United States Patent [19]

Rodler

[11] **3,895,639**

[45] **July 22, 1975**

[54] **APPARATUS FOR PRODUCING AN INTERFERENCE SIGNAL AT A SELECTED LOCATION**

[76] Inventor: **Hans Rodler,** Karntnerstrasse 161, A-8053 Graz, Austria

[22] Filed: **Sept. 20, 1973**

[21] Appl. No.: **399,067**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 178,159, Sept. 7, 1971, abandoned.

[52] **U.S. Cl.** **128/422;** 128/420

[51] **Int. Cl.** **A61n 1/36**

[58] **Field of Search** .... 128/419 R, 420, 421, 422, 128/423

[56] **References Cited**

UNITED STATES PATENTS

2,622,601 12/1952 Nemec 128/420

FOREIGN PATENTS OR APPLICATIONS

871,672 6/1961 United Kingdom 128/420

467,502 6/1937 United Kingdom 128/420

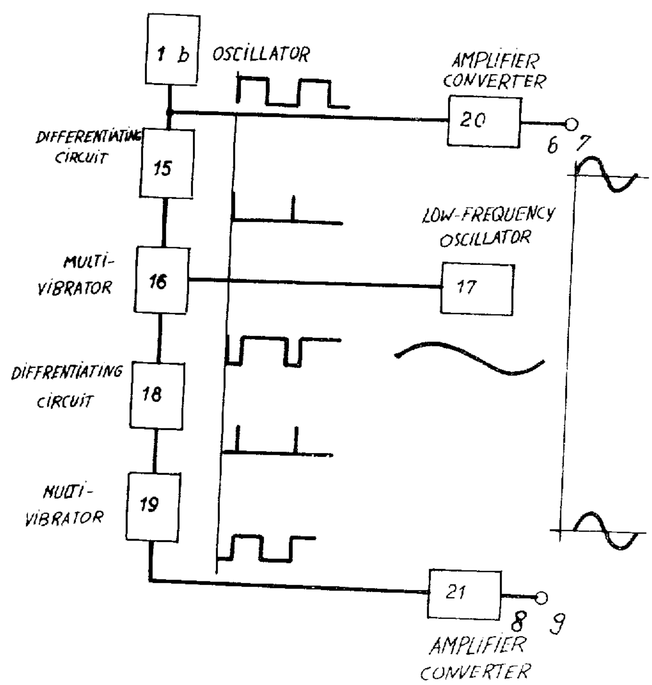
Primary Examiner—William E. Kamm

Attorney, Agent, or Firm—Kurt Kelman

[57] **ABSTRACT**

An electrotherapeutic apparatus for producing a beat or interference frequency at a selected body location comprises two pairs of electrodes connected to the body. Alternating current is supplied to each pair of electrodes from the two outputs of an oscillator, with the current paths between the electrodes of each pair crossing each other at the selected body location. A phase shifter rhythmically changes the phase of the current in one of the current paths.

