TWO WAY TELEMETRY FOR HOSPITAL USE

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Summary A radio telemetry system for transmitting physiological data from a patient is used in a receiver complex to locate the patient. Methods of stimulating the patient for research or remedial control are discussed.

Introduction The advances in electronics in medicine are of two general types. One is in instrumentation for aiding in laboratory diagnosis, while the other concerns the patient and remedial medicine. Electronics performs a third service for the researcher in physiology, psychology, and human behavior for it aids in gathering, displays, and processing data. Much of this research is performed under instrumentative conditions which severely curtail the subject's activity. Telemetry offers much to alleviate this by releasing the subject from instrument wires.

This project was undertaken to develop two way radio telemetry techniques for stimulation and control as well as acquiring the evoked response and certain other physiological data from an unencumbered subject. This project is purely investigative and does not embrace the arguments of altered function, permanent damage, or clinical efficacy. It is to develop equipment and utility techniques rather than a remedial procedure.

The various equipments were constructed from modules of standard function and design. Most modules are available in microminiature or monolithic form. Modules can be repaired, substituted, or replaced. Different configurations and approaches can be tried by re -arranging the various modules. Obsolescence is reduced since new modules can be added for updating the system, and modular design allows portions of a system to be used in various ways for different system concepts, or for more expanded research.

Since hospitals notoriously generate high ambient noise levels FM is used. The system uses PDM of approximately 100 KC frequency excursion in the standard 88 - 108 MC band.

Purpose The purpose of these investigations was threefold. The first objective was to locate a subject within the hospital. The second was to determine if a two way system could be of value in energizing or regulating physiological functions such as the externally pulsed cardiopacemakers developed by the City of Hope Medical Center and others. The third was to determine the utility of a two way system in altering neuropsychotic states by methods similar to those described by Lippold in relieving depression with a series of electric pulses.

Patient Localization For the patient localizer the EKG and peripheral pulse were transmitted from each patient. Each transmitter was tuned to a different frequency.

The localizer uses an antenna and receiver at each end of a corridor, thus 3 are required to cover two corridors meeting at a right angle. A separate antenna receiver combination is required for each recreational room, coffee shop, etc. covered.

Receivers The receivers were made from standard FM Tuners. The front end is disconnected from the IF amplifier. A series of transistorized heterodyne circuits are tuned to the individual patient frequencies. They remain functional at all times as will be explained later. Each tuned circuit is sequentially switched to the IF amplifier. The output of the IF is taken ahead of the normal de-emphasizing network.

Patient Indicator and Alarms Two types of Malfunction Indicators are used in the experiments. These are the results of the System Philosophy for Multiple Patient Monitoring Equipment. Any malfunction in the equipment is indicated by the Equipment Light. This indicator is normally green indicating proper function. In the event there is an equipment failure it changes to a steady amber color and at the same time locks out the patient alarm.

The Equipment Light is kept in the green lighted-proper function state by the output of the heterodyne tuned circuits. The signals of each particular tuned circuit is amplified and combined by a resistor-diode OR gate. The OR gate input holds a transistor switch to cutoff. If no carrier signal is received (indicating a malfunction in the patient’s transmitter) the transistor switch energizes the Light Driver which turns “ON” the Amber lights in the Equipment Light.

The patient alarm is in the Patient Light. This indicator is lighted green by the sequencer to indicate which patient is being monitored. In the event no pulses indicative of heart action are received within 1.5 seconds after that particular patient is selected for monitoring, his particular Patient Light changes to a Flashing Red Light. Coincident with the flashes a chime sounds.

There is another way the Alarms may be activated. One of the design criteria was to provide a means by which a patient experiencing a catastrophic emergency could break the sequence and activate the alarms. This design requirement was not achieved, however, the outputs of the individual heterodyne tuners are differentiated by an RC network. This results in a series of pulses which keep a Resettable Single-Shot in the reset state. If there are only positive pulses which would occur if there were no biosignal inputs at the transmitter the Resettable Single-Shot goes to the “ON” state. This activates the Light Driver which turns that particular Patient Light to a steady Red. The monitor personnel then presses the Patient Light which switches the monitor facility to that patient. Thus the Patient Light serves as the Command Monitor Switch.

