The Marconi U1107 data modem

W. C. Mills

Summary The new modem described operates at 1200 or 600 bit/s with a 150 bit/s backward channel in accordance with CCITT recommendation V23.

Designed for use by the British Post Office, the modem has a number of alternative modes and configurations in which it can be operated on public or private networks.

By wide use of digital and linear large scale integrated circuits it has been possible to package a full-facility, public network modem within one plug-in module. This may be used as a table top unit or fitted in shelves for multiple installations.

Performance has been measured under conditions representing the worst cases that can occur on telephone circuits.

W. C. Mills
Served an apprenticeship with The Marconi Company and, after National Service in the R.A.F., joined the Research Division at Great Baddow. As a member of the Communications and Advanced Development Group he was involved in early developments in mechanical filters, tropospheric scatter and air-ground data communication. After joining Line Communication Division in 1967 he became responsible for the development of a number of data communication equipments. In 1973 he became Chief of the Telegraph and Data Equipment Group and controls the development of data modems, v.f. terminals and baseband supervisory equipments.

Introduction

The latest addition to the range of data modems designed by Marconi to the stringent requirements of the British Post Office is the 1200 bit/s U1107, an asynchronous f.m. modem meeting the CCITT Recommendation V23 based on the same modular concept as the earlier 300 bit/s U1106[1]

Channel arrangement

Two alternative maximum data rates are allowed by V23, 600 bit/s with tone frequencies of 1300 and 1700 Hz, and 1200 bit/s with tone frequencies of 1300 and 2100 Hz. Provision is made for a low speed return channel of 150 bit/s maximum rate using tones of 390 and 450 Hz. The position of these channels in the telephone bandwidth is depicted in figure 1. With this channel arrangement it is possible to transmit data at one of the higher speeds and to receive low speed control data simultaneously on a two wire circuit such as a public switched telephone network (p.s.t.n.) connection. For example on the Post Office Prestel service[2] a modem of this type may be used to transmit a 'page' of information at 1200 bit/s in response to a command from a viewer sent at 75 bit/s via the modem attached to the television

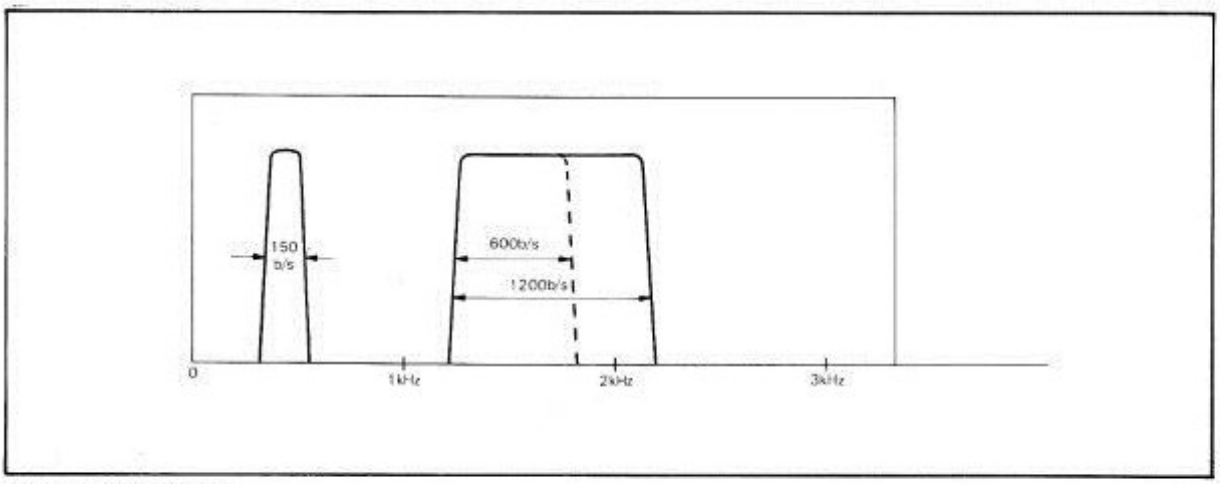

Fig. 1. Channel spectrum

receiver. If a four-wire leased circuit is available, data can be transmitted simultaneously in both directions. The U1107 is fitted with the requisite number of transmit and receive circuits to enable one of four alternative modes of operation to be selected in the field. Table 1 shows the options.

