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Review of Multiband Antenna for Mobile Communication

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Abstract **– Due to highly increasing of mobile user, wireless communication become more sophisticated and advanced, each decade at least one generation of mobile or wireless communication system is released with additional features. While each time one generation is released. It has its own working principle with different operating band. Some of them is GSM (880 to 960 MHZ and 1710.2 to 1879 MHz), UMTS (2110 to 2200 MHz), LTE2300 (2305 to 2400 MHZ), Bluetooth (2.402 -2.480 GHz) or (2.400 and 2.4835 GHz) and WLAN (2400–2484MHz). All additional features need antenna that resonate at specific frequency spectrum range. Which means multiple antennas is needed inside one mobile device to be functional in all generation for all frequency spectrum. To decrease this number of antennas inside one device it is necessary to design new antenna type that operate at different frequency range. Multiband antenna is designed by changing shapes, size, and material property of different antenna types, mostly PIFA, Fractal antenna, and monopole antenna is used for mobile device. Multiband antenna is best solution for mobile device to operate under different wireless communication generation infrastructure.**

Keywords- multiband antenna, spectrum, PIFA, Fractal antenna, monopole antenna

I. INTRODUCTION

The tremendous advancement in wireless communication technologies together with the growing on consumer are leading the creation of mobile handsets which are smaller, lighter and more multifunctional [1, 2, 3]. This drive the developments of antenna from the early single-band, dual-band to the multi-band even the ultra-wideband antenna design with compact size, low cost, lightweight and easy to fabricate/integrate within hand-held mobile devices [4, 5]. Along with the wearable mobile communications needs, designed with a light, thinness, multi-band and high gain antenna and other characteristics of smart phone become to a new generation of smart phone antenna design challenges [6, 4].

The miniaturization of internal antenna for the mobile devices is also an inevitable trend and, Over the last ten years, a large number of antenna designers have done plenty of researches [7]. But because of the quite long wavelength of LTE 700, the realization of the antenna small size is difficult, especially the operating frequency bands of the antenna are requested to cover all current 2G/3G/4G/5G communication standard bands, such as LTE 700 (698-787 MHz), GSM 850 (824-894 MHz), GSM 900(880-960 MHz), DCS1800 (1710-1880MHz), PCS1900(1850-1990MHz, UMTS (1920-2170 MHz), LTE 2300(2300-2400 MHz) and LTE 2500 (2500-2690 MHz), NR (Sub-1 GHz, 1-6 GHz and above 6 GHz), Bluetooth (2400–2480 MHz), WLAN (2400–2484MHz) it will be a greater challenge [3, 5, 8]

For antennas to satisfy the requirements of the current technological development, they must be compact while having multiband capability. Accordingly, attention is being focused on high-performing antennas with simple structures, to achieve met the requirement. Various techniques of designing multiband antennas based on different structures have been proposed like planar inverted-F antenna (PIFA), fractal antenna, monopole antenna, slotted antenna and hybrid antenna [1]-[14].

II. TYPES OF ANTENNA DESIGN FOR MULTIBAND

A. *Planar Inverted F-Antenna (PIFA)*

Planar Inverted F-Antenna (PIFA) is developed from monopole antenna, inverted L is realized by folding down the monopole in order to decrease the height of the antenna at the same time maintaining identical resonating length. When feed is applied to the Inverted L, the antenna appears as Inverted F. The thin top wire of Inverted F is replaced by planar element to get the Planar Inverted F antenna [9, 10]. PIFA is composed of a ground plane, radiator, feed line, and short pin. Top radiating patch plane is folded at one edge of a patch and shorted to the ground plane to decrease the antenna length. The size of the patch and resonating frequency can be determined by [3, 6, 9]:

$$L_P+W_P-W= \lambda/4 \quad (1)$$

$$f_r = \frac{C}{4(LP+WP-W)\sqrt{\varepsilon r}} \quad (2)$$

where Lp- patch length, Wp- patch width, W-width of shorting line, εr-dielectric permittivity, C- speed of light [9, 10]. Because it operates at a resonant length of λ/4, it is highly conducive to a small and lightweight design, and thus well-suited for use mobile device as an internal antenna. The PIFA has the advantage of a low profile, but its narrow bandwidth makes it difficult to realize multiband capability with a single resonator [2, 3, 10]. While this problem can be resolved by using additional parasitic patch, parasitic plane and parasitic stub. such additions tend to increase the size of the antenna. In PIFA, it is difficult to simultaneously achieve miniaturization and multiband capability [10, 11].

