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[54] **ELECTRO-MEDICAL STIMULATOR SYSTEM**

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[52] **U.S. Cl.** **128/423;** 128/423

[51] **Int. Cl.²** **A61N 1/36**

[58] **Field of Search** ..... 128/419 C, 419 E, 419 P, 128/419 PG, 419 PS, 421, 422, 423, 2.05 R, 2.06 R, 2.1 R

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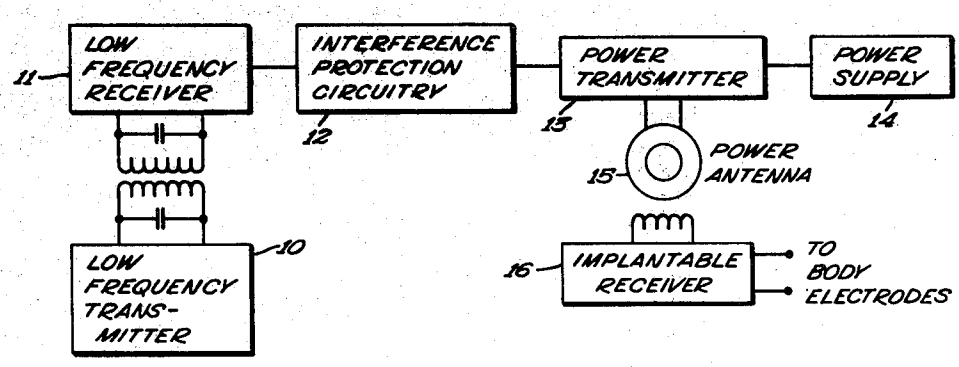
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[57] **ABSTRACT**

A body stimulation system including a remote low frequency transmitter, a low frequency receiver, a power transmitter controlled by the low frequency receiver, and an implantable stimulator device with means for receiving signals from the power transmitter. The power signal is synchronized to the low frequency transmitter, and interference protection circuitry is included in the system. Special circuitry is also provided to decrease the effect of the spacial relationships between the power antenna and the implanted receiver.

7 Claims, 7 Drawing Figures



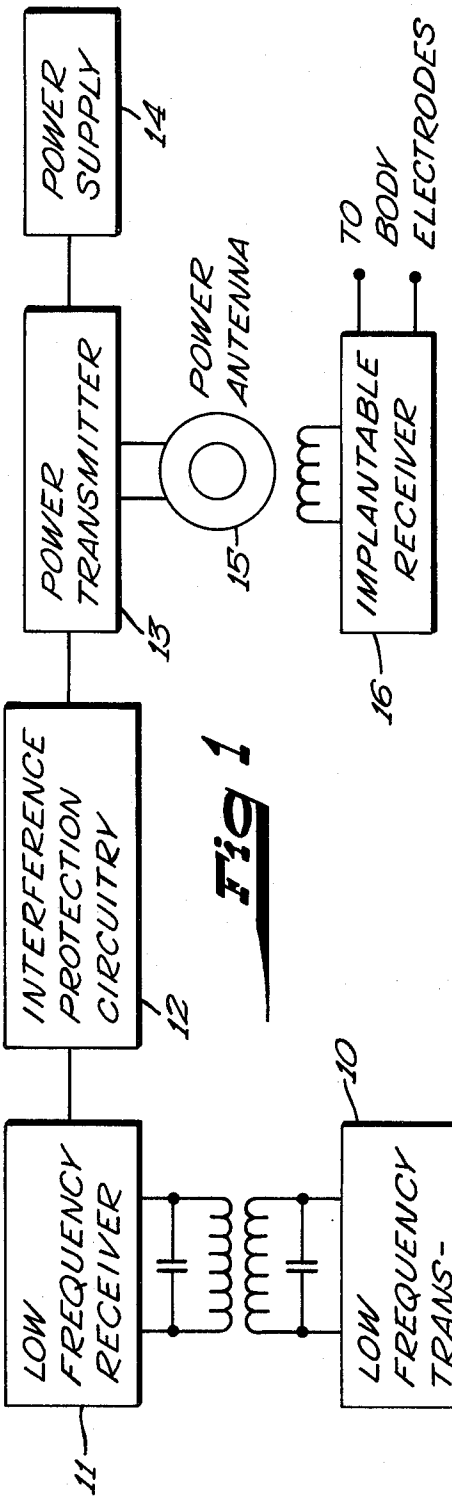

POWER SUPPLY
14
POWER TRANSMITTER
13
POWER ANTENNA
15
TO BODY ELECTRODES
IMPLANTABLE RECEIVER
16
INTERFERENCE PROTECTION CIRCUITRY
12
LOW FREQUENCY RECEIVER
11
LOW FREQUENCY TRANS-MITTER
10

