The Clansman UK/PRC-351 and its Variants

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Introduction

Official literature on Clansman is still reputedly restricted. Consequently, this note has been compiled from commercial sources, such as 'Jane's Military Communications', early Racal/BICC sales and promotional literature and dealers' advertisements. Some of the early Racal auxiliary equipment described in these sources failed to become final issue and was replaced by equipment from other suppliers. Additionally, some of the early set parameters were adjusted in the light of service experience. Commercial information has been supplemented by equipment strip-down, inspection and test. Consequently, the information that follows is given in good faith but is not fully guaranteed.

The PRC-351 is complex. The topics covered in this note are limited to a few specific features of the set and the identification of set variants, major equipment and accessories. An attempt is also made to show how the PRC-351 designers overcame previous equipment deficiencies.

Prior to the PRC-351, new designs of VHF/FM backpack military radios had been analogue synthesised using discrete transistors. Most developed from US work on the PRC-25. Prior to the PRC-351 one of the last designs in this field had been the French TR-PP 13 in about 1966. Britain had retained the A41 and A42 sub miniature valve sets awaiting the PRC-351. The PRC-351 takes 3 major steps forward in design. It is digitally frequency synthesised, it makes large use of integrated circuits and wherever possible it uses electronic switching rather than electromechanical switching.

Apart from its frequency selector switches, a FUNCTION switch and a REMOTE switch the basic PRC-351 uses no other switches, no operator variable controls or electromechanical relays. This simplifies operation, minimises the need for operator training, reduces the risk of operator error and increases reliability. The PRC-351 was claimed 20 times more reliable than the A41.

Clansman is an integrated HF/VHF/UHF communication system with standardised ancillaries spanning vehicles, aircraft and foot soldiers. It represented massive component and equipment design and development programmes.

It was intended that Clansman would be in service in the early 1970s. However, the high cost of Clansman gear, the need to stock pile full sets of equipment and components before converting each army unit and the complexity of conversion and re-training caused delays. It was 1982, almost a decade after design, before 'tail end', regular army units in the UK were fully converted to Clansman. This is indicative of the delays in bringing complex, costly, high volume systems of new technology, into military service. Because of the delays, manpack radios such as the PRC-351 were often issued before conversion of an army unit to Clansman.

There were also early hopes that military units still equipped with Larkspur and those converted to Clansman might be able to communicate during the conversion process. This was not reliably achieved overall with the PRC-351. Older manpack radios such as the A41 No.1 were designed for 100 kHz channel spacing. The A41 No.2 was provided with 50 kHz channel markers but retained an IF bandwidth for 100 kHz channel spacing. More importantly their frequency stability relied on free running LC oscillators. The PRC-351 was designed for 25 kHz channel spacing with a 4.5db receiver bandwidth of $\pm$9 kHz. Battery discharge and ambient temperature change could cause A41 and A42 transmitters to drift out of the PRC-351 working channel. Even the crystal controlled A40 had a channel frequency uncertainty of $\pm$9 kHz.

Limited Larkspur/PRC-351 communication was possible with the B47, B48, C42 No.2 and the C45 No.2 and with 50 kHz channel analogue synthesised sets such as the US PRC-25, the German SEM 35 and the French TR-PP 13 radios where all channel frequencies were controlled by synthesiser crystals.

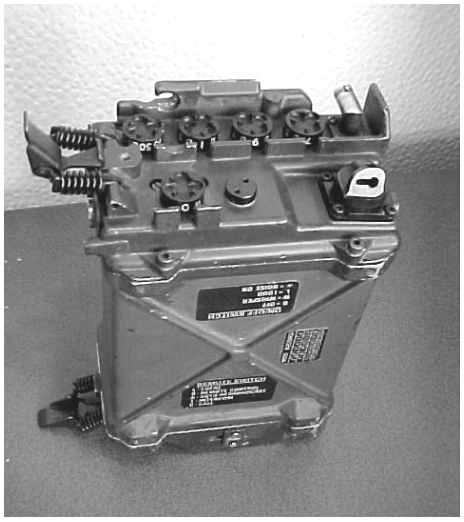

Fig.1 RT-351

UK/RT-351 (5820-99-114-3639)

The RT-351 is the radio of the PRC-351. It was developed by Racal/BCC against a NATO requirement for a VHF/FM manpack radio with a range of at least 8 km (5 miles) over typical western European terrain. Its design dates from the early 1970s.

