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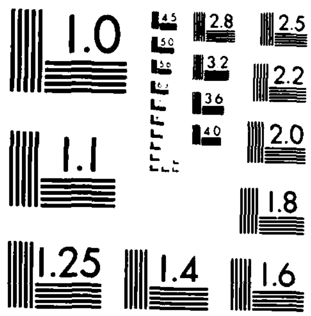
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EP 3-83

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ENGINEERING PUBLICATION NO. 3-83

DCS NETWORK SYNCHRONIZATION DESIGN CRITERIA

MAY 1984

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This publication describes the proposed network synchronization capability for the near-term Defense Communications System (DCS), and in particular the methodology for developing this capability. The basic network synchronization capability using existing technology, followed by major and minor transmission node implementations, are described. Finally, a detailed implementation plan for the DCS is given, with the admonition that the dynamic nature of timing and synchronization will cause update and revision of the plan.

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DCS NETWORK SYNCHRONIZATION DESIGN CRITERIA

MAY 1984

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FOREWORD

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EXECUTIVE SUMMARY

This engineering publication describes the criteria and rationale used in developing the network synchronization capability for the near-term Defense Communications System (DCS). Not only are there near-term requirements for this network synchronization capability, but there also exist long-term benefits to be derived from an improved timing capability. The purpose of this report is to provide the methodology for applying this network synchronization capability in the DCS.

For the near-term network synchronization capability within the DCS, no research and development is necessary since state-of-the-art technology is available. Chapter III describes in generic terms the basic configuration of the equipment used to provide network synchronization. This basic configuration is composed of a station clock, clock distribution subsystem, and the digital data buffer. The performance characteristics of this system as well as the performance characteristics of the individual equipments are stated in Chapter III.

Chapter IV defines the criteria by which the implementation of network station timing is determined for each of the two types of transmission node, called major and minor. The major node typically has a heavy concentration of traffic, several incoming and outgoing links, perhaps switching equipment, and perhaps interfaces with another major system such as the DSCS or TRI-TAC. A separate, self-contained timing subsystem is proposed for the major node. The minor node has none of the attributes of the major node and typically is a simple repeater or a terminating site off the major backbone. For the minor node, loop timing will be used to provide the required clock.

In Chapter V the application of the previously developed network design to the DCS is presented. Based on this network design, a detailed network implementation description is provided, defined in terms of DCS area as well as digital transmission upgrades (e.g., DEB, DTN, DSN, DSCS).

Since the timing and synchronization project is dynamic in nature, it must be recognized that as future requirements are identified, the planning and implementation strategies will need to be adjusted. Therefore, it is anticipated that future updates/revisions of this engineering publication will be necessary.

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I. INTRODUCTION

This technical report describes the criteria and rationale used in planning the network timing and synchronization (T&S) capability for the planned digital portion of the Defense Communications System (DCS). This timing and synchronization capability will be required for certain equipments, subsystems, and system interfaces.

The interface of synchronous data channels between the terrestrial DCS and the Defense Satellite Communications System (DSCS) will require synchronization of these two subsystems. Widespread application of the Low Speed Time Division Multiplexer (LSTDM) and its synchronous data channel capability will require this timing and synchronization capability. The introduction of digital troposcatter will require synchronization of associated equipment. The network of digital switches and interconnecting digital trunks being implemented as the European Telephone System (ETS) must also be synchronized.

In addition to these near term requirements described above, there exist long term requirements for, and benefits to be derived from, a timing and synchronization subsystem. Benefits to be derived are improved performance, efficiency, and availability of digital transmission links, and the potential for dissemination of precise time/frequency to other users. An improved timing capability will also aid in establishing or reestablishing communications, reduce the time to acquire synchronization of a spread spectrum signal that is being jammed, and facilitate the synchronization of crypto equipment.

The purpose of this report is to provide the methodology for applying this timing and synchronization equipment in the DCS, both generically and to specific areas of the DCS.

II. BACKGROUND

Prior to implementation of the proposed timing and synchronization (T&S) equipment, the DCS digital transmission subsystems will be timed by clocks intrinsic to the transmission equipment (e.g. clocks within the DRAMA radio) and by use of pulse stuffing and buffering, also intrinsic to the transmission equipment. However, with the introduction of certain subsystems, such as the Low Speed Time Division Multiplexer (LSTDM) and digital troposcatter, a timing subsystem was also determined to be required to: (1) allow synchronous transmission within the low speed digital data network, (2) provide acceptable performance of digital troposcatter by using synchronous interfaces for all levels of multiplex, and (3) provide extension of satellite derived synchronous circuits into the terrestrial DCS.

DCEC TR 23-77, [1] described the technical performance aspects of the timing subsystem proposed for implementation to support the aforementioned near-term synchronous subnetworks in the Defense Communications System. This requirement was originally submitted for Military Department consideration in the DCA Five Year Program (FYP 76) and has since been updated annually in each year's FYP.

The U.S. Army has been tasked by DCA to acquire the ti[illegible]g and synchronization subsystem. Because of the widespread avai[illegible]ility of commercial timing components, the required equipment is be[illegible]g [illegible]ocured off-the-shelf.

III. TIMING AND SYNCHRONIZATION CONFIGURATION

The proposed configuration of the timing and synchronization (T&S) subsystem consists of the station clock, clock distribution subsystem, and digital data buffer. A functional diagram of the station clock and the clock distribution subsystem is shown in Figure 1, while their electrical characteristics are defined in Appendix A. For terrestrial nodes collocated with DSCS sites, existing cesium beam standards used in the DSCS may be used as the primary reference for the DCS station clock. The two precision oscillators provided as backup will have an initial accuracy equal to the reference and a long term stability of $\pm 2 \times 10^{-10}$ (according to AFCC EPS-82-012, 27 Aug 82). For non-DSCS sites, Loran C will be used as the primary reference source for the station clock. Both the DSCS atomic clocks and the LORAN C navigational system have transmit frequency sources that are synchronized to UTC.

LORAN C was selected as the clock source for the near-term DCS T&S subsystem primarily because of its low cost, off-the-shelf availability, commonality with existing DCS timing standards, and proven performance. LORAN C is a pulsed, low-frequency (LF), radio navigational system operated by the United States Coast Guard. Use of LF provides propagation stability and low attenuation of the groundwave with distance. Thus, highly stable, long range transmission is possible.

All LORAN C transmitting stations are equipped with cesium beam frequency standards. Synchronization among these frequency standards is maintained by monitoring and updating each standard in comparison to UTC as determined by the U.S. Naval Observatory. LORAN C is currently available to nearly all DCS sites.

The LORAN C system as it operates today has demonstrated a 99.7 percent availability, excluding scheduled off-the-air maintenance which reduces that figure to about 99 percent. Frequency accuracy of 1 part in 10^{12} is easily attainable and accuracy of a few parts in 10^{14} is in fact typical. Such performance cannot be achieved with independent free-running atomic clocks.

1. STATION CLOCK

It should be noted that the JCS Master Navigation Plan (SM-266-83) proposes a phase out of the LORAN system in favor of the NAVSTAR Global Positioning System during the period 1987-1992. In the event that this planning is executed, available alternatives will be substituted to provide requisite UTC reference.

The station clock, as functionally depicted in Figure 2, will provide an accurate and stable source of frequency and time standards at rates of 1 MHz, 5 MHz, and 1 pps. The station clock has the option of being driven by the LORAN C receiver or by an external reference source (such as cesium beam standard), dependent upon the best available reference. In priority order, first choice will be the primary reference; second choice, the alternate reference; and third choice, the two oscillators. The selection of the LORAN C or the external reference source as the primary or alternate reference is an operator selectable function.

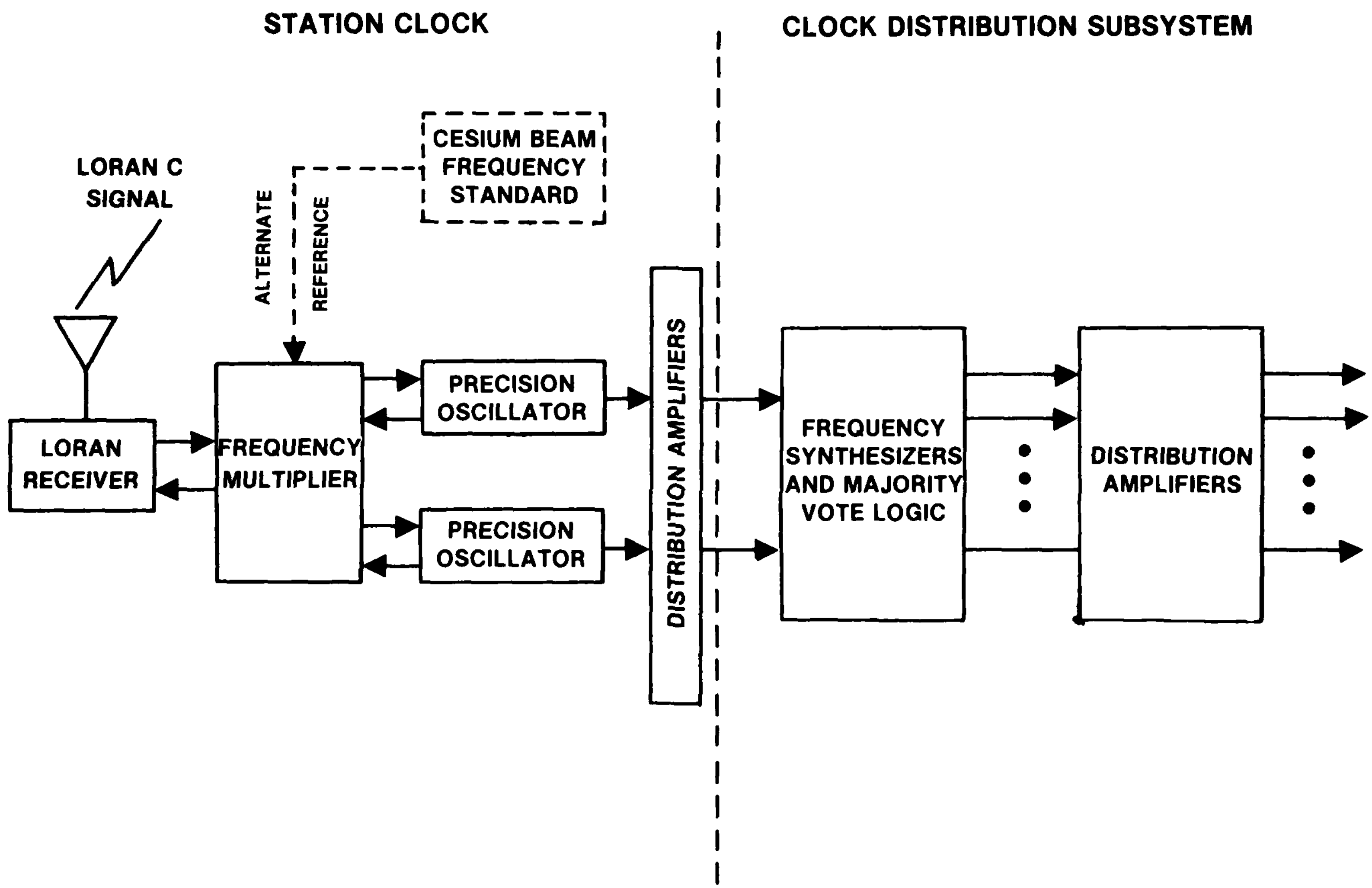


FIGURE 1. DCS STATION CLOCK AND CLOCK DISTRIBUTION SUBSYSTEM

When driven by the LORAN C receiver, a 3-foot loop antenna and a 9-foot whip antenna are provided for reception of the LORAN C 100 kHz carrier signal.

a. LORAN C Receiver. The LORAN C receiver provides automatic acquisition and tracking of operator selected LORAN C signals for use as a precise reference against which other frequency standards may be compared or controlled. After the Group Repetition Interval (GRI) and desired LORAN C station have been selected by the operator, no other intervention will be needed. The receiver will automatically acquire the selected station of the LORAN C chain and then automatically go into the tracking mode. Without intervention, the receiver will continue to track until the incoming signal fades beyond the sensitivity of the receiver or the operator takes action to halt the tracking process. In the event that this signal is lost, the receiver will automatically reacquire the ground wave of the initially selected station.

Using the LORAN C ground wave, the receiver will provide a 1 MHz signal output which tracks the long term accuracy of the LORAN C signal, and a 1 pps output. This 1 MHz signal is phase locked to the received LORAN C signal. The 1 MHz reference output will have an accuracy of at least 1 part in 10^{11} in one hour, 1 part in 10^{12} in one day, and 1 part in 10^{13} thereafter, maintained with respect to the received signal. The 1 pps reference output as provided by the receiver is tied to the received LORAN C signal. The 1 pps output is accurate to 1 microsecond with respect to the received signal. The 1 pps pulse, at least 20 microseconds wide, will be used as an unambiguous timing pulse.

In order to satisfy the set of performance objectives (as defined in reference [1]) for timing subsystem availability, station clock accuracy, station clock stability, meantime between outage (MTBO), mean time to repair (MTTR), mean time to timing slips (MTTS), and buffer lengths, the station clock has been specified to provide redundancy in the form of two precision oscillators in order to compensate for any loss of LORAN C due to equipment failure or signal loss. The station clock is also capable of accepting an external reference (such as a cesium beam standard) when available.

b. Frequency Multiplier. The frequency multiplier provides the functions of frequency synthesis, distribution, manual selection and failure mode operation and all necessary interfaces within the station clock, to include the LORAN C receiver, the external source, the primary and back up oscillators and the distribution amplifier.

Should the primary reference fail, the frequency multiplier will automatically switch to the alternate reference. The frequency multiplier will then continue to operate using the alternate reference until it is manually reset. Should both the primary and alternate references fail, all reference input signals to the oscillators will discontinue, and the oscillators will operate unlocked (not phase and frequency locked to the 1 MHz primary and alternate reference).

As depicted in Figure 2, the frequency multiplier (for monitoring) accepts 5 MHz sinewave signals from each of the two oscillators. The oscillators are designated as primary and backup. Manual intervention shall be required to restore either oscillator after failure. For steering purposes, the frequency multiplier provides each oscillator with a 1 MHz sinewave. If either the primary or backup signal from the oscillators fails, switchover to the remaining oscillator occurs automatically without changing the outputs to the LORAN C receiver or distribution amplifier.

c. Oscillators. Two oscillators are provided as separate independent components. Each oscillator is locked to its respective input from the frequency multiplier. Should the reference signal be lost, reacquisition of phase lock will be automatic after the reference signal is restored.

The oscillators accept the reference input and provide outputs that assume the long term stability of the reference. Upon removal of the reference signal, the oscillators will continue to provide the output signals without immediate degradation greater than 1 part in 10^{12}. Thereafter the oscillators will degrade in accuracy not more than 3 parts in 10^{11} per day.

d. Distribution Amplifier. The distribution amplifier provides the drive capability to interface the frequency multiplier and the oscillators' 1 MHz output signals to remote equipment. In addition to its use within the Station Clock, the distribution amplifier is also capable of independent operation. The distribution amplifier employs three separate synthesizers to synthesize the 5 MHz output signals. The distribution amplifier has the capability to drive the 1 MHz output reference, a distance of at least 1000 cable feet.

The distribution amplifier as a minimum provides six 5 MHz and six 1 MHz sinewave outputs continuously that are individually adjustable from 0.5 to 5.0 volts RMS into 50 ohms. The outputs are separated to provide two 1 MHz and two 5 MHz outputs from each of three synthesizer sections.

2. CLOCK DISTRIBUTION SUBSYSTEM (CDS)

The clock distribution subsystem interfaces with the station clock to generate and distribute timing signals to transmission and user equipments. In order to meet DCS availability criteria, triple redundant frequency synthesis followed by majority vote logic is provided. Voting logic will select one of the three frequency synthesized outputs and provide the selected frequency rate to the distribution amplifier. The distribution amplifier then provides an individually isolated output to each equipment as required.

The principal functions of the CDS include:

(1) Accepting up to three independent frequency reference input signals.

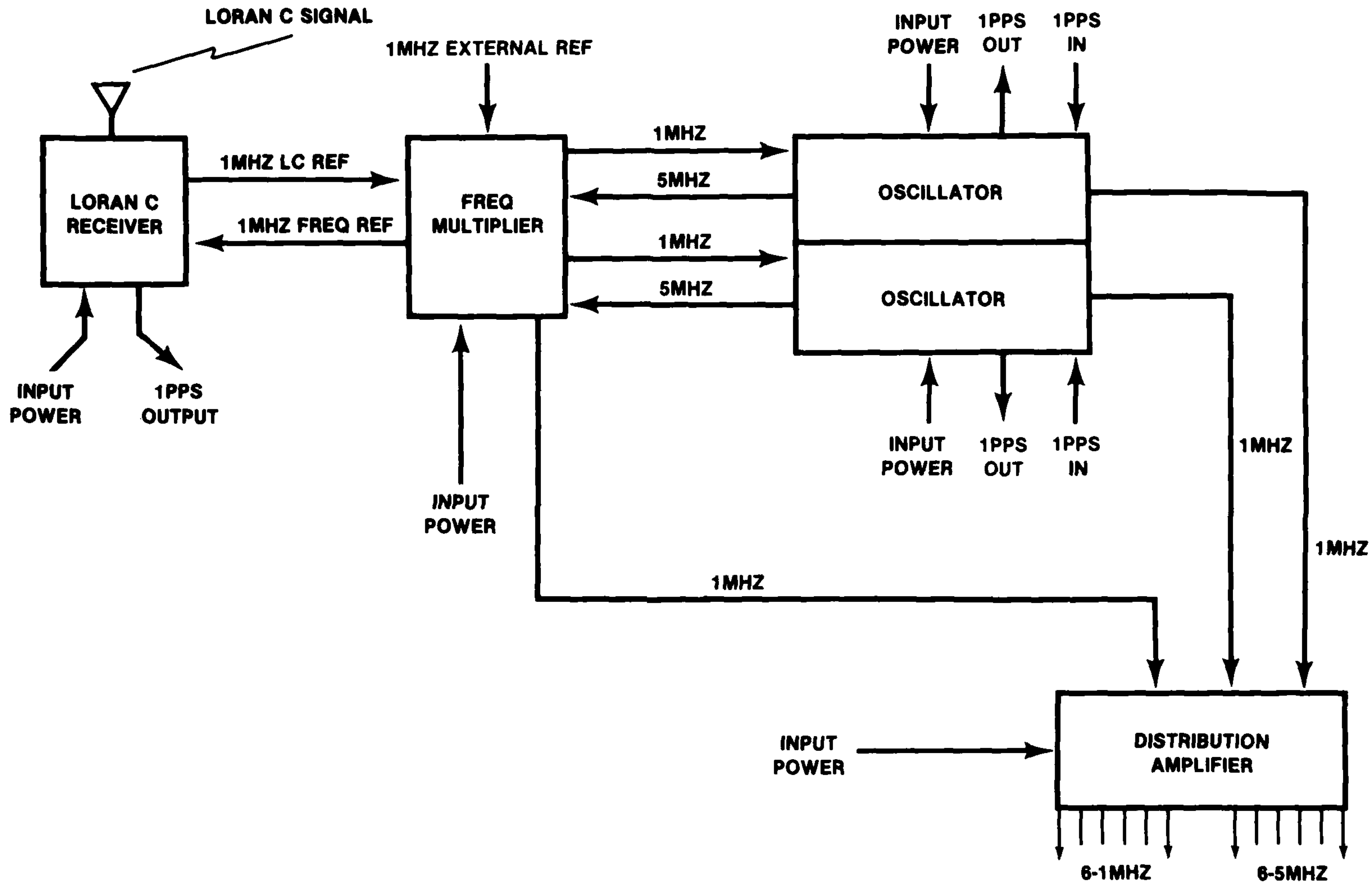


FIGURE 2. FUNCTIONAL DIAGRAM OF THE STATION CLOCK

(2) Providing redundancy in generating (synthesizing) clocking frequencies for the required families of rates (to be discussed later).

(3) Distributing these clocking signals to individual transmission and switching equipment.

(4) Providing alarm indications for failures.

A functional schematic of the CDS, depicting the interrelationship of its elements, is shown in Figure 3.

The CDS and the associated frequency sources will provide timing to some or all the transmission and switching subsystems located at a Defense Communications System (DCS) communications node. The clock signals generated by the CDS will be applied to external clock inputs of the transmission and switching equipment consistent with the input interface parameters of each equipment.

a. Frequency Synthesizer. The CDS frequency synthesizer accepts as inputs three 1 MHz or 5 MHz signals that may or may not be phase coherent sinusoidal or squarewave outputs from the Station Clock or other frequency standard. The CDS also accepts as inputs three 1.544 MHz squarewave signals that may or may not be phase coherent inputs from external sources (e.g., AN/FCC-98). Simultaneous inputs of any combination of 1.544, 1, or 5 MHz cannot be used. When available, the frequency synthesizer of the Clock Distribution Subsystem can also interface with the Hewlett Packard Model 5061A Frequency/Time Standard with option 004 (high performance cesium tube) and option 001 (clock), of the type used in the Defense Satellite Communication System (DSCS). The frequency synthesizer is capable of synthesizing all clock rates listed in Table I. For each generated family of clock rates specified in Table I, the redundant frequency synthesizers will provide outputs to the voting logic. The voting logic will then select one of these synthesizer outputs and provide the selected frequency rate to the distribution amplifier. The voting logic determines which (if any) of the frequency synthesizer outputs are in disagreement. If one frequency synthesizer is found to disagree with the other two synthesizers, its output is removed from the input to the distribution amplifier, and will require operator intervention for return to service. If all frequency synthesizers are found to disagree, the voting logic will lock to any one of the synthesizer outputs. If two or more of the frequency synthesizers are found to agree, the voting logic will select any one of the synthesizers which agree for output to the distribution amplifier.

The frequency synthesizer and voting logic are modular, such that a given module would only generate or vote upon a subset of the full complement of rates specified in Table I. A typical configuration of the CDS would require only a few of the clock rates listed in Table I.

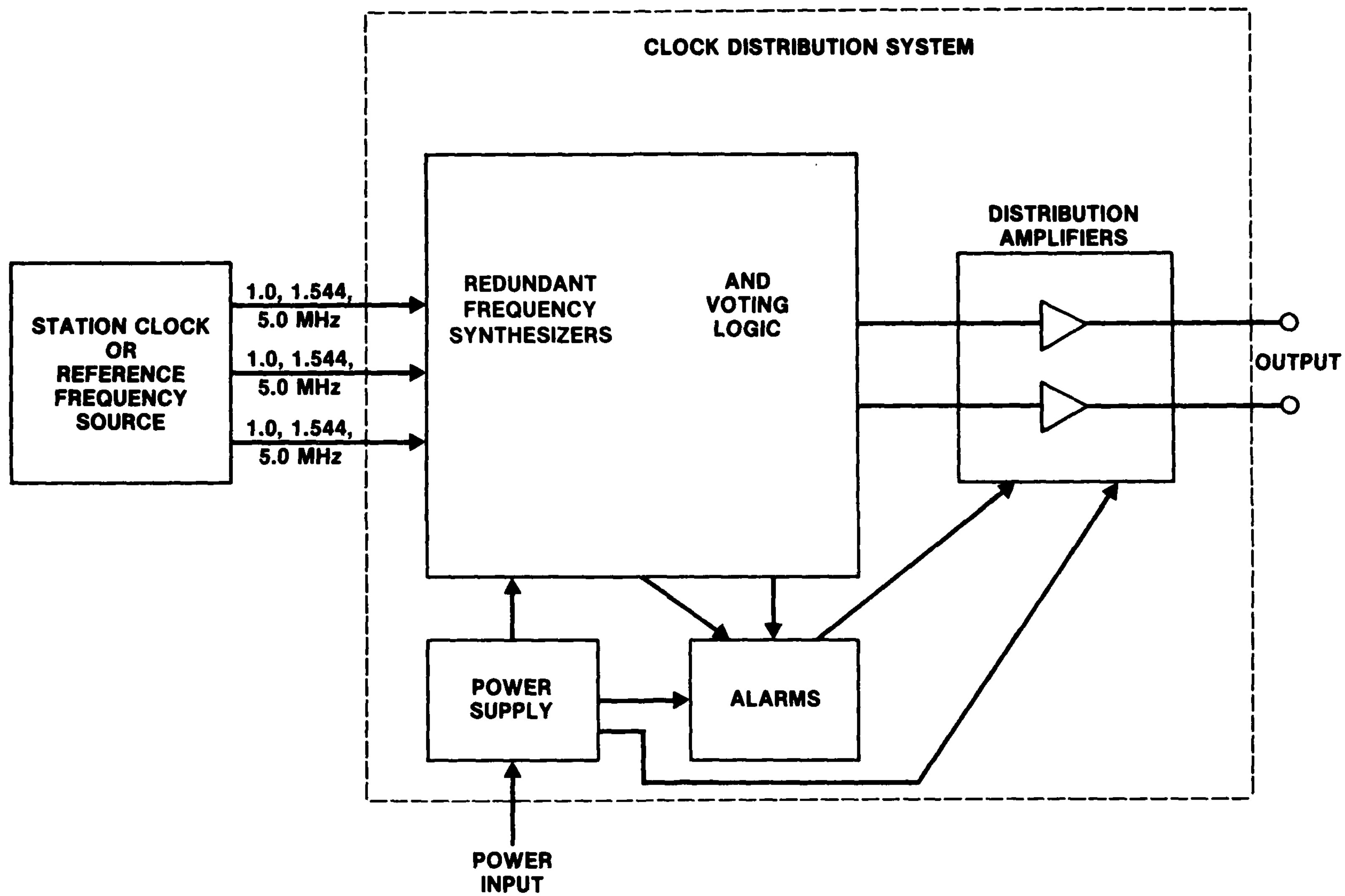


FIGURE 3. FUNCTIONAL SCHEMATIC OF CLOCK DISTRIBUTION SUBSYSTEM

TABLE I. CLOCK FREQUENCY FAMILIES

I.	75 (2^N) Hz family	-	N = 0 to 11
II.	600 (N) Hz family	-	N = 1 to 12
III.	8000 (N) Hz family	-	N = 1 to 8
IV.	2^N kHz family	-	N = 6 to 11
V.	192 (N) MHz family	-	N = 1, 2, 3, 8
VI.	1.544 (N) MHz family	-	N = 1 to 4
VII.	3.232 (N) MHz family	-	N = 1 to 4
VIII.	5.0 (N) MHz family	-	N = 1

b. Distribution Amplifier. The distribution amplifier accepts the output of the frequency synthesizer voting logic and has the capability of deriving, for each family of rates, the specific frequency outputs required, which are then provided as individually buffered outputs. Failure of any single output will not affect other buffered outputs. A typical DCS application would require one or two outputs for only a few of the frequencies specified. For this reason, the distribution amplifier is modularized so that each module of the distribution amplifier may have a number of outputs and a mix of frequency rates.