Figure 1. Basic single band PIFA structure [10]

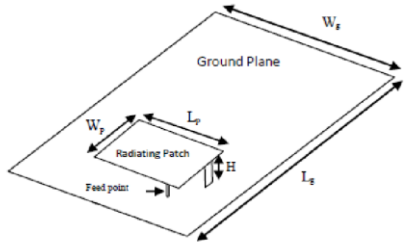


TABLE I. SUMMARY FOR PIFA MULTIBAND ANTENNA REVIEW

No	Proposed Antenna	size	Operating band	Reflection Coefficient	Gain	BW	Efficiency	ECC
1.	Compact Octa-Band PIFA antenna [12]	30*25*7 mm^3 5250 mm^3	GSM900, GSM1800, GSM1900, UMTS, LTE2300, LTE2500, HIPERLAN/2, IEEE 802.11a (5150-5350/5725-5825MHz)	<-6dB -24dB(max)	——	>2GHz @ -6dB	——	No need
2.	Reconfigurable PIFA antenna [14]	26.5×37 mm^2 =980.5 mm^2	770MHz, 900MHz, 1.54GHz, 1.7GHz, 1.8GHz, 2.1GHz, 2.4GHz, 3.4GHz and 3.55 GHz)	-6dB	8dB(max) @3.4GHz	narrow	95%@ 3.4GHz	No need
3.	PIFA antenna with MIMO system [13]	229.26 mm^2	900MHz, 1700-1900GHz, 2500-2700GHz	< -10dB	4.52 dB(max) @2.6GHz	580MHz	——	0.01@2.6, 0.02@1.8, 0.34@900 MHz

Recently numerous numbers of researcher working on PIFA multiband antenna. A compact Octa-Band PIFA antenna was proposed [12], to cover a frequency range of GSM900 (880-960 MHz), GSM1800 (1710-1880MHz), GSM1900 (1850-1990MHz), UMTS (1920-2170MHz), LTE2300 (2305-2400MHz), LTE2500 (2500-2690MHz), HIPERLAN/2 in Europe (5150-5350M Hz/5470-5725MHz), and IEEE802.11a in the U.S.(5150-5350/5725-5825MHz) band by using a U-shaped slit in the driven patch, a quarter-wave resonator connected to the feed strip and two slots in the ground plane. The antenna consists of three major elements: driven patch with a U-shaped slit, a nearly quarter-wave resonator connecting to the feed strip and two slots etching on the ground plane. A 1-mm thick FR4 substrate with a size of 115*60mm2, with PIFA size of 30*25*7 mm3. It able to cover the entire frequency band with return loss better than -6dB [12]. But in this paper, they only explain the reflection coefficient, which is not give us total information about the proposed antenna. They didn't include the Gain at each band, efficiency of the antenna, directivity of the antenna. So, the far-field radiation performances are good enough for practical application.

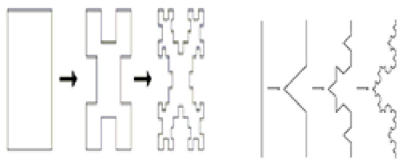
The reconfigurable PIFA antenna was proposed [13] with antenna structure of four layers. The first layer is a rectangular patch with dimensions of 37 x 26.5 mm2, the second layer is the Rogers Duroid 5880 substrate with a dielectric constant of 2.2 and a thickness of 1.6 mm. The third layer is an air gap of 4.4 mm height and the final fourth layer is a ground plane of dimensions 105×70 mm2 that relies on two p-i-n diodes to achieve frequency reconfiguration. The antenna operates at the following frequency bands (770 MHz, 900 MHz, 1.54 GHz, 1.7 GHz, 1.8 GHz, 2.1 GHz, 2.4 GHz, 3.4 GHz and 3.55 GHz) with maximum Gain of 8dB and efficiency up to 95% @ 3.4GHz. With appropriate matching of p-i-n diode the achieved up to 60% surface reduction which also create variation on resonant frequency. But the reflection coefficient of this antenna is not good enough the achieve more than -6dB with narrow bandwidth.

