American Journal of Electrical and Electronic Engineering, 2018, Vol. 6, No. 2, 66-71
Available online at http://pubs.sciepub.com/ajeee/6/2/3

DOI:10.12691/ajeee-6-2-3

Dual-layer Microstrip Antenna Design for Wireless Communications

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Abstract The present work deal with the design of a triple band, dual layer Microstrip Patch Antenna. The frequencies of three bands are 0.9GHz, 1.798GHz, 2.402GHz. the S-parameter and the gain characteristics as well as radiation pattern are investigated. The proposed antenna is suggested to be used in a mobile phone handset that covers three frequency bands which include GSM 900 (889-960), GSM 1800 DCS 1800 (1710-1885), Bluetooth and Wi-Fi/WLAN (IEEE 802.11 b/g/n) ISM 2450 (Industrial, Scientific and Medical) (2400-2500). The proposed antenna shows return loss (RL) of -17.79dB at 0.9 GHz; -18.5 dB RL at 1.798 GHz; and -44.2 dB RL at 2.4 GHz which are encouraging results. Designing and simulation of the proposed antenna were based on CST software package. Finally enact three bandwidth are got and the antenna shows an encouraging results for WLAN applications.

Keywords: *triple band, dual layer, mobile*

Cite This Article: Ghadah M.Faisal, "Dual-layer Microstrip Antenna Design for Wireless Communications." *American Journal of Electrical and Electronic Engineering*, vol. 6, no. 2 (2018): 66-71. doi: 10.12691/ajeee-6-2-3.

1. Introduction

Antenna is a device used to transform an RF signal, traveling on a conductor, into an electromagnetic wave in free space. Microstrip antennas was introduced for the first time at 1950s [1]. It has been in use for about twenty years before development of the printed circuit board(PCB) technology in1970s. Since then the Microstrip antenna, become to be the common type of antennas due to many its advantages which they have like: light weight, low cost, low profile, planer configuration, superior port ability, easy for fabrication and easy integration with microwave monolithic integrate circuits [2,3]. They have been widely used for the civilian and military applications, such as mobile systems, and global positioning systems(GPS), satellites …ect.

In spite of the many advantages of the microstrip antennas, they have many disadvantages such as: narrow band-width, low gain, and relatively long size, One of the main drawbacks of such an antenna is the is the narrow bandwidth , there were many researches work which dealing with such a problem, S.B.Tajane et al. [4] had designed and investigation of rectangular Microstrip antenna withtri-band applications covering Bluetooth (IEEE: 802.15), WiMAX (IEEE: 802.16) and WLAN (IEEE:802.11a, 802.11b/g/n) bands of modern wireless broadband communication, The desiredtri-band operation had been obtained by proper loading for a rectangular patch antenna using slots and truncations alongside of patch width. K.R.M.Huq et al. [5] had designed a triple band microstrip patch antenna for cellular and Wi-Fi application. This will perform on the frequency 0.97 GHz, 1.35 GHz and 3.54 GHz. H-H Wang et al. [6] had designed two broad band microstrip antenna using planer line feeding, they had successfully implemented the antennas and got an enhanced band width by 25%. Yashar Zehforosh et al. [7] had design multilayer MSA to get 3.1-10.6 GHz BW for mobile applications, they increased the bandwidth by 50%. Shoichiro Hirai et al. [8]had designed a high performance ultra compact chip antenna . they got a bandwidth of 2.4-2.5 GHz. There were many other research, works devoted toward the improvement of the gain. Neala Chattorraj et al. [9] has written an algorithm for optimization of the MSA gain with and without dielectric substrate, using genetic algorithms. Abdullah AL Noman et al. [10] had designed a single layer single feed miniaturized MPNA. They had increased the bandwidth by 4.7% and got the a directivity a bone 6dB.due to the need for the multi services a multi band antennas has been invented. To get a multi-band PA, a multi-layer separated by a dielectric substrates had been used. During using the multi-layer and a dielectric substrates, study of the effects of the dielectric thickness on the performance of the antenna. Kharade A.R.Patil V.P. [11] had enhanced the gain of the MSA, using multi-layer multi-dielectric layer which is separated from patch by air as an another dielectric . Hussain A.Hammas [12] had study the effect of dielectric layer substrate on the MSPA performance lick Half power beam width , antenna efficiency, radiation efficiency, antenna directivity and radiation pattern. LuLu et al. [13] had studied the effect of the variation of the patch width and length, and height and εr , of the substrate on the band-width. They designed a 2.4 GHz Bw antenna for Bluetooth application. K.H.sagidmarie et al. [14] had designed a compact dual-band dual ring printed monopole antennas for

