

Radio relay for 1.5GHz

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Summary The article describes the latest addition to the range of Marconi microwave relay equipments, the H7201, which is designed for applications in the 1.5GHz private user band, and which can accommodate up to 36

f.d.m channels. A detailed description is given, together with the overall design objectives and philosophy which have resulted in a unique equipment in terms of its small size, flexibility and ease of operation and maintenance.

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Mr Stears joined the Marconi Wireless Telegraph Company as an apprentice in 1950, and was subsequently employed in the research laboratories at Baddow. He left in 1959 to join the Plessey Company where he became group leader responsible for naval u.h.f. communications. Returning to the Marconi Company in 1973 he is currently a group leader in Space & Microwave Division and is responsible for line of sight and tropospheric scatter equipment development.



Introduction

There is now an ever-increasing demand for private user microwave communication systems, that is, systems which do not form part of the public telephone network. This interest stems from the increasing use of sophisticated computerized control and monitoring systems for oil and gas production and for the distribution of electrical power, water and gas by public utilities.

The Department of Trade and Industry (DTI), formerly the Home Office, authorized three frequency bands for private use, whilst a fourth at 22GHz is to become available shortly. These bands are centred on 1.5GHz, 7.5GHz and 13GHz. The 1.5GHz band is reserved for low-capacity systems with up to 36 f.d.m channels. The other two bands are intended for larger capacities, the 13GHz band in particular accommodating very large systems using either analogue or digital techniques.

The majority of private user systems require only modest channel capacities

and for this reason there is currently a considerable interest in the 1.5GHz Radio Relay. This prompted Marconi Communication Systems to examine the possibility of extending the popular H7200 1.7GHz to 2.3GHz band radio relay to cover the 1.5GHz band. The result is the H7201 Microwave Radio Relay Equipment, the subject of this

article, which is now in production.

A picture of the H7201 is shown in figure 1. It bears a close resemblance to the H7200, retaining many of its attractive features e.g. small size, good modularity and comprehensive built-in metering and alarm facilities.

Type approval has been granted by the DTI against MPT1408 for 8-channel systems, and MPT1402 for 12, 24 and 36-channel systems. Both specifications involve rigorous tests designed to ensure that the Department's regulations concerning generation of interference and operation in high-density frequency plans are complied with fully. The H7201 is also compliant with CCIR Recommendations and with British Telecom specification RC4031A. It is also expected to be compliant with the latest BT specification RC4032 when it is formally issued.

General description

The H7201 is a fully duplicated f.m./f.d.m radio relay equipment suitable for hot standby or space diversity applications in the band 1427MHz to 1535MHz. Versions are available for 8, 12, 24 and 36 channels with optional pre-emphasis for the two higher capacities.

The complete radio is accommodated in a standard 19in rack shelf with



Fig. 1. Front view of H7201

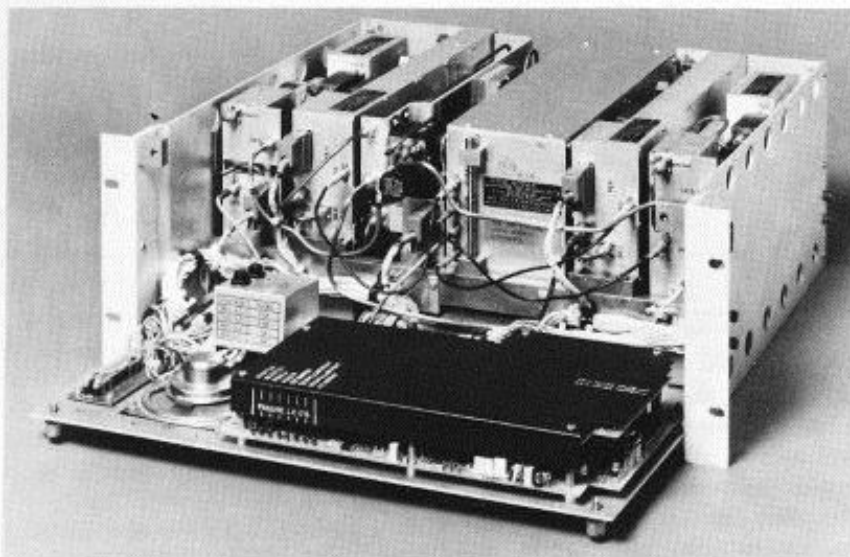


Fig. 2. Front view of H7201 with front panel lowered to show metering and control

front panel dimensions 7in by 19in, and 20in depth behind the front panel. A second shelf with the same front panel dimensions and only 4in deep accommodates the power supplies. Transmitter power output for the standard version is 0.5W but an integral power amplifier giving 2W output is available as an option.

The front panel is fitted with easily observable red and green L.e.d indicators to show whether the MAIN or STANDBY transmitter and receiver is in use or if a fault has occurred. Selection of MAIN or STANDBY may be

carried out manually using push-button switches, or in the 'Auto' mode entirely automatically, according to the functional status of the modules. In normal operation the MAIN transmitter output is connected to the antenna socket via a coaxial relay with the STANDBY connected to an internal dummy load. For hot standby operation the incoming signal is shared equally between the two receivers by means of a power splitter at the input. A post-detection combiner recombines the signals at baseband.

A comprehensive metering system

comprising an L.e.d digital display and push-button selector switches is located on the front panel. This allows monitoring of the receive signal level on both paths, MAIN and STANDBY transmitter power outputs and the d.c voltages from the power supply modules. An additional monitor is also available as an option to enable the transmitter output after the MAIN/STANDBY coaxial relay to be displayed.

