ENERGY DEPOSITION IN BIOLOGICAL TISSUE NEAR PORTABLE RADIO TRANSMITTERS AT VHF AND UHF

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I. SUMMARY

This paper presents the results of measurements of temperature increase, due to RF energy deposition, in simulated biological tissue near 6 W portable transmitters with helical and whip antennas. At close distances (< .5″) VHF helices deposit energy in the surface fatty layers, with practically no penetration into muscle tissue; 450 MHz helical antennas transfer energy mostly into the surface fat, with the penetration into deep tissue increasing by a factor of 10 from 150 MHz. UHF quarter-wavelength whips deposit power mostly in the muscle tissue. At larger distances (> 2.″), the detected temperature increases are extremely small, indicating that portable radios are safe.

II. INTRODUCTION

In recent years, there has been increasing concern about human exposure to RF power. A thorough investigation, both experimental and theoretical, of energy penetration in human tissue has been performed for plane incident or essentially TE waves[1-2]. Only a limited amount of research[3-4] has been done on the penetration of RF energy in human tissue placed in the immediate vicinity of the sources, where the EM fields have a more involved structure than a plane wave. In the region close to the radiators, where power concentration can be rather high, it is very difficult to perform a meaningful measurement of incident power density not only because of the non-simple relation between E and H vectors, but because real power flow may not be established by the fields so near to the sources. Power deposition in this region has not been thoroughly investigated, although it is most significant in determining the safety of portable transmitters, especially at UHF and lower frequencies.

The advances in solid state technology have made available higher power transmitters in portable radios. This fact, coupled with the increased awareness of RF hazards in consumer products, has stimulated the interest in the energy deposition near portable transmitters.

If commercially available field probes (e.g. Narda) are used in evaluating power densities near the radio, one can read values that are above 100 mW/cm². However, if the measured values of power density are integrated over a surface inclosing the radio, the total power radiated thus determined is much higher, in some cases an order of magnitude greater than the power available at the battery. These discrepancies have prompted a research project, at Motorola, to determine the effective RF power penetration in a portable radio operator and thus correlate field probe readings with RF power deposition. Some results of this research project are presented herein.

III. EXPERIMENTAL METHOD

Simulated human tissue ("phantoms" or "dummies") has been used throughout the experiments to determine RF power penetration near portable transmitters. The energy deposition has been evaluated through temperature measurements. Although implantable high sensitivity thermal probes have been devised and used in similar projects[5], these instruments are not yet commercially available. The commercial products (e.g. LCT-1 Temperature Measuring System, RAMAL, Inc.) are too bulky or lack sensitivity. It was decided to use thermocouple probes and a .01° sensitivity digital thermometer (Bailey Instruments, BAT-8). Parallelepipedal and human head-shaped phantoms have been built for VHF and UHF tissue simulation. The VHF phantoms have already been described in a previous paper[6]. The UHF "dummies" have the same geometry as the VHF phantoms, the only difference being the mixture composition. At UHF, muscle and bone tissues have been simulated by using the materials recommended by Guy[7].

The details of the data gathering technique have already been given[6] and will not be repeated here. From the temperature measurements, if the exposure time is known, it is possible to determine the power deposition by equating the thermal energy aborbed by the "dummy" with the penetrating RF energy, this being the only cause of the temperature increase[9]. Given the high dielectric constant of the biological tissue, it is correct to assume that, whatever is the direction of incidence of the RF energy, power penetrates along the normal to the surface at the point of incidence. These assumptions have been used in generating the penetrating power density diagrams shown in this paper. The method is essenially correct for short time exposures, so that heat exchange does not substantialy alter the temperature gradients set up by the EM fields.

in this version (pps. 1-5 + 31 Figs)