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SAR REDUCTION IN SLOTTED PIFA FOR MOBILE HANDSETS USING RF SHIELD

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ABSTRACT

This paper proposes a multiband handset antenna combining PIFA and novel slots on a radiating patch of PIFA for mobile applications. Two slots were introduced in order to embody 900 and 1800 MHz band. Radiation patterns are computed in free space as well as in the presence of the head. Specific Absorption Rate (SAR) of the slotted PIFA antenna is calculated and is compared with the SAR limits in the safety standards. SAR is investigated, by discussing the effect of RF shield which is introduced between the slotted PIFA antenna and head. Simulation results show that with the introduction of the RF shield of thickness of 1mm, SAR reduces by 12%. All simulations are done in FEKO software.

Keywords: SAR, mobile phone, RF shield, relative permittivity, permeability.

1. INTRODUCTION

Mobile phones have been used extensively in our daily basis. Human interaction with mobile has become a pioneering area of research for the welfare of human health preventing from hazardous absorption of radiations. The purpose of this paper is for the investigation of interactions between slotted PIFA handset antennas and human head where SAR is defined as a figure of merit to evaluate the power absorbed by biological tissue. For mobile phone compliance, the SAR value must not exceed the exposure limits [1]. For example, the SAR limits specified in IEEE C95.1: 1999 is 1.6 W/kg in a 1 G averaging mass.

Traditionally used external antennas such as monopoles and helical antennas increase the size of the handset. They are easily broken or there is a possibility of bending. These antennas also have a significant effect on the human body because they are not easy to shield. PIFA antenna is a recent antenna used in mobile technology. So for all experiments are done based on monopole and dipole antenna which has so many drawbacks such as lack of shielding, backward radiation and increasing the size of the mobile antenna. So in this paper slotted PIFA antenna for supporting dual band 900 MHz and 1800 MHz is designed and the interaction of the antenna with the designed homogeneous head model with tissue properties are determined by using the metric called SAR which is discussed below.

2. SPECIFIC ABSORPTION RATE (SAR)

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the body when exposed to a radio frequency (RF) electromagnetic field. It 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:

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

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/m^3) [2].

3. PLANAR INVERTED F ANTENNA (PIFA)

The PIFA is resonant at a quarter-wavelength due to the shorting pin at the end as shown in Figure-1. The feed is placed between the open and shorted end, and the position controls the input impedance.

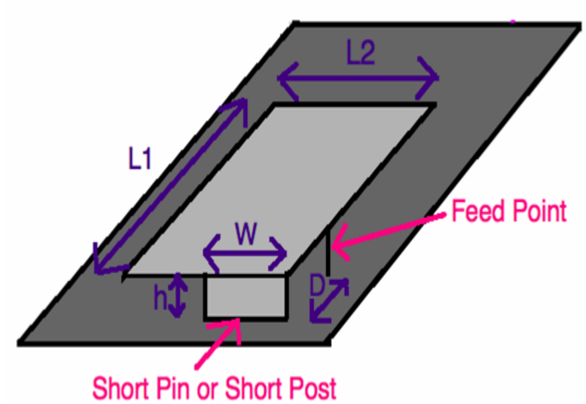

Figure-1. PIFA antenna.

The resonant length of PIFA is given by:

$L1 + L2 - W = \lambda/4$

Where
L1 = length of PIFA
L2 = width of PIFA
W = width of shorting pin
h = height of shorting pin
D = distance of the feed from the shorting pin

4. SLOTTED PIFA

In slotted PIFA antenna proposed in this work, the modified dual-band PIFA having 900 MHz and 1800 MHz was designed. Two resonances were acquired by the use of L and L shaped slots in the radiating patch of slotted PIFA antenna as shown in the Figure-2.

