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# THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

NIL SINE LABORE

Vol. 59 Part 2

JULY 1966

# A Modem for the Datel 600 Service—Datel Modem No. 1A

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U.D.C. 621.376.3 : 621.394.4 : 681.142

**The Datel 600 Service, which provides for the transmission of binary data signals over telephone circuits, requires a unit to convert the binary d.c. signals to a form that will pass through voice-frequency amplifiers and similar equipment. The facilities provided by this unit, which is known as the Datel Modem No. 1A, are described together with details of the design adopted and the factors influencing the design.**

## INTRODUCTION

THE Datel 600 Service,[1] which was briefly described in an earlier issue of this Journal, provides for the transmission of binary d.c. data signals between widely-separated locations by making use of the public switched telephone network or of private circuits. The d.c. signals must be converted to a form that will readily pass through voice-frequency (v.f.) amplifiers and similar equipment so that they can be transmitted over telephone-type circuits. The unit which carries out this function is referred to as a modem, since it will, generally, contain a modulator to convert the d.c. data signals to v.f. signals for transmission and a demodulator to convert received v.f. signals to d.c. signals. Such equipment has been developed for the Datel 600 Service and is known as the Datel Modem No. 1A. The facilities that this unit provides are given below.

A modem for general purpose use must be able to work over the many types of telephone connexion which may be encountered. It must, therefore, be relatively insensitive to the signal impairment that may be caused by variation of line characteristics, including circuit transmission loss, loss/frequency distortion and group-delay/frequency distortion. In addition, it should be able to accept data for transmission at any rate up to its design maximum, and not impose any restriction on the character code and, hence, on the number of consecutive 0's and 1's that may be used. This latter requirement necessitates the choice of a form of modulation which ensures that the line signal received by the demodulator is unambiguous.

## LIMITATIONS IMPOSED ON MODEM DESIGN BY CHARACTERISTICS OF THE TELEPHONE NETWORK

A modem for general purposes must be suitable for use on connexions established over the public switched telephone network, as well as on private circuits. The characteristics of the latter circuits can be controlled to a large degree, and may generally be made equal to the best found in the public telephone network. Thus, they need not be specially considered in modem design, as the more stringent requirements are those imposed by the public switched telephone network.

A summary of the characteristics of the public switched telephone circuits which affect data transmission are as follows.

(*a*) *Overall Transmission Loss.* Overall loss varies from connexion to connexion and may be as much as 30 db at the reference frequency (800 c/s) on extreme connexions.

(*b*) *Variation of Transmission Loss with Frequency.* The loss/frequency characteristic of an extreme connexion, routed over long trunk and junction circuits which include old-type line plant such as heavily-loaded cables, is shown

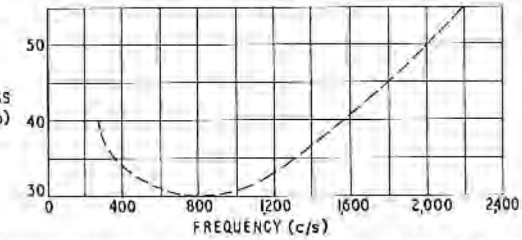


FIG. 1—LOSS/FREQUENCY CHARACTERISTIC OF NOMINAL EXTREME CONNEXION

in Fig. 1. This figure shows that the difference between the loss at 800 c/s and that at 2,000 c/s may be as much as 20 db. When the basic loss of about 30 db at 800 c/s is added, the loss at 2,000 c/s reaches 50 db; this is about the limit for practical purposes and it would not be reasonable on a connexion of this type to extend the usable frequency range any higher. Many connexions will be much better than this, and have a reasonable loss up to 3,000 or 3,400 c/s.

(*c*) *Variation of Group Delay with Frequency.* The variation of group delay with frequency is usually referred to as the group-delay/frequency characteristic and is measured in milliseconds. The group-delay/frequency characteristic of the connexion illustrated in Fig. 1 is shown in Fig. 2. The group delay shown here would not

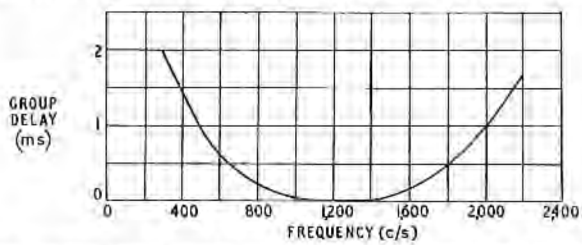


FIG. 2—GROUP-DELAY/FREQUENCY CHARACTERISTIC OF NOMINAL EXTREME CONNEXION

be detectable in speech, but it does have a serious adverse affect on data-transmission line signals. For a practical system working on this type of connexion a change of 1 ms between 1,200 and 2,000 c/s would be the maximum tolerable.

(*d*) *Noise.* The noise on telephone connexions is of two types; background mush, roughly approximating to white noise, which, except on long intercontinental connexions, is of a low order and may be ignored, and impulsive noise due to dial pulses and to switching in exchanges. Impulsive noise tends to vary widely, depending on the age of an exchange and its location. The effects of such noise depend on the power level of the signal transmitted from a modem, and, whilst it is desirable to make the signal-to-noise ratio as great as possible by using a high signal level, the send level must be limited to avoid overloading the telephone line equipment, particularly telephone carrier channels.

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[1]SMITH, N. G. An Introduction to the Post Office Datel Services. *P.O.E.E.J.*, Vol. 59, p. 1, Apr. 1966.

(*e*) *Echoes.* The use of modern telephone transmission techniques, e.g. carrier systems, results in inland circuits in the United Kingdom having short propagation times. Any echoes that may occur on lines used for speech purposes appear as sidetone in the talkers' telephone receiver and, thus, are relatively unimportant. The main affect of echoes on the data-transmission line signals is to produce an interfering signal equivalent to listener echo* at the demodulator, and this tends to reduce the total number of trunk links that can be included in a data call.

