CHAPTER V

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Apparent discrepancy exists between the theoretical explanations available, known effects on molecules and isolated components and the effects observed in complex biosystems (Gordon and Schwan 1973). To bridge the gap, proper understanding of interaction of microwaves with biological systems at various levels of organisation should be acquired.

The protein bound molecules would exhibit a different dielectric behaviour compared to the native molecules. The relaxation frequency of the native molecules would not be very much different from the values in aqueous environment, but the loss would be modified by inter molecules interactions. The various binding in hormones play an important physiological role, since it is the only unbound fraction which is freely exchangeable with the extra vascular and intra cellular compartments and has biological activity. Rabinovitz et. al (1973) observe that though the macroscopic dielectric properties of biological systems can be under-
stood in terms of the molecules, structure of water and the amount of free and bound water present in the system, the interaction of the field with functionally significant biomolecules will have negligible input into the dielectric constant but may have important functional implications.

In view of the foregoing comments, the parameters determined in the present study and the observation that the real permittivity is the source in the native and the solution form, (Aruna & Behari, 1983) may help in identifying the state of these molecules under physiological conditions and to ascertain the nature of interactions.

In the present study we have found that the dielectric parameters agree fairly well with those found by Ray and Behari (1986) and Grant et al (1968).

The results confirms that the existence of the dispersion are compatible with the suggestion that it is due to the rotation of bound water. However, it has been pointed out previously by Schwan (1957) that the polar side chains could also relax in this frequency region. Although at the beginning of this research it had been hoped that it would be possible to account unambiguously for the δ disper-
sion in molecular terms, this has not been proved to be the case. Measurements on very pure proteins of known structure will have to be carried out to illuminate the situation further, and future progress will also depend on some theoretical advancement being made on the question of the appropriate mixture formula.

It is found that the most practical important frequency range falls in between 300 MHz to 10 GHz. Besides their intended beneficial uses, they carry untoward side effect also. Ill effect from microwave exposure is reflected from the fact that exposure of the scrotal area results in varying degree of testicular damages such as edema, enlargement of testes, fibrosis, and coagulation necrosis of seminiferous tubules in rats, rabbits or dogs exposed to 300, 3450, 10,000 and 24,000 MHz at power density of 10 to 15 mw/cm²; 10 mw/cm² is the threshold for testicular damage for indefinite exposure. Although the condition of temporary sterility and damage to seminiferous tubules may occur, the condition is not permanent.

Studies have been performed on the effect of low level frequency fields on the development in mammals, where detrimental effect (Marino et al., 1976, 1980; Behari et
al., 1986; Mathur et al. 1988) or no effect was observed (Fam, 1980). Fertility and development studies were carried out to evaluate the effect of electric fields on multiple generation of swine. Significant increase in malformation incidence were observed in fetuses and offsprings from second generation (Sikov et al., 1987a, 1987b).

Interesting study of development and reproduction in rats chronically exposed to 60-Hz electric field was also performed by Rommerein et al. (1987, 1989) and Sikov et al. (1984). Two replicate experiments on rats were performed to investigate whether exposure to this frequency produce similar changes under comparable regime. Statistically significant decrease in the fertility was observed in case of exposed females and increase in the fraction of exposed litters with malformed fetuses.

Ralph et al., (1981) have studied the effect of chronic exposure of rats to 100 MHz (continuous wave) radio frequency radiation to assess the possible biological effects. Pregnant rats and later their offsprings were exposed daily for 4 hrs upto 97 days. Specific absorption rate (SAR) for rats of varying ages were determined to be
2.8 ± 1.5 W/g. Between exposures, animals were evaluated using various developmental and biological indices. No mutagenic effect on the sperm cells of rats exposed, was observed which means there was no change in the male reproductive function under these experimental conditions.

However, there are reports that exposure of male mice to non-ionizing electromagnetic radiation (NEMR) causes mutagenic effects (Varma and Traboulay, 1976; Sarkar et al., 1994) leading to decrease in fertility. Microwave radiation has produced somatic mutations (Chromosome aberrations) in persons who have been occupationally exposed (Garaj-Vrhovac et al., 1987). It was also found in a study on human volunteers that exposure of testis to 2.45 GHz for 30 min once a month reduced sperm count leading to dyspermatogenic sterility (Frang et al., 1982). Effects on reproduction (Lu et al., 1987) in rats after low level microwave exposure have been reported. Spermatocytes are most sensitive to microwave radiation followed by spermatids, spermatogonia, stem cells and interstitial cells (Lebovitz et al., 1987).

The effects of microwaves on the testis is indicated in several studies (Varma and Traboulay, 1976; Michaelson 1970). Advance knowledge of mammalian spermatogenesis
during recent years have arisen from the patient use of quantitative methods of histologic analysis. Histological studies in the field of antifertility have provided important contribution. Investigations have been concentrated on spermatogenesis in rodents especially in the rat and mouse.

In the present study adult male rats were exposed to 200 MHz radio frequency radiation, amplitude modulated at 16 Hz (power density = 1.47 mW/cm², specific absorption rate = 2.24 W/kg). After four weeks of exposure (2 hrs a day) the rats were mated with normal female rats. Significant decrease in fertility was observed in case of exposed rats as compared to the control ones. This may be attributed to disrupted spermatogenesis due to exposure to RF fields. Ultrastructural observations of seminiferous tubules, leydig cells and spermatids, revealed defects responsible for producing infertility.

The biological effect for testes must be considered from three aspects : 1) Effect on mature sperm stored, 2) Effect of developing spermatogonia, 3) Effect on Interstitial Leydig cells which are responsible for the
secretion of androgenic hormone. Thus a realistic safety standards for human tolerance of microwave radiation requires a more thorough analysis of the interaction of electromagnetic fields with human body.

The study on the interaction of the electro-magnetic field with biological body includes quantification of electromagnetic field inside arbitrarily shaped biological body, maximum and total power deposition inside it, electromagnetic field scattered by the system as well as the electromagnetic probing of the simulated biological system during the exposure. Since the biological body, is heterogeneous and irregularly shaped and its permittivity and conductivity is frequency dependent, the distribution as well as scattering of electromagnetic field depends on physiological parameters, geometry, frequency and polarization of the incident electromagnetic field. The tensor integral equation provides a link between the known incident field and the unknown total induced field. A numerical technique - moment method with Pulse function expansion of the unknown electric field transforms the tensor equations into simultaneous equations that is solved by numerical techniques for different locations of the body.
It is observed that the patterns of the dissipated power are quite complicated function of location. It is also seen that field induced at one location may be quite different than the field induced in similar body at the same location but of higher dimension as seen in the brain part of head model and the brain model separately. The tensor integral equation is applied to quantity the induced electric field and absorbed power density inside head model of man and breast tissue.

The size of the human body also determines the induced field inside the body at a given frequency. For a child's torso, strongest field is induced at 120 MHz for the torso height about 0.408. (Bhag Singh Guru; 1976). The highest rate of energy deposition in the head occurs at a frequency when head diameter is approximately one quarter of free space wavelength. At head resonance, the absorption cross-section is approximately three times the physical cross-section. The volume average SAR is 3.3 times the whole body average SAR. Enhanced absorption in the head resonant frequency may be important for the behavioural effect, blood brain barrier permeability, cataractogenesis etc. For
resonant biological bodies close to each other antenna theorem may predict the modification of SAR value relative to that of free space.

In conclusion, it should be emphasized that more sophisticated conceptual approaches and more rigorous experimental device using sound biomedical and biophysical approaches at various organisational levels must be developed. The results may modify the present day safety standard and will identify frequencies also where exposure limit should be higher or lower than the specified value.