A Study of Specific Absorption Rate and Shielding Effectiveness for Money Plant at 2.4 GHz

Md. Faruk Ali[1], S.B. Belamgi[2], Sudhabindu Ray[3]

Abstract — **Now-a-days researchers are very much concerned to evaluate Specific Absorption Rate (SAR) at different human organs due to the Electromagnetic (EM) wave radiation coming from cell phone antennas or other wireless communication devices at radiofrequency (RF). But, the time has come to change the vision slightly toward the effect of RF on agricultural field and plant kingdom. The purpose of this paper is to study the effects of RF radiation coming from Base Station Antennas (BSAs) on a Money plant. In this work, the radiation coming from a 2.4 GHz base station at the occupational and general public exposure levels prescribed by ICNIRP have been taken into consideration and then SAR induced inside a Money plant has been calculated. Shielding effectiveness (SE) provided by the Money plant has been experimentally measured and calculated in the frequency range of 2.35 GHz to 3.0 GHz. Maximum value of Local Point SAR at 2.4 GHz induced inside the Money plant for occupational and general public exposure levels are found to be 9.50 W/kg and 1.88 W/kg respectively. Whereas, Maximum value of SE obtained by the simulation and measurement are found to be 9.48 dB and 9.01 dB respectively.**

Keywords – **Antenna Factor, Bonsai tree, Money Plant, RF Power Meter, Shielding Effectiveness.**

I. INTRODUCTION

The human, plants, crops and all other living beings are exposed to the electromagnetic (EM) waves radiated from the wireless communication devices, base station antennas (BSAs) and repeaters [1]. But, only to protect human beings, different radiofrequency (RF) exposure guidelines are proposed by reputed organizations like IEEE, ICNIRP and FCC and there is no such RF exposure guideline is available for those speechless lives which are being exposed 24 × 7 × 365 hours per year without any radiation shield to the RF sources on the earth [2-4]. Though, people do not take any care for providing radiation shield to the trees but the trees provide good radiation shield to reduce the effects of EM radiation on human beings [5].

Shielding means attenuating radiated emissions and protecting products from external sources of interference such as licensed broadcasting transmitters, government equipment radars WLAN, Bluetooth devices, GSM/UMTS equipments, etc. As a result, in an increasingly electromagnetically crowed environment, electronic devices are commonly packaged in a RF shielded enclosure in order to protect them inside the shield from radiating emissions efficiently and prevent the EM fields external to the devices from coupling inside the shield [6]. As a human body contains 70% of liquid so when it is within an increasingly electromagnetically crowed environment where it is exposed to the EM waves radiated from the mobile base station antenna (BSA) and other microwave devices, it absorbs the radiation and causes cooking like in the microwave oven [7]. Therefore, EM shielding is necessary to protect the humans and equipments from hazardous RF radiation [8].

To protect our environment, trees not only absorb carbon-di-oxide and produce oxygen during photo synthesis but they have another role of EM absorption [5]. Absorbing the EM radiation in an electromagnetically crowed environment, trees provide EM shielding by the absorption of EM waves passing through them. EM Wave absorption and shielding characteristics for a Bonsai Tree obtained by simulation at GSM-900 band has been reported. It has been found that maximum value of Shielding Effectiveness (SE) provided by the Bonsai tree is 13.18 dB at 925 MHz.

In this study, SAR induced inside a Money plant has been calculated and SE provided by the Money plant in the frequency range of 2.35 GHz to 3.0 GHz has been calculated as well as measured experimentally by means of a handheld RF power meter. All the required simulations are developed by commercially available software CST Microwave Studio® [9].

II. SYSTEM MODEL

A. Computational Model of Money Plant

Money plant has been modelled considering the electrical parameters for internal and external structures of the actual Money plant. For simplification in simulation, Money plant is assumed to be comprised of only one type of tissues i.e., phloem as the major portion of leaves for Money plant are made of phloem. At 2.4 GHz, value of relative dielectric constant (ε_r) of the phloem is obtained by measurement using Agilent 85070E dielectric probe in conjunction with E5071B NA [10-11] as shown in Fig. 1. To avoid any systematic errors, the dielectric probe with Agilent Technologies 85070E software has been calibrated before measurement. Three calibrations were performed, i.e., air (open), short (metal), and water. Measured value of ε_r along with conductivity (σ) and mass density (ρ) of the phloem obtained from literature are shown in Table 1 [12].