The distribution amplifier of the Clock Distribution System provides squarewave signals at the clock rates listed in Table I.

The interface of the distribution amplifier of the clock distribution system includes but is not limited to the following transmission and switching equipments at their respective external clock inputs:

AN/FRC-170 (Series)	Digital Radio
AN/FCC-99	Multiplexer
AN/FCC-98	Multiplexer
AN/FCC-100	Multiplexer
CY-104(A)	Multiplexer
AN/FCC-97	Multiplexer
MD-918	Tropo Modem
GSC-36	Group Data Modem
KG-81	Encryption Device
KG-84	Encryption Device
DSN Switch	Digital Switch
DCS Channel Packing	Switch
AUTODIN Switches	Switch
AN/USC-26	Group Data Modem
MP 96	VF Modem
AN/GSC-24	Sat. Multiplexer
KG-13	Encryption Device
KG-34	Encryption Device
TD 13XX	Multiplexer
CV 3511/TD 1220	Multiplexer
DPAS	Electronic Patch
Tropo Radio RF (Transmitter/Receiver) Local Oscillators	
AN/USC-28	Spread Spectrum Modem
LRM	Low Rate Satellite Multiplexer
TD 1303	Multiplexer
C30	Packet Switch

3. BUFFERS

All received digital signals entering a digital transmission network node from other nodes have clock accuracies and stabilities determined by the transmitting node clock. These received signals also exhibit the transition delay variations introduced by the intervening link(s). Received digital signals will either be dropped at a particular node or through-routed.

TABLE II. DRAMA EQUIPMENT BUFFER LENGTHS

	PORT TRANSMISSION RATE (kb/s)	PORT BUFFER LENGTH (BITS)	AGGREGATE BUFFER LENGTH (BITS)
AN/FRC-170 (V)	12,928	± 11	
SERIES DIGITAL LOS	9,696	± 11	
RADIO	6,464	± 11	
	3,232	± 11	
AN/FCC-99	6,176	± 8	
SECOND LEVEL	3,088	± 8	
MULTIPLEXER	1,544	± 8	
AN/FCC-98	512	± 64	
FIRST LEVEL	256	± 64	
MULTIPLEXER	128	± 64	
	64	± 64	
	56	± 64	
AN/FCC-100 (V)			
LSTDM			± 1024 (Maximum)*
SYNCHRONOUS PORTS	64	+6, -16	
	32	+6, -16	
	19.2	+4, -19	
	16.0	+3, -20	
	9.6	+2, -21	
	8.0	+2, -21	
	7.2	+2, -21	
	4.8	+1, -22	
	2.4	+1, -22	
	1.2	+1, -22	
	.6	+1, -22	
	.3	+1, -22	
	.150	+1, -22	
	.075	+1, -22	

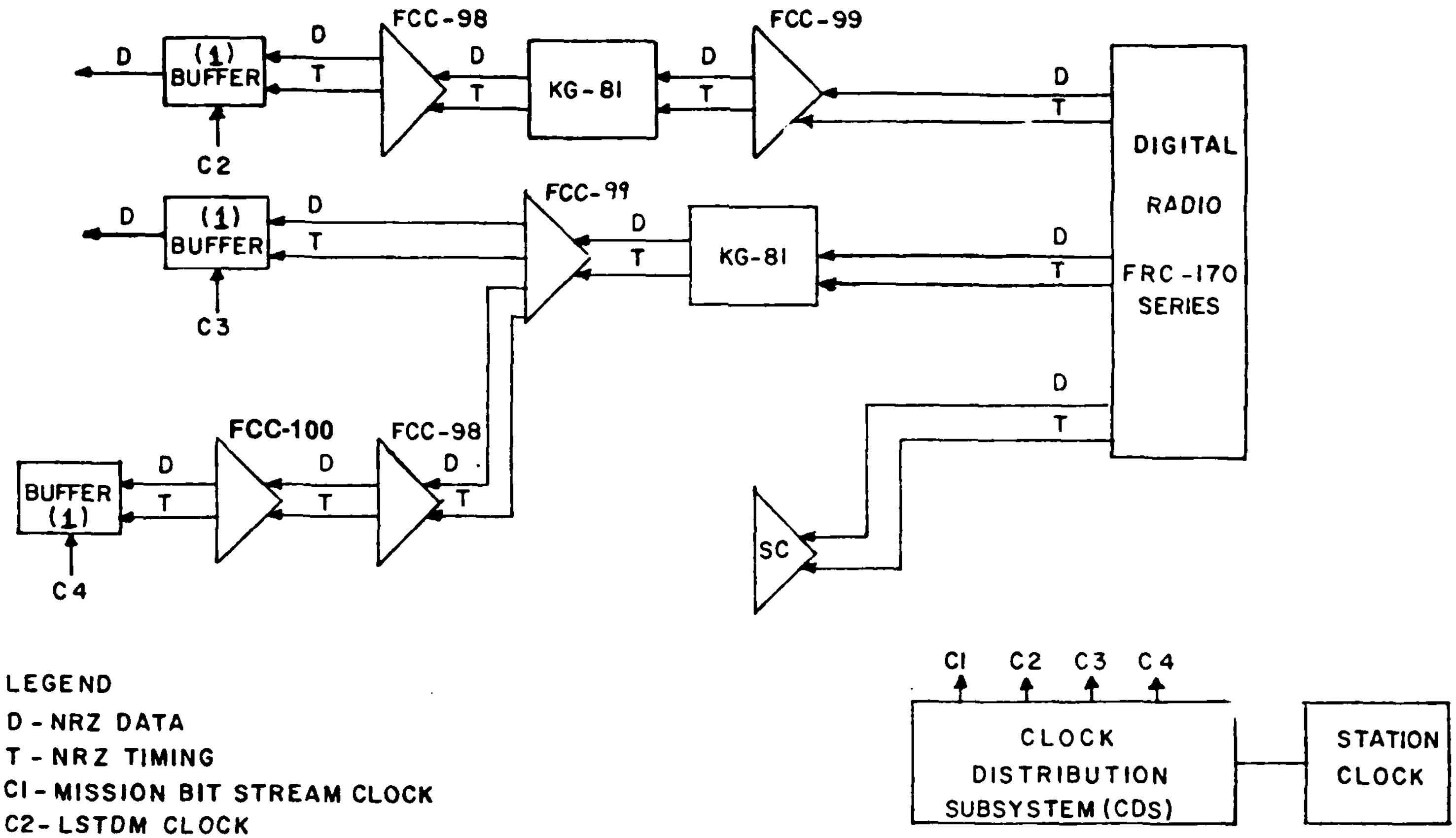
* The AN/FCC-100 is equipped with a programmable aggregate buffer at aggregate rates through 64 kbps.

Through-routing can be accomplished at the user rate, or the data trunk or digroup levels. Through-routed circuits that are to be transmitted from the node via synchronous transmission equipment must be brought into synchronization with the local station clock. Synchronization is accomplished using data buffers, which are either built into the transmission equipment or are separate stand-alone units. As an example, Table II gives the buffer lengths intrinsic to the input ports of the DRAMA equipment. The stand-alone buffers will be capable of buffering from a minimum of 64 bits to a maximum of 32,768 bits with an upper speed of 2.048 Mb/s.

In the receive direction of the major node, as shown in Figure 4, received data is buffered for synchronization purposes. Data is clocked into the buffer by received timing derived in the radio or multiplexer, and clocked out by the local clock.

The buffers for the higher speeds (greater than 2.048 Mb/s) are built into the transmission equipment and have sufficient length to compensate for clock differences and path delay variations for terrestrial transmission. Interface with satellite-derived synchronous circuits will require the additional buffer length provided by the stand-alone digital data buffer to compensate for satellite delay variations that are caused largely by satellite orbit inclination, orbit eccentricity, and atmospheric/ionospheric variations. The satellite is initially orbited with a maximum inclination in one direction and during the satellite operational lifetime the orbital plane inclination shifts through 0^{o} and then in the opposite direction. The path length delay variation due to orbital inclination varies with the inclination angle and ranges from 1 to 4 ms. The delay variation is largest at the beginning and end of the satellite operational lifetime and is minimum during mid-life. The path delay variation is also a function of the orbital eccentricity, which is a daily variation. DSCS satellites are allowed a 1 percent eccentricity, which contribute as much as 5.6 ms additional delay variation. Future DSCS satellites will be better controlled and thus reduce the orbit eccentricity delay contributions. Propagation delay due to atmospheric and ionospheric variations contributes an additional delay variation of approximately 1 ms. This results in a total maximum diurnal delay variation of approximately 10 ms.

The network synchronization system cannot be considered truly synchronous in that the network nodes are not always slaved to a single common timing source. Even if they are, some data buffers are required to account for delay variations of the transmission media. The most critical buffer design requirement, however, is to accommodate the plesiochronous mode of operation. In a plesiochronous system, data and transmission system digital signals generated under the control of one station clock may be at a slightly different rate from those generated under the control of other station clocks within the network. To maintain Bit Count Integrity (BCI), buffers are used to compensate for the phase difference between these signals. Buffers are required also to compensate for small timing differences which may arise because of differences and perturbation in LORAN C transmission. By design, internal buffers have been included as an integral part of most of the input circuits for the digital transmission equipment that will be used to implement the future DCS. The equipment input buffers have been designed to provide BCI for 24 hours in a plesiochronous system when the station clock stability is 10^{-9}.



LEGEND

D - NRZ DATA

T - NRZ TIMING

C1 - MISSION BIT STREAM CLOCK

C2 - LSTDM CLOCK

C3 - 1.544/3.088/6.176 MB/S RATE CKK

C4 - C D S PROVIDED CLK

SC - SERVICE CHANNEL MULTIPLEXER

NOTES:

(1) RECOMMENDED BUFFER LOCATION. EACH BUFFER AT THIS LEVEL IS NORMALLY BUILT DIRECTLY INTO THE TRANSMISSION EQUIPMENT FOR ALL RATES BELOW 1.544 MB/S.

FIGURE 4. RECEIVE TIMING FOR DCS MAJOR NODE

In a plesiochronous system that has station clocks of 10^{-11}, BCI theoretically would be extended to 2400 hours. For those stations slaved to a single clock or coordinated with UTC, BCI will be maintained for an indefinite period of time. Note, however, that buffer sizing is critical in that if a buffer reaches an underflow or overflow condition, it will reset to its midpoint, causing a loss of BCI.

The following is an example of the calculations required to determine the proper buffer lengths, both for the terrestrial and the satellite portions of a circuit. For this example, a hypothetical, full-duplex 512 kb/s circuit traversing both satellite and terrestrial paths will be analyzed. This circuit originates at a DSCS site and is transmitted via satellite to another DSCS location where it is tandemed into a synchronous multiplexer for transmission terrestrially to its termination site. To compensate for the satellite path delay variation (design goal of +10 ms for DSCS paths) and to provide a proper mean time between loss of synchronization (design requirement of at least 24 hours), a stand alone buffer capability is required.

To determine the appropriate size of this buffer, both terrestrial and satellite segment requirements must be taken into account. Terrestrially, a mean time between loss of synchronization of 24 hours is required end-to-end. The buffer length required to accommodate this requirement can be determined in two steps: first, by taking the number of seconds in 24 hours (86,400 seconds/24 hours) multiplied by the circuit rate in bits/second (in this example: 512 kb/s) to determine the number of bits transmitted per day (4.42368×10^{10} bits/day), and then multiply the number of bits transmitted per day by the average clock accuracy of the circuit in question (in the DCS the average design goal is $\pm 1 \times 10^{-11}$). Thus,

$$(4.42368 \times 10^{10} \text{ bits/day})\ (2 \times 10^{-11}) = 8.84736 \times 10^{-1} \text{ bits of buffer.}$$

Therefore, terrestrial buffer requirements approximate 1 bit of buffer.

As would be expected, the major factor in determining the buffer size is the satellite delay variation. This buffer length can be calculated by multiplying the circuit rate (512kb/s in this example) by the (conservative design goal) maximum delay variation of approximately $\pm$10m sec for DSCS paths. Thus,

$$(512 \text{ kb/s})\ (20 \times 10^{-3}) = 10240 \text{ bits of buffer.}$$

Therefore, the total buffer size is found by adding the terrestrial portion (1 bit) and the satellite portion (10,240 bits) together: 1 + 10,240= 10,241 bits of buffer.

IV. STATION TIMING

The implementation of the network does not require that every node have a LORAN C receiver or other primary reference standard. The allowable implementation will be to provide these primary clock sources at major nodes, with minor nodes slaved (looped) to them.

The determination as to major versus minor node designation and hence the timing and synchronization (T & S) configuration for each node is made using a number of specific criteria.

Specific criteria for major nodes include:

(1) The widespread application of the Low Speed Time Division Multiplexer (LSTDM - AN/FCC-100) and its synchronous data channel capabilities (as shown in Table III) require in most cases separate timing and synchronization capabilities. The exception to this rule is noted below.

(2) The introduction of digital troposcatter will require synchronization of associated equipment to include the MD 918 tropo modem and internal oscillators.

(3) With the DCS evolving toward an all-digital communications system, there are T & S requirements for the application of digital switching (including the implementation of the European Telephone Systems (ETS)). Therefore, major nodes within the ETS realm will consist of those colocated ETS/DCS sites not defined as terminating nodes. These major nodes are specifically identified in Appendix D.

(4) The interface of synchronous data channels between the terrestrial DCS and the Defense Satellite Communications System (DSCS) will require synchronization of these two systems. Buffers, station clocks, and clock distribution subsystems may be required for satisfying these DSCS-terrestrial interface requirements and are discussed in more detail in Section V.

(5) Timing and synchronization systems have been allocated at those repeater locations (which are more than through-routed repeaters) branching in three or more directions, in order to maintain the overall performance characteristics of the network.

Specific criteria for minor nodes include:

(1) Where LSTDM's are located at terminating sites, looped timing will be used.

(2) Through-routed repeater locations are not provided separate timing and synchronization subsystems.

TABLE III. DRAMA EQUIPMENT SYNCHRONOUS CHANNEL CAPABILITIES

AN/FCC-99	AN/FCC-98	AN/FCC-100
1.544 Mb/s	56 kb/s	75 b/s
3.088 Mb/s	64 kb/s	150 b/s
6.176 Mb/s	128 kb/s	300 b/s
	256 kb/s	600 b/s
	512 kb/s	1.2 kb/s
		2.4 kb/s
		4.8 kb/s
		7.2 kb/s
		8.0 kb/s
		9.6 kb/s
		16.0 kb/s
		19.2 kb/s
		32 kb/s
		64 kb/s

1. MAJOR NODE TIMING

For the major node, the distribution of clock lines for the transmit direction can be accomplished by (1) synthesis of the transmission rates from the timing and synchronization subsystem and distribution of these appropriate rates to the radio, encryption equipment (e.g., KG-81), and each level of multiplex, using internal phase adjustment within the transmission equipment (as shown in Figure 5); (2) providing the highest transmission equipment level (usually the radio) its external timing at the appropriate rate from the T&S equipment and then cascading the timing through the transmission hierarchy (shown in Figure 5), or (3) as shown in Figure 6, using the arrangement described also in method (2) above with the exception that the timing is provided to the FCC-99 level multiplex and then to the encryption equipment (e.g., KG-81).

Figure 5 represents an approach for dissemination of timing through the equipment hierarchy referred to as cascading. When used in conjunction with the KG-81 encryption device, caution should be exercised. Preliminary results indicate that when the HNF-81-2-TSEC frame is placed into the bypass mode, the transmit reference clock is triple terminated. This results in an impedance mismatch that causes signal reflections which distort the timing signal and cause loss of bit count integrity. This problem is related to the length of the equipment interconnecting cable. With short enough cable length configurations, proper operation of the transmission equipment (even with the HNF-81-2-TSEC frame placed into the bypass mode) should result, but can not be guaranteed. For this reason, cascade timing directly from the radio (or MD918 for troposcatter applications) to the KG-81 is not recommended.[1]

The alternative approach indicated by the broken lines in Figure 5 is acceptable; however, the recommended approach for dissemination of timing through the equipment hierarchy is depicted in Figure 6. This timing configuration alleviates the problems experienced when placing the HNF-81-2-TSEC into the bypass mode by eliminating the multiple terminations of the transmit reference clock. This preferred approach will also reduce the number of output modules (in the CDS) and cable connections required. This timing configuration would appear to violate red/black criteria by using black transmit clock on the red side of the KG-81. However, the DCS application of the KG-81 is limited to bulk encryption, only, i.e., for encryption of unclassified traffic, so that red/black criteria does not apply.

2. MINOR NODE TIMING

The minor transmission node has no free-standing timing system, but rather utilizes the timing generation and distribution capability inherent in transmission equipments. Two options are available for this timing system. The first option uses received timing, derived by a master equipment (e.g., radio), as a clock source for transmit timing. Timing derived from the master

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[1] This problem exists only when using the KG-81 with the HNF-81-2-TSEC frame in the bypass mode for unclassified traffic. When the KG-81 is used with the HNF-81-1-TSEC frame for encryption of classified traffic this problem does not exist because the HNF-81-1-TSEC frame has no bypass mode. When the KG-81/HNF-81-1-TSEC is used for encryption of classified traffic, cascaded timing is required.

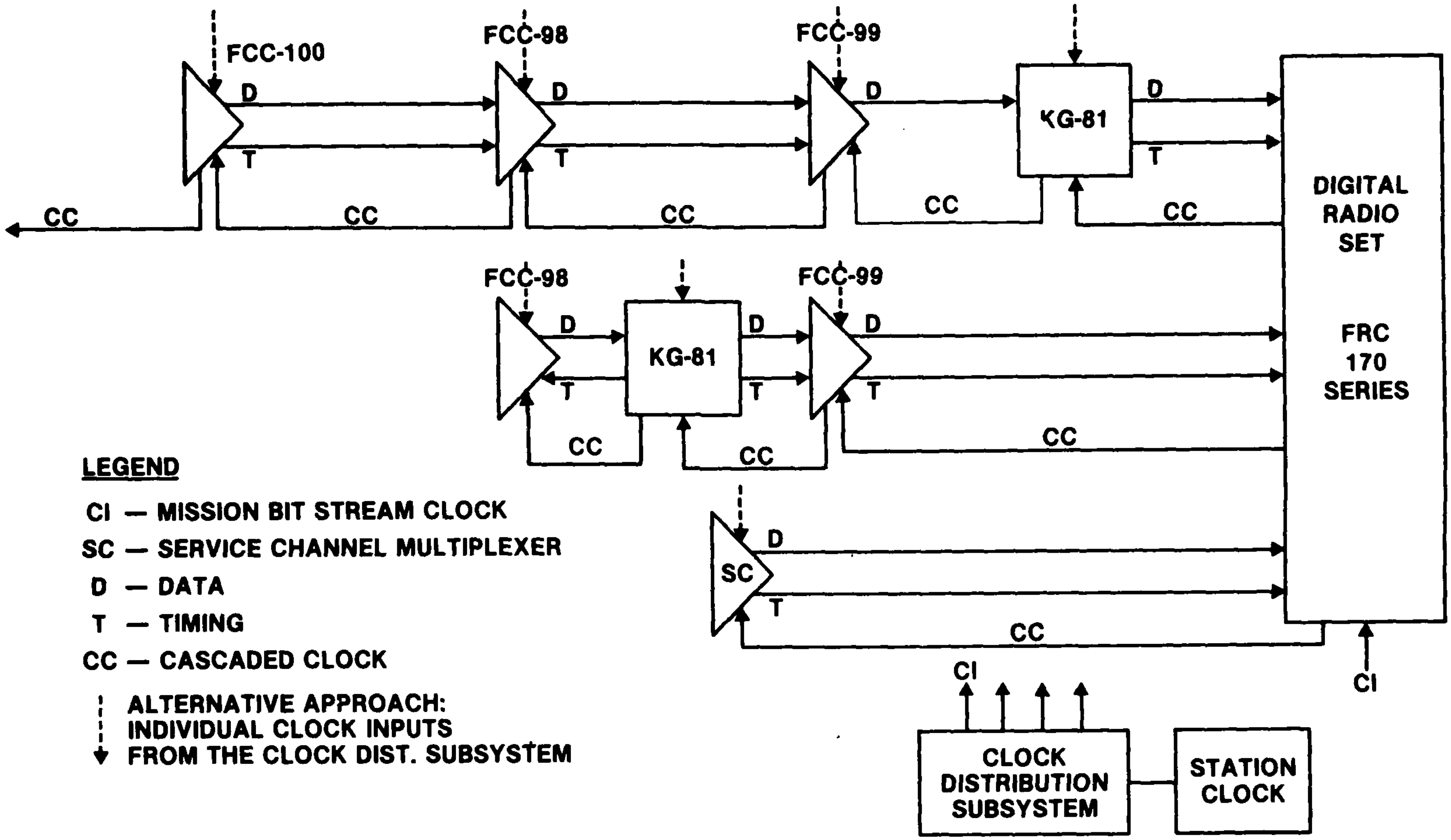


FIGURE 5. TRANSMIT TIMING FOR MAJOR NODE

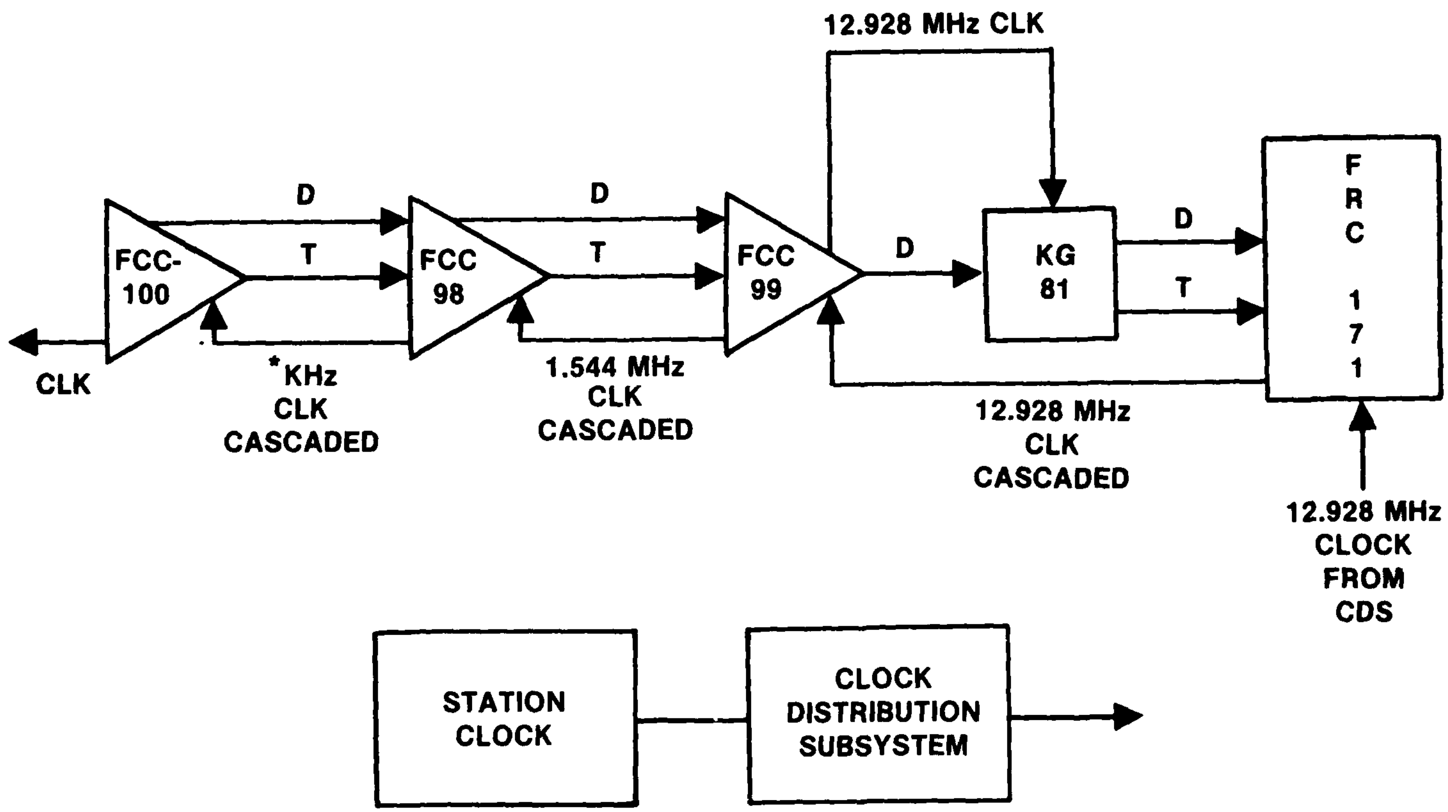


FIGURE 6. EXTERNAL T & S CONFIGURATION
(TRANSMIT TIMING)

*THE CLOCK FREQUENCY CASCADED TO THE FCC-100 FROM THE FCC-98 WILL BE AT THE AGGREGATE RATE AT WHICH THE FCC-100 IS OPERATING. (TYPICALLY 56 KHz OR 64 KHz).

equipment is based on a timing system located at a remote major node with attendant accuracy of the major node station clock. This first option is utilized where the existence of synchronous users dictates the need for an accurate timing source. The second option uses internal timing of the highest level transmission equipment (usually the radio) as the station master. The internal timing source of the radio, with accuracy of 1 part in 10^6, is suitable for applications where no requirement exists for synchronous users.

