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A RADIATING CABLE INTRUSION DETECTION SYSTEM

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Work on VHF intrusion detection systems using radiating cable is reported. Modification in a previously constructed system as well as the design of a new system employing quiescent signal cancellation and quadrature detection are described. Results of performance evaluation tests are presented.

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Because of the value of resources, the costs of security personnel, and the threats of vandalism and sabotage, a need exists for an intruder detection system to protect isolated high value resources. Present systems suffer severe deficiencies: a high false alarm rate, difficulty in controlling the extent and uniformity of the detection zone, and critical set-up procedures. To overcome these problems a radio frequency intruder detection system concept has been developed which makes use of a transmitting leaky coax cable, receiving monopole antennas, and signal processing circuitry. This report concentrates on the design and development aspects of the signal processing circuitry. Signal processing circuitry using signal cancellation and quadrature detection techniques was designed, constructed and tested. The circuits performed well and within their design limits. During the testing, the circuits were continually modified and updated so that the present design is sound and can serve as a solid foundation for future advanced development.

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Project Engineer

1. INTRODUCTION

This report describes the development of a radio frequency intruder detection system intended to protect high value individual resources. The work included some modifications of an already existing system as well as the development of a new instrument. The mechanism of the interaction between the single radiation wire system and the intruder has not as yet been fully understood. Therefore, the emphasis in both of the tasks was placed on the development of a data gathering research tool rather than on the production of an operational system.

The existing instrument[1] was originally developed under contract F19628-77-C-0142 for the Rome Air Development Center at Hanscom Air Force Base. The original intent was to demonstrate only the feasibility of an area intrusion detection system using radiation coaxial cable, but in the continuous process of data gathering to determine the RF field characteristics of a single wire intrusion detection system, the device was also used in conjuction with other instruments, to make measurements during field operations. In that application some shortcomings were noted. Therefore, to make the instrument more versatile as a research tool some modifications of the existing circuits as well as some new additions were incorporated into the portable transmitter-receiver unit.

In parallel with these modifications another system design was considered. In the single wire system, where the leaky coaxial cable was driven at one end while the other was terminated by a matched load, the amplitude of the envelope of the detected disturbance exihibited considerable variation. The

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disturbance originating at the driven end of the cable was always larger than the one originating near the termination. Also, some shadowing by the resources being protected was found to exist. To counteract these problems, a split coaxial cable drive with two receiving monopole antennas was considered. The coaxial cable was to be driven at both ends while a matched termination was to be placed at the midpoint between the driven ends. This was to reduce to some extent the dependance of the disturbance signal amplitude on the position of the intruder along the cable. To reduce the shadowing problem two receiving antennas feeding a single receiver through a signal combiner were considered. Also, considered was a switching arrangement where the two sides of the coaxial cable would be alternately driven. This arrangement together with a synchronous detection could provide information on the sector in which intrusion was taking place. This project was carried through the preliminary design stages and then set aside for a design of an instrument to test some new ideas on the single wire intruder detector system.

At the time a new hypothesis[2] was proposed by Dr. J. L. Poirier of RADC on the behavior of the RF signals in a radiating cable area intrusion detection system. The hypothesis was based on the data gathered during a series of experiments with a single radiating coaxial cable and a centrally located single receiving antenna. The findings seemed to indicate that a receiving system employing a carrier suppression and a quadrature detection scheme could eliminate some of the more objectionable features of the previous approach.

There were considerable variations in the quiescent received signal strength that depended on the location of the receiving antenna within the area enclosed by the radiating cable. A relatively small displacement of the cable could produce considerable changes in the quiescent signal levels at the antenna. The RF field strength at any given point within the area was determined by the phase and amplitude relationship between the contributing signal components originating along the cable. Thus there were large signal strength variation within a relatively small area inside the perimeter where reinforcements and cancellations took place. An intruder disturbed only a small fraction of the contributing components. When the antenna was near the peak of the RF field the disturbance introduced only a small variation with respect to the quiescent signal level. On the other hand, when the antenna was located near or in a valley of the RF field the same disturbance produced very large variation with respect to the latent signal. Therefore, the old approach which used AGC worked in direct opposition to the desired effect. Instead of equalizing the disturbance signal under the various deployment and enviroment conditions, it further exaggerated the variation. In the new instrument the quiescent signal was suppressed by cancellation every time the system was deployed. This was accomplished by summing the quiescent signal with a signal of equal amplitude and opposite in phase. This eliminated, to some extent, the variations in the alarm threshold due to deployment.

A sinusoidal variation in the detected signal level was exhibited by the original system when the cable was approached by an intruder. This behavior was also explained and duplicated on a computer at RADC. In simple terms it was thought to be caused by the variation in the amplitude of the disturbance as well as by the relative phase shift produced by an approaching intruder. As the distance traveled by the radiated signal to the intruder and back to the receiving antenna changed, so did the relative phase between the distrubance and the quiescent signal. The resulting oscillations contained zero crossings which represented effective nulls in the disturbed RF field. Similar signal oscillations were observed during the circumferential walks.[3] In turn these nulls produced voltages at the detector below preset threshold levels during a portion of the cycle. Thus, at least theoretically, an intruder could approach and cross the cable without being detected.

To reduce the effect of the large oscillations in the detected disturbance signal caused by an approaching intruder the phase dependent components had to be elimated from the signal at the detector. For that purpose a quadrature detection scheme was employed. In addition to the amplitude detection a phase detection circuits were also incorporated in the instrument. No threshold or alarm circuits were included.

In the first part of this report some of the modifications of the previously constructed instrument are described. The circuit diagrams shown should be viewed in conjunction with the circuit descriptions presented in Reference 1. The rest of the report is devoted to the description of the latest instrument. Since the design of the switchable instrument did not proceed beyond the advanced planning stages no description of that system is presented.

2. MODIFICATIONS OF THE EXISISTING SYSTEM

The original area Intrusion Detection and Alarm System[1] developed in 1977 was intended to demonstrate only the feasibility of an intruder detection system employing a leaky coaxial cable and a simple monopole antenna. During tests designed to determine the RF field characteristics of such a system the unit was employed to gather data. In that capacity some shortcomings were noted.

During prolonged circumferential walks the alarm threshold levels appeared to be changing. Considerable changes in the threshold levels occurred when several of these walks were repeated within a short time of each other. This behavior was caused by the normal response of the AGC circuit. The circuit interpreted the rapid but unsymetrical variations in the signal strength caused by a person walking around the perimeter as a long term signal strength change and tried to adjust the receiver gain accordingly. A repeated walk just compounded the problem. To correct this deficiency a switch selectable manual gain control was added to the circuit. Similar problems may be encountered with other systems during evaluation and testing, if a manual overide of the AGC circuits is not provided.

In conjunction with this AGC modification a new digitally controlled circuit was constructed. It was intended as a replacement for the existing highly nonlinear RF atternator within the AGC loop. To keep the time constant of the AGC the same at all operating levels the characteristic required lineraization. The control signal to the RF atteunator was shaped by a bootstrap circuit. Acceptable, but not invariant time constant was achieved throughout the operating range. Also, during the tests, when the AGC was disabled, the system had to be manually adjusted to a signal level chosen by the operator and could not seek its preset operating point upon a command.

The digitally controlled attenuator shown in Figures 1 and 2 eliminated these problems. It could be operated over a 64dB range in 0.25dB increments. An eight bit UP/DOWN counter, driven by a clock and controlled by a comparator maintained the design signal level. The reaction time of the AGC was controlled by the clock: a high frequency signal for initial adjustment and a low frequency clock for normal operation. An inhibit switch was included to maintain the quiescent level during the periferal tests walks to establish the detection probabilities and/or to set the alarm threshold levels. A manual control mode was also retained in the design. This AGC loop was not installed into the existing system only because, at that time, the emphasis was shifted to the development of an instrument to test new ideas on the single wire intrusion detection system.

Originally the alarm threshold levels for both the increasing and the decreasing signal levels due to a distrubance were set at 3dB with respect to the quiescent signal level. They were thought adequate to detect an intruder crossing the radiating cable. In experimentation with circumferential walks at various distances from the cable the settings were found to be restrictive. Controls were provided to set the lower and the upper deflection threshold levels independently over zero to 6dB range. This modification of the existing comparator circuit is shown in Figure 3.

To test the characteristics of the system with a buried coaxial radiating cable, the transmitter power was increased from 10 to 200 mw. A cascade of AVANTEK GPD - 401, 402 and 403 RF amplifiers with a total gain of 38dB replaced the Q-BIT QB-614 amplifier to provide the necessary power boost.

The battery configuration and its output voltage was changed to 24V to accommodate the power requirements of the new RF amplifier. A battery charger, shown in Figure 4, was also added. Two battery packs in the original system were damaged during field operations due to massive overcharges. The charger allowed for a continuous operation of the system from an external power source and an unlimited charging time without damage to the batteries. The battery voltage and the three internal regulator output voltages could be monitored on a panel meter. The incoming RF signal level and the AGC voltage could also be selected for display on the same meter.

These additions and modifications improved the overall usefulness and reliability of the instrument. The digital AGC loop, although not actually installed into the system, could further contribute to the improvement if incorporated in a similar area intrusion detection and alarm system.

3. AREA INTRUSION DETECTION SYSTEM II

A. General Description

The second Area Intrusion Detection System (AIDS) was designed to reflect the thinking at that time on the behavior of the RF field near and within the area encircled by a single radiation cable. As pointed out in the introduction of this report, the AGC employed in the received signal path, as was the case in the first system, was thought to be counterproductive in the stabilization of the alarm threshold levels. Therefore, it was replaced by a quiescent signal cancellation circuit. In addition, a quadrature detection of the disturbance signal was used to eliminate the phase related variations in the detected signal. Since the transmitter-receiver unit was envisioned to be used as a research tool rather than as an alarm systen, the circuits associated with the settings of the decision thresholds and the alarm were not incorporated in the design.

A block diagram of the system is shown in Figure 5. The RF portion of the system operated at 57 MHz while the other operations were performed at an intermidate frequency of 455 kHz and a base band of 0 to 10Hz.

A crystal controlled oscillator and an amplifier produced approximately 250 mw of RF signal to drive the radiating cable or the antenna, if desired. A small portion of the oscillator output was also used to power a mixer where the 455 KHz intermediate frequency reference signal was generated. For that purpose a crystal controlled local oscillator of 57.455 MHz was used. The output of the same local oscillator was also employed to drive another mixer to produce the IF signal from the received and amplified RF.

A 20dB attenuator and an isolation amplifier were inserted into the local oscillator signal path. This was done to prevent the reference signal, which was considerably stronger than the received signal, from feeding through the local oscillator into the received signal mixer. A 60dB isolation was achieved by that combination.

The output of the mixer located in the receiver section was amplified and filtered in the IF strip. An integrated IF amplifier and a ceramic narrow band-pass filter formed that circuit. The output of the IF strip was routed into the summing amplifier.

The reference IF signal was used to drive an integrated circuit phase locked loop to generate one of the two reference signals for quadrature detection. The PLL output, arbitratily assumed to be the "in phase" (I) reference component of the two signals was applied to another PLL to generate the quadrature (Q) reference component. The I component was also used to generate the waveform for suppression of the quiescent received signal. Since the output of the PLL was a square wave it was passed through an isolation amplifier and a ceramic band-pass filter before it entered the phase shift newtork. From there, after proper phase and amplitude adjustment, it was summed with the received IF signal to cancel the quiescent component.

The output of the summation amplifier was multiplied by the two reference quadrature components to generate two quadrature components of the disturbance signal. These in turn were passed through an active 10Hz low pass filter. The resulting low frequency signals were applied to a precision absolute value circuit before being processed by the vector computation circuit. The output of that circuit was the desired waveform. The phase components have been eliminated and only the amplitude of the disturbance signal was preserved.

To observe the phase variations of the disturbance signals with respect to an arbitrary quiescent phase, another PLL, multiplier and filter combination was employed. The PLL was inserted before the multiplier to remove amplitude variations in the disturbance signal at the output of the summing amplifier. The band-pass filter following the PLL removed harmonics from the amplitude limited signal before it was multiplied by the sinewave used to cancel the quiescent received signal. The output was obtained directly from the multiplier where the high frequency components were removed by a simple RC low pass filter.

A monitor circuit was included in the instrument. Each of the six signals indicated in the diagram could be selected one at a time for display on a panel meter.

The system operated from a 12 to 15 volt external power source. An internal dc - dc converter provided the regulated voltage to power the individual circuits.

B. Circuits of AIDS

The design of the intrusion detection system utilized wherever possible, commercially available hybrid, integrated, and kit type circuits. When a particular functional block had to be designed, a well known configuration and/or circuit published in the application notes by the manufacturer were used. The choice of the 455kHz intermediate frequency was influenced by these considerations and by the relative ease with which some of the signal processing could be accomplished at that frequency.