When and if such an emergency occurs the alarm circuitry activates the patient location logic. The block diagram for the Location Logic is shown in Figure 1.

Figure 2 shows the logic format when a stricken patient is nearer one antenna than another. Figure 3 typifies the logic format for that rare instance when the patient is equidistant to two antenna.

In these experiments only three receivers were used. However, the Location Logic developed applies to as many receivers as a given system installation requires.

The logic format is shown in pulse form. Actually, the logic is handled in amplitude analog form. Conversion to pulses takes place in the adjustable threshold logic. These are Resettable Single Shots which remain “ON” so long as a threshold signal is applied. This action is somewhat like a Schmitt-Trigger except the RSS will remain “ON” after the last stimulus for a period of time determined by an RC circuit in the feedback loop. Developed for another biomedical application it was found necessary here since persons walking between the stricken patient and the receiver antenna caused jitter in the logic by varying the received signal strength.

The AGC voltage of each receiver is amplified and compared in pairs with every other receiver. The outputs of these paired comparators are again compared with the amplified AGC voltages. This establishes which antenna is receiving the strongest signal and which antenna is receiving the next strongest signal.

The outputs of these comparators fan out to an OR gate and paired AND gates. The output of the OR gates is applied directly to the adjustable threshold Resettable Single Shot. This Resettable Single Shot converts the analog signals to a pulse. The pulse remains “ON” so long as there is a threshold level input. This pulse turns on one set of lights through the Light Driver in the Location Indicator nearest the patient.

The paired AND gates produce an output for both the receiver having the strongest signal and the next strongest signal. These outputs are converted to a square wave pulse by another set of adjustable threshold Resettable Single Shots. The outputs of these also turn on lights in the appropriate Location Indicators through Light Drivers.

The lights now turned “ON” in the Location Indicators are such that 2 sets of lights are “ON” in one indicator. One set of lights is “ON” in another Location Indicator. All the rest are “OFF”. The patient is in the corridor defined by the two lighted Location Indicators and nearer the one which is brightest, ie: has 2 sets of lights “ON”.

The function of the logic for that rare instance when a patient is equidistant from any two antenna is such as to turn these defining Locations Indicators “ON” bright. The AGC voltages of the two receivers nearer the patient are approximately equal and greater than that of all other receivers.

The AGC voltage of each receiver is amplified and compared in pairs with every other receiver. The outputs of each pair of AGC voltages is again compared with each individual AGC voltage. This establishes which two antenna are nearer the patient.

The outputs of these comparators fan out to an OR gate and an AND gate. The output of the OR gates is applied directly to the adjustable threshold Resettable Single Shot. The RSS remains “ON” so long as there is a threshold level input. This turns on one set of lights through Light Drivers in the two Location Indicators equidistant from the patient.

Paired AND gates produce an output for both receivers having the stronger signals. These outputs are passed to adjustable threshold RSS which turn on the other set of lights in the Location Indicators through Light Drivers.

This results in two Location Indicators “ON” bright again defining the approximate location of the patient. However, in this instance the patient is approximately midway between the two locations indicated.

The threshold adjustments are set empirically and no values can be established for the settings prior to the installation. This is because the logic used is analog. Threshold levels could be preset if digital logic were used. However, it would have to be three level logic if the same logic format were used. Such logic is more complex and possibly more reliable. It was not tried because of the cost.

Any patient can be selectively monitored by pushing his Name (Number) Patient Light. This switches his challenge signal “ON”. It breaks the sequence which is re-established after 5 seconds with the patient next in the sequence.

