MULTI-MICROSTRIP APPLICATOR FOR HEATING AND TEMPERATURE MEASUREMENT

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ABSTRACT: A new applicator using multi-microstrip antenna for hyperthermia is proposed and developed. The applicator has two different functions as a heating applicator and as a coupled microstrip applicator for the temperature estimation inside the body noinvasively. In case of heating, an array applicator can heat deep region with surface cooling. In case of temperature measurement, the applicator detects the change of the transmission coefficient of electric field 0.78 dB/°C. Furthermore the depth of discontinuity (which is assumed to be the position of temperature change position) is assumed by simple geometrical investigation.

I. INTRODUCTION

For microwave hyperthermia treatment of cancer, the development of noninvasive temperature measurement techniques for human tissues inside the body are strongly demanded [1].

Microstrip antenna may design small and light in weight for the applicator to apply hyperthermia in the microwave frequencies.

This paper describes the study of a multi-microstrip applicator not only as a heating applicator but also as a detector of an information about temperature and position of the discontinuity in the human body, noinvasively.

II. MULTI-MICROSTRIP APPLICATOR

The applicator consists of three elements. In case of heating, each element performs as a transmitter. When it is used for the detector of the temperature change inside the human body, one element performs as a transmitter and the other performs as a receiver. The general view of the element is shown in Fig. 1. The design of the element is based on the microstrip antenna theory. As is shown in Fig. 1, it consists of a slight rectangular strip radiator and a ground plane. A ground plane is semi-cylindrical plate. The surface of the applicator is covered with a thin silicone rubber sheet. The space between surface sheet and a ground plane is filled with water as a dielectric substrate which is shown in Fig. 2 [2].

Because of the existence of water as dielectric substrate, the following advantages are expected. The wave length is reduced and an element is designed smaller,and the applicator is expected to have surface cooling function when it is used as a heating applicator. And the applicator is expected to have better impedance matching with a human body. Moreover the temperature elevation of the dielectric material can be neglected by the flowing water of which temperature keeps at a constant, therefore the property of the element as microstrip antenna is very stable when power is loaded. As mentioned above, this applicator is designed contacting with surface of human body directly without bolus. The element is very compact and the contact surface consists of soft rubber. Therefore the applicator is fit to the uneven surface like of human body.

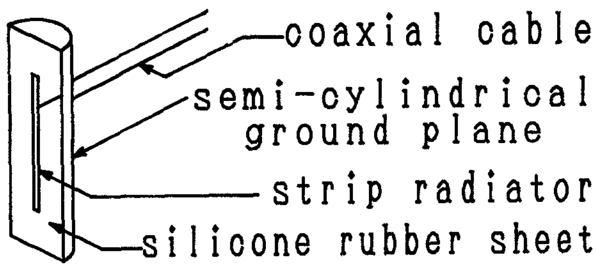

Fig. 1. Element of multi-microstrip applicator.

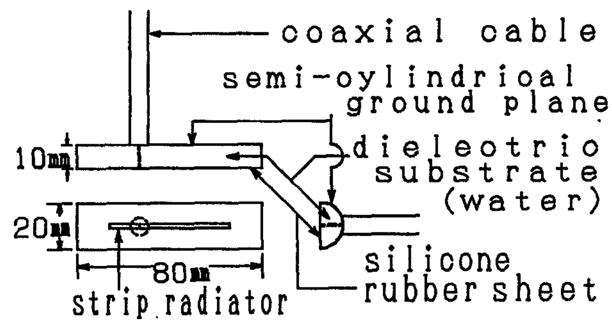

Fig. 2. Dimension of element.

The dimension of the strip radiator is a half wave length considering effective dielectric constant. A feed-point is located at a fourth length from the end of the strip radiator. Figure 3 shows the reflection coefficient vs. frequency of an element. The reflection coefficient of the applicator is minimum at 430 MHz.