WLAN applications. They got an antenna with dand-width 2.4-2.48 GHz, 5.15-5.35GHz & 5.57-5.8 GHz. M.R.C.Mahdy…et al [15] for the first time they had tried to design meta material. they got an antenna of bandwidths with three center frequencies (2.5 , 3.55, 5.1 GHz). finally. S.I.AL Mously [16] had covered most of previous works to get triple band multi-layer patch antenna .He got an antenna with bandwidth (0.9 GHz , 1.8 GHz , 2.4 GHz) , but the frequency center were not exact there were small deviations in their values.

The present work deals with design and simulation of a triple band multi-layer patch antenna to get (0.9 GHz , 1.7987 GHz, 2.402 GHz) band widths. different dielectric substrates are used, their effect also are studied.

2. Antenna Design

A multi-layer triple band patch antenna is designed in this section. The designed antenna isometric geometry is given in Fig.(1a). As it is shown from Fig.(1a), the antenna consists of ground plane, dielectric substrate 1, active patch, dielectric substrate 2 and the parasitic patch. Active patch is fed by a coaxial probe fed. There is a single short pin between the ground plane and the active patch. The designed antenna parameters and physical dimensions are given in Table1 and Table2. The three bands center frequencies has been got are 0.9 GHz , 1.798 GHz & 2.402 GHz. As it is known from the theory of micro strip antenna there are different methods for designing the dual band antennas. In this work two of those methods has been hybridized to design a triple band antenna separated by a suitable distance to get the two resonance frequencies 1.8 and 0.9 GHz. A second patch which is called a parasitic patch has been added This patch has been separated from the active patch by a substrate dielectric material. The first one is designing single layer micro strip antenna by putting single short pin in the same axis of the feeding point two substrates are different in their dielectric constants values and heights.

The procedure of deign are: first full a simple micro strip patch antenna has been designed to get a resonance frequency of 1.8 GHz, using the following formulas: [17].

$$f_r = \frac{c}{2W\sqrt{(\varepsilon_{r1}+1)/2}} \tag{1}$$

$$\varepsilon_e = \frac{\varepsilon_{r1}+1}{2} + \frac{\varepsilon_{r1}-1}{2}\left[1+12\frac{h_1}{W}\right]^{-1/2} \tag{2}$$

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_e}} \tag{3}$$

$$L = L_{eff} - 2h*0.412\left[\frac{(\varepsilon_e+0.3)}{(\varepsilon_e-0.258)}\frac{\left(\frac{W}{h_1}+0.26h_1\right)}{\left(\frac{W}{h_1}+0.8\right)}\right] \tag{4}$$

$$L_g = 6h + L \tag{5}$$

$$W_g = 6h + W \tag{6}$$

$$xf = \frac{L}{\pi} * \frac{Zin}{Zf} \tag{7}$$

$$\frac{Zin}{Zf} \approx 1$$

Where f_r is the resonant frequency of the antenna, c is the free space velocity of the light, W is the width of patch, h is the height of the substrate, L_{eff} is the effective length L is the length of the patch, ε_r is the dielectric constant of the substrate , L_g is the length of ground plane, W_g is the width of ground plane and x_f is the position of the feeding point in the x-axis. The antenna is fed with a coaxial connecter modeled as a standard SMA connector with the following specifications [18]:

• Radius of inner conductor = 0.62 mm.

• Radius of insulator = 2.3 mm. • Radius of outer conductor = 2.64 mm.

