2.0 REVIEW OF LITERATURE

It has been known for many years that high energy electromagnetic fields (EMFs) like x-rays, gamma rays and cosmic rays have sufficient energy to directly break chemical bonds, causing damage to molecules ranging from water to DNA that results in cancer and birth defects, hence they are ionizing. There is a controversy though about the bioeffects caused by low-level, non-thermal EMFs, such as radiofrequency electromagnetic field (RF-EMF) radiations, particularly from cell phones and cell phone towers. The safety standards for RF-EMF exposure set by International Commission on Non-Ionizing Radiation Protection (ICNIRP), adopted by India, has only taken into account the short-term effects and not the biological effects from long-term, low-level microwave exposure from mobile phones, cell phone towers and many other wireless devices. Numerous studies have shed light on this very current issue and the evidence is mounting that indeed RF-EMF is an invisible health hazard pollution.

According to Sage and Carpenter, (2009), physics and engineering communities must work in tandem with biomedical community to convince the national and international bodies to set biologically-based standards for safe RF-EMF exposure. There are evidences for association between EMFs and a variety of diseases, and of most concern are cancer and neurodegenerative diseases, which can lead to significant morbidity and mortality in humans. RF-EMF radiation fall within a particular waveband of non-ionising electromagnetic fields, covering frequencies between 30 kHz to 300 GHz, which are used for communication technologies such as mobile telephony (2G, 3G, 4G and 5G in the pipeline), Wi-Fi, Bluetooth and RFID applications (ANSES, 2013). With the advent of enormous increase in the use of cell phones, a very large segment of society is regularly exposed to high levels of RF-EMF radiation through the placement of mobile phone towers, wireless buildings and even wireless cities.

The strongest evidence for hazards has come from the Scandinavian countries, where mobile phones were initially manufactured, and have been in wide use for a longer period of time as compared to other parts of the world. So much so, a case study in Sweden showed that 250,000 Swedes were allergic to mobile phone radiation and were termed as being electrohypersensitive. EHS (electrohypersensitivity) was recognised as a physical degradation and EHS sufferers were entitled to have metal shielding installed in their homes free of charge from the local government (Kumar, 2010; Fragopoulou A. et al., 2010).
Various studies have shown that even at low levels of this radiation, there is evidence of damage to cell tissue and DNA, and it has been linked to brain tumors, cancer, suppressed immune function, depression, miscarriage, Alzheimer's disease, and numerous other serious illnesses. Oncogenesis studies at molecular and cellular levels due to RF-EMF radiations are considered particularly important (Marino and Carrubba, 2009). Orientation, navigation and homing are critical traits expressed by organisms ranging from bacteria through higher vertebrates. Every living being is tuned into the earth’s electromagnetism and uses it for various purposes. A natural mineral magnetite, which is found in living tissues seems to play an important role. These magnetite crystals are found in the ethmoid bone above the eye, sinuses and blood-brain barrier (Warnke, 2007). Eye, beak and brain tissues of birds are loaded with magnetite, sensitive to magnetic fields and RF-EMFs interfered with navigation (Ritz T. et al., 2004; Beason and Semm, 2002). Migratory birds rarely get lost, but sometimes exhibit confusions due to storms and man-made electromagnetic disturbances (Kirschvink JL. et al., 2001).

All electromagnetic field sensitivity in living organisms, including elasmobranch fishes, is the result of a highly evolved, finely-tuned sensory system based on this single-domain, ferromagnetic crystals. Monarch butterflies and locusts migrate great distances using their antennae to sense air currents and earth’s electromagnetic fields. Moths are drawn to light frequencies. According to Warnke (2007), animals that depend on the natural electrical, magnetic and electromagnetic fields for their orientation and navigation through earth’s atmosphere, are confused by the much stronger and constantly changing artificial fields created by technology and fail to navigate back to their home environments, apart from exhibiting various other abnormalities.

In human health studies, concerns have been expressed about the possible interactions of RF-EMF radiations with several human organ systems such as nervous, circulatory, reproductive and endocrine systems. In order to reveal the bioeffects of RF-EMF on gene and protein expression, high-throughput screening techniques (HTSTs) such as transcriptomics and proteomics were employed in EMF research with an intention to screen potential EMF-responsive genes and/or proteins (Nylund and Leszczynski, 2004). The traditional and most effective approach to study cause-effect relationships in biological sciences is by experimentation with cells and organisms. The areas of enquiry and experimentation in in vitro studies includes genotoxicity, cancer-related gene and protein expression, cell proliferation and differentiation, and apoptosis and in vivo studies including thermal effects, animal behavior, brain biochemistry, neuropathology teratogenicity,
reproduction and development, immune function, blood-brain barrier, visual auditory systems and effects on genetic material, cell function and biochemistry (Repacholi and Cardis, 2002).

According to World Health Organization’s Research Agenda for Radiofrequency Fields (2010), high-priority research needs were studies on dosimetry, epidemiology and in vivo animals studies. It is still an open question whether children are more susceptible to RF-EMF since the brain continues to develop during childhood and adolescence. Also, children are starting to use mobile phones at a younger age. Research is also emphasised on the effects of early-life and prenatal RF exposure on development and behaviour due to the widespread use of mobile phones by children and the increasing exposure to other RF sources such as wireless local area networks (WLANs) and the reported effects of RF-EMF on the adults, especially on problems relating to fertility and endocrine system.

2.1 DOSIMETRY

A measurement of public exposure to RF-EMF in the living environment in areas around base stations were carried out in Salzburg, Austria, in cities and towns at 100 sites and rural areas at 102 sites from 1997 to 1999 (Neubauer, 2000). Dosimetry measurements were carried out in Australia for 24 hours at 14 different locations (Line, 2000); at 118 locations at 17 sites in UK (Mann SM, 2000); and in Canadian schools (Gajda and Thansandote, 1998). A similar study in Chandigarh city in India was performed to measure RF-EMF radiation near schools and hospitals (Dhami, 2011). The results of these varied studies indicated that although adhering to standards, the power densities were found to be much higher than the biological limit at which effects were noted. Ismail A. et al., (2010), measured the RF-EMF values around cell phone towers in two cities in Malaysia and found them to be less than 1% of the maximum permissible exposure and within the international limits, although the number of cell phone towers in the city were increasing. Mahfouz Z. et al., (2011), measured the real-life exposure to 3G base stations of the general public in environment during a period of one day and concluded that it was higher during daytime than at night due to the traffic demands. The RF-EMF exposure standards of European countries, United States and Russia were elaborated in detail by Stam (2011).

