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UHF STIMULATION SYSTEM

Jose M. R. Delgado, M.D.
Gerhard Weiss, B.E.E.
Yale University School of Medicine

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6571st Aeromedical Research Laboratory
Aerospace Medical Division
Air Force Systems Command
Holloman Air Force Base, New Mexico

The animals used in this study were handled in accordance with the "Guide for Laboratory Animal Facilities and Care" as promulgated by the National Academy of Sciences - National Research Council.

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FOREWORD

This research was conducted by the Yale University School of Medicine under Contract No. F29600-67-C-0058 from 1 July to 31 December 1968. The contract was monitored by Captain Jan D. Wallace, Bio Effects Division, 6571st Aeromedical Research Laboratory under project and task number 6892/02.

The views expressed herein are those of the author and do not necessarily reflect the views of the U. S. Air Force or the Department of Defense.

This technical report has been reviewed and approved for publication.

ROBERT G. McIVER, Colonel, USAF, MC
Commander

ABSTRACT

A UHF remote stimulation system working in the 915 MHz band is described, which generates current pulses in three stimulation channels. The amplitude, duration, repetition rate and channel can be controlled from a remotely located control panel. This system has been installed at Holloman Air Force Base, New Mexico, to stimulate the brain of free ranging chimpanzees and study the induced modifications on individual and social behavior.

INTRODUCTION

Remote controlled stimulation of the brain based on RF transmission in the 100 MHz band has been used in our laboratory for several years (Delgado, et al 1969[1]).

In some locations, however, restrictions imposed on the transmitting power make convenient the use of less crowded bands of frequency and the present report describes the system that we have developed for brain stimulation in free ranging chimpanzees, using a carrier frequency of 915 MHz.

Figure 1 indicates the signal flow in the system. The signals determining channel, intensity, duration and repetition rate originate in the control circuit section (1). The output of the control circuit is a low power pulse train which controls the output of the gated power supply (2) and, therefore, the power to the UHF transmitter (3). Bursts of radio frequency at 915 MHz are generated by the transmitter according to the signals from the control circuit section (1) and radiated by the antenna (4). This equipment is stationary and located outside the animal compound or cage.

The instruments carried by the animal consist of the 915 MHz to 100 MHz down converter (5) and the stimulator receiver (6) connected to the converter. The receiver demodulates the 100 MHz signal from the converter and generates the stimulation pulses at the appropriate channel as directed by the modulating signals from the control circuit section (1).

SUMMARY

A UHF remote stimulation system working in the 915 MHz band is described, which generates current pulses in three stimulation channels. The amplitude, duration, repetition rate and channel can be controlled from a remotely located control panel. This system has been installed at Holloman Air Force Base, New Mexico, to stimulate the brain of free ranging chimpanzees and study the induced modifications on individual and social behavior.

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[1] Jose M. R. Delgado, M.D., Ronald J. Bradley, Ph.D., Victor S. Johnston, Ph.D., Gerhard Weiss, B.E.E. and Jan D. Wallace, M.D. "Implantation of Multilead Electrode Assemblies and Radio Stimulation of the Brain in Chimpanzees." 6571st Aeromedical Research Laboratory Technical Report, ARL-TR-69-2.

