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Electromagnetic Shielding Solutions for Cell Tower Radiation Exposure

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Abstract: Shielding is a most effective Electromagnetic protection method. Shielding Effectiveness(SE) is the degree of isolation provided by a shield from electromagnetic radiations. When the distance between the radiation source and the shield is more than $\lambda/2\pi$ it is considered as in the far field shielding region and if less, it is in the near field shielding region. Electromagnetic plane wave theory is applicable in the far field and the theory of dipoles is applied in the near field. Metals are good conductors which can absorb, reflect and transmit electromagnetic interferences. All metals and metallic compounds including brass, copper, aluminium, silver, steel etc are used for quality shielding materials. Plastics embedded with thin metal foils are also used. The aim of the study is to investigate the shielding effectiveness of different materials which are easily available and affordable to the common public. The purpose is to provide suitable roofing solutions to those forced to live near the cell towers. Our experiments found the materials like Gi and Aluminium sheets are easily available and demand lower price, found comparatively better performed when properly grounded. Concretes with a thin Aluminium mesh of 10cm x 10cm length and breadth attached as a top layer will give enough protection and safe guard the residents when properly grounded.

***Index Terms* - RF exposure, cell tower radiation, exposure limits, radiation effects.**

I. Introduction

Electromagnetic Shielding is a most effective Electromagnetic protection method. As soon as an electric field is applied to a conductor , it will dislocate charge carriers (Electrons) in it induces a current in it. The inside field thus forms opposes the applied field and cancel it out. At that point , the induced current will stop. Similarly, varying magnetic fields will produce eddy currents and the inside magnetic field thus produced will cancel the applied field. But practically, due to the electrical resistance of the conductor , the applied field will not cancel out completely. Many factors also affect the Shielding effectiveness of the conductor sheet. The ferromagnetic response of the conductors also will create problems at some frequency ranges.The part of the field which is not cancel out may be absorbed by the material depends on the thickness. The depth by which the radiation can penetrate is the skin depth of the layer.

S geetha et.al[1] conducted a survey on the properties of different shielding materials such as conducting plastic and conducting polymers for controlling electromagnetic radiations. Electromagnetic shielding is an important part in the design of RF and microwave devices. It is necessary for the safe living of living things and also for safeguarding electronic appliances. [2][3][4].

Testing the effectiveness of shielding is also very important side of RF design and Robinson et al [5] conducted such a study and it is extended to circular and multiple apertures. Benhamou et al [6] conducted a study for checking the reflection loss, absorption loss and electromagnetic shielding usefulness of a different range of shield. Scientists also tested methodologies for enhancing the different shielding effectiveness of chlorinated polyethylene carbon nanofiber nanocomposites [7]

Veronica and Militky [8] investigated the fabrication and characterization of multifunctional light weight flexible fabrics for resisting EM radiation. The basic properties of textile structures designated for clothing or technical purposes remains preserved. They also proposed a percolation threshold and a relation is defined that connects between conductive component and total shielding effectiveness.

Vikas and Varji [9] proposed a conducting composite sheet for coating of various electronic devices. This shield is intended to provide electromagnetic interference shielding for various applications in near- and far-field region. A similar study was done by Bachir et al [10] for shielding electronic circuits from electromagnetic interference from mobile phones. Several studies were already done that clearly demonstrates the health impacts of EM radiations due to mobile phone and ell tower in living things [11-13].

Shielding Effectiveness(SE)

Shielding Effectiveness(SE) is the degree of isolation provided by a shield from electromagnetic radiations.

$$SE = 20\log\left(\frac{E_0}{E_1}\right)$$

$$SE = 20log\left(\frac{H_0}{H_1}\right)$$

$$SE = 10log\left(\frac{P_0}{P_1}\right)$$

Where E_0, H_0, P_0 and E_1, H_1, P_1 are electric , magnetic field strength values and power density values measured without and with the enclosure. In the absence of the enclosure, both the values are the same and SE will be equal to 0 dB. Positive values correspond to attenuation and negative values correspond to amplification. The shielding effectiveness depends on several factors such as frequency , polarisation , thickness of the enclosure , the hole dimensions , material permittivity , permeability and conductivity.

