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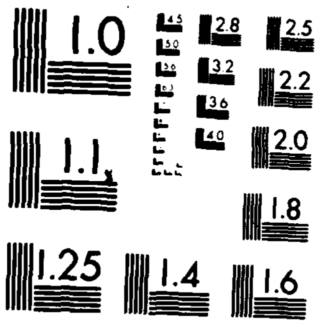

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EFFICIENT UTILIZATION OF THE DRAMA SERVICE CHANNEL

By
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The DRAMA service channel must provide communications for a variety of users. The architectural implications of configuring the network using conventional multiplexers are examined and several feasible implementations are presented. A high speed communications processor that can be used as a service channel controller is described. Networks configured with the service channel controller provide greater reliability and flexibility than the multiplexer networks.

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1.0 INTRODUCTION

The service channel supports the Operation and Maintenance (O&M) functions of a communications system. The number of functions included under operation and maintenance is increasing rapidly. This increase is expected to continue in the future. Communication must be supplied to support the functions as each is implemented. The following functions have been identified as necessary for the operation and maintenance of the Defense Communications System (DCS):

- Voice Orderwire.
- Message Orderwire.
- Transmission Monitoring.
- Maintenance Dispatch.
- Maintenance Management.
- Fault Isolation.
- Switch Monitoring.
- Network Control.
- Network Reconfiguration.
- Electronic Countermeasures (ECM) Detection and Electronic Counter Countermeasures (ECCM) Response.
- Performance Evaluation.
- System Control.

The voice orderwire function is presently implemented throughout the DCS. Automated transmission and switch monitoring is partially implemented for some subsystems. Enhanced capabilities are planned for the monitoring and maintenance dispatch functions. The other functions are being investigated by several agencies to determine the optimum strategy for implementation of automated systems.

These functions listed above are generally grouped into four programs:

- o Orderwire.
- o TRAMCON.
- o SYSCON.
- o ECM/ECCM.

The programs are closely related and will share some common equipment. The service channel is expected to supply the primary communications resource for many of these programs.

The evolution of the service channel technology has not kept pace with the growth in the functions that must be supported. The DRAMA microwave radios provide a digital service channel that operates at 192 kb/s. The DRAMA service channel multiplexer restricts access to the bit stream such that the interface is either very inefficient or very difficult to access. The easier implementation of the service channel, using the DRAMA multiplexer, will not support the communications for the functions identified above. This paper explores alternative techniques for accessing the service channel. The primary concern is the DRAMA service channel; however, some of the techniques may be applicable to the service channels of older equipment types.

A brief review of the analog service channel implementation is presented. The DRAMA implementations that use an analog voice channel, derived from the digital service channel, are similar to the analog service channel implementations. The system considerations that determine the design of service channel network implementations are examined briefly and the alternative implementations that are considered to be most effective are developed in substantial detail.

One of the alternatives is to replace the DRAMA multiplexer with a special purpose communications processor that is used as a service channel controller. One processor could interface with several radio service channels and terminals at a site. An implementation using service channel controllers can provide several features not available with DRAMA multiplexer implementations. Equipment redundancy, adaptive routing, and flexible user interconnection are among the more significant features. A brief functional description of a service channel controller is included as an appendix.

2.0 ANALOG SERVICE CHANNEL IMPLEMENTATIONS

The implementation of the service channel in analog systems is presented to illustrate the evolution of the utilization. The future DCS transmission systems will be primarily digital. However, the existing analog and quasi-analog systems will be operational for many years. The analog and digital service channel implementations will have to interoperate during those years.

2.1 Voice Orderwire

The initial concept of the service channel was to provide voice communications between adjacent transmission sites for maintenance coordination. This type of usage is illustrated for a small communications system in Figure 1. Each radio has an orderwire telephone associated with it. Direct communications is possible only between adjacent sites. To communicate past an adjacent site requires verbal relaying of the message.

The awkward and inefficient operation of the adjacent site implementation led to an improved regional orderwire concept. The service channels of all the radios (within the regional orderwire configuration) at a site are interconnected such that any signal received by one radio is transmitted on all other radios. The interconnecting element is a conference bridge. A typical arrangement of a regional orderwire service channel interconnection is illustrated in Figure 2. Any site can communicate with any other site; however, only one conversation can occur at a time. The entire region is a party-line.

The earliest signalling was a simple ringdown circuit that would ring at all sites. Selective signalling is used in most recent orderwire implementations. A site can call any other site without ringing at unselected sites. However, only one conversation is possible at a time. Communications privacy is impossible since any site can monitor the service channel at any time.

2.2 Data Transmission

The operational concept of not manning transmission relay sites requires a mechanism for monitoring the status of the transmission equipment and reporting to a manned site. This mechanism is usually called a Fault Alarm System (FAS). The earliest FAS implementation displayed only alarm and status indications. Current implementations include parameter display and remote control activation capabiliti s. Futur implementations are expected to support some degree c ated fault isolation.