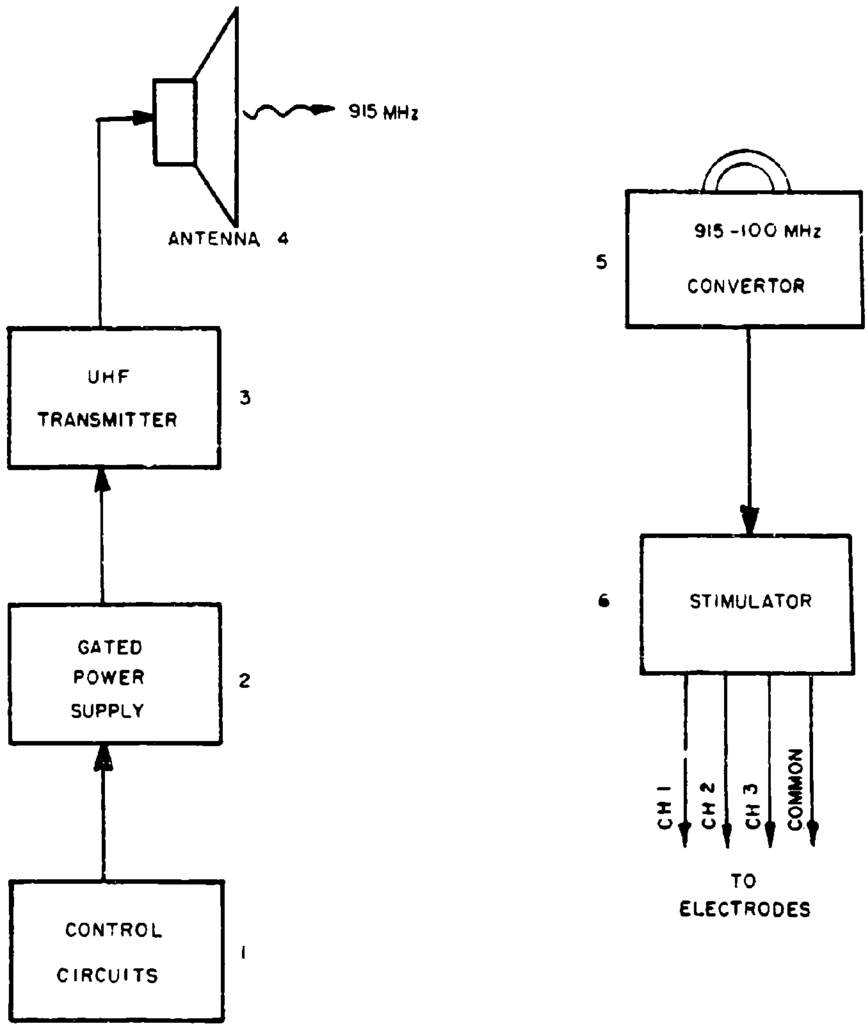


Figure 1. UHF Stimulator System

CIRCUIT DESCRIPTION

A. Control Circuits

Figure 2 shows the control console and Figure 3 the block diagram of the control circuits. The circuit diagram is shown in Figure 4A and 4B. With all three ON-OFF switches in the ON position the sequence of signals is as indicated in the timing diagram Figure 5. The letters in the timing diagram refer to the parts of block diagram Figure 3 at which these signals occur. The repetition rate of the control signals is determined by the astable multivibrator (b).

The frequency of this multivibrator can be varied by a frequency control (a). This control varies the time constant of the frequency determining RC network in conjunction with a voltage control which limits the charge of the capacitor in the RC network and thus influence the frequency.

The monostable multivibrators (c) and (d) are triggered by alternate half cycles of multivibrator (b). Multivibrator (d) triggers a delay circuit (e) which in turn triggers multivibrator (f). The outputs of the three monostable multivibrators (c, d, and f) are connected each to one input of the three AND-gates (h, i, and k). Another input of each AND-gate is connected to an ON-OFF switch for each channel. The third input of each gate is connected to a subcarrier oscillator, one for each channel. With the switch for any one of the channels in the ON position and the corresponding monostable multivibrator in the triggered (unstable) condition the oscillator signal is allowed to pass through the gate to an OR (summing)-Gate which passes any of the three signals which arrives to the driver circuit.

The duration of the ON-time of the monostable multivibrator determines the duration of the actual current pulse from the stimulator. As shown in the circuit diagram of the control circuit, Figure 4A, the timing capacitor is charged by a constant current circuit which obtains its reference voltage from the duration control (g). The duration control is a step attenuator which determines the charging rate of the timing capacitors in all three monostable multivibrators by varying the reference voltage to the constant current circuit.

