THE SR A41 NO.3

Introduction

This is the story of an end and a beginning. Station Radio (SR) A41 No.3 was the last Mk of the British Army A41 VHF FM backpack transceiver. It was also the first fully transistorised British military VHF FM manpack radio. In Ref.1, Chris Horswell gave a good part-page resumé of its history and general capabilities. According to Chris only about 50 of the sets were produced by Bush Murphy Electronics in 1966 and then disposed of in 1971. This note considers the SR A41 No.3 in more detail, its circuitry and performance and the historical conditions that may explain why it was built.

Historical

By the mid 1950s national military authorities were starting to draw up concepts for VHF FM backpack radios to replace the PRC-10 series of sets. These US designed radios were also used by Holland, France and Germany and had been the base design for the British A41 and A42 and for the Canadian CPRC-509 and -510 radios. The main thrusts of the developing requirements were to:

- put the full military VHF tactical spectrum into one box rather than cover it with three sets (the PRC-8,-9 and -10), i.e. to reduce set types, improve logistics and increase operational flexibility
- reduce channel spacing and so increase the number of available channels
- simplify set controls, dispense with variable tuning and netting and reduce the need for specialised operator training
- employ transistors for improved reliability, reduced portage load and lessened power demands on the battery

In 1962, RCA completed the development of the first transistorised and synthesised VHF FM backpack for the US military, the PRC-25 (Ref.2). It produced a nominal 2+ watts RF output, covered 30 to 75.95MHz in 920 channels and allowed two channels to be pre-selected. The set retained one valve in the transmitter output stage, awaiting the development of suitable RF power transistors.

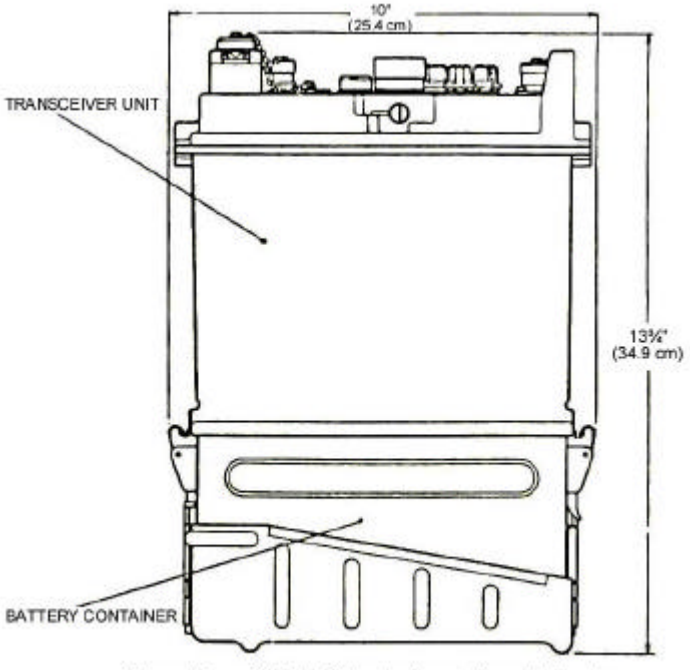
The PRC-25 introduced two further significant advances:

- The 150Hz tone squelch. This required no adjustment and was claimed by the Americans to have been 'grunt proofed'.
- A Dynamic, electro-mechanical, microphone insert replaced the older carbon insert that could have poor environmental withstand and variable performance.

By the mid 60s the French (Thomson-CSF) and the Germans (Standard Elektrik Lorenz) were well advanced in their hardware development for the PRC-10 series replacements. The French set, the TR-PP-13, (ER-95), covering 26 to 72 MHz and providing 1.5 watts of RF was introduced in 1966 (Ref.3). The German set was the SEM 35 (Ref.4). It covered 26.00 to 69.95Mhz, produced a maximum RF output of 1 watt and was introduced in 1968 (Ref.5). Both sets were fully transistorised. The TR-PP-13 employed 43 transistors and the SEM 35 had 52.

