THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 61, No. 9, November 1982
Printed in U.S.A.

D4 Digital Channel Bank Family:

Dataport—Digital Access Through D4

By T. J. APRILLE, S. NARAYANAN, P. G. ST. AMAND, and F. E. WEBER

(Manuscript received July 10, 1981)

Digital carrier transmission, first introduced into the Bell System in the early 1960s, now offers a nationwide network of digital facilities. A portion of this interoffice digital capability, the Digital Data System (DDS), provides high-quality data channels to support Dataphone* *Digital Service. A new series of D4 channel units, called dataport channel units, has been developed to exploit the potential of the in-plant digital facilities more fully. Dataport channel units are unique in that they allow digital signal access, at rates up to 64 kb/s, to digital T-carrier repeatered lines. This article describes the dataport concept, its capabilities, and its applications in providing ubiquitous access for the Digital Data System. Companion articles in this issue describe in detail dataport designs and the channel encoding techniques used to ensure high-quality service in the existing T-carrier digital transmission plant.*

I. INTRODUCTION

Today the Bell System T-carrier network has digital transmission facilities that serve most major cities in the United States. Since its introduction in 1962 this network has grown to include more than 400,000 channel banks and 80,000,000 channel miles of T-carrier repeatered lines. Digital facilities have enabled each new equipment generation to offer smaller size, less power dissipation, and more features.

* Service mark of AT&T.

To date these digital facilities have been used almost exclusively for voice-frequency (VF) channels. In general, data communication over these facilities is achieved with voiceband data modems that employ digital-to-analog (D/A) conversions to utilize the VF channels. Such analog techniques allow data rates of up to 9.6 kb/s over private line connections, but do not allow the full potential of the 64-kb/s T-carrier channel to be utilized. Moreover, the voiceband data terminals employ relatively complex modulation and detection schemes and essentially duplicate the analog-to-digital (A/D) processes performed by the D-channel banks.

There is a rapidly growing demand in the telecommunications industry to support high-speed digital data services. The Bell System, recognizing the inherent efficiencies in providing digital connectivity to serve the data communications market, began deploying the Digital Data System in 1974. By incorporating a family of dedicated data multiplexers (e.g., T1DM, T1WB4/5, SRDM) interconnected by digital facilities, the DDS eliminated the analog interface and the costly A/D hardware from data connections. Although these conventional DDS arrangements use T-carrier lines to interconnect the data banks, the potential digital connectivity of the vast D-bank/T-carrier network has essentially remained untapped. The dataport channel units uniquely allow direct digital access to channels in the D4 bank. Equipped with dataports, every D4-bank/T-carrier facility can be considered a potential extension of the DDS. By avoiding A/D conversions, each D4-bank/T-carrier channel can accommodate the *Dataphone* Digital Service rates of 2.4, 4.8, 9.6, or 56 kb/s. The dataport capability thus permits efficient voice/data sharing of the D4-bank/T-carrier facilities.

II. DDS BACKGROUND

The dataport channel unit provides a digital signal interface with the extensive D-bank/T-carrier network. Although a variety of new digital services will likely result from this development, the initial application uses the dataport channel to extend the serving areas of the DDS. To better understand this application, a brief review of DDS is given here. A detailed description of the DDS may be found in a recent issue of the *Journal.*[1]

The DDS is a full duplex, private line network designed for point-to-point and multipoint digital data transmission at synchronous rates of 2.4, 4.8, 9.6, and 56 kb/s.[2] (The quantities 2.4, 4.8, and 9.6 kb/s are referred to as "subrates.") In *Dataphone* Digital Service, a typical point-to-point DDS channel interconnects two customer stations in different digital serving areas (DSAs), as shown in Fig. 1. The connection consists of three basic network elements:

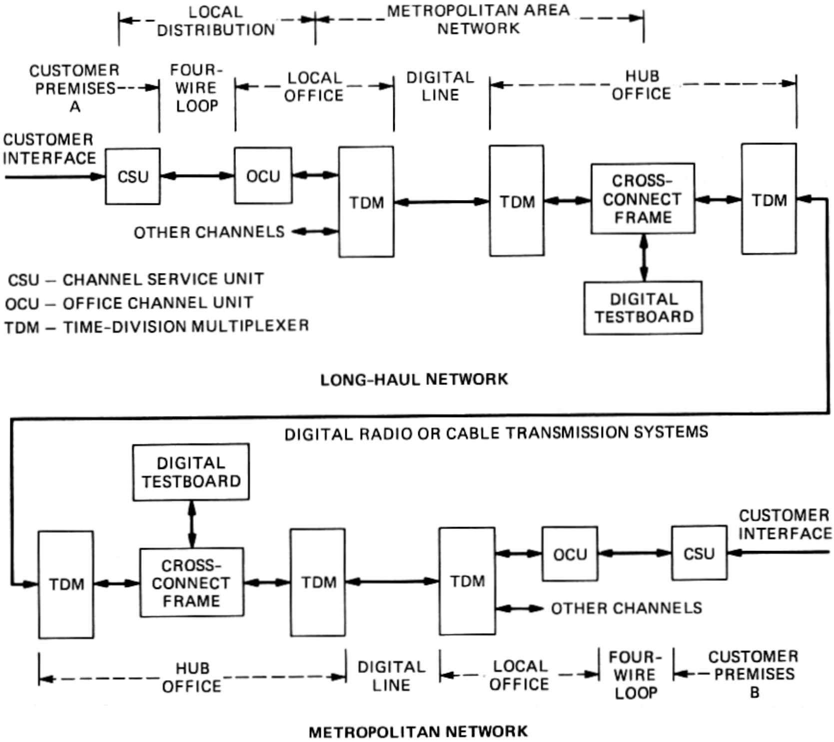


Fig. 1—Point-to-point DDS connection.

