The French/Italian TR-PP-13/RV-3 (ER-95A) VHF FM Radio

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Fig.1 TR-PP-13 in a ground static role

Introduction

An Internet scan in January this year found the Italian Website ESCO (http://www.esco.it) was selling non-working, but internally complete, RV-3/ER-95A radios at 35 euro, about £25. The radios had no accessories or battery boxes.

The 1990 - 1991 issue of 'Janes' lists the RV-3 as then current Italian army equipment. It was identified as the French designed, TR-PP-13 VHF/FM analogue synthesised transceiver, manufactured under licence by Elmer, in Pomezia, Italy. Italy apparently adopted the TR-PP-13 after trial competition with PRC-25 variants, SEM-25 and similar. The radios are primarily voice communication sets with a limited data handling capability, using external equipment. With appropriate accessories they can also be remotely controlled and function as relay sets.

The Italian RV-3/13/P was the French TR-PP-13 manpack, Its 1.5 watt RF vehicle version, the Italian RV-3/13/V was the French TR-VP-13.

The Italian 20/15 watt RF vehicle set RV-4/213/V was the French TR-VP-213.

The French and the Italians called the basic transceiver the ER-95A. (Émetteur-Recepteur-95A). Elmer also manufactured a receiver only version called the R-95C.

The set looked interesting; there had been no general surplus release of French TR-PP-13s; curiosity won and an RV-3 was purchased.

The Development of VHF/FM Analogue Synthesised Radios

In the mid 1950s the company radios of most NATO armies were the RCA designed, US PRC-10 series of sub miniature valve, VHF FM backpack radios, or variants thereof. Britain used the SR A41 and A42 which were based on the PRC-9A and 10A.

The PRC-10 series consisted of 3 physically identical sets:

PRC-8, 20 to 27.9 MHz
PRC-9, 27 to 38.9 MHz
PRC-10, 38 to 54.9 MHz

The series had a nominal 100 kHz channel spacing and provided a total of 350 channels in their combined frequency coverage of 20 to 54.9 MHz.

The military wanted to extend the frequency coverage provided by the combined PRC-10 series and put it into one box, to increase the number of channels and to simplify the set's controls. A prerequisite was the development of a synthesiser to generate the receiver local oscillator and the transmitter frequencies. This was made possible by the arrival of the transistor which allowed the synthesiser to be engineered for field use with acceptable size, ruggedness and power demand.

The initial design work on VHF FM synthesised military radios was carried out in the US in the 1950s and early 1960s. The sets that resulted were the AVCO VRC-12 VHF FM vehicle radio and the RCA PRC-25 VHF FM backpack radio. Both sets employed transistors and covered 30 to 76 MHz in 880 50 kHz channels. The PRC-25 retained one valve in its transmitter RF output.

The PRC-25 entered service in small quantity in 1961 but it was nearly 4 years later before it was in volume production (Ref.1). When suitable RF power transistors became available a fully transistorised PRC-25 was later issued as the PRC-77.

Important aspects of the PRC-25 design were its ruggedness, reliability and the simplicity of its controls. It could be used by operators with the minimum of training. The switch selection

