

TACTROP – Encrypted 15/30/60 Channel Transportable Trans-horizon Telecommunication System

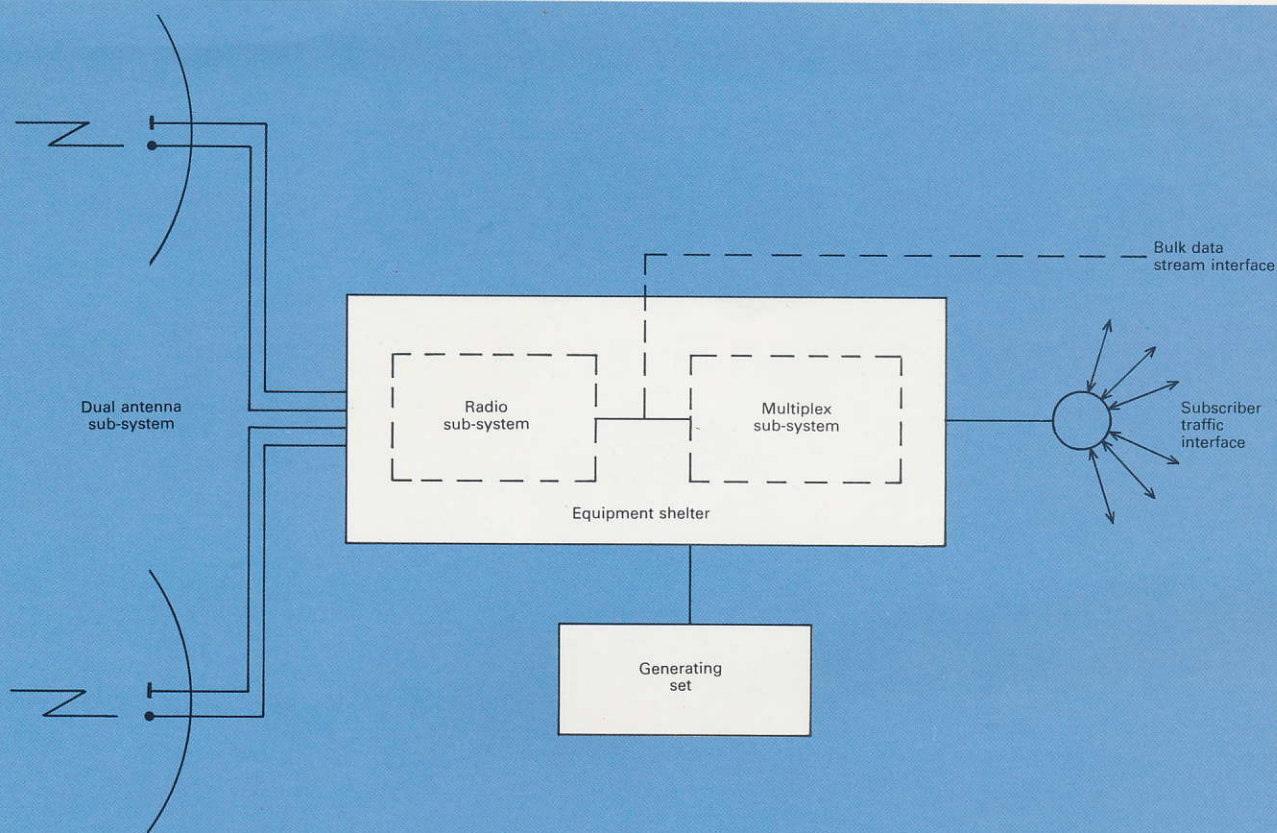


Features

- 4.4–5.0GHz frequency band
- Long range secure communication
- Output adjustable between 5–1000W
- Wide range of interfaces
- Digital transmission
- Wide range of options

Advantages

- Complete flexibility
- 6000 frequency channels
- Very fast link set-up time
- ECM resistant, EMI protected
- Bulk encryption
- High quality circuits



Major TACTROP terminal elements

Introduction

Marconi TACTROP is a containerised microwave radio telecommunication system. Supporting up to 60 encrypted two-way telephone channels, it is a point-to-point transmission system for single hop paths extending to transhorizon distances.

From audio input to audio output, it is a complete transmission system, with the additional advantage of possessing an exceptionally high degree of operational flexibility.

Permanent, semi-permanent, or temporary links may be established at the user's sole discretion. The system may be redeployed very quickly for urgent or emergency requirements because it is transportable and does not require buildings or antenna foundations to bring it into service. On site, the environmentally-controlled equipment shelters provide weatherproof and permanent accommodation for the rugged digital radio, multiplex, encryption and other equipments.

TACTROP simplifies new route deployment in the presence of other electronic installations or networks. Potential problems of Electromagnetic Interference (EMI) are minimised because the shelters are screened and lines are filtered. Moreover the radio equipments are 'Frequency Agile' which simplifies frequency planning and permits very fast integration with existing frequency allocations in the area.

For overland transhorizon link applications, the elimination of intermediate relay repeaters between the TACTROP terminals

simplifies system security. With less sites to guard and maintain than a traditional line-of-sight radio-relay solution, manpower and support requirements may be significantly reduced. Radio Silence is also easier to implement.

TACTROP will provide similar grades of service to high-quality satellite or line-of-sight systems for most of the time. Moreover, the built-in encryption provides transmission security resistant to all known forms of computer attack.

Although primarily intended for military use, TACTROP will also satisfy many civil requirements where flexibility and a fast re-route capability for long distance trunk links are of vital importance.

System Characteristics

General

A terminal comprises:

- a transportable Equipment Shelter;
- a prime power Generating Set;
- an Antenna sub-system.

The Equipment Shelter can be fitted for either 15, 30 or 60 channels capacity, and accommodates a Marconi manufactured:

- microwave Radio Bearer sub-system including 1kW transmitters and a sensitive quadruple diversity (D4) receiving system;
- time division multiplex (t.d.m) sub-system with associated line termination items and a bit-by-bit bulk encryption device (MARCRYPMUX).

The Radio and Multiplex sub-systems are discrete

arrangements and can be accommodated in separate shelters if required.

A typical Generating Set has two diesel-alternators. These are site rated at nominally 14-25kW each depending on the environment and the power consumption of the Equipment Shelter's air-handling plant.

The standard TACTROP Antenna sub-system has either one or two Marconi R2100 4.5 metre diameter transportable antennas.

Digital Transmission

TACTROP is designed as a digital transmission system to provide traffic security through advanced bulk encryption technology.

Moreover it provides a dependable service under the atmospheric constraints associated with long range transhorizon propagation. These attributes are achieved by the integration of encryption compatible delta modulated multiplex with a fade resistant, spectrally efficient, radio modem.

Delta Modulation Multiplexers

The Multiplex sub-system is based on Marconi time division multiplexers conforming to EUROCOM standards for 15 channels. Using a Syllabically Companded and Logically Encoded (SCALE) form of delta modulation, superb speech quality is provided.

The advantages of delta modulated t.d.m over pulse code modulation (p.c.m) for long radio systems are that the former will - support a greater number of high-quality channels in a given bandwidth;

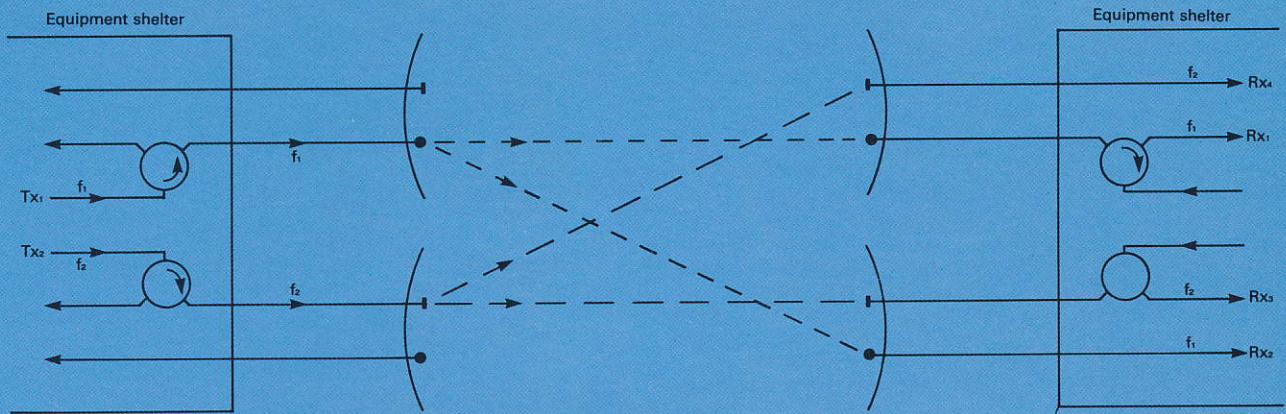
- maintain superior multiplex and crypto synchronisation, voice intelligibility, and data/telegraph performance under bad atmospheric conditions. TACTROP will maintain voice intelligibility at average link bit error rates worse than 3%. Moreover telegraph and data error rates are reduced to 0.01% for an average link error of 1%.