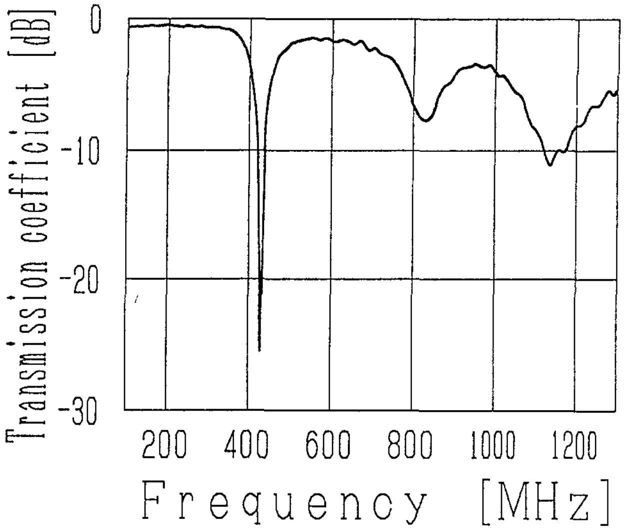

Fig. 3. Reflection coefficient vs. frequency.

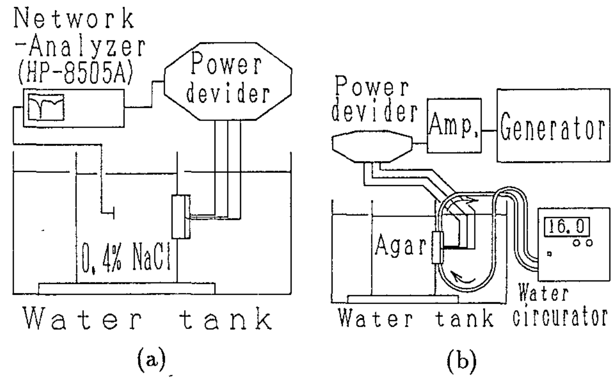

Fig. 6. (a) Experimental system of electric field measurement.
(b) Experimental system of heating experiment.

The general view of the experimental set up as a multi-microstrip applicator is shown in Fig. 4.

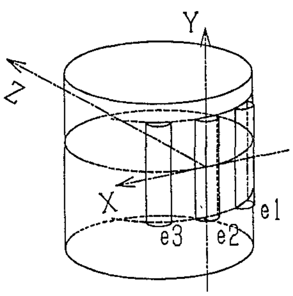

Fig. 4. Set-up as multi-microstrip applicator.

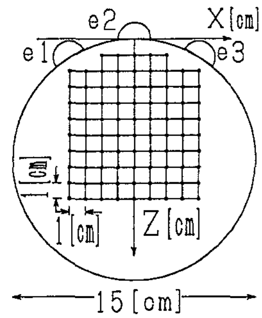

Fig. 5. Set-up of electric field measurement.

III. EXPERIMENT

The experiment of the applicator was performed as a heating applicator and as a detector for the temperature.

[A] HEATING APPLICATOR

The experimental set up is shown in Fig. 5, three elements are fit on the surface of the cylinder as the array microstrip applicator. The diameter of the cylinder is 15 cm.

In the measurement of electric field distribution, it is filled with 0.4 % saline solution, which has an equivalent dielectric constant to the human muscle. The electric field distribution is measured by Network-Analyzer (HP-8505A) on the cross point of the mesh shown in Fig. 5. The experiment has two cases. One case, the applicator radiates electric field in phase, the other case, the applicator radiates electric field out of phase. In the latter case, phase lag is realized by stretching the coaxial cable. The experimental system is shown in Fig. 6(a).

Heating experiment was performed using phantom modeling material consists of 4 % agar, 0.35 % NaCl, 0.05 % NaN_3 and 95.6 % deionized water which has an equivalent dielectric constant to the muscle. Cooling water flows the space enclosed by semi-cylindrical ground plane and surface silicone rubber sheet. The experimental system is shown in Fig. 6(b).

