Jan. 13, 1970 L. J. BARBARA 3,489,152

ELECTROTHERAPEUTIC APPARATUS WITH BODY IMPEDANCE-SENSITIVE INTENSITY REGULATION

Filed April 18, 1967 2 Sheets-Sheet 1

Fig. 1.

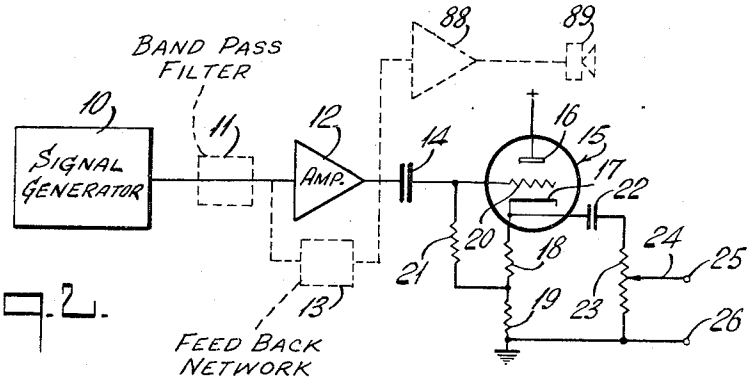

Fig. 2.

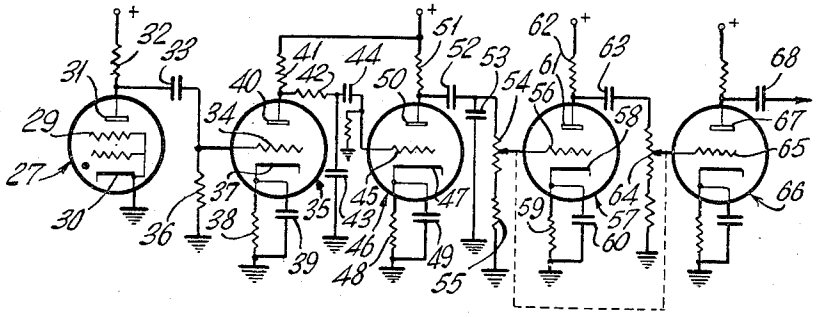

Fig. 4.

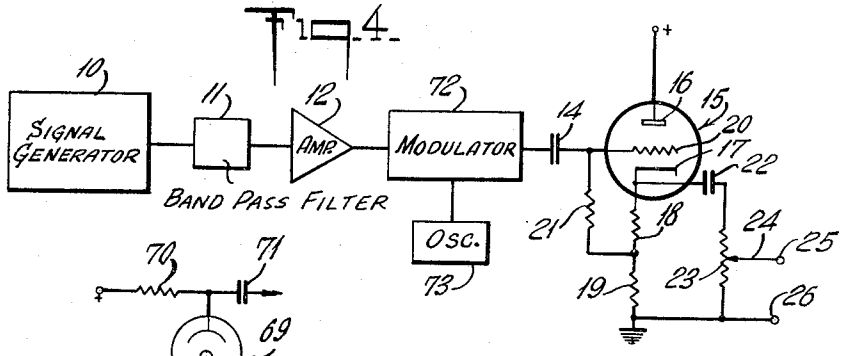

Fig. 3.

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Fig. 5.