MODE	TRANSMIT RATE (bit/s)	RECEIVE RATE (bit/s)	LINE
1	600/1200	150	2W
2	150	600/1200	2W
3	600/1200	600/1200	4W
4	600/1200	600/1200	2W
	or 150	or 150	

Table 1: In Mode 4 the transmission rate is selected by the appropriate interchange circuits from the data terminal equipment (d.t.e.).

Typical configuration

(i) Public switched telephone network (p.s.t.n.)

A typical data communication network using the p.s.t.n. as a link between a computer centre and its remote terminals is shown in figure 2. The interchange circuits between the modem and the communications controller at the instation are defined in CCITT Recommendation V24[3]. These control the exchange of data, the connection of the modem to line and indicate the status of the modem and its received signal. To initiate data transmission the operator at the remote terminal dials the telephone number of the computer centre where a modem not in service will detect the ringing and commence an automatic answering sequence. This entails signalling the communications controller across the V24 interface and transmitting an answer tone to the calling terminal. On receipt of this tone the d.t.e. is signalled that data transmission may commence. Connection and disconnection to line may be either controlled manually from the telephone or by signals from the d.t.e.

(ii) Private circuit (p.c.)

When a direct telephone line connects the remote terminals to the computer, dialling is unnecessary and the modems may be permanently connected to line. Alternatively the remote user may need a telephone for voice communication and also require means of signalling to the computer centre. These facilities can be provided by the optional Line Unit interposed between the modem and the line as shown in figure 3 and described in an earlier article[2].

The modem

It is a requirement of the Post Office specification that all the functional circuits of the modem, i.e. modulators, demodulators, control circuits and line interfaces, be contained within a 1.6 in wide, 62 type module. This degree of circuit density implied extensive use of large scale integrated (l.s.i.) circuit techniques and miniature components. The final form of the module is shown in figure 4 and can be seen to comprise the principal printed circuit card with integral edge connector and a sub-board mounted on pillars above the main board.

The block schematic diagram, figure 5, shows the arrangement of the main functional circuits and their switching to achieve the four modes of operation given in Table 1, and the alternative configuration shown in figures 2 and 3.

As with the U1106 the greatest reduction in volume compared to earlier designs has been achieved by designing all the control circuits and the modulator in digital form and implementing them as l.s.i. circuits. The control circuit takes inputs from mode control links, d.t.e. interchange circuits, line signal detection, telephone switches

