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D2 Channel Bank:

Per-Channel Equipment

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Traditionally, the design of switching machines has assumed that the transmission plant consists of physical wire pairs. Therefore, appropriate interface equipment is necessary when a multiplex transmission system is substituted for wire pairs. This interface, or per-channel, equipment performs such functions as (i) 2-wire to 4-wire conversion to separate the two directions of transmission, (ii) detection of signaling and supervision information, and (iii) band-limiting and level compensation of the signal prior to sampling. Since failures of the multiplex system can cause massive service interruptions and tie up switching equipment, provision is made to detect such failures and alert the switching machine.

Design of per-channel equipment is complicated by the number of options required to account for the large variety of ways in which switching machines utilize wire-pair plant. This article describes the per-channel equipment of the D2 Channel Bank and some of the considerations that went into its design.

I. INTRODUCTION

In PCM terminals, much of the signal processing takes place in common equipment, where the cost is shared by many or all channels in the system. Although this equipment is more costly than per channel equipment because of higher operating speeds and increased complexity, a net reduction in the per-channel cost is achieved because of time-sharing. However, some functions cannot be performed economically in this way, and per-channel equipment is needed for this purpose.

For the case of the D2 Channel Bank, this equipment includes (*i*) the lowpass filters and gates, and (*ii*) the interface equipment between the switching system trunk circuit (or other assigned circuit) and the D2 Channel Bank. The latter circuits are concentrated in the channel units which contain the signaling scanning and converting circuits in addition to the voice frequency interface circuits.

Looking at a cross section of the telephone plant will reveal a wide variety of switching and transmission equipment in current use. The continued effort to improve the quality of service, the rapid growth of the telephone plant, and the relatively long life of a switching machine have resulted in many switching machines, differing in functions and vintage, existing side by side. In addition, communication between these different machines has also evolved into many schemes. Any new equipment being designed to fit into the existing plant is faced with complex compatibility problems. For the D2 Channel Bank, this meant that many different types of channel units had to be designed and several other types are still in development.

This paper discusses the design of all the per-channel equipment, the manner in which the D2 Channel Bank interfaces with the toll and exchange plant, and how it achieves a measure of compatibility. Included in the general area of interface compatibility are such considerations as VF circuits, signaling and supervision, alarms and service restoration.

II. CHANNEL UNITS

2.1 *General*

Figure 1 shows the major building blocks that constitute one end of a representative 2-wire toll connecting trunk. The location within an office of each of the components will differ, depending on the type carrier system, the means used to signal over it, and the general office layout plan. The D2 Channel Bank was designed as a unitized bay, that is, all equipment shown external to the trunk circuit is included as part of the transmission terminal. To achieve flexibility, all D2 Channel Bank per trunk circuitry is concentrated in a plug-in unit called a channel unit. This permits the channel bank to be adapted to many different trunk types by designing a series of channel units with each channel unit type containing that circuitry unique to a specific trunk.

The major functions of the channel units are (*i*) to provide voice frequency circuit level and impedance conversion and to provide 2-wire to 4-wire conversion for 2-wire trunks, (*ii*) to detect local signaling and/or supervision for transmission to the far end terminal and to reconstruct, from the received digital signal, the far end signaling and/or supervision, (*iii*) to provide jack access to both the voice

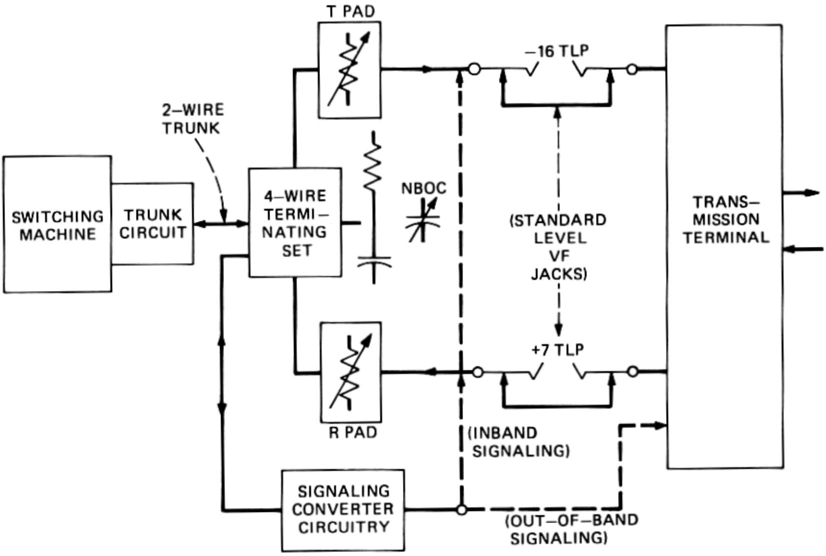

Fig. 1—Typical 2-wire toll connecting trunk.