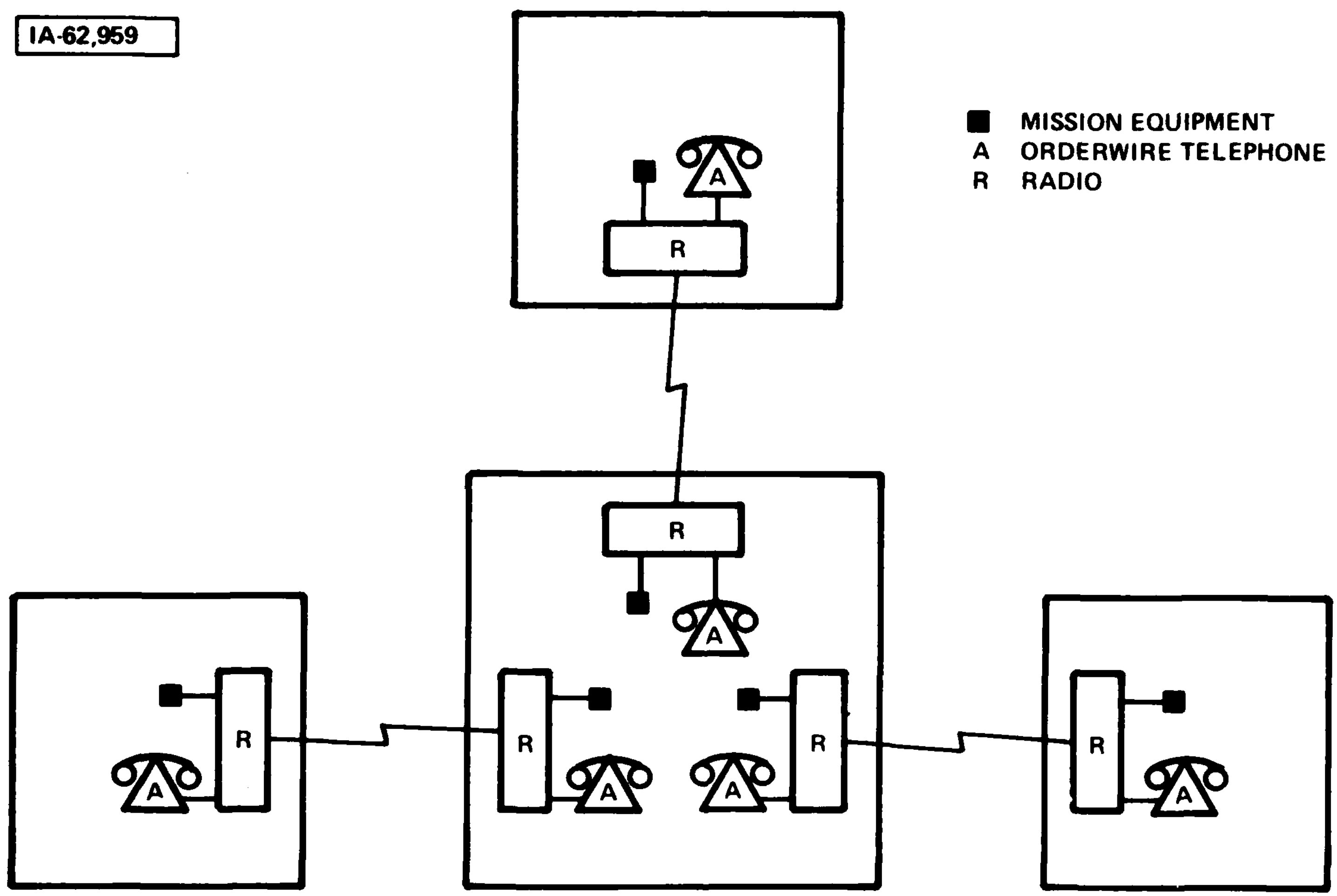

Figure 1. PRIMITIVE VOICE ORDERWIRE

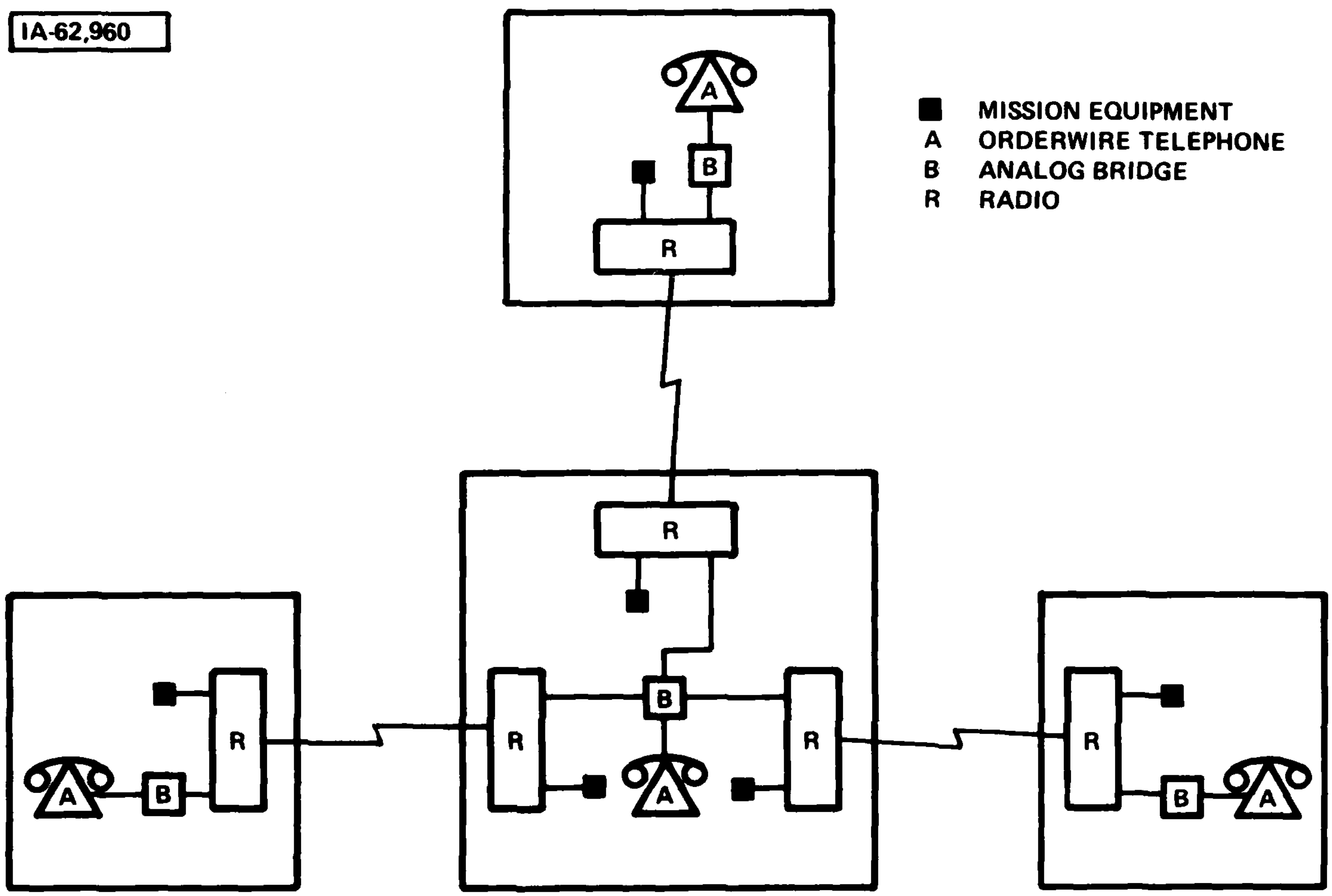

Figure 2. REGIONAL VOICE ORDERWIRE

The transmission to support FAS operation is usually provided by the service channel. A typical station implementation is shown in Figure 3. The voice orderwire and the FAS communications share the service channel. Filters are used to separate the service channel spectrum so that mutual interference is avoided. A modem is used to convert the FAS digital data into quasi-analog signals for transmission over the analog service channel.

The spectrum utilization and the communications protocols become important issues when data transmission for a fault alarm system shares the service channel with a voice orderwire. These topics are discussed in the next sections.

2.2.1 Service Channel Spectrum

The service channel is implemented in analog FDM radios (e.g., LC-8) and quasi-digital radios (e.g., AN/FRC-162) by modulating a separate subcarrier. This subcarrier is transmitted along with the mission traffic but is an independent signal that has not passed through the multiplexer equipment. The baseband spectrum of the service channel is typically from 300 Hz to above 8 kHz.

When voice and data are transmitted on the service channel, filters are used to separate the spectrum into voice and data segments. Typically, voice occupies the 300-3400 Hz segment and data occupies 4000-8000 Hz segment as shown in Figure 4. The spectrum between 3400 and 4000 Hz is not usable.

Modems are used to modulate the digital data onto a carrier frequency in the 4000-8000 Hz segment of the service channel spectrum. More than one carrier frequency can be used. Figure 4 illustrates an assignment of four carriers. Each carrier can represent an independent data communications system, but carriers are commonly used in pairs to provide full duplex communications. In theory, any number of carriers can be combined in the service channel. In practice, the number is limited by the bandwidth requirements of the data transmission and the filter characteristics. With one carrier frequency, the 4000-8000 kHz segment of the service channel spectrum can be used to reliably transmit data at speeds up to 4800 b/s. The filters necessary to separate two or more carriers make part of the spectrum unusable and reduce the data transmission capacity. The approximate capacity of each channel, with more than one carrier frequency, is 1200 b/s for two carriers, 600 b/s for four carriers, 300 b/s for six carriers, and 75 b/s for sixteen carriers.

The service channel can implement independent subnetworks by assigning groups of users to a carrier frequency (or pair of

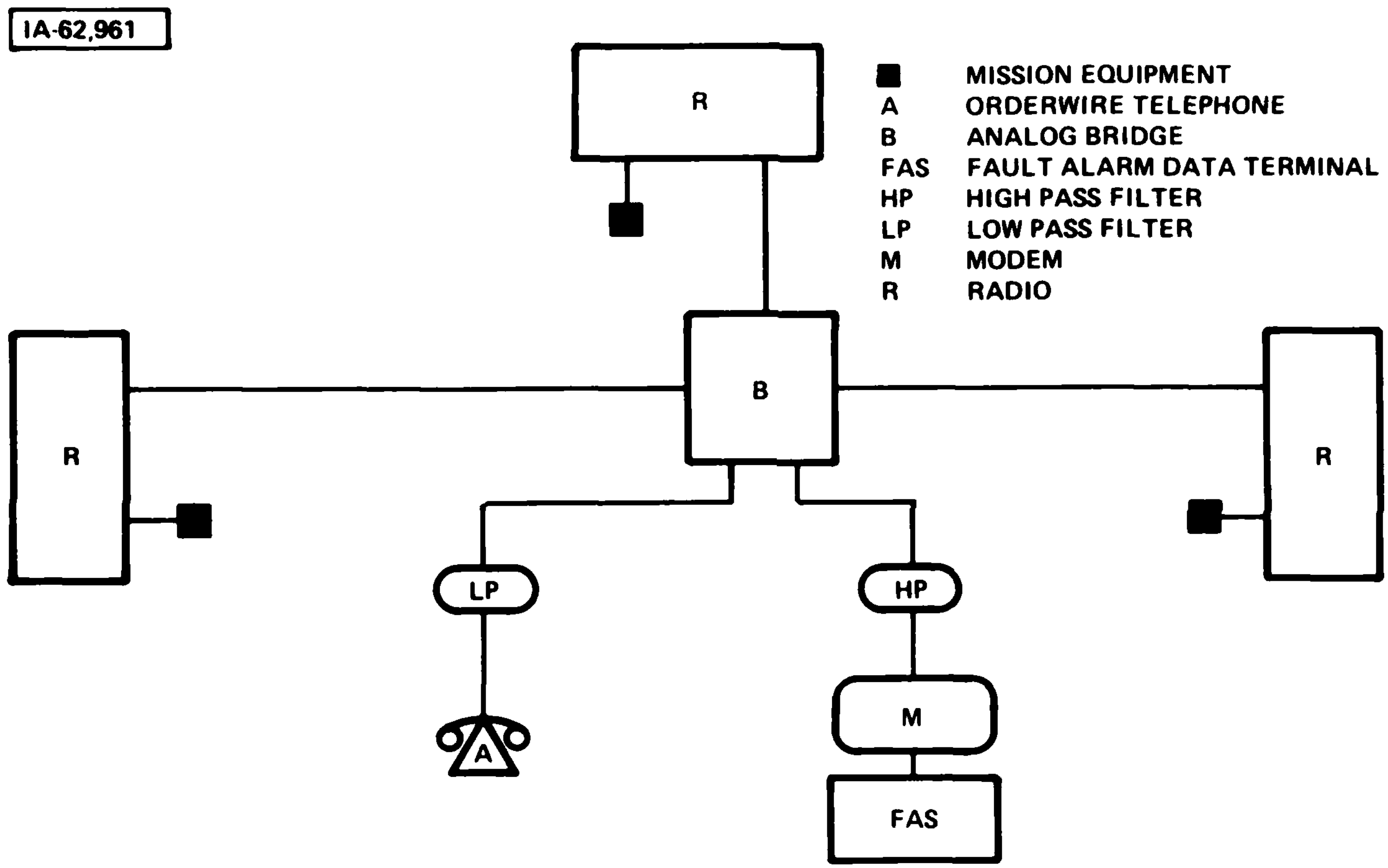

Figure 3. BASIC SERVICE CHANNEL INTERCONNECTION FOR DATA TRANSMISSION

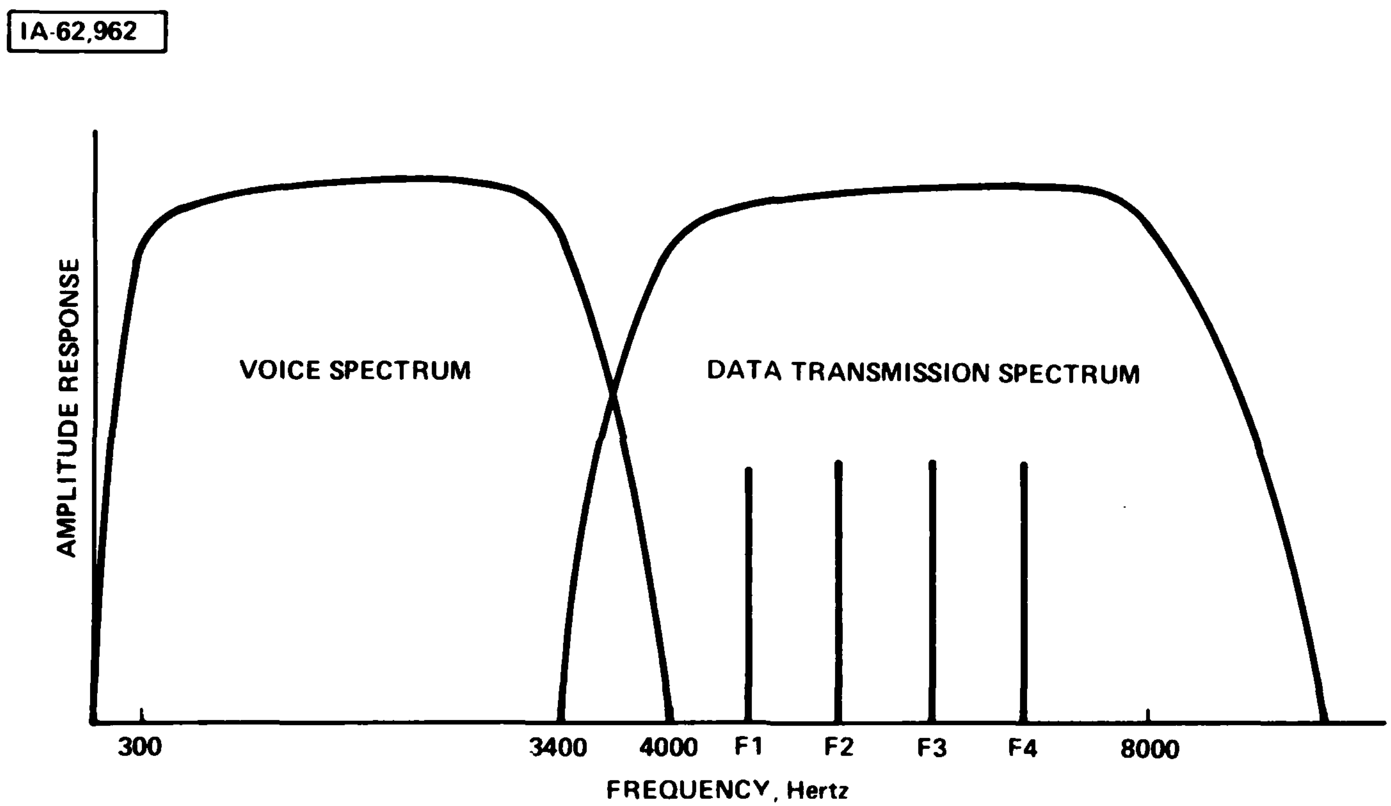

Figure 4. ANALOG SERVICE CHANNEL FREQUENCY RESPONSE

frequencies). Each subnetwork is isolated from other subnetworks and all users within the subnetwork share a common carrier. The number of subnetworks is limited by the required data transmission speed and the number of possible carriers at that speed.

