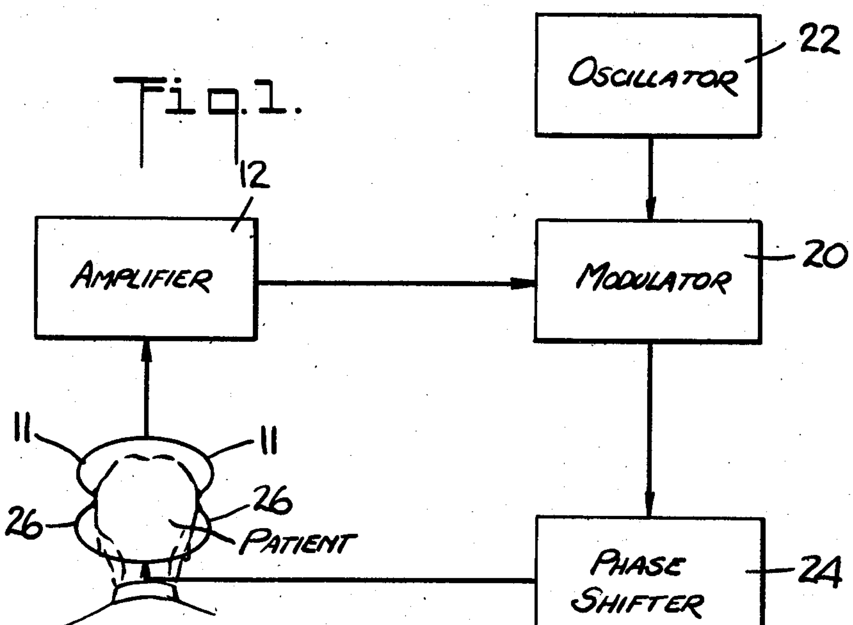
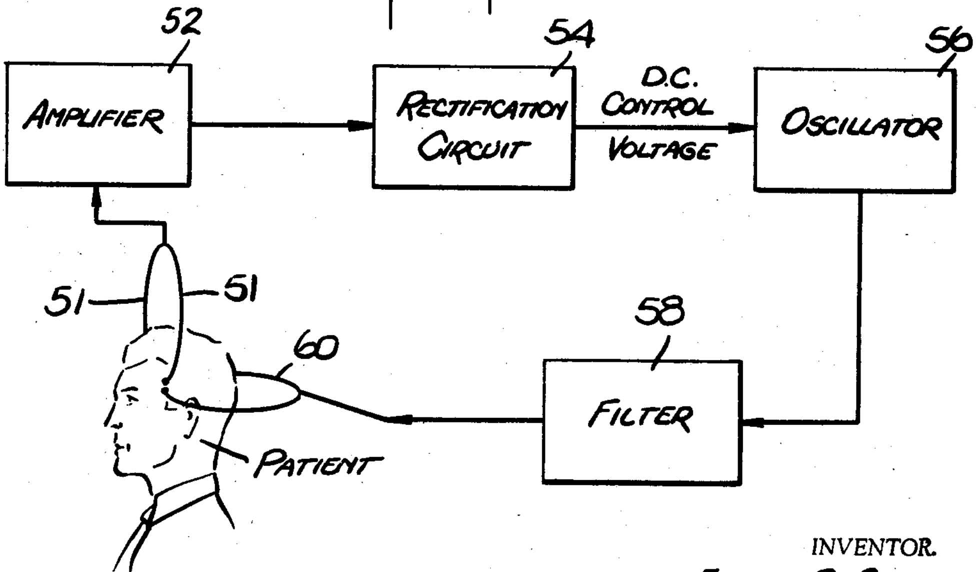
APPARATUS FOR AND METHOD OF PROCESSING A BIOELECTRICAL SIGNAL

