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Reduction of Specific Absorption Rate using carbon foam inside enclosures

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Abstract: ***The interaction of a mobile antenna and a passenger is analyzed inside a metallic enclosure. The specific absorption rate (SAR) of the passenger in the elevator using a mobile phone is calculated. A standardized model of human head is filled with liquid that simulates the RF absorption characteristics. The non-uniform mesh technique in frequency domain is employed to obtain 1g SAR [Specific Absorption Rate] and other important parameters. The mobile phone is modeled as a quarter wavelength Planar Inverted F Antenna (PIFA), and it is of .01m from the head. PIFA is operated at frequencies of 900 and 1800MHz with transmitting power .3 W . It is observed that the values of SAR inside the metallic enclosure exceeds the RF safety limits. Therefore, this project proposes a novel method to reduce the SAR by using carbon foam which absorbs microwave radiation. Simulated results have evidenced the efficiency of the proposed technique of SAR reduction inside the enclosures.***

Keywords : SAR, PIFA, Carbon Foam,Enclosure

I. INTRODUCTION

Mobile phones are becoming unavoidable in the world today. The increasing number of mobile phone usage is a huge concern because the antennas in the mobile phone interact with the human tissue leading to various health hazards. The mobile handset manufacturers are also showing their interest in this interaction and finding new ways to reduce the damage done to the human tissue [7]. When a mobile phone is exposed to the vicinity of the human tissue the internal antenna parameter is distorted . The electromagnetic interface with the human is found by specific absorption rate (SAR). SAR is defined the power absorbed per mass of tissue and has units of watts per kilogram (W/kg). If the values of SAR are high then the electromagnetic absorption is also high. SAR is calculated by (σ × Erms2) / ρ where σ is the conductivity of various human tissues, Erms is the RMS of electric intensity of the body and ρ is the density of human tissue. SAR limit as specified by IEEE Standard-1528 for 1g averaging mass is 1.6W/Kg. The human tissue has got greater tendency to absorb the electromagnetic radiation that is coming from the mobile phone. If SAR is increased than its specified limits it alters the DNA, affects the brain, may lead to Alzheimer's disease, dementia and breast cancer.

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Evidence has been given by the scientific study that our safety standards are insufficient and that we must safeguard ourselves from EMF emitted by the cell phones and the like by using suitable shielding techniques[1-2] .

The usage of mobile phone in the closed environment increases the electromagnetic field (EMF) levels. Enclosures that are made of metal like Elevators, automobiles and aircraft cabins have more tendency to reflect and increase the EM radiation . Unlike the aircrafts and automobiles have seats which act as the dielectric loading, whereas an elevator is a metallic enclosure simply made of metal, without any high dielectric loading thereby leading to reflection and the resonance effects. It is observed that the electromagnetic absorption is increased massively inside a closed enclosure made of metal. Many researchers have investigated this effect, but only proved the increase of SAR inside the elevator. In this work we study the SAR values inside the enclosure using Planar Inverted F antenna and also reduce SAR values inside the elevator.

After a detailed study of the reduction techniques we have found that ferrite sheet, metamaterial split ring resonators (SRR), resistive sheets and RF shields can absorb the radiation from the antenna . For economical reasons, they cannot be used as a shielding layer inside an elevator. Moreover tailoring these materials to fit huge structures is difficult. This paper proposes an idea to reduce the microwave radiations by using carbon foam to the walls of the built spaces.

PLANAR INVERTED–F-ANTENNA (PIFA) is extensively used in smart phones because of its and shape and easy design. It can be comfortably placed into the board of the handset. Backward radiation is less in PIFA as compared to other internal antennas .

II. ANTENNA STRUCTURE

Due to the shorting post the antenna resonates at quarter-wavelength . Feed of the internal antenna controls the input impedance. Capacitive top loading can be introduced to enhance impedance matching and the efficiency. The power transfer is maximum in PIFA with high efficiency. The signal reflection from the load is very less. PIFA is designed based on the formula,

$$x+y= \lambda/4 \qquad [2]$$

Where the values of x and y gives the length and the width of the antenna, z gives the value of shorting post width, h' is the pin height and d' gives the distance value between pin and the feed. The patch is kept at a distance of .03m for 900MHz and .01425m for 1800 MHz from the ground plane. The antenna feed point and the shorting pin is separated by.013m for 900 MHz frequency and .0125m for 1800 MHz frequency.

