Internal Antennas Performance Evaluation in Mobile Handsets

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ABSTRACT
The performance of two internal antennas namely Planar Inverted F Antenna (PIFA) and Inverted F Antenna (IFA) is evaluated in this paper. The effects of radio frequency on human exposure to these antennas are analyzed. Human phantom is designed with dielectric properties and the levels of absorption in terms of 1g SAR (Specific Absorption Rate) values are calculated. Results show that PIFA outperforms IFA in terms of SAR, efficiency, gain, backward radiation, return loss characteristics. All numerical modelling are performed using FEKO Suite 5.5 software which uses MOM for computation.

General Terms
Valuating the performance of two Antennas

Keywords
PIFA, IFA, SAR, Gain, Efficiency

1. INTRODUCTION
Experiments conducted so far have been based on external antennas such as monopole, helical, whip and rod. These antennas have many drawbacks in terms of its size, radiation, shielding and flexibility. Nowadays mobile phone manufacturers like Nokia, Sony-Ericsson, Motorola, and Apple go for for internal antennas that offer better shielding, low profile and increased antenna performance [1]. This paper discusses the design of two such internal antennas namely PIFA and IFA. Antenna parameters such as scattering parameter, efficiency, gain, radiation pattern and Specific Absorption Rate are reported for the surveyed handsets. Interaction of these antennas with the homogeneous head model designed with tissue properties are determined by using the parameter called SAR (Specific Absorption Rate).

Radio frequency (RF) exposure is one of the main concerns of using a mobile phone. Although the radio frequency emissions of wireless handsets are classified as non-ionising they are able to transfer energy in the form of heat to any absorptive materials [3]. Therefore the human tissue that has high conductivity absorbs the Electromagnetic radiations that are coming from the mobile phones and hence alters the performance of the antenna [5]. Earlier, the design included variety of factors such as gain, bandwidth and polarization. However there exists recent stress on size reduction, providing increased power efficiency and meeting Federal Communication Commission (FCC) requirements. Two additional elements such as antenna efficiency and control of Specific Absorption Rate (SAR) have come up in equal importance with the traditional design parameters [6]. The proposed antenna operates in GSM band (900 and 1800 MHz)

The Planar Inverted F Antenna (PIFA) has been an appealing antenna structure in SAR reduction for mobile handset application due to its relatively low profile, simple structure, and reasonable antenna performance [8].PIFA is also attractive for designing multi-band antennas [9].IFA is considered in this paper because of its simple structure and size. IFA performs better than the external antennas and it is widely adopted in mobile technology [11].Comparative study is drawn between these two antennas in terms of SAR values, gain, efficiency and backward radiation. It is found that the Planar Inverted F Antenna has less backward radiation, low SAR values, high efficiency and gain values both at 900MHz and 1800MHz. The drawback of PIFA is its narrow bandwidth. This can be overcome by introducing slots in the radiating patch of the antenna [12].

2. SAR
SAR is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg).The SAR (W/kg) at any point in the model can be determined from the calculated electric field E (V/m) and it is given by the following equation

$$\text{SAR}=\frac{\sigma E^2}{\rho}\ \text{W/Kg} \qquad (1)$$

Where E is the internal electric field (V/m), SAR is the Specific Absorption Rate (W/kg), σ is the conductivity (S/m) of the tissue and ρ is the mass density (kg/m3).SAR values can be expressed over 1g or 10g mass and it is called as 1 g or 10 g spatial average SAR.

The SAR limit specified in IEEE C 95.1: 1999 is 1.6W/Kg in a SAR1g averaging mass [13]. In this paper 1g SAR is calculated for the two internal antennas. It is important for a good antenna to have low SAR values. A SAR value depends on the position of the head, radiation patterns of the antenna, radiated power and antenna types [14].

3. ANTENNA STRUCTURE
3.1 Planar Inverted F Antenna (PIFA)
PIFA (Planar Inverted F Antenna) is generally considered to be a microstrip antenna on a finite ground plane. In this paper the PIFA is more strictly defined as a microstrip antenna with a ground connection. The size of PIFA can be reduced with appropriate loading in the form of dielectrics, inductive-slot loading and capacitive loading. PIFAs can easily be made into multiband antennas by creating separate current paths on the antenna, through the use of slots [16]. PIFA is resonant at quarter wavelength due to the shorting pin at the end. The proposed PIFA is shown in Figure 1.
The feed is placed between the open and shorted end, and the position of the feed controls the input impedance. It has reduced backward radiation towards the user's head, minimizing the electromagnetic wave power absorption (SAR) and enhanced antenna performance. The design values

of PIFA operating at two frequencies (900 MHz and 1800 MHz) are given in Table 1.

