DIGITAL CROSS-CONNECT AND DROP AND INSERT SYSTEMS

CONTENTS

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers and other interested parties with information and recommendations regarding the use of Digital Cross-Connect Systems (DCS) and digital Drop and Insert (DI) systems.

1.2 Digital technology is being used more and more in rural telecommunications as the usage of digital central office switching equipment and carrier systems increases. Although classic digital carrier technology has proven to be very cost effective in many instances, certain network problems have arisen for which solutions must be found to make the most cost effective and technically sound use of the technology.

1.3 This section describes the operation and application of Digital Cross-Connect and Drop and Insert systems Both types of equipment can provide effective solutions for various network problems which have been encountered. This section describes many of these problems and discusses possible solutions.

1.4 Certain manufacturers are providing DCS and DI equipment for operation at the DS3 level. These systems provide similar functions as the DS1 equipment described in this section. These DS3 systems are not covered in this section at this time.

2. DIGITAL CROSS-CONNECT SYSTEMS (DCS)

2.1 Digital Cross-Connect Systems (DCS), or Digital Access and Cross-Connect Systems (DACS) as they are sometimes called, provide the capability to connect, under software program control, any one or more of the 24 voice channels (DS0 channels) of a DS1 bit stream to any one or more of the 24 channels of other DS1 bit streams. It is also possible to change the time slot arrangements of an individual DS1 stream (time slot inter-change). This cross-connection does not require digital-to analog (D/A) conversion or subsequent analog-to-digital (A/D) conversion. That is, the cross-connection is accomplished entirely at the DS0 level. Additionally, the DCS permits access to individual DS0 channels for monitoring and test purposes.

2.2 Historically, T1 span lines have been connected to the T1 ports of digital switching equipment and to D-channel banks in analog offices using jackfields (manual DSX cross-connects). These jackfields provide access for testing and for manual patching to other T1 span lines. When cross-connection of individual voice channels is required, back-to-back channel banks are used. This arrangement can prove very expensive particularly where only a few of the channels require treatment. Additionally, each time a D/A and subsequent A/D conversion takes place, some transmission degradation occurs.

2.3 The manual cross-connection capability described above is being replaced in many instances by electronic computer program controlled DCS equipment. Patch cords are replaced by memory maps stored in non-volatile memory immune to power failure, i.e., cross-connect instructions are not lost when power to the memory is interrupted. These memory maps indicating the required cross-connections are entered/changed via a local or remote administration terminal. Certain DCS equipment also enable the cross-connections to be changed under program control automatically based on the time of day or in case of defined failures in the local network.

2.4 The basic theory of operation of a typical DCS is shown in Figure 1 and described in the following paragraphs. Only one direction of transmission is described. The opposite transmission direction is a mirror image.

2.4.1 Each T1 port of a DCS has an assigned time slot interchange (TSI) which consists basically of an input buffer, an output buffer and transfer logic. Each direction of transmission has a separate TSI.

2.4.2 Each of the 24 DSO channnels of a DS1 bit stream is assigned a time slot. Each time slot of an incoming DS1 bit stream is written to a memory locaton in the input buffer of the TSI assigned to the incoming T1 port. An internal time slot is assigned by the central processor to transfer the informaton from the TSI of the incoming T1 port to the TSI of the appropriate outgoing T1 port via the matrix. In Figure 1, time slot A1 is read from input buffer A and written to time slot X2 of output buffer A. During time slot X2 a matrix path is established between TSI A and TSI B. Thus, information in time slot A1 is passed from output buffer A to input buffer B. Transfer logic in TSI B than transfers the information in time slot X2 of input buffer B to time slot B24 of output buffer B. Therefore, time slot A1 is cross-connected to time slot B24 of the DS1 bit stream outgoing at Port B.

2.4.3 The DCS matrix enables any TSI assigned to an incoming T1 port to be cross-connected to any TSI assigned to an outgoing T1 port. The combination of the TSI's and the matrix permits any time slot of any incoming DS1 bit stream to be cross-connected to any time slot of any outgoing DS1 bit stream.

2.5 DCS equipment was originally intended to provide special service circuits without requiring nailed-up connections using back-to-back channel banks. Additional uses have been found to reduce network costs and produce new revenue. DCS equipment is less costly than back-to-back channel banks, requires less power and space and since D/A and A/D conversions are not required, transmission is not significantly degraded.

2.6 The digital cross-connect function introduces a delay of from 2 to 4 frames (250 to 500 microseconds) into the transmission.

2.7 DCS equipment conforms to the Stratum 3 criteria of the Bellcore Network Synchronization Plan. This plan defines the stability and accuracy requirements of system clocks.

3. DCS APPLICATIONS

3.1 For proper cross-connection, the services on either side of the DCS must have the following characteristics.

3.1.1 Same signaling type (or no signaling)

3.1.2 Compatible channel banks and channel units

3.1.3 Consistent transmission direction, e.g., if the traffic entering the DCS is from an office toward a subscriber, it must continue toward the subscriber upon leaving the DCS.

3.1.4 Compatible customer premise equipment

3.2 The following paragraphs describe several major applications for Digital Cross-Connect Systems. This list of applications is not intended to be all-inclusive. There are certainly other conceivable arrangements. It is left to the readers' ingenuity and knowledge of their individual network requirements to utilized DCS equipment to solve any special network problems which they may have.

