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VOICE-CONTROLLED TRANSCEIVER FOR FREE-FALL PARACHUTISTS

by

W. M. RICE

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SUMMARY

A requirement exists for speech communication by radio between parachutists, e.g. student and instructor, during free-fall training. Such equipment must be very compact, and provide fully "hands-off" operation, using voice-controlled changeover from receive to transmit. Prototype transceivers have been developed using sub-assemblies from AN/PRC-90 equipment with an added voice-control module. The equipment and its trial results are described and considerations relating to possible production are discussed.

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16. *ABSTRACT*

A requirement exists for speech communication by radio between parachutists, e.g. student and instructor, during free-fall training. Such equipment must be very compact, and provide fully "hands-off" operation, using voice-controlled changeover from receive to transmit. Prototype transceivers have been developed using sub-assemblies from AN/PRC-90 equipment with an added voice-control module. The equipment and its trial results are described and considerations relating to possible local production are discussed.

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1. INTRODUCTION

In 1977 the Army requested the Defence Science and Technology Organisation (DSTO) (and ultimately Aeronautical Research Laboratories) to determine the feasibility of a parachutist remotely controlling the trajectory of a stores bundle carried by a steerable parachute, so that both parachutes would land in a pre-designated area. Initially it was considered that this might be difficult in view of the problem of trajectory assessment from observed relative motion, concurrently with maintaining control of both parachutes.

Prior to the construction of a radio-controlled parachute[1] attempts were made to assess the ability of the controlling parachutist to guide a second (slave) parachutist by means of one-way verbal commands. Initial tests were made by members of the Army Parachute Training School (PTS) using modified 27 MHz transceivers. Due mainly to the excessive length of resonant antennas for this frequency (a quarter-wavelength being about 2·75 metres) it was found impossible to achieve adequate communication between parachutists with antennas which they could conveniently carry on their persons.

Accordingly, it was decided that a much higher frequency should be used, permitting the use of horizontal dipole antennas which it was envisaged might be worn across the parachutist's shoulders. This implied a frequency in the order of 300 MHz, conveniently within the military aeronautical band of 225–400 MHz.

To avoid time-consuming development of suitable transmitters and receivers, the availability was investigated of suitable miniaturised equipment already in service. This led to the supply to ARL by the RAAF of a number of modular sub-assemblies from the AN/PRC-90 transceivers eminently suitable for use in equipment assembled to meet the specific requirement.

Initial results were so satisfactory that PTS suggested further development to serve as a training aid for free-fall parachutists. Since parachutists (particularly trainees) have their hands fully occupied during descent, normal push-to-talk control is undesirable. By using a voice-control circuit (popularly known as VOX) the first few milliseconds of speech turns on the transmitter. After the speaker stops talking, reception recommences.

Two such transceivers were developed in prototype form by ARL, and are described in this Note. Comments are also made on some aspects which would be relevant if local production in any volume were envisaged.

2. PRC-90 SUB-ASSEMBLIES

2.1 Original Application

The AN/PRC-90 is a battery-powered hand-held item of radio equipment which may be used either as a distress beacon to permit location of surviving crew after escape from a crashed aircraft, or as a means of speech communication with a search aircraft, or for other purposes. In the beacon mode it operates on the international distress frequency of 243·0 MHz, with a choice of either swept tone-frequency modulation, MCW (keyed-tone) telegraphy, or speech. In the communications mode it operates on a frequency of 282·8 MHz with the facility of speech transmission and reception only. For compatibility with normal military aeronautical equipment used in the band 225 to 400 MHz the signal is amplitude-modulated.

2.2 Construction of PRC-90

The PRC-90 equipment is composed of a number of replaceable thick-film sub-assemblies. Most are packaged in rectangular plastic casings, approximately 50 mm by 31 mm by 6 mm. Connections are made by a row of pins along one edge, typically 12 in number, at a spacing of 3·85 mm (0·15 inch). Two sub-assemblies depart from this general style. These are the receiver amplifier, which is 24 mm by 31 mm by 6 mm and has only five pins, and the antenna switch module, which is an unencapsulated double-sided PCB 47 mm by 21 mm with 11 pins at irregular spacings along one edge. The complete list of modules is:

(*a*) guard transmitter (243·0 MHz);
(*b*) guard receiver (243·0 MHz);
(*c*) alternate transmitter (282·8 MHz);
(*d*) modulator–amplifier;
(*e*) alternate receiver (282·8 MHz);
(*f*) receiver amplifier;
(*g*) antenna switch.