Fig 1

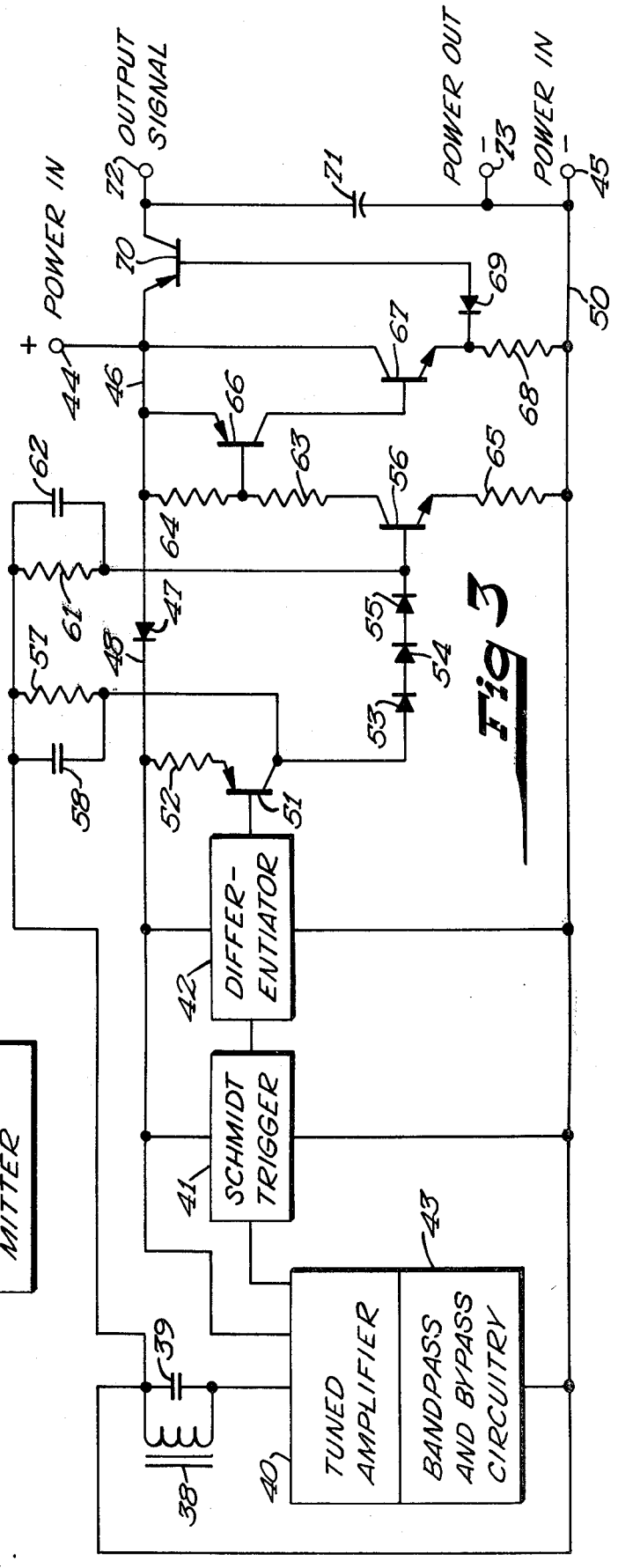
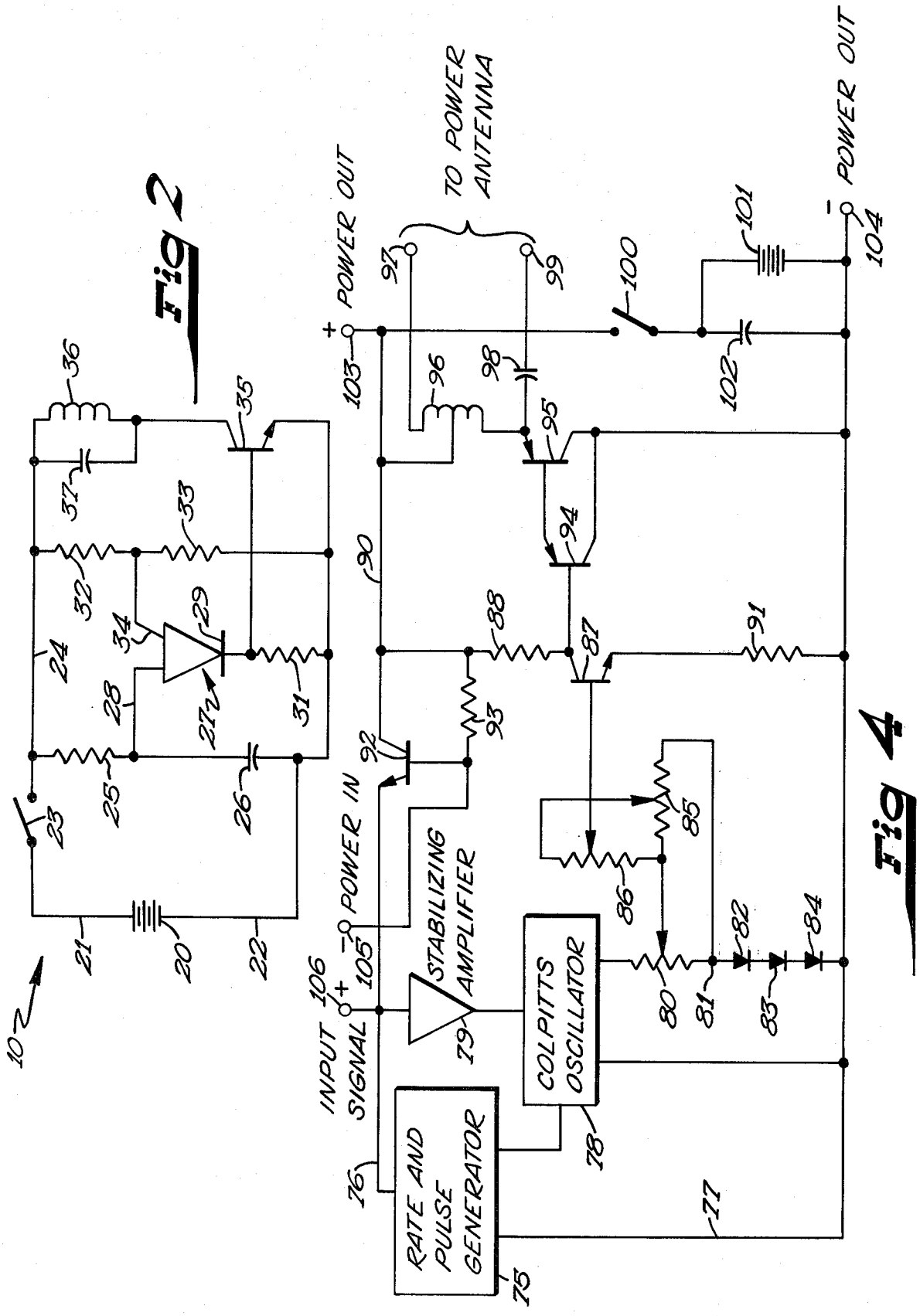