Also on the front panel is a loudspeaker and a socket for the engineering order wire (e.o.w) handset. In addition to its e.o.w function the loudspeaker is used to produce an audible calling signal for the operator, activated by a push button on the remote equipment front panel, and an alarm signal in case of a fault. The calling signal is a continuous 1000Hz tone while the alarm is a 1000Hz tone interrupted at a 1Hz rate. A RECEIVING ATTENTION push button mutes the audible alarm while the fault is identified and the faulty module replaced. A linear potentiometer on the front panel controls the loudspeaker level for the e.o.w but neither the calling nor alarm signals are affected.

The H7201, identical in layout to its predecessor, contains six discrete modules in the radio plus two power supply modules mounted in the separate power supply shelf assembly. In

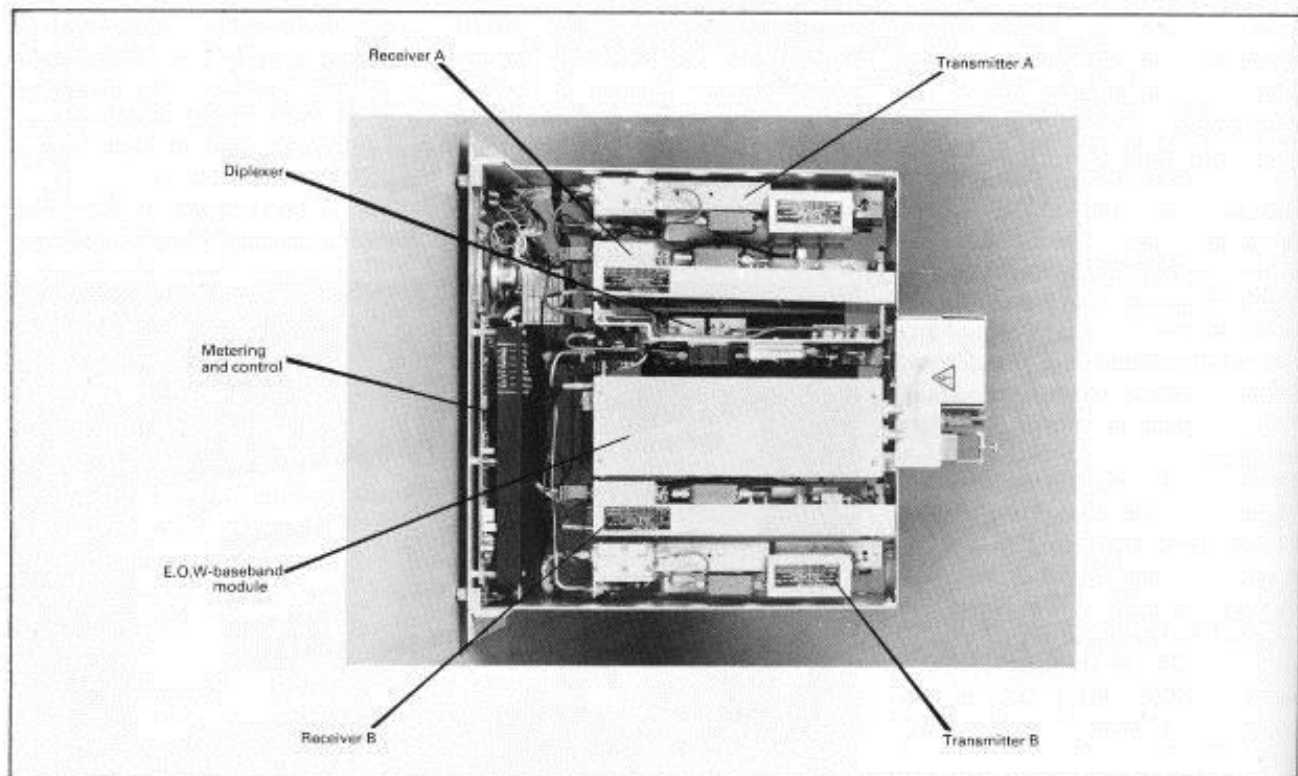


Fig. 3. Top view of H7201

the radio shelf the modules comprise: two receivers, two transmitters, a diplexer and an e.o.w./baseband unit. Circuits for the control and monitoring system are mounted on a printed circuit fitted to the rear of the front panel. With the aid of the front panel l.e.ds augmented by further l.e.ds on the control and monitoring circuit, most faults can be traced to specific modules quickly and unambiguously. Access to the l.e.ds on the control and monitoring circuit is obtained by lowering the front panel (figure 2). All modules can be reached from the top of the radio shelf (figure 3), and removal is accomplished easily by releasing two fixing screws.

The individual power supply modules are removed by releasing four fixing screws on the front panel and withdrawing from the front.

Various options are available to meet specific requirements. These include the 2W transmitter option mentioned previously, a receiver low-noise option for use in systems with long or partially obstructed signal paths, and optional pre-emphasis for 24- and 36-channel equipments.

Design philosophy

The primary aim of the design was to produce a low-cost, reliable equipment meeting requirements defined in DTI specifications MPT1402 and MPT1408 and British Telecom (BT) specification RC4031A. A secondary aim was to produce a small compact equipment, since for many applications space is at a premium.

The requirements for low cost and high reliability have been achieved by the use of simple, well proven circuit techniques. Direct modulation of the radio frequency carrier and limiting i.f. amplifiers without a.g.c. are the most notable examples of this approach. Direct modulation avoids the complication of up-conversion from an intermediate frequency and also avoids the need for additional r.f. filters in the transmit chain to reject unwanted up-converter mixing products. A limiting i.f. amplifier enables proprietary integrated circuit amplifiers to be used and this results in a complete i.f. strip which is a fraction of the size achievable using a conventional a.g.c. design with discrete components.