2.3 Sub-assemblies Used in Transceiver

Sample quantities of all the above-listed items except the first two ((*a*) and (*b*)) were provided by the RAAF for experimental use by ARL, together with a number of receiver and transmitter crystals for the alternate frequency of 282·8 MHz. The transmitter modules were of nominal 0·5 watt output power, and had been discarded during a modification which replaced them (in RAAF PRC-90s) with transmitters rated at 1·0 watt.

3. VOICE-CONTROL [VOX] MODULE

3.1 Requirement

To enable the transceiver, normally in the receive mode, to change over to transmit as soon as the user begins to speak, it was necessary that a microphone amplifier should be permanently energised in either mode. Amplified speech signals could then be rectified and used as a control voltage to switch over to transmit, maintaining the transmitter on as long as speech was present. Speech from the microphone would simultaneously be fed to the modulator–amplifier to modulate the transmitter. In order to hold the transmitter on during the short gaps between syllables and words, it was further necessary that there should be a time-delay of about 0·5 sec before the system reverted to receive. Also, to ensure that the control voltage was at either the receive or transmit level, without ambiguity, it was decided that a Schmitt trigger circuit be employed, controlled in turn by the somewhat-variable rectified speech.

3.2 Details of Module

Mechanically, to conform with the dimensions of the other modules in the transceiver, the VOX module was completely accommodated on a small matrix board (in lieu of a PCB) its dimensions being 50·8 mm by 30·5 mm (2 in. by 1·2 in.). Connections were made by five wire pins protruding from one of the long edges.

Electrically, the circuit involves a 741 operational amplifier (metal can, not dual-in-line package) used as the microphone amplifier; two germanium diodes as a voltage-doubler rectifier (also known as a "diode-pump"); time delay using a 1 microfarad capacitor and 1 megohm resistor; a Schmitt trigger of FET-bipolar configuration (2N5459 and 2N5088); a 2N3638 switching transistor; and a dual-in-line package reed relay. The circuit is shown in Figure 1.

Some minor aspects of the circuit are as follows:

(*a*) the 470 pF capacitor across the amplifier input is to eliminate transmitter RF voltage at this point, which would otherwise produce "RF feedback" and lock the transmitter on;
(*b*) no provision has been made for adjustment of amplifier gain, or dropout-delay time-constant, as both these parameters were found to be reasonably non-critical;
(*c*) the relay (which draws 24 mA) is energised only during the relatively short periods of transmission, rather than the longer receive periods, to minimise battery drain.

4. SYSTEM INTERCONNECTION AND PACKAGING

4.1 Interconnections

The various connections between the PRC-90 modules and the VOX module are shown in Figure 2. Although shown as separate terminals on the diagram, the microphone and headset connections are actually made via a standard NATO type four-contact plug and jack assembly, the jack (type U-92A/U) being attached to the transceiver via a short length of three-core cable, using a common earth for both transducers. The headset (two earpieces type 53 in series, total resistance 200 ohms, fitted to an Army-supplied helmet) and microphone (200 ohm dynamic insert fitted to an oxygen mask) are connected via about 0·5 m of four-core cable to the plug (type U-174/U). The headset and microphone assembly is shown in Figure 3.

The six modules which comprise the transceiver are physically interconnected and also held in position by a printed circuit mother-board. Figure 4 shows the underside of this board, and Figure 5 is the obverse view, i.e. the top edges of the modules. Since the receiver amplifier module is only about half the length of the others, the board space thus left clear conveniently accommodates the two miniature crystal units and the off–on switch.

4.2 Packaging

Figures 4, 5 and 6 indicate the method of assembling and encasing the complete transceiver. Slightly less than half the case volume is occupied by batteries (eight penlight cells, size AA). A fibreglass bulkhead across the centre of the case carries eyelets for battery contacts and their interconnecting wires, while a detachable bulkhead at the end of the case is fitted with wire "beehive" spring contacts to provide pressure connections to the batteries. The photographs were taken before adopting these springs. The phosphor-bronze leaf spring contacts used previously were found to be unreliable.

The side-covers which enclose the unit are retained by small screws in their edge lips, and are readily detachable for battery changing or other maintenance. The antenna connector is a BNC receptacle. Complete with batteries, the transceiver unit weighs about 400 grams. It measures 118 mm by 62 mm by 39 mm, not including the connectors and switch. It readily fits into a pocket, or, as found convenient by the Army parachutists, under elastic webbing straps which retain a dual altimeter panel to the chest-pack reserve parachute.

