International Journal of Engineering Works
Kambohwell Publisher Enterprises
ISSN: 2409-2770 Vol. 3, Issue 12, PP. 87-91, December 2016
www.kwpublisher.com

Design and SAR Analysis of a Space Efficient Multiband Handset Antenna for Cellular Applications

[1]AsadRiaz, [2]Khadimullah Jan, [3]Syed waqar Shah, [4]Naeem Khan,[5]M. Kamran Shereen

***Abstract*—**In this paper a multiband miniaturized antenna is analyzed in close proximity to human head. The portable devices in modern Personal Communication System (PCS) uses frequency bands for 3G services in the range of 1.9-2.1 GHz. Most of the handheld devices used for the Wi-Fi applications is 2.45GHz. Integrating both features in a single miniaturized antenna normally degrades the performance. Hence the frequency of simulation selected for this design is 2.1 GHz which is the 3G range of frequency for cellular networks in Pakistan and 2.4 GHz Wi-Fi frequency. Planar Inverted F antenna is used for analysis which is extensively used as an optimal low profile, high efficiency antenna in modern mobile devices. The results are analyzed and compared for both the cases(with human head and without human head) with varying antenna dimensions. Specific Absorption Rate (SAR) is calculatedat design frequencies.After a detailed analysis, the antenna with optimal performance at required frequencies is selected.

***Keywords*—** Specific Absorption Rate, Finite Difference Time Domain,

I. INTRODUCTION

Mobile phones and other portable devices of communication are in extensive use nowadays. Due to their widespread use an extensive research has been carried out upon the interaction between the antenna and the human body. These type of research activities has a great importance with respect to the human health and the performance of antenna [1].

Some work has been performed in [4][5][6] to differentiate the ideal antenna impedance with respect to the antenna impedance in a real working environment. The main focus of this work is to analyze and measure the antenna impedance in the vicinity of the human body as well as to define arelationship between the antenna impedance, its performance relative to position of the human head. Another technique used is the wheeler cap technique which is used to measure the efficiency of an antenna. In [2] the wheeler cap technique is employed to measure the value of the whole body Specific Absorption Rate (SAR), which is further expanded and employed for the human head phantom. Using Finite Difference Time Domain (FDTD) method, the simulation concludes that it is an effective method.

In [2] an effective measurement of the 'whole body' SAR is suggested by the authors using wheeler cap technique. The method suggested is further applied to a phantom having the size of a human head. FDTD simulation is performedby analyzing the obtained results, which shows the utility and effectiveness of the proposed method

II. SPECIFIC ABSORBTION RATE (SAR) ABSORBTION

SAR is an effective parameter to find out the effect of the electromagnetic radiation while in a region of near field of the radio frequency (RF) source,[5]. The value of the SAR(W/kg) at a point of interest is calculated with respect to the 'electrical field'(V/m) impringing at that point Eq.(1)[6]:

$$\text{SAR}= \sigma\ |E|^2/\rho \quad (1)$$

where 'E' represents the 'RMS' value of an electric field in units of (V/m). Whereas the symbols of 'σ' and 'ρ' shows the conductivity into the human tissue as well as the value of mass density (kg/m3) respectively. The three major techniques uesd for the measurement of SAR are,(a) point measurement ,(b) whole body measurement of SAR and, (c) the surface SAR value distribution as described by[2]. The value of the point SAR is calculated by using the temperature sensor also called electric field measuring probe. The SAR value using a temperature sensor can be calculated using Eq.(2).

$$\text{SAR}= (\Delta T/\Delta t)\ [w\ /\ kg] \quad (2)$$

Where the symbols 'ΔT', 'Δt' shows the temperature elevation andthe heating time value respectively. r technique used for the calculation of SAR is surface SAR technique, which can be evaluated and measured by using a thermography camera. In addition to this, the 'whole body' SAR technique is used which represents the total amount of the absorption power in the targeted human body. One way of measuring it is by using the electric field probe whereby scanning it afterwards. [2]. The drawback of this method is that it is valid if the target is of liquid type as the probe can't scan in case of a target. One other technique is to measure the amount of Total rRadiated Power (TRP). Since the human body normally absorbs only a part of total radiated power. Hence the whole body SAR can be calculated by comparing the TRP and the total input power. This technique also helps in measuring the effiecincy of antenna but a large scale equipment is needed in order to measure the amount of TRP in the form of 3D-field-scanner. [2].

III. ANTENNA DESIGN

The antenna for our design is using the resonant frequencies of 3G and Wi-Fi bands. The material for substrate is FR-4 with dielectric constant (ϵ_r) value of 4.3. Since the designed antenna for a mobile phone must not be bulky hence the substrate height (h) has been kept to be 1.6mm for the proposed design.