3.2.1 Hubbing - Where several central offices are contained within a telephone company's system, individual trunk groups are normally used to connect each office to every other office as shown in Figure 2a. In many of these situations, DCS equipment can be used to provide efficient routing of the DS1 circuits via an alternate or tandem route rather than by direct point-to-point circuits between central offices. Figure 2b illustrates such routing for the network shown in Figure 2a. Hubbing provides the advantages of increasing facility fill to an optimum level, eliminating back-to-back channel banks and creating a network which can flexibly respond to demand. To demonstrate the efficiency produced by hubbing, assume that each of the trunk routes in Figure 2a requires 8 channels. It can be readily seen from Figure 1b that hubbing provides a 100 per cent fill in this example. That is, in Figure 2b, the span line between offices A and B now carriers A-D and A-C traffic in addition to A-B traffic. Thus 24 channels would be required. (In actuality, somewhat less than 24 channels may be required when actual traffic totals are considered.) In any case, use of the T1 span line is much more efficient. The same results can be shown for the span lines between offices C and D and B and D. The original trunk routes which are not required (shown as dashed lines in Figure 2b) may be provided/left in place to serve as alternate (overflow) routes in case of overload or network failures.

3.2.2 Grooming - Circuit grooming techniques can be used to segregate and/or concentrate traffic. In many cases special services and voice (message) traffic is combined on the same span lines. The DCS allows the two types of traffic to be separated onto different span lines and the T1 fill to be increased. Figure 3 illustrates this application. A DCS can also be used to concentrate traffic and increase the fill of T1 spans without segregating traffic types. This function also enables nailed-up circuits to be routed around a digital switch on a T1 basis. The switch is thus deloaded giving it more capacity to process normal switched traffic.

3.2.3 Test Access - For testing purposes, DCS equipment allows access to individual DS0 channels within a 24 channel DS1 bit stream. The accessed channel can be monitored and/or tested either on a bridged or a split and terminated basis. It is possible to perform tests locally or from a remote maintenance center. Figure 4 illustrates this capability. Remote testing can be accomplished without a test device at the remote location. It should be noted that some DCS systems provide D/A conversion for analog testing of the dropped channels whereas others do not. In cases where the DCS does not provide D/A conversion, a channel bank or Drop and Insert system must be used for the conversion.

3.3 DCS equipment provides performance and alarm monitoring. Each DS1 signal interfaced to the DCS is monitored for proper performance including framing losses, frame slips and Bit Error Rate. Carrier Group Alarms are generated when required as for normal carrier operation. External alarms are also provided for power and carrier failures.

3.4 Many, but not all, types of DCS equipment provide additional features such as Subrate Data capability and Digital Multipoint Bridging.

3.4.1 The Subrate Data feature provides cross-connection for data circuits within a single DS0 voice channel. This function eliminates the need for back-to-back Digital Data System equipment.

3.4.2 Digital Multipoint Bridging enables the bridging of DS0 voice channels for voice conferencing and the broadcasting of multipoint voice and data circuits. This feature replaces costly analog voice bridges and the associated channel banks.

3.5 Some types of DCS equipment provide Extended Superframe (ESF) capability and Bipolar 8-bit Zero Suppression (B8ZS) which enables Clear Channel operation. Refer to TE&CM Section 954 for details on these features.

4. DROP AND INSERT (DI) SYSTEMS

4.1 Drop and Insert (DI) systems provide access to individual DS0 channels of a 24 channel DS1 bit stream so that individual channels can be dropped from and/or inserted into the bit stream. DI systems can also be used as end terminals, i.e., in the same manner as classic centralized subscriber carrier. DI systems contain channel units for 2-wire and 4-wire voice frequency interface such as E & M, Foreign Exchange (FX), Transmission Only (TO) and duplex (DX). Channel units are also available for asynchronous, synchronous and subrate data including high speed data which could provide Integrated Services Digital Network (ISDN) capabilities. Also available are special 5 kHz, 7.5 kHz, 8 kHz and 15 kHz program units which can be used to transmit and receive audio broadcast signals.

4.2 In effect, DI systems are a subset of Digital Cross-Connect Systems in that they can be used to perform many of the same functions although on a limited scale. In addition, a DI system can be considered analogous to a distributed subscriber carrier system in many regards.

4.3 Traditionally, individual voice frequency channels are dropped from and/or inserted into a DS1 bit stream via back-to-back channel banks as shown in Figure 5a. In this application, all 24 channels of the DS1 bit stream must be converted from digital to analog and then the channels not being dropped are converted back to digital. The disadvantages of this arrangement are the same as described previously (expensive, larger power consumption, transmission degradation and larger size). Figure 5b illustrates the same function being performed by a DI system. In this case, only the channels being dropped are converted from digital to analog and only the channels being inserted are converted from analog to digital. Other channels pass through the DI system unchanged with insignificant delay. This method is less costly, requires less power and there is no significant transmission degradation in the channels which pass through the system (no D/A and A/D conversions).

4.4 DI systems can be arranged in several configurations dependent upon the particular network requirements. In general, a DI system can be set up as a one-way or two-way system. Additionally, the system can be arranged as a drop only or an insert only system. Figure 6 illustrates these various configurations.

