A NEW MICROWAVE POWER SOURCE AND ITS APPLICATION

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ABSTRACT

We present here a new 2450 MHz power source in which the anode current of the magnetron can be linearly controlled. The tube is powered by a constant high voltage DC power supply and controlled by a current source circuit. Accurate control of the output power and the produced temperature in various medical applications can be realized by the modern control technologies, such as fuzzy control, robust control and adaptive control etc., through a computer system with a D/A converter. The applications to medical treatments and accurate moisture measurements are discussed.

INTRODUCTION

Hyperthermia as a treatment for cancer has been intensively investigated for many years. The effectiveness has been proved by large amount of biological and clinical data[1]. Being able to penetrate into the deep region of the body, microwave of 2450 MHz are often adopted[2]. The high power microwave is generated from a magnetron which works under a high voltage, typically over one thousand volts, and has strong nonlinear behaviors. Hence, accurate control of the magnetron anode current is almost impossible for its traditional power supplies, let alone to control it by computer in modern methods. This makes the experiments on cancer hyperthermia quite imprecise and hinders the further study. Moreover, it often happens that a quite stable temperature within the best range for esophagus cancer treatment may be obtained by a traditional power source with a feedback control, but in the case of treating the cancer in bladder the temperature can never be stable with the same power source. It is quite dangerous because the healthy cells will be possibly hurt if the temperature is too high.

We present here a new power source in which the anode current of the magnetron can be linearly controlled. The tube is powered by a constant high voltage DC power supply and controlled by a current source circuit. Accurate control of the output power and the produced temperature in various medical applications can be easily realized by a computer system with a D/A converter or the other modern control methods, such as fuzzy control, robust control, etc..

It is interesting that the new power source also find its application in moisture measurements with increasing requirement of the measuring accuracy.

BASIC PRINCIPLES

Magnetron has the nonlinear V-I characteristic as shown in Fig.1. There is a sharp increasing of the cathode voltage V_k in the beginning. After the anode current I_a reaches a small value I_T, typically less than 5mA, V_k keeps almost constant with little increasement. Assume that the efficiency of the magnetron is constant and the magnetic field is quit stable (It is true if a permanent magnetic material is used), the output power P_o is approximately in proportion to I_a. Therefore, control of the anode current can regulate the output power of the magnetron-based power source.

It is also evident in Fig.1 that a little variation of V_k will result in a remarkable influence on I_a and P_o when I_a is higher than I_T. That is why the

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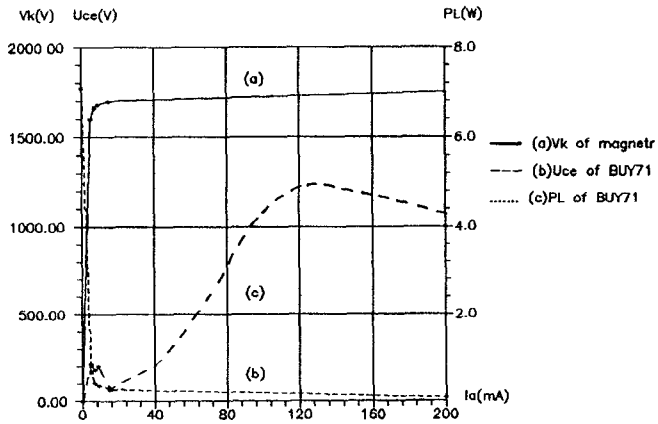


Fig.1 Behavior of the new power source

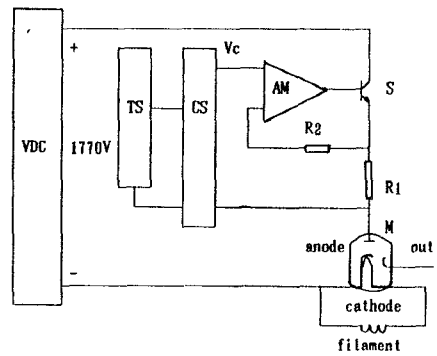


Fig 2 Circuit structure of the new power source

conventional power sources can not produce stable output power.