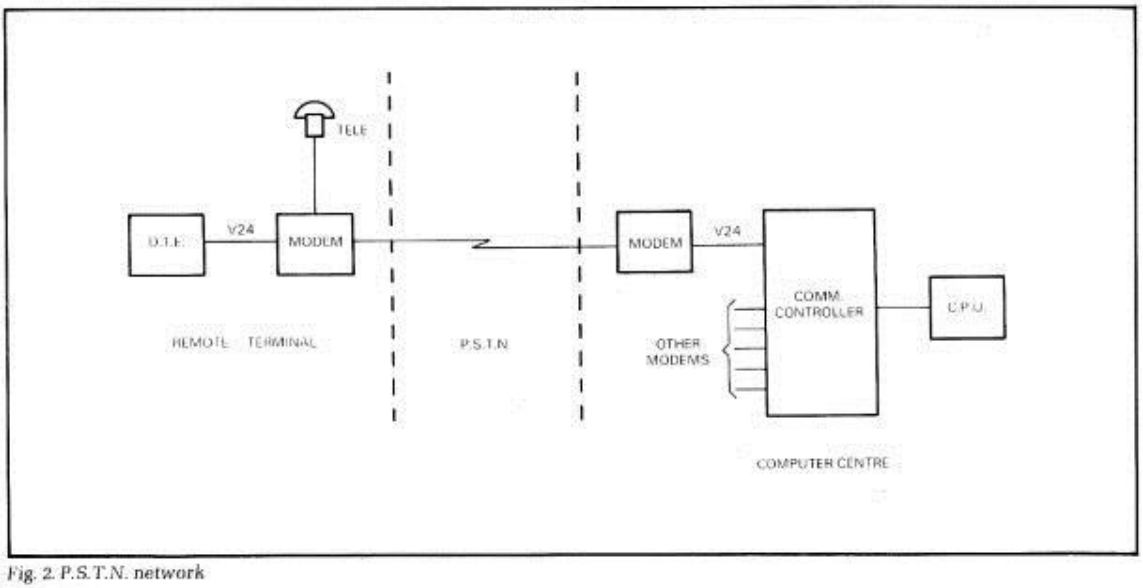

Fig. 2. P.S.T.N. network

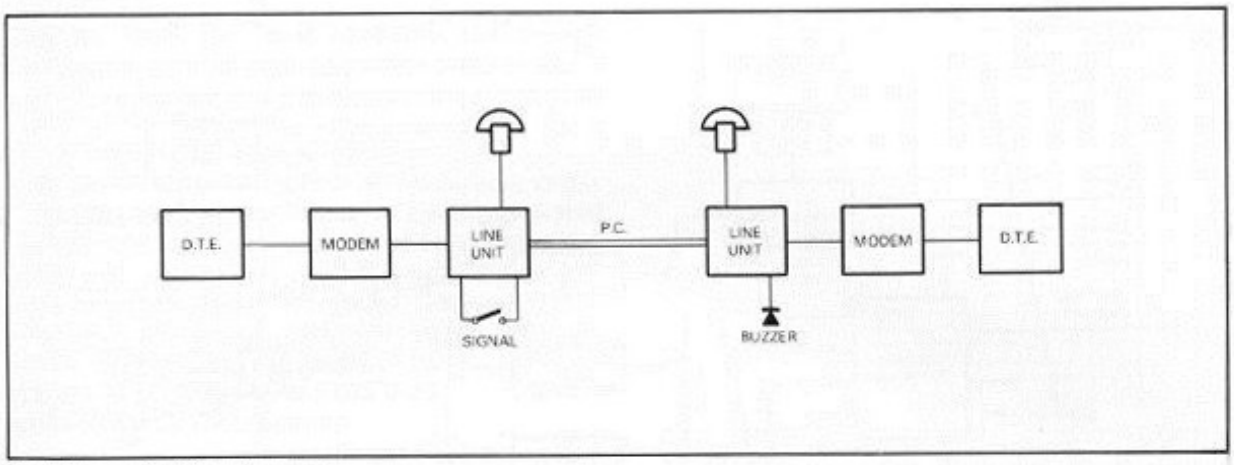

Fig. 3. Private circuit arrangement

and the loop test switch to generate the signals for the selection of modulator frequencies, channel filters and telephone line. Detection of ringing, initiates one of two alternative automatic answer sequences. For inland calls the modem is connected to line. Binary 1 is signalled back to the calling modem and the Calling Indicator signalled to the d.t.e. For international calls the procedure laid down in CCITT Recommendation V25 is adopted and includes a burst of 2100 Hz tone for the disablement of echo suppression on the circuit. These and other handshake routines demand accurate time delays between stimulus and response. These are achieved by division from a 100kHz oscillator on the integrated circuit. This has the added advantage that in production only the oscillator frequency need be set for all the dependent time delays to be correct.

The digital l.s.i. modulator generates the five alternative tone frequencies by division from a high frequency crystal oscillator. Careful choice of fixed and variable divide ratios gives frequencies within 1 Hz of nominal and minimizes any distortion introduced by the division process.