(*i*) A local distribution system using four-wire metallic facilities to connect the customer premises and serving central office

(*ii*) A metropolitan network of T-carrier digital lines terminated in time-division multiplexers for collecting customer channels from a number of central offices into a hub that serves as the testing and administrative center

(*iii*) The intercity network of long-haul digital transmission facilities.

2.1 DDS network elements

The local distribution portion of a DDS connection uses metallic, twisted-pair cables for the full-duplex four-wire transmission path between the customer premises and the serving DDS office. A Channel Service Unit (CSU),* furnished as an integral part of a DDS channel,

* A Data Service Unit (DSU) available at customer option provides the following additional features: timing recover, signal encoding and decoding, and EIA standard RS-232C type D or E interfaces for subrates, or a CCITT V.35 interface for 56 kb/s.

serves to terminate the four-wire loop at the customer premises.[3] The CSU is a well defined interface for connecting the customer terminal equipment; it incorporates circuitry to permit signal loopback from a DDS test center.

The digital signal on the four-wire loop is transmitted and received in a bipolar format (50-percent duty cycle, return-to-zero format). This signal has a symbol rate equal to the data rate and uses bipolar violation patterns to encode test and supervisory control information in the bit stream. At the DDS serving office the loop is terminated with an office channel unit (OCU). The OCU encodes the incoming data signals into an 8-bit byte format that adds necessary control information and, regardless of the data service rate, builds the signal up to a rate of 64 kb/s. For example, in the case of a 2.4-kb/s subrate data signal, the OCU adds two bits to each block of six customer data bits to form an 8-bit byte and repeats the byte 20 times in succession (byte stuffing). This procedure is repeated 400 times in a second to achieve the 64-kb/s rate. For the 56-kb/s data rate the OCU merely inserts a control bit after each block of seven customer data bits. This process yields the 64-kb/s signal illustrated in the last two diagrams of Fig. 2. The resulting 64-kb/s signal is defined as the digital signal zero (DS0) level of the digital hierarchy and is used as the standard for interconnecting DDS transmission equipment.

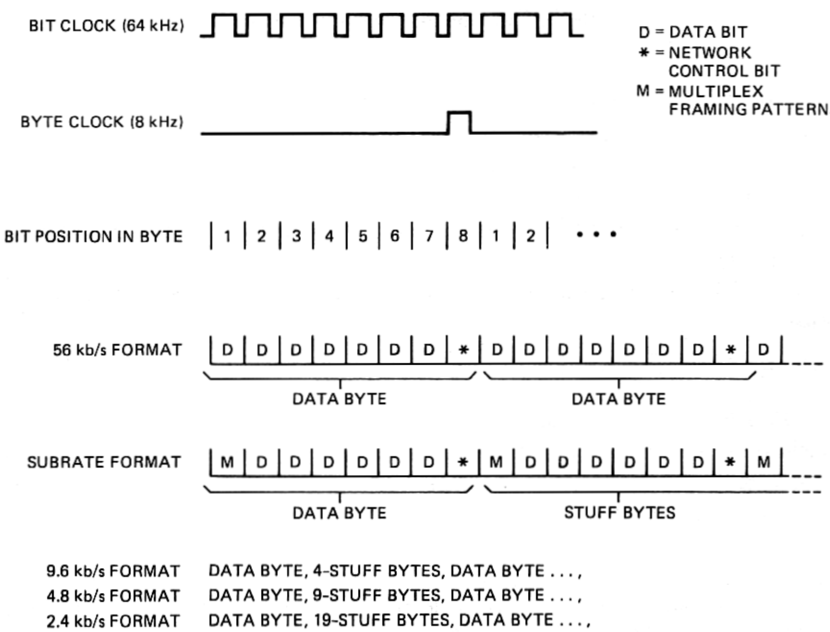


Fig. 2—DS0 signal format.

Individual DS0 signals in the same serving office may then be combined into a 1.544-Mb/s signal by a time-division multiplexer (e.g., T1WB4/5) for transmission over a digital line to a hub office. The hub office acts as a collection point for channels coming from numerous serving offices in a metropolitan area. In the hub office, baseband DS0 channels are recombined with other channels destined for the same distant DSA. These efficiently packaged high-speed signals are transmitted via the long-haul intercity network composed of cable and radio systems. At the destination DSA, the individual channels are again separated for distribution through the metropolitan area network to the terminating stations via the local loop plant.

2.2 Performance objectives

The DDS has been designed to provide high-quality digital signal transmission.[4] The error performance objective is error-free transmission in 99.5 percent of all one-second intervals. Availability, a measure of dependability, is equal to the complement of the average annual down time. The objective is to meet an average availability of at least 99.96 percent.

The major techniques used to meet these objectives include automatic protection switching of digital facilities, centralized and remotely controlled fault isolation, pre-service facility qualification testing, and continuous in-service signal monitoring of digital signal one (DS1) (1.544 Mb/s) facilities.