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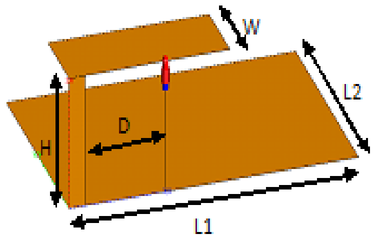


Figure.1.PIFA

Table.1.Design parameter of PIFA

Parameters	900MHz(m)	1800MHz(m)
X	0.085	0.06
Y	0.05	0.072
h'	0.032	0.02
d'	0.015	0.026
z	0.005	0.003

The width of the shorting post is .003m and .005m for the two frequencies. Figure 1explains the antenna design. The antenna parameters are demonstrated in Table 1 for two different frequencies[3-4]

III . TISSUE PROPERTIES OF HUMAN HEAD AT DIFFERENT FREQUENCIES

Head phantom with its related dielectric properties is designed by FEKO software. The radius of the head is considered as 0.05 m in this paper. The relative permittivity, conductivity and mass density is also taken into account for modeling human head. Table 2 displays the values of tissue parmeters for different operating frequencies.[6]

Tabel.2. Design of human head with dielectric properties

Parameters	At 900 MHz	At 1800 MHz
Dielectric permittivity (ε_r)	45.8	43.5
Conductivity σ (S/m)	0.77	1.15
Mass density (kg/m3)	1030	1030

IV.PERFORMANCE OF ANTENNA

(A) Antenna performance

Figure 2 shows the omnidirectional radiation pattern of PIFA. It is observed that backward radiation is minimised in PIFA. Because of reduced backward radiation, PIFA is widely used as internal antennas.

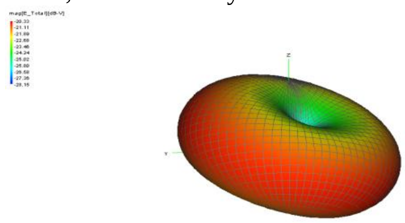


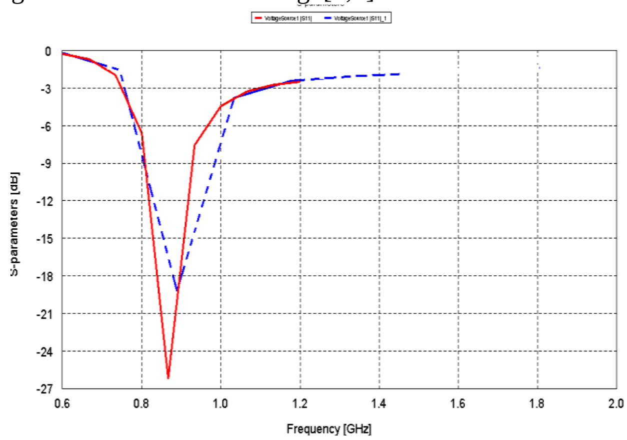
Figure.2. Far field Radiation pattern of PIFA

Antenna parameters namely efficiency, gain and return loss simulated for PIFA are demonstrated in Table 3 under two conditions: with and without passenger head. The performance of the antenna varies when it is prone to the passenger head in the enclosure. The distance between the antenna and the passenger is 0.01m and it is kept constant throughout. The model is simulated using CADFEKO.

Table.3.Effieincy,gain,return loss values

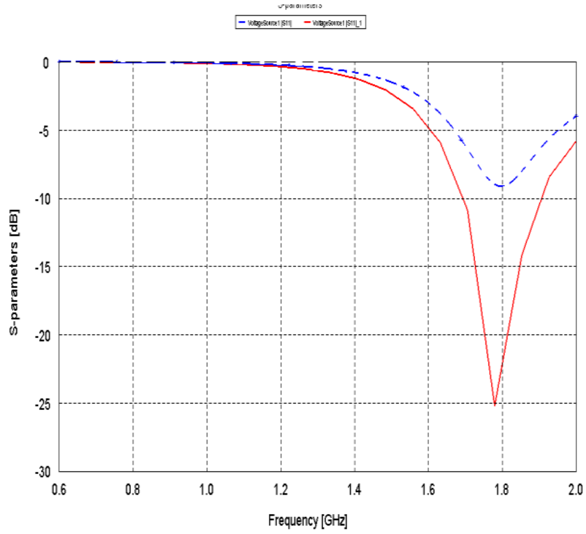
Resonating Frequency	0.9GHz without head	1.8 GHz Without head	0.9 GHz With head	1.8GHz With head
Return Loss (dB)	-26.3	-25	-19.4	-9.24
Efficiency (%)	98%	89%	79%	77.49%