(*f*) *In-Band Telephone-Signalling Equipment.* Although it cannot properly be called a line characteristic, the presence of v.f. signalling equipment in trunk lines does impose a limitation on the exploitation of the telephone network. Pure tones within the band to which the signalling receivers are sensitive cannot be tolerated, as their false operation will interfere with the connexion, and, in the extreme case, cause it to be disconnected. Arrangements are included in signalling receivers to prevent false operation due to speech, but due to variations in equipment design it is not possible to make use of this facility except in modern signalling receivers, e.g. those of Signalling System A.C. No. 9. Frequencies from data-transmission modems must not fall within the band 450–900 c/s because adequate guarding against false operation of the trunk-signalling equipment (early type Signalling System A.C. No. 1 and Signalling System A.C. No. 3) is difficult to guarantee without placing further restrictions on the form of line signals from the modems.

From the above it will be seen that data-transmission signals must be confined to those parts of the frequency spectrum below 450 c/s and above 900 c/s, with a minimum upper limit of about 2,000 c/s for some connexions.

## GENERAL-PURPOSE MODEM DESIGN

In considering the desirable design parameters for a general-purpose modem it is clear that, due to the likely variations of level of a received signal, amplitude modulation is unattractive and that frequency or phase modulation would be preferable. There has been considerable discussion of the relative merits of these latter two methods of modulation for this particular application, and arguments can be produced in favour of both. However, for a modem to provide the characteristics suggested earlier, i.e. for it to be a robust, general-purpose equipment capable of transmitting data at any modulation rate up to the design maximum, without restrictions on the code used or the number of consecutive 0 or 1 signals, frequency modulation has been chosen internationally.

The International Telegraph and Telephone Consultative Committee (C.C.I.T.T.) at its Plenary Meeting in June 1964 approved a Recommendation for a general-purpose modem for use on the public switched telephone network; the characteristics for this modem take into account the limitations of telephone lines mentioned above. The C.C.I.T.T. Recommendation is No. V23, and it recommends that a modem for use on the public switched telephone network should include two modes of operation allowing the transmission of data at rates up to 600 or up to 1,200 binary digits/second (bits/second), using frequency modulation. The transmission may be synchronous or asynchronous, and an optional return channel for use at modulation rates up to 75 bits/second is included. The modulation rates and characteristics of the forward data channel are shown in Table 1.

TABLE 1
Characteristic Frequencies Recommended by C.C.I.T.T. for 600/1,200 bits/second Modem

| Mode | Nominal Mean Frequency ($F_0$ c/s) | Binary Symbol 1 ($F_Z$ c/s) | Binary Symbol 0 ($F_A$ c/s) |
|---|---|---|---|
| A1 (up to 600 bits/second) | 1,500 | 1,300 | 1,700 |
| A2 (up to 1,200 bits/second) | 1,700 | 1,300 | 2,100 |

Mode A1 is for use when line conditions prevent the use of Mode A2. The return-channel maximum modulation rate is 75 bits/second, and the characteristic frequencies recommended are: mean, or carrier frequency, $F_0 = 420$ c/s; binary 1, $F_Z = 390$ c/s; binary 0, $F_A = 450$ c/s.

The Recommendation also covers frequency tolerances, power levels and time constants of the carrier detectors.

## CONNEXION OF MODEM TO DATA-TERMINAL EQUIPMENT

The C.C.I.T.T. has drawn up Recommendation No. V24 for the standards of the type and form of signals to be exchanged at an interface between data-processing terminal equipment and data-communications equipment.

This recommendation lists 28 interchange circuits between the data-processing terminal equipment and data-communication equipment. Each circuit is identified by a number and a descriptive name, and it is intended that equipment designers shall select those circuits applicable to the particular system being considered from those listed in the Recommendation.

Also included in the Recommendation are the electrical-signal characteristics in terms of d.c. voltage, and the significance of positive and negative signals.

Those circuits chosen by the British Post Office for use with their Datel Modem No. 1A and the signal characteristics are given in detail in a British Post Office Specification entitled "Specification for Customer's Data Input and Output Devices for use with the Post Office Datel Modem No. 1A".[2]

## CONSTRUCTION OF DATEL MODEM No. 1A AND ASSOCIATED ITEMS

The Datel Modem No. 1A has been developed for use over either the public switched telephone network or private circuits with 2-wire or 4-wire local ends. It operates in conjunction with customers' privately-owned data terminal equipment, and the modems and data terminal equipments together form a data-transmission system between the premises of two customers.

The Datel Modem No. 1A comprises the following units.

(*i*) Data Main Unit No. 1A.
(*ii*) Data Modulator No. 1A.
(*iii*) Data Modulator No. 2A.
(*iv*) Data Demodulator No. 1A.
(*v*) Data Demodulator No. 2A.

The Data Main Unit No. 1A is the basic unit, and is

*Listener echo—interfering reflected signals heard by the listener, not the talker.

[2]Specification for Customer's Data Input and Output Devices for use with Post Office Datel Modem No. 1A. Post Office Engineering Department Specification TG2269A.

constructed in the form of a free-standing metal cabinet, 17$\frac{3}{8}$ in. × 6$\frac{7}{8}$ in. × 12$\frac{1}{8}$ in. Fig. 3 shows this unit with an associated 700-type telephone. The finish is in two-tone grey to match that of the telephone. Access for installation and maintenance purposes is achieved by removing the front and back panels. The body of the unit is covered by a wrap-round cover, which can also be removed when desired, the cover being secured by screws underneath the cabinet which are not normally visible. The Data Main Unit No. 1A consists of the power unit, 2-wire/4-wire termination, line transformers, line-holding coil, Data Modulator No. 1A transmit-filter delay equalizer, relays, and printed-circuit boards for common circuits. Terminal blocks are provided for the termination of the standard telephone and power cords.

