Base Stations and Headsets Mobile Radio Systems Radiation: Analysis, Mitigation and Simulations Techniques

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ABSTRACT

Nowadays the numbers of mobile Radio equipment and users have increased both tremendously and have exceeded two thousand Millions. However this increase also the probability and number of harmful mutual interference and of people exposed to non ionized radiation from the transmitting radio equipments. A significant part of the transmitted energy is wasted as interference and parasitic radiation source to a multitude of users. The power density levels of radiation from mobile base station are usually significantly less than the stricter standard power density level thresholds to exposed people due to the high separation distance effects under far field propagation conditions. In comparison, radiation effects to mobile headsets users are significantly stronger and unpredictable due to the reactive near field proximity distance to the radiation sources, complexity and hot spots of the Electro-Magnetic (EM) field components near the user head or body. Will be analyzed: simple radiation effects from far field base station antennas, techniques for enhancing the efficiency of power and energy transmission for mobile radio systems. This will be followed by describing the complex radiation field components absorbed by the individual users from their headsets and the actual importance of the Specific Absorption Rate (SAR) expression, considering that the power density level is not well defined under near field conditions. Will also be described mitigation techniques and simulations for increasing the efficiency of base stations and headsets, the batteries life-time and for decreasing significantly the radiation intensity effects in the mobile radio users head and body.

1. PREFACE

A tremendous increase in mobile radio users, equipment and systems leads to one of the main economic forces and revenue sources of modern society. [1] Nowadays the number of mobile phones and users have exceeded two thousands Millions phone and the number of mobile laptops (PC) four hundred Millions, significantly more than the wired equipment as shown in figures 1, [2]. Thus increasing the receivers and people probability to be exposed to non ionized radiation. [2;3]

The main sources of Radio interference and radiation effects offenders are derived from transmitters (TX) and the victims become the systems multitude of receivers (Rx) and individual users, who are exposed to mutual interference and to parasitic radiations. [4,5].

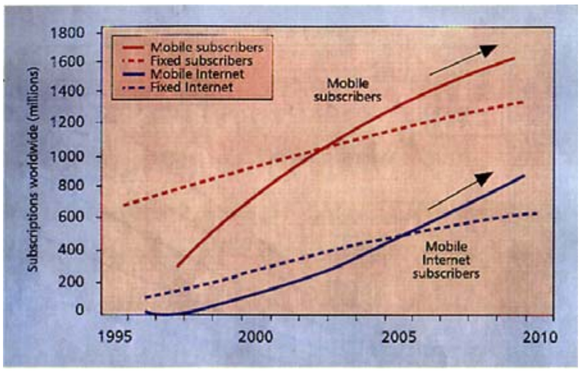

Fig 1. Global growth of radio mobile and fixed subscribers as function of time [2].

2. BASE STATIONS RADIATION AND MITIGATION TECHNIQUES

Base stations TX radiated power levels are higher than handset ones, with usually very low mobile radio system energy efficiency. However, the distances from base stations TX to victim Rx and to exposed people are significantly higher than the transmitted wavelength. Therefore, in almost all cases the people and Rx exposed to base station effects are located in the well defined Franhofer far field radiation zone, where the radiated power density levels decrease usually at the square of the separation distance and even more.[4] Measurements, simulation and statistic analysis results, (obtained from a two-year research grant from the Israel Environmental Ministry Report and other references) [6-8] show that the power density levels of radiation from urban cellular base stations are typically much lower that the most stringent internationally recommended safety power density guidelines usually of $1\frac{mW}{cm^2}$. [6,7] For rural base stations, the power density levels may be more significant because of the higher radiated power levels due to the cellular radius coverage but still lower than the standard threshold power density levels.[8] Thus if security guidelines are applied for base station installations excessive radio power density from radiating antennas to exposed people will be avoided.