Another PIFA antenna with MIMO system was proposed [14], the antennas are design for LTE application with bandwidth of 240MHz and 340MHz, with two types of four antenna to support 4X4 MIMO system. The PIFA are designed on FR-4 substrate thickness = 1.6mm with 65mm × 100mm ground plane & PIFA size of (11*22+ 2.2*16.2+ 3.8*4+ 2.2*81.1) and (8.2*(3.96+3.98)-0.25*8.2*(3.96+3.98)). The longer path resonates at lower band (1700-1900GHz) while the shorter path at (2500-2700GHz) with reflection coefficient of more than -10dB. The gain at 2.6GHz, 1.8GHz and 900MHz are 4.52 dB, 0.44 dB and -1.72 dB. The envelope cross-correlation coefficient (ECC) is getting 0.01, 0.02, and 0.34 at 2.6GHz, 1.8GHz and at 900MHz respectively [14]. Meanwhile in this paper they didn't include how efficient the antenna work, and cross reflection coefficient is necessary because the antenna is designed for MIMO system.

B. *Fractal Antenna*

Fractal is generally irregular or fracture geometric shape that can be subdivided in parts, each of which is a reduced-size copy of the whole [4]. Fractal antennas allow compact, multiband and broadband antenna designs. fractal objects have self-similar shape, with different scales [15]. Most antenna is not operating with size under λ/4, because its radiation resistance, gain, and bandwidth are tumble-down and PIFA has a narrow bandwidth and needs a height from ground to substrate for matching and additional shorting pins near the feed to reduce the size of antenna. Fractal geometry is a remarkably pleasant solution for this dilemma on account of its two characteristics: self-similarity and space filling [1, 16]. The space filling property, when applied to an antenna element, leads to an increase of the electrical length and also have superior data rate, multipath fading reduction and co-channel interference suppression capability when the antennas are implemented in MIMO arrangements. Thus, fractal theories have become an innovative approach for designing wideband and multiband antennas [15]. Several fractal configurations including Koch, Sierpinski, Minkowski, Hilbert, Cantor sets and fractal Tree antennas [4].

Figure 2a: Koch Fractal [17], 2b: Minkowski Fractal Antenna [18]



A Compact Multiband Hybrid Fractal Antenna [4] was proposed which cover GPS (L1=1227.60 MHz), Bluetooth (2.41–2.49 GHz) of ISM band, WLAN 802.11 a/b,(5.15–5.35 GHz), mobile/fixed satellite and aero-nautical navigation (3.876–4.375, 6.6188–7.0045, 7.9698–8.3373 and 9.1648–9.6214 GHz) by using Hybrid Koch curve and Minkowski curve fractal with feed structure of coaxial outer diameter=2 mm, coaxial material=Teflon, ε=2.1, δ=0.001 and mass density 2250 kg/m3. Length of coaxial pin =4 mm, length of probe pin=1.2 mm and antenna area of 420 mm2. With this antenna structure they able to achieve overall bandwidth of 2.954GHz with reflection coefficients of less than -6dB and maximum of -21.33dB at 6.759GHz, and 4.1686dB maximum gain. While in this paper the efficiency of the antenna is not measures and the gain for each band are not determined additionally this is basic mobile communication frequency band are not included.

A New E-Shape Fractal antenna [16] was proposed to cover GSM850/900/1800/1900 UMTS, LTE2300, LTE2500 operation bands, to achieve this they use third iteration of E-shape fractal geometry which leads to self-similar structures, constructed on FR4 substrate. With this antenna the able to the proposed band with overall bandwidth of 910MHz under -6dB return loss and antenna gain of 5.6-5.8dBi at GSM850/900, 5.8-6.5dBi at GSM 800, UMTS and 6-6.5dBi at LTE2300/2500 with antenna efficiency of 90-98%. But this paper is not cover LTE lower bands and WLAN and Bluetooth band.

A compact triband Fractal PIFA antenna [1] was proposed which has three resonant frequencies including 0.92GHz, 2GHz and 2.33GHz. to achieve the operation band the they use FR4 substrates with height of .5mm and ground size of 60mm x 50mm with hybrid PIFA of (48*21) and Minkowski fractal at center of PIFA. At GSM and DCS frequency bands S11 <-6 dB, At WLAN frequency band S11 <-10 dB but antenna efficiency and Gain is not explained in this paper, and the use of fractal geometry is not visible because if the fractalize the antenna with more iteration they may get better multiband.

