Survey of Electromagnetic field Standards for Cellular Networks by Computational

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Abstract - *An abstract summarizes, cellular networks have revolutionized the way users access communication networks but they required a huge effort to operators for the development of a wireless infrastructure which has been designed considering deployment costs with ubiquitous coverage and service quality targets. The traditional "macro" Base Stations (BSs) that have been used so far turned out to be inefficient from the operational costs point of view mainly because of their high energy consumption. Today, green communication is one of the main design goals of future mobile networks and current research aims to enable sustainable growth of broadband wireless infrastructure. Different solutions have been proposed so far for improving the energy efficiency of wireless networks. Small cells based on low-cost low-power Access Points (APs) are a promising solution to limit emission power and improve the spectral efficiency. Dynamic radio resource management can avoid energy wastage by adapting network parameters to load variations while satisfying quality constraints. Comparison of energy absorbed from RF Waves in a finite time with Sunlight in line of sight scenario as a worst case analysis with actual measurement results for the model used has been done to show that the RF energy we are exposed to is minuscule. Safety is achieved in three ways - by the inherently lower energy of the photon itself leading to its non ionizing nature, the decay of RF Waves with distance and by the limit on total power by the EMF standards. All analysis must be based on RF Energy in actual areas of public. Access wherein the decay of RF waves with distance is an important factor and further ensures compliance of safety norms by many multiple times.*

Key Words: EMF, FEMTO, ICNIRP, RF Waves, Radiation, Radio Propagation, Safety, Small Cells

1.INTRODUCTION

A cellular network is a radio network distributed over land through cells where each cell includes a fixed location transceiver known as base station. These cells together provide radio coverage over larger geographical areas. User equipment (UE), such as mobile phones, is therefore able to communicate even if the equipment is moving through cells during transmission. Cellular networks give subscribers advanced features over alternative solutions, including increased capacity, small battery power usage, a larger geographical coverage area and reduced interference from other signals. Popular cellular technologies include the Global System for Mobile Communication, general packet radio service, 3GSM and code division multiple access. Cellular network technology supports a hierarchical structure formed by the base transceiver station (BTS), mobile switching center (MSC), location registers and public switched telephone network (PSTN). The BTS enables cellular devices to make direct communication with mobile phones. The mobile devices communicate unit acts as a base station to route calls to the destination base center controller. The base station controller (BSC) coordinates with the MSC to interface with the landline-based PSTN, visitor location register (VLR), and home location register (HLR)

Cellular networks maintain information for tracking the location of their subscribers' mobile devices. In response, cellular devices are also equipped with the details of appropriate channels for signals from the cellular network systems.

These channels are categorized into two fields:

- Strong Dedicated Control Channel: Used to transmit digital information to a cellular mobile phone from the base station and vice versa.
- Strong Paging Channel: Used for tracking the mobile phone by MSC when a call is routed to it.

A typical cell site offers geographical coverage of between nine and 21 miles. The base station is responsible for monitoring the level of the signals when a call is made from a mobile phone. When the user moves away from the geographical coverage area of the base station, the signal level may fall. This can cause a base station to make a request to the MSC to transfer the control to another base station that is receiving the strongest signals without notifying the subscriber; this phenomenon is called handover. Cellular networks often encounter environmental interruptions like a moving tower crane, overhead power cables, or the frequencies of other devices. As shown in the fig 1

