PUB 41405

Bell System

TECHNICAL REFERENCE

DATA SETS 402C AND 402D INTERFACE SPECIFICATION

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Bell System Data Communications

TECHNICAL REFERENCE MANUAL

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Data Sets 402C and 402D Interface Specification

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November 1964

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ENGINEERING DIRECTOR - TRANSMISSION SERVICES

PREFACE

This specification is specifically intended for designers of business machine equipment to be used with Bell System Data Sets 402C and 402D in DATA-PHONE and similar services.

If additional details on the interface and its operation are needed, please contact:

Engineering Director – Transmission Services
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195 Broadway
New York 7, N.Y.

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1. GENERAL

Data Set 402C is a new transmitter incorporating the features of Data Set 402A and new features, repackaging and improved performance. The earlier model transmitter, Data Set 402A, will continue to be available until the presence or lack of a demand can be established for a 402-type transmitter with minimum features. Data Set 402D is a new receiver and supersedes Data Set 402B. The features of Data Set 402B are incorporated in Data Set 402D and several new features and performance improvements are added. The intended field of use of the data sets is as follows:

Data Set	Use
402C	DATA-PHONE Service or privite line service (either alternate voice or data only) where a transmitter is required.
402D	Data only private line service where a receiver is required.
402D with Data Auxiliary Unit 804A	DATA-PHONE Service and alternate voice-data private line service where a receiver only is required.
402C with 402D	DATA-PHONE Service or private line service (either alternate voice or data only) where a transmitter and a receiver are required.

A detailed comparison of the differences between the new and the earlier models of Data Sets 402 is contained in the Appendix.

2. THE SYSTEM

The 402 data sets provide a medium speed, binary, parallel data transmission system for use in DATA-PHONE Service or in private line service. The system will transmit any number of data levels up to 8 at any speed up to 75 characters per second. Timing signals are also transmitted. A non-simultaneous answer-back feature is provided at a maximum speed of 20 two-bit characters per second.

The parallel system offers those advantages arising from the facts that parallel-serial conversion is not required and that a timing output is supplied to the receiving business machine. The relatively low cost of the transmitter makes the system attractive for data gathering applications.

All of the signals interchanged between the business machines and the data sets are in the form of contact closures.

An arrangement is available for using a transmitter and a receiver alternately on the same line.

An optional simultaneous reverse channel is available from the receiver (Data Set 402D) to the transmitter (Data Set 402C) to permit break and circuit assurance features and for supervisory signals that may be used in retransmission requests for error control systems.

Data Set 402D (when associated with a Data Auxiliary Set 804A) and Data Set 402C have an unattended answering feature and are compatible with Bell System Automatic Calling Units.

3. DATA SETS 402C AND 402D AND DATA AUXILIARY UNIT 804A

3.1 PHYSICAL CHARACTERISTICS

3.11 Data Set 402C

Data Set 402C shown in Figure 1, has the following capabilities:

a. Transmit eight-level parallel data and timing information.
b. Receive one of three answer-back states transmitted from the receiving data set. Data transmission must be interrupted when answer-back transmission is desired.
c. Operate as a telephone set for voice communication.
d. Answer incoming calls automatically and transmit an answer tone.
e. Receive a reverse channel signal from the receiving data set during data transmission. (This feature is optional).
f. Operate with automatic calling units.
g. Communicate with a data test center for comprehensive testing of the data set.

The overall dimensions of the data set are 11 inches wide, 5½ inches high, and 14¾ inches deep. The data set will operate satisfactorily over a temperature range of 40° to 120°F and a relative humidity range of 20% to 95%. It weighs 25 pounds.

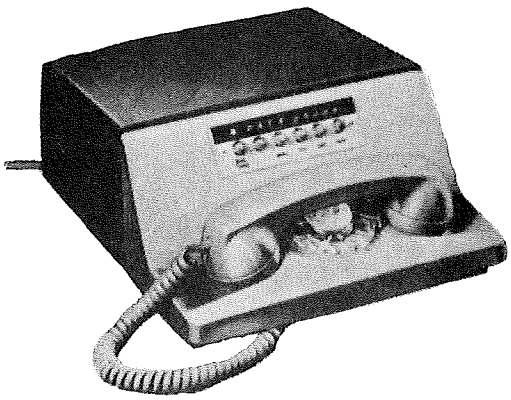


Fig. 1 – Data Set 402C

3.12 Data Set 402D

Data Set 402D, shown in Figure 2, has the following capabilities:

a. Receive eight-level parallel data and timing information.
b. Transmit one of three answer-back states to the transmitting data set. Data transmission must be interrupted when answer-back reception is desired.
c. Transmit a reverse channel signal to the transmitting data set during data transmission. (This feature is optional).

Data Set 402D, when used with Data Auxiliary Set 804A, shown in Figure 2, has the following additional capabilities:

d. Operate as a telephone set for voice communication.
e. Answer incoming calls automatically and transmit an answering tone.
f. Operate with Automatic Calling Units.
g. Communicate with a data test center for comprehensive testing of the data set.

The overall dimensions of the data set are 17½ inches wide, 7¾ inches high, and 11-5/8 inches deep. The data set operates satisfactorily over the same ranges of temperature and humidity as Data Set 402C. It weighs 45 pounds.

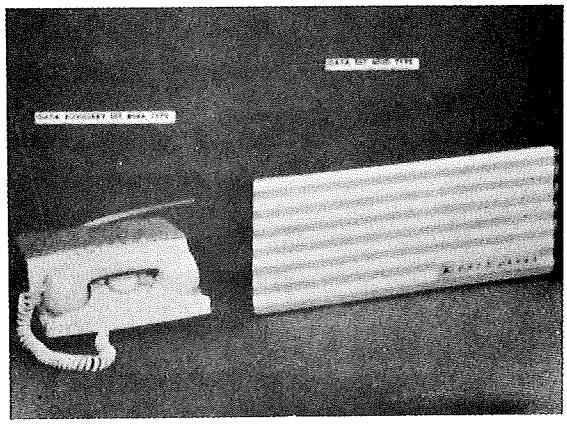


Fig. 2 – Data Set 402D with Data Auxiliary Set 804A

3.13 Data Auxiliary Set 804A1

Data Auxiliary Set 804A1 has the following capabilities, in addition to those listed above with Data Set 402D:

a. Transfer from TALK to DATA.
b. Transfer from DATA to TALK.
c. Match data set impedance to a 600 or 900 ohm line.
d. Protect data set from lightning or other electrical disturbances on the telephone line.
e. Disconnect line automatically (under business machine control) at the end of data transmission.

These features are also available in Data Set 402C as it is an integrated unit.

The overall dimensions of data auxiliary set are 9 inches wide, 5-3/8 inches high, and 9 inches deep. The Data Auxiliary Set 804A operates over the same ranges of temperature and humidity as Data Sets 402C and 402D. It weighs approximately 8 pounds.

3.2 INTERFACE

3.21 Connector

The 25 lead Interface Connectors of Data Sets 402C and 402D are located at the rear of the data sets. The business machine manufacturer must supply a matching plug and hood such as:

DB-19604-432 connector (Cannon or Cinch)
DB-51226-1 hood (Cinch only) or equivalent

The allocation of the pins in the connector is shown in Figures 4 and 5. A detailed discussion of the characteristics of the interface connector is contained in:

Bell System Data Communications
Technical Reference
Interface Connectors

3.22 Lead Definitions – Data Set 402C, Transmitter. See Figure 3

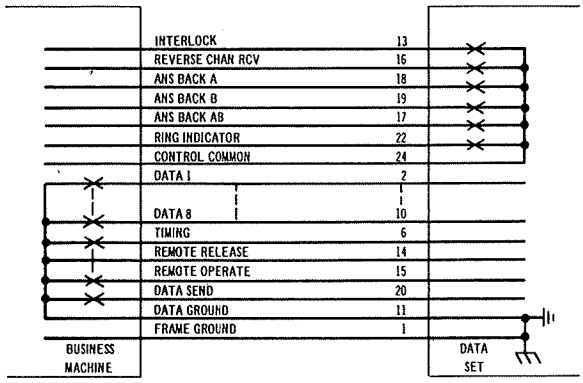


Figure 3 Data Set 402C Interface

(1) *Frame Ground, Lead 1.* This conductor is electrically bonded to the data set frame. It is further connected to external grounds through the power cord.

(2) *Data Ground, Lead 11.* This conductor establishes the common ground reference for all signals from the business machine to the data set. It is connected to the data set frame and to the Frame Ground Lead to minimize the introduction of noise into the data set.

(3) *Data, Leads 2 through 10 – From Business Machine to Data Set.* The business machine must open and close the Data Leads to the Data Ground to transmit. Changes of state of the Data Leads must occur within ± 1.5 milliseconds of a change of state of the timing lead in order for the system to work properly at 75 characters per second. Closures are considered to be marks and opens are considered to be spaces.

(4) *Timing, Lead 6 – From Business Machine to Data Set.* The business machine must change the condition of the timing contact at the beginning of a character and the contact must remain constant for the duration of the character. If the timing channel is marking for one character; it must be spacing for the next. The Timing lead must be closed to the Data Ground lead for mark. This timing input is required because the receiving 402 data set uses the timing transitions to determine when the data channels should be sampled.

(5) *Remote Release, Lead 14 – From Business Machine to Data Set.* The business machine must maintain a closure between the Remote Release lead and the Data Ground lead to permit the data set to be held in the data mode. Business machines should open the Remote Release lead (from Data Ground) to terminate a call.

(6) *Remote Operate, Lead 15 – From Business Machine to Data Set.* The business machine must hold a closure between the Remote Operate lead and the Data Ground lead to permit the data set to answer calls unattended.

(7) *Data Send, Lead 20 – From Business Machine to Data Set.* The business machine must close the Data Send lead to the Data Ground lead to permit transmission of data. The business machine must open the Data Send lead from the Data Ground lead to permit Answer-Back signals to be received.

(8) *Control Common, Lead 24.* Control Common is the lead to which all leads signaling from the data set to the business machine are closed. It is not grounded in the data set, but may be grounded in the business machine, if so desired.