Figures 7 and 8 illustrate station layouts for transmit and receive timing for digital radio applications of the minor node timing subsystem. Note that Figure 7 shows two selectable options for transmit timing: (1) slaving the digital radio to receive timing from a master radio, or (2) operating off the internal clock of the radio. For either option, the digital radio generates the timing rates required for the associated multiplexers/cryptographic equipments. Each transmission equipment in turn generates and distributes required timing lines for the next equipment downstream. Receive timing as shown in Figure 8 is the straightforward distribution of timing derived in the radio to associated multiplex and cryptographic equipment.

The minor node timing system would typically be either at a terminating site at the end of some spur off the main backbone or at a repeater with no VF breakout. This type of node does not have the capability to generate transmission rates other than those inherent in the radio and multiplex, since no separate timing system would exist to generate other required rates. Additionally, this option presupposes no requirement to provide timing to any other equipment.

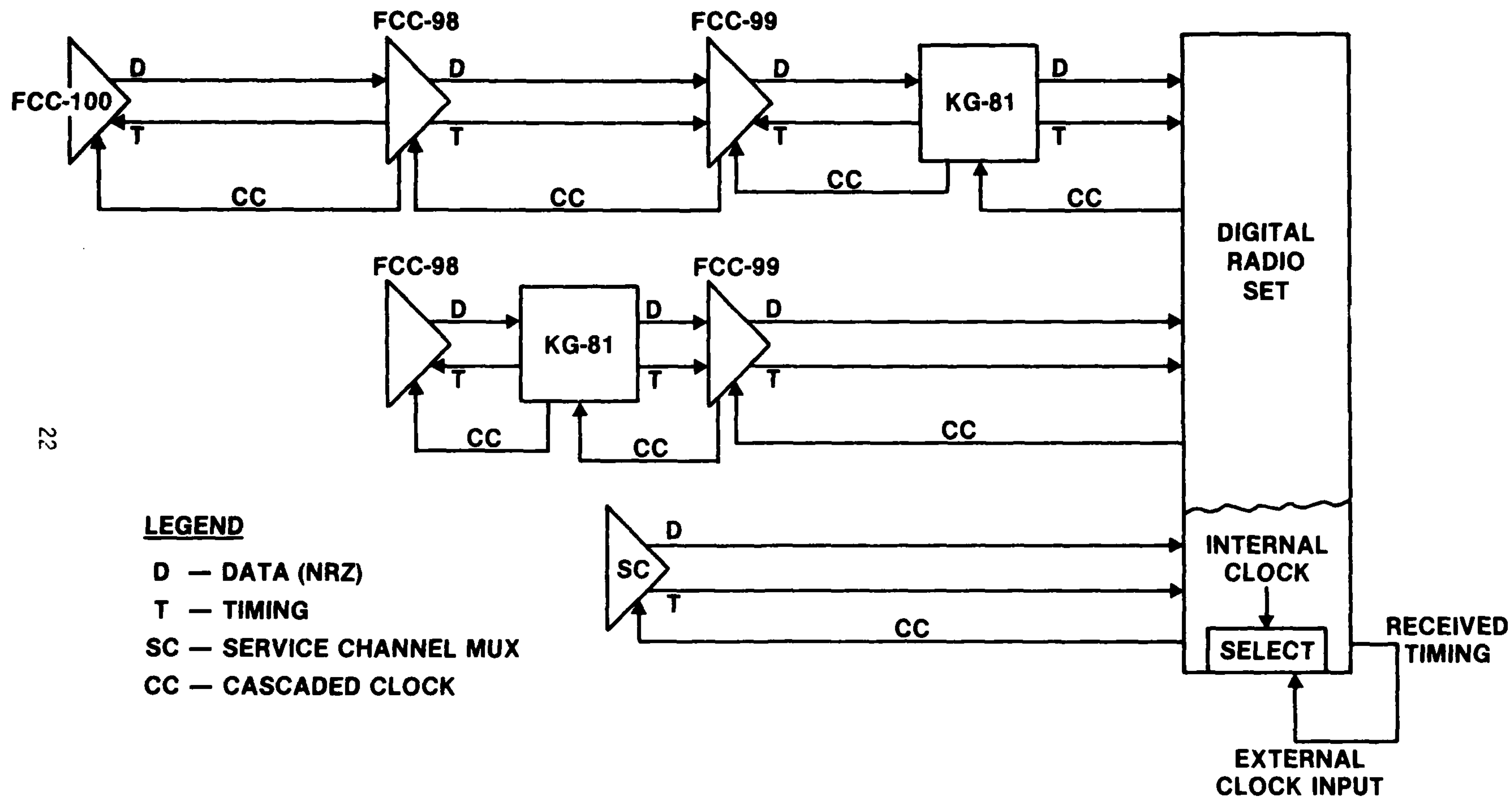


FIGURE 7. TRANSMIT TIMING FOR MINOR NODE

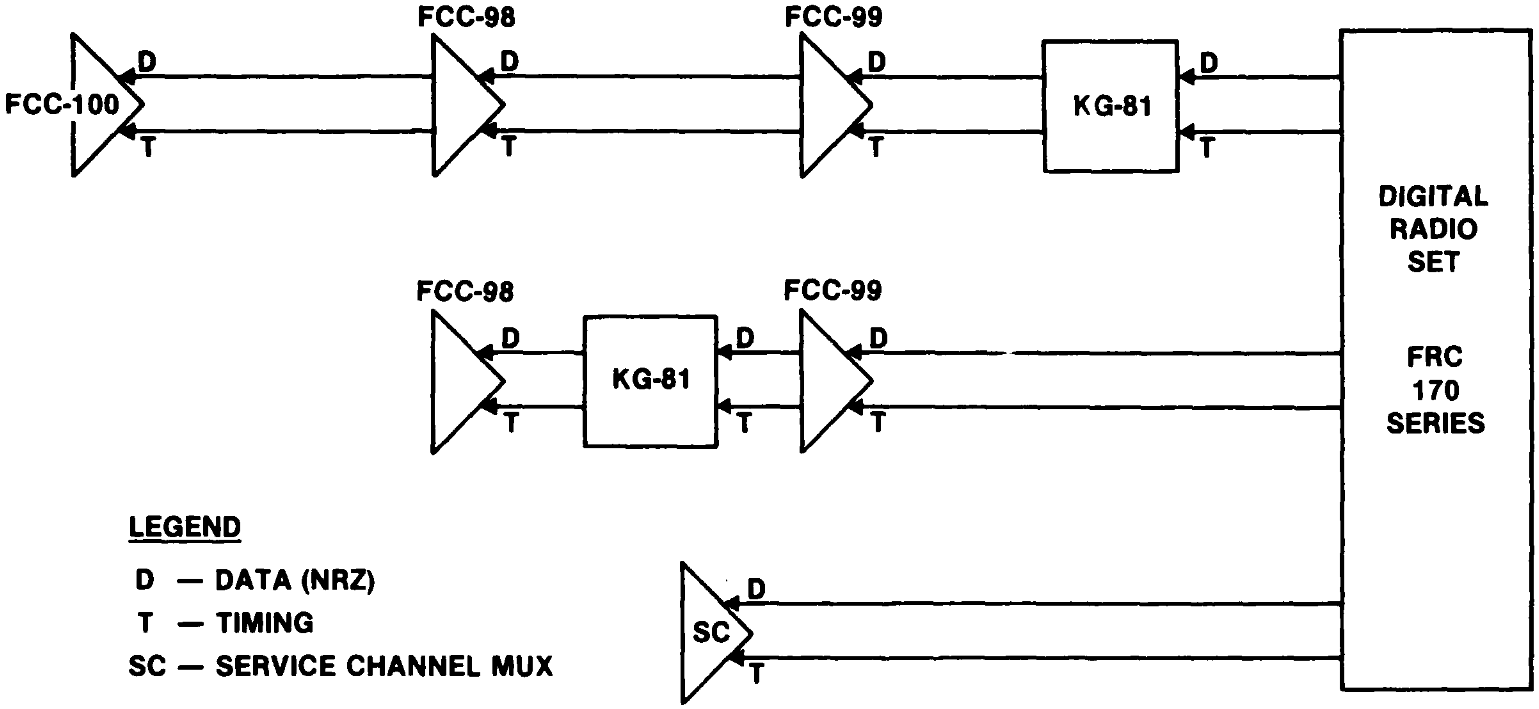


FIGURE 8. RECEIVE TIMING FOR MINOR NODE

V. APPLICATION OF NETWORK DESIGN TO THE DCS

Based on the rationale developed in Section IV, Appendix B illustrates the timing and synchronization configuration for the worldwide DCS. Included within Appendix B is an alphabetized listing of all the major nodes within the DCS European, Pacific, and Western Hemisphere areas. The information in Appendix B should be viewed as a "snapshot in time" due to the dynamic nature of the digital upgrade plans.

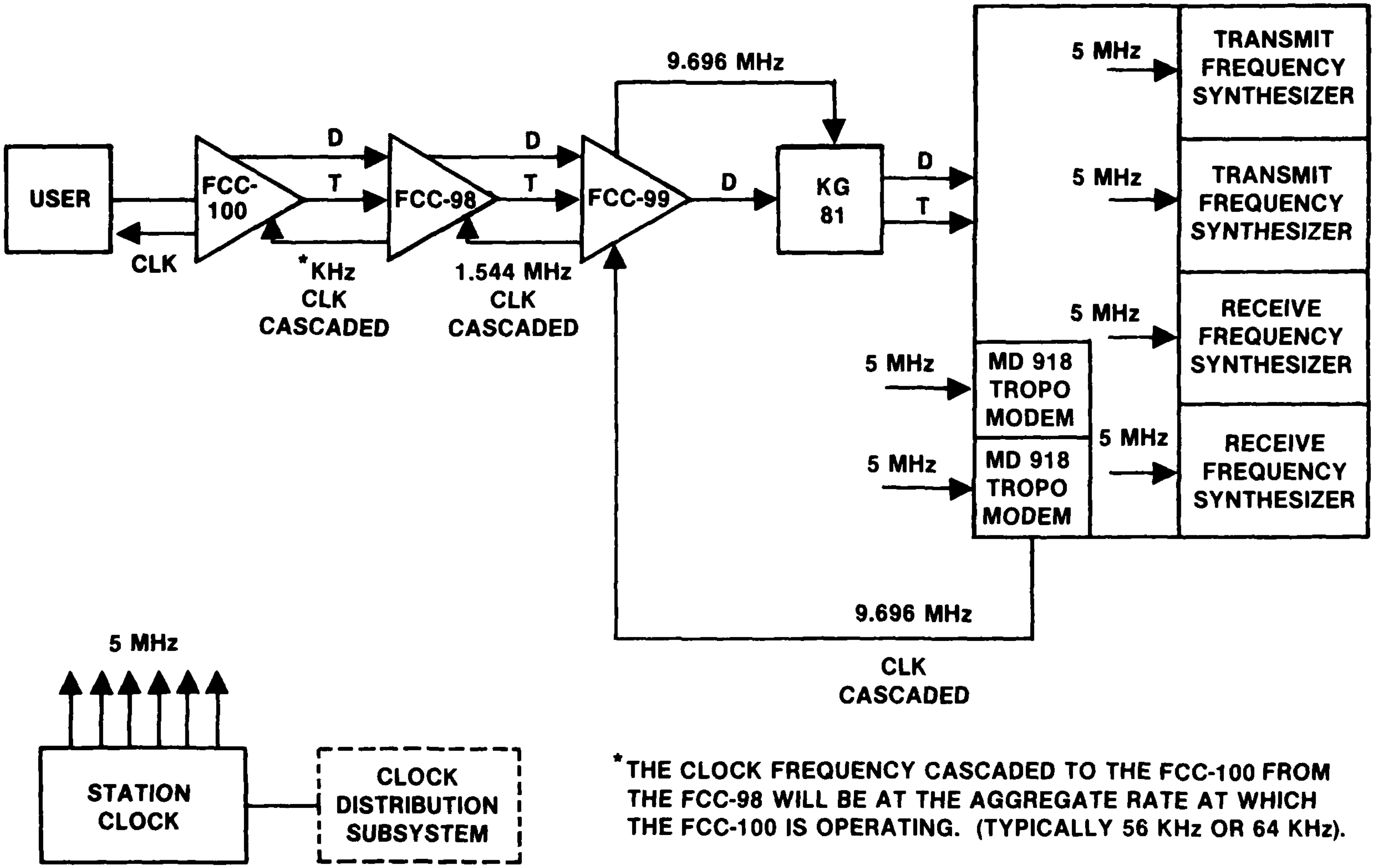
Initially, the European Timing and Synchronization project is intended to: (1) provide an operational evaluation phase of both equipments and concepts for DCS network timing and synchronization in Europe; and (2) support initial implementation of various other subsystems including the LSTDM pilot program, initial digital troposcatter upgrades, synchronous interfaces between the DCS and DSCS, and digital switching applications. As future efforts continue to evolve, the knowledge derived from the European implementation will form the basis for the other areas (Pacific and Western Hemisphere) as their various projects develop (to include KIP and HAWS in the Pacific area and the WAWS in the Western Hemisphere).

1. DATA TRANSMISSION NETWORK TIMING AND SYNCHRONIZATION

During the 1980-1990 time frame, the DCS will be rapidly transitioning from a system based on analog transmission and switching facilities to one based on digital technology. This transition, which is driven by the need for security and the economic and operational benefits of digital processing, will be accompanied by the growth and restructuring of the digital data requirements to be satisfied by the DCS. To accommodate changes in digital data requirements and to capitalize on the evolution of the DCS to digital operation, a Data Transmission Network (DTN) is being planned to achieve a more efficient and effective transmission of data. This DTN is an extension of other digital transmission upgrades (e.g., the Digital European Backbone (DEB)) which are introducing multiplex and radio equipment using PCM, TDM, and digital LOS and troposcatter radio equipment into the DCS.

Figure 9 depicts the timing and synchronization configuration for troposcatter radio equipment. Transmit timing will be provided by external clock at a frequency of 5 MHz. The troposcatter radio equipment requires six separate 5 MHz frequencies, two for each of the MD 918 tropo modems (redundancy), transmit frequency synthesizers (diversity), and receive frequency synthesizers (diversity). It is recommended that in troposcatter application, the 5 MHz frequencies be provided directly from the station clock. The 5 MHz frequencies can also be provided from the clock distribution subsystem although the signals may not be quite as stable as those of the station clock. The troposcatter modem will cascade clock to the next level in the transmission hierarchy.

Figure 10 depicts the predominant, internodal, Government-owned transmission facilities that will be used to implement the Data Transmission Network (DTN). Digital channels are provided for the DTN by the Low Speed



*THE CLOCK FREQUENCY CASCADED TO THE FCC-100 FROM THE FCC-98 WILL BE AT THE AGGREGATE RATE AT WHICH THE FCC-100 IS OPERATING. (TYPICALLY 56 KHz OR 64 KHz).

FIGURE 9. TIMING AND SYNCHRONIZATION CONFIGURATION FOR TROPOSCATER RADIO EQUIPMENT

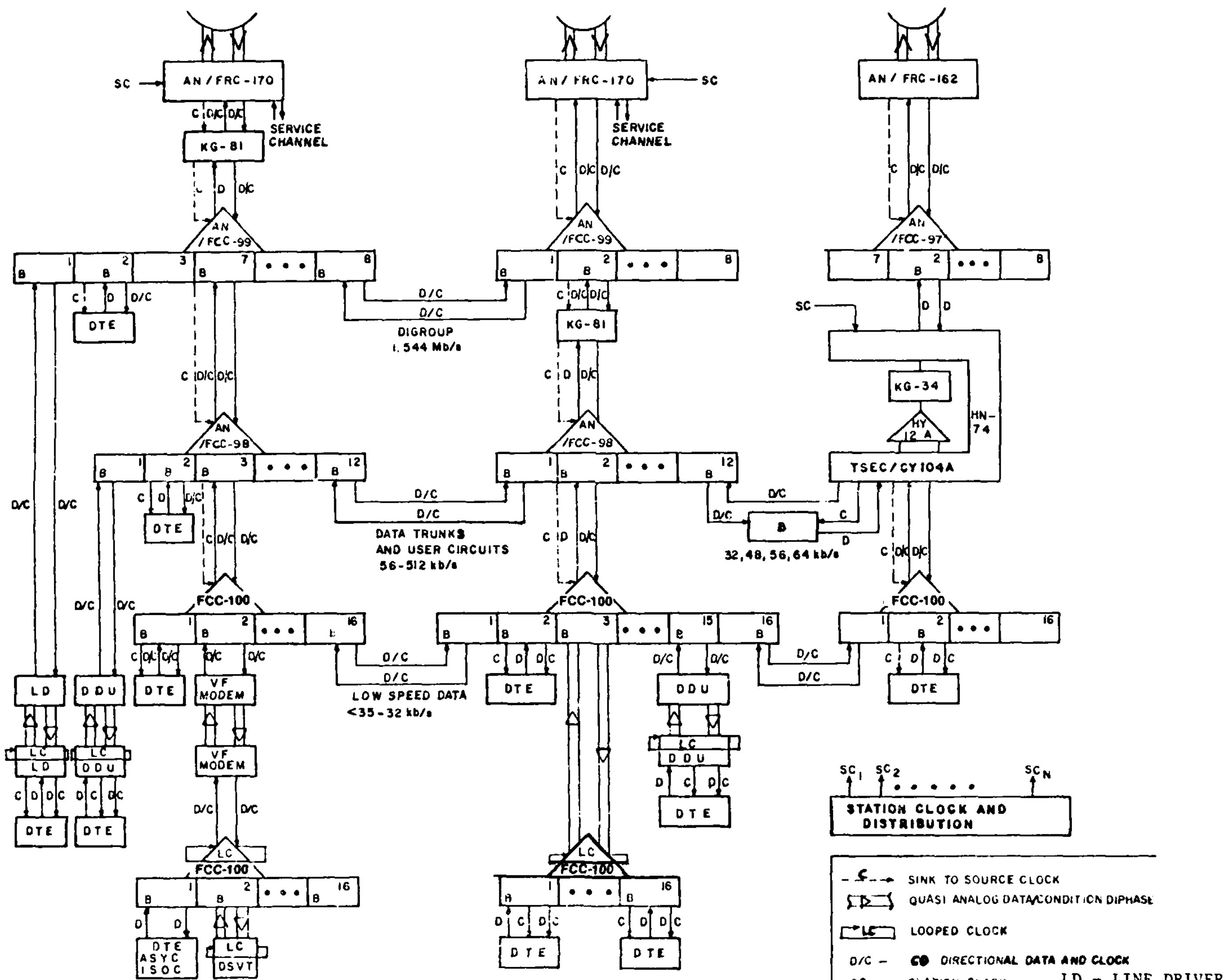


FIGURE 10. DCS DIGITAL TRANSMISSION EQUIPMENT

Time Division Multiplexer (LSTDM), which interfaces with the low speed data circuits and time division multiplexes them into data trunks (usually at 56 or 64 kb/s). The data trunks and medium speed data users are provided digital channels by first level multiplexers, the AN/FCC-98 and CY-104A, using a multirate synchronous data channel module. These data channels are multiplexed into digroups (1.544 Mb/s) along with voice signals that have been digitized using pulse code modulation (PCM). These digroups are multiplexed by either the AN/FCC-99 or the AN/FCC-97 (second level multiplexers) into mission bit streams (MBS) at 3.232, 6.464, 9.696, or 12.928 Mb/s (AN/FCC-99), or 12.6 Mb/s (AN/FCC-97) for internodal transmission.

The AN/FCC-98 and AN/FCC-99 multiplexers and the AN/FRC-170 Series (V) digital radio are currently being used to upgrade and digitize overseas Defense Communications System (DCS) analog transmission facilities. (The European portion of the digitization program is known as the Digital European Backbone (DEB)). The AN/FCC-99 (second level multiplexer) uses pulse stuffing to maintain bit synchronization between the first and second level multiplexers. As the timing and synchronization system is implemented, synchronous operation of the LSTDM with the multirate digital data module in the AN/FCC-98 and CY-104 will also be implemented. In higher levels of the network, the AN/FCC-99, using its pulse stuffing capability, could continue to operate nonsynchronously; however, the AN/FCC-99 multiplexer has the capability of operating synchronously and will be converted to the synchronous mode to provide improved network performance. This will eliminate two problems, pulse stuffing errors which cause loss of bit count integrity (BCI), and pulse stuffing jitter which reduces bit synchronization performance.

In the synchronous mode of operation, all transmitted signals from a DCS digital terrestrial facility are timed by the station clock and are therefore without long-term frequency error. The encryption equipment and the multiplexing equipment are slaved, in turn, to the transmitter as shown by the dashed clock lines in Figure 10. Received signals at each digital level in the hierarchy are slaved to the source clocks at their originating nodes.

Figure 10 shows a generalized configuration of nodal equipment depicting how the mission bit streams, digroups, digital data groups, and low speed data circuits can be either dropped and inserted or through-routed at the appropriate level of the digital hierarchy. A digital circuit provided by the DTN and passing through the DCS digital transmission system will be processed at each node as illustrated in the figure. There are also repeater and branching repeater configurations where the mission bit stream is received, regenerated, and retransmitted. In a synchronous network, with accurate timing sources at each transmission node, these configurations are special cases of the one shown.

The DTN implementation will be phased over a long period of time. Appendix C depicts the proposed configuration of the initial DTN implementation. Sites were selected such that interfaces with all types of transmission facilities will be encountered. The various types of transmission facilities in the initial implementation include:

- DCS terrestrial digital transmission facilities using representative digital multiplexers. The timing and synchronization configuration for this various transmission equipment (including FCC-100, FCC-99, FCC-98) has previously been described.

- DSCS digital transmission facilities that provide both non-ECCM and ECCM capabilities. DSCS facilities are provided Cesium beam frequency standards for their timing and synchronization requirements. As new requirements are identified, other timing and synchronization rates may need to be provided and thus may necessitate the use of a clock distribution system.

- Leased digital facilities (WAWS, HAWS, etc). In most digital leased facilities, the contractor's equipment provides its own clock with the same performance as that of the government system described here. As an alternative if desired, their equipment is capable of accepting the Government external reference.

- Undersea cable systems. Cable systems, whether in the external, internal, or looped timing mode, may necessitate the usage of line drivers/repeaters to provide the appropriate clock signals to the various transmission equipment.

- Analog and leased analog (FDM) transmission facilities using VF and/or Group modems. Synchronous transmission is accomplished via timing provided by an internal source, external source, or the data source.

- Tactical/NATO interface. The synchronism between the DCS and tactical or NATO digital signals (e.g., 16, 32, 64, 128, 256, 512, and 2,048 kb/s) is plesiochronous. A more detailed explanation is given in DCEC TR 23-77.

The DTN implementation is being further developed under the auspices of the DTN working group.

Note that in order to operate the initial implementation of the DTN synchronously, timing and synchronization systems are required. The Military Department with prime site operations and maintenance (O&M) responsibility will provide a timing and synchronization system for each site (identified in FYP 86) within the DTN initial implementation. Certain locations have timing and synchronization equipment for various programs already in place. Some of these include DSCS sites and AUTODIN locations. Although in some cases the T&S equipment has been in the field for quite a few years (therefore not necessarily state-of-the-art) an effort will be made to use this existing equipment where feasible.

For those sites in the DTN in which low speed time division multiplexers (AN/FCC-100) are to be located, timing and synchronization systems are required. The exception to this rule is for locations which have no drop and insert function (termination or minor nodes). These LSTDM's will use cascaded clock derived from the higher level transmission equipment via the incoming mission bit stream.

2. DEFENSE SWITCHED NETWORK TIMING AND SYNCHRONIZATION

The Defense Switched Network (DSN) will evolve from the existing AUTOVON network and other circuit switched projects, including all DoD telecommunications (voice and data, common-user, and dedicated) from user terminal to user terminal across all connectivity means (government owned and leased, terrestrial and satellite transmission paths, and switching facilities). The present DSN architecture permits this evolution to proceed incrementally.