frequency and the signaling circuitry of the channel bank for alignment and maintenance purposes, and, in some cases, to provide per channel restoration capability. The D2 Channel Bank provides built-in per channel signaling by periodically time sharing the least significant bit of each encoded VF word with a signaling information bit. (A companion article concerning digital functions describes the common signaling circuitry.[1]) Thus, referring to *(ii)*, the channel units provide the necessary signaling interface and conversion to the digital format required by the D2 Channel Bank common signaling circuitry.

2.2 *Channel Unit Functional Description*

Figure 2 shows a simplified block diagram of one of the more complex types of channel units. The channel unit circuitry itself can be functionally separated into two parts; trunk related and channel bank related. The trunk-related circuitry, which is shown to the left of the jacks in the diagram, serves to interface with the specific voice frequency and signaling circuits of the trunk, and to furnish converted signals to the channel bank related circuitry. These circuits account for the primary differences between channel unit types. The channel bank related circuitry shown to the right of the jacks in the diagram has a

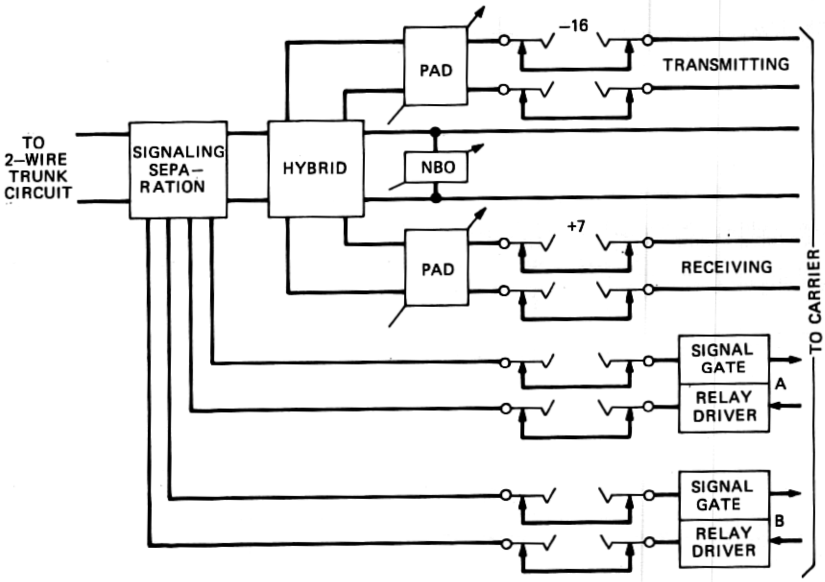

Fig. 2—Simplified diagram of a more complex type of channel unit.

standard output regardless of the channel unit type. Thus there are no restrictions on the physical placement of any channel unit type within the available 96 channel unit positions in the terminal.

For the case of the toll trunk and special service channel units, there are jacks at the interface between the trunk-related and bank-related circuits. These jacks are mounted on the faceplate of the channel unit. At these points, signals (both voice frequency and signaling) appear at standard levels. This permits the restoration of service on an individual channel basis. For example, in case of a failure of channel bank digroup equipment, a trunk may be processed in the trunk-related circuitry in the channel unit associated with the failed channel. The output of these circuits are then patched to the bank-related circuitry of another working channel unit of similar type, either in the same channel bank or in another D2 Channel Bank.

Channel units designed primarily for use with exchange area trunks are not required to provide per channel restoration capability, hence they do not have jack access to standard level signaling circuitry. However, the 4-wire voice-frequency patch jacks with the −16 dBm transmit, and +7 dBm receive levels appear on all channel units for maintenance purposes.