Traffic Data Stream

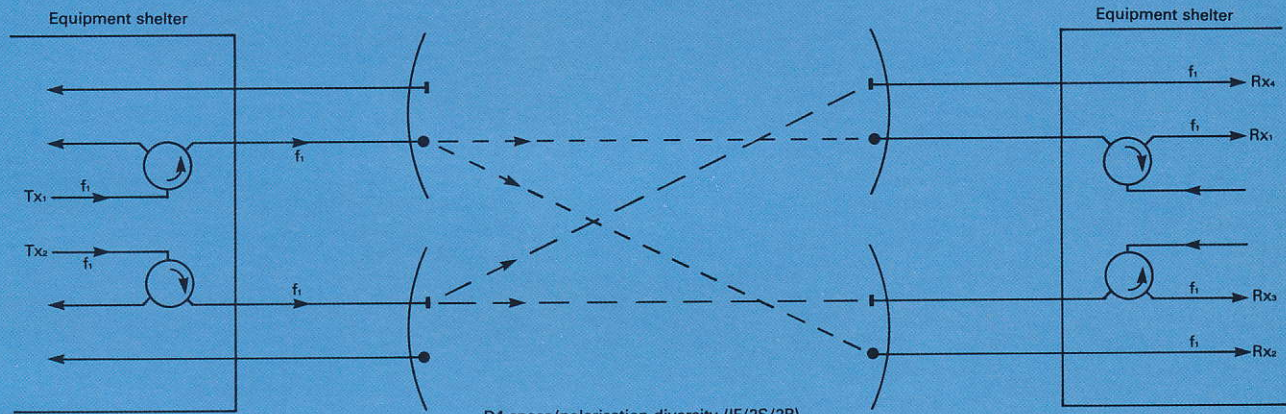
A primary delta multiplexer supports 15 channels. The output data stream rate is either 256 or 512kbit/s depending on the user selected channel sampling rate for the system (16 or 32kbit/s per channel). The MARCRYPMUX encryption equipment super-multiplexes up to four primary multiplexers to provide the composite encrypted traffic data stream interface with the radio equipment.

Channel Capacity	Channel Rate (kbit/s)	Traffic Rate (kbit/s)
15	16	256
	32	512
30	16	512
	32	1024
60	16	1024
	32	2048

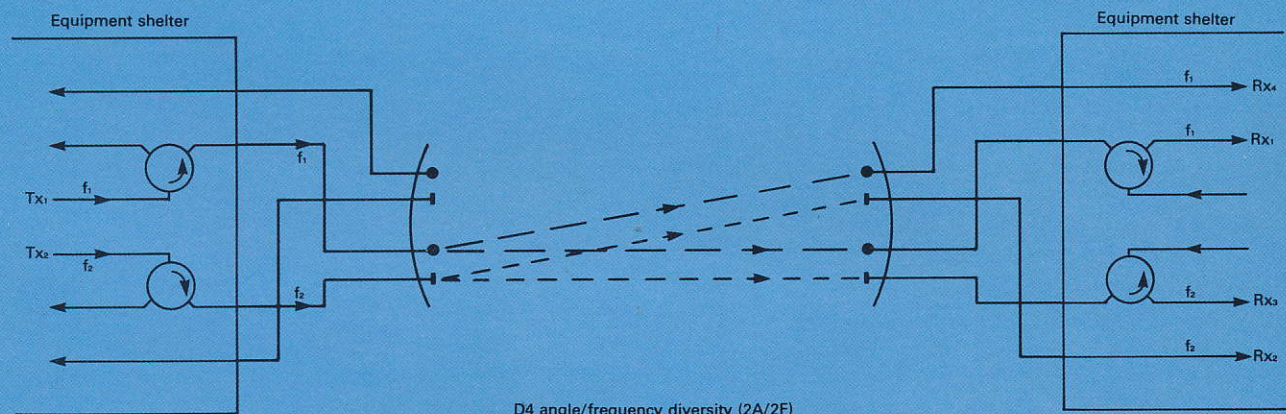
A 32kbit/s channel sampling rate is recommended for the majority of general purpose applications, and all multi-hop routes. For the more difficult path profiles or conditions, particularly with 60 channels capacity, a 16kbit/s channel sampling rate is advantageous. 120 channels at 16kbit/s per channel is feasible.



D4 frequency diversity (2F/2S)



D4 space/polarisation diversity (1F/2S/2P)



D4 angle/frequency diversity (2A/2F)

Single antenna configuration

Tx = Transmitter
 Rx = Receiver
 f = frequency
 — = Vertical polarisation
 ● = Horizontal polarization

Diversity configuration flexibility

QPSK Radio Modulation

The Marconi H7450 radio equipment incorporates an advanced fade resistant Quadrature Phase Shift Keying (QPSK) modem.

QPSK will support double the number of identical channels in the same bandwidth as a binary modulated system (2DPSK or 2FSK). The advantage obtained is that either longer ranges, better system implementation margins or increased channel capacities will be achieved for equivalent performance.

Dual or Single Antenna Sub-System Alternatives

TACTROP is arranged for quadruple diversity (D4) reception. The four independent diversity paths may be obtained with either a Dual or a Single Antenna sub-system per terminal. The Equipment Shelter radio content remains identical for both configurations.

Dual Antenna Configuration

Two antennas per terminal are required to achieve transmission reliability at the longer path distances and higher traffic data rates. Each of the R2100 dual-polarised antenna feedhorns are

connected by two feeders to the Equipment Shelter. The antenna spacing is arranged to be 100 wavelengths nominal between centres.

The user can select either a 2F/2S (2 frequency/2 space) or a 1F/2S/2P (1 frequency/2 space/2 polarisation) quadruple diversity configuration by his choice of frequency plan. The 1F/2S/2P configuration has the advantage of requiring only two frequencies to be allocated for the entire two-way system.

Single Antenna Configuration

The R2100 antenna is modified with a special dual-angle feedhorn

for this option. Four feeders connect the feedhorn cluster to the Equipment Shelter. The diversity configuration is 2A/2F (2 Angle/2 Frequency).

Maximum range is typically some 60–80% of that obtained with a Dual antenna sub-system (depending on the path terrain), due to the different diversity efficiency. The maximum recommended traffic data rate is 1024kbit/s.

The Single Antenna sub-system has the advantage of a reduced terminal site area for short-to-medium range, low capacity, applications. The concept also lends itself to highly transportable TACTROP system derivations.

Operational Range Considerations

The transhorizon range in a given geographical area depends largely on the path profile between the two terminals and the traffic data rate.

For non-specific prediction purposes it is assumed that the sites and path rest on a theoretical smooth earth profile. The performance criterion is to achieve:

an average bit error rate (b.e.r) not worse than 1 in 10^{-3} for 99.9% of all hours of a typical year.

The range/margin curves shown represent a general prediction model covering average conditions for a large part of the world. The threshold b.e.r assumes delta modulated multiplex is used. Many regions will give greater ranges than shown for most of the time, particularly near coastal areas.

When the terminals are sited on high ground overlooking any prominent path obstructions, significantly longer path distances will be achieved for the same performance.

Long-term predictions for specific transhorizon paths have to be calculated on an individual basis, using the prediction methods appropriate for fixed link

engineering. In this case a system implementation margin may be included in the calculations to provide an increased prediction confidence level; for TACTROP ranges this can be in the order of 5-12dB on the average prediction model. A TACTROP prediction program for a microprocessor can be prepared to aid long-term prediction calculations.