• εr of insulator (Teflon-lossy) = 2.1.

• Length underground plane = 2.1 mm.

The antenna geometry is shown in Figure 1. All the dimensions are given in mms.

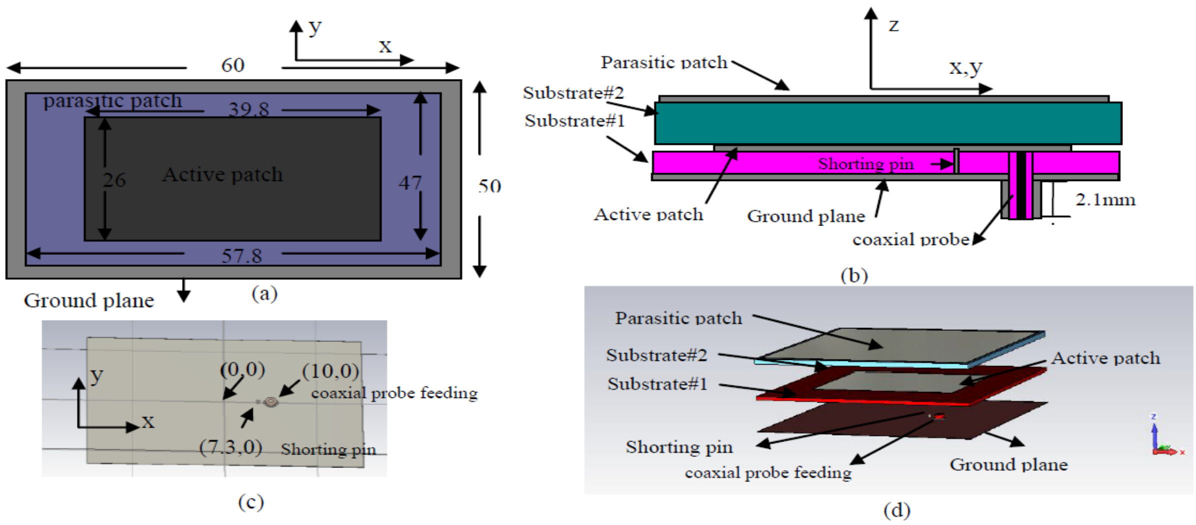

Figure 1. (a) ground plane with two patches dimensions, (b) Side view of the antenna, (c) x y cross section of the final triple-band MPA, (d) final antenna isometric geometry

The dimensions and parameters got for ε_{r1}=4.4, and h_1=0.8mm are: W=50mm, L=36.38mm, ε_e=5.2, (x_f =11.58mm, y_f =0). Simulating the designed antenna using the previous values a first resonance frequency f_{r1} equal to 1.35 GHz were got as shown in Figure 2a. Since the dimensions of the patch is inversely proportional to the frequency, then they has been decreased to W=35.3mm, L=34.0 mm in order to increase the resonance frequency to 1.8GHz as shown in Figure 2b. A single short pin has been put in the origin (0,0), (x_s =0, y_s =0) between ground plane and active patch to get a second resonance frequency f_{r2} of value 0.935GHz as shown in Figure 2c. For multilayer broadband antenna design generally, εr_1 is chosen to be greater than or equal to εr_2 and h1 is taken smaller than or equal to h_2 [1]. Therefore a second patch with dimensions W=60mm, L=50mm, h_2=1.3mm, separated from the active patch by substrate with dielectric constant, ε_{r2}=1.2 was used Simulating the antenna using these values got the third resonance frequency f_{r3} equal to 2.375GHz has been got, then f_{r1}, f_{r2} were changed to 1.64, and 0.88GHz respectively as shown in Figure 2d. To obtain f_{r3} =2.4 GHz the dimensions of parasitic patch#2 has been decreased to W=59.4, L=48mm. Dimensions of the active patch#1were changed and a suitable position for the short pin and the feeding point were chosen at x_f=10mm, x_s=7.3mm from the center of antenna f_{r1}, f_{r2} got were not exactly of the desired values as shown in Figure 2e. As it is known with decreasing the height of the substrate the resonance frequency increase. This phenomena has been used to choose the height of the substrate#1 and the height of substrate#2 by changing one of them and keeping the other constant and vise versa. The process of changing with their results are given in Table 1, Table 2 and Table 3. From the Table 1 noticed that if h_1 increase f_{r2} increase and f_{r3} decrease and from the Table 2 noticed that if h_2 decrease f_{r2} decrees and f_{r3} increase to avoiding increase the dimensions of the antenna h_1 has been decrees as shown in Table 3.The final chosen values for the dimensions of the active patch#1 and parasitic patche#2 are given in Table 4 with the specifications of the simulated MPA layers. Table 5 explains the dimensions and positions of the two rectangular patches used in the adopted antenna. The detailed return loss of the final triple-band MPA is shown in Figure 3. The design simulated using CST software package [19].