According to Shandala and Vinogradov (1977), there will be high electromagnetic radiation near a re-emitting element such metal-coated structures like wires, pipes, playground equipments,
cranes, power transmission lines, and metal fences. An invisible ocean of electromagnetic waves from cell towers among others, travelling at the speed of light, can be reflected and refracted by metal appliances, rain, snow, glass and conductive materials. In 2010, an independent study in Delhi commissioned by the Cellular Operators Association of India (COAI) and Association of Unified Telecom Service Providers of India (AUSPI) found that the cumulative measurement levels of radiation from cell phone towers were 100 times below international safety guidelines and in compliance with the limit set by ICNIRP. According to Kaur and Dhami, (2012), radiofrequency radiation (835 MHz, 915 MHz, 1900 MHz and 2450 MHz) from cell phone towers are higher at a closer distance from the cell-phone tower than further away. The peak in power density values was observed at a distance of 40 meters for most of the antenna orientations. According to Tanwar, (2006), in the over-exuberance of the speed of network roll out and covering the full population for good communication range, structural stability, heritage protection and radiation health effects have been neglected. The general public has been continuously exposed to EMR leading to have permanent effect on human health and behavior. From dosimetry done by Hauman T. et al., (2002), the average threshold value for non-thermal biological effects was found to be 1 mW/sq.m. Two of the most important factors were the distance and the direct line of sight to the antenna. At the typical residential cell tower distance of about 250 m in cities, with direct line of sight, the observed levels were in the range of 0.2 mW/sq.m, with the maximum value exceeding 100 mW/sq.m.

According to the Bioinitiative Report (2012), RF-EMF levels were associated with bioeffects and adverse health effects. At least five new cell tower studies had reported bioeffects in the range of 0.01 mW/sq.m to 0.5 mW/sq.m, which are levels lower than what was reported in 2007. Mantiply ED. et al., (1997), measured and reported common sources and levels of RF in the environment. Areas near cellular base stations on the ground near towers were found to be from 0.03 to 0.3 mW/sq.m. Background level ambient RF exposures in cities and suburbs in the 1990s were generally reported to be below 0.03 mW/sq.m. Hamnerius Y., (2000), reported that ambient RF power density measurements in 12 large cities in Sweden were roughly ten times higher than in the United States for equivalent measurement locations by Mantiply in 1978, when no cellular phone service existed in the US. He reported a total mean value of 26 measured sites in the study was 0.5 mW/sq.m. An office location with a base station nearby at about 300 feet distance tested 1000 mW/sq.m. A train station with antennae mounted indoors tested at about 30 mW/sq.m. Both indoor and outdoor ambient RF power density measurements showed high variability depending on proximity to transmitting antennae.
It was reported that within the first 100 to 300 feet, power density levels were found to be 0.1 to 30 mW/sq.m. Elevated RF power density levels from a major wireless antenna site can often be detected at 1000 feet or more. Power density levels away from wireless antenna sites measure between 0.01 mW/sq.m to 0.00001 mW/sq.m (Sage, 2000). Vegetation often reduced signals, but buildings do not appreciably diminish signal transmission. Cell phone towers incorporated into stealth designs, such as church steeples, water tanks, trees and flag poles called as stealth installations produce elevated RF levels in nearby areas where people who were unaware lived and worked.

2.2 EPIDEMIOLOGY

A meta-analysis by Hardell L. et al., (2006, 2007), has found an elevated risk of brain tumors, low-grade astrocytoma and acoustic neuroma in individuals who have regularly used the cell phones for ten years or longer. The same team found a higher risk of developing glioma in individuals who had started to use the cell phones in their 20s when compared to the older persons. The results of INTERPHONE, (2012), the international case-control epidemiological study, conducted in 13 countries namely, Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden and UK, to assess the risks of tumours of the brain (glioma and meningioma), acoustic nerve (schwannoma) and parotid gland, in relation to mobile telephone use, revealed that there was no increase in risk of glioma or meningioma, but there were suggestions of an increased risk of glioma at the highest exposure levels. In a study by a team from Israel, which was a part of the INTERPHONE study, showed an elevated risk of parotid gland cancer among long-term users of cell phones (Sadetzki, 2008). Carpenter, (2010), concluded from his analysis that cordless phones increased both exposure levels and disease by about the same magnitude as cell phones do and that the use of either resulted in an increased risk of gliomas. Cordless phones emit RF-EMF radiations, frequency being 900 MHz to 2 GHz (FCC, 1995) inside the premises even when the phone is not in use, similar to a cell phone tower radiation 24/7. Due to the surmounting research on the ill-effects of RF-EMF radiation, the Federal Communications Commission (FCC), USA, in June 2012 was advised to review its exposure limits set in 1990s, especially for children and cell phones (IAC, 2013).

Many experiments have detected the deleterious effects of RF-EMF fields on cognitive functions such as short- and long-term memory, attention, reaction time, and concentration, among
people living near cell phone towers (Stewart Report, 2000). CERENAT, a multicenter population-based case-control study, through a questionnaire, initiated in 2004, was designed to study the role of environmental and occupational factors in the occurrence of primary central nervous system (CNS) tumors in adults (men and women over 16 years) in France in comparison with regular mobile phone use, which was defined as mobile phone use more than once a week for 6 months or more (Coureau G. et al., 2014). The authors concluded that their results support the previous findings concerning a possible association between heavy mobile phone use and brain tumors, especially gliomas and temporal tumors for occupational use and urban cell phone use. Vertigo was one of the complaints frequently made by people who were hypersensitive to RF radiation emitted by cell phones. There were investigations on the acute effects of RE-EMF on auditory perception and hearing deterioration using standard audiometry. Other studies included auditory-evoked response and brain-evoked response audiometry (BERA). People who were electrohypersensitive reported a sensitivity to cell phone tower-like signals (Eltiti S. et al., 2007; Furubayashi T. et al., 2008), signals from cell phones (Kwon et al. 2008), and mobile phone symptoms especially related to hearing (Bamiou DE. et al. 2008; Hillert L. et al. 2008).

According to a postal survey, increasing number of people in Japan have electrohypersensitive syndrome (EHS), due to chronic nervous system arousal, with the main symptoms being dizziness, ringing in the ears, fatigue, headaches and sleeplessness. Moreover, 85.3% had to take measures to protect themselves from EMF, such as moving to low EMF areas or buying low-EMF electric appliances. EHS persons were suffering not only from their symptoms, but also from economical and social problems (Kato and Johansson, 2012). A survey by a team of medical doctors led by Eger H. et al., (2004), in Naila, Germany, to examine whether people living close to cell phone towers were exposed to a heightened risk of developing malignant tumors, it was observed that the relative risk of getting cancer had trebled for the residents of the area in the proximity (within 400 m) of the cell phone tower installation compared to the inhabitants of Naila outside the area. Pritchard C. et al., (2013), point to the fact that there was a steady increase in auto-immune diseases, motor neuron diseases, dementia, cancer, infertility, and asthma from 1979 to 2010, more women being affected than men in UK and USA, pointing to lifestyle and environmental influences augmented due to electropollution.

Hagström M. et al., (2013), carried out a survey in Finland where 206 self-diagnosed electrohypersenstive (EHS) Finns replied to a questionnaire and 81% were women. Before EHS
onset, the most common health complaints were allergies at 35%. During the acute phase of EHS the most common symptoms were nervous-system related, such as stress 60%, sleeping disorders 59% and fatigue 57%. The sources most often triggering EHS were personal computers 51% and mobile phones 47%; 76% reduced their exposures to RF-EMFs or avoided completely, which helped them in their partial or full recovery. The best treatments for EHS were dietary change 69%, nutritional supplements 68% and increased physical exercise 62%. The official treatment recommendations of psychotherapy 3% and medication 4% were not significantly helpful. The avoidance of RF-EMF radiations effectively removed or lessened EHS symptoms.