9 Claims, 15 Drawing Figures



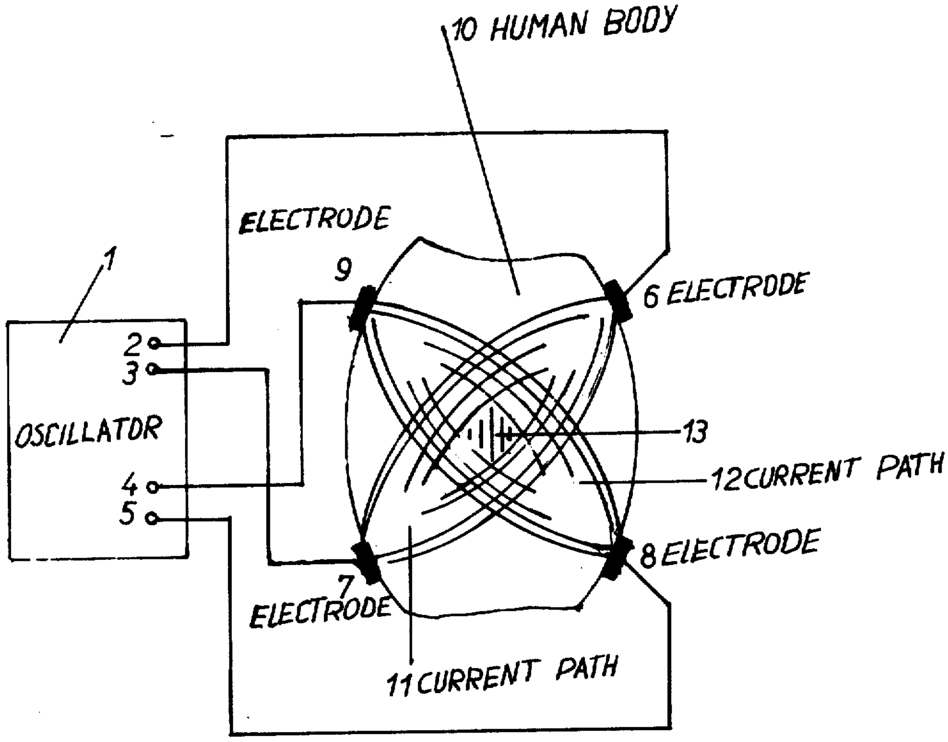

10 HUMAN BODY
ELECTRODE
1
9
6 ELECTRODE
2
3
OSCILLATOR
13
4
12 CURRENT PATH
5
8 ELECTRODE
7
ELECTRODE
11 CURRENT PATH

Fig. 1

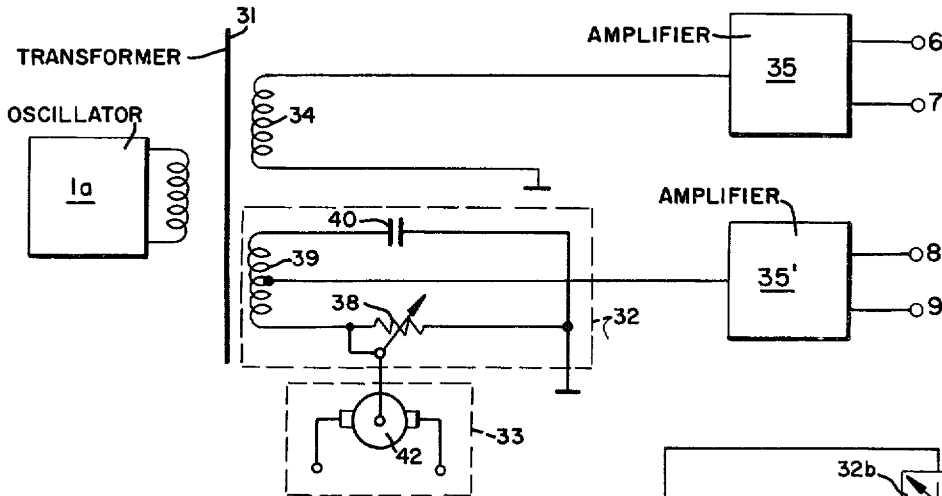


FIG.2

FIG.10

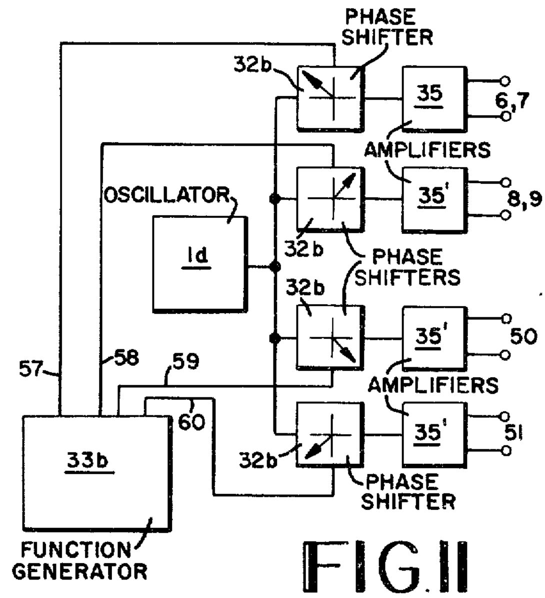


FIG.6

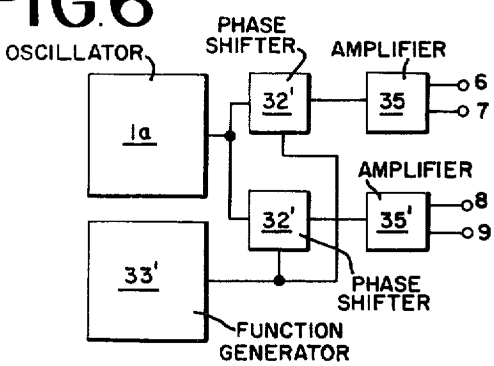


FIG.8

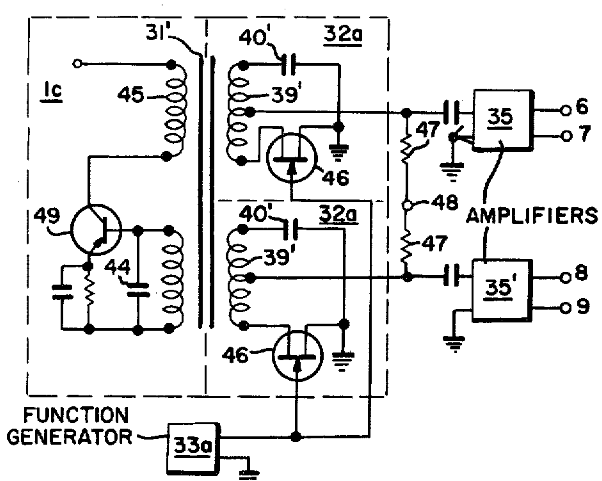


FIG.11

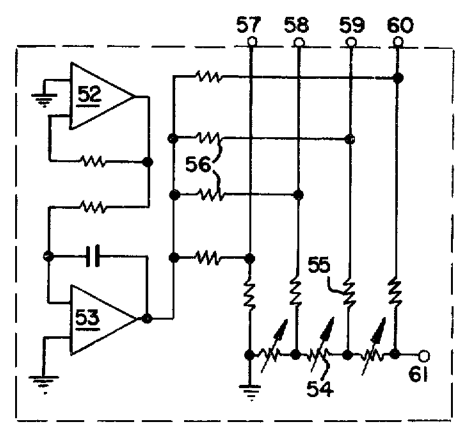


FIG.9

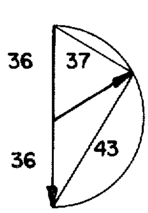


FIG.7

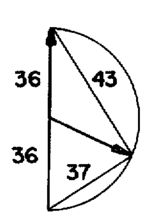


FIG.5

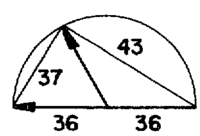
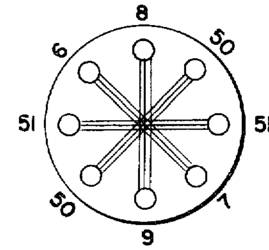