Each military department as well as DCA has been proceeding with switching programs designed to improve telecommunications effectiveness, reduce costs, meet user demands for new and improved service, and replace obsolete and inefficient plants. The DSN provides the means to integrate these switch programs into a coherent focused effort. The majority of work within the DSN to date has been under the European Telephone System (ETS) program, which is the only portion of DSN discussed in depth here.

a. European Telephone System Synchronization. The European Telephone System (ETS) is to be the common user, general purpose, direct dial telephone communications network for the United States forces in the European theater, providing cost effective, reliable, and survivable switched telecommunications. The ETS design is based on the use of off-the-shelf commercially available digital switching systems employing PCM technology. These switches are to be connected by a mix of U.S. government-owned and leased transmission media.

The ETS when initially implemented will have digital switches connected via both analog and digital transmission media. By the time the complete ETS has been implemented much of the European DCS transmission network will be digital, hence permitting direct digroup interfacing between the digital switch and the digital transmission systems. Such evolution will eventually produce an integrated digital transmission and switched network in which information, once digitized, can be transmitted through the switched network and not be converted back to analog form until it reaches its final destination. A major design requirement within such an all digital network is synchronization of transmission and switching equipment.

ETS implementation will require the installation of highly accurate station clocks (described earlier) at the switching nodes and buffers designed into the switch of sufficient size to absorb timing differences between station clocks. Specific buffer sizing and clock accuracy requirements will be discussed later. A typical network connectivity with DCS interface and digital switch timing requirements is shown in Figure 11. Although external buffers are shown, these normally will be incorporated as part of the digital interface unit (DIU) on the switch. In addition, the digroup interface may occur at either 1.544 Mb/s or 2.048 Mb/s. Specific DCS transmission equipment with which the switch must interface and the timing subsystem are described in Section 11 of the DCA European Telephone System (ETS) System Engineering Architecture [6], and summarized below.

In the transmit configuration, the timing subsystem supplies timing to the ETS switch and to each transmitting transmission equipment. Alternatively, the switch may operate on its internal clock if it does not directly connect to digital facilities on either the trunk or the loop side. The digital outputs of the switch will be at 1.544 Mb/s to interface with U.S. owned digital systems and at 2.048 Mb/s to interface with leased (Deutsche Bundespost) PCM-30 systems. The 1.544 Mb/s interface with U.S. systems will employ a bipolar format. All U.S. multiplex equipments will use external clock, supplied from the T&S subsystem to provide synchronization with the ETS switch, although a pulse stuffing interface can be used for those DCS locations where station clocks are not yet installed. On the receive side, the second level multiplex is synchronized to the received timing derived from the mission bit stream. Both data and timing are transferred downstream in the multiplex hierarchy to the lowest level multiplexers. The established switch performance objective for the ETS digital switched network conforms to the CCITT Recommendation G811 [3], which specifies one slip or less in 70 days (1680 hours). Station clock performance and buffer size requirements are derived based on the switch-to-switch performance objective. The clock performance required to meet the ETS system timing objective will have a long term frequency inaccuracy of not greater than 1 part in 10^{11}, which is also part of CCITT Recommendation G.811.

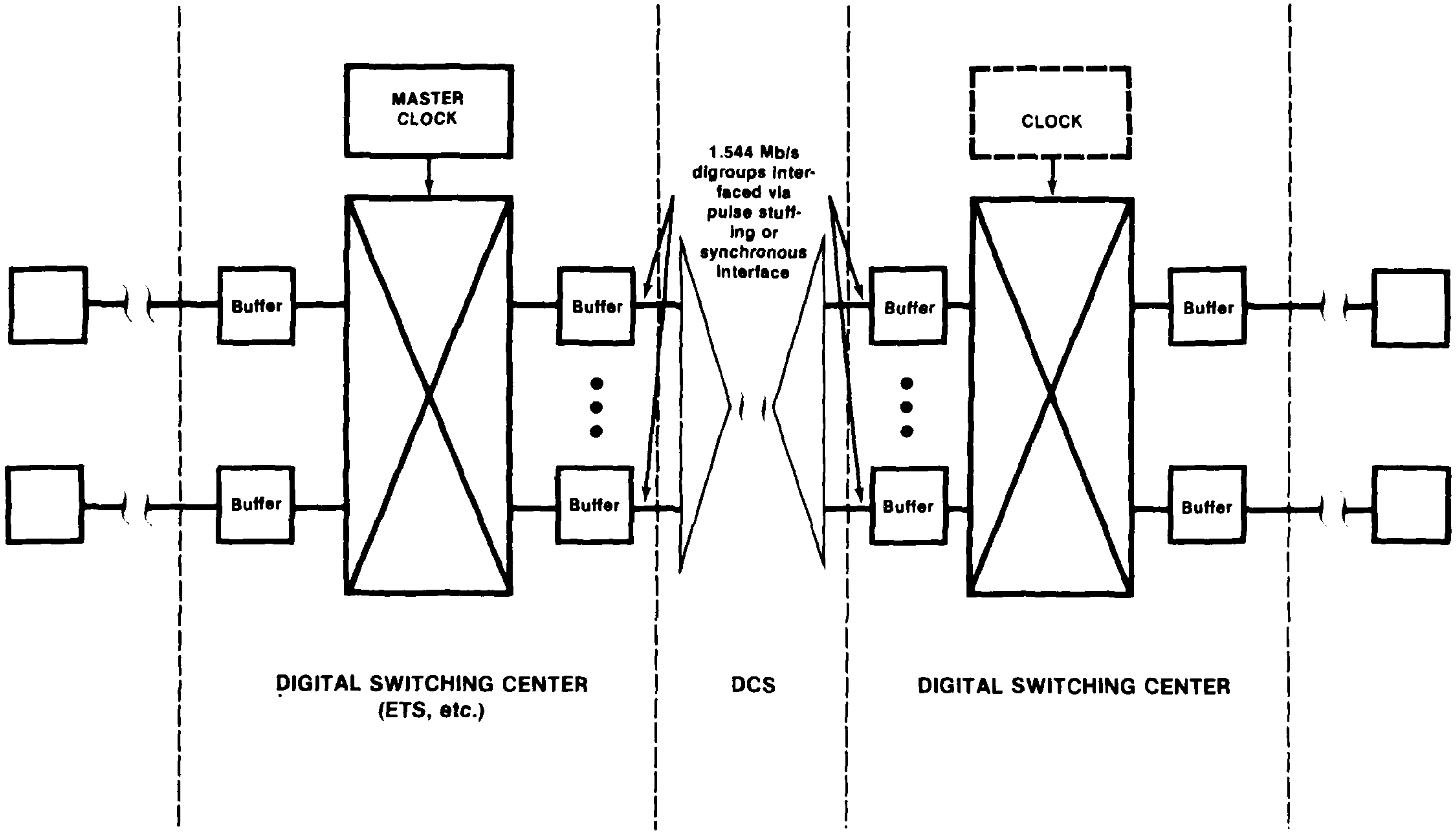


FIGURE 11. DCS INTERFACE WITH DIGITAL SWITCH

b. ETS Switch Synchronization Characteristics. The ETS switch includes a Central Clock Generated (CCG)/Reference Clock Interface (RCI) unit which accommodates one primary and one backup source for external synchronization. Both the primary and backup sources are constantly monitored for loss or instability. Each of these have a range of frequencies, waveforms, and levels with the following specifications:

(1) Frequency range: 1000 Hz to 16.384 MHz in integer steps of 250 Hz

(2) Waveform: Sine or Square wave

(3) Level: 0.3V RMS to 3V RMS (load impedance = 50 ohms)

The CCG/RCI is based on a microprocessor (8086) controlled intelligent phase locked loop control system which processes digital phase measurements and controls a highly stable, double ovenized, voltage controlled crystal oscillator (OVCXO) via a high stability, ultra linear, 16 bit digital to analog converter (DAC). The intelligent phase locked loop system provides the capability of rapid acquisition of lock by adaptive bandwidth control and phase normalization techniques.

Synchronization in a master-slave network is made possible by the CCG/RCI ability to operate with very narrow bandwidths which allow for attenuation of both jitter and diurnal wander. Synchronization accuracy is better than 1×10^{-11} under all worst case conditions, and error decreases with time. The ETS switch is also capable of deriving its clock from incoming PCM digroups or using its own internal clock. When the external synchronization sources fail or have become unreliable, a "Coast Mode" is effected and the overall accuracy and stability of the coast mode (internal clock) frequency is better than $\pm 1 \times 10^{-9}$ per 24 hours.

Buffer requirements are stated in terms of buffer lengths and are specified to provide synchronism over a specified period in accordance with the Mean Time to Timing Slip objective. The MTTS gives an estimate of the time before buffer underflow or overflow occurs, a condition which results in a bit slip. Factors which influence choice of buffer length include (a) clock accuracy and stability, (b) time-varying propagation delays (see reference [1]), and (e) allowed slip rate. The buffer lengths required to meet the ETS performance criteria are stated below for PCM-24 and PCM-30 type systems.

PCM-30: 64 Bytes (512 bits)

PCM-24: 48 Bytes (384 bits).

The equipment components of the ETS external timing and synchronization subsystem described earlier include the station clock and the clock distribution subsystem. It is envisioned that the clock distribution subsystem, or the station clock directly, will provide the ETS switch a 1 MHz frequency reference.

c. Timing Interface Between International Systems. As shown in Figure 12, the ETS must be capable of interfacing with U.S. owned and DBP leased transmission facilities. As presently proposed, the ETS switches will be capable of interfacing at the digital group level (e.g., 1.544 and 2.048 Mb/s port rates) via digital interface units (DIU). These units shall be capable of establishing phase compensation, frame alignment, clock synchronization, and buffering. The ETS switch will be capable of operation in the plesiochronous mode as governed by CCITT Recommendation G.811, timing interface between international systems, where it has been assumed the PTT leased transmission facilities will employ a timing reference different from that of the United States.

The criterion applied to determine which sites receive timing and synchronization systems in support of the ETS is to provide station clocks at all tandem switch centers and intermediate switch centers (TSC and ISC) and to those DCS sites collocated with ETS end office switches (EO). Appendix D defines the timing and synchronization configuration of the ETS.

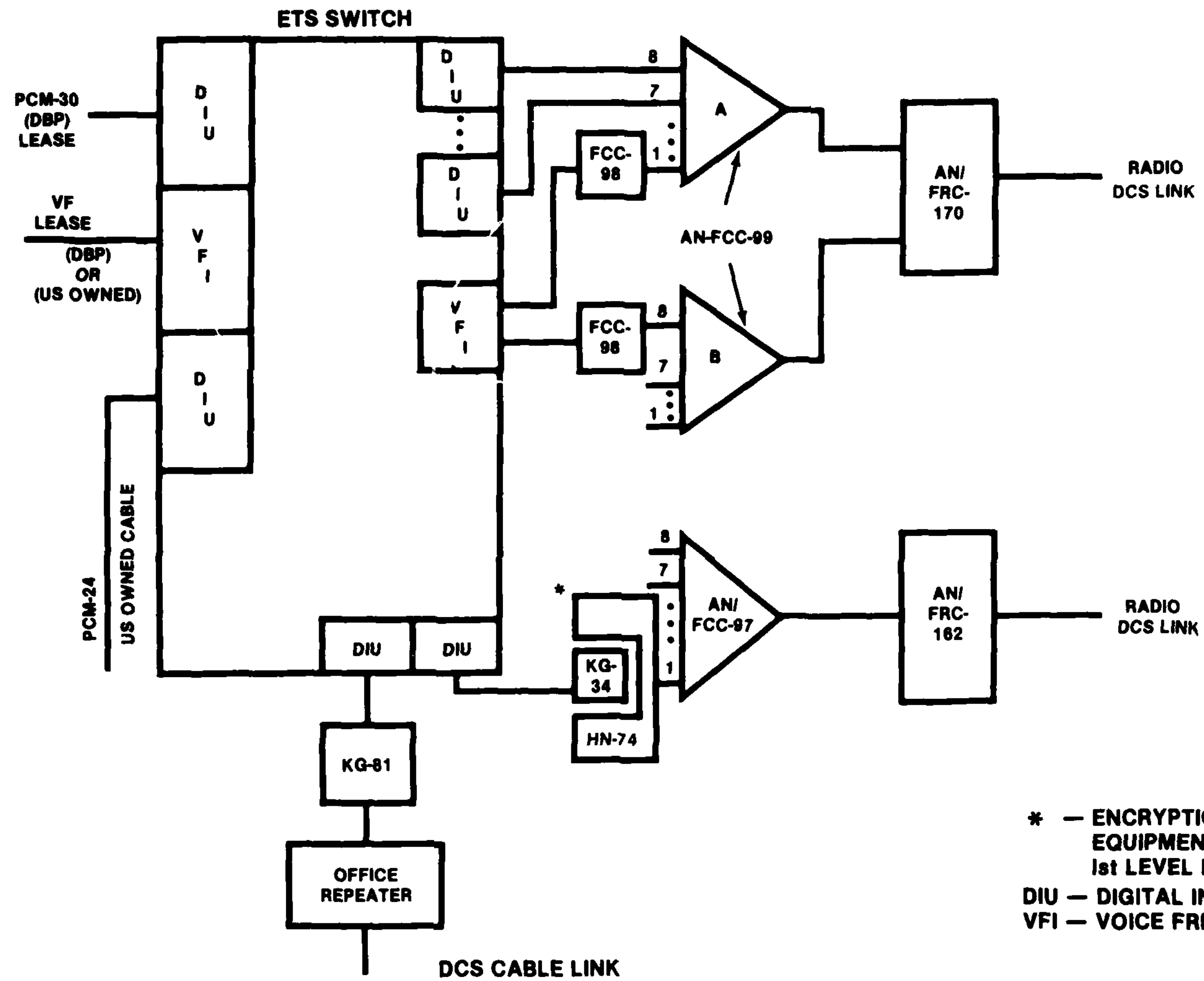
3. FREQUENCY STANDARD EXTENSION (DSCS/TERRESTRIAL DCS)

The interface of synchronous data channels between the terrestrial DCS and the Defense Satellite Communications System (DSCS) will require synchronization of these two subsystems. Where atomic clocks already exist in the DCS, such as with DSCS earth terminal locations, the oscillators within the station clock may be disciplined to the atomic clock rather than LORAN C if such an approach proves economically and technically acceptable.

Interfaces between the terrestrial DCS and DSCS require buffers to compensate for relatively large path delay variations. Satellite path delay variations are caused largely by satellite orbit inclination, orbit eccentricity, and atmospheric/ionospheric variation. These result in a total maximum diurnal delay variation of approximately 10 ms. To compensate for this satellite path delay variation (doppler), a $\pm$ 10 ms stand-alone satellite buffer capability is required.

Since the number of bits of buffering required to compensate for the satellite path transmission delay variation is a function of data rate, a separate buffer is not always required. For example, since a much smaller buffer is required for low data rate circuits, it is possible to compensate for satellite delay variation in the output circuits of certain transmission equipment (e.g., the Low Speed Time Division Multiplexer (LSTDM)). The LSTDM buffer will compensate for satellite delay variations for aggregate rates up to 64 kb/s.

The possible use of existing DSCS earth terminal frequency standards as station clock references for the synchronous data interface between terrestrial and satellite systems has been identified. All but three (see Appendix E) DCS DSCS earth terminal locations are equipped with the Hewlett Packard Model 5061A Frequency/Time Standard with Option 004 (high performance cesium tube offering increased short term stability and greater immunity to effects of shock and vibration) and Option 001 (digital clock providing precise 1 pulse-per-second outputs and an equally readable LED display of hours, minutes, and seconds), and therefore are candidates for frequency and time extension.



* — ENCRYPTION & INTERFACE EQUIPMENT PORTION OF THE Ist LEVEL MULTIPLEX, CY-104
DIU — DIGITAL INTERFACE UNIT
VFI — VOICE FREQUENCY INTERFACE

FIGURE 12. GENERIC ETS SWITCHING AND DCS TRANSMISSION NODE

Extension of the 1 MHz or 5 MHz reference frequencies provided by the earth terminal standard to the serving Technical Control Facility (TCF) (as shown in Figure 13) to provide a TCF frequency reference is constrained by the Interconnect Facility (ICF) connecting the two.

The ICF consists of the cable and/or microwave radio, digital multiplexers, and associated equipment necessary to interface the earth terminal and the TCF. Appendix E provides a listing of current DSCS earth terminal locations, responsible MILDEP, ICF media type, case type, and ICF media length. The general ICF configurations and the associated viable solutions fall into four categories, referred to as cases, and will be discussed separately.

Figure 14 is a block diagram of a Case I ICF. The TCF and earth terminal are located near each other, but in two separate buildings or vans. The modulation and multiplex equipment is located in the earth terminal building/van. The TCF supplies VF line conditioning. The transmission lines between the TCF and the Earth Terminal Complex (ETC) can be coaxial cable, multipair cable, or a combination, depending on the data rate to be transmitted between the two sites. Data rates of 9.6 kb/s and above utilize coaxial cable, while those of 4.8 kb/s and below use multipair cable. This ICF configuration is used for distances where adequate cable exists or can be provided most economically, and where the location of multiplex equipment at the ETC is operationally acceptable. Fiber optic cable may also be used for this type ICF. The distances involved are nominally 7000 feet and below. It is possible to extend the DSCS frequency standard in this case using off-the-shelf equipment in combination with the DCS timing and synchronization system components. The available off-the-shelf 1 and 5 MHz line drivers for cable applications are capable of driving signals approximately 3000 feet. For distances greater than 3000 feet, line drivers used in tandem can be used.

Figure 15 is a block diagram of a Case II digital radio ICF. The traffic making up each RF link to be transmitted via satellite, together with the SSMA baseband traffic, will be combined in the TDM equipment at the TCF. All such link basebands will be further combined in a final stage of TDM to form a single digital ICF baseband. At the ETC Patch and Test Facility (PTF), a corresponding TDM stage will separate the ICF baseband into its component links, one per RF link. The SSMA baseband will, where applicable, be the digital radio link that is amplitude or frequency, modulated in the RF or IF carrier. This ICF configuration is used where, because of distance or other geographical considerations, a microwave system is more economic than a wideband cable system. In Case II, the TCF and earth terminal are located in separate buildings and interconnected by analog or digital microwave radio.

A requirement to distribute a precise time or frequency standard over digital microwave links has three possible solutions. The alternative solutions 1, 2, and 3 are depicted in Figure 16. To accomplish this extension of a time standard over existing DCS digital microwave links would require modifications of the DRAMA digital radio and use of a disciplined oscillator that accepts a timing signal as opposed to a frequency standard. This modification would involve manipulation of the overhead bits provided in the aggregate bit stream of the radio. Because a multiplexing function exists within the radio, overhead (frame) bits are present at a 64 kb/s rate for all