Filed March 23, 1965 2 Sheets-Sheet 1





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Feb. 17, 1970 E. R. CONDICT 3,495,596
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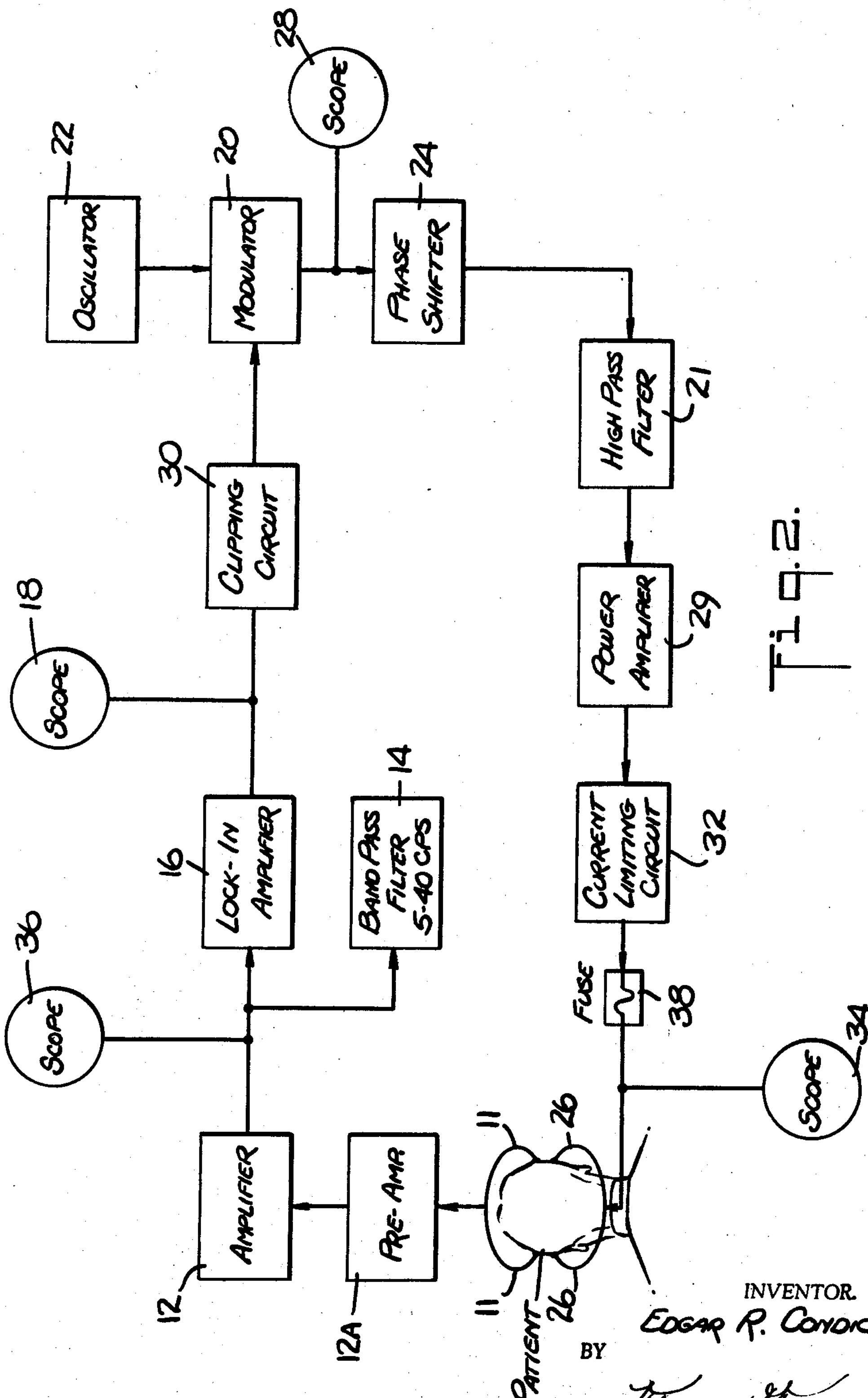

Fig. 2.

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APPARATUS FOR AND METHOD OF PROCESSING A BIOELECTRICAL SIGNAL

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Continuation-in-part of application Ser. No. 392,216, Aug. 26, 1964. This application Mar. 23, 1965, Ser. No. 441,958

Int. Cl. A61n *1/32;* A61b *5/04*

U.S. Cl. 128—422 19 Claims

ABSTRACT OF THE DISCLOSURE

Processing an individual's EEG signal in such a fashion that it may be fed back to the patient to induce anesthesia. The processing involves amplitude modulating the EEG signal onto a higher frequency carrier and applying the modulated signal to the patient by means of electrodes fastened to the patient. Anesthetization is manifested by a decreased patient generated EEG signal. The modulated carrier signal applied to the patient to effect anesthesia has low amplitude and thereby avoids both injury and discomfort to the patient.

This is a continuation-in-part of now abandoned application Ser. No. 392,216 filed on Aug. 26, 1964.

This invention relates in general to the processing and use of electrical signals that are picked up from a living organism and more particularly to the employment of an electroencephalograph signal to bring about anaesthesia.

In the embodiment of this invention described in detail herein, an electroencephalograph (hereinafter EEG) signal is processed and fed back to the patient to anaesthetize the patient. A major feature of this processing is that the EEG signal is used to modulate a radio frequency carrier. The modulated carrier is fed back to the same patient from whom the EEG signal was derived in order to bring about anaesthesia.

Although it is known to employ an electrical signal in order to bring about anaesthesia, the signal employed has required a current level greater than is desirable for use with human beings. Accordingly, most electronic anaesthesia equipment today is employed in the course of operating on animals and particularly the larger animals such as horses and cows. In any case, the presently known techniques of electronic anaesthesia are not suitable for long application to a patient without danger to the life and sanity of the patient; possibly because nerve paths are destroyed in the treatment.