The transmitter and the receiver circuits are shown in Figure 6. Except for the isolation amplifier the circuits were bought in a kit form. The 57 MHz crystal oscillator from International Crystal Mfg. Co. Inc (ICM) MODEL OF-1 produced approximately -5dBm of output power. More than 80% of that power was used to drive the RF power amplifier. The hybrid amplifier TRW CA-2812 was also obtained in its kit form with all the required external components already assembled. The amplifier boosted the oscillator signal to approximately 250 mw. The remainder of the oscillator power was diverted into the 200 ohm resistor in series with the 50 ohm input of the ICM MXX-1 RF mixer. A +10dB conversion gain was obtained in the active mixer module. The local oscillator signal of 57.455 MHz was supplied to the mixer from the receiver section. An isolation amplifier with a section of an LC filter was inserted into the signal path to prevent the composite reference signal at the output of the mixer from reaching the receiver circuits. An excess of 60dB isolation was realized by the casaded source follower circuit.

To further improve the isolation between the stages a TEKTRONIX 011-0059-02 20dB attenuator preceeded the isolation circuit.

The received signal was amplified by ICM SAX-1 RF amplifier. That unit provided approximately 12db gain at the operating frequency. A MXX-1 mixer once again was used to obtain the intermediate frequency signal. An LC network filtered the incoming local oscillator signal.

An intergrated broadband communications subsystem LM374 and a MURATA CFM-455F ceramic filter were used to amplify and band limit the IF signal. The LM374 was connected to operate in the video amplifier configuration with manual gain control at pin 1. The IF strip, including a 6dB insertion loss of the ceramic filter, was capable to provide approximately 64dB of gain.

From the IF strip the received signal was directed to the nulling circuits shown in Figure 7. There the signal passed through a low gain isolation stage before entering the summation junction where it was combined with the reference signal. The reference signal obtained from the PLL-1 was passed through a ceramic band pass filter (CEM-455F) to remove the harmonic content. The phase of the resulting sinusoid was manually controlled by the two multiturn potentiometers. A total phase shift approaching 360° was possible. The amplitude of this reference signal was adjusted by the potentiometer at the output of the second stage of the phase shift circuit.

The residual signal at the output of the summation amplifier was once more filtered by a band-pass filter. To compensate for the insertion loss of the filter the signal was amplified in the output stage of the nulling circuit.

To help in the nulling process the received, the reference and the residual signals could be selected for display on a panel meter. First the amplitude of this reference signal was adjusted to approximate the quiescent received signal level. Then the phase was shifted to produce a null in the output signal. Some repetitive readjustment of the amplitude and phase was required until an acceptable null was reached. The output of the cancellation circuit was processed in the circuits of Figure 8. There it was multiplied by two signals derived from the reference IF signal and in quadrature to each other. These quadrature components were generated by the casade of EXAR XR-215 monolithic PLL circuits. The voltage controlled oscillator (VCO) outputs of the PLL's maintained the IF frequency and the required phase relationship to each other. In order to maintain a 90° phase shift at the VCO of the PLL-Q witn respect to the VCO output of the PLL-I the free-running frequency of the former was set as near as possible to the intermediate frequency of the system. For that purpose a frequency trim resistor was introduced at pin 10 of the PLL-Q circuit. Pin 10 of PLL-I was open. Otherwise, the two PLL and multiplier combinations are identical.

The selection of other external components for the PLL circuits closely followed the recommendations of the manufacturer.[4] The configuration of the EXAR XR-2228 monolithic multiplier/detector was also taken from the application notes for a standard multiplication circuit.[5] Care was taken to adjust the gains and the offset of both multipliers in order to produce indentical output amplitudes for a given range of the input signal.

The outputs of the two multipliers were further processed by the circuits shown in Figure 9. Once again the circuits for the I and the Q components of the received signal were identical. The signal first passed through a 3-pole 10Hz low pass filter with a gain of two where the high frequency components of the product signals were removed. There the signals underwent precision full wave rectification before entering the vector computation circuits. This process was necessary since the ANALOG DEVICES-433 programable multifunction module could not accept negative signals. The description of the operation of the vector computation circuit may be found in Reference 6.

The phase detector circuit also utilized the PLL - multiplier configuration. The external component selection was almost identical to the one described in conjunction with the quadrature circuits. An exception was the insertion of a band-pass filter between the PLL and the multiplier (Figure 5). In the phase detector circuit the PLL was used, because of its large dynamic range (3mV to 3V.), to remove the amplitude variations from the disturbance signal. Since the output of the VCO was rich in harmonics, the filter was inserted to recover the fundamental sinusoid. This 455kHz sinusoid was multiplied by the reference waveform used to cancel the quiescent received signal. The variations in the amplitude of the product waveform were independent of the amplitude of the disturbance signal and represented only the phase shift relative to the reference signal. An RC low pass circuit removed the high frequency components from the output.

To aid in the preliminary adjustments of the system, a monitor circuit as shown in Figure 10 was also incorporated. The level IF signals were peak detected and amplified to produce reasonable deflections in the micrometer. High level signals such as the I, Q and the vector (V) signals were applied through appropriate resistors to the meter. Output ports were also produced for these signals where a multichannel chart recorder could be connected.

The described intrusion detector circuits were divided into subsystems and packaged into separate boxes. To minimize leakage and interference problems interconnections between the subsystems were made through RF connectors and shielded cables. Servicing or modifying the separate circuit blocks was relatively simple. New functional blocks could easily be added or removed to try some new configurations. The subsystems were mounted in a metal instrument carrying case for transportation.

C. Performance

Several tests were conducted at the RADC test site at Hanscom Air Force Base to evaluate the performance of the intrusion detection system. The tests were primarily intended to establish the validity of the system design concepts and to observe its performance in a field enviroment. Due to time limitations imposed by the approaching end of the contract only qualitative observations were made on the system behavior. These led to a discovery of a few minor defficiences, mostly in the alignment procedures, which were corrected. No attempt was made to gather quantitative data regarding the variations in the disturbance signal caused by various system deployment configurations or due to the position and /or size of the intruder.

The tests were conducted using Type 285 radiating coaxial cable manufactured by the Times Wire and Cable Co. A monopole antenna mounted on a ground plane was placed near the center of a 44 meter diameter circle formed by the cable. The monopole was stabilized against wind by four nonconducting guy wires attached to the ground plane. No attempt was made to optimize the antenna for the operation at 57MHz. When measured the overall signal path loss of the system ranged between 85 to 94db on several occasions and under differing cable deployment. During each of the tests the system was operated at quiescent conditions for long periods at a time to observe any spurious deviations of the output from a preset value that could be interpreted as a false alarm. On each of the occasions there was vehicular as well as pedestrian traffic on a road approximately 15 meters from the radiating cable. Only once a small but significant deviation occurred from the quiescent level which coincided with a bus passing the test site. A portion of that quiescent test is shown in Figure 11. The top trace represents the vector signal. The two lower ones show the Q and I components respectively, while the very bottom trace represents the phase detector output. In this figure and in all that follow the channel deflections of the chart recroder were approximately set to 200mV/cm for the vector signal and 500mv/cm for the other signals. It must be emphasized that these were only very approximate settings in which the vernier gain controls were ignored. Therefore, the diviation of the signals from their quiescent values should be viewed in conjunction with other traces where the disturbances by a person near the cable are shown. The deviation coinciding with the passing of the bus was less than 10% of the minimum deflection observed in any of the circumferential walks. It should be noted that other traffic was also present during the time period represented by the traces. Also, wind gusts estimated in excess of 50 km/hr were also present during that particular quiescent signal test. As may be observed the wind and the traffic had no significant effect on the system.

A quadrature alignment check and a circumferential walk results are shown in Figure 12. The traces from top to bottom represent the vector, Q, I and phase signals respectively. The left hand portion of the figure shows the vector and the quadrature signals during an aligrment check. After each deployment the system was exercised to confirm its proper operation. One of these tests involved a check for balance of the two quadrature components. A phase deviation of only a few degrees from a true quadrature introduces substantial error in the computed vector signal. When driven by sinusoids out of quadrature, the vector signal exhibits error voltage at twice the frequency of the input signal. Amplitude differences and dc offset voltages also contribute to the output errors with dc and ac components. In this test a signal generator was tuned to if IF frequency of the system. Its output was applied to the summing amplifier with the cancellation signal disconnected. Two quadrature components were generated in the PLL-multiplier circuits. While the oscillator signal slowly drifted within the base of 0 to 10Hz from the system IF signal a vector signal was obtained. The magnitude of the ripple in that signal was a good indication of the balance in the quadrature circuit under dynamic conditions. The phase circuit was not connected during the test shown in the figure.

The right hand side of the figure shows the results of a circumferential walk taken immediately after the system check. The cable was approached from the end terminated in a load. The walker then proceeded towards the end connected to the transmitter. Thus the increasing received signal strength when the cable losses decrease. The envelopes of the vector as well as of the two quadrature components show the interference pattern between the radiated and the surface wave signals. It was expected that the vector signal would be a relatively smooth envelope of the quadrature components. Therefore, when the fine noise like structure was first observed it was thought to be caused by the signal processing circuits. Although the quadrature balance tests shows some imperfections in the vector signal, the variations in the signal obrained during the circumferential walk could not be attributed to the imperfections of the quadrature detector. It was concluded that the fine structure was caused by the motion of the body, its arms and legs. To test this assumption another walk was taken. The results are presented in Figure 13. During the first half of the walk the "intruder" produces mininum motion by keeping his arms against the body and by taking small robot like steps. The fine structure in the vector signal was reduced considerably. The body motion during each small step may be observed in portions of the quadrature components. In the second half of the walk normal motions were resumed as evidenced by the increase in the amplitude of the higher frequency components.

Figure 14 shows the response of the system to an intruder crossing the cable and to the motion within the encircled area. First, the radiating cable was crossed at the high power end near the feed line. Then the intruder passed within approximately one meter of the receiving antenna and left the encircled area approximately 180° from the entrance point. On the return path the cable was crossed near the place where the exit has been made. Now the antenna was passed on the other side and the exist was made at the termination of the coaxial cable. The disturbances at the 180° crossings were much more pronounced then at the both ends of the cable. This, of course, was a pure coincidence for this crossing. But it points out the fact that a large variation in the disturbance signal amplitude can be expected, making it difficult to choose the alarm threshold levels to insure detection while minimizing the false alarm rate from a nearby activity. It should be noted that the phase detector outputs showed less amplitude variation in the cable crossings but were more sensitive to the activity near the receiving antenna.

Figures 15 and 16 represent two circumferential walks with an expended time scale to show in more detail the fine structure in the waveforms. In the walk shown in Figure 15 the usual cable drive was used. In Figure 16 the walk was made while the antenna was connected to radiate and the cable was used to receive the signal. In this configuration there was an increase in the received power. Therefore, the system was readjusted to cancel the quiescent signal. Also, during both of these walks the phase detector circuits were driven directly from the reference PLL and not from the cancellation signal. For that reason there were no differences in the amplitude of the phase detector output for the two configurations. Although the amplitudes differed, the general shape in the envelope of the vector signals were preserved. The signal amplitude in the antenna driven case was limited by the chart recorder and not by the signal processing circuit.

D. Conclusion

An intrusion detection system using quiescent signal cancellation and quadrature detection was designed, constructed and tested. It was intended to be an instrument for observation and data gathering rather than for field deployment to protect high value individual resources. Time limitations curtailed the intended testing program to several performance evaluation tests in which the emphasis was placed on qualitative observations to identify areas where further refinement in the system concept and/or circuits would be necessary.

From these tests it may be concluded that the system performed well and within its design limits. The indirect gain control by cancellation of the quiescent signal while leaving the disturbance component unaffected presented no difficulties. The manual adjustment of the reference signal phase and amplitude to achieve the desired cancellation proved to be somewhat inconvenient. It could be replaced by an automated process. The quadrature detection scheme required some attention and care in balancing of the quadrature circuit components to achieve the desired results at the output of the vector computation circuit. A more serious problem was presented by the leakage of the reference signals from the transmitter into the received signal circuits through the common local oscillator connections. The proximity of the transmitter to the receiver also contributed to the leakage problem.

The field tests indicated that the system was not very susceptible to an activity away from the radiating cable. Vehicles at 15 meters did not produce a signal that could be interpreted as an intrusion. Humans could not be detected at distances in excess of 3 meters. No substantial deviation from the quiescent level was ever detected that was not caused by a person crossing or passing close to the radiating cable. Activity within the enclosed area and especially near the receiving antenna produced detectable disturbance levels.

The quadrature detector output showed much more activity than expected. The body motion produced higher frequency components superimposed upon the dc level representing the amplitude envelope of the disturbance caused by a circumferential walk. The envelope also varied somewhat more than expected. There appeared to be less variation in the amplitude of the detected disturbance signal caused by deployment than in a system using a AGC. It should be noted that this is only a qualitative observation. Comparative and quantitative tests should be conducted to determine if indeed this is true.