According to Havas (2013), Health Canada Safety Code 6 protects the public from cell phone tower exposures based only on preventing a heating effect averaged over six minutes, which invalidates the assertion over many years by Health Canada that Safety Code 6 protecting the public from both thermal and non-thermal effects. They considered the thermal and non-thermal effects for 3 to 100 kHz, but only thermal effects for 100 kHz to 300 GHz and omitted the fact that certain members of the general public may be more susceptible to harm from RF-EMF exposures. The landmark investigation by Havas, (2008), led to the conclusion that there was a third type of diabetes called brittle diabetes or Type 3 diabetes, caused by transient electromagnetic fields or dirty electricity, generated by electronic equipment and wireless devices, and that exposure to electromagnetic pollution from kHz to GHz may account for higher plasma glucose levels, contributing to the misdiagnosis of diabetes.

According to Fox, (2004), the nervous system of every species including humans can detect EMFs, but it is not developed in most humans because it was not useful to them historically. While living next to a cell phone tower, due to constant RF-EMF radiation, the nervous system detects a change, which is interpreted as a threat, and the fight or flight response is switched on. Calming this response by avoiding exposure to such pollutants is very difficult to do in modern life. Earthing devices have proven to be helpful. People who are in a constant state of nervous system arousal suffer the most. When such people get additional exposures, the nervous system goes from order into a chaos state, leading to chronic pain, anxiety, sleeplessness, short-term memory loss, lack of concentration and increased fear psychosis. The criteria identified in 1999 by researchers for the diagnosis of multiple chemical sensitivity (MCS) can be applied to electrohypersensitivity (EHS), such as migraines, irritable bowel and bladder, fibromyalgia, chronic fatigue and chronic pain. They can be triggered by an acute or chronic RF-EMF exposure, with symptoms reproducible
with repeated exposures, the condition persisting for a significant period of time, levels of exposure lower than commonly tolerated resulting in increased sensitivity, symptoms improving or resolving completely when the triggers are removed, responses often occur to multiple unrelated triggers and symptoms involved multiple organs. Patients have lower threshold of tolerance to various stressors and higher excitation within the nervous system. EHS can be limited by avoiding the environmental triggers. Most living organisms, including bacteria, are electrosensitive and that certain susceptible organisms become more intolerant to electromagnetic fields (EMFs) than others as a result of prolonged EMF exposure. They also cause severe depression (Belpomme, 2011).

An epidemiological assessment was done to determine whether the incidence of cancer cases among individuals exposed to a cell phone transmitter station in Netanya, Israel, in comparison with people who lived away from it. Cancer incidences were significantly higher (p<0.001) in this area with eight cases of cancer being reported in one year, women being more affected than men. Hence, an association between increased incidence of cancer and living in proximity to a cell phone tower was established (Wolf and Wolf, 2004). Comparisons of complaints in relation with distance from base station showed a significant (p<0.05) increase when compared to people living greater than 300 m or not exposed to base station; up to 300 m for tiredness, 200 m for headache, sleep disturbance and discomfort, 100 m for irritability, depression, loss of memory, dizziness and libido decrease. Women significantly more often than men (p<0.05) complained of headache, nausea, loss of appetite, sleep disturbance, depression, discomfort and visual perturbations (Santini R. et al., 2002). Urban electromagnetic contamination (electrosmog) due to 900 and 1800 MHz pulsed waves interfered with the nervous system of living beings (Hyland, 2000).

There was prevalence of neuropsychiatric complaints among people living near base stations. In 2008, the Austrian Department of Health found a higher risk of cancer among people living within 200 m of a mobile phone base station and that cancer risk rose with increasing exposure, reaching 8.5 times the norm for people most exposed (Abdel-Rassoul, 2007). A study in Spain found that the most exposed people had a higher incidence of fatigue, irritability, headaches, nausea, loss of appetite, sleeping disorders, depression, discomfort, difficulties concentrating, memory loss, visual disorders, dizziness and cardiovascular problems. The authors recommended a maximum exposure of 0.001 mW/sq.m (Oberfeld et al., 2005). It was evident from a study on the effect of a cell phone tower on human subjects, that skin disease and hair loss was common, along
with marked incidences of diabetes, cardiac and respiratory problems among people who lived within 50-100 m of cell phone towers. Cancer, epilepsy and insomnia were insignificant (Chandran M. et al., 2012).

Higher exposure combined with sensitive, developing brain tissue leave children at a greater risk for cell phone radiation. Radiation exposures are higher for children than adults because children have thinner skulls, and their brains have higher water and higher ion (charged particle) content. These factors enhance radiation penetration. Researchers in the United States, France, and Japan have reported that a child’s brain absorbed twice the amount of radiation compared to that of an adult (Rosenberg, 2013). Research reported headaches, concentration difficulties and behavioural problems in children and adolescents, and sleep disturbances, headaches and concentration problems in adults. Mobile phone use after lights out may be associated with poor mental health, suicidal feelings and self-injury in both early and late adolescents (Oshima N. et al., 2012).

The BioInitiative 2012 Report, prepared by 29 research scientists from 10 countries, such as Sweden, USA, India, Italy, Greece, Canada, Denmark, Austria, Slovac Republic and Russia state that exponentially increasing RF-EMF exposures are deleterious to the biosystem and ecosystem. There was substantial evidence that EMF could cause inflammatory reactions, allergy reactions and change normal immune function at the current public safety standards. Medical conditions were successfully treated using EMFs at levels below the current public safety standards, proving another way that the body recognised and responded to low-intensity EMF signals. Moreover, these treatments were controlled for a specific time period, unlike the RF-EMF exposure in the environment, terming it as the biggest biological experiment. Continuous exposure could result in diminished capacity for thinking, judgment, memory, learning, and control over behaviour. Drugs used in medical treatments and prevention of disease cannot be given without a prescription, especially to children, yet they are being exposed to constant EMFs in the environment as well as through the addictive use of wireless devices.

According to a Brazilian study by scientists at the Federal University of Minas Gerais (UFMG), a direct link to 4,924 cancer deaths from cellular antenna radiation has been established. The victims (80%) lived within 500 meters from the cell phone towers on premises (Hamad Ameen,
According to the Seletun Scientific Statement (2011), low-intensity, non-thermal RF-EMF exposure-related health effects were demonstrated at levels significantly below existing standards and that new, biologically-based public exposure standards were urgently needed to protect public health world-wide. EMR exposures should be reduced now rather than waiting for proof of harm before acting (Fragopoulou A. et al., 2010). A study by Divan HA. et al., (2012), concluded that cell phone use was associated with behavioural problems in children (age 7 years), who had both prenatal and postnatal exposure to cell phones compared with children not exposed during either time period.