The present invention, in one of its aspects, proceeds on the theory that since EEG signals are generated by brain activity, or at least are concomitant therewith, the modification of such brain activity will have an effect on the nervous system. Accordingly, electrodes are placed on the skull of a patient to sense electrical impulses which are then fed back in synchronism with the generating signals. The signals picked up and processed by the electrodes are fed back by means of a feedback network so as to have the required phase relationship with the impulses internally generated by the subject's brain.

Applicant has found, by experimentation on small monkeys, that prolonged sleep and anaesthesia can be induced in mammals by feeding back suitably selected frequency components of EEG signals, that the effects can be maintained for as long as desired with no apparent ill-effects, and that on breaking the feedback circuit the effects can be promptly terminated. The same animal has been so treated many times with no evidence of discomfort, no breakout of neurotic symptoms such as would be expected if pain had been experienced, and with no extraneous and undesirable medical symptoms developing at the time or over a long period thereafter.

Applicant has further discovered that the feedback impulses preferably should occur as modulations on a radio frequency carrier (10 kc. and higher). In such case feedback at relatively low levels of carrier current amplitude are successful, and small currents are conveyed to the output electrodes. Danger to the patient is thus minimized, and optimum effects obtained without destruction of pre-existing nerve paths. Applicant believes the effects are due to the relative ease with which high frequencies can penetrate to cerebral pathways which control perception.

It has been found that selected frequency components of the signal picked up by the pickup electrodes are effective in producing the desired effects and that other frequency components are not required, and in fact may be harmful. Applicant has therefore filtered out those frequencies (essentially all frequencies over 40 c.p.s. and under 5 c.p.s.) which seem to affect cardiac and respiratory functions. Further, in order to eliminate 60 c.p.s. artifacts, a high pass filter is employed to condition the signal fed to the patient. The remaining frequency components are quite effective in inducing anaesthesia, when imposed as amplitude modulation on a radio frequency carrier.

If, instead of modulating a carrier with EEG signals, EKG (electrocardiograph) signals are picked up, used to modulate a carrier and fed back in the same manner as described for EEG signals, applicant has found it possible to effect heart stoppage in all animals tested.

Accordingly, although this invention is described in connection with the processing of an EEG signal and the attaining of anaesthesia, it shall be understood that the inventive techniques involved herein may be applied to any body electrical signal in order to provide a feedback signal that may be effectively coupled to the patient's nervous system.

The embodiment described herein is described in connection with its employment to achieve total anaesthesia. However, applicant has found, in experiments performed on himself, that by selecting the frequencies fed back he has been able to anaesthetize parts of his body, as one arm, one leg, the other arm, the other leg, without losing consciousness. It is evident from the experiments that the effects attainable are frequency and phase selective in respect of body functions, but repeatability has not been attained and precise relationships have not yet been determined. Generally speaking, a very narrow frequency band (only a few cycles wide) of the EEG is involved in establishing local anaesthesia for any part of the body. However, the frequency value will generally vary with the part of the body anaesthetized. This partial anaesthesia is obtained with the output electrodes at the head of the patient and with the same circuit arrangement described herein in conjunction with attaining total anaesthesia.

Accordingly, it is a major purpose of this invention to provide a means for producing anaesthesia which can be maintained safely and effectively over an extended perior of time.

It is a more specific object of this invention to provide a means for employing the EEG signal produced by a patient as the effective signal in inducing anaesthesia.

It is a broadly related purpose of this invention to employ the EEG signal provided by the patient being anaesthetized as the means for controlling the anaesthesia.

It is a broad purpose of this invention to provide a technique for impressing low frequency signals on a patient's nervous system.

It is a related broad purpose of this invention to provide a means for reinserting into a patient's nervous system a treated or modified signal that is picked up from the patient's nervous system.

For convenience, the term "patient" has been employed throughout the claims and in most of the specification to indicate the organism which may be affected by the system of this invention. It shall be understood that the term "patient" herein is by no means limited to a human being.

Other objects and purposes of this invention will become apparent from a consideration of the following detailed description taken in conjunction with the drawings, in which:

FIG. 1 is a block diagram of the basic system of this invention employed to produce anaesthesia;

FIG. 2 is a block diagram of a more complete system for producing electronic anaesthesia employing the basic modulation and feedback technique illustrated in FIG. 1; and

FIG. 3 is a block diagram of a second embodiment of this invention in which the EEG signal is employed to control the magnitude of the current output by a prior art electronic anaesthetic system.

With reference to the figures, FIGS. 1 and 2 represent the same basic system and embodiment with FIG. 2 illustrating a large number of additional features included for the purposes of safety, monitoring and flexibility. FIG. 1, in starkest terms, illustrates the basic invention. Accordingly, the same designating numerals will be used for corresponding block elements in FIGS. 1 and 2.

