RF POWER AND CONTROL SYSTEMS FOR PHASED DIPOLES ARRAY SYSTEM FOR HYPERTHERMIA

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Abstract

Cylindrical array of independently phased dipoles is suggested for hyperthermia of deep-situated tumors as a kind of treatment of cancer coupled with other methods such as radiation therapy and chemotherapy. It was proposed to focus the maximum of electromagnetic field at the site of tumor to produce high efficiency heating of tumor and to prevent overheating of surrounding healthy tissues. That's why we use system of independently fed dipole antennas. The operating frequency is 150 MHz. The independent feeding permits us to focus electromagnetic field producing by phased array in desirable area by means of changing of amplitudes and phases of each dipole. The RF power system schematic layout for 8 independently phased dipole antennas is presented. The control system of RF power system elements is considered. The software developing to provide the choosing of amplitude's and phase's values of dipoles are discussed.

INTRODUCTION

Many clinical and experimental studies have shown promising results in using of hyperthermia coupled with radiotherapy or chemotherapy for treatment of malignancies [1-3]. Treatment requires that temperatures within tumor remain above 43 °C during 30-60 min, while maximum temperature in normal tissues have to be lower than 42°C. Cylindrical phased dipole array is proposed to produce difference between temperature in healthy tissues and tumor. Range in 100-200 MHz of electromagnetic wave produced by dipoles is prior because wave length in human body is proportional with body's sizes. Phased array consists of eight dipoles arranged on inner side of plastic shell and surrounds patient body like it shown on Figure 1. Deionized water filling space between patient and array is for cooling outer side of body and for better matching. The E-field energy is extremely concentrated in the inner side of a shell due to the electric field energy density inside the shell is higher by a factor ε (the relative dielectric constant of the medium) than outside the shell.

Phased array provides desirable distribution of electromagnetic field inside of the patient body. The specific absorption rate (SAR) or absorbed power per unit mass (W/kg) is given by:

$$SAR(x,y) = \frac{\sigma E E^*}{2\rho}, \qquad (1)$$

where E is the total electric field at the point (x,y), E^* is the complex conjugate of E, σ and ρ are the electrical conductivity and the density of tissue respectively.

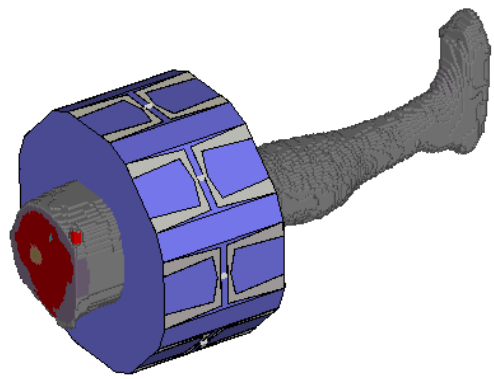

Fig. 1: Voxel model of leg inside phase array.

E_j is the E-field for antenna j scaled by the amplitude and phase take into account:

$$E_j = A_j E_{j0}(x,y) e^{i\Phi_j}, \qquad (2)$$

where E_{j0} is the complex field for $A_j = 1, \Phi_j = 0$, and $A_k = 0$ for $j \neq k$. A time variation of the form $\exp(-i\omega t)$ is dissembled.

Necessary distribution of E-field can be reached by means of independent feeding of each dipole that permits us to vary amplitudes and phases of electromagnetic field. In other words we can concentrate absorption energy of E-field and deliver therapeutic heat in tumor and at the same time prevent extra heating of normal tissues.

RF POWER SCHEME

As it was noted above, the RF power supply have to be independent for each dipole. The RF power system schematic layout is shown in Figure 2: 1 – driving generator with input signal's frequency range 100 – 300 MHz and input impedance 50 Ohm; 2 – 8-out power splitter (for example Mini-circuits ZBSC-8-82+); 3 – voltage-controlled phase shifter (Mini-circuits JSPHS-150) with frequency range 100 – 150 MHz, phase range 180°, control voltage 0 – 12 V; 4 - solid state amplifier (Mitsubishi RA60H1317M1A-101) with frequency range 135-175 MHz, output power – 60 W, supply voltage – 12.5 V, control gate voltage 12.5 V; 5 – 10 dB uni-directional coupler (Werlatone Model c7929, 100-

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200MHz, 200 W, 10.0±1.0 dB Nom, 6 – load absorbed, 50 Ohms, 7 – phased array with patient body inside.

