εr=4.4, tan δ=0.02, 0.8mm thickness
	Longer coupling strip	LTE2300/2500 MHz	1.4-2.7dBi	larger than 52%	1050MHz		
[14]	shorter and longer radiating strip	LTE2300/2500 MHz	0.4-2.74 dBi	larger than 43%	1210MHz	115*50 mm²	FR4, εr=4.4, tan δ=0.02, 0.8mm thickness
[15]	feeding strip	LTE2300/2500 MHz	0.8-4.2dBi	44-70%	1375MHz	100*50 mm²	FR4, εr=4.4, tan δ=0.02, 0.8mm thickness
[42]	Inverted-L shaped; two meandered shorting strips	LTE700/2300/2500(698~787, 2305 ~2400, 2500~2690 MHz)	−0.27~2.02 dBi	44.5~72.3%.	268MHz	9*50*5mm³	FR4, εr=4.4, tan δ=0.022, 0.8mm thickness
[43]	circular patch, parasitic double T-stub	350/410/110/650 MHz for LTE 2300 for on state	1.58-2.03 dBi	…………	15.22%(2.1-2.45GHz)	40*30 mm²	Rogers 5880 εr=2.2, tan δ=0.0009, 0.79mm thickness
	two inverted L-stubs. PIN Diode for switching						
[45]	Using varactor diode for switching BB833	2.05GHz	3.05dBi	…………	800MHz	23.5*43 mm²	PCB
[46]	Squre ring with two	2.4GHz	4.01dB	43.7%	68degree	20*5m	εr=4.4,tanδ=0.08,

	horizontal gap, PIN Diode HSMP(3860 SOT-23)		i		HPBW	m^2	1.6mm thickness FR4
[47]	Wide Radiating plate using coupling feed and shourt-circuiting	LTE700MHz	-0.8dBi-0.9dBi	57%&78%	………..	3*6*40 mm^3	εr=3tanδ=0.02, 0.8mm thickness FR4
[48]	Simple printed multiband antenna with parasitic element	LTE2300/2500 MHz	……… …	Greater than 70%	………… ...	18*37mm^2	εr=4.4 tanδ=0.02, 0.6mm thickness FR4
[52]	Radiating element and PIN diode HSMP 3860	For both on and off condition 2300/2500MHz	6dBi	……… ….	17.8% & 37.4%	36*10mm^2	εr=4.4 tanδ=0.02, 1.6mm thickness FR4
[53]	PIFA	LTE band3(1710-1880) & band7(2500-2690)	……… ..	……… ….	………..	25*43mm^2	εr=4.4 tanδ=0.02, 1.6mm thickness FR4
[62]	PIFA PIN Diode	LTE700/2300/2500MHz	……… …	……… …	(729-806MHz) &(1470-2200MHz)	45*17mm^2	(75*40*0.8)mm^3 εr=4.4 tanδ=0.02, 0.8mm thickness FR4
[65]	Parasitic ground strip	LTE2300/2500 MHz	0.3~1.7 dBi to 1.2~4,2 dBi	45.60% && 47%	(824-960MHz) to(1710-2610MHz)	945mm^2	εr=4.4 tanδ=0.02, 0.8mm thickness FR4 130*67*0.8

Table 1: Analysis of results of different monopole antennas for LTE application

Ref .No.	Techniques	Bands	Gain	Efficiency	Bandwidth	RL	VSWR	Size	Substrate & parameters
[16]	shorting strip and interdigital capacitor	WLAN (2.4GHz)	1.5-4dBi	58-79%	1500MHz	…	…	110*40*0.8mm^2	FR4, εr=4.4, tan δ=0.02.
[17]	folded monopole	WLAN (2.4GHz)	1.5-4.2dBi	70%	810MHz	…	…	100*45*0.8 mm^2	FR4, εr=4.4, tan δ=0.02.
[19]	rectangular arm	LTE, Wi-MAX (2.3-2.9GHz)	2.5dBi	85%	…	…	…	22*44*1.6 mm^2	FR4, εr=4.4, tan δ=0.02.
	Two semi annular ring on both sides of arm	WLAN (4.2-10.6GHz)	2.5dBi	85%					
[20]	CPW feeding and L-shaped slots	Wi-MAX (3.4-3.6GHz)	3dBi	…	3.34-4.052GHz	…	1 to 2	40*26*1.6 mm^2	FR4, εr=4.4, tan δ=0.02.
	CPW feeding and L-shaped slots	WLAN (5.15-5.35GHz)	3dBi		4.736-5.432GHz				
[21]	rectangular ring monopole	WLAN(2.46/5.2/5.8GHz)	2.1/3.02/3.48 dBi	…	16.70%	…	…	37*25*1.6 mm^2	FR4, εr=4.4, tan δ=0.02.
	T-shaped monopole				24.40%				
[22]	2 radiating symmetrical strips	WLAN5.2GHz	…	…	180MHz	-17dB	1.5	28*23 mm^2	FR4, εr=4.3, tan δ=0.025
		Wi-MAX 2.4GHz			160MHz				
[23]	CPW feeding techniques	WLAN 2.4GHz	…	…	100MHz	…	…	57.37*67.5 *1.6 mm^2	FR4, εr=4.4
		Wi-MAX 3.5GHz			100MHz				
[24]	L-shaped radiating elements	LTE 2.5GHz	Avg. 5.14dB	58.70 %	2.11 to 5.01GHz	…	…	30*30 mm^2	FR4, εr=2.65, tan