The data from the phase detector seems to offer an alternative to the amplitude based detection system. By hard limiting the reference as well as the disturbance signals the amplitude related threshold problems could be eliminated. On the other hand, the nulls in the detected threshold voltage which have been elimated by the quadrature detection scheme would reappear. There may exist a detection method, which not unlike the quadrature method, could fill in the nulls to insure detection with stable threshold levels.

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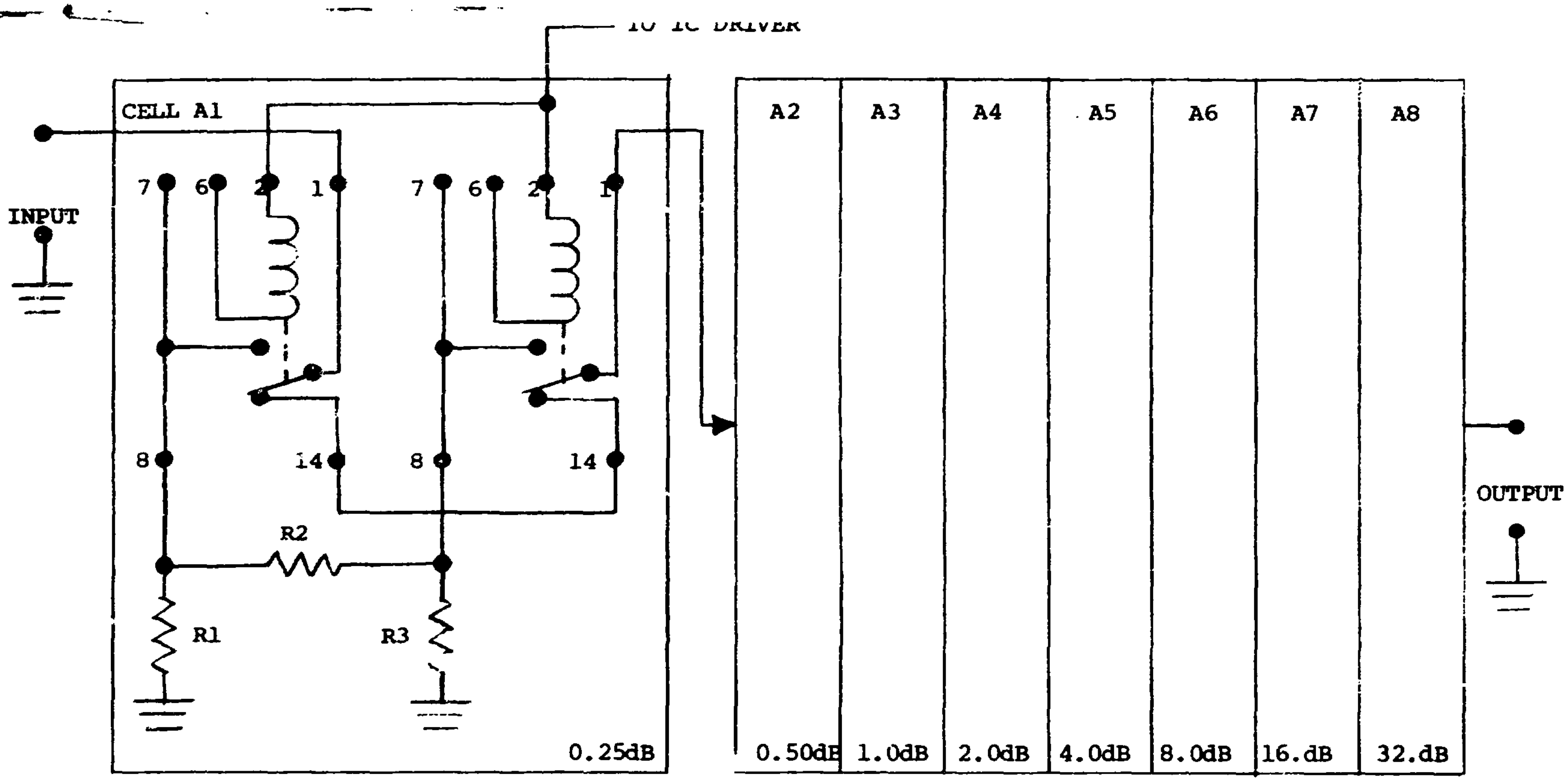
F19628-77-C-0142, 15 May 1977 through 15 February 1978

F19628-78-C-0160, 18 September 1978 through 3 December 1979

Rochefort, J.S., Sukys, R. and Poirier, N.C. (1978), "An Area Intrusion Detection and Alarm System." RADC-TR-78-258



	CELL A1	A2	A3	A4	A5	A6	A7	A8
R1	3475Ω	1738Ω	870Ω	436Ω	221Ω	116Ω	68.8Ω	52.6Ω
R2	1.44Ω	2.88Ω	5.77Ω	11.61Ω	23.8Ω	52.8Ω	153.8Ω	995Ω
R3	3475Ω	1738Ω	870Ω	436Ω	221Ω	116 Ω	68.8Ω	52.6Ω

RELAY
MAGNACRAFT
W172DIP-7
(2 PER CELL)