2.3 *Voice Frequency Circuits*

Both 2-wire and 4-wire trunks are in common use in the telephone plant. The D2 Channel Bank requires a 4-wire 600-ohm balanced standard level VF circuit at its transmit and receive ports. Therefore, all 2-wire channel units have a built-in 4-wire terminating circuit to provide the necessary 2-wire to 4-wire conversion. The 4-wire terminating circuit consists of a 2-transformer hybrid, transmit and receive loss adjustment pads, a balance network, and a selection of network build-out capacitors. The 4-wire terminating circuit meets all toll transmission requirements.

The 4-wire channel units do not require the hybrid and its associated balance network, but they do provide the transmit and receive loss adjustment pads. These pads, in both the 2-wire and 4-wire channel units, are tantalum thin-film resistor networks controlled by slide switches. The attenuation range is 16.5 dB adjustable in 0.1 dB steps.

As previously mentioned, all channel units provide jack access to the 4-wire standard level VF circuit.

2.4 *Signaling*

2.4.1 *General Considerations*

The term signaling, as used in this paper, is assumed to include both address and supervisory information. Since most switching machines are designed to work with physical wire pairs, signaling systems used by switching machines are based on wire plant. Different switching machines however use the wire plant for signaling in a variety of ways as determined by their trunk circuit. Thus it becomes necessary for carrier systems including the D2 Bank to provide signaling interfaces that imitate the wire plant in a variety of ways. Effort is being made by the telephone industry to separate the signaling information path from the voice frequency path, especially when signaling information is to be transferred from one switching office to another. Economy and efficiency of operation will result with the introduction of the proposed common channel interoffice signaling (CCIS). While the D2 Bank has provisions for carrying a CCIS channel, until CCIS is implemented, signaling interfaces must be designed that look like wire plant to the trunk circuit of the switching machine.

2.4.2 *Signaling System Considerations in the Channel Unit Design*

The signaling systems encountered in the Bell System plant that were considered in the channel unit design are:

(*i*) Dial pulse
(*ii*) Revertive pulse
(*iii*) E and M lead
(*iv*) Special access.

Signaling systems (*i*) and (*ii*) are used primarily in exchange area trunks. Both are considered 1-way trunks in that a call can only originate from the outgoing end. Different circuitry is required in the channel units that face the outgoing and incoming ends of these trunks. Therefore, different originating and terminating channel units were designed for both systems. Dial pulse and revertive pulse both require 2-state signaling in the forward direction. In the reverse direction, dial pulse requires 2-state and revertive pulse requires 3-state signaling. Figure 3 is a diagram of a representative channel unit for these signaling systems.

Revertive pulse signaling, being a feedback system, is sensitive to round-trip delay. The revertive pulse originate channel unit reduces the round trip time somewhat by taking advantage of the fact that only 2-state signaling is required in the forward direction, and transmits this information in both signaling channels A and B. Because the signaling channels in the D2 Bank are derived serially, transmitting the same signaling information in both channels reduces the time to detect a signaling transition by a factor of two.

E and M lead signaling, (*iii*), is found primarily in toll applications. It is a symmetrical signaling system that can be used for both one- or two-way trunks. The same type channel unit serves both ends. The signaling takes place on the E and M leads which are separate from the VF circuit. Two-state signaling is required. Figure 4 shows a diagram of a 4-wire E and M channel unit.

Special access, (*iv*), is a type of service characterized by a trunk that signals toward the station by ringing and toward the office by dial pulsing. It is a nonsymmetrical 2-way signaling system. Ground start PBX trunks are an example of this type of signaling system. The full 4-state signaling capacity of the D2 Bank is used in both directions. Different channel units are required at each end of the trunk. Figure 5 is an example of a channel unit designed for this service.

2.4.3 *Detecting the Local Signaling States*

The standard signal conditions that must be detected and reconstructed by the channel unit fall into three categories:

