journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group. – 2015. – N 31 (7).
2. Curto Sergio. Design of a compact antenna with flared groundplane for a wearable breast hyperthermia system. [J] / Curto Sergio, Prakash Punit // International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group. – 2015. – N 31 (7).
3. Design of hybrid miniaturized waveguide hyperthermia antenna. [J/OL] / Wang Ting [et al.] // Microwave Journal. – 2023. – N 04-01. – P. 1–7.
4. Design of Ultra-Wideband Phased Array Applicator for Breast Cancer Hyperthermia Therapy. [J] / Lyu Cheng [et al.] // Sensors. – 2023. – N 23 (3).
5. Wang Yanyang. Conformal array antenna design for breast cancer microwave hyperthermia. [D] / Yanyang Wang. – Inner Mongolia University of Science and Technology, 2019.
6. Çelik Ömer Faruk. Compact triple-band implantable antenna for multitasking medical devices. [J] / Çelik Ömer Faruk, Başaran Sıddık Cumhur // Journal of Electrical Engineering. – 2022. – N 73 (3).
7. Sleeve dome antenna design for interventional hyperthermia. [J] / Du Yongxing [et al.] // Space medicine and medical engineering. – 2008. – N 21 (06). – P. 529–532.
8. A miniaturized external-sleeve microstrip circular patch microwave hyperthermia antenna. [J] / Gao Jiaxing [et al.] // Microwave Journal. – 2022. – N 38 (02). – P. 38–43.

DESIGN OF MICROWAVE DIAGNOSIS AND TREATMENT INTEGRATED REAL-TIME DETECTION SYSTEM

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This project designs an integrated real-time detection system for microwave diagnosis and treatment. Non-invasive temperature estimation using microwave conformal array antenna and Nakagami distributed temperature calculation based on BP neural network can effectively assist doctors in better treatment of breast cancer patients.

Keywords: microwave ablation, Nakagam idistribution, ultrasonic noninvasive temperature monitoring, Thermal antenna, Breast cancer.

Introduction. In the treatment of cancer, microwave hyperthermia has been proved to be effective in making up for the deficiency of simple surgery, chemotherapy and radiotherapy, and can effectively improve the cure rate and remission rate of malignant tumors [1]. The microwave conformable array antenna is used to radiate the tumor area, and the data is collected through the ultrasonic data acquisition system. The collected data is transmitted to the server, and the temperature measurement algorithm is used to visualize the ablation area and predict the temperature, so as to assist doctors in better treatment [2]. The purpose of this project is to solve the problem that the location of microwave thermal field is not controllable, and the real-time visualization of the hyperthermia area and non-invasive temperature monitoring can not be carried out while microwave hyperthermia.

Research Content. An integrated real-time detection system for microwave diagnosis and treatment is designed, including microwave hyperthermia heating part, ultrasonic data acquisition part, ultrasonic signal processing part and interface display part.

Microwave hyperthermia module uses breast conformal array antenna. The antenna array mode is shown in Fig. 1. The staggered ring array is adopted to divide the entire antenna array into multiple rhomboid structures with 7 array elements as groups, so that the antenna radiation can better eliminate each other and form a beam with stronger energy, so as to enhance the penetration and focusing ability of the antenna array.

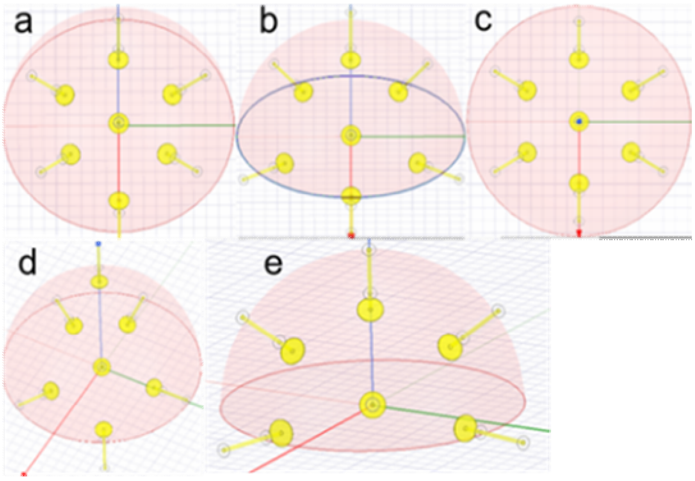


Fig. 1. Antenna array: *a–c* – the center line of array elements forms an azimuth Angle of 0 deg; *d–e* – the center line of array elements forms an azimuth Angle of 30 deg