2.3 Synchronization

The synchronous timing structure of the DDS network is in the form of a master-slave tree ultimately synchronized to the reference frequency standard at Hillsboro, Missouri.[5] The hierarchy of the timing supplies in rank ordering are the master timing supply (at the St. Louis Regional Hub), the nodal timing supply (NTS), the secondary timing supply (STS), the local timing supply (LTS), and T1WB4/5 integrated timing supply (ITS). This ordering reflects relative ability to ensure slip-free operation during loss of input synchronization and to drive other output DDS equipments. In this network, timing supplies are slaved via DS1 facilities to other supplies that are higher or equally positioned in the hierarchy but never to a supply that is lower in the hierarchy. Integrating D4 bank dataport circuits into this network requires a mechanism for the appropriate timing interface.

2.4. Testing and maintenance

Reliability and maintainability of the DDS are important for ensuring that the performance objectives of *Dataphone* Digital Service will be met. The DDS maintenance philosophy is based on the concepts of single point of contact for customers, centralized administration and restoration control, remotely controlled sectionalization of troubles, and automatic protection switching.[6]

At the DS1 levels the maintenance capability includes performance monitoring and protection switching of T-carrier lines and terminal equipment. Further, on-line monitoring of intercity DS1 transmission facilities is being implemented in the network by means of the Digital Transmission Surveillance System.[7]

At the DS0 and lower rates, equipment is made modular on a customer-circuit basis so that a failure usually affects only one customer. Circuit troubles are sectionalized by a series of remotely controlled loopbacks at OCU and customer-premises station equipment.

III. DATAPORT CAPABILITY

The initial hardware configuration for DDS is ideally suited for central offices that serve many data customers. This equipment, therefore, has been deployed primarily in metropolitan areas. The dataport concept complements the existing arrangements by offering low-cost implementation in low-demand serving offices. The fundamental guideline in dataport designs has been to provide data channels that are interchangeable with those of the existing DDS network.

This requires that dataport channels be:

(*i*) Integrable into the DDS synchronization network

(*ii*) Transparent in performance to the end user in terms of error rate, availability, and transmission delay

(*iii*) Consistent with DDS maintenance

(*iv*) Interface-compatible with existing DDS equipment

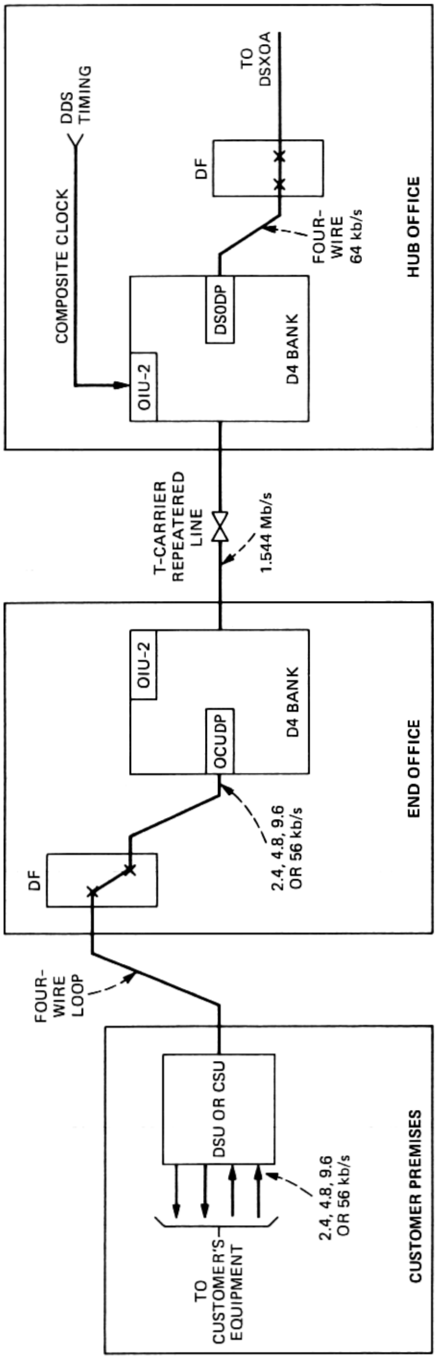
(*v*) Format- and protocol-compatible in a DDS connection.

The following sections describe the dataport applications and discuss the hardware designs that meet these performance requirements.

3.1 The standard application of dataport

Dataport channel units allow digital signal access to the T1, T1C, and T2 digital lines via the D4 banks.[8] Figure 3 shows a typical application of dataports in extending a DSA. In this arrangement a D4 channel acts as a DDS circuit between hub and end offices. At the end office the DDS connection to a DSU or CSU at the customer location is made via the local cable distribution network.

The hub office D4 bank uses a DS0-level dataport channel unit that can be inserted in any of the channel positions. This dataport provides the interface between the DDS 64-kb/s system rate on the drop side and the T1 line rate on the line side of the bank. Drop-side wiring consists of the existing D-bank connection to the distribution frame



CSU – CHANNEL SERVICE UNIT
DSU – DATA SERVICE UNIT
DDS – DIGITAL DATA SYSTEM
DF – DISTRIBUTION FRAME

DS0DP – DS0 DATAPORT
OCUDP – OCU DATAPORT
OIU – OFFICE INTERFACE UNIT
DSXOA – DSO CROSS CONNECT A

Fig. 3—Standard dataport application.

(DF) and, from there, an installed connection to the DDS entry point (the DSX0 bay).