Hybrid Fractal Shape Planar Monopole Antenna [15] was proposed, which was implemented for MIMO system with coverage of LTE/WiFi/WiMAX/WLAN frequency band. To achieve this band the use individual iteration of both Koch curve and Minkowski island fractals are combined over compact size of 10x10 mm2 of monopole antenna area. MIMO antenna consists of the edge-to-edge separation of 28.02 mm between the two symmetrical hybrid fractal radiating elements.

TABLE II. SUMMARY FOR MULTIBAND FRACTAL ANTENNA REVIEW

No	Proposed Antenna	Size	Operating band	Reflection coefficient	Gain (dB)	BW(GHz)	Efficiency	ECC
1.	A Compact Multiband Hybrid Fractal Antenna [4]	area =420 mm^2	GPS, Bluetooth WLAN 802.11 a/b, 3.876–4.375, 6.6188–7.0045, 7.9698–8.3373, 9.164–9.621GHz	<-6d -21.33dB (max)	4.16 max	2.954	____	No need
2.	New E-Shape Fractal antenna [16]	_____	GSM850/900/1800/1900, UMTS, LTE2300, LTE2500	-6Db	5.6-6.5	0.910	90-98%.	No need
3.	triband Fractal PIFA antenna [1]	1008 mm^2	0.95GHz,2GHz, 2.33GHz	-6dB -25dB max		0.80	_______	
4.	Hybrid Fractal Shape Planar Monopole Antenna [15]	10*10= 100 mm^2	1.65-1.9GHz 2.68-6.25GHz	< -10dB	6.78@6GHz	3.82GHz	97%@6Ghz	< 0.5

To improve the impedance matching and isolation between the antennas a T-shape strip plate is used between both antennas. In this antenna they able to achieve two bands with bandwidth of 250MHZ (1.65-1.9GHz) and 3.57GHz (2.68 – 6.25GHz) with both S11 and S22 more than -10dB and the isolation is S12, S21 below -10 dB and -15 dB for the band 1 and band 2 respectively. The antenna has maximum gain of

6.78dB and maximum efficiency up to 97% at 6GHz, with measures ECC value of less than 0.5 and capacitive loss of 0.3 b/s/Hz and 0.4 b/s/Hz for both bands. It was good if they would determine envelope correlation coefficient (ECC) for all frequency range and basic mobile communication frequency bands like GSM, LTE700, LTE2100 LTE2300 are not included.

C. Monopole Antenna

Monopole Antenna is easy to fabricate and can operate at its quarter-wavelength mode as the lowest resonant mode, which makes it promising to achieve wideband operation with a small size for handset applications [19]. Multiple resonances can be excited in monopole antenna to cover a large band with reasonable system size [8]. For planar monopole antennas, there are two ways to generate the multiple resonances in the lower band parasitic strip for multiple resonances and combining a driven strip and a parasitic strip [11].

TABLE III. SUMMARY FOR MULTIBAND MONOPOLE ANTENNA

No	Proposed Antenna	Size	Operating band	Reflection coefficient	Gain (dB)	BW(GHz)	Efficiency
1.	A Compact Monopole Antenna for Smartphones [5]	area = 256 mm^2	GSM850/900, DCS, PCS, UMTS. LTE-40(2300–2400MHz), LTE41(2496-2690MHz), LTE42(3400-3600MHz), LTE-43(3600–3800MHz).	<-6dB -35dB (max)	(0.13 - 5.12) (0.56-4.78) 5.12dBmax	2.326	54.5-68.3%
2.	A Compact Multiband Antenna for 4G/LTE [8]	20x70x 0.8 mm^3	LTE-1, LTE-2, LTE-3, LTE-7, LTE-13, LTE-14, LTE-40, LTE42, LTE-43, and WLAN	-6dB -30dB	(-1.58to - 4.28) (2 - 4) 4dB max	1.795	50- 90%
3.	A planar Printed Mobile Phone Antenna [11]	15×60 mm^2	GSM850, GSM900, LTE700, DCS, PCS, UMTS, LTE2300/2500	-6dB-25dB max	0.5-3dB max	1.74	42-88%.

A Compact Monopole Antenna for Smartphones [5] was proposed to cover operation band of GSM850, GSM900, DCS, PCS, UMTS. LTE-40(2300–2400MHz), LTE41(2496-2690MHz), LTE42(3400-3600MHz), LTE-43(3600–3800MHz). by using S-shape and L-Shape monopole antenna with total area of 256 mm2, they able to generate two band at 824-960 MHz and 1710-3800MHz. with bandwidth of 136MHz and 2.09GHz respectively, antenna gain from -0.13 to 5.12 dB and -0.56 to 4.78 dB, and radiation efficiencies of 54.5% and 68.3% in lower and higher band respectively for return loss of less than -6dB (-35dB maximum at 3550MHz). While more antenna gain and radiation efficiency can be achieved in PIFA or Fractal antenna with smaller size.