POWER IN
+
44
OUTPUT SIGNAL
72
POWER OUT
-
73
POWER IN
-
45
71
70
69
67
66
63
56
65
68
64
46
62
61
57
58
47
48
55
54
53
52
51
50
DIFFER-ENTIATOR
42
SCHMIDT TRIGGER
41
TUNED AMPLIFIER
40
BANDPASS AND BYPASS CIRCUITRY
43
39
38

Fig 3


Fig 2
Fig 4
10
20
21
22
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87
88
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
INPUT SIGNAL
+ POWER IN
- POWER IN
STABILIZING AMPLIFIER
COLPITTS OSCILLATOR
RATE AND PULSE GENERATOR
+ POWER OUT
TO POWER ANTENNA
- POWER OUT

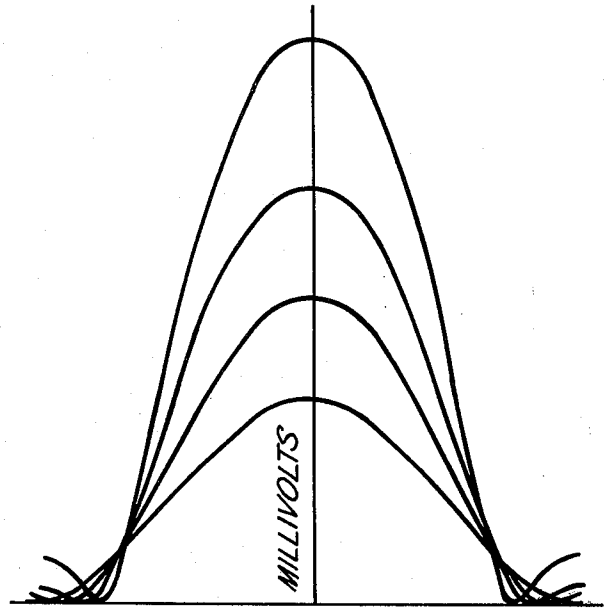


Fig 5a

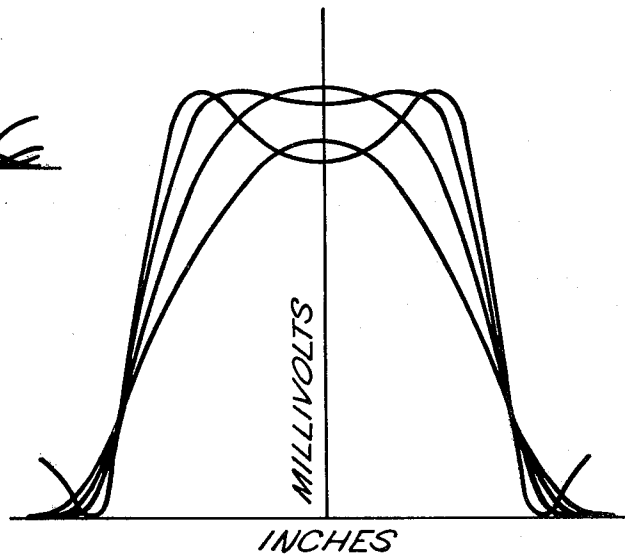


Fig 5b

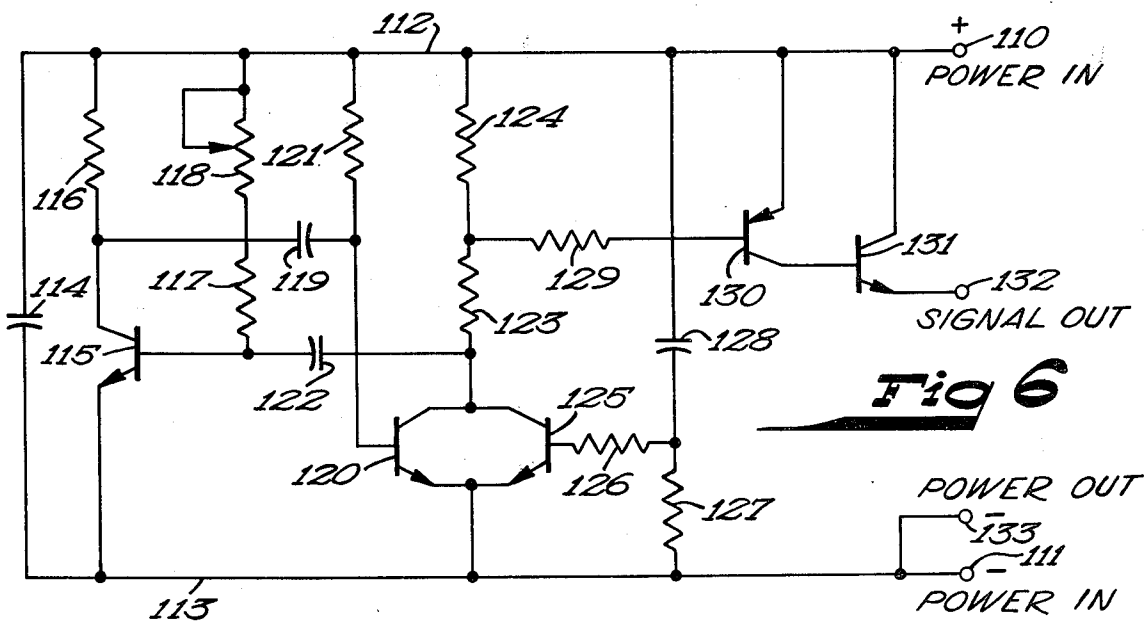


Fig 6

ELECTRO-MEDICAL STIMULATOR SYSTEM

BACKGROUND OF THE INVENTION

Implantable body stimulators exist in the prior art and are of many types and for many purposes. A particular function of the system of this invention is as an orthotic system, such as for stimulating the peroneal nerve to aid paraplegic patients. The prior art includes such orthotic systems including one described in "Development of Orthotic Systems Using Functional Electrical Stimulation and Myoelectric Control," UNIVERSITY OF LJUBLJANA, Faculty for Electrical Engineering, Project No. SRS-YUGO 23–68, Progress Report No. 2, Apr., 1970. The system described in that article has a remote transmitter which gives a high frequency signal burst. The signal is picked up by a high frequency receiver which then causes a power transmitter to emit a predetermined number of pulses, which are in turn picked up by an implanted stimulator.

The apparatus of this invention has advantages over the prior art, some of which derive from the use of the low frequency transmitter, including the ability to synchronize the stimulation signal with the remote transmitter signal, a decreased use of power, and an increased ability to block interference signals. The apparatus of this invention has further advantages over the prior art including structure for loading the power antenna to flatten the curve of the antenna field to avoid rapid changes due to minor spacial displacements between the power antenna and the implanted receiver.

SUMMARY OF THE INVENTION