5. DI SYSTEM APPLICATIONS

5.1 The following paragraphs describe typical applications for DI systems. The list of uses should not be taken to be all-inclusive.

5.1.1 Dropping/Inserting Special Services - Individual DS0 channels can be inserted into and/or dropped from a DS1 bit stream. This function allows the insertion (and removal) of Special Services circuits to/from a DS1 bit stream, e.g., audio programs, data service, Foreign Exchange services, etc. This application is shown in Figure 7. This function can also perform a digital switch bypass. When nailed-up connections are interfaced to a digital switch, valuable call processing time and resources must be used to handle this traffic. As shown in Figure 7, a DI system can be used to bypass this nonswitched traffic around the digital switch. This deloading allows the digital switch additional computer time to process normal switched traffic. Additionally, not all digital switches currently provide nailed - up connections.

5.1.2 Distributed Pair Gain System - A DI system can be utilized to drop/insert individual DS0 channels at various sites along a T1 route as shown in Figure 8.

5.1.3 Microwave Radio Access - As shown in Figure 9, a DI system can be used to provide Voice Frequency (VF) access to a digital microwave radio backbone without use of back-to-back channel banks.

5.1.4 End Terminal Capability - DI systems can be employed as stand-alone voice/data terminals (end terminals). This application provides the same function as standard D-channel banks.

5.1.5 Digital Tandeming - A DI system can tandem digital circuits through an analog office without D/A and subsequent A/D conversions, i.e., back-to-back channel banks are not required.

5.2 Most DI systems provide alarm monitoring and some have the capability to transmit terminal-to-terminal alarms such as the "yellow alarm" through the DI sites without disrupting communications between two different DI sites. Some DI systems can also bypass the through circuits in the event of DI equipment failure.

6. DESIGN EXAMPLES

6.1 The following paragraphs describe several design examples using DCS and DI equipment to solve network problems. It should be noted that the cost figures used were those applicable at the time this TE&CM section was developed. However, it is expected that the cost differential between the alternative designs will remain fairly constant in the future.

6.2 Example 1 - Analog office A has three incoming T1 span lines each carrying a mixture of message and special services traffic. The message traffic is to be routed to office B and the special services traffic to office C.

6.2.1 One method which can be used to provide this network arrangement is shown in Figure 10a. This method consists of providing back-to-back channel banks. Each of the incoming T1 span lines is connected to a separate channel bank (1, 2 and 3 in Figure 10a). Channel banks 4 and 5 are utilized to extend the message and special services traffic to offices B and C respectively. After digital to analog conversion and demultiplexing is performed in channel banks 1, 2 and 3, all of the VF channels carrying message traffic are physically cross-connected to channel bank 4. In a like manner, special services VF channels are connected to channel bank 5. Channel banks 4 and 5 then convert the analog traffic to digital and multiplex the DSO channels into DS1 bit streams.

6.2.2 An alternative method is shown in Figure 10b. This method uses a Digital Cross-Connect System to segregate the message and special services traffic received on the incoming T1 span lines and connect the traffic to the appropriate outgoing T1 span lines. In this method, no digital to analog and subsequent analog to digital conversions are required.

6.2.3 The back-to-back channel bank design shown in Figure 10a requires 5 channel banks each costing approximately $4000. Thus this method would cost about $20,000. The DCS in Figure 9b costs about $6000 plus $1200 per T1 port or a total of $12,000 [$6000 + 5 ($1200)]. Therefore, the DCS design costs about 40 per cent less than the back-to-back channel bank design. As mentioned previously, the DCS method also has the advantages of requiring less power and less space and providing better transmission quality.

6.3 Example 2 - Analog office A has an incoming T1 span line which has a single channel to be dropped at office A. The remaining channels are to be extended to office B. Additionally, a VF channel is to be inserted into the DS1 bit stream at office A.

6.3.1 As illustrated in Figure 5a, two back-to-back channel banks could be used to provide the required functions. Channel bank 1 is used to convert the DS1 bit stream into individual analog VF channels. The VF channels which are to be extended to office B are physically connected to channel bank 2 where analog to digital conversion is performed. The VF channel that is to be dropped at office A is physically connected from channel bank 1 to its required termination. The VF channel to be inserted into the DS1 bit stream toward office B is connected to channel bank 2 where it is converted from analog to digital and multiplexed into the DS1 bit stream.

6.3.2 In Figure 5b, a DI system is used to provide the required network functions. The DSO channels to be extended to office B are passed unchanged through the DI system, i.e., no D/A or A/D conversions. The DSO channel to be dropped in office A is demultiplexed from the incoming DS1 bit stream and digital to analog conversion is performed by the DI system. The VF channel to be inserted at office A is converted from analog to digital and multiplexed into the outgoing DS1 bit stream by the DI system.

6.3.3 The channel banks shown in Figure 5a cost about $4000 each for a total of $8000. A typical DI system costs $3700 plus $300 per VF channel unit. In the design shown in Figure 5b, two channel units are required, one for the channel to be dropped and one for the channel to be inserted. Therefore, the total cost of the DI system is $4300. Thus, the DI design costs about 46 per cent less than the back-to-back channel bank design. The other advantages of using the DI system are the same as described for the DCS system in the previous example.