FIG.12



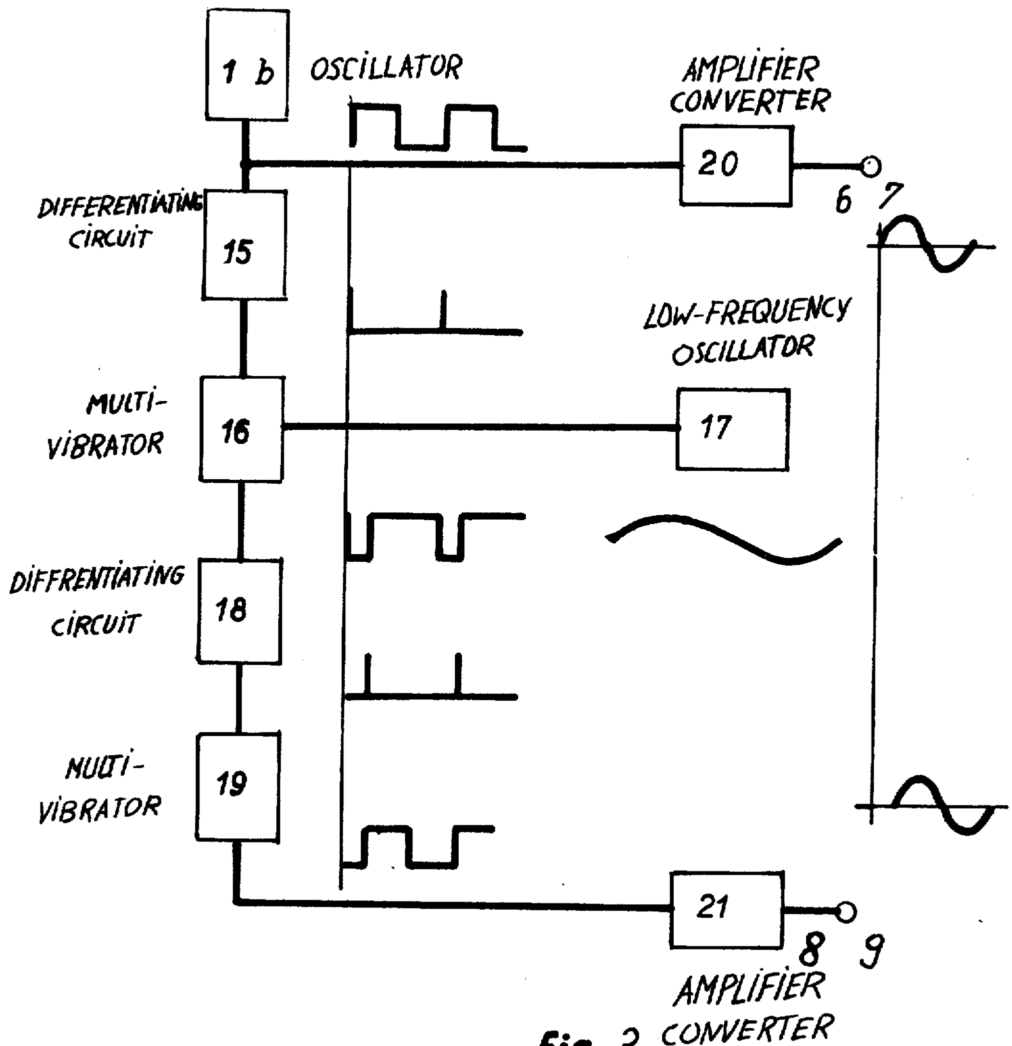
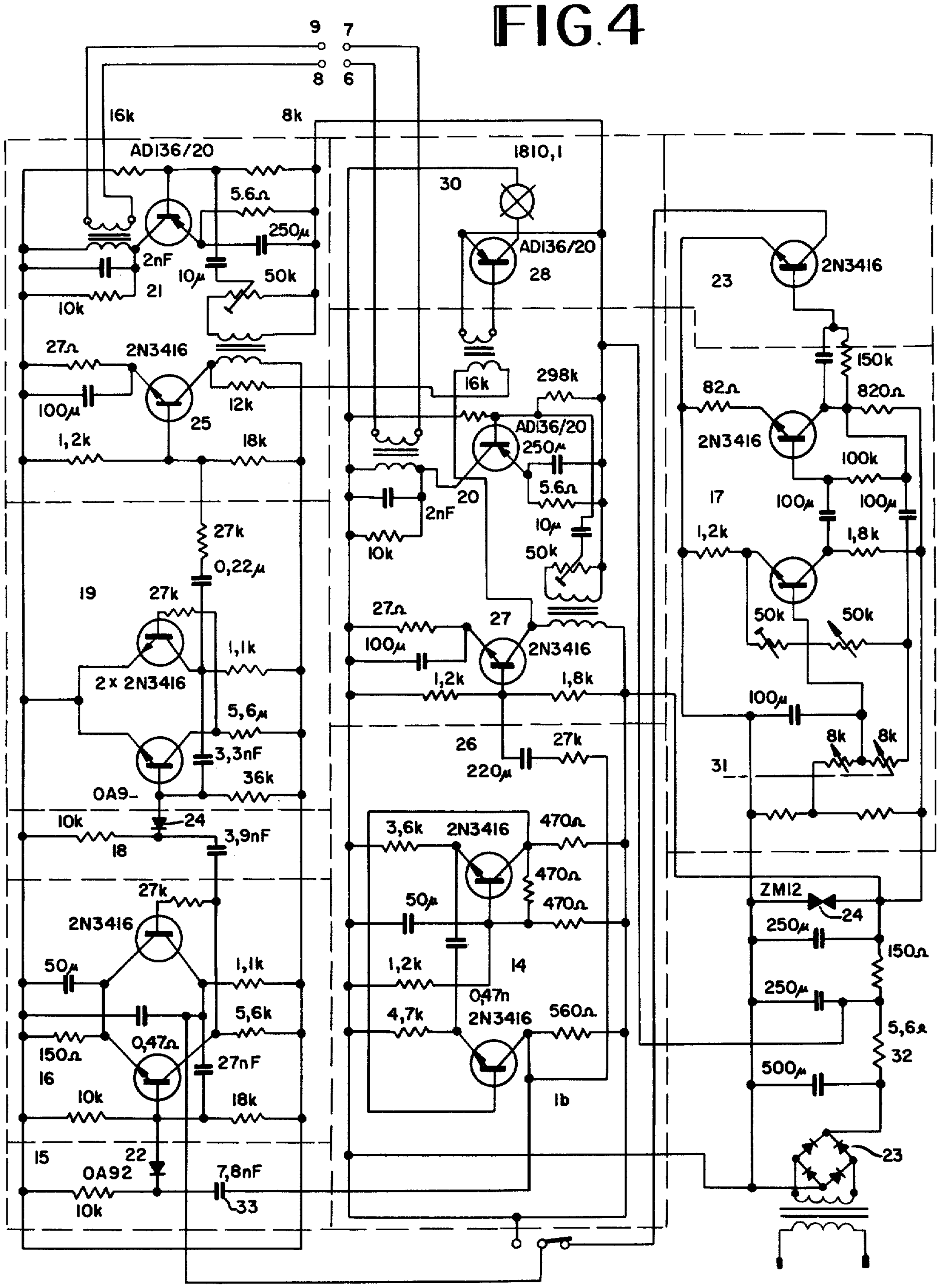