The data modulators and demodulators are constructed in the form of plug-in modules, and provision is made in the Data Main Unit No. 1A for insertion of these as required. The modules use one or more printed-circuit boards for mounting the circuit components, and the edges of these boards are located in the main unit by metal guides which ensure correct location with the edge connectors appropriate to each board. The units are protected by transparent plastic covers supported by stand-off pillars attached at the corners of the printed-circuit boards. Correct positioning of the modules is ensured by polarization of the edge connectors and by varying the widths of the plastic covers on the modules. In addition, each module has a handle with the title of the unit inscribed. The modules are held in position by a retaining bar located by screws after the modules have been fitted. Fig. 4 shows a Datel Modem No. 1A with the covers removed and a modulator and demodulator partially inserted in the main unit; the transparent plastic covers have been removed to give a clear photograph, but the pillars for supporting these covers can readily be seen.

Connexion to the modem from the customers' equipment is made via a 25-way plug and socket; the latter can also be seen in Fig. 4. A non-locking press-button key is fitted below this socket to enable the equipment to be tested remotely.

The Datel Modem No. 1A has been designed to comply with C.C.I.T.T. Recommendations V23 and V24, and this is achieved in the following manner.

The Data Modulator No. 1A and Data Demodulator No. 1A form a data, or forward, channel capable of operation at data-signalling rates of up to 1,200 bits/second covered in two ranges: (*a*) up to 600 bits/second, or (*b*) up to 1,200 bits/second. Selection of the range is carried out by a control signal from the customer's equipment, but the actual data-signalling rate will be determined by (*i*) speed of operation of the customer's equipment, and (*ii*) the line characteristics.

The Data Modulator No. 2A and Data Demodulator No. 2A form the supervisory or return channel, operating at data-signalling rates of up to 75 bits/second.

The provision of plug-in modules at any one installation is determined by the

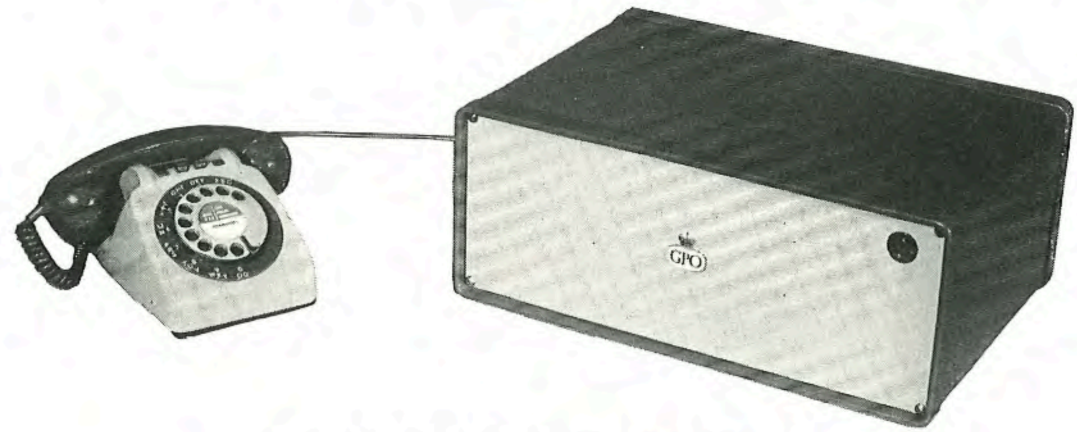



FIG. 3 —DATEL MODEM No. 1A WITH 700-TYPE TELEPHONE

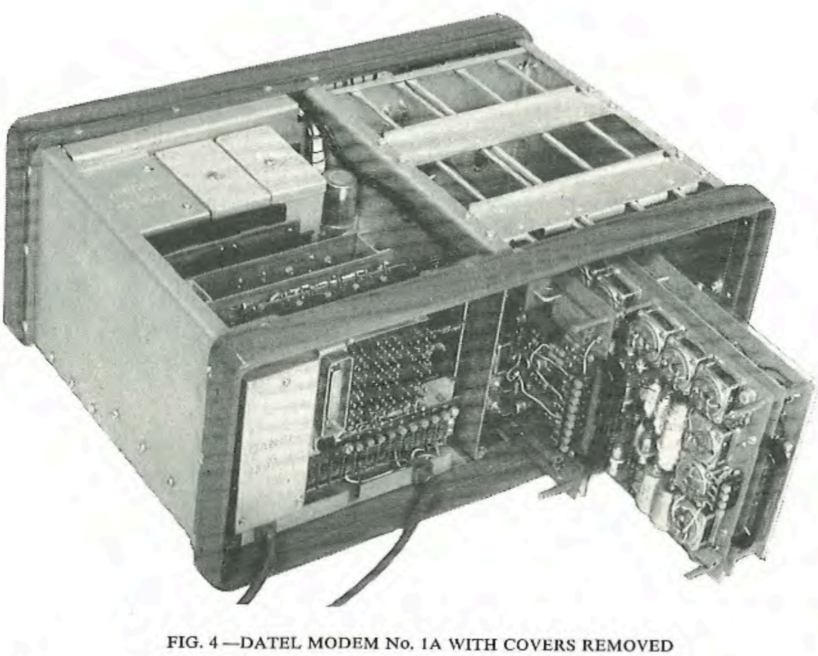


FIG. 4 —DATEL MODEM No. 1A WITH COVERS REMOVED

customer's requirements, and in order to provide flexibility in the facilities offered, five models of the equipment are available, providing the facilities given in Table 2, and are made up by inserting into a Data Main Unit No. 1A the following units.

(*i*) Model 1: Data Modulator No. 1A.
(*ii*) Model 2: Data Demodulator No. 1A.
(*iii*) Model 3: Data Modulator No. 1A and a Data Demodulator No. 2A.
(*iv*) Model 4: Data Modulator No. 2A and a Data Demodulator No. 1A.
(*v*) Model 5: Data Modulator No. 1A and a Data Demodulator No. 1A.