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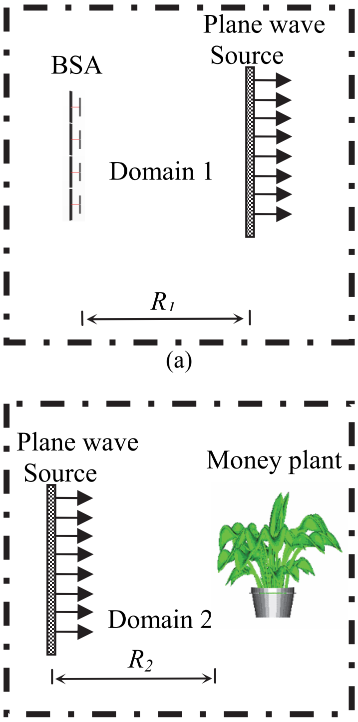
Actual Money plant lies in a small tub which is filled with wet soil. So in order to approach towards the realistic condition a solid tub made of soil is added at the bottom of the Money plant model. Values of relative ε_r and σ of soil used in the simulation obtained from literature are shown in Table 1 [13].

Fig. 1. Dielectric measurement set-up

TABLE 1
ELECTRICAL PROPERTIES OF TREE TISSUE AND SOIL

Tissue type	Dielectric constant (ε_r)	Conductivity σ (S/m)	Mass density ρ (kg/m^3)
Phloem	41	0.07	950
Soil	15	0.01	—



(b)

Fig. 2. Geometry of (a) Domain 1 and (b) Domain 2 [R_1+R_2 = R]

Geometry of the Money plant along with a BSA is shown in Fig. 2. The field from most antennas behaves like a plane wave after travelling a distance in the order of tens of wavelengths [14]. Therefore, a plane wave source may be used a replacement of the radiating BSA placing at a distance R from the Money plant. For that reason for convenience in calculation the simulation space is divided into two domains namely Domain 1 and 2 as shown in Fig. 2 (a-b). Domain 1 is used to compute the characteristics of the fictitious plane wave source and Domain 2 is used to compute the EM absorption characteristics of the Money plant.

B. Simulation Set-up for SAR Calculation

In this study, Transient analysis has been used in CST Microwave Studio® for SAR calculation and the corresponding simulation set-up is sown in Fig. 3. A plane wave with linear polarization has been used as the RF radiation source which passes through the Money plant model in separate simulation environment. A 5-layered conventional perfectly matched layer (PML) with 0.0001 reflection coefficient has been used as the absorbing boundary. The separation between the Money plant and the boundary wall has been kept fixed at 2.5 cm by varying the mesh-lines per wavelength for different frequency of exposure. Fig. 3 shows the Money plant gets exposed to a plane wave propagating in Z direction whereas the *E* field and *H* field are in X and Y direction respectively. All the SAR results for Money plant model have been evaluated with the above mentioned direction of plane wave propagation for occupational as well as general public exposure levels prescribed by ICNIRP.

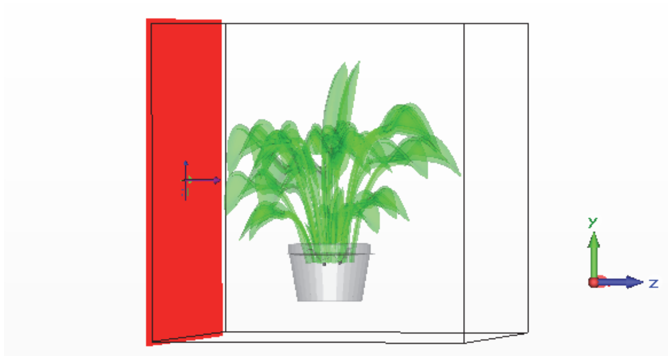
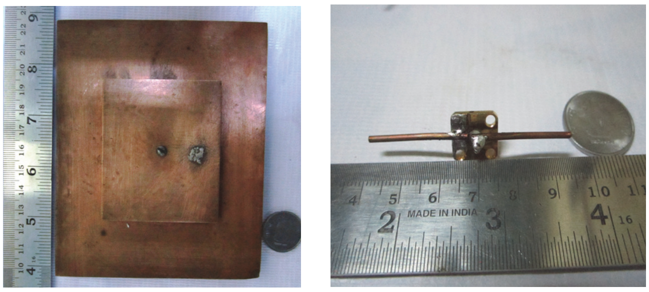