Briefly described, the apparatus of this invention in its preferred embodiment comprises a low frequency electromagnetic transmitter which can be remotely located with respect to the portion of the body to be stimulated. The low frequency transmissions are picked up by an electromagnetic receiver which includes interference detection circuitry for removing unwanted noise signals. The receiver controls the output of a power transmitter which is connected to a power antenna adapted to be placed in spaced relation to an implanted power receiver which receives the power signals and in turn provides stimulation pulses to implanted electrodes connected to the portion of the body to be stimulated.

In the preferred embodiment, the system is in modular form and the low frequency receiver can be unplugged from the power transmitter which carries the power supply for the receiver-transmitter system. When the receiver is unplugged from the power transmitter, the transmitter will provide continuous stimulation signals. A cycler module is provided which may be plugged into the power transmitter in place of the low frequency receiver. The cycler module will provide control of the power transmitter such that the stimulation signals are turned on and off for adjustable periods of time.

Also provided in the power transmitter is a control comprised of three adjustable members whereby an attending physician can set the limits of maximum and minimum power for the stimulation signal, to assure that the patient is receiving benefit from the stimulation without undue discomfort; the patient is free to adjust a third control which will vary the power output between the maximum and minimum controls to the patient's feeling of greatest comfort.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of the system of this invention;

FIG. **2** is a schematic diagram of the low frequency transmitter of the apparatus of this invention;

FIG. **3** is a combined block and schematic diagram of the low frequency receiver and interference signal detector portion of the apparatus of this invention;

FIG. **4** is a combined block and schematic diagram of the power transmitter apparatus of this invention;

FIG. **5a** is a graph of a prior art antenna field plot;

FIG. **5b** is a graph of the power antenna field plot of the system of this invention; and

FIG. **6** is a schematic diagram of the cycler module of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. **1** there is shown a low frequency transmitter **10** which carries its own power supply and includes a switch by means of which a patient may cause operation of the transmitter from a remote portion of his body, for example by placing his weight on one foot or the other.

