Improvement of Mobile Radio Scrounging Radiation Effects

Reza Sheikhi
Master's student of IT, Ghazvin Branch, Islamic Azad University, Ghazvin, Iran
Ali Naseri
Associate Professor, Imam Hossein University, Tehran, Iran

Abstract
In this paper, mitigation techniques useful for improving mobile radio systems power efficiency and decreasing electro-smog and SAR induction, affecting human head and body, are presented. An analysis of main radiation effects from far field base stations and review of mitigation techniques for enhancing the efficiency of power transmission for mobile radio systems is shown, followed by an investigation of the complex radiation field components from operating headsets. The importance of the SAR expression is revealed, considering that the power density level doesn't really matter under near field complex propagation conditions. Mitigation techniques are suggested to improve the power efficiency especially for headsets by decreasing the SAR, affecting headsets user's head and body. The efficiency of mitigation techniques for usual headsets using an auxiliary antenna or a special space separation method is discussed. It is shown that small physical or multi-bands low SAR and power efficient headsets can be realized using high dielectric substrates and/or polarization diversity. Recent novel mitigation techniques are proposed for small headsets using meta-material or meta-cloak fractal antennas, allowing MIMO applications. Different efficient numerical simulation methods, allowing computing the SAR from different headsets, are compared.
Keywords:
Mobile Radio Scrounging, MIMO Applications, Meta-Materials, Radiation Effects.

1. Introduction

Tremendous increase in the number of mobile radio users, equipments and systems leads to one of the main economic forces and revenue sources of modern society [1]. Nowadays, the number of mobile phones in use, subscribers and users has exceeded 4 Billions each, while the number of mobile laptops has exceeded 700 Millions, significantly higher than any wired equipment. New mobile phones have added internet applications to the existing voice and short messaging service (SMS) services. According to Fig. 1, the 2003 prediction of 1600 Millions subscribers in 2010 was significantly underestimated. This tremendous increase of subscriber numbers raises the probability of exposure to interference and non-ionized radiation. Hence, efficient mitigation techniques are required to reduce Electro-Magnetic Field (EMF) pollution and improve radio communication performance [2] -[5].

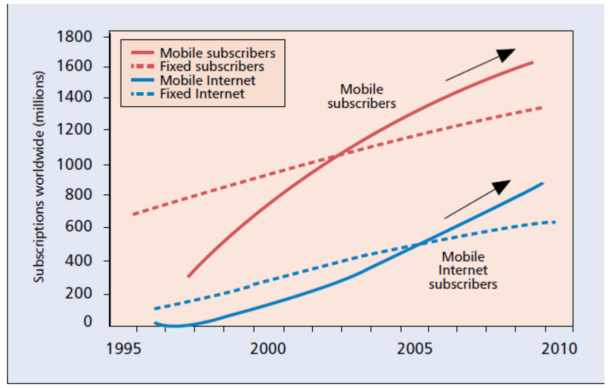

Fig 1: Global expansion of mobile and fixed subscribers, estimated in 2013 [1]

The sources of radio interference and radiation effects are the offender Transmitters (TX). A significant part of the transmitted energy is wasted as parasitic radiation pollution and interference to radio systems users. The victims are the Receivers (Rx) in general and individuals (especially mobile headset users) in particular, who are exposed to both mutual interference and parasitic EMF thermal non-ionized radiation [3], [6].

The power density levels of base stations radiation to which people are exposed are usually significantly lower than the standard human exposure thresholds for and are relatively easy to measure in case of relatively long separation distances, resulting in simple far field propagation conditions. Nevertheless, radiation influence on users due to their operating mobile headsets transmitters is significantly stronger, complex and difficult to measure because of the very short distance from the radiation source, resulting in complex near field propagation conditions. The headsets radiation effects imply complexity of reactive near field propagation induction effects and hot spots of the EMF components, induced in the user's head and body. This results in significant wasted parasitic radiation power and leads to higher transmitter and battery power requirements in order to guarantee a sufficient signal to noise ratio (SNR) at the receiver.