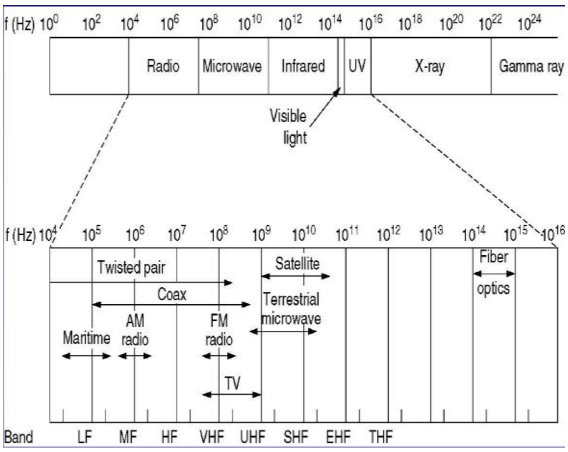

Fig -1: Electromagnetic Spectrum

Most of the countries in world follow the ICNIRP Standard (International Commission for Non Ionizing Radiation Protection). In India the new EMF exposure limits from towers fixed by the inter-ministerial committee are 1/l0th of ICNIRP Limits as (with f as frequency in MHz) fl2000 $^{W}/_{m^2}$ for the range 400 MHz to 2 GHz,1 $^{W}/_{m^2}$ for the range 2 GHz to 300 GHz which means ten times more stringent than 90% countries in the world. Equivalent Standards adopted in various countries are - USA, Canada and Japan as 12 , ICNIRP and European Union recommendation as 4.5 $^{W}/_{m^2}$ Australia as 9 and India as 0.45 $^{W}/_{m^2}$ for 900 MHz band

2. Classification of radio waves

Radio waves are electromagnetic waves. Electromagnetic waves include waves such as X rays, ultraviolet light, visible light, infrared rays and so on, but you probably imagine radio waves to be quite different from these waves. Of the various kinds of electromagnetic waves, radio waves have a longer wave length than infrared rays, and are defined by the Radio Law as 'electromagnetic waves with a frequency of less than 3,000 GHz (3 THz)'. The shorter the wave length of radio waves becomes, the more they take on the qualities of light, and the greater their straightness becomes. In other words, their energy is concentrated in one direction, and they are said to have strong directivity. Furthermore, the higher the frequency, the more acute is the attenuation of the wave's energy. In general, radio waves are considered to propagate in a straight line, but what happens if there are various physical obstacles in their path such as mountains, buildings, walls, or people and so on? If we consider an example of an urban area where there are many buildings, there are direct waves that arrive directly, reflected waves that arrive after hitting buildings and the like, diffracted waves that circumvent the shadows of buildings, transmitted waves that arrive by passing through the glass or walls of buildings, and so on. The kinds of wave differs according to type (material) of obstacle. Radio waves can pass through glass and ceramics (permeation), but they are reflected by metal and concrete. Furthermore, waves with frequencies higher than several GHz are scattered and absorbed by rain, snow, fog and the like, and their power tends to attenuate.

This means that if P_t is the transmitted power, then Power Density S at d is given by $P_t/4\pi d^2$. The received Power P_r depends on the antenna aperture Arand is given by P_r= S. A_r. The free space path loss, FSPL, is used in many areas for predicting radio signal strengths that may be expected in a radio system. Although the free space path loss does not hold for most terrestrial situations because of other effects from the ground, objects in the path and the like, there are still very many situations in which it can be used. It is also useful as the basis for understanding many real life radio propagation situations.

Accordingly, the free space path loss, FSPL, is an essential basic parameter for many RF calculations. It can often be used as a first approximation for many short range calculations. Alternatively it can be used as a first approximation for a number of areas where there are few obstructions. As such it is a valuable tool for many people dealing with radio communications systems. As shown in Fig 2

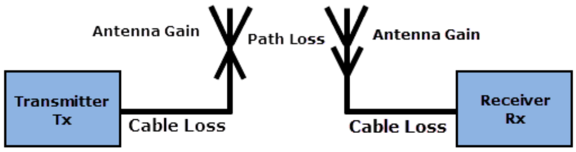

Fig-2: Path loss

Thus if the EMF standards are complied on the roof top housing the Mobile Tower which is usually achieved at a small distance, say x from the antenna, then at distance l0x from the antenna the RF Power Density would be further lower than that received at x by an additional factor of 100. With x as 2 m then at just 20 m from the antenna the RF power density would be lower by 220,000 times than that received from the Sun.