In order to solve the problem of real-time temperature monitoring in the process of microwave hyperthermia, combined with the study of ultrasonic nondestructive temperature measurement, it is necessary to design ultrasonic jack in the model and introduce ultrasonic equipment into the whole microwave hyperthermia system. Shape design is to meet the probe rotation, translation and other testing requirements, through HFSS simulation to optimize the size of the jack, so that it does not affect the use of array antenna. The actual array antenna is shown in Fig. 2.

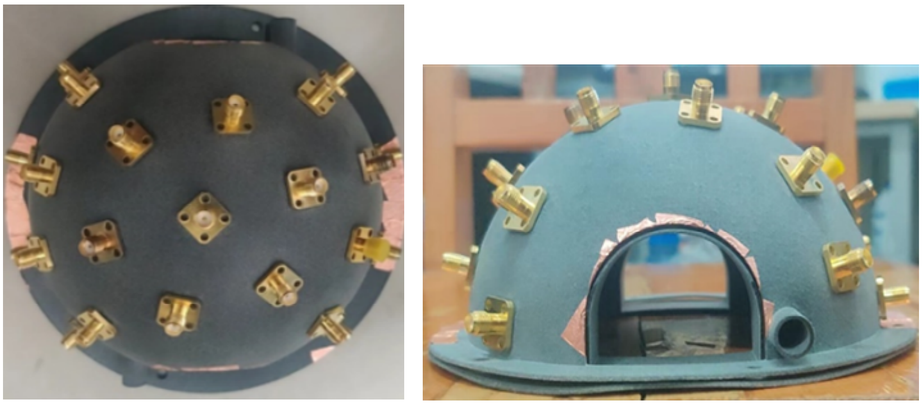
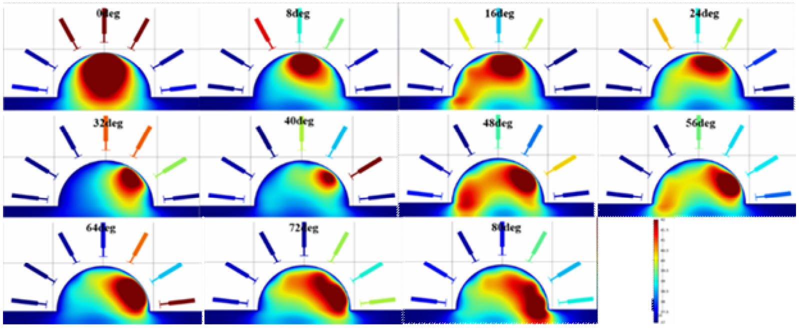
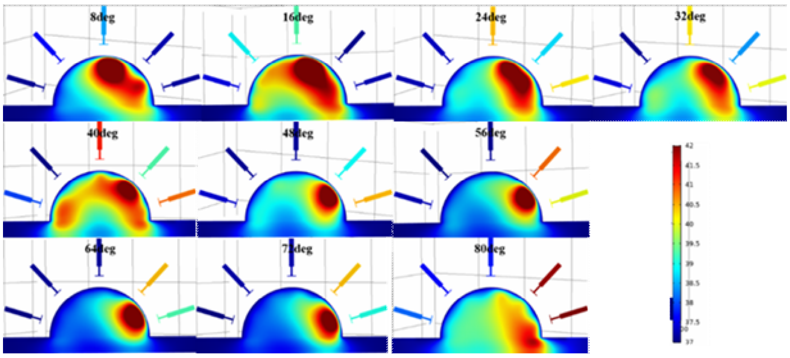


Fig. 2. Shape and structure diagram of microwave array antenna

COMSOL software was used to simulate the change of temperature field inside breast tissue. Because the temperature inside human tissue would spread around, the coverage range of 0–80 deg elevation Angle would spread to 0–90 deg elevation Angle. As shown in Fig. 3, the corresponding temperature field can fully cover the whole breast tissue.



a)