(9) *Interlock, Lead 13 – From Data Set to Business Machine.* The data set closes the Interlock lead to the Control Common lead to indicate that it is in the data mode (prepared to transmit data or receive answer-back or reverse channel signals), is connected to a working telephone circuit, and has an operating power supply.

(10) *Ring Indicator, Lead 22 – From Data Set to Business Machine.* The data set closes the Ring Indicator lead to the Control Common lead to indicate that a ringing signal is being received on the telephone line. If the business machine has the Remote Operate lead closed to the Data Ground lead, the Call will be answered approximately 150 milliseconds after the Ring Indicator lead is closed to the Control Common lead. If the business machine is required to prepare some part of its circuitry before answering a Call (such as getting a motor up to stable speed), a number of closures of the Ring Indicator lead can be counted before the call is answered. The Ring Indicator lead closures follow the ringing of the telephone lines which is typically 2 seconds ON and 4 seconds OFF.

(11) *Reverse Channel Receive, Lead 16 – From Data Set to Business Machine.* The data set closes the Reverse Channel Receive lead to the Control Common lead to indicate that Reverse Channel signals are being received. The Reverse Channel Receiver is an option in the data set and, therefore, this lead is only provided on those sets containing the Reverse Channel option.

(12) *Answer Back, Leads 17-19 – From Data Set to Business Machine.* The data set closes the appropriate Answer Back lead to the Control Common lead when answer back signals are being received. Only one answer back lead will be closed at any given time.

3.23 Lead Definitions – Data Set 402D, Receiver See Figure 4 – It should be noted that some of the logic for the leads in the interface of data set 402D is derived from an associated data auxiliary set.

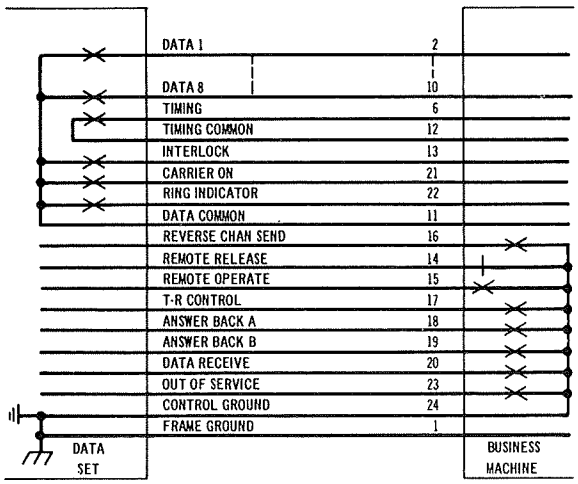


Figure 4 Data Set 402D Interface

(1) *Frame Ground, Lead 1.* This conductor is electrically bonded to the data set frame. It is further connected to external grounds through the power cord.

(2) *Control Ground, Lead 24.* This conductor establishes the common ground reference for all signals from the business machine to the data set. It is connected to the data set frame and to the Frame Ground lead to minimize the introduction of noise into the data set.

(3) *T-R Control, Lead 17 – From Business Machine to Data Set.* In applications including both a transmitter and a receiver on the same loop, the receiver will be connected to the line (for either data reception, answer back transmission, or reverse channel transmission) when the business machine closes the T-R control lead to the Control Ground lead. The transmitter will be connected to the line (for either data transmission, answer back reception, or reverse channel reception) when the business machine opens the T-R control lead from the Control Ground lead.

(4) *Data Receive, Lead 20 – From Business Machine to Data Set.* The business machine must close the Data Receive lead to the Control Ground lead to permit reception of data. The business machine must open the Data Receive lead from the Control Ground lead to permit transmission of answer back signals.

(5) *Answer Back, Leads 18 and 19 – From Business Machine to Data Set.* The business machine must close the answer back A lead (18) to the Control Ground lead to transmit answer back A, the Answer Back B lead (19) to the Control Ground lead to transmit Answer Back B and both the Answer Back A and Answer Back B leads to the Control Ground lead to transmit Answer Back AB.

(6) *Reverse Channel Send, Lead 16 – From Business Machine to Data Set.* The business machine must close the Reverse Channel Send lead to the Control Ground lead to transmit a reverse channel signal. The Reverse Channel Transmitter is an option in the data set and therefore, this lead is only provided on those sets containing the Reverse Channel Option.

(7) *Remote Release, Lead 14 – From Business Machine to Data Set.* The business machine must maintain a closure between the Remote Release lead and the Control Ground lead to permit the data set to be held in the data mode. Business machines should open the Remote Release lead (from Control Ground) to terminate a call.

(8) *Remote Operate, Lead 15 – From Business Machine to Data Set.* The business machine must hold a closure between the Remote Operate lead and the Control Ground lead to permit the data set to answer calls unattended.

(9) *Out-of-Service, Lead 23 – From Business Machine to Data Set.* Where data sets are installed on receive only lines (no calls can be originated from these lines) the business machine can make a particular line appear busy by closing the out of service lead to the Control Ground lead.

(10) *Data Common, Lead 11.* Data Common is the lead to which all leads signaling from the data set to the business machine are closed. It is not grounded in the data set, but may be grounded in the business machine, if so desired.

(11) *Data, Leads 2-10 – From Data Set to Business Machine.* The data set closes the Data leads to the Data Common lead for mark and holds them open for space. The condition of the data leads will remain unchanged for the duration of a character. A change in the condition of the data leads will occur prior to the closure of the timing lead.

(12) *Interlock, Lead 13 – From Data Set to Business Machine.* The data set closes the Interlock lead to the Data Common lead to indicate that it is in the data mode (prepared to receive data or transmit answer back or reverse channel signals), is connected to a working telephone circuit, and has an operating power supply.

(13) *Carrier On, Lead 21 – From Data Set to Business Machine.* The data set closes the

Carrier On lead to the Data Common lead when the all Space signal has been received and continues to maintain the closure so long as the data set continues to receive carrier. The data set will open the Carrier On lead from the Data Common lead within 30 milliseconds after carrier is no longer received. Once the Carrier On lead is open from the Data Common lead the All Space signal must be received for the data set to re-operate the Carrier On circuit, Data leads should not be sampled by the business machine until the carrier on lead is closed.

(14) *Ring Indicator, Lead 22 – From Data Set to Business Machine.* The data set closes the Ring Indicator lead to the Data Common lead to indicate that a ringing signal is being received on the telephone line. If the business machine has the Remote Operate lead closed to the Data Ground lead, the call will be answered (but not ready to receive data) approximately 150 milliseconds after the Ring Indicator lead is closed to the Control Common lead. If the business machine is required to prepare some part of its circuitry before answering a call (such as getting a motor up to stable speed), a number of closures of the Ring Indicator lead can be counted before the call is answered. The Ring Indicator lead closures follow the ringing of the telephone lines which is typically 2 seconds ON and 4 seconds OFF.

(15) *Timing Common, Lead 12.* The Timing Common lead is the lead to which the data set closes the Timing lead. It is not grounded in the data set, but may be grounded in the business machine, if so desired.

(16) *Timing, Lead 6 – From Data Set to Business Machine.* The data set closes the Timing lead to the Timing Common lead for approximately 5 milliseconds at the beginning of each character. Business machines should be designed to overlook spurious timing transitions that may occur on changes of mode, loss of carrier, or various other times by blinding the business machine receiver against all data signals until the carrier on indication is given. Business machines should also be designed to sample the data leads during the timing closures. Leading or lagging edge is considered part of the timing closure.

3.24 Electrical Characteristics of Data and Timing Leads

The closure generating circuitry used in signals from the data sets to the business machine is capable of closing 100 milliamperes (with capacitive surges of up to 500 milliamperes) at up to 50 volts and is protected by 470 ohm –0.13 microfarad networks.

The circuitry used to signal from the business machine to the data set should be capable of closing a dry circuit, have less than 20 ohms resistance when closed, have greater than 300K ohms resistance when open, have 300 ± 100 picofarads capacitance between it and the Data Ground (402C) or Control Ground (402D) lead when all other leads are closed to the ground lead, have no greater than ½ millisecond chatter, and have no contact protection (capacitance would detune the transmitter oscillators).

The Data leads of Data Set 402C have an ac open circuit voltage of 6 volts peak, a peak ac current of 300 microamperes, and a blocking capacitor.

3.25 Electronic Interface for Data and Timing Leads

The interface arrangement of Data Set 402 transmitters was designed with electromechanical business machine contacts in mind but, transistorized circuitry can be used to successfully drive the data set transmitter. A typical circuit arrangement is shown in Figure 5. Using this circuit, for a Mark condition the business machine would hold a voltage on point A of $.2 \times 10^{-3} R_B$ volts. For Space condition a voltage equal or more negative than –6 volts would be held at point A. In the Mark condition the collector-emitter resistance should be less than 20 ohms. In the Space condition the collector-emitter sistance should be greater than 300K ohms.

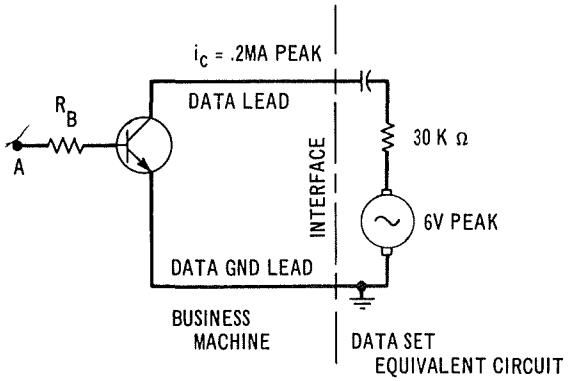


Fig. 5 – Transistorized interface for Business Machines Working with Data Sets 402C (Data and Timing Leads)

3.26 Electrical Characteristics of Leads Other Than Data and Timing

The interface control leads of the data sets generally employ relay contacts for functions from the data set to the business machine. The contacts have the same rating as described

TABLE: Data Set Input Characteristics for Control Function Leads from Business Machine to Data Set.