Table -1: RF Power decay with distance for 900 MHz band, would be higher for higher frequencies

Frequency Range (MHz)	Signal
870 –896	Cellular mobile phone uplink
896-902	Private land mobile radio
902-928	Amateur radio service reserve
928-932	Domestic public radio service (paging)
944-947	Broadcast radio service (intercity relay)
950-2100	DBS (Satellite over coax)

The model has been further cross checked at many cell sites for measurements done on the roof top and the result of one of them has been presented in Table 1. As can be seen the Path Loss Model slightly over predicts the RF power given by EIRP in such line of sight conditions as per measured results at this site at Hyderabad where ten Base Stations are live. Also for the same site calculations as per DOT have been done and as mentioned in these recommendations themselves, the models in such near field regions lead to large but safe side overestimation of Power Density with respect to measurement as can be seen in Table 1. Also in actual deployment the emitted power is further reduced by features like Dynamic Power Control (DPC) in good coverage areas and Discontinuous Transmission (DTX) which further ensure compliance. With lower traffic in night time the emitted power reduces to less than half of that during the day ensuring further compliance.

Table-2: Path loss and actual measurments

Lat/Long :	24.54149/81.29584	C1	C2	C3	C4
Azimuth (deg)		20	90	150	260
Distance form Tower Base (m)		10	12	9	6
EMF Standard (W/m^2)		0.45	0.45	0.45	0.45
Measured Power Density (W/m^2)		0.06	0.06	0.06	0.07
Power Density as per Path Loss		0.07	0.07	0.07	0.08
Ratio (Measured/EMF Standard)		0.14	0.13	0.14	0.15
EIRP/EIRPth using calculation		0.61	0.61	0.61	0.61
Ratio (Calculation/ Measurement)		4.23	4.63	4.31	3.97

Thus with an average human life of 80 years, the life time RF exposure at just 20 m in line of sight from the antenna is equivalent to 40 hours in Sunlight, in the floor below as less than five hours in Sunlight and at 100 m is less than two hours of Sunlight. With a bare minimum exposure of an hour in sun light, we normally have more than 300 hours of Sunlight exposure in a year alone. As shown in table 2.

3. Energy of the photon of RF waves

Photons of Gamma rays and X-rays carry so much energy that they have the ability to break bonds between molecules cause genetic damage and are hence called 'ionizing emission'. Fields whose quanta are insufficient to break molecular bonds are called 'non-ionizing emission' which start from Visible Light onwards and extend further towards lower frequencies Radio Frequency fields are found at even lower frequency than Sun Light and their Photons are unable to break chemical bonds, since their energy is around 0.0000021 of the energy of the Photons of Visible Light as reiterated in table 3. It is also very important to note that even if the intensity of the RF waves increases, the energy of each Photon and its behavioral impact remains the same as per its frequency

Table-3: Energy of Photons in e_v and Comparison with Visible Light

	RF waves	Visible Light	X rays	Gamma Rays
Energy of Photon	0.0000037	1.77	1,241	124,070
Ratio wrt Visible Light	0.0000021	1	700	70,012

Thus safety is ensured in three ways -firstly by the miniscule energy of the RF wave's photon itself leading to its non ionizing nature, the decay of RF Waves with distance & inbuilding penetration loss making its power as minuscule in areas of public access and finally by the overall limit of power density as per EMF standards. Two examples that we observe in our day to day life about the energy of the individual photon are - Visible light irrespective of its intensity cannot be used to produce X rays reports by Doctors since the energy of their photons is insufficient and similarly the photoelectric effect is observed above a certain threshold frequency above which the energy of the Photon is adequate to dislodge an electron. The RF waves' Photons comparatively have very little energy and are thus harmless.