Table 1. Variation of h_2 with h_1=1mm

h_2 in mm	f_{r1} in GHz	|S|11 in dB	f_{r2} in GHz	|S|11 in dB	f_{r3} in GHz	|S|11 in dB
1.5	0.89	-17	1.82	-18	2.35	-25
1.4	0.9	-35	1.78	-18	2.4	-40
1.3	0.9	-6	1.63	-36	2.41	-20
1.2	0.9	-6	1.62	-30	2.45	-25
1.1	0.9	-6	1.618	-30	2.47	-32

Table 2. Variation of h_1 with h_2=1.4mm

h_1 in mm	f_{r1} in GHz	|S|11 in dB	f_{r2} in GHz	|S|11 in dB	f_{r3} in GHz	|S|11 in dB
0.8	0.91	-7.5	1.65	-27	2.4	-15
0.9	0.91	-7.5	1.64	-36	2.41	-20
1	0.905	-6	1.64	-36	2.43	-20
2	0.904	-14	1.815	-22	2.385	-21

Table 3. Variation of h_1 with h_2=1.1mm

h_1 in mm	f_{r1} in GHz	|S|11 in dB	f_{r2} in GHz	|S|11 in dB	f_{r3} in GHz	|S|11 in dB
1	0.89	-34	1.76	-15	2.44	-17.5
0.9	0.895	-26	1.77	-16	2.42	-21
0.8	0.898	-20	1.79	-17	2.41	-31
0.7	0.905	-15	1.8	-20	2.39	-25
0.765	0.9	-17.79	1.798	-18.5	2.402	-44.5
0.762	0.9	-18	1.8	-18	2.4	-50
0.761	0.9	-18	1.796	-18	2.4	-45
0.760	0.9	-18	1.798	-19	2.4	-40
0.75	0.9	-18	1.798	-19	2.4	-45
0.751	0.9	-18	1.8	-19	2.4	-46
0.752	0.9	-18	1.8	-18	2.4	-40
0.753	0.9	-17	1.8	-18	2.4	-37
0.754	0.9	-17	1.8	-18	2.4	-35
0.756	0.9	-17	1.8	-18	2.4	-32
0.747	0.9	-17.5	1.8	-19	2.4	-35
0.743	0.9	-17	1.8	-18	2.4	-33
0.742	0.9	-17	1.8	-19	2.39	-34
0.741	0.904	-14	1.815	-22	2.385	-21