Shielding effectiveness of a shield is the ratio of the radiated power received without and with the shield. It is usually expressed in dB.

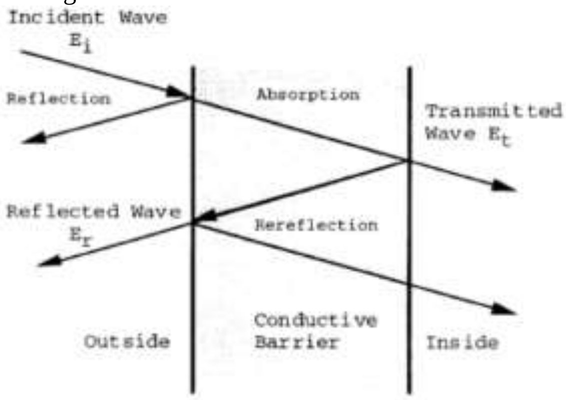


Figure 1: Shielding Mechanism

The attenuation of EM field is mainly due to two different mechanisms (figure ())

1. Absorption
2. Reflection

Absorption

$$SE_A = 20Log_{10}\left[Exp\left(\frac{t}{\delta}\right)\right]$$

$$\delta = \frac{0.066}{\sqrt{f\sigma\mu_r}}$$

where, t – thickness in meters
δ – depth of penetration
σ - conductivity of the material
μ_r - relative permeability

Reflection

$$SE_R = 20Log_{10}\left[\frac{1}{4}\sqrt{\frac{\sigma}{\mu_r\ f}}\right]$$

SE = $SE_A + SE_R$

It is observed that electric shielding is effective at low frequencies, but magnetic shielding is not. As frequency increases, Shielding Effectiveness decreases for electric field and increases for magnetic field. But after some certain frequencies both may be in the similar range. In practice SE of 30 – 60 dB is well acceptable. SE with values more than 70 dB are considered as high-quality shields. SE of several hundred are practically possible. The discontinuities in the shield such as holes, joints, bends will affect the shielding performances. Positive SE corresponds to EM isolation, 0 dB points to full transparency and negative value corresponds to amplification, due to the resonating effects. We cannot observe that SE will always increases with frequencies. More over every experiment will not produce the same results. It will depend on several factors and experimental conditions. The slots in the shield must be always smaller than the wave length. Otherwise wave will pass through it.

Near field and far field shielding

When the distance between the radiation source and the shield is more than $\lambda/2\pi$ it is considered as in the far field shielding region and if less, it is in the near field shielding region. Electromagnetic plane wave theory is applicable in the far field and the theory of dipoles is applied in the near field.

6.1.4 Shielding Materials

Metals are good conductors which can absorb, reflect and transmit electromagnetic interferences. All metals and metallic compounds including brass, copper, aluminium, silver, steel etc are used for quality shielding materials. Plastics embedded with thin metal foils are also used. It has been observed that proper grounding is effective in increase the shielding effectiveness.

The same experiments repeated in different conditions may produce varying results. This will not invalidate the results. That depends on several factors like apertures, joints, bending and holes in the shield. The distance between the source and the shield will also affect the result.

Aim of the Study

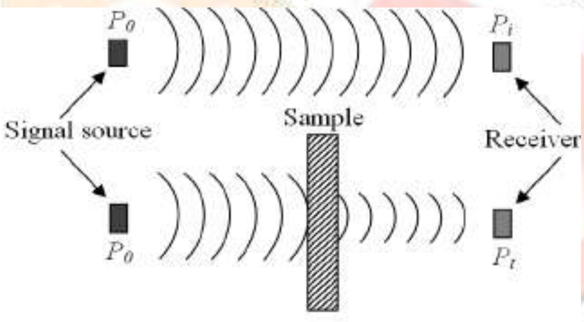
The aim of the study is to investigate the shielding effectiveness of different materials which are easily available and affordable to the common public. The purpose is to provide suitable roofing solutions to those forced to live near the cell towers. The aim consists of three parts

1. To find out a suitable, cheap and easily available solution to protect the houses, situated in the highly exposed regions near the cell towers.
2. To find out the truth behind the claims of manufacturers, providing shielding solutions with higher rates
3. To examine the effectiveness of Shielding Paints available in the market.