Figure 1. Digitally Controlled Attenuator

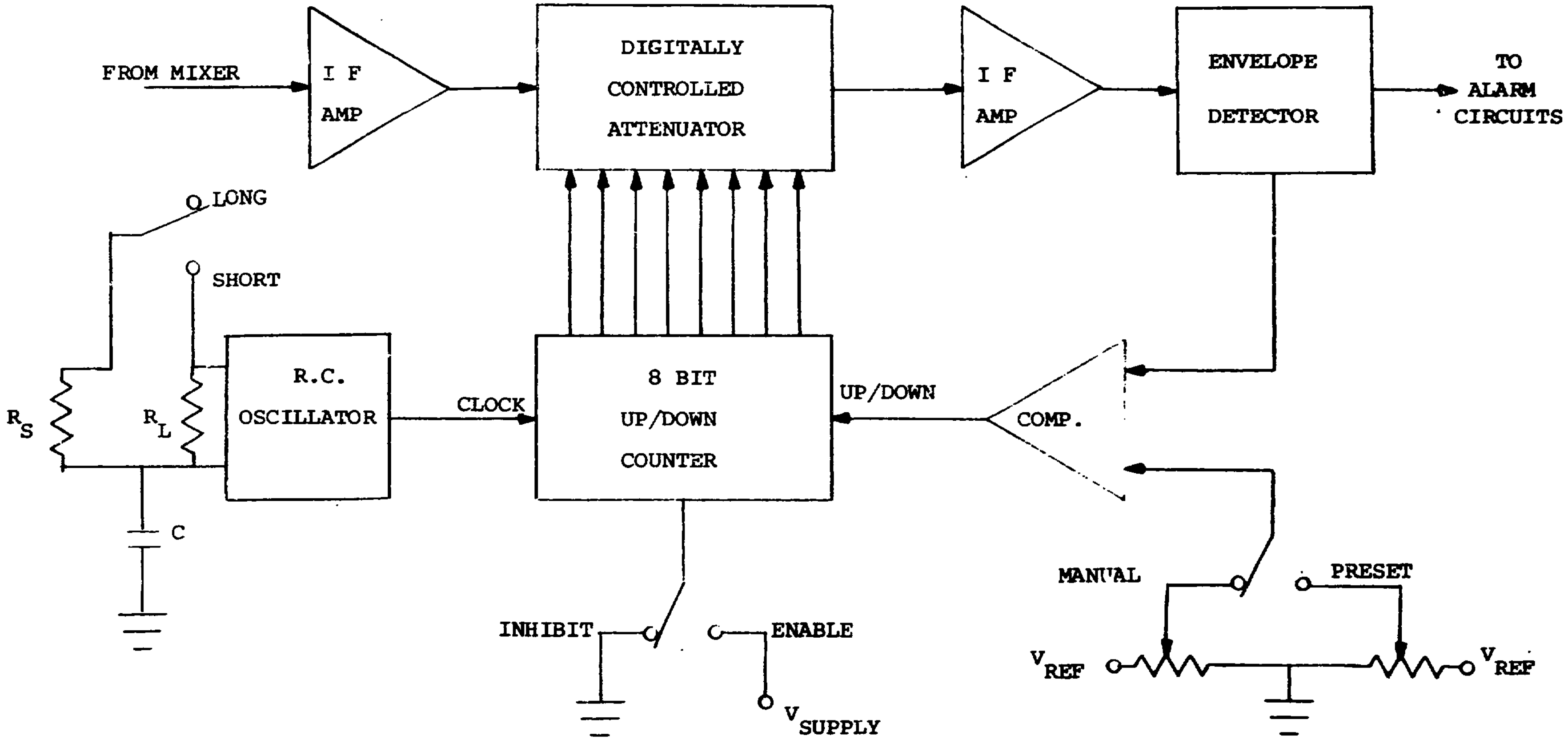


Figure 2. Digital AGC

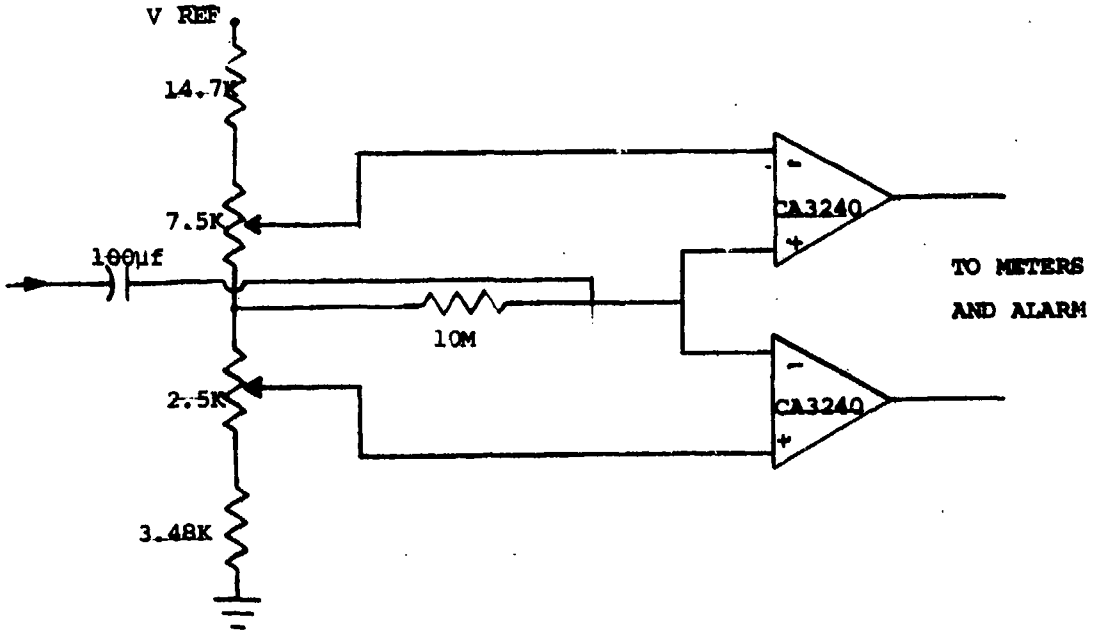


Figure 3. Modified Alarm Threshold Circuit

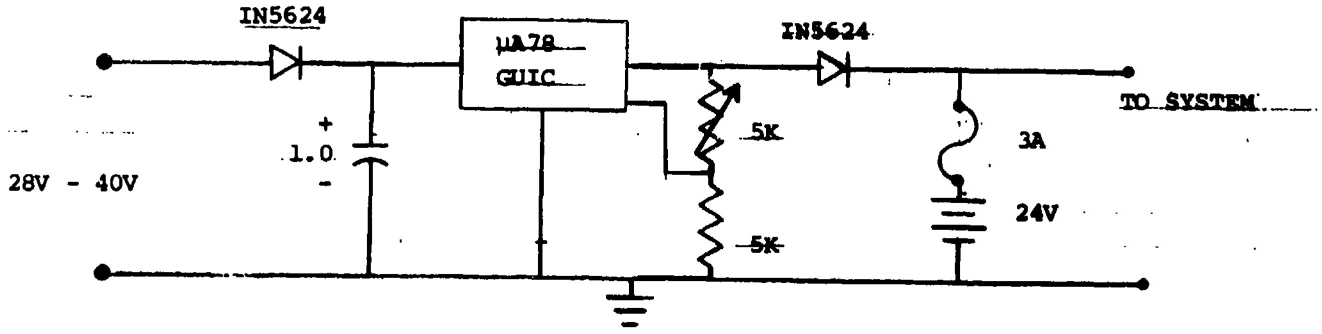


Figure 4. Power Supply