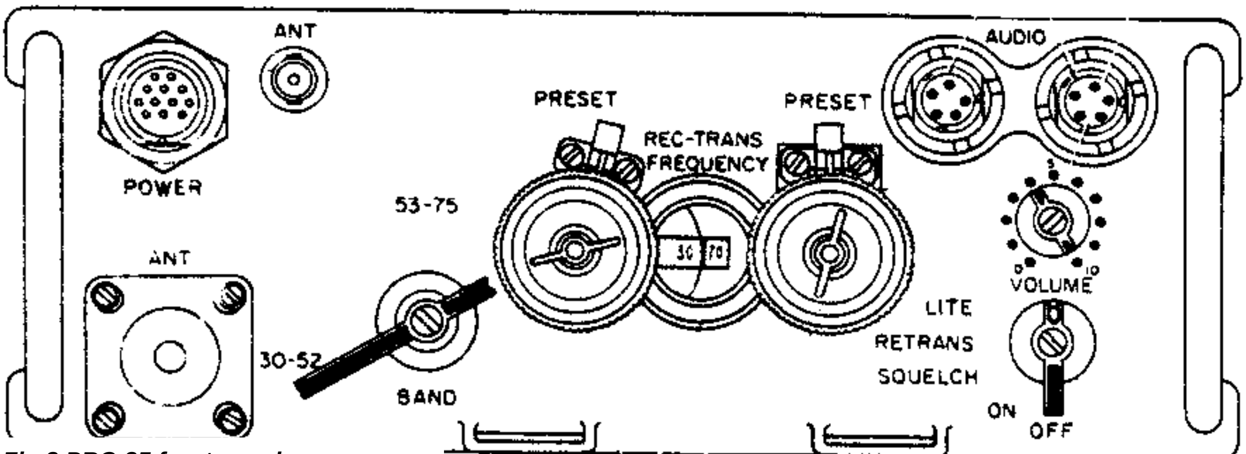

Fig.2 PRC-25 front panel

of channels did away with the need for netting and field calibration. The sets used tone squelch so there were no missed transmissions due to a maladjusted squelch control. For this type of radio the US evolved a circuit configuration of a 2 waveband radio using a single band, analogue synthesised local oscillator. On the receiver low band the received frequency was local oscillator frequency minus intermediate frequency (IF). On the high band the received frequency was local oscillator plus IF frequency. The receiver first IF was 11.5 MHz and each receiver band was twice IF frequency wide, i.e. 2 x 11.5 = 23 MHz.

The use of a single band local oscillator simplified band switching, reduced component count and provided two working RF frequencies for each synthesised local oscillator frequency. However, band switching and tuning the RF circuits could be complex.

European Radios

Germany, Holland, and France, among others, used the US designed PRC-10 series and by the early 1960s they were looking for synthesised sets to update their military VHF FM field communications. The above countries decided to develop the sets themselves - taking account of the US work.

Germany developed the SEM-35 providing 880 50 kHz channels from 26 to 69.95 MHz,

Holland developed the RT-3600 providing 880 50 kHz channels from 26 to 69.950 MHz.

France developed the TR-PP-13 providing 920 50 kHz channels from 26 to 71.950 MHz

The SEM-35 and RT-3600 have been generally available on the surplus market for some time but there has been little sign of surplus French TR-PP-13s.

France wanted a VHF/FM transistorised, synthesised back pack company radio plus a transistorised squad/section radio to replace their TR-PP-8-A, 'Banana'/handie-talkie. They decided that a common development programme should produce both sets. The work was awarded to Thomson and CSF, later to become Thomson CSF.

The French programme produced the TR-PP-13 VHF/FM synthesised backpack set and the TR-PP-11 a 6 channel ‘handie-talkie’ squad radio (Ref.2). As with the PRC-25 there was an initial lack of RF power transistors for the transmitters. The trial batch of 100 off TR-PP-11s was produced with a valve in the transmitter output and a high tension inverter. Fortunately, during prototype trials suitable RF power transistors became available allowing the production models of the TR-PP-11 and TR-PP-13A to be released about 1966 as fully transistorised sets. A ‘B’ version of the TR-PP-13 was later produced with improved squelch.

The radio included internal interfaces to allow add-on options to extend its field of use. These included:

Vehicle power supplies (BA-301A and BA-302). The ‘BA’ supplies contained drive circuits for a BX-33-A remote aerial base unit.

A bolt on 15 watt RF amplifier (AM-215-A), (The early AM-215 appears to have been subsequently uprated by Elmer from 15 to 20 watts output.)

Control units that allowed the set’s main front panel controls to be motorised and controlled remotely for aircraft use as the TR-AP-113.

An FI.90 suppressor that protected the radio from voltage transients on vehicle supplies.

For manpack duty the long 2.6m, self-erecting aerial, was the AN-224. The short 0.92m tape aerial was the AN-225-E, with an EA-53-A ‘swan neck’ flexible base. These aerials had different lengths of mounting stud. The stud length operated a switch in the front panel aerial base that automatically connected the correct matching circuit for the aerial in use. (The stud threads are not the same as those used on PRC-10 aerials). The manpack battery box was KO-410-A. The range of the manpack was from 5 to 15 km, depending on the terrain and the aerial used.

Vehicles generally used a 2.5m aerial made up of rods MS 116, MS 117 and AB-24/GR. These mounted on the BX-33-A remote aerial tuning and matching unit.

Circuit Description

The block diagram of the radio is shown in Fig.3 and its specification in Table 2.

Receiver

The receiver has 2 RF transistor amplifiers with diode clamps across the base-emitter of the first amplifier to prevent RF burn-out by local transmitters.