2.2.2 Message Separation and Communications Protocols

The regional connectivity of the service channel is determined by the conference bridge interconnections. Within a region, the service channel has a party line connectivity. The separation of user messages is maintained either by using different carrier frequencies or by communications protocols. The separation by frequency is described above. Within the subnetwork, protocols are required to maintain message separation.

The simplest conceptual implementation of message separation protocols is to assign only one user with transmit capability to a subcarrier. One or more other users can receive the transmission but cannot reply. This type of communication is called simplex. It is used in very basic monitoring systems. Figure 5 illustrates simplex communications as used in the FKV segment of the DCS. The unmanned site is monitored by a remote fault alarm unit that transmits the status continuously to one or more manned sites. The master units receive and display only. Control of the mission equipment at the remote site is not possible. Since there is no interaction between the master and remote units, the communications protocol is trivial. The separation of the FAS message from other orderwire users (including FAS units at other unmanned sites) is by assignment of separate carrier frequencies.

Multiple transmitting units can be operated over the service channel on the same carrier frequency, if a communications protocol is adopted to ensure message separation. The message separation is accomplished by restricting access so that only one unit transmits at a time. Numerous protocol variations have been used to control access to the channel. The major categories of access protocols are: fixed time slot, carrier detection, and token passing. Polling is a special case of token passing in which the master passes the token to the selected remote and the remote always passes the token back to the master.

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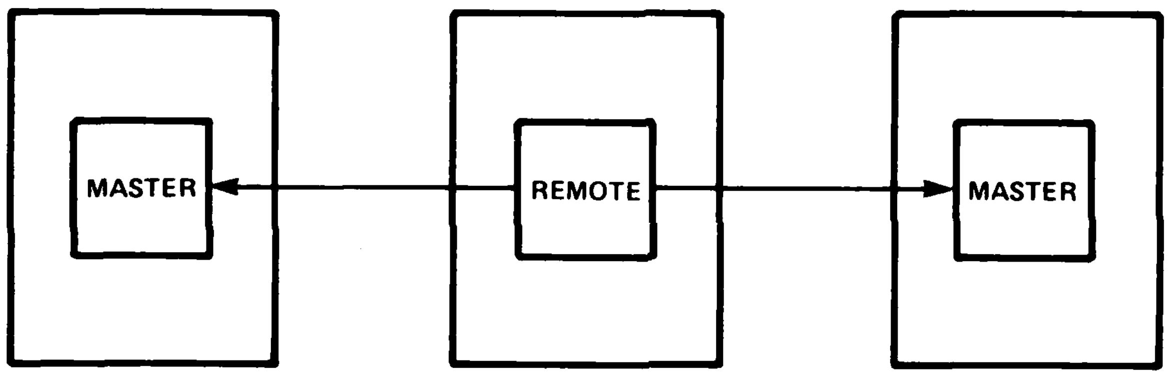

Figure 5. FAS COMMUNICATIONS AS USED IN FKV

The FAS communications in the DEB I system uses a polling protocol with two carrier frequencies. The master transmits on one frequency and all remotes transmit on the other. Full or half duplex communications is possible. The DEB I FAS communications are illustrated in Figure 6. Only one of the masters in the DEB I FAS can issue polls. The other masters are operated as slaves that only receive information from the remotes. Any of the masters can be manually selected as the polling master. Operator coordination and data base maintenance among the masters require a separate interprocessor communications (IPC) channel. The IPC is implemented over a mission channel in DEB I.

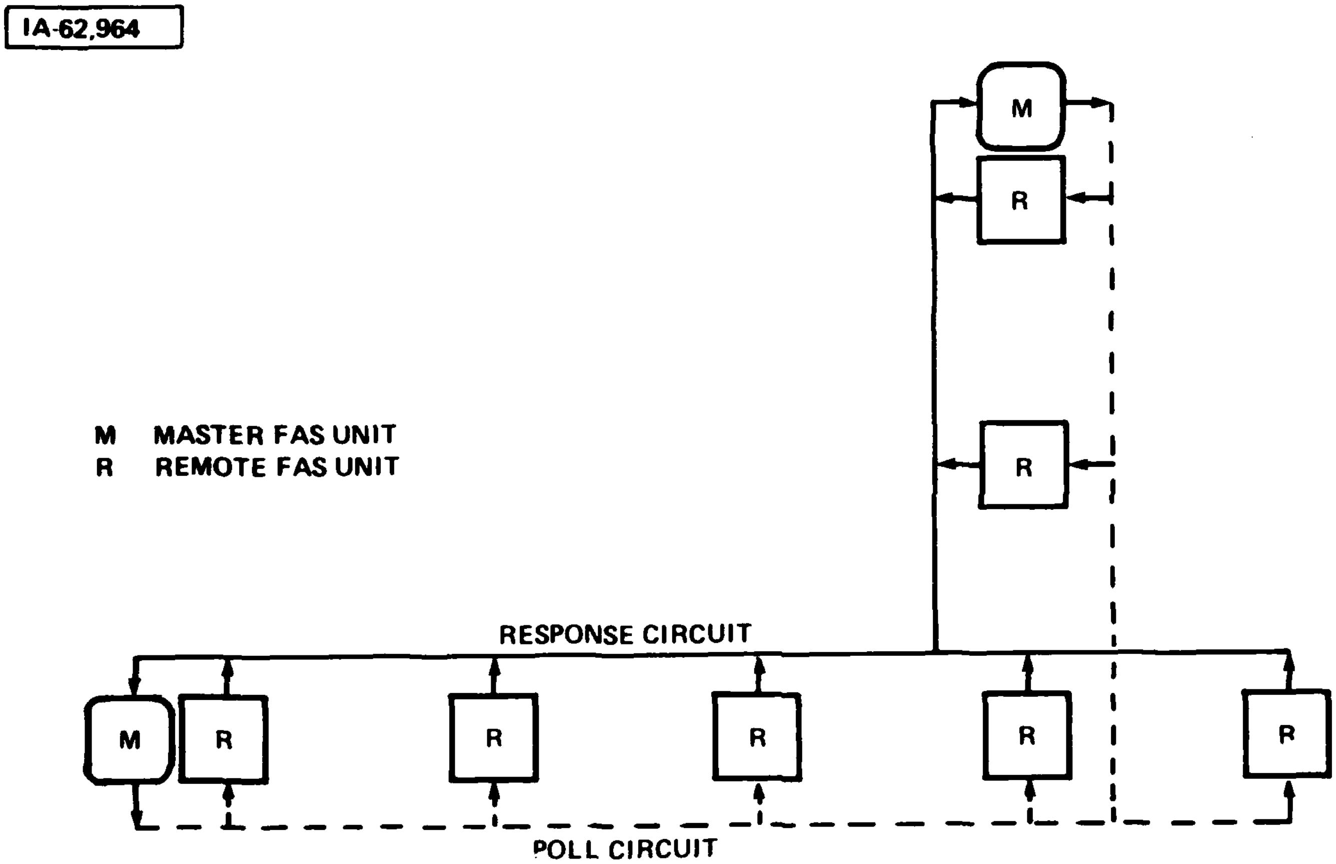

Figure 6. FAS COMMUNICATIONS AS USED IN DEB STAGE I

3.0 DIGITAL SERVICE CHANNEL CONSIDERATIONS

A service channel network cannot be rationally implemented by simply selecting from a set of hardware. There are many factors that must be considered. Some of these factors are examined briefly in this section, including:

- Available equipment.
- Interface characteristics.
- User requirements.
- Access techniques.
- Reliability.
- Logistics.

These considerations are necessary to define a feasible DRAMA service channel network and to compare alternative network implementations.

3.1 Service Channel Equipment

3.1.1 DRAMA Equipment Family

The DRAMA program has developed a series of digital radios and multiplexers. The AN/FRC-170 series of radios include versions that operate at 4 or 8 GHz, and with space or frequency diversity. The digital interface has one or two mission bit stream (MBS) ports and one service channel bit stream (SCBS) port. Each MBS port operates at bit rates up to 12.9 Mb/s and the SCBS port operates at 192 kb/s. Each MBS is multiplexed by the AN/FCC-99 second level multiplexer. The AN/FCC-99 multiplexes 2, 4, 6, or 8 T1 bit streams (1.544 Mb/s) into one MBS. The AN/FCC-98 digital channel bank multiplexes up to 24 voice (or data) circuits into a T1 bit stream. A special version of the first level multiplexer (AN/FC^-98[3]) is used to interface the radio service channel at 192 kb/s. The AN/FCC-98[3] multiplexes three voice or data channels.

The Megabit Digital Tropo System (MDTS) includes a troposcatter modem that is compatible with the DRAMA digital interfaces. The AN/FCC-99 can multiplex up to six T1 circuits into the MDTS mission bit stream. The MDTS service channel also operates at 192 kb/s.

The low speed multiplexer (LSTDM) is under development for DRAMA. The LSTDM has a variable data transmission rate and configuration. The LSTDM can be configured to multiplex circuits with data rates from 35 b/s to 32 kb/s into bit streams up to 256 kb/s. When configured for one of the DRAMA data rates, the LSTDM can multiplex up to 32 data circuits into one channel.

3.1.2 Service Channel Controller

The service channel controller (SCC) is a sophisticated communications processor that will be configured for operation with the DRAMA service channel. A brief functional description is presented in the appendix. The SCC is functionally similar to the nodal processors used by commercial data networks. The SCC internodal data transmission speed (192 kb/s) is higher than the transmission speed used in most commercial networks (typically 56 kb/s). The SCC will require software development. Hardware development may be required to achieve the DRAMA service channel transmission speed.

3.1.3 Accessory Equipment

Accessory equipment may be required to interconnect the service channel ports and the terminals. The major items are conference bridges, modems, and simple communications processors. Minor items include amplifiers, attenuators, filters, and patch bays.

Analog Conference Bridge - An analog conference bridge interconnects several analog circuits such that a signal received from one circuit is transmitted on all other circuits. If signals are received from more than one circuit, the signals are combined into a composite signal. The bridge is typically modular with four ports per module.

Digital Conference Bridge - A digital conference bridge interconnects several digital circuits such that a signal received from one circuit is transmitted on all other circuits. Receiving a digital signal on one port will inhibit reception from any other port. The bridge uses the level transitions to determine the presence of a signal. Hence, the digital conference bridge can fail to recognize transmission of blocks of synchronous data. The bridge is normally used with asynchronous data where the start/stop bits guarantee frequent transitions. The better digital conference bridges can discriminate between data and noise and inhibit a noisy circuit. A digital conference bridge is sometimes called a data hub.