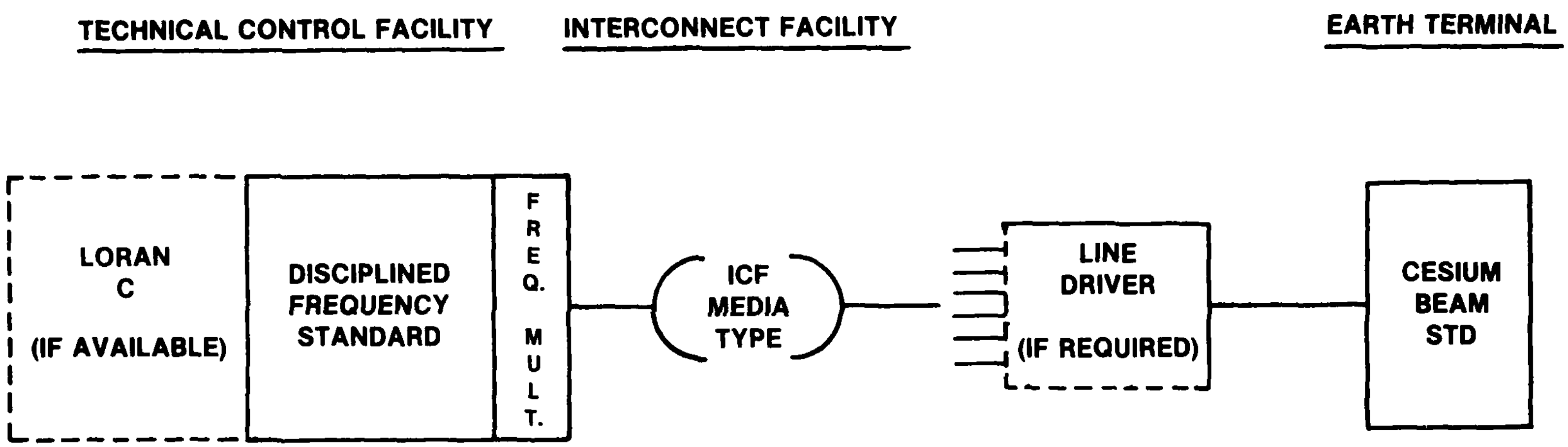


FIGURE 13. FREQUENCY STANDARD EXTENSION FROM EARTH TERMINAL TO TECHNICAL CONTROL FACILITY

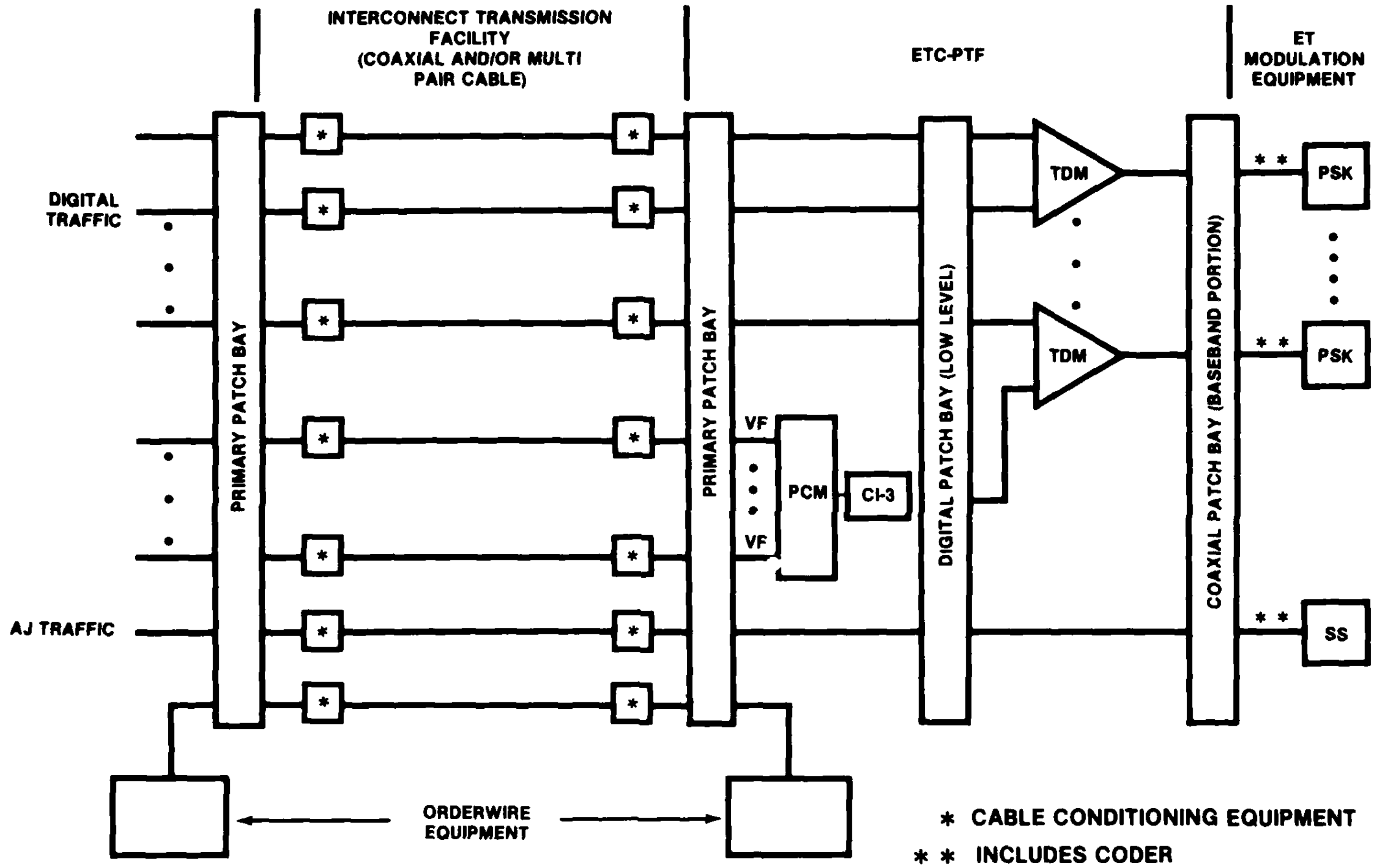


FIGURE 14. CASE I INTERCONNECT FACILITY

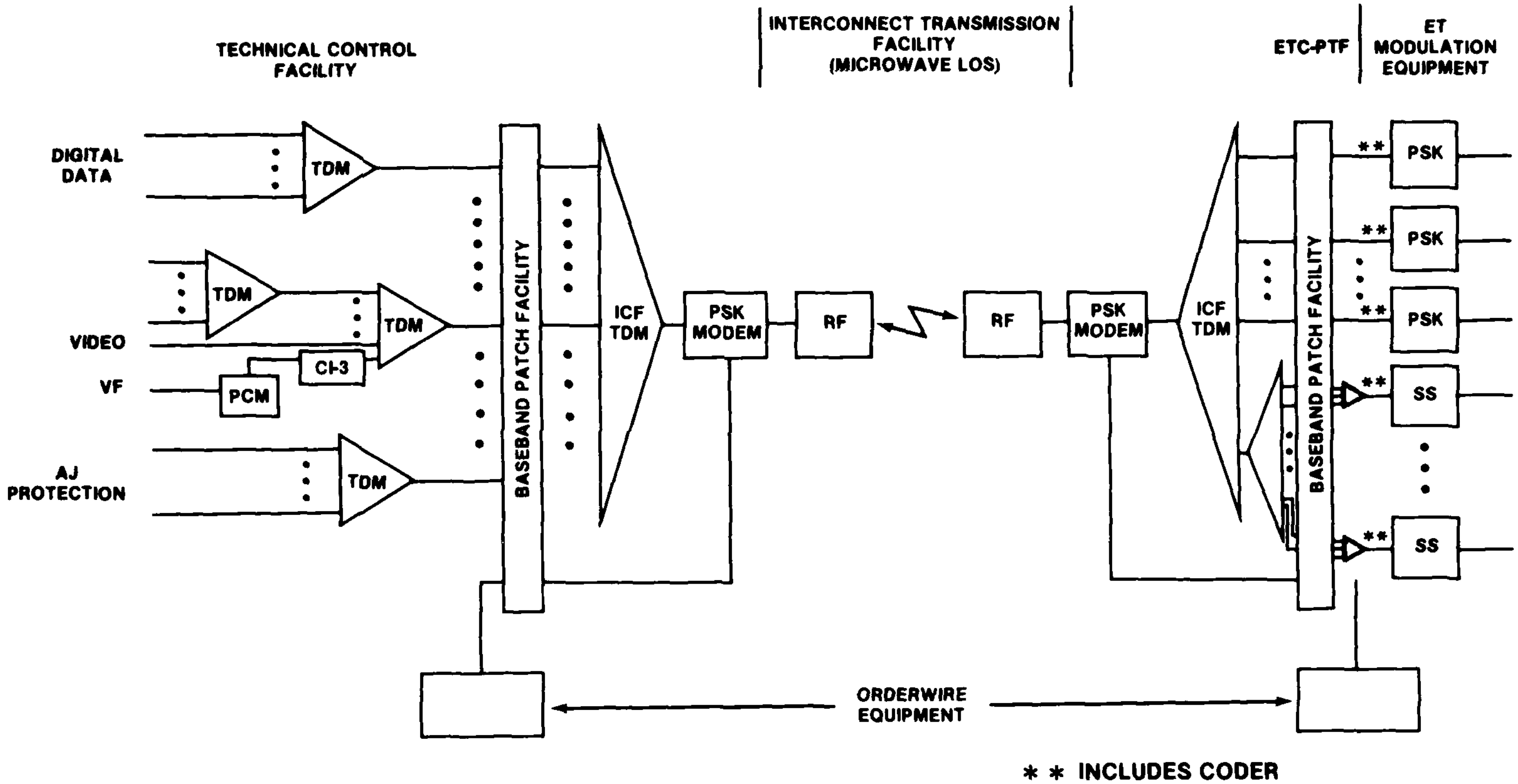


FIGURE 15. CASE II INTERCONNECT FACILITY

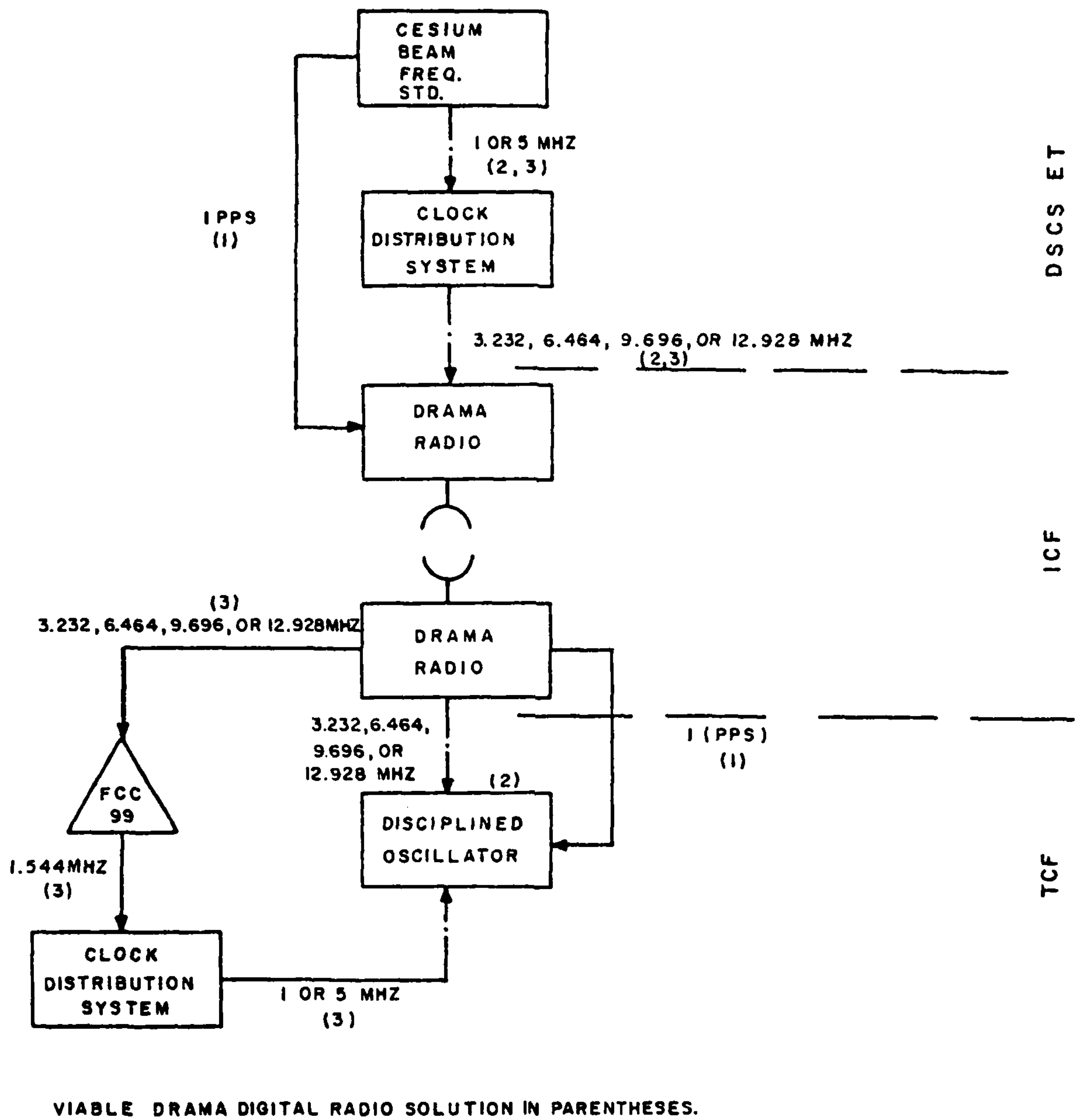


FIGURE 16. DRAMA DIGITAL RADIO SOLUTION ALTERNATIVES

versions of the DRAMA radio. A timing code could be superimposed on the frame bit pattern to allow transmission of a timing standard (probably 1 pulse per second). Such a time code could then be used to discipline a remote (e.g., at DCS Tech Control Facility) time or frequency standard, although it must be pointed out that most existing disciplined oscillators require synchronization by a frequency standard and are not capable of synchronization from a time standard. The performance and cost of this radio modification are currently being investigated with the DRAMA contractor. Because of the anticipated cost and uncertainty of performance, the results of this investigation may indicate a better solution to be the use of a stand alone station clock at such DCS sites or one of the other two alternatives described below, both of which involve extension of a frequency standard.

A second alternative would be a modification to the disciplined oscillator (part of station clock) which would allow the acceptance of the DRAMA rates (3.232, 6.464, 9.696, and 12.928 MHz) by the oscillator. This modification was not defined in the oscillator description within the station clock performance specification and therefore can be dismissed.

The third and recommended alternative requires that the clock distribution system accept a 1.544 MHz signal as a standard frequency. This 1.544 MHz frequency would be derived from the output of an FCC-99 multiplexer which would produce the rate from the standard DRAMA rates of 3.232, 6.464, 9.696, or 12.928 MHz. This capability is defined in the performance specification for the clock distribution system.

Another option for providing precise time dissemination would be the use of an FM analog microwave radio link for time transfer via the Naval Research Laboratories Time Transfer Unit (TTU). The TTU as described in NAVELEX 0967-425-2010 Technical Manual for Time Transfer Unit CM-427 (XB-1)/URC 1 Aug. 1971, can be used to extend a 1 pps signal from the Earth Terminal to the Technical Control Facility. Other applications of the TTU exist. The TTU is intended for use in comparing time standards through various communications systems and has provisions for synchronizing communications equipment and for calibrating other local time standards. For DCS applications, the TTU would require use of a disciplined oscillator capable of frequency synchronization from a time standard (a capability not normally found with disciplined oscillators), so that the TTU is not a viable solution to the requirement for frequency standard extension.

Figure 17 is a block diagram of a Case III ICF. In this case, the earth terminal is located in the same building with, or in a van adjacent to, the TCF, and no drivers, extra multiplexers, or microwave radios are required for interconnection. The cable lengths generally used are no greater than 250 feet.

Figure 18 is a block diagram of a Case IV wideband cable ICF. The traffic making up each RF link baseband is combined in the TDM equipment at the TCF and then either (1) combined in a final stage of TDM with other RF link basebands via an ICF multiplexer or (2) connected directly to PSK modems without intervening multiplex equipment, utilizing tubes in a multitube coaxial cable. The method used at each terminal location will be determined on a site-by-site basis. The SSMA baseband shall, where applicable, utilize

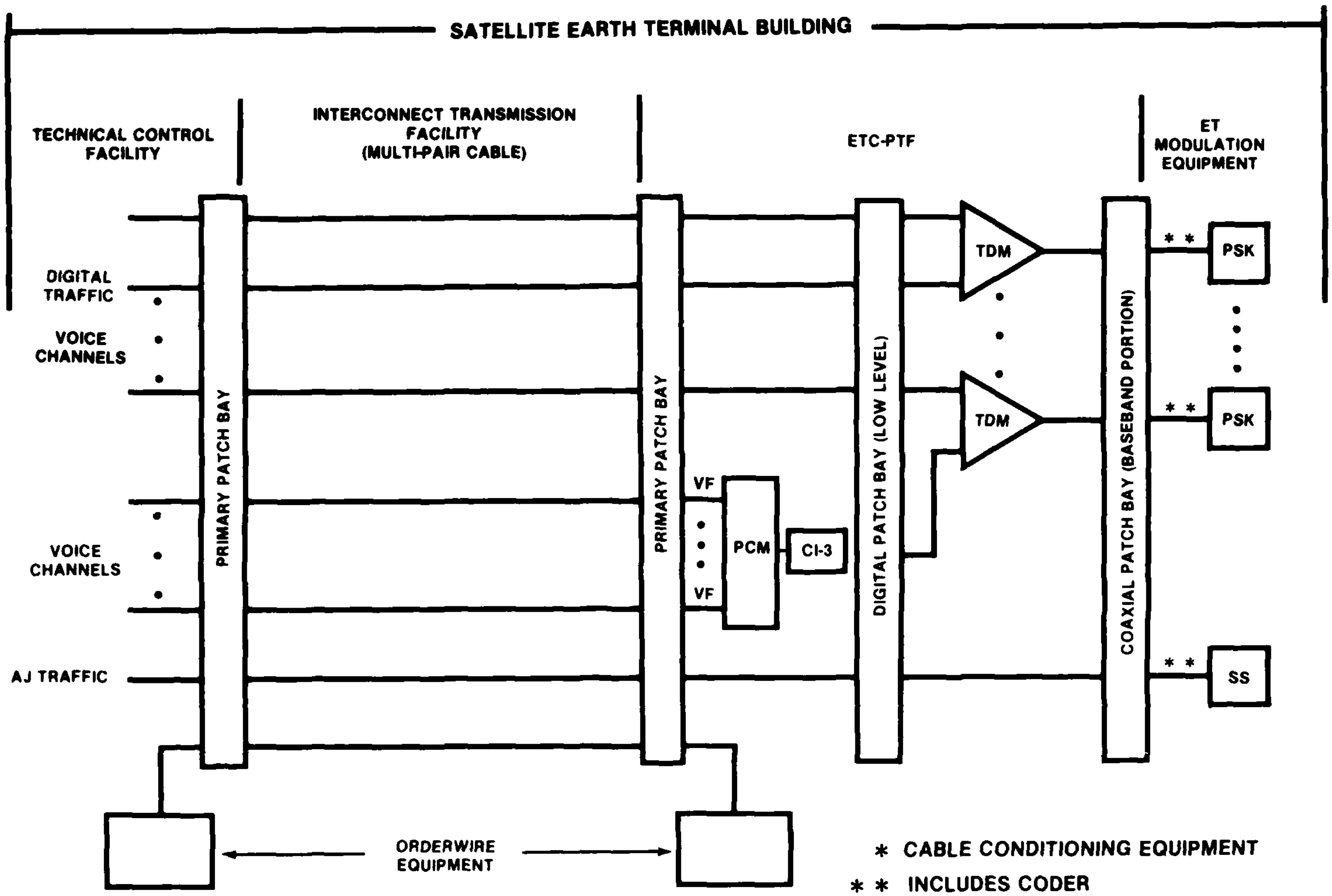
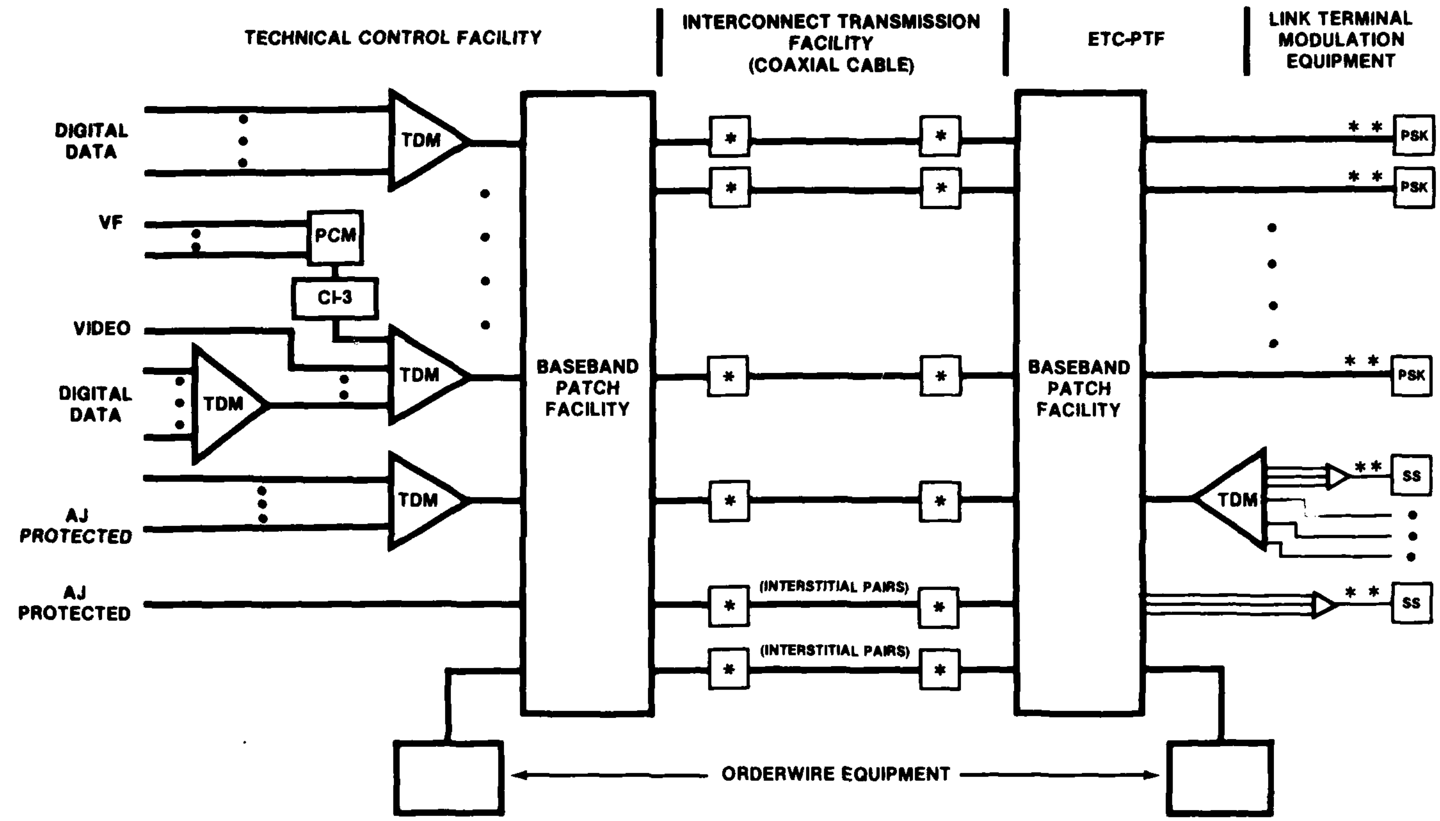


FIGURE 17. CASE III INTERCONNECT FACILITY



* CABLE CONDITIONING EQUIPMENT

* * INCLUDES CODER

FIGURE 18. CASE IV INTERCONNECT FACILITY

TDM equipment at the ETC PTF to derive separate channels for the several SSMA interstitial pairs occupying the spaces between the coaxial tubes. These pairs shall be used for orderwire channels ana low speed digital access to the SSMA equipment. Other coaxial tubes in the same cable may be used for TDM basebands during the transitional period wnen only a portion of the links at a nodal terminal have been converted to digital operation. This ICF configuration shall be used where, because of distance or other geographical considerations, a coaxial or fiber optic cable installation will be more economical than a microwave system. Using fiber optic cable with the appropriate fiber optic line drivers, it is possible to extend a frequency standard from the earth terminal to the technical control facility. Thus, over multipair and coaxial cable as well as fiber optic cable, frequency standard extension appears acceptable.

Certain questions are raised not only as to the feasibility of frequency extension but also as to the lengths possible for the extensions and the availability of repeaters that might be required. These subjects will be addressed during testing by the Navy at their facility at NAVCAMS EASTPAC to commence during CY84. Test media expected to be used will include multipair and coaxial cable, fiber optic cable, and digital microwave.

Engineering studies of the interconnects between satellite nodes and serving technical control facilities will determine the exact equipment required to extend the DSCS clocks. The timing and synchronization capability is predicated on the assumption that access to the cesium standard will be available to the serving TCF. It is anticipated that not all DSCS clocks can be extended back to the serving tech control due to interconnect limitations; therefore, new timing and synchronization requirements would be identified at that time. Where technical control facilities have access to two or more Cesium beam frequency standards, separate cesium standards would be used to supply the references (primary and alternate) to the station clock. It must be stressed, however, that it is not advisable to base the TCF communications capability on the supposition that reliable frequency extension will be maintained continuously. For this reason, it is recommended that sites using DSCS frequency extension also be equipped with LORAN C receiver capabilities to serve as a backup.

REFERENCES

1. DCEC TR 23-77, "DCS II Timing Subsystem," December 1977.

2. U.S. Army Technical Manual, TM 11-5895-822-14.

3. CCITT Yellow Book, Vol.III.3, "Digital Networks Transmission Systems and Multiplexing Equipment," ITU, Geneva, 1981.

4. DCEC TR 12-76, "DCS Digital Transmission System Performance," Nov. 1976.

5. TRW Report SM 33753, "Drama Equipment System and Compatibility Analysis," Apr 1979.

6. DCA Circular, "European Telephone System (ETS) System Engineering Architecture," Sep 1981, Draft.

7. DCEC TR 8-81, "System Design Plan for a DCS Data Transmission Network," July 1981.

8. U. S. Air Force, EPS-82-012, "Equipment Performance Specification for Station Clock," Aug 1982.

9. U. S. Air Force, EPS-82-013, "Equipment Performance Specification for Digital Data Buffer (DDB)," Aug 1982.

10. U. S. Air Force, EPS-82-014, "Equipment Performance Specification for Clock Distribution System," Aug 1982.

TERMS AND DEFINITIONS

ACCURACY - A term used to define how well a frequency agrees with its designated standard value.

AGING - The process whereby crystals change their characteristics (e g., resonance).

DIURNAL PHASE SHIFT - The phase shift (diurnal meaning daily) associated with sunrise or sunset.

DOPPLER EFFECT - An apparent change in frequency caused by motion of either the transmitter or receiver.

FREQUENCY - The number of events per unit of time.

FREQUENCY DRIFT - The change in frequency of a source caused by aging or environmental fluctuations.

SETTABILITY - The degree to which the frequency of an oscillator can be adjusted to correspond with a reference frequency.

STABILITY - A term used to specify the rate at which a clock will change from some nominal frequency over a selected period of time. Short-term stability typically refers to frequency changes over periods of time less than or equal to one second. Long-term stability refers to frequency changes which occur over times greater than one second.

STANDARD - A universally accepted reference.

ACRONYMS

ICF	Interconnect Facility
TDM	Time Division Multiplexer
ETC	Earth Terminal Complex
TTU	Time Transfer Unit
CDS	Clock Distribution Subsystem
LSTDM	Low Speed Time Division Multiplexer
ETS	European Telephone System
T & S	Timing and Synchronization
UTC	Universal Coordinated Time
GRI	Group Repetition Interval
MTBO	Mean Time Between Outages
MTTR	Mean Time To Repair
MTTS	Mean Time To Timing Slip
BCI	Bit Count Integrity
KIP	Korean Improvement Project
HAWS	Hawaiian Area Wideband System
DTN	Data Transmission Network
FDM	Frequency Division Multiplex
O & M	Operations and Maintenance
DIU	Digital Interface Unit
CCG	Central Clock Generated
RCI	Reference Clock Interface
PTT	Public Telephone and Telegraph
TCF	Technical Control Facility
PSK	Phase Shift Keying
DEB	Digital European Backbone
DAC	Digital To Analog Converter

APPENDIX A

ELECTRICAL CHARACTERISTICS

The station clock is composed of four major equipments. The electrical characteristics defined in terms of input and output for each equipment are as follows:

SECTION	INPUT	OUTPUT
LORAN C Receiver		0 MHz sinewave .5-5 volts RMS into 50 ohms
Frequency Multiplier interface with LORAN C Receiver	1 MHz sinewave .5-5 volts RMS into 50 ohms or 1 MHz squarewave .5-5 volts peak-to-peak	
Frequency Multiplier interface with Oscillators	5 MHz sinewave 5.5 volts RMS	1 MHz sinewave $\geq$1 volt peak-to-peak into 50 ohms
Frequency Multiplier interface with Distribution Amplifier	1 MHz sinewave .5-5 volts RMS into 50 ohms	
Oscillators interface with Frequency Multiplier	1 MHz sinewave $\geq$1 volt peak-to-peak into 50 ohms	1 MHz sinewave 1-5 volts RMS into 50 ohms
Oscillators interface with Distribution Amplifier		1 MHz sinewave 1-5 volts RMS into 50 ohms
Distribution Amplifier interface with Frequency Multiplier	1 MHz sinewave .5-5 volts RMS into 50 ohms	
Distribution Amplifier interface with Oscillators	1 MHz sinewave .5-5 volts RMS into 50 ohms	
Distribution Amplifier interface with Clock Distribution Subsystem		1 MHz sinewave .5-5 volts RMS into 50 ohms or 5 MHz sinewave .5-5 volts RMS into 50 ohms

The clock distribution subsystem electrical characteristics are as follows:

SECTION	INPUT	OUTPUT
Clock Distribution Subsystem	1 MHz sinewave/squarewave .5-5 volts RMS into 50 ohms or 1.544 MHz squarewave +3v ±.5 to -3v ±.5 into 78 ohms or 5 MHz sinewave .5-5 volts RMS into 50 ohms	squarewave outputs strappable for 50, 78, or 124 ohms

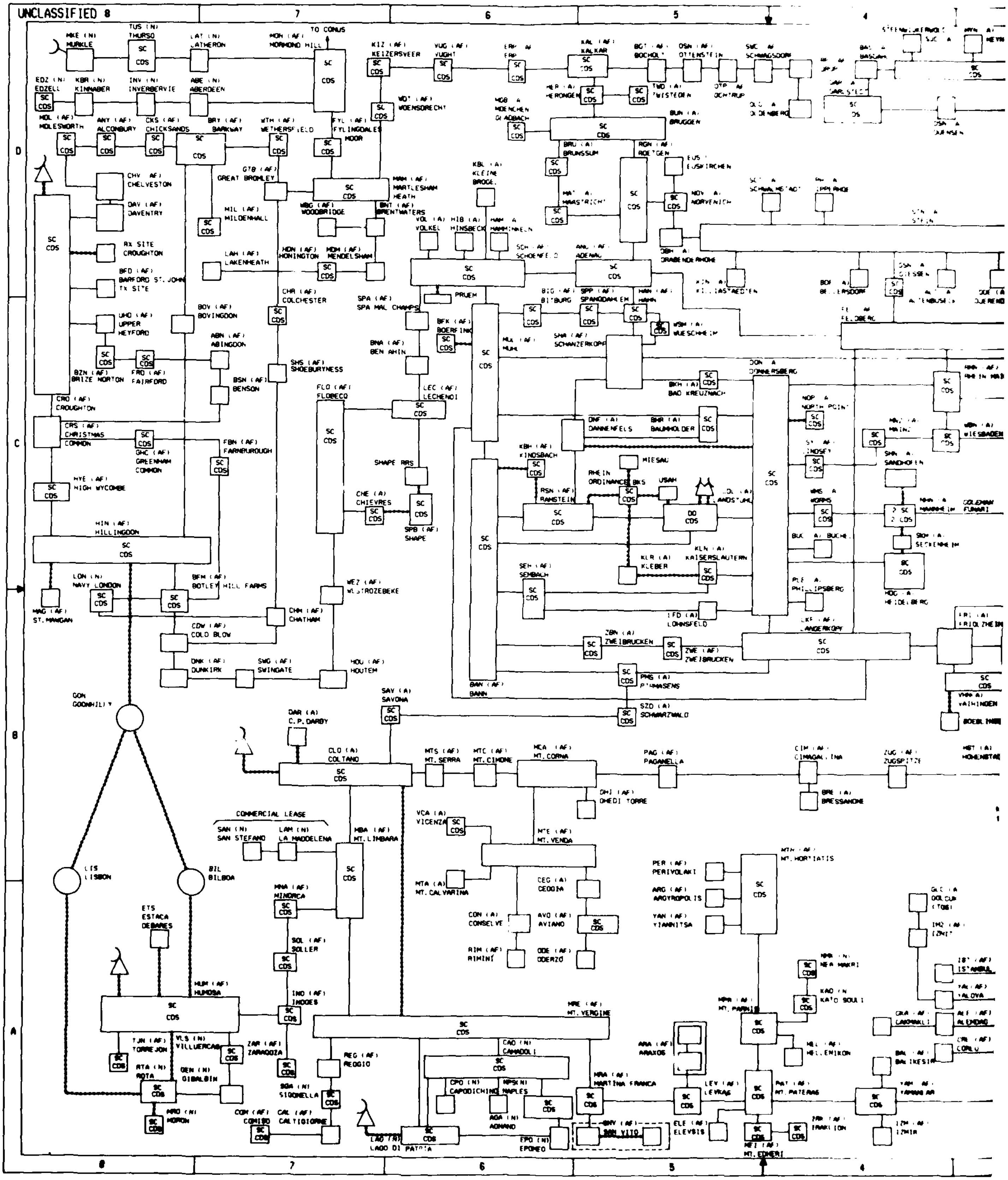
APPENDIX B

TIMING AND SYNCHRONIZATION CONFIGURATION FOR THE DCS

Based on the rationale developed in Section IV, Figures B-1, B-2, and B-3 (sheets 1 and 2) depict the timing and synchronization configuration for the DCS in Europe, the Pacific, and the Western Hemisphere (Outside CONUS and CONUS). The implementation of this configuration is to be spread across a number of years (beginning late 1983 and scheduled for completion in pre-1990's). It must be recognized that as future requirements are identified, the implementation strategies will need to be adjusted.