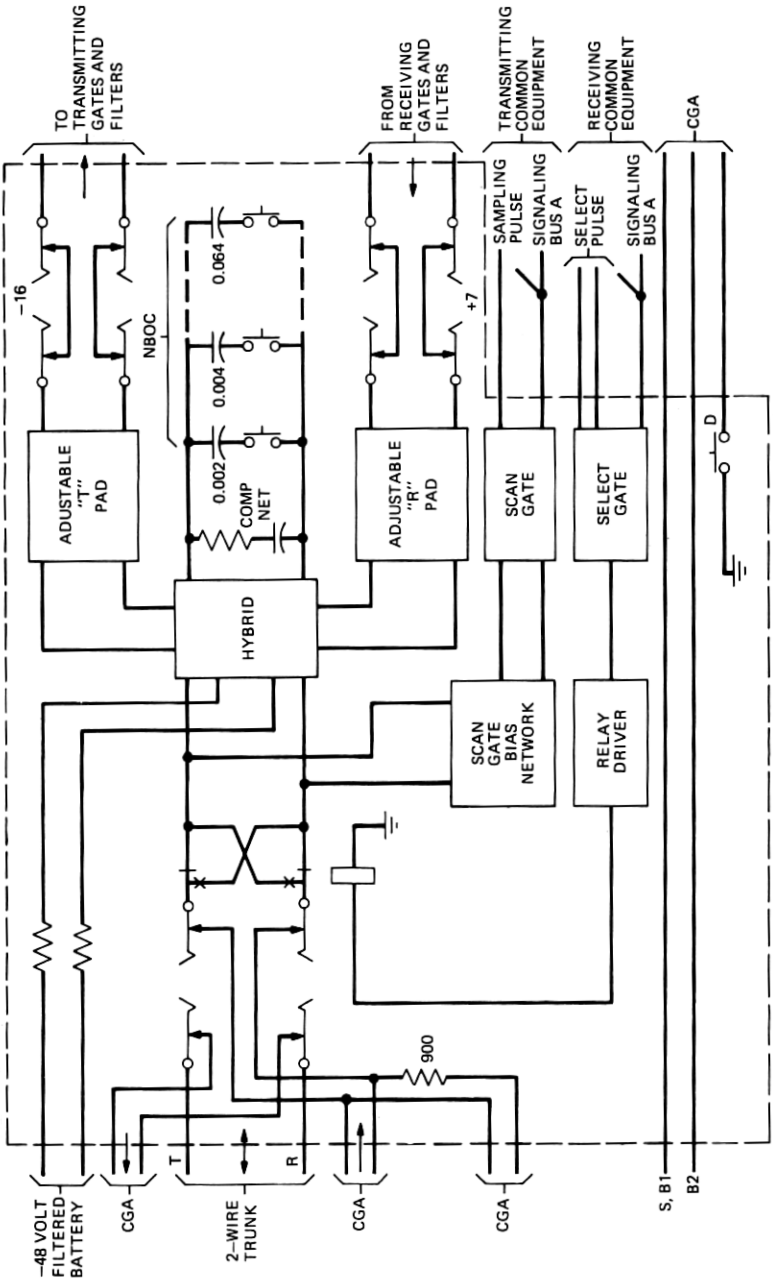

Fig. 3—Dial Pulse Originating channel unit.