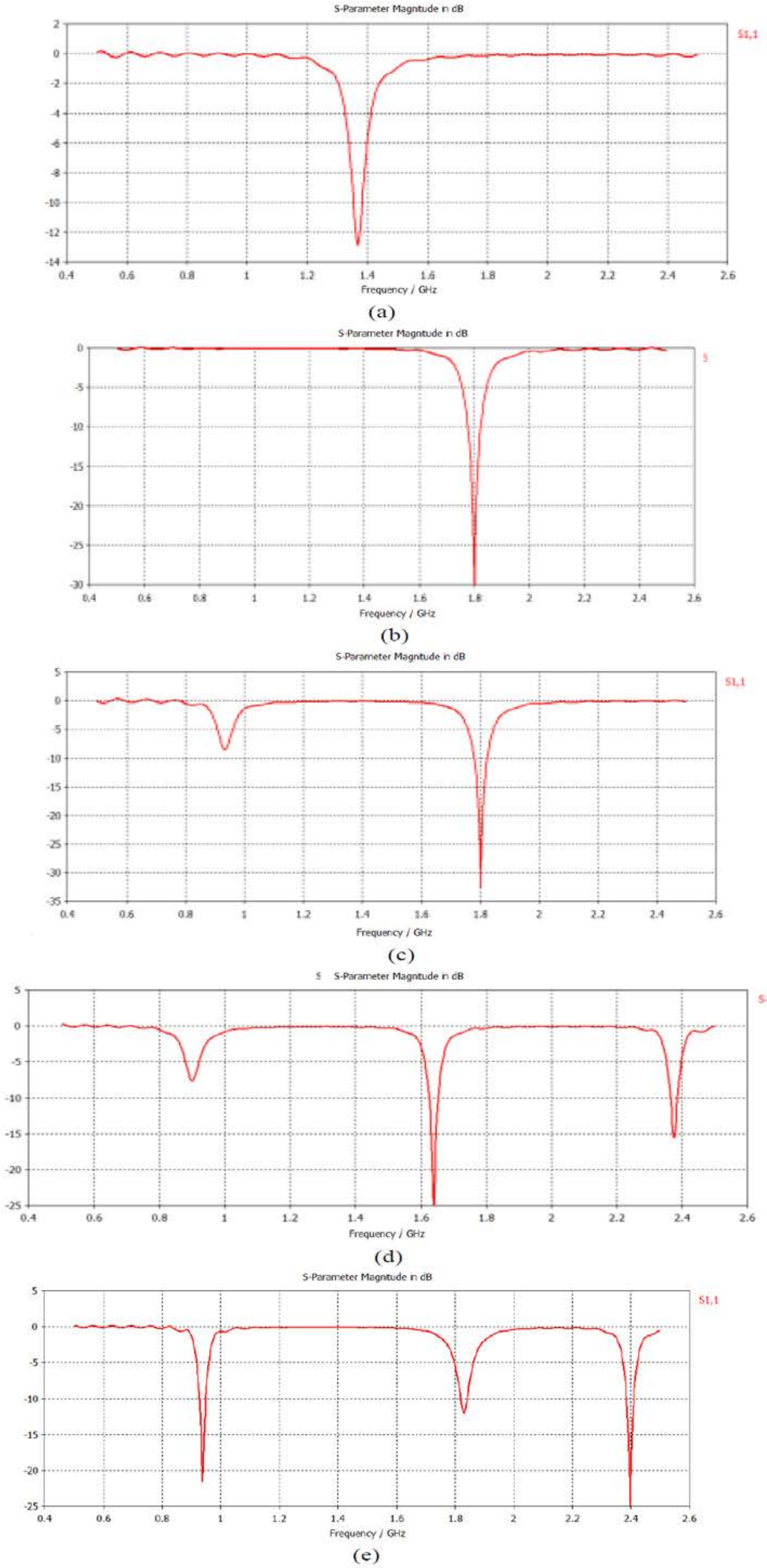

Figure 2. (a): first resonance frequency f_{r1} equal to 1.35 GHz, (b): increase the resonance frequency f_{r1} to 1.8GHz, (c): get a second resonance frequency f_{r2} of value 0.935GHz, (d): get the third resonance frequency f_{r3} equal to 2.375GHz, (e): obtain f_{r3} =2.4 GHz