The manuscript begins with an analysis of main radiation effects from far field base stations and review of mitigation techniques for enhancing the efficiency of power transmission for mobile radio systems, presented in

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Section 2. This is followed by an investigation of the complex radiation field components from operating headsets, given in Section 3, revealing the importance of the Specific Absorption Rate (SAR) expression, considering that the power density level doesn't really matter under near field complex propagation conditions. Mitigation techniques are suggested in order to improve the power efficiency especially for headsets by decreasing the SAR, affecting headsets user's head and body. The efficiency of mitigation techniques for usual headsets using an auxiliary antenna or a special space separation method is discussed. It is shown that small physical or multi-bands low SAR and power efficient headsets can be realized using high dielectric substrates and/or polarization diversity. Recent novel mitigation techniques are proposed for small headsets using meta–material or meta-cloak fractal antennas and allowing MIMO applications. The manuscript is concluded in Section 4.

2. Base Stations Radiation and Mitigation Procedures

Base stations TX radiated power levels are higher than headset ones and are characterized by low energy efficiency. However, the distances from base stations TX to victim RX and to exposed humans are significantly higher than the transmitted wavelengths if a security perimeter is respected [7] ,[8]. Therefore in almost all cases people and victim RX, exposed to base station effects are located in the well defined Fraunhofer Far Field (FFF) radiation zone, in which the radiated power density levels decrease as a square of the separation distance and in several cases even more [3], [4]. Measurements, simulations and statistical analyses results, obtained from the Israel Environmental Ministry Reports and other references show that the power density levels of radiation from urban cellular base stations are usually lower than the recommended safety power density standards thresholds [4] – [9]. The base stations TX power density and other EMF parameters are very easy to measure and compute due to the FFF propagation conditions [8], [9]. For rural base stations the power density levels may be higher due to the typically increased required cellular radius coverage. However in most cases it is still lower than the standard threshold power density levels if a proper free of human presence security perimeter is respected [8].

The main FCC/ANSI/IEEE power density standards (www.ieee.org, www.iec.ch) thresholds are 1 mW/cm2 while the International Commission of Non-Ionized Radiation (ICNIRP) power density standards thresholds are 0.45 mW/cm2 at the 900 MHz cellular band and 0.95mW/cm2 at the 1900 MHz band. The European CENELEC standards are similar to the IEEE. Nevertheless, several countries such as Switzerland, Italy, Russia and China are using stricter standards considering the probability of cellular non-thermal radiation effects as well [10].

The energy efficiency, quality of service and capacity of base stations can be enhanced by using 3 or 6 segments directional antennas instead of omni-directional ones. A better solution is the use of smart antenna arrays which require signal processing units as well [11], [12]. The smart antenna concentrates the energy transmission towards the desired mobile RX user and as a result significantly reduces the interference from near TX by forming a null steering at the base station RX, as shown in Fig. 2 [4], [11].

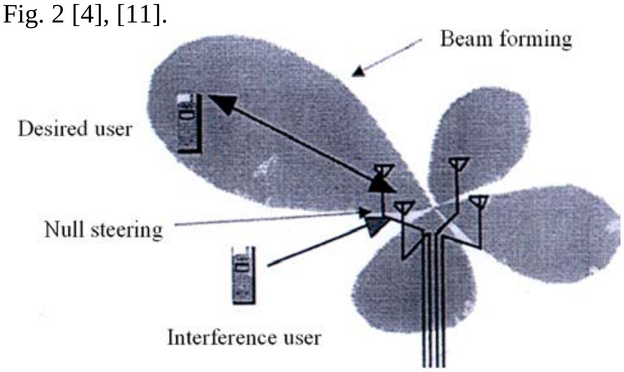

Fig 2: Smart antennas applied in a radio base station: principle of operation [11]

The smart antenna method may also contribute to the enhanced transmitted power and energy efficiencies, RX signal to noise and interference ratio increase and the required base station TX power decrease as well as to the electro-magnetic pollution and interference levels reduction to other radio users [12], [13].