II. METHODOLOGY

There are different methods available to measure the shielding effectiveness of materials. They include

1. Open Field or Free Space Method
2. Shielded Box Method
3. Shielded Room Method
4. Coaxial Transmission Line Method



Open field method is applicable here because the study is to assess the shielding effectiveness of materials which are used for roofing. Cell towers are the RF transmitters here and usually situated distant away from the house roofs and comes under far field shielding.

The test method involves mounting the testing materials more than 5 meters from the radiation source to satisfy far field conditions. All the experiments were done with a source distance of 5 metre from the sample shield and the measuring point 1 metre from the shield surface to satisfy far field condition. Stray radiation levels were measured at the beginning of every experiment. Stray radiations were controlled to a minimum. Materials which are easily available were tested, in a range 800 MHz to 2.8 GHz. Exposure values were measured without and with the sample. Experiments were repeated minimum 3 times.

EXPERIMENTAL SETUP

(a)Signal Generator 9KHz – 3 GHz

(b)12dBi High Gain Omni-Directional SMA Male Antenna, 700MHz-2700MHz Wide Band 2.4GHz

(c) MECHO's Radiation Meter

Figure 2: Experimental setup

The radiation source is placed 5 meters away from the testing shield and the radiation meter is placed 1 meter away from the shield in the other direction. (figure()) Readings are taken with and without the shield. Experiment is done for frequencies from 800 MHz to 2800 MHz to cover 1G to 4G range. SE is calculated using the equations.

In the case of cell towers, which is shared by different carriers and different operators, it is usually more practical to calculate the SE using the power densities.

$$SE = 10log\left(\frac{P_0}{P_1}\right) \text{..........Eq(1)}$$

Where P_0 , P_1 are the power density measured without and with the shielding sheet.

III. CASE STUDY- RF SHIELDING EFFECTIVENESS OF ROOFING MATERIALS

SE Considerations

SE of 40 dB and above are considered as satisfactory and above 50 dB as good whereas above 60 dB values are taken as high quality. (The stray radiation power density in the experimental environment: 92µW/m2 Variations found in repetition of experiment: ±2dB)

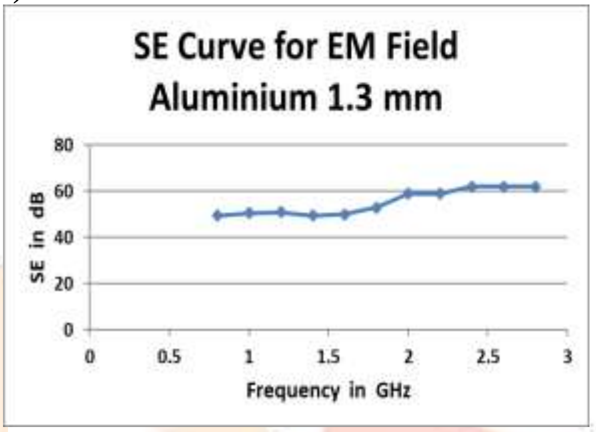


Figure 3: SE curve for EM field AL 1.3mm.

Conclusion: SE varies in between 50 to 62 dBs for the 1G- 4G range. Can be taken as a good shield for far field RF exposure and is suitable against cell tower exposure.

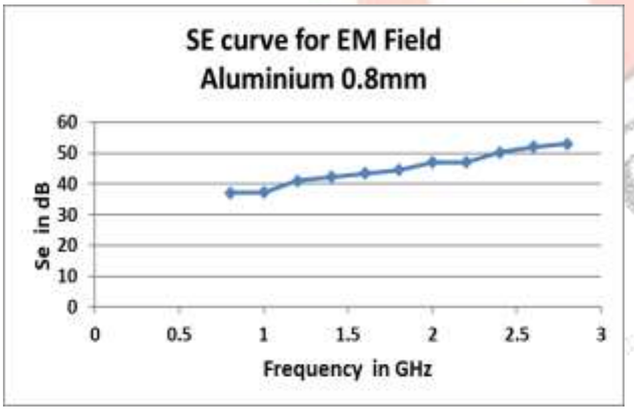


Figure 4: SE curve for EM field AL 0.8 mm.