Lead	Polarity of 18 vdc	Relay Coil Protection RC	Relay Coil Protection Diode	Resistance ohms	Approx. Induct Henrys
Data Set 402C					
Remote Release	+	✓		590	.7
Remote Operate	+	✓		590	.7
Data Send	+		✓	1380	.3
Data Set 402D (w/804A or 402C)					
Remote Operate	+	✓		590	.7
Remote Release	+	✓		590	.7
T-R Control	–	✓		671	5.
Answerback A, B	–		✓	1295	.2
Data Receive	+	✓		6000	5.
Out-of-Service	+	✓		590	.7
Reverse Channel Send*	+	N/A		2370	N/A

*This is a resistive transistor input circuit.

in the first paragraph under part 4.23. The control functions from the business machine to the data set generally operate relay circuitry which draws currents of 100 milliamperes or less. The relay coils are protected against inductive transients by either RC networks or diodes.

3.3 SEQUENCE OF MANIPULATIONS FOR DATA COMMUNICATION

3.31 Establishing A DATA-PHONE Service Call

If a call is to be placed and answered manually it is established by the operators in the same way as any ordinary telephone call. Information about the procedure to be used when dialing a call with an Automatic Calling Unit is contained in the material referred to in Part 3 of the Appendix. If the call is to be answered automatically the RING INDICATOR lead will be turned ON for a period of approximately 2.0 seconds for each ring of the telephone line (typically, once per six seconds) the Ring Indicator lead follows the rings of the telephone line to permit the answering data terminal to prepare itself, (such as getting a motor up to a stable speed) if necessary, before it answers the call by closing Remote operate to either Control Ground (402D) or Data Ground (402C). When Remote Release is grounded the call will be answered, a recognition and disabling signal will be transmitted, and Interlock will be closed to Data Common (402D) or Control Common (402C). If the answering station is an unattended transmitter and the transmitting business machine is arranged so that it will not transmit until it receives a particular signal (say answer-back AB) (See Figure 6), the business machine should hold the Data Send lead OFF (to permit answer-back reception). This provides some protection to keep the station from transmitting to unauthorized parties. During this period Answer-back B will be received (because the recognition and disabling tone has the same frequency as Answer-back B) but it should be ignored in anticipation of Answer-back AB. The transmitting station should then bring the Data Send lead ON and transmit all space for a minimum of 200 milliseconds. The 200 milliseconds is based on 125±25 milliseconds to turn undisabled echo suppressors in the proper direction and 40 milliseconds to operate the carrier on circuit. Data transmission can then begin. Once the receiving station has transmitted answer-back AB, it should be prepared to receive all space (thereby operating the Carrier On lead), so that at least 40 milliseconds of that signal will be received. During the all space transmission at least one timing transition should be transmitted to insure that the receiving data set will recognize the first timing transition and thereby deliver the timing signal for the first character of a message. It should be noted that the timing output will generally be delivered to the receiving business machine while the data leads all indicate spacing. Once the Carrier On lead is operated by the all space signal, that signal will remain ON until carrier is turned off.

If reverse channel is to be used in the system, then a two way facility is required, i.e. echo suppressors must be disabled. Echo suppressors are disabled by application of a signal of 2025 cps (generated by data set) to the echo suppressor for a period of 300±50 milliseconds

at a time when there is relatively little signal at other parts of the voiceband frequency spectrum. This requirement is met by the unattended answering sequence mentioned above and by the manual call operation described in Part 6. Echo suppressors will become enabled if there is any period at which there is no signal for as long as 100 milliseconds. In a system employing the reverse channel this last requirement must be met by the business machine terminals. This can be done by insuring that either the reverse channel transmitter or data transmitter is ON at all times after echo suppressors are disabled.

3.32 Turning a DATA-PHONE Service Call Around

Once a call is established and data is being transmitted in one direction it may be desirable to turn the system around (to transmit answerback information from the receiver to the transmitter, or in cases where each station is equipped with both a receiver and a transmitter to transmit data from the end that had been receiving). At the end of a data message it is recommended that an end-of-transmission (EOT) code be transmitted so that the receiving business machine can be blinded against any line transients that may occur when the Data Send lead of the transmitter is opened and prior to the Carrier On lead being opened. All Space signals must always precede the transmission of data in a new direction. The required length of transmission for this signal and also the first answerback character depends on whether or not echo suppressors are disabled. If active echo suppressors can be encountered these signals must last for 200 milliseconds, if not All Space must last for 40 milliseconds and the Answer Back for 25 milliseconds. Turn-around time in DATA-PHONE Service is reflected for three service arrangements in figures 7a, b, c.

3.33 Terminating A DATA-PHONE Service Call

DATA-PHONE Service calls may be terminated automatically by opening the Remote Release lead or manually by pushing the TALK key and hanging up. It is desirable for transmitting stations to send an end-of-transmission signal before terminating the call so that the receiving business machine can be prepared for any transients which may result from removing the data set transmitter from the line.

In some arrangements a switched telephone connection will not be released until the called party hangs up. If a subscriber dials an unattended answering station in one of these situations, the connection will stay up until the business machine releases the call by opening the Remote Release lead. To avoid problems in this area, business machines arranged for unattended answering should be designed to open the Remote Release lead whenever the Interlock lead is closed but Carrier-On (in receiver) or answerback A, B, or AB (in transmitter) is open for a period of 30 seconds and has not been closed for this particular call.

3.34 Unattended Transmit-Receive Stations

Some customer systems may find use of unattended transmit-receive stations attractive. In this case, remote business machines may be arranged to open and close the T-R lead. If, when the T-R lead is closed All Space is received, the station may be locked in the receive mode. If when the T-R lead is open (for example) Answer-back A (Data Send lead also open) is received the station may be locked in the transmit mode by the business machine if desired. Thereby, the calling station may control whether the remote station is a transmitter or reciever.

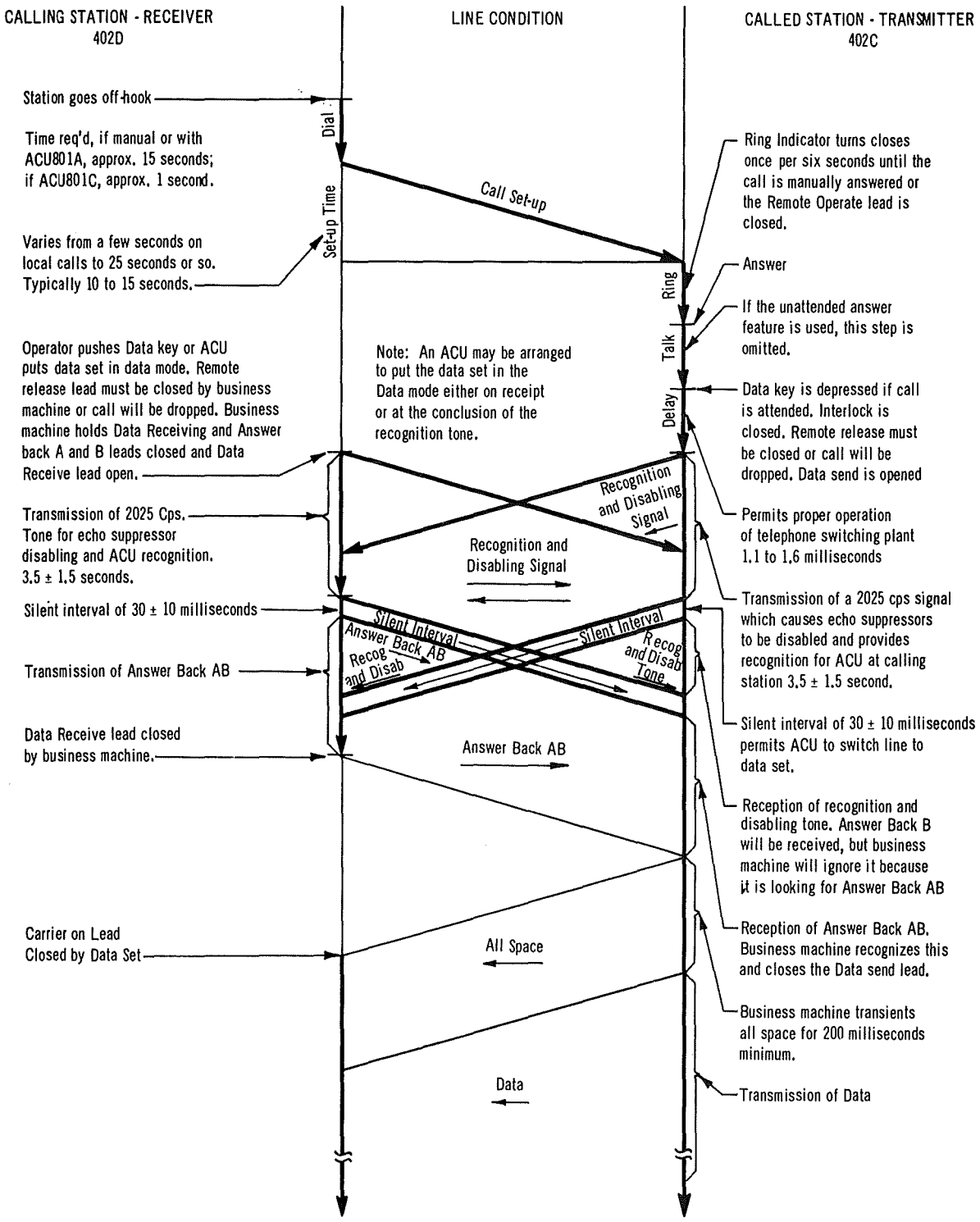
3.35 Point-to-Point Private Line Service

Data Sets 402 operate two wire only. They may be used in one way or half-duplex service on two wire circuits. If a full duplex arrangement is required, it can be provided by connecting the transmitter and receiver to separate sides of a four wire facility. (In which case Answer-back and Reverse Channel can not be used.) There would be no connection between the data sets.

In data only private line service echo suppressors are not useful and, therefore, it is only necessary to transmit 40 milliseconds of the All Space signal and 25 milliseconds of the first answer-back character. If the data sets are used in alternate voice-data service echo suppressors will likely be found on circuits of 1000 miles or more. The telephone company can advise whether or not echo suppressors are used on particular private line circuits. Where they are used, the timing requirements are the same as for DATA-PHONE Service. Data Sets 402 require Schedule 4 private lines with Type 4A conditioning.