Alphabetized listings of all the major nodes within the worldwide DCS in each area (Europe, Pacific, and Western Hemisphere) are provided in Tables B-I, B-II, and B-III. Included in these tables for each major nodes is the required timing and synchronization equipment, country code, the military department responsible for providing the T&S equipment, and the funding year (for implementation purposes). Due to the dynamic condition of the digital upgrade plans, this information is continually changing. The timing and synchronization project in the Defense Communications Agency Five Year Program (published each year) provides a means for updating these requirements. The numbers in each equipment and subsystem column are the quantities required.

Included under the required timing and synchronization equipment heading are two columns not previously discussed. Both "DISCIPL. OSCILL." and "FREQ. INTERCON." are associated with DSCS sites where their Cesium Beam Standard (located at the Earth Terminal) is within 300 cable feet of the Technical Control Facility (TCF) and can be used as the primary reference for the station clock. Where this is possible, the "DISCIPL. OSCILL." (disciplined oscillators) of the station clock are slaved directly to the Cesium beam frequency standard, and thus no requirement for the LORAN C Receiver and antennae exists. However, other equipment (denoted as "FREQ INTERCON." meaning Frequency Interconnect) may be required to transfer the Cesium beam frequency standard output over the media (cable) to the TCF. Typical equipment includes the distribution amplifier and the media itself. It should be pointed out that currently only four sites (Landstuhl, Ge.; Diego Garcia, Br; H.E.Holt, Aust.; and Camp Roberts, Cal.) in the entire DCS use this arrangement. However, future testing to be conducted by the Navy in this area may lead to an expansion of the number of sites using frequency extension as the primary timing source for the Station Clock as well as to a better definition of the exact equipment required for the extension.



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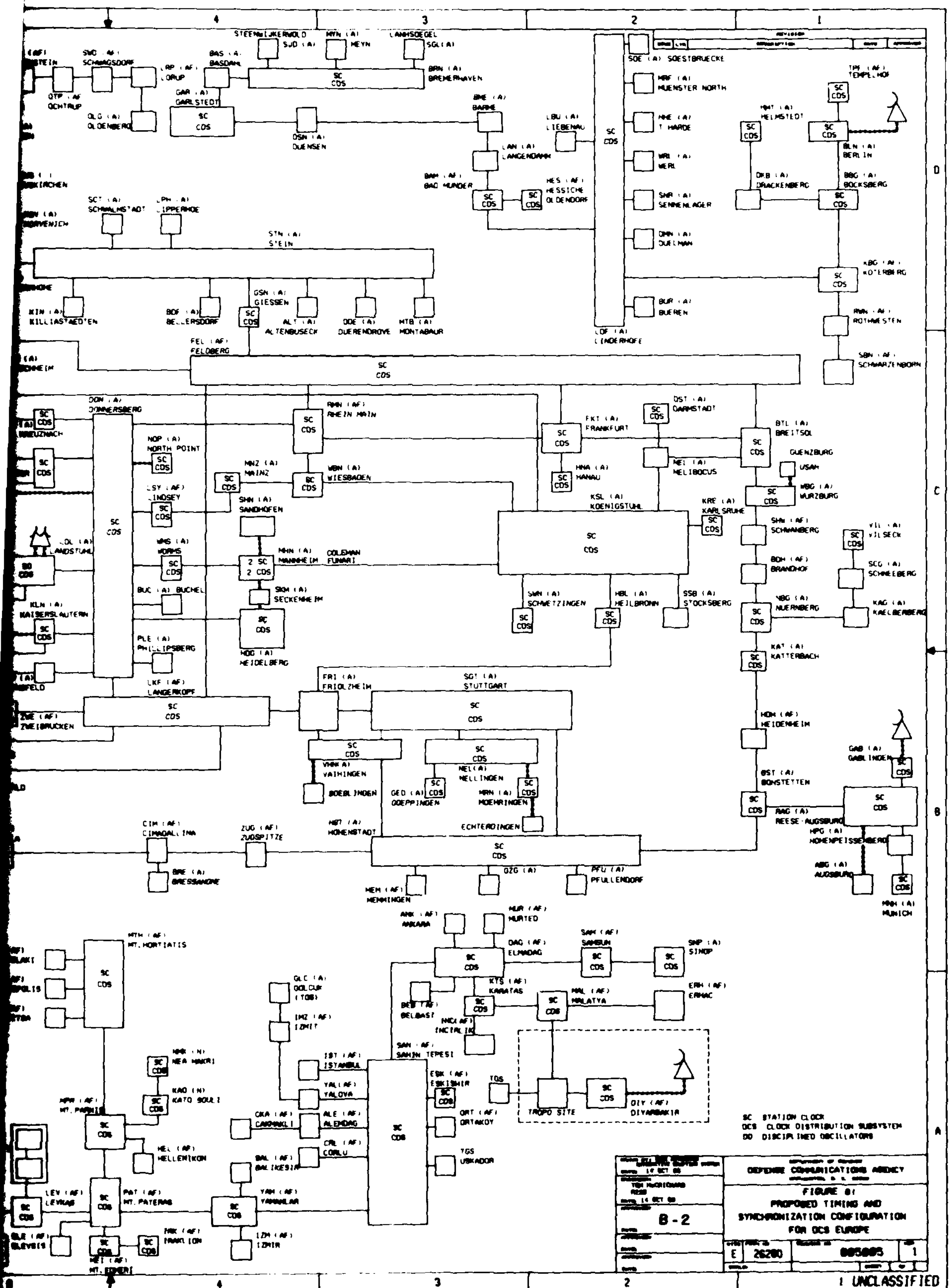

B-2

FIGURE 8: PROPOSED TIMING AND SYNCHRONIZATION CONFIGURATION FOR DCS EUROPE

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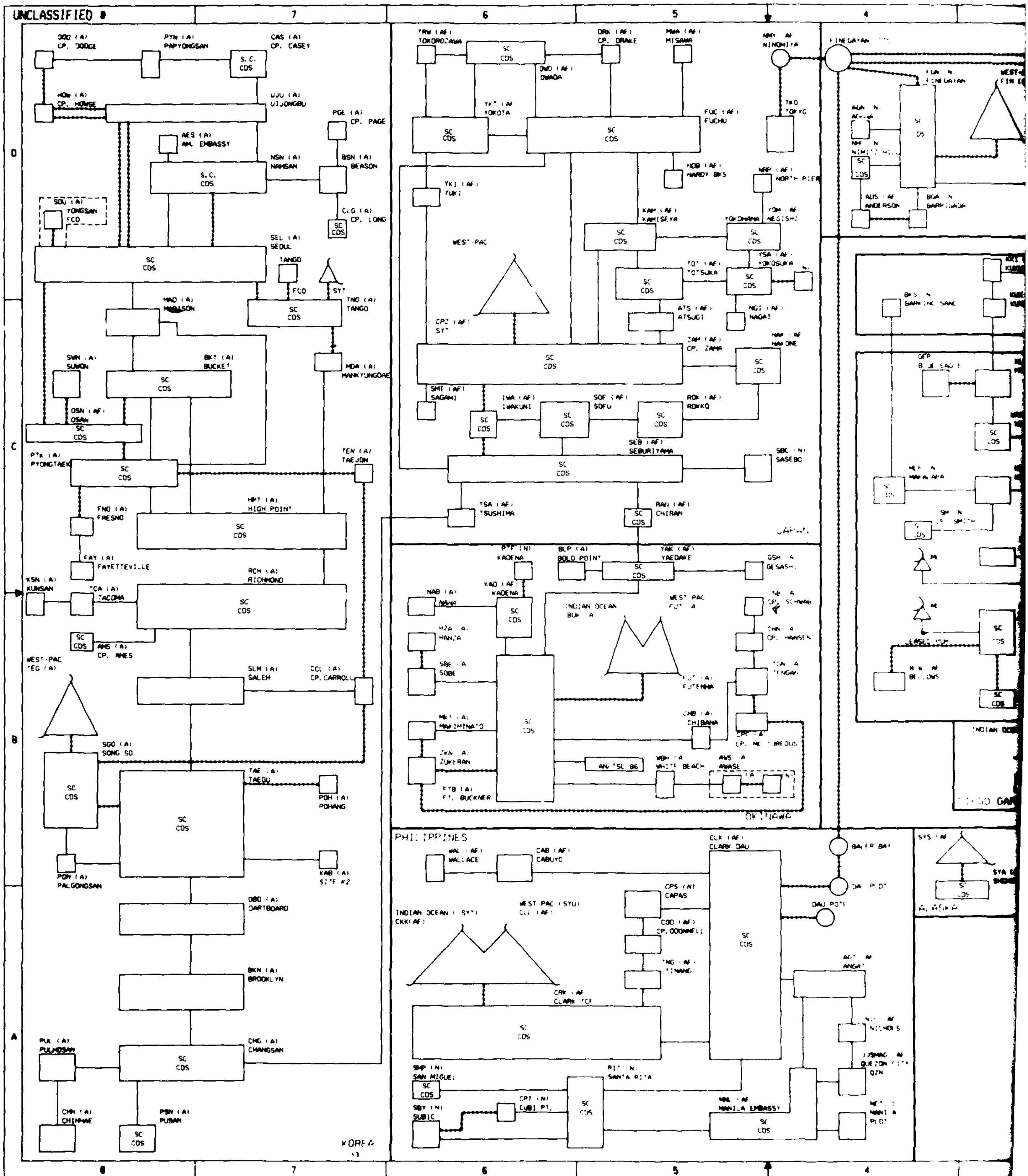

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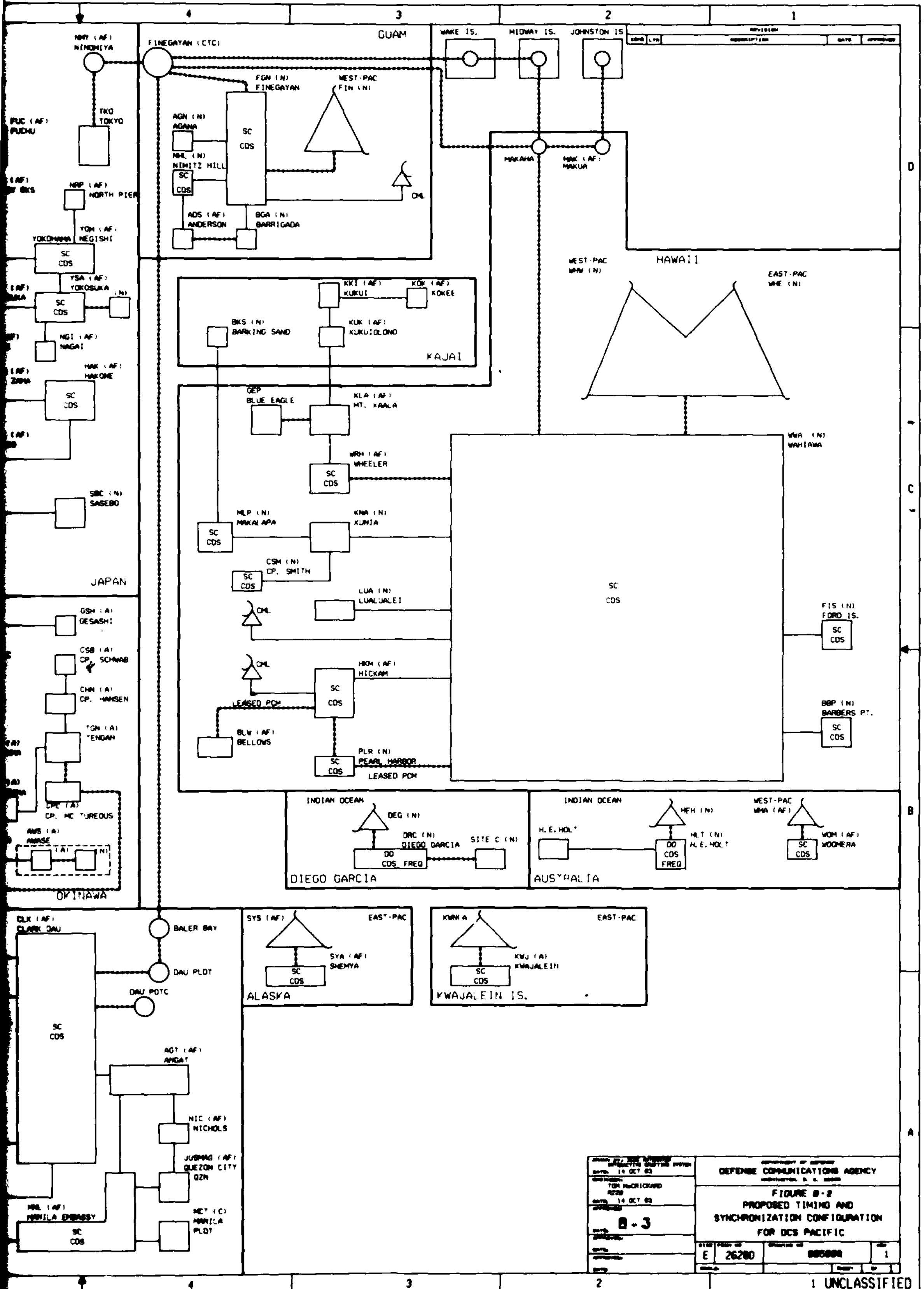

GUAM
FINEGAYAN (CTC)
FGN (N) FINEGAYAN
WEST-PAC FIN (N)
AGN (N) AGANA
NHL (N) NIMITZ HILL
SC CDS
CML
ADS (AF) ANDERSON
BGA (N) BARRIGADA
WAKE IS.
MIDWAY IS.
JOHNSTON IS
MAKAHA
MAK (AF) MAKUA
NMY (AF) NINOMIYA
TKO TOKYO
FUC (AF) FUCHU
NRP (AF) NORTH PIER
YOM (AF) NEGISHI
YOKOHAMA
YSA (AF) YOKOSUKA
NGI (AF) NAGAI
HAK (AF) HAKONE
SBC (N) SASEBO
JAPAN
GSH (A) GESASHI
CSB (A) CP. SCHWAB
CHN (A) CP. HANSEN
TGN (A) TENGAN
CPC (A) CP. MC TUREOUS
AWS (A) AWASE
OKINAWA
HAWAII
WEST-PAC WHW (N)
EAST-PAC WHE (N)
KKI (AF) KUKUI
KOK (AF) KOKEE
BKS (N) BARKING SAND
KUK (AF) KUKUIOLONO
KAUAI
GEP BLUE EAGLE
KLA (AF) MT. KAALA
WRH (AF) WHEELER
WWA (N) WAHIAWA
MLP (N) MAKALAPA
KNA (N) KUNIA
CSM (N) CP. SMITH
LUA (N) LUALUALEI
FIS (N) FORD IS.
HKM (AF) HICKAM
LEASED PCM
BLW (AF) BELLOWS
PLR (N) PEARL HARBOR
BBP (N) BARBERS PT.
INDIAN OCEAN
DEG (N)
DRC (N) DIEGO GARCIA
SITE C (N)
DO CDS FREQ
DIEGO GARCIA
H.E. HOLT
HEH (N)
HLT (N) H.E. HOLT
WEST-PAC WMA (AF)
WOM (AF) WOOMERA
AUSTRALIA
CLK (AF) CLARK DAU
BALER BAY
DAU PLDT
DAU POTC
AGT (AF) ANGAT
NIC (AF) NICHOLS
JUSMAG (AF) QUEZON CITY QZN
MNL (AF) MANILA EMBASSY
MET (C) MANILA PLDT
SYS (AF)
EAST-PAC
SYA (AF) SHEMYA
ALASKA
KWAJALEIN IS.
KWJ (A) KWAJALEIN
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FIGURE B-2
PROPOSED TIMING AND SYNCHRONIZATION CONFIGURATION FOR DCS PACIFIC
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B-3
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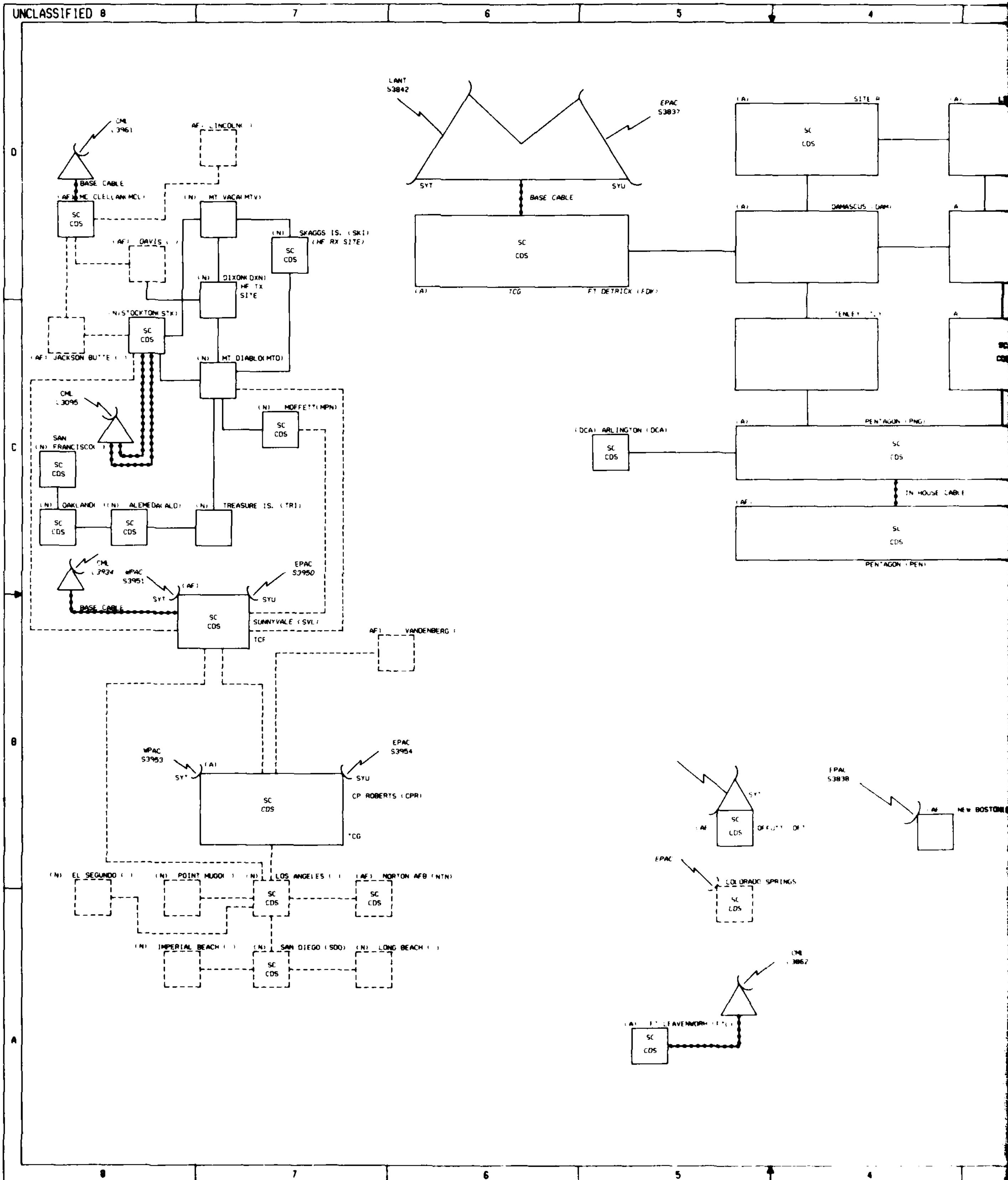

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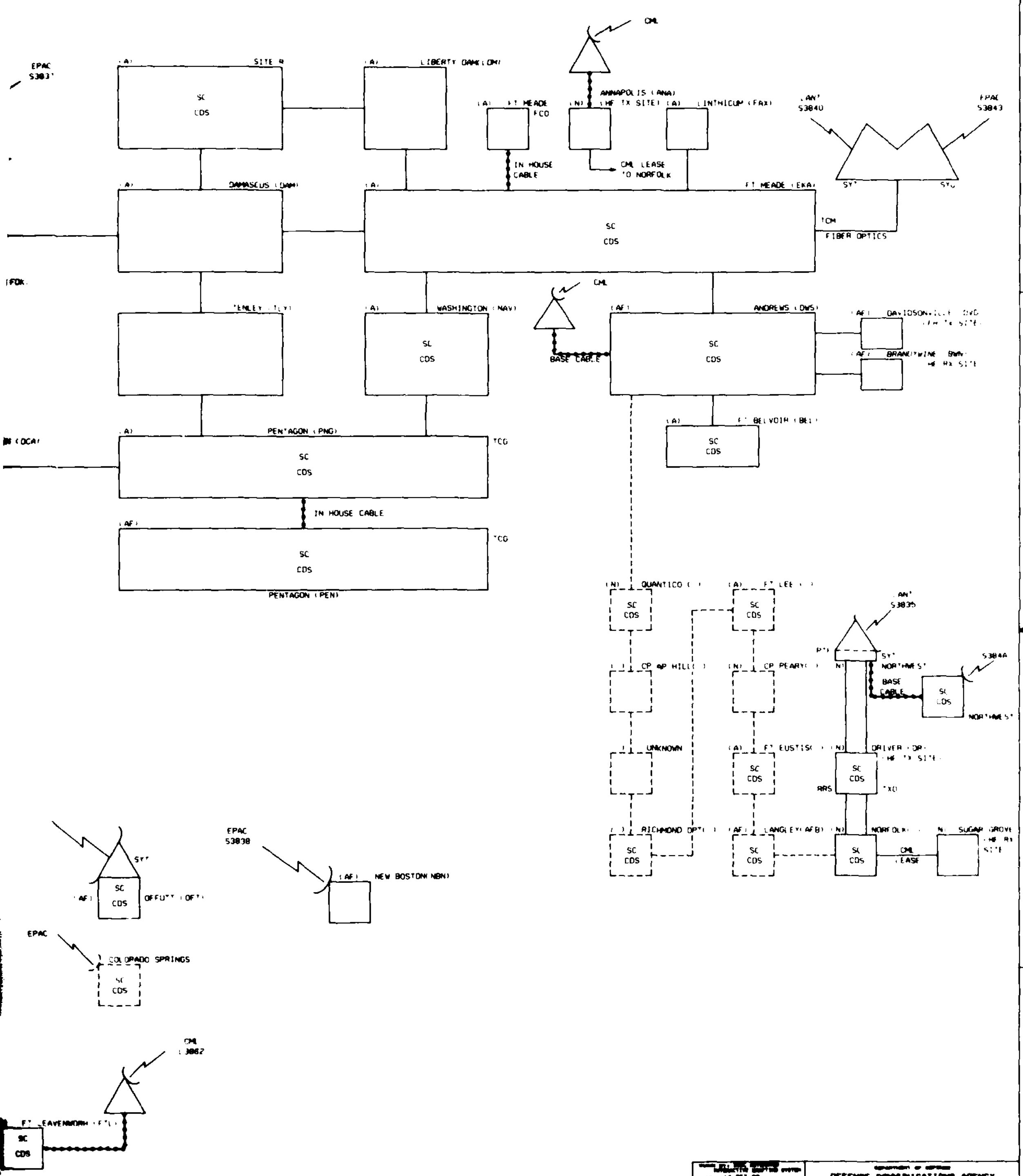