Three channel filters are needed to serve the four operating modes, those for the high speed

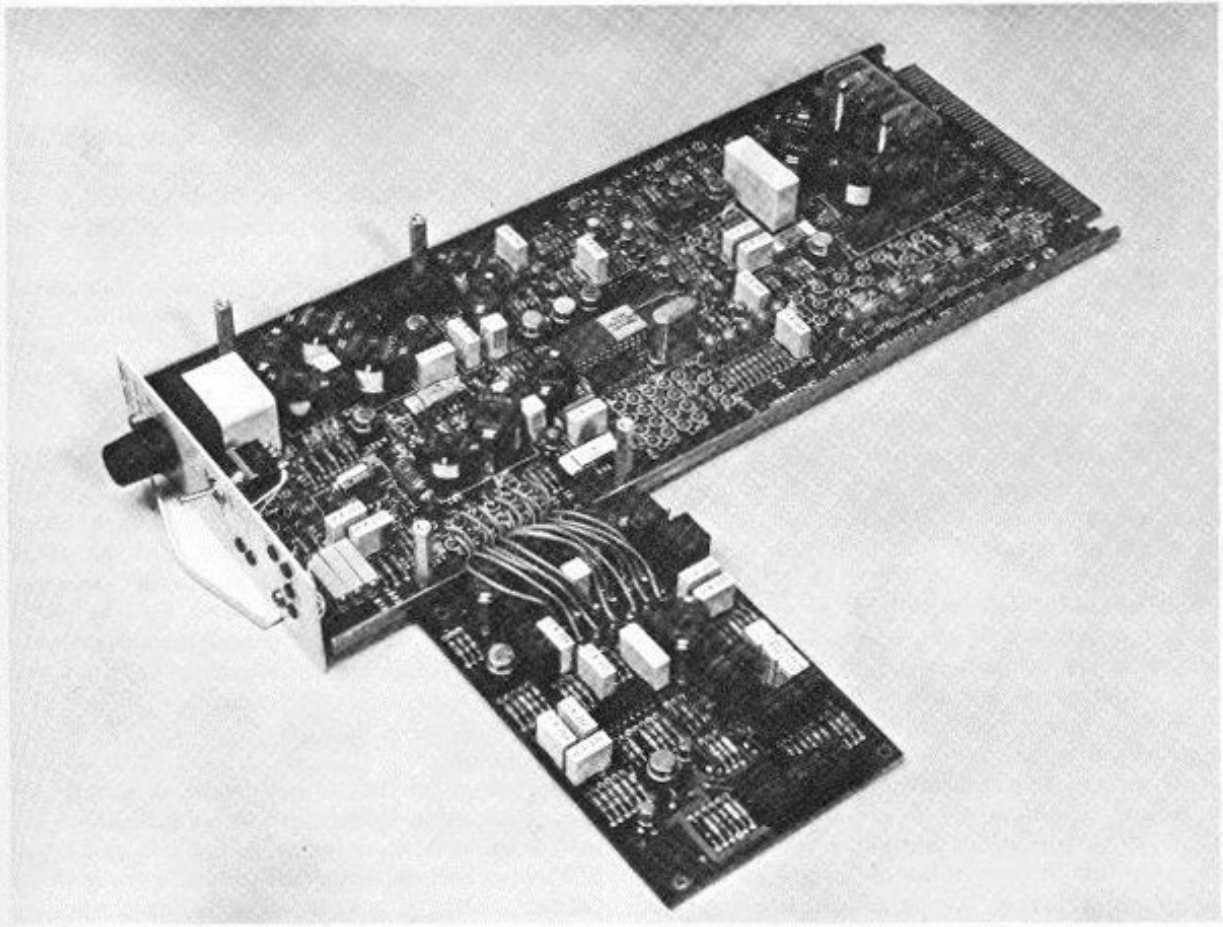

Fig. 4. Final form of the module

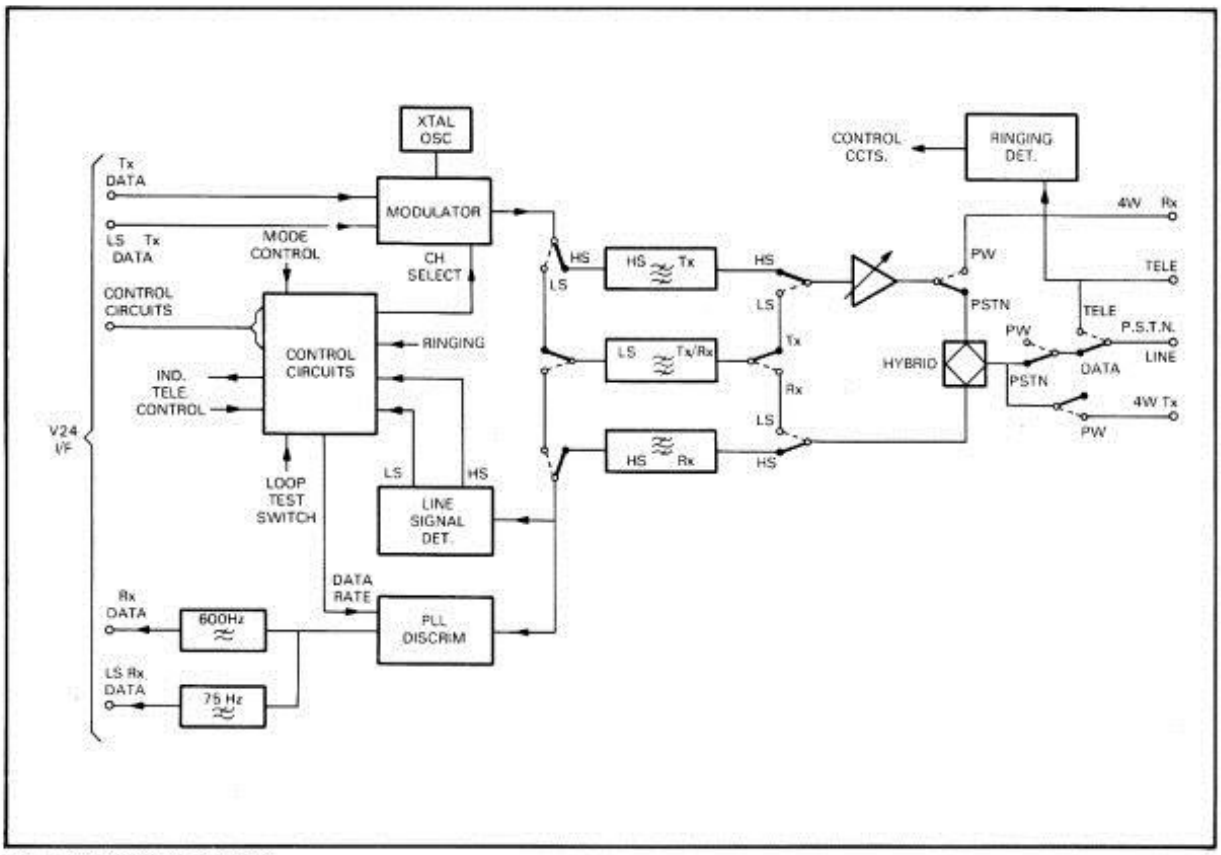

Fig. 5. Modem block diagram

transmit and receive paths, which are separate as they can operate simultaneously in Mode 3, and a low channel filter which can be switched between transmit and receive paths as required. Of the three the high speed receive filter is the most critical in both its amplitude and group delay characteristics. Not only has the filter to optimise the channel bandwidth for the modulation frequencies and rates, it must also filter out components of the transmitted low speed channel that are introduced when the line hybrid transformer is connected to a mismatched load. Additionally the worst case p.s.t.n. line can introduce differential group delay across the pass band which increases isochronous distortion of the data signal output. The resultant design struck a compromise between these conflicting factors, being a three stage filter comprising two passive LC sections and and active group delay equalizer section with a buffer between them.

The phase-locked loop detector represents a further application of l.s.i. techniques. The SL652 integrated circuit contains all the elements of a p.l.l. circuit plus a limiter. It has the facility whereby three alternative time constants appropriate to the three maximum data rates can be selected by two control signals. It has a voltage controlled oscillator with a sufficiently low temperature coefficient to remain stable over the operating temperature range of the modem.