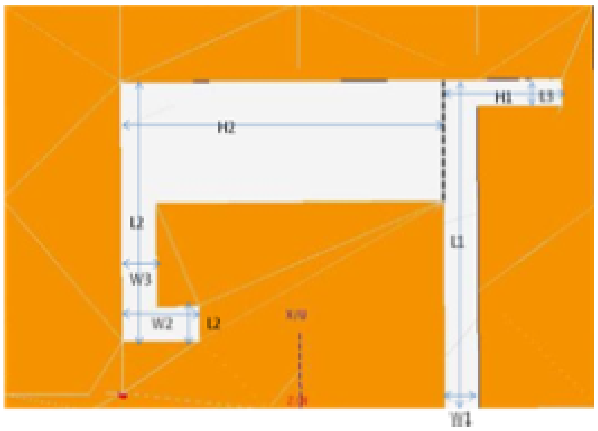

Figure-2. Slotted PIFA antenna.

5. METHOD OF MOMENTS (MOM)

The MoM or boundary element method (BEM) is one of the first full-wave numerical methods used for electromagnetic compatibility (EMC) and antenna applications. During the last few years, where computer performance has increased dramatically, the importance of MoM has decreased while the use of other techniques like FDTD or FEM has increased. Nevertheless, the MoM still provides advantages for certain structures, especially when metal objects and wires are of interest. The MoM is applicable to problems for which Green's functions can be calculated. These usually involve fields in linear homogeneous media. This places considerable restrictions on the range and generality of problems to which boundary elements can usefully be applied. Nonlinearities can be included in the formulation, although they will generally introduce volume integrals which then require the volume to be discredited before a solution can be attempted, thus removing one of the most often cited advantages of Bioelectromagnetics.

6. NUMERICAL MODELLING

a) Modelling background

The specific absorption rate experiments with real human bodies were strictly limited. They lead to a poor approximation of real human bodies when the real time experiments were performed with the animal bodies. So it is decided to investigate the possible impacts with numerical field calculations using several numerical models of the human body [3].

b) Planar inverted F antenna geometry and dimensions

The Planar Inverted F antenna is increasingly used in mobile phone market. The antenna is resonant at quarter wavelength thus reduces the size of mobile phones. PIFA is popular because of its low profile and omnidirectional pattern and less backward radiation. The design parameters are as shown in Table-1.

Table-1. Design parameters of PIFA.

PIFA Parameters	**Values** (900 MHZ) **in meters**
L1	0.09078
L2	0.02000
H	0.03
D	0.03378
W	0.0045

c) Slotted PIFA antenna

The design parameters of the dual band slotted PIFA antenna (Figure-2) is shown in Table-2.

Table-2. Slot specification of slotted PIFA.

Design parameters	**Values** (in mm)
L1	21.51
H1	5.5
W1	21.5
L2	15
H2	18.5
W2	5
L3	1.5
W3	2

d) Human head model and dielectric properties of human head tissues

The human head is simulated with brain equivalent material (muscle and skin) with a relative permittivity, conductivity and mass density for 900 and 1800 MHz as in Table-3.

Table-3. properties of head tissue used in the simulation at 900 MHZ [4].

Properties of tissue	900 MHz
Dielectric permittivity (ε_r)	50.5
Conductivity (σ) in S/m	1.5
Mass density (ρ) in kg/ m^3	1020

e) Metal sheet

The purpose of this paper is to reduce Specific Absorption Rate (SAR) by introducing RF shield of thickness 1mm between mobile loaded with slotted PIFA antenna and human head. RF shield attached has electrical

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conductivity. 02670 and relative permeability of 2.07 [5]. The distance between RF shield and head is 10mm.

7. FEKO SIMULATIONS AND VALIDATION

A. Free space condition

Slotted PIFA is simulated under free space condition with the design parameters as specified in Table-2 (9) is shown in Figure-3.