Two-Way System Once the telemetry system for monitoring and locating a stricken patient was functioning, methods of controlling the patient were investigated. No human patients were treated in the manner described, however, Heath, Olds, Redfearn and others have used stimulators wired directly to patients in developing the clinical techniques.

These experiments were to investigate methods of coupling signals to and from chronically implanted brain electrodes and the external environment. This data transfer was to be accomplished by some means other than direct wiring. Available integrated circuits are not sufficiently developed to allow reasonable success of two way multiple channel telemetry implants. Any welded module micro -circuits were considered too cumbersome for the experiments. Each of these would require a rechargeable battery power source which would presumably be implanted in the abdominal cavity. This would require a double surgical procedure; one for the power supply, the other for the brain implant. Therefore, a different approach was to be used. Part of the circuitry was to be chronically implanted. The remaining circuitry was to be attached to the outside of the skin.

The system radiates a continuous EEG waveform. This EEG is the output of an electrical disturbance center, such as an epileptogenic focii from within the brain. A probe electrode is surgically implanted into or near the focus. The lead protrudes through a small trephine in the skull bone overlying the lesion/probe site. This lead attaches to an encapsulated inductor. The dura and skin close over the implant.

Signals resulting from the brain activity vary the inductors magnetic pattern. These variations are picked up by an external inductor taped to the skin. A telemetry transmission of the signals to a Central Monitor Facility for recovery and processing completes the reception of the EEG waveform.

For this experiment stimulation was initiated by the operator and not on an automatic basis. Stimulation was of one-half second bursts of 50 usec 8 to 10 cps pulses. These were transmitted with sufficient power to be received, inductively coupled to the implant, and result in a 1 to 5 microvolt pulse in the lesion/probe site. Limiting of the signal was determined empirically by using the two encapsulated inductors separated by a human skin fold. An appropriate gain set control regulates the receiver voltage applied to the external or driver inductor.

Each inductor consists of approximately 65 turns of enameled copper wire woundinto a 1/2 inch ferrite cup core. Two such inductors are required for each unit.

The implantable inductor is encapsulated in RTV S5392 Silicone Rubber. A hole was drilled axially through the rubber. One of the inductor leads terminated in a tantalum wire wound into a spiral and placed along one surface of the encapsulation. This served as the implant indifferent or ground electrode.

At implant the skull was barred. The upper table of bone was curretted leaving a pocket the size of the encapsulation. A trephine was made in the center of this pocket. The electrode to be implanted was introduced through this hole into the proper site in the brain substance. Once it was determined that the electrode was in the proper position the implantable inductor was threaded over the electrode lead wire like a donut. This lead wire was soldered to the other inductor wire and the joint inverted into the hole. RTV Silicone Rubber S5392 was used to plug the hole and cover any exposed wire so that the implant was completely encapsulated. Normal dura and skin closure completed the implantation. Figure 4 diagrams the implant and the implantable core.

Patient Unit The patient unit consists of an external inductor, signal amplifier, transmitter, receiver, and a rechargeable battery pack. These units are of standard modules. The amplifiers are identical except for the inputs and outputs. The gain is approximately 40 db for a battery drain of about 6 milliamps at 6 volts.

The transmitter is a base current modulated 88 to 108 MC FM unit. It radiates sufficient power from the tank circuit for successful operation up to a few hundred feet. No antenna is used.

The inductor is encapsulated in Silicone Rubber for mechanical protection. However, other encapsulating resins would offer better protection.

The core is taped directly over the implanted core. The rest of the patient unit is held in a harness elsewhere on the body. No particular problems result from this method of monitoring so long as the inductors remain in place.

Central Monitor Facility The Central Monitor Facility was designed for experiments in determining clinical use of radio telemetry. As such it has features which axe not essential to this experiment. It contains a receiver, signal processors, data display, transmitter, and a battery charger. The receiver is a standard FM tuner. The signal processor amplifies the EEG signal and serves as a preamplifier for the display. This display is a- large screen oscilloscope which has a P7 long persistent phosphor. A strip chart recorder is provided for use when a permanent EEG copy is desired.