Two active, Bessel, low pass filters serve as post-detector filters, one for the high speed channel with a cut-off frequency of 600 Hz, the other for the lower channel cutting off at 75 Hz so eliminating any remaining components of the carrier frequency.

Line signal detection for each channel operates when the level drops below the minimum level of –43dBm. The condition is signalled to the d.t.e. and the received data output is clamped to Binary 1 to avoid receipt of errors data by the d.t.e.

Extensive use is made of linear integrated circuits for the active filters, buffer amplifiers, the level detection, limiters and the V24 interchange circuit line drivers. Packaged as dual or quad units they make a significant contribution to the compactness of the modem.

As figure 5 indicates there are a number of switched options within the modem. The most critical of these are in the signal paths to the channel filters and for these, solid state switches are used which are compact yet provide adequate isolation. Miniature reed relays are used for the other switching functions except connections to line and telephone where multiple contact devices are necessary.

Performance

A telephone network is not designed initially for the transmission of data and so a data modem has to operate satisfactorily in the face of a number of disturbing factors. The amplitude and group delay characteristics of a switched network connection worsen above 2kHz and if the subscriber is some

distance from the local exchange the overall attenuation may be high. Impulsive noise is also a corrupting feature and a clamping circuit has been designed to restrict the errors introduced by a severe impulse to less than two on average.

To prove the performance of the modem under the most adverse conditions it has been tested under worst case combinations of received signal level and transmitted signal level with a 10:1 impedance mismatch. Effects of Gaussian noise, impulsive noise and networks which simulate worst case private and public circuits are then plotted. In all cases error rates are better than the limits of the curves in figure 6.

Test loops

Within a data communication network it is vital that any fault in the system be rapidly diagnosed. To that end, four different test conditions whereby data is looped back from receiver to transmitter have been devised. Figure 7 shows these diagrammatically. A Mode 1 and a Mode 2 (Table 1) modem can be tested by looping the input to the output of the Mode 1 unit and feeding in 150 bit/s data and checking it out at the Mode 2 unit. The check may be done in the opposite direction by the arrangement shown in diagram B. A pair of Mode 3 modems can be checked out at 1200 or 600 bit/s by the arrangement in diagram C. A self check of a Mode 4 modem can be made by inverting the data in the loop back and creating a self-sustaining feed back loop.