Adjustable Transmit Power

The transmit output from TACTROP's 1kW power amplifiers (H3742) is continuously adjustable in the range 5-1000W. Power margins can be optimised to take into account:

- differences between long and short paths;
- abnormal propagation periods;
- unfavourable terminal siting;
- camouflage losses;
- multi-terminal EMI considerations;
- Electronic Counter Counter Measures (ECCM) and Anti Jam (AJ) procedures;
- system implementation corrections.

When TACTROP is used in an emergency line-of-sight role, the power amplifiers can be switched off and by-passed with suitable leads. In this instance, the transmit power will be 250mW.

Subscriber Interface Flexibility

Each of the 15 channel primary multiplexer channels is fitted with a subscriber line interface to suit the user's specific traffic requirements. The following interfaces are available.

Analogue Audio Boards

- (a) 2-wire/4-wire with either E&M or ring-down magneto signalling;
- (b) 2-wire only with either ring-down magneto or CB auto-extension signalling.

Telegraph Sub-Multiplexer Board

Multiplexes up to 15 telegraph channels to the selected primary multiplexer channel. Separate boards, each interface up to four CCITT V24 circuit with the sub-multiplexer. Telegraph speeds up to 100bit/s may be processed.

Asynchronous Data Boards

Interfaces two asynchronous data channels of up to 4800bit/s for access to the primary multiplexer channels.

Synchronous Data Digital Audio Boards

Provides digital access to two primary multiplexer channels at the channel bit rate (16 or 32kbit/s).

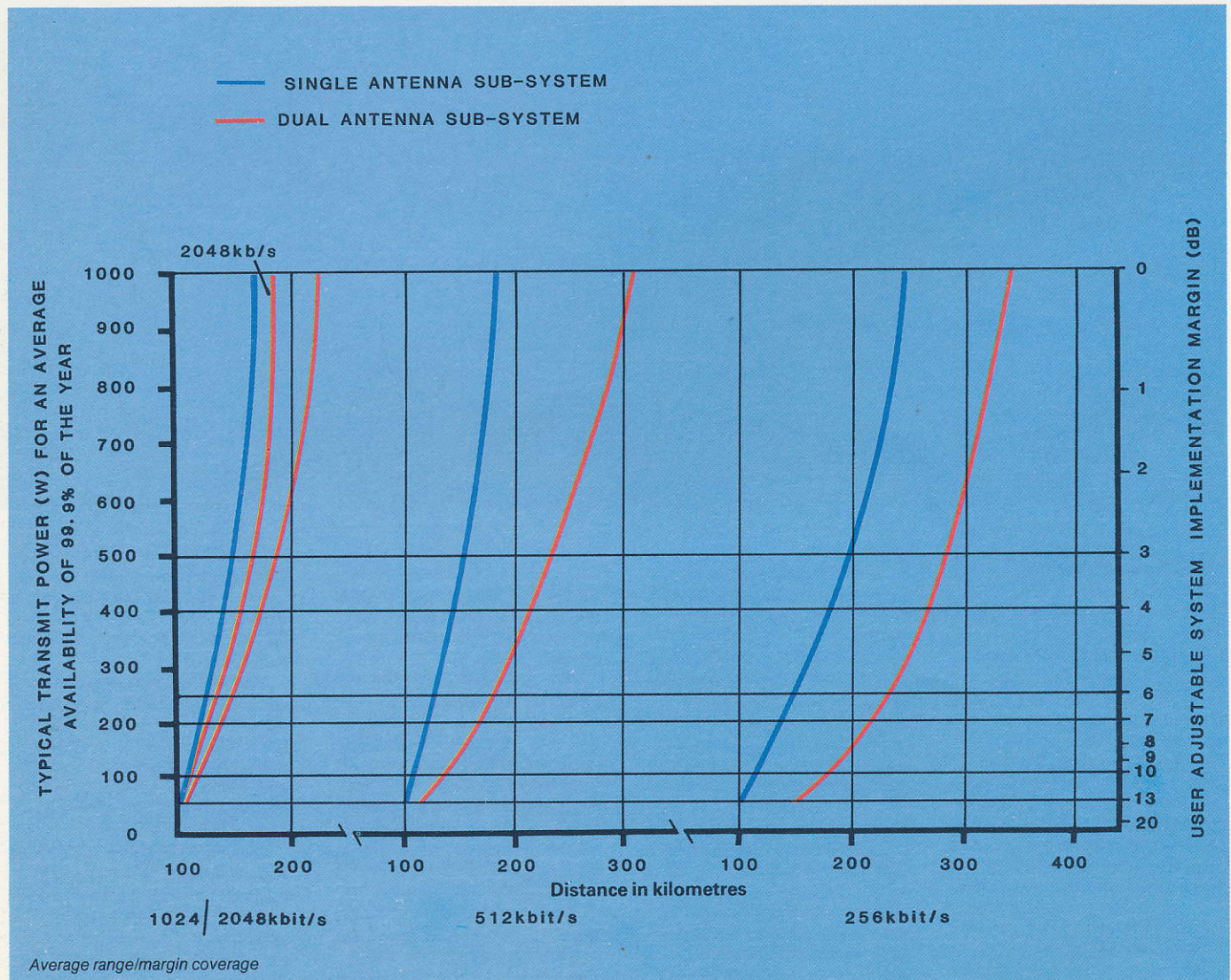
Telegraph Converter Unit

This independent unit provides a line interface between a teleprinter machine and the V24 input of the Telegraph Sub-Multiplexer Board.