(The stray radiation power density in the experimental environment: 72µW/m2Variations found in repetition of experiment : ±0.8dB)

Conclusion: SE varies in between 37 to 53 dBs for the 1G- 4G range. Can be taken as a good shield for far field RF exposure from 2G onwards

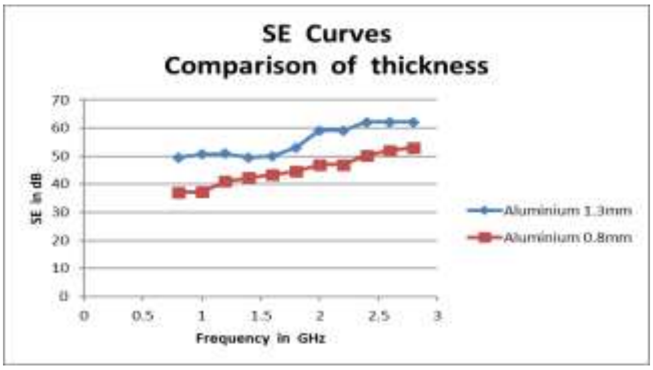


Figure 5: SE curve comparison of thickness.

Conclusion: It can be seen that SE increases with thickness for the given material for almost all frequencies in the taken range.

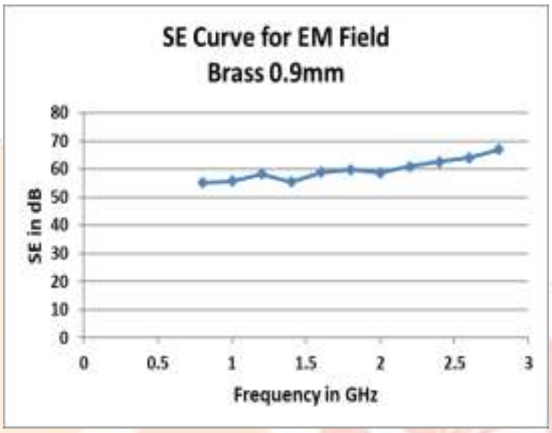


Figure 6: SE curve for EM field Brass 0.9mm.

(The stray radiation power density in the experimental environment: 21µW/m2
Variations found in repetition of experiment: ±2dB)
Conclusion: SE varies in between 55 to 67 dBs for the 1G- 4G range. Can be taken as a good shield for far field RF exposure and is suitable against cell tower exposure. But cost is not affordable to the common public.

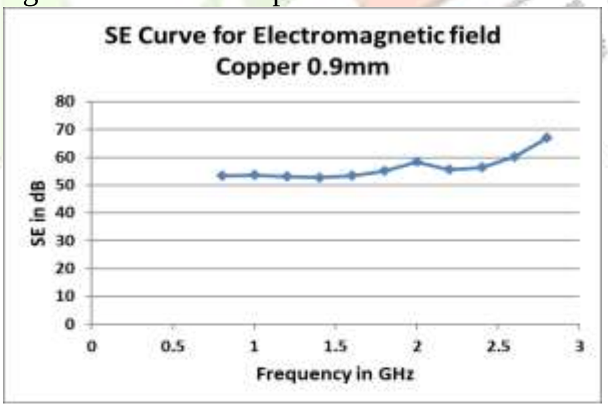


Figure 7: SE curve for EM field Copper 0.9mm.

(The stray radiation power density in the experimental environment: 91µW/m2
Variations found in repetition of experiment: ±1dB)

Conclusion: SE varies in between 53 to 67 dBs for the 1G- 4G range. Can be taken as a good shield for far field RF exposure, but also not affordable to the common public.