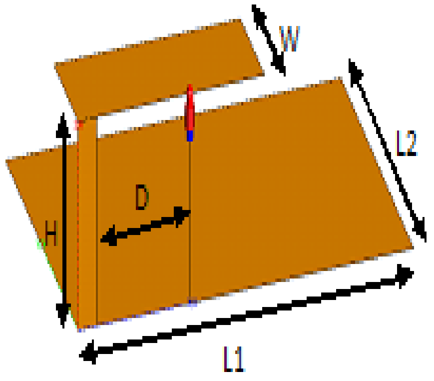

Figure 1.PIFA antenna

Table 1. PIFA dimensions

Parameter	For 900 MHz (meters)	For 1800MHz (meters)
L1	.09	.072
L2	.06	.068
H	.03	.01425
D	.013	.0125
W	.003	.005

3.2 Inverted F Antenna [IFA]

The Inverted F Antenna (IFA) shown in Figure 2 typically consists of a rectangular planar element located above a ground plane, a short circuiting pin and a feed for the planar element. IFA is a variant of the monopole where the top section has been folded down so as to be parallel with the ground plane. By doing this, the height of the antenna is reduced, while maintaining the resonant trace length.

The ground plane of the antenna plays a significant role in its operation. Excitation of currents in the pin causes the currents to be excited in the ground plane. The electromagnetic field is formed by the interaction of the IFA and an image of itself below the ground plane. Its behavior as a perfect energy reflector is consistent only when the ground plane is infinite or very much larger in its dimensions than the monopole itself. The antenna ground combination will behave as an asymmetric dipole. The design values of IFA are shown in Table2.

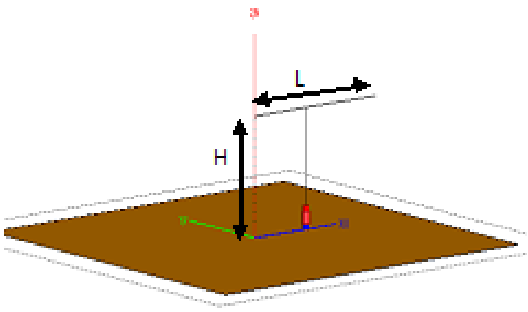

Figure 2. IFA antenna

Table 2. IFA dimensions

Parameter	For 900 MHz (meters)	For 1800MHz (meters)
L	.08	.06
H	.03	.01125

4. HUMAN HEAD MODEL

The specific absorption rate experiments with real human bodies are strictly limited and highly dangerous to an extent it may lead to fatal consequences. So it is decided to investigate the possible impacts with numerical field calculations using several numerical models of human body. The human head model of about 0.08m radius is simulated in this paper with a muscle equivalent material.

The dielectric permittivity(ε) of human head at 900 MHz and 1800 MHz are 45.8 and 43.5. The conductivity σ (S/m) of human head at these two frequencies is 0.77 and 1.15. The mass density is 1030(kg/m^3) for both the frequencies. The simulated head model is shown in Figure 3.

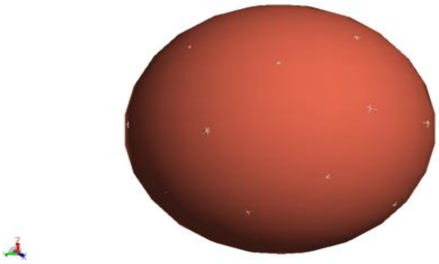

Figure 3. Human head model

5. RESULTS AND DISCUSSIONS

5.1. Return Loss

Return loss can be found using scattering parameters. Scattering parameters describes the electrical behavior of the system that undergoes various steady state stimuli by the electrical signals. The width of the short circuit plate in PIFA determines the resonant frequency. The resonant frequency decreases with the decrease in width of the short circuit plate. The height of the folded parallel section determines the resonant frequency in IFA.