In case of an efficient radiator antenna the radiator width (W) is calculated using Eq.(3).

$$W = \frac{c}{2f_0\sqrt{\frac{(\epsilon_r+1)}{2}}} \quad (3)$$

Where 'c' represents the velocity of light. In order to find the value of 'W' we have to put the values of ϵ_r, c,and resonant frequencyf_0 in the above equation.

The valueofeffectivedielectric constant can be calculated from Eq.(4).$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$ (4)

Eq.(4) gives the effective dielectric (ϵ_{reff}) value for a desired frequency of resonance.. Effective length of the patch antenna can be calculated using Eq.(5).

$$L = \frac{1}{2f_0\sqrt{\epsilon_{reff}}\sqrt{\epsilon_0\,\mu_0}} \quad (5)$$

Eq.(5) gives the effective length value when other parameters are given. But because of the effects introduced by the fringing effects the patch length keep on changing so that the patch actual length is shorted when compared with the patch effective length. The amount of length extension introduced due to the fringing effect can be calculated from the following formula.

$$\frac{\Delta L}{h} = 0.412\,\frac{(\epsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad (6)$$

Eq.(6) gives the value for$\Delta L$when other parameters are given.The patch actual length can be calculated by usingthe following equation

$$L = \frac{1}{2f_0\sqrt{\epsilon_{reff}}\sqrt{\epsilon_0\,\mu_0}} - 2\Delta L \quad (7)$$

IV. EXPERIMENTAL RESULTS

Modeling of different antennas has been performed both in the presence as well as in the absence of the human head. Simulation showschanges in different parameters like directivity, return loss, angular width and SAR values both in the presence as well as in the absence of the human head.

(A). Directivity

The antenna is simulated in the presence and absence of the human head model at resonant frequencies of 2.1GHz and 1.9GHz resulting in different acceptable values of directivity as shown in Fig.1-(a) and Fig.2-(b) respectively.

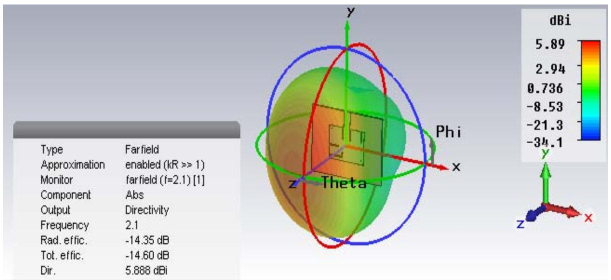

Fig. 1-(a): The Directivity of antenna at 2.1GHz in the absence of the human head**.**

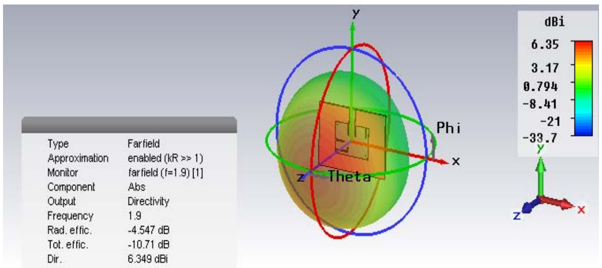

Fig.1-(b): TheDirectivity of antenna at 1.9GHz in the absence of thehuman head.

When antenna is tested in presence of human head phantom, the overall radiation is again examined.Simulation results shows that the directivity is slightly affected by the presence of human head as shown in Fig.2-(a) and Fig.2-(b).

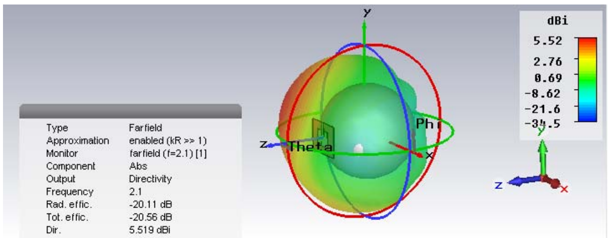

Fig. 2-(a): Directivity of antenna at 2.1GHz in the presence of the humanhead.

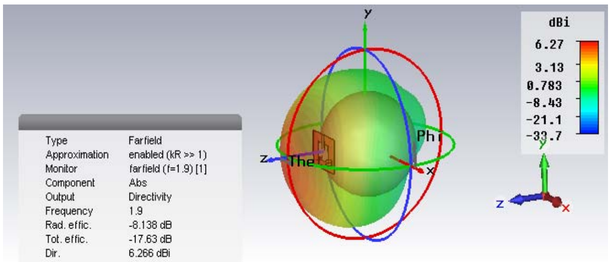

Fig. 2-(b): Directivity of antenna at 1.9GHz in the presence of the human head.