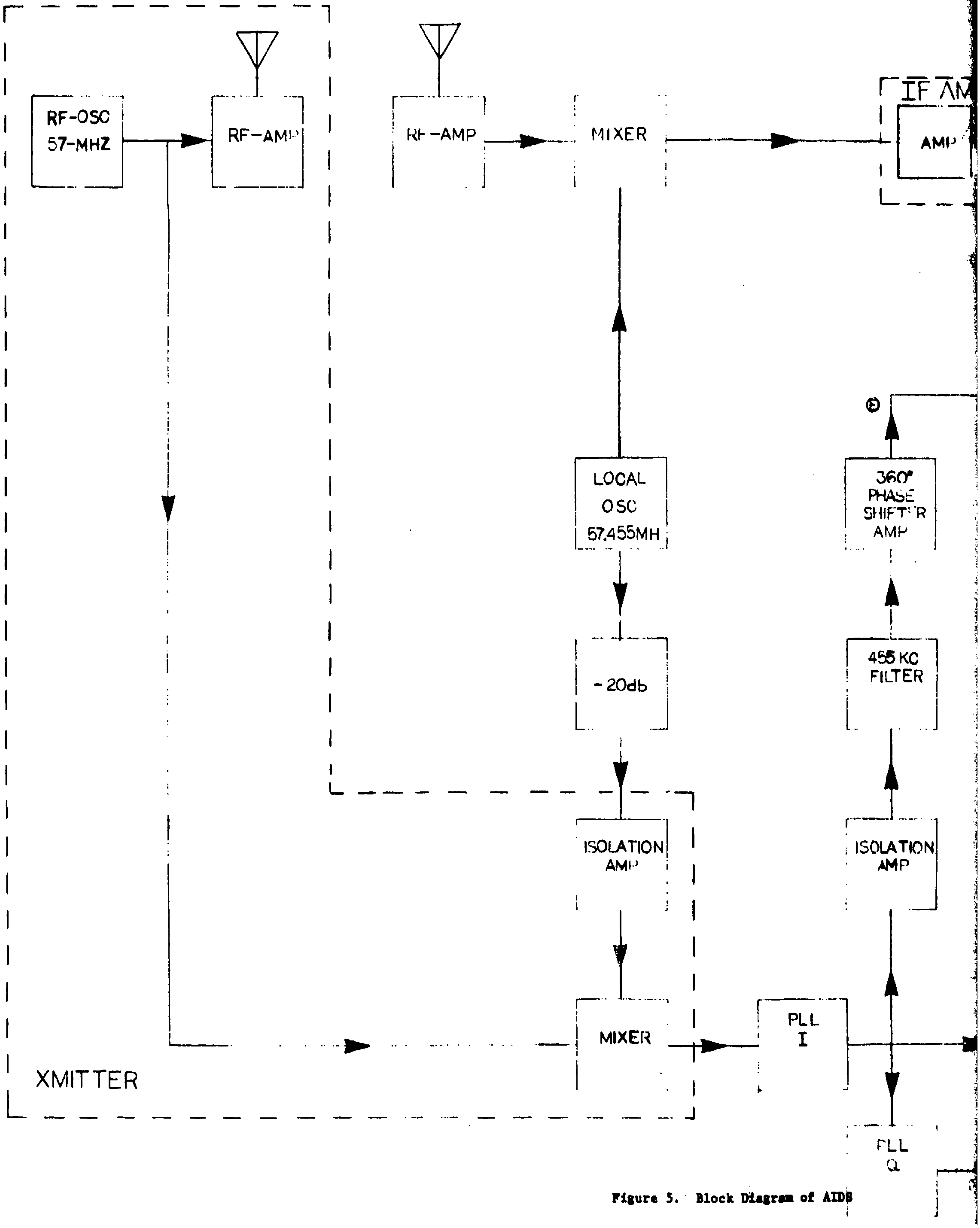
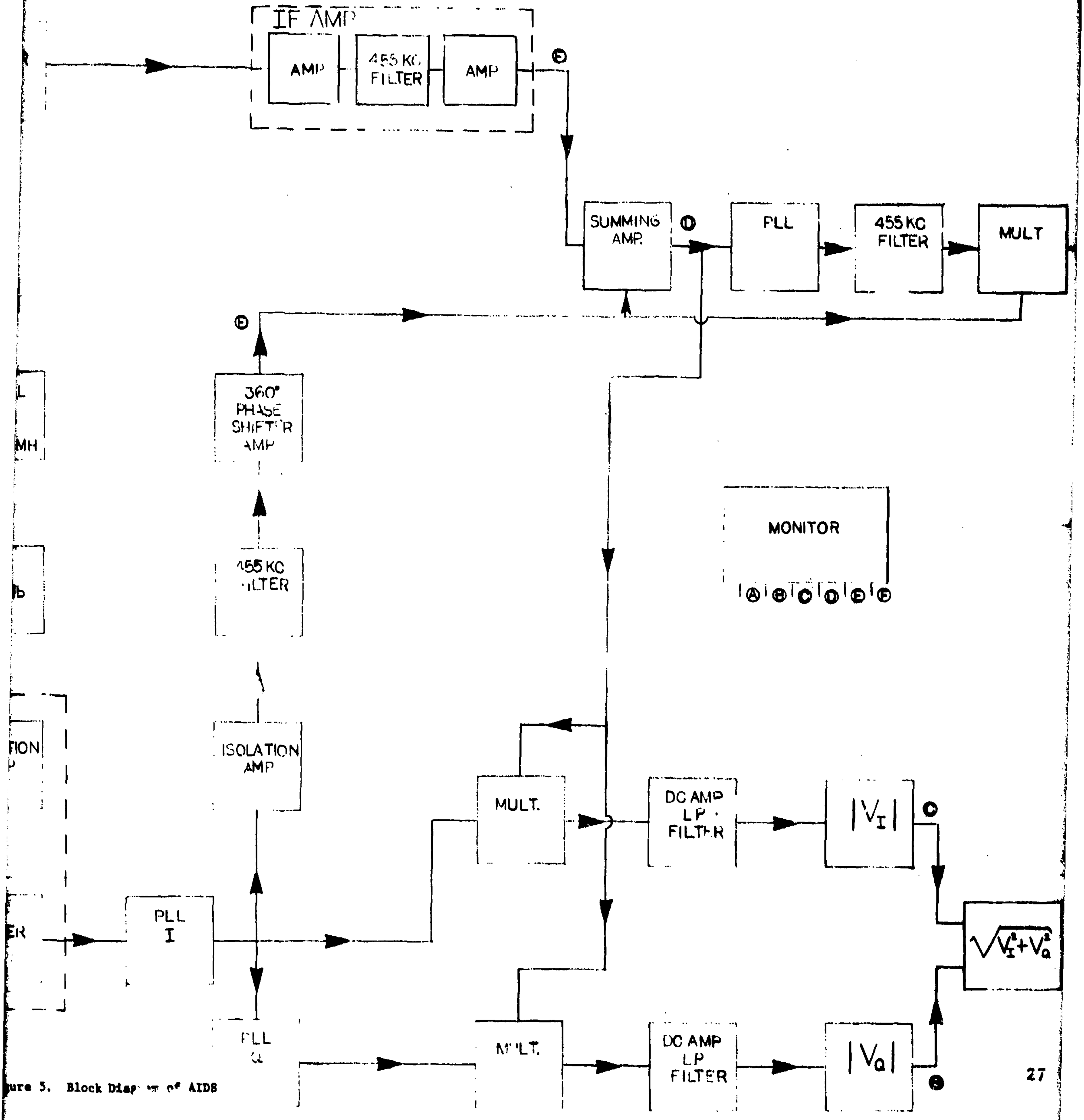


Figure 5. Block Diagram of AIDS



ure 5. Block Diag▪▪▪ of AIDS

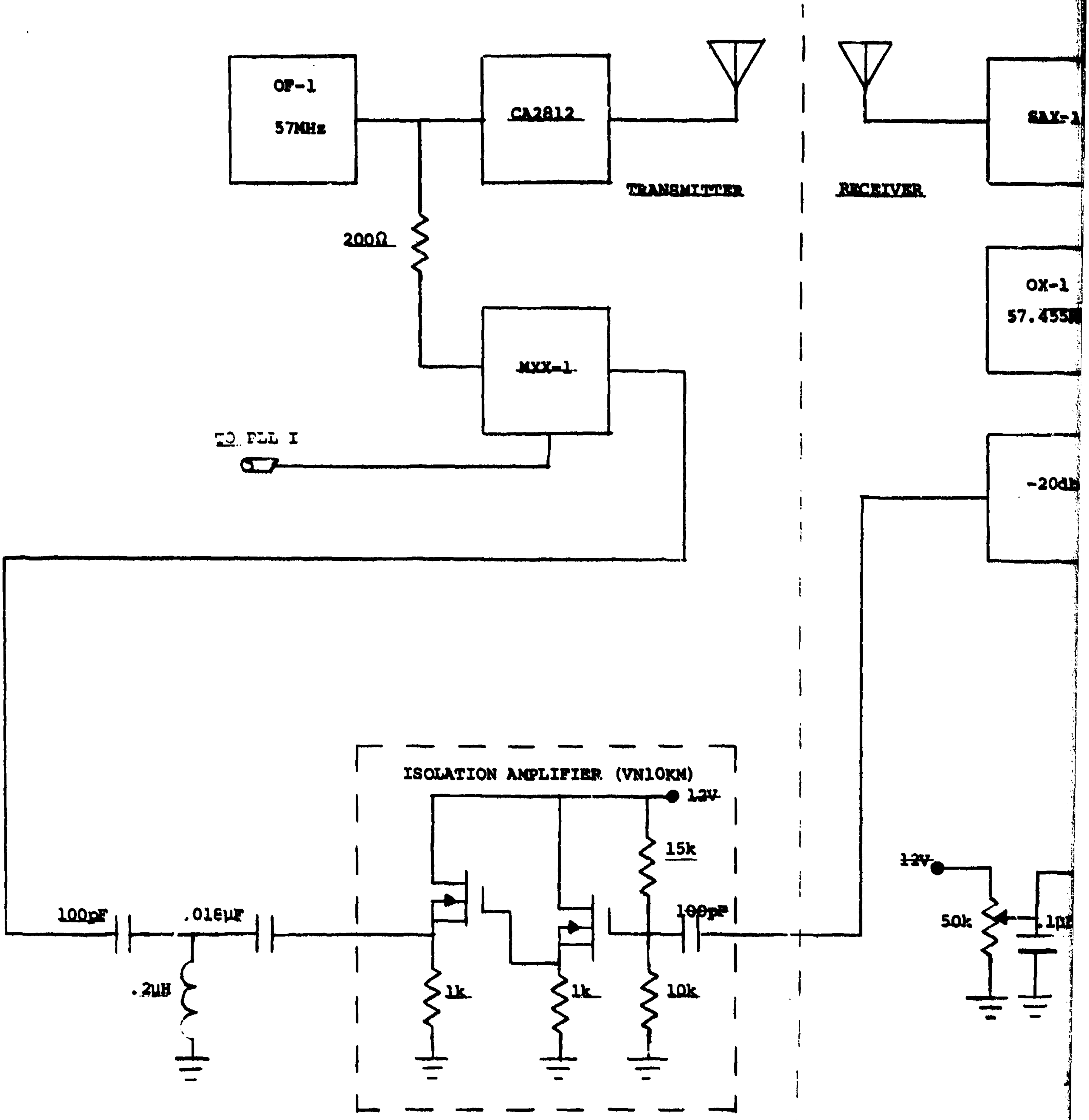
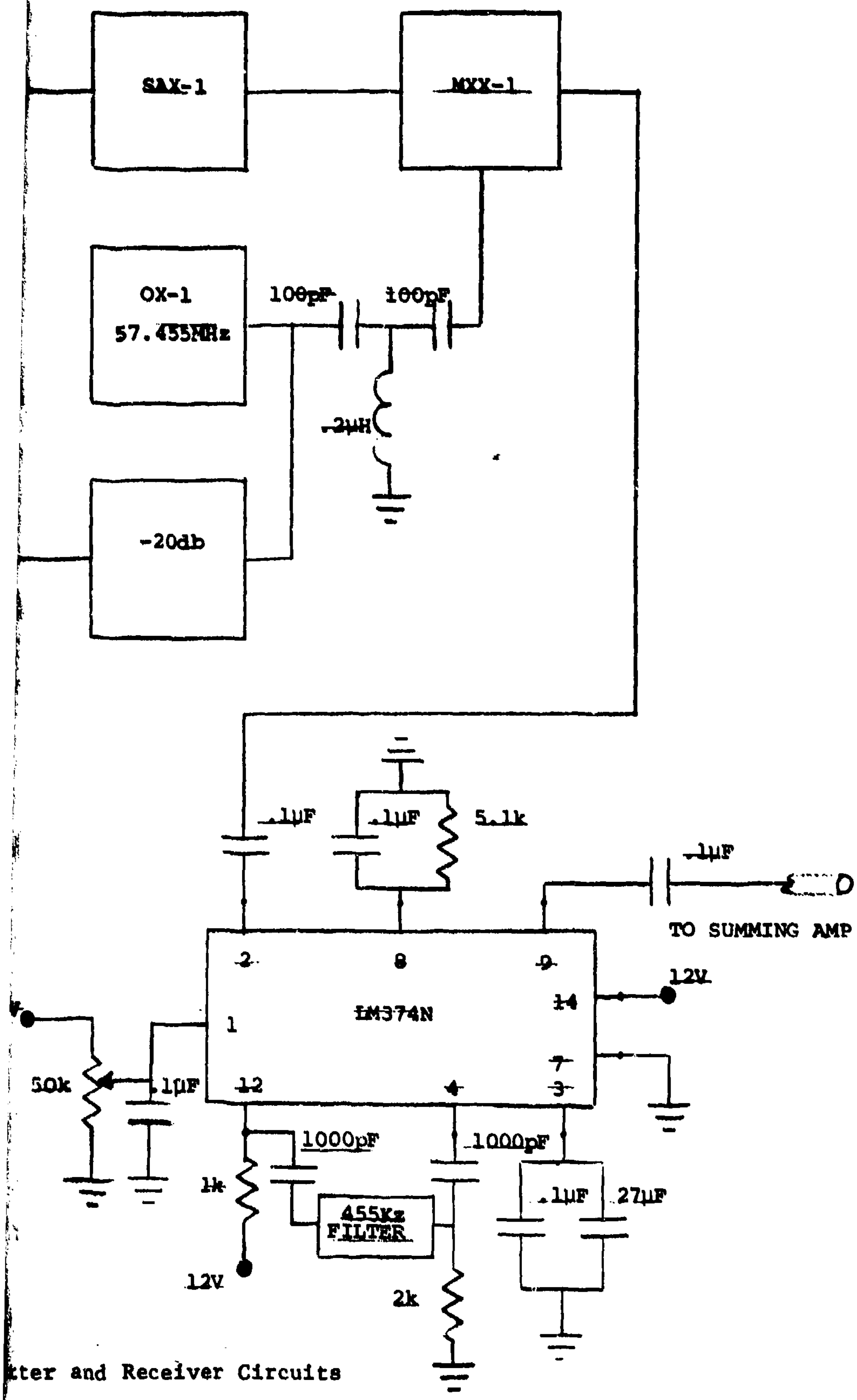
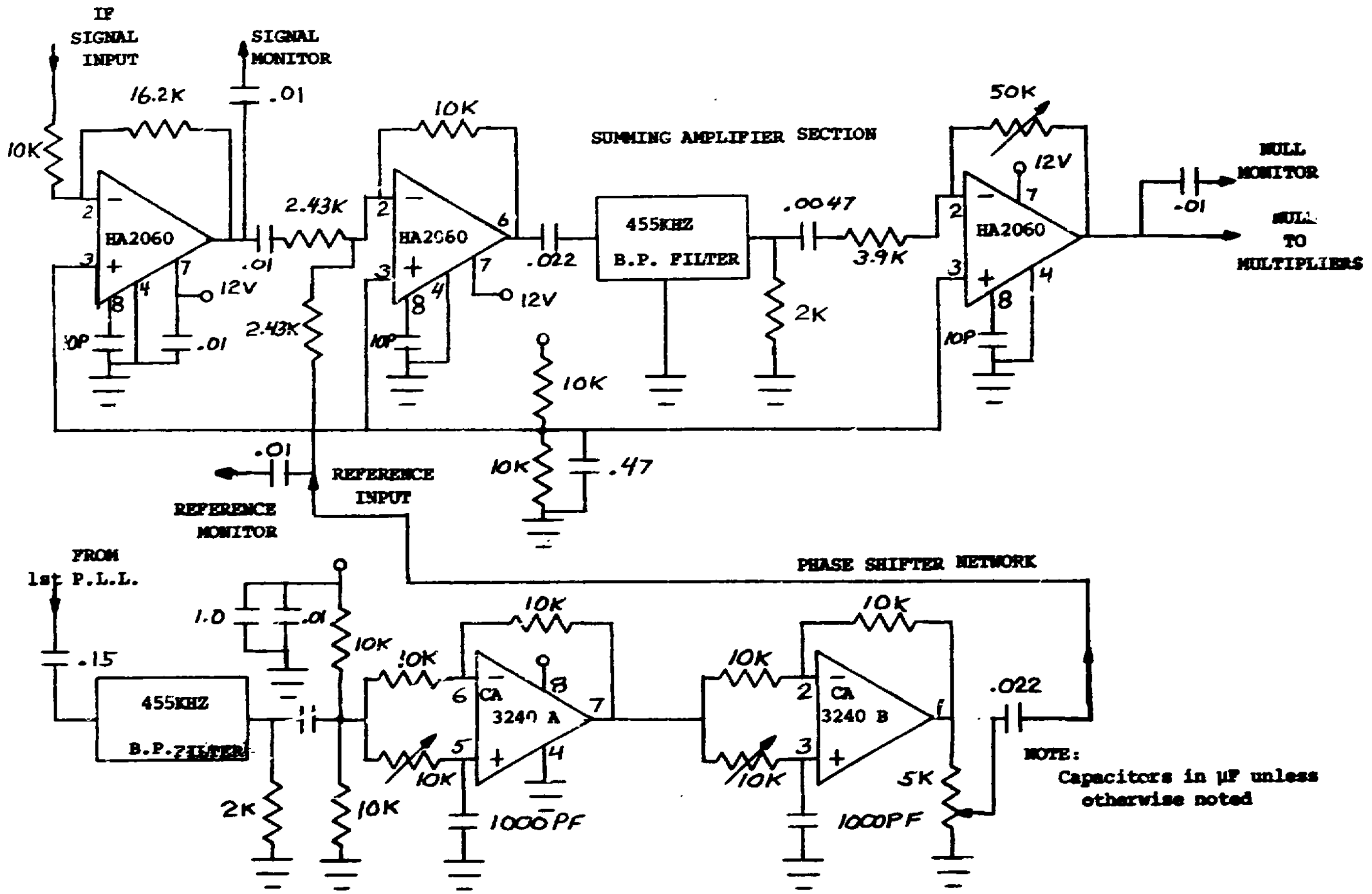