The basic PRC-351 replaced the Larkspur A41 and A42 radios. Like the earlier French TR-PP 13 a separate 20 watt RF amplifier AM-352 was provided for the PRC-351. The PRC-351 with the AM-352 fitted is designated the PRC-352 and replaced the B47 and B48.

The PRC-351 is fully transistorised and uses silicon transistors and integrated circuits (ICs).

It has a transmitter RF output of 4 watts nominal and provides simplex, narrow band FM, 5 kHz deviation communication, on any one of 1841 synthesised channels spaced by 25 kHz from 30 to 76 MHz in two wavebands. The set is tuned by four digital switches that select MHz x10, MHz, 0.1 MHz and 0.025 MHz. Auxiliary contacts of these switches automatically band switch so that band switching is transparent to the operator. A maximum frequency of 79.975 MHz can be set on the switches but the radio is aligned for 76 MHz

maximum. A standard set should not be assumed capable of working above this frequency. No illumination of the controls is provided for operation in the dark. It was intended that the operator should be capable of changing mode and frequency by counting switch `clicks'.

Brief Technical Specification

Frequency range	30 to 76 MHz
Channel spacing	25 kHz
No. of channels	1841
Mode	F3, 5 kHz deviation
Service	1 channel simplex

Receiver	Single conversion
Local oscillator	Signal + IF
IF Frequency	11.525 MHz
4.5 db selectivity	±9 kHz
100 db selectivity	±20 kHz
Sensitivity	1µV RF input for 10db+ (S+N)/N
AF output	2 mW for 1µV RF
AF response	Level 0 to -6db, 400 Hz to 3 kHz ref. 1kHz

Synthesiser frequency	± 5ppm freq. stability
Unwanted FM	less than 100 Hz peak
Spectral purity	better than -80db
Temperature	-40 to +55°C + solar

Transmitter	
RF output	(3-6) 4 watts nominal
Tx. Harmonics	40 db below carrier
FM deviation	±5kHz

Battery	4 Ahr 24 volt NiCd
Receive drain	105 mA at 24 volts
Transmit drain	800mA at 24 volts

The receiver is a single superhet with an IF of 11.525 MHz and a synthesised local oscillator frequency of signal plus IF. The IF strip has two crystal filters and, like the earlier TR-PP 13, a crystal discriminator. The first amplifier of the IF strip is a wideband IC that generates out of band noise. The second IF crystal filter removes this noise from the signal. Unlike early PRC-25s, the receiver RF input is protected from adjacent high power transmitters and can withstand up to 65 Volts RF rms without permanent damage. The 65 volts corresponds to a PRC-352 transmitting at a distance of 3 meters from the PRC-351.

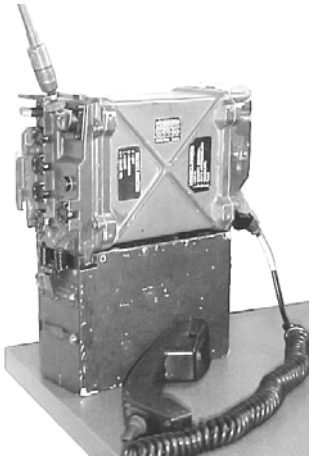

Fig.2 Basic PRC-351

Construction

The set circuitry is constructed on two main printed circuit boards (PCBs) of glass/resin material joined by flexible printed circuit. This allows the two main boards to open like a book for servicing. These main circuit boards connect to the front panel switches via additional flexible printed circuits. There is a further minor circuit board on the back panel beside the REMOTE switch. Some of the flexible printed circuits are now more than 30 years old. As they age their resins lose volatiles and they embrittle. With multiple bending during servicing their copper tracks can work harden and crack. Consequently, the flexibles should be handled with care, especially the flexible connecting the frequency setting switches.