The major influence on the design resulting from meeting the DTI and BT specifications has been on r.f. and i.f. selectivity.

Compared to the 1.7GHz to 2.3GHz band, the operating environment at 1.5GHz is far more stringent as regards r.f. channel separation. For 8-channel systems, frequency planning is based upon only 200kHz separation between r.f. channels and for 12- to 36-channel systems only 500kHz separation. This places very stringent requirements upon receiver r.f. and i.f. selectivity and on the transmitter radiated spectrum. Highly selective fifth-order comb-line filters have been designed for the r.f. system to provide the necessary degree of protection for the receiver front end, whilst for 12- to 36-channel systems it has been necessary to develop a sixth-order helical resonator i.f. filter. The latter is 1MHz wide and provides over 65dB attenuation at 1MHz from the 70MHz band centre.

Reliability has been enhanced by giving careful consideration to cooling, which is by natural air convection, and by the use of high quality components. During the design stage a rigorous programme of thermal modelling and proving tests was carried out to eliminate potential hot spots and to ensure all constituent parts were operating well within their design rating. Accessibility for fault location and repair was also carefully considered, along with a comprehensive metering system allowing the majority of faults to be pinpointed to a discrete module. Modules in the MAIN or STANDBY path can be removed without interruption to traffic in the other path.

Description of modules

A block diagram for the H7201 is given in figure 4. This shows the functional make-up of the individual modules. In the descriptions which follow it is assumed that the equipment is operated in the 'Auto' mode. When 'Manual' is selected, selection of either the MAIN or STANDBY transmitter or receiver is controlled by push-button switches on the front panel.

Diplexer module

The diplexer module (figure 5), contains the r.f. filters for the transmitter and receiver, transmit-receive diplexing, the transmit hot standby switch and the optional low-noise amplifiers.

The characteristics of the r.f. filters are determined by the frequency planning requirements for the band. For the r.f. filters the main constraint is the minimum transmit-receive separation

which for 8-channel systems may be as close as 35MHz. The need to attenuate the level of the transmit signal at the receiver input dictated a fifth-order Chebyshev design with a nominal bandwidth of 15MHz, this being the best compromise between passband loss and stopband rejection. An identical filter was chosen for the transmitter to suppress wideband noise which could otherwise interfere with the receivers.

Without the low-noise amplifiers in the hot standby configuration the receiver noise figure is 14dB as measured at the equipment antenna port. This results from the basic receiver module noise figure of 9dB measured at the mixer input and losses introduced by the diplexer. For space diversity the elimination of the splitter improves this by 3dB. A noise figure of 14dB is adequate for the majority of applications but where improved performance is required the low-noise amplifier is available which reduces this to 7dB for hot standby or 4dB for space diversity. A single receive filter before the power splitter is justified on the grounds of high reliability inherent in a passive component.

Transmitter module

The transmitter module contains the entire transmitter path from the modulator pre-amplifier input to the r.f. amplifier output. Direct modulation at r.f. is employed, the modulator consisting of a phase-locked voltage-controlled oscillator (v.c.o.) which is modulated by applying the input to a varactor diode in the oscillator-tuned circuit. The r.f. output from the oscillator is nominally 1W which guarantees 0.5W at the antenna port.

The v.c.o. is locked to a highly stable crystal reference source via a divider chain with a division ratio of 128. Crystal frequencies between 11MHz and 12MHz are therefore required to cover the band. A feature of the v.c.o. performance is its low phase-noise characteristic. This has been achieved by careful tailoring of the phase-locked-loop characteristics and choice of a high-Q resonator circuit for the v.c.o. Poor phase-noise will have a detrimental effect upon channel signal-to-noise ratio.

In the standard version, the output from the v.c.o. is connected via an isolator to a level monitor and then to the module Type N output connector. The level detector forms a part of the