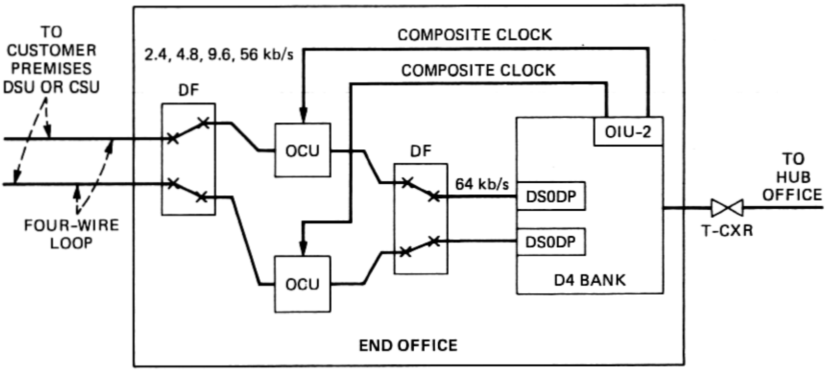
The associated channel slot in the end office D4 bank is equipped with an OCU dataport. This dataport provides an interface between a customer rate of 2.4, 4.8, 9.6, or 56-kb/s and the 1.544-Mb/s DS1 line rate. Again, existing wiring between the D bank and the DF is used; the final connection to the customer-premises DSU or CSU is made with existing loop plant facilities.

Dataport channel units obtain their timing from common circuitry in the D bank. Since DDS is synchronous, this common circuitry must be synchronized to the DDS reference clock. Timing is derived and distributed to the dataports by a new D4 common unit, the office interface unit (OIU). (The OIU is further explained in Section V.) As shown in Fig. 3, a DDS-referenced composite clock (COMP CLK) connection is made to the OIU from a DDS timing source in the hub office. The OIU in the end office bank recovers DDS timing from the receive T line; this timing signal is then used to synchronize the end office D-bank and dataports.

3.2 Alternate configurations using dataport

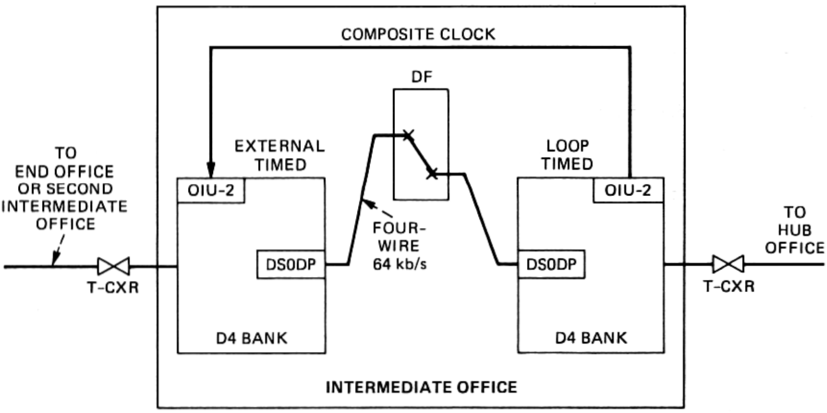
Three alternative configurations of dataport are discussed in this section. Fig. 4 shows a DDS arrangement where the end office uses only DS0 dataports. Note that 64-kb/s DDS channels, derived by the demultiplexing operation of the DS0 dataports, are connected to two external DDS OCUs. This D4 arrangement offers a direct alternative to the T1WB4/5 hardware normally equipped in DDS end-office installations.[9] This arrangement could also make use of the subrate data multiplier (SRDM) and integral subrate multiplexer (ISMX). Each of the OCUs must be synchronized to the DDS reference clock. This timing is provided by the D4 OIU common unit, as Fig. 4 indicates. The OIU generates two independent composite clock signals for such purposes. It should be noted that nothing precludes equipping the D4 bank of Fig. 4 with additional DS0 or OCU channel units.

DDS channels can also be extended using dataports. Fig. 5 shows the equipment setup that would be used in the intermediate office to implement the link. In the hub office, the channel would terminate in a DS0 dataport. The channel termination in the end office would be either an OCU dataport or another DS0 dataport (used as shown in Fig. 4). The intermediate link is created by connecting the DS0 of the system facing the hub-office side to the DS0 dataport of the system facing the end-office side. The DS0 dataports can be assigned independently and arbitrarily to any set of channel unit positions in each DS1 system. For synchronization, a clock signal from the hub-office-side OIU must terminate on the end-office-side OIU. Finally, the data-



CSU – CHANNEL SERVICE UNIT
DSU – DATA SERVICE UNIT
DF – DISTRIBUTION FRAME
DS0DP – DS0 DATAPORT
OCU – OFFICE CHANNEL UNIT
OIU – OFFICE INTERFACE UNIT
T-CXR – T-CARRIER FACILITY

Fig. 4—DS0 dataport in the end office.



DF – DISTRIBUTION FRAME
DS0DP – DS0 DATAPORT
OIU – OFFICE INTERFACE UNIT
T-CXR – T-CARRIER FACILITY

Fig. 5—A tandem connection.

port channel could be further extended by again linking at a second intermediate office.

To indicate the versatility of the dataport approach, a non-DDS application is included and is shown in Fig. 6. In this situation the customer interfaces with standard DSU or CSU equipment. The system is synchronous, but clock reference is provided by one internal D4 bank oscillator, either in Office 1 or 2. The OIU in that reference bank

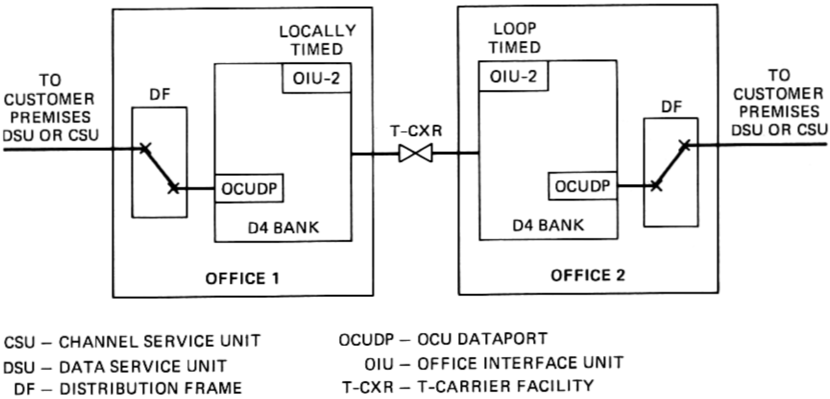


Fig. 6—A stand-alone dataport system.

