An Overview of an Esoteric Pollution EMI- EMC

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Abstract -- Water, air and Sound pollution is well within the human perception, but esoteric pollution of frequency spectrum called Electromagnetic Interference (EMI) must address in today's world of computerization where authors emphasize on high band width / high speed along with miniaturization of products. Electromagnetic Interference (EMI) is either a continuous or intermittent electromagnetic disturbance or electrical signal that, if not properly addressed, can be transmitted into, or out of, electronic equipment and can disturb the normal and intended operation of electronic systems. EMI is discernible across the entire electromagnetic spectrum and can be generated across either a narrow band or a broad spectrum of frequencies, with the more typical areas of interest extending from the low kHz range to the upper GHz range. Adverse effect if EMI have increased manifold so all the electrical and electronic products should be Electromagnetically Compatible (EMC). This paper reviews the aspect of EMI/EMC, Standards, testing and control requirement of EMC along with coupling mechanism and adverse effect of EMI/ EMC.

Indexed Terms: Electromagnetic Interference, EMI, EMC, Aspects of EMI

I. INTRODUCTION

We all are aware of several pollutions like water pollution, air pollution, sound pollution, etc. These pollutions are well within human perception. But there exists one more type of pollution called pollution of frequency spectrum. It is called Electromagnetic Interferences (EMI).

Electromagnetic Interference (EMI) also called Radio Frequency Interference (RFI) is a disturbance that effects an electrical circuit due to either electromagnetic conduction or electromagnetic radiation emitted from an external source.

EMI is more esoteric, i.e., it cannot be directly seen, tested, smelled or felt. In today's scenario of computerization, where the thrust is on high bandwidth / high speed along with miniaturization of products, adverse effects of EMI have increased manifold. All Electronic devices gives off electromagnetic emission. This is radiation that is a by product of electrical or magnetic activity. Unfortunately, the emission from one device can interfere with the other devices, causing potential, problems. Interference can lead to data loss, picture quality degradation on monitors, and other problems with your PC, or problems with other devices such as television sets and radios. Whenever a circuit is operated, some signal is generated that may be desired for one circuit but undesired for another. EMI is the presence of undesired signals (voltage or current) that adversely influence the performance of a device.

Occurrence of EMI is a common phenomenon in day-to-day operation of electronic equipment, like jamming of radio sets under high-tension wires, white spots on TV screens or hissing sound in TV or radio when a bike or airplane passes nearby, or a motor or mixer grinder is operated. These types of effects are quite common. One can have a casual approach towards them. But think of situation when a pacemaker fitted in a heart patient gets affected by EMI. Here it is a question of life and death. Other consequences of EMI can be loss of data transmission, unintended detonation of explosive devices, malfunctioning of missile guidance systems, malfunctioning of critical process control systems in industries, etc. In this situation, the consequences of EMI can be disastrous. So, all the electrical and electronic products should be Electromagnetically Compatible (EMC).

Electromagnetic Compatibility is a branch of electrical sciences which studies the unintentional generation, propagation and reception o Electromagnetic energy with reference to its unwanted effects that such energy may induce. The goal of EMC is the correct operation, in the same electromagnetic environment, of different equipment which use electromagnetic phenomenon, and the avoidance of any interference effects.

While designing any product, following two conditions should be considered: (1) The product itself should not produce EMI beyond a certain level, i.e., it should not act as a source of EMI. (2) The product should not get affected while operating in an EMI environment. i.e., it should not act as a receptor of EMI. If the product fulfils these two conditions, it is said to be electromagnetically compatible (EMC).

II. ELEMENTS OF EMI

There are three elements of EMI, namely, source, media and receptor. The basic arrangement of Noise Source, Coupling Path and Receptor or sink is shown in Fig. 1. Source and Receptor are usually electronic hardware devices, though the source may be natural phenomenon such as lightning strike, Electromagnetic Discharge (ESD) or in famous case, the Big Bang at origin of the universe. If any of these elements is missing, EMI will not occur.