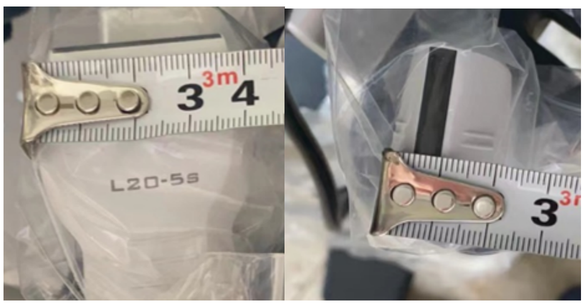


b)

Fig. 3. Azimuth (*a*) = 0 deg, pitch Angle 0–90 deg;
Azimuth (*b*) = 30 deg, pitch Angle 0–90 deg

The ultrasonic data acquisition module adopts mindray M 9 Vet portable ultrasonic diagnostic instrument produced by Mindray Company. The ultrasonic probe adopts linear array *L*20–5*s* ultrasonic probe adapted to B-ultrasound equipment and suitable for small organs. It has 192 array elements and the sampling center frequency is 17.25 MHZ. The device can collect ultrasonic image data while performing microwave hyperthermia, and upload the collected data to the server for further data processing.The ultrasonic data acquisition equipment is shown in Fig. 4.

a)

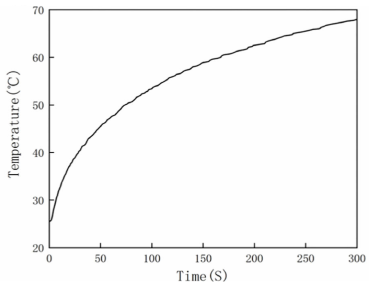


b)

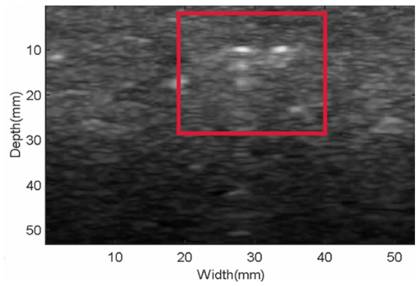
Fig. 4. Size of ultrasonic data acquisition equipment (*a*) and ultrasonic probe (*b*)

Signal processing and display module: Nakagami distributed temperature calculation based on BP neural network was used for non-invasive temperature estimation of the collected ultrasonic data, and then GUI interface was designed to realize tumor site imaging and temperature monitoring in the thermal coagulation area.By calculating the Nakagami distribution parameter m of ultrasonic data acquisition, BP neural network algorithm is used to train the relationship between Nakagami parameters and temperature, so as to predict the temperature.

Experimental Result. The Nakagami distribution parameter m in ROI region was calculated by sliding window method. Figure 5 shows that the thermal scale image of the absolute value (ARCN) of the change of m value ratio also gradually brightens with the increase of temperature.



a)



b)

Fig. 5. Image of temperature (*a*) and thermal scale (*b*)

The fitting results of the BP-Nakagami temperature model are shown in Fig. 6, and the comparison results between the temperature actually measured by the thermocouple and the model temperature are shown in Fig. 7. Through calculation, we find that the error of temperature estimation is less than 1 °C at 25–50 °C. In addition, the two-dimensional temperature distribution map of B-ultrasound image generated by this temperature model can be used to predict the size of the ablation region, and the results are shown in Fig. 8. By comparing with the results predicted by the model, the estimated ablation area range of the model and the actual ablation area range are the same.

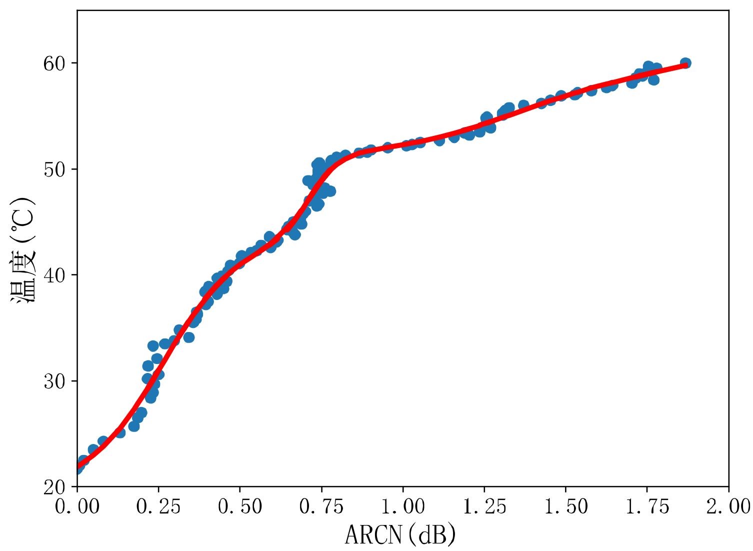


Fig. 6. Fitting results of Nakagami distribution parameters and temperature in ROI region by BP neural network