The base station transmitted power density and EMF pollution effects may be further decreased by increasing the number of base stations and decreasing the operation radius, using more nano and pico-cells instead of micro-cells. In case of indoor communications, femto-cells with an operation range of a few meters only may be used even in the 60GHz oxygen absorption frequency band [12], [13].

Additional protective mitigation techniques are useful for decreasing the radiated power density absorbed by human maintenance workers, sited in the security perimeter at short distances from base stations TX. For example, base station power control, realized by means of switching off or decreasing the power supply reduces the radiated power density significantly [12]. On the other hand, this technique can not be used when the base station must be active permanently. Another mitigation method is based on shielding techniques by using metallic objects, special clothes and spectacles to protect the maintenance workers [5a]. A selective filtering technique can be realized by providing maintenance workers with special shoes or metal helmets. This artificially increases the length and significantly decreases the resonance frequencies of the human body and head, usually extending from 30 to 400MHz according to the physical dimensions. This yields less EMF absorption by the human head and body, attaining its maximum near their resonant frequencies [4].

A novel improvement of the future mobile radio systems is the development of High Altitude Platforms (HAPS), based on base stations, located in the stratosphere at an altitude of 17 to 24 km from the ground [14], [15], characterized by significantly lower radiation intensity levels compared to terrestrial base stations. The HAPS base station performances are better than the geo-stationary satellites due to significantly lower dispersion losses, time delay and cost. Experimental HAPS are being built in the USA, Russia and Europe [14], [16]. It seems that in a few years HAPS will be used commercially and be especially useful as base stations for the 4th generation of cellular radio systems.

3. Handsets Radiation and Mitigation Procedures

Compared to the base stations, the effects of headsets radiation on users are much more complex, unpredictable and significantly stronger because of the reactive near EMF influence [3]. Measurements and simulation results show that from 30% and up to 75% of the radio frequency power, transmitted from headsets may be absorbed in the users head, hand and body due to the very short separation distances [10]. At short distances of a few centimeters in the reactive near field zone of the antenna, strong coupling loading occurs between the headset antenna and the user's head. Without considering the health issues, it is obvious that this important part of the headset transmitted energy is wasted instead of reaching the base station RX. The main issue is that due to the power control mechanism, used in most modern headsets, the transmitted power is increased as the EMF energy is absorbed by the human users. The measurements and computations of the electrical and magnetic field component magnitudes and especially of the power density are very complex and not well defined in the headset reactive propagation near field zone [6], [10]. Therefore, the FFF standard of power density is not well defined and has been standardized by the complex Specific Absorption Rate (SAR) of the temperature increase measured in Watt per kg, which represents the non-ionized thermal radiation effects generated from headsets EMF induction in human tissues and especially in the user's head [3]

Measurement results show that EMF effects on cellular handsets users are significantly stronger compared to those of standard base stations and can exceed the secure standard levels because of the short separation distances [8], [9], [17]. For instance, 1mW of transmitted power at a distance of 1cm from the headset has a higher or similar EMF effect than 1000W at a distance of 10m from the base station. The usual power levels of headsets are of 100mW to 600mW average and 1000mW peak, which are usually significantly higher than 1mW. To compare, the power level of high transmitted power base stations of 200W is significantly less than 1000W and the distances are higher than 10m [2], [17]. Therefore, the real problem lies in the radio headsets and not in the base stations [4], [10].

The FCC/IEEE US threshold limit standard for SAR spatial peak is 1.6 W/kg averaged over a volume of 1g of head tissue for 30 minutes averaging time and 0.08 W/kg averaged over the whole body. These values are for the general public exposure including children; for occupational exposure these are 5 times less stringent. The CENELEC and most European countries threshold limit SAR standard to 2W/kg averaged over a volume of 10g of head tissue for a 6 minutes averaging time and 0.08 W/kg averaged over the whole body [6].