TABLE 2
Facilities Provided by the Five Models of the Equipment

| Facility | Models Required | |
|---|---|---|
| | A End | B End |
| 1: Data in direction A–B only. Note: This facility will not normally be available for use on the public telephone network. | Model 1 | Model 2 |
| 2: Data in direction A–B and simultaneously on return channel B–A | Model 3 | Model 4 |
| 3: Data in direction A–B or alternative direction B–A, but not both ways simultaneously | Model 5 | Model 5 |
| 4: As in 3 but with return channels | Model 3 with Model 4 | Model 3 with Model 4 |
| 5: Data in both directions simultaneously (4-wire private circuits only) | Model 5 | Model 5 |
| 6: As in 5 but with return channels | Model 3 with Model 4 | Model 3 with Model 4 |

The different models and facilities are obtained by inserting wire straps on a tag block at the rear of the case and by fitting the appropriate modulators and demodulators. The tag block also provides facilities for adjusting the transmitted signal level of the modem, for controlling the demodulator, and for changing the equipment impedance presented to the line. The wire straps and cord connexions that are available to produce the various facilities are indicated on the rear cover of the Data Main Unit No. 1A.

### CONTROL OF THE EQUIPMENT BY THE CUSTOMER

The Datel Modem No. 1A is controlled by d.c. signals from the customer's data terminal equipment over interchange circuits. D.C. signals are also sent from the Datel Modem No. 1A to the customer's data terminal equipment over other interchange circuits to indicate the operational state of the modem, data modulators and data demodulators.

The interchange circuits between the Datel Modem No. 1A and the customer's equipment are connected together via a 25-way plug and socket at the rear of the modem. This connexion is known as the interface, and the individual functions of the interchange circuits are listed below.

(*a*) *Transmitted Data.* Connects data input to the Datel Modem No. 1A from the customer's data terminal equipment (used on Models 1, 3 and 5).

(*b*) *Transmitted Supervisory-Channel Data.* Connects supervisory data to the Datel Modem No. 1A from the customer's data terminal equipment (used on a Model 4).

(*c*) *Received Data.* Connects data-channel output to the customer's data terminal equipment (used on Models 2, 4 and 5).

(*d*) *Received Supervisory-Channel Data.* Connects supervisory-channel output to the customer's data terminal equipment (used on Model 3).

(*e*) *Request to Send.* This circuit suppresses the output from the Data Modulator No. 1A until the customer is ready to transmit binary data signals (used on Models 1, 3 and 5).

(*f*) *Transmit Supervisory-Channel Carrier.* This circuit performs a similar function on the Data Modulator No. 2A to that of circuit (*e*) on Data Modulator No. 1A (used on Model 4).

(*g*) *Ready for Sending.* Connects an output signal to the customer's data terminal equipment to indicate the condition of circuit (*e*) in the Datel Modem No. 1A. Facilities are available in the equipment to delay this signal by either 20 ms or 200 ms after the application of the appropriate signal on circuit (*e*) (used on Models 1, 3 and 5).

(*h*) *Supervisory-Channel Ready.* Performs the same function for circuit (*f*) as circuit (*g*) does for circuit (*e*) (used on Model 4).

(*j*) *Data-Set Ready.* Connects an output signal to the customer's data terminal equipment to indicate whether the Datel Modem No. 1A is switched to line or not (used on all Models).

(*k*) *Data-Carrier Detector.* Connects an output signal to the customer's data terminal equipment indicating the presence of a signal at the input of the Data Demodulator No. 1A (used on Model 2, 4 and 5).

(*l*) *Supervisory-Channel-Carrier Detector.* Performs the same function on the Data-Demodulator No. 2A as circuit (*k*) does on Data Demodulator No. 1A (used on Model 3).

(*m*) *Data Signalling-Rate Selector.* Sets the data-modulation-rate range of the forward channel (used on all Models).

(*n*) *Connect Data-Set to Line.* Controls the switching of the Datel Modem No. 1A to and from the line. Alternatively, this control can be carried out by a push-button key on the associated telephone.

The interchange circuits used for control purposes are operated by a nominal $\pm 6$ volts, the $-6$ volts indicating the "OFF" condition and the $+6$ volts the "ON" condition. Those interchange circuits used for data signalling use $+6$ volts for binary 0 and $-6$ volts for binary 1. With $-6$ volts applied to the data signalling-rate selector circuit, the equipment is in the 600 bits/second mode, and is operated to the 1,200 bits/second mode when $+6$ volts is applied. These are nominal voltages, but the circuits are so designed that they will operate satisfactorily over the range $-3$ to $-9$ volts and $+3$ to $+9$ volts.

### CIRCUIT DESCRIPTION OF THE 600/1,200-BAUD MODEM

The equipment employs a frequency-modulation transmission system using the characteristic frequencies detailed in Table 1.