The transmitter is in all respects standard. It transmits an AM signal of sufficient power to assure operation of the stimulators at ranges up to 300 feet. For this experiment the CB Band was used. Therefore, the power was limited to 5 watts.

Comments These equipments, other implantable equipments, and small size, light weight biotelemetry units in general open a new avenue of physiological and behavior research. The greatest advantage is the freedom of the research animal (human) in his environment. A concomitant advantage to the researcher is the absence of cables or wires. Telemetry almost completely avoids the risk of limiting the animal's activity. Thus long term research into many physiological and psychological functions become a reality. It is even conceivable that migratory studies could be carried out by a network of co-operative Amateur Radio Operators.

The ability to monitor and stimulate remotely opens other avenues of interest. As technical proficiency in implanting increases the sites of implants may involve the spinal cord, segmental nerves as in paralysis from cord damage, various organs, and other anatomical structures. The remote monitor and stimulation avoids the introjection of the researcher into the environment. These often cause psychological or auto-stimulations which conceivably alter the results. All things considered the ability of remote stimulation by this or other means of direct implant offers the research another tool with which to investigate the nature of natural phenomena.

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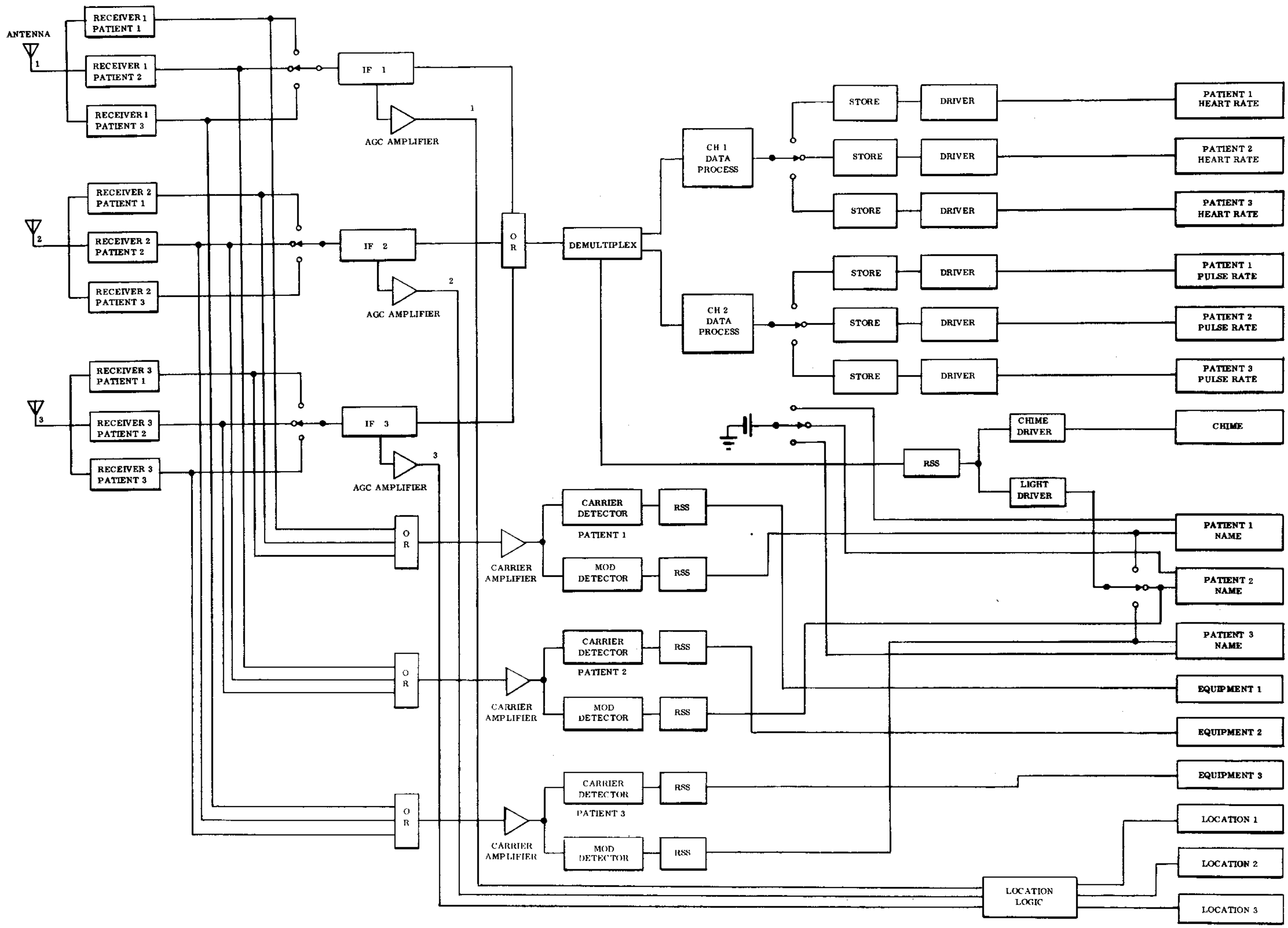

