Mobile Radio Base Stations and Handsets Radiation Effects: Analysis, Simulations and Mitigation Techniques

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1. INTRODUCTION

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 global number of mobile phone subscribers has exceeded the number of fixed phone subscribers and in a few years the number of mobile (laptops) PC will exceed the number of fixed one as shown in figure 1.
Recently, the global numbers of Mobile Radio equipment and users have each exceeded the thousand million, significantly increasing the probability and number of people exposed to non ionized radiation. [2;3] The main sources of Radio interference and radiation effects are from transmitters (Tx) offenders and the victims are the systems multitude of receivers (Rx) and individual users, who are exposed to mutual interference and parasitic radiations. [4,5].

2. BASE STATIONS TX RADIATION EFFECTS AND MITIGATION

Base stations Tx radiated power levels are significantly higher than handset ones, with generally very low mobile radio system power efficiency. However, the distances from base stations Tx to victim Rx and to exposed people are significantly higher than the signal wavelength. Therefore, in almost all cases the people exposed to base station effects are located in the well defined 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 . These results are true even for locations very near to the antennas of the base stations but generally under far field radiation conditions. [6,7] For rural base station, the power density levels may be more significant because of the higher cellular radius coverage but still lower than the standard threshold power density levels.[8] In all cases security guidelines have to be applied for base station installations to avoid excessive power density from radiating antennas to exposed people.

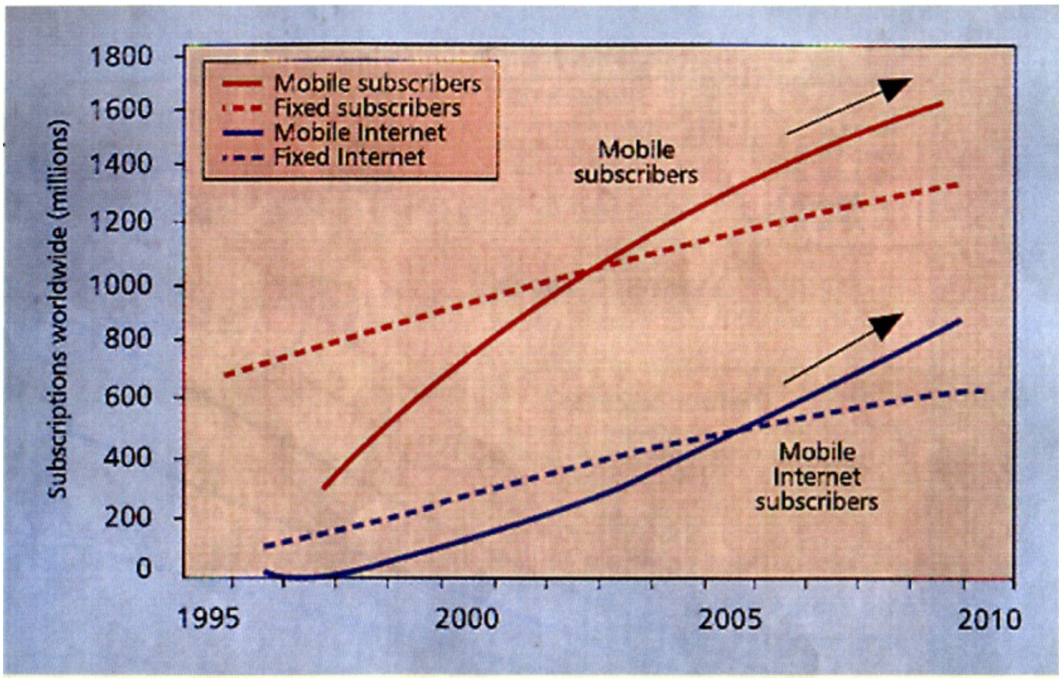

Figure1. Global growth of mobile and fixed subscribers [3].

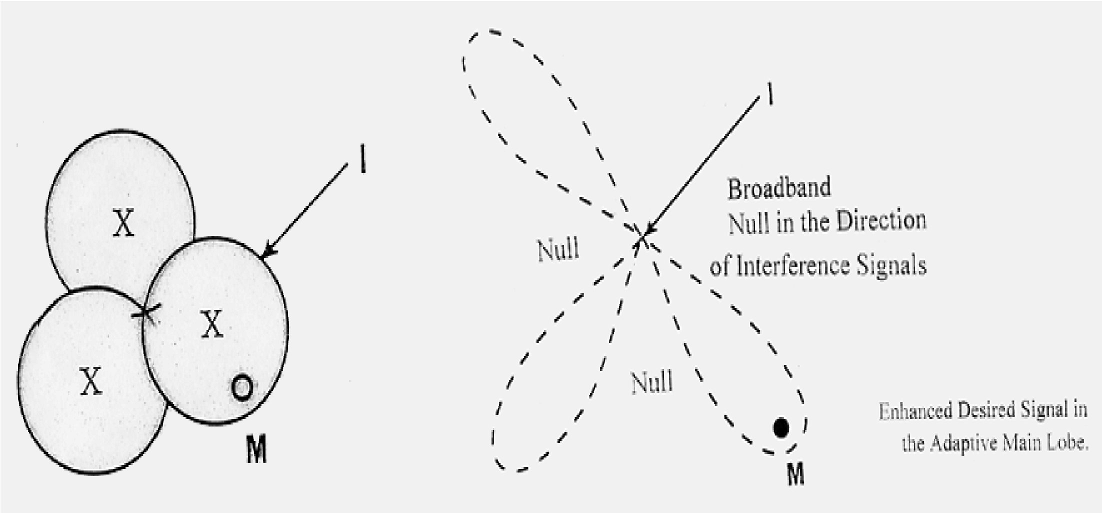

Figure 2. Comparison between conventional sector and smart antennas

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 recent 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 "M"and reduce significantly interference "I" from near Transmitters (Tx) as shown in figure 2.[5]
The following mitigation techniques may also be applied for enhancing transmitted energy efficiency, increasing Rx signal to noise and interference ratio and decreasing the required base station Tx power, which can decrease the radiated power density absorbed by human maintenance workers or the general public. [7,10]: Power control [11], shielding by metallic objects or special clothes [2] and or selective filtering [10] as will be explained in the presentation.