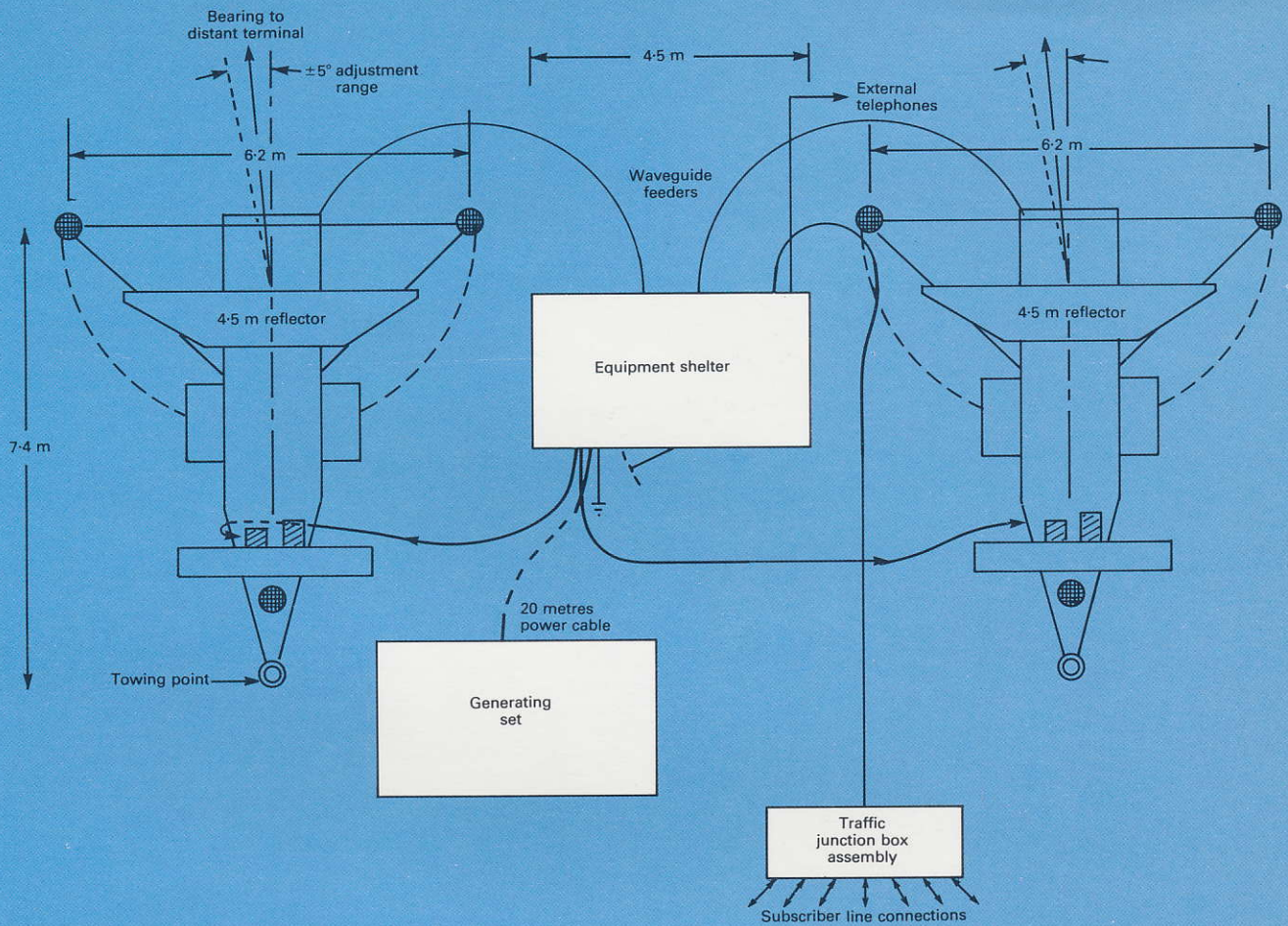
Automatic Signalling Capability

A Marconi Microprocessor-controlled eight channel Automatic Signalling Unit (ASU) is available for connection to the primary multiplex. This provides the link interface for the following subscriber types:

- (a) LB Telephone to LB Telephone
- (b) LB Telephone to LB Exchange
- (c) LB Exchange to LB Exchange
- (d) CB Telephone to CB Exchange
- (e) CB Exchange to CB Exchange
- (f) CB Hot Line (Sole User)
- (g) Auto Exchange to Auto Exchange
- (h) CB Telephone with Loop Disconnect Dialling to Auto Exchange



Average range/margin coverage



Typical site layout

Transportation

A TACTROP terminal can be transported to site on two suitable 6–8 tonne flatbed vehicles which are fitted with towing hooks. The Equipment Shelter and the Generating Set each require one vehicle and the antennas are towed.

The terminals can also be helicopter lifted to site.

The shelters are fitted with ISO corner fittings so that standard ISO container lifting equipment can be used. Moreover manually operated container lifting jacks are available which will enable equipments to be easily loaded/unloaded on site without the aid of any other lifting gear.

All sensitive items in the Equipment Shelter are fully shock-mounted to provide the necessary protection for arduous cross-country transportation.

Shelters fitted with Mobilizers, to aid loading/unloading from a C130 aircraft, can be provided.

Deployment

A communication link can be established by a team of three personnel in 20–30 minutes of arrival of the TACTROP on site. Two men are required to erect and adjust the antenna whilst the other

man checks the equipment and starts the Generating Set.

When fast deployment is required, the Equipment Shelter and Generating Set may be left on the vehicles.

The azimuth bearings of the far-end sites must be known to within $\pm 5^\circ$ approximately. The antennas are easily adjustable and an Antenna Operators Unit is provided to assist in the rapid alignment procedure.

As a general rule, the terminals should be located where the antenna beams overlook their respective horizons.

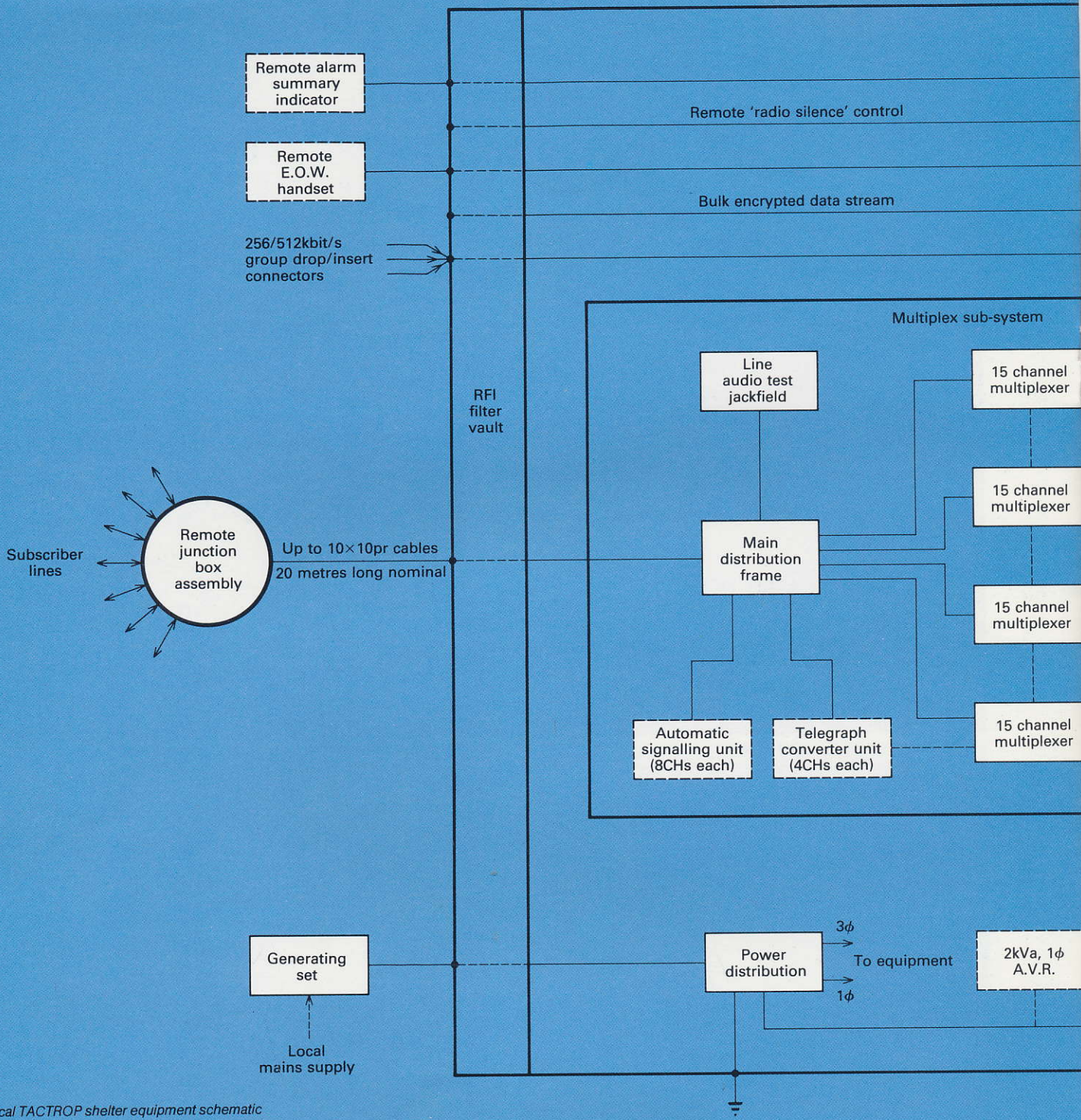
Frequency Agility

A complete frequency change can be accomplished in 2–5 minutes. The time depends on how far the new frequencies are off the existing frequencies. The four receivers and two transmitter drives can be tuned in a total of 1–1.5 minutes whilst the power amplifiers require approximately 1.5–2 minutes each.