Circuit structure of the new power source is shown in Fig.2 where M is the magnetron CK140 which is made in NanJing, China. Its cathode voltage is about 1750 V and I_a can be as high as 200 mA. A high voltage transistor BUY71 with V_{ceo} of 2200 V, I_{CM} of 3 A and P_{CM} of 30 W is chosen as the high power switch S. The VDC, a constant HV source with a rated output power of -1770V/300mA, is a thyristor-based switching power supply. Anode current I_a of the magnetron is provided by a voltage-controlled current source which is mainly constituted by an operational amplifier AM, sampling resistors R_1 and R_2 and the switch S. I_a is controlled by the voltage V_c. A computer system CS with a 12-bit D/A converter is employed to control V_c thus I_a. The temperature sensor and its support circuit TS is connected with the computer system through the 12-bit A/D converter.

Variations of the voltage across BUY71 and its power losses are shown in Fig.1 and Fig.1, respectively. It can be seen that a high voltage appears on BUY71 when the current is quite low. As the current through BUY71 rises, the voltage across it drops to a small value, typically less than 20V, Thus the power losses of BUY71 can be constrained within 5W. Experimental results indicate that the anode current can have a stability superior to 0.1%.

APPLICATIONS

Being able to be controlled by computer systems, the new microwave power supply can employ the modern control technologies to adjust its power output and the produced temperature in its medical applications. In this work, the fuzzy control method is adopted to ensure a stable temperature output within the best range required in various tumor treatments, such as that in intestines, stomach, womb, esophagus and bladder.

Adaptive control method has also been adopted. This method sets up corresponding models for the treated objects so as to obtain a fine control result.

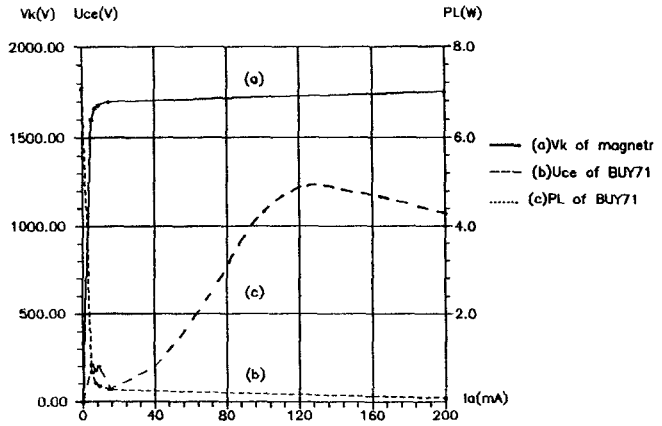
In moisture measuring, X-band microwave source is conventionally adopted with output power less than 1W[3]. In this way, the moisture is tested through measuring the attenuation of microwave conducting along the sample, Because the microwave source has a rather low power output capability, the detector should be highly sensitive. For the conventional microwave power sources, precision no better than 5% can be obtained. But, for the new power source, an accuracy of 3% can be obtained for water saturation measurement in sandstone cores because it can provide the tested sample a stable input power as high as 20 W.

REFERENCES

[1] J.W.Strohbehn et al., "Special issue on hyperthermia and Cancertherapy", IEEE. trans. Biomed. Eng., Vol. BME-31, 1984

[2] M.K.Hessary, et al, "EM local heating with HF electric fields", IEEE. Trans. Micro-wave Theory and Tech., Vol. MTT-32, pp.569-576, 1984.

[3] S.K.Aggarwal, et al, "Oil and Water Content Measurement of Sandstone Cores Using Microwave Measurement Techniques", IEEE. Trans. Instrum. Meas., Vol. IM-35(4), pp.630-637, 1986



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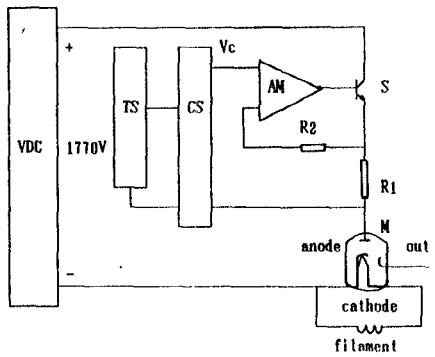

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