THE SEM-35 MANPACK

by Murray McCabe

Introduction

The West German SEM-35 VHF FM manpack radio is available from various UK and EU dealers. This note gives a brief description of the set, its historical relevance, circuit and performance. The SEM-35 performance and characteristics are given in Table 1.

Table 1: SEM-35 Specifications

Frequency Coverage	26 to 69.95MHz
Channels	880 spaced 50kHz
Modulation	F3 (FM)
Deviation	15kHz max.
Transmitter RF Output	150 mW or 1Watt
Frequency Stability	$\leq \pm$ 3.5kHz from -40 to +60^{0}C
Receiver Sensitivity	$\leq$ 0.5 micro volts for 10db reduction in S/N
Receiver Selectivity	$\geq$ 80db at $\pm$ 50kHz
AF bandwidth	400 to 3000Hz
Receiver AF Output	50mW into 600 ohm or 600 ohm earth free line output
Receiver Squelch	Switched
Weight	Approx. 13kg
Antennae	1m nom. tape whip (“short”) 2.5m self erecting whip (“long”) SEM-25 remote antenna
Power Supply	24 Volt DC external (21 to 29V, 32V transient max.) or Internal 12 off U2 cells - normal or NiCd
Overall Size	359x270x125 mm

Historical

Military radios do not just pop into existence. Most result from a steady, progressive improvement to existing designs. Some, however, are landmark designs that made a major step forward. These resulted from a comprehensive, innovative, well financed and thought out development that appraised all aspects of a radio including the man-to-set interface.

In the case of VHF FM synthesised military radios the ground breaking design work was conducted in the US in the 1950s and early 1960s. This was by force of circumstance because, especially in the early 1950s, only the US had the finance, resources and volume requirements to undertake and justify the work.

The 'landmark' sets that resulted were the RCA PRC-25 VHF FM backpack radio and the AVCO VRC-12 VHF FM vehicle set. Both sets covered 30 to 76 MHz and both employed transistors. The PRC-25 retained one valve in its transmitter RF output. The fully transistorised PRC-25 was later issued as the PRC-77.

It was the arrival of the transistor that allowed the complexities of the synthesiser to be engineered for field use with acceptable physical size, performance and power supply requirements.

The US evolved a circuit configuration for military, synthesised VHF FM transmitter receivers that was almost as significant, in its field, as the development of the superhet. It consisted of a two band receiver, synthesised in 50kHz steps by a single band local oscillator. On the receiver low band (30 to 52.95MHz) the received frequency was local oscillator frequency minus intermediate frequency (IF). On the high band (53 to 75.95MHz) local oscillator plus IF frequency. The receiver first IF was 11.5MHz 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.

The transmitter frequency of the US radios was locked to the synthesiser frequency by the use of a crystal controlled 11.5MHz 'side step' oscillator that beat with the synthesiser output frequency to generate the transmitter frequency. This synthesiser configuration became the basis for subsequent VHF FM military radio designs.

The VRC-12 and PRC-25 were quite different radios, because, internally and externally each had been optimised for its duty as a vehicle and a manpack set respectively. The PRC-25 replaced the three valve sets of the PRC-10A series. The most important aspects of its design were its ruggedness, reliability and the basic simplicity of its controls. It was not a prima ballerina requiring excessive workshop attention and, in an emergency, anyone could pick it up and use it without previous training. The PRC-25 was introduced to US service in small quantity in 1961 but it was nearly 4 years later before it entered volume production (Ref.1).

SEM 35 Development

West Germany had used the US designed PRC-10 series radios. By the early 1960s they had a requirement for synthesised sets to update army VHF FM field communications. Their home electronics industry was by then re-established after the war. They decided to develop the synthesised sets themselves as a first foray in the field.

The receiver synthesiser format would be based on the US work but lacking the US's budget, the manpack and vehicle sets would be developed in a single programme.