There is also shown a low frequency receiver **11** which is constructed to receive the low frequency signals from transmitter **10.** Preferrably, the low frequency range will be from about 2 kilohertz to approximately 10 kilohertz. Low frequency receiver **11** provides the received signals to interference protection circuitry **12** which will reject all signals which are not of the proper frequency, which do not have the proper pulse height and which do not have the proper pulse width. The output signal of circuitry **12** is provided to power transmitter **13** which is connected to power supply **14.** Supply **14** is connected to circuitry **12** and receiver **11** through transmitter **13.**

Power transmitter **13** provides radio frequency signals to power antenna **15** which is placed in space relation to an implanted receiver such as implantable receiver **16.** Receiver **16** is adapted to be connected to electrodes connected to the portion of the body to be stimulated, and receiver **16** will accept the RF signals from power antenna **15** and provide stimulation pulses to the electrodes.

Referring now to FIG. **2** there is shown a schematic of low frequency transmitter **10.** A power supply **20** has one terminal connected to a conductor **21,** and another terminal connected to a conductor **22.** Conductor **21** is connected to one terminal of a normally open switch **23.** The other terminal of normally open switch **23** is connected to a conductor **24.** A resistor **25** and a capacitor **26** are serially connected between conductors **24** and **22.** A programable unijunction transistor **27** has its anode **28** connected to a junction between resistor **25** and capacitor **26.** The cathode **29** of transistor **27** is connected through a resistor **31** to conductor **22.** A pair of resistors **32** and **33** are serially connected between conductors **24** and **22,** and the gate **34** of transistor **27** is connected to a junction between resistors **32** and **33.** The cathode **29** of transistor **27** is also connected to the base of a transistor **35.** The emitter of transistor **35** is connected to conductor **22.** A collector of transistor **35** is connected through a coil **36** to conductor **24.** A capacitor **37** is connected in parallel with coil **36.**

In operation, the circuitry operates in the manner of a relaxation oscillator utilizing the properties of the programable unijunction transistor. When switch **23** is closed, capacitor **26** will begin to charge through resistor **25**. When capacitor **26** has charged to a predetermined level dependent on the biasing at the gate **34**, transistor **27** will turn on causing a current flow through resistor **31** and a resultant turn on of transistor **35**. When transistor **35** turns on there will be a current flow through the tank circuit comprising coil **36** and capacitor **37**, thus transmitting the desired signals to be received by low frequency receiver **11**. The selected circuitry is designed to use a minimum of power and to provide a low frequency output, preferably in the range of 2 to 10 kilohertz.

Referring now to FIG. **3** there is shown a combined block diagram and schematic of low frequency receiver **11** and interference detection circuitry **12**. A receiving coil **38** is connected in parallel across a capacitor **39** which is connected to the input of a tuned amplifier **40**. Tuned amplifier **40** has internal bandpass circuitry **43**. Amplifier **40** is connected to a Schmitt trigger **41**. Schmitt trigger **41** is connected to a differentiater **42**. Blocks **40–43** represent circuitry well-known to those skilled in the art, and have been shown here in block diagram to facilitate understanding of the operation of the apparatus of this invention and avoid unnecessary description and extensive drawings.

Also shown in FIG. **3** are a positive power input terminal **44** and a negative power input terminal **45**. Terminal **44** is connected to a conductor **46** which is connected through a diode **47** to a conductor **48**. Conductor **48** is connected to each of blocks **40, 41** and **42**. Terminal **45** is connected to a conductor **50** which is connected to each of blocks **40, 41, 42** and **43**.

The output of differentiater **42** is connected to the base of a transistor **51**. The emitter of transistor **51** is connected to conductor **48**. The collector of transistor **51** is connected through a serial combination of diodes **53, 54** and **55** to the base of a transistor **56**. The collector of transistor **51** is also connected to a parallel combination of a resistor **57** and a capacitor **58** to conductor **50**. The base of transistor **56** is connected through a parallel combination of a resistor **61** and a capacitor **62** to conductor **50**.

The collector of transistor **56** is connected through a serial combination of resistors **63** and **64** to conductor **46**. The emitter of transistor **56** is connected through a resistor **65** to conductor **50**. A transistor **66** has its base connected to a junction between resistors **63** and **64**, its emitter connected to conductor **46** and its base connected to the base of a transistor **67**. The collector of transistor **67** is connected to conductor **46**, and the emitter of transistor **67** is connected through a resistor **68** to conductor **50**. The emitter of transistor **67** is also connected through a diode **69** to the base of a transistor **70**. The emitter of transistor **70** is connected to conductor **46**, and the collector of transistor **70** is connected through a capacitor **71** to conductor **50**. The collector of transistor **70** is also connected to an output signal terminal **72**. A negative power output terminal **73** is connected to conductor **50**.