FIGURE 1

BASIC DCS OPERATION

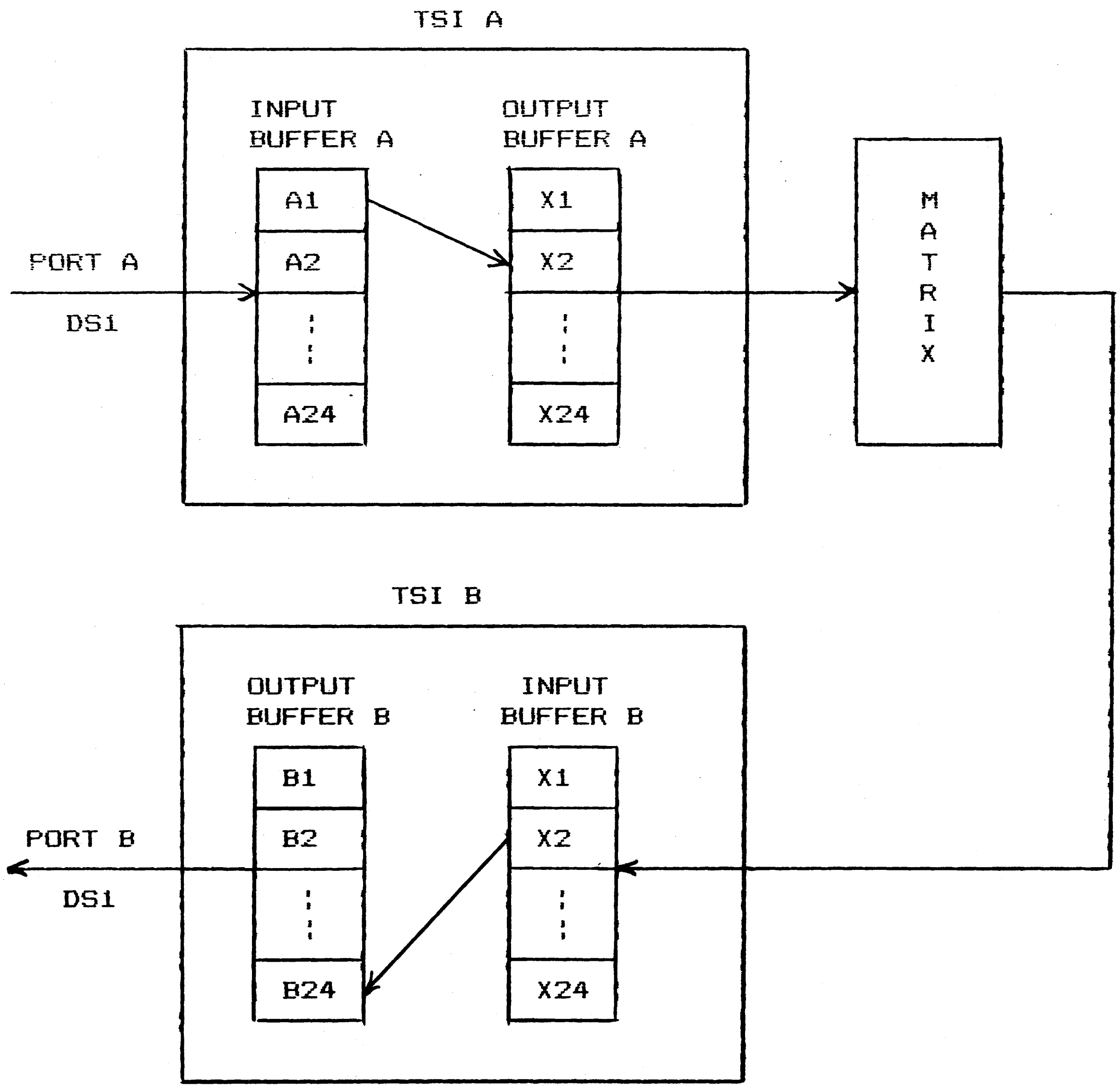


FIGURE 2

HUBBING

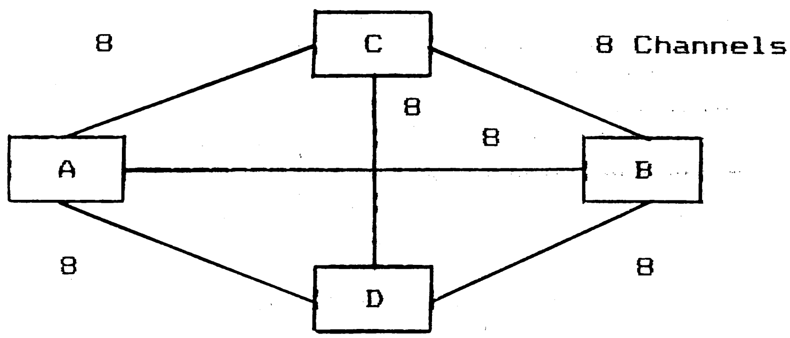


Figure 2a

Direct Trunking

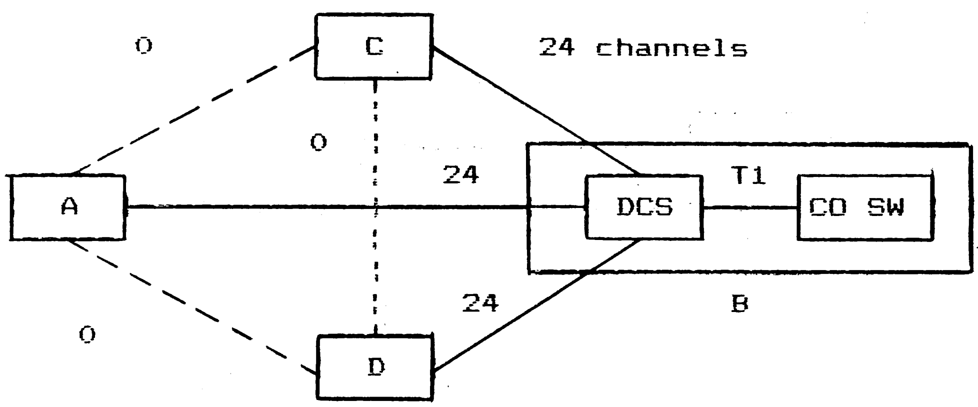
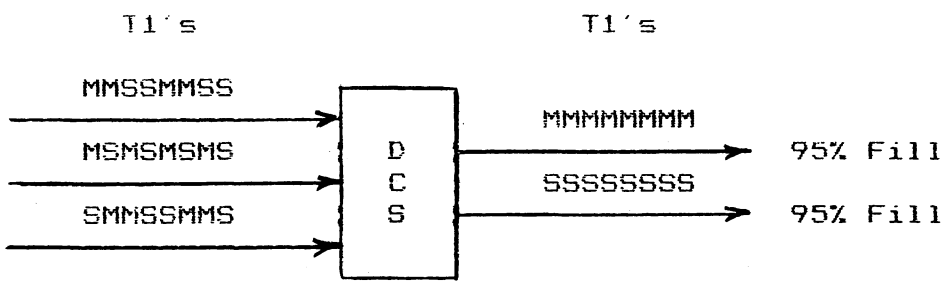