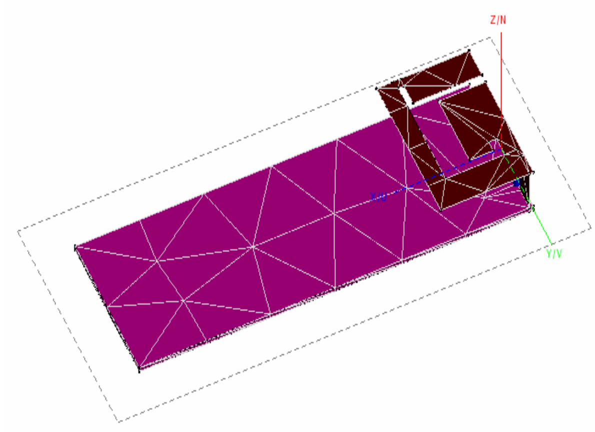

Figure-3. Slotted PIFA antenna.

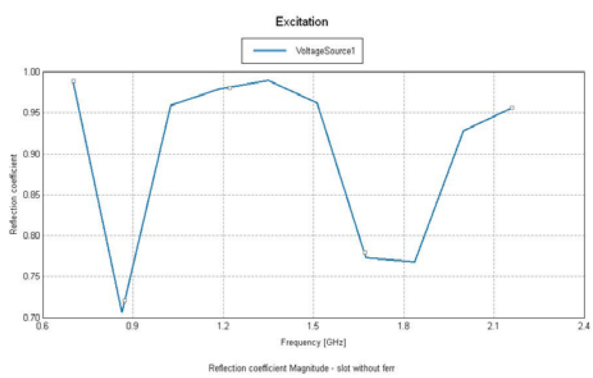

Figure-4. Simulated $s11$ of the complete model including handset and head and RF shield.

The antenna was designed in such a way that the return loss in two bands (900 and 1800Mhz) is less than -10 dB (s11< -10 dB).

B. Slotted PIFA with human head small

Slotted PIFA [6] with human head model [7] as shown in Tables 2 and Figure-5,

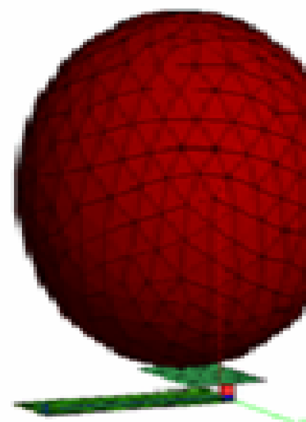

Figure-5. Slotted PIFA with human head in the presence of RF shield.

For reducing SAR in human using mobile phones, RF shield of thickness 1mm is introduced between human head and mobile handset with slotted PIFA antenna. From the far field simulated graph of slotted PIFA antenna shown in Figure-6, it can be seen that backward radiation is less for the desired frequency (800MHz) which is one of the important characteristics of PIFA antenna.

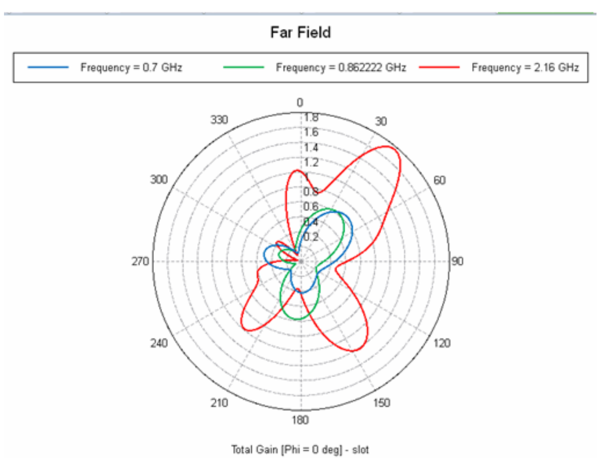

Figure-6. Far field.