5. ANTENNAS

A typical antenna is shown in Figure 6. It is a centre-fed half-wave dipole, which (for 282·8 MHz) measures 480 mm from tip to tip. The half-elements are flexible, but spring back after being flexed. They are made of tightly-wound spring wire (as used for curtain tracks) encased in tinned-copper braid for RF conductivity, and sheathed with PVC tubing. The centre insulator, which encapsulates the coaxial cable connections and mechanically unites the whole assembly, is moulded *in situ* from polyester resin. The elements are tipped with "blobs" of silicone rubber to reduce the risk of injury from the ends of the conductors.

The coaxial cable, type RG-58C/U, is about 1 metre long. This permits the antenna to be worn almost anywhere on the parachutist's person, e.g. across the shoulders or tucked into the waistband. Preferred polarisation is horizontal. Close proximity to the body produces considerable detuning of the antenna, thereby reducing communication range, but even under these circumstances a range of several hundred metres has been demonstrated.

6. PERFORMANCE

6.1 Technical Parameters

(*a*) Receiver

The PRC-90 receiver, as might be expected of a unit so compact, has substantial limitations. The intermediate frequency is 31·0 MHz and bandwidth about 600 kHz (to 6 dB down), thus the receiver is vulnerable to interference from nearby transmitters on frequencies differing by several megahertz from its own.

Due to the very limited amount of "front-end" selectivity available the image ratio is also poor. Sensitivity on the image frequency of 220·8 MHz is not much lower than on the wanted frequency of 282·8 MHz.

The sensitivity itself is fairly good. Measurements showed the minimum detectable signal at 282·8 MHz to be about 1·2 microvolt, comparing well with 0·1–0·5 microvolt which might be expected of far more sophisticated receivers.

Receiver supply-current drain is about 25 mA at 12 volts.

(*b*) TRANSMITTER

The performance tests possible on the transmitter were somewhat limited by availability of test equipment. No attempt was made to check for spurious frequency output, but output power on the wanted frequency is in the order of 100 mW or better. Tremendous variation was observed in output when the crystal was changed, and the circuit appears critically dependent on crystal activity. Two of the crystals supplied, although capable of oscillation at the correct frequency, gave extremely low transmitter output. This was reflected in the supply-current drain, which, with a good crystal, exceeded 100 mA, yet was as low as 10 mA with a poor crystal.

The audio modulation capability appears to be good, approaching 100% with a microphone input to the modulator amplifier of about 2 mV RMS. The dynamic microphone inserts used can provide this with good speech quality.

6.2 Operational Performance

Tests were carried out by PTS in June 1979. Communication was successful between parachutists both air-to-air in free-fall and under canopy, and from air-to-ground. Wind noise in free-fall was not a serious problem with the mask-mounted microphones. The system was considered potentially useful as a training aid. However, introduction to the Service would necessitate further pre-production development, both to meet all relevant specifications, and for other reasons now to be discussed.

7. PRODUCTION ASPECTS

7.1 Choice of Frequency Channels

The channel frequency of 282·8 MHz used for the prototype equipment was dictated by the availability of PRC-90 modules and crystals. However, since it is designated as a secondary search-and-rescue (SAR) channel it could not be used operationally for any other purpose. Also, rather than being restricted to one channel, it would be convenient if pairs of parachutists could operate independently on different channels although descending in close physical proximity to each other. This not only implies multi-channel capability on frequencies not currently allocated to other uses, but also would necessitate much better receiver performance in terms of unwanted signal rejection than can be obtained with the PRC-90. It is probable that a suitable group of channels (if available at all) would be near the 400 MHz end of the band. While this would provide the benefit of even smaller antennas it renders less likely the possibility of using RF hardware already in service in other equipments. The multi-channel PRC-803, for example, cannot be used above 276 MHz.

7.2 Hardware Requirements

Since, for the reasons indicated above, it is unlikely that "ready-made" modules would be available, it appears that local volume production would necessitate locally developed RF hardware, most probably in discrete form to some extent, although there is scope for the use of some linear integrated circuits, particularly in the receiver. There are also transmitter power-amplifier modules available (e.g. the Motorola MHW593). It should be quite practicable to develop locally a transceiver assembly having adequate performance without any serious weight or volume penalty.

8. CONCLUSION

A prototype pair of voice-controlled UHF transceivers has been constructed, and tests carried out in a parachute training environment. Results have been favourable. Interest has been expressed in obtaining similar sets in production quantities as training aids.