Figure 2b

DCS Hub

FIGURE 3

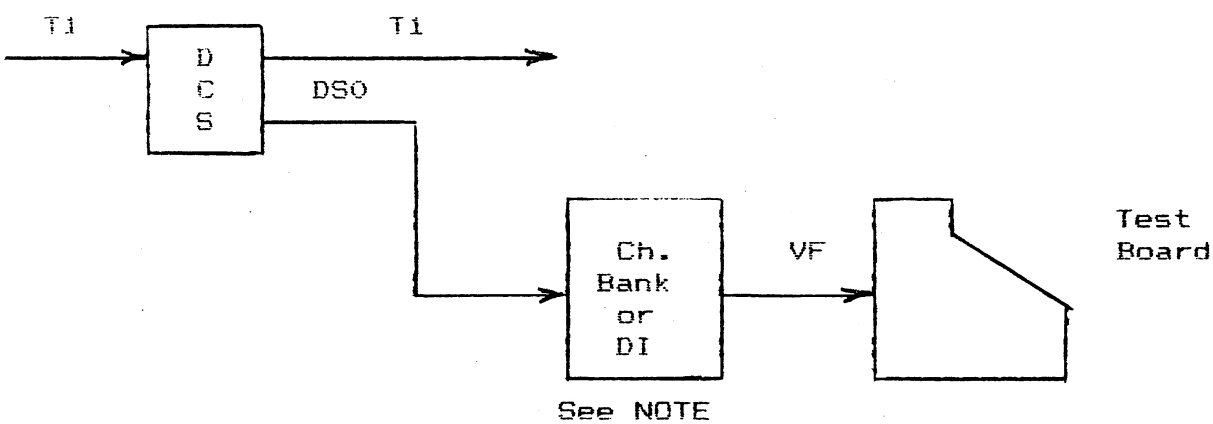
GROOMING



NOTE: All incoming traffic could also be of the same type.

FIGURE 4

TEST ACCESS



NOTE: Certain DCS equipment provide DS0 to VF decoding internally.