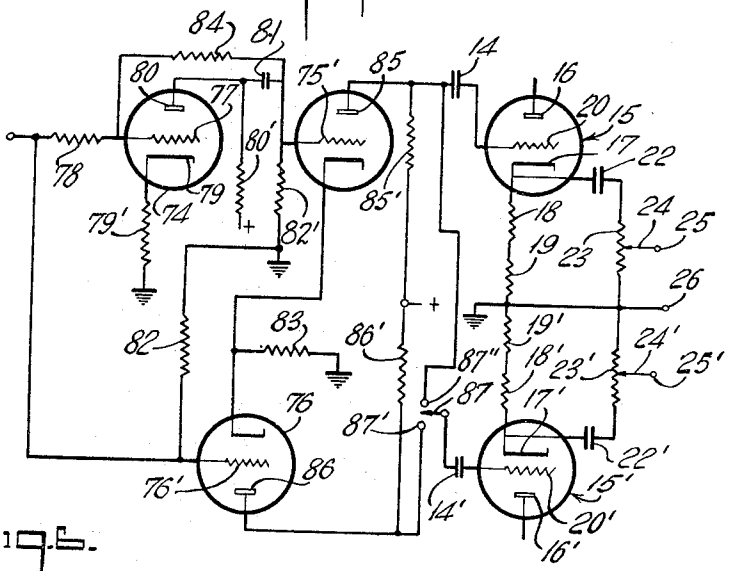
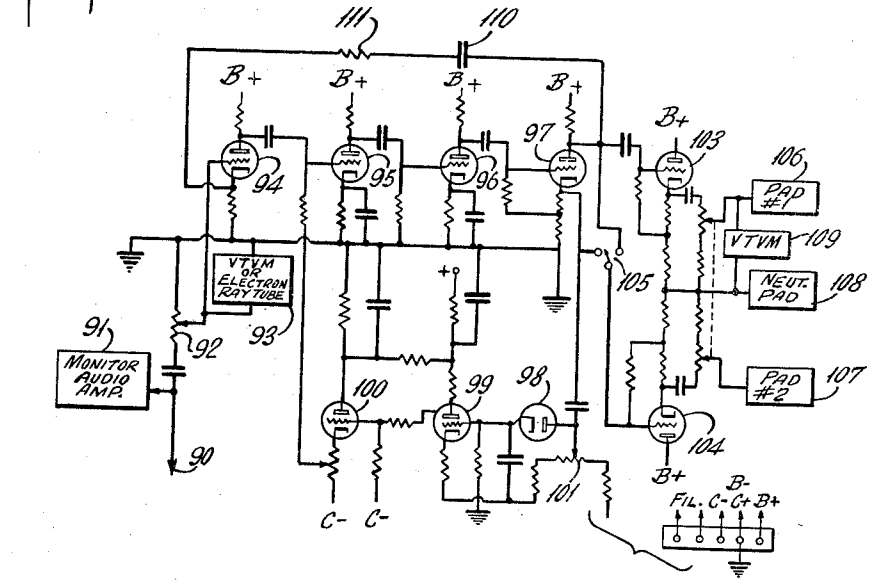


Fig. 6.



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ELECTROTHERAPEUTIC APPARATUS WITH BODY IMPEDANCE-SENSITIVE INTENSITY REGULATION

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U.S. Cl. 128—422 5 Claims

ABSTRACT OF THE DISCLOSURE

An electrotherapeutic device embodying means for generating random, infrasonic and other varying signals, amplifying said signals, and applying the amplified signals to the human body for diagnostic and therapeutic purposes. The intensity of the applied signals is controlled by means responsive to changes in the impedance of the patient's body.

This invention relates to electrotherapy and more specifically to a method and system for generating low intensity currents and appplying them to the body for diagnostic and therapeutic purposes.

The direct or galvanic currents are primarily for electrolytic treatment of body tissues by effecting more rapid and positive introduction of drugs and medicines into the body while the alternating and interrupted currents have been used for the diagnosis of neuromuscular disorders. In electrodiagnosis of this character, it is essential that the desired effects be produced with the minimum current and of course minimum discomfort to the patient. While some success has been achieved in electrodiagnostic methods of this character, the instability, unpredictable patient response, the possibility of severe nerve damage because of uncontrollable conditions and the severely limited usefulness of such equipment has led physicians to avoid its general use and rely on other alternative procedures.

It has been found that neuromuscular responses to electric currents vary with the character of such current and that properly generated currents can be used not only to diagnose neuromuscular disorders but also for therapeutic purposes while at the same time providing a simplified and rapid treatment in a completely safe manner. Accordingly, one object of the invention resides in the provision of low current therapeutic apparatus for generating purely random current variations that will produce more effective nerve stimulations without the danger encountered in the utilization of currents of the order of 50 to 100 milliamperes heretofore employed. Tests have indicated that if subliminal stimuli that normally of themselves would not produce a response, when these stimuli follow each other within a certain time a response is obtained. The most effective rate of such stimuli has been found to be in the range of infrasonic frequencies and generally of the order of 7 to 15 cycles per second with both the amplitude and occurrence being at a random rate in which case excellent stimulation is provided with currents of the order of 5 or 6 milliamperes or less. Thus if desired deep seated nerves can be stimulated without damaging the shallower nerves and without material patient discomfort. It therefore follows that this improved nerve stimulating apparatus and procedure opens avenues of therapy not heretofore available and that are of particular advantage to endocrinologists in correcting glandular disorders that very often form the basic cause of other more serious diseases.