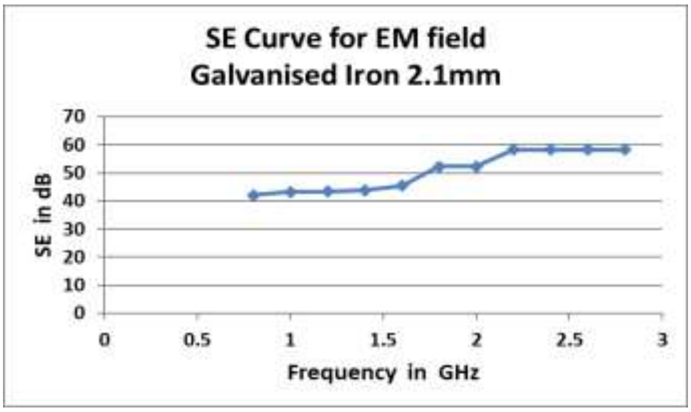


Figure 8: SE curve for EM field Galvanized Iron 2.1mm

(The stray radiation power density in the experimental environment: 12µW/m2
Variations found in repetition of experiment: ±1dB)
Conclusion: SE varies in between 42 to 59 dBs for the 1G- 4G range. Can be taken as a good shield for far field RF exposure and is suitable against cell tower exposures.
(The stray radiation power density in the experimental environment: 86µW/m2

Variations found in repetition of experiment: ±2dB)
Conclusion: It cannot be taken as a shield against RF

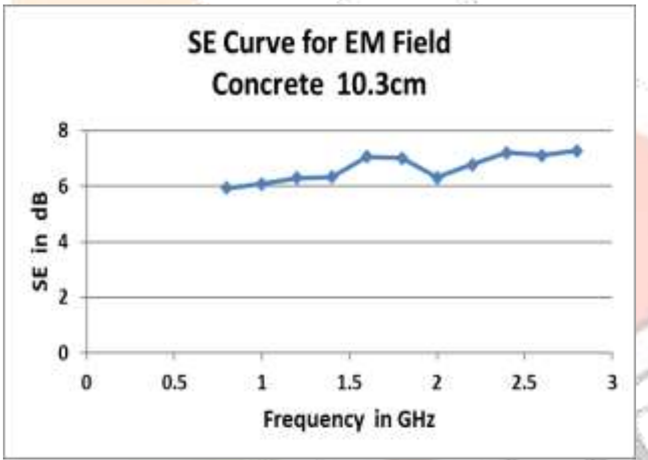


Figure 9: SE curve for EM field concrete 10.3cm.

Experimental Innovation
It is found that the roofs of most of the buildings in Kerala are of Concrete. But concrete doesn't have a good SE. Experimented several methods to improve its SE. When introduce an Aluminum mesh of less than 10cm X 10cm as a top layer just inside the concrete, tremendous improvement in SE is appreciated. The introduced mesh is cheap and easily available in the local markets.

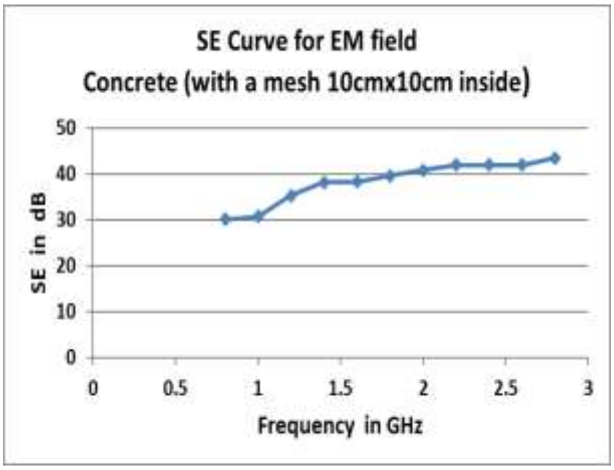


Figure 10: SE curve for EM field concrete 10cm X 10cm mesh.

(The stray radiation power density in the experimental environment: 83µW/m2Variations found in repetition of experiment: ±0.9dB)

Conclusion: SE varies in between 30 to 44 dBs for the 1G- 4G range. After the introduction of the specified mesh, concrete roofing is transformed as a better shield.

