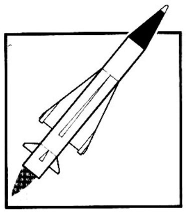


The Triffid tactical radio-relay equipment

A modern multichannel tactical radio-relay system, Triffid, has recently entered service with the British Army

by R.I. Dow

The operation and control of a modern army rely increasingly on the ability to communicate rapidly and reliably. In the front line this requirement is met by HF and VHF manpacks or vehicle radios. However, to provide effective co-ordination and feedback between headquarters and field units, a tactical trunk communication system is required, and this requirement is most readily met by a UHF radio-relay system.

A tactical radio-relay system must not only provide high-reliability multichannel communication over a long distance, but must also be easy to deploy and operate. In addition, the modern tactical scenario requires equipment which can carry secure speech or data, and can operate successfully in a hostile electronic environment.

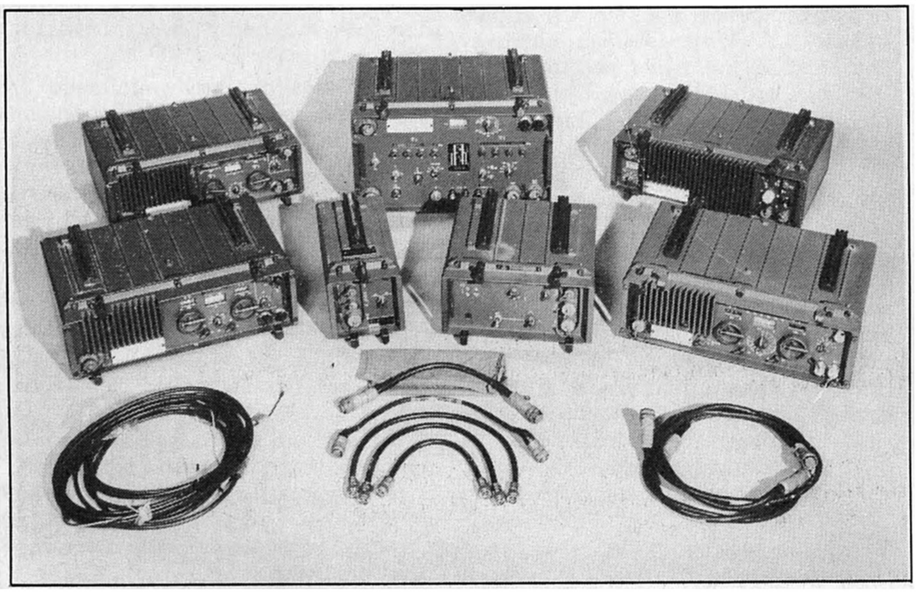
These requirements form the major factors influencing the design of the equipment, together with those of mechanical ruggedness and ease of maintenance common to all military equipment.

Equipment requirements

The design of Triffid was commenced in response to a requirement for a new generation of tactical radio-relay equipment for the British Army. The specification required that the equipment should act as a replacement for the several existing radios used in the Bruin trunk-communication network at traffic rates of 250 kbit/s and 500 kbit/s. However, the Bruin network is due for replacement by the fully automatic Ptarmigan system in the early 1980s, and Triffid had to be designed to be compatible with this system, with minimal change, and provide the main trunk radio bearer in Ptarmigan. The MoD specification has been met by a combination of extensive redesign of an existing radio together with the design of new units, in a collaboration agreement between Marconi Communication Systems Ltd., Siemens AG and AEG Telefunken.

The resulting design is of modular construction comprising a total of seven modules together with a set of interconnecting cables. Operation is possible in a choice of three frequency bands between 225 MHz and 1850 MHz by the use of one of the RF heads. The remaining four modules are common to operation in all three frequency bands, and provide power supply, signal processing, modulation and demodulation, frequency conversion and engineering-order-wire (EOW) facilities. The modular construction of the equipment has several advantages: only one module of the equipment and the antenna require changing to operate in a different frequency band; the operator need only replace a failed unit not the complete radio; and the individual modules are small enough to be handled by one person. However, if first line repair is to be carried out by replacement of only the failed modules, it is essential that they are fully interchangeable, and that the operator is presented with enough diagnostic information to enable him to identify a faulty module accurately.

