6.
PERFORMANCES STUDY OF PLANAR MONOPOLE ANTENNAS IN THE PRESENCE OF USER PROXIMITY

6.1 Introduction

Recently, significant efforts have been devoted to quantify the interaction between wireless terminals and biological tissues. Apart from possible health hazards, it is now apparent that the antenna′s proximity to the human body has a detrimental effect on the communication performance of the handset.

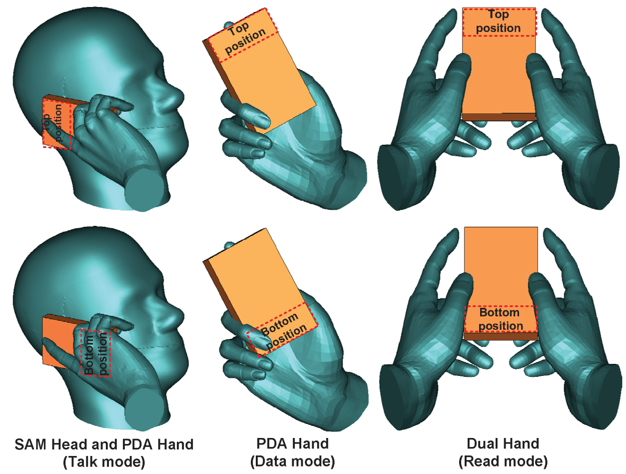
However, the amount of power received from mobile base station to mobile user depends on the antenna design and other factors of the mobile phone. Moreover, mobile phone generally used in close proximity of user's body, which reduces received power at the mobile terminal. The body loss (ratio of efficiency with and without user body) depends significantly on the antenna design for mobile phones [Pedersen *et al*. (1998), Nielsen *et al.* (2001)]. When mobile phone is placed near to the human body the amount of energy absorbed inside the human tissue, which can be estimated through specific absorption rate (SAR). Some of the authors' estimated the SAR characteristics of mobile phone antenna experimentally [Balzano *et al*. (1978a), Balzano *et al*. (1978b), Chatterjce *et al*. (1985), Nojima *et al*. (1994), Anderson and Joyner (1995)] and numerically [Jensen and Samii (1995), Gandhi (1995), Martens *et al*. (1995), Dimbylow (1993)]. User interaction (head, hand, and finger) also causes a change in the antenna driving point impedance that leads to a further, often significant, loss of performances [Balzano *et al*. (1975), King and Wong (1977), Toftgard *et al*. (1993)]. The researchers are making efforts to recover some of the performance losses from long back [Huang *et al*. (2005), Sjoblom and Sjoland (2005), Mingo *et al*. (2004), Ida *et al*. (2004)]. Certainly, the antenna parameters like antenna gain, radiation pattern, and input impedance are influenced in the close vicinity of the user. Some of the researchers investigated theoretically this effect by the moment method [Chuang (1994), Tsunekawa and Ando (1992)] and the finite difference time-domain method [Jensen and -Samii (1995)], [Toftgard *et al*.

(1993), Sato *et al.* (1997), Watanabe *et al.* (1996)]. With an increase in number of applications and the functions required for these applications, the interaction between the mobile phone antenna and the surrounding components is inevitable. However, the mobile terminal becomes smaller and thinner, which incorporates increased number of operating bands, improved transmit and receive performances. Thus one important challenge occurs in implementing multiband antennas within the confined space of the mobile handset. An additional challenge is the unavoidable interaction with the user.

In this Chapter, simulation study is carried out to analyze the effect of the user proximity on the performance of the antenna surrounded by mobile environment. In the present study, all the three planar monopole antennas referred as Antenna 1, Antenna 2, and Antenna 3 in this chapter are considered from Chapter 3, Chapter 4, and Chapter 5, respectively. There are three commonly used configurations i.e., talk mode, data mode, and read mode are considered for study point of view by placing the antenna at the top and bottom positions of the mobile circuit board. The *S*-parameters, radiation performances, SAR, and TRP calculations are studied.

6.2 Simulation Model

For the present study, all simulation setup models are created in CST MWS. The mobile phone (antenna with mobile environment) is placed near to the user's body in different configurations i.e., talk mode, data mode, and read mode. The position of mobile phone and user's body ["SAM head and PDA hand" (talk mode), "PDA hand" (data mode)] is in accordance with the cellular telecommunication industry association (CTIA) [CTIA Report]. There are no any standard available for read mode. For read mode both the hands are placed in common handling position. All the proposed antennas with mobile environment are kept at the top and bottom positions of the mobile circuit board. The simulation models with antenna positions are shown in Fig. 6.1. The dielectric properties of the human tissues are given in Table 6.1[Balzano *et al.* (1978b)].



(a) (b) (c)

Fig. 6.1: Model with antenna position (a) SAM head and PDA hand (Talk mode) (b) PDA hand (Data mode) (c) Dual hand (Read mode).

Table 6.1: Dielectric properties of the human head and hand tissues.

Frequency (GHz)	Human Head Tissue		Human Hand Tissue	
	ε	σ (S/m)	ε	σ (S/m)
0.75	42.5	0.88	32.2	0.51
1.8	40	1.4	27	0.99
1.9	40	1.4	26.7	1.04
2.1	39.8	1.49	26.3	1.14
2.45	39.2	1.8	25.7	1.32
3.5	37.9	2.92	24.2	1.89

6.3 Results and Discussion

All the simulations are carried out in CST MWS. Performances study of all the antennas (Antenna 1, Antenna 2, and Antenna 3) are carried out in all three configurations i.e., talk mode, data mode, and read mode along with free space. The effect of user proximity on the antenna performances is studied for top as well as bottom located antenna and discussed in the following section.