Fig. 3. Simulation set-up for SAR calculation in Money plant gets exposed in a plane wave at 2.4 GHz with setting of ICNIRP prescribed peak *E*-fields

C. SE Measurement

A rectangular patch antenna made of copper placed in the air medium resonating at 2.42 GHz shown in the Fig. 4 (a) has been used as a Transmitting (Tx) antenna for the measurement of SE in this study. Dimensions of patch and ground are 55.12 mm × 68.19 mm and 95.12 mm × 108.41 mm respectively. The patch is shorted at the centre with a supporting post of radius 1.5 mm and height of the suspended patch from the ground plane is 5.0 mm. The patch antenna is feeding at point of radius 0.62 mm at a distance of 17.05 mm from the centre.



(a) (b)

Fig. 4. (a) Rectangular patch acting as Tx antenna and (b) half-wave dipole acting as Receiving (Rx) antenna

Return loss (S_{11}) of the patch antenna in free space is computed using CST Microwave Studio® and compared that with the measured value obtained by Agilent ENA Series - E5071B (300 KHz - 8.5 GHz) Network Analyzer (NA) [10]. Variations of S_{11} with Frequency for the patch antenna computed using CST Microwave Studio® and measured by the NA are shown in Fig. 5. At the fundamental mode, the antenna resonates at 2.42 GHz and the value of S_{11} remains below –10 dB. Simulated and measured values of S_{11} at the fundamental resonance frequency are –17.16 dB and –19.42 dB, respectively.

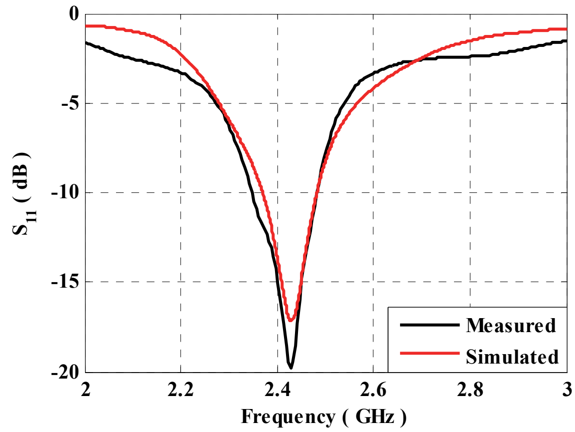


Fig. 5. Variations of S_{11} vs. Frequency of the patch antenna placed in free space

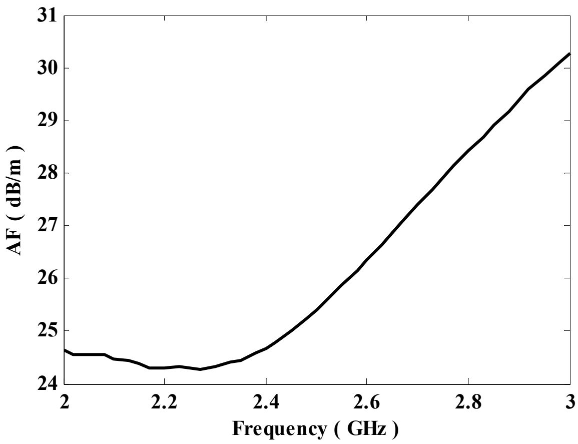
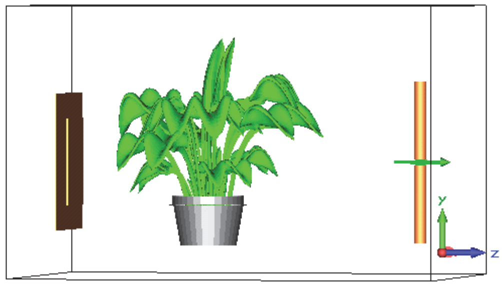