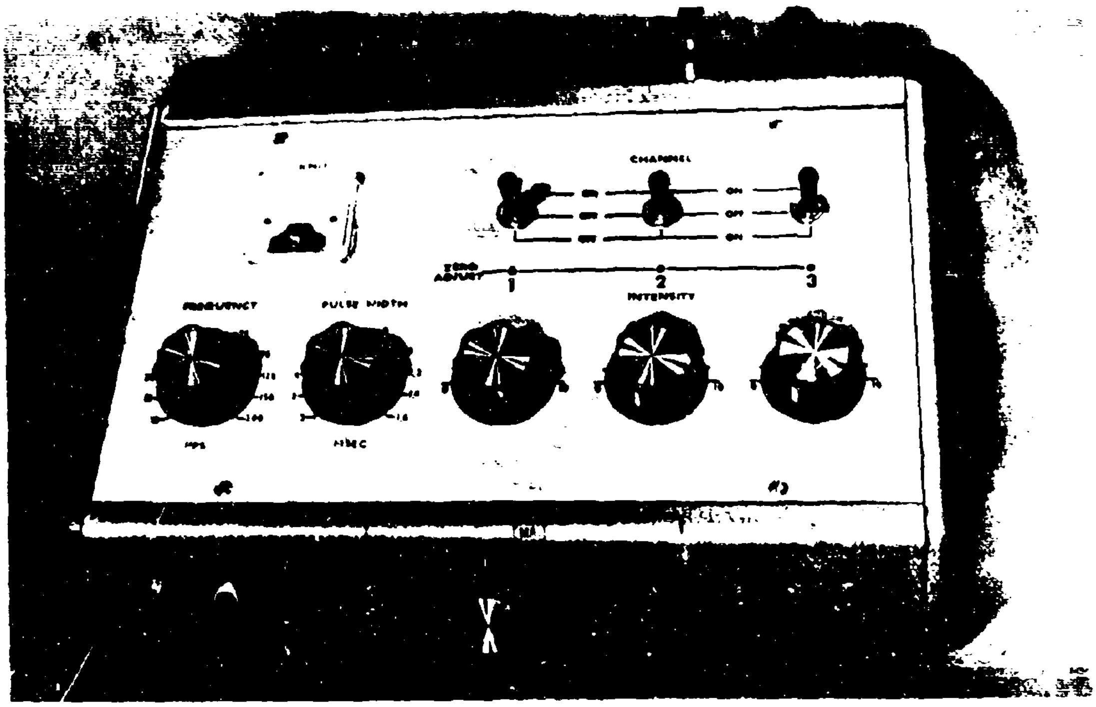


Figure 2. Control Console for the Three-Channel Transmitter

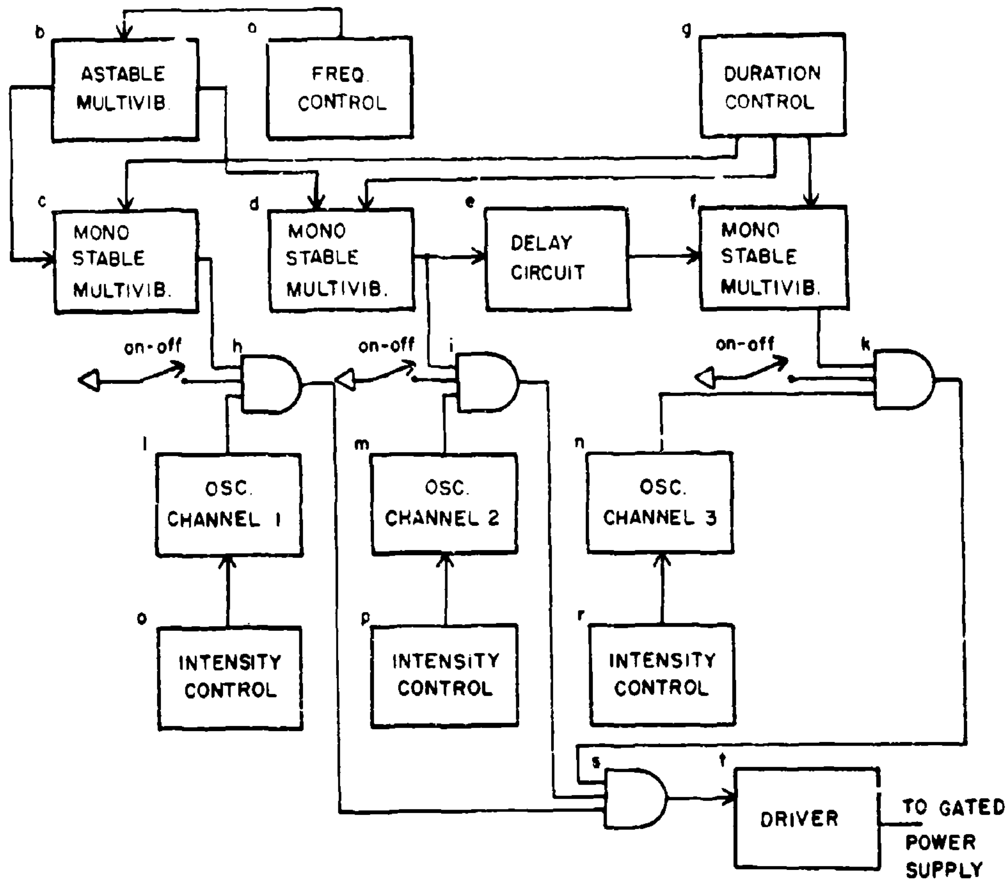


Figure 3. Block Diagram of Control Circuits

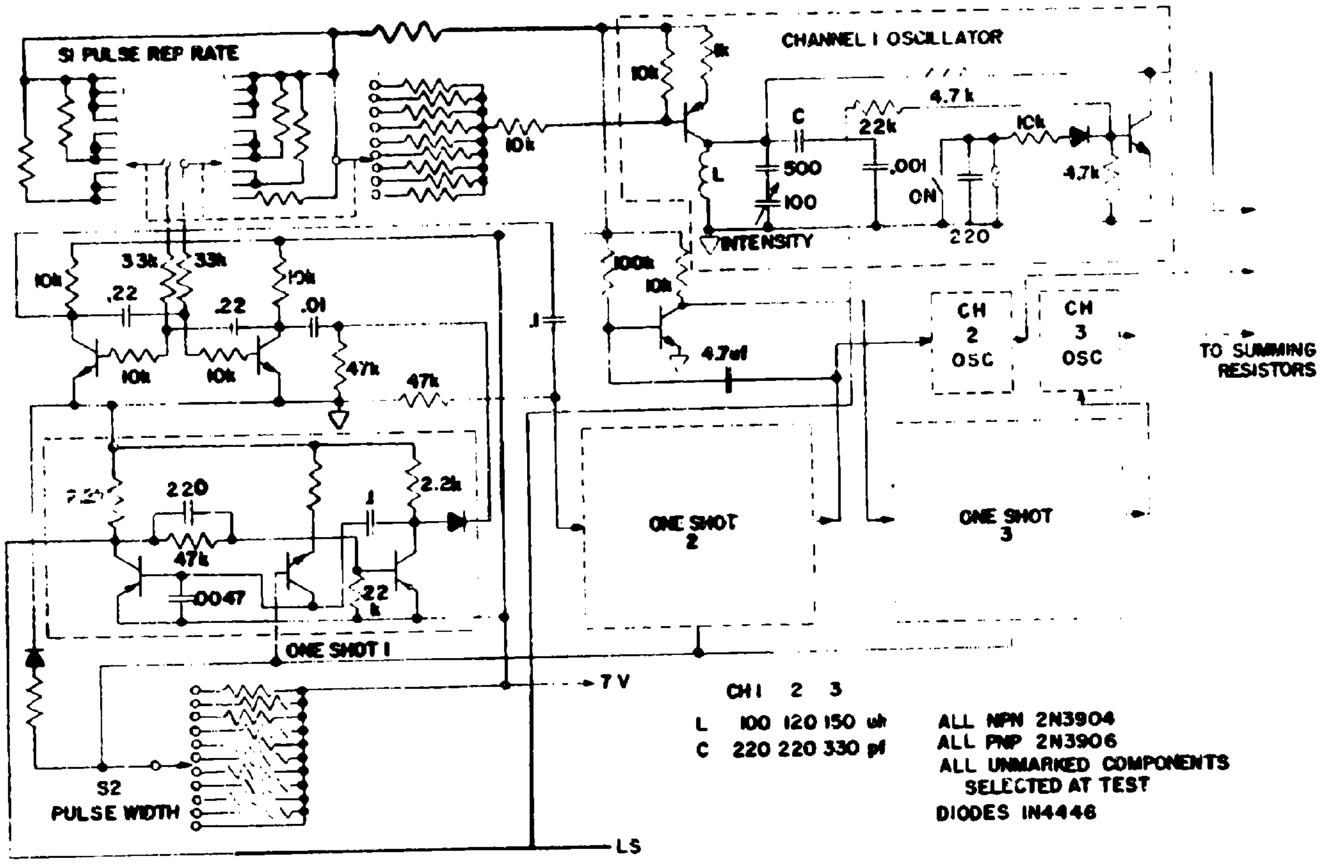


Figure 4A. Circuit Diagram of Control Console

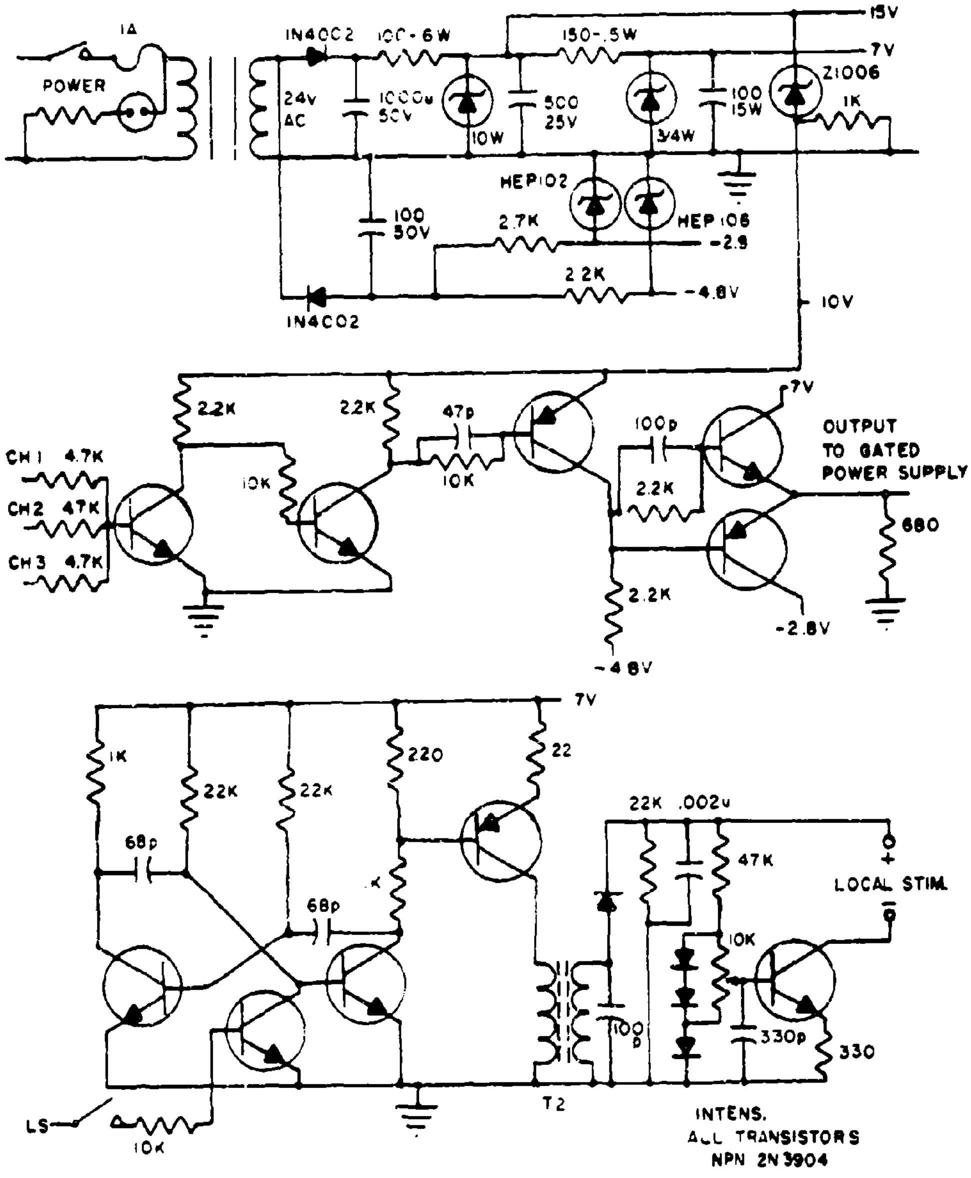


Figure 4B. Circuit Diagram of Control Console

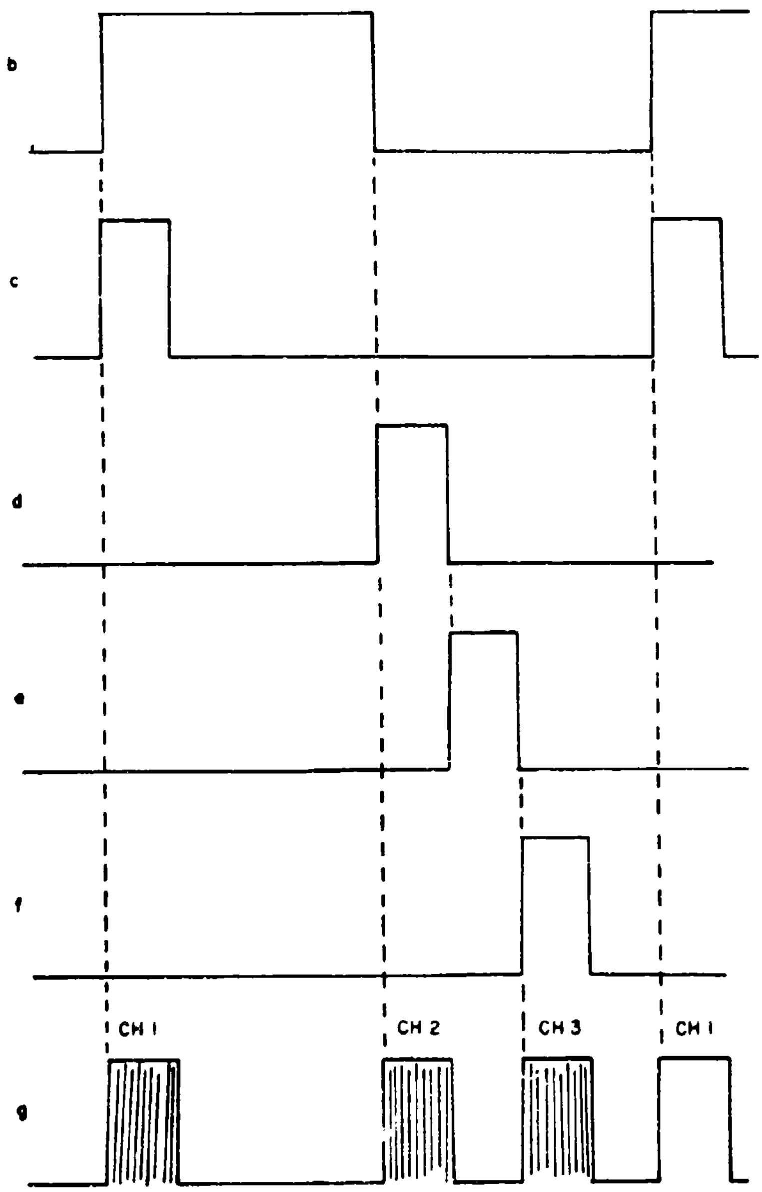


Figure 5. Timing Diagram

The first two monostable circuits (c) and (d) are always triggered one-half of a cycle of the astable multivibrator (b) apart while the third monostable circuit (f) follows the second by a constant delay of approximately 1 msec. This delay is provided by delay circuit (e), a single transistor which is temporarily turned off by a negative potential at the input capacitor. The duration of the off-time is determined by the coupling capacitor and the bias resistor at the base.

There are three subcarrier oscillators (l, m, and n), one for each stimulation channel. The oscillators employ a Colpitts circuit. The basic frequency determines the channel and a variation of this frequency the intensity of stimulation current. The intensity controls (o, p, and r) provided for each channel are variable capacitors in parallel to the tank circuit inductor.

The gated subcarrier oscillator signals from the outputs of AND-gates (h, i, and k) are connected to the driver stage (t) via OR-gate (s).

B. The Gated Power Supply

A photograph and a circuit diagram of this unit are shown in Figure 6 and Figure 7 respectively. The primary power is received from the A.C. supply line and stepped down in the power transformer. The secondary voltage is rectified, filtered and pre-regulated by transistor Q1 (2N3054) whose base is connected to D2, a 30 volt zener diode.