Most of the PRC-351 ICs were custom devices and are now obsolete, so repair can be a problem. Peter Chadwick's letter in VMARS Newsletter Issue 38 gives a good explanation of the IC position. Most of the ICs are early surface mounted type devices requiring delicate soldering to remove and remount them without damage.

Fig.3 Typical RT-351 Integrated Circuit

In manufacture and service the individual modules of the RT-351 are set up and aligned in dedicated test jigs before being soldered into the set. Modules can have up to 25 connections. De-soldering equipment is required and to avoid heat damage the time at temperature during de-soldering must be limited. In the event of a fault, it is preferable to change a complete module than to attempt to replace an IC in a module. A PRC-351 owner wishing to keep the set operational might consider obtaining a second set as a source of spares. This is not a cheap option since most dealers 'off the pile' price for a bare, untested PRC-351 has risen to £100+.

There are 4 test points on the RT-351 chassis:

- TP1 Varicap tuning voltage
- TP2 Frequency of VCO in service
- TP3 Output from synthesiser phase detector
- TP4 6V supply

Frequency Synthesiser

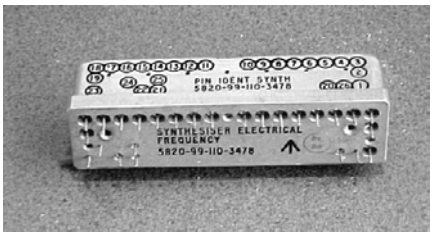

Fig. 4 Synthesiser Module

The heart of the PRC-351 (and PRC-350) tuning control is a Plessey digital frequency synthesiser module (5820-99-110-3478, RT-351 Module 10). In combination with a 6.4MHz crystal reference oscillator and variable frequency voltage controlled oscillators (VCOs) tuned by varactor diodes, the synthesiser produces frequencies from 30 to 76MHz for the transmitter and 41.525 to 87.525MHz for the receiver local oscillator.

A 6.4 MHz crystal reference oscillator is divided down by a fixed ratio divider in the synthesiser. A variable ratio divider, also in the synthesiser, is fed from the VCO being controlled. The PRC-351's frequency selector switches set the division ratio of the variable divider. The two divided signals are fed to a discriminator that produces an error signal if their frequencies differ. The error signal is used to coarse tune the VCO via varactor diodes until the divided frequencies of both oscillators are approximately the same. This brings the signals within the capture range of a phase locked loop. The loop locks the phase of the divided controlled oscillator signal to that of the divided reference oscillator to set and stabilise the frequency of the controlled oscillator. Division ratios are changed automatically when switching between receive and transmit.

The output of the phase detector is fed to a high voltage, non-linear amplifier (module 8) to produce the voltages necessary to tune the varactor diodes. The amplifier is powered from the 100 volt supply and its output to the varactor diodes is available on test point TP1.

As previously stated the PRC-351 frequency range is covered in 2 wavebands, from 30 to 47.975 MHz and from 48 to 76 MHz. Each waveband has its own RF amplifiers, oscillators, transmitter drivers and tuned circuits. All the RF circuits are pre-aligned to tune to the lowest frequency in their band with a non-linear amplifier output on TP1 of about 4.5 volts DC. All tune to the maximum frequency in their band with a TP1 voltage of about 83 volts DC. The signal on TP1 should be 4.5 volts at 30 MHz and climb to 83 volts DC at 47.975. It should then fall to 4.5 volts at 48 MHz and climb again to 83 volts at 76 MHz.