The energy efficiency and capacity of base stations can be enhanced by using segment directional antennas instead of omni-directional one. A better solutions is the use of smart antenna arrays which require also intelligent signal processing units.[9,10] The smart antenna concentrates the energy transmission towards the desired mobile Rx user "M" and reduce significantly interference user "I" from near Transmitters (TX) by forming a null steering as shown in figure 2.[5,9]

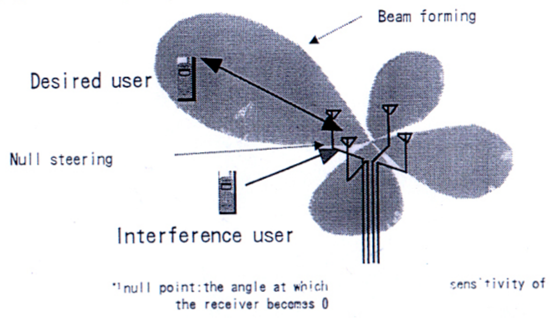

Fig 2 . Principles of a radio base station using smart antennas

The smart antenna technique may also contribute to enhance system transmitted energy efficiency, increase Rx signal to noise and interference ratio and decrease the required base station TX power. This is a crucial technique for decreasing the radiated power density absorbed by human maintenance workers or by the general public. [7,10]. Other mitigation techniques are : Power control [11], shielding by metallic objects or special clothes [1] and selective filtering [10] as will be explained in the presentation.

A novel improvement for mobile radio systems is the development of High Altitude Platforms (HAPs) which act as base stations in the (sky) stratosphere at an altitude of 18 to 24 kms. Experimental HAPs have been built in the US, Japan and soon in Europe [12]. The HAPS mobile radio performances are significantly better than from Geostationary and Low Earth Orbit Satellites [13] and in a few years it seems that they will begin to be used commercially.

3. RADIO HANDSETS RADIATION AND MITIGATION TECHNIQUES

In comparison to the base stations, the effects from handsets radiation are much more complex, unpredictable and significantly stronger because of the reactive near field Electro Magnetic (EM) conditions for the users. The measurements and simulation results show that 30% up to 70% of the transmitted power from an ordinary handset is absorbed in the user head, hand or body due to the very small distances and strong mutual interactions. [4, 11] At these small distances of the cm range in the reactive near field zone of the antenna, strong coupling and loading occur between the antenna and the user's head.

Without considering the health issues, it is obvious that an important part of the handset transmitted energy is wasted The main issues are that in spite of the power control mechanism used now in many cases the handset radiated power is increased as well as the energy absorbed by human users and the life-time of the portable batteries is reduced. Measurement results show that radiation effects to users of cellular handsets are significantly stronger compared to that of standard base stations and can exceed the security standard levels because of the small separation distances.[5]. For instance 1mw transmitted power at a distance of 1cm from the handset has a higher or similar radiation effect than 1000w at a distance of 10m from the base station. Considering that the power level of headsets are usually significantly higher than 1 mw (200mw) and the power level of even high power base stations are significantly less than 1000 W (200w). Therefore, the real problems for security are the radio headsets and not the base stations.

The measurement and computation of the electrical and magnetic field components magnitudes and especially of the power density are very complex and not well defined in the handset reactive near field zone [4]. Therefore has been standardized the Specific Absorption Rate "SAR" of temperature increase measured in Watt per kg representing the non-ionized radiation effects generated in human tissues especially in the head.[1]

The common headsets radiating antennas towards the user head are the low cost and compact helical or monopole quarter wavelength which are common.[3, 4] Latter were developed more efficient planar micro-strip antennas such as the Planar Inverted F Antenna (PIFA) where the absorbed radiation absorption by the head is reduced but the absorption due to the user hand is increased, significantly [14,15]

The use of a cable with external earphones connected to the head to reduce significantly the SAR can be applied but the method is cumbersome and the handset and cable have to be well shielded otherwise the radiation in the user head can even be enhanced.[10]

The Motorola Star Track implementation increases the distance of the monopole antenna from the user head by 2 to 3 cm but the reactive near field conditions and the radiation significant power absorption are still existing.[4;]