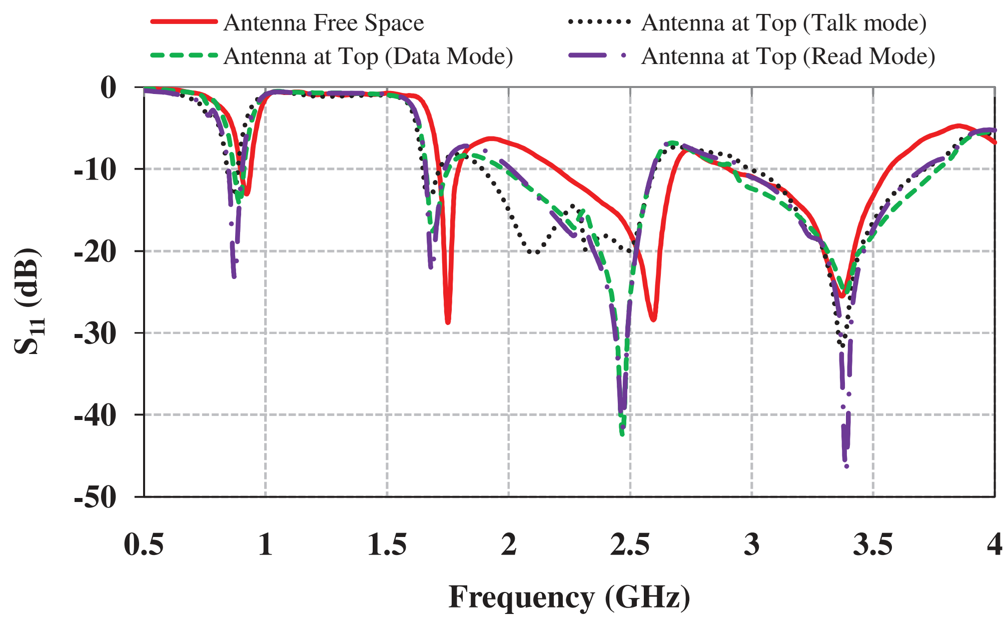
6.3.1 S-parameters Analysis

The variation of *S*-parameters in the user proximity for Antenna 1 is shown in Fig. 6.2. Fig. 6.2 (a) shows the variation of *S*-parameters when Antenna 1 is placed at the top of the mobile circuit board. It is observed that impedance matching is improved throughout the operating bands in the presence of user's body (in all three cases). The resonant frequency is also shifted towards lower side in both the bands i.e. lower and higher operating bands. When Antenna 1 is placed at the bottom of the mobile circuit board, similar phenomenon is observed (Fig. 6.2). Still, in both the cases proposed antenna covers the desired operating bands.

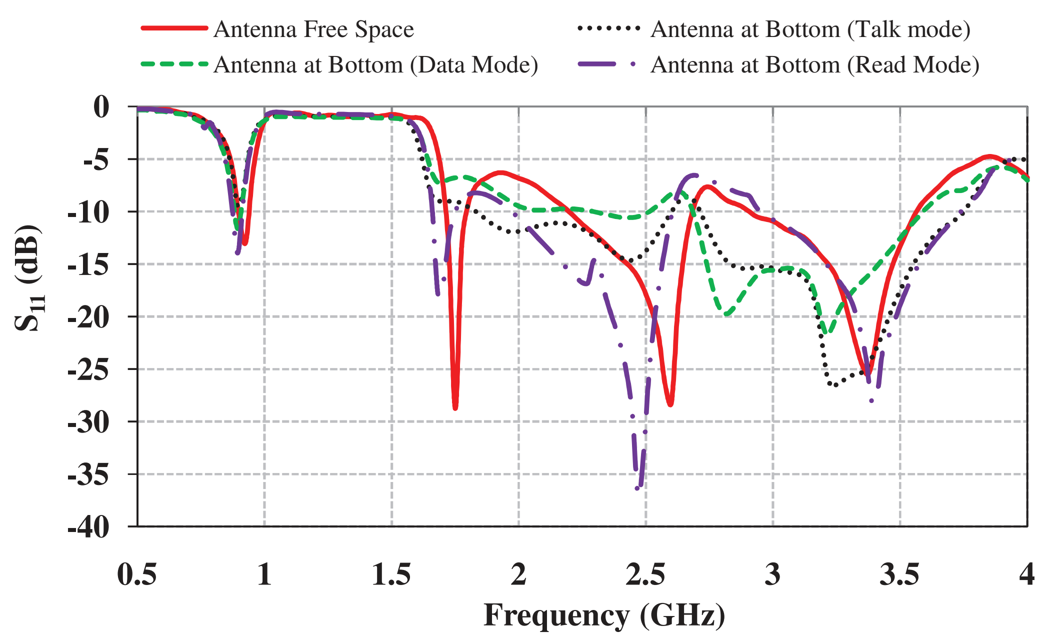
Similarly, the effect of user body on *S*-parameters of Antenna 2 is shown in Fig. 6.3. The variation of *S*-parameter is shown in Fig. 6.3(a), when Antenna 2 is placed at the top position of the mobile circuit board. It is observed that all the resonant frequency decreases and impedance matching got improved over all the operating bands. The desired operating bands are covers in all the cases. When Antenna 2 is placed at the bottom of the mobile circuit board, the effect on *S*-parameters are shown in Fig. 6.3(b). It is observed that at lower frequency bands the resonant frequency decreases and impedance matching got disturbed due to which the desired operating bands of communication is not covered whereas at higher frequency side resonant frequency decreases and impedance matching improved for all three cases. The desired operating bands can be achieved by detuned the some of the shape parameters of antenna in the presence of user proximity.

The variation of *S*-parameter of Antenna 3 in the presence of user body is shown in Fig. 6.4. Fig. 6.4 (a) shows the variation of *S*-parameters when antenna is placed at the top of the mobile circuit board whereas Fig. 6.4(b) illustrated the *S*-parameters when antenna is placed at the bottom of the mobile circuit board. It is observed that top located antenna covered the desired operating bands in the talk mode and data mode while slightly impedance matching is disturbed at the 2.5 GHz and 3.5 GHz frequency for read mode. In the case of read mode detuning of the shape parameters of Antenna 3 is required. In the case of bottom located antenna, *S*-parameters are slightly disturbed at lower frequency side for talk mode and all others cases show good impedance matching and covered the same frequency bands as of free space.

From the discussion of *S*-parameters of all three antennas it is observed that in most of the cases planar monopole antennas covered the desired operating band but in some of the cases the antenna shape parameters need to be detuned to achieve the desired operating bands.

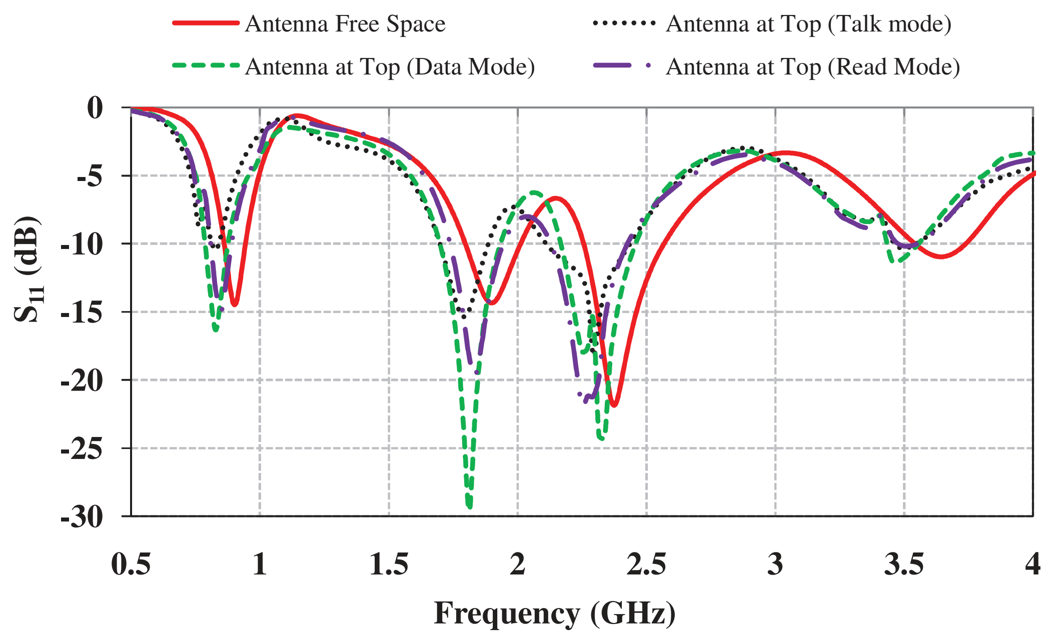


(a)