Figure 1. System Block Diagram

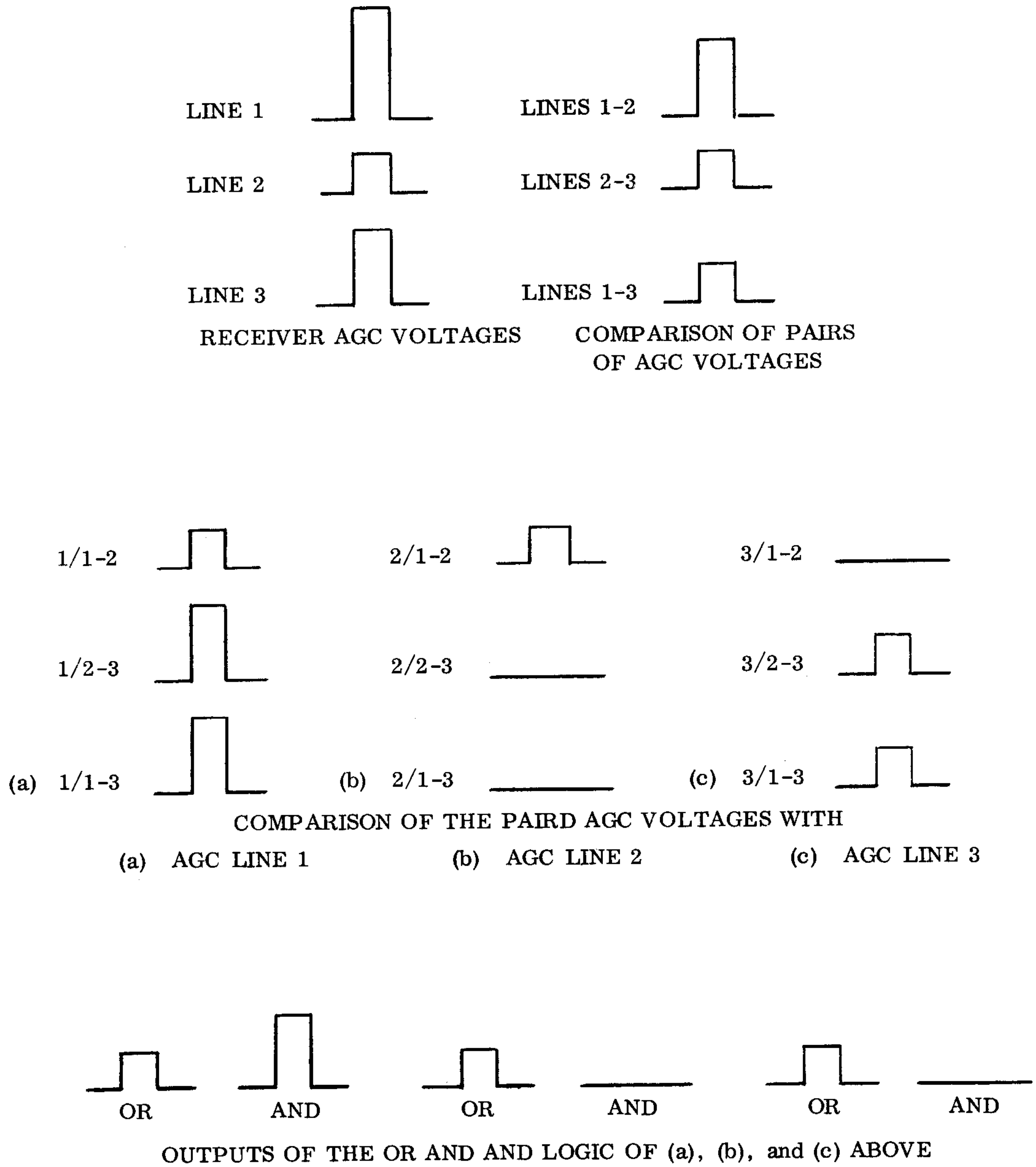

Figure 2. Logic Format when a Patient is Between Antennas 1 and 3 but Nearer Antenna 1