DEFENSE COMMUNICATIONS AGENCY

TOM McCRICKARD R220

14 OCT 83

FIGURE 83 SHEET 1 OF 2
PROPOSED TIMING AND SYNCHRONIZATION CONFIGURATION FOR DCS WESTERN HEMISPHERE (CONUS)

B-4

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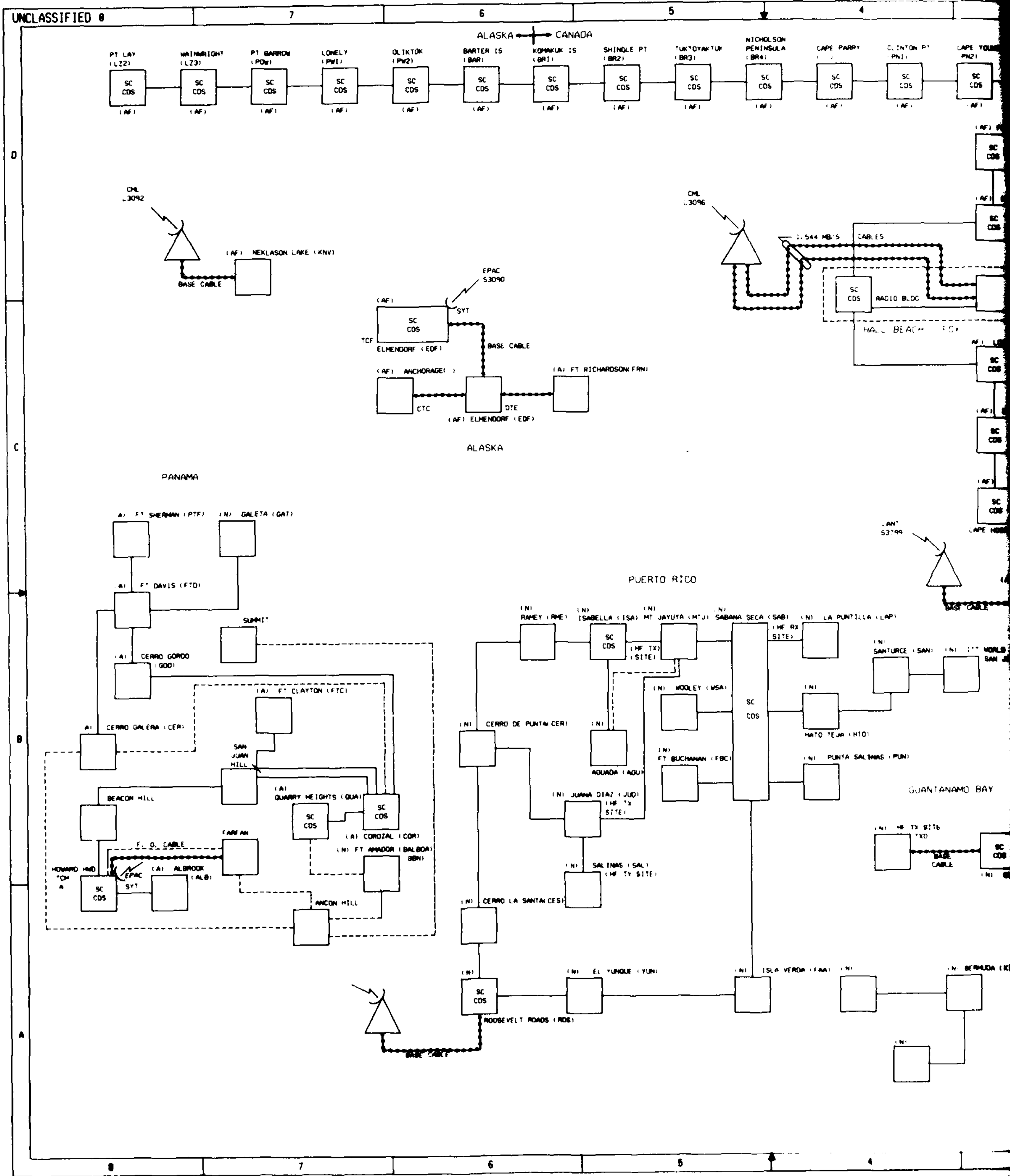

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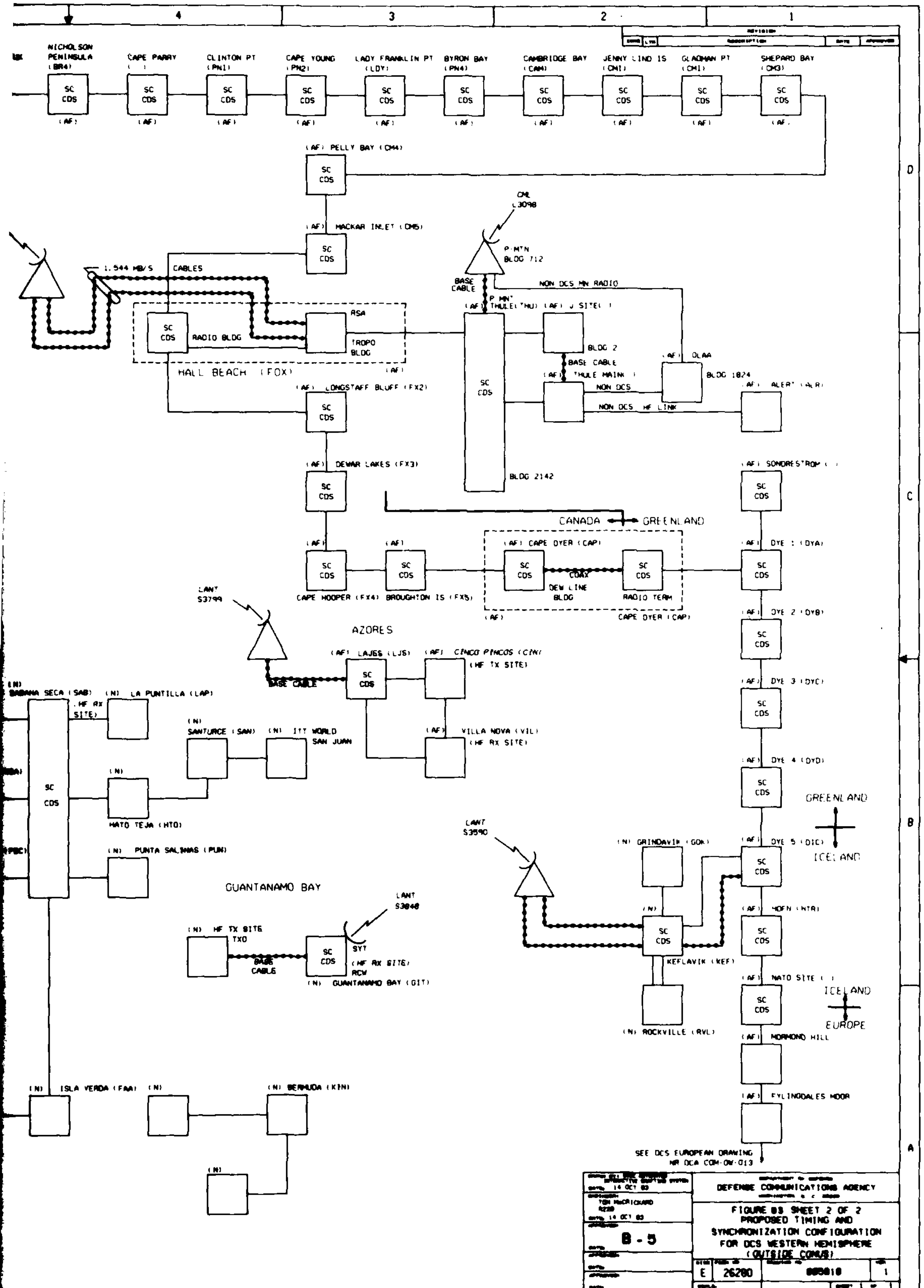

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TABLE B-I. TIMING AND SYNCHRONIZATION EUROPEAN AREA

	CTY	MILDEP	STATION CLOCK	CLOCK DISTRIB. SUBSYSTEM	DISCIPL. OSCILL.	FREQ. INTERCON.	DIGITAL DATA BUFFER
Adenau	GE	AF	1	1	0	0	0
Alconbury	UK	AF	1	1	0	0	0
Aviano	IT	AF	1	1	0	0	0
Bad Kreuznach	GE	A	1	1	0	0	0
Bad Munder	GE	AF	1	1	0	0	0
Bann	GE	AF	1	1	0	0	0
Barkway	UK	AF	1	1	0	0	0
Baumholder	GE	A	1	1	0	0	0
Berlin	GE	A	1	1	0	0	2
Bitburg	GE	AF	1	1	0	0	0
Bocksberg	GE	A	1	1	0	0	0
Boerfink	GE	AF	1	1	0	0	0
Bonstetten	GE	A	1	1	0	0	0
Botley Hill Farms	UK	AF	1	1	0	0	0
Breitsol	GE	A	1	1	0	0	0
Bremerhaven	GE	A	1	1	0	0	0
Brize Norton	UK	AF	1	1	0	0	0
Bruggen	GE	A	1	1	0	0	0
Brunssum	GE	A	1	1	0	0	0
Chicksands	UK	AF	1	1	0	0	0
Chievres	BE	A	1	1	0	0	0
Colchester	UK	AF	1	1	0	0	0
Coltano	IT	A	1	1	0	0	2
Comiso	IT	AF	1	1	0	0	0
Croughton	UK	AF	1	1	0	0	7
Darmstadt	GE	A	1	1	0	0	0
Diyarbakir	TU	AF	1	1	0	0	1
Donnersberg	UK	A	1	1	0	0	0
Edzell	UK	N	1	1	0	0	0
Erp	NL	AF	1	1	0	0	0
Eskishir	TU	AF	1	1	0	0	0
Fairford	UK	AF	1	1	0	0	0
Farnburough	UK	AF	1	1	0	0	0
Feldberg	GE	AF	1	1	0	0	0
Flobecq	BE	AF	1	1	0	0	0
Fylingdales	UK	AF	1	1	0	0	0
Frankfurt	GE	A	1	1	0	0	0
Gablingen	GE	A	1	1	0	0	1
Garlstedt	GE	A	1	1	0	0	0
Giessen	GE	A	1	1	0	0	0
Goeppingen	GE	A	1	1	0	0	0
Greenham Common	UK	AF	1	1	0	0	0

TABLE B-I (CONT'D)

EUROPEAN AREA

	CTY	MILDEP	STATION CLOCK	CLOCK DISTRIB. SUBSYSTEM	DISCIPL. OSCILL.	FREQ. INTERCON.	DIGITAL DATA BUFFER
Hahn	GE	AF	1	1	0	0	0
Hanau	GE	A	1	1	0	0	0
Heidelberg	GE	A	1	1	0	0	0
Heilbronn	GE	A	1	1	0	0	0
Helmstedt	GE	A	1	1	0	0	0
Herongen	GE	A	1	1	0	0	0
High Wycombe	UK	AF	1	1	0	0	0
Hillingdon	UK	AF	1	1	0	0	0
Hohenstadt	GE	A	1	1	0	0	0
Honington	UK	AF	1	1	0	0	0
Hessiche Oldendorf	GE	AF	1	1	0	0	0
Humosa	SP	AF	1	1	0	0	1
Inoges	SP	AF	1	1	0	0	0
Iraklion	GR	AF	1	1	0	0	0
Kaiserslautern	GE	A	1	1	0	0	0
Kalkar	GE	AF	1	1	0	0	0
Karatas	TU	AF	1	1	0	0	0
Karlsruh	GE	A	1	1	0	0	0
Kato Souli	GR	N	1	1	0	0	0
Katterbach	GE	A	1	1	0	0	0
Keizersveer	NL	AF	1	1	0	0	0
Kindsbach	GE	AF	1	1	0	0	0
Koenigstuhl	GE	A	1	1	0	0	0
Koterberg	GE	AF	1	1	0	0	0
Lago Di Patria	IT	N	1	1	0	0	3
Landstuhl	GE	A	0	1	1	1	6
Langerkopf	GE	AF	1	1	0	0	0
Le Chenoi	BE	AF	1	1	0	0	0
Levkas	GR	AF	1	1	0	0	0
Linderhofe	GE	A	1	1	0	0	0
Lindsey	GE	A	1	1	0	0	0
London	UK	N	1	1	0	0	0
Mainz	GE	A	1	1	0	0	0
Malatya	TU	AF	1	1	0	0	0
Mannheim C	GE	A	1	1	0	0	0
Mannheim F	GE	A	1	1	0	0	0
Maastricht	GE	A	1	1	0	0	0
Menwith	UK	AF	1	1	0	0	1
Mildenhall	UK	AF	1	1	0	0	0
Minorca	SP	AF	1	1	0	0	0
Moenchen Gladbach	GE	A	1	1	0	0	0
Moehringen	GE	A	1	1	0	0	0

TABLE B-I (CONT'D)

EUROPEAN AREA

	CTY	MILDEP	STATION CLOCK	CLOCK DISTRIB. SUBSYSTEM	DISCIPL. OSCILL.	FREQ. INTERCON.	DIGITAL DATA BUFFER
Molesworth	UK	AF	1	1	0	0	0
Mormond Hill	UK	AF	1	1	0	0	0
Moron	SP	N	1	1	0	0	0
Martina Franca	IT	AF	1	1	0	0	0
Mt. Hortiatis	GR	AF	1	1	0	0	0
Mt. Pateras	GR	AF	1	1	0	0	0
Mt. Camadoli	IT	N	1	1	0	0	0
Mt. Edheri	GR	AF	1	1	0	0	0
Mt. Limbara	GR	AF	1	1	0	0	0
Martlesham Heath	UK	AF	1	1	0	0	0
Mt. Parnis	GR	AF	1	1	0	0	0
Mt. Vergine	IT	AF	1	1	0	0	0
Muhl	GE	AF	1	1	0	0	0
Munich	GE	A	1	1	0	0	0
Naples	IT	N	1	1	0	0	0
Nea Makri	GR	N	1	1	0	0	0
Nellingen	GE	A	1	1	0	0	0
North Point	GE	A	1	1	0	0	0
Norvenich	GE	A	1	1	0	0	0
Nuernberg	GE	A	1	1	0	0	0
Pirmasens	GE	A	1	1	0	0	0
Ramstein	GE	AF	1	1	0	0	0
Reese	GE	A	1	1	0	0	0
Rheinmain	GE	AF	1	1	0	0	0
Rhine Ord Barracks	GE	A	1	1	0	0	0
Roetgen	GE	AF	1	1	0	0	0
Sahin Tepesi	TU	AF	1	1	0	0	0
Samsun	TU	AF	1	1	0	0	0
Savona	IT	A	1	1	0	0	0
Schoenfeld	GE	AF	1	1	0	0	0
Schwetzingen	GE	A	1	1	0	0	0
Sembach	GE	AF	1	1	0	0	0
Shape	BE	AF	1	1	0	0	0
Sinop	TU	A	1	1	0	0	0
Soller	SP	AF	1	1	0	0	0
Spangdehlem	GE	AF	1	1	0	0	0
Stuttgart	GE	A	1	1	0	0	0
Swarzwald	GE	A	1	1	0	0	0
Templehof	GE	AF	1	1	0	0	0
Thurso	UK	N	1	1	0	0	2
Torrejon	SP	AF	1	1	0	0	0

TABLE B-I (CONT'D)

EUROPEAN AREA

	CTY	MILDEP	STATION CLOCK	CLOCK DISTRIB. SUBSYSTEM	DISCIPL. OSCILL.	FREQ. INTERCON.	DIGITAL DATA BUFFER
Twisteden	GE	A	1	1	0	0	0
Vaihingen	GE	A	1	1	0	0	0
Vicenza	IT	A	1	1	0	0	0
Vilseck	GE	A	1	1	0	0	0
Vught	NL	AF	1	1	0	0	0
Weisbaden	GE	A	1	1	0	0	0
Woensdrecht	GE	AF	1	1	0	0	0
Worms	GE	A	1	1	0	0	0
Wethersfield	UK	AF	1	1	0	0	0
Wueschheim	GE	A	1	1	0	0	0
Wurzburg	GE	A	1	1	0	0	0
Yamanlar	TU	AF	1	1	0	0	0
Zaragoza	SP	AF	1	1	0	0	0
Zweibrucken	GE	A	1	1	0	0	0
Zweibrucken	GE	AF	1	1	0	0	0

TABLE B-II TIMING AND SYNCHRONIZATION PACIFIC AREA

	MILDEP	STATION CLOCK	CLOCK DISTRIB. SUBSYSTEM	DISCIPL. OSCILL.	DIGITAL FREQ. INTERCON.	DATA BUFFER
AF 4	AF	1	1	0	0	1
Barbers Point, Hawaii	N	1	1	0	0	0
Bucket, Korea	A	1	1	0	0	0
Canberra, Australia	N	1	1	0	0	0
Changsan, Korea	A	1	1	0	0	0
Chiran, Japan	AF	1	1	0	0	0
Clark Daw, Philippines	AF	1	1	0	0	0
Clark, Philippines	AF	1	1	0	0	0
Camp Ames, Korea	A	1	1	0	0	0
Camp Casey, Korea	A	1	1	0	0	0
Camp Courtney, Japan	A	1	1	0	0	0
Camp Long, Korea	A	1	1	0	0	0
Camp Smith, Hawaii	N	1	1	0	0	0
Camp Zama, Japan	AF	1	1	0	0	3
Diego Garcia, BR	N	0	1	1	1	1
Embassy, Philippines	AF	1	1	0	0	0
Finegayen, Guam	N	1	1	0	0	1
Ford Island, Hawaii	N	1	1	0	0	0
Ft. Buckner, Japan	A	1	1	0	0	2
Fuchu, Japan	AF	1	1	0	0	0
H. E. Holt, Australia	N	0	1	1	1	0
Hakone, Japan	AF	1	1	0	0	0
Hickam, Hawaii	AF	1	1	0	0	0
High Point, Korea	A	1	1	0	0	0
Iwakuni, Japan	AF	1	1	0	0	0
Kadena, Japan	A	1	1	0	0	0
Kamiseya, Japan	AF	1	1	0	0	0
Kwajalen Island	A	1	1	0	0	1
Makalapa, Hawaii	N	1	1	0	0	0
Namsan, Korea	A	1	1	0	0	0
Nimitz Hall, Guam	N	1	1	0	0	0
Osan, Korea	A	1	1	0	0	0
Owada, Japan	AF	1	1	0	0	0
Pearl Harbor, Hawaii	N	1	1	0	0	0
Pusan, Korea	A	1	1	0	0	0
Pyongtak, Korea	A	1	1	0	0	0
Richmond, Korea	A	1	1	0	0	0
Rizal, Philippines	A	1	1	0	0	0
Rokko, Japan	AF	1	1	0	0	0
San Migul, Philippines	N	1	1	0	0	0
Santa Rita, Philippines	N	1	1	0	0	0
Seburiyama, Japan	AF	1	1	0	0	0

TABLE B-II (CONT'D)

PACIFIC AREA

	MILDEP	STATION CLOCK	CLOCK DISTRIB. SUBSYSTEM	DISCIPL. OSCILL.	DIGITAL FREQ. INTERCON.	DATA BUFFER
Seoul, Korea	A	1	1	0	0	0
Shemya, Alaska	AF	1	1	0	0	2
Sofu, Japan	AF	1	1	0	0	0
Song So, Korea	A	1	1	0	0	1
Taegu, Korea	A	1	1	0	0	0
Tango, Korea	A	1	1	0	0	1
Totsuka, Japan	AF	1	1	0	0	0
Wahiawa, Hawaii	N	1	1	0	0	9
Wheeler, Hawaii	AF	1	1	0	0	0
Woomera, Australia	AF	1	1	0	0	0
Yaedake, Japan	AF	1	1	0	0	0
Yokohama, Japan	N	1	1	0	0	0
Yokosuka, Japan	N	1	1	0	0	0
Yokota, Japan	AF	1	1	0	0	0

TABLE B-III TIMING AND SYNCHRONIZATION WESTERN HEMISPHERE AREA

	MILDEP	CLOCK	CLOCK DISTRIB. SUBSYSTEM	DISCIPL. OSCILL.	DIGITAL FREQ. INTERCON.	DATA BUFFER
Adak, Alaska	N	1	1	0	0	0
Adcom (Colorado Springs)	AF	1	1	0	0	2
Alameda, California	N	1	1	0	0	0
Andrews, Maryland	AF	1	1	0	0	0
Ascensin	AF	1	1	0	0	2
Barter Island, ALS	AF	1	1	0	0	0
Bolling, Maryland	AF	1	1	0	0	0
Broughton Island, Canada	AF	1	1	0	0	0
Byron Bay, Canada	AF	1	1	0	0	0
Cambridge, Canada	AF	1	1	0	0	0
Cape Dyer (M), Canada	AF	1	1	0	0	0
Cape Dyer (TRM), Canada	AF	1	1	0	0	0
Cape Hooper, Canada	AF	1	1	0	0	0
Cape Parry, Canada	AF	1	1	0	0	0
Cape Young, Canada	AF	1	1	0	0	0
Clinton Point, Canada	AF	1	1	0	0	0
Corozal, Panama	A	1	1	0	0	0
Camp Roberts, California	A	0	1	1	1	2
Dahlgren, Virginia	N	1	1	0	0	0
DCA, Virginia	A	1	1	0	0	0
Dewar Lakes, Canada	AF	1	1	0	0	0
Driver, Virginia	N	1	1	0	0	0
Dye 1, Greenland	AF	1	1	0	0	0
Dye 2, Greenland	AF	1	1	0	0	0
Dye 3, Greenland	AF	1	1	0	0	0
Dye 4, Greenland	AF	1	1	0	0	0
Dye 5, Iceland	AF	1	1	0	0	0
Elmendorf, Alaska	AF	1	1	0	0	2
Ft. Belvoir, Virginia	A	1	1	0	0	0
Ft. Detrick, Maryland	A	1	1	0	0	7
Ft. Leavenworth, Kansas	A	1	1	0	0	6
Ft. Lee, Virginia	A	1	1	0	0	0
Ft. Meade, Maryland	A	1	1	0	0	0
Ft. Eustis, Virginia	A	1	1	0	0	0
Ft. Ritchie, Maryland	A	1	1	0	0	0
Gladman Point, Canada	AF	1	1	0	0	0
Guantanamo, Cuba	N	1	1	0	0	1
Hall Beach, Canada	AF	1	1	0	0	0
Hofu, Iceland	AF	1	1	0	0	0
Howard, Panama	A	1	1	0	0	1
Isabella, Puerto Rico	N	1	1	0	0	0
Jenny Lind Island, Canada	AF	1	1	0	0	0

TABLE B-III (CONT'D)