FIGURE 5a

DROP AND INSERT USING BACK-TO-BACK CHANNEL BANKS

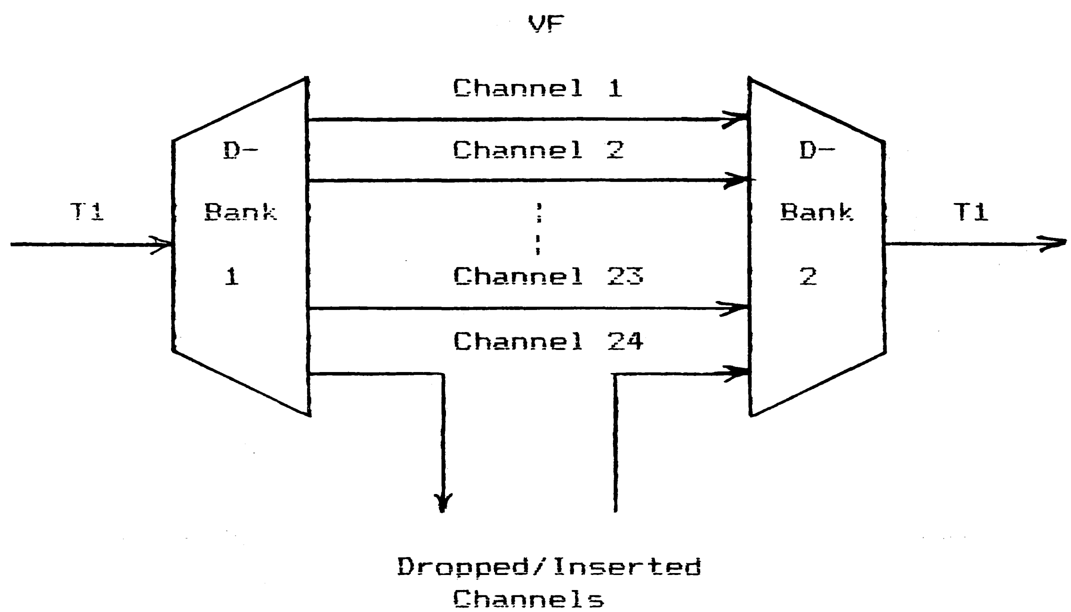


FIGURE 5b

DIGITAL DI SYSTEM

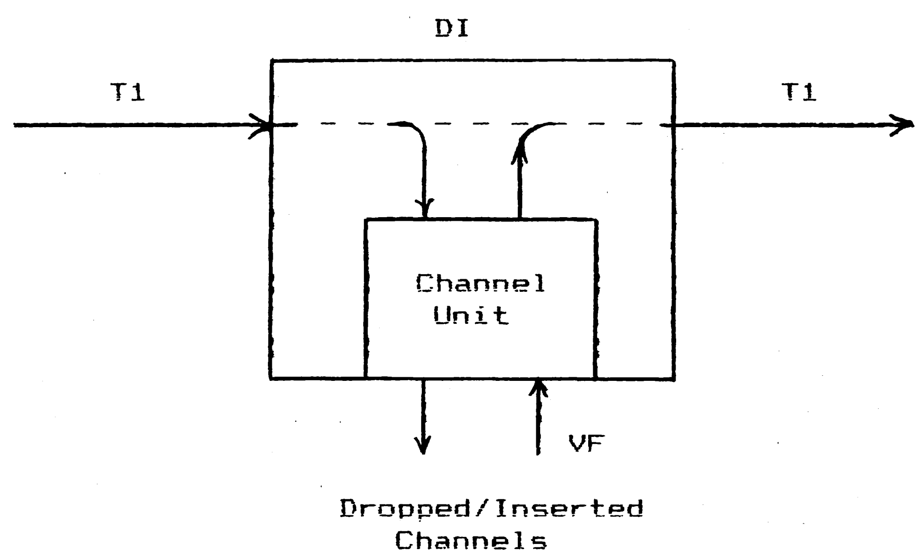
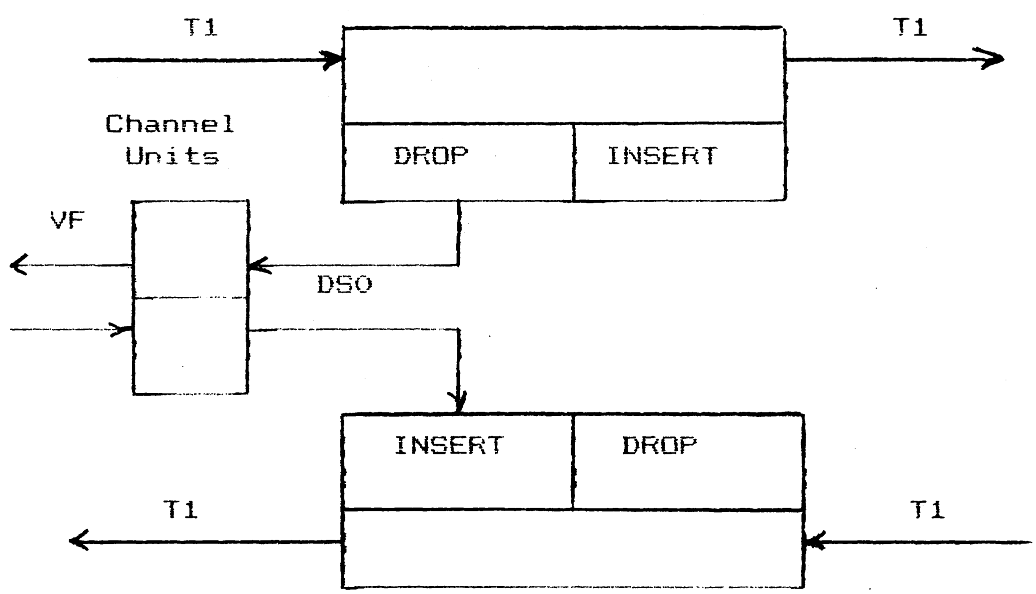
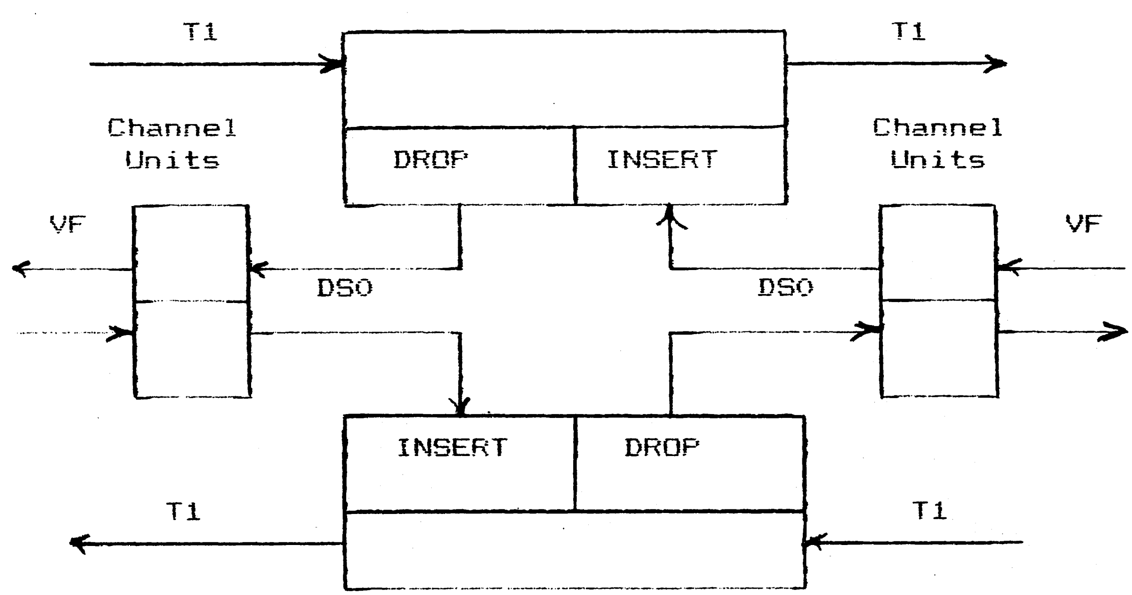