4. Computational for small cells

Cellular systems increase capacity by reusing the same radio frequencies across many cellsites – in dense urban areas that means cellsites with coverage areas of as little as 200 metres. In order to provide adequate capacity, plus good in building coverage (and thus quality), large numbers of small cellsites are required. Macrocells are the original, wide area high power basestations which cover areas up to about 20 miles radius (more in specific situation). In urban areas, a separate layer of microcells is installed to provide the capacity and in-building penetration needed, taking the load off the macrocellular network. For office buildings and shopping malls with extremely high demand, even smaller cellsites are used. All three types of cell operate in a very similar way, and are actively managed and configured by the mobile network operator. EMF Signals at 1 m for FEMIO Cells and comparison with Standards using the Free Space Path Loss Model as shown in table-4Each cell is configured with neighbour lists, so that mobile phones can switch over to an appropriate nearby cell and continue their conversation without interruption Picocells are normally installed and maintained directly by the network operator, who would pay for site rental, power and fixed network connections back their switching centre. Femtocells differ from picocells because they are intended to be much more autonomous. They are self-installed by the end user in their home or office, primarily for their own benefit. Femtocells automatically determine which frequency and power levels to operate at, rather than being directed from a centrally determined master plan. This allows the network to adapt automatically as new femtocells are added or moved without the need for a complete frequency replan. The disadvantage is that femtocells would not normally broadcast a list of nearby neighbouring cells. Mobile phones would thus maintain the connection on the femtocell as much as possible, but risk dropping the call or having an short outage if the call needs to be switched across to an external macro or microcell.

Femtocell vendors have been promoting the use of their products within the enterprise, in order to displace picocells. Their arguments are based on lower operational costs (ease of installation, ongoing maintenance etc.). The business case for femtocells in the enterprise is potentially stronger than for picocells, because of the lower installation and ongoing operational costs. It would piggyback on the existing IP network infrastructure provided by the business IT department, who could use mechanisms to prioritise the traffic above mainstream data traffic to ensure high voice quality. Corporations would expect to benefit from lower cost calls within their enterprise locations in return for installing and maintaining these systems, which would also be offset by not requiring fixed phones at the desk .Both the models reveal that the radiated power at 1 m away from the FEMTO Cells is more than 1000 times lower than the revised standard as adopted in India and is more than 100000 times lower than revised standard at 10 m from the FEMTO Cell with single TRX of 200 mW. The above are as per maximum power output of the Small Cells while in actual deployment the emitted power is generally half of the same due to Dynamic Power Control Mechanism which are an inherent part of the design. This applies to Macro cells as well and makes the Cells even more compliant to the safety norms as already discussed. Another very important aspect of Small Cells is that the emitted power of the Mobiles becomes much lower due to good coverage so provided.

Table -4: EMF Signals at 1 m for FEMIO Cells and comparison with Standards using the Free Space Path Loss Model

Small Cell	Output Power in milli Watts	Output Power in dBm	Antenna Gain in dBi	Feeder Loss dB	RF Signals at 1 mtr away in dBm	Ratio of RF Signals at 1 mtr with respect to EMF Standard (0.45 W /m^2)
Directly Feeding Omni Antenna	200	23	2	0	-12.51	0.00012
Feeding DAS Distributed Antenna System (40 mtrs cable)	200	23	2	3.6	-16.11	0.00005