1 b
OSCILLATOR
AMPLIFIER
CONVERTER
20
6
7
DIFFERENTIATING
CIRCUIT
15
LOW-FREQUENCY
OSCILLATOR
MULTI-
VIBRATOR
16
17
DIFFRENTIATING
CIRCUIT
18
MULTI-
VIBRATOR
19
21
8
9
AMPLIFIER
CONVERTER

Fig. 3

FIG.4


9
7
8
6
16k
8k
AD136/20
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250µ
2nF
10µ
50k
21
10k
1810,1
30
AD136/20
28
23
2N3416
27Ω
2N3416
100µ
25
12k
1,2k
18k
16k
298k
AD136/20
250µ
5.6Ω
20
2nF
10k
10µ
50k
150k
82Ω
820Ω
2N3416
100k
17
100µ
100µ
1,2k
1,8k
50k
50k
27k
0,22µ
19
27k
1,1k
2×2N3416
5,6µ
3,3nF
OA9
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27Ω
27
100µ
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27k
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100µ
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8k
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18
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50µ
1,1k
5,6k
150Ω
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27nF
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10k
18k
1,2k
14
0,47n
4,7k
2N3416
560Ω
1b
ZM12
24
250µ
150Ω
250µ
5,6Ω
32
500µ
23
15
22
OA92
10k
7,8nF
33

FIG.13

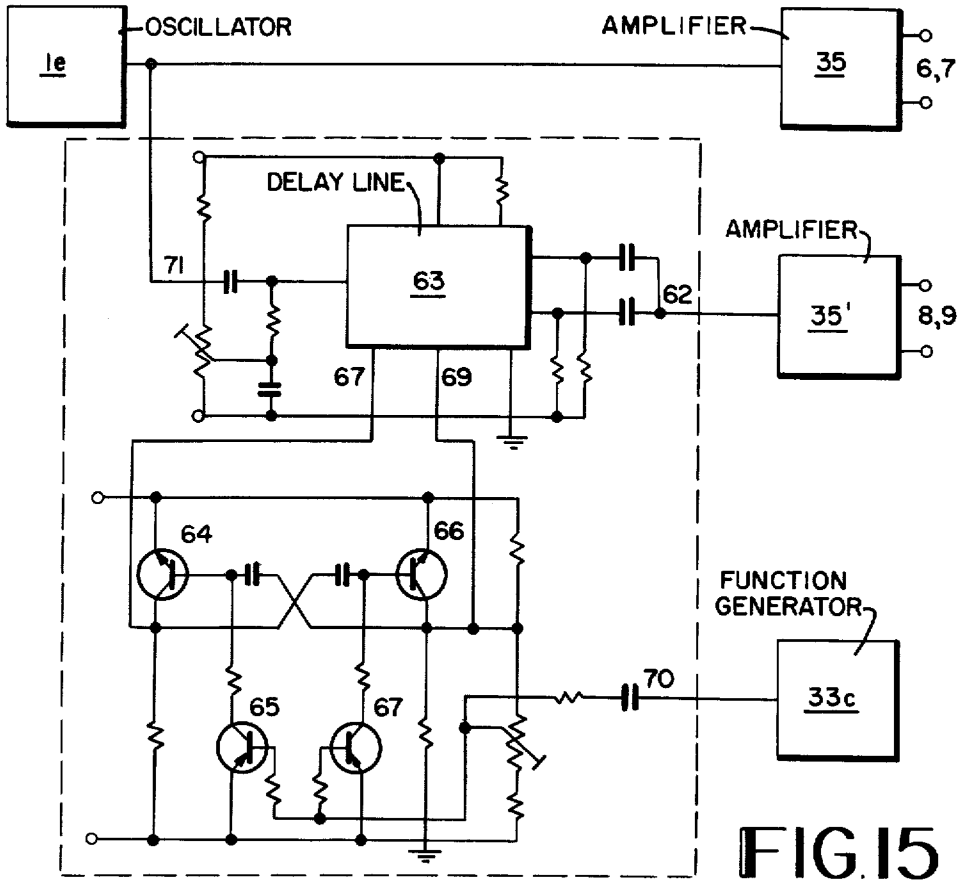


FIG.14

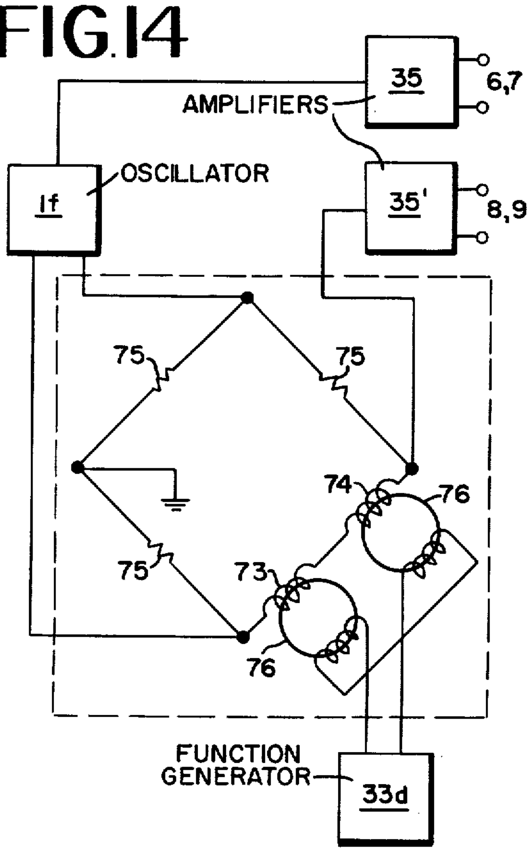
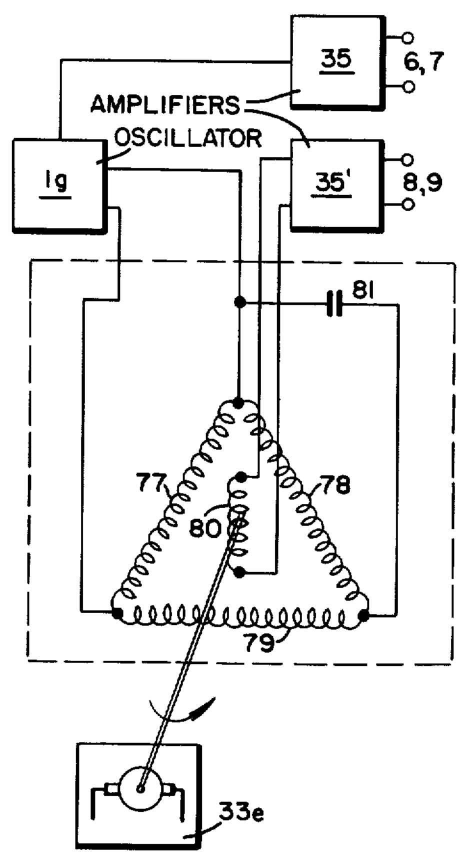