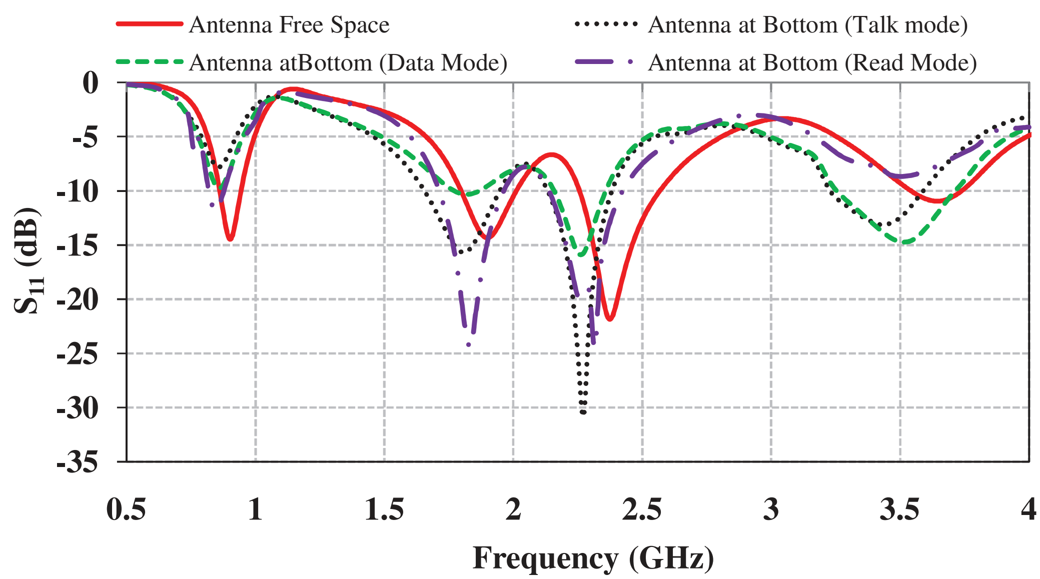


(b)

Fig. 6.2: Variation of *S*-parameters of Antenna 1 in user proximity; (a) Antenna at top position, (b) Antenna at bottom position.

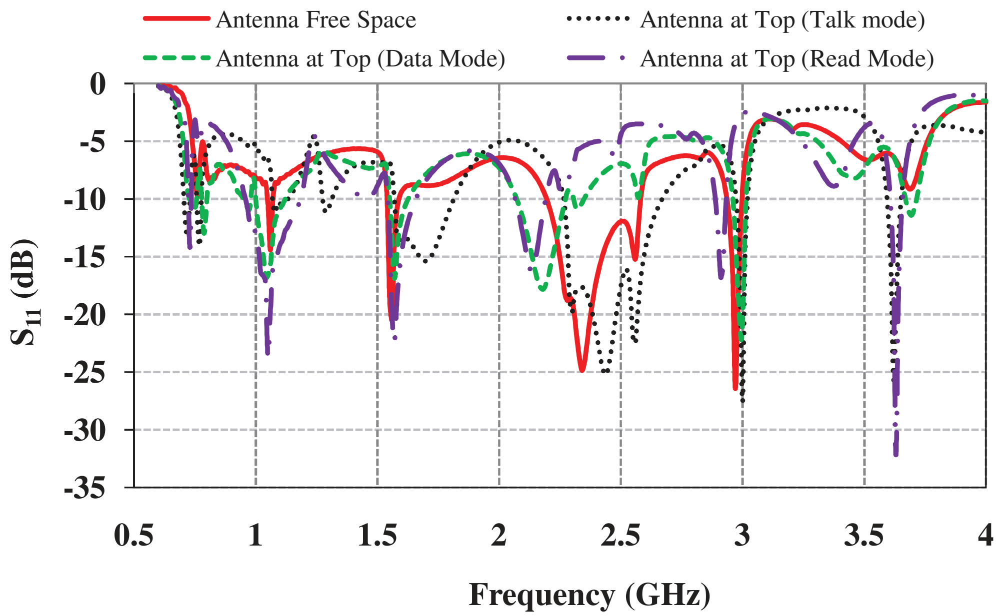


(a)

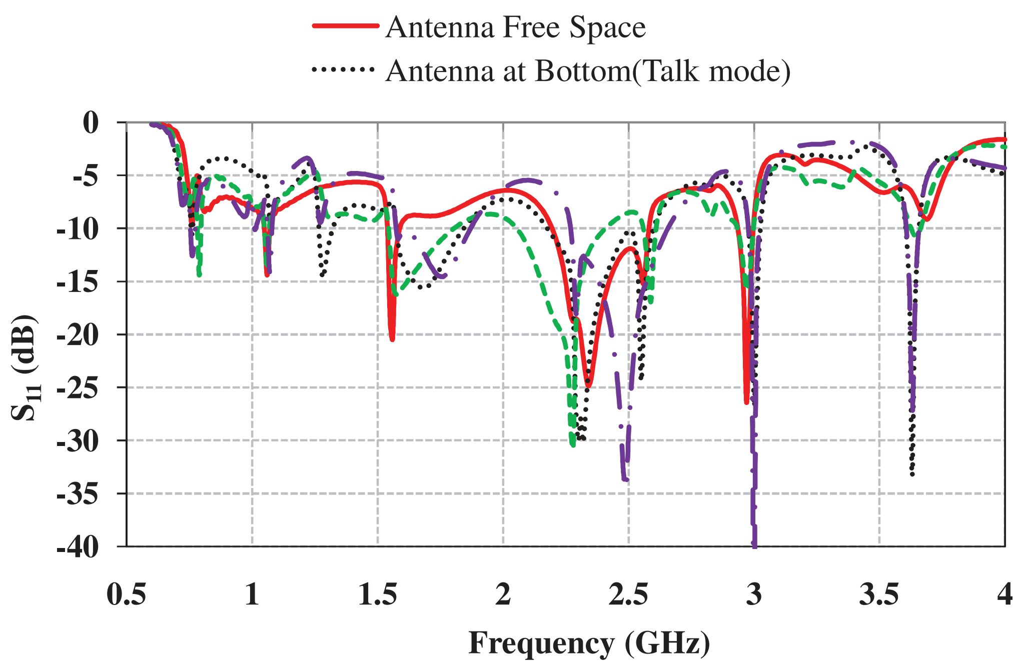


(b)

Fig. 6.3: Variation of *S*-parameters of Antenna 2 in user proximity; (a) Antenna at top position, (b) Antenna at bottom position.



(a)



(b)

Fig. 6.4: Variation of *S*-parameters of Antenna 3 in user proximity; (a) Antenna at top position, (b) Antenna at bottom position.