(e.g., Office 1) is capable of generating the necessary dataport clocks from the internal D4-bank oscillator. The OIU in the other office (Office 2, in this case) generates the necessary dataport clocks from the received T-carrier line signal.

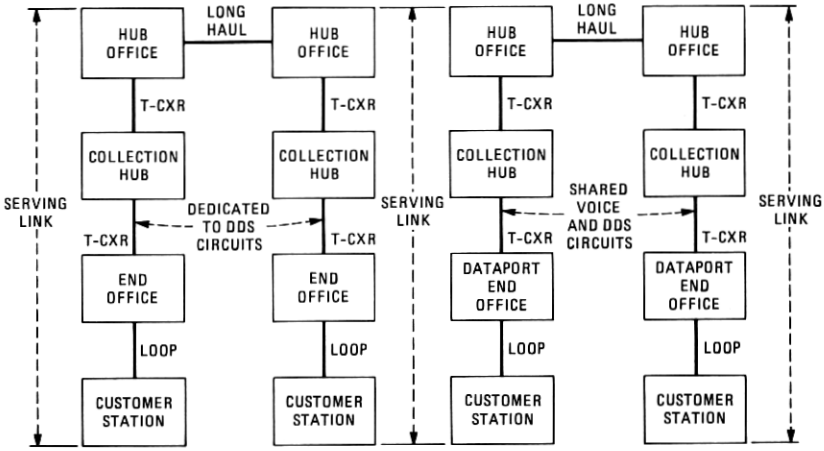
IV. DATAPORT PERFORMANCE

As we mentioned, the DDS provides high-quality data channels to support *Dataphone* Digital Service. The major performance parameters specified are error rate, channel availability, and transmission delay. Dataport channels have been designed to meet the established performance objectives. Thus, channels using dataports and channels using conventional DDS hardware are indistinguishable from a user's point of view. As we will discuss, dataport channels incorporate error control techniques and include maintenance features compatible with existing DDS network capabilities to meet these objectives.

4.1 Dataport connections

Dataport circuits have been integrated into DDS channel connections in configurations that closely emulate the present DDS structure.[10] This is apparent in Figs. 7a and 7b, which contrast a typical DDS connection with one derived via dataports. As shown in Fig. 7a, a DDS connection consists of a long-haul network interconnecting two DSAs with local serving links that consist of two T1 lines in tandem with local baseband facilities. In the conventional arrangement the T1 lines connecting the serving end office to the hub office are dedicated to carrying DDS circuits. These circuits originate from customers served by that wire center and are typically multiplexed into a 64-kb/s T1 channel.

The dataport connection in Fig. 7b is only slightly different in that the T1 line between the serving end office and the hub may be



T-CXR – T-CARRIER FACILITY

Fig. 7—(a) DDS circuit connection model. (b) DDS dataport connection model.

primarily used for *voice grade* services. This difference is important when the error-free second performance objective of such a connection is considered.

4.2 Error performance

Based on allocation procedures, the error performance requirement of a T1 line used in the DDS network has been established to be 99.6-percent error-free seconds. Surveys indicate that about 80 percent of T1 lines meet this performance requirement. For a T1 facility that is to be dedicated to DDS, performance is ensured by screening prospective connections against a quality criterion; however, dataport channels provisioned on in-service T1 lines intended primarily for voice services may not meet the DDS objective without additional treatment. Forward-acting error-correction techniques have been implemented in the dataport designs to ensure that DDS error performance criteria can be met without qualification of the carrier facility. As is discussed in a companion article[11] two techniques are used. A "vote with majority rule" scheme that takes advantage of the inherent redundancy in the DDS format is used for the subrate channel speeds. For the 56-kb/s data rate, two 64-kb/s carrier channels provide the data and parity bit streams required to implement a cyclic redundancy code. Field studies that take into account the actual bit error characteristics of T1 lines have demonstrated the capability of these codes to meet the DDS error-free-second criterion.

4.3 Transmission delay

A second parameter of importance in data transmission is round-trip delay. Although the circuit connections in Figs. 7a and 7b are similar, the use of dataport error-correction circuitry results in an increase in transmission delay. This delay is a result of the coding/decoding and buffering required for error correction. For example, a 9.6-kb/s channel may experience a coding delay of at least one byte. The maximum increase in delay caused by the error-correction circuitry has been estimated to be less than 0.6 ms for all subrate speeds and less than 0.4 ms for the 56-kb/s data rate. When compared with the end-to-end transmission delay that may be encountered on a DDS circuit (approximately 50 ms), the effect of the error-correction circuitry may be considered to be insignificant.