Figure 3 and 4 shows the antenna performance in different conditions.Antenna performance is determined by return loss.High return loss is desirable.it can be seen that the antenna deviates in its performance when exposed to human head model .The performance is considered to be good if the return loss is high[5,8].



human head model is not exposed to the antenna
human head model is exposed to the antenna

Figure 3. Return loss at 900 MHz



human head model is not exposed to the antenna
human head model is exposed to the antenna

Figure 4. Return loss at 1800 MHz

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(B) EXPOSING TO METALLIC ENCLOSURE

The passenger using mobile handset inside an elevator made of iron is considered. The metallic enclosure acts as resonators. The walls of the elevator are made of iron therefore the resonance effect is supposed to be more inside this cavity. Since elevators do not have any chance of dielectric loading like seats in cars, they greatly support resonance and reflection effects. Elevator made of iron with conductivity 1e7 is considered in this paper. Evaluation of SAR is done at 900MHz and 1800MHz. Due to the complexity, the dimensions of the elevator is reduced times its original value for the ease of simulation. The design values are exhibited in Table 4. Figure 5 explains the geometry of the elevator.

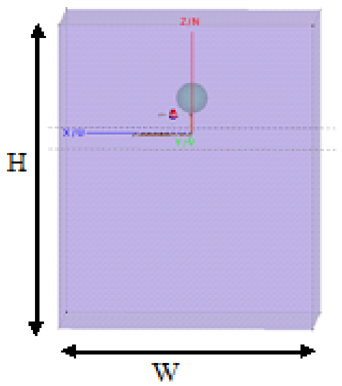


Figure 5. Metallic enclosure made of iron

Tabel.4.Design parameter metallic enclosure

Metallic enclosure	In meters
Length (L)	0.4
Height (H)	0.4
Iron(σ)	1e7

Figure 6 shows the near field pattern of the antenna inside metallic elevator. The two dimensional pattern of the near field is detailed in Figure 7 for the operating frequencies 900 MHz and 1800 MHz . It is clear from the simulated results that the radiation is much inside the closed space made of metal without any absorbing materials. The following result shows that the metallic enclosure greatly favors SAR.

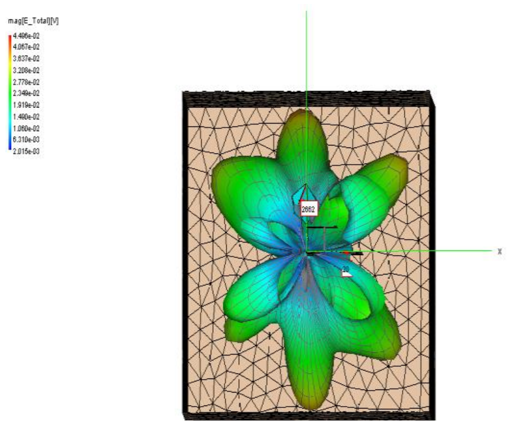
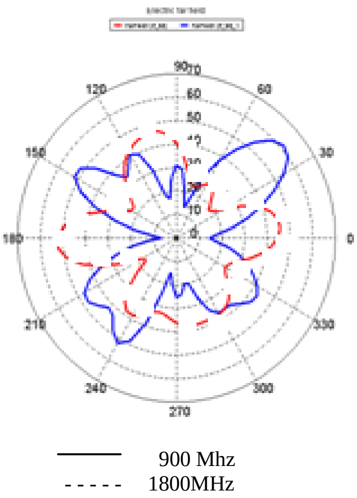


Figure 6. Far field pattern inside elevator



V. SPECIFIC ABSORPTION RATE WITHOUT ABSORBING MATERIAL

1g SAR is calculated along with PIFA exposed to a human exposure inside an electrically large metallic enclosure. EMF absorbed by the human tissue is large inside a closed space. SAR values for different frequencies are specified in Table 5 and 6. The EM wave is scattered back and forth inside the elevator due to its metallic body, thereby vehemently increasing the SAR value. A concern for human safety is raised because of the "hot spots" that occur inside the enclosure due to the increase of field intensity.