(B). Polar Plot of ***Radiation Pattern***

As shown in Fig.3-(a) and Fig.3-(b), the variation in the radiated power away of the antenna as a function of the direction is observed. These radiation patternat design frequenciesare plotted in absence of humanhead.Fig.3-(a): Radiation pattern at 2.1GHzin the absence of the human head.

ISSN: 2409-2770

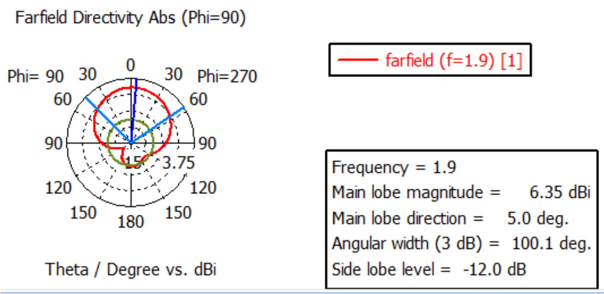

Fig.3-(b): Radiation pattern at 1.9GHz in the absence of the human head.

The angular width increased when simulated in the presence of human head as shown in Fig.4-(a), 4-(b):

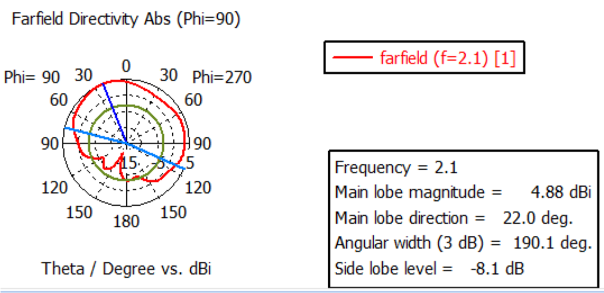

Fig.4-(a): Radiation pattern at 2.1GHzin the presence of the human head.

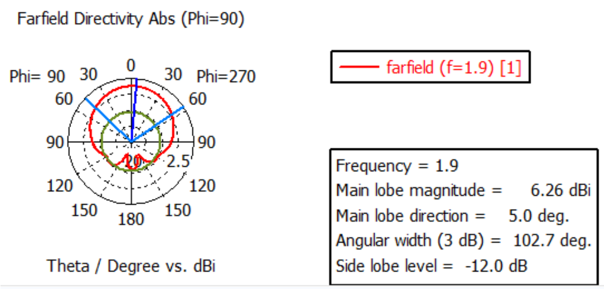

Fig.4-(b): Radiation pattern at 1.9GHzin the presence of the human head.

(C).S-Parameters/Return Loss

Return loss represents the loss in the signal power which is reflected back due to mismatch or discontinuity in the medium. The value of return loss increased in the presence of the human head. It is because some power is absorbed by the human head model. The value changes from -18.96 dBs and -23.07 dBs, at 1.9GHz and 2.1GHz, to -15.96 dBs and -20.67 dBs respectively as shown in the table below:

TABLE.1: EFFECT OF RETURN LOSS WITH AND WITHOUT HUMAN HEAD MODEL

Resonant Frequency	Return Loss in (dBs)	
	Without Human head	With human head
1.9GHz	-18.96	-15.96
2.1GHz	-23.07	-20.67
2.4GHz	-19.92	-17.92

Return loss graph at different frequency bands is shown the figurs below:

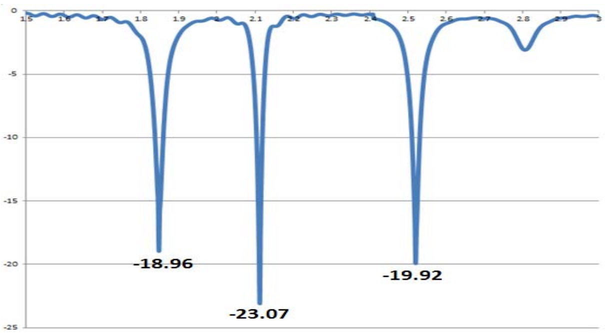

Fig.9: Return loss in absence of human head model

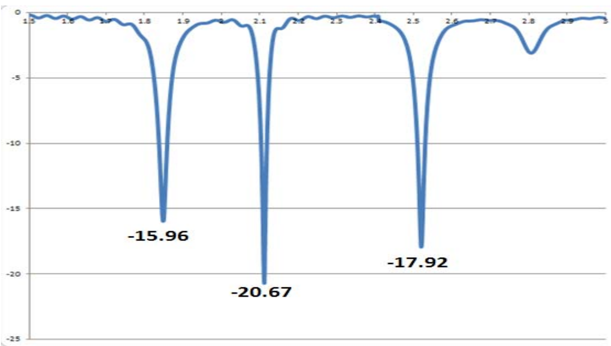

Fig.5: Return loss in presence of human head model

The figures shows clearly the increase in the value of return loss when antenna is simulated in the presence of the human head model.