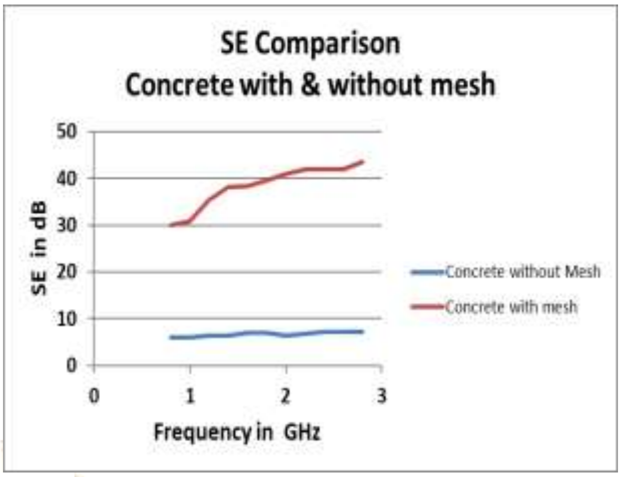


Figure 11: SE comparison concrete with and without mesh.

Grounding
Conducted some tests to find out how far the grounding will improve the shielding performance of conductors.
Test 1 (Aluminium 0.8mm)

Table 1: Test 1 (Aluminium 0.8mm)

FREQUENCY IN GHz	P0mW/m²	P1 mW/m² Without Grounding	P1 mW/m² With Grounding	SE dB Without Grounding	SE dB With Grounding	% of increase
0.8	1600	0.314	0.01210	37.07	49.17	32.64
1.0	1600	0.298	0.01134	37.30	49.45	32.57
1.2	1600	0.125	0.00814	41.07	50.89	23.91
1.4	1600	0.094	0.00693	42.31	51.59	21.93
1.6	1600	0.072	0.00563	43.47	52.49	20.75
1.8	1600	0.056	0.00401	44.55	53.97	21.14
2.0	1600	0.032	0.00282	46.99	55.50	18.81
2.2	1600	0.032	0.000954	46.99	60.20	28.11
2.4	1600	0.015	0.000671	50.28	61.73	22.77
2.6	1600	0.010	0.000211	52.04	66.76	28.29
2.8	1600	0,008	0.000231	53.01	66.36	25.18

Conclusion: An average of 23.11% of increase in SE is found when proper grounding is given.

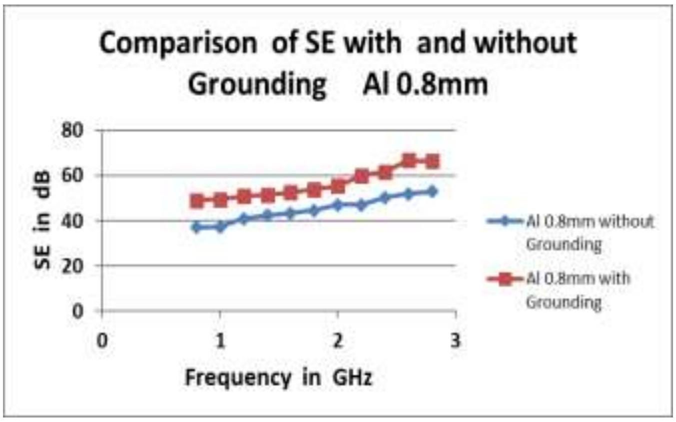


Figure 12: comparison of SE with and without grounding AL 0.8mm.
Conclusion: An average of 21.57% increase in SE is found when proper grounding is given.

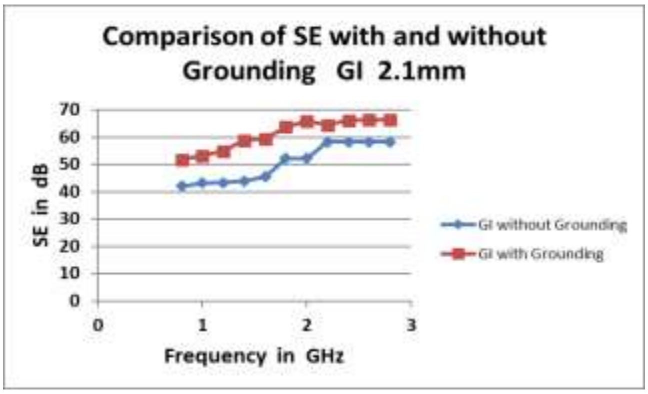


Figure 13: comparison of SE with and without grounding GI 2.1mm.