Another important factor in the use of electric currents for the stimulation of nerves resides in the coupling between the generator and the nerves to be treated. Conventional impedance and capacity coupling while effecting certain results have not afforded satisfactory current regulation because of substantially instantaneous metabolic changes of the body and resultant impedance variations. Since the body resistance or impedance is effectively in series with the generator, the current through the body will vary inversely with the body resistance. Another object of the invention therefore is to provide improved coupling means between an electric signal generator and the body that will instantaneously regulate the applied voltage in accordance with metabolic changes thus assuring stimulation at a predetermined level.

Still another object of the invention resides in the provision of electrotherapeutic apparatus for generating random stimuli for the stimulation of nerves wherein the intensity of the stimulating currents may be carefully and accurately controlled and wherein the amplitude range of the random pulses may be varied within predetermined limits.

A still further object of the invention resides in the provision of an improved method and apparatus for introducing electrical stimuli into the body for the stimulation of deep seated nerves without utilizing currents of a magnitude that will cause discomfort to the patient or adversely affecting those nerves closer to the surface of the body. Thus direct nerve stimulation is attained more safely and positively and the usefulness of electric energy for therapeutic purposes is greatly enhanced.

A further object of the invention is the provision of electrotherapeutic apparatus wherein two or more nerve stimulating currents may be simultaneously introduced into the body in like or different phases to effect beneficial results not attainable with prior apparatus.

Still another object of the invention resides in a new and improved electrotherapeutic apparatus and method of application of the stimuli produced thereby to the body.

The above and other objects and advantages of this invention will become more apparent from the following description and accompanying drawings forming part of this application.

In the drawings:

FIGURE 1 is a diagram of one embodiment of the invention with part thereof in block form and part thereof in circuit form.

FIGURE 2 is a circuit diagram of one form of signal generator in accordance with the invention.

FIGURE 3 is a modified form of a random signal generator useful in connection with the circuit shown in FIGURE 2.

FIGURE 4 is a diagram of still another embodiment of the invention for generating modulated nerve stimulation signals.

FIGURE 5 is a circuit diagram of still another embodiment of the invention, and

FIGURE 6 is a circuit diagram of still another embodiment of the invention.

Broadly, this invention contemplates the provision of an improved method and apparatus for the stimulation of nerves and utilizes signals of random frequency and amplitude that have been found to provide more effective diagnostic and therapeutic results with less discomfort to the patient. Moreover, because of the basic characteristic of the body structure these frequencies may be impressed on a higher frequency signal that will penetrate the body and be demodulated more effectively upon arrival at a nerve or nerves to be activated in the deeper tissue so that the random frequency will actuate or stimulate the nerves in the usual manner. This procedure enables the stimulation of deep seated nerves with negligible current thus avoiding considerable discomfort on the part of the patient as well as adverse effects on nerves that are closer to the body

surface. In addition, means are provided for insuring uniform transmission of energy into the body notwithstanding ing metabolic changes which constantly vary the body impedance. One embodiment of the invention for the attainment of these ends is illustrated in FIGURE 1.

In this figure, **10** denotes a signal generator adapted to produce a signal composed of random frequencies at random intensities. Such a signal generator preferably comprises a suitable noise source such as that obtained through the medium of a gaseous electronic tube that will be described in greater detail as the description proceeds.

The output of this signal generator is fed to an adjustable filter **11** so that different frequency groups preferably in the vicinity of the infrasonic range may be selected as required. One frequency group that has been found to be particularly effective in the stimulation of nerves is the range of 7 to 15 cycles per second though good results are obtainable with frequencies as low as one-half cycle per second. It will be observed that inasmuch as this group of frequencies is selected from a source of randomly varying energy that the occurrence of the several frequencies within this group and their amplitude will be entirely random.