8. RESULT ANALYSIS AND VALIDATION

The FEKO simulation model consists of homogeneous human head and Dual band slotted planar inverted-F antenna mounted on a mobile handset. By considering the problem size and complexity, the FEKO program is simulated using the Method of Moments (MoM) based platform. [8]. Specific Absorption Rate (SAR) for 1 G and 10 G by introducing RF shield slotted PIFA antenna and human head is calculated from the frequency range from 0.7 GHz to 2.16 GHZ and the simulated results are tabulated below.

The SAR comparison table shows that 1 G and 10G SAR for dual band slotted PIFA with the introduction of RF shield of thickness 1 mm is reduced

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considerably in the frequency range of 0.7GHz and 2.16 GHz compared to dual band slotted PIFA without RF shield.

Table-4. 1G SAR distribution (with and without RF shield).

Frequency (GHz)	1 G SAR	1 G SAR (RF shield)
0.7	0.0006358	0.000635
0.862222	0.01509	0.013506
1.02444	0.003855	0.0037885
1.18667	0.0020585	0.0019813
1.34889	0.002174	0.0021088
1.511111	0.00241	0.0026698
1.67333	0.0077578	0.011856
1.83556	0.01658	0.014547
1.99778	0.0025695	0.0025242
2.16	0.0015004	0.001455

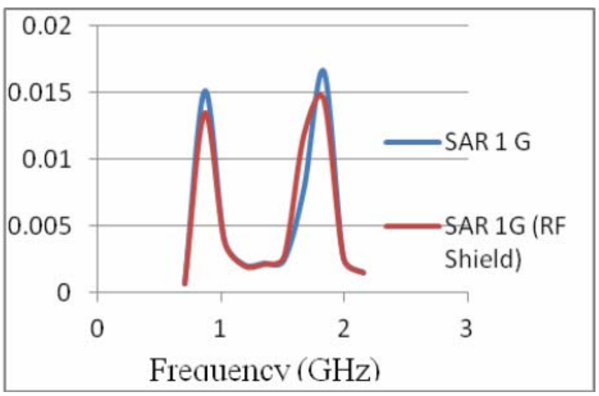

Figure-7. Graph for 1G SAR distribution (with and without RF shield).

Table-5. 10G SAR distribution (with and without RF shield).

Frequency (GHz)	10 G SAR	10 G SAR (Ferrite)
0.7	0.000362	0.000326
0.862222	0.013133	0.01156
1.02444	0.001653	0.001594
1.18667	0.000744	0.00073
1.34889	0.000589	0.000584
1.511111	0.000897	0.000798
1.67333	0.003586	0.003145
1.83556	0.004428	0.004083
1.99778	0.00089	0.000884
2.16	0.000468	0.00047

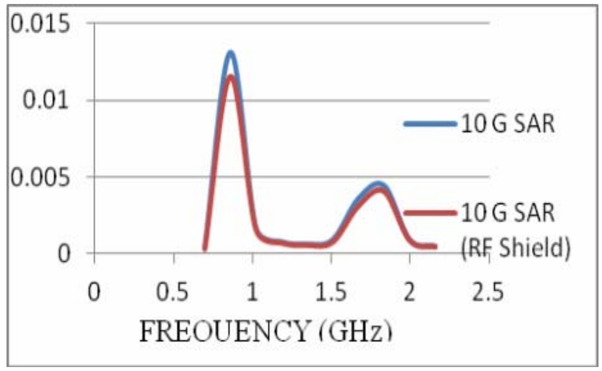

Figure-8. Graph for 10G SAR distribution (with and without RF shield).

CONCLUSIONS

The effect of the reduction in peak SAR for a handset with dual band slotted PIFA antenna using an RF shield is investigated experimentally. Simulation results show that with the introduction of the RF shield with a thickness of 1mm reduces the SAR value in the human heart for both 1 G and 10 G cases. The amount of reduction in the SAR at center frequencies is 10.497% and 12.261% for 1 G. The same for 10 G is calculated as 7.79% and 11.977%, respectively.

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