The input to the gating circuit is connected to the driver stage in the control circuit section via transistor Q2 which is used as a fast diode to decouple the base of the input transistor Q3 from the output of the driver. Transistor Q4 is switched by Q3. The collector of Q3 is connected to zener diode D3 at 20V while its base is driven from 30V resulting in a forward operation of both transistor junctions. In this way an accurate and low impedance reference voltage is supplied to the base of output transistor Q5 when Q4 is turned on. In the off condition the base of Q5 is clamped to ground potential by the collector of Q3 through the base emitter junction of Q4. As a result, pulsed power is applied to the transmitter at the rate of the frequency of the subcarrier oscillator which is passed through at that time.

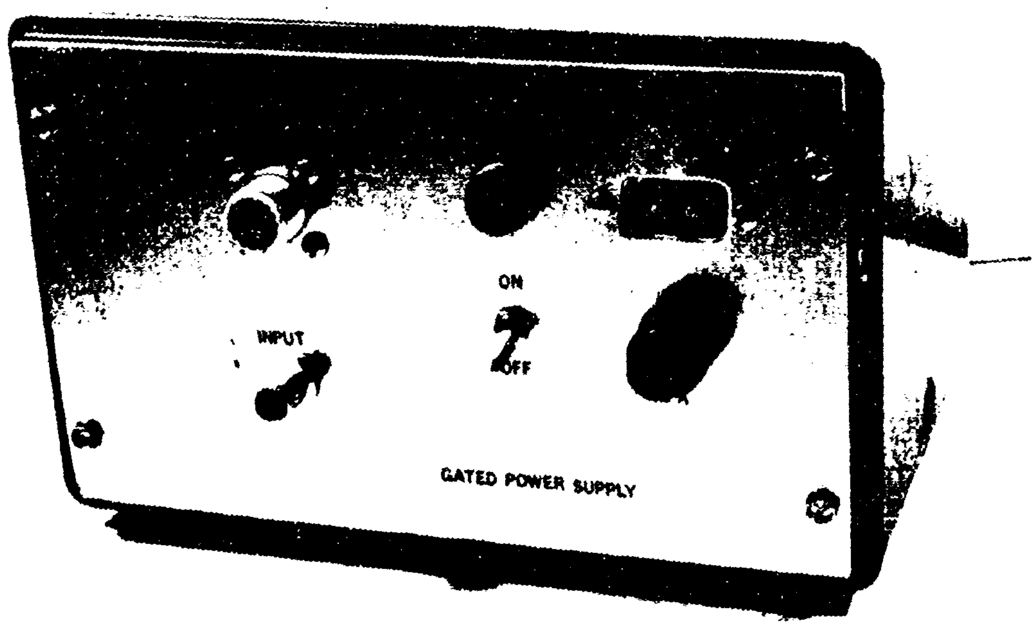


Figure 6. Control Console for the Gated Power Supply

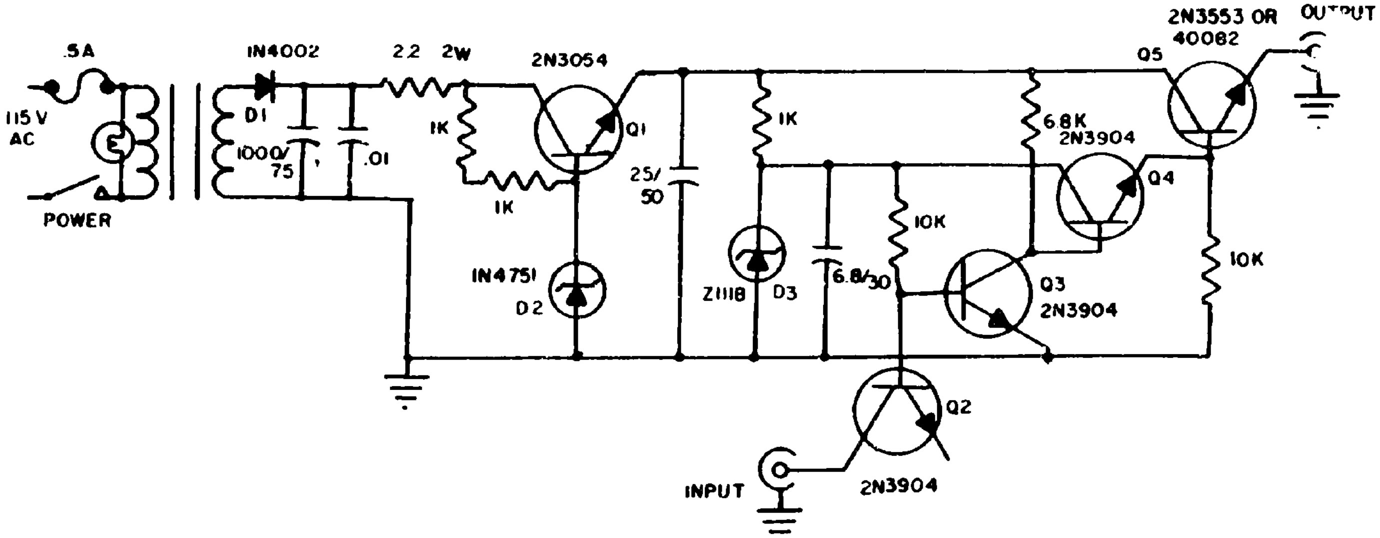


Figure 7. Gated Power Supply

C. The Transmitter

No schematic of the transmitter, Model DG511, is available. It was manufactured by Sanders Associates[2] and subsequently modified by Systems Research Lab., Inc.[3]. The transmitter contains one transistor 2N5108. The tuning and antenna coupling circuit is a cavity in the collector of the transistor. A tape in the cavity provides proper matching to the antenna impedance.