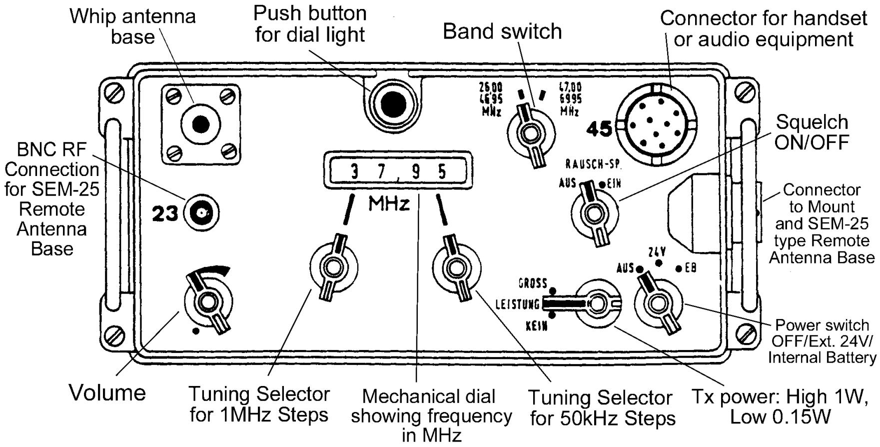
The transmitter would employ a simpler automatic frequency loop similar from that used for earlier VHF FM radios such as the PRC-10. It would use an 11.5MHz discriminator before the receiver IF filter to regulate the transmitter oscillator at 11.5MHz from the receiver synthesiser frequency. This would replace the PRC-25 side step crystal oscillator. It would be less accurate than the PRC-25 arrangement since it would rely on the tuning of a discriminator rather than an 11.5MHz crystal. However, the SEM-35 circuit achieved an acceptable transmitter frequency accuracy of better than + 3.5kHz from -40 to +60oC.

The German contract was awarded to Standard Elektrik Lorrenz AG of Stuttgart. The end result was the SEM-35 manpack, the SEM-25 vehicle transceiver and the EM-25 vehicle receiver. The EM-25 receiver is basically the SEM-25 hardware in a SEM-25 case with the internal transmitter sections omitted. The EM-25 is, therefore, externally similar to, and easily confused with, the SEM-25. The sets entered service in the late 1960s.

The SEM-35 was primarily intended as a manpack but a vehicle mounting and a rebroadcast/relay adapter were produced for it and it could use the SEM-25 remotely tuned aerial base. These allowed the SEM 35 to fulfil vehicle, ground static and re-broadcast/relay roles.

All three sets share two common large-circuit modules with obvious advantages in spares holding and maintenance.

However, the requirement that one programme develop both a manpack and a vehicle set produced conflicting goals. As a result, the SEM-35 has features and components more appropriate to a vehicle radio. In this respect the most obvious vehicle type component is a large multi-gang permeability tuner reminiscent of the techniques employed in the auto radios of the day.