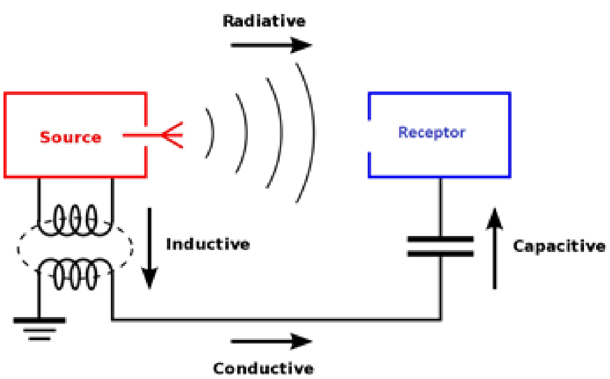

Fig.1 Electromagnetic Interference Coupling Modes

2.1 Sources of EMI

An EMI source can be any device that transmits, distributes, processes, or utilizes any form of electrical energy where some aspect of its operation generates conducted or radiated signals that can cause equipment performance degradation.

Complex Electronic Circuitry is found in all sorts of device used in home. This results in a vast interference potential that did no exist in earlier decades. Broadcast transmitters, two-way radio transmitters, paging transmitters and cable TV are potential source of RFI and EMI. Other possible sources of interference include a wide variety of devices, such as doorbell transformers, toaster oven, electric blankets, ultrasonic pest control devices, electric bug zappers, heating pads and touch controlled lamps. Multiple CRT computer monitors or television sitting too close to one another can sometimes cause a "Shimmy" effect in each another, due to the electromagnetic nature of their picture tubes, especially when one of their de-guassing coil is activated.

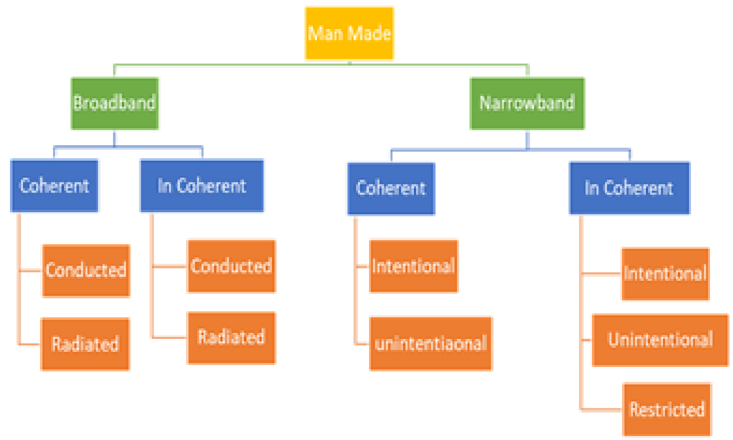

Fig.2 Types of Sources of EMI

Electromagnetic interference at 2.4 GHz can be caused by 802.11 b and 802.11 g wireless devices, Bluetooth devices, baby monitors and cordless telephones, video senders and microwave ovens. Switching inductive load, such as electric motors. Often cause interference, but it is easily suppressed by connecting snubber network, a resistor in series with a capacitor, across the switch. Exact values can be optimized for each case, but 100 ohms in series with 100 nano-farads is usually satisfactory. Switched mode power supplies can be source of EMI but have become less of a problem as design technique have improved, such as integrated power factor correction. Integrated circuits are often a source of EMI, but they must usually couple their energy to larger objects such as heatsinks, circuit board planes and cable to radiate significantly.

There are three types of sources of EMI:

1. Natural EMI sources - Sources that are associated with natural phenomena. They include atmospheric charge/discharge phenomena such as lightening and precipitation static, and extraterrestrial sources including radiation from the sum and galactic sources such as radio stars, galaxies, and other cosmic sources. This type of Interference is commonly called static or

atmospheric noise. It can be cause problems with RF communications and older data links between shore, ship and air. However, it does not cause many problems with modern digital equipment. As shown in the above diagram, all-natural sources are classified as broadband, incoherent, radiated, and unintentional.