Phase lock of the loop is detected and used to enable the conventional circuits of the RT-351. If lock is lost on receive there is no audio output in the `Noise On' mode and no reception in squelch mode. If lock is lost on transmit there is no sidetone. These features are designed to alert the operator to a set malfunction.

Consider what happens if (say) the LC components of the receiver high band local oscillator circuit change value with age or are mistuned in error. Suppose this results in phase lock being achieved at 76 MHz on the frequency setting switches, with a VCO frequency of 76 + 11.525MHz (i.e. signal plus IF) but with only 60 volts on TP1 rather than the design value of 83 volts. The confidence check will be positive and all will appear to be in order. However, the receiver RF circuits will not be aligned to the oscillator since they require 83 volts to tune to 76 MHz. The set will not be operating correctly. This demonstrates that the PRC-351 is complex and all might not be as simple as it seems. Trial tuning and twiddling is not recommended.

Internal Power Supplies

The A42 transmitter RF output could fall by 66% between a new battery and a discharged battery at the end of life. There was a corresponding degradation in receiver sensitivity. To overcome these problems the PRC-351 internal supplies are provided by an inverter circuit with voltage regulated outputs of 100, 17, 9, 6 and 3 Volts.

There is little fall off in receiver performance as the battery comes to the end of its discharge because the regulated inverter maintains its output voltages. However, when called upon to transmit the set can fail to do so. An audible warning is, therefore, provided for a low battery voltage of 19.5 volts. When working in squelch this takes the form of pulses of noise from the receiver. The 6 volt output of the inverter is available on test point TP4. The inverter is not fault limited. If TP4 is shorted to chassis the inverter transformer and other hard to obtain components fail.

The inverter has a soft start. The soft start timer capacitor is discharged when the set is switched to OFF. The set should be switched ON and OFF by the function switch not by disconnecting and reconnecting the battery.

Squelch

Squelch (or receiver muting) had been a bone of contention before the arrival of Clansman. An FM receiver has high noise output in the absence of signal. This can be tiring to listen to for long periods. The noise level reduces as the signal strength increases. The first VHF FM portable set the US SCR 300/BC 1000 had a squelch control that kept the receiver muted until noise was adequately reduced by an incoming signal. The squelch threshold was set by an operator variable control. This raised concerns that if the operator set the control incorrectly important signals might be lost. Consequently, most of the British variants of the SCR 300, the WS 31, had no squelch. Variable squelch was retained by the US on the PRC-10 series that replaced the SCR 300 but omitted by the UK on their equivalents, the No.1 versions of the A41 and A42. Muting was however provided on the No.2 versions of those UK sets.

When the US designed their VRC-12 and PRC-25 sets they introduced a squelch system that needed no operator adjustment. The transmitters had a sub-audio, 150 Hz tone. The receiver listened for this tone and lifted the muting when the tone was received. When the Europeans came to develop their analogue synthesised VHF FM radios such as the SEM 25 and 35 and the TR-PP 13 they did not provide tone squelch. The full reason is unclear - it could be that they had a large compliment of older radios without tone squelch that they wished to retain in service. The position then became – if the UK wanted to cross work with US forces tone squelch was necessary. If they wished to cross work with the Europeans and earlier Larkspur sets noise squelch was necessary.

The PRC-351 designers solved the problem by accommodating both systems. The PRC-351 always transmits a 150Hz FM tone to allow it to operate with US and similar radios with tone squelch. On receive the PRC-351 tone oscillator is switched to 160 Hz and injected into the receiver local oscillator to FM modulates it. The 10 Hz frequency difference avoids undesirable very low frequency beat effects that could occur if a US tone squelch station is being received with a 150 Hz tone and the PRC-351 receiver were also injecting a near identical 150 Hz tone.