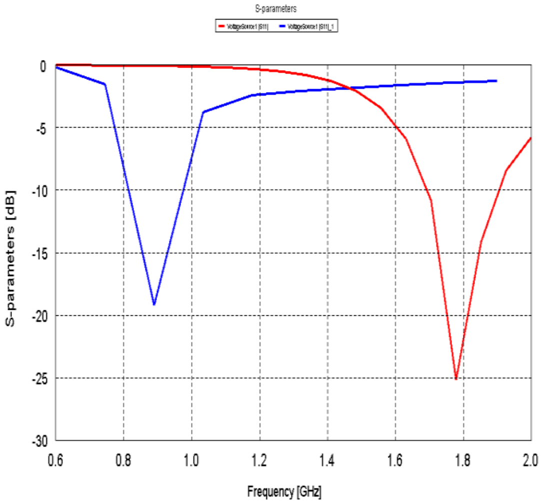

Figure 4 Return loss of PIFA at 900 MHz and 1800 MHz

Simulation results of the proposed antenna are shown in Figure 4 and 5.The return loss for PIFA at 900 MHz and 1800 MHz is found to be -20 dB and -25dB. The return loss for IFA at 900 MHz and 1800 MHz is found to be -9 dB and -19.5 dB.

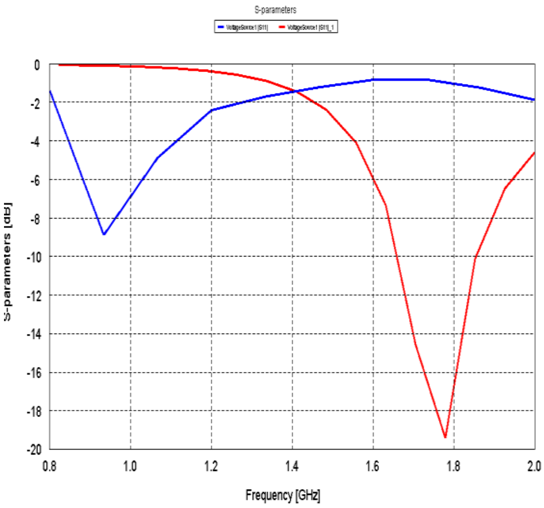

Figure 5 Return loss of IFA at 900 MHz and 1800 MHz

Results reveal that PIFA has good return loss coefficients than IFA due to the presence of short circuit plate.

5.2 .Radiation Characteristics

In modern mobile handsets, Planar Inverted F Antennas and Inverted F Antennas are generally used as inbuilt antennas. Farfield pattern for the simulated antennas are shown in Figure 6 and 7.

5.2.1 Without Human Head

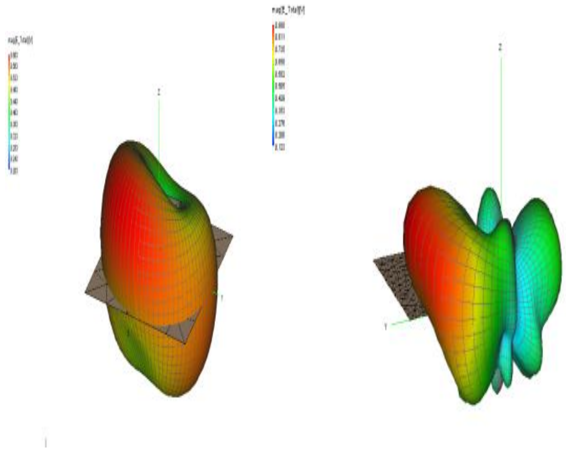

Figure 6 a) PIFA b) IFA Farfield pattern

It is found that PIFA has unidirectional radiation pattern. It is prominent from Figure 6 that PIFA has less backwrad radiation whereas radiation pattern of IFA has more backward radiation and has no unidirectional pattern

6.2.2 with Human Head

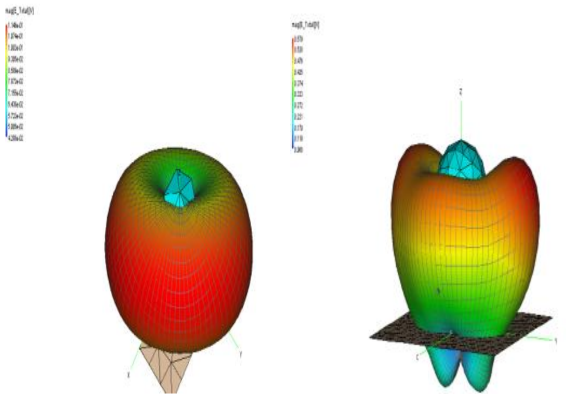

Figure 7 a) PIFA b) IFA Farfield pattern alongwith human head

The performance of PIFA is more prominent when a human head is exposed to the antenna. It is clear from Figure 7 that the radiation from PIFA is not moving towards head but are widely spreaded. In the case of IFA, human head absorbs more radiation .