3.36 Multi-Point Private Line Service

Data sets can be applied to two-wire data only multi-point private line service only when



Note: It is assumed for the purpose of this example, that the data sets are not equipped for reverse channel and that the called station is a transmitter.

Fig. 6 Establishment of a DATA-PHONE Call

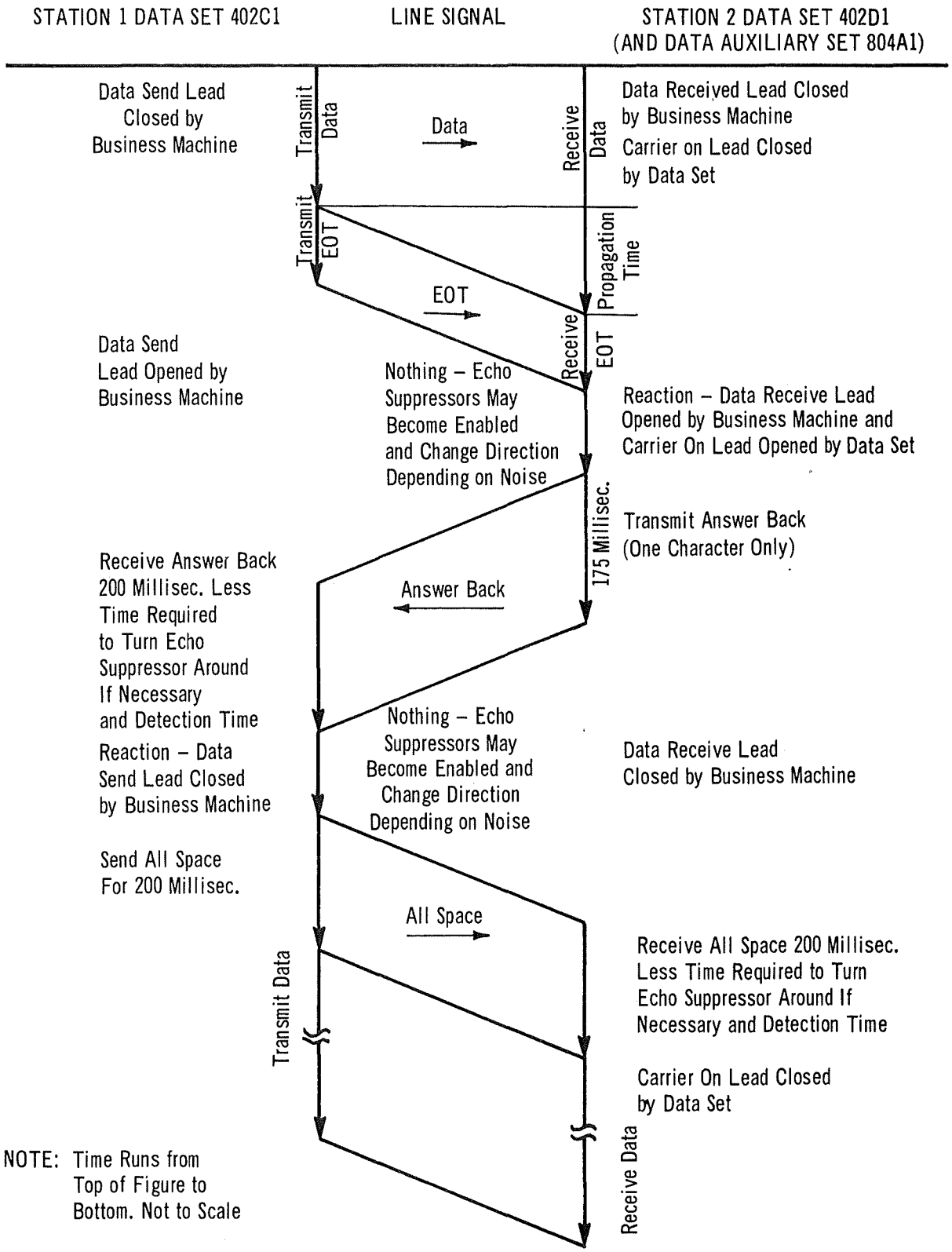


Fig. 7a – Turn-Around in DATA-PHONE Service-Stations not Equipped with Reverse Channel

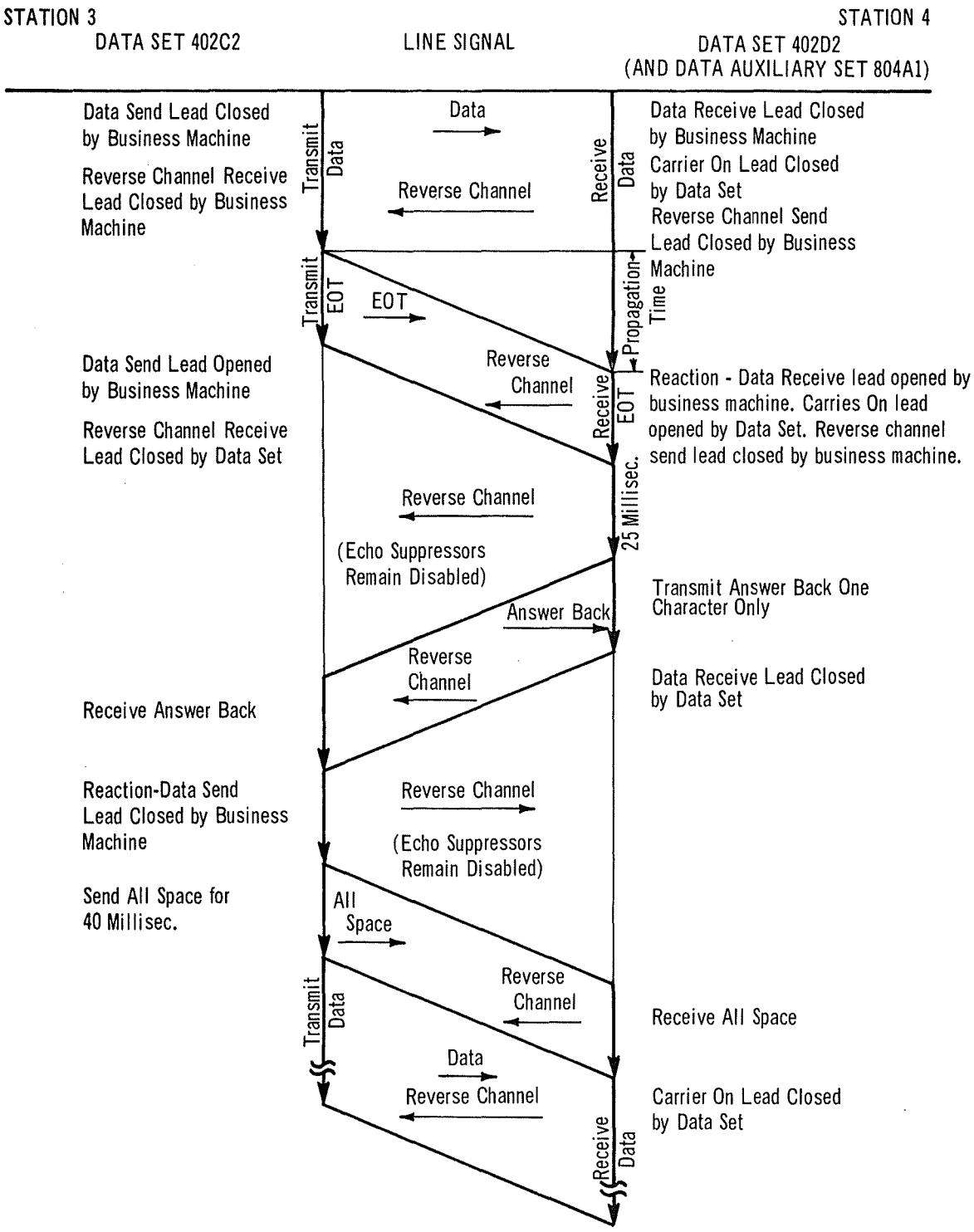


Fig. 7b – Turn-Around in DATA-PHONE Service-Stations Equipped with Reverse Channel