[B] TEMPERATURE MEASUREMENT APPLICATOR

In the case shown in Fig. 7, the element [el] and [e3] are used as coupled microstrip applicator. The element [el] is used as transmitter and [e3] is used as receiver. The microwave comes directly from the applicator and reflected from the boundary affects the transmission coefficient of the coupled microstrip. Because dielectric constant is changed by the temperature, the reflection coefficient is changed by the change of the measured medium. Therefore the transmission coefficient of microwave is changed. Figure 7 shows that the inner cylinder filled with 0.4 % NaCl solution (as equivalent dielectric constant of muscle) synmetrically sets off-axis in outer cylinder.

The experimental system is shown in Fig. 8. The temperature of the 0.4 % saline solution is changed by water circulator and temperature is measured by thermocouple. And the change of the peak transmission coefficient of the electric field is measured by network analyzer (HP-8505A).

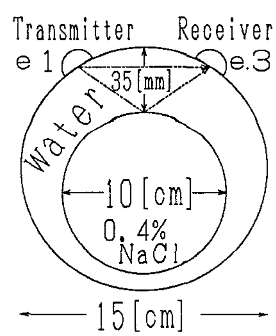

Fig. 7. Set-up of temperature measurement.

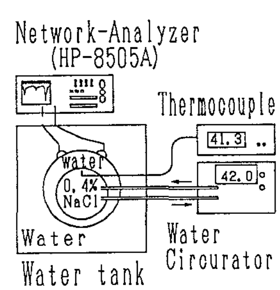

Fig. 8. Experimental system of temperature measurement.

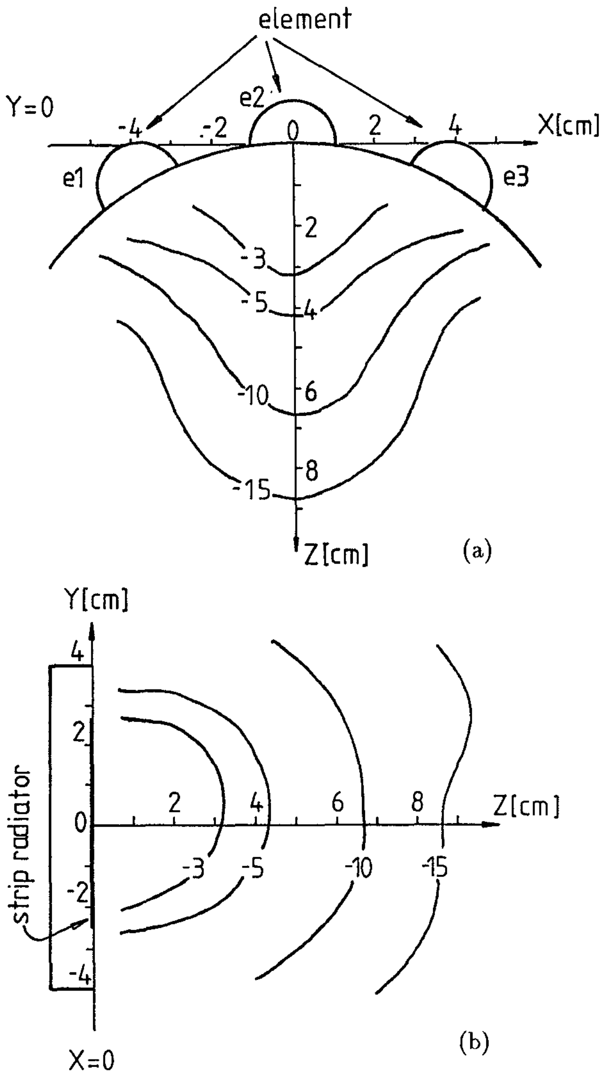

Fig. 9. Electric field distribution in the human tissue model of 0.4 % NaCl solution. (unit; dB)
(a) X-Z plane (b) Y-Z plane