- ✓ Man-made EMI sources - Sources associated with man-made devices such as power lines, auto ignition, fluorescent lights, etc.
- ✓ Broadband EMI - Electromagnetic conducted and radiated signals whose amplitude variation as a function of frequency extends over a frequency range greater than the bandwidth of the receptor.
- ✓ Narrowband EMI - Electromagnetic conducted and radiated signals whose amplitude variation as a function of frequency extends over a frequency range narrower than the bandwidth of the receptor.
- ✓ Coherent broadband signals - Neighboring components of the signal (in the frequency domain) has a well-defined amplitude, frequency, and phase relationship.
- ✓ Incoherent broadband signals - Neighboring components of the signal (in the frequency domain) are random or pseudo-random (bandwidth limited) in phase or amplitude.
- ✓ Conducted EMI - Noise signals transmitted via electrical conduction paths (i.e. wires, ground planes, etc.).
- ✓ Radiated EMI - Electric and magnetic fields transmitted through space from source to receptor.
- ✓ Intentional radiating emitters - Emitters whose primary function depends on radiated emitters. Examples include electronic licensed communication systems. These include communication, navigation, and radar systems.
- ✓ Unintentional (incidental) radiating devices - Devices that radiate radio frequencies but is not considered their primary function.
- ✓ Restricted radiating devices - Devices that intentionally use electromagnetic radiation for purposes other than communication or data transfer. (i.e. garage door operating systems, wireless microphones, etc.)

2. Inherent EMI: Inherent interference is noise within a piece of electronic equipment, caused by thermal agitation of electrons flowing through circuit resistance. EMI may be also originating from any source designed to generate electromagnetic energy that may create interference as a normal part of its operation, e.g., communication sources such as TV and radio broadcast transmitters, mobile radio and computing devices.
3. Man-made EMI: Man-made EMI is produced by several different classes of electrical and electronics equipment. These are the sources that are not designed for propagation of electromagnetic energy, but cause interference and they include but are not limited to: switches, vehicle systems, machine and tools, consumer electronic products transmitters, welders, power lines, motors and generators, lighting, engines and igniters, and electrical controllers. These devices can cause severe EMI, which can degrade the operation of shipboard or shore-based data processing equipment.

2.2 *Receptors of EMI*

A receptor is also called a "victim" source because it consists of any device, when exposed to conducted or radiated electromagnetic energy from emitting sources, will degrade or malfunction in performance. Many devices can be emission sources and receptors simultaneously. For example, most communication electronic systems can be emission and receptor sources because they contain transmitters and receivers. Figure 2 shows a taxonomy of different receptors that are susceptible to EMI. Like the emission source taxonomy, receptors can be divided into natural and man-made receptors. Potential receptors of EMI include radio receivers, electronic circuits and appliances, people and just anything that utilizes or detects electromagnetic energy.

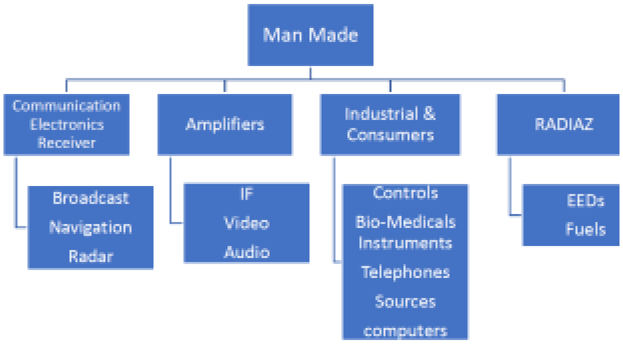

Fig.3 Types of Receptor of EMI

2.3 Propagation of EMI

There are two ways for EMI to travel and accordingly it is classified as conducted and radiated EMI.