The receiver mixer is an NPN transistor. Its local oscillator is the prime synthesiser controlled oscillator and covers 37.50 to 60.45 MHz in 50 kHz steps. Its operation is described in the Synthesiser section of this note. The mixer is followed by a single, wideband IF pre amplifier at 11.5MHz. This feeds an 11.5 MHz, 36 kHz bandwidth crystal filter, which, in turn, is followed by 5 NPN transistors providing IF gain and limiter functions. The FM discriminator is a narrowband crystal unit.

There is a 7 transistor noise muting circuit (the set does not use tone squelch/muting) and a 5 transistor AF amplifier with a push pull Class B audio output stage delivering 5mW of AF output. There are two handset connectors on the front panel for H-33*/PT handsets with U-77/U connectors as used on the PRC-10.

Receiver Synthesiser

The receiver local oscillator is frequency stabilised by the synthesiser. The local oscillator VFO is rough tuned by the channel select mechanism and fine tuned by a varactor diode. In addition to feeding the receiver mixer the VFO output is fed to the first mixer of the synthesiser. The local oscillator signal for this first synthesiser mixer is generated from a 1 MHz crystal oscillator. The 1 MHz oscillator output is clipped and shaped to make it rich in harmonics and then passed through a low pass filter (LPF) to the mixer. The LPF lets through the 1 MHz harmonics from 1 to 11 MHz but attenuates the higher harmonics to ensure that they do not appear in the receiver tuning range.

The synthesiser first IF is a bandpass amplifier from 48.50 to 49.45 MHz. Only one of the 1 MHz harmonics can beat with the receiver local oscillator to produce a signal in the first synthesiser IF. As with the receiver local oscillator, the 1 to 11 MHz (0 to 11 MHz) beats with the receiver local oscillator on a sum and difference basis to cover a full 22.95 (23) MHz sub band tuning.

Table 1 - Receiver LO Synthesiser

	MHz	
TR-PP-13 tuned to	26.550	A
Receiver first IF	11.500	B
Receiver first local oscillator.	38.050	C = A + B
11th Harmonic of 1MHz osc.	11.000	D
Synthesiser first IF	49.050	E = C + D
Overtone oscillator	44.700	F
Synthesiser second IF signal	4.350	G = E - F
2nd 50 kHz crystal	4.350	H
Lock is achieved with		G=H

The local oscillator for the second synthesiser mixer is an overtone crystal oscillator with 10 switched crystals spaced by 100 kHz from 44.2 to 45.10 MHz. The overtone oscillator frequency is selected from switches on the tuning mechanism. The second mixer output feeds an amplifier with a pass band from 4.30 to 4.35 MHz. This feeds a phase comparator to which is also fed by a crystal oscillator of 4.30 or 4.35 MHz. The crystal in service is selected by the tuning mechanism to provide

50 kHz channel selection. When in lock the phase comparator generates the tuning voltage that is fed to the varicap diode in the VFO via an LPF. The phase comparator includes a search oscillator to sweep the system into phase lock. When phase lock is achieved the search oscillator is automatically switched off.

The synthesiser uses 13 crystals and is designed to achieve phase lock in less than 10 milliseconds.

Transmitter Synthesiser

To this point, the synthesiser described is for the receiver local oscillator. Its frequency is 11.5 MHz different from the transmitter frequency. A second frequency control loop, still based on the receiver synthesiser, is used to generate the transmitter frequency. A transmitter master oscillator is roughly tuned to frequency by the channel selection mechanism. A portion of this oscillator output is fed to the receiver mixer. Part of the mixer output is fed to the wideband 11.5 MHz preamplifier. This feeds a wideband discriminator with a bandwidth of nearly 2 MHz. The receiver mixer still feeds the receiver IF crystal filter and amplifier plus the crystal discriminator. The wideband and narrowband discriminators are connected in series. Their combined output is fed to a DC amplifier which in turn feeds a saturable reactor whose inductance is varied by changing the currents in its control windings. The saturable reactor is connected to the tank circuit of the transmitter master oscillator to close the frequency control loop.

When the set switches to transmit its frequency is not initially on channel. An error signal is generated by the wideband discriminator. This is amplified by the DC amplifier to alter the inductance of the saturable reactance and tune the master oscillator towards the required channel frequency.