To meet the requirement of high availability of speech and data circuits, and the possibility of encryption, digital communication is now almost exclusively used for military multichannel links. There has been a gradual progression towards a standardisation on bit rates of



1 The seven Triffid modules. Back (L to R): Band II RF head, system module, power supply. Front (L to R): Band I RF head, line terminating module, engineers-order-wire module, Band III RF head. Foreground: antenna feeder cables and interconnecting cables

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16 kbit/s per channel with a group of 256 kbit/s carried by the radio bearer. However, this standard is not yet fully in operation and so the Triffid equipment has been designed to handle data rates of 250, 256, 500 and 512 kbit/s, thus meeting both Bruin and Ptarmigan requirements by simply setting a front-panel switch.

Apart from electrical performance, one of the main requirements of a tactical radio must be ease of operation. It is essential that an operator with a minimum of training can consistently engineer successful radio links even in high-stress situations. To ensure this is possible the operation of the equipment must be simple and require the minimum number of adjustments. The Triffid equipment meets this requirement by the provision of direct frequency readout on the transmit and receive synthesisers, which can be set in 125 kHz steps. The only other adjustments required by the operator are the tuning of the transmit and receive filters in the appropriate RF head, and again direct frequency readout is provided. The operator is also provided with a digital engineering-order-wire (EOW) facility which allows voice communication with the other operators.

Check routine

Once the antenna is aligned and a link established on EOW, the operator requires a means of checking the traffic carrying ability of the link before loading with traffic. This can be carried out by the injection of a pseudorandom signal into the traffic path of the transmitter. The remote radio has the facility for looping this simulated traffic at baseband to retransmit back to the originating station. The receivers at both ends of the link can synchronise the simulated traffic and count the error rate which is then displayed in powers of ten on the equipment. This facility can also be used to check the traffic path from the radio equipment to the multiplexer, so assuring the operator of the traffic carrying capability of the path and radio link.

To enable rapid identification of fault conditions by the operator, a series of indicator lights is provided on the various modules. On the system module the lights are arranged in the form of a mimic diagram showing the flow of traffic through the transmit and receive paths. Each of the five major modules is also provided with a meter and associated multiposition switch enabling the operator to check various voltages and power levels to be within the specified limits. With the aid of this built-in test equipment (BITE) it is possible to diagnose a failed module in two minutes and restore the radio to operational state within ten minutes.

In a tactical scenario the principal requirement is for the radio to be returned to an operational state in the minimum time. This is accomplished by replacing the failed module with a spare carried in the radio installation. However, the rapid repair of the failed module is now a priority as any further failure could result in loss of the radio link. This necessitates repair at field level and therefore requires minimum test equipment and repair time and no complex mechanical operations or soldering. Owing to the complexity of the equipment the approach adopted is to use replaceable plug-in submodules. By means of the comprehensive BITE facilities available on the equipment, and the minimum of additional test equipment, it is possible to diagnose an individual submodule, and by substitution return the module to operational state in a mean time of 35 min.

Power supply

In field use the equipment is powered from 24 V lead-acid batteries, with a petrol generator and power-conditioning unit float charging the batteries. The Triffid power-supply module provides the various regulated DC voltages required by the other Triffid modules from this raw supply, and uses a switching inverter to cope with the large voltage range from fully charged to discharged batteries. Full overload protection of the regulated DC voltages is incorporated in the module.

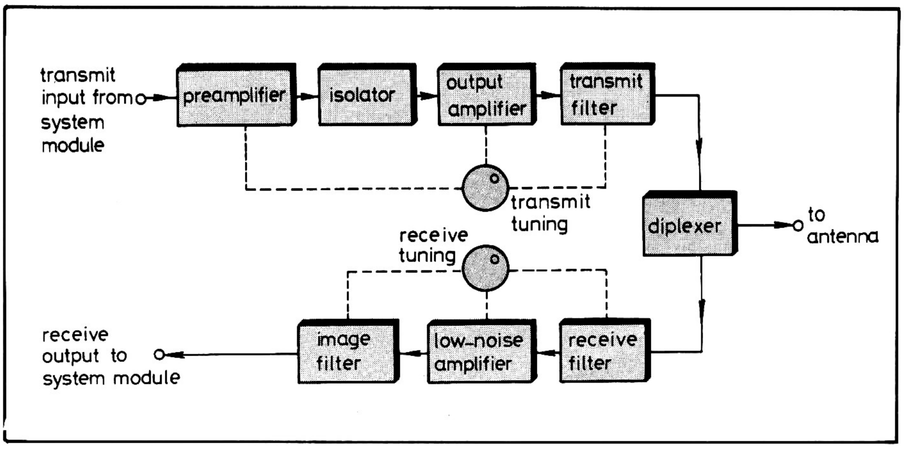
For base use a 240 V AC mains supply may be used, or both mains and battery can be connected to give no-break operation in the event of a single-supply failure.