However, local production would necessitate several operational and technical differences from the prototypes as regards frequency channels and provision of hardware. A programme of local development to meet more stringent performance specifications and make use of currently available hardware would necessarily precede local production.

REFERENCE

1. A Feasibility Study of a Remotely-Controlled Free-Fall Stores Bundle. To be published.

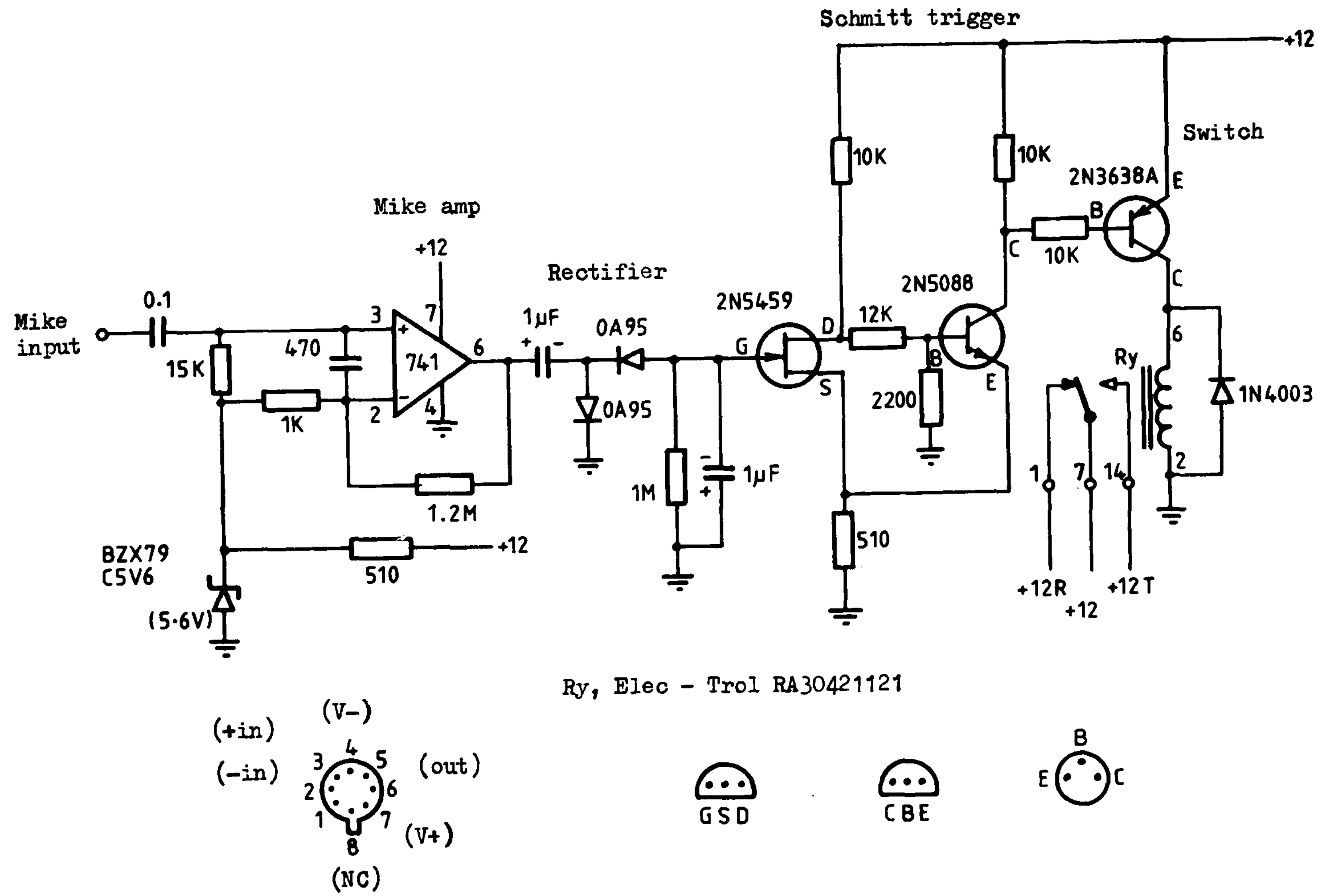

FIG. 1 : CIRCUIT OF VOICE-CONTROL MODULE

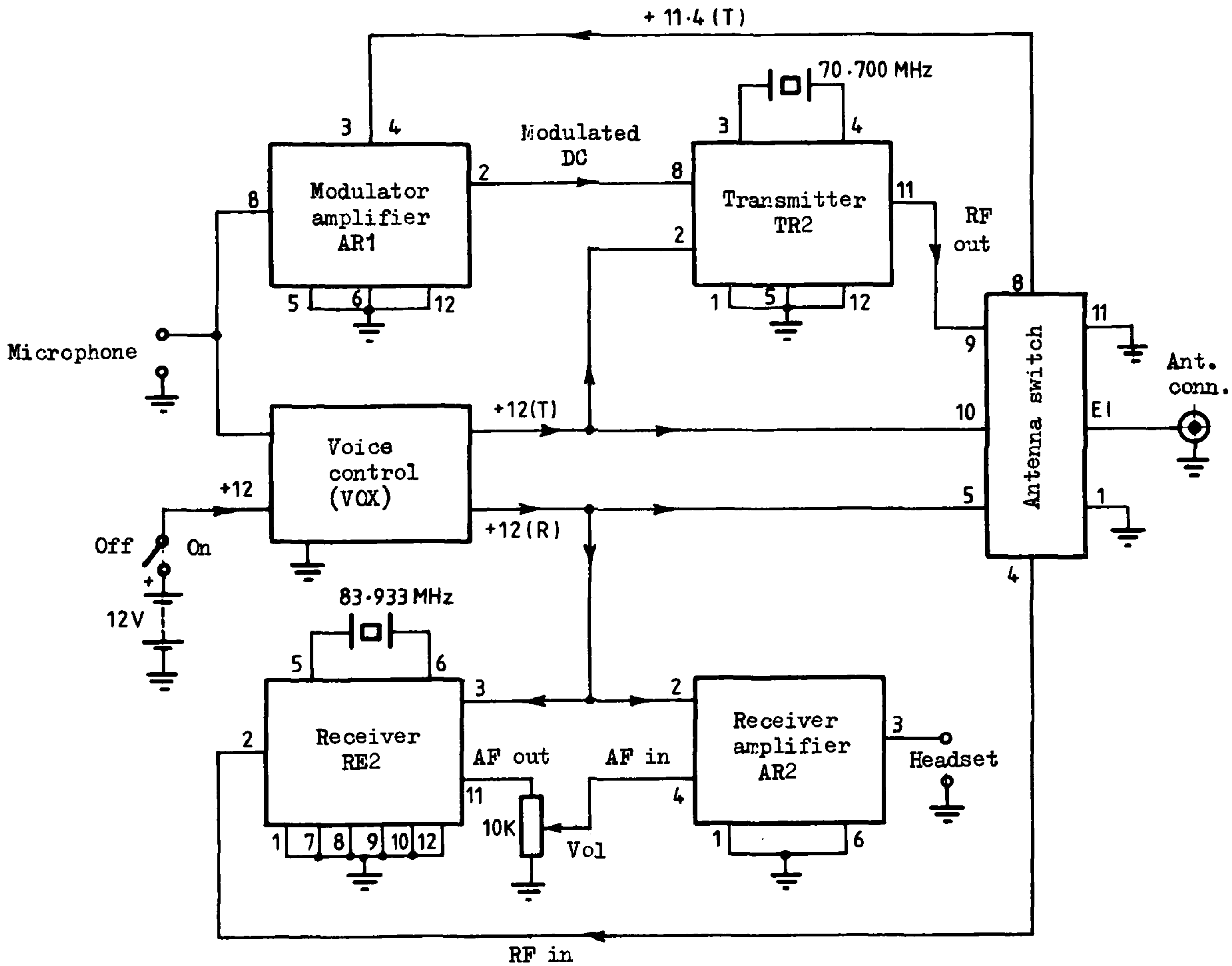

FIG. 2: SYSTEM INTERCONNECTIONS