(D). Effect on Bandwidth

The effect on the antenna bandwidth and upon the value of SAR is tabulated as below. The effect of the antenna chassis upon the different parameters of the antenna is shown. Both the value of SAR and the bandwidth is increased in the presence of the antenna chassis while the return loss value is decreased.

TABLE 2.EFFECT OF CHASSIS ON DIFFERENT PARAMETERS OF

Chassis Effect	Resonance frequency (GHz)	S11 Parameter (dBs)	B.W (MHz)	SAR (Watt/Kg) At 2.1GHz	SAR (Watt/Kg) At 1.9GHz
Antenna with chassis	f1=2.108	-23.95	20.45	0.01743	0.02245
	f2=2.462	-19.37	35.76		
	F3=1.848	-17.76	28.02		
Antenna without chassis	f1=2.112	-20.65	15.13	0.01375	0.01665
	f2=2.520	-17.90	20.42		
	F3=1.848	-15.95	21.40		

ANTENNA FOR DIFFERENT RESONANCE FREQUENCIES

(E). Effect of Substrate Width on SAR

The simulation is carried out with varying width of the antenna resulting in different values of the SAR in the Human head tissues. In our simulation the substrate width of the substrate is varied versus antenna feed line. It is seen that the antenna width has an inverse relationship with the surface current and the signal strength.

TABLE3:EFFECT OF WIDTH OF SUBSTRATE ON BANDWIDTH AND SAR OF ANTENNA

Antenna Width	**BW at 1.9GHz**	**BW at 2.1GHz**	**SAR (10g) at 2.1GHz**	**SAR(10g) at 1.9 GHz**
58.8	22.37	15.30	0.01375	0.02058
59.8	21.21	15.48	0.01375	0.01665
60.8	20	14.98	0.01296	0.0135
62	19.25	14.98	0.01063	0.009976
64	17.36	14.57	0.007143	0.007272
66	13.63	14.25	0.003662	0.00564

The surface current is measured in the units of Ampere per meter which implies that the current density has an inverse relationship with the area into which the wave impinges. The EM wave entering the feed line has the same direction as its direction in the substrate. Furthermore, the surface current is the current which is produced by the same EM wave upon the patch surface as well as in the substrate.

From the table it can be seen that by increasing the antenna width the value of both the bandwidth and SAR decreases at the frequencies of resonance. But the antenna width cannot be increased beyond certain limits because of the constraints imposed by the shift in the resonance frequencies and decreasing efficiency of the antenna. Here a shift in the frequency occurs to the left i.e. towards the lower frequencies. Hence this shift can be compensated by varying other antenna parameters such as length of the patch within the designing limits of the antenna.

(F). Constraint on Decreasing Length of Substrate

It is seen previously that the value of the SAR can be decreased increasing the width of the patch, but within certain limits. Here we shows how the SAR value changes as we change the length of the patch.

TABLE.4:EFFECT OF LENGTH OF SUBSTRATE ON BANDWIDTH AND SAR OF ANTENNA

Substrate Length	**BW At 1.9GHz**	**BW At 2.1GHz**	**SAR (10g) At 2.1GHZ**	**SAR (10g) 1.9 GHZ**
70.8	13.2	13.70	0.01658	0.1056
76.8	21.40	15.13	0.01375	0.01665
79.6	21	15.52	0.00625	0.006062
82	21.46	15.57	0.006175	0.003384
88	19.46	15.63	0.00210	0.8335
92	16.71	15.0	0.867e-03	0.594e-03

From the table it is clear that the value of SAR can be decreased be increasing the patch length. Again there is an upper limit i.e. reaching to the boundary of the patch but increasing the length beyond will cause the distance to be in negative direction resulting some part of the patch to be in the open air causing fringes in the field and thus increasing the SAR and hence the losses.

V. COMPARISON OF DIFFERENT ANTENNAS

The simulation is carried out by placing the antenna at a distance of 5mm from the human head model. Firstly the length of the substrate is varied while keeping the width and other parameters constant and by simulation found the value of SAR. Secondly the width of the antenna substrate is varies and SAR value calculated while keeping other parameters constant. Finally the SAR value of all the antennas was compared and the antenna with the lower value of SAR is selected.