5.3. Efficiency

The electrical losses that occur in the antenna are given in terms of radiation efficiency. Radiation efficiency is often abbreviated to just efficiency. It is defined as a figure of merit for an antenna. For an efficient antenna the electrical losses should be minimum.

The in-built antennas have better radiation efficiency than external antennas. This is the main reason why the handset manufacturers are opting in-built antennas. It is found that greater the efficiency less is the backward radiation. The simulated results are shown in Figure 8 and 9.

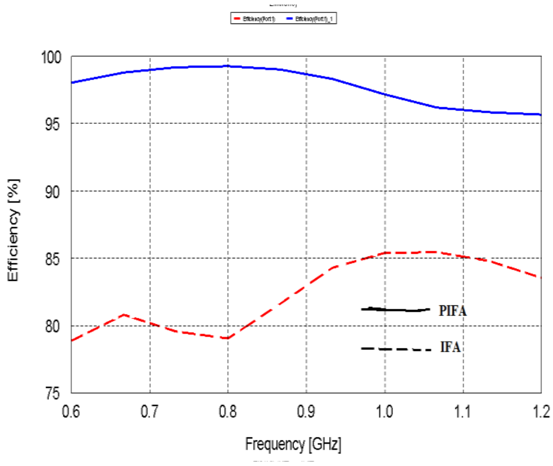

Figure 8 Efficiency comparison of PIFA and IFA at 900 MHz

Results have shown that the the efficiency of PIFA at 900 MHz and 1800 MHz is 98% and 89%. For IFA it is 84% at 900 MHz and 75 % at 1800 MHz. It is found that PIFA is more efficient than IFA.

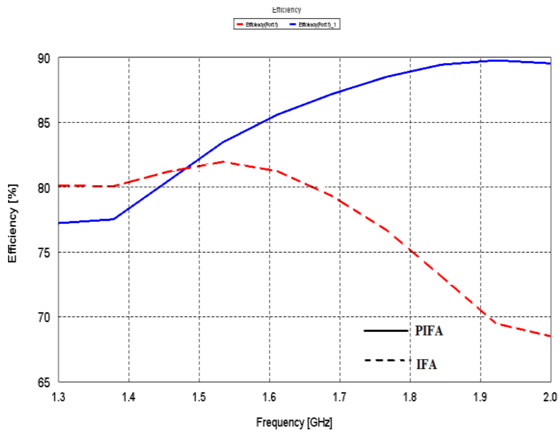

Figure 9.Efficiency comparison of PIFA and IFA at 1800 MHz

5.4. GAIN

From the simulated results shown in Figure 10 and 11 it is observed that the gain values of PIFA are higher when compared to IFA.

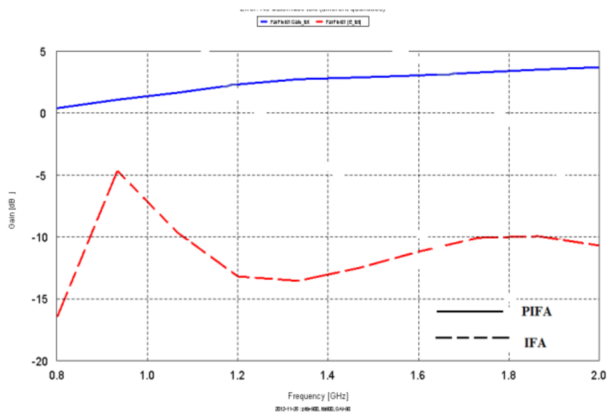

Figure 10 Gain comparison of PIFA and IFA at 900 MHz

The gain of PIFA at 900 MHz and 1800 MHz is 2 dB and -8dB. For IFA it is -5dB and -7dB. It is found that the gain values of PIFA are higher than IFA.