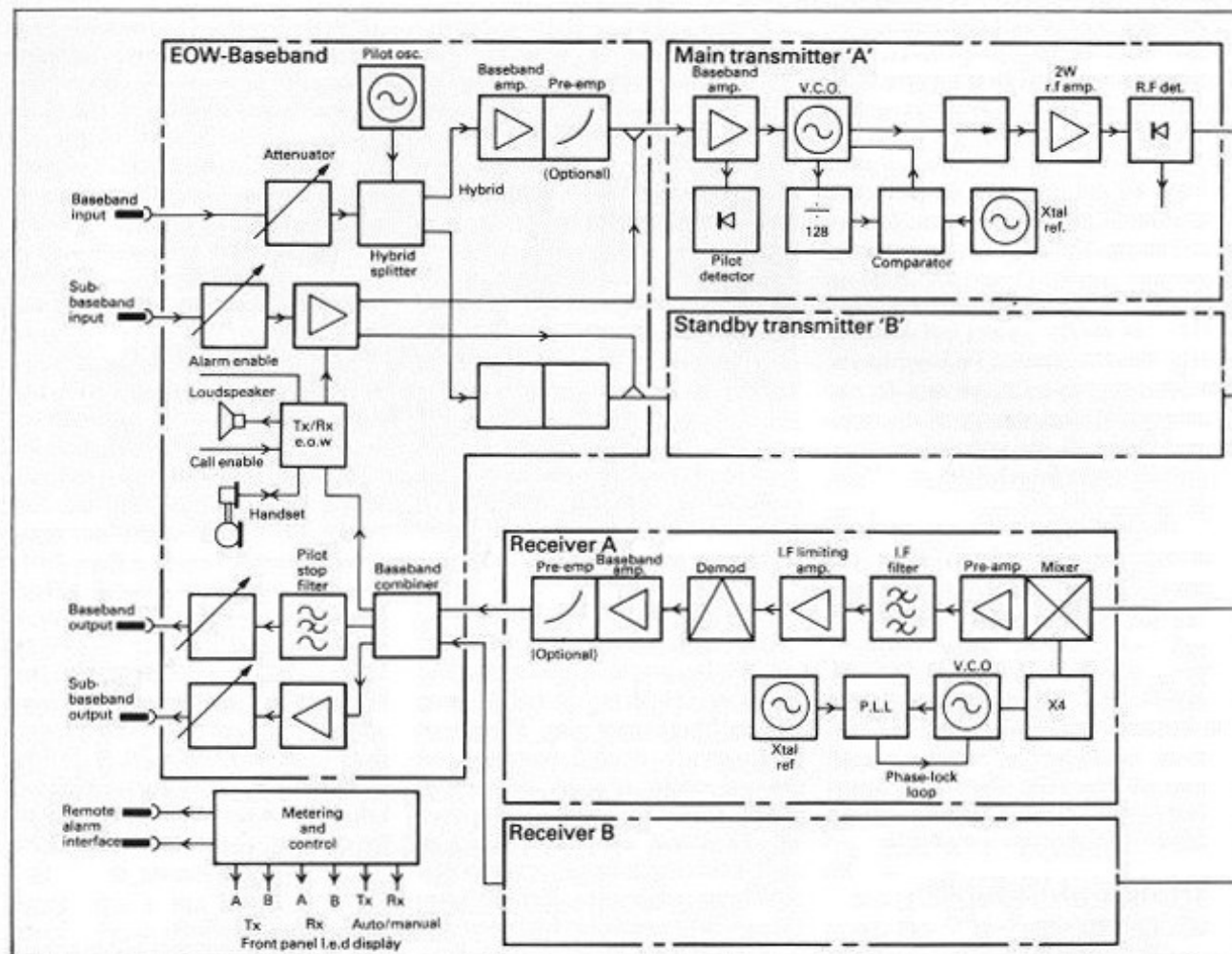


Fig. 4. H7201 block diagram

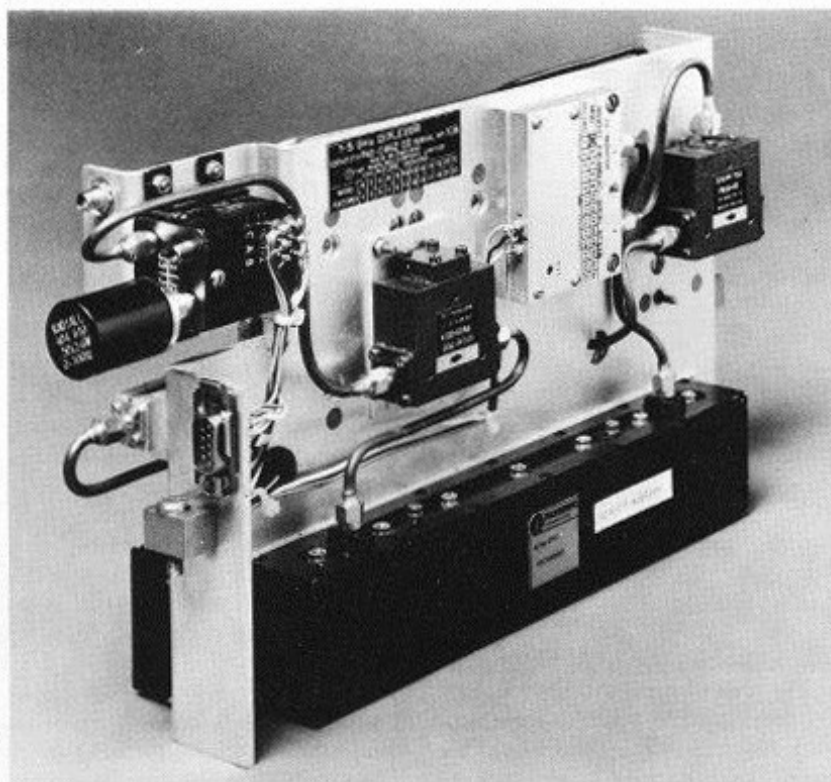


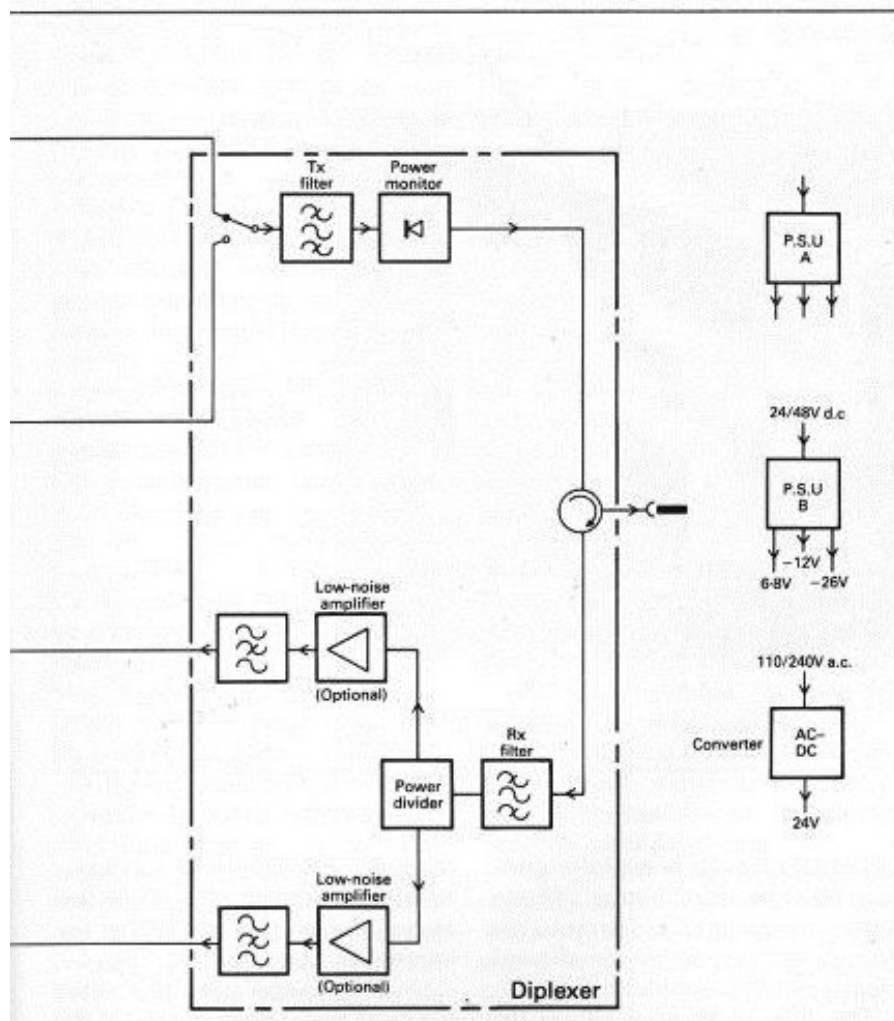
Fig. 5. Diplexer module

metering and fault monitoring system. In the 'Auto' mode of operation a drop of 3dB in the v.c.o output will initiate a change to the standby path which will be signified by a red l.e.d fault alarm on the front panel. Loss of lock in the v.c.o phase lock loop will also initiate a changeover.

The optional power amplifier fits between the isolator and the level detector. It is a broadband design giving an output in excess of 3W which guarantees 2W at the equipment antenna port.

A detector monitors the pilot level at the baseband input to the modulator. A drop of 3dB in the pilot level will initiate a changeover to the standby path.

The transmit module is housed in a single, machined aluminium block (figure 6). The picture shows the power amplifier with the cover removed. On the other side of the block is the modulator pre-amplifier and phase-lock circuitry. The v.c.o is housed in the compartment at the top left of the picture.



Receiver module

The receiver is of the single down conversion type with an i.f. of 70MHz. It is accommodated in a single, machined aluminium block (figure 7), and contains the entire receive chain from the downconverter mixer input to the demodulator output.

A double-balanced diode mixer was chosen because of its superior linearity compared to 'active' transistor types. Good linearity is essential to avoid third-order intermodulation problems arising from interfering carriers. A typical noise figure of 9dB is obtained with the mixer, which includes 'second circuit' contributions from the following stages.

The local oscillator signal for the downconverter mixer is derived from a v.c.o. operating at one quarter of the final frequency. Multiplication to final frequency, which may be 70MHz either above or below the signal frequency, is achieved with a step recovery varactor multiplier. The v.c.o. is phase-locked to a crystal reference via a divider with a division ratio of 32, thus the net division ratio from r.f. is 128 which is the same as for the transmit v.c.o. Hence crystals for the transmitter and receiver are in essentially the same frequency range, the only difference being that the receive local