Figure 6. Transmitter and Recei



tter and Receiver Circuits



NOTE:
Capacitors in µF unless otherwise noted

Figure 7. Summing Circuits

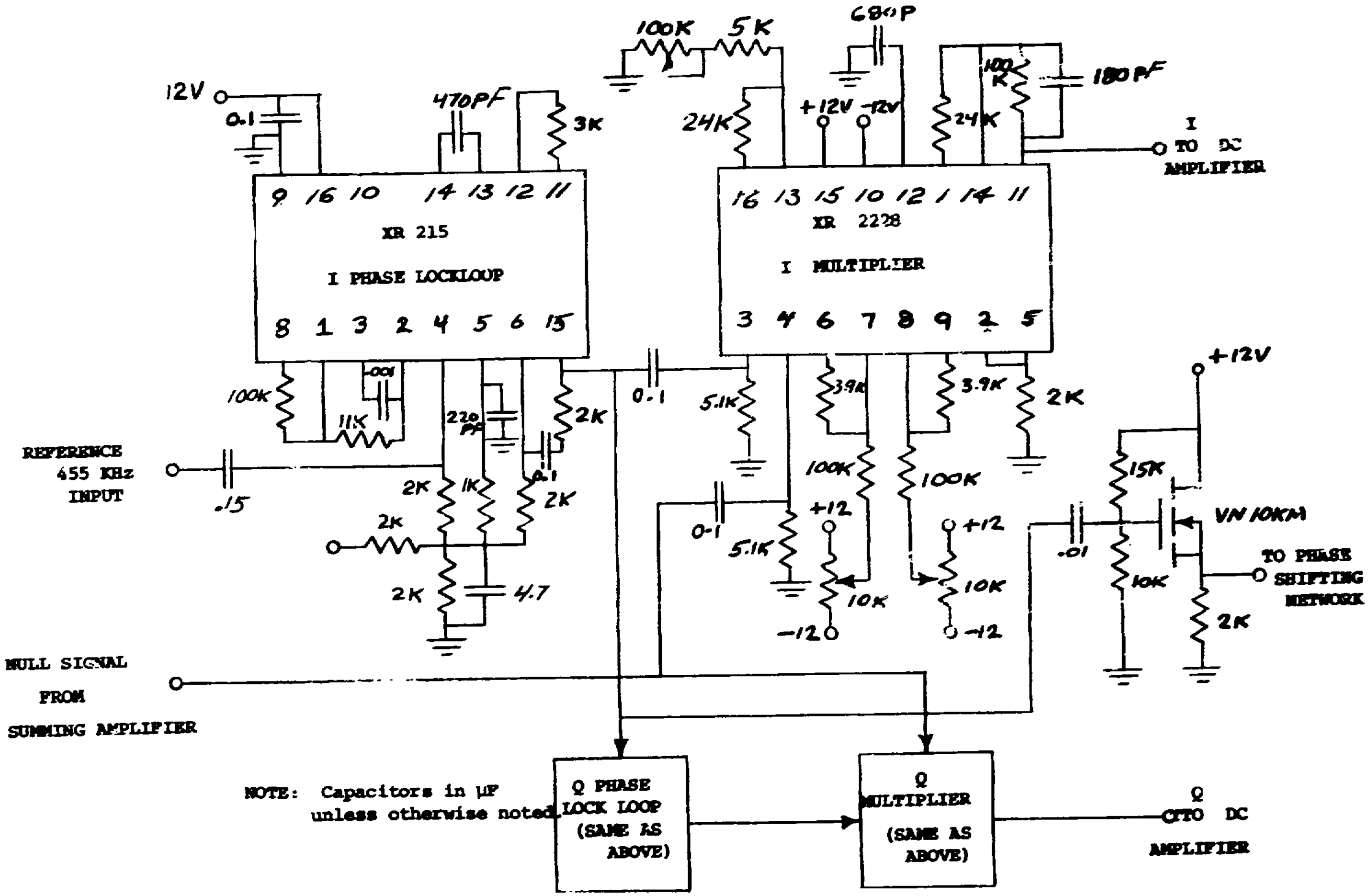


Figure 8. Quadrature Circuits

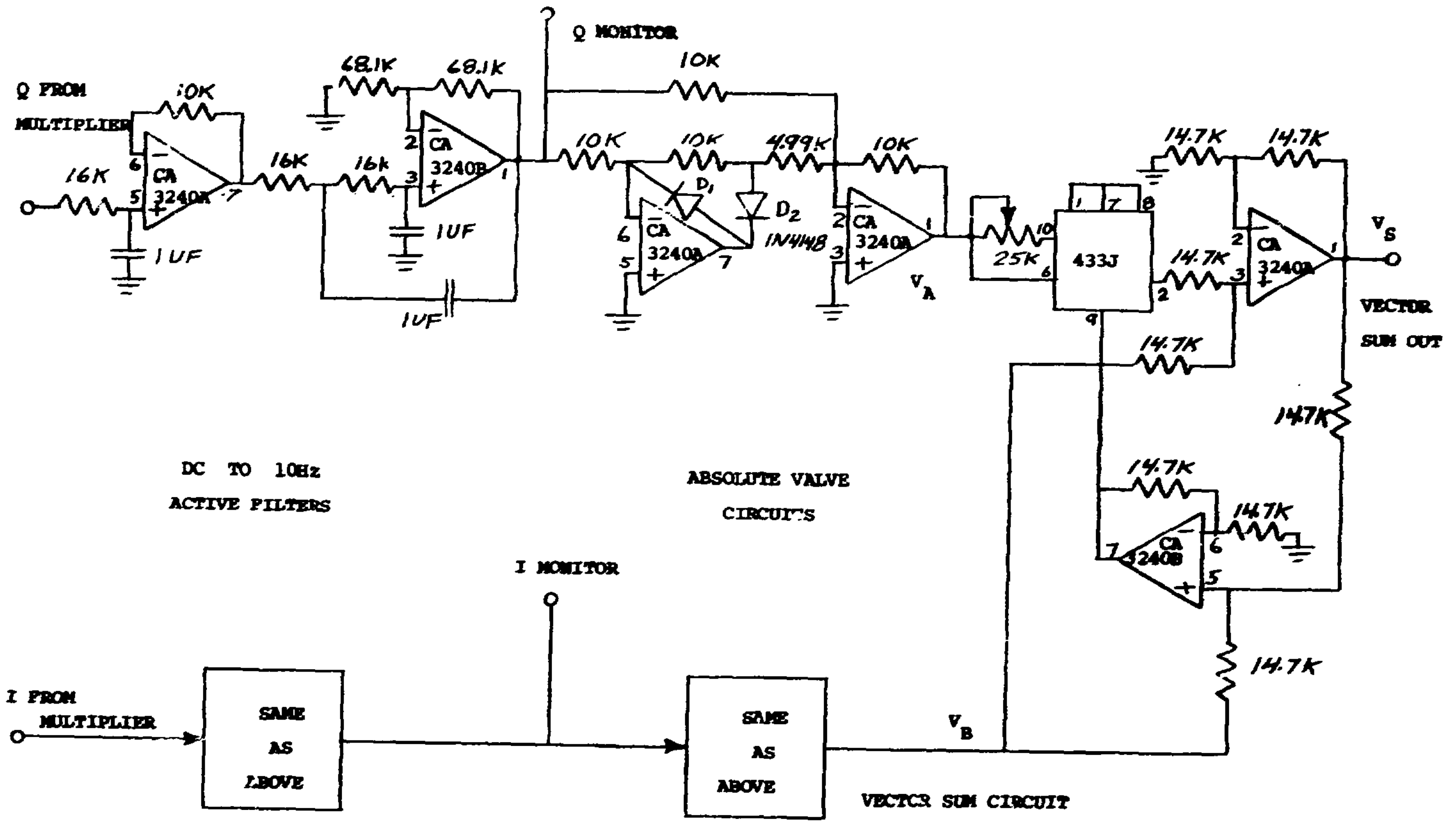


Figure 9. Vector Computation Circuits

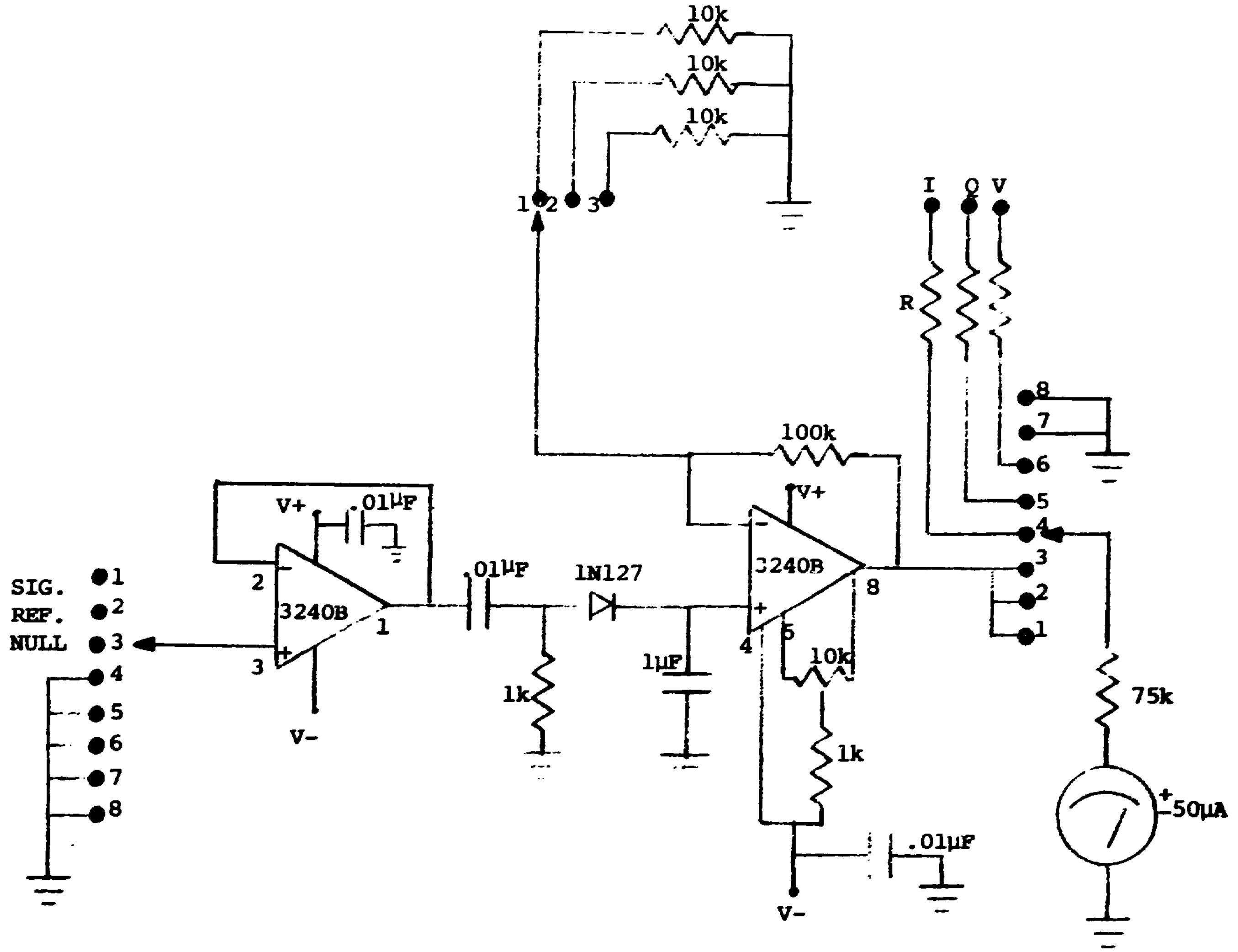


Figure 10. Monitor Circuit

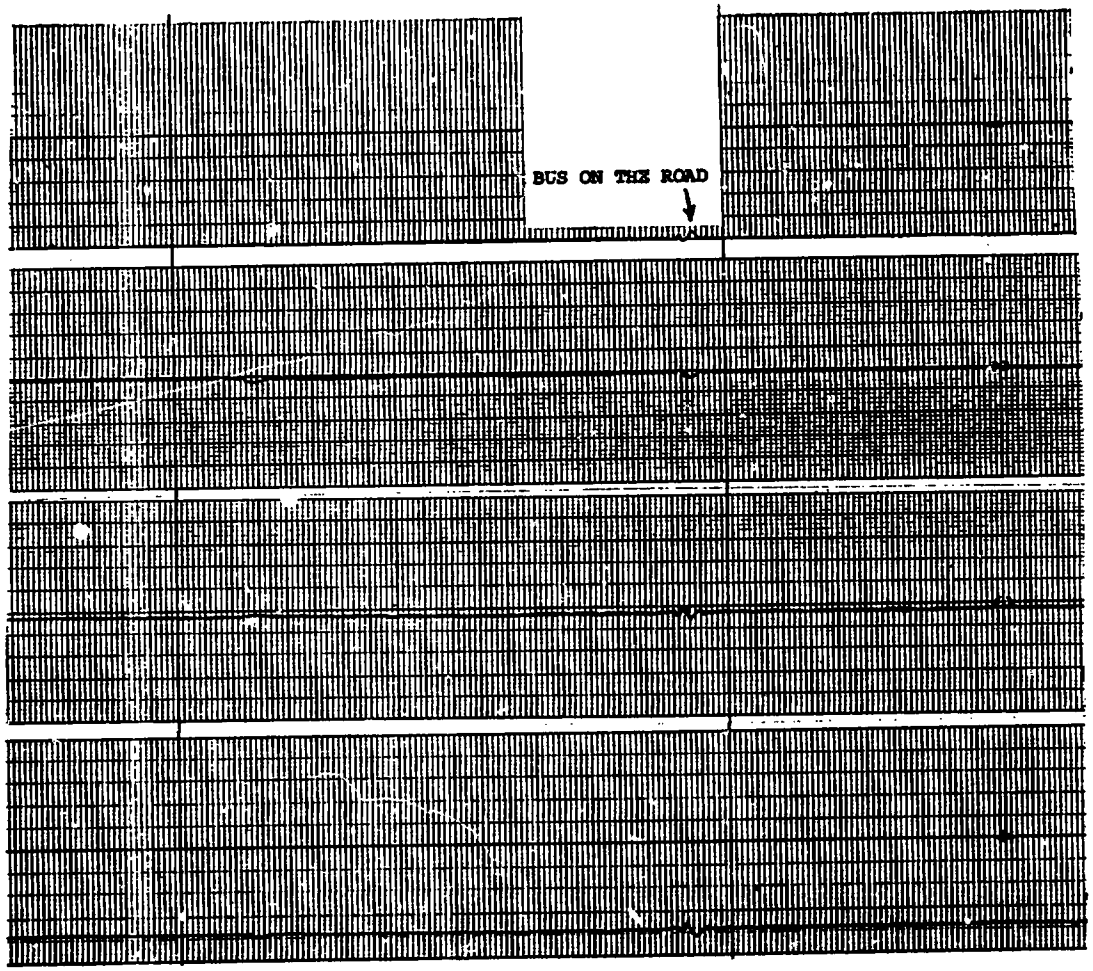


Figure 11. Quiescent Test

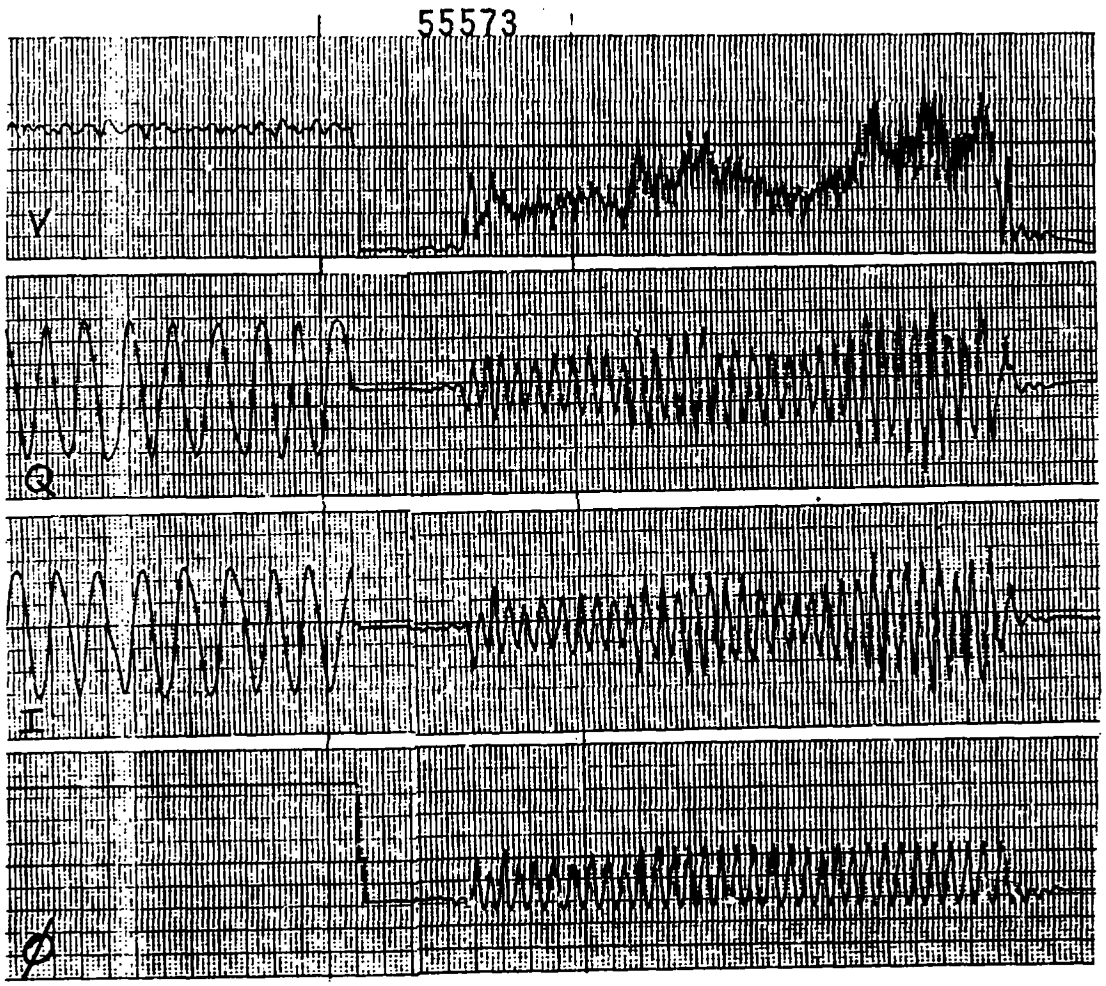