FIG.15



APPARATUS FOR PRODUCING AN INTERFERENCE SIGNAL AT A SELECTED LOCATION

This is a continuation-in-part application of my copending application Ser. No. **178,159**, filed Sept. **7, 1971**, now abandoned.

The present invention relates to improvements in apparatus for producing a beat or heterodyne frequency at a selected location of a body, and is particularly useful in electrotherapy for the human body.

In known apparatus of this type, two pairs of electrodes are connected or applied to the body. Independent oscillating means supplies each pair of electrodes with alternating current, and the current paths between the electrodes of each pair cross each other at the selected body location.

This type of electrotherapy has the particular advantage that a weak current of relatively high frequency is transmitted between the skin and the applied electrodes, which does not irritate the skin, while a relatively strong interference current of low frequency is produced at the intersection of the two current paths, due to the superposition of one current on the other and the corresponding frequency difference between the two currents. Furthermore, the selected location may be accurately determined by a suitable arrangement of the electrodes, and this location may be in regions deep in the body and remote from the skin. Accordingly, this type of electrotherapy has been successfully used to relieve pain, to exercise muscles, to treat joint diseases or neuralgia, to induce sleep, to improve blood circulation, and to alleviate inflammations.

In known apparatus of this general type, two separate and independent oscillators have been used to supply the oscillations to the electrodes, the difference between the frequencies of the two oscillators being very small, i.e. within the range of about **0.5** to **20** cycles per second (cps). In the usual oscillator frequency of **5000** cps, one cycle per second corresponds to a tolerance of **0.02** percent, which is an almost unattainable accuracy since the two oscillators influence each other and their frequencies tend to become equal when the difference becomes too small. Since the frequency of at least one of the oscillators must be controllable, it is impossible to attain such accuracy even with the use of quartz oscillators. Furthermore, these conventional electrotherapeutic machines produce only interference currents of sine waves.

It is the primary object of this invention to avoid the indicated disadvantages of such apparatus and to provide a beat or interference frequency generator of simple construction and capable of producing interference currents of any desired wave shape and frequency.

The above and other objects are accomplished in accordance with the invention by providing a single oscillator having two outputs respectively connected to a respective one of the pairs of electrodes, and a phase shifter for rhythmically changing the phase of the current in one of the current paths. The oscillator outputs supply an alternating current to each pair of electrodes, and the electrodes are arranged about a selected location so that the current paths of the pairs of electrodes intersect at this location. The phase shifter is arranged between one of the oscillator outputs and the pair of electrodes connected thereto for rhythmically changing the phase of the current in one current path.

In one embodiment, the oscillator is a rectangular wave oscillator. One of the oscillator outputs is connected to a first pair of the electrodes, and an output amplifier and if desired a wave converter are arranged between the one output and the first pair of electrodes. A monostable multivibrator, whose pulse width is controlled by a low-frequency oscillator, is connected to the other output, a first differentiating circuit being arranged between the other output and the multivibrator. A further differentiating circuit is connected to the multivibrator, and the other pair of electrodes is connected to another oscillator controlled by the differentiated edge of the oscillations produced by the multivibrator. An output amplifier and if desired a wave converter are arranged between the other oscillator and the other pair of electrodes.

Since a low-frequency oscillator controls the pulse width of the multivibrator, the generated pulse becomes narrower and wider in correspondence to the rhythm of this oscillator. Therefore, the trailing edge of the oscillations produced with the multivibrator changes its phase position in respect to the basic oscillation rhythmically in the frequency of the controlling low-frequency oscillator. By differentiating the trailing edge and controlling a further oscillator, which may also be a monostable multivibrator but may be a sine wave oscillator, too, the further oscillator may be made to generate oscillations rhythmically phaseshifted in respect to the first oscillations generated in the rectangular wave oscillator. The phase shift may be changed between **5°** and **355°**. The frequencies of the two output currents are the same, the phase of the second output current being variable in respect of the phase of the first output current. When the two frequencies are brought into interference at the point of intersection of the two current paths, an interference oscillation is produced. With an alternating current source, the enveloping curve of the interference oscillation may take any shape or form, the wave shape being controlled by the low-frequency oscillator. If this oscillator changes the pulse width of the first monostable multivibrator rectangularly, a rectangular wave interference oscillation is generated. If the low-frequency oscillator generates a sine wave oscillation, the interference oscillations is sineshaped, too.

According to one preferred feature of the present invention, the output amplifiers have an output for alternating current and an output for direct current. Also, the transformers may preferably be switched out of the operating circuit of the apparatus. This has the advantage that a rectangular direct current pulse is received from the D.C. output. When brought into interference, this makes two variations possible, i.e. the D.C. pulses may be brought into interference in opposite polarity, in which case the pulses cancel each other at the same phase and produce alternating current at the opposite phase, or they may be brought into interference at the same polarity, in which case a D.C. pulse of the same frequency as the basic frequency is produced at the same phase and a D.C. pulse is produced at opposite phase as long as the phase shift is **180°**. Thus, it is possible to produce a direct current deep in the tissues of the body although pulses of relatively high frequency are generated.