A Compact Multiband Antenna for 4G/LTE [8] was proposed to cover LTE-1(1920–2170MHz), LTE-2(1850–1990MHz), LTE-3(1710–1880MHz), LTE-7(2500–2690MHz), LTE-13(746–787MHz), LTE-14(758–798MHz), LTE-40(2300–2400MHz), LTE22(3410–3590MHz), LTE-43(3600–3800MHz), and WLAN(2400–2484MHz) bands with antenna size of 20x70x0.8mm3. To achieve the operation band, they use C-shaped and L-shaped monopole elements, printed on low cost thin FR4 substrate with ground plane (Size: 20x46mm2. With this antenna they able to achieve 55MHz (745-800MHz) with return loss less than -6dB, 1300 MHz (1.7-3GHz), and 440MHz (3.4-3.84GHz) with return loss -10dB (-30dB maximum). As well as the gain is varied from -1.58 dB to -4.28 dB (745-800MHz and from 2 dB to 4 dB for (1.7-3.48GHz) with radiation efficiency 50- 90% at the lower bands and almost constant 95%. For upper band. The lower band of this paper is not applicable from practical point of view because of 45MHz is very narrow bands for GSM purpose. As well as the antenna size is too large for mobile Phone application, same property can achieve by small size of other antenna type.

A planar printed mobile phone antenna [11] was proposed to cover the GSM850/900, LTE700 DCS, PCS, UMTS, LTE2300/2500 bands. λ/4 modes of a driven monopole strip and a parasitic ground strip method is used to cover lower band (< 1.5GHz) and a shorter driven branch is added to the driven monopole strip and an open slot is etched on the parasitic ground strip bands method is used for upper band (> 1.5GHz) with antenna size of 15×60 mm2. This antenna has bandwidth of 405 MHz (660~1065 MHz) and 1335 MHz (1665 -3000 MHz) with -6-dB return loss (-25dB maximum at 2.75GHz) and antenna gain 0.5-2 dB with total radiation efficiency 60% - 84% for lower band and antenna gain 0.5-3 dB with total radiation efficiency of 42%-88%. While more antenna gain and radiation efficiency can be achieved in PIFA or Fractal antenna with smaller size, even A Compact Monopole Antenna for Smartphones [5] achieves more bandwidth and operating band with small.

D. Literature Review on other types of Antenna

Triple Band MIMO Antenna System for 5G [20] was proposed to cover frequency band of n77 (3.3-.42GHz) and n79 (4.4-5GHz), and WLAN 5.15-5.85GHz. The proposed band is achieved by antenna array consists of four triple band antennas, with each antenna contains an L-shaped feeding element and a deformed F-shaped radiating element with an extra rotated L-shaped element located in the reverse extension line of the upper branch of the F-shaped element place one FR4 substrate with a 134mm× 75mm ground plane. While all antenna is placed on edge to edge of the ground plane with area of single antenna is 50mm2. Totally with this 4x4 MIMO antenna it covered the proposed area, they achieve bandwidth of 3GHz (3-6GHz) with return loss less than -6dB with maximum of -30dB and isolation between each port is more than -14dB as well as the total MIMO antenna efficiency is 60-85% with antenna gain of 4.39dB, 3.66dB,4.65dB at 3.4GHz,4.7GHz, 5.4GHz respectively and envelop correlation coefficient (ECC) less than 0.05 in the working bands. The proposed antenna has very good simulation result as compared to its size but its working band is only above 3GHz which will cause great problem because this antenna is not operate may mobile communication area in lower band including LTE bands.

The planar coupled-fed multiband antenna for Mobile [6] was proposed to achieve frequency band of (698-960, 1710-2690 MHz),LTE-700/2300/2500, GSM-850/900, DCS-1800, PCS-1900, UMTS-2000, WiMAX-2300, WLAN-2400, by using an inductive-coupling radiator and a simple L-shaped stub and a parallel strip antenna architecture placed on FR4 substrate with ground plane of 115 x 52.5 mm² and antenna size is 52.5x 15mm2. With proposed antenna they achieve Two wide operating bands, lower band (684-1142MHz) with bandwidth of 458MHz and higher band (1618-2935MHz) with bandwidth of 1317MHz under return loss of below -6dB with maximum -25dB, the antenna gain is varies form 1.8-3.24dB with efficiency of 64-87% at lower band and 1-4.2 dB antenna gain and 54-95% antenna efficiency in the higher band. In this paper the antenna size is to large, many antennas are there with smaller size, give us better performance than this proposed antenna.