As may be seen from FIG. 1, a pair of electrodes **11** are attached to the temples of a patient in order to pick up the EEG signal which is generated by the patient. This signal is then amplified by an amplifier **12** so that it can be raised from a magnitude in the order of microvolts to a magnitude in the order of hundreds of millivolts. The amplified EEG signal is fed as the information input to an AM modulator **20**, which modulator **20** serves to modulate a carrier signal from the oscillator **22** with the EEG signal. The modulated signal is passed through a manually operable phase shifter **24** so that the operator can adjust the phase of the input to the patient to achieve maximum anaesthetic effect with minimum current input. The phase shifting network **24** has been found essential, thus far, to achieving anaesthesia. The appropriately phase shifted modulated signal is applied to the patient by a pair of electrodes **26**. It should be noted that the output electrodes **26** may or may not be the same as the pickup electrodes **11**.

Many additional features are added to the basic circuit of FIG. 1, as will be discussed in connection with FIG. 2, for purposes such as eliminating many of the frequencies which are normally picked up by the electrodes **11**. In effect, by filtering out signals due to cardiac and muscle sources as well as extraneous signals picked up from the atmosphere, applicant provides what he considers to be a purified EEG signal. This purified EEG signal is much safer to use and eliminates unnecessary components of the signal that are normally picked up by the electrodes **11**. It shall be understood herein that the term "EEG signal" shall be used variously to describe both the signal that is picked up by the electrodes **11** as well as the processed signal which is supplied by the various features illustrated in FIG. 2. Whether or not the processed or purified EEG signal obtained by the device of this invention contains all of the signals produced by the brain or, possibly contains certain signals which are extraneous to those produced by the brain, is not to be considered a limiting factor in this invention. Applicant filters out those frequencies and spikes which appear to be dangerous to the patient and finds that the resultant signal is effective and safe. Because of the nature of what is filtered out, it would appear fairly obvious that as a consequence the signal obtained is in fact a much purified EEG signal. However, it seems equally certain that this processed and purified EEG signal omits certain frequencies produced by the brain. The extent of purification of modification afforded in the processed EEG signal is a matter of speculation, the resolution of which does not affect the scope of this invention.

Again, with reference to FIG. 2, the electrodes **11** are connected directly to an EEG preamplifier **12A** which is nothing more than a stable low noise amplifier with a very high input impedance and a relatively low gain of about 50. The output of this preamplifier **12A** is then amplified by a standard amplifier **12** having a gain of approximately 1000 to provide an amplified EEG signal for processing by the remainder of this anaesthetizing circuit.

The amplifier **12** output is an EEG signal in the order of hundreds of millivolts. The amplifier **12** output has a great deal of noise (both background noise as well as information other than the EEG signal generated by the brain). This noise includes electrocardiograph signals, muscle produced signals, a possible 60 cycle signal picked up from the electronic equipment, and ambient interference which may be picked up by the electrodes **11**. This ambient noise may come from spark plug operation, the operation of other electrical machinery as well as the various electronic equipments which may be located in the hospital where this anaesthetic equipment is likely to be used. In order to eliminate as much of the noise as possible, a band pass filter **14** and lock-in amplifier **16** arrangement is employed.

The amplifier **12** output is divided into two branches. One branch passes through a band pass filter **14** having cut-off characteristics to eliminate the very low frequency electrocardiograph and muscle produced signals on one end and the higher frequency 60 cycle (as well as other higher frequency noise) on the other end. There is nothing very critical about the band pass of the filter **14** employed except that in order to make sure that no 60 cycle signals get through it is very important that it filter out all signals substantially higher than 50 c.p.s. A fairly inexpensive band pass filter **14** has been employed which has a relatively flat transmission characteristic from five to twenty cycles and is down three db at 40 cycles. As a practical matter, a five cycle lower end cut-off for the filter **14** eliminates much undersirable noise and many muscle produced signals while retaining the EEG frequencies significant for our purposes. The filter **14** output is thus a somewhat purified EEG signal, which, however, carries whatever noise has been picked up or generated within the band pass range of this filter **14**. The output of the filter **14** provides the reference signal for the lock-in amplifier **16**.

The output of the amplifier **12** is fed along a second path to provide the input signal to the lock-in amplifier **16**. With the filtered reference signal output from the filter **14** beat against the input signal to the lock-in amplifier **16**, the amplifier **16** will produce an EEG signal which is relatively free of background noise and other extraneous signals. A usable lock-in amplifier is described in an article by Robert D. Moore, entitled "Lock-In Amplifiers for Signals Buried in Noise," published in the June 8, 1962 edition of Electronics magazine.

Although it is generally desirable to monitor the EEG signal in the circuit of FIG. 1 at a number of points, an oscilloscope **18** at the output to the lock-in amplifier **16** is of particular value in giving an indication of the true EEG signal generated by the patient. It might also be noted that because the output of the lock-in amplifier **16** is a relatively pure EEG signal, it can be recorded to provide a reference for the patient as to his normal EEG signal.