Table 2: Test 2 (Galvanised Iron 2.1 mm)

FREQUENCY IN GHz	P0 mW/m^2	P1 mW/m^2 Without Grounding	P1m W/m^2 With Grounding	SE dB Without Grounding	SE dB With Grounding	% of increase
0.8	2000	0.126	0.0134	42.01	51.74	23.16
1.0	2000	0.096	0.00951	43.19	53.23	23.25
1.2	2000	0.092	0.00649	43.37	54.89	26.56
1.4	2000	0.082	0.00263	43.87	58.81	34.06
1.6	2000	0.058	0.00117	45.38	59.32	30.72
1.8	2000	0.012	0.000846	52.22	63.74	21.54
2.0	2000	0.012	0.000519	52.22	65.86	26.12
2.2	2000	0.003	0.000711	58.24	64.49	10.73
2.4	2000	0.003	0.000483	58.24	66.17	13.62
2.6	2000	0.003	0.000479	58.24	66.21	13.68
2.8	2000	0.003	0.000464	58.24	66.35	13.92

TABLE 3: TEST 3 (CONCRETE WITH MESH)

FREQUENCY IN GHz	P0 mW/m^2	P1 mW/m^{2}Without Grounding	P1 With Grounding mW/m^2	SE dB Without Grounding	SE dB With Grounding	% of increase
0.8	800	0.781	0.123	30.10	38.13	26.68
1.0	800	0.674	0.0984	30.74	39.10	27.20
1.2	800	0.231	0.0687	35.39	40.66	14.89
1.4	800	0.121	0.0139	38.20	47.60	24.61
1.6	800	0.118	0.00641	38.31	50.96	33.02
1.8	800	0.0874	0.00281	39.62	54.54	37,66
2.0	800	0.0652	0.00276	40.89	54.62	33.58
2.2	800	0.0511	0.00254	41.95	54.98	31.06
2.4	800	0.0511	0.00258	41.95	54.91	30.89
2.6	800	0.0511	0.00261	41.95	54.86	30.77
2.8	800	0.0356	0.00259	43.52	54.90	26.15

Table:

Concision: An average of 28.77% increase is found in SE when proper grounding is given to the mesh in the concrete.

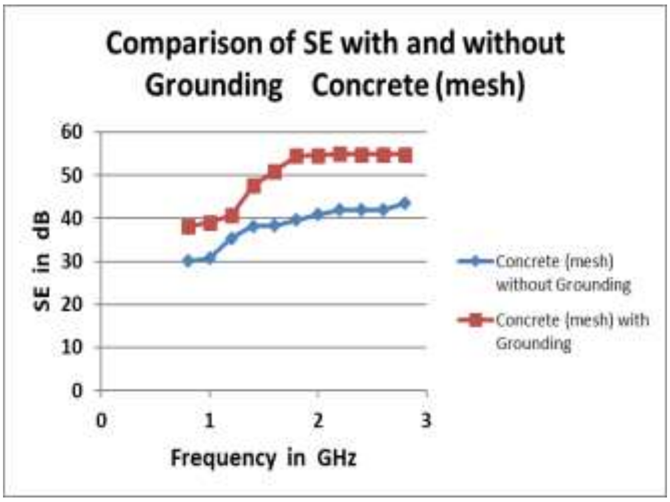


Figure 14: comparison of SE with and without grounding Concrete (Mesh

Concrete transformed as a better shield

When proper earthling is applied, the concrete with mesh performance attain far better levels. After 1.5 GHz, it gives an SE of above 50. It is one of the cheapest ways to achieve protection from Cell Tower exposure. If people are planning to build or forced to build a house near Mobile towers , it the best way. This is one of the principal contributions as far as this work is concerned. Figure (0 & ().

IV. Conclusion

Our experiments confirm the following facts regarding the protection from cell tower.

1. Shielding is found to be an effective way of protection for the houses which are very near to the cell towers.
2. Grounding will considerably increase the shielding effectiveness of the conductor sheets.
3. The materials like Gi and Aluminium sheets are easily available and demand lower price, found comparatively better performed when properly grounded.

Our experiments found that concretes with a thin Aluminium mesh of 10cm x 10cm length and breadth attached as a top layer will give enough protection and safe guard the residents when properly grounded.

V. Acknowledgement

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