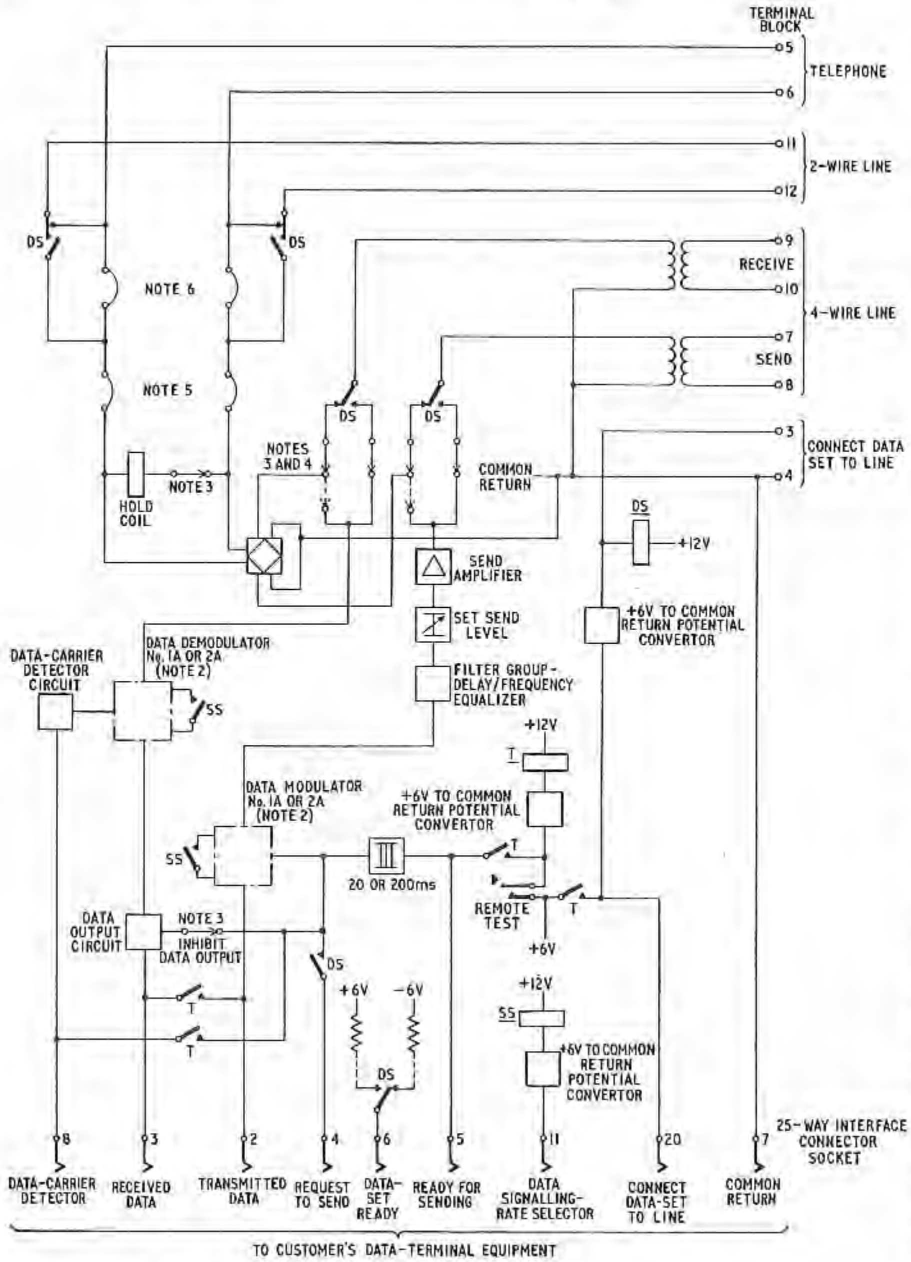
The equipment is operated from an a.c. mains supply, and the mains power unit within the main unit is adjustable in 10-volt steps to enable the equipment to work over the range 190–260 volts. The power unit provides six d.c. supplies: five are used to operate the circuits within the equipment, and the sixth provides 4·5 volts d.c. for use with an associated local-battery-type telephone, required on certain types of private circuits.

A simplified schematic diagram of the equipment is shown in Fig. 5. The following description assumes that the equipment has been wired for 4-wire working, and that a Data Modulator No. 1A and a Data Demodulator No. 1A have been inserted in the case, i.e. the modem is a Model 5.

In the idle condition the telephone will be connected to the 4-wire line via test links on the 2-wire side of the 2-wire/4-wire termination, with the send and receive lines extended to the termination via the line transformers, DS relay contacts normal and the 4-wire telephone straps. The d.c. signalling path is taken from the centre points of the line transformers to the termination in the conventional manner.

In the idle condition the d.c. signals listed in Table 3 will be present at the 25-way interface connector.

When the customer is ready to transmit data, voice communication is established between the two terminals, and then the modem is switched to line by applying a +6-volt signal from the customer's data-terminal equipment to the connect-data-set-to-line circuit in the modem, so operating relay DS. This extends the transmit and receive lines through to the modulator and demodulator, respectively, via the DS relay contacts, disconnecting the telephone from the line in the process.




Notes:
1. All circuit units are connected by unbalanced pairs on the equipment side of the 2-wire/4-wire termination and the line transformers. In the diagram only the non-earthy lead is shown.
2. Interchangeable plug-in modules.
3. Wire straps.
4. Straps shown thus → are inserted for a 4-wire line, and are shown thus- - -→ for a 2-wire line.
5. These links are removed for a local-loop test (with Model 5 only).
6. These links are inserted for a local-loop test and for a 4-wire line. The links are removed for a 2-wire line.

FIG. 5—SIMPLIFIED BLOCK SCHEMATIC DIAGRAM OF DATEL MODEM No. 1A

*Transmission of Data*

When data is ready to be sent a +6-volt signal is applied to the request-to-send circuit (see Note 1 of Table 3) from the customer's data-terminal equipment, causing (*a*) the ready-for-sending circuit to change the signal sent back to the customer's data-terminal equipment from −6 volts to +6 volts after a delay of 20 or 200 ms, which is predetermined on setting up the equipment by a wire strap on the tag block, and (*b*) the removal of an inhibit condition on the modulator output allowing carrier frequency to be transmitted to line through the group-delay/frequency equalizer, the attenuator and send amplifier. The attenuator is adjustable in 2 db steps by wire straps on the rear tag block. The frequency of the carrier will be dependent on the signals on the transmitted-data circuit and the data signalling-rate selector circuit, as indicated in Table 4.

With an OFF signal applied to the data signalling-rate selector circuit,

TABLE 3

Idle-Condition D.C. Signals at the 25-Way Interface Socket

| Interchange Circuit | Signal at Interface Socket | Signal Source |
|---|---|---|
| Request to send | − 6 volts | Customer's equipment (see Note 1) |
| Ready for sending | − 6 volts | Modem |
| Data-set ready | − 6 volts | Modem |
| Data-carrier detector | − 6 volts | Modem |
| Data Signalling-rate selector | ± 6 volts | Customer's equipment (see Note 2) |
| Connect data-set to line | − 6 volts | Customer's equipment (see Note 3) |

*Note* 1. The operation of the request-to-send circuit has been designed to respond either to −6 volts or to a disconnexion for the OFF condition, and to +6 volts for the ON condition. Since, in the idle condition, the input to the request-to-send circuit is disconnected at a DS contact, in practice the input voltage could be either +6 or −6 volts.
*Note* 2. This signal depends on the customer's requirements, i.e. whether he wishes to operate the equipment in its 600 bits/second or 1,200 bits/second mode, line conditions permitting.
*Note* 3. As previously mentioned this interchange circuit can be operated in one of two ways:
(*i*) by ±6 volts on the interchange circuit, or
(*ii*) by push-button key on the customer's telephone.