6.3.2 Peak Realized Gain Analysis

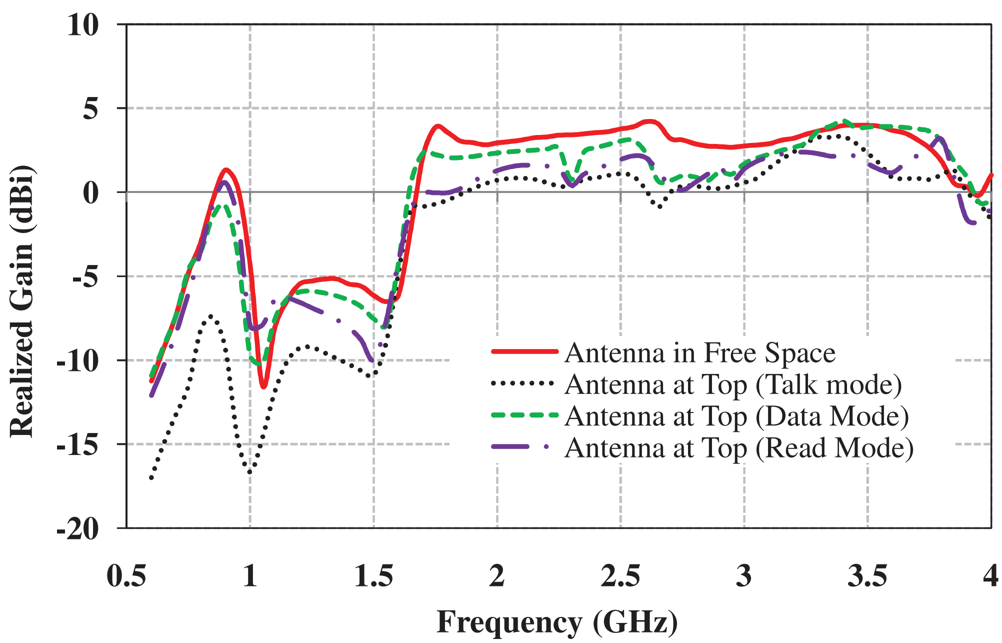
The variation of peak realized gain of Antenna 1, Antenna2, and Antenna 3 in the presence of user proximity for top as well as bottom located antenna is shown in Figs. 6.5, 6.6, 6.7, respectively. It is observed that top located antenna shows better gain compare to the bottom located antenna element. This is because of the thumb or tip of the little finger which is nearest to the bottom located antenna elements. Due to nearest body area larger reflection is occurred from human body leads losses resulting in lower peak realized gain for bottom located antenna as compare to the top located antenna elements. Due to which talk mode case shows minimum gain compare to the other configuration.

From the discussion of peak realized gain of three different antennas, it can be concluded that user body bring losses and decrement in gain is appeared for top and bottom placed antenna over mobile circuit board. In the case of mobile antenna higher gain is not required. Therefore, it is sufficient level of gain which is obtained in the presence of user's body for satisfactory operation of mobile handset antennas.

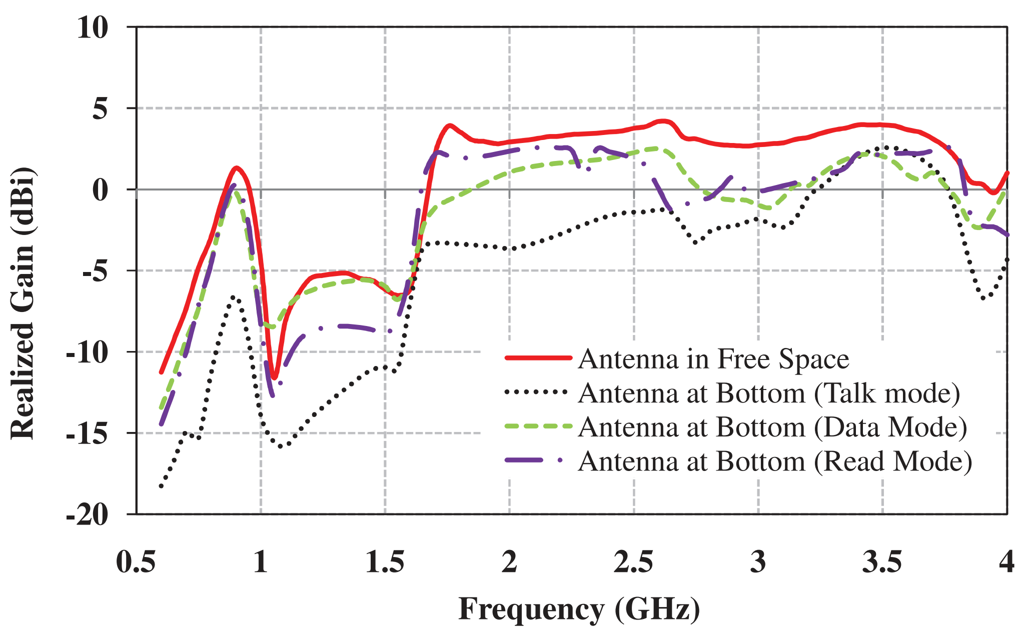
6.3.3 Total Antenna Efficiency Analysis

The total radiation efficiency is calculated by considering the mismatch losses because it is important factor during the calculation of efficiency. The user's body provides maximum reflection due to which the radiation efficiency decreased rapidly in the presence of user's body.

The variation of total antenna efficiency for Antenna 1, Antenna 2, and Antenna 3 in the presence of user's proximity is shown in Fig. 6.8, 6.9, 6.10 for top and bottom located antenna elements. It is observed that when user's body comes into picture means when user uses mobile phone in actual platform, the total antenna efficiency decreases sharply either antenna placed at top or bottom position of the mobile circuit board. The bottom position antenna shows lower efficiency than top located antenna elements because the maximum area are covered by user body which leads to maximum reflection losses for bottom positioned antenna. The order of losses in the presence of user body is talk mode, read mode, and data mode. Similarly, total antenna efficiency is occurred in same order. It means that the maximum total antenna efficiency is obtained for data mode among all three different user cases.