A standard type of AM modulating circuit **20** is then employed to modulate this relatively pure EEG signal on the output of an oscillator **22**. It is important that the frequency of the oscillator **22** be considerably higher than the frequencies which have generally been employed hitherto in electronic anaesthetization. Tests to the present time show that the frequency of the oscillator is not critical as long as it is kept at a relatively high frequency range. Frequencies anywhere within the rather broad range from 50 kc. to 15 mc. have been found perfectly satisfactory. Indeed, frequencies lower than 50 kc. can be safely used but it has been found that, as the frequency is materially decreased from 50 kc., higher input currents to the patient are necessary to effect equivalent anaesthetization. One of the major purposes of providing a radio frequency carrier for the EEG signal is in order to obtain the effectiveness of the EEG signal at minimum current level inputs to the patient.

Applicant is not certain as to why the radio frequency carrier is preferable to lower frequencies but at the present time hypothesizes that the higher frequency may cause a better distribution of the EEG signal throughout the nervous area that is being affected. One experimental result that indicates the nature of the frequencies of concern here is that, with the animals tested thus far, an oscillator **22** frequency of 250 kc. has been found to be generally better than 40 kc. If there is a single optimum frequency it undoubtedly varies with the specie and indeed even with the individual. However, there is nothing critical in any narrow frequency range sense in order to obtain excellent results for the purposes of inducing anaesthesia.

The output of the modulating circuit **20** is fed through a phase shifter **24** before being applied to the patient in order to effect anaesthesia. The phase shifter **20** is manually operated by the doctor or attendant while viewing the oscilloscope **18**. For each patient and for each application of this anaesthetic technique, a particular position will be found for the phase shifter **24** that will result in a minimum EEG signal on the scope **18** thereby indicating maximum anaesthetic effect. The coupling device **26** is normally a pair of electrodes which can be placed on the patient's temple if general anaesthesia is to be effected. Indeed, the pickup electrodes **11** may even be employed as the output coupling device **26**; providing the oscillator **22** circuit is sufficiently well isolated from the pickup electrodes **11** circuit.

Because of the danger of sixty cycle signals of any magnitude to a patient and the possibility that such signals may produce convulsions or cardiac disturbance and even cardiac stoppage, it is desirable to include a high pass filter **21** prior to the output electrodes **26** in order to filter out all frequencies below some relatively safe frequency such as 10 kc.

In general, it is desired to have the maximum degree of modulation without distorting the EEG signal. It has been found desirable to aim for a maximum of 90% modulation of the oscillator **22** output so as to avoid over-modulation with the attendant harmonics. An oscilloscope **28** at the output of the modulator **20** will enable the operator to monitor the extent of modulation and to avoid over-modulation. An amplitude clipping circuit **30** is included just before the input to the modulator **20** in order to minimize the risk of over-modulation by clipping any excessively large spikes that might come through.

A current limiting circuit **32** is employed as a further safety measure just prior to the output electrodes **26** in order to clip any peak currents that may be put out by the power amplifier **29**.

As yet another safety measure, an oscilloscope **34** is preferably connected at the input to the patient so as to provide a warning to the operator in case the signal being fed to the patient should become deviant or dangerous in any fashion for any reason whatsoever.

It will also usually be desirable to monitor the signal picked up by the pickup electrodes **11** on an oscilloscope **36** so that the operator will be aware of the entire range of signals that are picked up and thus may spot deviant or danger signals.

Though it is very difficult to measure the average current level fed to the patient by means of this anaesthetizing circuit, the maximum current is probably well under

one milliampere, particularly at frequencies above 100 kc. The actual current will vary considerably since it is a function of the particular patient, the carrier frequency, and the quality of the electrode contact between the patient and the output electrodes **26**. Five milliamperes is understood in this art to be a standard safe input current to a patient and thus a five milliampere fuse **38** is used after the output from the power amplifier **29**. In addition, the current clipping circuit **32**, which may be simply a Zener diode, is set at a high point of approximately ten milliamperes so as to clip any instantaneous currents over that magnitude. However, since one of the major purposes and results of this invention is to provide effective anaesthetization at the very minimum in current input to the patient, the current input is normally at a level much under the safety limits established by the fuse **38** and clipping circuit **32**.

The anaesthetizing system of this invention has been used hundreds of times with no ill effects on five test monkeys and two test rabbits as well as a few times on applicant himself. There are no observable ill effects or side effects and anaesthetization was instantaneous, effective and complete.

The band pass filter **14** has been simply described as one which eliminates all frequencies less than five cycles and all frequencies higher than forty or fifty cycles. However, it should be recognized that in the operation of this invention, the band pass filter **14** is a variable band pass filter whose upper and lower limits can be set by the operator to achieve optimum results. It is rare that the entire range five through forty cycles is desired or needed in order to affect total anaesthesia. Since there is typically more noise than is desirable in a portion of this five to forty cycle band, the operator will typically adjust the limits of the band pass filter **14** to obtain the general anaesthesia desired with a minimum of noise being transmitted through to the modulator **20**. The noise level can be monitored on the oscilloscope **18**. For a human patient it is typical that the band pass filter may be set from five to fourteen cycles (which for a filter **14**, of the type involved here, that does not have sharp cut-off characteristics, means an effective pass that runs higher than fourteen cycles). A compromise is struck between minmizing noise and transmitting the full scope of the EEG signal. As long as the band that is passed through the system is a frequency band wide enough to provide general anaesthesia, the purpose is served. This band that is transmitted is kept as small as possible consistent with that general purpose in order to eliminate as much noise as possible.