An independent case study in Mumbai found that people living within 50 to 300 m radius were in the high radiation zone and more prone to ill-effects of electromagnetic radiation. Four cases of cancer were found in three consecutive floors (6th, 7th, 8th) directly facing and at similar height as four mobile phone towers placed at the roof of the opposite building (Kumar, 2010). NORDPRED software was used to predict future cancer incidence rates and numbers of cancer cases for the period 2007-11 and 2012-16 in Chennai by Swaminathan S. et al., (2011). It was found that breast cancer would dislodge cervical cancer as the top-ranking cancer in the state, while lung, stomach and large bowel cancers would surpass cervical cancer in ranking in Chennai by 2016 and a 100% increase in future thyroid cancer incidence was predicted with a 42% increase in prostate cancer.

2.3 ANIMALS STUDIES, INCLUDING IN VIVO PURSUIT USING ANIMAL MODEL GUINEA PIG

Various studies abroad have shown that even at low levels of RF-EMF radiation, there was evidence of damage to cell tissue and DNA, and it has been linked to brain tumors, cancer, suppressed immune function, depression, miscarriage, Alzheimer's disease, and numerous other serious illnesses. Salford LG. et al., (2003), found highly significant evidence for neuronal damage in the cortex, hippocampus and basal ganglia of rats exposed to 2 hours of Global System for Mobile Communications (GSM) RF-EMF mobile phone electromagnetic fields of different strengths. This team had previously shown that weak pulsed microwaves gave rise to significant leakage of albumin through blood-brain barrier. The EMR altered the immune, nervous, and endocrine systems, and operated independent or together with other factors like ultraviolet radiation or chemical pollutants (Blaustein AR. et al., 2003, Middleton EM. et al., 2001). EMR produced stress on the immune system (Novoselova and Fesenko, 1998; Grefner, 1998) that obstructed DNA
repair (Hallberg and Johansson, 2004). Cells sensitive to weak electromagnetic fields, accelerate electron transfer and destabilize the H-bond of cellular macromolecules (Blank and Goodman, 2004). After RF-EMF exposure, transcription and protein expression were observed. These fields do not possess sufficient energy to directly break a chemical bond in DNA. It was concluded that the genotoxic effects were mediated through indirect means by generation of reactive oxygen species (ROS) or improper DNA repair process (Lee S. *et al.*, 2005; Nylund and Leszczynski, 2006).

Various studies have shown that RF-EMF radiation has the capacity to induce blood-brain barrier alterations, whereby it loses the precise control to block toxic molecules from entering the brain. The first study was carried out by Polyashchuck in 1971 followed by Frey AH. *et al.* (1975) who reported the penetration of fluorescent-labelled albumin across the rat blood-brain barrier as a result of 1.2 GHz radiation at power densities of 1000 mW/sq.m. Oscar and Hawkins, (1977), demonstrated that single 20-minute exposure of rats to pulsed or continuous wave 1.3 GHz radiation increased the permeability of the blood brain barrier for saccharides, mannitol and inulin. In a study by Merritt JH. *et al.*, (1978) showed that there were no transfer of parenterally-administered fluorescent across the blood brain barrier after 30 minutes of 1.2 GHz radiation at power densities from 20,000 to 7,50,000 mW/sq.m, but under hyperthermic conditions, in a warm-air environment, there was increased fluorescent uptake.

### 2.3.1 EFFECT OF RF-EMF ON INSECTS

#### 2.3.1.1 FRUIT FLY

A study by the University of Athens in 2004 on fruit flies exposed to 6 minutes of 900 MHz pulsed radiation for five days showed reduction in reproductive capacity. Likewise in 2007, in both 900 MHz and 1800 MHz, similar changes in reproductive capacity with no significant difference between the two frequencies were observed. A third study concluded that it was due degeneration of large numbers of egg chambers after DNA fragmentation. When *Drosophila melanogaster* adult insects were exposed to the radiation of a GSM 900/1800 mobile phone antenna at different distances ranging from 0 to 100 cm, these radiations decreased the reproductive capacity by cell death induction at all distances tested (Panagopoulos DJ. *et al.*, 2010).
2.3.1.2 HONEY BEES

The effect of RF-EMF radiations on various biomolecules in the adult worker bees (*Apis mellifera* L.) were investigated. Reduced motor activity of the worker bees on the comb followed by mass migration and movement towards the cell phone on talk mode were observed. The initial period demonstrated rise in concentration of biomolecules including proteins, carbohydrates and lipids, perhaps due to stimulation of body mechanism to fight the stressful condition created by the radiations. At later stages of exposure, there was a slight decline in the concentration of biomolecules probably because the body had adapted to the stimulus (Kumar, 2011). Recently, a sharp decline in population of honey bees has been observed in Kerala. According to Pattazhy, (2012), constant vigilance by bee keepers could prevent most problems arising due to diseases and natural enemies of bees. The present plunge in bee population (p<0.01) was attributed to increasing man-made RF-EMFs in the environment from cell phone towers and wireless devices. The honey bee numbers in USA and UK have declined due to Colony Collapse Disorder (CCD) (Cane and Tepedino 2001). CCD was being documented in Greece, Italy, Germany, Portugal, Spain and Switzerland. Studies performed in Europe documented navigational disorientation, lower honey production and decreased bee survivorship (Kimmel S. *et al*., 2006).

RF-EMFs from telecommunication infrastructure interfere with bees’ biological clocks that enable them to compensate properly for the sun's movements, as a result of which they may fly in the wrong direction when attempting to return to the hive (Rubin EB. *et al*., 2006). Bee colonies irradiated with Digital Enhanced Cordless Communications (DECT) phones and mobile handsets had a dramatic impact on the behavior of the bees, namely by inducing the worker piping signal. In natural conditions, worker piping either announces the swarming process of the bee colony or was a signal of a disturbed bee colony (Favre 2011). At the global scale, the UN’s Food and Agriculture Organisation (FAO) estimated that around three-quarters of all pollinators have declined in the past decade. There are several reasons for this which include habitat decline, pesticide use and the spread of disease vectors (Stathers, 2014). From the above studies it is clear that electropollution could be the major reason for the decline of bees. In the case of honey bees, when a mobile phone with a frequency of 900 MHz was kept for 10 minutes in the beehives, it resulted in Colony Collapse Disorder (CCD) with sudden disappearance of a hive's inhabitants, leaving only queen, eggs and a few immature workers behind. With navigational skills affected, worker bees stopped coming to the hives after 10 days and egg production in queen bees dropped drastically to 100 eggs per day compared to 350 eggs (Sharma VP. *et al*., 2010).
2.3.1.3 ANTS

Ants, with the help of their antennas, are adept at electrical transmission and found to respond to frequencies as low as 9 MHz. Flying ants are very sensitive to electromagnetic fields. In an experiments on ants, it was found that RF-EMF-exposed ants could not be conditioned and previously conditioned ants very quickly lost their learning. These were similar to problems being reported about many children currently (Cammaerts MC. et al., 2012).