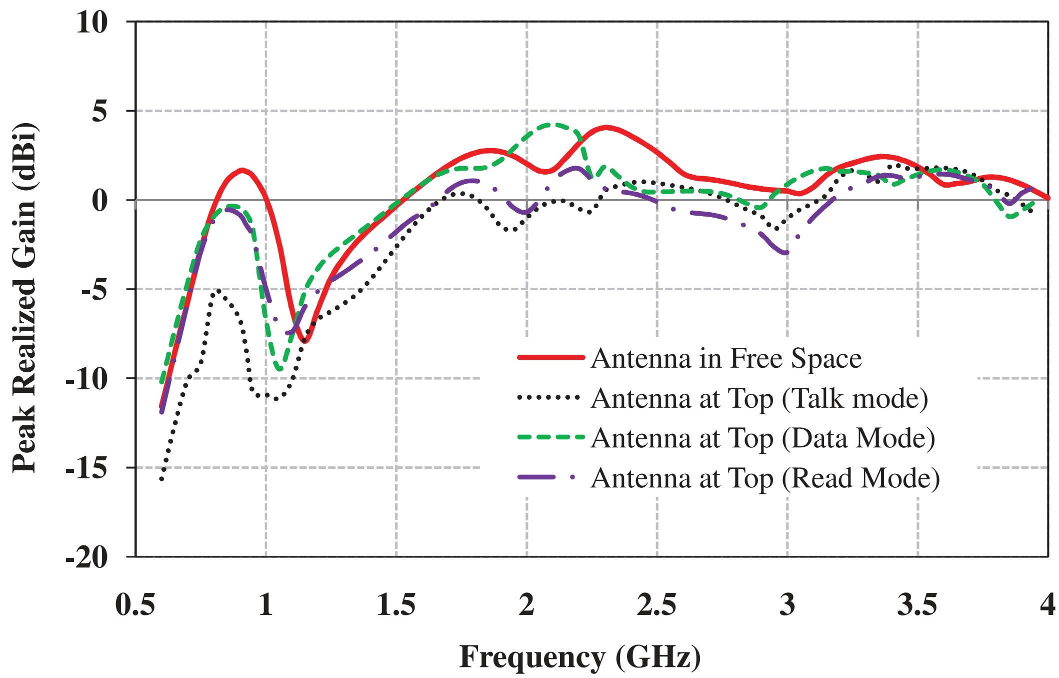


(a)

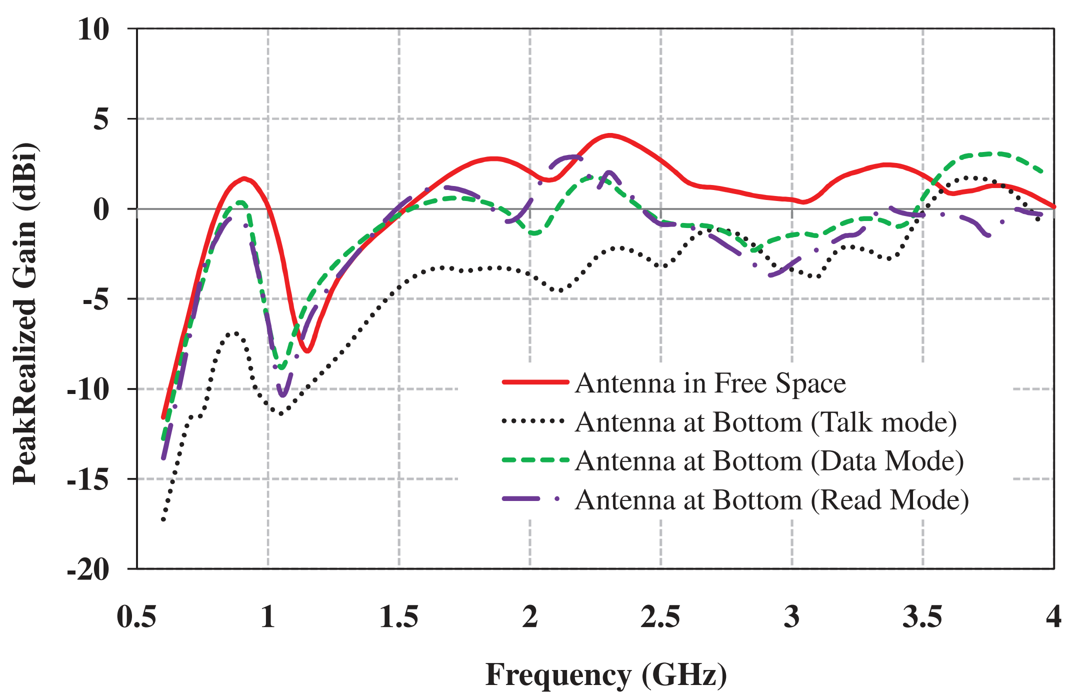


(b)

Fig. 6.5: Variation of peak realized gain of Antenna 1 in user proximity; (a) Antenna at top position and (b) Antenna at bottom position.



(a)



(b)

Fig. 6.6: Variation of peak realized gain of Antenna 2 in user proximity; (a) Antenna at top position and (b) Antenna at bottom position.