In operation, the apparatus of FIG. **3** will receive signals from low frequency transmitter **10** at the tank comprising coil **38** and capacitor **39**. These signals are provided to tuned amplifier **40** where they will not only be amplified but where frequency detection will take place to prevent the passage of noise signals outside the tuned range of amplifier **40**. The signals will then be presented from amplifier **40** to Schmitt trigger **41**. Here pulse height detection takes place, for if the input pulses are not of sufficient magnitude they will not be able to turn on Schmitt trigger **41**. The output of Schmitt trigger **41** is a well-known pulse shape dependent on the length of time between the turn on of the Schmitt trigger and its turn off by the input pulses. These Schmitt trigger output pulses are differentiated by circuitry **42** which has the effect of pulse width detection to further eliminate noise signals. The output of differentiater **42** is presented to the base of transistor **51** which is connected as a current source. Diodes **53, 54** and **55** act as a threshold detector and will cause the turn on of transistor **56** when the charge on capacitor **58** has reached the threshold level of transistor **56**. Transistors **66** and **67** act as a complementary current driver, well-known to those familiar with the art, and transistor **67** will turn on when transistor **56** turns on. This in turn will cause transistor **70** to turn off thus providing an output signal at terminal **72**.

When the signal from low frequency transmitter **10** ceases, and no further input is provided to amplifier **40**, the lack of output at differentiater **42** will cause the turn off of transistor **67** to turn on transistor **70**. The signal to enable power transmitter **13** can be taken off terminal **72** or from the emitter of transistor **67**. If the signal is taken from terminal **72**, the transmitter **13** will be off during the time the low frequency transmitter **10** is transmitting. If the signal is taken from the emitter of transistor **67**, the transmitter **13** will be on during the time the low frequency transmitter **10** is transmitting. Thus, the output signal is synchronized to the input signal from low frequency transmitter **10**. It is important to recognize that the advantage of synchronization is offered in the apparatus of this invention with comparatively low power drain because of the use of the low frequency system. Prior art systems used high frequency and did not synchronize but merely used a burst from the remote transmitter to turn on the signal for a predetermined period of time. This was because of the significant power drain required to provide continuous high frequency signals from the remote transmitter. The synchronous signal has many advantages; for example, when the device is being used to help a paraplegic patient to walk, he can control his own gait through the synchronous method.

In the preferred embodiment of FIG. **3**, it has been found to be of great value to pot the circuitry in a substance resistant to vibration for minimizing magnetostrictive reaction due to mechanical shocks.

Referring now to FIG. **4**, there is shown a block diagram and schematic diagram of power transmitter **13** and power supply **14** of FIG. **1**.

A rate and pulse width generator **75** is connected between a positive power conductor **76** and a negative power conductor **77**. The output of generator **75** is connected to the input of a Colpitts oscillator **78** which is also connected to conductor **77**. A stabilizing amplifier **79** is connected between conductor **76** and oscillator **78**. Blocks **75, 78** and **79** are well-known to those familiar with the art and have been shown in block diagram form to avoid excessive description and drawings.

The output of oscillator **78** is connected through a potentiometer **80** through a junction **81**. Junction **81** is connected through a serial combination of diodes **82, 83** and **84** to conductor **77**. The wiper arm of potentiometer **80** is connected through a potentiometer **85** to

junction **81.** The wiper arm of potentiometer **80** is also connected through a potentiometer **86** to the wiper arm of potentiometer **85.** The wiper arm of potentiometer **86** is connected to the base of a transistor **87.** The collector of transistor **87** is connected through a resistor **88** to a positive power conductor **90.** The emitter of transistor **87** is connected through a resistor **91** to conductor **77.** A transistor **92** has its base connected through a resistor **93** to conductor **90,** its collector connected to conductor **90** and its emitter connected to conductor **76.** A transistor **94** has its base connected to the collector of transistor **87,** its collector connected to conductor **77** and its emitter connected to the base of a transistor **95.** The collector of transistor **95** is connected to conductor **77.** The emitter of transistor **95** is connected through a coil **96** to an output terminal **97.** The emitter of transistor **95** is also connected through a portion of coil **96** to conductor **90.** The emitter of transistor **95** is further connected through a capacitor **98** to an output terminal **99.** Terminals **97** and **99** are adapted to be connected to power antenna **15** as shown in FIG. **1.**

A power switch **100** has one terminal connected to conductor **90,** and the other terminal connected to the positive terminal of a power supply **101.** The negative terminal of supply **101** is connected to conductor **77.** A capacitor **102** is connected in parallel across supply **101.** A positive power output terminal **103** is connected to conductor **90,** and a negative power output terminal **104** is connected to conductor **77.** A negative power input terminal **105** is connected to the base of transistor **92.** An input signal terminal **106** is connected to conductor **76.**

To best understand the operation of the apparatus of FIG. **4,** it should be understood that the apparatus of this invention is intended in its preferred embodiment to be in modular form. Preferably, blocks **11** and **12** of FIG. **1** would be in a single module which would be plugged through standard connectors into a second module which would comprise blocks **13** and **14.** Therefore, power output terminal **103** of FIG. **4** would connect to power input terminal **44** of FIG. **3.** Power output terminal **104** of FIG. **4** would connect to terminal **45** of FIG. **3.** Power output terminal **73** of FIG. **3** would connect to power input terminal **105** of FIG. **4,** and signal output terminal **72,** or the emitter junction of transistor **67,** of FIG. **3** would connect to input signal terminal **106** of FIG. **4.**

