July 9, 1963 B. W. GRIFFITH, JR 3,096,768

ELECTROTHERAPY SYSTEM

Filed May 27, 1960

Fig. 1

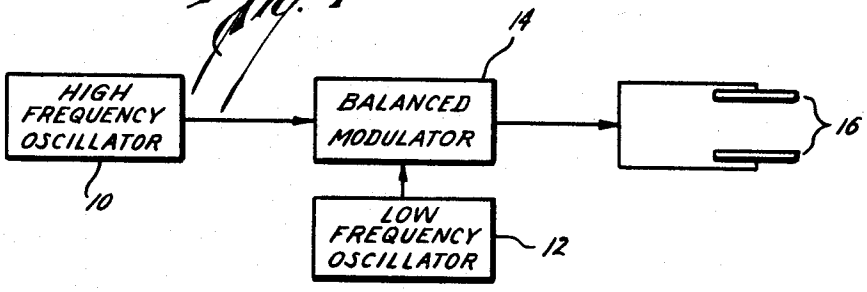


Fig. 2

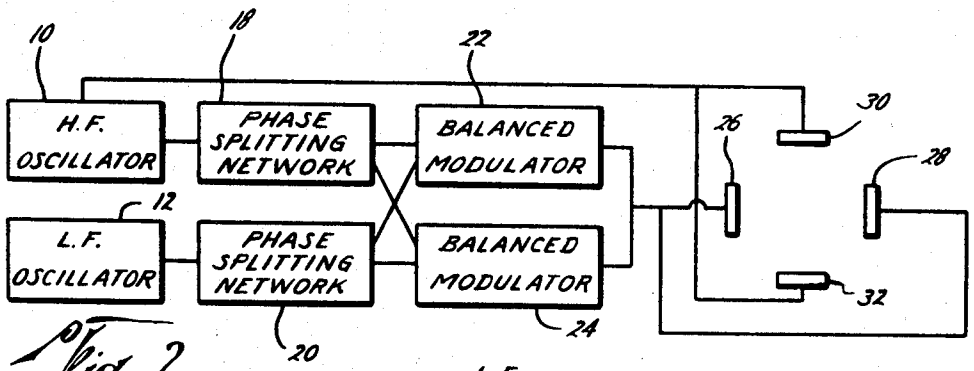


Fig. 3

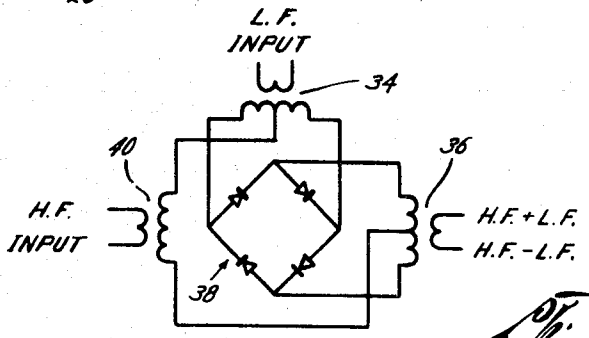
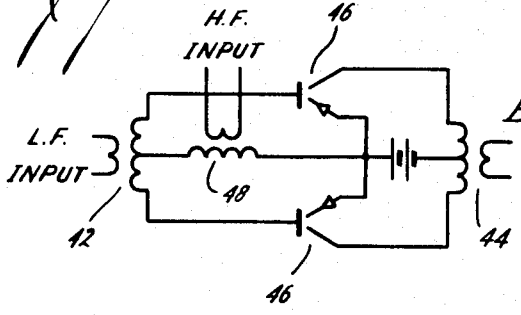


Fig. 4



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ELECTROTHERAPY SYSTEM

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This invention relates to means and apparatus for the application of currents of various frequencies to the body in order to excite the natural physiological response frequency of the nerves.

From the earliest times of electrical knowledge, the response of organic tissues to the stimulus of electric current has been known. The first detailed scientific investigation of these effects was performed in Italy by Luigi Galvani, Professor of Anatomy at the University of Bologna. Due to the primitive state of development of electrical equipment in his era, his work was of necessity limited to the application of steady-state D.C. and very low frequency (manually pulsed) A.C. Galvani also observed and investigated the effect upon organic tissue of the induced energy resulting from the spark discharge of a nearby electrostatic generator, such discharges being largely oscillatory in nature and containing components of several frequencies.

