ON THE ACCURACY OF DOSIMETRY IN UHF THERAPY

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Objective dosimetry in uhf therapy requires the knowledge of the high-frequency power* absorbed in the patient's tissue. In practice, however, only the uhf generator output power lends itself to direct measurement.

To measure this power we have designed a high-frequency wattmeter connected into a grounded intermediate loop in the uhf generator output stage [2]. A simplified circuit diagram of the uhf generator output stage including this wattmeter is shown in Fig. 1. Obviously, the power \( P_{\text{mea}} \) measured by the wattmeter differs from the power \( P_L \) absorbed in the patient's body by the magnitude of resistive loss \( P_{\text{los}} \) in the circuit between the wattmeter (2) and patient (8), i.e., \( P_L = P_{\text{mea}} - P_{\text{los}} \) or \( P_L = \eta P_{\text{mea}} \), where \( \eta \) is the efficiency of the circuit to the right of the wattmeter (see Fig. 1). The efficiency \( \eta \) depends both on the design and components of the tuned circuit and on the conditions of treatment (i.e., the electrode area, the gap width, the region being treated, etc.). Thus, to evaluate the error in \( P_L \) due to different conditions of treatment we must know the range of variation of \( \eta \).

If the wattmeter was calibrated with an equivalent (dummy) load under conditions of maximum output tuned circuit efficiency \( \eta = \eta_{\text{max}} \), the relative error in load power measured under conditions of minimum efficiency is given by

\[
\delta_{\text{max}} = \frac{\eta_{\text{max}} - \eta_{\text{min}}}{\eta_{\text{min}}}
\]

As an example, Fig. 2 shows \( \delta = (P_{\text{mea}} - P_L)/P_L \) as a function of the gap measured with the above wattmeter using a "Ekran-1" uhf power generator and different electrodes (the equivalent load was a photometer designed by the All-Union Scientific-Research Institute of Medical Instrument Design). The wattmeter was calibrated with minimum gap widths (5 mm on each side) and using large electrodes (170 mm diameter); this corresponds to maximum tuned circuit efficiency. The curves indicate that \( \delta \) is significantly affected by the conditions of treatment.

In this article we discuss the nonproductive power losses that are responsible for such a dependence.

All power losses in the circuit between the wattmeter and patient can be divided into three groups: 1) resistive losses in the coil wires and feeder leads, 2) dielectric losses in insulators, and 3) radiation losses.

For a quantitative evaluation of all these losses we must find the equivalent impedances of the load \( Z_L \). An experimental determination of \( Z_L \) [3] proved that the impe-

*For the sake of brevity we shall use the term "power" meaning in fact high-frequency power.
Fig. 2. Relative error $\delta = (P_{\text{mea}} - P_L)/P_L$ as a function of gap for electrodes of different diameters.

Fig. 3. Equivalent output circuit (a) and equivalent wattmeter load.

dances vary between $Z'_L = (20-j1200) \, \Omega$ (corresponding to the irradiation of the forearm by electrodes 55 mm in diameter spaced 30 mm from each side) and $Z'^n = (15-j70) \, \Omega$ (corresponding to transversal irradiation of the chest by 170 mm electrodes spaced 5 mm from each side). The impedances as seen from the feeder input (i.e., at the points a, b in Fig. 1) are respectively

$$Z'_{Lo} = r_{Lo} - jX_{Lo} = (3 - j150) \, \Omega \text{ and } Z_{Lo} = r_{Lo} - jX_{Lo} = (25 + j450) \, \Omega.$$

**Resistive Losses in Coil Wires and Feeder Conductor**

Figure 3a shows a typical simplified equivalent output circuit of a uhf power generator for uhf irradiation (neglecting the dielectric and radiation losses). The efficiency of such a circuit is given by

$$\eta_c = \frac{r_{Lo}}{r_{Lo} + 2r_c},$$

where $r_c$ is the resistance of the coil.

Let us evaluate practical values of $\eta_c$. In the UVCh–4 instrument the coil inductance is $L_C \approx 0.9 \mu H$ with $Q \approx 300$. With an operating frequency $f = 40.68 \, \text{MHz}$,

$$r_c = \frac{\omega L_C}{Q} \approx 0.75 \, \Omega$$

Whence

$$\eta_{\text{min}} = \frac{r_{Lo}}{r_{Lo} + 2r_c} = 0.65,$$

$$\eta_{\text{max}} = \frac{r_{Lo}}{r_{Lo} + 2r_c} \approx 0.95.$$

The corresponding maximum relative error due to changes in $\eta$ is

$$\delta_{\text{max}} = 45\%.$$

In order to evaluate the effect of the loss in the intermediate loop coil $L_{\text{int}}$ on $\eta$, consider the equivalent circuit to the right of the wattmeter (Fig. 3b). It is found that with the output circuit tuned for maximum output power the resistance reflected into the intermediate loop is of the order of tens of hundreds of ohms. At the same time the dc-resistance of this coil $r_{\text{int}} < 1$, i.e., $r_{\text{int}} > r_{\text{ref}}$. It is thus evident that the effect of coil resistance on $\eta$ can be neglected.

Resistive losses in the feeder wires depend on the feeder attenuation factor, length, and reflection coefficient. Calculations indicate that even with large reflection coefficients, the resistive loss in feeders used with medical uhf equipment is less than 2% of the load power, so that its effect on $\eta$ is practically nil.