2.3.2 EFFECT OF RF-EMF ON AMPHIBIANS AND BIRDS

Deformities in amphibians and mortality in tadpoles was attributed to wireless telecommunications and exponential increase of electromagnetic contamination (Balmori, 2010). Several experiments with bird eggs showed a high mortality of embryos exposed to EMR from mobile phones. Tower-emitted microwave radiation affected bird breeding, nesting, and roosting in Valladolid, Spain. House Sparrows, White Storks, Rock Doves, Magpies, Collared Doves exhibited nest and site abandonment, plumage deterioration, locomotion problems and even death among some birds. No symptoms were observed prior to construction of the cell phone towers. White Storks were heavily impacted by the tower radiation during the 2002-2004 nesting season in Spain (Balmori, 2005). Evidence of a connection between sparrow decline in UK and the introduction of phone mast GSM was established. In a study in Spain, the effects of mobile phone mast has been noted in common frog (Rana temporaria) tadpoles, house sparrow (Passer domesticus), white stork (Ciconia ciconia), reporting problems with reproduction, circulatory and central nervous system, general health and well-being (microwave syndrome) (Balmori, 2009). Neural responses of Zebra Finches to 900 MHz radiation were tested under laboratory conditions and showed that 76% of the neurons responded by 3.5-times more firings (Beason and Semm, 2002). Deaths and deformities were noted in the domestic chicken embryos subjected to low-level, non-thermal radiation from the standard 915 MHz cell phone frequency under laboratory conditions (Litovitz and DiCarlo, 1999).

2.3.3 EFFECT OF RF-EMF ON SMALL MAMMALS

Rats exposed to a typical cell phone tower 900 MHz signal, continuously for 6 weeks, below ICNIRP heating limits, showed changes to the body energy balance. RF-EMF biological effects included disruption of REM sleep, thermoregulation with peripheral vasoconstriction, lower peripheral temperatures and increased food intake (Pelletier A. et al., 2013). Magras and Xenos, (1997), studied the possible effects of RF-EMF radiation on prenatal development in mice. This
study consisted of RF-EMF measurements and in vivo experiments at several places around an antenna park, where the power densities were between 168 nW/cm² and 1053 nW/cm². A progressive decrease in the number of newborns per dam was observed followed by irreversible infertility. A power density of 20 mW/sq.m RF-EMF induced double-strand DNA damage in rat brain cells. Chronic exposure to these radiations may cause significant damage to brain, especially the hippocampus. A decrease in mitochondrial-free radical production in the hippocampus and cerebral cortex of the mouse was reported after RF-EMF exposure. Learning and memory functions were found to be affected in the rodents (Kesari KK. et al., 2011). Increase in free radical activity and changes in enzymes involved in cellular oxidative processes were the most consistent effects observed in cells and animals after EMF exposure (Kesari and Behari 2009). All of these studies point towards possible tumor promotion.

There are studies which show that RF-EMF exposures can cause genotoxic effects (Tice RR. et al., 2002; Sarimov R. et al., 2004). This is brought about by RF-EMF exposures impacting the formation and stability of certain reduced forms of oxygen in a given organism (Lai and Singh, 2004). These are referred to as Reactive Oxygen Species (ROS). Glutathione transferase (GST) plays an important role in catalyzing the conjugation of reactive electrophilic agent to glutathione (GSH) and antioxidant enzymes drive chemical reactions to convert ROS into non-toxic molecules. Yan JG. et al., (2008), exposed adult Sprague-Dawley rats to regular cell phones for 6 hours per day for 126 days (18 weeks). RT-PCR was used to investigate the changes in levels of mRNA synthesis of several injury-associated proteins. Calcium ATPase, Neural Cell Adhesion Molecule, Neural Growth Factor, and Vascular Endothelial Growth Factor were evaluated. The results showed statistically significant mRNA up-regulation of these proteins in the brains of rats exposed to cell phone radiation. These results indicate that relative chronic exposure to cell phone microwave radiation may result in cumulative injuries that could eventually lead to clinically significant neurological damage.

It was found that at a GSM signal of 915 MHz, all standard modulations included, output power level in pulses 2 W, specific absorption rate (SAR) 0.4 mW/g exposure for 2 hours, 11 genes were up-regulated and one down-regulated, hence affected expression of genes in rat brain cells (Belyaev IY. et al., 2006). The induced genes encode proteins with diverse functions including neurotransmitter regulation, blood-brain barrier (BBB) and melatonin production. When rats were exposed for 2 hours a day for 45 days at 0.21 mW/cm² power density SAR (0.038 W/Kg), a significant decrease in melatonin and increase in both creatine kinase and caspase 3 were found.
This shows that chronic exposure to these radiations may be an indication of possible tumor promotion.

A study on pregnant rats and brains of fetal rats was carried out after irradiating them with different intensities of microwave radiation from cellular phones for 20 days three times a day. Superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), malondialdehyde (MDA), noradrenaline (NE), dopamine (DA), and 5-hydroxyindole acetic acid (5-HT) in the brain were assayed. The significant content differences of noradrenaline and dopamine were found in fetal rat brains (Jing J. et al., 2012). A study in rabbits exposed to continuous wave and pulsed power at 5.5 GHz found acute effects in the eyes, where lens opacities developed within four days (Birenbaum L. et al., 1969). Death in domestic animals like hamsters and guinea pigs were noted. Bats use electromagnetic sensors in different frequencies. A study on a free-tailed bat colony, Tadarida teniotis, and Pipistrellus pipistrellus in Spain showed a decrease in number of bats with several cell phone towers being installed 80 m from the colony (Balmori, 2009).

In regards to DNA damage or cell death induction due to microwave exposure, in a series of early experiments, rats were exposed to pulsed and continuous-wave 2450 MHz radiation for two hours at an average power density of 2 mW/cm2 and their brain cells were subsequently examined for DNA breaks by comet assay. The authors found a dose-dependent (0.6 and 1.2 W/kg whole body SAR) increase in DNA single-strand and double-strand breaks, four hours after the exposure to either the pulsed or the continuous-wave radiation. The same authors found that free radical scavengers, melatonin and PBN (N-tert-butyl-alpha-phenylNitrone), blocked the above effect of DNA damage by the microwave radiation (Lai and Singh, 1996; 1997; 2005).

Behavioral tasks, including the Morris water maze (MWM), radial arm maze and object recognition task have been extensively used to test cognitive impairment following exposure of rodents to mobile phone radiation (GSM 900 MHz) on various frequencies and specific absorption rate (SAR) values. Exposed animals in most cases revealed defects in their working memory possibly due to cholinergic pathway distraction (Fragopoulou A. et al., 2010). Mobile phone RF-EMF exposure significantly altered the passive avoidance behaviour and hippocampal morphology in rats (Narayanan SN. et al., 2010). RF-EMFs (875 MHz, 700 mW/sq.m) generated extracellular ROS by stimulating cell membrane nicotinamide adenine dinucleotide (NADH) oxidase in Rat1 and HeLa cells in vitro. ROS then activated metalloproteases on the outer surface of the cell, which cleaved membrane-anchored progrowth factors and triggered the activation of p38 as well as the
ERK (extracellular-signal-regulated kinase) mitogen-activated protein kinases (MAPKs) (Friedman J. et al., 2007). An enhanced production of ROS after combined exposure to RF radiation (930 MHz, SAR 1.5 W/kg) and iron ions was also reported in an experimental model of rat lymphocytes (Zmyslony M. et al., 2004) and induced lipid peroxidation, accompanied by decreased activity of superoxide dismutase (SOD), myeloperoxidase (MPO) and glutathione peroxidase (GSH-Px) by RF exposure has been reported in various organs, such as rat kidney and guinea pigs liver (Oktem F. et al., 2005). Moreover, in the latter animal model, treatment with epigallocatechin-gallate, the main active component of green tea, and N-acetyl cysteine, a glutathione (GSH) precursor, provided protection against oxidative stress-induced liver injury caused by RF-EMFs (Ozgur E. et al., 2010).