A Simple Wide Band Microstrip Loop Antenna [21] was proposed to achieve the frequency band of GSM(880-960 MHZ, 1710.2-1879 MHz), UMTS (2110-2200 MHz) and LTE2300 (2305-2400 MHZ) by using a four rectangular ring type microstrip patch antenna has area of 300mm2 is placed on FR4 substrate with 44 mm x 44 mm x1.6 mm. this antenna covered the proposed band with the following simulated results bandwidth of 2.730GHz (690-3120MHz) with return loss better than -6dB and maximum of 44.9dB at 2440MHz and antenna gain of (3.5- 8.3dB) with maximum at 980MHz. in this paper the efficiency of antenna is not determine as well as the antenna size is to large for mobile application.

TABLE IV. SUMMARY ON OTHER TYPES OF MULTIBAND ANTENNA REVIEW

No	Proposed Antenna	Size	Operating band	Reflection coefficient	Gain (dB)	BW(GHz)	Efficiency	ECC
1.	Triple Band MIMO Antenna System for 5G [20]	area = 50 mm^2	n77 (3.3-.42GHz) and n79 (4.4-5GHz), and WLAN 5.15-5.85GHz.	<-6dB - 30dB (max) < -14dB isolation	4.65dB max	3GHz	60-85%	<0.05
2.	The planar Coupled-fed Multiband Antenna for Mobile [6]	787.5 mm^2	(698-960, 1710-2690 MHz), LTE-700/2300/2500, GSM-850/900, DCS-1800, PCS-1900, UMTS-2000, WiMAX-2300, WLAN-2400,	-6dB -25dB	1- 4.2 dB	1.775	54- 95%	NAN
3.	A Simple Wide Band Microstrip Loop Antenna [21]	300 mm^2	GSM (880-960 MHZ, 1710.2-1879 MHz), UMTS (2110-2200 MHz) and LTE2300 (2305-2400 MHZ)	-6dB -44dB max	3.5-8.3dB	2.73GHz	_____	-____–

CONCLUSION

Because of enormous change in wireless communication technology through time, highly increasing of user demand on high data rate, and high-speed communication system (video streaming and downloading); we needed more efficient multiband antenna with large bandwidth, compact size, light weight and easily manufactured. To fix this problem, large number of researchers conducting researches on multiband antenna using different techniques on various antenna types like PIFA, Fractal antenna, Monopole antenna, Hybrid and others. While all antenna types have their own features regarding power radiation, impedance matching, size minimization, and multiband properties. Monopole antenna give us multiband resonant but it requires large electrical length, which leads to increment on overall antenna length; to address this problem, PIFA antenna is introduced from monopole antenna but have difficulties with achieving miniaturization and multiband simultaneously due to resonant frequency operating at quarter wavelength.