In another embodiment of the invention, two or more monostable multivibrators are connected to the rectangular wave oscillator via a differentiating circuit, the pulse width of the first monostable multivibrators being controlled by a low-frequency oscillator and each monostable multivibrator having an end stage with a patient output, an output amplifier with a patient output being additionally directly controlled by the rectangular oscillator.

This has the advantage that three or more output amplifiers and thus three or more current streams for patients may be operated simultaneously. The first circuit receives directly the basic frequency, the second circuit receives the frequency from one monostable multivibrator, and the third one receives it from the other monostable multivibrator in the indicated operating circuit. By suitably adjusting the basic pulse width and thus the phase position of the first monostable multivibrator, current amplification may be attained at the interference point, i.e. the interference point may be located more accurately. The considerable advantage of such an arrangement resides in the fact that the operating circuit comprises only one frequency-determining oscillator, the frequency constant of this oscillator not being critical. Therefore, the interference frequency may be made as small as desired. Furthermore, by using D.C. pulses of the same amplitude and equidistantly paced, D.C. voltage may be produced at the interference point. A multiphased arrangement makes it possible to project the interference point more accurately and to increase the energy at the interference point in respect of the electrodes.

The above and other objects, advantages and features of this invention will be better understood by reference to the following detailed description of one preferred embodiment, taken in conjunction with the accompanying drawing wherein

FIG. 1 is a schematic view of a portion of a human body to which two pairs of electrodes of an apparatus according to the invention are applied;

FIG. 2 is a circuit diagram illustrating a very simple circuit for operating the apparatus;

FIG. 3 is a circuit diagram illustrating another operating circuit;

FIG. 4 is a detailed diagram of the operating circuit of FIG. 3;

FIG. 5 diagrammatically illustrates a detail of the circuit of FIG. 2;

FIG. 6 shows yet another operating circuit;

FIGS. 7 and 9 diagrammatically illustrate a detail of the circuit of FIG. 6;

FIG. 8 shows still another operating circuit;

FIG. 10 is a circuit diagram of a further embodiment of the operating circuit;

FIG. 11 shows a control circuit for the phase shifting means of FIG. 10;

FIG. 12 shows the arrangement of the electrode pairs in the operating circuit of FIG. 10; and

FIGS. 13 and 15 are circuit diagrams of three additional operating circuit embodiments.

Referring now to the drawing and first to FIG. 1, there is shown the oscillator 1 having two outputs constituted by pairs of terminals 2, 3 and 4, 5. The terminals 2, 3 of one output are connected to electrodes 6, 7 of a first pair of electrodes, and terminals 4, 5 are connected to electrodes 8, 9 of a second pair of electrodes. The two pairs of electrodes are connected or applied to a portion of the human body 10 to be subjected to electrotherapy. When alternating currents whose phases are shifted in respect of each other are supplied to the respective pairs of electrodes from the output terminals, an interference current is produced at the location of intersection of the current paths 11 and 12 between the electrodes of the respective pairs. The desired location 13 and depth of the location of intersection of the current paths is determined by the positions of the electrodes on the body, the electrodes being quadrangularly arranged, as is well understood by those skilled in this art.

In the very simple operating circuit shown in FIG. 2, terminals 2, 3 of one of the outputs of oscillator 1a is connected to the pair of electrodes 6, 7, see FIG. 1, by means of secondary winding 34 of transformer 31 receiving the sine wave output of the oscillator, the signal being amplified by amplifier 35 connected between the transformer winding and electrodes 6, 7. The oscillator produces a sine wave of about 5 KHz (thousand cycles per second).

Phase shift circuit 32, part of phase shift means 32, 33, is connected between the other oscillator output terminals 4, 5 and electrodes 8, 9 of the other pair in accordance with the present invention. Phase shift circuit 32, part of phase shift means 32, 33, comprises secondary winding 39 of transformer 31 from whose center tapping point a phase-shifted signal is transmitted to amplifier 35′ connected between the tapping point and electrodes 8, 9 so that this pair of electrodes receives an amplified phase-shifted signal. It further comprises function generator 33 connected to one end of winding 39 and controlling motor 42 driving the adjustable element of potentiometer 38 for adjustment of the same, and condenser 40 connected to the other end of winding 39. In this manner, the generator 33 electromechanically controls potentiometer 38 and thus the current phase supplied to electrodes 8, 9 rhythmically.

The diagram of FIG. 5 shows the two parts of the voltage of transformer winding 39 as vectors 36, 36, the part voltage of potentiometer 38 as vector 37 and the part voltage of condenser 40 as vector 43. The two vectors 36, 36 form the base of a right triangle whose two sides are constituted by vectors 37 and 43. The output voltage vector is tapped from the center of the base and the point of intersection between vectors 37 and 43, which point lies in a circle about the center point of the base. As vector 37 decreases, the output voltage becomes closer and closer to the voltage of vector 36. If the resistance of potentiometer 38 increases to decrease vector 43 and proportionally increase vector 37, the phase of the current is shifted in the opposite direction.

If desired, the potentiometer and the condenser could be adjusted together, thus increasing the region of the phase variation.

The circuit diagram of FIG. 3 shows rectangular wave oscillator 14 having a differentiating circuit 15 connected to one pair of its output terminals, which generates an impulse from the leading edge of the rectangular pulse of the oscillator. This pulse controls a monostable multivibrator 16 whose pulse width is controlled by low-frequency oscillator 17. The differentiating circuit 18 connected to the multivibrator generates a new pulse from the trailing edge of the oscillations generated in the multivibrator, and this new pulse controls a second monostable multivibrator 19. The pulse width of the multivibrator 19 is so adjusted that the pulse durations and interruptions are of equal duration. The output amplifier and wave converter 21 delivers the current from multivibrator 19 to electrodes 9, 8 which are applied to the patient. Another output amplifier and converter 20 is connected to the other pair of output terminals of oscillator 14 to deliver current to electrodes 6, 7 applied to the patient. The two currents are phase-shifted in relation to each other by the amount of the pulse width of the multivibrator 16.

FIG. 4 is a circuit diagram showing the operating circuit of the circuit components of FIG. 3 in more detail. The circuit elements are well known and, as readily available articles of commerce, require no further description.