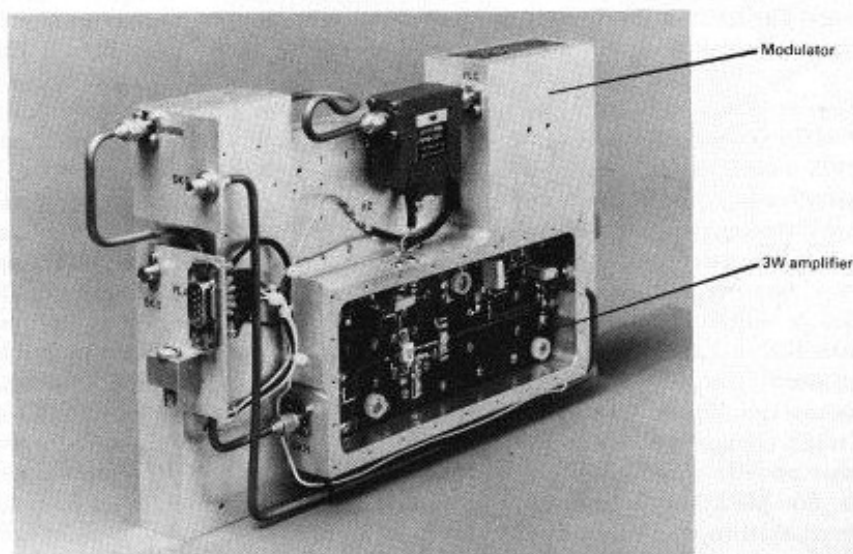


Fig. 6. Transmit module

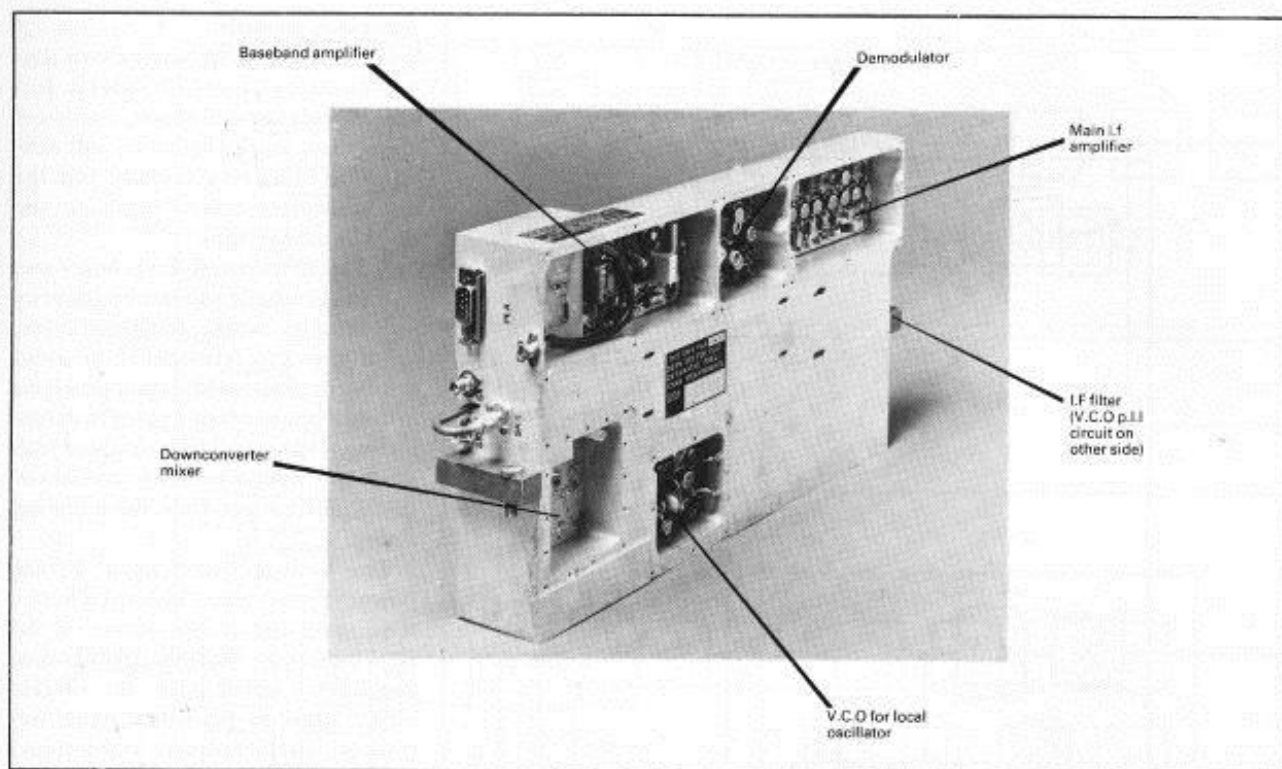


Fig. 7. Receive module

oscillator has to cover 70MHz above and below the signal frequency range to allow for either lower or upper side-band mixing.

Following the mixer is the i.f. pre-amplifier and i.f. filter. The i.f. filter defines the overall receiver selectivity and provides the main protection against large close-in interfering carriers. Specifications MPT1402 and MPT1408 both give selectivity and spurious response tests which set the minimum requirements. The spurious response test is the more severe of the two.

Essentially this consists of measuring the effect of a -60dBW interfering signal upon a -120dBW wanted signal as the frequency separation is varied. For MPT1402 the separation may be as close as 2MHz and this dictated a sixth-order Chebyshev filter with a bandwidth of 1MHz. A helical line resonator filter construction was used to obtain a low insertion loss. At 70MHz a helical resonator can achieve Q_s in excess of 800, which is considerably greater than that possible with lumped components. For MPT1408, which covers 8-channel systems, the minimum interference-to-wanted signal separation is increased to 2.4MHz, but the r.f. channel separation is reduced to 200kHz. The latter required a 0.5MHz bandwidth but a somewhat simpler fourth-order filter

was found adequate to meet the spurious rejection specification. Group delay equalization of the filters was not deemed necessary for the low-channel capacitors being considered.

The main i.f. amplifier follows the filter. This consists of eight integrated circuit stages giving a total gain of 85dB minimum. The first two stages act as linear amplifiers while the last six act as limiters. This configuration avoids the use of a.g.c and results in an extremely compact design.

A feature of the integrated-circuit limiting amplifiers is that they provide a detected output voltage proportional to input level. This is used to display the received signal level on the front panel meter.

The discriminator is a conventional Round Travis type using two tuned circuits.

Immediately following the demodulator is a baseband amplifier and optional plug-in de-emphasis circuit. A discrete-component amplifier design was chosen for this application since it was found to give a noise and linearity performance superior to equivalent integrated circuits.

E.O.W. - baseband module

The e.o.w. - baseband module contains the baseband circuits for the transmit and receive paths and the circuits for the e.o.w. The latter includes the

engineers' calling tone, a continuous 1000Hz tone and an audible fault alarm consisting of a 1000Hz tone interrupted at a 1Hz rate.

On the transmit side the incoming baseband signal in the range -30dBm to -45dBm is first attenuated according to the actual level and then split equally between the MAIN and STANDBY paths. This latter operation is accomplished in a high-reliability hybrid transformer which also serves to introduce the continuity pilot signal. The pilot frequency is situated above the baseband.

After splitting, the signal in each path is amplified in a broadband low-noise amplifier. This amplifier is a discrete-component design to achieve the noise and linearity specifications. As stated previously for the receiver baseband amplifier, integrated circuit designs were not found capable of meeting the stringent noise and linearity requirements. After amplification, pre-emphasis, if fitted, is applied and the sub-baseband signal added before the composite signal is passed on to the transmit module. The sub-baseband system will be dealt with later.