The output of the band pass filter **11** is fed through a conventional amplifier **12** to increase the signal level. If desired, a feedback network **13** shown in dotted outline may be connected about the amplifier **12** in order to provide a controlled output signal in the manner well-known in the art. The output of the amplifier **12** is coupled through a condenser **14** to a vacuum tube **15** connected as a cathode follower for impression of the signal between two points of the body. More specifically, the plate **16** of this cathode follower is connected to a regulated source of potential, while the cathode **17** is connected through a pair of resistors **18** and **19** to ground. The grid **20** is coupled to the condenser **14** and through a grid return resistor **21** to the junction of the cathode resistors **18** and **19**. The output from the cathode follower cathode **17** is taken off through a condenser **22** and applied to one side of a potentiometer **23**. The adjustable tap **24** of the potentiometer is connected to a positive electrode terminal **25** while the negative electrode **26** is connected to ground as illustrated.

It will be observed that in the use of the cathode follower in this manner as the body impedance changes it will reflect a change in the load on the cathode follower between the cathode **17** and ground since the load circuit for the tube **15** includes all the elements between the cathode **17** and ground. This change in body resistance as a result of metabolic changes will reflect a corresponding change in the AC potential of the cathode **17**. If the increase is in a positive direction, the cathod load will increase in impedance with the result that the cathode becomes more positive. This reacts on the operation of the tube **15** by effectively increasing the grid bias or the negative potential between the grid **20** and the cathode **17**. This decreases in the plate current through the cathode load and tends to maintain the voltage across the potentiometer and hence the voltage between the terminals **25** and **26** at a constant level. The nature of this regulatory action is substantially instantaneous and can be controlled by relative values of the cathode resistors **18** and **19** since the cathode resistor **18** determines the bias on the tube and the resistor **19** merely constitutes a load resistor for attaining an increased signal across the potentiometer **23**. In addition, the maximum current through the body is limited by the maximum output available from the tube before saturation.

FIGURE 2 illustrates one form of a signal generator and band pass filter corresponding to the elements **10** and **11** of FIGURE 1. This circuit also includes means for controlling the range of random amplitude desired in the stimulating signal. More specifically, the random signal generator includes a gaseous tube **27** connected as a diode with the grids **28** and **29** coupled directly to the cathode **20** which in turn is connected to ground. The plate **31** is connected through a resistor **32** to a source of positive potential as illustrated. The application of a potential across this diode will produce a randomly varying signal having sub-sonic, sonic and super-sonic frequencies at the plate **31** and this signal is fed through a condenser **33** to the grid **34** of an amplifier tube **35**. The grid is returned to ground through a resistor **36**. The cathode **37** of the tube **35** is connected to ground through a parallel connected resistor **38** and condenser **39** while the plate **40** is coupled through a resistor **41** to a source of positive potential. The plate circuit of the tube **35** includes a filter comprising a resistor **42** and a condenser **43** between the plate and ground for attenuating the high frequencies and forms a portion of a band pass filter **11** as shown in FIGURE 1. The junction resistor **42** and condenser **43** is fed through a coupling condenser **44** to the grid **45** of a second amplifier tube **46**. This tube has its cathode **47** connected to ground through a resistor **48** and condenser **49** and its plate **50** is connected through a resistor **51** to a source of positive potential. The output circuit from the plate **50** of the tube **46** includes a pair of condensers **52** and **53** connected in series between the plate **50** and ground and the junction of these condensers is fed through an adjustable potentiometer **54** and a series resistor **55** to ground. This arrangement will maintain the response of the tube **46** in the center of a desired band of frequencies determined by the value of the condensers **43**, **52**, **53**, and **63** and associated resistors. The condensers **43** and **53** serve to bypass the higher frequencies while condensers **33**, **44**, **52**, and **63** tend to attenuate the lower frequencies. In this way good filtering action can be attained to limit the range of frequencies to any desired band in the infrasonic range.