	C-shaped strip Modified inverted F structure	Wi-MAX 3.5GHz WLAN 2.4GHz							δ=0.001
[25]	CPW feeding technique	Wi-MAX WLAN	2.5dB 2dB	…	…	…	2	26*36 mm^2	FR4, εr=4.4, tan δ=0.024
[26]	Rectangular ring with 2 slots A cut in rectangular slots	WLAN 2.7GHz WLAN 5.5GHz	2dBi 3.25dBi	90.29 % 88.98 %	29.95% 15.43%	…	…	20*25 mm^2	FR4, εr=4.4, tan δ=0.02
[27]	C-shaped slot open loop resonators	Wi-MAX 3.5GHz WLAN 5.8GHz	2.08dB 3.58Db	…	…	-25dB -17dB	1.1 1.5	28*45*0.0035 mm^2	Taconic TLY 5, εr=2.2
[28]	C-shaped ground stub C-shaped metal strip, L-shaped strip, crooked ground stub	WLAN(2.4/5.2/5.8GHz) Wi-MAX (3.5/5.5GHz)	0.9dBi 1.4dBi	…	120MHz 250MHz	…	…	20*14*1 mm^2	FR4, εr=4.4
[29]	combination of slots & slits in patch & ground plane	WLAN 2.4GHz	0.30dBi	…	…	…	…	50*19*1.5 mm^2	FR4, εr=4.4
[42]	Inverted-L shaped two meandered shorting strips	WLAN2400MHz	6dBi	(52.5~74.2) %	1065(1660~2725MHz)	....	<2	9*50*5mm^3	FR4, εr=4.4, tan δ=0.022, 0.8mm thickness
[43]	circular patch, parasitic double T-stub two inverted L-stubs. PIN Diode for switching	Both condition on&off (2.4,4.9(public e safety),5.8GHz)WLAN WiMAX (5.5,2.5,5.8GHz)	(1.85-2.14)dBi &&(2.8-3.49)dBi &(2.1-3.37)dBi (2.93-3.77)dBi &(3.54-5.41)dBi	……	18.46% 2.22% 12.33% 17.4%	…..	<2	40*30 mm^2	Rogers 5880 εr=2.2, tan δ=0.0009, 0.79mm thickness
[46]	Squre ring with two horizontal gap, PIN Diode HSMP(3860 SOT-23)	WLAN Both on and off state 2.5GHz & 5GHz	….	……	8.5% &12%	…..	….	20*5mm^2	εr=4.4,tanδ=0.08, 1.6mm thickness FR4
[49]	They allow various group of their operating frequency band mode of different common system using PIN diode MPP4203	2.4GHz	0.3-0.6dBi		(2400-2484MHz)				Foger4003 substrate (42*100*0.508)mm^3
[50]	Filter response with center frequency(9,10,11GHz) using PIN diode	(9,10,11GHz) Both on off condition	15.10dBi to 19.10dBi	7.7% to 14.4%	(690 to 1590MHz)	…….	…	………..	εr=10.2, tan δ=0.0025 0.25mm thickness
[45]	Using varactor diode for switching BB833	2.77GHz WLAN	3.05dBi	84.5%	64.17 degree HPBW	…….	….	23.5*43mm^2	PCB
[51]	Asymmetrical coplanar strip	5.6GHz WLAN 3.8 & 2,8GHz	0.7-0.9dBi 1.6dBi	…….	………	……	….	14*16mm^2	εr=4.4, tan δ=0.024 0.1mm