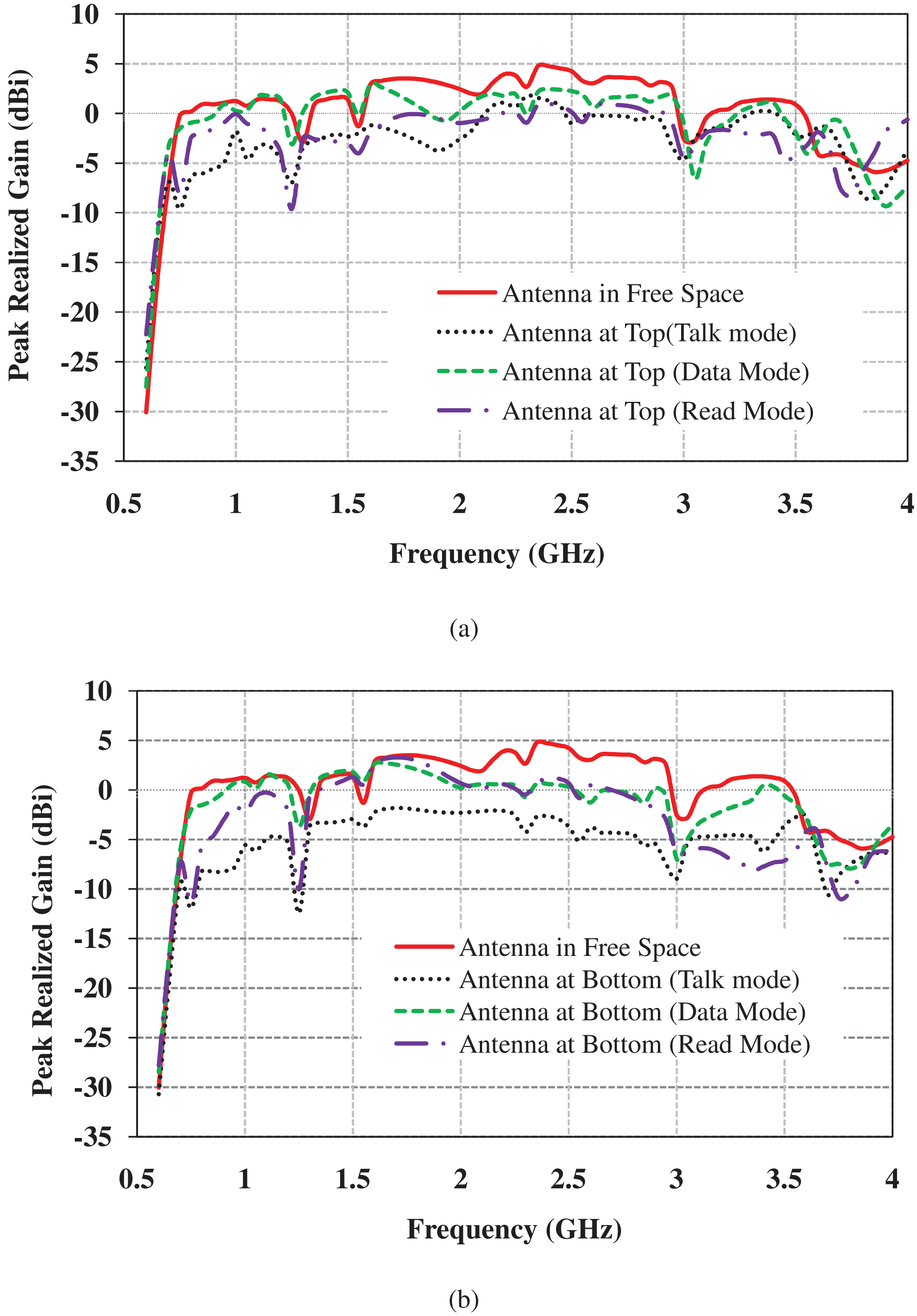
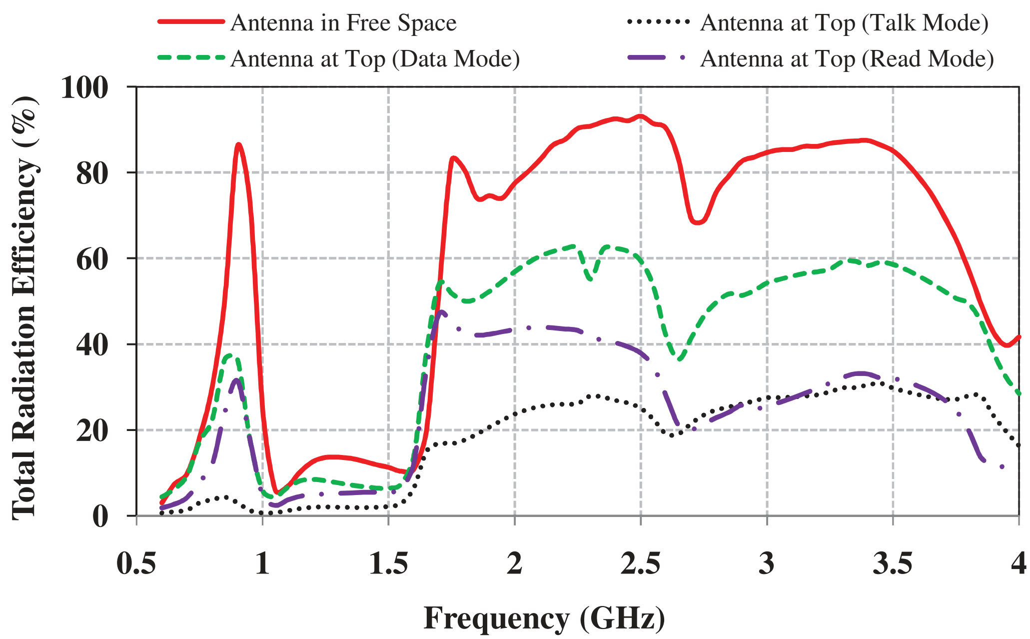
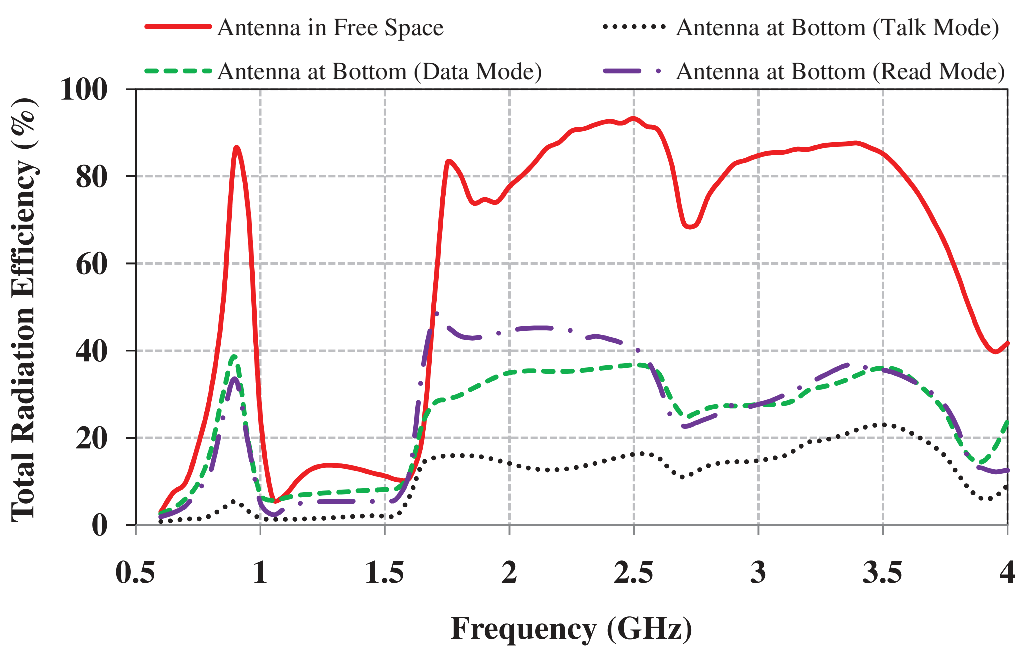


Fig. 6.7: Variation of peak realized gain of Antenna 3 in user proximity; (a) Antenna at top position and (b) Antenna at bottom position.

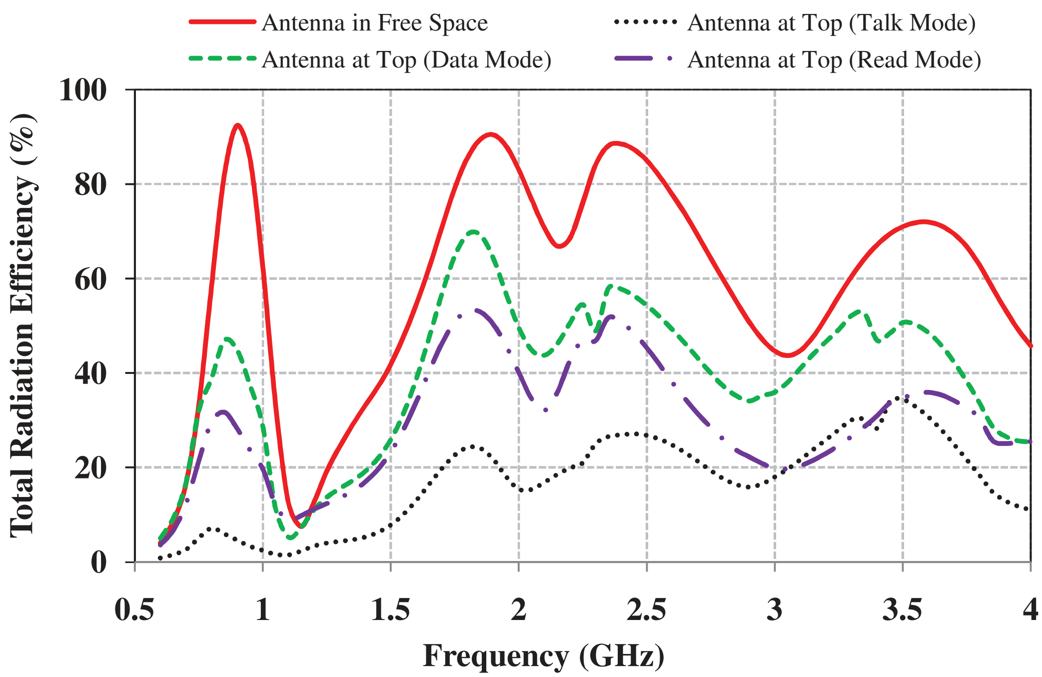


(a)