4.4 Availability

Much of the DDS equipment operating at DS1 and higher rates employs continuous performance monitoring and manual or automatic switching to standby equipment in the event of failure. Since the DDS uses existing carrier systems for both the exchange area and long-haul transmission, the availability objectives have included allowances for carrier system failures and restoration. On a per-circuit basis the concepts of single point of customer contact and one person testing are important parts of the DDS maintenance philosophy. This philosophy is embodied in test features that permit trouble sectionalization by means of a series of remote loopbacks under control of a centralized maintenance center. The dataport incorporates the circuitry necessary to preserve this important test capability. Thus, from a maintenance viewpoint, the dataports are functionally equivalent to the displaced equipment.

V. DATAPORT IMPLEMENTATION IN D4

The D4 channel bank has two main functions that allow the dataport channel units to operate. The first function is signal translation between the bipolar format on the T-carrier facility and the unipolar, logic-level format on the channel unit backplane. The second basic function is that of timing synchronization between the DDS network and the D4 bank.

5.1 Signal translation

The D4 bank may operate with T-carrier facilities working at the basic T1, T1-C, or T2 rate. In addition, the T2 rate may be carried over regular cable or over a fiber lightguide medium. The bank converts logic-level signals to the appropriate analog bipolar pulse format for transmission on the facility.[8]

The basic T1 carrier rate of 1.544 Mb/s is obtained by performing 8-kHz sampling on analog channels, using 8-bit pulse code modulation (PCM) coding of each sample and grouping 24 such channels together with one additional bit that provides framing information. Thus, there are 24 groups of eight bits plus a 193rd bit to perform framing every 125 μs. In the direction from the DS1 facility toward the dataport, this digital stream is made available by a common backplane bus to all 24 channel units of a digroup. A 1.544-MHz clock signal is also supplied via the backplane. Regular analog channels ignore the digital bus and accept a signal produced in the common circuits and distributed on a pulse amplitude modulation (PAM) bus. As shown in Fig. 8, the appropriate PAM sample is gated into each analog channel unit under the timing control of two selection leads (P and Q) and a timing pulse (window). These same timing control signals also gate the correct byte of digital data bus information into the dataport channel units.

The data bus presents to each channel one 8-bit byte every 125 μs in a burst at 1.544 Mb/s, for an effective bit rate of 64 kb/s. The dataport channel unit converts the 8-bit burst into the proper DDS DS0 format signal. In the D4 transmit direction toward the T-carrier facility, the dataport units must place onto the backplane bus an 8-bit burst of data at 1.544 Mb/s when directed by the D-bank's timing signals.

One additional control signal is presented to each channel unit to inform the unit that the D bank is "out-of-frame." This information is

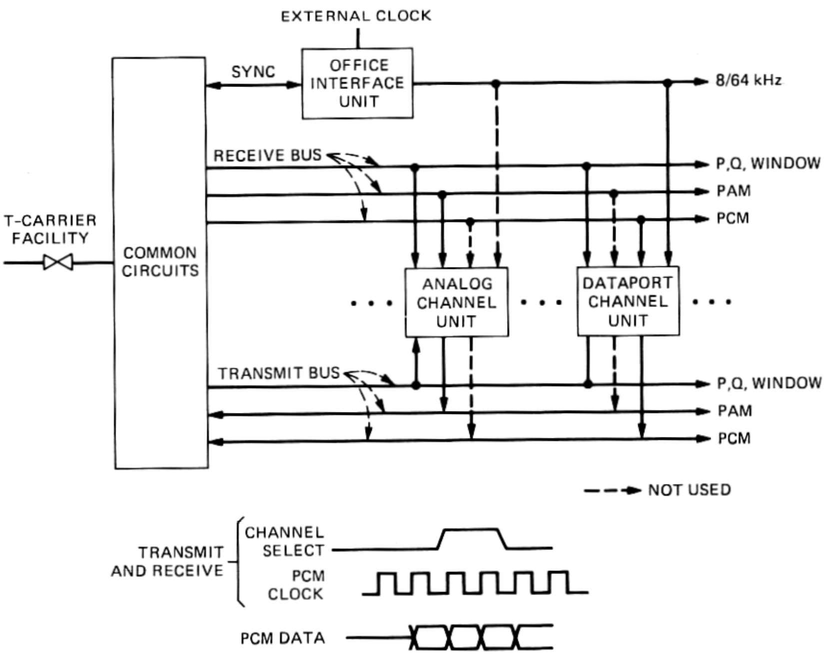


Fig. 8—D-bank channel unit interface.

used to initiate a "multiplex out-of-sync" control signal to the DDS station equipment.

5.2 Clock synchronization

As previously mentioned, the DDS is a synchronous network, and a D4 unit must be locked onto the DDS clock system. As described in Refs. 5 and 6, the cross-connection scheme for all DDS signals within an office requires that DS0 64-kb/s signals be timed to a common 64-kHz bit clock and a common 8-kHz byte clock (see Fig. 2). This allows DS0 signals within an office to be easily interconnected.

5.2.1. DDS clock signals

The clock signal distributed within an office is referred to as a composite clock. This signal is a bipolar 64-kHz waveform with a five-eighths duty cycle. This duty cycle allows for transmission delays between interconnected DDS equipment in the office. Each bipolar pulse marks a new bit in the DS0 signal. All DDS equipment will start a bit transmission on the leading edge of the bit clock and will sample a received bit on the trailing edges of the bit clock. Figure 9 shows the clock waveforms.

The byte information clocking is obtained from bipolar violations contained in the composite clock. Every eighth pulse is a violation that signals the eighth bit of each DS0 byte.