Ilhan A. et al. reported a marked oxidative damage in brain tissues of rats exposed to 900MHz signal for GSM (Global System for Mobile communications) (SAR of 2 W/kg in the brain) for seven days. They first proved that RF-EMFs exposure of the brain in rats cause histopathological changes typical of brain injury, accompanied by oxidative stress, as biochemically revealed by increased levels of malondialdehyde (MDA) among others. In a different experimental model of guinea pigs, Meral I. et al., evaluated the effects of GSM signal (890 to 915 MHz, SAR 0.95 W/kg, for 12 h/day for 30 days) on the oxidative stress pathway, by assessing MDA, GSH, CAT and vitamin A, D3, and E (considered part of antioxidant defense systems of tissues) levels in both brain and blood. Authors reported an increase of MDA and a decrease of both GSH and CAT levels in brains, without any modulation in vitamin concentration, thus suggesting that RF exposure could trigger depression of the antioxidant systems, due to increased lipid peroxidation and formation of free radicals. Also in a model of rats brain, locally exposed to GSM900 MHz signal (SAR 1.5 W/Kg and 6 W/Kg), the activity of the cytochrome oxidase, a specific redox-sensitive enzyme and marker of neuronal functional activity in brain, was found compromised, but only at the higher SAR used, and exclusively in specific brain areas, such as frontal cortex, posterior cortex, hippocampus, and septum.

It has been found that transcription factors, such as NF-kappa B are activated during oxidative stress (Kratsovnik E. et al., 2005, Vile G. et al., 2008). This results in reaction between Reactive Oxygen Species (ROS) and proteins, lipids and DNA. Megha K. et al., (2012), evaluated the intensity of oxidative stress, cognitive impairment and inflammation in brain of Fischer rats exposed to microwave radiation at 900 MHz microwave for 30 days (2 h/day). Significant
impairment in cognitive function and induction of oxidative stress in brain tissues of microwave exposed rats were observed, with a significant increase in level of cytokines (IL-6 and TNF-alpha). Oxidative stress and erythrocyte hemolysis induced by exposure to 2450 MHz continuous wave microwave (MW) were studied by Hassan NS. et al., (2010). The level of malondialdehyde (MDA) was significantly elevated and the levels of antioxidative enzymes significantly decreased, in addition to the increased erythrocyte hemolysis rate.

Male Wistar rats were exposed to RF-EMF radiation for 40 and/or 60 days, to determine the bioeffects of base station on glutathione reductase (GR), lipid peroxidation (LP) and total cholesterol levels in different tissues of rats exposed to base station radiation. Animals were randomly located at 10 m at the vicinity of base station and sham control animals were located greater than 300 m from the base station in a similar environmental conditions, but in the vicinity of a non-functional base station. No bioeffects were observed at 40 days, but at 60 days, decreased activity of GR, decreased levels of lipid peroxidation marker, malondialdehyde (MDA) and total cholesterol were observed. These subtle bioeffects at 60 days could mean greater potential health risk at much longer period of exposure (Achudume AC. et al., 2009). Another study by El-Ezhabi, (2010), indicated that RF-EMF did damage the DNA after exposure to 900 MHz microwave radiation in vivo rats and the increased HSP70 stress response to RF-EMF exposure might be involved in protecting cells from DNA damage.

GSM-like RF radiation induced biochemical changes by increasing free radical attacks to structural biomolecules in the rabbit as an experimental animal model (Guler G. et al., 2012). Chaturvedi, (2011), found an increase in erythrocyte and leukocyte counts, a significant DNA strand break in brain cells and the loss of spatial memory in mice exposed to 2.45 GHz microwave radiation, and hence may have an adverse effect on the brain function by altering circadian system and rate of DNA damage. RF-EMF exposure to 900 MHz affected the development of the dentate gyrus granule cells in the rat hippocampus and cell loss was due to inhibition of granule cell neurogenesis in the dentate gyrus (Odaci E. et al., 2008). Fesenko EE. et al., (1999), showed that whole body microwave sinusoidal irradiation of male mice with 8.15 to 18 GHz at a power density of 10 mW/sq.m caused a significant enhancement of TNF production in peritoneal macrophages and splenic T lymphocytes, proving microwaves as a factor interfering with the process of cell immunity.
Mouse embryonic stem (ES) cells, exposed to RF-EMF simulating the Global System for Mobile Communication (GSM) signals at 1.71 GHz, followed by quantitative RT-PCR analysis revealed that RF-EMF exposure of neural progenitor cells resulted in down-regulation of neural-specific Nurr1 and in up-regulation of bax and GADD45 mRNA levels. No effects of RF-EMF on mitochondrial function, nuclear apoptosis, cell proliferation, and chromosomal alterations were observed and hence concluded that RF-EMF exposure affected the genes related to apoptosis and cell cycle control, however, these responses were not associated with detectable changes of cell physiology, suggesting compensatory mechanisms at the translational and posttranslational level (Nikolova, 2005). In a study on cows and calves on the effects of exposure from mobile phone base stations, it was noted that 32% of calves developed nuclear cataracts, 3.6% severely. Oxidative stress was increased in the eyes with cataracts and there was an association between oxidative stress and the distance to the nearest mast or cell phone tower (Hassig M. et al., 2009).

2.3.4 EFFECTS OF RF-EMF ON HUMAN HEALTH

The action of high frequency electromagnetic waves could be mediated by direct action on glandular tissue and/or on basal brain and hypophysis or pituitary gland. According to Levitt, (2010), radiation from a cell phone penetrates deeper into the head of children (Wiart J. et al. 2011; Gandhi OP. et al. 2012) and certain tissues of a child’s head like the the bone marrow and the eye, absorb significantly more energy than those in an adult head (Christ A. et al. 2013). In the human studies, the most common effect studied was cognitive function, since the exposure in most of these human studies was localized in the brain, particularly in the temporal cortical area. RF-EMF exposure led to tumor promotion due to the overproduction of reactive oxygen species (ROS).