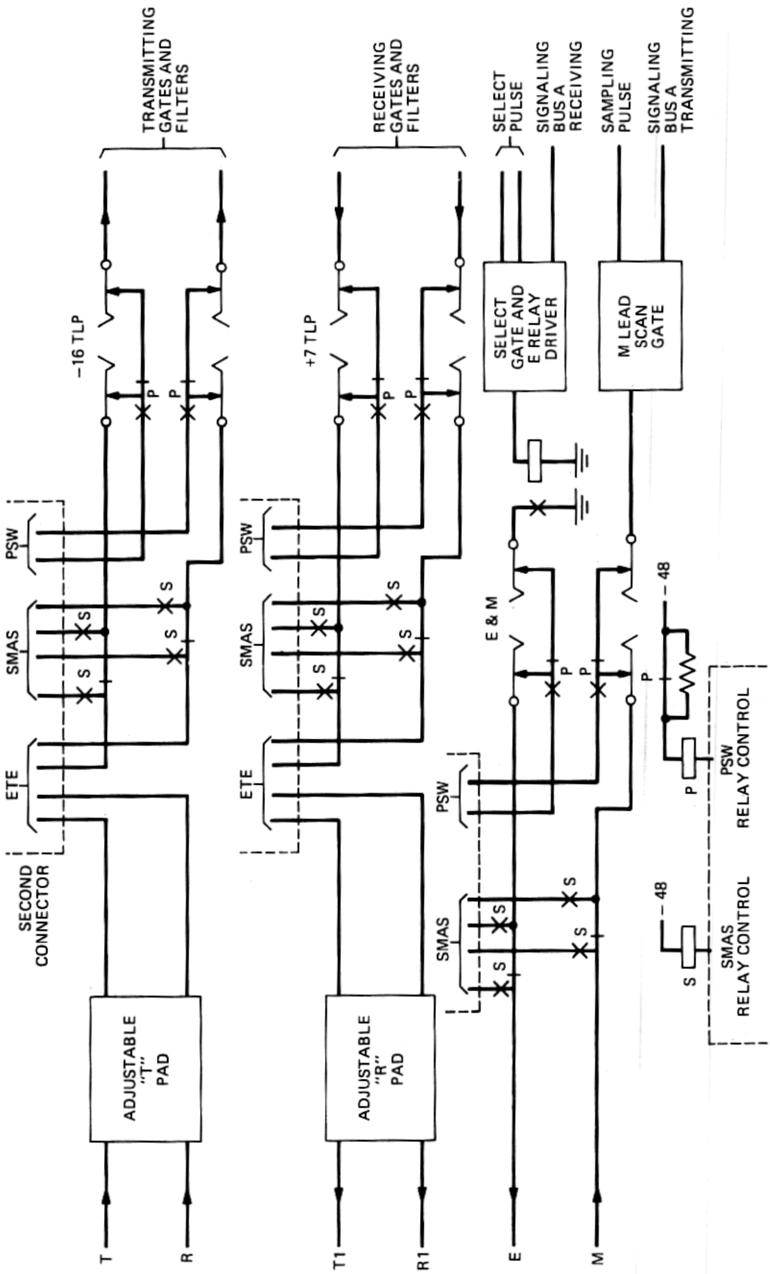

Fig. 4—E & M 4-W + ETE + SMAS + PSW.