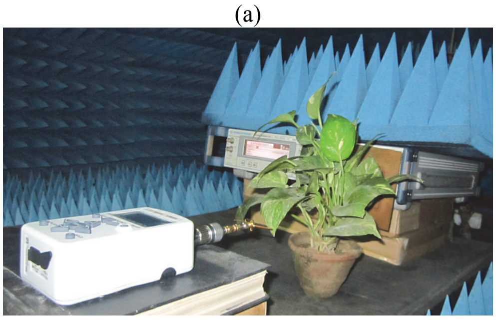
Fig. 6. Variation of AF vs. Frequency of the for the half-wave dipole antenna of length 5.5 cm placed in free space

Variation of Antenna Factor (AF) with Frequency for the half-wave dipole antenna of length 5.5 cm acting as a far field RF power sensor has been computed using CST Microwave Studio® as shown in Fig. 6. In this case approximate linearity of AF is seen from 2.4 GHz upto 3.0 GHz.

Geometry of the simulation and experimental set-up consisting of computational and actual Money plant along with the necessary equipments are shown in Figs. 7 (a-b). The half-wave resonating dipole antenna of 5.5 cm length made of copper shown in Fig. 4 (b), acting as a far field RF power sensor has been incorporated in measurement setup. Similar far field RF power sensor also has been included in the simulation setup as shown in Fig. 7 (a).



(a)



(b)

Fig. 7. (a) Simulation and (b) experimental set-up with Money plant for computing SE

III. Formulation and Measurement of SE

SE is defined as the ratio in dB of the field without and with the shield [6]:

$$SE = 20\log_{10}\left|\frac{E_0}{E_t}\right| \qquad (1)$$

where, E_0 = electric field without shield and E_t = electric field with shield. In this study, the Money plant acts as an EM shielding material.

In terms of power, SE is defined as the difference of power in dB of without and with the Money plant [3]:

$$SE = P_0 - P_t \qquad (2)$$

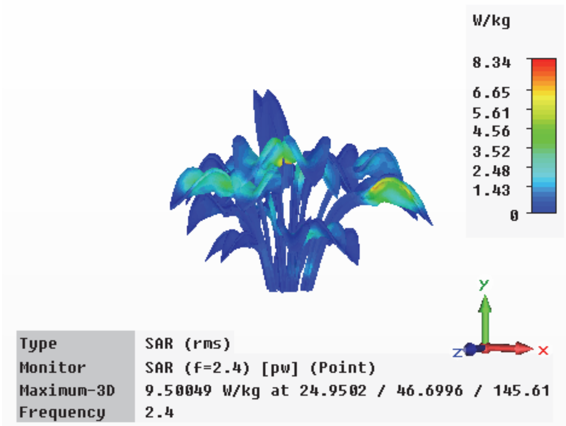
where, P_0 = power without Money plant and P_t = power with Money plant.

Far field distance for the half-wave dipole antenna of length 5.5 cm acting as a RF power sensor at 2.4 GHz be greater than $2D^2/\lambda$ = 4.8 cm. In this work, the RF power sensor dipole antenna has been placed at a distance of 7.0 cm from the Money plant for both in simulation as well as in measurement setup. In simulation, three probes directed along x, y and z axis are placed at the gap between two arms of the dipole antenna to pick-up the respective *E* field components, shown in Fig. 7 (a). But in the measurement, the dipole antenna shown in Fig. 7 (b) is connected with Agilent V3500A handheld RF power meter (10 MHz - 6 GHz) to measure power [10].