Modem - A modem modulates a digital bit stream into a quasi-analog signal and vice versa. A modem may provide half or full duplex communications. Some modems accept digital signals asynchronously over a range of transmission speeds. Other modems accept digital signals synchronously at a fixed transmission speed.

Simple Communications Processor - Communications processors are available with a wide range of capabilities. The simple communications processor referred to herein is functionally an intelligent digital conference bridge. A signal is transmitted only on those ports that are specified for the message destination. The message routing is fixed when the network is implemented.

3.2 Service Channel Interface Characteristics

The DRAMA service channel bit stream can be accessed through the AN/FCC-98[3], through the LSTDM, or directly at 192 kb/s. The FCC-98 and the LSTDM provide various interface options. Accessing the service channel directly requires a high speed sophisticated communications processor to multiplex the users into the channel.

3.2.1 AN/FCC-98[3] Interface

Each channel of the AN/FCC-98[3] can be configured for an analog or a digital interface. The analog interface is a voice circuit. The digital interface can be asynchronous or synchronous with data transmission rates up to 56 kb/s. Three standard digital interface modules are available.

The analog voice circuit has a usable bandwidth of 300 to 3400 Hz. The nominal receive and transmit signal levels can be selected between 0 and -16 dBm. The AN/FCC-98[3] digitizes the analog signal into a 64 kb/s PCM format and multiplexes the digital signal into the service channel bit stream. The analog interface includes the "E" and "M" leads for signalling.

The asynchronous data module operates at any data rate up to 20 kb/s. The data format is NRZ and the signal levels are similar to MIL-STD-188-144 (balanced). The specified input voltage range is ± (0.2 to 7.0) volts and the specified output voltage is ± (2.5 to 3.5) volts. The impedance is specified as 135 ohms balanced. The asynchronous module does not require any timing signals at the interface.

The 50 kb/s data module uses the NRZ data format. The specified signal levels are the same as for the asynchronous module but the impedance is different. The impedance can be selected as 78 ohms balanced or 50 ohms unbalanced. The interface includes input and output timing, but does not include transmit source timing.

The synchronous data module can operate at data transmission rates of 56, 64, 128, 256, and 512 kb/s; however, when installed in the AN/FCC-98[3], only the 56 kb/s rate is usable. The data format is NRZ and the signal levels are the same as for the asynchronous module. The impedance is 78 ohms balanced. The interface is fully synchronous; including input, output, and transmit source timing as well as data signals.

3.2.2 LSTDM Interface

Each channel of the LSTDM can operate at one of the data rates shown in Table 1, using the interface characteristics indicated. The asynchronous, synchronous, and isochronous interface options correspond to MIL-STD-188-114 except for the 78 ohm impedance. The conditioned diphase interface operates at 125 ohms with signal levels of ±3 volts.

The LSTDM can be configured with up to 32 input modules. The combined data rate of all inputs must be less than the output data rate, which is 192 kb/s for the DRAMA service channel.

A voice interface module has been proposed for the LSTDM. This module would use CVSD encoding at a digital rate of 16 or 32 kb/s.

3.2.3 Direct Interface

The service channel can be accessed at the DRAMA radio SCBS port directly. The specified input voltage range is ± (0.2 to 7.0) volts and the specified output voltage range is ± (1.8 to 2.2) volts. The impedance is 78 ohms balanced. The interface is fully synchronous including input, output, and transmit source timing. The interface signal levels correspond to MIL-STD-188-114 (balanced) except for the impedance.

A service channel controller is required to interface user terminals to the DRAMA radio service channel. The interface between the user terminals and the service channel controller must be compatible. Most of the terminals should be compatible with MIL-STD-188-100 or MIL-STD-188-114.

Table 1

LSTDM Port Rates

Interface Characteristics

Port Rate	MIL-STD-188-114		*	Isoch.	Async.	Sync.	Cond.
(b/s)	(balanced)	(unbalanced)					Diphase
35	X		X		X		
37.5	X		X	X			
44.5	X		X		X		
44.5	X	X	X	X	X		
50	X	X	X		X		
61.12	X		X	X			
74.2	X		X	X	X		
75.0	X	X	X		X		
110	X	X	X		X		
150	X	X			X	X	
300	X	X				X	
600	X	X				X	
1200	X	X				X	
2400	X	X				X	
4800	X	X				X	
7200	X	X				X	
9600	X	X				X	
8k						X	X
16k						X	X
32k						X	X

*The digital line interface unit and signal level converter unit (CCC-75063) shall be used to interface the high level data with the LSTDM.

3.3 Architectural Considerations

The service channel communications architecture and protocols should not be selected without consideration of access technology. Although most architectures could be implemented with any of the access technologies described above, some combinations are inefficient or difficult to implement.

The communications requirements of the users can preclude some architecture alternatives. The requirements for the voice orderwire and TRAMCON are presented, and feasible architectures for each access method are discussed. The other user requirements have not been fully defined and are estimated only to the extent necessary to select a preferred architecture.

3.3.1 User Requirements

Each group of users of the service channel communications will have individual requirements. The basic requirements for the voice orderwire and TRAMCON are defined fairly well. The SYSCON requirements are presently being evaluated. The ECM/ECCM programs have not progressed to the extent necessary to define communications requirements.

3.3.1.1 Voice Orderwire. The basic requirement for the voice orderwire (VOW) is to provide voice communications among the communications sites within a region. The region size is determined by DCS, but reflects the connectivity of the transmission network and the maintenance responsibilities of the operating agencies. Any VOW user can selectively signal any other user in the same region. Manual interconnection of adjacent regions is possible.

Existing and planned VOW systems accommodate conferencing of the users, by interconnecting the VOW terminal with the service channels at a site, with a conference bridge. This creates a party-line for the regional VOW. While the conferencing provisions are excellent, only one conversation is possible at a time. Also, the party-line connection does not provide privacy since the conversation can be monitored at any node in the regional system.

The extent to which conferencing of the VOW is a requirement is not clear. Since the analog VOW provides conferencing as an inherent feature, exploration of alternatives has not been pertinent prior to the development of the digital service channel. It is now possible to implement an architecture that would ensure privacy but would limit conferencing.

From the user viewpoint, the major VOW architectural considerations are:

- o Regional connectivity.
- o Selective signalling.
- o Blocking probability.
- o Speech quality.
- o Conferencing.
- o Privacy.
- o Terminal instrument.

Additional system considerations include the encoding technique, transmission format, data transmission rate, and conferencing protocols.

3.3.1.2 TRAMCON. The *basic TRAMCON communications requirement* is to exchange data messages between a master terminal and various other terminals. Within the TRAMCON system, the types of terminals presently envisioned are:

- o Master (TMT).
- o Remote unit (RU).
- o Maintenance dispatch (MDT).
- o Theater (TTT).

The TMT can communicate with any other type of TRAMCON terminal, including another TMT. The current TRAMCON requirements do not envision communications among other types of terminals (e.g., RU--RU or RU--MDT). The requirements may be changed to permit communications between some types of terminals, particularly between a TTT and a MDT. The TTT, and possibly the TMT, may communicate with higher level SYSCON terminals.

The messages between TRAMCON terminals are variable. The message formats have not been defined for all TRAMCON communications. Interim formats for the TMT-RU communications have been adopted for the early phases. The length and frequency of occurrence can be characterized with reasonable confidence. The message length can be short (about 50 characters), medium (about 500 characters), or long (about 2000 characters). The frequency of occurrence may be frequent (less than 10 seconds), occasional (a few times per hour), or rare (a few times per day).

The RU--TMT communications is characterized by frequent short messages and rare medium messages. The messages from the RU will be transmitted to two or more TMTs. RU messages are always transmitted in response to a polling message from a TMT.

The TMT--TMT communications are used for data base updates, time-of-day synchronization, and operator messages. The messages are characterized by occasional short and medium messages, and rare long messages.

The MDT permits maintenance personnel to access information compiled by TRAMCON. The MDT--TMT communications are characterized by occasional to rare sessions. Within each session, frequent short and medium messages will be exchanged.

The TTT--TMT communications are characterized by occasional short and medium messages, and rare long messages.

3.3.1.3 SYSCON and ECM. The SYSCON and ECM/ECCM communications requirements can be characterized only in general terms. The requirements will not be clear until the programs have started implementation planning.

SYSCON includes a variety of programs that may develop monitor and control systems. These programs and TRAMCON may be integrated into a supervisory system control network. SYSCON projects that are presently being developed include circuit switch monitoring, performance monitoring, and network reconfiguration. Fault isolation, network control, and network management are functions that can be provided by the supervisory network. The TTT may be an element of the supervisory network. SYSCON implementation will probably be an evolving process, with the various projects implemented at different times. The communications requirements will track with the project evolution. The SYSCON communications may be similar to the TRAMCON RU--TMT communications. The supervisory system control communications should be similar to the TTT--TMT and MDT--TMT communications.

The ECM/ECCM communications would be almost nonexistent except when an ECM threat exists. During the threat, the communications will probably consist of occasional sessions of frequent short messages.

3.3.2 Access Alternatives

Three architectural levels of access to the service channel can be identified: link, user interface, and network interconnection. Each level consist of physical arrangements and protocol procedures. This section addresses the physical arrangements. Protocols are discussed only to the extent necessary to illustrate the physical architecture.

As discussed in Section 3.2, the DRAMA program has developed the AN/FCC-98[3] and the LSTDM for possible use with the service channel. These multiplexers can be implemented in various configurations. Each configuration can support some architectural alternatives at the user and network levels. Link level alternatives using these multiplexers are very limited. The link level architecture is determined by the equipment design.

A communications processor can be used as a service channel controller to provide architectural alternatives not available with the DRAMA multiplexers.

3.3.2.1 Link Level. The link level electrical interface occurs at the DRAMA radio service channel port. The electrical parameters are defined within the DRAMA specifications. The only architectural alternatives at the link level are the techniques of multiplexing the user messages into the service channel bit stream. The basic multiplex techniques that are applicable to the service channel are: fixed time division, statistical time division, and message.

Fixed Time Division Multiplexing - Fixed time division multiplexing uses a rigid frame format. Each time slot within a frame contains a data bit for one user. If a user is not transmitting data, the reserved time slot is occupied by a dummy bit. The frame structure is established in the hardware configuration and cannot be interactively changed. The AN/FCC-98 and LSTDM use fixed time slot multiplexing. The AN/FCC-98 frame structure is fixed in manufacturing. The LSTDM frame structure can be configured during installation.

The aggregate transmission capacity of all users must be less than the link capacity, although the users may be transmitting only intermittently. For example, the DRAMA service channel might be multiplexed to contain 31 data users at 4.8 kb/s and one VOW user at 32 kb/s. Assume that the data users each transmit one message of about 30 characters per second and the VOW user transmits one five minute message each hour. The average data transmission is only 12 kb/s, or about 6 percent of the link capacity. However, the link is fully utilized in the sense that no more users can be connected. If all users transmitted continuously, almost 95 percent of the link capacity would be used.