SEM-35 Front Panel

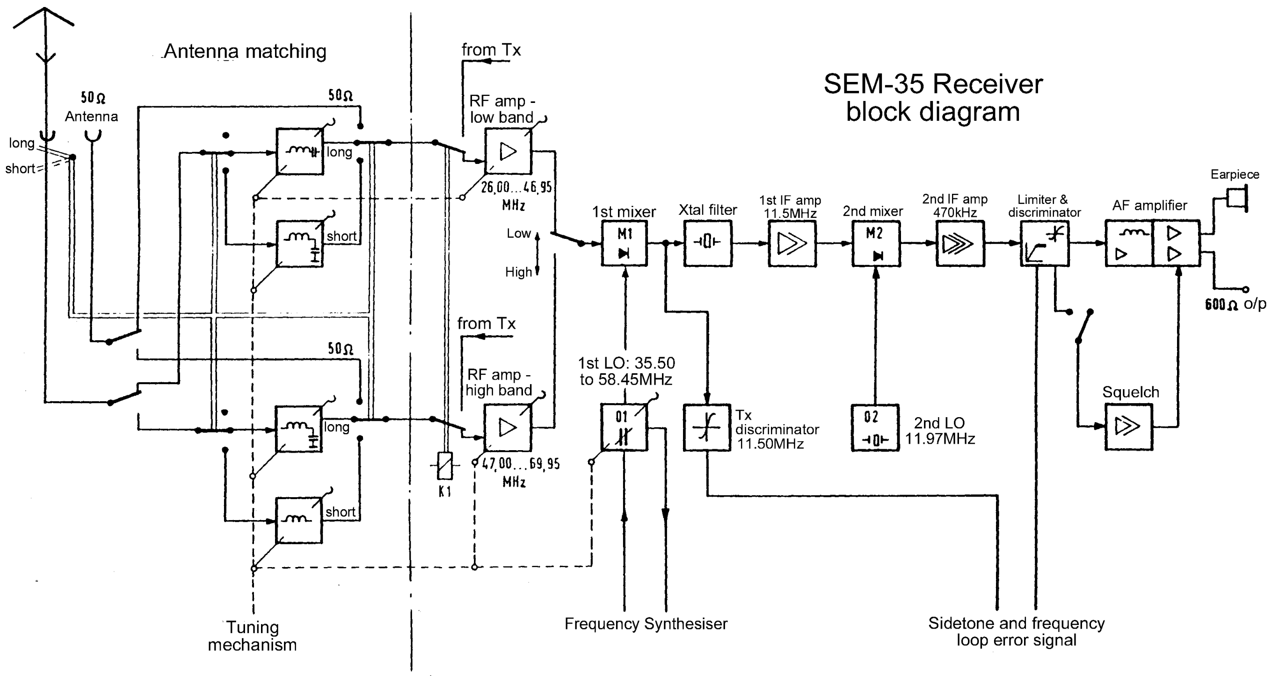
SEM-35 Detail

The SEM-35 covers the early European tactical spectrum of 26.00 to 69.95MHz rather than the US 30 to 76MHz spectrum of the PRC-25 and VRC-12. The set provides a total of 880 channels spaced by 50kHz. These are covered in two frequency bands. A high band from 47 to 69.95 MHz and a low band from 26 to 46.95 MHz. The SEM-35 has the same 11.5MHz receiver first IF as the PRC-25 and each band could be 23MHz wide permitting a low band of 24 to 46.95MHz. The SEM-35 receiver can operate down to 24 MHz but the transmitter is automatically disabled below 26 MHz. The tuning display is a mechanical counter dial giving direct read out of frequency. The tuning arrangement does not permit two channels to be pre-set as on the PRC-25.

The transmitter output power can be switched for 150mW or 1Watt RF output. The receiver sensitivity is better than or equal to 0.5microvolts for 10db signal-to-noise. Squelch is pre-set and selected by switch but it is not the US 150Hz tone squelch.

A battery box toggle clamps below the set and contains a holder for 12 off U2 cells, either normal BA 30 or rechargeable Ni.Cd. cells. On a 9:1 Rx:Tx ratio the BA 30 cells give a 14 hour life while the NiCd cells give 20 hours per charge. Battery exhaustion, i.e. the minimum battery voltage for operation is quoted as 13.2V. The battery box also contains a transistor inverter producing supplies of +6V, +16V, -17V and -30V DC from the internal battery or from a 24Volt external source.

The set uses a 1m laminated tape aerial and a 2.5m self-erecting whip like the PRC-25 but unlike the US PRC ancillaries each whip has a tapped cup at its base that screws over a stud type antenna mount on the set front panel. The set stud base has a sprung piston at its centre which, when depressed, operates switches to select the appropriate antenna matching circuits.



With no whip fitted the set RF output is switched to the 50 ohm BNC socket for connection to the remote antenna base. The cup on the bottom of the 1m tape antenna fully depresses the plunger while the cup on the bottom of the 2.5m whip only depresses the plunger by about 50% of its travel. A similar antenna base is used on the West German SE-6861 SSB manpack radio.

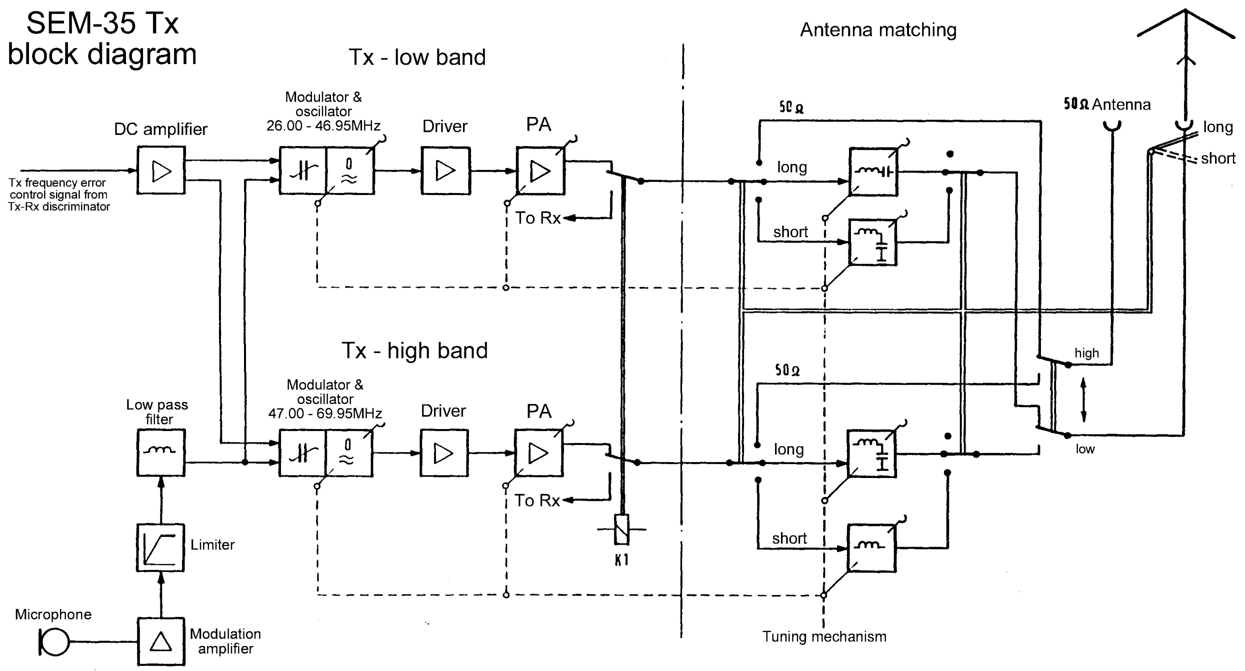
The set employs transistors throughout but because of its design age the transistors are a mix of PNP, NPN, germanium and silicon types.