On the receive side, the incoming demodulated signals from the MAIN and STANDBY path receivers are added together in a combiner. When the equipment is operating in the 'Auto' mode and the signal levels in

both paths are the same, the baseband signals are added directly. Should, however, the noise level in one path increase by nominally 6dB relative to the other, then that path is automatically muted by the combiner switch. Reduction of the pilot level in one path by 4dB will also produce the same result. However, should the pilot level on both paths reduce, no action is taken on the grounds that the fault is unlikely to be in the receive system. A compensating resistor network automatically maintains the signal level constant irrespective of whether both paths contribute to the output or only one. A high-noise mute operates if the noise level on both paths exceeds a pre-determined level. This is to prevent excessive noise levels being passed out to the line, which would otherwise disturb following multiplex equipment. Typically, the mute is set to operate when the input signal level falls just below the receiver threshold.

In 'Manual' mode the receive path is selected by the MAIN and STANDBY push-button switches on the front panel. After combining, the signal is passed to the e.o.w. circuitry and to the main baseband output via a pilot stop filter and a pre-set variable attenuator.

Pilot and noise detection in the H7201, as in the H7200, greatly simplifies the process of channel changing compared to more conventional methods. The pilot and a noise

measuring 'slot' are both heterodyned down to a 10kHz intermediate frequency where they are selected by narrowband active filters and detected. Selection of channel capacity is then achieved simply by fitting the appropriate plug-in crystal for the heterodyne mixer local oscillator. To avoid the use of the physically very large crystals necessary for the lower pilot frequencies, a variable divider is used. This allows crystals to be selected in the optimum frequency range for stability. The outputs from the noise detectors in the two paths are compared in a differential detector to control the baseband switch as described above.

The microphone signal from the engineers' handset is band limited to 2kHz. This is to allow the band 2-2kHz up to 3.4kHz to be used for supervisory purposes in applications where the normal sub-baseband is already occupied. After amplification the e.o.w. signal is combined with the transmitter sub-baseband input before being added to the baseband at the transmit baseband amplifier output.

The receive sub-baseband is extracted at the baseband combiner output by appropriate filtering and routed to the sub-baseband output port and to the receive e.o.w. circuit. The receive e.o.w. signal may be monitored on the loudspeaker, for which a level control is provided. This control is automatically overridden by the cal-

ling and alarm tones. When the e.o.w. handset is plugged in to the front panel socket the loudspeaker is automatically disengaged except for the calling and alarm tones.

As an optional item a two- to four-wire bridge is available for the sub-baseband. This permits the H7201 to be connected back-to-back at repeater stations whilst allowing supervisory signals to be inserted or extracted. It allows an omnibus e.o.w. system to be used in multi-hop applications.

A view of the e.o.w. baseband module is shown in figure 8. Discrete functions are mounted on separate printed-circuit boards and individual boards may be removed without affecting traffic on the alternative path.

Metering and control module

The metering and control module provides the following functions:

- auto/manual selection of transmitters and receivers;
- front panel indication of transmitter and receiver operational status by green l.e.d and failure status by red l.e.ds,
- metering of receiver signal, input levels and transmits output,
- metering of output voltages of power supplies,
- local and remote failure alarm,
- 'alarm receiving attention' and 'reset' functions.

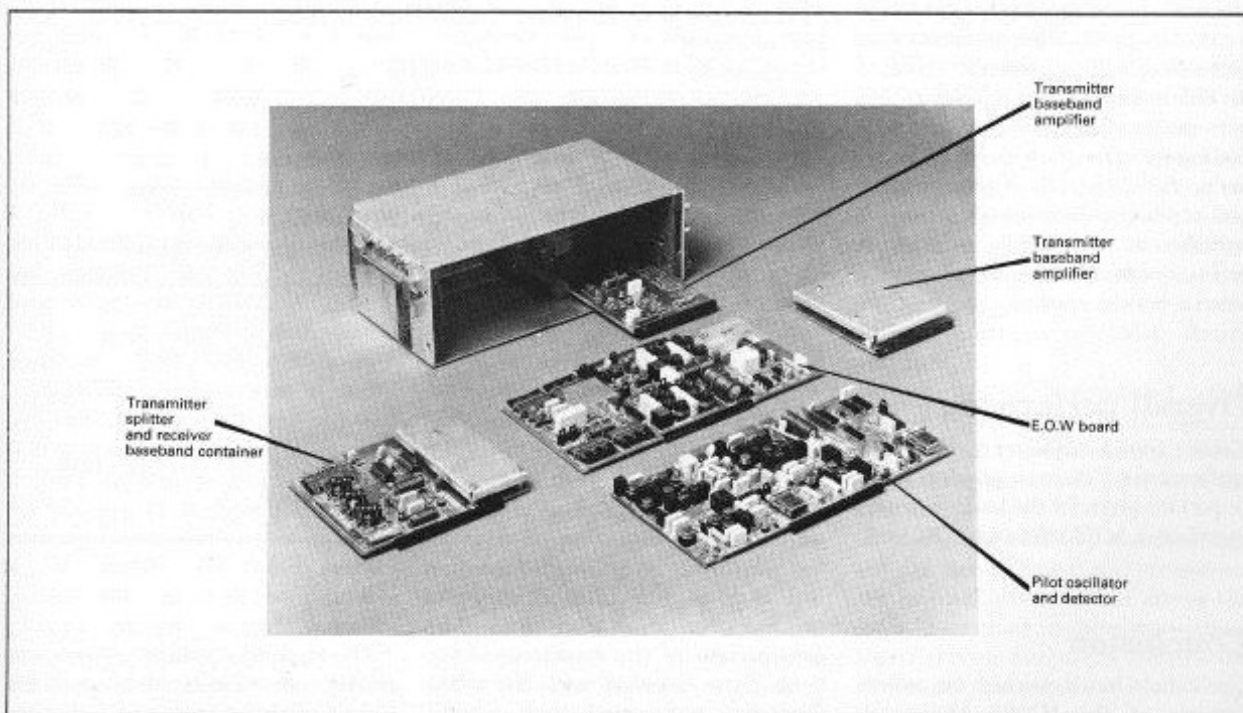


Fig. 8. E.O.W. - baseband module

The metered functions are selected by 12 push-button switches on the front panel and are shown on a 3-digit 7-segment digital l.e.d display.