5.2.2 OIU functions

The main dataport task for the D4 office interface unit is to generate a DDS clock and distribute synchronization signals to each channel

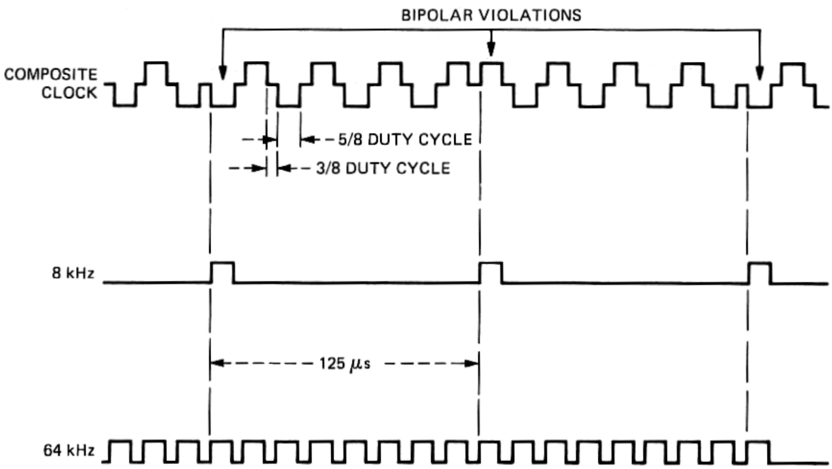


Fig. 9—DDS clock waveforms.

unit. In addition, there are several D4 timing synchronization functions that the OIU performs, as described in Ref. 8. There are three OIU timing modes—local, loop, and external.

In the external-timed mode, used in DDS hub offices, an existing source of DDS composite clock will supply a signal to the D4 bank, which will cause the outgoing T-carrier signal frequency to be locked to the DDS clock (Fig. 3). In the loop-timed mode, the OIU provides signals that lock the outgoing T-carrier signal to the received T-carrier signal. This is the usual case for a DDS end office served by dataport. The DDS synchronization in this case is not obtained directly from a local DDS clock, but comes from the hub office clock through the hub-located D4 bank and the connecting T-carrier facility. The OIU can serve as a source of composite clock to another D bank located in the same office. Such D banks would be conditioned to accept composite clock by being provisioned in the external-timed mode. In this way the DDS can chain a digital connection from a hub office to an end office through an intermediate office (see Fig. 4).

The local-timed mode is used when external synchronization of the D4 bank is not required. This is the case when dataport channel units are installed to provide a point-to-point connection isolated from the DDS network (Fig. 6), or when the D4 is equipped with only VF channel units. For such cases, the D4 bank transmit clock is allowed to run freely. The far-end D bank would be loop-timed for dataport applications. This yields an isolated connection for serving special needs outside the DDS. Figure 10 illustrates the various timing options. The functions of the OIU will be examined next from a block diagram view.

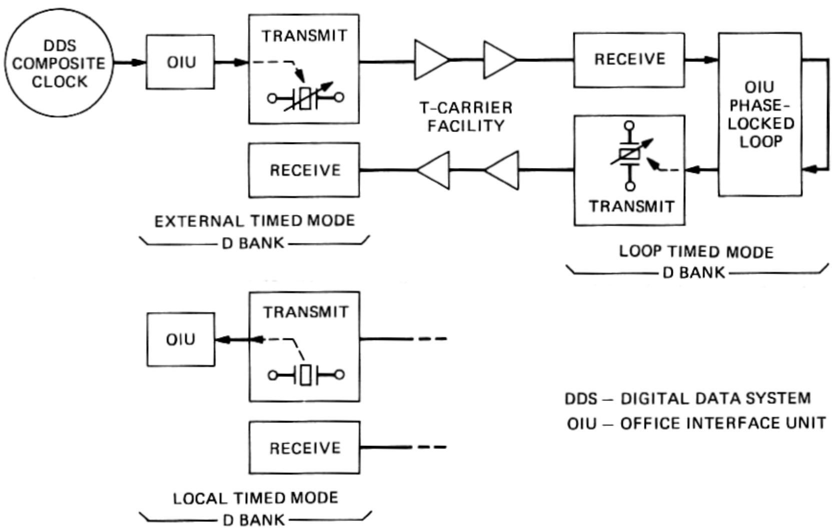


Fig. 10—D-bank timing.