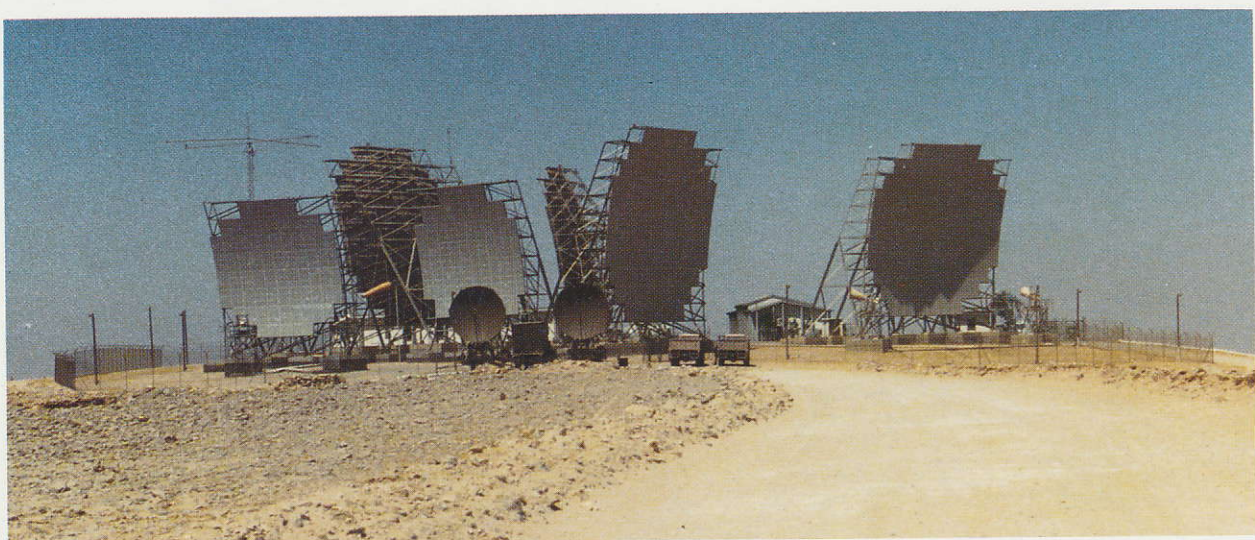
It is possible to completely change the link frequencies without a break in traffic.



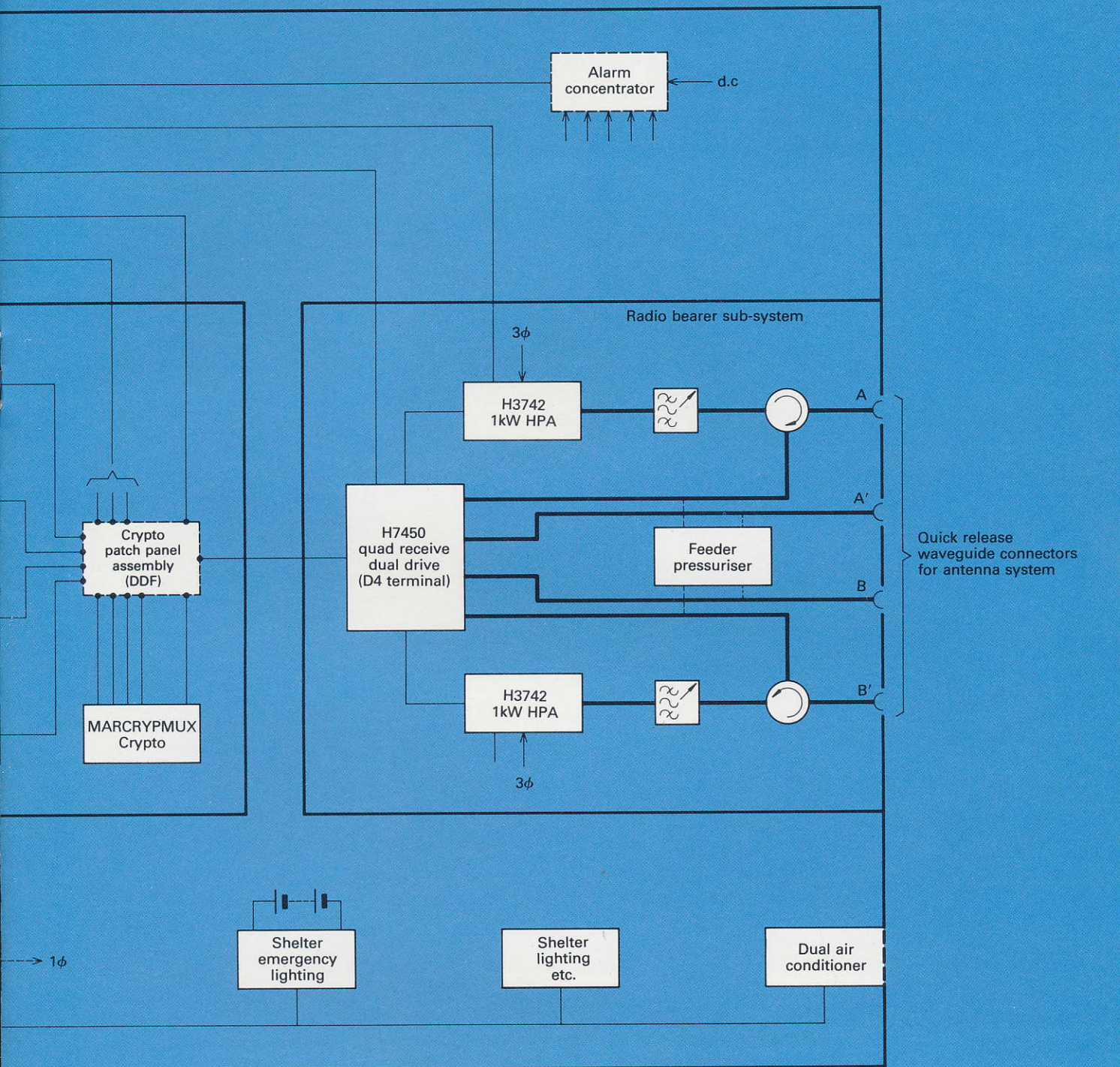
TACTROP antenna in the stowed position



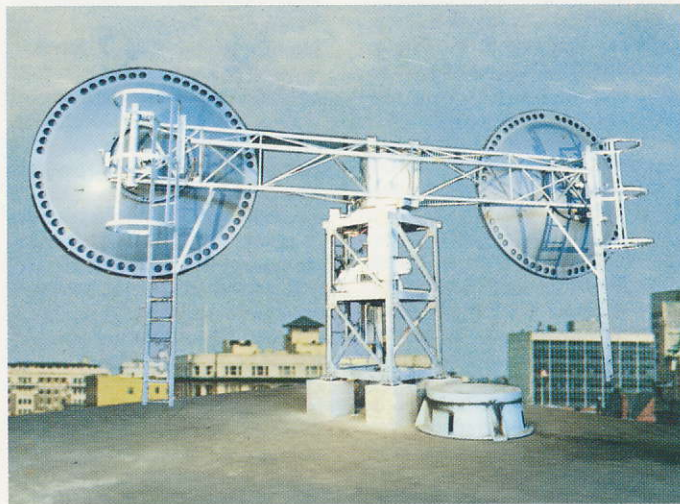
Typical TACTROP shelter equipment schematic