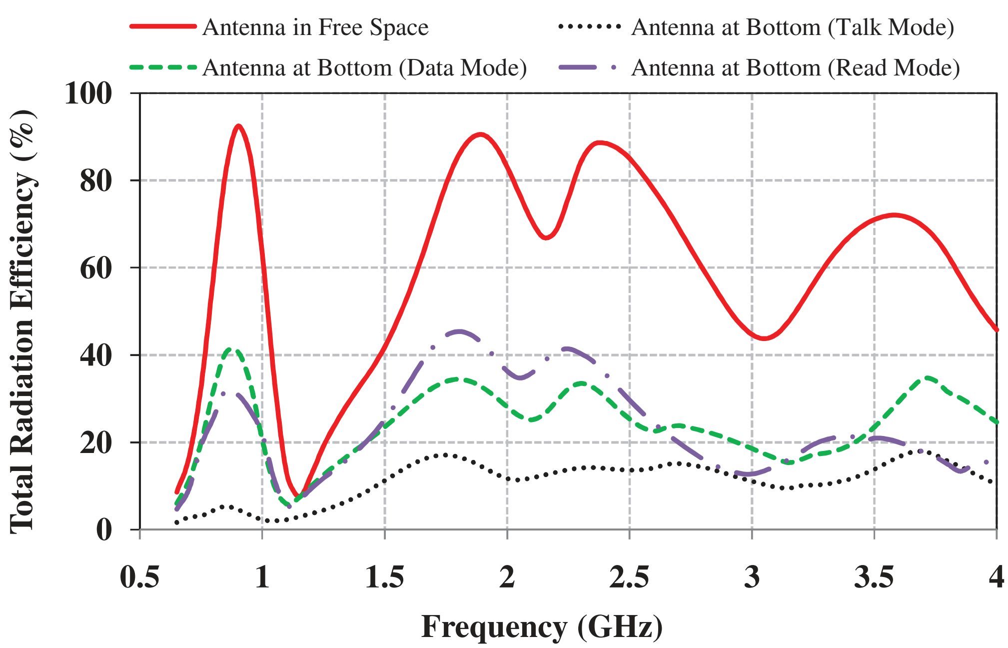


(b)

Fig. 6.8: Variation of total radiation efficiency of Antenna 1 in user proximity; (a) Antenna at top position and (b) Antenna at bottom position.

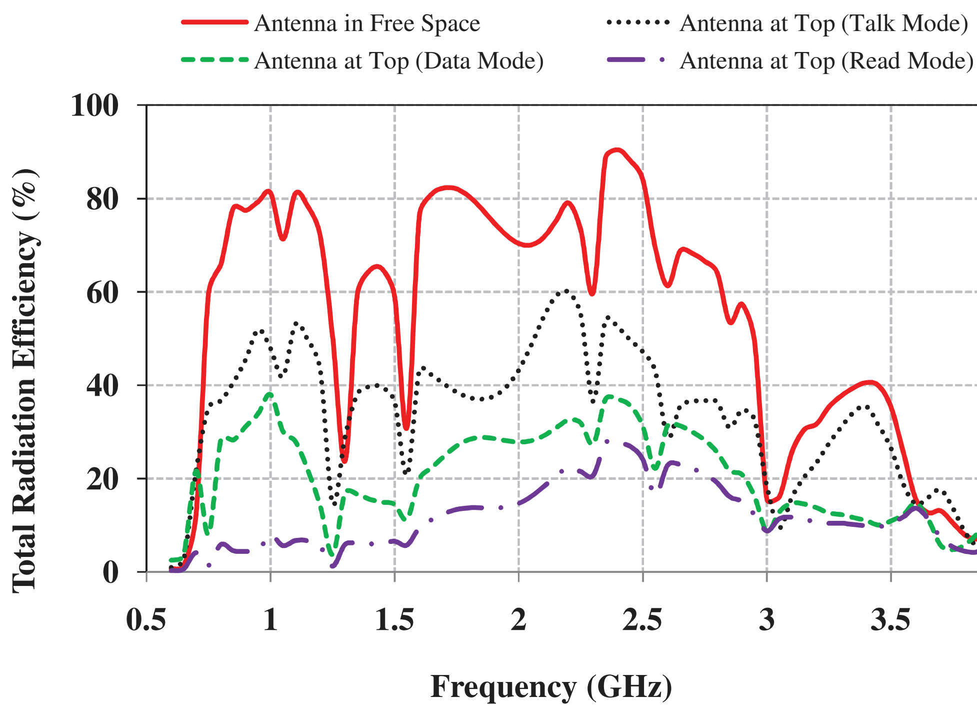


(a)

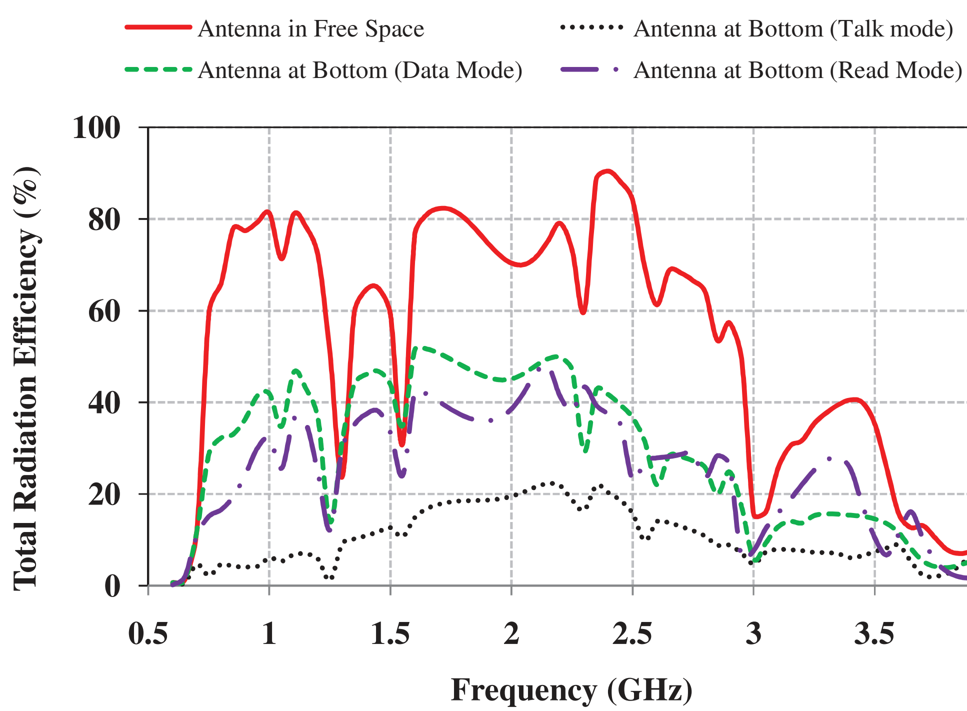


(b)

Fig. 6.9: Variation of total radiation efficiency of Antenna 2 in user proximity; (a) Antenna at top position and (b) Antenna at bottom position.