TABLE 4

Equivalence of Transmitted-Data Potential and Frequency Transmitted

| Potential on Transmitted-Data Circuit (volts) | Data Signalling-Rate Selector Circuit (volts) | Output Frequency (c/s) |
|---|---|---|
| −6 | −6 | 1,300 |
| +6 | −6 | 1,700 |
| −6 | +6 | 1,300 |
| +6 | +6 | 2,100 |

relay SS is unoperated and holds both modulator and demodulator in the 600 bits/second mode. With a +6-volt ON condition applied, the equipment is switched to the 1,200 bits/second mode.

*Reception of Data*

With no line signal incoming to the Datel Modem No. 1A the d.c. output signal on the received-data circuit is predetermined, when setting up the equipment, to binary 1 or 0 by a wire strap on the tag block. With the carrier-detector circuit in its idle state, an OFF signal will be returned to the customer's terminal-equipment via the data-carrier-detector interchange circuit. When a line signal is received, it will be applied to the Data Demodulator No. 1A and the signal on the received-data circuit for a given frequency will correspond to that shown in Table 3 for the transmitted-data circuit.

The carrier-detector circuit is operated by the received line signal and an ON signal is returned to the customer's equipment on the interchange circuit. There is also an additional output from the demodulator which is applied to pins 24 and 25 of the interface socket. The customer can connect these pins to an external loud-speaker-amplifier to monitor incoming data signals; this is known as the audio-monitor output.

When the modem is connected to a 2-wire telephone circuit, the 2-wire straps are inserted on installation, thereby connecting the carrier signals from the send amplifier to the 2-wire line via a 2-wire/4-wire termination, and incoming line signals are fed via the termination to the input of the demodulator. When the modem is in the speech mode, the telephone is connected to line via DS relay contacts, the appropriate test link being removed at the installation stage.

With the straps set for 2-wire operation, an a.c. path is formed between the modulator and demodulator across the 2-wire/4-wire termination. The attenuation of this path will depend on the impedance of the 2-wire line. Consequently, if Model 5 is used, the signals from the Data Modulator No. 1A will be fed to the Data Demodulator No. 1A and the transmitted-data signals will appear on the received-data circuit. This is overcome by using the request-to-send ON signal to clamp the received-data circuit to a predetermined 1 or 0 condition. This is carried out at the installation stage by wire straps on the tag block. If the modem is connected to a telephone line on the public switched telephone network or to a P.B.X. extension, the holding coil shown in Fig. 5 is wired in to provide a d.c. holding loop when the modem is connected to line.

The operation for Models 1 and 2 is the same as for a Model 5, except that transmission of data is possible in one direction only.

Models 3 and 4 operate as for a Model 5, except that the Data Demodulator No. 2A and Data Modulator No. 2A are fitted in each model, respectively, and consequently the line frequencies for the return direction will be 390 c/s for binary 1 and 450 c/s for binary 0. The request-to-send inhibit facility is not required on these models because the receive filters in both demodulators will reject the line signals from the modulators within the same main unit.

When facility 6 of Table 2 is provided it is necessary to connect two Datel Modems No. 1A together in parallel, and, to overcome impedance-matching problems, each equipment may be arranged to have an output impedance of 1,200 ohms instead of its normal 600-ohm impedance. This change is effected by wire straps on the tag block at the time of installation.

## TESTING FACILITIES

Installation and maintenance test facilities are provided in the modem in the following manner.

*Remote-Test Facility*

A remote-test facility is available with the equipment wired as a Model 3 or Model 4. This facility is used by a Datel Test Centre, to ascertain which end of a data transmission link is faulty, before calling out the local maintenance engineer. The procedure is described below.

The Datel Test Centre establishes a connexion over the public switched telephone network to the installation to be tested. This connexion is terminated at the Datel Test Centre on a compatible modem, and the customer is asked to remove the interface plug and operate the non-locking REMOTE TEST switch as soon as tone is heard in the telephone receiver. The tone will be either 1,300 c/s or 1,700 c/s for testing a Model 4, or 390 c/s or 450 c/s for testing a Model 3.

Operation of the REMOTE TEST switch operates relay T, one contact of which operates relay DS, and the modem under test is now connected to the line. The incoming line signal operates the data-carrier-detector circuit, which changes to the ON condition and a potential of +6 volts is connected to the request-to-send circuit via another T-relay contact, so causing the modulator to transmit to line.

The receive-data circuit is connected to the transmitted-data circuit by a third T-relay contact so that the frequency transmitted by the modulator is dependent on the received line frequency, i.e. if a frequency of 1,300 c/s is applied to the Data Demodulator No. 1A a binary 1 condition will be applied to the Data Modulator No. 2A and consequently 390 c/s will be transmitted to line. Relay T is held operated by +6 volts from the ready-for-sending circuit via one of its own contacts, thus allowing test signals to be passed through the demodulator and transmitted back to the test centre by the modulator. This method of testing imposes two restrictions:

(*i*) it is only possible to test at the 600 bits/second setting of the equipment as no control signal is applied to the data signalling-rate selector circuit, and

(*ii*) the equipment can only be tested at a data signalling rate of up to 75 bits/second, as there will always be a return-channel unit in the main unit.

To restore the modem to normal, the line signal is removed, causing the carrier-detector circuit to restore to the OFF condition, thus releasing relay T and reconnecting the telephone to the line.

The remote-test facility cannot be used with a Model 5 equipment at the present time, but a method of enabling this to be done is being developed and will be available on later equipment.

*Test Transmission of Binary* 1 *or Binary* 0 *Signals*

Test switches mounted at the rear of the case connect the appropriate d.c. signals on the various interchange circuits to allow binary 1 or binary 0 signals to be transmitted to line.

*Back-to-Back Test*

The modem can be connected back-to-back, if wired for 2-wire operation, by suitably positioning the appropriate test links (see Fig. 5, Notes 5 and 6). This open-circuits the 2-wire side of the 2-wire/4-wire termination so causing minimum loss between the send and receive sides of the termination and thereby allowing signals from the modulator to appear at the input of the demodulator. This test is only suitable for use at a Model 5 installation; the modulator and demodulator are then operated at the same modulation rates and characteristic frequencies. The facility for inhibiting the received-data circuit by the request-to-send circuit must be disconnected during testing.