Statistical Time Division Multiplexing - Statistical time division multiplexing uses the random occurrences of messages from different users to multiplex more users into the bit stream. A user is assigned a time slot within the frame only when the message is transmitted. The instantaneous aggregate data rate of all transmitting users must be less than the link capacity, but the combined transmission rate of all users can be much greater than the link capacity. If the combined data rate of users attempting to transmit exceeds the link capacity, some users will be temporarily blocked. The probability of blockage depends on the statistical properties of the user messages. The multiplexer must include protocols that determine which users are to be blocked, and each user must have protocols that define the recovery procedures to be used when blockage occurs.

Message Multiplexing - The link can be multiplexed with short sequential messages, with each message containing data from only one user. Messages are transmitted at the link data rate. The multiplexer must receive the message from the user at a lower speed and provide buffering until the link is available.

Link protocols are required to separate the messages. The High-level Data Link Control (HDLC) set of protocols is typical (SDLC and ADCCP are variations of HDLC). HDLC provides for message framing, error control, flow control, and message identification.

3.3.2.2 User Interface Level. The electrical interface for the data users may be MIL-STD-188-100, MIL-STD-188-114 (balanced or unbalanced), or 20 ma current loop. The data may be synchronous or asynchronous for any transmission rate shown in Table 2.

The multiplexer should be transparent to the data users in a restricted sense. For all types of multiplexers, the user must have procedures to recover from a blocked or inactive interface. For a service channel controller, the user may adopt additional protocols to select the destination of messages.

The digital VOW electrical interface will be MIL-STD-188-114 (balanced). The transmission rate will depend on the encoding technique. Probable rates are 16, 19.2, or 32 kb/s for CVSD, and 50 or 64 kb/s for PCM. Adaptive predictive coding (APC) is also possible at rates of 2.4, 4.8, or 9.6 kb/s.

Table 2

User Port Rates

Port Rate (b/s)	Interface Characteristics: MIL-STD-188-114 (balanced)	MIL-STD-188-114 (unbalanced)	Current Loop	Asynchronous	Synchronous
35	X	X	X	X	
44.5	X	X	X	X	
45.5	X	X	X	X	
50	X	X	X	X	
75.0	X	X	X	X	
110	X	X	X	X	
150	X	X	X	X	X
300	X	X	X	X	X
600	X	X	X	X	X
1200	X	X	X	X	X
2400	X	X	X	X	X
4800	X	X	X	X	X
7200	X	X	X	X	X
9600	X	X	X	X	X
8k	X				X
16k	X				X
19.2k	X				X
32k	X				X

3.3.2.3 <u>Network Interconnection Level</u>. The architectural concerns at the network interconnection level are topology and routing. The network topology describes the connectivity of the network. Routing defines the path traversed by a message. Topology and routing may have physical and logical layers.

The basic types of topologies, in order of increasing connectivity, are <u>ring</u>, <u>tree</u>, and <u>grid</u>. These topologies are illustrated in Figure 7. A star is a special case of a tree. A network can be a combination of basic topologies. Physically, the DCS transmission system is a loosely connected grid with short trees branching from the grid. The service channel network can be interconnected to implement any topology with connectivity not greater than the transmission system topology. If necessary, each multiplexed circuit of the service channel can have a different type of topology.

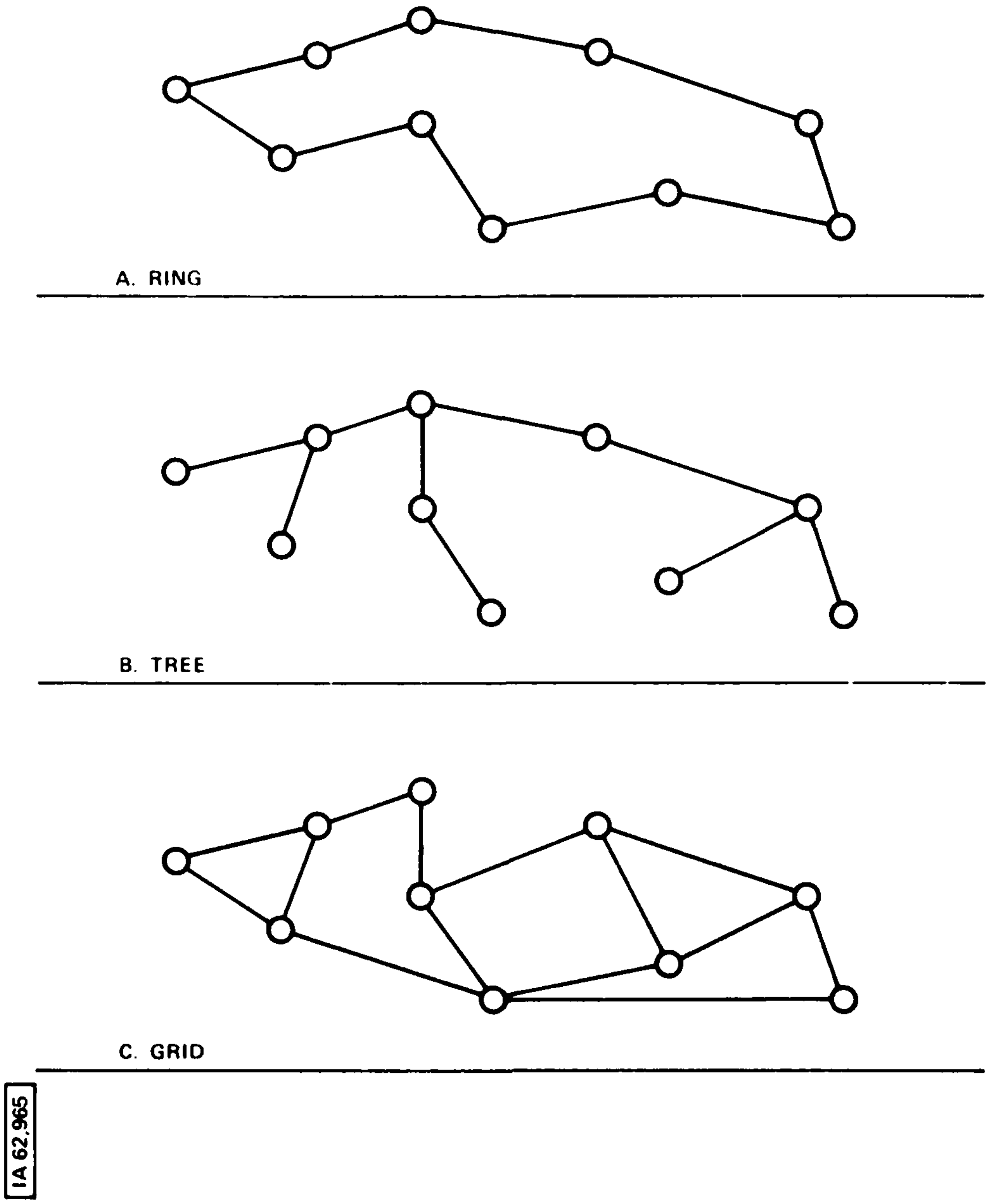

Figure 7. BASIC TOPOLOGIES OF COMMUNICATIONS SYSTEMS

The topology of the basic TRAMCON communications is a logical tree. When TRAMCON is implemented with multiple masters, each master is at the root of a logical tree, and the communications system is an overlay of several logical trees. The SYSCON communications topology may be similar. Although the ECM/ECCM communications is not yet defined, the optimum topology appears to be a logical grid.

There are many techniques for routing messages through a network. Some techniques are closely associated with a topology. Daisy chain routing is almost synonymous with ring topology, although a ring can support other routing techniques. Fixed point-to-point and multi-drop routing are usually used with trees. Switched circuits, virtual circuits, and dynamic packet switching are techniques normally associated with grids. Table 3 shows the routing techniques that are practical for the different topologies.

Table 3

Message Routing Techniques

	Ring	Tree	Grid
Daisy Chain	X		
Fixed Point-to-Point	X	X	X
Multi-drop	X	X	
Switched Circuit		X	X
Permanent Virtual Circuit			X
Switched Virtual Circuit		X	X
Dynamic Packet Switching			X

The AN/FCC-98[3] analog interface can support multi-drop and daisy chain communications, if conference bridges and modems are included. The LSTDM and AN/FCC-98[3] digital interfaces can support daisy chain and fixed point-to-point communications without peripheral equipment. However, since the AN/FCC-98[3] can support only two digital circuits in addition to the VOW, fixed point-to-point routing is not practical for this multiplexer. With a digital conference bridge (or data hub) or simple communications processor, the digital interface can support multi-drop routing. Neither the LSTDM nor the AN/FCC-98 can support switched, virtual, or packet routing without an external processor.

3.4 Reliability Considerations

The mission of the service channel communications is to support monitoring and controlling of the communications system. To accomplish this mission, the service channel network must provide very reliable communications. The reliability can be achieved through reliable equipment, redundant equipment, redundant routing, or adaptive routing.

The DCS has used reliable and redundant equipment to ensure reliable communications on the mission channels. The radio path provides propagation diversity. The AN/FRC-170 series of radios and the AN/FCC-99 multiplexers are fully redundant, with automatic switchover in case of a failure. The mission AN/FCC-98 is not redundant but is located only at manned sites. The manual capability to rapidly repair or replace a failed AN/FCC-98 provides an acceptable reliability for the mission communications. This rapid repair capability does not exist at an unmanned site.

The service channel access equipment that is used with the AN/FCC-98[3] or LSTDM is not redundant. This equipment includes conference bridges and modems, or simple communications processors. A failure of any service channel equipment item would interrupt monitoring and control communications until maintenance personnel could repair the equipment. For unmanned sites, the travel time could be several hours.

The failure probabilities of the equipment associated with the service channel are shown in Table 4. The propagation path failure probability is based on the DCA design availability of 0.99999 for a terrestrial microwave link. The MTBFs of the DRAMA equipment are from the specifications. The MTBFs of the other equipment are estimated from commercial specification. The MTBF of the service channel controller is assumed to be at least as long as that of the AN/FRC-170 radio. The MTTR is based primarily on the average travel time. After arrival of maintenance personnel, the MTTR is 20 to 30 minutes for the DRAMA equipment. The other equipment is assumed to have a similar MTTR. The DRAMA radio and the SCC are redundant; the other equipment types are not.

Table 4

Equipment Failure Probabilities

Equipment Type	MTBF (hours)	MTTR (hours)	Redundancy Factor	Failure Probability (X 10^{-6})
Propagation Path	--	--	--	10
AN/FRC-170	1600	2	2	1.6
AN/FCC-98	3500	2	1	571
LSTDM	4000	2	1	500
Bridge (analog or digital)	10000	2	1	200
Modem	10000	2	1	200
Service Channel Controller	1600	2	2	1.6

The communications reliability depends on the integration of the equipment into a system. The composite failure probability and expected annual outage is shown in Table 5 for a reference path consisting of six sites and five radio links. This path length is typical for TRAMCON. The redundancy of the SCC results in a dramatically lower failure probability compared to the implementations using non-redundant multiplexers.