(a)



(b)

Fig. 6.10: Variation of total radiation efficiency of Antenna 3 in user proximity; (a) Antenna at top position and (b) Antenna at bottom position.

6.3.4 Specific Absorption Rate (SAR) Analysis

The SAR simulation model based on CST MWS and values of SAR is calculated for 1-g and 10-g head tissues. The human head phantom model available in CST MWS is considered in this study which consists of two layers namely fluid and shell. Fluid is confined in the shell which is outer layer. The dielectric properties of the fluid and shell are considered from CTIA. The testing power for SAR calculation is sets according to the CTIA standard. The calculated values of SAR are given in the Table 6.2. All the three different antennas are taken into account for study purpose which covers different frequency band at lower and higher frequency side. However, it has already been discussed at lower frequency side the bandwidth increases as go from Antenna 1 to Antenna 3. In view of this Table 6.2 shows values of SAR at different frequency band according to available operating bands of antennas. The calculated values of SAR for all three antennas are well below the standard limit i.e. European standard (<2W/kg over 10 g of tisue) and American Standard (<1.6W/kg over 1 g of tissue) [Durney *et al.* (1986)]. Form the Table 6.2, it is clearly observed that Antenna 3 shows lower SAR value as compare to the Antenna 1 and Antenna 2 because in the case of Antenna 3 meandered parasitic element is placed on the back side of the main radiation element. This parasitic element helps to enhance the bandwidth and also act as reflector due to which the radiated power from antenna is reflected back and less power is penetrated inside the human tissue which leads lower SAR values for Antenna 3.

Table 6.2: SAR values of different antennas on SAM head.

Frequency (GHz)	Input Power (dBm)	Antenna 1		Antenna 2		Antenna 3	
		SAR over 1g (W/kg)	SAR over 10g (W/kg)	SAR over 1g (W/kg)	SAR over 10g (W/kg)	SAR over 1g (W/kg)	SAR over 10g (W/kg)
0.77	21	---------	--------	---------	---------	0.0702	0.055
0.925	24	1.16	0.897	1.19	0.876	0.535	0.40
1.8	21	NA	NA	NA	NA	0.422	0.279
1.925	21	0.534	0.341	0.72	0.462	--------	--------
2.45	21	0.697	0.409	0.457	0.272	0.383	0.213
3.5	21	0.406	0.194	0.257	0.152	0.0725	0.03

6.3.5 Total Radiated Power (TRP) Analysis

The TRP is calculated for the all three antenna (Antenna 1, Antenna 2, and Antenna 3) to check the operation of all three antennas in the presence of user's body. The calculated values of TRP for Antenna 1, Antenna 2, and Antenna 3 are given in Table 6.3, Table 6.4, and Table 6.5, respectively. The TRP is directly related to the total antenna efficiency. It is observed that maximum power is radiated in free space i.e., more than 25dBm because there is no any scattering objects are present around the antenna element. Among all three case of user proximity for all three antennas, talk mode poses maximum reflection losses and lower efficiency which leads lower TRP values but still better than 12dBm.

Table 6.3: Calculated values of TRP of Antenna 1 in user proximity.

Frequency (GHz)		TRP (Antenna Top)	TRP (Antenna Bottom)
0.9	Free space	26.3207	26.3207
	Talk Mode	11.7852	14.3263
	Data Mode	22.6021	22.8298
	Read Mode	23.2306	22.2362
1.9	Free space	25.5690	25.5690
	Talk Mode	20.1434	18.9035
	Data Mode	24.1765	22.1356
	Read Mode	23.1552	23.3508
2.45	Free space	26.5812	26.5812
	Talk Mode	21.1832	18.9428
	Data Mode	24.8836	22.6153
	Read Mode	23.7669	23.2048
3.5	Free space	26.1622	26.1622
	Talk Mode	21.7273	20.6104
	Data Mode	24.6670	22.5566
	Read Mode	24.0758	22.5009

Table 6.4: Calculated values of TRP of Antenna 2 in user proximity.

Frequency (GHz)		TRP (Antenna Top)	TRP (Antenna Bottom)
0.9	Free space	26.6475	26.6475
	Talk Mode	13.6559	13.5992
	Data Mode	23.5075	23.0879
	Read Mode	21.4963	21.8826
1.9	Free space	26.5525	26.5525
	Talk Mode	20.3742	18.5465
	Data Mode	25.0755	22.1137
	Read Mode	24.0085	23.2802
2.45	Free space	26.4009	26.4009
	Talk Mode	21.3231	18.3741
	Data Mode	24.4969	21.4248
	Read Mode	23.8428	22.1253
3.5	Free space	25.5024	25.5024
	Talk Mode	22.3587	18.3845
	Data Mode	24.03845	20.7011
	Read Mode	22.39293	20.1991

Table 6.5: Calculated values of TRP of Antenna 3 in user proximity.

Frequency (GHz)		TRP (Antenna Top)	TRP (Antenna Bottom)
0.9	Free space	25.8804	25.8804
	Talk Mode	14.8605	13.1152
	Data Mode	23.5742	22.5980
	Read Mode	21.9279	20.8346
1.9	Free space	25.7321	25.7321
	Talk Mode	17.9033	19.7018
	Data Mode	22.7514	23.5652
	Read Mode	21.5494	22.5466
2.45	Free space	26.4405	26.4405
	Talk Mode	20.6176	19.6844
	Data Mode	23.9525	22.9489
	Read Mode	22.5049	22.4495
3.5	Free space	22.4727	22.4727
	Talk Mode	19.1172	15.7037
	Data Mode	21.2249	18.6286
	Read Mode	17.3761	17.2093

6.4 Discussions

From the above discussions about *S*-parameters, peak realized gain, total antenna efficiency, SAR, and TRP of all three antennas (Antenna 1, Antenna 2, and Antenna 3), it is confirm that all three antennas are operated in the respective operating bands with good impedance matching. In the case of Antenna 2, some impedance matching is disturbed and not covered the desired operating bands so it is required to detune the shape parameters in the presence of user proximity. The calculated values of SAR for all three antennas satisfy the defined standard and TRP is also more than the required limit.

After analyzing the performance study of the proposed antennas in user proximity, the entire investigations carried out in various chapters is summarized in the last chapter of summary and conclusion which is given in the following chapter seven.