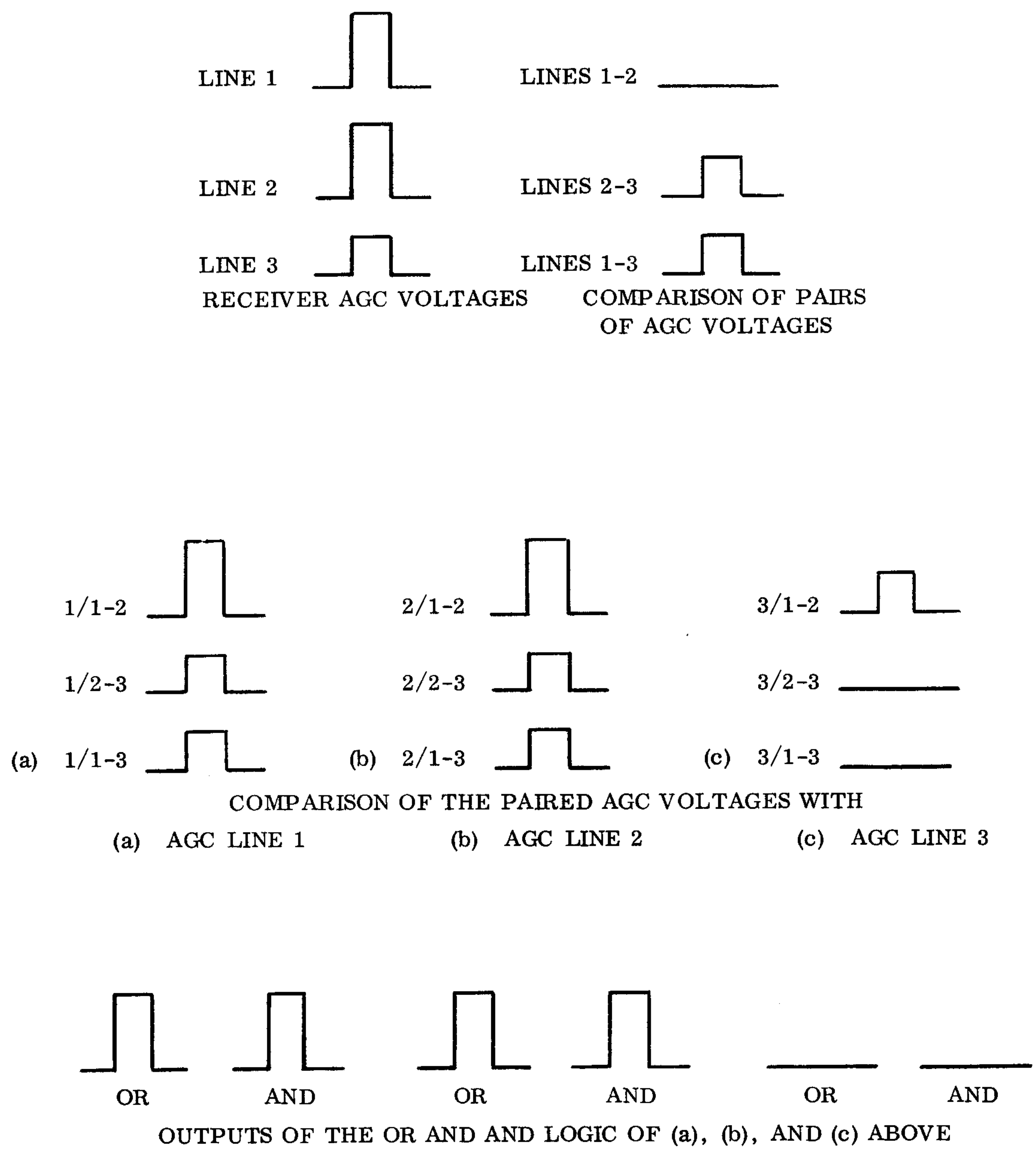

Figure 3. Logic Format when a Patient is Midway Between