FIGURE 6

DI CONFIGURATIONS



ONE-WAY OPERATION



TWO-WAY OPERATION

FIGURE 7

DROPPING/INSERTING SPECIAL SERVICES AND DIGITAL SWITCH BYPASS

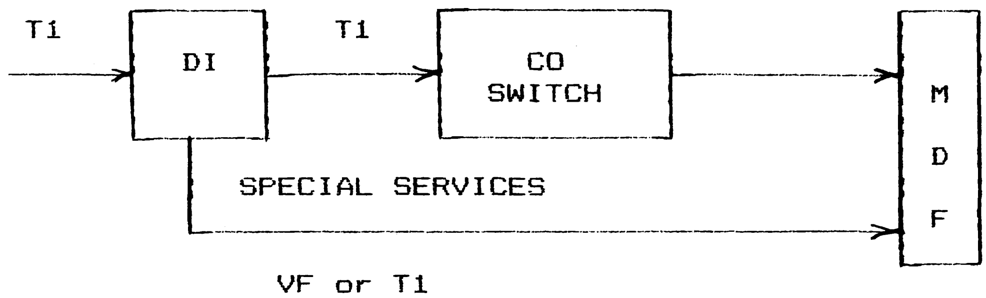


FIGURE 8

DISTRIBUTED PAIR GAIN SYSTEM

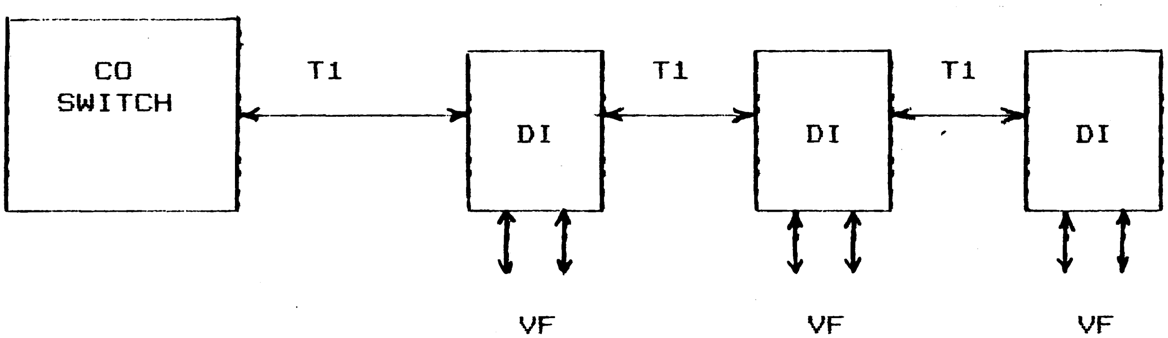


FIGURE 9