Circuit Description

Each receiver band has a separate RF amplifier (to simplify band switching). These amplifiers are single germanium PNP AFZ12, TO18 transistors, in a grounded base configuration with diode clamps to prevent RF burn-out. There are 2 permeability tuned LC circuits in front of each RF amplifier and one between it and the receiver first mixer.

The first mixer is a diode ring of 4 x OA90 germanium diodes with 50 ohm ports, mounted on a small, unscreened printed circuit board (PCB). The receiver first IF is 11.5 MHz with a 30 kHz bandwidth crystal filter. The first receiver local oscillator covers 35.50 to 58.45 MHz in one band.

The second receiver mixer is a transistor with a crystal controlled 11.97 MHz local oscillator. The second IF and limiter frequency is 470 kHz. This is followed by a discriminator, an AF pre-amp with low pass filter (LPF) and a push pull Class B audio



output stage. Unusually, the volume control is between the AF output transformer and the handset. The handset is an H-33*/PT as used on the PRC-10 series, complete with a U-77/U connector.

The squelch circuit has a relay output.

The receiver first local oscillator is frequency stabilised by the synthesiser. A signal from the receiver local oscillator goes via a buffer amplifier to the first mixer of the synthesiser. The local oscillator signal for this 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 an 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 46.50 to 47.45 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 the full 22.95 (23) MHz single band tuning.

The local oscillator for the second synthesiser mixer is an overtone crystal oscillator with one of two frequencies spaced by 0.500MHz, i.e. 33.425 or 33.925 MHz. The overtone oscillator frequency is remotely selected from switches on the 50 kHz tuning selector via decoupled control lines that enable the appropriate oscillator output. The two frequencies are used for alternate bands of 0.500MHz, e.g. one for receiver tuning from 26.00 to 26.45 MHz, the other from 26.5 to 26.95 MHz, then back to the first from 27.00 to 27.45 and so on. Both overtone frequencies are midway between receiver channels and are attenuated by the receiver IF crystal filter should they leak into the receiver RF input circuits.

The second synthesiser IF is a bandpass amplifier from 13.075 to 13.525 MHz. The local oscillator for the third synthesiser mixer is controlled by one of 10 crystals spaced by 50kHz from 14.525 to 14.575 MHz. These are ganged to, and selected by, the 50 kHz channel selector switch. In combination with the switched overtone oscillator for the second synthesiser mixer they provide the 20 off 50 kHz channels per MHz, i.e. the first 10 channels on one overtone oscillator then a further 10 on the second overtone oscillator.

The IF output of the third mixer is 1.45 MHz. This feeds two discriminators, a wideband discriminator to capture the signal initially and a narrow band crystal discriminator for the final frequency lock. The discriminator outputs feed a varactor diode in the receiver local oscillator to complete the synthesiser loop.

Table 2 shows typical synthesiser internal frequencies for the SEM-35 tuned to 26.5MHz.

Table 2: synthesiser frequencies

Circuit point	***MHz***	
SEM-35 tuned to	26.500	A
Receiver first IF	11.500	B
Receiver first local oscillator.	38.000	C = A + B
9th Harmonic of 1MHz oscill.	9.000	D
Synthesiser first IF	47.000	E = C + D
Overtone oscillator No.2	33.925	F
Synthesiser second IF signal	13.075	G = E - F
First crystal in decade	14.525	H
Synthesiser third IF signal	1.450	I = H - G

As with the receiver RF amplifiers, there are two transmitter RF sections. One High band and one Low band. A sample of the transmitter output feeds the appropriate receiver RF amplifier, passes through the receiver first mixer to an 11.5 MHz discriminator at the input to the crystal filter. The discriminator output feeds a varactor diode in the TX oscillator to lock the transmitter frequency to the receiver local oscillator. The two transmitter RF sections share a common microphone processing circuit consisting of a pre amplifier, an AF clipper/limiter and an LPF.