The popular headsets antennas radiating towards the users head used to be the low cost, high SAR helical or monopole quarter wavelength [2] – [4]. Later numerous planar micro-strip antennas such as the compact and multi-band Planar Inverted F Antenna (PIFA or PILA) were used, where the radiation absorption by the head was slightly reduced, but the absorption due to the user hand was significantly increased [18] – [20]. The headsets implementation of Motorola and Samsung increased the distance of the monopole antenna from the user head by 2 to 3 cm, but the reactive near field conditions and the significant EMF power absorption by the user head are still too strong [2], [4].

The use of a cable with external earphones connected to the head for reducing significantly the SAR can be applied. However the method is cumbersome and both the headset and cable have to be very well shielded since otherwise the cable and headset act as an antenna and the EMF in the user's head can be even enlarged [12]. Recently, the use of a small array including two antenna elements connected to the headset was suggested [21], based on the smart antenna concept explained above. The two elements reduce the headset power absorbed by the user's head and enhance the propagation efficiency in the direction of the base station. However the phase cancellation principle used in this technique is efficient mostly for base stations or voluminous radio equipments but much less for compact mobile headsets, where the small dimensions, separation distances and the coupling between the radiating parts of the headsets and the user's head are generally strong and very difficult to compute [3], [4].

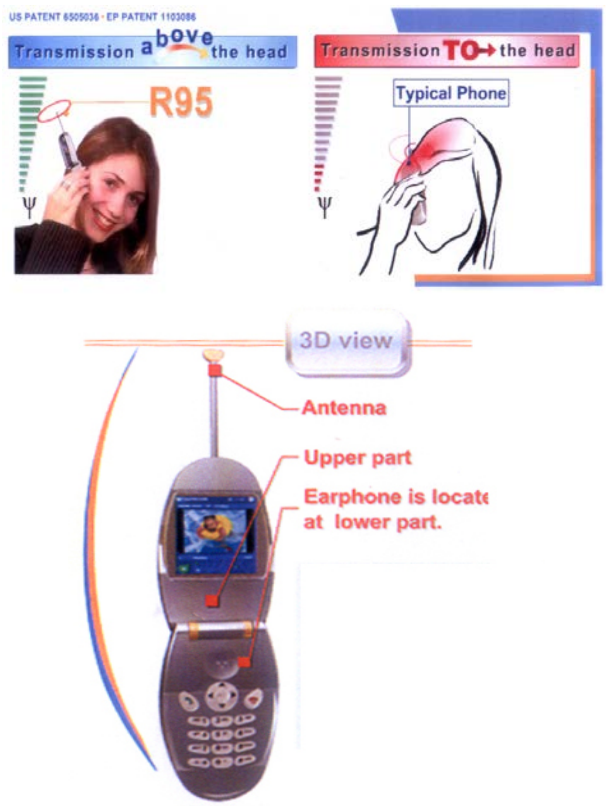

Fig 3: Planned R95 technique headset

A more efficient mitigation technique consists of a compact mobile headset apparatus employing a two part fold-over mobile phone such as the Motorola Star Track or Samsung special models, where the lower part, which will be near the human ear, contains the keyboard, microphone, earphone and all the non radiating low frequency/low power circuits [4], [22]. The upper part is a pivotally connected cover for the headsets, containing the high frequency power amplifier, duplexer and monopole antenna. The antenna is extendable through the cover at the opposite end of the pivotal connection to the headset to a distance of (8-16 cm) from the ear and above user's head, raising the locus of radiation laterally and vertically above the head as shown in Fig. 3. The headset duplexer output is connected via a simple adaptive circuit and a short coaxial cable of less than 0.1 dB insertion loss to the top of the monopole quarter wave antenna, where current and radiation intensity peaks are developed. The described technique, named as R95, significantly increases antenna efficiency and drastically reduces the SAR to the user's head, as shown in Appendix. Simulation results, obtained in cooperation with a scientific team of the Toronto University in 2004 show that the SAR of the proposed R95 mobile headset model are more than 50 times better than of classical headsets. Other advantages of this mitigation technique are longer battery life, higher SNR, better sound quality and higher possible operation distances of the mobile radio system as most of the transmitted energy is directed towards the base station and only a negligible part is absorbed in the user's head and body.