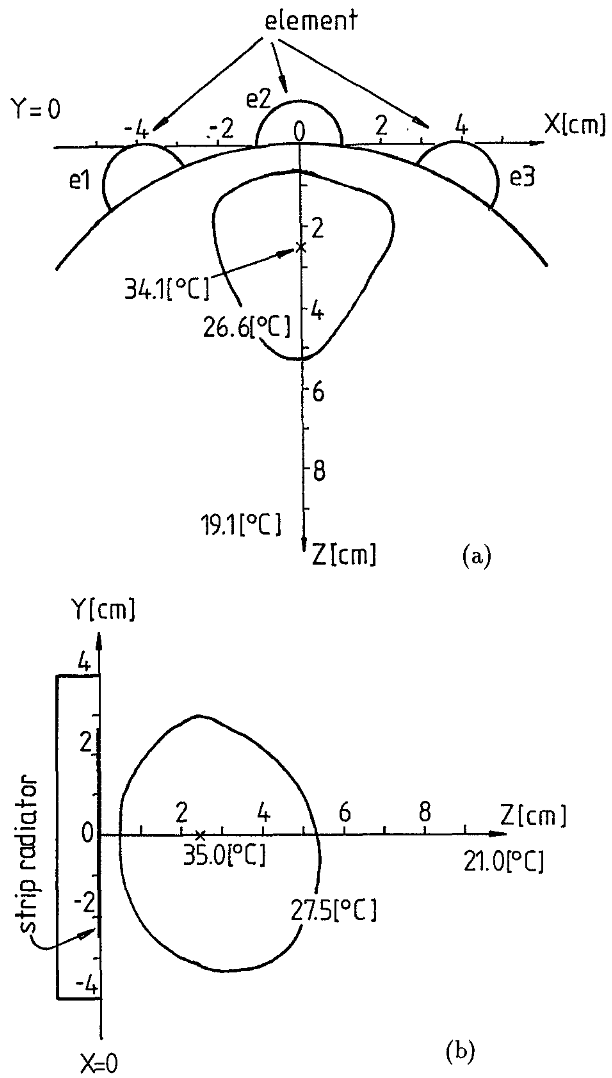

Fig. 10. Temperature distribution in the simulated human model.
(a) X-Z plane (b) Y-Z plane

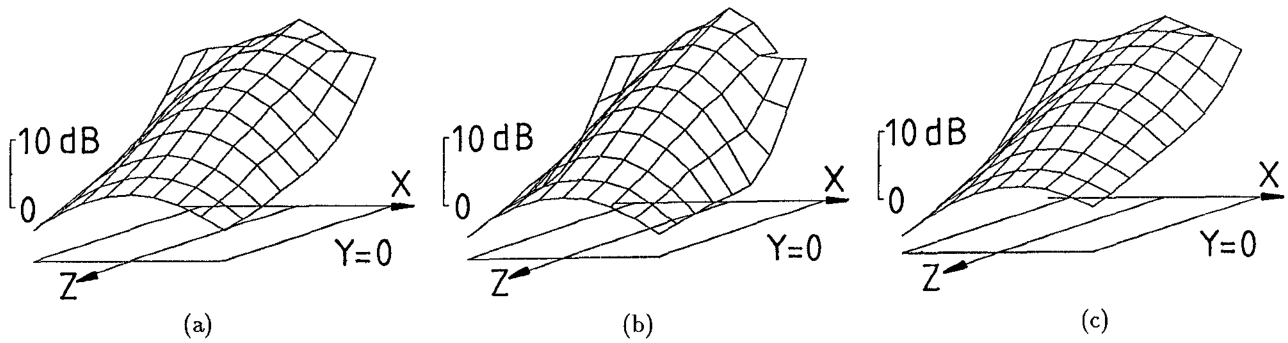

Fig. 11. Electric field distribution in case of phase controlled.
(a) in phase (b) give a phase lag to [e2]
(c) give a phase lag to [e3]

The heat capacity of water tank is large enough, therefore we can neglect the temperature elevation of the water in the tank.

IV. EXPERIMENTAL RESULTS

Figure 9(a) shows the electric field distribution of X-Z plane and Fig. 9(b) shows that of Y-Z plane. In these cases, all elements are in phase.