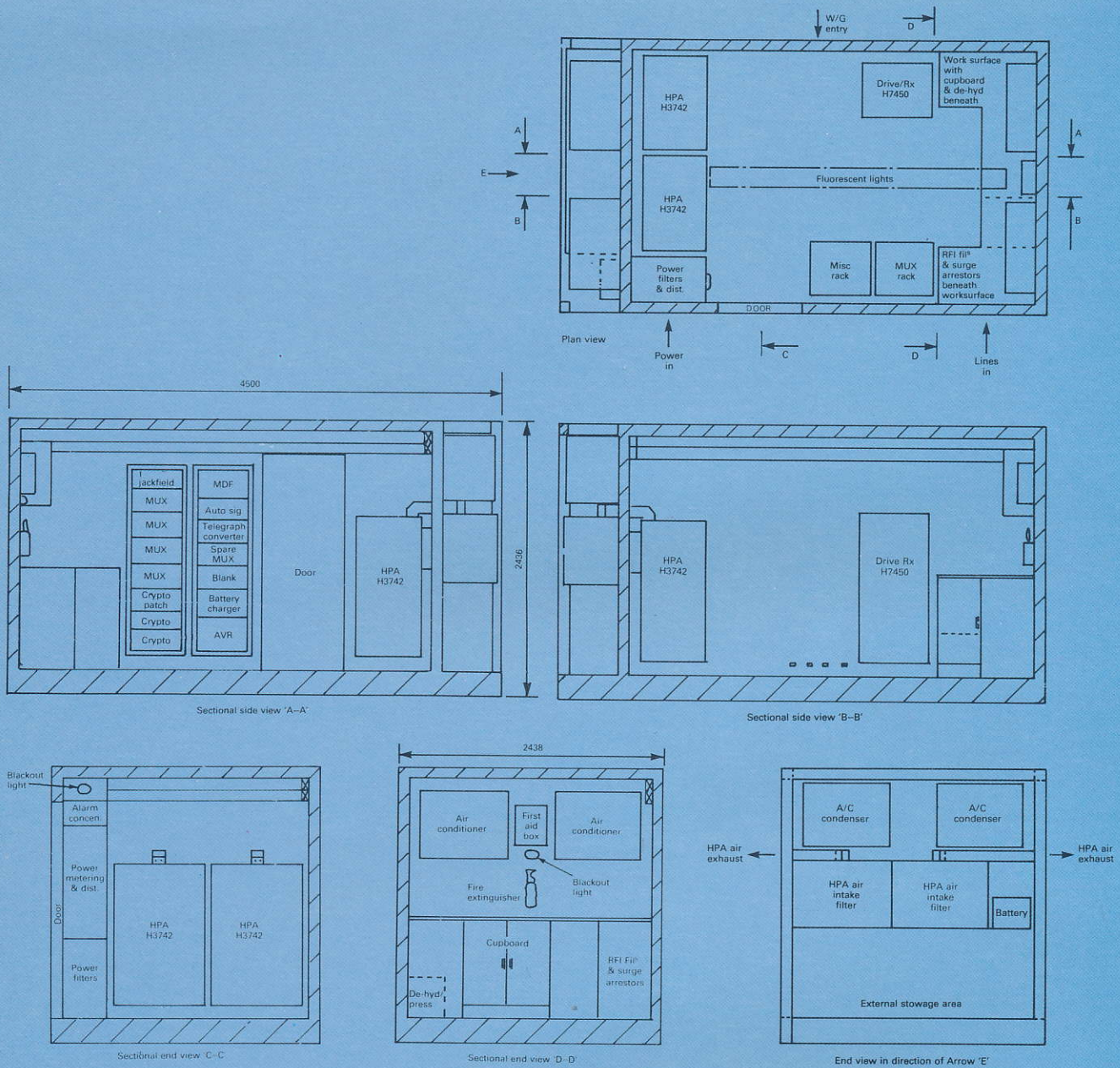
The complete tropospheric scatter capability



Typical TACTROP/COMCEN terminal complex



Remotely controlled rotatable 3m rooftop antennas for working with a distant TACTROP terminal



Typical TACTROP equipment shelter layout including a 60 channel multiplexer sub-system

Description

Equipment Shelter Construction

The shelter construction is based on an aluminium framework with aluminium-faced, foam-cored sandwich panels. This results in a light but extremely rigid construction which is arranged to provide at least 60dB EMI protection. ISO corner blocks are fitted. All materials are fire and corrosion resistant, and inhibit mould growth.

The nominal dimensions of a standard channel Equipment Shelter fitted with both Radio and Multiplex sub-systems are 4.5 metres long, 2.44 metres wide and 2.44 metres high. Fitments include air conditioners, main and emergency lighting, EMI filter vault, input panels, air filters, worktop and stowage space.

Other shelter dimensions and forms of construction are available including shelters designed for Nuclear Electromagnetic Pulse (EMP) protected installations.

Power Distribution

The Equipment Shelter is powered from a Generating Set by a 3-phase 4 wire supply at the national voltage and frequency. The Distribution System incorporates an EMI low leakage Power Filter, a mains circuit breaker, VAF metering, earth leakage protection (e.l.p.), and circuit breaker protected outlets.

If the Equipment Shelter is also intended to operate from an unregulated public mains supply as well as from the Generating Set, a 2kVA Automatic Voltage Regulator (AVR) and a transient suppressor can be provided as options to feed voltage sensitive items. The shelter will then operate with an input voltage tolerance of $\pm 15\%$ nominal. A High/Low voltage cut-off trip is also incorporated to protect the equipments from any extreme voltage variations.

Radio-Bearer Sub-System H7450

The Marconi H7450 is a quadruple

diversity 4-5GHz Tactical Tropospheric Scatter Radio Equipment. It incorporates two transmitter up-converters, four frequency synthesisers, four low-noise receiver down-converters, a predetection optimal-ratio receiver combiner and a digital modem for traffic, EOW, and supervisory data. A separate leaflet is available for details.

H3742

The Marconi H3742 is a 4-5GHz 1kW Transportable Tropospheric Scatter Transmitter Amplifier that has an output power variable between 5 and 1000W. Two H3742 amplifiers are installed. A separate leaflet is available for details.

RF Branching

A high-power circulator is fitted in the output circuit of each H3742. This enables one antenna feeder (and feedhorn port) to be used for both the transmit and receive functions simultaneously. The other orthogonally polarised

feedhorn port is connected by a separate feeder to a receiver. The method of branching provides TACTROP's diversity mode flexibility since it remains the same for 2A/2F, 1F/2S/2P and 2S/2F configurations, and it contributes to the system's operational frequency-changing flexibility.

Each transmitter feeder also includes a tunable RF filter to provide transmitter spectrum control.

Quick-release waveguide connectors are used on the external flexible waveguide feeders. The waveguides are pressurised during wet periods to prevent the ingress of moisture.

Multiplex and Encryption Sub-system

The 15 channel primary multiplexers and the MARCRYMUX encryption unit are mounted in racks together with patch panels and other line and data stream items. Details of the major items are available on separate leaflets.



Layout of equipment in a large container

The primary multiplexer channel ends (together with those of the ASU and Telegraph Converter items – if fitted) are connected to the equipment terminal blocks of a Main Distribution Frame (MDF). The MDF line blocks are connected through filters to 10-pair couplers on the external shelter wall.

Subscriber lines can be arranged for direct connection to the 10-pair couplers on the Equipment Shelter. Alternatively individual subscribers can be connected to a free standing Junction Box Assembly which can be located at a nominal distance from the Equipment Shelter.

EOW/Alarm Extension

The Equipment Shelter does not require manning for normal operation. However the Engineering Order Wire and an

Alarm Summary are available for extension into the nearest manned location, e.g. into a radar operations cabin or into a Headquarters complex. Typical extended alarms are:

- Urgent;
- Non-Urgent;
- Power Failure;
- Loss of Synchronisation.

Generating Set

The two diesel-alternators are accommodated in a skeleton container together with a 500 gallon bulk fuel storage tank. This tank normally has sufficient capacity for 9–18 days continuous running depending on the equipment load. The container has ISO corner blocks fitted.

The diesel-alternator control circuits are arranged for dual mutual standby operation. If the set is also intended as a standby

for an incoming independent mains supply, additional circuits are included to give a standby-to-mains configuration.

Alternative Generating Sets are available including skid or trailer mounted versions fitted with outdoor canopies.

Antenna Sub-system

The Marconi R2100 is a self-contained parabolic antenna mounted on its own integral two-wheel trailer. A separate leaflet is available for details.

System Options

Modular Radio-Bearer and Multiplex Sub-systems

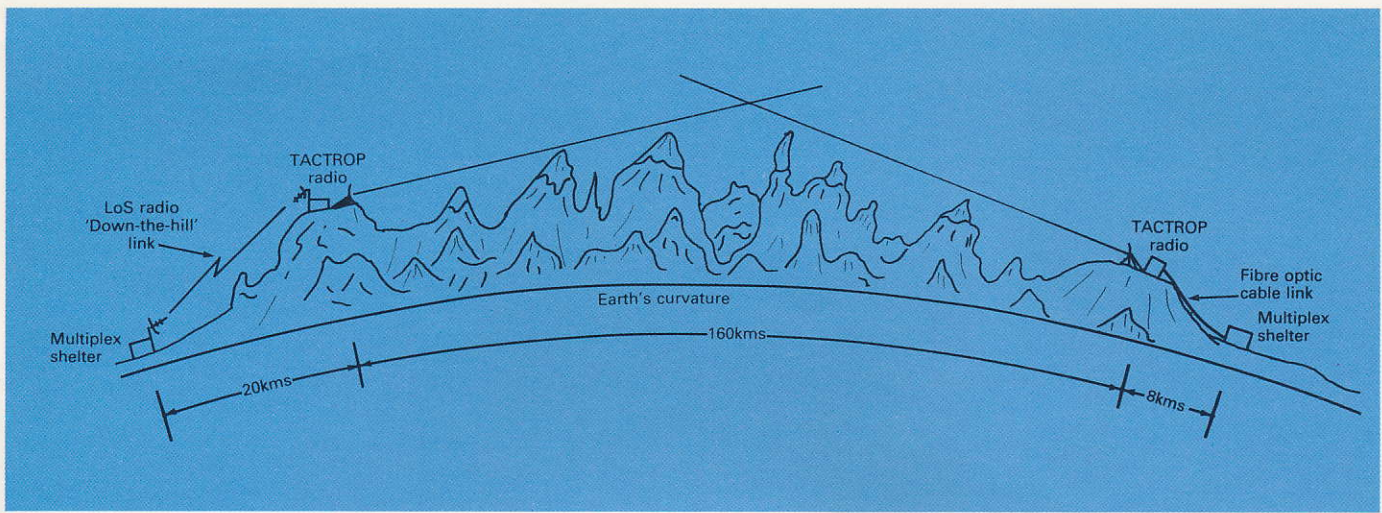
The Radio-Bearer and Multiplex sub-systems can be accommodated in separate shelters. This arrangement