Referring now to the operation of FIG. **4,** assume first that the two modules have not been plugged together. When switch **100** is closed, which can be manually done by the patient, power will be applied between conductor **90** and conductor **77.** Transistor **92** will be biased on and positive power will appear on conductor **76.** This will cause rate and pulse width generator **75** to operate, in the preferred embodiment at a rate of from **20** to **50** pulses per second. The output of rate generator **75** will be felt on Colpitts oscillator **78** to provide a current flow through potentiometer **80.** Stabilizing amplifier **79** serves to stabilize the amplitude of the system as supply **101** ages. The current flow through potentiometer **80** will be felt on potentiometers **85** and **86.** These three potentiometers comprise a unique circuit for setting an adjustable range for an individual patient using the system of this invention. Potentiometer **80** can be adjusted by an attending physician to set a maximum level for the power of the output signal. Potentiometer **85** can be used by the physician to set a minimum setting for the power of the output signal. Thereafter, the patient may have available to him the control of potentiometer **86** which will allow him to adjust the power of the output signal between the maximum and minimum settings. Therefore, he has full control over the entire range of potentiometer **86** to find the most comfortable setting for his own reactions to the stimulation signal but cannot adjust the signal to be above maximum, thus avoiding unpleasant sensations, or below minimum to a point where the signals would not cause the desired function.

The wiper arm of potentiometer **86** is connected to transistor **87** to provide the signal on the wiper arm of potentiometer **86** to the power amplifier combination of transistors **94** and **95.** The output of the power amplifiers will be felt across coil **96** and through capacitor **98** on the power antenna output terminals **97** and **99.** The function of coil **96** in the apparatus of this invention will be more fully described below in a discussion of FIGS. **5***a* and **5***b*.

It is apparent from the above description that the apparatus of FIG. **4** will continually provide stimulation signals when the module containing receiver **11** and circuitry **12** is not plugged into it. When the module is plugged in, not only is power from supply **14** provided to receiver **11** and enter interference protection circuitry **12** through the above described terminals, but the base of transistor **92** is connected to the negative power line through the connection of terminal **105** to terminal **73.** Thus, transistor **92** will be turned off and no positive power from conductor **90** will reach conductor **76.** The apparatus of FIG. **4** therefore stops providing stimulation signals until a signal appears at input terminal **106** in the manner described in the operation of FIG. **3** above.

From the above description of the operation of the circuitry shown in the drawings, it becomes apparent that when transmitter **10** is on, its signal turns off the stimulation signal, and when there is no signal from transmitter **10,** the stimulation signal is operable. This on-off relationship could be reversed, but has been chosen as described in the preferred embodiment to perform in the situation where the stimulator is implanted and connected to the peroneal nerve of a paraplegic patient and where switch **23** is located in the shoe of the patient. Thus, when the patient's foot is down the low frequency transmitter will be on and no stimulation will occur. However, when the patient raises his foot to step, switch **23** will open and transmitter **10** will turn off thus allowing stimulation. In the specific case described the stimulation will result from the lifting of the patient's foot to enable walking without dragging the foot.

One of the major problems in a patient used stimulation system, such as the apparatus of this invention, is that of spacial relationship between power antenna **15** and the receiving coil of receiver **16.** Two of the factors involved are the depth of the implant and the lateral displacement between the power antenna and the implanted receiver. As can be seen in the graph of the prior art antenna field of FIG. **5***a*, the voltage peaks sharply when there is no lateral displacement between the power antenna and the implanted receiver, however, when lateral displacement occurs, the voltage drops off sharply. This causes a problem as it is difficult for the patient to place and keep the external power antenna in the most desirable spaced relation to the implanted receiver.

To avoid this problem the apparatus of this invention includes circuitry which results in the antenna field shown in the graph of FIG. 5*b*. Here it is seen that the curve has been deliberately flattened and that lateral displacement of the power antenna from the implanted receiver has much less effect until the displacement becomes great.

The flattening of the curves as shown in FIG. 5*b* is accomplished through detuning. As can be seen in FIG. **4**, the apparatus of this invention does not use an output power oscillator which would result in the curves of FIG. 5*a*, but uses a power amplifier which is loaded with the receiver. The output tank is driven by a voltage source, which is preferable over a current source because with a current source the available voltage will not enable the output tank to have a lower impedance as desired. By loading the output power amplifier with the mutual conductance of the receiver, the desired result is achieved.

Reference is now made to FIG. **6**, which comprises a schematic diagram of a cycler module to be used with the apparatus of this invention. As described above, in this preferred embodiment the system is comprised of modules, and the cycler can be plugged into power transmitter **13** in place of receiver **11** and circuitry **12**. The purpose of the cycler of FIG. **6** is to enable a patient to exercise his muscles, for example, when he is bedridden. The effect of the cycler is to cause the stimulation signal from transmitter **13** to alternately turn on and off. Provision is made for varying the proportions between the on and off parts of the cycle.