It is desirable to eliminate as much of the noise as is possible while still producing general anaesthesia since this noise signal will just be modulated onto the carrier and fed back to the patient to serve no effective purpose in producing anaesthesia. Furthermore, there is the very real possibility that this noise can produce harmful side effects such as epileptic type seizures. After all, one of the major purposes of this invention is to achieve general anaesthesia with a minimum of total current input and a minimum of extraneous signal input to the patient.

It should be understood that certain other features illustrated in the figures may be combined with one another in a single circuit that performs more than one function. For example, the filter **21** and power amplifier **29** could well be deemed a single block and labeled a tuned amplifier. Thus if the amplifier **29** were tuned to the carrier frequency, the filter **21** could be eliminated.

Similarly, it should be understood in connection with both the description and the claims that the various functions which are illustrated as separate blocks in the diagrams can be interchanged in sequence. Thus although it is probably preferable that the voltage clipping circuit **30** be in the loop subsequent to the lock-in amplifier **16**, there is no inherent reason why the voltage clipping function could not occur at the output of the main amplifier **12**.

Even the phase shifter **24**, which is a very important element in the anaesthetizing circuit, could be located at any position subsequent to the output of the modulator. Accordingly, the various means in the claims must be understood to operate on the signal to perform the function claimed but they need not necessarily operate in the sequence claimed.

It is also possible that what have been described as separate blocks to perform separate functions can be combined within a single circuit. One of the more significant examples of this combining of two functions in a single element is in the pickup electrodes **11** and output electrodes **26**. Although these are normally provided as separate electrodes, the very same electrodes may be employed to perform both functions. Accordingly, it shall be understood in the claims that the recitation of separate means or separate elements shall be understood to cover those designs where the separate means or separate elements are embodied in a single means or single element.

One of the major purposes of this invention is to effect electronic anaesthesia with a much smaller input current than has hitherto been applied to the patient thereby making electronic anaesthesia much safer and more effective. It is presently known to apply the output of an oscillator to a subject, particularly animals, in order to induce anaesthesia. With previously known methods of electronic anaesthesia, the muscle contractions or spasms are sufficiently serious so that a muscle relaxant such as curare has to be used.

FIG. 3 illustrates an improved system and technique which can be added to presently available electronic anaesthesia equipment. In FIG. 3, the patient has the standard pickup electrodes **51** attached to his temples to provide an EEG signal which is amplified by a standard amplifier **52**. The output of the amplifier **52** is passed through a rectifier or RC circuit **54** to provide a DC control voltage. The level of the DC control voltage will be a function of the average magnitude of the EEG signal so that when the patient has been anaesthetized, the level of the control voltage will decrease considerably. This DC control voltage is then employed to control the current output level of an oscillator **56**. The oscillator **56** output, which is generally set at a given frequency, is passed through a protective filter **58** to electrodes **60** attached to the temples of the patient, thereby producing anaesthesia. With the improvement of FIG. 3, the output of the oscillator **56** is decreased as soon as the anaesthesia becomes effective so that the patient is not given more of a current input than the minimum necessary to provide the desired anaesthetic effect.

The critical elements of this invention include the concept of using the patient's own EEG signal in a closed loop system to be fed back to the patient to effect anaesthesia. The modulation of this EEG signal on a radio frequency carrier in order to feed the modulated carrier back to the patient is a key novel element in this invention. The phase shifting device **24** is further necessary in order to assure immediate and safe anaesthetization. Within this basic inventive framework, many improvements and variations may be effected without departing from the basic scope of this invention.

For example, the band pass filter **14** and lock-in amplifier **16** arrangement appears to be the least expensive and most practical means for eliminating noise and undesirable frequencies. However, it shall be understood that this invention is by no means limited to the particular technique shown in FIG. 2 for achieving this result. I have (for most of the experimentation) employed a spectrum analyzer in lieu of the filter **14** and amplifier **16** to provide this general (essentially filtering) function. Ideally, if the appropriate filter were available on the market, it would be preferable to use a variable band pass filter by itself if one could be obtained which would have sharp enough cut-off characteristics. Thus if we wish to set the band pass filter at let us say five to fourteen cycles per second, we would want a fairly sharp cut-off at five as well as at fourteen cycles. Such a band pass filter with variable limits is not readily available on the market and thus the arrangement of lock-in amplifier **16** and variable band pass filter **14** shown in FIG. 2 is preferred at present.