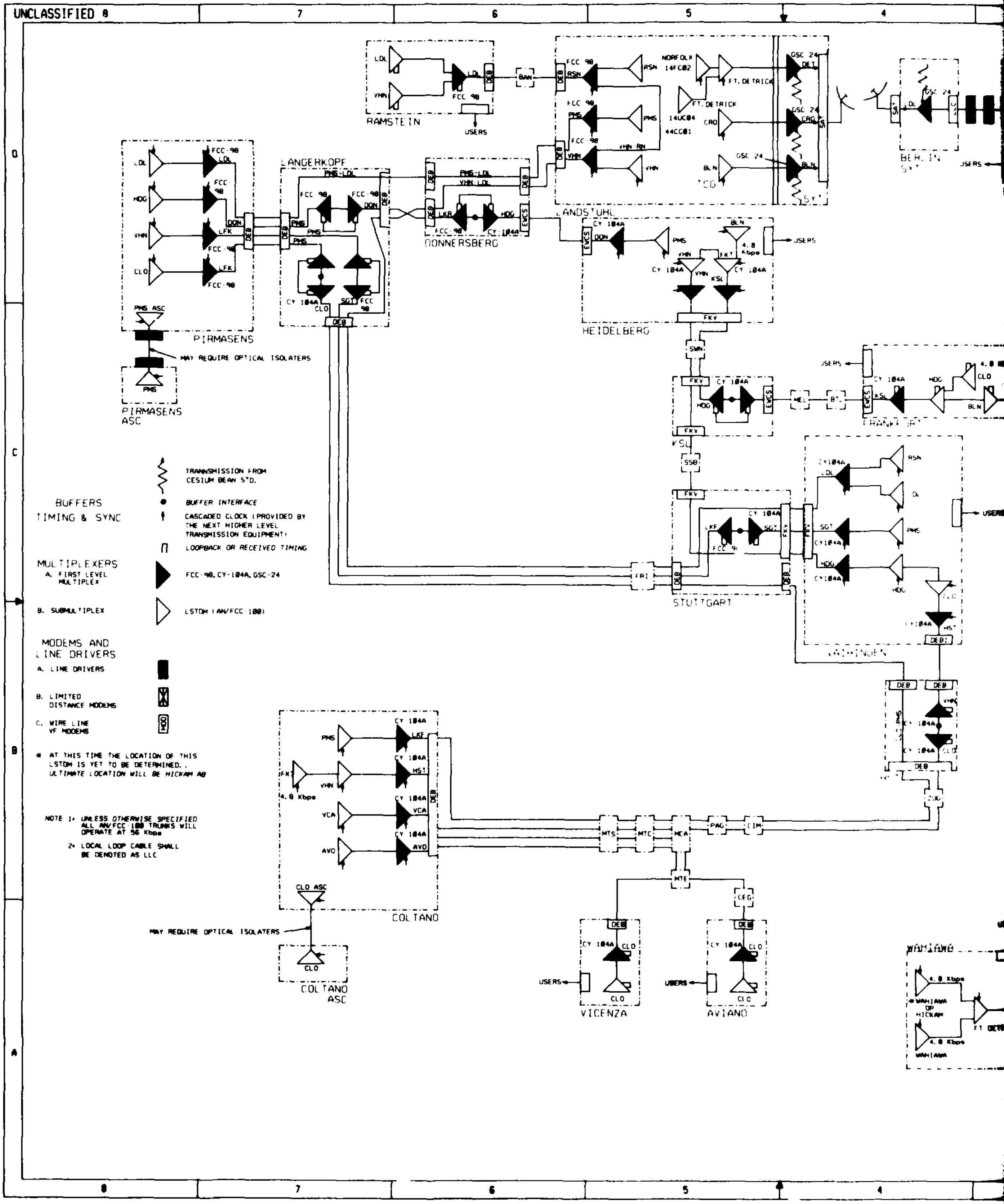
WESTERN HEMISPHERE AREA

	MILDEP	CLOCK	CLOCK DISTRIB. SUBSYSTEM	DISCIPL. OSCILL.	DIGITAL FREQ. INTERCON.	DATA BUFFER
Keflavik, Iceland	N	1	1	0	0	0
Komakuk Beach, Canada	AF	1	1	0	0	0
Lajes, Azores	AF	1	1	0	0	1
Langley, Virginia	AF	1	1	0	0	0
Lady Franklin Point, Canada	AF	1	1	0	0	0
Lonely, Alaska	AF	1	1	0	0	0
Longstaff Bluff, Canada	AF	1	1	0	0	0
Los Angeles, California	N	1	1	0	0	0
Mackar Inlet, Canada	AF	1	1	0	0	0
McClellen, California	AF	1	1	0	0	0
Moffett, California	N	1	1	0	0	0
Nato Site, Iceland	AF	1	1	0	0	0
Naval Security Station, DC	A	1	1	0	0	0
Nicholson Peninsula, Canada	AF	1	1	0	0	0
Norfolk, Virginia	N	1	1	0	0	4
Northwest, Virginia	N	1	1	0	0	0
Norton, California	AF	1	1	0	0	0
Oakland, California	N	1	1	0	0	0
Offutt, Nebraska	AF	1	1	0	0	4
Olitok, Alaska	AF	1	1	0	0	0
P. Mountain, Greenland	AF	1	1	0	0	0
Paris, Virginia	A	1	1	0	0	0
Pelly Bay, Canada	AF	1	1	0	0	0
Pentagon, Virginia	A	1	1	0	0	0
Pentagon, Virginia	AF	1	1	0	0	0
Point Lay, Alaska	AF	1	1	0	0	0
Point Barrow, Alaska	AF	1	1	0	0	0
Quantico, Virginia	N	1	1	0	0	0
Quarry Heights, Panama	A	1	1	0	0	0
Richmond, Virginia	A	1	1	0	0	0
Roosevelt Rds., Puerto Rico	N	1	1	0	0	0
Sabana Seca, Puerto Rico	N	1	1	0	0	0
San Diego, California	N	1	1	0	0	0
Shepard Bay, Canada	AF	1	1	0	0	0
Shingle Point, Canada	AF	1	1	0	0	0
Skaggs Island, California	N	1	1	0	0	0
San Francisco, California	N	1	1	0	0	0
Sondrestrom, Greenland	AF	1	1	0	0	0
Stockton, California	N	1	1	0	0	0
Sunnyvale, California	AF	1	1	0	0	5
Tuktoyaktuk, Canada	AF	1	1	0	0	0
Wainwright, Alaska	AF	1	1	0	0	0
White Oak, Maryland	N	1	1	0	0	0

Appendix C

TIMING AND SYNCHRONIZATION CONFIGURATION FOR THE DATA TRANSMISSION NETWORK (DTN)

The implementation of the DTN will occur gradually, phased over a long period of time. Figure C-1 depicts the proposed configuration of the initial DTN implementation defined as stage 1A. The DTN initial implementation will serve as a field trial and will provide a basis for development of a finalized operations and maintenance concept for the mature DTN. The initial implementation will also enable a detailed analysis of specific user requirements to be provided by the DTN, and will serve as a test bed to obtain performance data.



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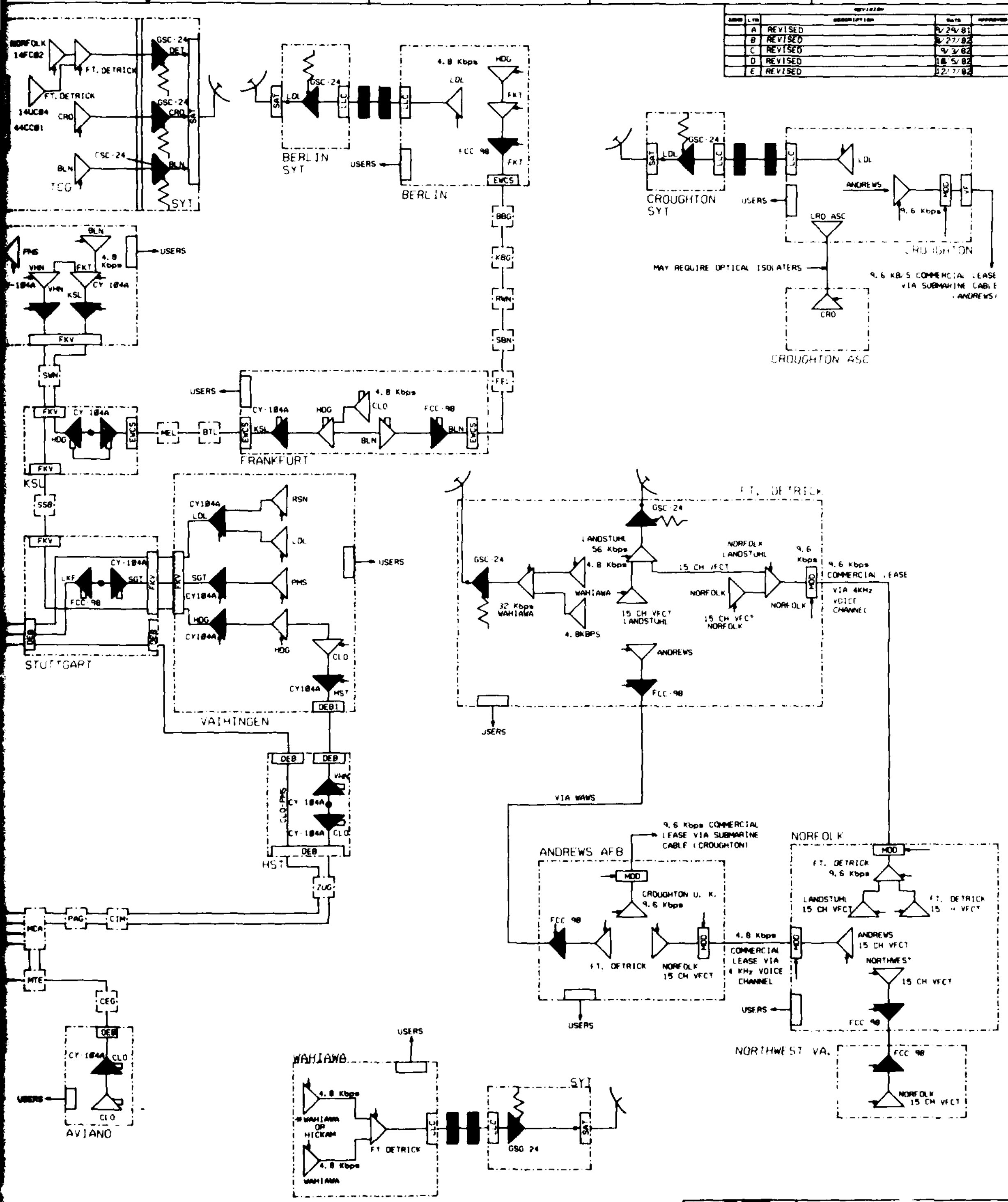
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	REVISED	9/29/81	
	B	REVISED	8/27/82	
	C	REVISED	9/3/82	
	D	REVISED	10/5/82	
	E	REVISED	12/7/82	



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C-2

FIGURE C1
PROPOSED TIMING AND SYNCHRONIZATION CONFIGURATION FOR DATA TRANSMISSION NETWORK (DTN) INITIAL IMPLEMENTATION STAGE 1A

E	26280	805004	1

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APPENDIX D

TIMING AND SYNCHRONIZATION CONFIGURATION FOR THE ETS

At present, the near-term (pre-1986) ETS locations requiring timing and synchronization will be at sites with PCM-30 (2.048 Mb/s) lease connectivity as shown in Figure D-1. Table D-1 depicts the PCM-30 sites by initial operation requirement date, and defines either the date for which T&S muste be available, or suggests a possible interim loop timing arrangement. The ETS switches within the PCM-24 (1.544 Mb/s) connectivities may be satisfied by the T&S systems employed in the Digital European Backbone (DEB) upgrades as they are cutover.

The timing and synchronization configuration for the European Telephoine System is shown in Figure D-2. As was discussed previously, those ETS sites that are not equipped with station clocks and clock distribution subsystems (designated as minor nodes) will use looped timing from the T&S system located at the nearest major node.

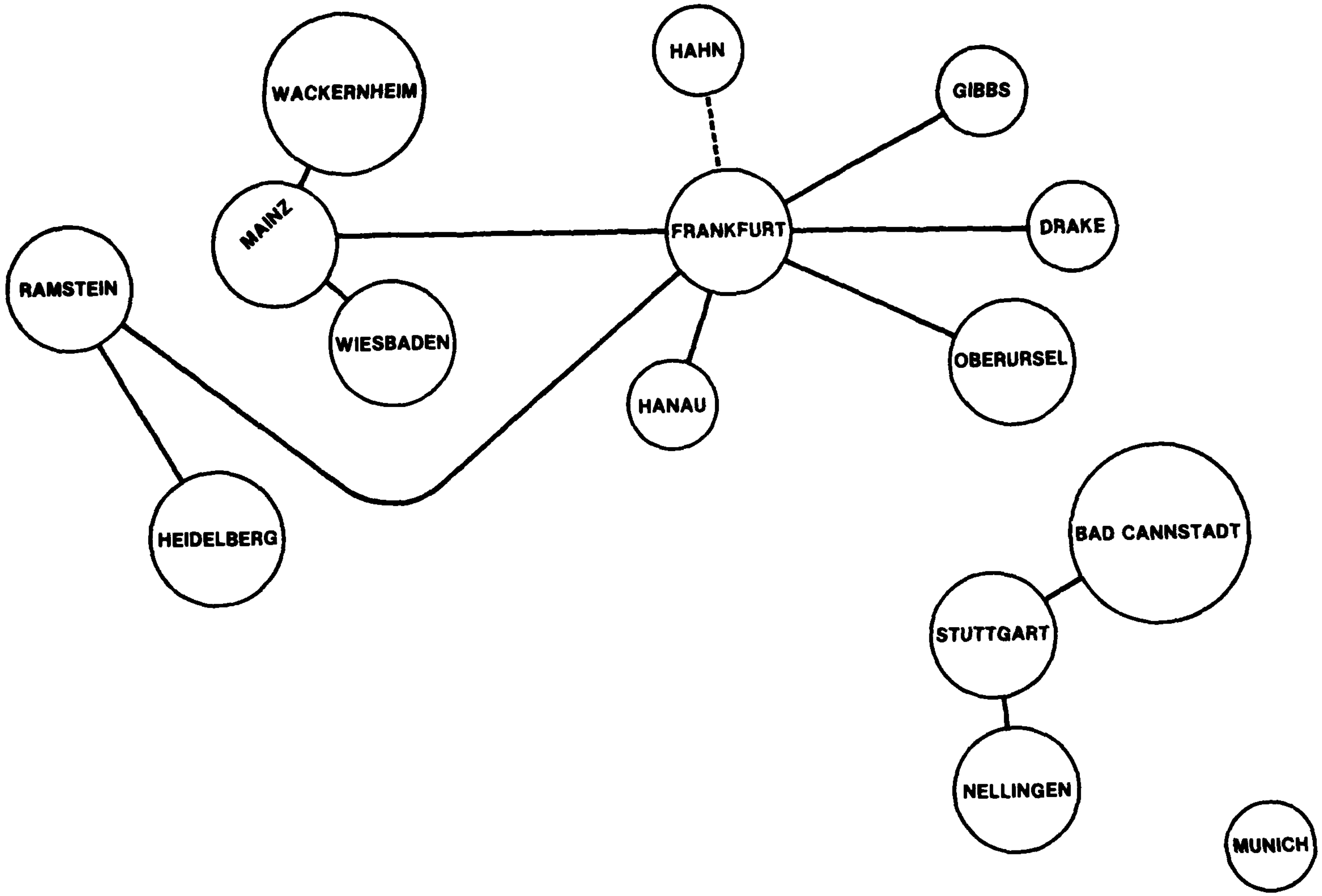

FIGURE D-1. PCM-30 LEASE CONNECTIONS

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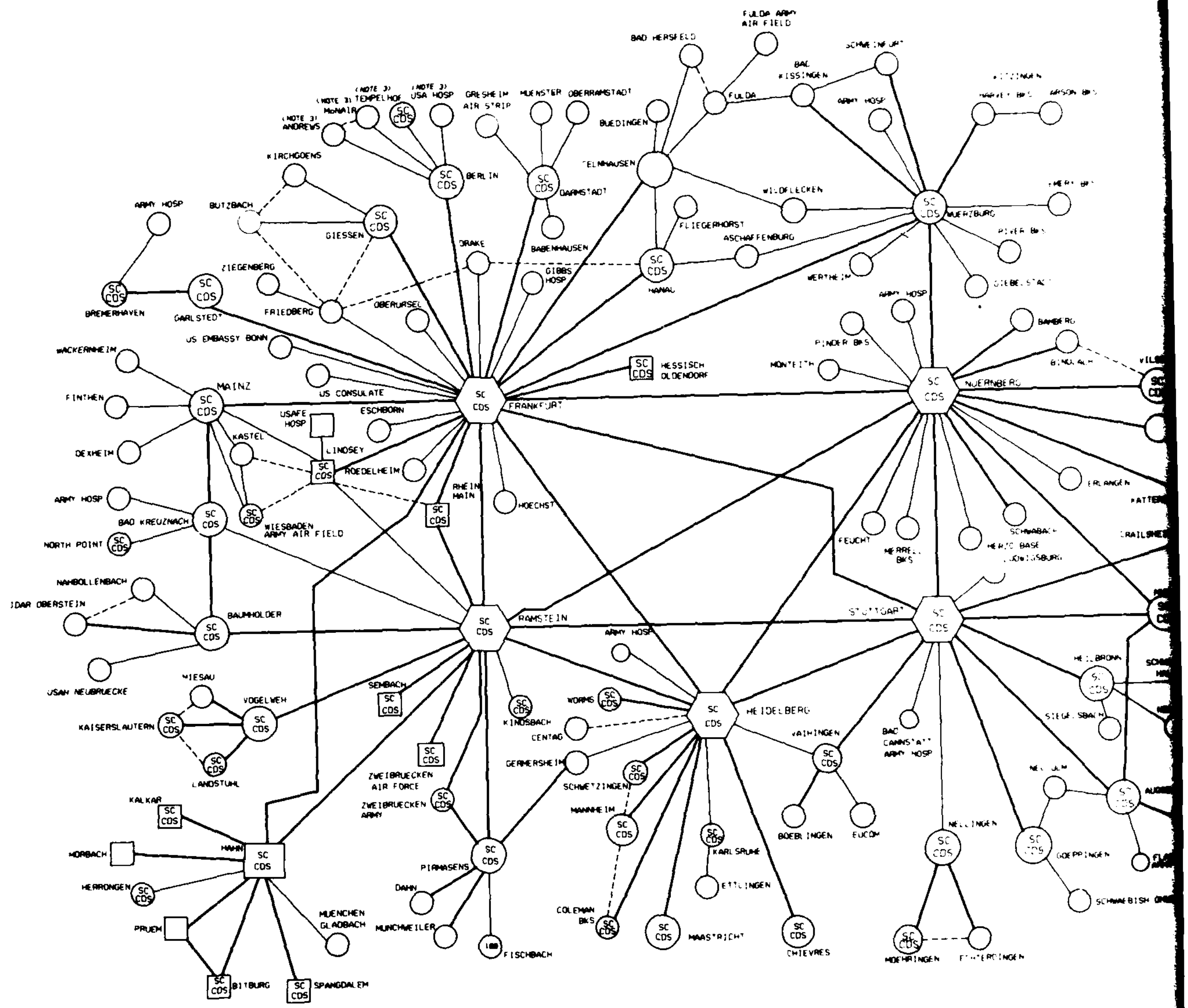

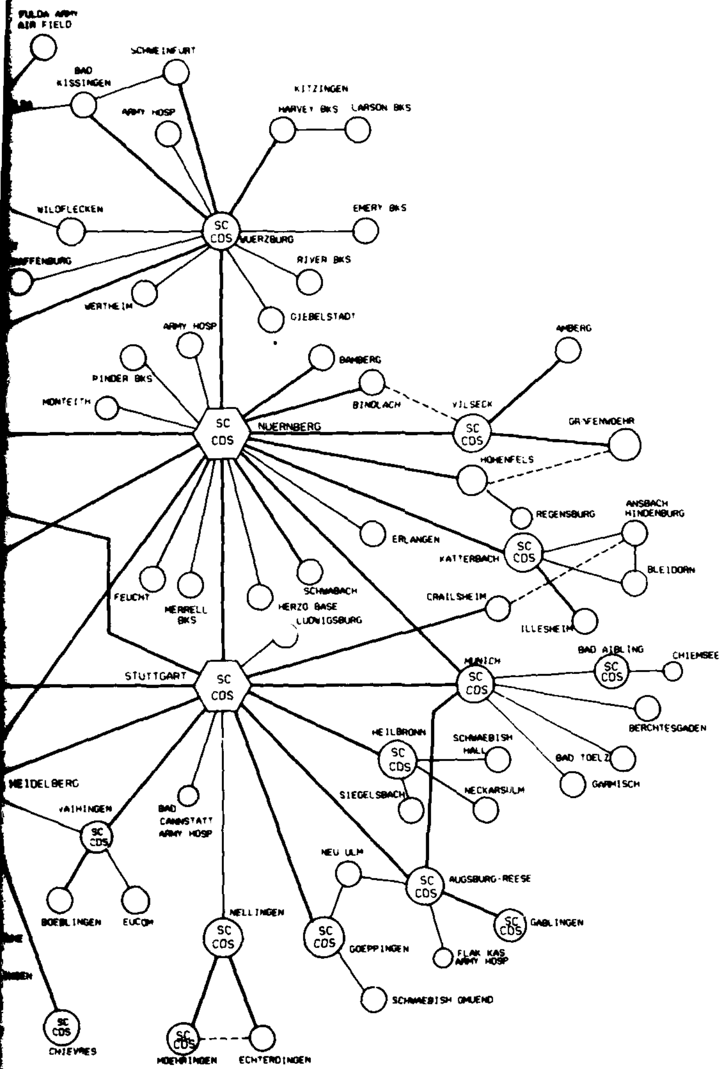

SC STATION CLOCK
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FIGURE D2
PROPOSED TIMING AND SYNCHRONIZATION CONFIGURATION FOR EUROPEAN TELEPHONE SYSTEM (ETS)

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D-3

E 26200 005006 1

2

TABLE D-I. ETS TIMING AND SYNCHRONIZATION NEAR-TERM (PRE-CY85) REQUIREMENTS

SITE	MILDEP	ETS/IOC	DEB IOC	T&S REQ'D TO SUPPORT ETS/PCM 30 IOC
FRANKFURT (FKT)	A	5/84		5/84
STUTTGART (SGT)	A	8/84		8/84
GIBBS		3/84	LOOP FROM FKT (5/84)	
HAHN	AF	11/84		11/84
HEIDELBERG	A	10/84		10/84
NELLINGEN	A	9/84		9/84
HANAU	A	12/84		12/84*
MAINZ (MNZ)	A	1/85		1/85
WACKERNHEIM		1/85	LOOP FROM MNZ (1/85)	
WIESBADEN	A	1/85		1/85*
RAMSTEIN	AF	2/85		2/85
DRAKE		3/85	LOOP FROM FKT (5/84)	
OBERURSEL		3/85	LOOP FROM FKT (5/84)	
BAD CANNSTATT		2/85	LOOP FROM SGT (8/84)	
MUNICH	A	INSTALLED		6/84

*LOOP TIMING POSSIBLE ON INTERIM BASIS

TABLE D-I (CONT'D)

SITE	MILDEP	ETS/IOC	DEB IOC	T&S REQ'D TO SUPPORT ETS/PCM 30 IOC
GARLSTEDT	A	INSTALLED	84	84
KAISERLAUTERN	A	6/84	83/85	83
LANDSTUHL	A	9/84	IN/83	83
SCHWETZINGEN	A	10/84	IN/87	83*
KATTERBACH	A	10/84	85	85*
NUERNBERG	A	9/84	85	85
VAIHINGEN	A	11/84	IN	83*
SEMBACH	AF	12/84	85	85
MOEHRINGEN	A	9/84	83	83*
GEOPPINGEN	A	6/84	83	84*
HEILBRONN	A	7/85	88	88
PIRMASENS	A	5/85	83	84
ZWEIBRUCKEN	A	6/85	86	86
BITBURG	AF	8/85	85	85

*LOOP TIMING POSSIBLE ON INTERIM BASIS

APPENDIX E

DSCS INTERCONNECT FACILITY DATA

Table E-I provides a listing of the current earth terminal locations within the Defense Satellite Communications System. Along with the earth terminal location, the responsible MILDEP, type of media connecting the earth terminal and technical control facility (denoted "ICF"), case type (defined earlier in the text), and the distance between earth terminal and technical control facility (denoted "Distance") are provided.

TABLE E-I. DSCS INTERCONNECT FACILITY DATA

LOCATION	MILDEP	ICF	CASE TYPE	DISTANCE
AUGSBURG	A	22 Gauge/Multipair	I	2300/2500 Ft.
CAMP ROBERTS	A	22 Gauge Cable	III	100 Ft.
COLTANO	A	Std. Cable	I	500 Ft.
BERLIN	A	22 Gauge Cable	I	3 Miles
FT. BUCKNER	A	22 Gauge Cable 22 Gauge Cable	III	250 Ft. 500 Ft.
KWAJALEIN	A	19 Gauge Cable	I	2400 Ft.
LANDSTUHL	A	22 Gauge Cable	I	200 Ft.
TANGO*	A	Std. Cable		600 Ft.
FT. MEADE	A	Fiber Optic	IV	5000 Ft.
FT. DETRICK	A	22 Gauge Cable	IV	850 Ft.
SONG SO	A	Line of Sight 22 Gauge Cable	II	7 Miles 400 Ft.
H. E. HOLT	N	Cable	III	200 Ft.
DIEGO GARCIA	N	Cable	III	200 Ft.
WAHIAWA	N	Fiber Optic	IV	7000 Ft.
GUAM	N	Fiber Optic	IV	7000 Ft.
NAVY No. 2	N	Cable	III	200 Ft.
NAVY No. 3	N	Cable	I	600 Ft.
ELMENDORF	AF	19/24 Gauge Cable	I	2000 Ft.
CROUGHTON	AF	19/24 Gauge Cable	I	5000 Ft.
CAMP ZAMA	AF	19 Gauge Cable	I	7000 Ft.
AZORES	AF	19 Gauge Cable	I	5000 Ft.
SHEMYA	AF	19 Gauge Cable	I	2500 Ft.

TABLE E-I (CONT'D)

DSCS INTERCONNECT FACILITY DATA

LOCATION	MILDEP	ICF	CASE TYPE	DISTANCE
HUMOSA	AF	18 Gauge Twisted Pair Cable	I	300 Ft.
DIYARBAKIR	AF	TBD	TBD	TBD
GEODSS I*	AF	TBD	TBD	TBD
GEODSS II*	AF	TBD	TBD	TBD
NORTHWEST	N	Line of Sight (2 hops)	II	30 Miles
ASCENSION	AF	19 Gauge Twinax Cable	I	1 Mile
THURSO	N	Line of Sight	II	15 Miles
LAGO DI PATRIA	N	Line of Sight	II	30-35 Miles
GUANTANAMO	N	Cable	I	500 Ft.
AF No. 4	AF	TBD	TBD	TBD
SUNNYVALE	AF	Cable Cable	I	100 Ft. 8000 Ft.
OFFUTT	AF	Fiber Optic 22 Gauge Cable	I	5000 Ft. 200 Ft.
HOWARD	A	Fiber Optic	I	5000 Ft.
NEW BOSTON	AF	TBD 19 Gauge Cable	I I	TBD 7000 Ft.
CLARK	AF	Line of Sight	II	6 Miles
WOOMERA	AF	Cable	I	5000 Ft.
AF No. 1	AF	TBD	I	TBD
AF No. 2	AF	TBD	I	TBD

* Three locations with earth terminals not equipped with Cesium beam frequency standards are Tango, GEODSS I, and GEODSS II, and therefore, will not be addressed further in this analysis.

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