The PRC-25, French and German sets were mechanically tuned, analogue synthesised sets with 50kHz channel spacing and IF frequencies in the region of 11MHz. The German set was unusual in that it employed bulky mechanical permeability tuning like the car radios of its day. This arose because it shared a common development (and two main modules) with the larger SEM 25 vehicle set. The French on the other hand combined the TR-PP-13 development with its associated squad radio the TR-PP-11 'handie-talkie' with which it shared common components.

Britain had decided to await the development of digitally synthesised, electronically tuned sets. These were to be the Clansman series. The Clansman replacement for the A41 and A42 was the PRC-351, scheduled for first deliveries



External view of A41 No.3 showing the shortened battery box

around 1970. It would cover 30 to 80MHz in 1841 channels with 25kHz channel spacing, provide remote control and re-broadcast adapters built into the set and 150Hz tone squelch. Its size and weight would be reduced by the use of integrated circuits, (some of which would be custom devices) and flexible printed circuit boards (PCBs).

The A41 10 foot whip provided ranges of up to 10 km. However, this large whip was very restrictive for portable, manpack operation in wooded country or in urban environments. It was also a clear and obvious 'target designator' for enemy fire. To remedy matters, the PRC-351 would provide a 4 watt RF output, so allowing it to provide set-to-set ranges of over 8km on a relatively inconspicuous four foot whip.

These were ambitious targets for their day, especially since the PRC-351 without its battery was to be similar in size to an A40 without its battery box. There must have been concern in some quarters that the above targets could not be met in the programme time. Also, the enhanced technology had to be paid for, making the PRC-351 significantly more expensive than the A41.

Until the Clansman prototypes were available Britain would have limited experience of operating military transistor VHF FM sets in the field. The American experience with early PRC-25 sets showed that there was a down side to using transistors. In the late 50s and early 60s the dynamic performance of transistors in RF circuits was not fully understood. Compared with valves they had poor cross modulation, intermodulation, blocking and overload characteristics, not all of which showed up in the established laboratory tests of the day.

On early PRC-25s the first receiver RF amplifier transistor had no protection against high reverse base-emitter voltage (Ref.5). It could fail if operated too close to a high power transmitter. The receiver selectivity required improvement and transmitter spurii reduced. It was into 1964 before these problems were rectified.

There was also need to carefully select the frequencies of sets coupled as a re-broadcast pair to prevent mutual interference. A special chart was provided to allow operators to select acceptable combinations of re-broadcast frequencies (Ref.6).

It was important that Britain operate transistor sets in the field, discover the pitfalls and feed these lessons into the PRC-351 development.

The A41 No.1 was designed for 100kHz spaced channels. The A41 No.2 was improved to allow it to tune to 50kHz channels but it retained a receiver IF selectivity optimised for 100kHz channels. A transistor version of the A41 No.2 could be produced with receiver selectivity optimised for 50kHz channel working. By using existing A41 No.2 hardware and standard components the development costs would be modest. There may also have been a school of thought that believed there still could be a place for manually tuned sets in less demanding roles, alongside the synthesised sets and that by using both, budgets could be reduced.

Alternatively, Murphy, who had been the main manufacturer of the WS31, A41 and A42 sets, may have seen a product line disappearing to a competitor, RACAL, the PRC-351 developer. The No.3 set could have been a private venture attempt to retain some of the business, i.e. to extend the A41 series life to Murphy's benefit. The No.3 set manual (Ref.7) is a commercial publication without a 'Restricted' classification or an official document number. It also has errors that would be unusual in an official document that had passed full military scrutiny. These factors could indicate a private venture.

How the above aspects weighed in the final outcome is uncertain but a decision was made to produce a batch of A41 No.3 sets for field trials. The sets were withdrawn in 1971 when the PRC-351 development was completed and its production established.

Construction

The A41 No.3 employed the A41 No.2 front panel including its switch legends. The set case, power connector, battery plug and the tuning condenser, its drive and dial also appear to be A41 No.2 parts. The main chassis was a modified version of the No.2 set unit. The RF amplifier and oscillator modules were built on small PCBs in screened boxes similar to the RF stages of the No.2 set. Other circuit modules were built on larger PCBs, some of which were screened. A 10.7MHz crystal filter provided the improved receiver IF selectivity.