The R95 can be efficient for both ordinary and large dimensions headsets, especially for children who usually have smaller head than adults. Nonetheless, the R95 technique will not be useful for very small dimensions headsets and for multi-bands requirements, where high SAR will be induced in the user's head, since the separation distance to the transmitting headset will be significantly smaller. In these cases a couple of planar antennas with smaller physical dimensions such as the Ethertronics Isolated Magnetic Dipole antennas may be used, employing a high dielectric constant substrate and polarization diversity to enable small physical dimensions which decrease the coupling between the radiating antenna and the headsets ground plane and human head and body [23]. The polarization diversity implementation increases the useful power to and from the base station and decreases the parasitic radiation power and the SAR to the user's head and body [20], [24].

A novel and more promising technique for small physical dimensions, a frequency multi-bands and multi-functions headset is based on the use of Meta-Materials (MM). MM are characterized by negative refractive index, which allows negative permeability and/or negative permittivity and bend light or radio signals in the opposite direction from conventional materials. The theoretical feasibility of the material was developed by Veselago in 1968. Yet, it took many years to develop several practical MM applications in optics and radio technologies. Recently it was revealed that MM antenna resonance can occur at wavelengths 5 to 10 times longer than their physical size by storing RF energy and re-radiating it [25], [26], which may significantly reduce the required physical dimensions of wireless headsets. The MM also possesses the benefit of decreasing the interactions between the antenna and its ground plane, reducing the near field energy stored inside the substrate and making impedance matching easier [26], [27]. Thus, utilizing these functional substrates MM technology can confine the currents to the area near the antenna structure, decreasing headset SAR and increasing power efficiency by directing most of the RF energy away from the handset user's head and hand toward the base stations [27], [28]. Due to the smaller dimensions of the MM antennas and multi-bands smart arrays inside the headsets, the efficient Multi- input Multi-Output (MIMO) technology can be applied, which can increase the power transmission toward the base station and reduce it significantly towards the user's head and body [29], [30]. Recently a few companies began implementing MM antennas for multi-bands, low SAR and broadband

frequencies headsets (www.rayspan.com, www.fractus.com , www.antenova.com).
In 2010, the development of a new technology was announced to implement low SAR and power efficient headsets, which use fractals and MM antennas techniques. Fractals antennas are complex geometric shapes, built up from a repetition of a simple unit [31], while MM are composites with unusual properties, not found in nature. The new antenna, shown in Fig. 4 (www.meta-cloak.net, www.fractenna.com) is called "Meta-cloak" and has unique performance abilities in bandwidth, gain, directivity and power efficiency along with small physical dimensions and broadband frequency capacity [31].

Fig 4: A novel meta-material fractal antenna for low SAR headsets

4. Conclusions

Due to the tremendous increase in the amount of mobile radio-communication equipments and users, significant improvement of transmission efficiency and decrease of the radio electro-smog pollution are a must. The mitigation techniques presented in this paper are useful for improving mobile radio systems power efficiency and decreasing electro-smog and SAR induction, affecting human head and body.
The main mitigation techniques contributions presented in this paper are:

– The reduction of the useless transmitted power of the electro-smog parasitical radiation and mutual interference to other radio users;
– The reduction of the energy required by the base stations and the mobile headsets TX, power supply power consumption and battery capacity requirements, leading to the performance improve of the radio mobile systems;
– The reduction of the power density and SAR wasted power and energy, especially affecting human users of mobile headsets.