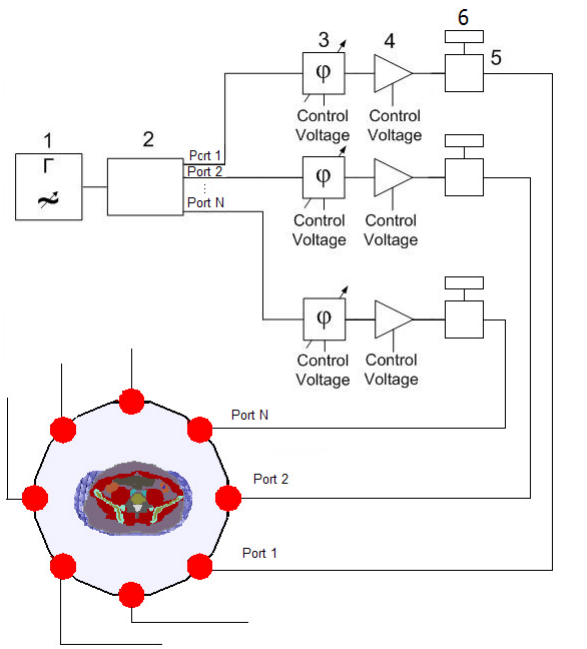

Fig.2: RF power system schematic layout.

The operating principle of such layout is the following. The RF signal at 150 MHz from signal source splits into 8 channels. Then by means of controlled 8 phase shifters and 8 solid state amplifiers we can adjust phase and amplitude of every signal. Due to these adjustments electric field focusing in the desire region is available. Directional couplers prevent reaching reflected wave to generator. Reflected wave will be absorbed by 50 Ohm load.

Modern solid state amplifiers are simple and stable in operation and can derive the necessary amplification. For example, solid state RF amplifier Mitsubishi RA60H1317M with amplify frequency range of 135-175 MHz and supply voltage 12.5 V can be used to provide the necessary RF power (to 60 W) and SAR values. The control of RF power can be realized using amplifier's gate channel which provide the turn on/off of amplifier.

CONTROL SYSTEM

RF power system control scheme is shown in Figure 3: 1 – control unit; 2, 3 – signal shaping units for amplifiers and phase shifters correspondingly. Control system of phased array is based on Arduino Mega. Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack. Control unit gets data about amplifier's and phase shifter's values from PC and generates signals, which passing through units 2 and 3 operate amplifiers and phase shifters. Signal from 1 generates a pulse-width modulation (PWM) signal. Further signal passing through RC-filters situated in both 2 and 3 units, goes to gate pin of amplifier. Because of control voltage of phase shifter varies in 0-12 V, we have to use operational amplifier with $K_u=2.6$ in unit 3.

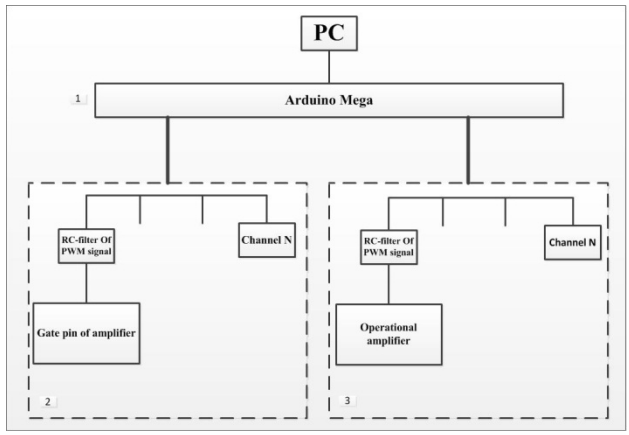

Fig.3: Control system schematic layout.

CONCLUSION

Phased dipole array is proposed for hyperthermia of oncological disease. RF dipole antennas produce difference between temperatures in tumor and healthy tissues because of ability to focus electromagnetic field in tumor side. Also different dielectric properties influence on absorption process. Focusing of E-field is achieved by varying of phases and amplitudes of each dipole, i.e. we have to use independent feeding of dipoles.

RF power system realizing this approach is discussed. Control system based on microcontroller board Arduino Mega Schematic layout is described. Also software for convenient controlling of hyperthermia phased array is developed.

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