The rectangular wave generator 1b is an astable multivibrator which is connected to the differentiating circuit 15 by means of coupling transformer 33. The differentiating circuit 15 is connected to monostable multivibrator 16 by means of a coupling diode 22 to suppress the pulses of the second portion of the pulses delivered by differentiating circuit 15.

The pulse width of the monostable multivibrator 16 is controlled by the low-frequency oscillator 17 which is connected to multivibrator 16 via amplifier 23, the oscillator 17 being a Wien bridge generator. Potentiometers 31 control the frequency of the Wien bridge generator 17. If desired, the wave shape of the oscillations generated by the Wien bridge may be adjusted in a known manner by potentiometers (not shown).

The rectangular pulses generated by multivibrator 16 are differentiated in differentiating circuit 18 and are delivered to the monostable multivibrator 19 via diode coupling 24 which suppresses the ascending pulse portion. The latter multivibrator is so adjusted that the lengths of the pulses and interruptions are equal. Therefore, the phase position of the rectangular pulses varies rhythmically in respect of the rectangular pulses generated directly by the astable multivibrator. Since the monostable multivibrator 19 is always controlled by the astable multivibrator, proper operation is assured even at stationary phase shifting.

The rectangular oscillation is supplied from the multivibrator 19 to a driving stage 25 and amplified at output amplifier 21. By suitably dimensioning the switching elements of driving stage 25 and amplifier 21 the rectangular pulses may be converted into sine wave pulses. The output amplifier 21 is connected by means of a transformer coupling to the first pair of terminals 4, 5.

The rectangular pulses of astable multivibrator 16 are delivered via condenser 26 and a driving stage 27 to output amplifier 20. By suitable dimensioning the switching elements of the driving stage and the amplifier the rectangular pulses may be converted into sine wave pulses. The output amplifier 20 is connected by means of a transformer to the second pair of terminals 6, 7.

The two phase-shifted rectangular pulses are superimposed in a transformer coil 29, the generated interference current is amplified and supplied to an indicator lamp 30 which shows the interference voltage.

The circuit is supplied by a current source 23 which includes a Wheatstone bridge, condensers and a Zener diode 24 to maintain the voltage constant.

The operating circuit of FIG. 6 is a modified version of that of FIG. 2, differing therefrom in that phase shifting circuits 32', 32' are connected between each output of sine wave oscillator 1a and each electrode pair, the phase shifted signals being amplified by amplifiers

35, 35'. Function generator 33' controls the phase shifting potentiometers in the phase shifting circuits in the same manner as described in connection with FIG. 2. In this circuit arrangement, each phase shifter needs to effectuate only a 90° shift since this will encompass a phase shift region between 0° and 180° for the two phase shifters.

FIGS. 7 and 9 show the phases of a respective one of the phase shifters 32', 32' in the same manner as described in connection with FIG. 5.

FIG. 8 illustrates an operating circuit with electronic circuit elements. Since wave generator 1c is constituted by transistor 49, resonance circuit 44 and feed-back winding 45. Phase shifting means 32*a*, 32*a* are connected to the secondary 39', 39' of transformer 31' which is connected to one output of the sine wave generator (compare FIG. 2). Each phase shifting circuit 32*a* again comprises a condenser 40' and an adjustable resistance constituted by field effect transistor 46. Function generator 33*a* rhythmically controls the transistors 46, 46 to change the resistance thereof rhythmically. Resistances 47, 47 transmit the biasing potential from terminal 18 to the transistors.

FIGS. 10 and 11 show an embodiment of the apparatus wherein four pairs of electrodes are arranged for application to a patient so as to provide a multi-phase treatment for the patient's body. As shown, sine waves from oscillator 1d are transmitted to two pairs of electrodes 6, 7 and 8, 9 as well as two additional pairs of electrodes 50, 50 and 51, 51, the output signals from the oscillator being phase shifted by respective phase shifting circuits 32*b* connected between the oscillator and each of the four pairs of electrodes. Function generator 33*b* controls the phase shifting circuits so that each circuit produces a different phase shift, as in the embodiments of FIGS. 6 and 8, the phase shifted signals again being amplified by amplifiers 35, 35', each of the four amplifier feeding an amplified phase-shifted signal to a respective one of the four pairs of electrodes. The phase shifting circuits may be those illustrated in FIG. 8, for example.

FIG. 11 illustrates the phase shift control for the four circuits to obtain different phases in each circuit. The two integrated analog amplifiers 52, 53 form a triangular function generator, different direct current voltages being added to the control voltage of this generator at connection 31 receiving these voltages from resistors 55, 56 and resistance controls 54. This produces triangular voltages at control signal output points 57, 58, 59, 60 which have added thereto different direct current voltages.

If desired, the phase shifting circuits may be differently dimensioned whereby the initial output signal phases are different so that the function generator 33b may be in parallel circuit with the phase shifting circuits 32b.

FIG. 12 shows the arrangement of the four pairs of electrodes, the electrodes of each pair being substantially diametrically opposite each other in respect of a common point of intersection where the current density is multiplied so that an intensive electrical treatment is obtained in depth at a desired point within a patient's body, the amplitudes of the current at the respective electrodes being uniform.

In the operating circuit of FIG. 13, the phase shifting of the output signal from oscillator 1e to the pair of electrodes 8, 9, via amplifier 35', comprises a conventional bucket brigade delay line device **63** and an impulse generator whose frequency is controlled by function generator 33c. The impulse generator consists essentially of a multivibrator constituted by transistors **64** and **66**, the frequency-controlling resistances being formed by transistors **65** and **67** which, in turn, are connected to generator *33a* at **70**, the generator controlling the resistances and thus rhythmically changing the frequency of the impulse generator **64, 66**. As is known, bucket storage devices store analog signals, the storage time depending on the frequency of the impulse generator. In this manner, a phase change is produced between the input signal at input **71** of the phase shifting circuit and the output signal at output **62** thereof, this change being linearly proportional to the frequency of the impulse generator. Thus, a rhythmic change in the frequency of the impulse generator produces a rhythmic phase change.