When EMI travels through some physical conductor, it is called conducted EMI. In conducted EMI, the propagation medium is power lines, common ground, or interconnecting cables or data lines. This is generally observed below 30 MHz. In radiated EMI, the propagation medium is free space. It is generally observed above 30 MHz.

2.4 Types of Interference:

Electromagnetic Interference divided into several categories according to the nature and signal characteristics. The origin of noise can be Continuous or Transient Interference.

1. Continuous Interference: Continuous interference arises where the source regularly emits a given range of frequency. This type is naturally divided into sub-categories according to frequency range and is sometimes referred to as “DC to Daylight”.

   From very low frequency to 20 KHz is known as audio frequencies, sometimes up to 100 KHz may be classified as audio. Sources include main hum from power supply units, nearby power supply wiring, transmission line and substations.

   Radio Frequency Interference from 20 KHz to a limit which constantly increases as technology pushes it higher. It includes Wireless and Radio Frequency Transmission, Television and Radio Receiver, Industrial, scientific and medical equipment, high frequency circuit signals.

   Broadband noise may be spread across parts of either or both frequency ranges, with no frequency accentuated. Sources includes solar activity, continuously operating spark gaps such as are welders.
2. Pulse of Transient Interference: Electromagnetic Pulse (EMP) also sometimes called Transient Disturbance arises where the source emits a short-duration pulse of energy. The energy is usually broadband by nature, although it often excites a relatively narrow-band damped sine wave response in the receptor.

III. COUPLING MECHANISM OF EMI

There are four basic coupling mechanisms: Conductive, Capacitive, magnetic or inductive, and radiative. Any coupling path can be broken down into one or more of these coupling mechanisms working together.

3.1 Conductive Coupling

Conductive coupling occurs when the coupling path between source and the receptor is formed by direct contact with a conductive body, For Example a transmission line, wire, cable, PCB trace or mental enclosure.

1. Conduction mode: Conducted noise is also characterized by the way it appears on different conduction: Common-mode or common-impedance coupling: noise appears on two conductors in the same direction.
2. Different-mode coupling: noise appears on two conductors in the opposite direction to each other.

3.2 Inductive Coupling

Inductive coupling occurs where the source and receiver are separated by as short distance (typically less than a wavelength). Strictly, inductive coupling can be of two kinds electrical induction and magnetic induction. It is common to refer to electrical induction as capacitive coupling and to magnetic induction as inductive coupling.

1. Capacitive Coupling: Capacitive coupling occurs when a varying electrical field exists between two adjacent conductors typically less than a wavelength apart, inducing a change in voltage across the gap.
2. Magnetic Coupling: Inductive coupling or magnetic coupling occurs when a varying magnetic field exists between two parallel conductors typically less than a wavelength apart, inducing a change in voltage along the receiving conductors.

3.3 Radiative Coupling

Radiative coupling or electromagnetic coupling occurs when source and receptor are separated by a large distance (typically more than a wavelength). Source and receptor act as radio antennas: the source emits or radiates an electromagnetic wave which propagates across the open space in between and is picked up or received by the receptor.

Coupling mechanism often uses a complex combination of these methods, making the path difficult even when the receptors are known. There may be multiple coupling paths and steps taken to attenuate one path may enhance another.

Interference may be radiated from equipment via several different paths, depending on the frequency of that interference. At high frequency, tracks on PCBs may radiate directly. At lower frequencies, interference may be coupled from equipment via connecting leads such as signal / mains power supply cables as conducted emission. These conducted emissions may get radiated at a different location between conducted and radiated emission is generally assumed to be around 30MHz-conducted emission below 30 MHz and radiated emission above 30 MHz.

Elements Affecting EMI on the Receptor are Strength of the source, Distance from the source, Coupling mechanism and Degree of susceptibility of the receptor.