TABLE V. COMPARISON OF ALL PROPOSED PAPER

No	Proposed Antenna	Size	Operating band	Reflection coefficient	Gain (dB)	BW(GHz)	Efficiency	ECC
1.	triband Fractal PIFA antenna [1]	1008 mm^2	0.95GHz,2GHz, 2.33GHz	-6dB -25dB max	———	0.80	———	No need
2.	A Compact Multiband Hybrid Fractal Antenna [4]	area =420 mm^2	GPS, Bluetooth WLAN 802.11 a/b, 3.876–4.375, 6.6188–7.0045, 7.9698–8.3373, 9.164–9.621GHz	<-6dB -21.33dB (max)	4.16 max	2.954	——	No need
3.	A Compact Monopole Antenna for Smartphones [5]	area = 256 mm2	GSM850/900, DCS, PCS, UMTS. LTE-40(2300–2400MHz), LTE41(2496-2690MHz), LTE42(3400-3600MHz), LTE-43(3600–3800MHz).	<-6dB -35dB (max)	(0.13 - 5.12) (0.56- 4.78) 5.12dBmax	2.326	54.5- 68.3%	
4.	The planar coupled-fed multiband antenna for Mobile [6]	787.5 mm^2	(698-960, 1710-2690 MHz), LTE-700/ 2300/ 2500, GSM-850/900, DCS-1800, PCS-1900, UMTS-2000, WiMAX-2300, WLAN-2400,	-6dB -25dB	1- 4.2 dB	1.775	54- 95%	NAN
5.	A Compact Multiband Antenna for 4G/LTE [8]	20x70x 0.8 mm3	LTE-1, LTE-2, LTE-3, LTE-7, LTE-13, LTE-14, LTE-40, LTE42, LTE-43, and WLAN	-6dB -30dB	(-1.58to - 4.28) (2 - 4) 4dB max	1.795	50- 90%	
6.	A planar printed mobile phone antenna [11]	15×60 mm2	GSM850, GSM900, LTE700, DCS, PCS, UMTS, LTE2300/2500	-6dB- 25dB max	0.5-3dB max	1.74	42-88%.	
7.	compact Octa-Band PIFA antenna [12]	5250 mm^3	GSM900, GSM1800, GSM1900, UMTS, LTE2300, LTE2500, HIPERLAN/2 , IEEE 802.11a (5150-5350/5725-5825MHz)	<-6dB -24dBmax	———	>2GHz@ -6dB	———	No need
8.	PIFA antenna with MIMO system [13]	229.26 mm^2	900MHz, 1700-1900GHz, 2500-2700GHz	< -10dB -35dBmax	4.52 dB(max) @2.6GHz	580MHz	———	0.01@ 2.6, 0.02@ 1.8, 0.34@ 900MHz
9.	reconfigurable PIFA antenna [14]	=980.5 mm^2	770MHz, 900MHz, 1.54GHz, 1.7GHz, 1.8GHz, 2.1GHz, 2.4GHz, 3.4GHz and 3.55 GHz)	-6dB -24dBmax	8dB(max) @3.4GHz	narrow	95%@3.4 GHz	No need
10.	Hybrid Fractal Shape Planar Monopole Antenna [15]	10*10= 100 mm^2	1.65-1.9GHz 2.68-6.25GHz	< -10dB	6.78@6G Hz	3.82GHz	97%@6G hz	< 0.5
11.	New E-Shape Fractal antenna [16]	———	GSM850/900/1800/1900 , UMTS, LTE2300, LTE2500	-6dB	5.6-6.5	0.910	90-98%.	No need
12.	Triple Band MIMO Antenna System for 5G [20]	area = 50 mm^2	n77 (3.3-.42GHz) and n79 (4.4-5GHz), and WLAN 5.15-5.85GHz.	<-6dB -30dB (max) S21< -14dB isolation	4.65dB max	3GHz	60-85%	<0.05

For this problem fractal antenna is remarkable solution because as the iteration of fractalization increases the electrical length increases with decreasing total antenna area. So, in fractal antenna as iteration increase the multiband will also increase, but it become more difficult to print the exact shape of fractal as the iteration increases which leads to limitation of fractal antenna.

From multiple proposed, 10x10mm2 antenna size Hybrid Fractal Shape Planar Monopole Antenna [15] cover large operating bandwidth with 3.82GHz (1.65-1.9GHz and 2.68-6.25GHz) which is suitable for GSM1800, UMTS, LTE 2100/2300/2500, LTE40/ 41/42/43 GPS, Bluetooth, WiMAX, WLAN 802.11(both 2.4 and 5GHz), even new 5G network band n77 (3.3-.42GHz) and n79 (4.4-5GHz) with MIMO system, and antenna gain of 6.78dB and up to 97% antenna efficiency with return loss of more than -10dB.

Due to the next generation mobile network or 5G frequency operation band is include less than 1GHz, up to 6GHz and 6-28GHz for different communication standards (Device to Device, UltraWideBand (UWB), Sensor Network, Internet of things and others), while communication device needed to be multifunctional in existing network and new coming 5G NR, to overcome this, multiband antenna with wide bandwidth is necessary. Because of high data rate and high-speed communication, the antenna should have to be design for MIMO system with minimum cross reflection coefficient, high gain, high efficiency, minimum envelope cross-correlation coefficient (ECC) and return loss. To achieve all the above requirement, hybrid of fractal with other antenna type may give us good result. fractal is geometry type which have self-similarity and self-affinity, so it is possible to implement fractal with antenna type to get multiband and wider bandwidth.

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