The table below shows the three main advantages of the No.3 set:

- A six fold reduction of average battery power consumption
- 50kHz channel selectivity (at least statically)
- Reduced portage weight.

Table 1 Comparison of set types

	A41 No.2	**A41 No.3**
Active Components	13 valves, 6 transistors	37 transistors
Frequency Coverage	38 - 55MHz Continuously tuned	38 - 55MHz Continuously tuned
Receiver IF	4.3 MHz	10.7MHz
6db Selectivity	65 - 90kHz	40kHz
60db Selectivity	300kHz	80kHz
Sensitivity	20db (S+N)/N for 1.25microV input	20db (S+N)/N for 1.0microV input
Limiting	<2.5db change in AF from 3microV to 1mV input	<2.5db change in AF from 3microV to 1mV input.
Muting (Squelch)	>20db reduction in noise	>20db reduction in noise
Discriminator Type	LC	Crystal
Calibration Oscillators	1MHz and 4.3MHz	1MHz and 10.7MHz
RF Power Output at normal battery voltage	> 0.75Watts	> 0.75Watts
RF Power Output at battery exhaustion	> 0.25Watts	> 0.25Watts
Deviation	± 5 - 10kHz	± 5 - 10kHz
Average battery power demand on a 9:1 Rx/Tx Ratio	3.39 Watts	0.526 Watts
Overall Height	48 cms	34.9 cms
Weight of bare set plus one battery	8.3kg	5.25kg

Portage Weights

The weights in the table above are for the set and battery only. The signaller could have to carry a full radio station including pack frame, aerials, audio accessories, extension leads, battery tester, RF indicator, remote aerial base, re-broadcast adapters etc. Precise weights could not be found for the No.3 set whole station. Its pack frame was marginally smaller and lighter but its accessories were otherwise the same as the No.2 set.

The No.2 set whole station weighed about 16kg with Carrier Manpack GS. This rose to 20kg with Carrier Radio Station Manpack and compared unfavourably with the original PRC-10 which with a webbing carrier and lacking the clutter of extra bits and pieces had a full station weight of less than 11kg.

The No.3 whole station could weigh up to 17kg. Given that the signaller also carried his personal weapon and gear, his overall load was appreciable.

The basic station weight of the PRC-351 was 6.5kg. Given the choice of a PRC-351 or an A41 No.3 it is not difficult to predict which one the signaller would prefer.

Temperature Stability

There is an omission in the data given in the No.3 set manual (Ref.7). The A41 Nos.1 and 2 EMERs quote the warm up frequency drift of the receiver. However, no data on the No.3 set warm up frequency drift or of the temperature dependence of the local oscillator frequency, is provided. This, plus the generic problems of temperature compensation on early free running VHF transistor oscillators raises the suspicion that the No.3 set temperature drift may not have been as good as the No.2 valve set.

Voltage Compensation with Battery Discharge

The voltage supply of the critical circuits of the No.3 set, such as the receiver master oscillator were stabilised against battery discharge by analogue voltage regulators. However, the overall performance of the set fell off as the battery discharged. The French showed, with their BA-511 inverter for the PRC-10 series, that RF output and performance could be maintained down to battery exhaustion by using a voltage regulated inverter for the set power supply. The SEM 35 had a similar inverter but this feature was not provided in the No.3 set.

unprotected against high reverse base to emitter voltage and appears vulnerable if operated in close proximity with high power transmitters. The PRC-25 solution was to fit a reverse biased signal diode across the transistor base emitter. A peculiarity of the No.3 set is that the screened boxes of both receiver RF stages are shown connected to the RF input of their respective stage rather than to earth. The reason for this is unclear.