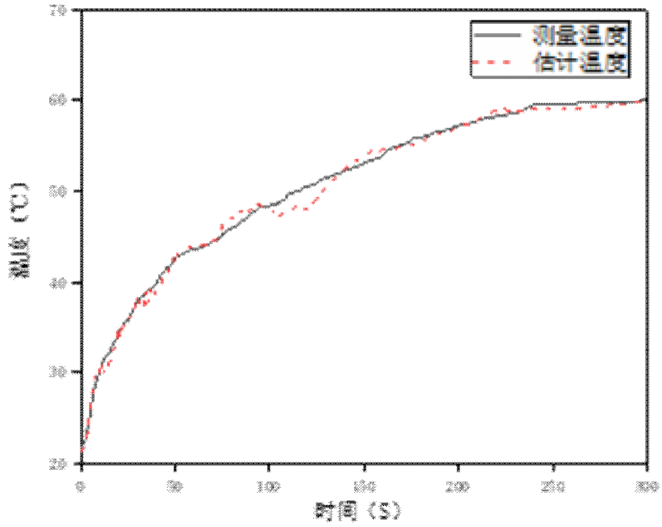
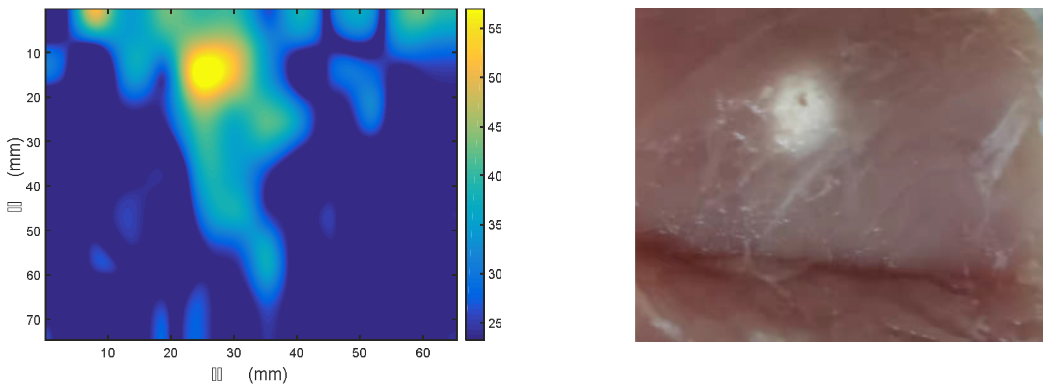


Fig. 7. Comparison between the temperature estimated by the model and the actual temperature measured by the thermocouple



a) *b*)

Fig. 8. Two-dimensional temperature distribution of B-ultrasound images generated by the model (*a*); cross-section of fresh isolated pork tissue after ablation (*b*)

References

1. Hyperthermia MRI temperature measurement: evaluation of measurement stabilisation strategies for extremity and breast tumours / C. Wyatt [et al] // Int J Hyperth. – 2009. – N 25. – P. 422–433.
2. Temperaturemonitoring in fat with MRI / Hynynen K [et al] // MagnReson Med. – 2000. – N 43. – P. 901–904.
3. Temperature elevationby HIFU in ex vivo porcine muscle: MRI measurement and simulation study / M. A. Solovchuk [et al.] // Med Phys. – 2014. – N 41. – P. 052903.
4. Ultrasound thermal mappingbased on a hybrid method combining physical and statisticalmodels / B. T.Chen [et al.] // Ultrasound Med Biol. – 2014. – N 40. – P. 115–129.
5. Liu, D. L. Real-time 2-D temperature imaging usingultrasound / D. L. Liu, E. S. Ebbini // IEEE Trans Biomed Eng. – 2009. – N 57. – P. 12–16.