Therefore more recently were suggested the use of two antenna elements in the handset which represent an approach to the smart antenna concept explained previously. These two smart elements reduce the absorption by the user head and enhance the propagation efficiency in the direction of the base station. [16] However the phase cancellation

principle used in this technique is efficient for base stations or big radio systems but not for small compact mobile handsets where the proximate separation distance and the high coupling to the user head are always changing. [1,4]
A recent mitigation techniques suggest a compact mobile handset apparatus using a two part fold-over mobile phone where, the lower part contain a keyboard, microphone, earphone and all the non radiating low frequency/low power circuits. The upper part, is a cover for said handsets pivotally connected containing a high frequency power amplifier multiplexer and monopole antenna extendable through the cover, at the opposite end of the pivotal connection to the handset, to a distance of (8-16) cm from the earphone distance and above the user head, raising the locus of radiation laterally and vertically above the head as shown in figure 3. This technique named R95 significantly increases antenna efficiency and reduces drastically the SAR to the user head. [17] Other advantages of this technique are longer battery life, higher signal to noise, better sound quality and higher possible operation distances of the mobile system as most of the energy is directed towards the base station and only an insignificant minor part is absorbed in the user head and body.

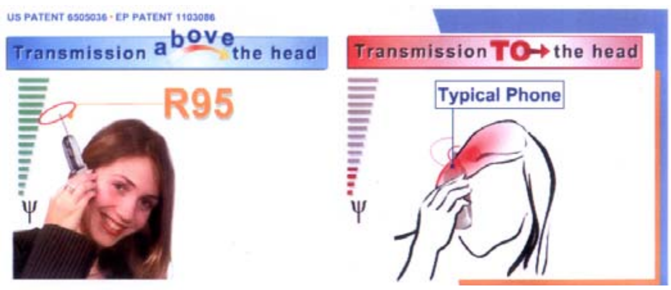

Fig 3. The R95 concept

In Summer 2004 a group of scientists from the University of Toronto Canada applied the numerical Galarkin moment method for computing the SAR of conventional radio handsets to homogeneous and heterogeneous head models as part of a contract from the Canadian and the US Ministry of defense. The tested handsets radiating antennas are helical at 893 and 1881 MHz and monopole whip at 907 MHz. In their simulations and computations [18] they included also the suggested handset model R95 described in figure 3 and in [17; 18]. The results at 907 MHz using the solution of a matrice with around 1000 unknows show that the SAR of the R95 model is about 100 time less than for the conventional headset monopole whip model using the heterogeneous head model as shown in figure 4. The University of Toronto team obtained similar higher SAR results for headsets will helical antennas operating at 893 and 1881 MHz. Considering that at 1881 MHz the number of the matrice unknows is significantly higher but the SAR results are better due to the higher wavelength [18].

Antenna Type	Number of unknows	Simulation time using Galerkin method	SAR (Galerkin sample for homogeneous head model	SAR (Galerkin sample for heterogeneous head model
Helical @ 893 MHz	922	7.6 minutes	2.1	0.65
Helical @ 1881 MHz	3538	74 minutes	1.5	0.19
Monopole/ whip@ 907MHz	881	6.9 minutes	1.9	1.0
Modified R95 @ 907 Hz	881	7 minutes	0.020	0.012

Figure 4. SAR Simulation results of headset Antennas Next to Homogeneous and to Heterogeneous Head Models[18]

4. CONCLUSIONS

Considering mobile radio communication, we are all witnesses to the tremendous increase of the number of users, equipments and of the social, economic and security dominant impacts. Therefore improvements in the quality of service, power efficiency and reduction of parasitical interference and radiation are a must as presented in this paper. It is especially true for the new 3G and the next 4G cellular generations where the system handset power levels and bandwidth are increased.[19]

The mitigation techniques described and analyzed in this paper for mobile radio systems base stations and mobile handsets can contribute significantly to the required improvements. The suggested techniques are effective for improving the quality and power efficiency of base stations operating under far field and headsets operating under complex near field propagation conditions [1;4]. Especially emphasize was dedicated in the analysis to reduce strongly the SAR and improve the performances of a proposed model of headset. A qualified independent team simulation results show that the SAR of the proposed model are more than 50 times better than for classical headsets. However considerable more efforts are still needed in order to improve mobile radio communication to an efficient, secure and convenient system useful for the welfare and positive advancement of our global society.