Much work was performed during the 19th century by many workers in applying electric currents to the human body for medical purposes, with study being devoted to the effects of various intensities, frequencies, directions of current flow, and electrode arrangement. In 1922, U.S. Patent 1,425,743 was issued to S. N. Baruch covering apparatus which produced an alternating electrostatic field of a plurality of different frequencies, so that a heterodyne effect was produced. Baruch made use of the now-obsolete spark oscillator as his source of high frequency energy, and utilized two rotary interrupting devices to produce two different frequencies of modulation simultaneously. In the application of his invention, Baruch applied his mixed frequencies to a pair of insulated condenser plates, one of which was placed under the patient and the other over him. According to Baruch, the body of the patient formed the condenser dielectric, in which dielectric hysteresis losses took place, thereby affecting the general metabolism of the patient.

French Patent 859,618, published December 23, 1940, describes a method which comprises the application to the body of two high frequency currents which intersect each other at tissue to be treated. The frequencies of the currents differ somewhat, so that, upon intersecting they create a beat frequency which is equal to the difference between the two high frequency currents. Such a beat frequency was found to cause a muscular contraction. A similar method was developed by Dr. Hans Nemec, and is described in his U.S. Patent 2,622,601, issued December 23, 1952. However, both the French patent and the Nemec patent describe apparatus which includes two separate oscillators for the two high frequency currents. The Nemec patent describes the use of a variable capacitor for varying the frequency of one current with respect to that of the other so that the frequency of the heterodyne effect in the body can be varied. The natural frequency drift of the oscillators makes it quite difficult to maintain the desired beat frequency. It is apparent that where two oscillators operating at, for example, 4000 cycles and 4010 cycles per second must be maintained at just 10 cycles frequency difference, a drift of just 0.1% in frequency of each oscillator will cause a wide variation in the beat frequency. The accurate maintenance of such a small difference between two high frequencies is therefore extremely difficult, while it has been shown that the stability and controllability of the

beat frequency is quite important in therapeutic applications.

It is an object of this invention to provide means for accurate maintenance of beat frequencies in electrotherapy systems.

It is another object to provide an electrotherapy system which utilizes only one high frequency oscillator and one oscillator operating at the desired beat frequency, the second high frequency being produced by the use of balanced modulators for the suppression of a carrier and one side band.

Another object is to provide an electrotherapy system in which the variation of the beat frequency produced is dependant solely on the stability of a low frequency oscillator.

A further object is to provide an electrotherapy system which utilizes a circuit which is readily adaptable to the use of transistors and other semiconductor devices as well as to vacuum tube application, so that battery-operated equipment operating on these principles can readily be produced.

The accomplishment of these and other objects of the invention will become more apparent upon consideration of the following description and the accompanying drawings, wherein

FIGURE 1 is a schematic diagram of one embodiment of the invention,

FIGURE 2 is a schematic diagram of another embodiment of the invention,

FIGURE 3 is a diagram of one form of balanced modulator suitable for use in the system of this invention, and

FIGURE 4 is a diagram of another form of balanced modulator.

A balanced modulator is a circuit wherein intermodulation of two frequencies may be accomplished, with one of the frequencies being suppressed in the output of the circuit. Such a device is used in the system shown in FIGURE 1, wherein the outputs of a high frequency oscillator **10** and of a low frequency oscillator **12** are fed into the carrier and signal inputs, respectively, of the balanced modulator **14**, wherein the low frequency signal is modulated upon the high frequency carrier. The carrier, or high frequency, is suppressed in the process of modulation, so that the output of the balanced modulator contains only the sideband energy, which consists of frequencies equal to the sum and difference of the two frequencies. These two frequencies are therefore just above and just below the original carrier frequency, and their difference is equal to twice the original low frequency signal. In the embodiment shown in FIGURE 1, these two frequencies are delivered on a single circuit to a single pair of insulated electrodes **16**, which are applied to the body for therapeutic purposes.