Referring now to FIG. **6** there is shown a positive power input terminal **110** and a negative power input terminal **111**. When the cycler is plugged into transmitter **13**, terminal **110** will be connected to terminal **103**, and terminal **111** will be connected to terminal **104**. Terminal **110** is connected to a conductor **112** and terminal **111** is connected to a conductor **113**.

A capacitor **114** is connected between the conductors **112** and **113**. A transistor **115** has its emitter connected to conductor **113**, its collector connected through a resistor **116** to conductor **112**, and its base connected through a serial combination of a resistor **117** and a variable resistor **118** to conductor **112**. The collector of transistor **115** is also connected through a capacitor **119** to the base of a transistor **120**. The base of transistor **120** is also connected through a resistor **121** to conductor **112**. The base of transistor **115** is connected through a capacitor **122** to the collector of transistor **120**. The collector of transistor **120** is connected through a serial combination of resistors **123** and **124** to conductor **112**, and is directly connected to the collector of a transistor **125**. The emitters of transistors **120** and **125** are connected to conductor **113**. The base of transistor **125** is connected through a serial combination of a resistor **126** and a resistor **127** to conductor **113**. A capacitor **128** is connected from a junction between resistors **126** and **127** to conductor **112**. A resistor **129** is connected from a junction between resistors **123** and **124** to the base of a transistor **130**. Transistor **130** has its emitter connected to conductor **112**, and its collector connected to the base of a transistor **131**. The collector of transistor **131** is connected to conductor **112**, and the emitter of transistor **131** is connected to an output terminal **132** which connects to input signal terminal **106** of FIG. **4**. A negative power output terminal **133** is connected to conductor **113**, and when the cycler is plugged into transmitter **13**, power output terminal **133** will be connected to power input terminal **105** as shown in FIG. **4**.

It will be recognized by those skilled in the art that the circuitry shown in FIG. **6** comprises an astable multivibrator connected to amplifiers which provide the output signal. The astable multivibrator has a period which is controlled by adjustment of variable resistor **118**, which will vary the charging time of capacitor **122**, thus apportioning the on/off cycle of the astable multivibrator, and thus controlling the amount of time that a stimulation signal will be provided to the patient.

When the module of FIG. **6** is plugged into the apparatus of FIG. **4**, the connection of terminal **133** to terminal **105** will cause transistor **92** to turn off, and the input signal from terminal **132** will appear at terminal **106** to control the on off time of transistor **95** in the same manner as for the above description of the operation of the circuitry when the module including the apparatus of FIG. **3** was plugged into the apparatus of FIG. **4**. Therefore utilizing much of the same circuitry, the patient can be provided with the cycler module of FIG. **6** to provide him a capability for controlling the exercise of his muscles.

It will be apparent that what has been described specifically above is the preferred embodiment of the apparatus of this invention and that variations can be made therefrom without departing from the scope of the invention.

What is claimed is:

1. A body stimulation system comprising: first means adapted to be implanted in a body and including receiver means for receiving externally transmitted signals of radio frequency energy and means adapted to connect the receiver means to a portion of the body; second means adapted to be mounted external to the body for establishing an electromagnetic connection with said receiver means and including controlled radio frequency energy transmitter means for transmitting signals of radio frequency energy to the receiver means; third means for controlling the transmission of radio frequency energy from the second means, and including low frequency electromagnetic receiver means; fourth means including remote low frequency electromagnetic energy transmitter means for transmitting energy waves at a frequency in the range of approximately 2 kilohertz to 10 kilohertz, and including switch means connected to the low frequency transmitter means for controlling the operation thereof; and synchronizer means connected to the third means for turning the controlled radio frequency energy transmitter means on and off substantially coincident with a switching of the low frequency transmitter means between on and off states.

2. The apparatus of claim **1** in which the third means includes: protection circuit means connected between the low frequency receiver means and the second means and including frequency detection means, pulse height detection means and pulse width detection means, for blocking interference energy signals from effecting the second means.

3. The apparatus of claim **1** in which: the third means is potted in a substance resistant to vibration for minimizing magneto-strictive reaction in the third means due to mechanical forces striking the third means.

4. The apparatus of claim **1** including: cycler means for providing selectable series of control pulses to the second means for actuating the controlled transmitter means, said apparatus further including means for se-

lectively connecting one of said cycler means and said third means to said second means.

5. The apparatus of claim **1** in which the switch means includes: means for selectively providing a signal to actuate the low frequency transmitter means; and electrical time constant means connected to the switch means and the low frequency transmitter means for deactuating the low frequency transmitter means after the switch means signal has ended for a predetermined period of time.

6. The apparatus of claim **1** in which the second means includes: output voltage control means connected to the controlled transmitter means, and including means manually adjustable for setting a maximum voltage output level, means manually adjustable for setting a minimum voltage output level and means manually adjustable for selecting an output voltage between the maximum and minimum set levels.

7. The apparatus of claim **1** in which the second means includes means for detuning the electromagnetic connection between the controlled energy transmitter means and the receiver means, to allow for less critical placement of the controlled energy transmitter means with respect to the receiver means.

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