Two Antenna (Antennas 1 and 2)

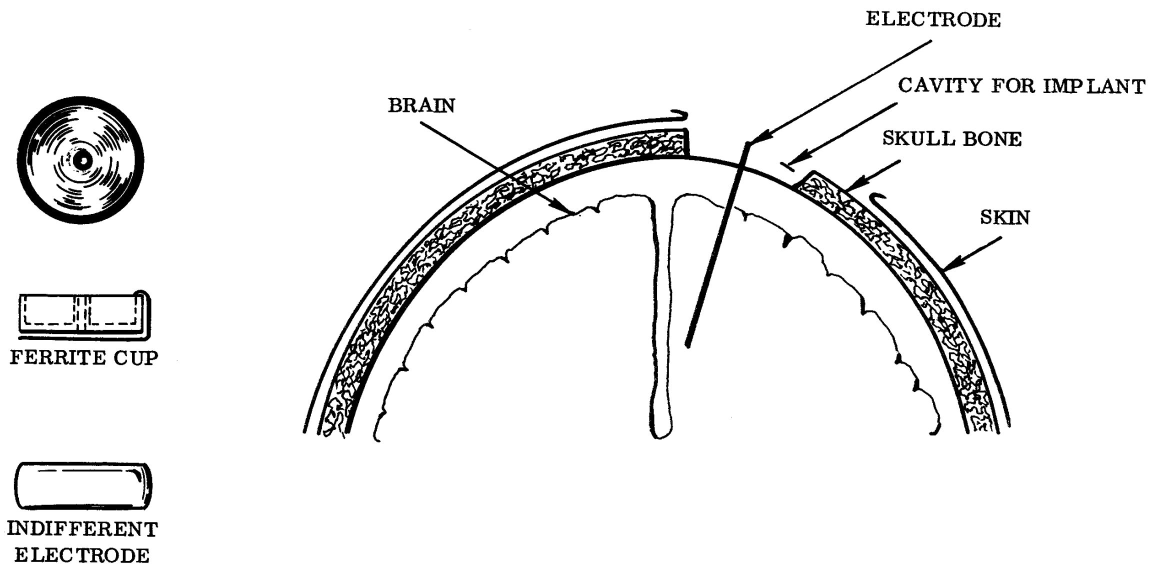

Figure 4. Implant and Site