This invention has been described in connection with a system where the carrier signal is amplitude modulated by the EEG signal because such a technique of modulation has been employed and found to be successful. However, the purpose of modulation is to provide a substantially higher frequency carrier signal in order to obtain better tissue penetration and more effective anaesthesia. Accordingly, nothing herein should be construed to limit this invention to a technique of amplitude modulation. Any modulation technique may be employed which is effective to carry the EEG signal into the nervous tissue in a fashion that will permit demodulation of the signal and thus subsequent anaesthesia.

Thus, the nature of the modulation could be a pulse frequency modulation wherein the magnitude of the EEG signal is represented by the instantaneous pulse repetition rate of a pulse train.

One technique of modulation that might be employed is to use a chopper (either electromechanical or electrical) to chop the EEG signal which chopped signal is then fed back to the patient. As long as the chopping rate is sufficiently high to assure effective propagation in a nervous system, this technique is merely one of the modulation techniques that may be employed. It should be understood in the claims that this as well as the various other modulation techniques which are appropriate are covered by the appended claims.

What is claimed is:

1. A system for affecting the nervous system of a patient comprising:
- pick up means adapted to be coupled to said patient to provide an electrical signal in response to a signal generated by the patient,
- means to provide a carrier signal,
- modulator means to amplitude modulate said electrical signal onto said carrier signal to provide a modulated signal, and
- means for coupling said modulated signal to the nervous system of said patient.

2. Apparatus for feeding an electrical signal to a patient comprising:
- pickup means adapted to be electrically coupled to said patient to provide an electrical signal in response to a signal generated from a predetermined portion of said patient's body,
- means to provide a carrier signal,
- modulator means to amplitude modulate said carrier signal with said electrical signal provided by said pickup means to provide a feedback signal, and
- means to couple said feedback signal into the nervous system of said patient.

3. A system adapted to anaesthetize a patient comprising:
- pickup means adapted to be coupled to said patient to provide an EEG signal,
- means to generate a carrier signal,
- means to modulate said EEG signal onto said carrier signal to provide a modulated signal, and
- means for coupling said modulated signal into the nervous system of said patient.

4. The anesthetizing system of claim **3** further characterized by variable phase shifting means to provide operator control over the phase between said EEG signal and said modulated signal.

5. A system for anaesthetizing a patient comprising:
- pickup means adapted to be coupled to said patient to provide an EEG signal,

means to generate a carrier signal,
means to modulate said EEG signal on said carrier signal to provide a modulated signal,
variable phase shifting means coupled to said modulated signal to provide a phase shifted modulated signal, and
means for coupling said phase shifted modulated signal to the nervous system of said patient.

6. A system adapted to anaesthetize a patient comprising:
pickup means adapted to be coupled to said patient to provide an EEG signal,
an oscillator to provide a carrier signal,
a modulator coupled to said EEG signal and to said carrier signal to modulate said carrier signal with said EEG signal to provide a modulated signal, and
a variable phase shifter coupled to said modulated signal to shift its phase to provide an anaesthetizing signal, and
means to impress said anesthetizing signal onto the nervous system of said patient.

7. A system adapted to anaesthetize a patient comprising:
a pickup electrode adapted to be coupled to said patient to provide an EEG signal,
an oscillator to provide a carrier signal,
a modulator coupled to said EEG signal and to said carrier signal to modulate said carrier signal with said EEG signal to provide a modulated signal,
a variable phase shifter coupled to said modulated signal to shift the phase of said modulated signal to provide an anaesthetizing signal, and
electrodes coupled to said anaesthetizing signal and adapted to be connected to said patient to impress said anaesthetizing signal onto said patient.

8. A system adapted to anaesthetize a patient comprising:
a pickup electrode adapted to be coupled to said patient to provide an EEG signal,
an oscillator to provide a carrier signal,
a modulator coupled to said EEG signal and to said carrier signal to amplitude modulate said carrier signal with said EEG signal to provide a modulated signal,
a manually operable phase shifter coupled to said modulated signal to shift the phase of said modulated signal and thus provide an anaesthetizing signal, and
electrodes coupled to said anaesthetizing signal and adapted to be connected to said patient to impress said anaesthetizing signal onto said patient.

9. Apparatus for inducing anaesthesia in a patient comprising:
pickup means adapted to be coupled to said patient to provide an EEG signal,
band pass filter means coupled to said EEG signal to provide a first filtered EEG signal,
a lock-in amplifier having as its signal input said EEG signal and having as its reference input said first filtered EEG signal to provide a second filtered EEG signal,
an oscillator to provide a carrier signal,
a modulator coupled to said carrier signal and to said second filtered EEG signal to amplitude modulate said carrier signal with said EEG signal to provide a modulated signal, and
a manually operable phase shifter coupled to said modulated signal to shift the phase of said modulated signal and provide an anaesthetizing signal, and
means to impress said anaesthetizing signal onto the nervous system of said patient.