Separate push buttons enable parameters for both paths to be selected independently.

The RECEIVING ATTENTION push button cancels the audible alarm without affecting the visual alarms.

Audible and visual alarms will be raised if the following faults occur on either path:

- a) transmitter module power output reduction of 3dB,
- b) loss of phase lock on either the transmit or receive v.c.o.,
- c) transmitter and receiver continuity pilot-level reduction greater than 4dB,
- d) transmit r.f. output power reduction of 3dB measured after the hot standby relay,
- e) failure of power supply d.c rail voltages.

In the event of an alarm the cause can be isolated to a discrete module by observing the status of l.e.ds mounted behind the front panel. Single isolated 'dry' relay contacts are provided for remote indication of transmit output power failure and the loss of the receiver pilot in either path.

Red and green l.e.d indicators on the front panel show the status of the transmitters and receivers in each path and whether the MAIN or STANDBY is selected. Loss of the receiver pilot or a phase-lock-loop failure causes a red alarm to be illuminated against the particular path. The occurrence of either fault will override the action of the differential noise mute circuit. This is to prevent high noise on one path initiating a mute when the other path is faulty. Similarly, loss of phase lock or loss of pilot in the transmit module is indicated by illuminating a red alarm and automatic changeover is inhibited when a fault is present.

Overall performance

Table 1 gives a summary of the H7201 performance. Noise power ratios (n.p.r) are given for the loading factors specified in MPT1402 and MPT1408.

Conclusion

The article has described the salient features of the H7201 Microwave Radio Relay equipment. Details of the

Table 1: Summary of H7201 performance

General Characteristics	
Frequency range	1427MHz to 1535MHz
Modulation	F.M./F.D.M
Channel capacities	8, 12, 24 and 36
Pre-emphasis	Optional for 24 and 36 channels
Linearity	N.P.R better than 52dB, all capacities
Continuity pilot frequencies	
8 Channels	49kHz
12 Channels	66kHz
24 Channels	119kHz
36 Channels	172kHz
Baseband levels	
Input	-30dBm to -45dBm adjustable in 0.5dB steps
Output	-14dBm to -30dBm adjustable in 0.5dB steps
Frequency deviation	
8 Channels	20kHz
12 Channels	45kHz
24 Channels	35kHz
36 Channels	25kHz
Power supplies	
d.c	24V or 48V. Nominal range 0.9 to 1.3 of nominal voltage
a.c	120V or 240V +10% -20%, 45 to 65Hz
Power consumption	120W for fully duplicated terminal
Operating temperature range	0°C to +55°C
Type approval	DTI approval to specifications MPT1402 and MPT1408
Receiver	
Noise figure (without 3dB power splitter)	
Standard	10dB
Low noise option	4dB
I.F frequency	70MHz
I.F bandwidth	
8 channels	0.5MHz
12, 24 and 36 channels	1.0MHz
Threshold	
8 channels	-127dBW standard
	-133dBW with low noise option
12, 24 and 36 channels	-124dBW standard
	-130dBW with low noise option
Transmitter	
Power output	
Standard	0.5W
High power option	2W
Spurious levels	Less than -56dBW 0 to 10GHz
Radiated spectrum	According to MPT1402 and MPT1408
Carrier stability	10 parts per million

construction of the equipment have been given together with the main operating parameters and control functions.

The equipment offers a number of unique features in terms of small size and simplicity of operation and maintenance.

RÉSUMÉ

L'article décrit le dernier élément apporté à la gamme des matériels de relais radio Marconi microondes, le H7201 conçu pour les applications dans la bande utilisateur privé 1,5GHz et qui peut desservir 36 canaux multiplex à répartition en fréquence. Une description détaillée du H7201 est donnée accompagnée de l'exposé des objectifs et de l'optique qui ont présidé à sa conception et ont abouti à la réalisation d'un matériel exceptionnel quant à ses dimensions réduites, sa flexibilité, la facilité de son emploi ainsi que ses besoins de maintenance.

ZUSAMMENFASSUNG

Der Aufsatz beschreibt den letzten Zuwachs zur Reihe der Marconi Mikrowellen Radio-Relaisgeräte, die Einheit H7201, die zum Einsatz im 1,5GHz Privatband bestimmt ist und bis zu 36 f.d.m-Kanäle aufnehmen kann. Eine eingehende Beschreibung des Geräts H7201 sowie Erläuterung der allgemeinen Konstruktionsziele und Philosophie, die mit Bezug auf kleine Größe, Anpassungsfähigkeit sowie Betriebs- und Wartungsfreundlichkeit zu einem einzigartigen Gerät führten.

RESUMEN

El artículo describe la última adición a la variedad de equipos Marconi del relé radioeléctrico H7201 por microondas, el cual se diseña para aplicaciones en la banda de usuarios privados de 1,5GHz, y puede acomodar hasta 36 canales múltiplex por división de frecuencias. Se da una descripción detallada del H7201, junto con los objetivos y filosofía globales del diseño que ha dado lugar a la existencia de un equipo único, en lo que respecta a su pequeño tamaño, flexibilidad, facilidad de manejo y conservación.

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