The main mitigation techniques suggested for base stations include significant increase of the of base stations number, use of adaptive smart antennas, protection methods for the maintenance people onsite and future use of troposphere located HAPS for the coming LTE, WIMAX and 4G generation of mobile radio.
The required improvements in power efficiency and SAR of mobile headsets are much more important and cumbersome for computation than of base stations. The main reasons are the significantly higher amount of mobile headsets in use, small size and the near field propagation conditions due to the small distances between the radiating parts of the headsets and the user's head and body.
The main mitigation techniques suggested for the mobile headsets include the use of cables with external earphones connected to the user head, space diversity using a main and an auxiliary antenna elements and an efficient space separation, which are efficient for ordinary physical dimensions headsets. However for small physical dimensions and multi-function headsets polarization diversity and recent Meta-Material and Meta-cloak antennas seem promising.
Significant efforts are still required in order to improve mobile radio communication systems, especially in order to reduce transmitting power and parasitic radiation and improve reception quality. This is also true for the present 3G and the upcoming 4G cellular communication generations, where the headsets power levels and bandwidths are increased.

References.

[1] Y.Kim, B.J. Jeong, J. Chung, C.-S. Hwang, J.S. Ryu, K.-H. Kim and Y.K. Kim, "Beyond 3G: vision, requirements and enabling technologies," IEEE Commun. Mag., vol. 41, no. 3, pp. 120 - 124, Mar. 2003.
[2] N. Kuster., Q. Balzano and J.C. Lin, Mobile Communications Safety. Chapman & Hall, 1997.
[3] R. Perez, Handbook of Electromagnetic Compatibility. Academic Press, 1995.
[4] J. Gavan, "Base stations and headsets mobile radio systems radiation: analysis, mitigation and simulations techniques", presented at the 1st Int. Conf. on Sig. Proc. Comm. Syst., Gold Coast, Australia, Dec. 2007.