Groans and Whinges

The SEM-35 suffers from having shared a common development programme with the SEM-25 vehicle radio. For vehicle duty there is ample power available from the vehicle battery and the designer can be lax about designing for energy efficiency. This mindset carried over into the SEM-35.

The PRC-10 series valve sets that preceded the SEM-35 required a total battery power of 8.4watts in transmit to generate a nominal 1watt RF output. The SEM-35 requires 10watts of battery power to generate a similar RF output. On the receiver front the position is better but still not good. On receive the PRC-10 drew 2.6watts while the SEM-35 draws 2watts.

Because of the lack of valve filaments and HT supplies most transistor versions of valve sets should require about 20% of the valve set power. It goes against logic that a transistor transmitter should require a larger power supply than its valve equivalent for the same power output.

Where does the power go? The power supply inverter is not nearly as efficient as it could be. The French BA-511-A is a good example of what could be achieved by the late 1960s and the SEM-

35 inverter falls far short of this in efficiency, size and weight. The SEM-35 has too many supply rails with too many dropper resistors. Unusually for a manpack it uses 6 relays. All these features are perfectly acceptable for vehicle sets but for portable sets they represent substantial life costs for battery procurement and re-supply and/or additional portage weight. It was within the technology of the day to double or triple the battery life and similarly reduce battery re-supply costs. This could have given significant payback over the operational life of the set.

On the receiver of the SEM-35 example examined the local VHF broadcast stations 'broke through' at frequencies around 30MHz. For example the local music station on 89.9MHz was picked up when the SEM-35 was tuned to 27.7MHz. At that frequency the SEM local oscillator was 39.2MHz and its second harmonic 78.4MHz. The 78.4MHz beat with the 89.9MHz station to produce the 11.5MHz first IF frequency of the SEM-35.

When the SEM-35 was developed there would not have been the current profusion of VHF FM entertainment stations and the breakthrough would not have been as obvious.

The strength of the break through varied with hand proximity to the SEM control knobs. Further investigation showed that the control knobs, shafts and bushes were not making contact with the set front panel. There were star washers under their shaft bush nuts that should have scraped through paint and earthed the controls but the quality of painting (thought to be powder spray epoxy) had been too hard and durable to allow the star washers to cut through.

The paint was scraped away in the spot faces for the washers, the nuts and washers were replaced and hand sensitivity was reduced. The breakthrough continued but it was not coming from the aerial base or BNC connector but from the battery box and leads. The battery leads are decoupled to the inverter chassis in the battery box. There was, however, poor electrical contact between the battery box and the set case. Consequently, an earth to the battery box is not a good signal earth for the receiver. A general clean-up of the contact faces between the battery box and the set plus a check with a low resistance ohmmeter did not remove the problem. The designers had effectively RF decoupled the front panel audio and control connectors but had left the back door open by not decoupling the leads from the battery box to the set RF earth.

Leads from the battery box to the set ON/OFF switch loop up into the set passing close to the unscreened first receiver diode ring mixer. Decoupling these leads as they enter the base of the SEM-35 with small 10nF ceramic capacitors cured the RF break through and appeared to marginally improve overall performance. It was as if the battery box had been acting as a wideband aerial passing general noise directly to the mixer, bypassing the selectivity of the set RF amplifier.

With its web rucksack, antennae and the Ni.Cd battery the SEM-35 has a portage weight of approximately 12.8kg. This is heavier than the PRC-10 and the PRC-25.

Other than its tuning controls, the PRC-25 has two panel controls. ON/OFF and VOLUME. The SEM-35 has four. This is no great hassle but it indicates that the benefits from rigorous simplification of controls have not been realised on the SEM-35.

The SEM 35 is built with precision and with components of quality. Wiring, PCB design and construction are good but it is as if the designers lacked experience in the specific field of military manpack radios. Consequently, the SEM-35 was not the step forward from the PRC-25 that it could have been.

Equipment and Data

SEM-35 manuals in German are available from http://www.algra-funkarchiv.de and http://www.milradio.com/

At the time of writing the SEM-35 rucksack and 2.5m antenna are advertised by http://www.helmut-singer.de

References

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