Table 5

Service Channel Failure Probability

Five Link Reference Path

Equipment Type	Number Used	Implementation Technology FCC-98 (analog)	FCC-98 (digital)	LSTDM	Service Channel Controller
Propagation Path	5	50	50	50	50
AN/FRC-170	10	16	16	16	16
AN/FCC-98	10	5710	5710	--	--
LSTDM	10	--	--	5000	--
Service Channel Controller	6	--	--	--	10
Bridge	6	1200	1200	1200	--
Modem	2	400	--	--	--
Failure Probability ($X\ 10^{-6}$)		7376	6976	6266	76
Annual Outage (hours)		64.6	61.1	54.9	0.66

Routing redundancy is used by TRAMCON to reduce the outage time. Separate paths are used, where possible, from each site to at least two master terminals. The only common equipment to the paths is the conference bridge (and modem for analog access) for the multiplexer implementations, or the SCC. Assuming two reference paths as the redundant routing, the expected annual outage for the different implementations are:

Implementation	Outage
AN/FCC-98 (analog)	3.9 hours
AN/FCC-98 (digital)	2.2 hours
LSTDM	2.1 hours
SCC	1 minute

3.5 Logistics Considerations

The various implementations of the service channel network can require different types of equipment. Logistics support must be supplied for each equipment unit that is used. The typical service channel equipment required at a three-way repeater site is shown in Table 6. A multiplexer is required for each radio, except for the SCC implementation. A conference bridge (analog or digital to correspond to the interface) is required on each multiplexer port. The analog implementation requires a modem for each data terminal. The SCC can combine the multiplexer, bridge, and modem functions into one unit. While the SCC would be more complex than the multiplexers, the number of equipment units and types to be supported would be much less than other implementations.

Table 6

Service Channel Equipment

3-Way Repeater Site

	Implementation Technology			
Equipment Type	AN/FCC-98 (analog)	AN/FCC-98 (digital)	LSTDM	Service Channel Controller
AN/FCC-98[3]	3	3	-	-
LSTDM	-	-	3	
SCC	-	-	-	1
Analog Bridge	3	1	-	-
Digital Bridge	-	2	5	-
Modem	3	-	-	-
Analog Voice Terminal	1	1	-	-
Digital Voice Terminal	-	-	1	1
Equipment Units	10	7	9	2
Equipment Types	4	4	3	2

4.0 DIGITAL SERVICE CHANNEL NETWORK IMPLEMENTATIONS

The service channel communications network can be implemented in various configurations using many different technologies. In the preceeding section, the critical factors that influence the network design were discussed. Implementation alternatives are presented in this section. The presentation is not exhaustive; there are many other implementation possibilities. The alternatives selected for presentation are considered to represent the best utilization of the technology. The technologies used in the alternatives are the AN/FCC-98[3] and LSTDM multiplexers, and the service channel controller. Several options are presented for the AN/FCC-98[3] and LSTDM implementations.

4.1 AN/FCC-98 [3] Implementations

The AN/FCC-98[3] has three channels available to support voice and data communications. Each channel can be configured with an analog or a digital interface.

4.1.1 Voice Orderwire

The analog interface is excellent for the voice orderwire. One channel of the AN/FCC-98[3] is dedicated for VOW use. An analog conference bridge is used to interconnect the VOW interface of the different radio links and the VOW telephone keyset. The VOW keyset supports DTMF signalling to selectively call any site. The circuit is a party-line.

4.1.2 Analog Data Interface

Utilization of the analog interface for data transmission requires a modem for each data terminal. An analog conference bridge is used on each channel to interconnect the multiplexers and modems. The resulting network topology is a tree using multi-drop communications. The interconnection of the service channels and terminals is shown in Figure 8 for a typical three-way site. The analog data interface is scheduled for implementation on the digital segments of the DCS.

The number of modems and terminals that can be connected depends on the conference bridge. An eight port bridge can support five terminals at a three-way site, or four terminals at a four-way site, for each data channel of the AN/FCC-98. Each channel uses a separate bridge.

Modem frequencies can be selected to partition each channel into separate data circuits. The practical channelization schemes

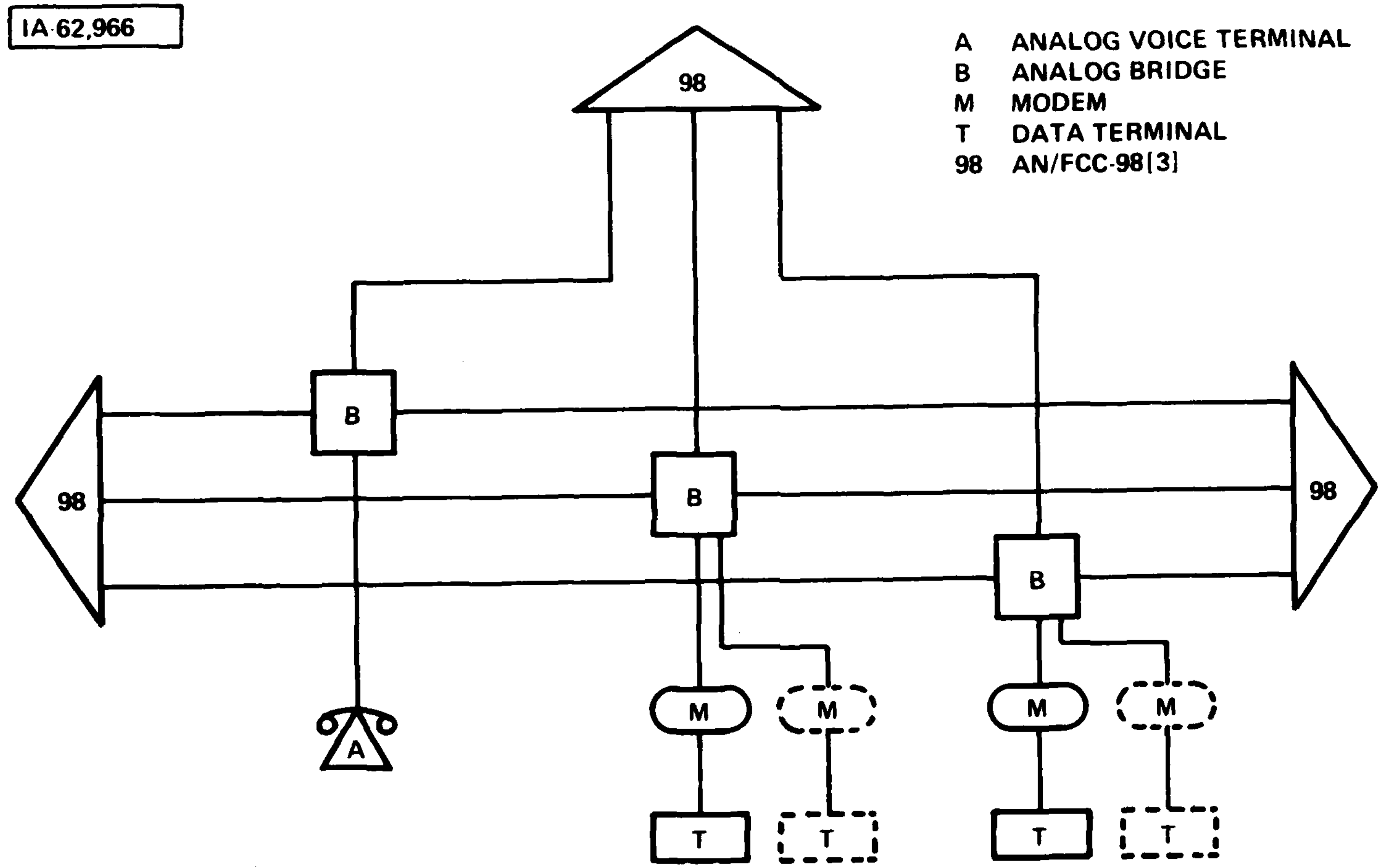

Figure 8. ANALOG AN/FCC-98 IMPLEMENTATION OF DRAMA SERVICE CHANNEL

are one half duplex circuit at 4800 b/s, one full duplex circuit at 1200 b/s, or three full duplex circuits at 300 b/s. The TRAMCON TMT--RU communications appear to require a 1200 b/s full duplex circuit. Thus, the TRAMCON TMT--RU communications alone would use one data channel on the AN/FCC-98. The channelization of the other data channel would depend on the speed requirements of the other users.

The multi-drop communications configuration presents all messages on a circuit to all terminals. Protocols must be used to separate the messages. These protocols must be implemented in the user terminals. Selective polling, or some other version of token passing, would be appropriate.

4.1.3 Digital Data Interface

The AN/FCC-98 can be configured with various digital interface modules. The asynchronous 0-20 kb/s module and the synchronous 56 kb/s module can be used for practical implementations service channel communications.

A digital conference bridge or a simple communications processor (CP) is required to interconnect the multiplexers and terminals. The digital conference bridge is designed to operate with asynchronous communications. A simple communications processor could be used for synchronous or asynchronous communications. It would provide a greater advantage in transmission efficiency, over a digital bridge, when used with the higher speed synchronous module. The simple communication processor would permit configuration of a channel into independent circuits. The conference bridge permits only one physical circuit on a channel.

The digital interface modules are used only for the data channels. The VOW would use an analog interface and conference bridge.

4.1.3.1 Asynchronous Interface. A digital conference bridge is used with the asynchronous interface module to configure a service channel network. A typical implementation for a three-way site is shown in Figure 9. A separate bridge is required for each data channel.

The digital bridge interconnection results in a multi-drop half duplex communications system for each data channel of the AN/FCC-98. Protocols must be implemented in all user terminals to maintain message separation. Since several user groups may share the same circuit, all users must adopt the same protocols.