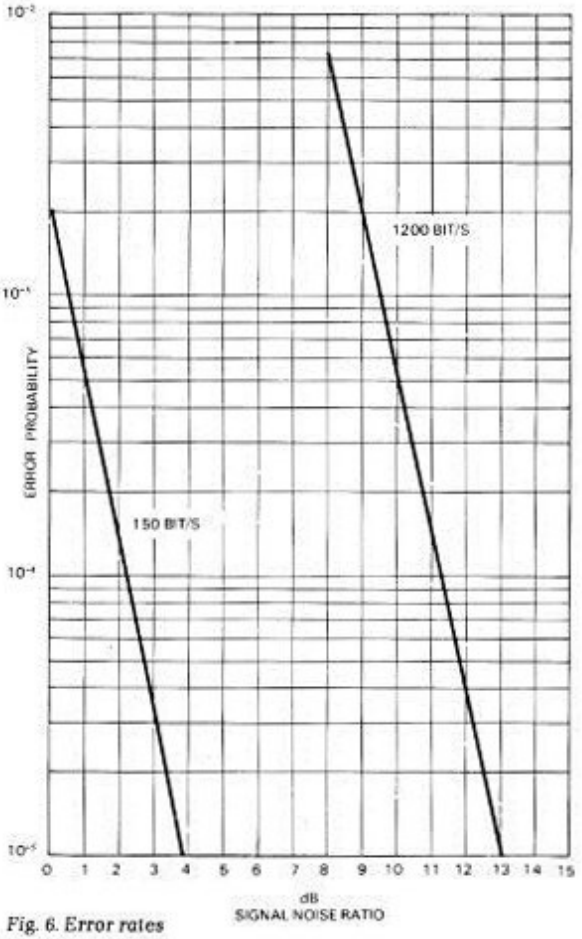

Fig. 6. Error rates

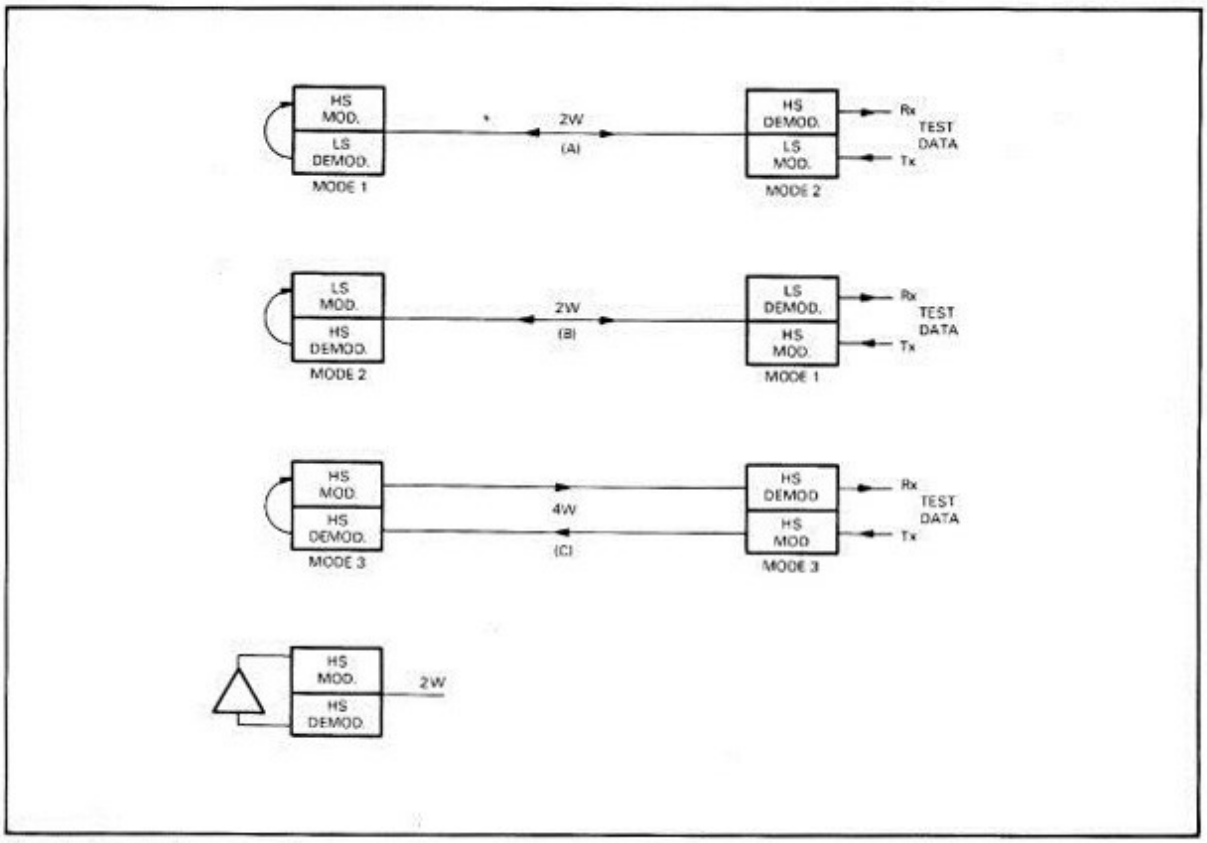

Fig. 7. Test loop modes

These loop conditions are set up by operating a selector switch on the front panel so enabling a maintenance engineer to ascertain rapidly whether a modem is faulty and needs replacement.