10. Apparatus for inducing anaesthesia in a patient comprising:
pickup electrodes adapted to be coupled to said patient to provide an EEG signal,
a band pass filter coupled to said EEG signal to provide a first filtered EEG signal,
a lock-in amplifier having as its signal input said EEG signal and having as its reference input said first filtered EEG signal to provide a second filtered EEG signal,
a voltage clipping circuit coupled to said second filtered EEG signal to establish a maximum voltage excrusion for said second filtered EEG signal and provide a conditioned EEG signal,
an oscillator to provide a carrier signal,
a modulator coupled to said carrier signal and to said conditioned EEG signal to amplitude modulate said carrier signal with said conditioned EEG signal to provide a modulated signal,
a manually operable phase shifter coupled to said modulated signal to permit selectively shifting the phase of said modulated signal and provide an anaesthetizing signal,
a high pass filter coupled to said anaesthetizing signal to provide a filtered anaesthetizing signal,
a power amplifier coupled to said filtered anaesthetizing signal to provide an amplified anaesthetizing signal,
a current clipping circuit coupled to said amplified anaesthetizing signal to establish a peak instantaneous current level, and
output electrodes coupled to the output of said current clipping circuit and adapted to be connected to said patient to impress said anaesthetizing signal onto the nervous system of said patient.

11. The method of impressing a patient's generated body electrical signal on the patient's nervous system comprising the steps of:
picking up the body electrical signal from said patient,
generating a carrier signal,
modulating amplitude said carrier signal with said body signal to provide a modulated signal, and
impressing said modulated signal onto the nervous system of said patient.

12. The method of anaesthetizing a patient comprising the steps of:
picking up an EEG signal from said patient, generating a carrier signal,
modulating a carrier signal with said EEG signal to provide said modulated signal, and
impressing said modulated signal onto the nervous system of said patient.

13. The method of claim 12 wherein said carrier signal is a radio frequency carrier signal.

14. The method of anaesthetizing a patient comprising the steps of:
picking up an EEG signal from said patient, generating a carrier signal,
amplitude modulating said carrier signal with said EEG signal to provide a modulated signal, and
impressing said modulated signal onto the nervous system of said patient.

15. The method of anaesthetizing a patient comprising the steps of:
picking up an EEG signal from said patient generating a carrier signal,
modulating said carrier signal with said EEG signal to provide a modulated signal,
impressing said modulated signal onto the nervous system of said patient, and
observing the magnitude of said EEG signal while simultaneously shifting the phase of said modulated signal to whatever extent is necessary to minimize the level of said EEG signal.

16. The method of anaesthetizing a patient comprising the steps of:
picking up an EEG signal from said patient generating a carrier signal,
amplitude modulating said carrier signal with said EEG

signal, said carrier signal having a frequency at least one order of magnitude greater than the dominant frequencies of said EEG signal to provide a modulated signal,

shifting the phase of said modulated signal by an amount that is determined from an observation of the anaesthetizing effect on said patient, and

impressing said phase shifted modulated signal onto the nervous system of said patient.

17. The method of anaesthetizing a patient comprising the steps of:

picking up an EEG signal from said patient generating a carrier signal,

amplitude modulating said carrier signal with said EEG signal, said carrier signal having a frequency substantially greater than the dominant frequencies of said EEG signal to provide an anaesthetizing signal,

applying said anaesthetizing signal to the nervous system of said patient, and

shifting the phase of said anaesthetizing signal while observing the magnitude of said EEG signal to attain a minimum magnitude for said EEG signal.

18. The method of anaesthetizing a patient comprising the steps of:

picking up an EEG signal from said patient generating a radio frequency carrier signal,

amplitude modulating said radio frequency carrier signal with said EEG signal to provide a modulated signal,

passing said modulated signal through a variable phase shifting network to provide an anaesthetizing signal, applying said anaesthetizing signal to the nervous system of said patient, and

shifting the phase of said variable phase shifting network to establish a minimum magnitude for said EEG signal.

19. The method of anaesthetizing a patient comprising the steps of:

picking up an EEG signal from said patient,

passing said EEG signal through a variable band pass network to provide a modified EEG signal, generating a radio frequency carrier,

modulating said radio frequency carrier with said modified EEG signal to provide a modulated signal,

passing said modulated signal through a phase shifting network to provide an anaesthetizing signal,

applying said anaesthetizing signal to the nervous system of said patient,

varying the parameters of said phase shifting network to shift the phase of said anaesthetizing signal until a minimum magnitude EEG signal is obtained, and

varying the band pass of said variable band pass filter network until a minimum frequency range for said modified EEG signal is obtained without causing an increase in the magnitude of said EEG signal.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,495,596 Dated February 17, 1970

Inventor(s) E. R. Condict

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Insert a comma between "patient" and "generating" in each of the following instances:

Col. 10, line 61

Col. 10, line 73

Col. 11, line 12

Col. 11, line 26

SIGNED AND
SEALED
DEC 29 1970

(SEAL)
Attest:

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Attesting Officer

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Commissioner of Patents