The output of the noise generator and filter thus far described is fed from a slidable contact on a potentiometer **54** to the grid **56** of the amplifier tube **57**. This tube has its cathode **58** connected to ground through the resistor **59** and condenser **60** while the plate **61** is connected through a resistor **62** to a source of positive potential. The tube **57** is preferably arranged to operate as a so-called clipper or compressor and this is accomplished by applying a very low positive voltage to the resistor **62** so that a very small signal applied to the grids **56** will cause the tube to reach a maximum plate current point and thus limit the output signal from the plate **61**. The output of this clipper is fed through a condenser **63** to a potentiometer **64**, and a slidable contactor on this potentiometer is fed to the grid **65** of a tube **66** connected as a conventional amplifier with the output being obtained from the plate **67** through a condenser **68**. The potentiometers **54** and **64** are preferably mechanically coupled one to the other and are arranged to be simultaneously operated in reverse directions by a single control knob. In this way the output appearing at the condenser **68** will remain substantially constant for all adjustments. For example, as the potentiometer **54** is adjusted to provide increased signal on the tube **57**, the potentiometer **64** is decreased to reduce the signal applied to the grid **65** of the tube **66**. Thus the output amplitude is maintained constant but the average variation in random amplitude is reduced. Similarly as the potentiometer **54** is adjusted to reduce the signal level to the tube **67**, the potentiometer **64** simultaneously increases the signal level to the tube **66**. This reduces the amount of clipping and enables a relatively wide range of amplitudes to be obtained in the output signal. This procedure has been found to be effective in regulating nerve stimulation since random peak pulses can be varied in intensity depending on specific requirements. If desired the band pass filters used in connection with tubes **35** and **46** can be of course be made adjustable nature so that the range in frequencies also can be selected at will.

An alternate noise generator that may be used in place of the tube **27** is shown in FIGURE 3. Here a gaseous

voltage regulator tube **69** is connected in series with a resistor **70** and across a suitable supply of positive potential and the output signal is obtained from the junction of the resistor **70** and the tube **69** through a coupling condenser **71** for the purpose of blocking the direct current applied to the tube.

An alternate embodiment of the invention is shown in FIGURE 4 and includes a signal generator **10**, a band pass filter **11** and an amplifier **12** as described in connection with FIGURES 1 and 2. The output of the amplifier **12**, however, is fed in this instance to a modulator **72** that is interconnected with a suitable oscillator **73**. The oscillator signal after modulation by the random frequencies attained from amplifier **12** is fed through a coupling condenser **14** to the cathode follower output tube **15** which functions precisely as the tube **15** of FIGURE 1 and like numerals have been applied to like elements of each figure. The oscillator **73** is preferably arranged to produce a signal upwardly of 8,000 to 10,000 cycles per second and may even be in the super-sonic range. With this arrangement, it has been found that the modulated signal fed into the body will be rectified or demodulated and thus effect the desired nerve stimulation. Demodulation eliminates the high frequency signal and leaves only the relatively low frequency random signal to effect the desired stimulation. This procedure enables more effective transmission of the stimulating source to the nerve and permits reduced currents to be used in order to effect the desired degree of stimulation. Consequently the patient experiences materially reduced discomfort and possible damage to nerves that may be closer to the surface and in the path of the stimulating pulse is avoided.

In certain applications, it is often desirable to stimulate nerves in the body with two signals simultaneously and in some cases it is desirable that these signals be in phase one with the other while in other cases it is desirable to have them out of phase. One method for the attainment of this end is illustrated in FIGURE 5. In this figure, the tube **74** operates as a phase inverter in conjunction with the tubes **75** and **76**. The output signal from amplifier **12** or the modulator **72** is fed to the grid **77** of tube **74** through a resistor **78** and directly to the grid **76'** of tube **76**. The cathode **79** of tube **74** is connected to ground through a resistor **79'** while the plate **80** is connected to a positive potential through a resistor **80'**. The output signal is obtained from tube **74** by condenser **81** and fed to the grid **75'** of tube **75**. By reason of the interposition of tube **74**, the grids of tubes **75** and **76** will now be 180° out of phase. Resistors **82'** and **82** return these grids to ground while the cathodes of the tubes **75** and **76** are connected to ground through the resistor **83**. In order to maintain the signal levels at grids **75'** and **76'** uniform, a feed back resistor **84** is connected around tube **74** to decrease its gain to unity. The plates **85** and **86** of tubes **75** and **76** are connected to a positive potential through resistors **85'** and **86'**. The cathode follower output tube **15** and associated circuit is identical to that shown in FIGURE 1 and is coupled to the plate **85** of tube **75** by a suitable blocking condenser. A second cathode follower output tube **15'** is identical to the tube **15** and connected in a similar manner. Accordingly, elements in the circuit associated with the tube **15'** are denoted by primed numerals corresponding to the numerals denoting the several components in the circuit associated with the tube **15**. The grid **20'** of the tube **15'** is connected to the movable arm **87** of a single pole double throw switch. One fixed contact **87'** of this switch is to the plate **86** of tube **76** while the other fixed contact **87''** is connected to the plate **85** of tube **75**. With the movable element **87** of the switch on contact **87'** the tube **15'** receives its signals from the plate **86** of the tube **76** while the tube **15** receives its signals from the plate **80** of the tube **75**. In this way the signals appearing at the terminals **25** and **25'** will be 180° out of phase. When the switch on **87** is thrown to the fixed contact **87''** the grids **20** and **20'** are connected in parallel to the plate **85** of tube **75** and the outputs **25** and **25'** will be in phase.