5. Other sources of electromagnetic waves and standards

Mobile Tower operates with output power of 20 watts per carrier. On the other hand TV and FM radios with 20,000 Watts output power have been installed for over 50 years with no evidence of health problems in these areas. Also exposure to public access areas from Mobile Towers are lower than radio stations, police wireless and TV stations which emit much higher power in similar frequency bands .WHO has repeatedly asserted that "mobile tower radiation is not dangerous since unlike ionizing radiations (like X-rays or gamma rays), they cannot break chemical bonds or damage the constituents of human cells" . A large nunber of studies have been performed over last two decades to assess whether mobile phones pose a potential health risk. "To date no adverse health effects have been established as being caused by Mobile Phone use" WHO June 2011. There is more concern due to possible road accidents that may be caused by people using the mobile phones while driving their vehicles. The only known biological effect of radio frequency energy is heating as per US Government's National Cancer Institute , and our discussion as per above is on the same lines with analogy of Sun Light . The human skin acts as a lossy dielectric for the RF waves whose impact on the skin can only lead to heating. It is important to note that we never feel hot even a little bit even when standing directly in front of an antenna itself due to the very low RF energy as emphasized earlier in comparison with the Sun Light.

CONCLUSIONS

As a key challenge for future EMF monitoring we recognize the need to change from ambient to personal exposure assessments and eventually to estimate dose for corresponding monitoring. The RF studies that have been performed previously have mainly considered infrastructure or mobile devices separately and therefore do not provide a clear view of the real personal exposure induced by wireless communication systems. Furthermore, it is expected that the complexity of EMF exposures continues to increase.
norms are themselves adequate, the additional safety margin added in India has ensured further compliance. The same has also led to requirement of network realignment and redesign in some congested areas. Also more important is to understand that the effect of RF waves on Human Beings would be much lower than the effect of Sun Light on us. While the discussions herein have been focused on Base Stations, it is very important to note that in good coverage areas like those near the Cell Sites or outdoors or in Small Cells, the emitted power of the mobiles as well as the serving BTS becomes much lower and thus further enhances safety and increases its battery life. The Path Loss Model can be effectively used, with slight overestimation on safe side, to arrive at the Power Density in line of sight conditions in near field regions for the purpose of EMF compliance. Also while the standard indicates the maximum limits, more important is to compute the Power Density in actual areas of public access and all comparisons must be based on these values only which are millions of times below that of Sun Light. The RF energy received during our entire lifetime is equivalent to that received from the Sun in a few hours.

REFERENCES

1. J. Gavan. 2007 Base Stations and Headsets Mobile Radio Systems Radiation: Analysis, Mitigation and Simulations Techniques", International Conference on Communication Systems, Gold Coast Australia.
2. M. Pllana, L. Ahma, E. Hamiti 2007 Human exposure assessment in the vicinity of 900 MHz GSM base station antenna. International Journal of Communications.
3. HP. Hutter, H. Moshammer, P. Wallner, M. Kundi 2006 Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup Environ Medicine.
4. Mild, K. H. Oftedal, G. Sandstrom, M. Wilen, J. Tynes, T. Haugsdal, B. Hauger 1998 Comparison of symptoms by users of analogue and digital mobile phones- A Swedish-Norwegian epidemiological study, National Institute for working life.
5. JA. Elder, CK. Chou 2003 Auditory Response to Pulsed Radiofrequency Energy", Bioelectromagnetics Supplement.
6. R. Andrzejak, R. Poreba1, M. Poreba, A. Derkacz, R. Skalik, P. Gac, B. Beck 2008 The Influence of the Call with a Mobile Phone on Heart Rate Variability Parameters in Healthy Volunteers, Industrial Health.
7. SK. Myung, W. Ju, DD. McDonnell, YJ. Lee, G. Kazinets, CT. Cheng, JM. Moskowitz 2013 Mobile phone use and risk of tumors: a meta-analysis, Journal of Clinical Oncology.
8. VG. Khurana, C. Teo, M. Kundi, L. hardell, M. Carlberg 2009 Cell phones and brain tumors: a review including the long-term epidemiologic data, Surgical Neurology.
9. National Council on Radiation Protection and Measurements 1986 National Council on Radiation protection & Measurements (NCRP), Biological Effects and Exposure Criteria for Radio Frequency Electromagnetic Fields.
10. Mobile phone radiation 2013 Available at http://www. electroschematics. com/5200/mobile-phone-radiation/ (last accessed July' 13).