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Optimized tissue heating by adopting high frequency electrotherapy

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Abstract
We have developed an electronics circuit that generates a high voltage with a frequency of 0.3-2 MHz to build an electro therapy system that can optimize tissue heating characteristics. These characteristics are used in medical applications. This paper is focused on the analysis of high frequency electro-therapy system to optimize tissue heating with the help of a high voltage pulse signal, which peak voltage is almost 2 kV. This optimized tissue heating between the inner tissue and the thermal distributions has examined in terms of frequency and voltage. The target tissue heating is composed of a single electrode in an experiment that has especially conducted to find the tissue heating characteristics. In the end, a new method for electro-therapy is developed, which is applicable to a specific tissue depth.

1. Introduction

The improvement of our quality life makes us more focused on healthcare and body treatment [1,2]. Recently, more attention has been paid on how to develop innovative healthcare machines and beauty instruments [3,4]. Electricity treatment machines are widely used in various fields in medical treatment such as pain management [5,6], neuromuscular dysfunction [7], tissue repair [8], etc. This machinery helping us to get psychological satisfaction that and the immune system is strong enough to preclude the deleterious diseases.

Apart from the electricity therapy, other technologies such as laser therapy, ultra sound therapy, and electromagnetic therapy are widely deployed for bio-medical applications.A randomized, double-blind, placebo-controlled study of low-level laser therapy (LLLT) in 90 subjects with chronic neck pain was conducted with the aim of determining the efficacy of 300 mW and 830 nm laser in the management of chronic neck pain. The laser therapy could peel the skin off the body with laser and chemicals, so it caused injuryto the skin - healing of these wounds could take weeks [9].

Therapeutic ultrasound has been extensively used to treat a variety of conditions because of its documented thermal effects. It has repeatedly been shown to increase tissue temperature at depths up to 5 cm with only minimal increases in skin temperature. It has been suggested that an increase of 18°C (mild heating) over baseline muscle temperatures of

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36.8°C to 37.8°C accelerates the metabolic rate in tissue. An increase of 2.8°C to 3.8°C (moderate heating) reduces muscle spasms, pain, and chronic inflammation and increases blood flow. Vigorous heating, or an increase of 4.8°C or more, has been suggested to alter the viscoelastic properties of collagen and inhibit sympathetic activity. Because of baseline temperature differences between individuals, however, it may be better to speak of the thermal effects of therapeutic ultrasound as occurring at specific absolute tissue temperatures rather than relative changes from baseline temperatures. For example, many of the authors, who performed the early work on thermal effects, described the desired physiologic effects as occurring at an absolute tissue temperature higher than 39.68°C. Regardless of whether we discuss absolute or relative temperature changes, producing a therapeutic increase in tissue temperature requires careful attention to the specific ultrasound settings being used [10]. Disadvantages of ultrasound powering implants include the need for physical coupling of the ultrasound to the body surface and in some cases the need to accurately maintain the transducer position on the skin depending on the requirement.

Electromagnetic therapy has been used with reported success in multiple clinical settings, including the treatment of seizure disorders, brain edema, migraine headaches, revascularization of burn wounds and diabetic ulcers. A randomized, prospective, double-blind, placebo-controlled pilot study was conducted to evaluate the effectiveness of high frequency pulsed electromagnetic energy using the dipulse device in the treatment of chronic tinnitus.The unit was set to deliver electromagnetic energy at a frequency of 27.12 MHz at a repetition rate of 600 pulse per second [11].

On the other hand, the term electrotherapy can apply to a variety of treatments in medical field, including the use of electrical devices such as deep brain stimulators for neurological disease. The term has also been applied specifically to the use of electric current to speed healing wounds. Additionally, the term "electrotherapy" or "electromagnetic therapy" has also been applied to a range of alternative medical devices and treatments. Electro-therapy provides safe treatment to patients. High frequency high voltage electric power is generated and controlled by the well-developed power electronics technology, so we are able to produce an electro-therapy system with good stability and efficiency. It can deliver very safe treatment [12,13].

From the review, we can understand that each and every therapy treatment has its own characteristics. As the different characteristics vary, it needs to adapt control for different kinds of body parts. In medical applications, the ways of approach to therapy treatment are different for different therapies and all of them give reasonable results and make this treatment more believable [14,15]. The nature of the human body also varies from person to person, so we are concernedwith those difficulties to invent an electro therapy system to achieve the intended goal formedical treatment. An electro therapy system includes a high range of kV and high frequency which requires great stability and reliability for use in medical treatment [16]. Therefore, the development of the high frequency electro-therapy machines could change the output frequency of electro-therapy to prevent the potential damage of the human body [17].

During the development of the high frequency electrotherapy, we monitored the output signal and analyzed how it was varying with respect to the applied frequency. We figure out which particular frequency in our bandwidth achieves themaximum remedial value. We found that electrotherapy gives a reasonable output for different frequencies. So, it is useful for more bio-medical treatments when it operates at different frequencies. Using power electronics technology, controllable high voltage high frequency can be designed and operate the electro therapy machine towards bio medical applications [18,19].

To heat the tissues using by electro therapy system, we need to regulate and control theapplied electrical energy of high voltagehigh frequency. Other important concern in medical treatment is safety of patients, we should more concern on circuits that regulating and controlling the high voltages properly. Furthermore the temperature control for the local tissues has to be studied simultaneously. The analysis has to be carried out with the frequency wave form and voltage differences [20]. The rest of this paper is organized as follows. After this introduction, our system design is presented in Section 2, including circuit design, high voltage high frequency generator, controller, power supply, the EMC protection, and Optimal temperature for palm tissue treatment. Section 3 describes the experimental results. Finally, a brief conclusion and future work are given in Section 4.

2. System design

2.1. Circuit design

The respected source element must be operated by controllable high voltage high frequency signal to invent electro therapy system. The circuit shown in the below figure, is designed to generate HVHF. The designed circuit can operate at a frequency between 500 kHz and 2 MHz and a voltage of 2 kV. This circuit design includes a DC-DC switched mode power supply, an AC to DC converter and control circuits.

The HVHF system adopts a hybrid modulation method to control the high frequency output pulses. In medical applications, the load should be a bio-chemical material which is not like any other electrical load, so most available regular voltage control methods, which are mainly designed for electrical load applications, are not suited for this kind of bio-medical application. Especially, the device needs fast speed of response due to safety concerns, so that constant voltage and constant current (CVCC) control was designed specially according to suit this application. Fig. 1 shows that a single phase 220 V common AC with an adapting PFC (power factor control) has been taken as a source. The characteristics of input power are improved to a high power factor and low harmonics. An LLC resonant converter is used to convert to a low DC voltage supply.

2.2. High voltage high frequency (HVHF) generator

Fig. 2 shows the schematic representation of HVHF generator.It has threemain characteristics: frequency, waveform and duty cycle. The circuit is designed with a fly-back topology. The range of driving frequency is variable from 300 kHz to 2.0 MHz and the duty cycle of this device is also