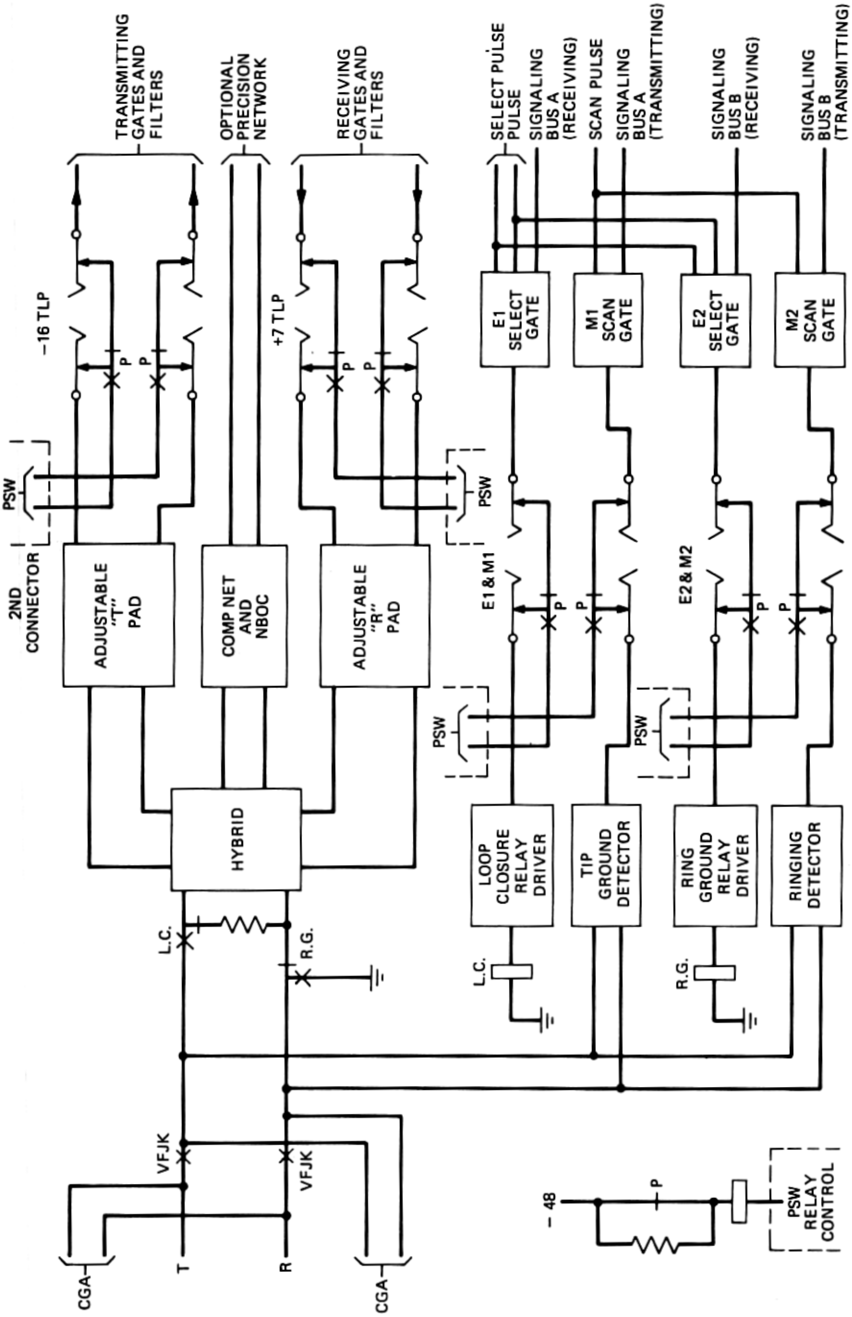

Fig. 5—Special Access-office end + PSW.

(*i*) Impedance, high or low
(*ii*) Voltage polarity
(*iii*) Ringing.

These conditions must be detected either on a 2-wire loop which also carries the voice frequency signal, or on separate leads devoted exclusively for signaling. For the detection of impedance conditions, a conversion to dc voltage conditions is made by supplying dc current to the loop via a resistive network at the center of the hybrid. In many cases, this current also serves as talking battery. The various scanning bias networks shown in the example channel units in Figs. 3 to 5 are high-impedance resistive networks bridged on to the circuit. They convert the dc signaling (and supervision) voltage to standard levels suitable for sampling by the scanning gates. The scanning gate bias circuitry also includes filters to suppress the 8 kHz sampling pulses which would feed back to the voice frequency circuit. The scanning gate circuitry is similar for all channel units, and consists of a sampling diode, a multiplex diode, and two dc isolation capacitors arranged such that the bias network will either forward or reverse bias the sampling diode, depending on the signaling state of the 2-wire circuit. The transmitting channel counter provides a pulse in each channel time slot which interrogates the sampling diode in the channel unit. This channel pulse is either passed or blocked by the sampling diode and its presence or absence is multiplexed on one of the transmitting signaling busses.

Each scanning gate handles two signaling states. When 4-state signaling is required, as shown in the case of Fig. 5, this circuitry is duplicated. For the case of revertive pulse signal, where signaling round trip delay is a critical requirement, one scanning gate drives both signaling channels in the revertive pulse originate channel unit, thus doubling the speed at which signaling information is transmitted in the forward direction.

2.4.4 *Reconstructing the Far End Signaling States*

Signaling information received from the far end is furnished to the channel unit from receiving common signaling on receiving signaling bus A (and bus B when required). A balanced channel pulse from the receiving channel counter interrogates the receiving signaling bus in the select gate. On the basis of the information on the receiving signaling bus, the select gate provides a positive or negative pulse to a flip-flop contained in the relay driver. The flip-flop bridges the time between incoming signaling information samples, and operates or releases a relay the contacts of which restore the far-end signaling condition to the near-end trunk. In the example shown in Fig. 3, the far-end supervisory state is indicated by the polarity of the battery supplied to the near-end switching equipment. As shown in Fig. 5, two additional signaling states can be detected by adding another select gate operating from receiving signaling bus B analagous to the transmitting end.

2.5 *External Trunking Equipment Option*

Some of the E and M lead signaling-type channel units are designed with additional access to the 4-wire, voice-frequency circuits. This access permits external trunking equipment (ETE) such as echo suppressors, delay equalizers, voice-frequency filters, etc. to be connected with either transmit or receive voice frequency circuits. Figure 4 shows how this access is implemented. The mass of additional wiring required for ETE necessitates an additional 40-pin connector on those channel units with ETE provision.