The 160 Hz receiver tone or the 150 Hz transmitter tone enables a noise quieting receiver squelch. The PRC-351 can, therefore, operate to equipments with and without tone squelch. The squelch was originally pre-set to operate on 6db noise quieting which is below the threshold of intelligibility. The 6db level is understood to have been changed subsequently due to service experience. It was intentionally below intelligibility to alert the operator to traffic on the channel and possible need to change location to improve reception.

In the radio relay (re-broadcast) mode the 160 Hz receiver tone is switched off. This minimises spurious re-transmissions by requiring radios triggering rebroadcast to have a 150 Hz transmitter tone. PRC-351 squelch can be switched off in general use by setting the FUNCTION switch to NOISE ON (*).

PRC-351 Controls

The PRC-351 controls are:

FUNCTION SWITCH

0 = OFF

W = WHISPER.

Used in covert type situations where noise must be minimised. The microphone sensitivity is increased by a factor of about 10 (20db) to allow the operator to whisper and the audio output to the headphones/handset is reduced by a similar amount to reduce noise leak. Squelch is ON.

L = LOUD

Returns audio gains to normal providing high level output compatible with the ambient noise in active service. Squelch is ON.

* = NOISE ON

Disables the squelch/muting circuit so that there is permanent audio noise output from the receiver in the absence of signal. In the NOISE ON mode audio levels are LOUD.

REMOTE SWITCH

L = LOCAL

The set is controlled as normal by the local operator.

R = REMOTE

The set is controlled by the remote operator.

A = AUTO-REBROADCAST

Allows the two sets to operate as a radio relay.

I = INTERCOM

Allows the local and remote operators to speak to each other without their exchanges being broadcast.

C = CALL

Remote operator call. A loud call tone is applied to the local and remote handset earpieces.

Batteries

Initially power was normally provided by a 24V, 3.3 Ah rechargeable, NiCd battery clipped below the set with a life between charges of 12 hours on a 1:9 Tx/Rx ratio. As battery design progressed the battery became available in 4 Ah and higher capacity versions. The battery now generally issued is 'Battery Secondary Alkaline, 24 volts 4.0 Ah 6140-99-620-8057'.

Colin Guy has a good article on refurbishing Clansman batteries with new cells in VMARS Newsletter No.27. The article also explains the battery charging methods and philosophy used by Clansman. The cost of a set of new cells is relatively high at about £70. However, the LIDL supermarket chain have occasional/infrequent offers of 4 Ah NiMH D cells at less than £1 each, allowing the battery to be refurbished for less than £20.

There is a 1Ah NiCd rechargeable battery (6140-99-620-8058) that can only power the PRC-351 for about 5 hours. It is normally employed with the 'sandwich' hand generator, 'Generator DC 5820-99-114-3390', which can be clipped between the battery and the set. 4 hours of generator hand winding will support about 5 hours of PRC-351 operation on a 9:1 Rx:Tx ratio. The hand generator can recharge the battery when the set is switched off or on.

Battery Chargers

Batteries can be charged using 'Charger Battery DC 28V, 6130-99-117-0450' (known as DCCU 28) on 24Volt FFR vehicles. 'Charger Battery DC 14V, 6130-99-620-2114' (known as DCCU 14) is used on non-FFR vehicles with 12V supplies.

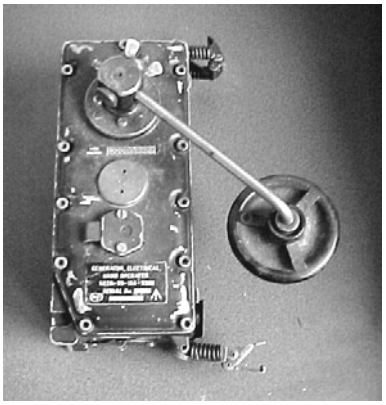

Fig.5 'Sandwich' Hand Generator

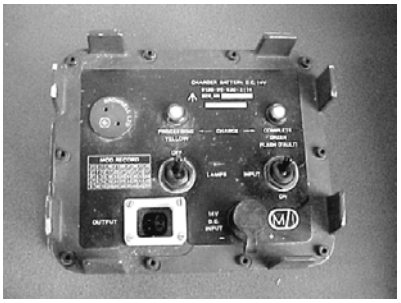

Fig.6 DCC 14 charger

In addition to their charging function these units ensure that voltage spikes and surges on the vehicle supplies do not damage the radio.