permits the multiplex channels to be located adjacent to the subscriber equipments to minimise the length of the subscriber wire connections. The radio can then be located where there are propagation or visibility advantages.

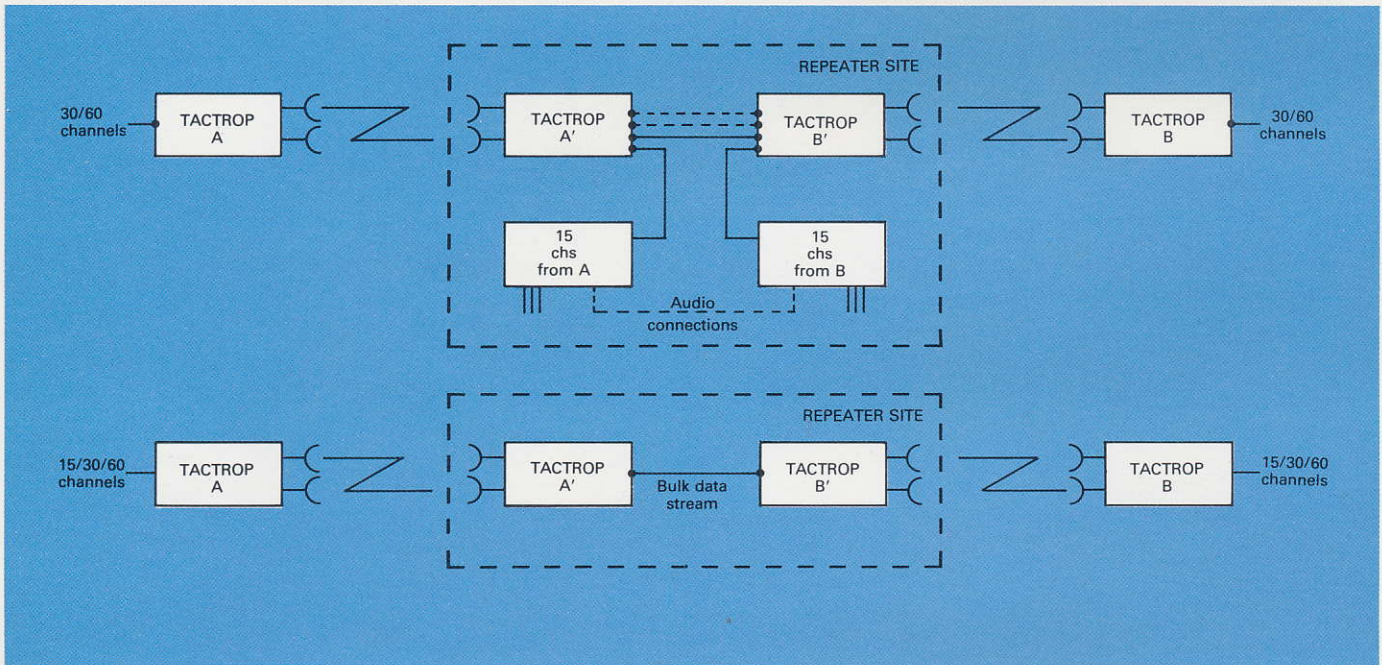
The additional siting flexibility obtained is particularly useful where the terrain is mountainous or where traffic is likely to be generated in urban areas.

Interconnection may be by a 'down-the-hill' type of link, typically Fibre Optic Cables for short distances, or line-of-sight radio for maximum flexibility. The appropriate link equipment would be installed in the shelters.

A Multiplex Shelter can also be used to accommodate a telephone exchange or a Communications Centre (COMCEN) facility to integrate and disperse traffic for a



Enhanced siting flexibility when radio bearer is separated from multiplex equipment



TACTROP repeater connections with crypto patch-panel option

large complex, e.g. for a field force or a radar/EW site.

The modular concept permits very long multi-hop tropo radio systems to be built-up by the user as the operational requirements demand. Also by locating Multiplex Shelters only at those repeaters where traffic access is required, fully adaptable systems can be realised with a minimum of equipment and manpower.

Adaptive Power Level Control

This sub-system automatically adjusts the transmit power output

to the optimum value for the far end receivers. By minimising beam over-shoot in times of good radio propagation, the possibilities of unauthorised reception and EMI are reduced. Moreover the full power output is still available for ECCM purposes.

'Radio Silence' Control

Transmitter extended control may be included to enable the terminal transmit power to be switched off quickly from a remote position, e.g. as part of a site protection system against an Anti-Radiation Missile (ARM) threat.

Civil Systems

TACTROP is adaptable to a large range of civil applications, particularly when the encryption and delta multiplex are substituted with standard civil multiplex accommodated in rugged shock-mounted cabinets.

For FM operation, the radio digital modem is replaced with an analogue modem which incorporates an efficient threshold extension demodulator. Ranges in excess of those shown on the curves will be obtained for equivalent channel capacities.

Alternatively, one edition of the

H7450 has a G703 interface for use with a standard CCITT 30 channel multiplexer. This system is advantageous for short-to-medium range applications requiring access to a national PTT digital system.

The 2.4-2.7GHz frequency band is also available for civil (or military) applications.

Data Summary

Radio-Bearer Sub-system

Frequency band: 4-4-5.0GHz.

R.F Channels: 6000.

R.F Channel Spacing: 100kHz.

Minimum Transmit Receive Spacing: 100MHz.

Reference Standard: 10MHz crystal oscillator.

Reference Frequency

Stability: 5×10^{-8} per day.

Power Amplifying Device: Klystron.

Transmit Output Power:

5-1000W (adjustable)

measured at Klystron.

Harmonic Suppression: Better than -70dB relative to carrier.

R.F Branching:

Transmit-receive duplexer circulators with spectrum control filters on each transmitter output.

Number of Transmitters: Two.

Number of Receivers: Four.

Fixed R.F Losses: 3dB nominal including external waveguide feeders.

Modulation: Quadrature Phase Shift Keying (QPSK).

Reception Arrangement:

Quadruple diversity (D4) with maximal ratio type predetection combining.

Diversity Configuration:

(a) 2 Space/2 Frequency

(b) 4 Space/1 Frequency (Space Polarisation)

(c) 2 Angle/2 Frequency (with appropriate antenna feedhorn).

Service Channels: Provided by built in Auxiliary Multiplexer, giving:

1 - Digital EOW channel

2 - 16kbit/s spare channels

EOW Access: Handset and Loudspeaker on H7450

equipment. Extensions for remote operation and antenna alignment functions.

Traffic Capacity: 256, 512, 1024 and 2048kbit/s. Traffic rate is field convertible by changing filters.

Radio Interface: EUROCOM. (Alternatively G703 for a CCITT multiplexer sub-system)

Multiplex Sub-system

Multiplex Type: Time division multiplex (t.d.m) conforming to EUROCOM standards and used with MARCRYPMUX encryption equipment.

A-D Conversion: Delta modulation with 3-bit syllabic companding to give 34dB dynamic range and return loss better than 16dB (300-3000kHz).

Channel Input/Output Impedance: 600 Ω .