MICROWAVE RADIO ACCESS

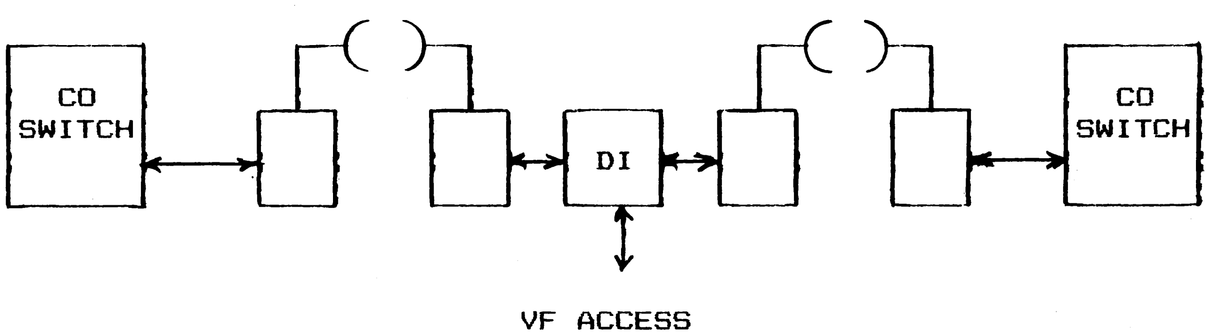


FIGURE 10
DCS DESIGN EXAMPLE

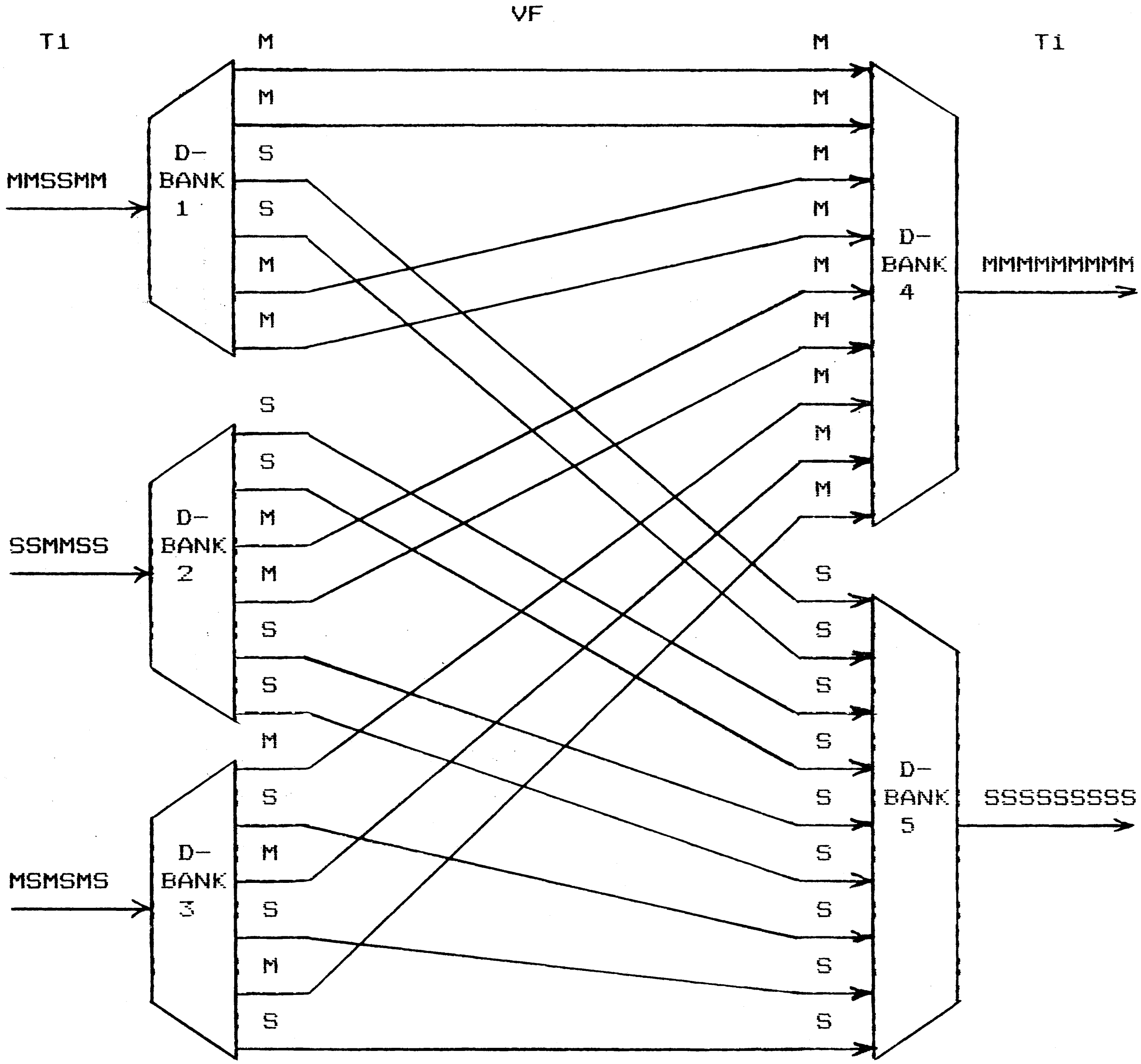


FIGURE 10a
ANALOG METHOD

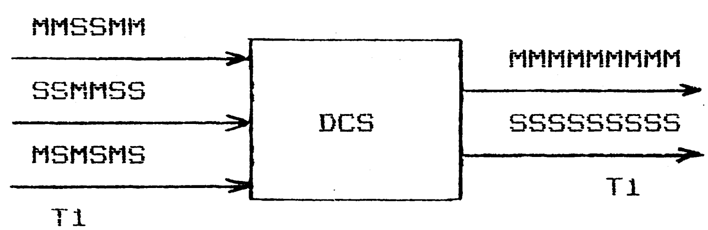


FIGURE 10b
DIGITAL METHOD

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