The RF amplifiers were followed by a single PNP transistor mixer, VT3. This was not an ideal device. Its local oscillator injection voltage had to be reduced in TRANSMIT, by auxiliary contacts of a T/R relay, to minimise the level of

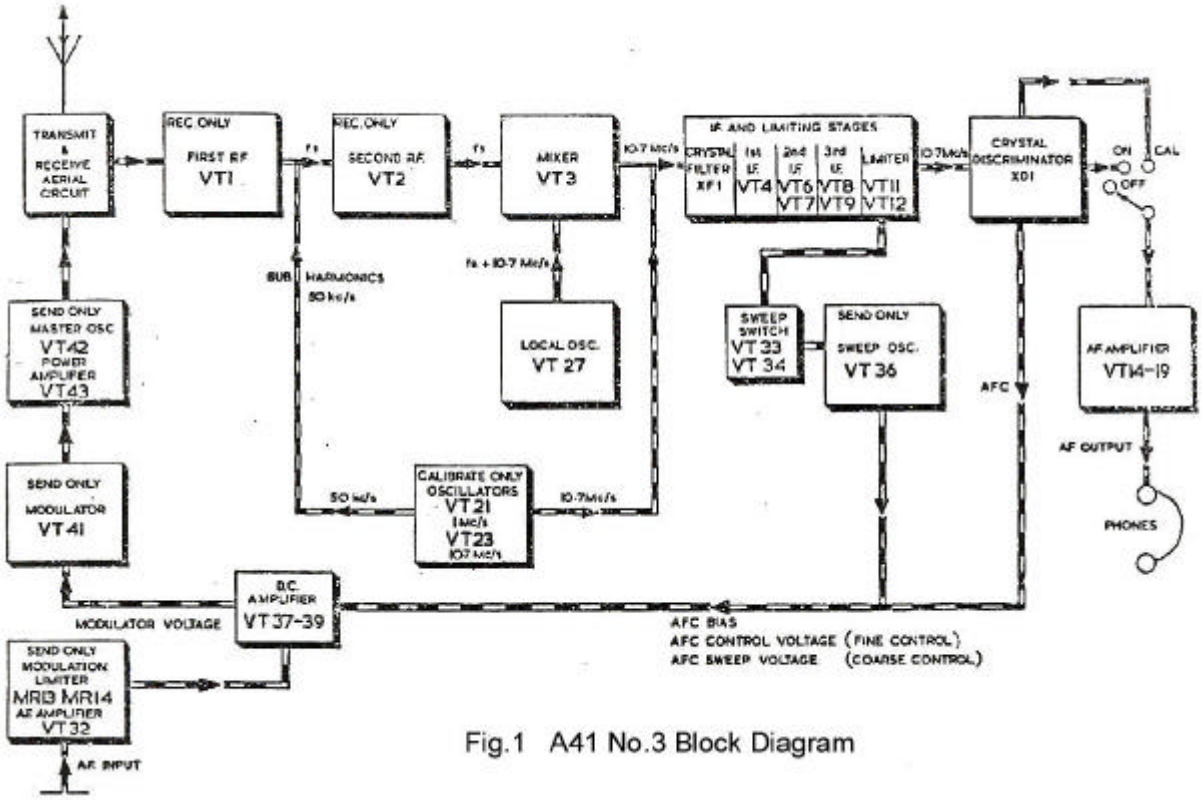


Fig.1 A41 No.3 Block Diagram

Circuit Detail

The block diagram of the No.3 set is shown in Fig.1. Apart from the use of transistors, a crystal IF filter, a crystal discriminator and separate transmitter oscillator and PA stages, the No.3 set block diagram is virtually identical the A41 No.2. As with the No.2 set the receiver local oscillator is permanently operated to maintain it warmed up at stable frequency. The transmitter oscillator is locked to it by an automatic frequency control (AFC) loop employing the receiver mixer, IF amplifiers and discriminator.

The No.3 set aerial input and matching circuits appears identical to the No.2 set. There were two PNP transistor receiver RF amplifiers. Like the early PRC-25s the first RF transistor was

spurious mixer responses and prevent the transmitter oscillator locking onto false frequencies. The SEM 35 used a balanced diode ring receiver mixer to improve performance and overcome this problem.

The No.3 set mixer output was matched to a 10.7MHz crystal filter, type LQA904A, which provided the main receiver selectivity. This was followed by a broadly tuned IF gain block of five transistors and then by a two transistor limiter circuit.