[5] D. Krishnaswamy, R.N. Hasbun and J.P. Brizek, "Secure manageable mobile handset platform architectures," IEEE Commun. Mag., vol. 44, no. 9, pp. 158-165, Sep. 2006.
[6] International Commission on Non-Ionizing Radiation Protection (2009), Exposure to High Frequency Electromagnetic Fields, Biological Effects and Health Consequences (100 kHz-300 GHz) [Online], Available: http://www.icnirp.de/documents/RFReview.pdf
[7] J. Gavan, "Transmitters interference to victim receivers and radiation hazards to humans: Are they correlated?" in Proc. 27th URSI General Assembly, pp. 856 - 859, Maastricht, Netherlands, Aug. 2002.
[8] R. Zemach, J. Gavan, S .Levy and E. Neeman, “Stochastic processes in radiation emission of cellular base stations,” in Proc. 27th URSI General Assembly, pp. 1418 - 1421, Maastricht, Netherlands, Aug. 2002.
[9] R. Ciccheti and A. Faraone, "Estimation of the peak power density in the vicinity of cellular and radio base station antennas," IEEE Trans. Electromagn. Compat., vol. 46, no. 2, pp. 275 – 290, May 2004.
[10] J.C. Lin, "Current standards and their bases for safe human exposure to radio-frequency Radiation," Radio Science Bulletin, vol. 309, pp. 50-52, Jun. 2004.
[11] T.H. Rappaport and J.C. Liberti, Smart Antennas for Wireless CDMA. IEEE Press, 1999.
[12] J.Gavan., "Power efficiency enhancement and parasitic radiation reduction methods for mobile radio systems," in Proc. IEEE Int. Symp. Electromagn. Compat., pp. 138-141, Aug. 2004.
[13] C.A. Balanis, Modern Antenna Handbook. John Wiley & Sons, 2008.
[14] T.C. Tozer and D. Grace, ”High altitude platforms for wireless communication,” Electron. Commun. Eng. Jour., vol. 13, no. 3, pp. 275-288, May 2001.
[15] J. Gavan and M. Haridim, "Stratospheric quasi-stationary platforms (SQSP): Can they replace communication satellite systems?" Telecommun. Space Jour., vol. 4, pp. 271-283, May 1997.
[16] J. Gavan, S. Tapuchi and D.Grace, "Concepts and main applications of high-altitude-platform radio relays," Radio Science Bulletin, vol. 330, pp. 20-31, Sep. 2009.
[17] L. Weismman, "Cell phone health hazards threat and opportunities," Strategy Business Mag., pp. 1-3, Nov. 2006.
[18] A. Byndas, R. Hossa, M.E. Bialkowski and P. Kabacik, “Investigations into operation of single and multi-layer configurations of planar inverted-F antenna,” IEEE Antennas Propagat. Mag., vol. 49, no. 4, pp. 22 – 33, Aug. 2007.
[19] S.H. Yeh, C.Y. Fang and K.L. Wang, “PIFA monopole internal mobile phone antenna for GSM/DCS/PCS triple band operations,” Microw. Opt. Technol. Lett., vol. 35, no. 3, pp. 217 - 219, Nov. 2002.
[20] P.Hall, Antennas and Propagation for Body Centric Wireless Communications. Artech - House, 2006.
[21] M. Bank and B. Levin, "The development of a cellular phone antenna with small irradiation of human organism tissues", IEEE Antennas Propagat. Mag., vol. 49, no. 4, pp. 65 – 73, Aug. 2007.
[22] M. Tahmassebpour, “A New Method for Time-Series Big Data Effective Storage,” IEEE Access, vol. 5, no. 1, pp. 10694-10699, 2017.
[23] L.Desclos, "Advances in high performance ceramic antennas for small form factor multi-technology devices", Ethertronics Technical Report, 2007.
[24] T.W.C. Brown, S.R. Stavrou and M. Fiacco, “Characterization of polarization diversity at the mobile," IEEE Trans. on Veh. Technol., vol. 56, no. 5, pp. 2440 – 2447, Sep. 2007.
[25] G.V. Eleftheriades and M. Antoniades, “Antenna applications of negative-refractive-index transmission-line (NRI-TL) structures,” IET Microw. Antennas Propagat, vol. 1, no. 1, pp. 12 - 22, Feb. 2007.
[26] B.-I. Wu, W. Wang, J. Pacheco, X. Chen, T.M. Grzegorczyk and J.A. Kong, "A study of using meta-material s as antenna substrate to enhance gain", Prog. Electromagnet. Res., vol. 51, pp. 295 - 328, Feb. 2005.
[27] R.W Ziolkowski and A. Erentok, "Meta-material based efficient electrically small antennas," IEEE Trans. Antennas Propagat., vol. 54, no. 7, pp. 2113 - 2130, Jul. 2006.
[28] A. Alu, F. Billoti, N. Engheta and L. Vegni, "Sub-wavelength, compact, resonant patch antennas loaded with meta-materials," IEEE Trans. Antennas Propagat., vol. 55, no. 1, pp. 13 – 24, Jan. 2007.
[29] S. M. Seyedhosseini, M. J. Esfahani, M. Ghaffari, “A novel hybrid algorithm based on a harmony search and artificial bee colony for solving a portfolio optimization problem using a mean-semi variance approach,” Journal of Central South University, vol. 23, no. 1, pp. 181-188, 2016.
[30] T. Nozawa, "Antenna technology advance for MIMO era", Nikkei Electronics Asia Newslett., pp. 1-5, Sep. 2008.
[31] H.Prasad, , "Micro-strip fractal patch antenna for multi-band communication" Electron. Lett., vol. 36, no. 14, pp. 1179 – 1180, Jul. 2000.
[32] J..Martinko, R.S.Adve, "SAR evaluation in an heterogeneous head model using the Galerkin moment method" in Proc. 28th URSI General Assembly, pp. 856 - 859, New Delhi, India, Oct. 2005.
[33] O. Sotoudeh and T. Wittig, "Electromagnetic simulation of mobile phone antenna performance," Microw. Jour., vol. 51, no. 1, pp. 78-82, Jan. 2008.