Intersystem EMI and Intrasystem EMI

Intrasystem interference is a result of self-jamming or undesirable emission coupling within a system, whereas intersystem EMI is the interference between two or more different systems or platforms that are frequently under separate user control. Intersystem EMI is more difficult to control.

IV. EFFECT OF EMI AT DIFFERENT FREQUENCY ON HUMAN BODY

Human is the prime source of the electrostatic discharge. This charge can be transferred from one person to any piece of sensitive electronic equipment in the form of electrostatic discharge. Human body model behaves as a capacitor and resistor. The primary contributor to the capacitance of the body comes from the capacitance between the soles of the feet and ground which is about 100pF.

1. Extremely Low frequency RF: High-power extremely low frequency RF with electric field levels in the low KV/m range are known to induce perceivable current within the human body that crate an annoying tingling sensation.
2. Shortwave frequency RF: Shortwave Diathermy heating of human tissue only heats tissues that are good electrical conductor, such as blood vessels and muscle, Adipose tissue receives little heating by induction fields because an electrical current is not actually going through the tissues.
3. Microwave: ANSI standards for safe exposure levels to RF and microwave radiation are set to a Specific Absorption Rate (SAR) level of 4 W/Kg, the threshold before hazardous biological effects occur due to energy absorption in the body. Microwave exposure at low-power levels below the specific absorption set by government regulatory bodies are considered harmless non-ionizing radiation and have no effect on the human body. However, levels above the SAR set by the Federal Communication Commission (FCC) are considered potentially harmful. Two areas of the body, the eyes and the testes, can be particularly susceptible to heating by RF energy because of the relative lack of available blood flow to dissipate the excessive heat load. A safety factor of ten was then incorporated to arrive at the final recommended protection guidelines of a SAR exposure threshold of 0.4 W/ Kg for RF and microwave radiation.

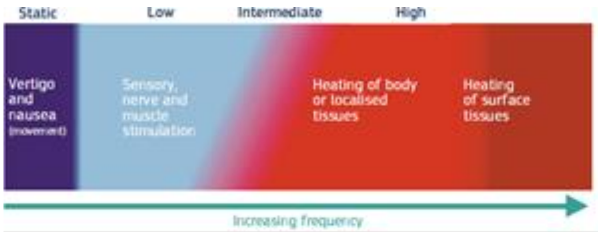

Fig. 4 Effect of EMI at Different Frequency Range

4. Millimeter Wave: Previously, microwave application in these bands were for point-to-point satellite communication with minimal human exposure. Recent technology advances in the developments of millimeter wave scanners for airport security and WiGig for personal area networks use the 60 GHz and above microwave band in SAR exposure regulation.
5. Infrared: Infrared wavelength longer than 750nm can produce change in the lens of eye. Glassblower's cataract is an example of a heat injury that damages the anterior lens capsule among unprotected glass and iron workers. Cataract-like changes can occur in workers who observe glowing masses of glass and iron without protective eyewear for many hours a day.
6. Visible light: As with its infrared and ultraviolet radiation dangers, welding creates an intense brightness in the visible light spectrum, which may cause temporary flash blindness. Some sources state that there is no minimum safe distance for exposure to these radiation emissions without adequate eye protection.
7. Ultraviolet: Short-term exposure to strong ultraviolet sunlight causes sunburn within hours of exposure. prolonged exposure to ultraviolet radiation from the sun can lead to melanoma and other skin malignancies. Clear evidence establishes ultraviolet radiation, especially the non-ionizing medium wave, as the cause of most non-melanoma skin cancer, which are the most common form of cancer in the world. UV rays can also cause wrinkles, liver spots, moles and freckles. In addition to sunlight, other source includes tanning beds, and bright desk lights. Damage is cumulative over one's lifetime, so that permanent effects may no be evident for some time after exposure.
8. Radio Frequency Fields: Apart from some suspicion that the electromagnetic fields emitted by mobile phones may be responsible for an increased risk of glioma and acoustic neuroma, the fields otherwise pose no risk to human health.