The result of the heating experiment as temperature distribution is shown in Fig. 10(a), (b) corresponding to Fig. 9(a), (b). The input power is 150 W, therefore each element is loaded 50 W. The operating time is 5 minutes. The temperature of cooling water is 16 °C.

The result of experiment adding phase lag or not is shown in Fig. 11.

Figure 12 shows the case that the space between the inner cylinder and the outer cylinder is 35 mm. In this case, the space between strip radiator of the element [e1] and that of [e3] is 76 mm. The spectrum of transmission coefficient has peak at 1043 MHz. At this frequency, the transmission coefficient is so unstable that we describes the fluctuation by using symbols [I] in Fig. 12.

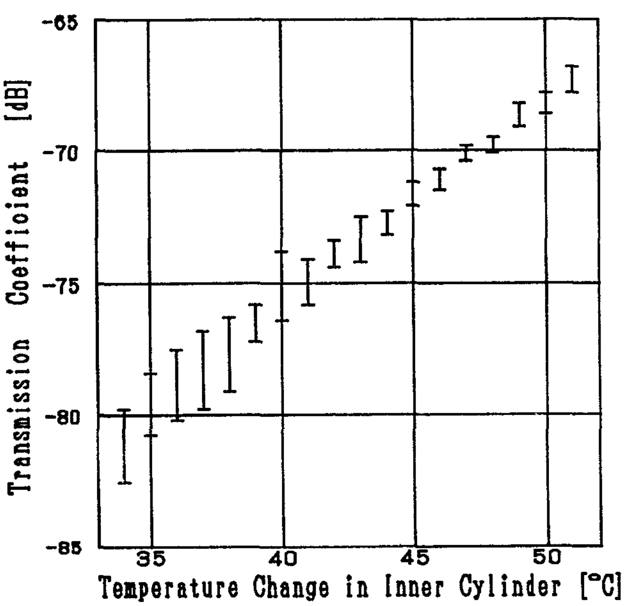

Fig. 12. Transmission coefficient of electric field vs. temperature of muscle model when distance is 35 [mm], f = 1043 [MHz].

V. CONCLUSIONS

A compact, light applicator has designed. The applicator can be used both for heating and for temperature measurement. In the case of heating applicator, it performs as array microstrip applicator. In the case of temperature measurement, it performs as coupled microstrip applicator. The applicator is directly contacted to the human body surface therefore it can fit on the complex configuration of human body and can avoid the over-heat of the human body surface. It is directly contacted to the human body surface. The surface cooling effect is resulted from cooling water flowing the space enclosed by semi-cylindrical ground plane and surface silicone rubber sheet.

When using as array applicator, the measurement of the electric field distribution from the applicator, and the temperature distribution of the heating experiment show that the effective heating depth of 52 mm and effective heating width of 45 mm can be realized.

The different electric field distribution is obtained by phase controlling, stretching cable respectively. From this result, this applicator performs as phased array.

When using as coupled microstrip applicator, the temperature change of 0.4 % NaCl solution simulated human tissues (muscle medium) which is away from the applicator can be detected by the change of the transmission coefficient of electric field using multi-microstrip applicator. In this experiment, the relation between temperature and transmission coefficient is 0.78 dB/°C.

By calculating wavelength, the distance from surface to discontinuity is assumed by geometrical investigation. In this experiment, the distance of setting is 35 mm and calculated value is 36.1 mm. From this result, this applicator can be applied to monitoring the hot spot at the boundary.

This applicator can be used two different purposes both heating and temperature estimation only switching electrically not changing the setting.

REFERENCES

[1] D. Kobayashi, Y.Nikawa, F.Okada and S.Mori, "Coupled Microstrip Applicator for Hyperthermia Applications", IEEE AP-S , vol.1 pp.532-535 ,1989

[2] J.R. James, P.S. Hall and C. Wood, "Microstrip Antenna Theory and Design," IEE Electromagnetic Waves, vol.12, 1981.