The limiter fed a crystal discriminator. The crystal discriminator was not essential for RECEIVE operation but it ensured that the TRANSMIT AFC loop was accurate and that the TRANSMIT frequency was held within 2kHz of the RECEIVE frequency. On the Nos.1 and .2

sets the discriminator was LC tuned and its misalignment, ageing or service drift could result in significant differences between the two frequencies.

There was a two transistor muting (SQUELCH) driver stage fed from the limiter and a five transistor audio amplifier with a push-pull output to the audio equipment ear pieces. There was no SQUELCH relay. The SQUELCH operated by biasing the input stages of the AF amplifier to cut off.

The transmitter oscillator was locked to the receiver oscillator by an AFC loop. This consists of the receiver mixer IF, stages and discriminator. The discriminator output fed a transductor (variable inductor) in the transmitter oscillator tuned circuit. If the transmitter frequency drifted high the IF signal frequency increased and the discriminator output reduced. This increased the inductance of the transductor and so reduced the transmitter oscillator frequency to correct its upward drift. By this means the AFC loop controlled the transmitter frequency to that of the receiver.

The above loop only worked if the transmitter IF signal was within the passband of the crystal filter and discriminator. To assure AFC lock at the start of a transmission the transmitter frequency was swept through the loop passband. On the No.2 set this was achieved by using a pulse sweep oscillator. On the No.3 set this function was performed by a 'Sweep Oscillator and DC Amplifier Circuit' consisting of a two transistor sweep control amplifier, a unijunction sweep oscillator and a four transistor DC amplifier. The DC amplifier controlled the variable transductor in the tuned circuit of the transmitter oscillator. The sweep oscillator was shut off by its control amplifier when the loop locked. The DC amplifier was also used to amplify the signals from the microphone.

The audio from the microphone passed through a single transistor preamplifier followed by a diode clipper before being fed to the DC amplifier.

The transmitter oscillator fed a Class C RF PA circuit using a 2N2950 NPN transistor.

The A41 No.3 manual (Ref.7) includes circuits for all of the set modules and PCB layouts for most but not all. The PCB layouts are not to scale but can be scaled from the known size of transistors, trim pots., etc..

Battery

The set battery consisted of two 9volt sections that were connected in series to provide an 18volt transmitter supply. For receive the two 9volt sections were connected in parallel to equalise battery section drain. The battery box could accommodate two batteries. In the base of the battery box there were flaps that could be raised like trestles. If only one battery was carried it sat on top of the raised trestles. If two batteries were carried the trestles were lowered and the spare battery was carried in the space otherwise occupied by the raised trestles. Each battery gave an operational life of approximately 36 hours. By carrying two batteries 72 hours of service was obtained.

Accessories

The set mounted and remote aerials for the No.3 set were the same as those for the No.2 set. The audio accessories were similar but not identical. They still used round, bayonet locking, 6 pin audio connectors but with slightly different keying and wiring. The microphone inserts were the later electromagnetic type rather than the earlier carbon inserts. There were 6m audio extension leads and 16.5m RF co-axial extension leads for the remote aerial.

Conclusions

Some of the No.3 set circuitry seems crude by modern standards but it should be viewed in context. The set was designed 1966, four years before the first fully transistorised colour TVs appeared on the UK market. Today's wide range of semiconductors and integrated circuits were not available to the set's designers. Viewed as a design of its day the No.3 set is creditable.

However, it was backward looking in that it tried to fit transistors to an established valve design rather than take advantage of the new possibilities that semiconductors offered.

It also perpetuated the logic that flexibility could be achieved by external add-ons and that the signaller should carry these. Typically, the PRC-10 series had an adequate internal re-broadcast facility. The A41 design removed this and replaced it with a 6kg external rebroadcast adapter unit.

Only about 4 years separate the introduction of the A41 No.3 and the PRC-351. The PRC-351 is a massively better set in performance, in-built facilities, portage weight and conspicuousness. In consequence, the SR A41 No.3 had little chance of being adopted for volume army service.

References

Not having a No.3 set, and having little hope of inspecting one, this note has been written from the following references.

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