2.6 *Channel Unit Design Summary*

The difficulty in the design of these circuits has been to accommodate large variation of loop length and tolerances of impedance and voltage encountered in the trunk circuit. Also, existing wire trunks were designed with components and voltages which produce circuit conditions hostile to solid state devices. Consequently, relays were used in some cases as the most practical device to reliably perform the required function. In spite of these problems, the per-channel signaling circuitry is extremely simple. Economy in providing signaling contributes considerably to the low cost characteristic of PCM channel banks.

III. FILTERS AND SAMPLING GATES

Lowpass filters are employed for bandlimiting prior to sampling in the transmitting terminal as well as for reconstructing the signal after demultiplexing in the receiving terminal. The transmitting and receiving filters and gates are shown in Figs. 6 and 7. The multiplexing gates will be discussed in more detail in the next article.[2]

Lumped element LC filters were chosen rather than active RC filters because at the time of introduction of the D2 Channel Bank, the large quantities of active filters required could not be produced at a cost competitive with lumped element LC filters. However, the impedance and signal voltage levels for the demultiplexing filters were chosen so that it will be possible at a later time to convert production of the

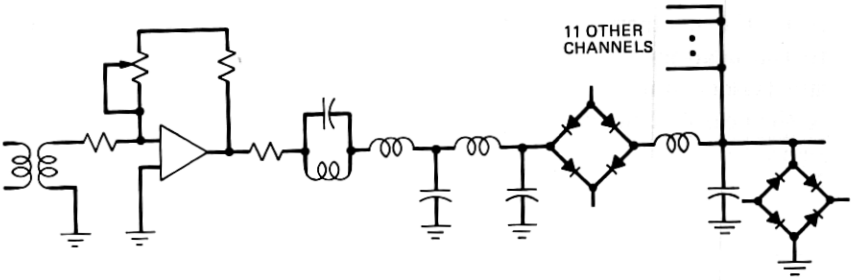

Fig. 6—Transmitting gates and filters.

demultiplex filter to active RC filters if it becomes economically attractive to do so.

The transmission characteristics of the transmitting and receiving terminals are shown in Fig. 8. The voice-frequency transmission characteristics of the terminal are primarily determined by these filters. However, the low frequency cut-offs are due to coupling capacitors and the voice frequency transformers at the input and output terminals.

The transmitting voice-frequency amplifier is a two-transistor circuit. The purpose of this amplifier is to provide a good return loss, and to provide a means of adjusting the level of the signal in the transmitting terminal. The transmitting gain control permits the lineup of signal levels in relation to the digital signal, and so permits the possibility of digital switching.

Two-transistor voice-frequency amplifiers are used in the receiving terminal to raise the output level to +7 dB at the impedance level of

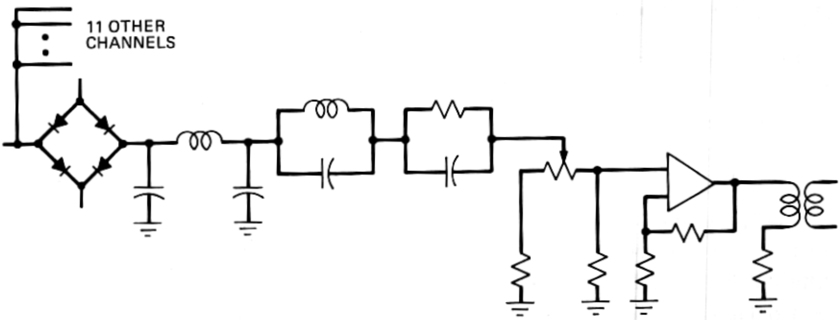

Fig. 7—Receiving gates and filters.

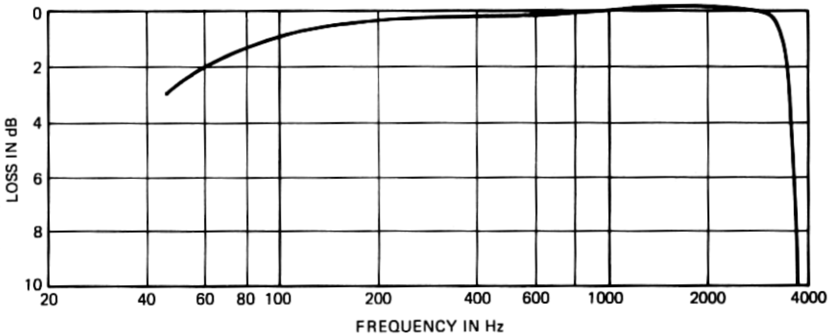

Fig. 8—D2 transmission.