System module

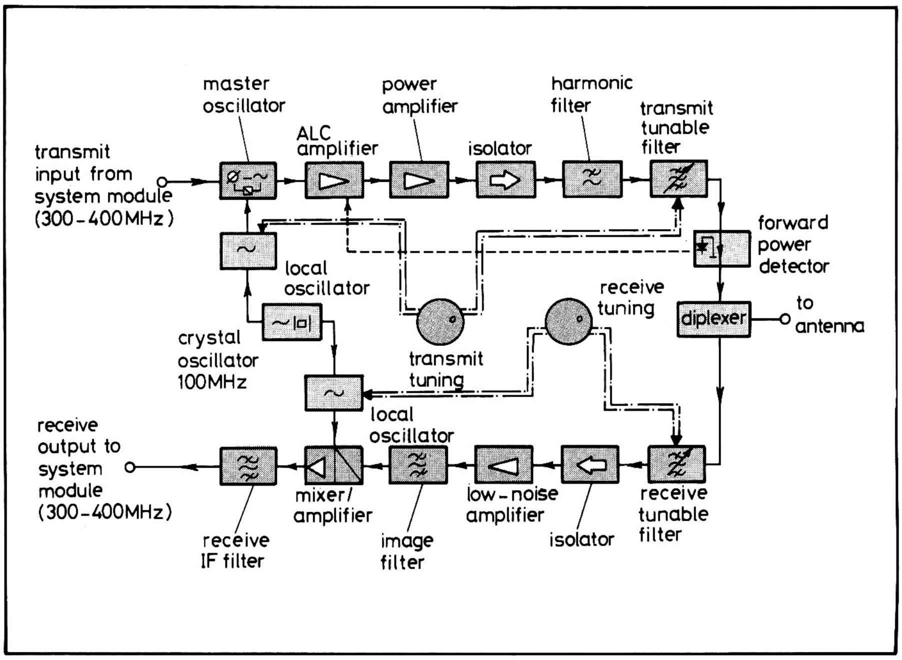
The system module contains the frequency-conversion circuits for both transmit and receive paths, together with modulation, demodulation and EOW circuits. The 16 kbit/s EOW signal is added algebraically to the traffic before filtering, modulation and up-conversion to the radiated frequency. The required frequency is controlled by a synthesiser which can be set in increments of 125 kHz by four front-panel switches with direct frequency readout.

The received signal is downconverted using an identical synthesiser arrangement before domodulation in a phase-locked loop demodulator. The traffic and EOW signals are now separated from the composite baseband signal by extraction of the EOW signal using a sampling technique.

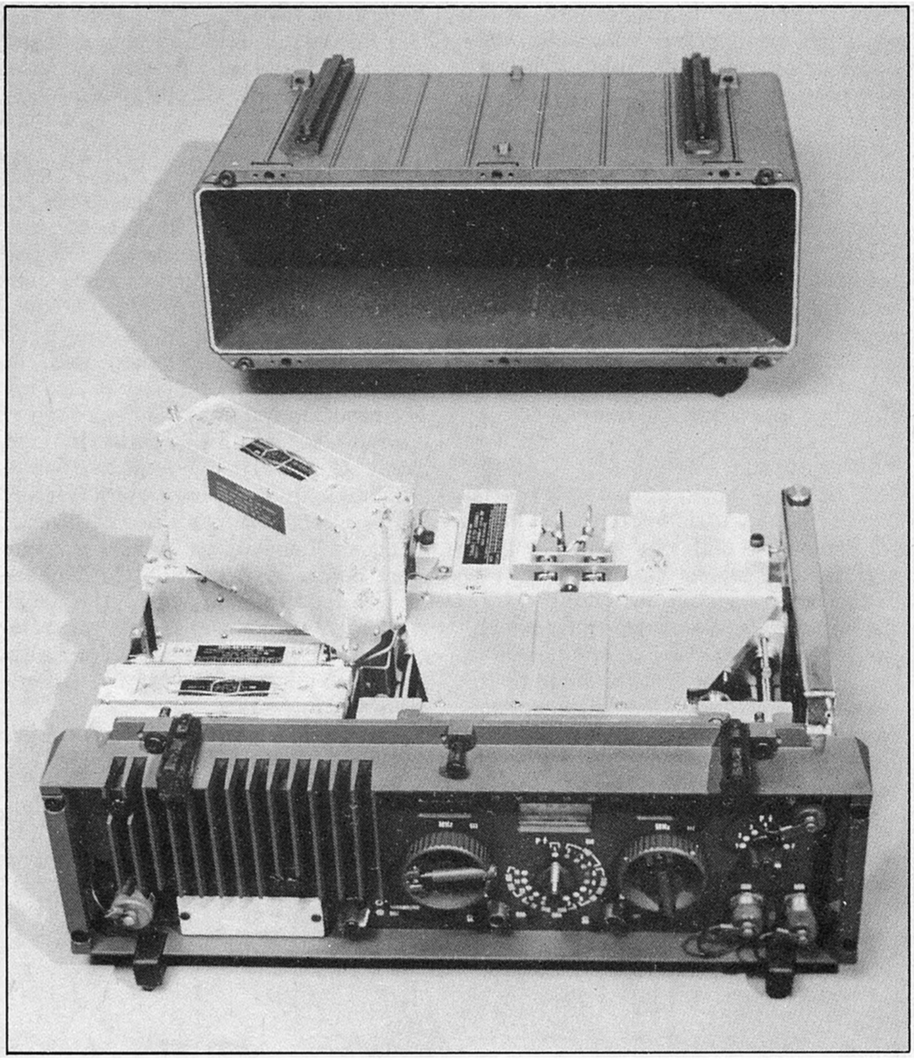
The arrangement adopted for EOW modulation is in accordance with Eurocom proposals and is designed so that no degradation of traffic occurs due