Table.5 and 6 Increased values of SAR at different operating frequencies

Frequency band for 900 MHz	1g absorption values
733.33	18.26
800	14.01
866.667	14.42
933.33	12.18
1000	12.95
1067	12.54
1200	12.73

Frequency band for 1800 MHz	1g absorption values
1378	24.13
1467	27.75
1556	32.87
1644	17.41
1733	19.02
1822	21.38
2000	21.27

According to IEEE Standard-1528 the limit for 1g SAR is 1.6 W/Kg , but Table 5 and 6 clearly indicates that SAR is increased 7 times for 900 GHz and 13 times for 1800 GHz inside metallic enclosure.The frequencies are randomly considered within the operating range of mobile phone.This impose a serious threat to the passengers of the elevator.

Electromagnetic field is considered to be a magnetic field created by the movement of electrically charged particles.It extends indefinitely throughout the space and prolonged interaction of such fields causes changeable effects in human body. Exposure to mobile phone radiation affects the brain ,damages the DNA, causes micronucleation and neurological effects and various other ill effects.In order to prevent these health hazards the value of SAR must be within the required limit.

VI. SPECIFIC ABSORBTION RATE REDUCTION USING CARBON FOAM

(3D) dielectric structures like carbon foam have the ability to absorb electromagnetic (EM) wave when they are exposed to it. Intensive research is carried out in dielectric structures. Carbon foams are traditionally used for providing thermal insulation. Carbon foam is considered to be porous electrodes. In this paper, carbon foam is coated over the walls of the metallic enclosure. Carbon foam is simulated with the thickness of about 0.03 m and with the conductivity range of about 0.695 to 0.078 Scm^{-1}. SAR reduction of about 29 times is produced using carbon foam. From the work, it is observed that the carbon foam samples possess EM absorbability strength. Reduced values of SAR after using carbon foam inside the closed region are indicated in Table 7 and 8 for various frequencies[9,10].

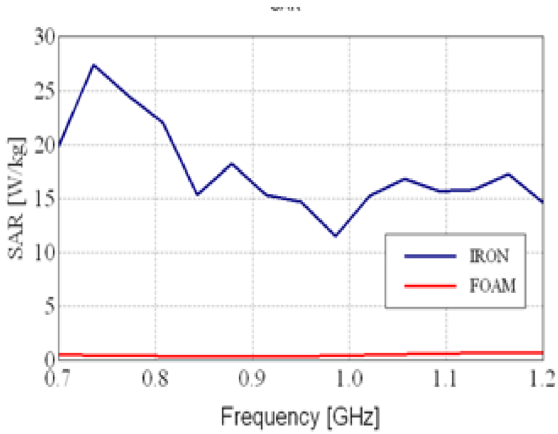
Table 7. Reduction achieved by foam for 900 MHz frequency band

Frequency band for 900 MHz	1g absorption values
700	0.477884
807	0.368467
914	0.312271
950	0.342574
1021	0.472055
1164	0.652721
1200	0.637794

Table 8. Reduction achieved by foam for 1800 MHz frequency band

Frequency band for 1800 MHz	1g absorption values
1300	2.7492
1350	2.1456
1400	1.93794
1600	1.43345
1750	0.838446
1800	0.742191
2000	0.899141

The comparison of SAR values inside the enclosure before and after using carbon foam can be viewed from Figure 8.



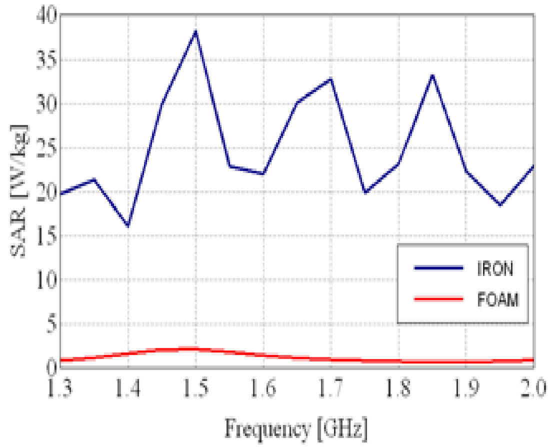


Figure 8 comparisons of SAR inside iron enclosure and enclosure using carbon foam as absorbing layer a) 900 MHz b) 1800MHz

VII. CONCLUSION

This paper examines the effect of SAR inside metallic enclosure. It is studied that the values of specific absorption rate inside a closed metallic space is very much high than its normal limits. A novel method is proposed in this paper for reducing SAR inside the elevator made of iron by using absorbing material like carbon foam as a shield over the inner body of the elevator. Experimental results demonstrated that carbon foam reduces SAR by 29 times.1g SAR measured after using the absorbing material is found to be less than 1.6 W/Kg which is according to IEEE-1528 standard.

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