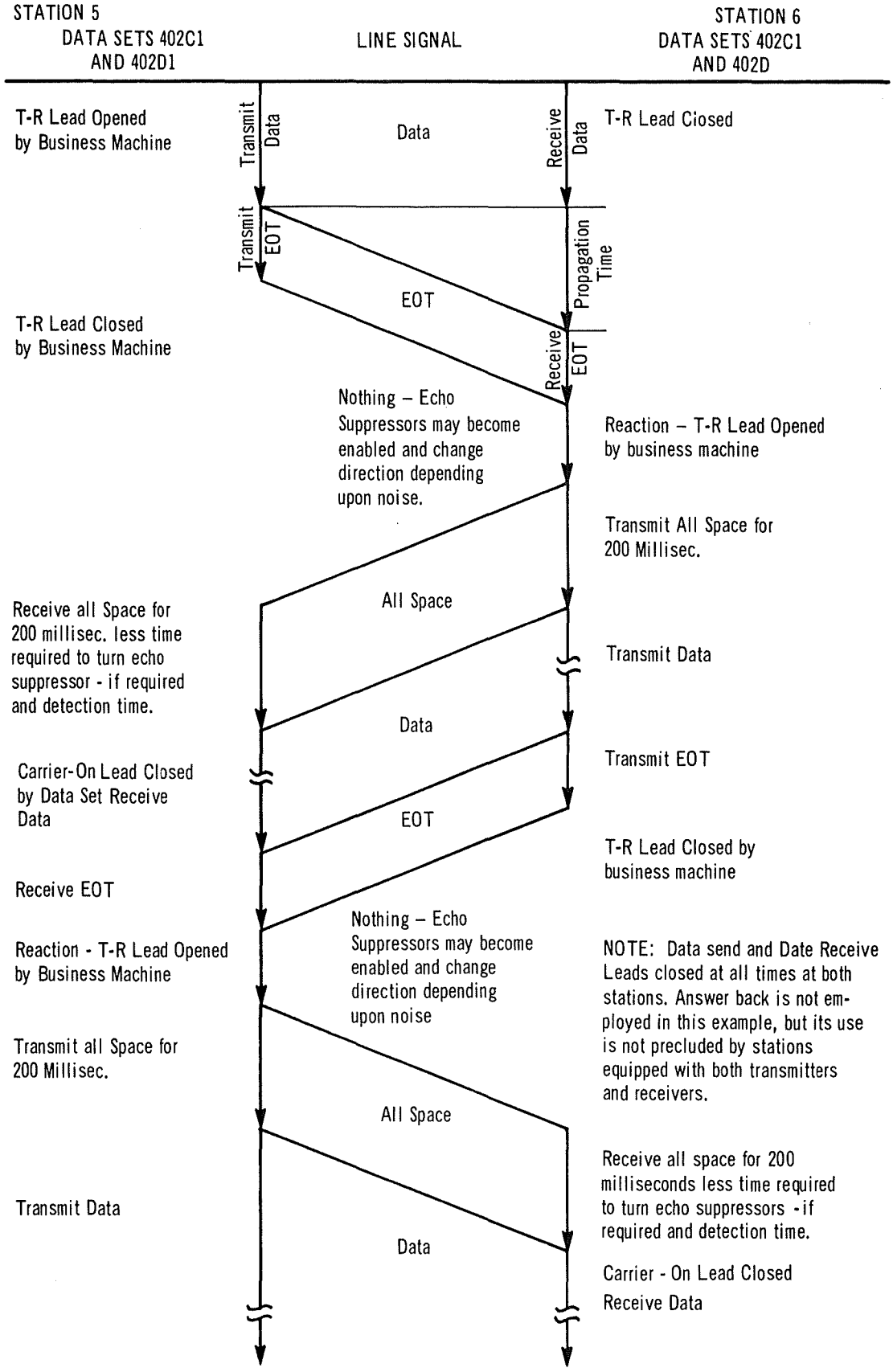


Fig. 7c – Turn-Around in DATA-PHONE Service-Stations Equipped with Both Transmitter and Receiver

the network is strictly a data dissemination system, i.e. two-wire private line systems can be made to work one-way but use of the answer-back capability is not generally practical in this arrangement. See Figure 8a.

If a two-way multipoint arrangement is required, then two separate networks can be established using a four-wire facility and a data set transmitter and receiver at the central location. Figure 8b is an illustration of one kind of network of this sort. In the network shown in Figure 8b the answer-back features can not be used.

3.4 POWER REQUIREMENTS

Data Set 402A contains a conventional full wave rectifier which is fed from a small external plug-in transformer. This arrangement has a moderate tolerance to the frequency of the AC supply. Data Sets 402C and 402D have ferro-resonant power supplies which are more sensitive to the frequency of the AC supply.

Electric power is fed to the data sets through a 10 foot detachable 3-wire power cord connected to the back of the data sets. The cord has a 3-wire plug for connection to a customer provided 105-125 volt, 60±0.6 cycle per second source not under switch control and on the same a.c. circuit which serves the associated business machine (to minimize noise causing impulse potentials by using the same ground bus for both machines).

Data Set	A.C. Power Consumption Watts	Positive 18 ±0.5 dc Power Requirements Milliamps	Negative 18 ±0.5 dc Power Requirement Millamps
402C	9 max.	80 to 250	80 to 250
402D with 804A	25 max.	250 to 600	250 to 600

4. APPLICATIONS

4.1 Locations

Data Set 402C should be located so that the business machine contributes 300 ± 100 picofarads to the data and timing interface leads. Data Set 402D should be located within reach of a 50 foot cable from the business machine. On all installations the housings should be left on the data sets.

The preferred installation locates the data set separate from the business machine equipment – on a nearby desk, table, stand or in Bell System provided equipment cabinets or racks (separations not to exceed prescribed limits).

4.2 Telephone Lines

In order to maintain high quality service and to minimize interference from related devices, it is preferable to use data sets on individual lines that do not have extensions. Data Sets 402 can be installed on conventional key telephone systems but the hold feature cannot be provided.

4.3 Reverse Channel (optional feature)

The reverse channel was designed to provide a means of simultaneous communication from the receiver to the transmitter of two-wire data transmission systems. This optional feature is intended as a means of circuit assurance, for a break signal, and to facilitate certain forms of error control. The circuitry for providing this feature is located on a removable unit within the data set. In calls where line distortions result in marginal conditions, keying the reverse channel may cause interference in the normal data channel.

4.4 Connection of Data Sets 402C and 402D to Same Line

Data Sets 402C and 402D may be connected to the same line thereby providing a combination send and receive station. In this arrangement, a Data Auxiliary Set 804A is not required because the line control and telephone of Data Set 402C are used for both data sets. When the Data key of Data Set 402C is depressed, the business machine can connect Data Set 402C to the line by leaving the T-R lead (of Data Set 402D interface) open. Closing the T-R lead will cause Data Set 402D to be connected to the line. In this kind of installation a single set of business machine contacts may be used, if desired for the Remote Release leads of both data sets. The same is true for Remote Operate leads.

5. OPERATION

The operation of Data Sets 402C and 402D

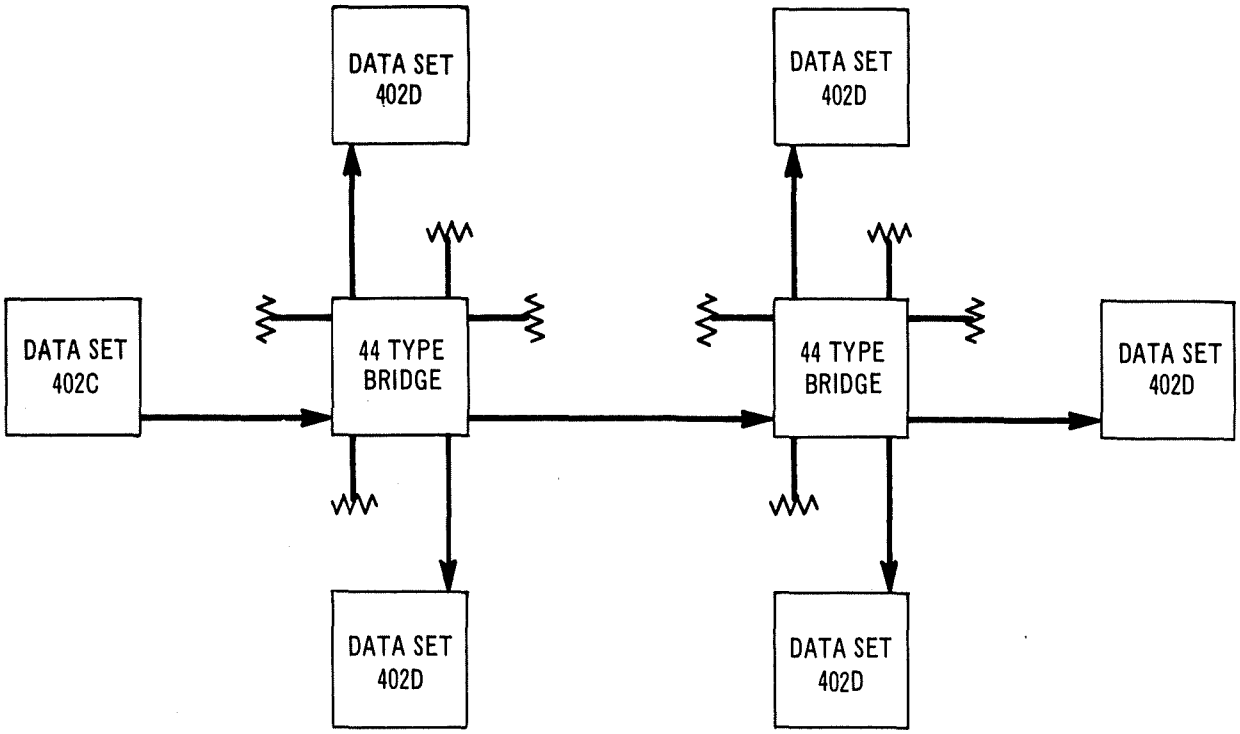
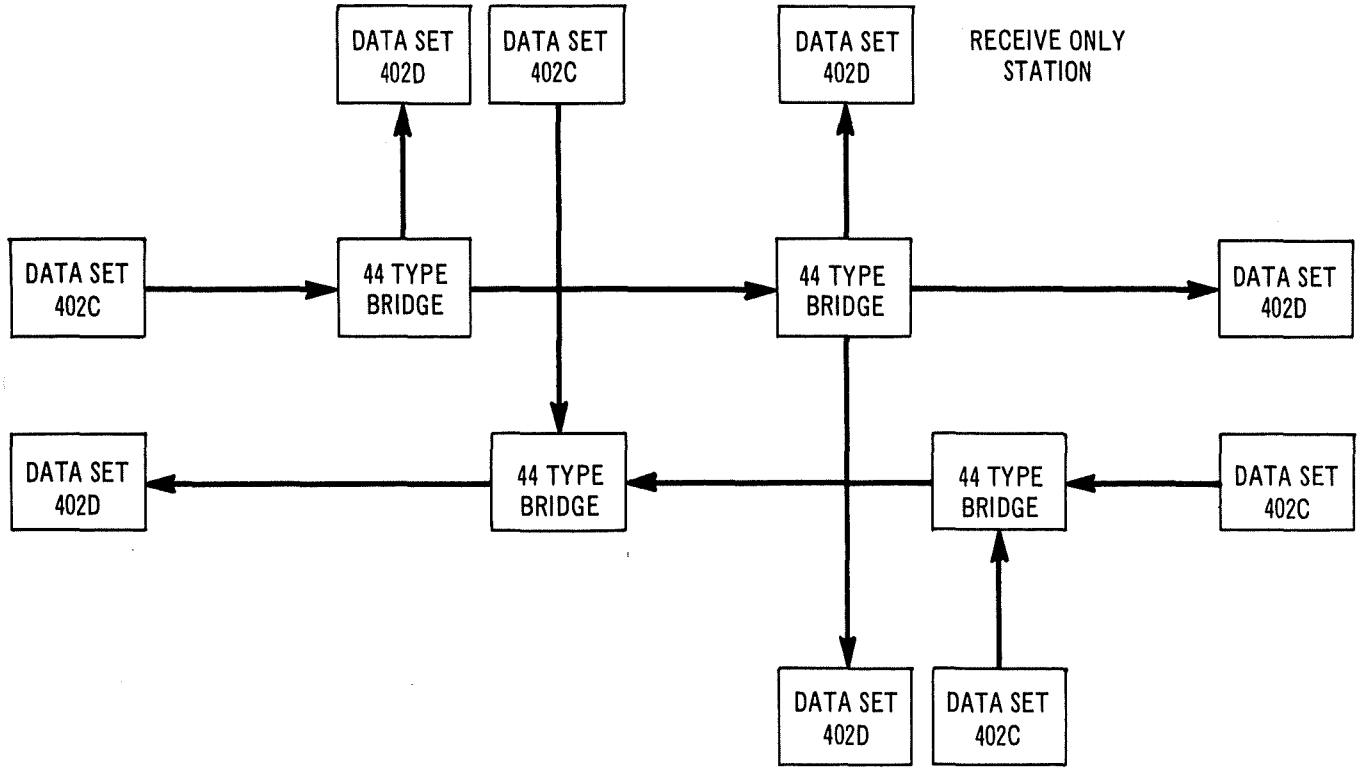