2 Band I and Band II heads block diagram



3 Band III head block diagram



4 Band III RF head showing easily replaced plug-in submodules and extensive RF screening

to the presence of an EOW signal. In addition, when first establishing the radio link and aligning antennas, a small improvement of EOW system figure is obtained in the absence of traffic.

In addition to the mimic diagram and BITE meter mentioned earlier, the system module also houses the pseudorandom sequence generator and receiver for error rate and system-performance testing.

Line terminating module

The line terminating module provides an interface facility to enable the radio-relay equipment to be sited up to 1 km from the multiplexer equipment. In a tactical scenario the multiplexer equipment is likely to be placed in a relatively safe position at a communication centre, with the radio relay sited near the top of a hill to give a good line-of-sight radio path.

The traffic connection to the multiplexer is by means of a quad cable carried on the radio-relay vehicle. EOW communication is provided between the multiplexer site and radio-relay operator using a field telephone connected to the 'phantom' of the quad cable.

EOW

The EOW facility is provided to enable operators at the radio-relay stations to communicate with each other without interrupting traffic carried on the system. A 16 kbit/s delta-modulated signal is used with full duplex circuits and omnibus listening. Selective calling of any of the stations is possible by a tone-burst sequence being generated by the caller and being decoded to trigger an audible and visual alarm at the called subscriber's station.

RF heads

The operating frequency range of the equipment is divided into three bands: 225-400 MHz, 610-960 MHz and 1350-1850 MHz. Each of these frequency bands is covered by an RF head which provides amplification, filtering and diplexing of the transmitted and received signals. All three RF heads have similar operating procedures with single-knob tuning of the transmit and receive frequencies and direct frequency readout. Apart from the usual alarm facilities there is a monitor of antenna-feeder continuity by measurement of a DC terminating resistor mounted in the antenna. This facility immediately alerts the operator to any damage to the antenna or feeder outside the vehicle.

In the lower two frequency ranges a similar configuration is adopted in each RF head to that shown in Fig.2 with transmit amplifiers, diplexer, and low-noise receive amplifiers. The diplexing and filtering allow operation on a single antenna with only 28 MHz transmit/receive spacing.

In the third frequency range the RF head incorporates automatic frequency conversion as well as amplification and filtering. This is necessary as the upper frequency limit of the system module synthesisers is 960 MHz. The output of the system module is therefore used as an IF frequency in the range 300 to 399·875 MHz. In the Band III RF head this signal is mixed with the output of a local oscillator operating in 100 MHz steps between 1000 MHz and 1500 MHz. Selection of the appropriate step results in the required radiated frequency, and is controlled by the setting of the single tuning knob.

The mixing of the 300-400 MHz signal with the local oscillator is carried out by modulation transfer in the feedback loop of a phase-locked oscillator running at the required output frequency. A sample of the output frequency is mixed with the selected local-oscillator frequency and then fed to a phase comparator. The transmit signal from the system module is also fed to the phase comparator which provides an output providing both oscillator frequency-error-correction information and the modulation information. This signal controls the UHF oscillator by means of a varactor diode.