V. EMI CONTROL

To control EMI, following measures can be taken:

1. Suppress noise (EMI) at the source
   a. Shield the noise source.
   b. Filter all leads leaving a noisy environment.
   c. Limit pulse-rise time.
   d. Optimize clock speeds.
   e. Shield and twist noisy leads.

2. Reduce the possibility of noise coupling
   a. Twist and Shield low-level signal leads and place them near chassis.
   b. Use shielded cables.
   c. Ground shield at one end for low frequency and at both ends for high frequency.
   d. Separate power cables or tracks from high frequency tracks as much as possible.
   e. Use ground track between two high frequency tracks to avoid crosstalk.
   f. Keep hardware grounds separate from circuit ground.
   g. Place sensitive circuits in shielded enclosure.
   h. Avoid or break or control ground loops.

3. Harden victim to make immune to noise
   a. Filter and decouple any lead entering enclosures containing sensitive circuit.
   b. Use only the required bandwidth.
   c. Provide proper power supply decoupling.
   d. Separate signal, noisy and hardware grounds.
   e. Use shielded enclosures.

EMI can be controlled at the following two stages:

a. Design stage: consider factors like track and cable routing, grounding, placement of components, etc.
b. System stage: At this stage, only EMI fixes like adding filters and grounding are added. Several choices or circuits are available for designers to achieve a desired function. EMI control measures taken at an initial stage result in a cost-effective design.

VI. EMC TESTING AND STANDARD ORGANISATIONS

To ensure that a product is electromagnetically compatible, EMC testing is done. EMC tests are divided into emission and susceptibility tests. Emission tests verify the ability of the product to operate without creating interference beyond a certain limit. Susceptibility tests verify the ability of the product to operate in presence of electromagnetic interference. The tests required to be performed depend upon many factors like product specifications, its use, place of installation, required reliability and behavior, environmental conditions, economic constraints and kinds of interference affecting the equipment. As described above, there are two ways for EMI to travel. Accordingly, the emission and susceptibility into radiated and conducted. Some of the EMC tests are shown in Fig. given below.

To carry out different EMC tests, different standards are available. There are several national and international EMC regulatory bodies or standard organizations that are involved in framing standards for different EMC tests for different products. Some of the international EMC standard organizations are:

1. International Electrotechnical Commission (IEC). Based in Geneva, it covers all testing aspects.
2. International Special Committee of Radio Interference (CISPR). Based in Geneva, it covers emission and some susceptibility testing aspects.
3. Radio Technical Commission for Aeronautics (RTCA). Based in Washington, USA, it covers avionics and aircraft testing.
4. International Telecommunications Union (ITU). Based in Geneva, it covers telecommunication aspects.
5. International Organization for Standardization (ISO). Based in Geneva, it covers general testing aspects.

VII. CONCLUSION

There are several important conclusions to take away from this section. Mainly, they are the following:

- EMI is a major problem in the development of embedded systems. Since embedded systems often exists in very noisy environments, even more attention must be paid to EMC.
- EMC must be taken into consideration during the design stage. Designing for EMC is a long process that starts early in the life cycle and proceeds through the testing stage and even in the post-production stage. Therefore, EMC is a concern for engineers at all phases of the development of an embedded system.
- Environmental reliability testing is used to eliminate potential problems that the system can experience when it is operating in its natural environment.
- There are many EMC standards used in the regulation of products that may cause EMI.

EMC is a very important issue that embedded systems designers have to deal with. Even though it is a very difficult topic, there are many practical design techniques that can be used to design for EMC. This will greatly assist designers who are unfamiliar with EM theory to be confident in their design for EMC.

REFERENCES

[1] Ali Zamanian and CyHardiman, “Electromagnetic Radiation and Human Health: A Review of Sources and Effects”, Summit Technical Media, July 2005.