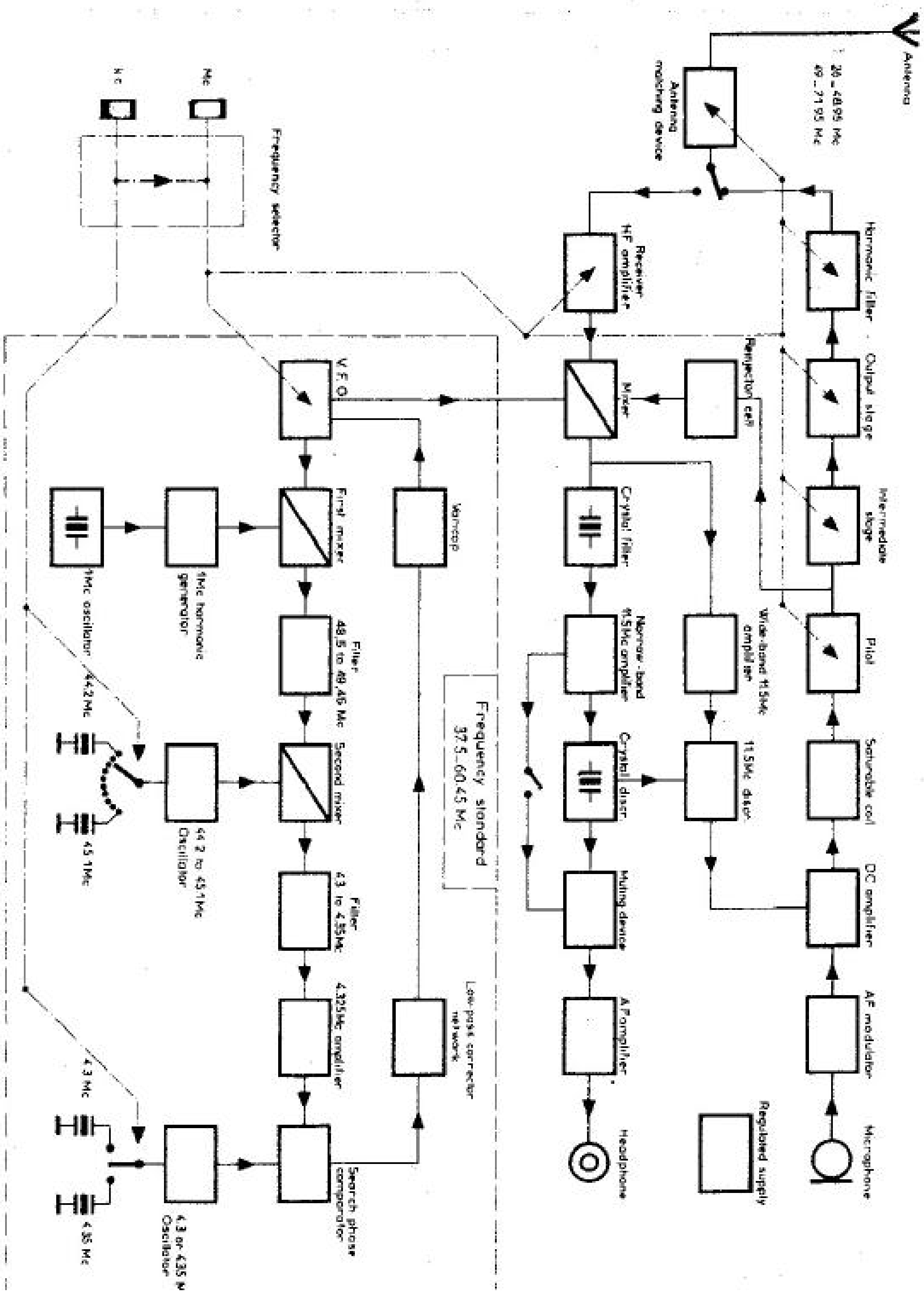

Figure 3 – FUNCTIONAL SCHEMATIC DIAGRAM

When the wideband discriminator brings the master oscillator within about 20 kHz of channel frequency the narrow band crystal discriminator takes over and fine tunes the master oscillator onto channel. This takes a few milliseconds and the final transmitter channel frequency is then accurate to 3.5 kHz over the sets operating temperature range of -40 to +55^{0}C.
Note: the receiver oscillator synthesiser is a phase locked loop but the additional 11.5 MHz for the transmitter is generated by a frequency control loop.