In an experiment by Takuya O. et al., (2013), the temperature elevation in the lens, the skin around the eye and the core temperature of numerical human and rabbit models for far-field and near-field exposures at 2.45 GHz were investigated and the results were compared with the threshold temperature at which cataracts were induced. For localised exposure of the human eye, the temperature elevation of the skin was essential, and the lens temperature did not reach its threshold for thermal pain. On the other hand, the lens temperature elevation was found to be dominant for the rabbit eye. RF-EMR can affect ear, skin, inner ear, cochlear nerve and temporal lobe surface, increasing the temperature of the inner fluids of the vestibular apparatus, which could induce neural responses in the receptor cells, such as vertigo and nystagmus. The proximity of the
mobile phone to the human eye also raises the question as to whether RF could affect the visual functions.

In the future, apart from the increased ambient RF-EMF, wireless technologies are hurtling towards wearable gadgets, smartwatches, where accessories and peripherals are charged wirelessly by a method called as near field magnetic resonance, a built-in near-field magnetic resonance (NFMR) power station quietly charges, unaware to the user as long as he is within its yard-wide range. According to latest research, in women within the ages from 21 to 39, with multifocal invasive breast cancer, it was found that all patients regularly carried their smartphones directly against their breasts in their inner-wear for up to 10 hours a day, for several years, and developed tumors in areas of their breasts immediately underlying the phones. All patients had no family history of breast cancer, tested negative for BRCA1 and BRCA2, and had no other known breast cancer risks. Their breast imaging was reviewed, showing clustering of multiple tumor foci in the breast directly under the area of phone contact. Pathology of all four cases showed striking similarity, in that all tumors were hormone-positive, low-intermediate grade, having an extensive intraductal component, with near-identical morphology. These cases raise awareness to the lack of safety data of prolonged direct contact with cellular phones (West J. et al., 2013).

Markova E. (2010) studied the effect of RF-EMF radiation from GSM (915 MHz) and UMTS induced DNA double-strand breaks (DSBs) or affect DSB repair in stem cells by analysing tumor suppressor TP53 binding protein 1 (53BP1) foci that are typically formed at the site of DSB location. The radiation inhibited formation of 53BP1 foci in human primary fibroblasts and mesenchymal stem cells. This was similar to the finding on human lymphocytes. The stem cells did not adapt to chronic exposure during two weeks, unlike the fibroblasts. This radiation affected the stem cells with significant imbalance in DSB repair and severe stress response. Mazer R. et al., (2008), investigated the effects of 72 h in vitro exposure of 10 human lymphocyte samples to radiofrequency electromagnetic fields (800 MHz, continuous wave) on genomic instability, at SAR of 2.9 and 4.1 W/kg in a temperature range of 36-37°C. They observed increased levels of aneuploidy in chromosomes 1 and 10 at higher SAR, while for chromosomes 11 and 17, it was at lower SAR. Multisomy appeared to be the primary contributor to the increased aneuploidy. These findings suggested the possible existence of an athermal effect of RF-EMF radiation that caused increased levels of aneuploidy.
Australian research conducted in 2009 by subjecting *in vitro* samples of human spermatozoa to radio-frequency radiation at 1.8 GHz and specific absorption rates (SAR) of 0.4 to 27.5 W/kg showed a correlation between increasing SAR and decreased motility and vitality in sperm, increased oxidative stress and 8-Oxo-2'-deoxyguanosine markers, stimulating DNAbase adduct formation and increased DNA fragmentation (Iuliis D. *et al.*, 2009). GSM mobile phone exposure can activate cellular stress response in both humans and animal cells and cause the cells to produce heat shock proteins (HSP27 and HSP70). HSPs inhibit natural programmed cell death (apoptosis), whereby cells that should have committed suicide continue to live. Recent studies have shown that these HSPs inhibit apoptosis in cancer cells. There was a two- to three-fold increase in rare form of cancers (Leszczynski D. *et al.*, 2002). From a study on *in vitro* cell response to mobile phone radiation (900 MHz GSM signal) using two variants of human endothelial cell line, it was suggested that the cell response to mobile phone radiation might be genome- and proteome-dependent. Therefore, it is likely that different types of cells and from different species might respond differently to mobile phone radiation or might have different sensitivity to this weak stimulus (Nylund and Leszczynski, 2006).

DNA damage via free radical formation inside cells has been recorded. Free radicals kill cells by damaging macromolecules such as DNA, protein, and membrane and are carcinogenic. EMR enhances free radical activity. Single- and double-strand DNA breaks are seen in rat brain cells after acute exposure to radiofrequency electromagnetic radiation, (Lai, 1996). A study indicated that a SAR of 0.11 W/Kg increased cell death (apoptosis) and DNA fragmentation at 2.45 GHz for 35 days exposure and that a SAR of 0.9 W/Kg decreased sperm count and more sperm cell death (apoptosis) after 35 days exposure, 2 hour per day (Kesari, 2012). Diem E. *et al.*, (2005), demonstrated increased single- and double-strand DNA breaks in human fibroblasts and rat granulosa cells after RF-EMF exposure by 1.8 GHz, SAR of 1.2 or 2 W/kg for 16 h. Similar results were obtained by Lai and Singh (2004, 2005), on exposed rat brain cells to 2.45 GHz, at SAR of 0.6-1.2 W/kg for 2 h. Pluder F. *et al.*, (2011), showed that low-dose radiation induced rapid and time-dependent changes in the cytoplasmic proteome of the human endothelial cell line, EA.hy926. Pathways influenced by the low-dose exposures included the Ran and RhoA pathways, fatty acid metabolism and stress response, similar to EMF impact studies.

Zhao TY. *et al.*, (2007), have investigated the effects of RF-EMF on gene expression of *in vitro* cultured rat neuron with Affymetrix Rat Neurobiology U34 array. Among 1200 candidate
genes, 24 up-regulated genes and 10 down-regulated genes were identified after 24-h intermittent exposure (5 min on/10 min off) at an average SAR of 2.0 W/kg, which are associated with multiple cellular functions. The changes of most of genes were successfully validated by real-time RT-PCR, including genes involved in cytoskeleton, signal transduction pathway, and metabolism. The results show that even relatively short-term exposure to cell phone radiofrequency emissions could up-regulate elements of apoptotic pathways in cells derived from the brain, and that neurons appeared to be more sensitive to this effect than astrocytes.

Beyond the frequencies used in cellular communication that changes were detected in the dermis of rats exposed to 35 GHz millimeter-waves in 56 genes at 6 h exposure and 58 genes at 24 h exposure at a power density of 750,000 mW/sq.m (Millenbaugh NJ. et al., 2008). Genes associated with regulation of transcription, protein folding, oxidative stress, immune response, and tissue matrix turnover were affected at both times. At 24 h, more genes related to extracellular matrix structure and chemokine activity were altered. Up-regulation of Hspa1a, Timp1, S100a9, Ccl2 and Angptl4 at 24 h by 35 GHz millimeter-wave exposure was confirmed by real-time RT-PCR.