FIG. 3: HEADSET AND MICROPHONE ASSEMBLY

FIG. 4: TRANSCEIVER, COVER REMOVED, MOTHER-BOARD SIDE

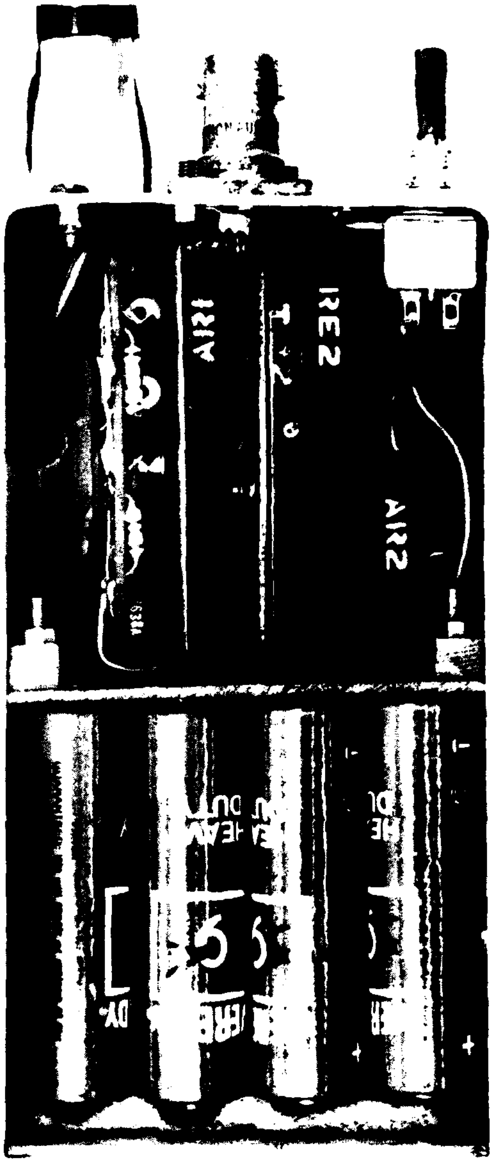

FIG. 5: TRANSCEIVER, COVER REMOVED, MODULE SIDE

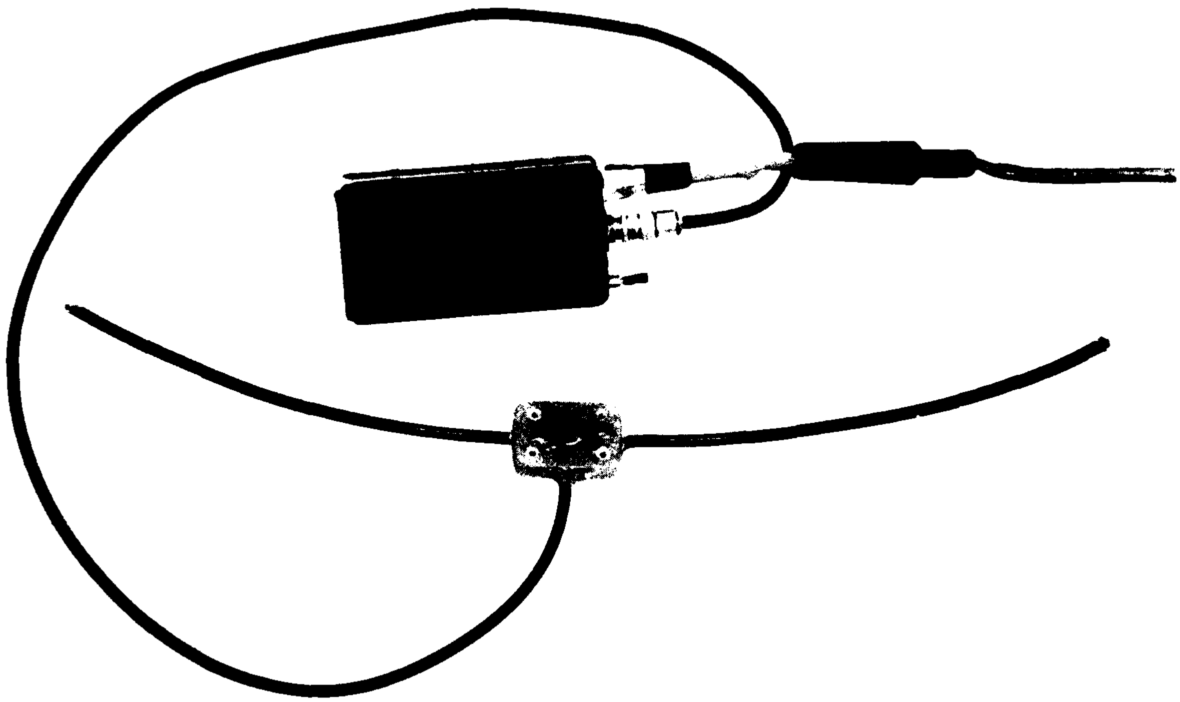

FIG. 6: TRANSCEIVER AND ANTENNA

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