[2] http://image.gsfc.nasa.gov/poetry/ workbook/stroms.html

[3] http://sunearth.gsfc.nasa.gov/podcasts/ media/ Blackout/Blackout_part4.htm

[4] "Standard for Safety Level with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3KHz to 300GHz". IEEE Std (IEEE) C95.1. Oct 2005.

[5] International Commission on Non-Ionizing Radiation Protection, “Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)”, Health Physics 74 (4), April 1998.

[6] Focke F, Schuermann D, Kuster N, Schar P, “DNA Fragmentation in Human Fibroblasts Under Extremely Low Frequency Electromagnetic Field Exposure”, Mutation Research 683(1-2), November 2009.

[7] Ahlbom A. Neurodegenerative diseases, suicide and depressive symptoms in relation to EMF. Bioelectromagnetics2001, Suppl 5, S132-S143.

[8] Anane R, Dulou PE, Taxile M, Geffard M, Crespeau FL, Veyret B. Effects of GSM-900 microwaves on DMBA-induced mammary gland tumors in female Sprague-Dawley rats. Radiat Res 2003a, 160, 492- 497.

[9] Anane R, Geffard M, Taxile M, Bodet D, Billaudel B, Dulou P. E, and Veyret B. Effects of GSM-900 microwaves on the experimental allergic encephalomyelitis (EAE) rat model of multiple sclerosis. Bioelectromagnetics2003b, 24, 211-213.

[10] Aran JM, Carrere N, Chalan Y, Dulou PE, Larrieu S, Letenneur L, Veyret B, and Dulon D. Effects of exposure of the ear to GSM microwaves: in vivo and in vitro experimental studies. Int J Audiology 2004, 43, 245-254.

[11] Auvinen A, Hietanen M, Luukkonen R, Koskela RS. Brain tumours and salivary gland cancers among cellular telephone users.Epidemiology 2002, 13, 356-359. Bak M, Sliwinska-Kowalska M, Zmyslony M, Dudarewicz A. No effects of acute exposure to the electromagnetic field emitted by mobile phones on brainstem auditory potentials in young volunteers. IntJ Occup Med Environ Health 2003, 16, 201-208.

[12] Bartsch H, Bartsch C, Seebald E, Deerberg F, Dietz K, Vollrath L, Mecke D. Chronic exposure to a GSM-like signal (mobile phone) does not stimulate the development of DMBA-induced mammary tumors in rats: results of three consecutive studies. Radiate Res 2002, 157, 183-190.

[13] Girgert R, Schimming H, Korner W, Grundker C and Hanf V. Induction of tamoxifen resistance in breast cancer cells by ELF electromagnetic fields. BiochemBiophys Res Commun2005, 336, 1144-1149.

[14] Glaser R. In-vitro studies of electromagnetic exposure between 300 Hz and 10 MHz. In: Matthes R, van Rongen E, Repacholi MH (eds.). Health Effects of Electromagnetic Fields in the Frequency Range 300 Hz to 10 MHz. Proceedings of the International Seminar on Health Effects of Electromagnetic Fields in the Frequency Range 300 Hz to 10 MHz, Maastricht, The Netherlands, June 7 and 8, 1999, International Commission on Non-Ionizing Radiation Protection; 1999, 105-121.

[15] Gotoh T, Terada K, Mori M. hsp70-DnaJ chaperone pairs prevent nitric oxide-mediated apoptosis in RAW 264.7 macrophages. Cell Death Differ 2001, 8, 357-366.

[16] Hardell L, Carlberg M, Hansson Mild K. Case-control study on cellular and cordless telephones and the risk for acoustic neuroma or meningioma in patients diagnosed 2000-2003. Neuroepidemiology2005a, 25, 120-128.

[17] International Commission on Non-Ionizing Radiation Protection (ICNIRP). Statement on the "Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz)", 2009.

[18] Institute of Electrical and Electronics Engineers (IEEE). IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz, IEEE Std C95.1, 2005.