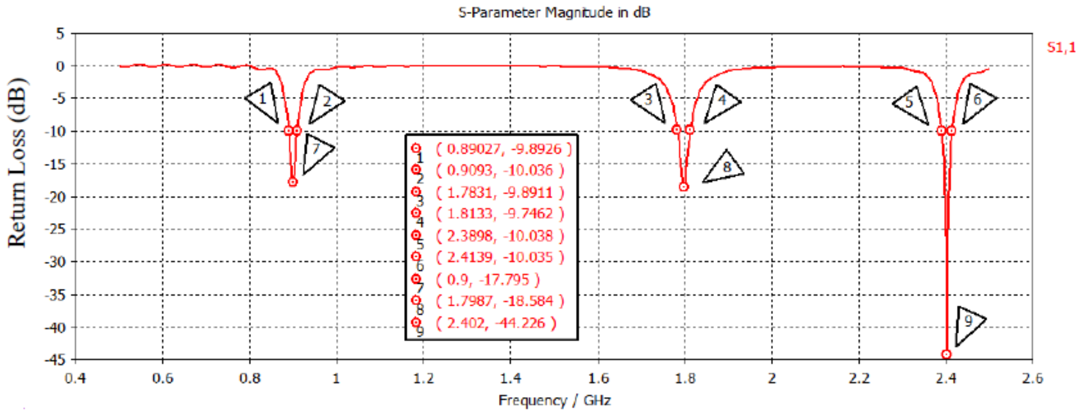

Figure 3. Simulated return loss of triple-band MPA

Table 4. The designed MPA layer specifications

Layers	Material	Height h_1,h_2	ε_r
Substrate #1	CEM-1 (lossy)	h_1= 0.765 mm	4.4
Substrate #2	Simulated dielectric material	h_2= 1.1 mm	1.2

Table 5. Designed MPA active, parasitic patches dimensions and positions

Patches	Type	positions	Width W	Length L
Patch #1	active	On Substrate #1	26 mm	39.8 mm
Patch #2	parasitic	On Substrate #2	47 mm	57.8 mm

The percent bandwidth is calculated using the following equation [20]:

$$Bw = \frac{f_h - f_l}{f_c} \times 100\%$$

where f_h and f_l are the upper and lower cut of frequencies of the band respectively at a return loss -10 dB and f_c is the center frequency of the operating band. The bandwidth at each band is given in Table 6.

Table 6. The triple-band designed MPA antenna

Band of	Resonance frequency (GHz)	RL (dB)	Bandwidth	VSWR
f_{r1}	0.9	-17.79	2.122	1.35
f_{r2}	1.798	-18.5	1.700	1.3
f_{r3}	2.402	-44.22	1.370	1.0

3. Results and Discussion

The S-parameters for the designed antenna is shown in Figure 3. As it is clear the center frequencies are 0.9GHz, 1.798GHz & 2.402GHz. this is the best of results of bandwidth, |S| parameter in dB and centers of three bands we obtained from design after studied the height of the substrate1 (h_1) and the height of substrate 2 (h_2) as shown in Table 1, Table 2 and Table 3 respectively. In Table 1 I change h_2 and remaining h_1=1mm, in Table 2 change h_1 and remain h_2= 1.4mm and in Table 3 I change h_1 with remaining $h_{2=}$ 1.1mm, the results are clear that the best value of (h_1 = 0.765mm) and (h_2=1.1mm). The overall antenna Smith chart for the designed antenna shown in Figure 4.

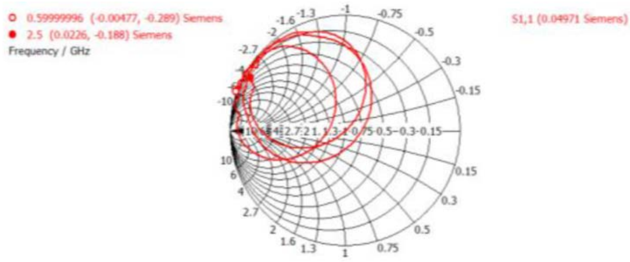

Figure 4. Smith chart for the designed antenna

4. Conclusions

A triple band dual layer patch antenna was designed. three center frequencies were 0.9GHz, 1.798GHz & 2.402GHz. The bandwidth for each frequency was 21 MHz, 17 MHz , 13.7MHz respectively. This work is rare up to now. I thing that it will be very useful for the mobile communication and the internet services. The dimension of the designed antenna was (60mm, 50mm). It is suitable for mobiles having an internet services. And the screen today for such a mobiles must be little bit large.

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