When it is desired that the two high frequencies produced be on two separate circuits, and therefore applied to separate and independent pairs of electrodes, the present invention contemplates an arrangement as is shown in FIGURE 2. A balanced modulation system of this type type is disclosed by Hartley in his Patent No. 1,666,206, granted April 17, 1928. In this embodiment of the invention, the outputs of the high frequency oscillator **10** and of the low frequency oscillator **12** are each split into two currents which are phased 90° apart, this being accomplished by phase splitting networks **18**, **20**, the construction and operation of which are well known in the art. One high frequency current becomes the carrier input to balanced modulator **22**, and is modulated by one of the low frequency currents, which is utilized as the signal in modulator **22**. The high frequency and low frequency signals, shifted 90°, are similarly fed into modulator **24**.

The combining of the outputs of these two balanced modulators results in the suppression of the carrier and one sideband, leaving the other sideband, which has a frequency equal to either the sum of or the difference between the high and low frequencies.

This sideband frequency is then supplied to a pair of insulated electrodes 26, 28. An additional output from the high frequency oscillator is applied to a separate pair of electrodes 30, 32.

When electrodes 26, 28, 30, and 32 are applied to the body, the two different frequency currents supplied intersect at a point within the body, so as to generate a beat frequency or heterodyne effect within the tissue of the body, the beat frequency being equal to the low frequency input to the balanced modulators. It will be apparent therefore that this beat frequency can be very accurately controlled, since it is affected only by variations in the low frequency input. Using the example set forth hereinbefore, if the high frequency used is 4000 cycles and the beat frequency desired is 10 cycles per second, a drift of 0.1% in the low frequency input would cause a variation of only 0.01 cycle per second in the beat frequency. Drift of the high frequency input will have no effect whatsoever on the beat frequency.

A wide range of frequencies have been used for electrotherapy treatments such as those for which the apparatus of this invention is suited. Normally, however, beat frequencies of from 1 to about 100 cycles per second are found most useful. The high frequency carrier input is usually from about 1000 to about 10,000 cycles per second.

In FIGURE 3 is shown a form of balanced modulator utilizing a diode ring connection which is suitable for use in the apparatus of this invention. In this form of balanced modulator the secondary coil 34 of the low frequency signal input is connected to the primary coil 36 of the output through a diode ring 38, and the secondary coil 40 of the high frequency carrier input is connected by center taps to coils 34 and 36.

The balanced modulator shown in FIGURE 4 illustrates one form of modulator which utilizes transistors. In this construction, the secondary coil 42 of the low frequency signal input is connected to the primary output coil 44 through triode transistors 46, and the secondary coil 48 of the high frequency carrier input is connected by center taps to coils 42 and 44.

It will be apparent that the phase splitting networks 18 and 20 will, from their separate terminals, provide currents to the inputs of modulators 22 and 24, such that these currents will differ in phase by 90°.

The apparatus of this invention thus provides a comparatively simple means for the application of electric currents for therapeutic purposes in which the frequency of stimulation of tissue may be very accurately controlled. The circuit is readily adaptable to the use of transistors or other semiconductor devices as well as vacuum tubes, so that portable battery-operated equipment can readily be produced. Such apparatus is useful for stimulating various tissues and structures of the body to relax such tissues and to improve the tone and general health of bodily parts.

A particularly advantageous form of treatment is one in which the electrodes are mounted in gloves made of an insulating material, so that the therapist may properly direct the pulses from the electrodes to the body part or tissue which is to be stimulated by the pulses.

Although several embodiments of this invention have been shown and described, the invention is limited only as set forth in the following claims:

1. An electrotherapy system comprising a high frequency source, a low frequency source, a phase splitting network coupled to each of said sources adapted to split the current from each source into two currents phased 90° apart, a balanced modulator adapted to receive one of the high frequency currents as a carrier and one of the low frequency currents as a signal, a second balanced modulator adapted similarly to receive the remaining two currents, means for combining the outputs of the two modulators, a pair of insulated electrodes adapted to receive the combined outputs of the two modulators, and a second pair of insulated electrodes adapted to receive current directly from the high frequency source.

2. Electrotherapy apparatus including a high frequency signal source, a low frequency signal source, a balanced modulator coupled to each of said signal sources for providing a single sideband signal output, and a pair of electrodes coupled to the output of said balanced modulator, said electrodes being adapted to contact a patient to provide a substantially constant beat frequency signal which is independent of the physiological manifestations of the patient.

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