In many instances it is found to be highly desirable to enable the patient to hear the nature of the signals being fed into the body during the treatment. This may be readily accomplished by the arrangement shown in FIGURE 1 and comprises a suitable amplifier **88** preferably coupled to the output of the amplifier **12**. This amplifier **88** in turn drives a loud speaker **89** adapted to reproduce the random signals used in the treatment. It is of course apparent that the amplifier **88** would be provided with suitable gain controls so that the volume of the sound emanating from the speaker **89** can be controlled at will.

FIGURE 6 illustrates another embodiment of the invention wherein other sources of signals may be employed if desired. In this figure the input terminal **90** may be connected to signal sources producing random variations suitable for this purpose as, for instance, random or repetitive sounds sometimes occurring in music. The monitor **91** may be utilized to listen to the signals being employed and may include either a set of head phones or a loud speaker. The input control device **92** may take the form of a potentiometer and a vacuum tube boltmeter **93** or its equivalent is preferably used to indicate the input level. The amplifier tubes **94**, **95**, and **96** are preferably voltage amplifiers for increasing the magnitude of the input signal in the conventional manner. The tube **97** which may be similar to the tubes **94** to **96**, inclusive, is connected as a phase inverter to obtain two out of phase signals. If desired, any other suitable procedures may be employed for the attainment of this end. In order to stabilize the operation of the amplifier tubes **94** to **96** and provide means for compressing the output signal, a feedback circuit including a diode **98** and a pair of amplifier tubes **99** and **100** are provided and interconnected between the tube **97** and the grid of the tube **95**. Compression control is effected by the compression potentimeter **101**. The cathode follower output tubes **103** and **104** are connected to the output tube **97** by means of a switch **105** to produce either out of phase or in phase signals at the pads **106** and **107** with respect to a neutral pad **108**. A vacuum tube voltmeter **109** may be provided between the pads **106** and **108** to provide an output level indication. In order to stabilize the operation of the amplifier, a conventional feed back circuit employing condenser **110** and a series resistor **111** may be employed between the plate of the tube **97** and the cathode of the tube **94**. It is also apparent that the circuit shown in FIGURE 1 may also include means for controlling the amplitude range as well as the frequency range of the signals delivered to the pads **106** and **108** in the manner described in the previous figures.

While several embodiments of the invention have been illustrated and described for the purpose of illustrating the advantages and operation of the invention, it is apparent that other modifications, alterations and changes may be employed without departing from the true scope and spirit thereof as defined by the appended claims.

What is claimed is:

1. Electrotherapeutic apparatus comprising a signal generator, an amplifier interconnected with said generator, and means connected with said amplifier for applying the amplified signal to the body to be treated including an impedance variable in response to the impedance of said body to automatically regulate the signal intensity, the last said means including a phase inverter, two cathode followers and means coupling said cathode followers with said phase inverter to produce in phase and out of phase operation of said cathode followers.

2. In electrotherapeutic apparatus according to claim **1** including a filter connected with said amplifier, said filter being tunable to select a band of frequencies in the infrasonic range.

3. In electrotherapeutic apparatus according to claim

1 including means connected with said amplifier for limiting amplitude variations in said amplifier to predetermined amplitude ranges while maintaining a constant maximum level.

4. Electrotherapeutic apparatus according to claim 1 including a high frequency oscillator, a modulator interconnected with said oscillator, and connections between said oscillator and amplifier for producing a modulated high frequency signal.

5. Electrotherapeutic apparatus according to claim 1

wherein said signal generator produces signals in the range of seven to eleven cycles per second.

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