REFERENCES

1. N. Kuster., Q. Balzano., J.C. Lin., Editors., "Mobile Communications Safety"., Chapman & Hall, 1997.
2. Y..Kim; et al; "Beyond 3G: Vision, Requirements and Enabling Technologies"IEEE Communications Magazine, March 2003 P.121.
3. A. Joel., "Telecommunications and the IEEE Communications Society" IEEE Communication Magazine. May 2002 PP (6-14), 162.
4. R. Perez, Editor., "Handbook of Electromagnetic Compatibility" Academic Press Chapters1,19,20, and Appendix 4,1995.
5. J.Gavan, "Transmitters Interference to Victim Receivers and Radiation Hazard to Human : Are they correlated ?" URSI General Assembly Session E/F – 4PP (1-4) August 2002.
6. R. Zemach; J. Gavan., S.Levy., E. Neeman "Stochastic Processes in Radiation Emission of Cellular Base Stations" URSI General Assembly Session K-1, M pp.(1-4) August 2002.
7. R. Ciccheti., A. Faraone., "Estimation of the Peak Power Density in the Vicinity of Cellular and Radio Base Station Antennas" IEEE Trans. On EMC Vol No2 pp (275-290) May 2004
8. R.Zemach, J. Gavan, S. Levi; E. Ne'man, "Fingerprints of Cellular Base Station Radiation Emissions and Related Measured Street-Values Radiation Density", Biological Effects of EMFs 2nd International Workshop, Rhode, Greece, pp7-11 October 2002.
9. T.H, Rappaport, J.C, Liberti,. " Smart Antennas for Wireless CDMA ", IEEE Press, 1999.
10. J.Gavan., "Power Efficiency Enhancement and Parasitic Radiation Reduction Methods for Mobile Radio Systems" IEEE/EMC International Symposium PP (138-141) August 2004.
11. J.C, Lin, "Mobile Phone Safety Testing and Fundamental Scientific Research" The Radio Science Bulletin. N^{o} 300 pp (31-33), March 2002.
12. J. Gavan , M. Haridim, "Stratospheric Quasi-Stationary Platforms (SQSP) Can they Replace Communication Satellite Systems." Telecommunications and Space Journal, Volume 4.97 PP (275-288)
13. R.Stuzak "Mobile Telecommunications Via Stratosphere "Intercomms. International Communication Project, 2003. www intercoms. net
14. I, Strikman., "Special Printed Antennas for Headset Radiation Reduction" PHD Thesis, Sept. 1997.
15. S.H, Yeh., C.Y., Fang., K.L. Wang, "PIFA Monopole Internal Mobile Phone Antenna for GSM/DCS/PCS Triple Band Operations" MW and Optical Technology Letters, pp 217-219, Nov.5.2002.
16. R. Mostafa "Implementation of Smart Antenna at the Handset. The propagator Virginia Tech Publication pp.9,10, 2000.
17. D. Zilbergerg., J. Gavan., "Apparatus and Method for Reducing Effect of Mobile Telephone Radiation" United States Patent 6505036, 2003. European Patent.
18. J. Martinko., R.S., Adve., "SAR Evaluation in a Heterogeneous Head Model Using the Galerkin Moment Method" URSI General Assembly New Delhi. October 2005
19. D.Krishnaswani, R.V. Hasbun, J.P. Brizek., "Secure Manageable Mobile Handset Platform, Architectures" IEEE Com. Magazine. pp. (158-165) Sept 2006.