Audio Frequency Response:

+2, -6dB, 300-600Hz and

3000-3400Hz.

\pm 2dB, 600Hz-3000Hz.

Input Level:

(a) 2-wire, 0dBm

(b) 4-wire, -4dBm

Output Level: -4dBm.

Channel Signalling: In-band digital or separate channel.

(a) Magneto

(b) E and M

(c) CB Auto Extension

Telegraph: CCITT V24

(6-0-6V unbalanced, V28 levels).

Telegraph Rate: Up to 100 bauds.

Asynchronous Data: CCITT V24.

Synchronous Data: CCITT V24 (unbalanced) 16/32kbit/s.

Line Impedance: 130 Ω

balanced and not referred to ground.

Clock Format: NRZ.

Composite Output Rate:

256/512kbit/s per primary multiplexer.

Number of Multiplexers: 1 or 2 or 4 depending on number of channels the system is specified for.

Crypto Type: MARCRYPMUX bit-by-bit bulk encryption.

Crypto Version:

(a) Single input/output for 256, 512, 1024 or 2048kbit/s.

(b) Accepts and super-multiplexes up to four 15 channel primary multiplexers with bit rates of either 256 or 512kbit/s (all the same). The crypto determines composite data stream for traffic.

Crypto Interface: EUROCOM D/1.

Key Variables: 2¹⁴⁴ total.

Key Variable Generation: By a separate Key Management Unit and transferred to MARCRYPMUX by an optical Fill Gun.

System Transmission Characteristics

Synchronisation Loss:

Typically when average BER is worse than 10%.

Resynchronisation: Typically when average BER is 3% or better.

Resynchronisation Time:

Typically 200mS.

Radio Equipment

Transmission Delay: Typically

50 microseconds.

Calculated Bit Count Integrity:

Better than 99-99% based on fade rate of 5Hz.

Traffic Interface

Traffic Interface Cables:

10-pair cables, 20 metres long.

10 cables (typically) for 60

channel system.

Traffic Data Stream

Connection: With a Crypto

Patch Panel Assembly, traffic can be patched either to the local MARCRYPMUX or out of the Equipment Shelter for back-to-back repeater applications.

Group Drop/Insert: With a Crypto Patch Panel Assembly, 256/512kbit/s groups can be extracted on a single link basis at a repeater.

Environment

Working Temperature: -30°C to +50°C for all major electronic equipments.

Humidity: 95% at 40°C.

Altitude: 3650 metres.

Air-conditioners: Two 18500 BTU split-level units typical (depending on location).

Equipment Shelter Internal Environment: Air-conditioning

and shelter insulation are designed to maintain internal temperature in the range 35-40°C, for an external ambient of +50°C.

Transmitter Cooling: The klystron collector cooling air (extraction) system is independent of the shelter air-handling system.

Dust Protection: Air inlet apertures are protected by filters.

Power

Supply Voltage:

380V/400V/415V \pm 10%, 3 phase, 4 wire.

Frequency: 47-63Hz.

Consumption: 14-25kW (depending on equipment content and capacity of air-conditioners) including domestic and maintenance test gear budgets.

Nominal Weights

Equipment Shelter

3-6-4-5 tonnes

Generating Set

4-5 tonnes

Antenna

3-5 tonnes

Additional Options

Automatic signalling units

Telegraph converter units

Automatic voltage regulation

Signal level chart recorders

Adaptive power level control

Specialist modems

Navigational receivers

H.F transceivers

Crypto patch panel assembly

Repeater connection cables

TACTROP performance

prediction program

Vehicles

Shelter lifting jacks

Mobilizers

Microwave down-the-hill links

Quad cable tail links

Fibre optic tail links

Cable trailer

Supervisory systems

Shelter fire protection system

Workshop special-to-type test equipment

Transportable base workshop

Field workshop

Equipment for training

Computer-based training

F.M/F.D.M transmission

PCM (CCITT) Multiplex

Alternative antenna systems

Traffic-rate conversion kits

Alternative shelter arrangements

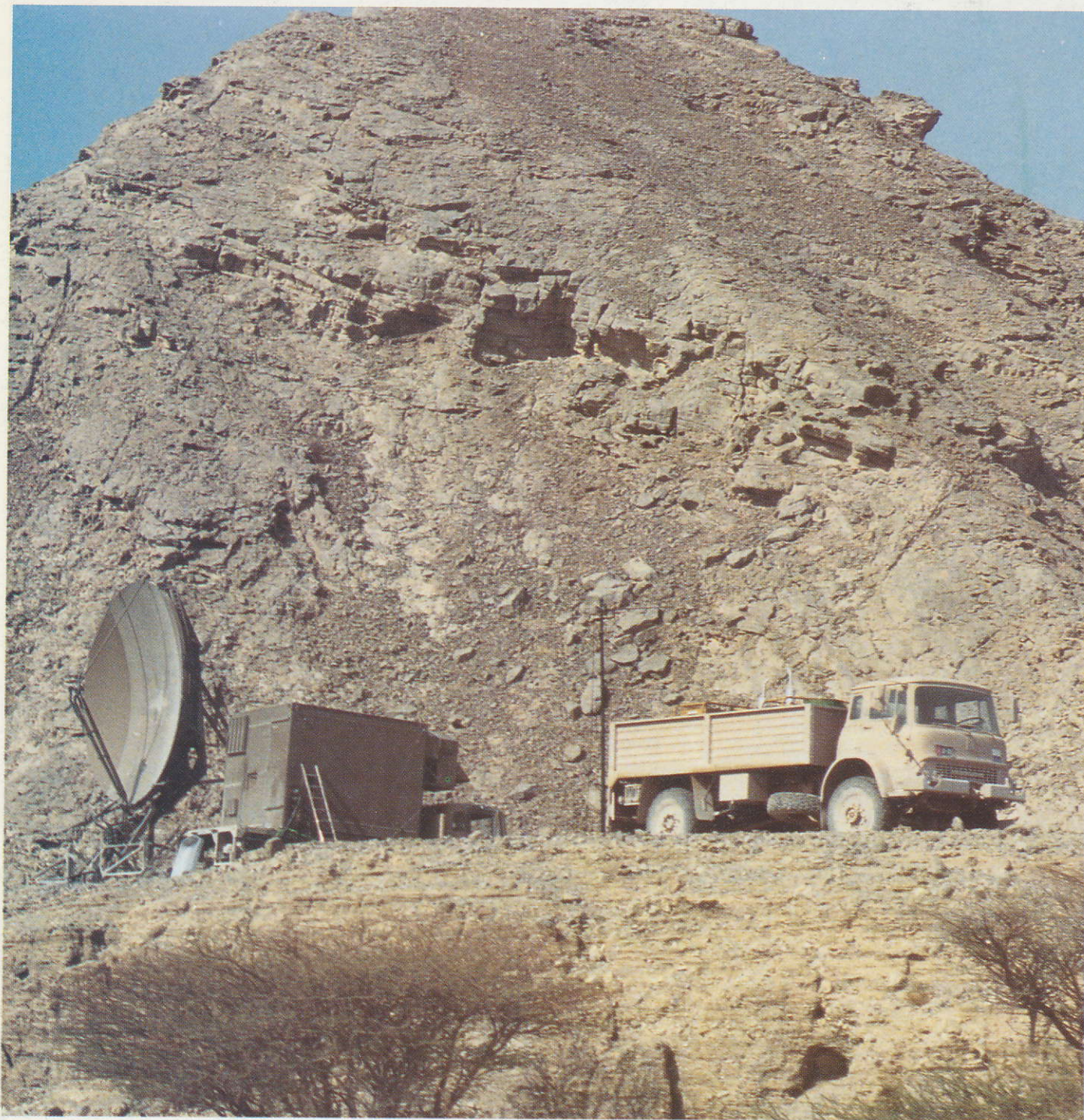
Rack-mounted spare modules

Alternative HPA systems

2.4-2.7GHz version

Field telephone exchange

Field telephones.



Marconi

Communication Systems

Marconi Communication Systems Limited
Space and Broadcast Division
Marconi House, New Street
Chelmsford, England CM1 1PL
Telephone 0245 353221 Telex 99201
Facsimile 0245 87125 Group 3



TD-1-TACTROP

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