In the operating circuit of FIG. **14**, the phase shifting is effected by a transductor or magnetic amplifier arrangement. Thus, the sine wave signal coming from oscillator **1f** is transmitted to a bridge circuit consisting of three resistors **75** and the transductor or magnetic amplifier means **73, 74**. A second winding **76, 76** controlled by function generator **33d** pre-magnetizes the inductors **73** and **74** differently so that the inductance of the inductors is rhythmically changed by generator *33d*. This produces a phase-shifted output signal which is transmitted to amplifier **35'** for electrodes **8, 9** while the original signal is transmitted directly from oscillator **1f** to amplifier **35** for electrodes **6, 7**. The vector diagram of this circuit is similar to that of FIG. **5**.

Finally, FIG. **15** shows a purely electromechanical phase shifting means. In this embodiment, the phase of the output signal from oscillator **1***g* to electrodes **8, 9** is shifted by an arrangement equivalent to a three-phase motor, the stator having three windings **77, 78**, 79 which receive the output signal from sine wave generator **1***g*, the third phase winding **78** receiving the signal from the generator via condenser **81**. A fourth winding **80** is rotatably mounted in the rotor space and produces a phase-shifted output signal which is transmitted to amplifier **35'** of electrodes **8, 9**. The phase depends on the angular position of coil **80** and this may be rhythmically changed by motor **33***e* driving the coil. Of course, the coil may also be rotated by an electronic 3-phase sine wave generator, the principle of operation being the provision of a rotary coil within the field provided by surrounding three surrounding coils. Thus, the same voltage is induced in the fourth, rotary coil **80** in each angular position thereof. Only the phase of the voltage is changed in dependence on this angular position.

It will thus be appreciated that a variety of phase shifting means may be devised by those skilled in the art and, depending thereon, the oscillator providing alternating current to the pairs of electrodes may generate rectangular or sine waves. What is essential is that the phase of the current receiving from the osillator by one pair of electrodes is shifted in respect to that of the other pair of electrodes.

While the invention is particularly useful in electrotherapy, it may be applied whenever it is desired to produce a beat or heterodyne frequency. For instance, the apparatus may be used to heat or melt metallic work pieces at selected locations, particularly in their interior. It may also be useful in signal transmissions, in which case the stable and phase-modulated oscillations may be transmitted over two independent transmission paths and then brought into interference in the receiver. In this manner, the modulation value is available in the receiver as amplitudemodulated value so that the modulation value may be reconstituted by simple demodulation and disturbances in the transmission path may be eliminated at the receiver by limiting the amplitude.

What is claimed is:

1. Apparatus for producing an interference signal at a selected location comprising, in combination, oscillator means for furnishing an oscillator output signal having a determined frequency and a reference phase; phase shift means connected to said oscillator means cyclically varying the phase of said oscillator output signal, thereby furnishing a phase-shifted oscillator output signal; first electrode means connected to said oscillator means for creating a first current having said determined frequency at said selected location in response to said oscillator output signal; and second electrode means connected to said phase shift means for creating a second current having said determined frequency and a phase varying cyclically with respect to the phase of said first current at said selected location in response to said phase-shifted oscillator output signal, whereby interference between said first and second currents creates said interference signal at said selected location.

2. Apparatus as set forth in claim **1**, wherein said oscillator means comprise a sine wave oscillator having a first and second output each for furnishing said oscillator output signal; and wherein said phase shift means comprise a first phase shift circuit including a capacitor and a variable resistor connected to said second output, and means for cyclically varying the resistance of said variable resistor.

3. Apparatus as set forth in claim **2**, wherein said first and second electrode means respectively comprise a first and second amplifier each having an output, and a first and second pair of electrodes respectively connected to said output of said first and second amplifier.

4. Apparatus as set forth in claim **3**, wherein said phase shift means further comprise an additional phase shift circuit having a capacitor and a variable resistor interconnected between said oscillator output and said first electrode means, and means for cyclically varying the resistance of said variable resistor in said additional phase shift circuit in the direction opposite to the variation of resistance of said variable resistor in said first phase shift circuit.

5. Apparatus as set forth in claim **1**, wherein said oscillator means comprise rectangular wave generator means for furnishing a rectangular wave having leading edges each indicative of the start of a cycle; and wherein said phase-shift means comprise delay means connected to said rectangular wave generator means for furnishing a trigger signal after a variable time delay following each of said leading edges, and second wave generator means connected to said time delay means for furnishing a cycle of a second wave in response to each of said trigger signals, whereby said second wave has the same frequency but a varying phase shift relative to said rectangular wave.

6. Apparatus as set forth in claim **5**, wherein said second wave generator means comprise pulse furnishing means for furnishing a pulse in response to each of said trigger signals.

7. Apparatus as set forth in claim 6, wherein said time delay means comprise first differentiating circuit means connected to said rectangular wave generator means for differentiating said rectangular wave and furnishing first trigger signals, each indicative of one of said leading edges; first monostable multivibrator means having a trigger input connected to said first differentiating circuit means and a control input, for furnishing a delay pulse having a pulse width varying as a function of the amplitude of a control signal applied at said control input in response to each of said first trigger signals; and low frequency oscillator means for furnishing a low frequency control signal to said control input of said first monostable multivibrator means, whereby each of said delay pulses has a trailing edge occuring at a varying time delay with respect to said leading edges of said first rectangular wave; second differentiating circuit means connected to said first multivibrator means for differentiating said delay pulses and furnishing second trigger signals in response to said trailing edges of said delay pulses; and wherein said pulse furnishing means comprise second monostable multivibrator means having a trigger input connected to said second differentiating circuit means, for furnishing a pulse having a determined pulse width in response to each of said second trigger signals.

8. Apparatus as set forth in claim 1, wherein said phase shift means comprise bridge circuit means having input terminals connected to said oscillator means and output terminals connected to said second electrode means, and magnetic amplifier means having output windings connected in an arm of said bridge circuit and having input windings, and means coupled to said input winding for applying a cyclically varying current thereto, thereby cyclically varying the inductance of said output windings and the phase of the signal at said output terminals of said bridge circuit.

9. Apparatus as set forth in claim 1, wherein said phase shift means comprise a three phase stator connected to said oscillator means, a rotor connected to said second electrode means, and means for continuously rotating said rotor relative to said stator.

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