3) <u>RADIO HANDSETS RADIATION EFFECTS AND MITIGATION TECHNIQUES</u>

In comparison to the base stations, the effects from handsets radiation are much more complex, unpredictable and significantly stronger due to the proximitive 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 ordinary handset is absorbed in the user head, hand or body due to the very small distances and strong interactions. [4, 11] At these small distances of a few cms 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 the power control mechanism used in modern cellular handsets increase the handset radiated power; the energy absorbed by human users and reduces the life-time of the portable batteries. Measurement results show that radiation effects to users of cellular handsets are significantly stronger compared to that of standard base stations.[5]
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.
The most radiating antennas towards the user head are the low cost and compact helical or monopole quarter wavelength which are very common.[2, 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 user hand is increased, significantly [12,13]
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 can even be enhanced.[2]

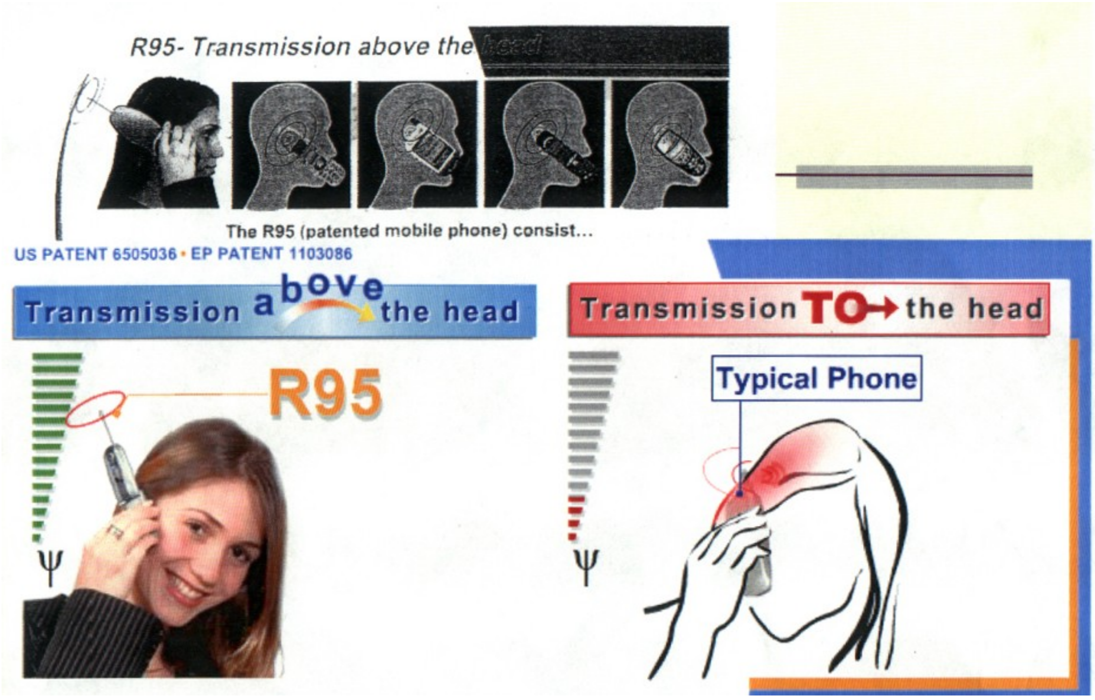

Figure 3. The R95 concept

Dual Meandering Antenna (DMA) or a vertical folded loop printed antenna with parasitic loading were also applied. The Motorola Star Track common implementation today 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.[10]

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. [14] However the phase cancellation principle used in this technique is efficient for fixed radio systems but not for mobile handsets where the proximate distance and the coupling to the user head are always changing.

One of the most recent mitigation techniques suggest a compact mobile handset apparatus using a two part fold-over mobile phone where, the lower part, is containing 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. [15] Other advantages are longer battery life higher signal to noise, better sound quality and higher distance operation of the mobile system as most of the energy is directed towards the base station and only an insignificant part is absorbed in the user head and body.

Recently in Summer 2004 a group of scientists from the University of Toronto Canada used the Galarkin moment method to compute the SAR from conventional handsets to homogeneous and heterogeneous head models. The handsets radiating antennas were helical at 893 and 1881 MHz and monopole whip at 907 MHz. In their simulations and computations [16] they included also the suggested handset model R95 described in figure 3 and in [16]. The results at 907 MHz including about 1000 unknows show that the SAR of the R95 model is about 100 time less than for the conventional model using the homogeneous head model and more than 50 time less using the heterogeneous model as shown in figure 4.

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/w hip @907MHz	881	6.9 minutes	1.9	1.0
Modified R95 @ 907 MHz	881	7 minutes	0.020	0.012

Figure 4. SAR Simulations of Antennas Next to a Homogeneous and a Heterogeneous Head Models[16]

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 impact. 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 4G cellular generations where the system handset power levels and bandwidth are increased.

The mitigation techniques described in this paper for systems base stations and mobile handsets can contribute to the required improvements for the presented purposes. However considerable more efforts are still needed in order to transform mobile radio communication to an efficient, secure and convenient system useful for the welfare and positive advancement of our global society.

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