Fig. 8a Two Wire Private Line Data Dissemination System



NOTE: ALL UNUSED BRIDGE PORTS ARE TERMINATED

Fig. 8b Four Wire Full Duplex Private Line Data System

(Data Auxiliary Set 804A is necessary with Data Set 402D if Data Sets 402C and 402D are not installed on the same line) has been changed from that used in earlier models so that echo suppressors can be disabled. The operation is consistent for all Data Sets 402C and 402D (whether they have reverse channels or not). Services installed on data only private lines and those used with Automatic Calling Units do not require operator attention.

To originate a data call, the operator depresses the Talk key and places a telephone call to the distant terminal in the normal telephone manner. After the distant terminal answers:

Manually – verbal agreement is reached as to when data is to be sent. Both operators push the DATA key down until the associated lamp lights.

Automatically – A high pitched tone will be heard for a few seconds. The DATA key at the calling station may be depressed as soon as the tone is heard.

In cases where Data Sets 402 are associated with Automatic Calling Units (ACU) and a power failure disables the operation of the business machine, data set, or ACU telephone calls can be made on an emergency basis by depressing the DIAL TONE key after depressing the TALK key.

Operators of Data Sets 402C can hear the data being transmitted or Answer-back being received by depressing the MONITOR key and listening through the handset after the data set is in the data mode. To return to the talk mode it is necessary to depress the TALK key. Operators must be cautioned against removing the handset from the switchhook when the TALK key is depressed since this will cause the data set to go out of the data mode.

A data call can be answered manually or automatically. If the call is answered manually, the operator should insure that the TALK key is depressed in the normal manner. When verbal agreement is reached as to when data communication is to begin, the operator should depress the DATA key until its associated lamp lights. If the call is answered automatically, no operation is required.

Data calls can be terminated in two ways; the operator can depress the TALK key, lift the handset, and hang up, or the business machine can be arranged to use the Remote Release lead to terminate the call as described in Part 3.33

The customer may be requested by Data Test Center personnel to depress the TEST key. This will facilitate the tests mentioned in Part 8. Customer depresses the key and then places the handset in the cradle. A lamp will light under the TEST key for the duration of the tests. When the testing is completed the data set will be restored to normal and the Test lamp will go out.

Data Sets used in alternate voice-data private line service are operated as described above.

6. GROUNDING

Ground is established for Data Sets 402C and 402D through the ground wire of the power cord. The Data Ground and Frame Ground leads of Data Set 402C and the Control Ground and Frame Ground leads of Data Set 402D are connected to this ground.

It is expected that the customers' data equipment, if powered from commercial power, will be grounded in an appropriate manner.

A Signal ground is provided as a return for certain control or data circuits. If necessary, the signal ground lead may be connected to the ground frame of the customers' equipment. It is not proper to derive the main ground for the customers' data equipment through a ground lead from the data set.

In general, it is desirable that circuits in the customers' data equipment which connect to the data set have some path to ground. A direct or resistance ground on one side of the power supply would be an example of such a path. This practice avoids the possibility of the entire circuit involved being at an indeterminate potential with respect to ground. Such a potential, perhaps a result of electrostatic induction, could result in insulation breakdown in the data set or the interface connector.

At the time of installation a measurement is made to determine if there are any impulsive differences of potential in the nominal voice band exceeding 2.2 volts peak to peak between the grounds of the business machine and data set. This measurement may also be taken when troubles occur.

7. COMPATIBILITY

7.1 Interface

Business machines designed to operate with the interface of Data Set 402B can be connected to the interface of Data Set 402D once one strap-

ping connection has been made in Data Set 402D. It should be noted that the 402D Carrier On lead will function differently than the 402B Space Detector lead. The interfaces of Data Sets 402A and 402C are sufficiently different that business machines designed to work with Data Sets 402A can not be directly connected to interfaces of Data Sets 402C. It is expected that this condition will not cause a hardship on business machine companies because Data Sets 402A will continue to be available (for an indefinite period) after Data Sets 402C are available.

7.2 Line Signals

An attenuation equalizer is used in Data Set 402B to combat the attenuation distortion of the transmission medium. Pre-emphasis of the various channels is used in Data Set 402C to combat the attenuation distortion of the transmission medium. The line signals of Data Sets 402C and 402D are the same as Data Sets 402A and 402B, but there are parameter limitations over which data communication between Data Sets 402A and 402D (no attenuation equalization) and between Data Sets 402C and 402B (double attenuation equalization) will not operate satisfactorily. When systems with these situations are being planned it is advisable to contact the telephone company involved at an early stage for advice.

8. TESTING

A comprehensive remote static test feature is contained in Data Set 402C. This feature permits Data Test Center personnel to determine with a high degree of confidence whether a Data Set 402C is in working condition. Further tests are possible if a telephone employee is dispatched to the data set. These tests examine the circuitry from the interior of the data set to the interface to insure that there are no open leads, grounds, etc., in the interface circuits. The remote tests measure margins as well as operability by checking such things as transmitter frequencies, transmitter signal levels, answer back receiver sensitivity and tuning, and control circuit functions such as unattended answering.

Data Set 402D contains a dynamic remote test feature that permits it to receive a test signal from the Data Test Center. The Test Center adds distortion to its signal to test margins. The data set lets the test center know whether or not an error has been made through the answer back transmitter. During the test sequence errors are transmitted to check the error detection circuitry. This test permits a comprehensive remote dynamic test of the receiver. The interface circuitry can also be tested if a telephone company maintenance man is dispatched to the data set.

9. ADDITIONAL INFORMATION

The absolute delay of signals through the data set transmitter and receiver (together) averages 17 to 20 milliseconds. The All Space – Carrier On circuit has a delay of 17 to 40 milliseconds. The absolute delay of signals through the optional reverse channel is approximately 50 milliseconds.

The rates charged by telephone companies for data service employing Data Sets 402 vary from location to location. For this reason, the Telephone Company operating in a specific location should be contacted to obtain rate information.

10. PERFORMANCE

This part is included to provide the business machine designer with some insight into the performance that can be expected from systems employing Data Sets 402. A comprehensive discussion of this subject was given at the Spring 1964 Meeting of the IEEE titled "Results of a Medium Speed Parallel Data Transmission Test" by Anderson, DeFreese, Soderberg, Brooke and Goldman. Figures 9, 10 and 11 reflect the overall performance of Data Sets 402A and 402B. The error prone characters were 10000000 and 00000001.

Two significant changes have been made to the receiver circuit that are expected to improve the performance outlined above. A relay contact has been added between the data channel discriminators and the All Space gate so that a signal of one channel marking and the rest spacing will not load the marking discriminators. This will prevent the code sensitivity which made these characters error prone previously. The bias to the data channel flip-flops has been changed to make the probability of mark error equal to the probability of space error, thereby eliminating the tendency of data set 402B to make more Mark errors than Space errors.

The capacity of the Answer Back channel has been described as 20 characters per second. This is based on a 25 millisecond character then a 25 millisecond rest. If the business machine could provide its own synchronization not requiring return to zero the capacity of the answer back could be doubled.

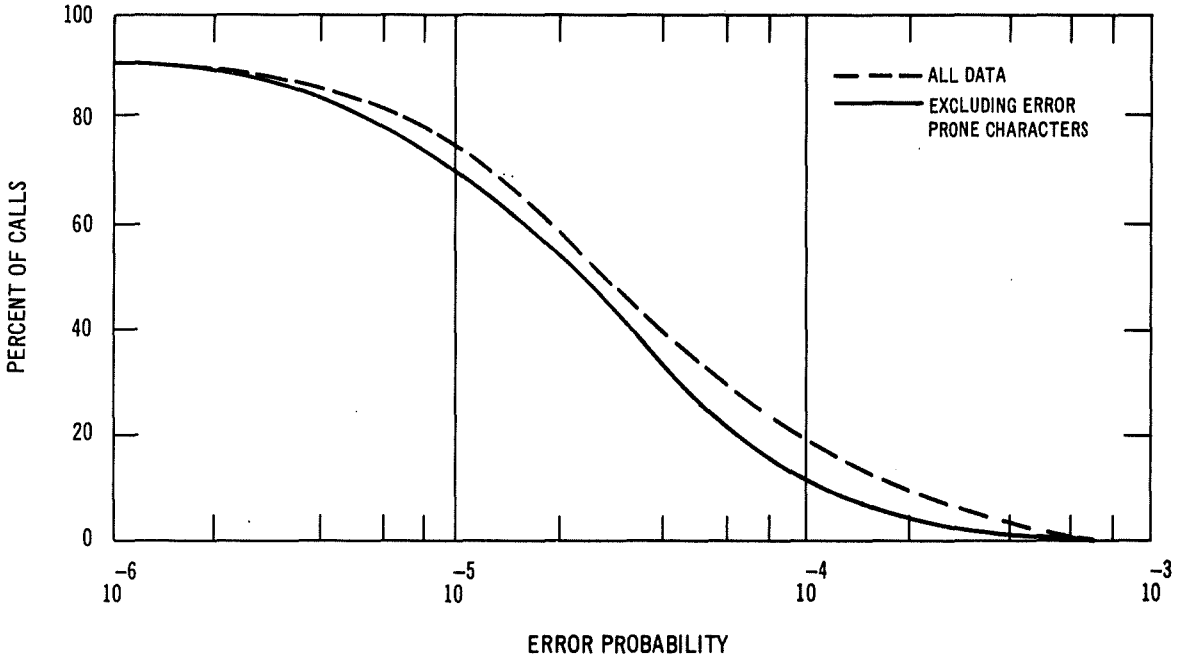


Fig. 9 – Character Error-Rate Probability Distribution – Percentage of Calls with Average Character Error-Rate Equal to or Greater than That Shown on Abscissa