The telephone is connected to line and is unaffected by the operation of relay DS, so that incoming telephone calls can be acknowledged.

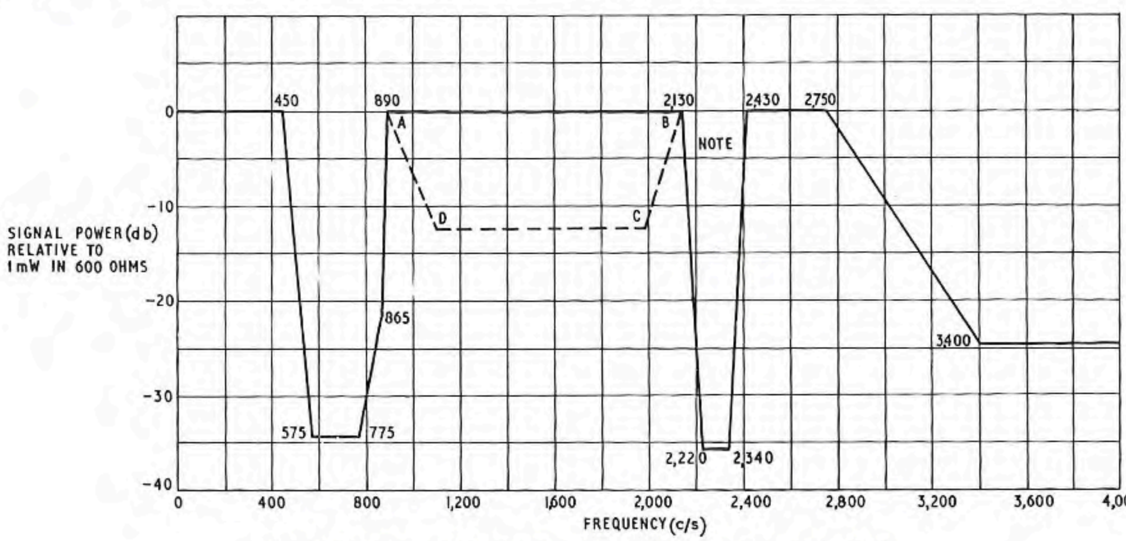
### MODULATORS AND DEMODULATORS

*Data Modulator No.* 1*A*

The Data Modulator No. 1A used in the Datel Modem No. 1A is an astable multivibrator whose frequency can be changed by voltage switching. The circuit is arranged so that with any voltage between −3 and −9 volts on the transmitted-data interchange circuit, 1,300 c/s is generated. With a signal in the range +3 to +9 volts on the input either 1,700 or 2,100 c/s is generated, depending on the mode of operation to which the equipment is switched under the control of a data signalling-rate selector interchange circuit.

The multivibrator output is controlled by the request-to-send circuit so that, with an OFF signal applied, the level of the line signals is reduced to below −50 dbm, and in the ON condition signals are transmitted without attenuation.

The output of the modulator is filtered by a band-pass filter to ensure a sinusoidal line signal and to restrict the level of those component frequencies sent to line that




Note: Signal components up to 0 dbm are permitted within this area if always accompanied by signals in area ABCD.

FIG. 6—MAXIMUM PERMISSIBLE POWER LEVELS OF INDIVIDUAL SIDEBAND COMPONENTS TRANSMITTED TO LINE BY DATEL MODEM No. 1A

would otherwise interfere with trunk-signalling equipment. The maximum level of any side frequencies to avoid false operation of trunk-signalling equipment is shown in Fig. 6. The level of the 750 c/s signal transmitted to line must not exceed −34 dbm, and to achieve this the transmit filter must have an insertion loss at 750 c/s of at least 20 db more than for a frequency in its pass band, otherwise the level of the second side frequency when transmitting at 950 bits/second in the A2 mode (1,200 bits/second) will be of sufficient level to cause false operation of early-type 2 v.f. trunk-signalling equipment.

The output from the filter is passed via a group-delay/frequency equalizer, housed within the Datel Modem No. 1A, before being connected to the modem output circuit. The equalizer has been designed to equalize the group-delay/frequency characteristic of the transmit filter to within ±0·1 ms over the frequency range 1,100–2,300 c/s so that the line signal is reasonably free from distortion.

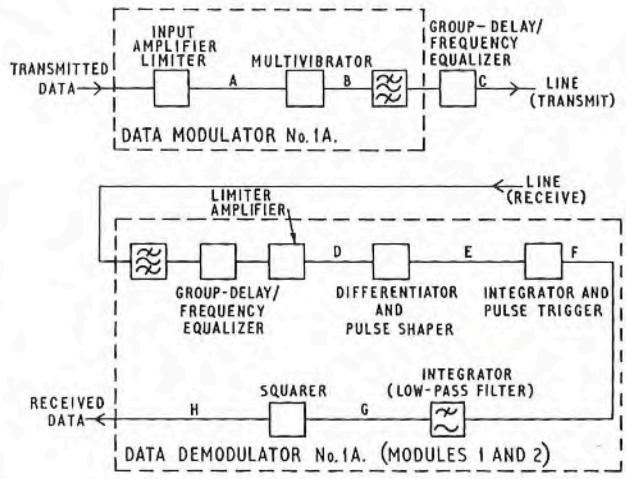
*Data Modulator No. 2A*

The operation of the Data Modulator No. 2A is similar to that of the Data Modulator No. 1A, the only difference being that the characteristic frequencies generated are 390 c/s for binary 1 and 450 c/s for binary 0. The binary 0 frequency remains at 450 c/s irrespective of the setting of the data signalling-rate selector circuit.