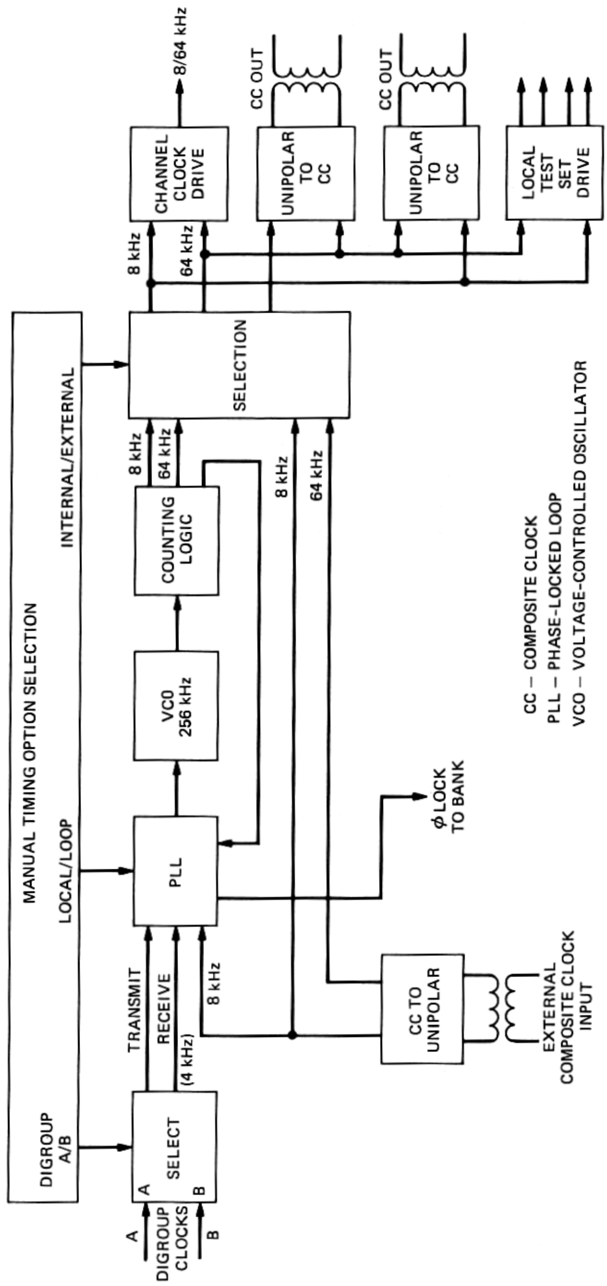


Fig. 11—OTU block diagram.

5.3 The OIU circuit

There are five functional blocks in the OIU circuit (Fig. 11). These blocks serve to properly option the OIU via manual switches, to select *A* or *B* digroup timing, to accept an office composite clock, to synchronize the bank, and to provide output clock signals.

The option settings for the OIU are determined by switches mounted on the faceplate of the unit. One switch selects either the A digroup or the B digroup of the bank to serve as the timing master for synchronization. A second switch serves to select either the external timing option or one of the two internal timing options, local or loop timing. The phase-locked loop (PLL) and voltage-controlled oscillator (VCO) synchronize the bank to the external clock, if present, and, in the absence of an external clock, serve to generate the 8- and 64-kHz clock signals. The output of the 256-kHz VCO is divided down and compared with the reference clocks. Counting logic formats the 256-kHz output into 8- and 64-kHz outputs with appropriate asymmetric duty cycles. An additional stage of selection logic steers either the internally generated or externally supplied 8 and 64 kHz to the output clock drivers.

The output driver section has three functions. An analog circuit converts the 8- and 64-kHz clocks into a tri-level voltage wave (integrated clock) distributed to all channel units in the bank. A duplicated set of drivers converts the unipolar signals back into a composite clock format with appropriate bipolar violations for driving other D banks. Finally, a buffer supplies clocks to local test equipment that can be connected to the bank.

5.4 D4 bank conditioning for dataport applications

As described above, by use of the OIU and dataport channel units the existing D4 channel bank can be conditioned to provide channel connection for the DDS. None of the other existing circuits of the D4 bank need modification to allow this capability. Through the OIU the D4 bank can be synchronized to the DDS system clock. The synchronization information is distributed to the channel units via a backplane bus structure; a similar bus arrangement is used to feed the digital channel information between the common equipment and the dataport.

VI. SUMMARY

The Bell System is continuing to evolve its capability to provide economical, high-quality data channels such as those provided by the Digital Data System. As originally designed, DDS equipment could be used most efficiently to serve geographic areas with a concentrated demand for data services. The dataport feature of D4 has been developed to complement the high-capacity DDS multiplexing equipment with serving arrangements that can be installed quickly and economically to serve small numbers of customers. Dataports provide a new interface to allow for voice and data sharing of the D family of channel banks and open up many new areas for innovative application of digital channels.

REFERENCES

1. B.S.T.J., *54,* No. 5 (May–June 1975).
2. N. E. Snow and N. Knapp, Jr., "Digital Data System: System Overview," B.S.T.J., *54,* No. 5 (May–June 1975), pp. 811–32.
3. E. C. Bender, J. G. Kneuer, and W. J. Lawless, "Digital Data System: Local Distribution System," B.S.T.J., *54,* No. 5 (May–June 1975), pp. 919–42.
4. J. J. Mahoney, Jr., J. J. Mansell, and R. C. Matlack, "Digital Data System: User's View of the Network," B.S.T.J., *54,* No. 5 (May–June 1975), pp. 833–44.
5. B. R. Saltzberg and H. M. Zydney, "Digital Data System: Network Synchronization," B.S.T.J., *54,* No. 5 (May–June 1975), pp. 879–92.
6. S. M. Fitch and D. L. Rechtenbaugh, "Digital Data System: Testing and Maintenance," B.S.T.J., *54,* No. 5 (May–June 1975), pp 845–60.
7. T. R. Lawrence, "Digital Transmission Surveillance System," Conf. Rec., ICC, Boston, MA, 1979, pp. 54.5.1–3.
8. C. R. Crue, J. H. Green, J. E. Landry, and D. A. Spires, "The D4 Digital Channel Bank Family: The Channel Bank," B.S.T.J., this issue.
9. P. Benowitz, S. J. Butterfield, M. P. Cichetti, Jr., and T. G. Cross, "Digital Multiplexers," B.S.T.J., *54,* No. 5 (May–June 1975), pp. 893–918.
10. T. J. Lee, "The Impact of Dataport on the Performance of a Digital Data System," Conf. Rec., *ICC-79,* Boston, MA (June 1979), pp. 54.4.1–6.
11. T. J. Aprille, D. V. Gupta, and P. G. St. Amand, "The D4 Digital Channel Bank Family: Dataport—Channel Units for Digital Data System Subrates," B.S.T.J., this issue.