Figure 12. Circumferential Walk

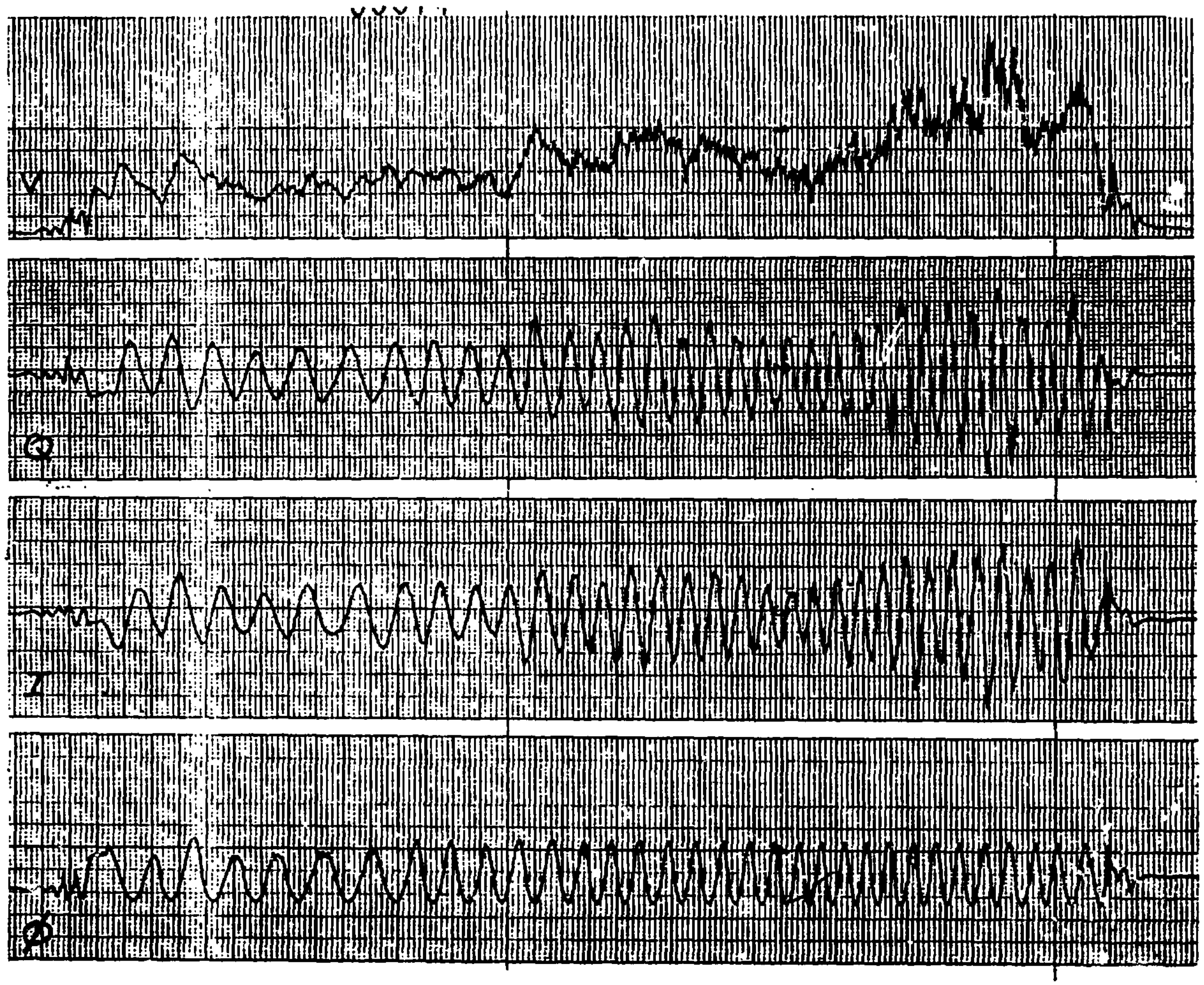


Figure 13. Circumferential Walk-Body Motion Test

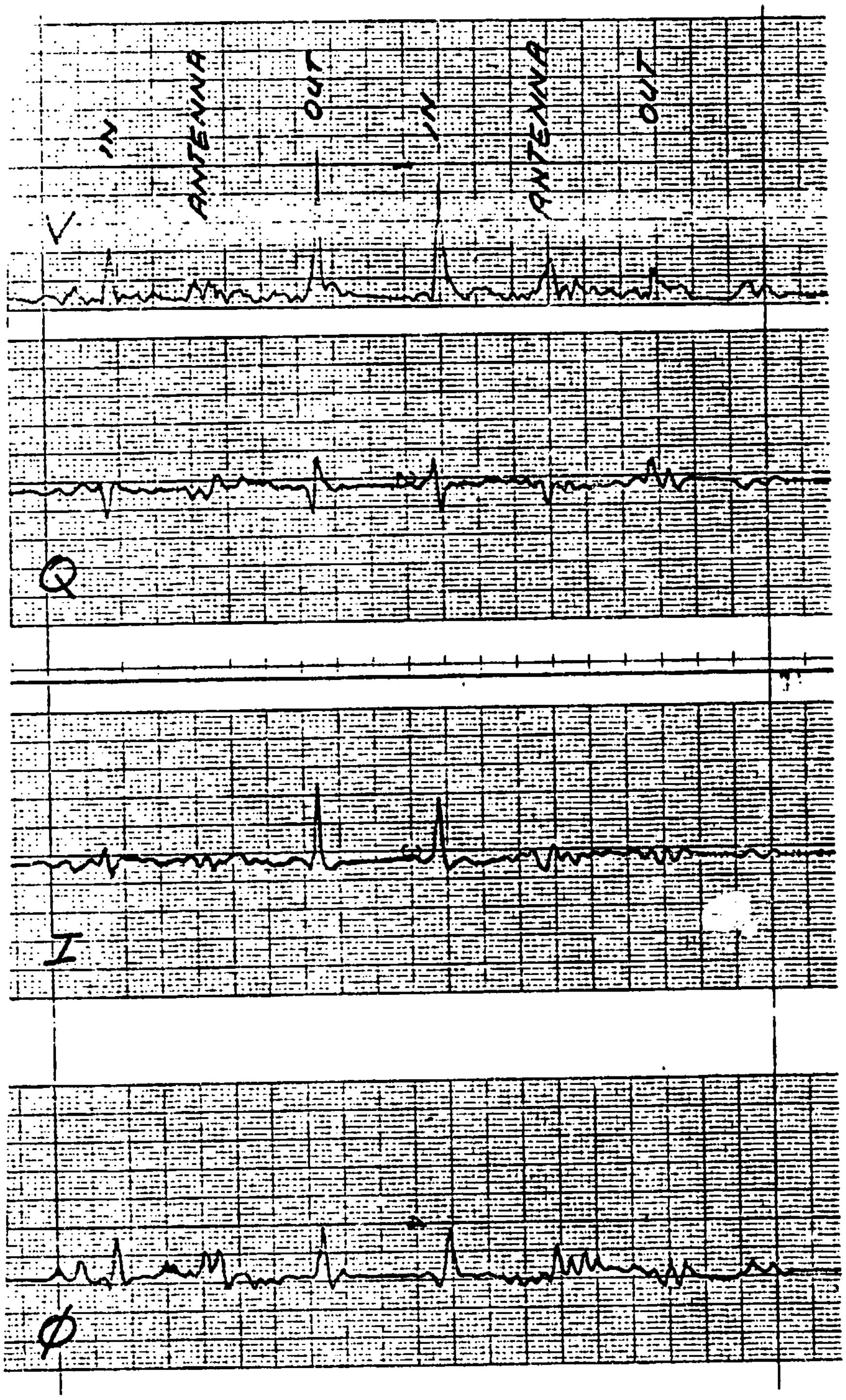


Figure 14. Response to Cable Crossings

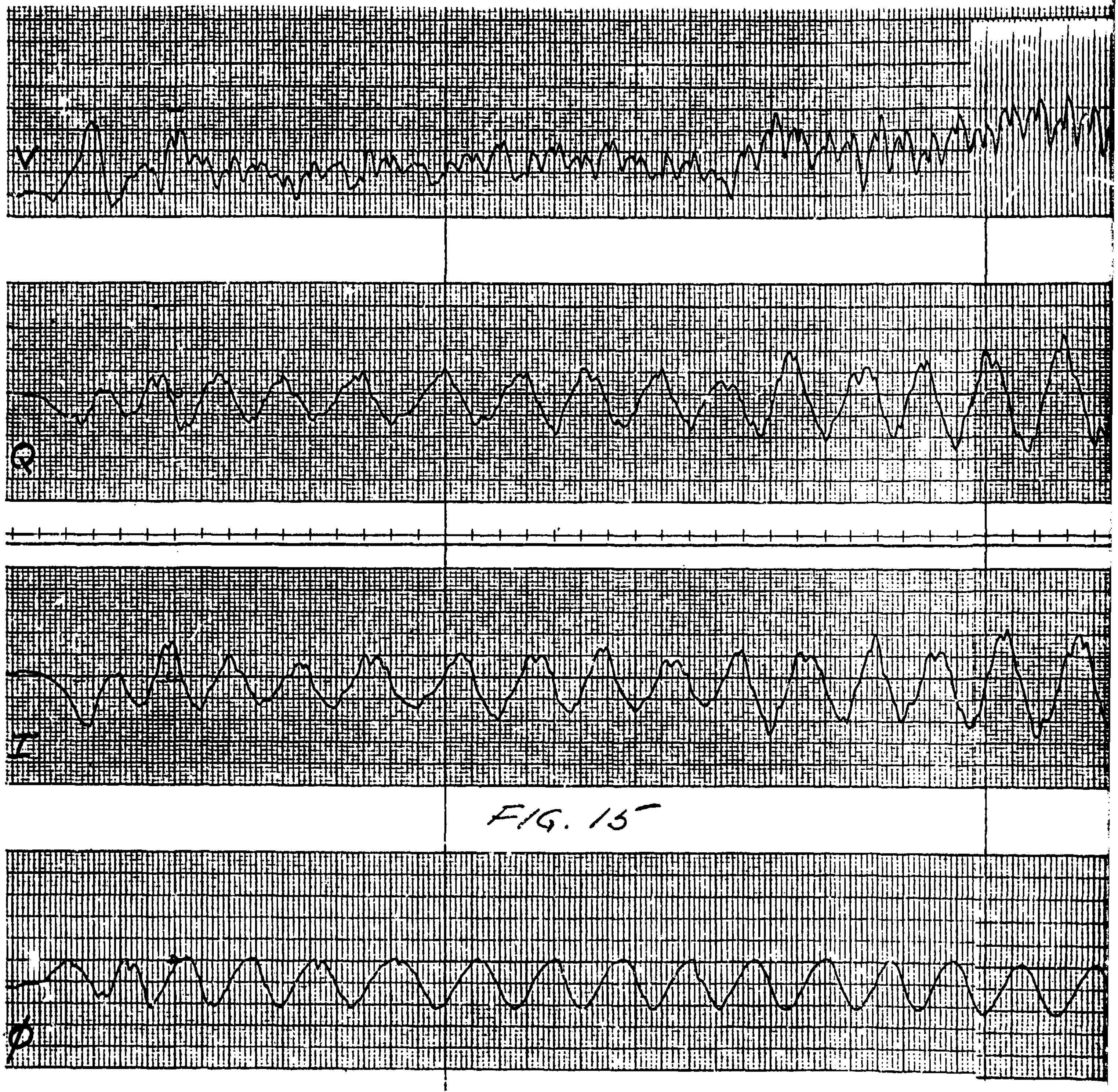


FIG. 15

Figure 15. Circumferential Walk - Cable Driven System

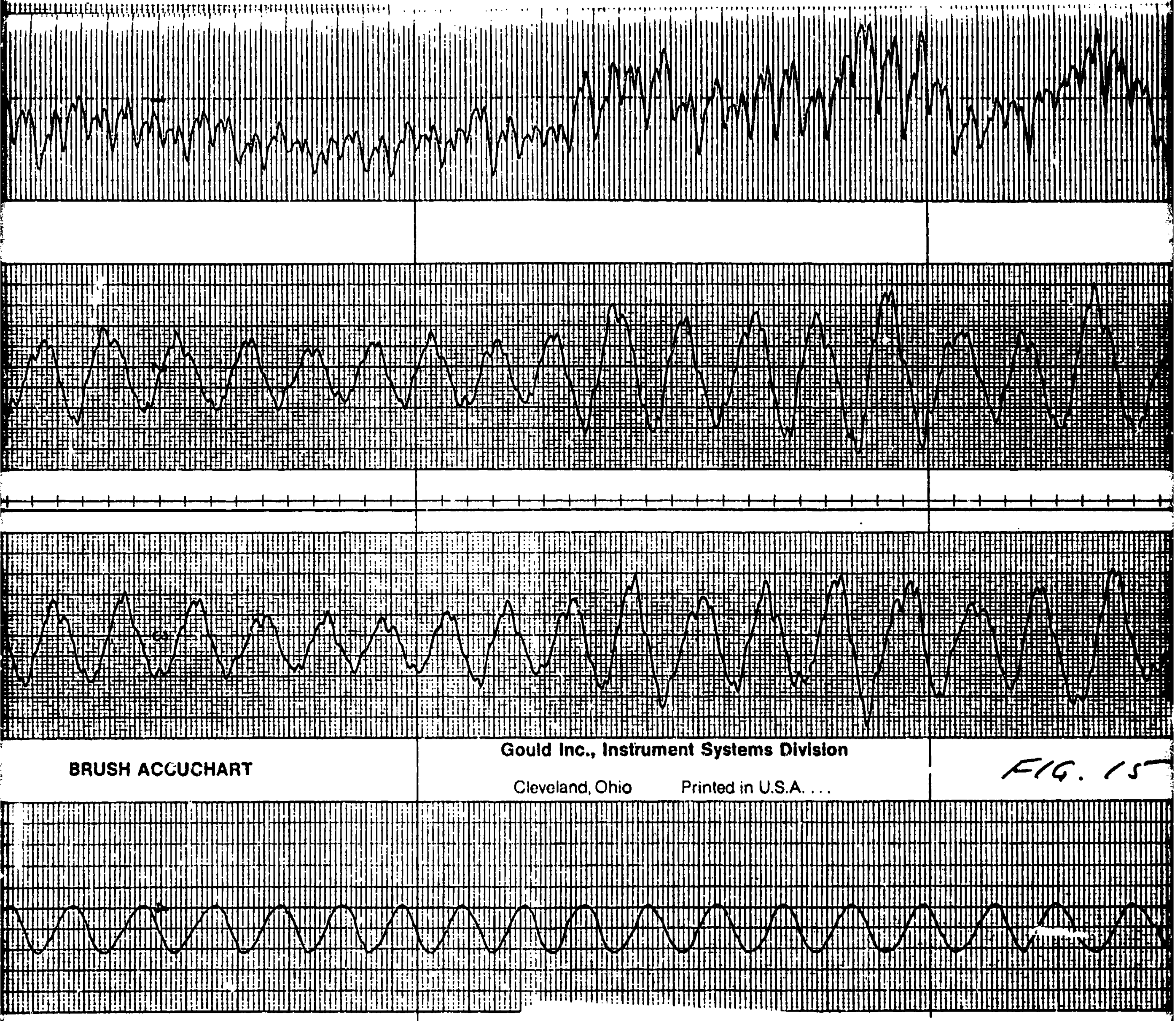

BRUSH ACCUCHART
Gould Inc., Instrument Systems Division
Cleveland, Ohio
Printed in U.S.A. . . .