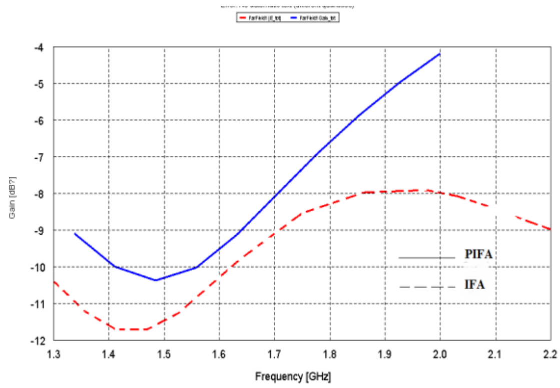

Figure 11 Gain comparison of PIFA and IFA at 1800 MHz

5.5 SAR under Free Space

Both PIFA and IFA antennas are simulated under free space condition with the design parameters specified in table 1&2. Human head with dielectric properties is also simulated using CADFEKO. Results have shown that the performance of PIFA antenna is good when compared to that of IFA. These results have shown that the backward radiation is less in PIFA. The simulated models of PIFA and IFA with human head are shown in Figure 12.

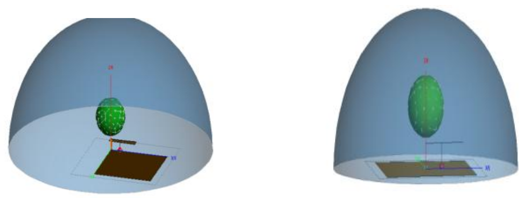

Figure 12 a) PIFA b) IFA exposed to human head

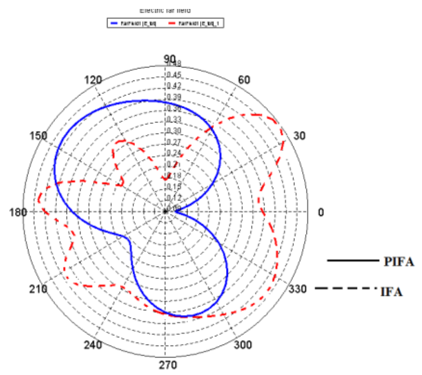

Figure 13 SAR comparisons of PIFA and IFA

The result shown in Figure 13 indicates the unidirectional pattern of PIFA and the backward radiation of IFA. The backward radiation causes the Electromagnetic waves to move closer to the human head in IFA thereby increasing the SAR values. As a result the absorption towards human head increases in IFA.

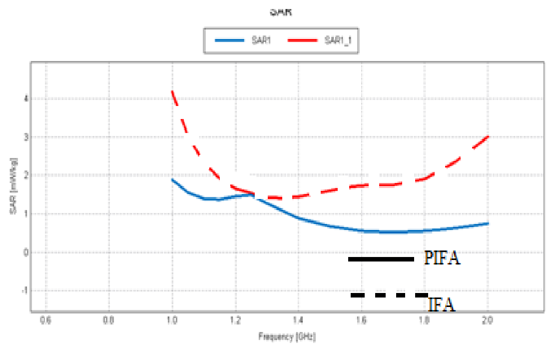

Figure 14 SAR comparisons of PIFA and IFA

The comparison of SAR values for the proposed internal antennas are shown in Figure 14. The SAR values at different frequencies is tabulated in Table 3. SAR from both the antennas are below the FCC limits. But still the SAR values of PIFA is low when compared to that of IFA. The human head absorbs very less radiation when it is exposed to PIFA.

Table 3. SAR values of PIFA and IFA

FREQUENCY (MHz)	**PIFA SAR(W/Kg)**	**IFA SAR (W/Kg)**
600	.000303	.001163
733.333	.001432	.002938
800	.004802	.007305
933.33	.00769	.02485
1000	.005641	.022241
1200	.0034	.009677
1400	.00083	.001394
1500	.000639	.001548
1700	.0004985	.001695
1800	.0005455	.001848

6. CONCLUSION

Comparison between PIFA and IFA proves that PIFA has better efficiency, gain and better return loss coefficients. Further absorption of electromagnetic radiation by PIFA in free space is less when compared to IFA. It is very clear from this analysis that the backward radiation is very less in PIFA than in IFA. Human phantom with dielectric properties is designed and SAR measurement is done for 1g cube. SAR induced in human head under free space condition is evaluated using MOM.

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