In case of simulation, E_0 and E_t are obtained from the probes connected with far field RF power sensor dipole antenna then by equation (1), SE is calculated. On the other hand, for the experiment measurement values of P_0 and P_t are obtained directly from the handheld RF power meter then by equation (2), SE is calculated.

IV. Result and Discussions

Three dimensional Local Point SAR distributions inside the Money plant model exposed by a plane wave at 2.40 GHz for occupational (peak *E* field = 137 V/m) and general public exposure levels (peak *E* field = 61 V/m) prescribed by ICNIRP are shown in the Figs. 8 (a-b). From Figures, it is seen that higher value of SAR is induced in the leaves than the stem. Maximum value of Local Point SAR obtained for occupational and general public exposure levels are 9.50 W/kg and 1.88 W/kg respectively.



(a)

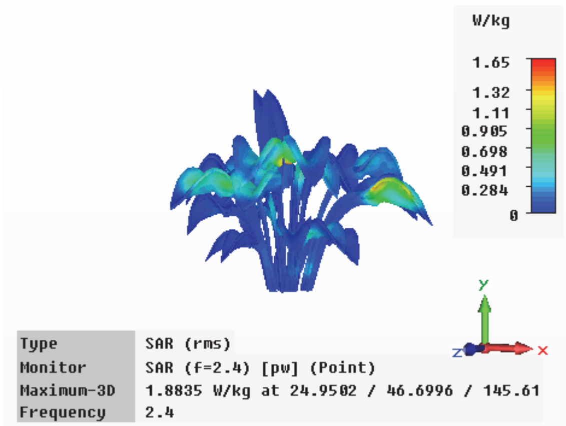


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Fig. 8. Local Point SAR distributions for (a) occupational and (b) general public exposure levels prescribed by ICNIRP at 2.4 GHz

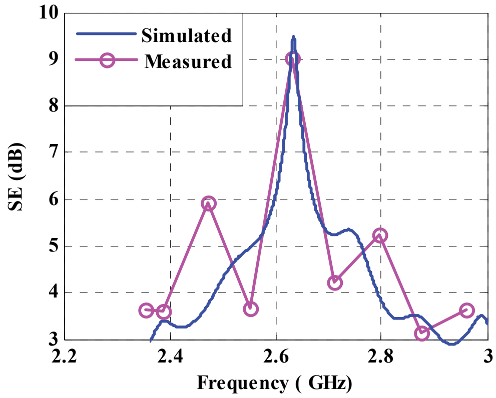

Fig. 9. SE vs. Frequency for Money plant

Variations of measured and simulated SE with Frequency in the frequency range of 2.35 GHz to 3.0 GHz obtained for the Money plant are shown in Fig. 9. From Fig. 9, maximum values of simulated and measured SE are found to be 9.48 dB and 9.01 dB respectively at (about) 2.64 GHz. The curve corresponding to the measured value of SE follows the curve corresponding to the simulated value of SE. But there is unwanted mismatch between simulated and measured value of SE, this may be due to the assumption in modelling of the Money plant.

V. Conclusion

In this study, Local Point SAR distributions at 2.40 GHz for occupational and general public exposure levels prescribed by ICNIRP have been obtained inside a Money plant model consisting of only one type of tissue and exposed by a plane wave coming from a BSA at 2.4 GHz using CST Microwave Studio®. Maximum value of Local Point SAR obtained for occupational and general public exposure levels are found to be 9.50 W/kg and 1.88 W/kg respectively. SE provided by the Money plant for the frequency range of 2.35 GHz to 3.0 GHz has been calculated by simulation and compared that with the results obtained by measurement using a handheld RF power meter. Maximum values of simulated and measured SE are found to be 9.48 dB and 9.01 dB respectively at 2.72 GHz of the far field RF power dipole antenna sensor.

Mismatch between the simulated and measured values of SE causes due to modelling technique of the Money plant by considering the electrical parameters for internal and external structures of the actual Money plant and assumption that the simulated Money plant is consisting with only phloem tissue. To remove the unwanted mismatch, further study is required for modelling of the simulated Money plant more realistically. In this study, one point is clear that a green plant provides us EM shielding by absorption of RF power.

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