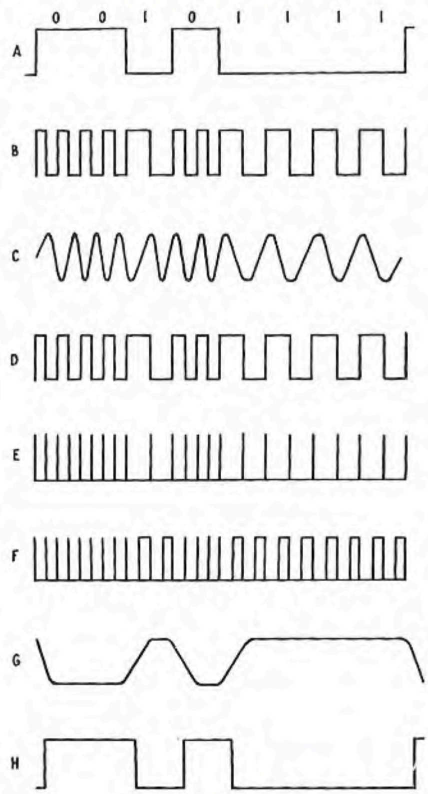
The transmit filter has a low-pass loss/frequency characteristic and has been designed to restrict the level of component frequencies sent to line that might interfere with telephone-signalling equipment and the forward data channel. A group-delay/frequency equalizer is not required for this channel.

*Data Demodulator No. 1A*

In the demodulator a problem occurs in that at 1,200 bits/second a single element will only have a duration of about 833 μs. One cycle at 1,300 c/s has a duration of about 769 μs, thus a single digit of binary 1 would be represented on the line by $1\frac{1}{12}$ cycles of 1,300 c/s signal. Furthermore, it is difficult to design a linear discriminator using conventional tuned-circuit techniques to cover the band of 1,200 c/s or more where the ratio of the bandwidth of the discriminator to carrier-frequency is small. One way of dealing with this problem is to use what is known as a zero-crossing detector, and this is the solution adopted for the forward data channel in the Datel Modem No. 1A. Fig. 7(*a*) is an explanatory diagram of a frequency-modulation modem using this method of demodulation. The waveforms shown in Fig. 7(*b*) are those obtained at the various points indicated by the respective letters in Fig. 7(*a*). Considering the operation of the demodulator, the signal from line (waveform C) is amplified, after passing through the receive filter, by a limiter-amplifier, and the waveform as shown at D is obtained. This waveform is differentiated, and the negative-going spikes are inverted to give a series of narrow positive-going pulses, the interval between the pulses being determined by the frequency of the received signal. This pulse-train, which is shown at E, is fed to an integrating circuit so that each pulse, corresponding to the zero crossing of the line signal, resets the integrating circuit. The output of the integrating circuit will be a series of pulses whose width is a function of the line frequency: this is shown at F. The train of varying-width




(*a*) Block Schematic Diagram of Modem




(*b*) Waveforms at Points A–H

FIG. 7—EXPLANATORY DIAGRAM OF MODEM WITH DEMODULATOR USING ZERO-CROSSING DETECTOR

pulses is then integrated in a low-pass filter to produce an output signal, G, whose d.c. amplitude is proportional to the width of the pulses fed to the filter. The output signal from the low-pass filter is then squared to form the received-data signal, as shown at H.

The band-pass receive filter is provided to reduce the unwanted-signal power to a minimum. This unwanted signal will include the return-channel signal. As has been mentioned, losses of up to about 50 db can be expected on extreme connexions at 2,000 c/s (Fig. 1). The loss at

1,700 c/s on such a circuit would be about 42 db; thus, the level of the received line signal on the data channel could be −42 dbm at the line terminals of the modem. The receive filter must accept this while at the same time rejecting the return channel, which could be at a level of 0 dbm at the line terminals. The discrimination must be sufficient to prevent the return-channel signal affecting the performance of the data-channel demodulator. The effect of the requirements of the send and receive filters, i.e. the send filter to pass 900 c/s but reject 750 c/s by at least 20 db and the receive filter to reject the return channel when there is a difference in level between forward and return channel signals of the order of 45 db, is to cause the filters to have a group-delay/frequency response at the lower end of their pass range which adversely affects the performance of the equipment. The Data Demodulator No. 1A is made up of two units known as Modules 1 and 2. Module 1 is the demodulator section and Module 2 is a group-delay/frequency equalizer to compensate for the filter characteristics. The characteristics of the equalizer are similar to those of the equalizer provided for the Data Modulator No. 1A.

*Data Demodulator No. 2A*

The return-channel Data Demodulator No. 2A, while including a receive filter and limiter-amplifier in the same way as the forward channel, employs a conventional tuned-circuit discriminator. The receive filter has a band-pass loss/frequency characteristic with 3 db points at 350 c/s and 490 c/s.

## PERFORMANCE

The Datel Modem No. 1A has been subjected to controlled tests in the laboratory and to tests on practical connexions as found in the public switched telephone network. The equipment has been available to customers since January 1965, and is being used mainly on connexions via the public switched telephone network and also for data transmission from the United Kingdom to the United States, the method of access in this country to the international trunk being via normal exchange lines.

Initially, comprehensive tests were made from each installation. Space does not permit the tests and results to be described in detail but they showed that satisfactory transmission at 600 bits/second is possible, and in many instances 1,200 bits/second can be achieved on connexions established via the public switched telephone network without the need for any special measures. For private circuits 1,200 bits/second is possible provided the characteristics of the circuit do not exceed those of three carrier links and/or 100 miles of 20 lb/mile cable loaded with 88 mH at intervals of 1·136 miles.

## CONCLUSIONS

The Datel Modem No. 1A is relatively complex equipment to be installed in customer's premises where maintenance facilities are generally severely limited. In addition, when the equipment was developed, little experience was available in the United Kingdom of the performance of the modulation and demodulation techniques adopted for the modem when used in association with circuits having characteristics found on the public telephone switched network. Subsequent experience has shown that the design parameters chosen and the circuit design are capable of giving satisfactory service at 600 bits/second and, under favourable conditions, at 1,200 bits/second, with a low equipment fault-rate.

## ACKNOWLEDGEMENT

The Datel Modem No. 1A described in this article was developed to a British Post Office specification by the Plessey Company, Ltd.