A BROADBAND AND COMPACT APPLICATOR FOR DEEP TISSUE HEATING USING FOCUSED MICROWAVES

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ABSTRACT

An important need in the study of hyperthermia methods in cancer therapy is a focused microwave system that will deliver adequate energy to deep-seated tumors without overheating the intervening normal tissue. This paper describes the design of a broadband (150 MHz to 1100 MHz) microwave applicator that is useful in this regard both as a single applicator and as a radiating element in a focused microwave system.

A broadband applicator is desirable not only to achieve heating at different depths but also to examine the optimum conditions for focusing the microwave radiation. The design procedure utilizes a tapered section of double-ridged waveguide as a broadband feed for a horn section. The waveguide ridges were extended logarithmically up to the aperture of the horn section. This procedure simply allows a smooth and broadband impedance transition between the 50-ohm coaxial input impedance and the 377-ohm free-space impedance. The measured VSWR values at selected frequencies in the operating frequency band were found to be less than 2.0. The double-ridged horn applicator was then filled with a circulating low-loss liquid (formamide, $\varepsilon_r' = 109$) to achieve both scaling the operating frequency band down by a factor of $1/\sqrt{\varepsilon_r}$ and cooling the surface of the overlaying tissue. Experimental results describing the measured VSWR, gain, beam width, and heating pattern of the horn as a function of frequency will be presented. This broadband applicator will also be used as a building block in a larger system for focused microwave heating of deep tissue.

SUMMARY

In spite of the many undesirable characteristics of electromagnetic shortwave diathermy [1], it is still widely used in clinical trials since it is a simple way to achieve the desired deep-tissue heating. Microwave diathermy, on the other hand, although it provides more controlled radiation and hence more controlled heating patterns, is considerably limited by a smaller depth of penetration, particularly at the higher frequencies. The use of higher frequencies is often desirable since the applicators are smaller.

Due to the ever-increasing desire to achieve a controlled heating pattern in deep tissue, attention has been turned to producing focused microwave heating. The main motivation towards the focused radiation is not only to deliver adequate energy to deep-seated tumors without overheating the invervening normal tissue, but also to be able to treat tumors even in the absence of differential heating in the tissue. To examine the optimum conditions for focused microwave radiation, it is necessary to operate over a relatively wide frequency range. This will allow controlling and experimentally optimizing parameters such as the depth of penetration, energy enhancement at the focus, and the size of the focal spot.

In this paper, we describe a broadband microwave applicator suitable for use as a single applicator and as a radiating element in the focused microwave system. Figure 1 shows the broadband applicator schematically. In consists of a short section of double-ridged waveguide used as a broadband feed for a horn section. The waveguide ridges were extended logarithmically up to the aperture of the horn section. The ridges were fabricated from a 0.375" thick aluminum plate and are spaced so that the distance between them increases logarithmically from 0.050" at the waveguide-horn junction to 5.2" at the aperture plane of the horn. The aperture cross-sectional dimensions are 5.2 x 7.2 square inches. The performance of the applicator was checked by measuring the VSWR over the frequency band from 1.0 GHz to 12.0 GHz. Typical measured VSWR values are given in Table 1, from which it is clear that small reflections can be achieved over the frequency band from 1.5 GHz to 11.0 GHz.

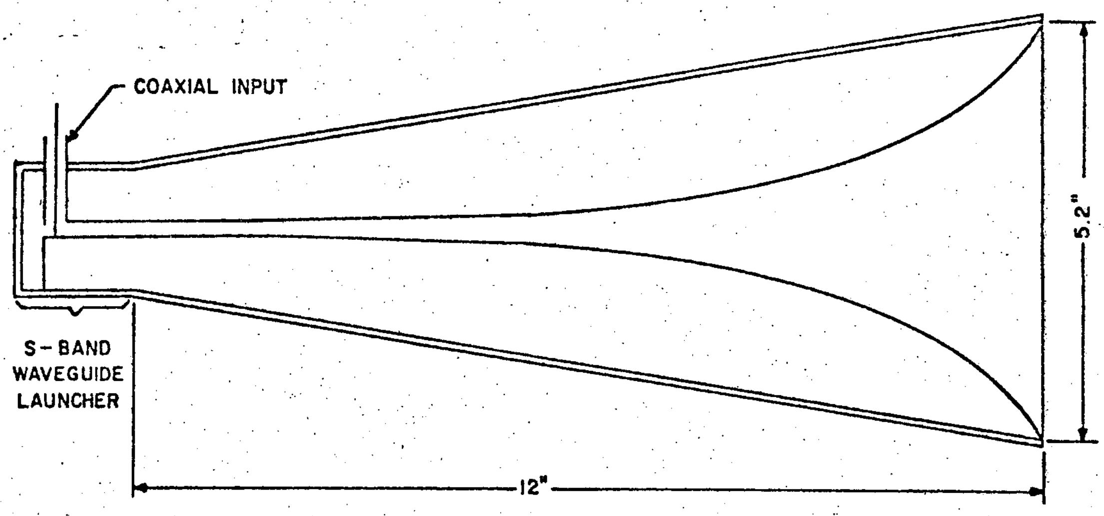

Fig. 1. The double-ridged, broadband applicator.

Table 1. Measured VSWR values as a function of frequency.

Frequency GHz	1.0	1.5	1.9	2.0	2-10	10.0	18.5	11.0	11.2	11.5	12.0
VSWR	4.8	2.15	1.6	1.28	Less than 2.0	1.28	1.4	1.19	1.85	3.2	4.0

The double-ridged applicator was then filled with a low-loss liquid (formamide $\varepsilon_r' = 109$). The dielectric loading was used to scale the operating frequency band down by a factor of $1/\sqrt{\varepsilon_r}$, namely between 150 MHz and 1.1 GHz. This liquid was also forced to circulate in a cooling system to help in cooling the surface of the overlaying tissue.

Experimental results of the measured VSWR values and heating pattern of the dielectrically loaded applicator will be presented. Results for the energy enhancement achieved by focusing the radiation from two applicators will also be presented as a function of frequency.

Reference

1. A. W. Guy, J. F. Lehmann, and J. F. Stonebridge, "Therapeutic Applications of Electromagnetic Power", *Proceedings of the IEEE*, Vol. 22, 1974, pp. 55-75.