Racal produced a BCC 528 charger for single batteries that could be powered from 10.8 to 32 Volts DC and so was suitable for both 12 and24 volt systems. A multi battery charger that operated from the same DC supplies is BCC 525 while a near equivalent unit for 24 Volt supply only is BCC 526. There is an AC charger 'Charger Battery AC 6130-99-117-0451'.

Set Mounted Antenna

The PRC-351's RF output is 3 to 6 watts (4 watts nominal). This achieves set-to-set ranges of about 8km with 1.2m set mounted whip antenna. (Note: this is a similar range to the A41 on a 3.5m antenna. In crude terms the antenna length has been reduced by a factor of 3 to reduce its conspicuousness and awkwardness and the RF power output increased by 3 to compensate).

The PRC-351 whip is (5995-99-661-6201) a 1.2m, 4 section, self-erecting, rigid tubular type with a spring loaded, ball joint in its bottom section to limit damage from mechanical impact.

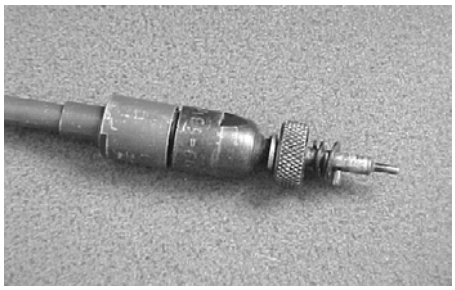

Fig.7 Ball joint base of 1.2m whip antenna

Remote Operation and Re-broadcast

The A41 required 2 separate auxiliary/interface units with separate batteries to construct a rebroadcast pair. On the PRC-351 radio relay and field telephone interfaces are built into the set itself and powered by its battery. Two spring loaded terminals above the audio connectors allow the set to be controlled by a remote handset (Handset R/C 5965-99-620-5670) over field telephone wire at distances up to 800 meters. Alternatively two sets can be connected back-to-back to form a re-broadcast station with up to 3km of telephone wire between them. The REMOTE switch controls operation in this mode. The small plate with a keyhole slot beside the REMOTE switch is a wire stripper for the telephone wire.

Fig.8 Remote handset showing the call button

The rebroadcast pair can consist of a PRC-351 and a second PRC-351 or a PRC-344 UHF set. The PRC-351 has two, standard Clansman 7 pin audio connectors so allowing the HF PRC-320 and the UHF PRC-344 to share common audio gear with the PRC-351. The two RT-351 connectors are not identically wired. SKT.2 has an unpainted ring around it and is used to couple to the initiator box when using the TUAAM.

Audio Gear - Headset

The headset normally issued has a 300Ω boom mounted, noise cancelling magnetic microphone and detachable right hand ear phone insert. It is designated (5965-99-620-8320). The headset is wired to a 7 way snatch plug that connects to Pressel box assembly (5965-99-620-5667). The Pressel box provides R/T switching. The headset has a 3 way connector for a respirator microphone.

Audio Gear - Handset

The normal handset is Handset (General Application) (5965-99-620-5669). Early models have a straight cable and later models a curly cable.

Fig.9 Handset

Selective Unit RF (SURF) 4 watts

This is an extra tuned antenna circuit to improve receiver front end selectivity and reduce transmitted spurii when sets are working in close proximity. It requires to be manually tuned to the operating frequency and carries its own antenna base for the 1.2m whip. See the health warning, which will appear at the end of part 2.

[Part 2 of this article will cover variants such as the PRC-352 and BCC-61, and various vehicle and transportable installations . It will also identify specific safety risks to avoid when working on this equipment. – Ed]

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