The effects of RF-EMF on global gene and protein expression have been investigated in different biological systems, and most of the studies were focused on the mobile phone utilization frequency (800-2000 MHz) at relative low exposure density (average SAR near 2.0 W/kg). Some studies reported negative results of RF-EMF exposure on gene expression. Whitehead TD. et al., (2006), did not find differentially expressed genes in RF exposed C3H 10T(1/2) mouse cells. Remondini D. et al., (2006), reported that NB69 cells, T lymphocytes, and CHME5 cells did not show significant changes in gene expression after RF-EMF exposure. In another study, although several RF EMF-responsive candidate genes were screened out, they could not be confirmed by RT-PCR method (Gurisik E. et al., 2006). A study systematically explored the effects of 1800 MHz RF-EMF on protein expression in MCF-7 cells by 2-DE, and revealed that a few but different proteins were differentially expressed under different exposure conditions (Zeng Q. et al., 2006). Leszczynski group identified two RF-EMF responsive proteins in EA.hy926 cells, HSP27 and vimentin, with help of 2-DE and MS analysis (Leszczynski D. et al., 2002, 2004).

Tumour necrosis factor-alpha (TNF-alpha) is a cytokine involved in many functions, including the inflammatory response, immunity and apoptosis. Some of the responses of TNF-


alpha are mediated by caspase-1, which is involved in the production of the pro-inflammatory cytokines interleukin-1β, interleukin-18 and interleukin-33 (Jain N. et al., 2007). The response of a cell to RF-EMF exposure depends on exposure condition, cell type, genome and proteome (Nylund and Leszczynski, 2006). HSPs inhibit natural programmed cell death (apoptosis), whereby cells that should have committed suicide continue to live. Recent studies have shown that these HSPs inhibit apoptosis in cancer cells (Leszczynski, 2002).

Lixia X. et al., (2006), investigated the DNA damage, expression of heat shock protein 70 (Hsp70) and cell proliferation of human lens epithelial cells (hLEC) after exposure to the 1.8GHz radiofrequency field (RF) of a global system for mobile communications (GSM), at SAR of 1, 2 and 3 W/kg for 2 and 4 hours. RT-PCR was used to determine the expression of the gene after exposure. The results indicated that exposure to non-thermal dosages of RF for wireless communications can induce no or repairable DNA damage and the increased Hsp70 protein expression occurred without change in the cell proliferation rate. The non-thermal stress response of Hsp70 protein increase to RF exposure might be involved in protecting hLEC from DNA damage and maintaining the cellular capacity for proliferation. A short-term exposure (15 and 30 min) to RFR (900MHz) from a mobile phone caused a significant increase in DNA single-strand breaks in human hair root cells located around the ear which is used for the phone calls (Cam and Seyhan, 2012). Various in vitro studies have shown that 1800 MHz RF-EMF radiation could cause oxidative damage to mtDNA in primary cultured neurons. Oxidative damage to mtDNA may account for the neurotoxicity of RF radiation in the brain (Xu S. et al., 2010).

Metastasis by cancer cells relies upon the acquisition of the ability to evade cell death process elicited by detachment from extracellular matrix (ECM). Striking increases in reactive oxygen species (ROS) occurred in ECM-detached mammary epithelial cells, threatening cell viability by inhibiting ATP production, suggesting that ROS must be neutralized if cells are to survive ECM-detachment. Research by Davison CA et al., (2013), reported the discovery of a prominent role for antioxidant enzymes, including catalase (CAT) and superoxide dismutase (SOD), in facilitating the survival of breast cancer cells after ECM-detachment. Enhanced expression of antioxidant enzymes in nonmalignant mammary epithelial cells detached from ECM resulted in ATP elevation and survival in the luminal space of mammary acini. Conversely, silencing antioxidant enzyme expression in multiple breast cancer cell lines caused ATP reduction and compromised anchorage-independent growth. Notably, antioxidant enzyme-deficient cancer
cells were compromised in their ability to form tumors in mice. Hence, antioxidant enzyme activity maintained metabolic activity and anchorage-independent growth in breast cancer cells, implying that eliminating antioxidant enzyme activity may be an effective strategy to enhance susceptibility to cell death in cancer cells that may otherwise survive ECM-detachment.

Exposure to 900 MHz-modulated RF-EMF radiation affected both Egr-1 gene expression and cell regulatory functions, involving apoptosis inhibitors like Bcl-2 and surviving (Buttiglione M., 2007). Cellular stress response, observed in different cell models and with different exposures, might affect the expression of genes involved in cancer. Yu Y et al., (2008), indicated that mobile phone radiation induced an immediate effect in the cytoplasm that activated ERK signalling and that long exposures activated JNK. The appearance of p-ERK1/2 and p-JNK1/2, together with Hsp up-regulation, suggests that non-thermal RF exposure can induce the stress response in human lens epithelial cells.

2.4 MITIGATION

Hu S. et al., (2014), administered a polybotanical dietary supplement rich in antioxidants, Kang-fu-ling (KFL), orally once a day for 14 days to male Wistar rats, exposed to high-power microwave (3,00,000 mW/sq.m) for 15 minutes a day, to evaluate the potential protective effects of KFL on cognitive deficit induced by this exposure and the underlying mechanism for this neuroprotection. The electron spin resonance technique was employed to evaluate the free radical scavenging activity of KFL in vitro and KFL exhibited scavenging hydroxyl radical activity. KFL reversed HPM-induced memory loss and the histopathological changes in hippocampus of rats, displaying a protective effect against HPM-induced oxidative stress and activated the nuclear factor-E2-related factor 2 (Nrf2) and its target genes in the hippocampus of rats. It was concluded that the Nrf2-antioxidant response element (ARE) signaling pathway might be involved in the neuroprotective effects of KFL against HPM-induced oxidative stress and that the dietary supplement KFL, a promising natural complex. Al-Damegh MA et al., (2012), concluded from their research that the adverse effect of the generated electromagnetic frequency had a negative impact on testicular architecture and enzymatic activity and that vitamins C and E played a vital role in mitigating the oxidative stress imposed on the testes and restored normality to the testes. Salivary flow, total protein, albumin, and amylase activity were decreased due to the use of mobile phones, which caused oxidative stress and modified the salivary function. (Hamzany Y. et al.,
2012). Vitamin C improved the antioxidant enzyme activity and decreased MDA, brought about due to RF-EMF exposure (Jelodar G. et al., 2013).

2.5 FUTURE OF MOBILE TELEPHONY

According to veteran EMF researcher, Dr. Neil Cherry, New Zealand, a water-filled upright human is a sizeable antenna and since all moving electrons generate electrical current, all those electromagnetic waves inundating our everyday lives pass into our bodies, where they each generate an electric current. These induced electric currents change the charge on which our complex bioelectrical body/brain/heart network operates to maintain our health and vitality. Every RF-EMF transmission disrupts cells directly. Being a bioelectrical system, the human heart and brain is regulated by internal bioelectrical signals. According to the book, Internet of Things, more than 30 billion devices will be wirelessly connected to the internet by 2020. The Internet of Everything (IOE), also described as the Internet of Things or M2M is the concept of linking billions of devices from smartphones to heart rate monitors in a simple and effective way, which will drive many improvements for mankind. Bluetooth, Wi-Fi, ZigBee, Cellular, RFID, and many other wireless technologies are all important to drive Internet of Everything growth. The long-term expansion of this technology will depend on the wireless technology becoming invisible, so that the people will be oblivious to the technology and only know that it works!