Two antennas with different width and length values and its effect upon different antenna parameters are tabulated as below:

TABLE .5:EFFECT OF SUBSTRATE DIMENSIONS ON DIFFERENT PARAMETERS OF THE ANTENNAA AND ANTENNA B

	F_r (GHZ)	S11 dBs	BW (MHz)	SAR (10g)
Antenna A Wp=76.8, Lp=62 (mm)	1.8283	-13.51	18.85	0.009976
	2.09	-19.63	14.59	0.01063
	2.45	-18.60	20.00	0.00789
Antenna B Wp=81.6, Lp=59.8 (mm)	1.89	-22.76	21.69	0.003728
	2.1	-27.64	18.75	0.006595
	2.43	-17.18	18.88	0.01737

The table shows that antenna 'B' has better results over the antenna 'A' with respect to the return loss, bandwidth and SAR absorption in the vicinity of the human head model. Hence antenna 'B' is selected for our simulation with the mentioned substrate dimensions in the table. The SAR for antenna 'B' is visually shown in the figures below for different bands of 1.9GHz and 2.1GHz, whereas the antenna 'B' has a larger length and smaller width of the substrate compared to the antenna 'A'.

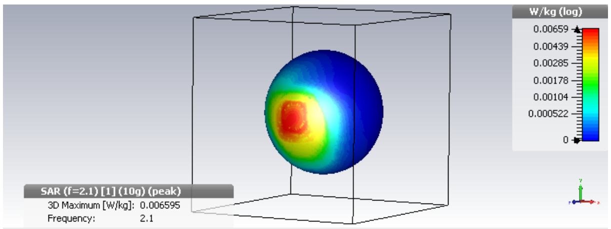

Fig. 6-
(a): SAR of antenna 'A' as modeled in human head at 2.1GHz

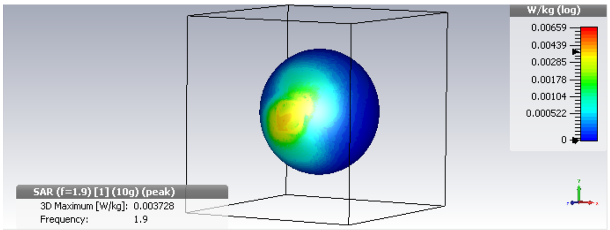

Fig. 6-(b)SAR of antenna 'B' as modeled in human head at 1.9GHz

VI. CONCLUSION AND FUTURE WORK

In our work the simulation is carried out to analyze the effect of the SAR upon the human head model. The antenna substrate b\width and length has been changed to analyze its effects upon different antenna parameters as well as on the SAR value in the vicinity of the human head. In future it would be shown how to compensate for the small frequency shifts that occur due changes in the antenna width, length or any other parameter. Also the effect of the SAR upon the human body would be analyzed at different frequency bands of 4G LTE, GPS and well as WiFibands.

REFERENCES

[1] Allen S G, (1996)Radiofrequency field measurements and hazard assessment, Journal of Radiological Protection, Vol11

[2] Arima T and Uno T, (2012)Whole body SAR measurement technique by using Wheeler Cap method for human head size phantom, ISAP2012, Nagoya, Japan

[3] Chan k,Cleveland R F, Means D L, (December, 1997)Evatuating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Edition 97- 01.

[4] Collin R E, (1966)Foundations for Microwave Engineering, McGraw-Hill

[5] Cripps S C, (2002)Advanced techniques in RF power amplifier design, Artech House

[6] Cripps S C, (1999)RF power amplifiers for wireless communications, Artech House

[7] Firrao E L, Annema A J, NautaB,(2004)Antenna Behavior in the Presence of Human Body,

[8] Riley D, Standards for the Management of Potential Health Risks of EM Fields, indexsar.com{Article on websitehttp://www.compliance-club.com/archive/old_archive/031124.htm }

[9] Sevgi L and Paker S, (March, 1998)FDTD Based RCS Calculations and Antenna Simulations, J. of Electronics &Commun , 52, No. 2, 65-75

First A. Author
[1]**Asad Riaz**is Lecturers at Department of Electrical Engineering UET, Peshawar Email: asadsherpao@hotmail.com Contact No.: 03339236246

[2]**Khadimullah Jan**is Lecturers at Department of Electrical Engineering UET, Peshawar

[3]**Syed waqar Shah**is Professors at Department of Electrical Engineering UET, Peshawar

[4]**Naeem Khan** is Assistant Professors at Department of Electrical Engineering UET, Peshawar

[5]**M. Kamran Shereen** is Lecturers at Department of Electrical Engineering UET, Peshawar

ISSN: 2409-2770