FIG. 15

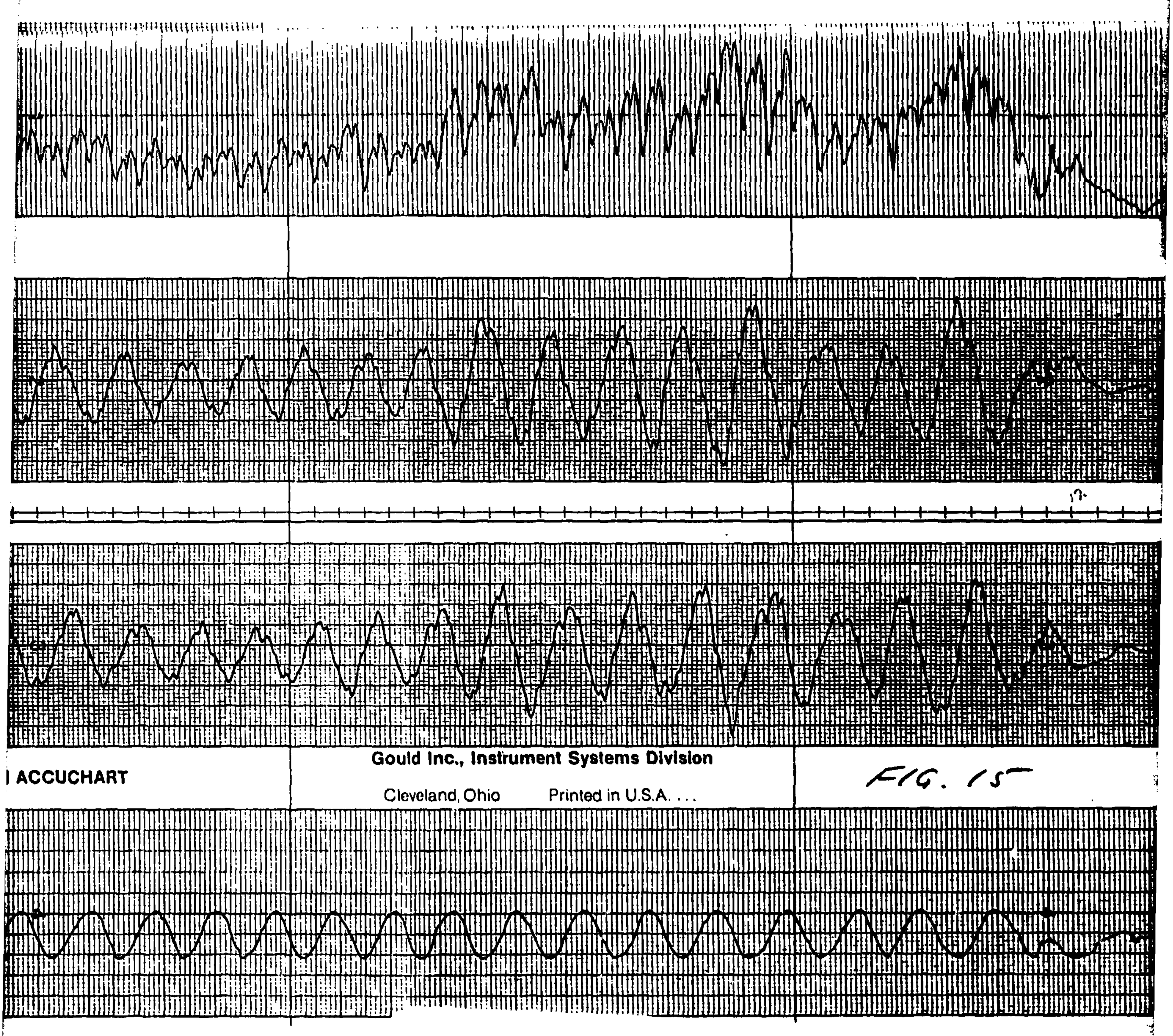

17.
| ACCUCHART
Gould Inc., Instrument Systems Division
Cleveland, Ohio Printed in U.S.A. . . .

FIG. 15

3

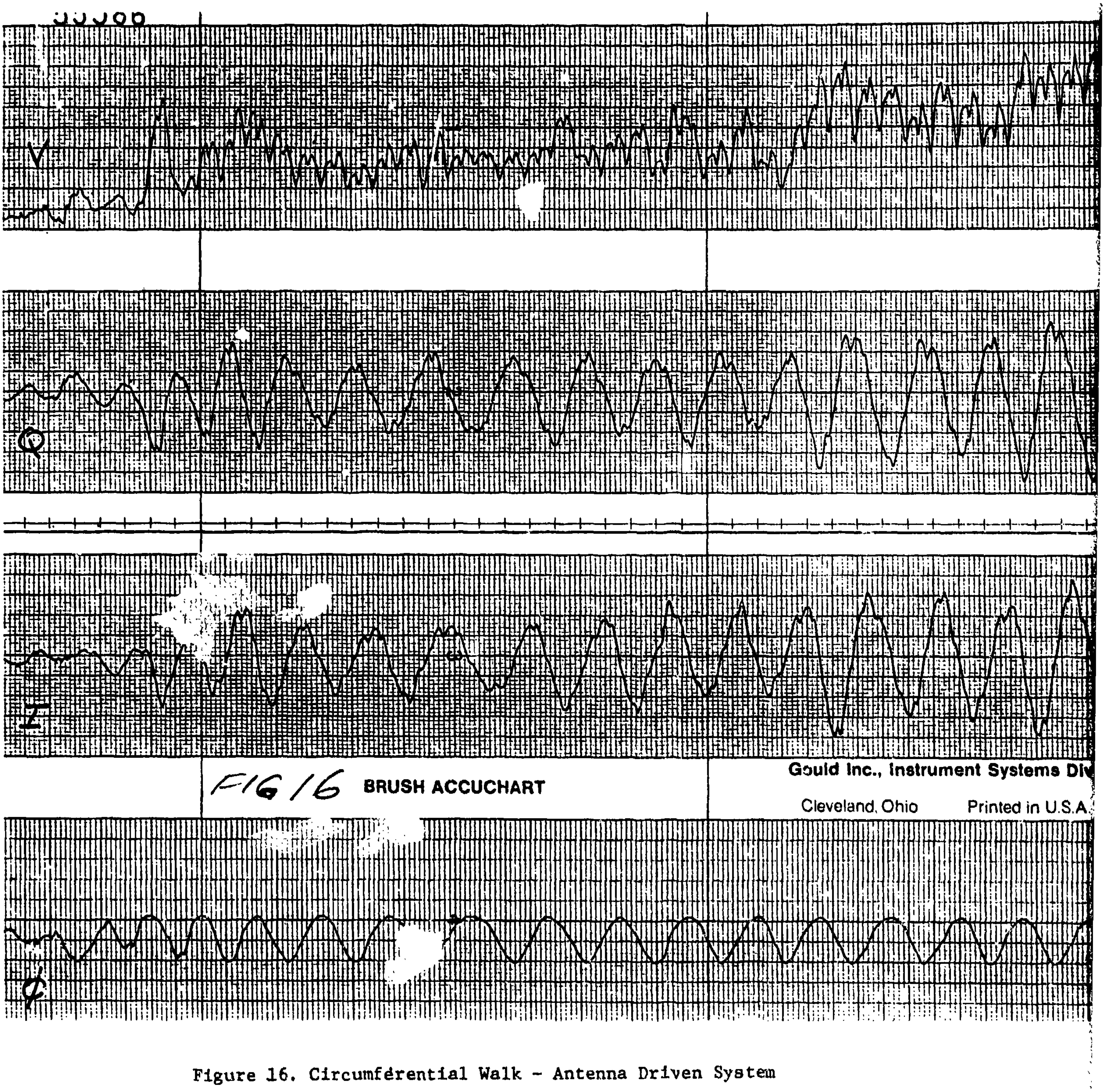


Figure 16. Circumferential Walk - Antenna Driven System

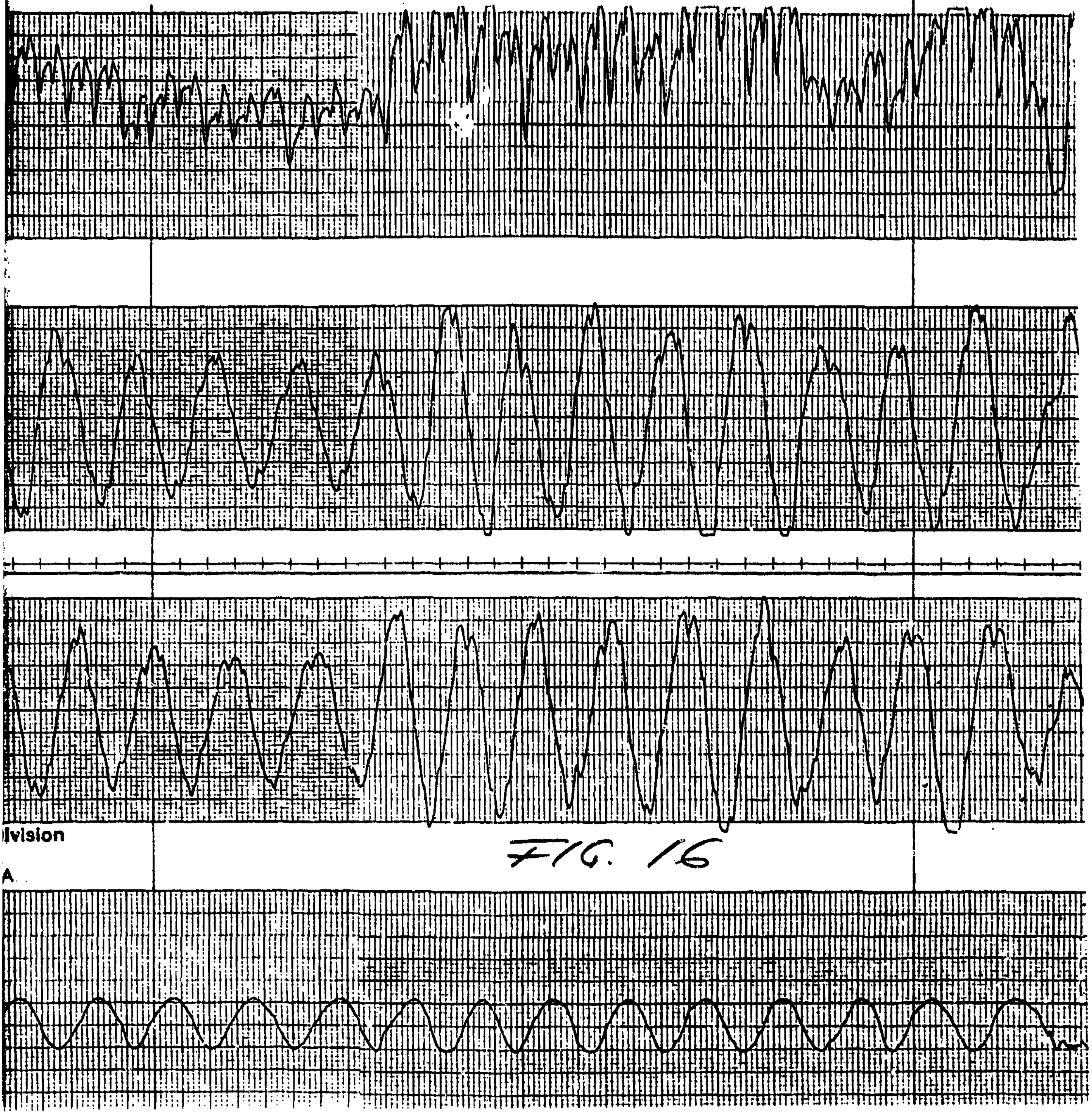


FIG. 16

MISSION
of
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