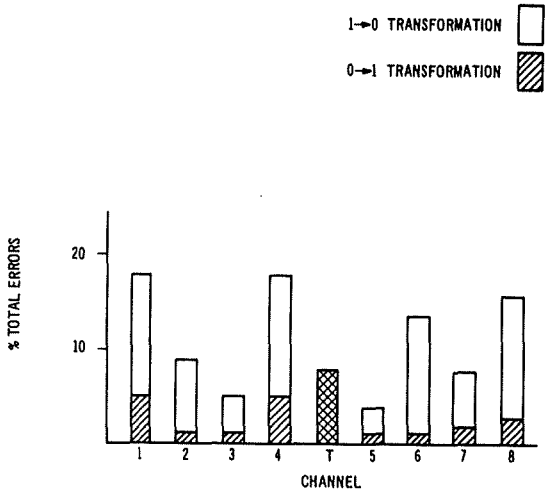


Fig. 10 - Error Distribution by Channel (Excludes Error Prone Characters)

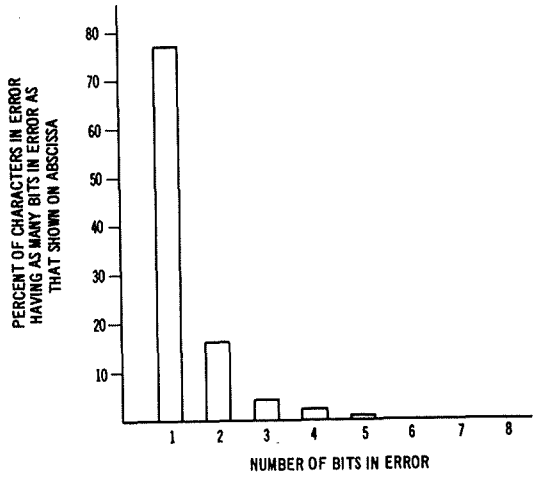


Fig. 11 - Error Density Distribution Characters (Excludes Error Prone Characters)

11. FUNCTIONAL DESCRIPTION

This part is intended to provide a somewhat deeper understanding of the interface of Data Sets 402 by describing some of the circuitry contained in the data sets.

A block diagram of Data Set 402C is shown in Figure 12. For the purpose of this discussion Data Set 402C can be broken into seven parts: Data Transmitter, Answer Back Receiver, Reverse Channel Receiver, Line Control, Power Supply, telephone set and test circuit. The last two items are not shown on Figure 12.

The line control circuit provides unattended answering and control features for the data set. It is basically composed of relays and one transformer, one timed oscillator, and one ringing detector circuit. The operation of the line control is largely self-evident. In answering calls automatically, the ring detector circuit causes a closure on the Ring Indicator lead and, also, causes the Control (C) relay to be operated if the business machine has the Remote Operate Lead grounded. When the C relay is operated a path is completed from the telephone line through the Hold (H) relay (which is then operated from the telephone line battery) and the primary of the line transformer. An H relay contact permits the C relay to be held up through the Remote Release lead. The echo suppressor disabling and recognition tone (2025 cps) is generated by a separate oscillator which is controlled by contacts of the Ring and Control relays and its own internal timer. When the tone is completed the Line Status (LS) relay is operated which gives the interlock signal to the business machine and permits the transmitter and receivers access to the line. The Line Control circuit also contains lightning protection and line impedance matching resistors (not shown in Figure 12).

The reverse channel receiver is an optional part of the data set. If it is present, signals from the line pass through a hybrid filtering network which divides the line frequency spectrum into two parts: Centered at 387 cps for the reverse channel receiver and 700 cps and above for the data transmitter and answer back receiver. If the reverse channel receiver is not present the signal is passed directly to other parts of the circuit. The reverse channel receiver is a conventional narrow band tone-on tone-off receiver which causes a relay to be operated if signal (387 cps) is present. The reverse channel receive (RCR) interface lead has a contact from this relay.

The figure shows one of three single transistor circuits in the Data Transmitter. For a mark condition the customer's interface lead switches capacitance into an already oscillating tank circuit thereby lowering its frequency. Each of the three transistors in the transmitter has three tanks (8 data channels plus timing). Two of the circuits are not shown in the figure. The collectors of the three circuits are tied together and drive an amplifier which can be controlled for desired line output level.

The answer back receiver is a conventional three-tone receiver which generates three contact closure interface leads.

The line control circuit and telephone for Data Set 402D are provided either by Data Auxiliary Set 804A or an associated Data Set 402C. Interlock, Ring Indicator, Remote Release, Remote Operate, Out of Service, Control Ground and Frame Ground are generated as shown for Data Set 402C. Data Set 402D (see Figure 13) contains an optional Reverse Channel transmitter which is a conventional tone-on tone-off transmitter at 387 cps. If it is in the data set, a filter is employed similar to the one used in Data Set 402C. Data Set 402D contains a T-R relay which controls whether Data Set 402C or 402D is connected to the line in joint installations. If the T-R lead is closed, the receiver is connected to the line. The connection of Data Receiver or Answer Back transmitters to the line is controlled by the mode relay which is controlled by the Data Receive lead.

The objective behind the Data Receiver is to minimize filtering expense by having one finely filtered channel (Timing) establish the proper sampling interval for the other channels. The timing channel is a fairly conventional narrow band zero crossing channel which provides a 5 millisecond timing output for each transition of the timing channel. The timing signal is delayed to permit the data channel discriminators to build up to optimal values then it causes them to be sampled through a diode gate circuit. The channel discriminators employ minimum filtering. They have adjacent channel rejection filters. They have collector tanks tuned to their own channel Mark and Space frequency. The nearly optimum sampling permits data to be recovered from fairly noisy discriminators. The signal from each channel discriminator is fed to an All Space gate until all space is detected. This circuit permits the detection of spacing signals in all channels which is generated by the customer as a start