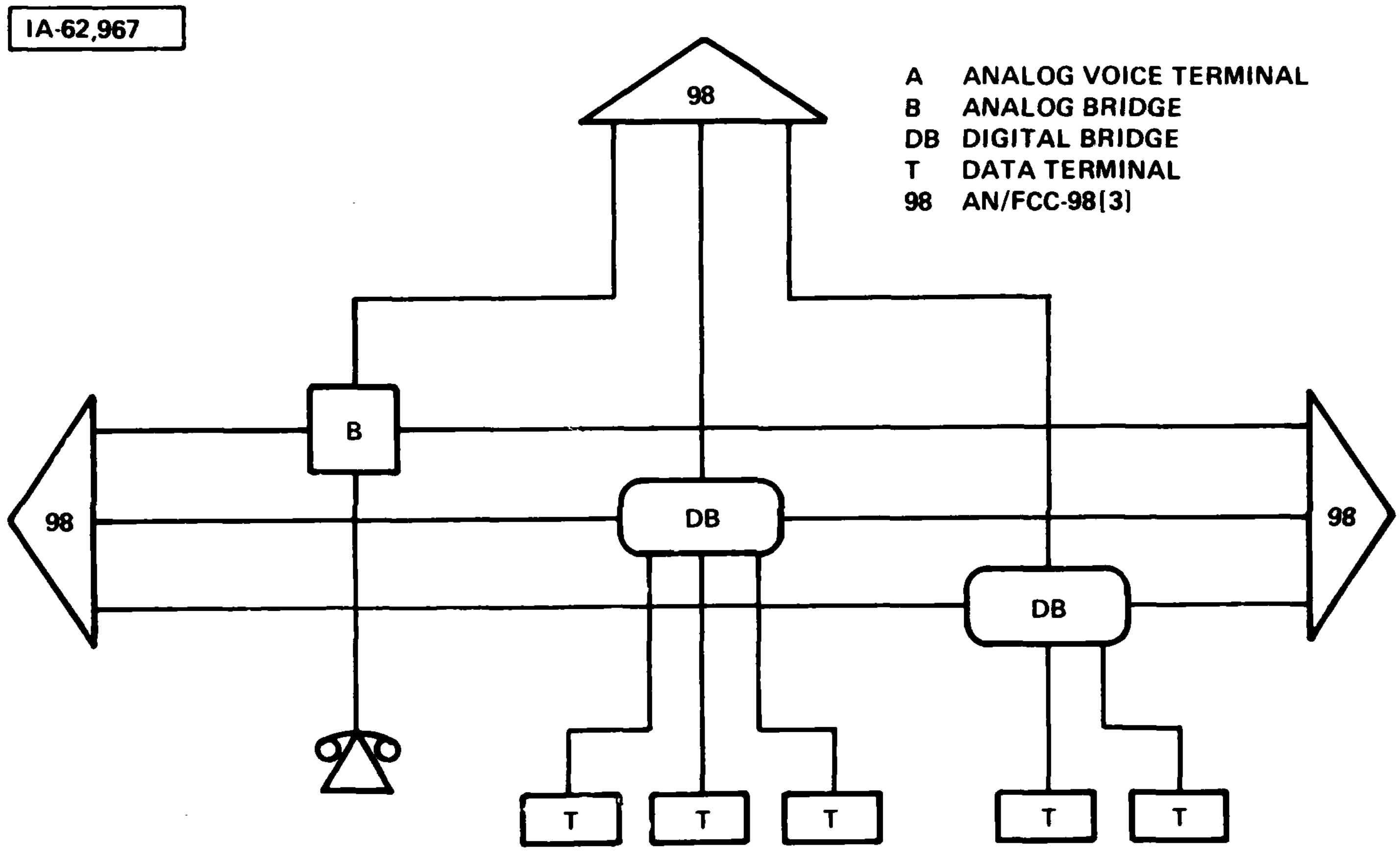

Figure 9. DIGITAL AN/FCC-98 IMPLEMENTATION OF SERVICE CHANNEL USING DIGITAL BRIDGE

The digital conference bridge can accommodate users that operate at different data transmission speeds. Implementing message separation protocols, for user terminals that operate at different speeds, would be very difficult. The transmission speed of all terminals, on each circuit, must be equal for practical implementations. Since many data terminals cannot operate at speeds greater than 9600 b/s, this speed is the effective limitation on data transmission.

4.1.3.2 Synchronous Interface. A simple communications processor is used with the synchronous interface module to implement a service channel network. A interconnection for a typical three-way site is shown in Figure 10.

The communications processor can be configured to provide several independent multi-drop and point-to-point circuits. Each user group operates on its private circuit. The message separation protocols are implemented in the data terminals independently for each user group.

The synchronous interface is between the communication processor and the multiplexer. The user interface can be asynchronous or synchronous. The processor accepts data from the terminals at a specified standard speed and multiplexes it into the 56 kb/s bit stream. Terminals within a user group must operate at the same speed, but other user groups can operate at different speeds.

4.2 LSTDM Implementations

The LSTDM is a variable configuration multiplexer. It can be configured to multiplex up to 32 channels into a 192 kb/s stream when used with the DRAMA service channel. Each channel may be configured for a synchronous or an asynchronous interface. The LSTDM does not support a PCM analog interface. A CVSD voice interface has been proposed.

A service channel network can be implemented for the data terminals using point-to-point and/or multi-drop communications. Digital conference bridges or communications processors are required for the multi-drop implementation. The VOW will be implemented with multi-drop communications.

4.2.1 Voice Orderwire

The VOW can be implemented using either the digital interface or the CVSD voice interface. The CVSD interface will require an analog bridge for interconnection at each site. The degradation

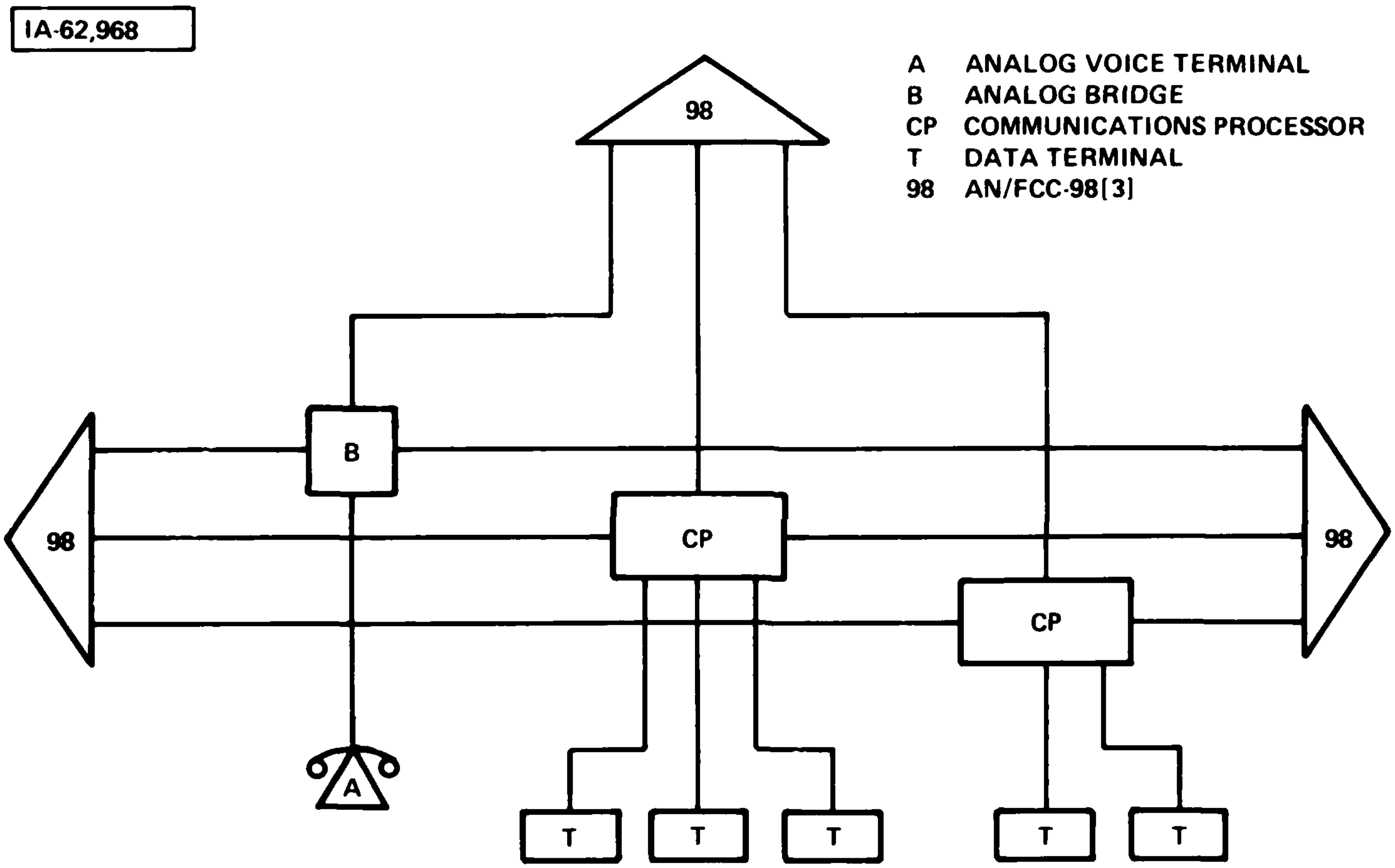

Figure 10. DIGITAL AN/FCC-98 IMPLEMENTATION OF SERVICE CHANNEL USING COMMUNICATIONS PROCESSOR

caused by successive analog-to-digital conversions will limit the voice orderwire connectivity to very small regions. The digital interface does not require successive conversions, and would avoid the degradation.

The LSTDM is assumed to be configured with only digital interfaces. Thus, a digital voice terminal must be used for the VOW. The terminal must support selective signalling. The TRI-TAC Digital Non-secure Voice Terminal (DNVT) appears to meet the requirement for the VOW terminal. The DNVT uses CVSD voice encoding with transmission speeds of 16 or 32 kb/s. Other available commercial voice terminals could be used.

The multiplexers and the voice terminal are interconnected with a digital conference bridge to implement a multi-drop VOW network. The interconnection is illustrated in Figures 11, 12, and 13. The digital conference bridge permits only one user to talk at any time. The users must adopt a push-to-talk protocol when using the VOW.

4.2.2 Point-to-Point Configuration

The LSTDM can be configured to provide one channel at 32 kb/s, plus 31 channels at lower speeds. The 32 kb/s channel is used for the VOW. The transmission speeds of the other channels is selected individually for any standard speed, subject to the maximum aggregate transmission speed of the service channel not being exceeded. If all 31 data channels were implemented for the same speed, the transmission rate on each data channel would be 4800 b/s.

The number of channels provided by the LSTDM makes fixed point-to-point communications feasible. The basic limitation is that not more than 31 data circuits can be routed over one radio link. The implementation of a point-to-point service channel network is illustrated in Figure 11.

Message separation protocols are not required with fixed point-to-point communications. Only those messages between a pair of terminals appear on a circuit.

A data terminal must have a communications port for each circuit over which it communicates. For example, if a TRAMCON master controls a segment of 15 RUs, the TMT will need at least 15 communications ports. If an RU can communicate with two TMTs, the RU must have at least two communications ports. The requirement for multiple communications ports can be a serious restriction for some user groups, TRAMCON in particular.

