19BME308 - Medical Radiation Safety

UNIT I - INTRODUCTION TO RF AND MICROWAVE RADIATION

1.4 Calculation of RF Field Quantities

Limb currents

Up to about 100 MHz, theoretical consideration of currents induced in the human body and especially the limbs, has given rise to some concern. As a result, research has been carried out to ascertain the magnitude of RF currents induced in the human body. It has been established that currents in the legs of an adult in an RF field may give rise to large SAR values at places where the effective conductive cross-sectional areas are small. Hence, the current density will be much larger than that implied by consideration of the actual cross-sectional area at that place. The knee and the ankle are examples of such areas, and some attention has therefore been given to SAR values associated with them, particularly the ankle.

An approximate formula (valid up to about 27 MHz) for the current in the leg of an erect barefoot person where the electric field is vertical is given as:

$$I\ (\text{mA}) = 0.108 \times h^2 \times f \times E$$

Where:
h = subject height (m)
f = frequency (MHz)
E = electric field (Vm^{-1})

Example:
For a field $E = 60\,Vm^{-1}$; $f = 1\,MHz$; $h = 1.75\,m$:

$$I\ (\text{mA}) = (0.108 \times (1.75)^2 \times 1) \times 60$$
$$= 19.85\ \text{mA}.$$

Above 27 MHz, the measured currents peaked around 40 MHz, reflecting resonance of the subject. An empirical expression for current above 27MHz which includes an element representing the resonance frequency of the 'standard man', gives a sine wave shape for I/E versus frequency.

Explanation of terms used:

Power

The rate of doing work in joules per second. The unit is the watt (W) which corresponds to 1 Js^{-1}. Sources of RF energy are rated in watts. Both the kilowatt (kW) and the megawatt (MW) are common in radio work, the latter typically for very high power equipment such as radar equipment.

Mean power

The r.m.s. power supplied or generated averaged over a period of time which is long compared with the longest period of any modulation component.

Power flux density (power density)

Power flow per unit area through a surface normal to the direction of that flow, usually expressed in watt per square metre (Wm^{-2}). However it is also often quoted in $mWcm^{-2}$.

Energy density

This is, strictly, related to volume (Jm^{-3}) but is almost universally used in radiation protection work as the product of power density and time and expressed either in units of watt-hour per square metre (Whm^{-2}) or joule per square metre (Jm^{-2}). 1 J = 1 Ws. It is sometimes used to express a total energy limit, for example, 'not more than 5Whm^{-2} in a six minute period'.

Electric field strength (E) at a point

A vector quantity defined as the force acting on a unit positive charge at that point. It is expressed in volt per metre.

Magnetic field strength (H) at a point

A vector quantity defined as the force acting on an isolated north pole at that point. It is expressed in ampere per metre.

Specific absorption rate (SAR)

The rate of absorption of RF energy in a substance, normally human tissue, expressed in watt per unit mass, e.g. watt per kilogram. If the substance is not human tissue, it should be specified. Note that a SAR limit may be expressed in this standard form but be limited to a maximum mass of tissue e.g. $10Wkg^{-1}$ (10 g) should be interpreted as an SAR of $10Wkg^{-1}$ in any 10 gram of tissue.

Frequency

The number of cycles of an alternating current per unit time where the international period is one second. The unit is the hertz. 1 Hz = 1 cycle per second.

Pulse repetition frequency (p.r.f.)

In a system which uses recurrent pulses, the number of pulses occurring per unit time. The unit is the hertz (Hz).

Peak pulse power density

In pulsed systems such as radar equipment the term 'peak pulse power' is used when what is actually meant is the r.m.s. power in the pulse

Reference: *Ronald Kitchen - RF and Microwave radiation safety handbook.*