Installation

The modem module can be fitted in two alternative housings. For the single, remote terminal, such as shown in figure 2, the module plugs into a low profile case containing an a.c. mains power unit. The mating edge connector is wired to the ISO recommended[4], 25 way connector carrying the V24 interchange circuits to the d.t.e. Another connector provides for the connection of the private wire line unit. Screw terminals within the case are available for the connection of the p.s.t.n. line and telephone. For a multiple installation such as the computer centre depicted in figure 2, the modems can be fitted into rack mounting shelves. For p.s.t.n. 12 modems may be housed on one shelf, for p.w. six modem/line unit pairs can be fitted. Power for a shelf of modems can be supplied by one of two types of power unit designed for the purpose. One is powered by a.c. mains, the other by exchange battery. Both are switching regulator types with high efficiency. This feature together with the 3 watt dissipation of each modem ensures a high packing density within a cabinet without recourse to forced air cooling.

Conclusion

The modem described represents a significant advance in design for this popular speed range. Within one plug-in module are all the facilities required of a p.s.t.n. modem including international or national auto-answering, a low speed return channel and a range of loop testing facilities. With its associated Line Unit, a number of option features including tone or d.c. signalling are available to the private circuit user.

Acknowledgements

The modem described has evolved from a concept created within the Telecommunications Development Department of the British Post Office from their knowledge of user requirements and a belief in what the British Telecommunication industry could achieve. The design was the product of a keen design team at the Writtle Laboratories of Marconi Communication Systems Ltd.

Permission from the Post Office to publish this article is acknowledged.

References

1. W. C. Mills: 'A New Approach to Modem Design', Communication & Broadcasting, Vol. 4, No. 2, pp. 32-39.
2. R. D. Bright: 'Abroad with Prestel'. Post Office Telecommunications Journal Vol. 30, No. 2, pp. 7-9.
3. CCITT (1977) Orange Book Vol. VIII.1 Data transmission over the Telephone Network, I.T.U. Geneva.
4. DOCUMENT ISO/TC97/SC6 No. 315. International Standards Organisation Geneva.

RESUME

Le nouveau modem décrit fonctionne à des débits de 1200 ou 600 bits avec un canal arrière de 150 bit/s conformément à la recommandation V23, du CCITT.

Destiné au B.P.O. ce modem comporte plusieurs variantes de modes et de configurations d'exploitation possibles dans le cadre de réseaux publics ou privés.

Grâce à l'utilisation intensive de circuits intégrés massifs numériques et linéaires, il est possible de grouper en un seul module enfichable le modem de réseau public à faculté compléte. Ce modem peut être utilisé en tant qu'unité posé sur une table de travail ou montée sur des étagères pour installations multiples.

Les performances ont été mesurées dans des conditions représentant les cas les plus défavorables possibles dans les circuits téléphoniques.

ZUSAMMENFASSUNG

Das hier beschriebene neue Modem arbeitet mit 1200 oder 600 Bit/s, Rückkanal 150 Bit/s, und entspricht der CCITT-Empfehlung V23.

Dieses für die britische Postbehörde entwickelte Modem bietet die Wahl zwischen mehreren Betriebsweisen und Konfigurationen und kann mit öffentlichen oder privaten Netzen eingesetzt werden.

Durch weitgehende Verwendung digitaler und linearer integrierter Schaltungen ist es gelungen, ein vollständig ausgestattetes Modem für ein öffentliches Fernsprechnetz in nur einer Einsteckeinheit unterzubringen. Diese Einheit kann auf einem Tisch aufgestellt oder bei Mehrfachinstallationen in einem Gestell montiert werden.

Die Leistung wurde unter den schwierigsten Bedingungen gemessen, die in Verbindung mit Fernsprechleitungen auftreten.

SUMARIO

El nuevo modema que se describe opera a 1200 ó 600 bitios/s con un canal regresivo de 150 bitios/s conforme a la recomendación V23 de CCITT.

Diseñado para uso de los Correso Británicos, el modema posee varias modalidades y configuraciones alternativas en que se puede utilizar en públicas o privadas.

Utilizando ampliamente circuitos numéricos y lineales integrados en gran escala ha sido posible contener un modema de facilitades completas y red pública en un solo módulo enchufable. Puede usarse como unidad que se coloca sobre una mesa o que se monta en estantes para instalaciones múltiples.

Se ha medido el rendimiento en condiciones que representan los peores casos que se pueden presentar en los circuitos telefónicos.