Other Circuits and Design Features
The transmitter master oscillator is followed by a driver stage and then by the RF power amplifier. Each of these stages employs two transistors. The final RF output is 1.5 watts.
The set has are 2 frequency sub-bands. The low band is 26.00 to 48.950 MHz. The high band is 49.00 to 71.950 MHz. Switching from sub band to sub band is achieved by an ingenious spring shuttle mechanism. This mechanically alters the positions of the trimming capacitor pistons and coil cores in the RF tuned circuits to change from one sub band to the other. It obviates the need to switch coils and trimmers and allows the same 8 ganged variable capacitors assembly to tune both sub bands.
The total frequency coverage is divided into 3 MHz bands. The channel selector mechanism produces a switch logic output that is decoded to tell the external equipment in which 3 MHz band the set is operating.
The microphone signal is diode clipped and feeds to the input of the DC amplifier in the transmitter frequency control loop and so modulates the transmitter master oscillator. The modulation

Fig.4 RV-3/*/* Front Panel

quality of the microphone signal is improved by negative feedback round the transmitter frequency control loop. Additionally, when the transmitter frequency loop is locked the microphone signal is present in the crystal discriminator output and provides sidetone to assure the operator that the transmitter is on channel.
An attractive feature of the set is that it has an efficient, regulated switching power supply that provides the sets internal supply voltages of +8, -8 and +34 volts DC. This ensures that the set performance does not fall off as its batteries discharge but remains constant over the battery discharge range of 32 to 20 volts.
Connection to the TR-PP-13 chassis is via standard 25 way D connectors. These couple the power supply and interface connections between the radio chassis, its case and its external auxiliary units.
Despite the design age and long service life of the TR-PP-13 only one significant modification could be traced. That is the improvement to the squelch. This speaks well of the thoroughness of the original design.

The TR-PP-13 with batteries and accessories weighs about 22 lbs. This compares with about 25 lbs for a PRC-10 load and 35 to 43 lbs for the SR A41 with accessories and packframe.

Inspection of the ESCO Radio
As received from ESCO, the ER-95A was externally 'rough'. Its front panel appeared to have been twice over painted by hand with darker shades of green. Internally the set was very clean thanks to its well sealed case. It had mechanical channel preset mechanisms similar to those of the PRC-25. These pre-set mechanisms were not fitted on French TR-PP-13s. A second difference is that the ESCO set lacks the TR-PP-13 end of travel stop on its function switch.
Otherwise the ESCO/Elmer unit appears identical to the French units. However, its panel lettering, module names and identification plates are in Italian. The function switch labelling is explained in Table 3.

Table 3 - Function Switch Legend
The French and English translations are listed for reference.

Italian	French	English
LUCE SCALA	ÉCLAIR	Dial Lamp
RITRAS	RELAIS	Relay
ACCESO	MARCHE	On
TELECOM	TELECOM	Remote
SPENTO	ARRETE	Off

Apart from the RF circuits, the main circuitry of the TR-PP-13 is contained in 11 silver plated, plug-in modules mounted on 2 swing-out panels. In their operational position the modules are forcibly and effectively retained by springs. (In its mounting, in an AFV, the TR-PP-13 was designed to withstand a single 40G shock from non penetrating missile impact).
Servicing is by module replacement. Modules were separately set-up on dedicated test jigs each with their own instrumentation - one jig for each module type. Consequently, for the enthusiast the set can be difficult to service especially since some module trimmers are inaccessible when the modules are mounted in the radio.
About 80% of the cabling in the TR-PP-13 chassis is run in sub miniature co-axial cable so there is effective control of spurious stage to stage coupling and RF leakage.
As received the ESCO RV-3 receiver was working but the transmitter was over frequency in the low band and under frequency in the high band. The problem proved to be that the centre frequency of the wide band discriminator had apparently drifted and the transmitter master oscillator was not being pulled into the lock range of the narrow band crystal discriminator. Re-trimming the wide band discriminator to centre it on 11.5 MHz cured the problem. This proved relatively easy because the discriminator trimmer was accessible when the module was mounted in the radio. Not all the ESCO sets will be as easy to service.
The set is much less susceptible to breakthrough from VHF/FM broadcast stations than a SEM-35 tested here previously (Ref.3). However, this test location has relatively low broadcast band signal levels and most sets of this type and age exhibit breakthrough to a greater or lesser degree. What can be said is that this TR-PP-13 is much better than the SEM-35 previously tested.
Thomson-CSF retained the relatively large U-79/U audio connectors. 2 mounted on the front panel is cramping and take up more space than the smaller PRC-25 audio connectors. These older connectors were probably retained because the French armed forces had a large stores inventory of good audio gear to use up such as H-33/PT handsets. By a similar logic it could be that the TR-PP-13 was not provided with tone squelch because it would have to work with older, existing valve VRC and PRC gear without tone squelch.
The PRC-25 front panel is shown in Fig.2, the RV-3/*/* front panel in Fig.4 and the TR-PP-13 front panel in Ref.4. These show the ancestry of the set.