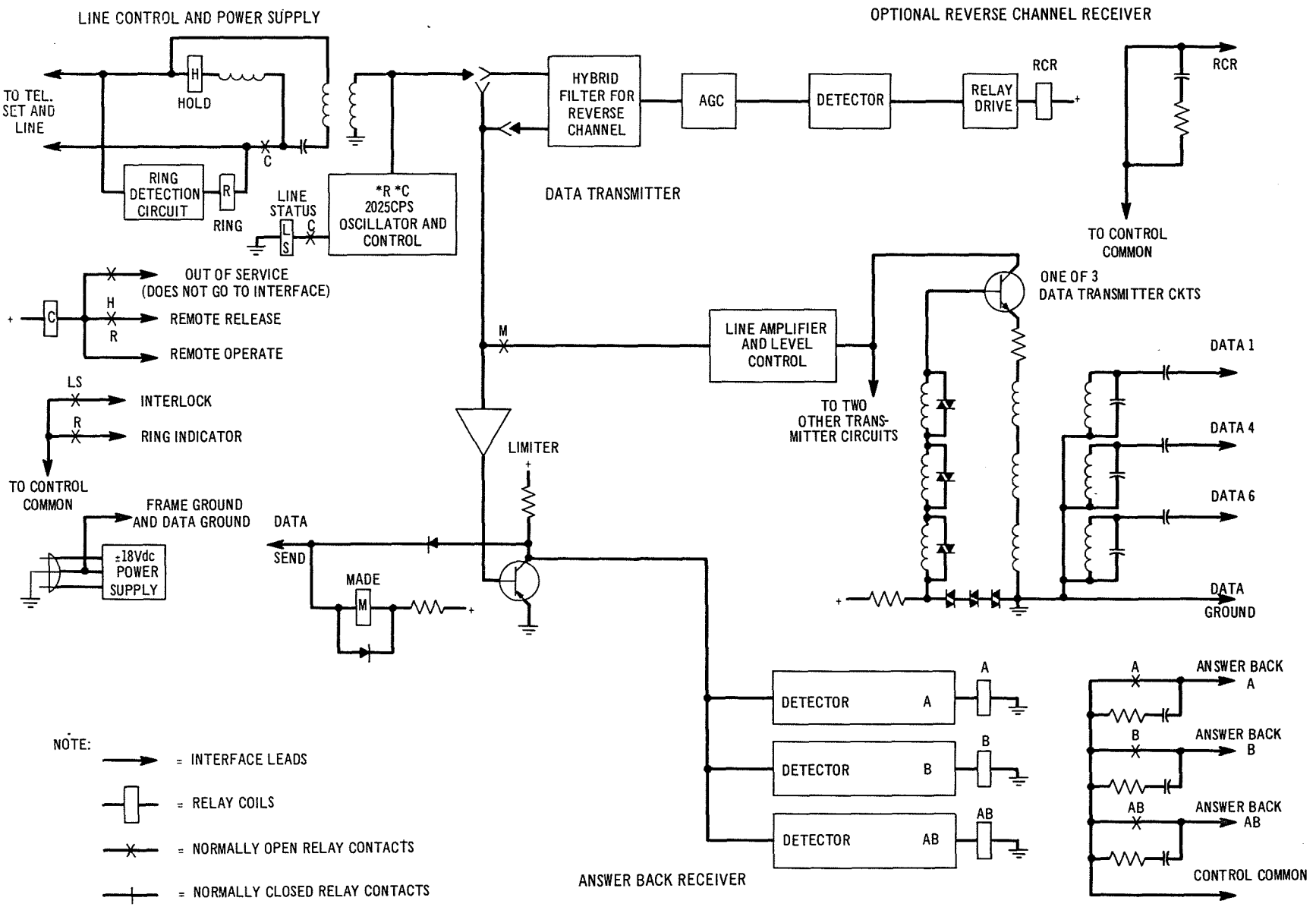


Fig. 12 Block Diagram of Data Set 402C

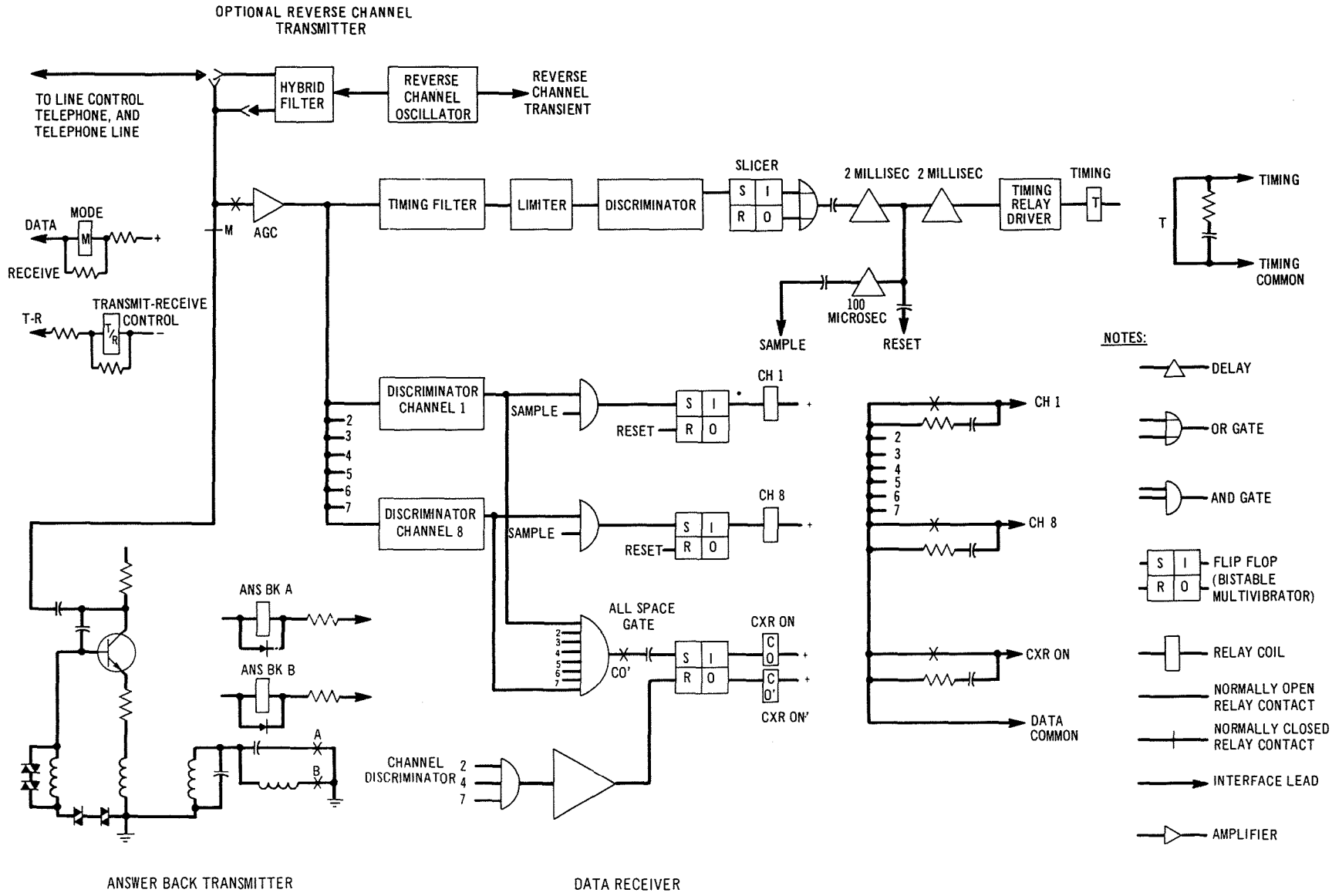


Fig. 13 Block Diagram of Data Set 402D

of message code. The output of the All Space And gate is used to set a Carrier On flip-flop. The flip-flop is reset by a carrier-off detector which is fed from the discriminators of channels 2, 4 and 7. This provides a reliable carrier detector circuit that is difficult to talk-on.

The answer-back transmitter circuit is similar to the data transmitter of Data Set 402C except that only one tank is connected to the oscillator. The Answer Back A lead switches capacitance into the tank thereby lowering the frequency. The Answer Back B lead switches inductance thereby increasing the frequency of oscillation. When both are closed another frequency lower than Answer Back B but higher than Rest results. Cable capacitance does not affect the answer-back frequencies because relays are used to isolate the answer-back oscillator from the cable.

Frequencies used in Data Sets 402C and 402D are as follows:

Channel	1	2	3	4	5	6	7	8	Timing
Mark	730	900	1070	1240	1580	1750	1920	2090	1410
Space	800	970	1140	1310	1650	1820	1990	2160	1480

	A	B	AB	Rest
Answer Back	1017	2025	2785	1152

Reverse Channel 387

Comparison with Earlier Models

Data Sets 402C and 402D differ from Data Sets 402A and 402B in the ways described in the following paragraphs.

1. *Interface* The interface is the same as used in earlier models except for the Answer Back Receive leads in Data Set 402C and renaming some of the leads. Three Answer Back Receive leads will be provided instead of two. The Carrier On lead of Data Set 402D differs from the Space Detector lead of Data Set 402B. A lead-by-lead discussion of the interface is contained in Part 3.2.

2. *Reverse Channel* An optional Reverse Channel is available. This feature is intended to provide a break feature, circuit assurance, and some forms of feedback for error detection and correction systems. More information about this feature is contained in Part 4.4.

3. *Compatibility with Automatic Calling Systems* The new data sets are compatible with Automatic Calling Units (ACU's). For information about ACU's please refer to:

Bell System Data Communications
Technical Reference
Automatic Calling Unit 801A

which is available from:

Data & Teletypewriter Planning Engineer
American Telephone & Telegraph Company
195 Broadway
New York, New York 10007

4. *Remote Testing* Test circuitry is included in Data Sets 402C and 402D to permit comprehensive tests of the data sets from a remotely located Data Test Center. Details about these tests are included in Part 8.

5. *Packaging* Data Set 402C will be contained in an integrated housing. The interface connector will not be at the end of a cord but will be located at the back of the data set. The 804A will be used to provide line control and telephone for alternate voice applications of Data Set 402D.
This will permit economical application of the transmitter and receiver to the same line because the built-in line control and telephone of the transmitter will serve for both data sets. It also permits economy in receiver applications to data only private lines (2-wire only).
The data sets have been packaged in modular form employing replaceable cards to facilitate manufacturing and repair. A connector has been added to the mounting cord and special connecting blocks have been developed to permit quicker installation.

6. *Improved Performance* The modulator has been given more line output levels to permit better matching with its loop facility. The demodulator has been given greater sensitivity. In the earlier models all frequencies were transmitted at the same power level and a compromise attenuation equalizer was built into the receiver. In the new models, the signals that can be expected to encounter the greatest amount of

attenuation are transmitted at a higher level. This will maximize the signal to noise for the individual channels.

The new models have been given increased tolerance to noise resulting from local business machines by requiring flip-flop set and reset signals of greater amplitude and longer duration than was used in earlier models.

The false timing pulses which occur in Data Set 402B some milliseconds after All Space is ON, will not be delivered by Data Set 402D.

The tendency of Data Set 402B to deliver more false mark to space transitions than space to mark transitions has been corrected by changing the discriminator bias.

The code sensitivity of Data Sets 402A and 402B with the error-prone characters 10000000 and 00000001 has been corrected by adding another tuned circuit to the Channel One Discriminator and by adding a relay contact between the Channel Discriminator outputs and the All Space Gate.

7. *Unattended Answering* An unattended answering feature has been added to Data Set 402D (When Data Auxiliary Set 804A is used) and to Data Set 402C.

8. *Carrier Detector* A Carrier Detector has been added to Data Set 402D. The Carrier Detector is enabled by 40 milliseconds of All Space (all channels spacing – no timing required) and will stay ON until Carrier is lost.

9. *Operation* A monitor feature has been provided at the transmitter for customer assurance. When the data set is in the data mode with the TALK key released, the data and answer-back tones can be heard in the handset receiver while the MON key is held operated. Monitoring the tones does not affect the reliability of the data.

It is not necessary to keep the handset off-hook during data communication.

An operating technique has been established to permit echo suppressors to be disabled. See Part 5.

10. *Business Machine Requirements* When data is being transmitted at 75 characters per second, changes in state of the data channels must occur within 1-1/2 milliseconds of changes of state of the timing channel.

All Space must be transmitted a minimum of 40 milliseconds instead of 25 milliseconds as specified for Data Sets 402A and 402B.

The optimum capacitance for circuits connected to Data Set 402C is 300 picofarads.

No interface connector cable is provided with Data Set 402C.

The Data Channels should be sampled by the Business Machine during the timing signal, not 2 milliseconds after as with Data Set 402B.

PROCEDURES FOR OBTAINING COPIES OF REFERENCED ARTICLES AND ADDITIONAL COPIES OF TECHNICAL REFERENCES

I. Bell System Technical Journals (BSTJ), Institute of Electrical and Electronics Engineers (IEEE), American Institute of Electrical Engineers (AIEE) and most other material from technical journals may be ordered from:

Engineering Societies Library
345 East 47th Street
New York, New York 10017

II. Bell Telephone Laboratories, Inc., "Transmission Systems for Communications," Fourth Edition; and additional Technical References may be obtained in the following manner:

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