600 ohms. A gain control is included to permit per-channel gain adjustments at the receiving terminal.

IV. MAINTENANCE AND ALARMS

4.1 *Maintenance Access*

In the design of the channel unit, great emphasis was placed on having convenient access to each channel for maintenance purposes. This resulted in the availability of standard 4-wire voice-frequency level and impedance points on all channel units. In the exchange-type channel units using loop signaling, 2-wire jacks were provided for use in conjunction with signaling tests.

Some of the E and M channel units were designed with provisions for switched maintenance access (SMAS). This system permits an operator at a centralized location to detect and condition a particular trunk through the switching machine, and to monitor remotely the 4-wire voice frequency and the signaling leads. For this purpose, a special interface circuit for the D2 Bank was designed. This circuit energizes the SMAS relay (Fig. 4) in the channel unit and routes the voice frequency and signaling points via a switching network to the maintenance center.

4.2 *Alarm Control*

The D2 Channel Bank is equipped with alarm control circuits. These circuits monitor power supply voltages, fuses, and coder zero set voltages. They also monitor the receiving terminal and its ability to maintain synchronization with the incoming bit stream. When a failure occurs, the alarm circuit initiates the appropriate action. This includes audible and visual alarms, operation of the carrier group alarm, and transmission of the alarm indication to the remote terminal. No action is taken by the alarm control circuit unless the trouble condition persists for a period greater than 300 milliseconds. This delay time is built into the system in order to prevent a complete alarm cycle to be initiated by short hits on the repeatered line, which under normal conditions will recover well within this period. The transmission of the alarm condition to the remote terminal is accomplished by forcing the second digit in all words to zero. Under normal conditions, a long string of zeros is extremely unlikely.

4.3 *Carrier Group Alarm*

The carrier group alarm is a trunk processing unit the function of which is to disconnect existing calls and make all trunks busy when an alarm condition occurs. Activation of the CGA starts a timing sequence which provides each trunk with on-hook supervision to disconnect active channels and to stop charges and then provides the appropriate signal to make the trunk appear busy to the switching machine. The timing sequence lasts for a minimum of 20 seconds upon the initial receipt of an alarm signal, or for 10 seconds after the alarm signal disappears. This timing sequence minimizes the susceptibility of the CGA to intermittent operation.

As is the case with the channel unit circuits, the CGA has to be matched to the processing requirements of the particular trunk circuit to which it is connected. This selection is done in the channel unit. Jumper wires in the channel unit connect together those leads which provide the proper sequence and final state necessary to remove that trunk from service. However, most channel units are used with different trunks or switching machines even though they use the same type of signaling and supervision method. Therefore, some channel units have CGA options which are selected at the time of initial installation.

V. RESTORATION

In addition to manual restoration patching, provision for manually-initiated protection switching has been made.

High-priority circuits, remotely monitored unattended offices, or other special services sometimes require rapid automatic means of restoring service on a failed facility. A special standby D2 Channel Bank has been designed which can be used to protect up to ten fully equipped D2 Channel Banks. When it is determined that a failure has occurred in one or more digroups of a protected D2 Channel Bank, all of the circuits being served by that digroup can be switched en masse to the standby bank. The digital line output of the standby bank is simultaneously switched to the digital transmission facility originally serving the failed channel bank.

As shown in Fig. 4, the per channel switching occurs at the standard level 4-wire VF point, and at a defined E and M like signaling point in the signaling circuitry. Provisions for 4-state signaling have been included. The actual per-channel switch is performed by a relay included in those channel units designed for protection switching and designated by the suffix PSW. As with external trunking equipment, the PSW channel units also make use of the second connector on the channel unit.

VI. SUMMARY

This article has described the per-channel equipment of the D2 Channel Bank. This includes (*i*) equipment that is used as the interface between the switching machine and the carrier transmission equipment, (*ii*) the filters and gates that condition the signal for sampling and multiplexing, and (*iii*) provision for maintenance and restoration of service in case of failure. This equipment constitutes the bulk of the physical space occupied by the D2 Bank and shares about half of the total cost. The design becomes complicated due to the large variety of trunk circuits and options encountered in the field.

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