The TR-PP-13 is later and neater in solving the design problems of this class of set than the PRC-25. It obviously lacks a tone squelch but that was apparently by force of circumstance.
On the ESCO example the knobs of the channel selector mechanism are tight to turn. The mechanism may need some lubrication and TLC. Alternatively, the round Italian knobs do not give as good a purchase as the French 'bar' knobs the mechanism was designed to work with (See Ref.4).
The set works well from 2 off 12 volt jelly accumulators connected in series. 1Ahr batteries provide about 30 hours operation on a 9:1 receive: transmit regime.

Conclusions
There is good attention to mechanical and electrical detail in the set design. For example, the spindles of the frequency selector mechanism have rubbing earthing contacts and the front panel includes a spring metal gasket to ensure good overall electrical connection between the front panel and the case.
Compared with the PRC-25 design, and benefiting from it, many of the TR-PP-13 design solutions are more elegant. Typically:
The PRC-25 band switching involves multiple switches. The SEM-35 used complete separate high band and low band transmitter stages and receiver RF amplifiers to simplify band switching. The TR-PP-13 spring shuttle mechanism uniquely avoids these problems. At the same time it helps reduce spurious interstage coupling and problems with switch contact deterioration with life.
The PRC-25 does not have the benefit of an 11.5 MHz crystal discriminator. To generate the transmitter signal from the receiver VFO the PRC-25 uses a 'side step' oscillator rather than the simpler TR-PP-13 arrangement.

Post Script
The bad news – ESCO's batch of this radio is now sold out but, hopefully, more should surface.

The authors are looking at the possibility of compiling a CD of detailed circuit descriptions in English, modification instructions and circuits for the ER-95 and its major auxiliary components. This work is not complete.
Does anyone know a source for the TR-PP-13 battery box, manpack whip aerials and webbing?

References

Reference 1 - The PRC-25 Legend
http://www.telalink.net/~badger/millist/prc25legend.html

Reference 2 – The French TR-PP-11, Parts 1 and 2, J.Feyssac and M.McCabe, VMARS Newsletter Issues 23 and 24, June, July 2002.

Reference 3 – The SEM-35 Manpack, M.McCabe, VMARS Newsletter Issue 12, August 2000.

Reference 4 - Good photographs of the TR-PP-13 manpack and its portage webbing are presently on Website:
http://perso.wanadoo.fr/maquette.garden/

Table 2 - Technical Specification for the TR-PP-13 A

Frequency range	26 to 71.950 MHz in 2 bands
Channel spacing	50 kHz
Number of channels	920
Number of transistors	46 (Including 3 dual transistors)
Receiver	Single conversion superhet.
IF frequency	11.500 MHz
Sensitivity	0.5 µV for 18 db signal-to-noise
6 db selectivity	± 18 kHz
70 db selectivity	± 50 kHz
Unwanted response rejection	66 db
Limiter performance	Less than 3 db output variation between 5µV and 10 mV RF input
AF output	5 mW maximum
AF distortion	Less than 7% between 300 Hz and 3 kHz
Transmitter	
RF power output	1.5 W
Modulation	± 10 kHz
Frequency stability	± 3.5 kHz from -40 to + 55 ^{0}C
Unwanted radiation attenuation	55 db on harmonic frequencies 70 db on other frequencies
Power Supply	2 off PS.28.A Dry Cells or 2 off AA-58/A NiCd batteries. Nominal 30 V (32 to 20 V)
Transmitter power drain	6 W
Receiver power drain	700 mW
Battery life (PS.28.A)	24 hours on a 9:1 Receive/Transmit regime
Battery life (AA-58/A NiCd)	10 hours on a 9:1 Receive/Transmit regime
Operating ambient temperature	- 40 to + 55^{0}C
Storage temperature	- 40 to + 70^{0}C