Upon application of power the transmitter begins to generate a frequency of 915 MHz and ceases when the power is removed. A train of ultra high frequency bursts is transmitted, therefore, at the rate of the subcarrier frequency. A video output is provided to observe the demodulated UHF on an oscilloscope. Figure 8 is a photograph of the transmitter and the antenna.

D. The Antenna

Connected to the transmitter output is a cavity-backed spiral antenna, AEL Model No. ASN 115A, with circular polarization. This type of antenna was chosen to minimize directional effects at the receiver.

E. The 915 to 100 MHz Down-Converter

To match the conventionally used stimulator which is operated at 100 MHz a converter was acquired. This unit is self contained and was designed and manufactured by Systems Research Lab., Inc.[3]. A photograph of the converter is shown in Figure 9 and the circuit diagram in Figure 10. The converter consists of a mixer, a local oscillator and an output stage. It is powered by two 1.4 volt mercury batteries of 500 mAh which provide approximately 100 hours of continuous operation.

The RF signal is received by a semi-circular antenna with an inside diameter of 0.75 inch. A loose coupling into the stub-tuned oscillator

[2]Sanders Associates, 95 Canal Street, Nashua, New Hampshire

[3]Systems Research Lab., Inc., 500 Woods Drive, Dayton, Ohio

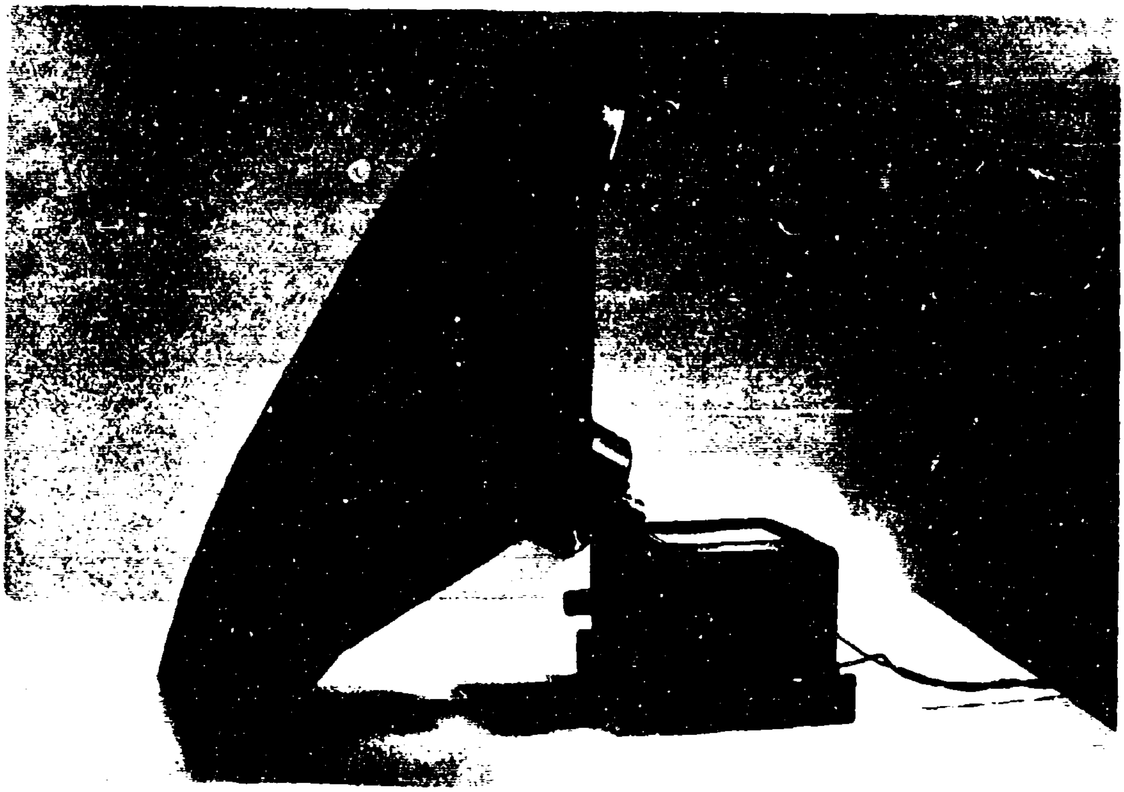


Figure 8. Transmitter and Antenna Working at 915 MHz

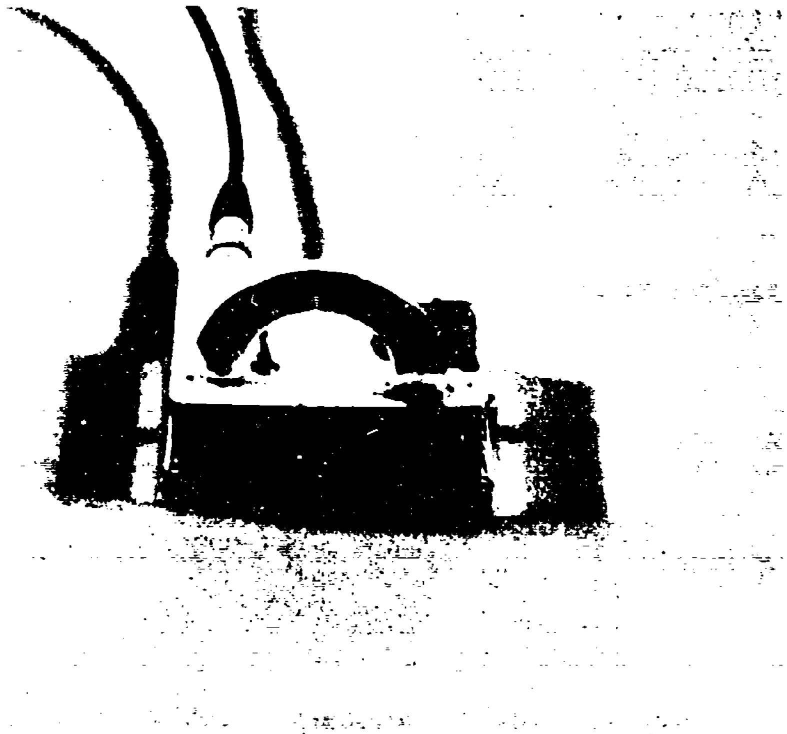
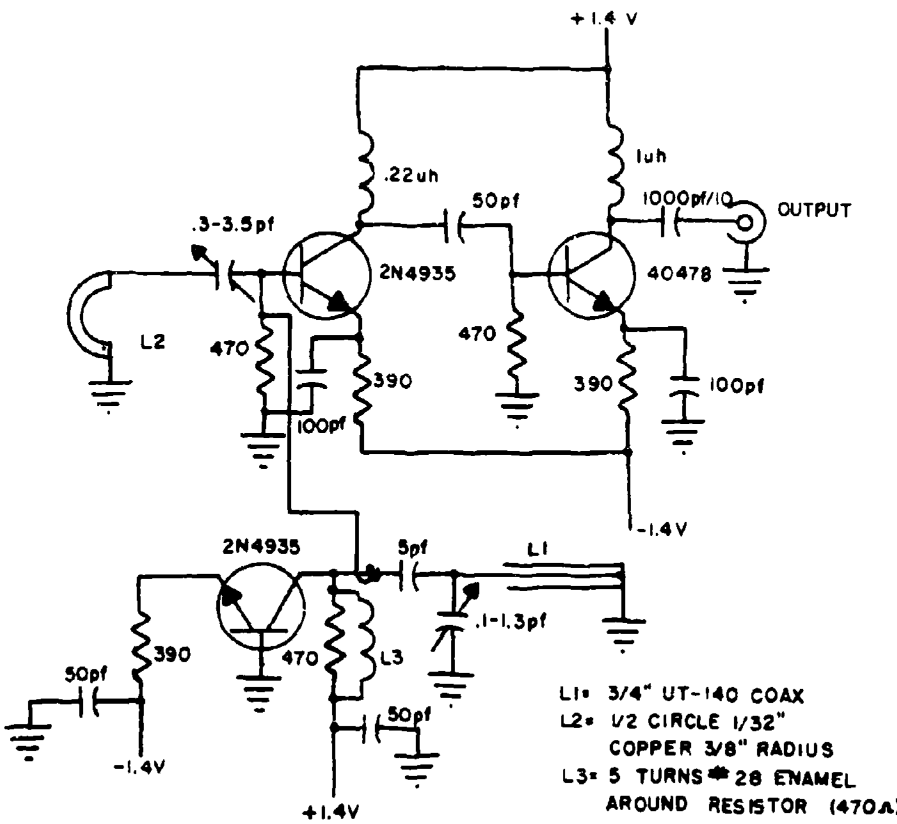


Figure 9. Down Converter from 915 to 100 MHz



ALL RESISTORS 1/10 WATT
ALL CAPACITORS 50V EXCEPT WHERE NOTED

Figure 10. 915-100 MHz Down Convertor

provides the mixing of the incoming signal with the oscillator frequency to an intermediate frequency of 100 MHz which is amplified in the third transistor and connected to the input of the stimulator.

F. The Stimulator

Manufactured by Neurotronics[4], it is a self contained unit operating from a 7 volt mercury battery. The stimulator receives the 100 MHz signal from the converter. It separates the subcarrier signals from the RF carrier and decodes the subcarrier signals into channel and intensity information. The stimulator generates negative pulses from a current source, i.e. the current amplitude is determined by the subcarrier signal, and is, within limits independent of the impedance of the load. Currents of up to 2.5 ma into a load of up to 10 K ohms can be generated. The unit is housed in an epoxy shell and potted in an epoxy compound. A circuit diagram is not available.

[4] Neurotronics, 72 South Turnpike Road, Wallingford, Connecticut

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Individual Behavior						
Social Behavior						