The approach described above was adopted in preference to the simpler direct-mixing approach as it enables the spurious outputs to be closely controlled. This is extremely important in an equipment of this type to ensure good electromagnetic compatibility performance. It also reduces the requirements on the tunable filters and therefore reduces mechanical complexity with the resultant improvement in MTBF and ease of maintenance.

The local-oscillator signal has to be stable and have low phase noise as this would be transferred directly to the radiated output in the configuration adopted. The local oscillator is therefore a fundamental oscillator phase locked to a harmonic of a 100 MHz crystal oscillator. The appropriate harmonic number is selected by DC signals from the contacts attached to the tunable filter assembly.

The transmit signal from the master oscillator is amplified in two broadband transistor amplifiers before filtering in the tunable filter. The first of these two amplifiers incorporates automatic level control.

Computer analysis and optimisation techniques and use of microstrip have enabled the amplifiers and other circuits in the Band III head to be designed with sufficient bandwidth to cover the frequency range without tuning. This has resulted in a considerable simplification in the mechanical tuning mechanisms and hence greatly improved the reliability and ease of maintenance of the module.

Similar design techniques to those used in the ALC amplifier are also employed in the single-stage power amplifier and in the two-transistor receive low-noise amplifier. However, the low-noise amplifier submodule also houses the balanced mixer which converts the received signal to the 300-400 MHz band. The mixer uses a diode quad with signal and local oscillator connected by miniature toroidal transformers and baluns.

Operational requirements

Although radio-relay equipment is normally housed inside a vehicle or shelter it has still to meet a harsh military environment. Apart from temperature extremes and humidity it has also to withstand severe shock and vibration, particularly if mounted in a tracked vehicle. Considerable attention was paid during the design phase to ensure the equipment would meet these conditions, while still being easy to maintain.

In a military communication environment, equipment has frequently to operate in a communication centre in close proximity to other radio or radar equipment. It is essential that interference to other equipment is minimised and that the radio-relay equipment will operate in high field strengths both in and out of the operating frequency band. Front-end protection of the receiver is incorporated to prevent damage occurring due to high-level in-band signals; but to ensure operation is unimpaired by unwanted signals careful design must be paid to filter and amplifier designs. However, ensuring good EMC performance with equipment of this type also requires excellent screening of the circuits, particularly as both transmitter and receiver are housed in the same box.

To meet the required standards, considerable effort has been directed towards the screening of the individual submodules and interconnecting cables and providing radio-frequency interference (RFI) filtering of all DC connections.

In the modern military scenario, attention at the design stage must also be given to nuclear survivability. In equipment of this type blast and flash damage are relatively insignificant as protection is provided by the vehicle. However, electromagnetic pulse (EMP) and radiation effects are significant.

The measures adopted to meet EMC criteria also ensure a good hardness of the equipment to EMP. However, it must be remembered that the radio can be connected by long cables to the multiplexer and antenna system, and high currents can be induced into these by EMP. Extreme care must be taken to ensure excellent earthing of the screens of these cables where they enter the vehicle skin together with provision of protection devices.

The degree of hardening to radiation effects has to be considered at an early design stage and incorporated by the appropriate choice of devices and circuit configuration to limit photo currents. With careful design it is possible to achieve a degree of hardness which will result in continued operation of the equipment after exposure to a nuclear burst.

5 A typical Triffid installation: three stacks of equipment providing relay operation plus standby

Field experience

The Triffid equipment has been subjected to extensive field trials by the Army School of Signals at Blandford. It is also now well into production with over 200 sets deployed with Signal Regiments in BAOR, and more than 470 sets of modules delivered to the customer.

Experience gained during the field trials and initial deployment has been very encouraging. The simple frequency changing and alignment arrangements have been enthusiastically received by the operators. In some instances it has permitted operators to set up and work radio paths where previously skilled technical assistance would have been necessary.

The builtin test equipment has permitted field diagnosis of faulty modules and has also given the operators increased confidence in the correct operation of the equipment. Path-loss capability was readily assessed using the pseudo-random generator and error detector and was found during trials to fully meet its expected performance.

During the trials, the effectivenes of the EMC design techniques was assessed both by direct measurement and operation in close proximity to other radio equipment. These tests confirmed that the equipment is capable of operating successfully in the harsh electromagnetic environment of a tactical scenario.

The Triffid radio-relay equipment has been designed to meet the stringent demands of the modern Army. During its design considerable attention was devoted to ease of operation, interchangeability and EMC. The use of microstrip design techniques and computer-aided design has enabled the frequency range of the equipment to be extended to 1850 MHz whilst retaining ease of operation and maintenance. The design philosophy has been confirmed by excellent reports during field use by Army personnel.

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