		WiMAX							thickness FR4
[54]	PIN diode work as aswitch	5.2GHz WLAN 3.5GHz WiMAX	2.77dBi 3.99dBi	93.5% &84.4 %	13.5% &35.7%	….	….	40*35mm^2	εr=4.5, tan δ=0.024 1.6mm thickness FR4
[55]	SRR	5.6GHz WLAN 3.5GHzWiMAX	…..	……	(3.31-3.74GHz) &(5.03-5.94GHz)	… …	…	33*24mm^2	εr=4.4, tan δ=0.024 1.6mm thickness FR4
[56]	Polarization Reconfigurable PIN diode HPND-4050	2.4GHz WLAN	3dBi to 9dBi	…….	43.4%-14.3%			3.2*4.41mm^2	εr=4.3, tan δ=0.02 0.8mm thickness FR4
[57]	Using DGS structure	2.4GHz to 8.6GHz	…..	…….	………..	-30dBi		32*32mm^2	Arlon AD 320 εr=3.2, 0.76mm thickness FR4
[58]	Rolled planer monopole antenna	(2.9 to15GHz)	7.5 to 8.5dBi	…..	(1.5-3GHz)	… ….	…. .	60*6*8mm^3 cylinder 2*1mm^2 spindal	….
[59]	DGS	WiMAX(3.5/5.5GHz) WLAN(2.4/5.2/5.8GHz)	…….	……	(2.14-2.52GHz) (2.82-3.74GHz) (5.15-6.02GHz)			32*32mm^2	100*100mm^2 εr=2.2, 0.588mm thickness FR4
[60]	PCB with PIN diode	2.4GHz& 3.5GHzWiMAX	4.61dBi 6.74dBi	……	23.3% & 18.3%			55*55*1mm^3	………….
[61]	Circular polarization reconfigurable complementary	WLAN	1.58dBi	58%	2.1%	… … …	….	………	……….
[63]	DGS	7.5GHz to8.9GHz	5.83dBi To 8.9dBi		330MHz			15*15mm^2	Roger R03006 εr=6.15, 0.64mm thickness FR4
[64]	C Slot patch PIN diode SNPI1320	WLAN & WiMAX	3.7dBi to 4.92dBi	130MHz to 150MHz				50*50*1.75mm^3	εr=4.4, 1.588mm thickness FR4
[66]	Coplanar waveguide (cpw) PIN diode switch MA4AGB LP912	Mode 1 2.4GHz(2.4-2.9) Mode 2 WLAN(2.4/5.2GHz) WiMAX(2.5GHz) Mode 3 WLAN(5.8GHz)	3.38dBi 3.16dBi 3.69dBi To 4.32dBi		(2.4-2.9GHz) (2.4/2.9GHz) To (5.09-5.47GHz) 5.27 to 8.5GHz			40*43mm^2	εr=4.4, 1.6mm thickness FR4 , tan δ=0.02

[67]	Circular slot, DGS switch as PIN diode	3.5GHz WiMAX 2.5WALN 5.7WLAN	………	……	…………	… …	…	28*16*0.8 mm^3	εr=4.4, 1.8mm thickness FR4
[68]	Horizontal and vertical polarization for millimeter wave SRR	Military Application Mode 10GHz Mode 2 & mode 3 10GHz		97% To 96%	……..	… …	…	………… ..	εr=2.2, 0.787mm thickness FR4 Duroid roger , tan δ=0.09
[69]	Reducing size of antenna and patch of ground	Without modified (7.27GHz to 4.267GHz) With Modified (4.65GHz to 6.18GHz	…….	……	………..	…..	…. .	30*30mm^2	εr=2.2, 1.575mm thickness FR4 Duroid roger , tan δ=0.09
[70]	LC based line (IMSL) (N-CELL) Array antenna	14.5GHz To 19.9GHz							
[71]	Magnet Resonance wireless power transfer(wpt)	Tx=1.2560MHz Rx=1.2525MHz Intermediat=1.24MHz							Tx and Rx resonant coils are designed using a helical coil (252mm, 90mm, 9 turns, a= 2.2mm) intermediate resonant coil is a single-layer spiral coil (Rin=200 mm, Rout=300mm,10turns, a=2.4mm)
[72]	Microstrip patch array and phase shifter(IMSL) LS substrate	14.5GHz To 16.4GHz	12.2dBi exceed						LC substrate G7323001 $εr_{liq}$=0.2, $εr_{llc}$=2.4, 1.575mm , tan δii=0.09 , tan δl=0.09
[73]	DGS used shaped	8to12GHz Xband	1.46 & 2.08dBi		5.40to1600			23.63*25.60mm^2	FR4 tan δ=0.02 t=1.6mm
[74]	MEMS switch	(2to5GHz)	8.9dBi To 18.9dBi	100% 100%					FR4 substrate εr=2.2, 1.575mm thickness , tan δ=0.02

Table 2: Analysis of results of different monopole antennas for WLAN and Wi-MAX and other applications

IV. Conclusion

A comprehensive review concerning multiband monopole antennas for mobile and wireless communication systems has been carried out. The gain, bandwidth, efficiency, size, VSWR and return loss of various monopole antennas have been identified. After study of literature survey it is conclude that the various small techniques can be used in antenna for better performance. The compact antenna can be designed by sacrificing more on gain and bandwidth. It is shown that the gain and bandwidth depends on ε and thickness of dielectric substrate.

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