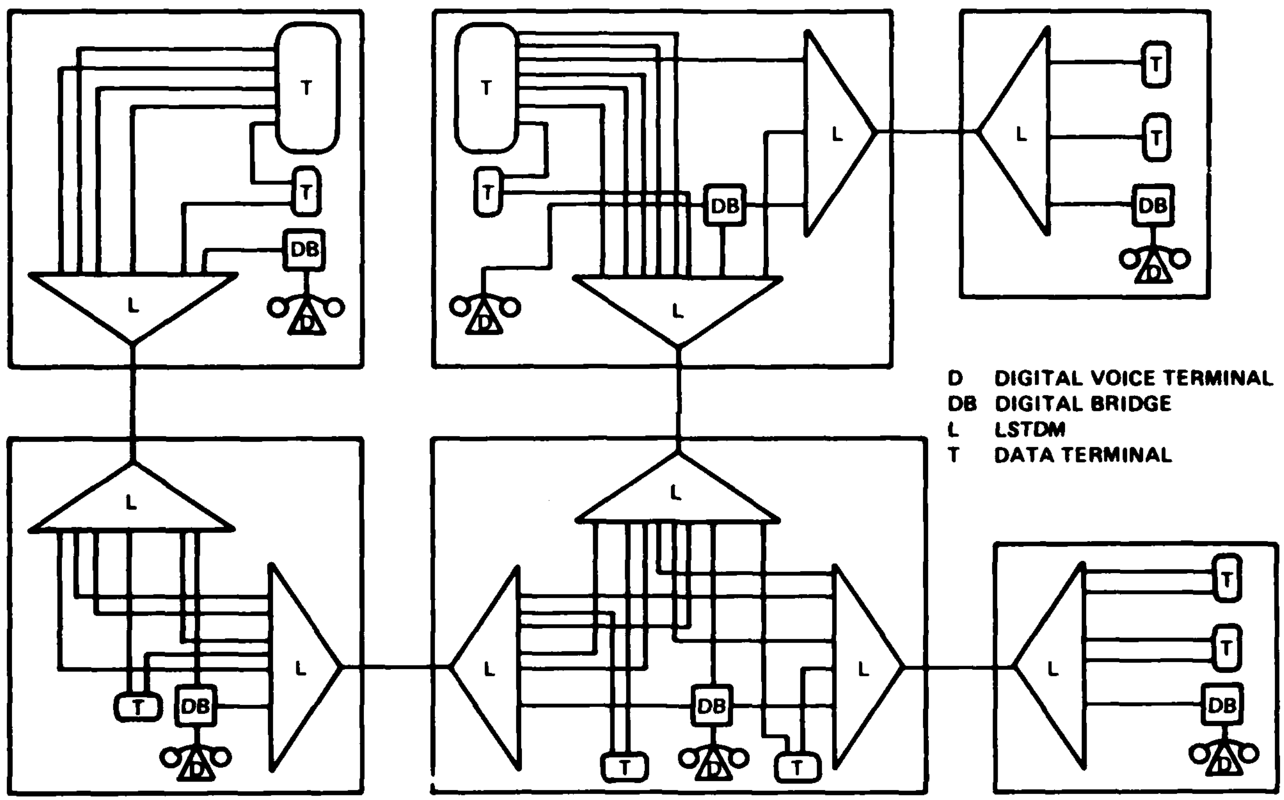

Figure 11. LSTDM IMPLEMENTATION OF SERVICE CHANNEL USING POINT-TO-POINT COMMUNICATIONS

4.2.3 Digital Conference Bridge Implementation

Asynchronous interface ports of LSTDMs and data terminals can be interconnected with a digital conference bridge to implement a multi-drop communications circuit. Figure 12 illustrates the interconnection at a typical three-way site. A separate bridge is required for each data channel.

Each user group is assigned to a different channel of the LSTDM. The transmission speed is selected to satisfy the user requirements. Message separation protocols are implemented independently for each user group.

There is a one-to-one correspondence between the number of user groups and the number of data channels used on the LSTDM. A digital conference bridge is required wherever an interconnection of more than two links or terminals occurs. At back-to-back repeater sites, some channels may be thru-patched without using a bridge. The total number of bridges required will be substantial.

4.2.4 Communications Processor Implementation

A simple communications processor is used with the LSTDM to implement service channel data circuits. The LSTDM is configured for convenience. User groups with similar requirements are combined on one channel. The total number of LSTDM channels is determined by the user requirements, but is less than the number used in the digital conference bridge implementation. The interconnection for a typical three-way site is illustrated in Figure 13. A processor is required for each LSTDM channel.

The communications processor separates the user groups into independent logical circuits. Terminals within a user group must operate at the same transmission speed and adopt protocols for message separation.

4.3 Service Channel Controller Implementation

The service channel controller is a special purpose sophisticated communications processor that interfaces directly with DRAMA radio at the SCBS port. A single SCC can interconnect several radios and terminals. Figure 14 illustrates the interconnection of the service channel network at a typical three-way site using an SCC. All of the switching necessary to perform the interconnection is contained within the SCC.

The service channel network implemented through an SCC can take many configurations. Some of these configurations are conceptually

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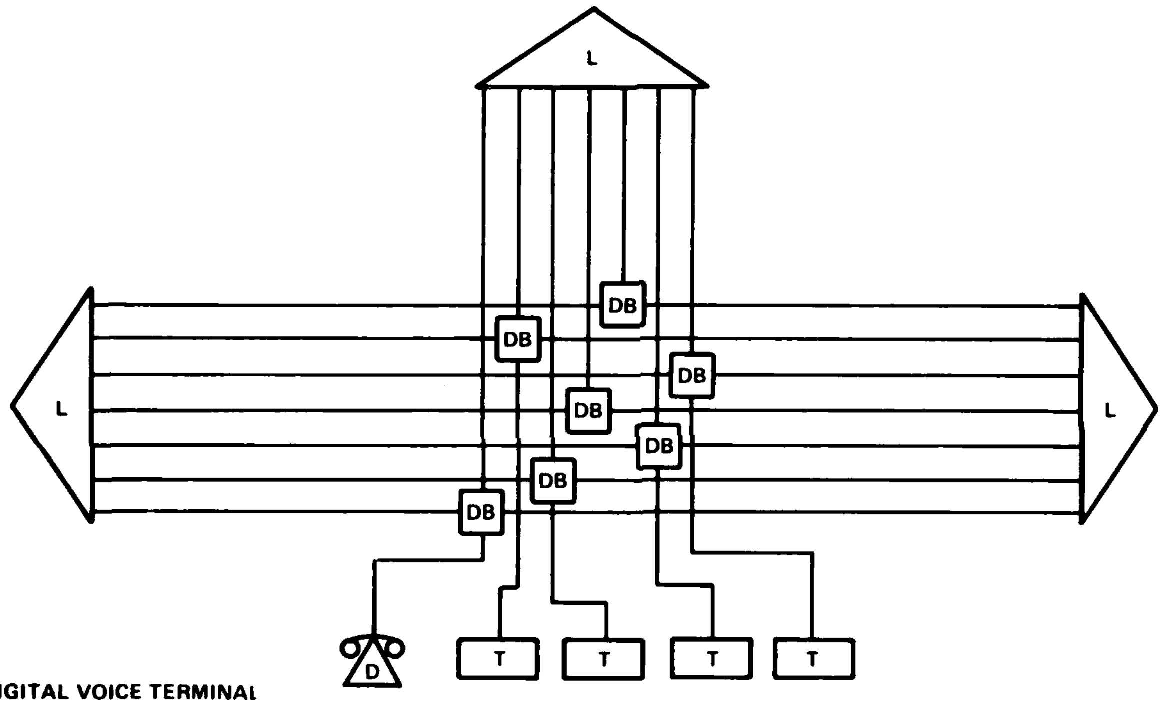

D DIGITAL VOICE TERMINAL
DB DIGITAL BRIDGE
L LSTDM
T DATA TERMINAL

Figure 12. LSTDM IMPLEMENTATION OF SERVICE CHANNEL USING DIGITAL BRIDGE

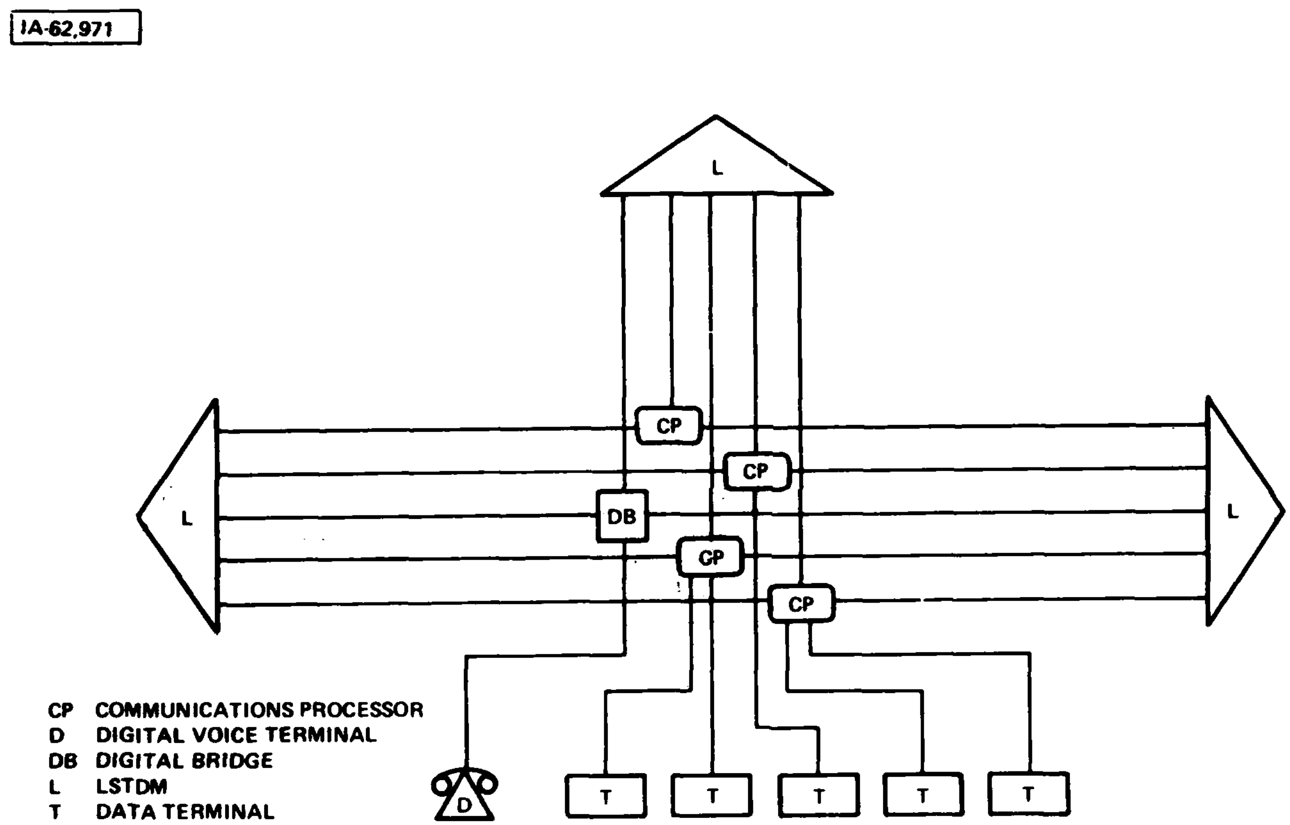

Figure 13. LSTDM IMPLEMENTATION OF SERVICE CHANNEL USING COMMUNICATIONS PROCESSOR

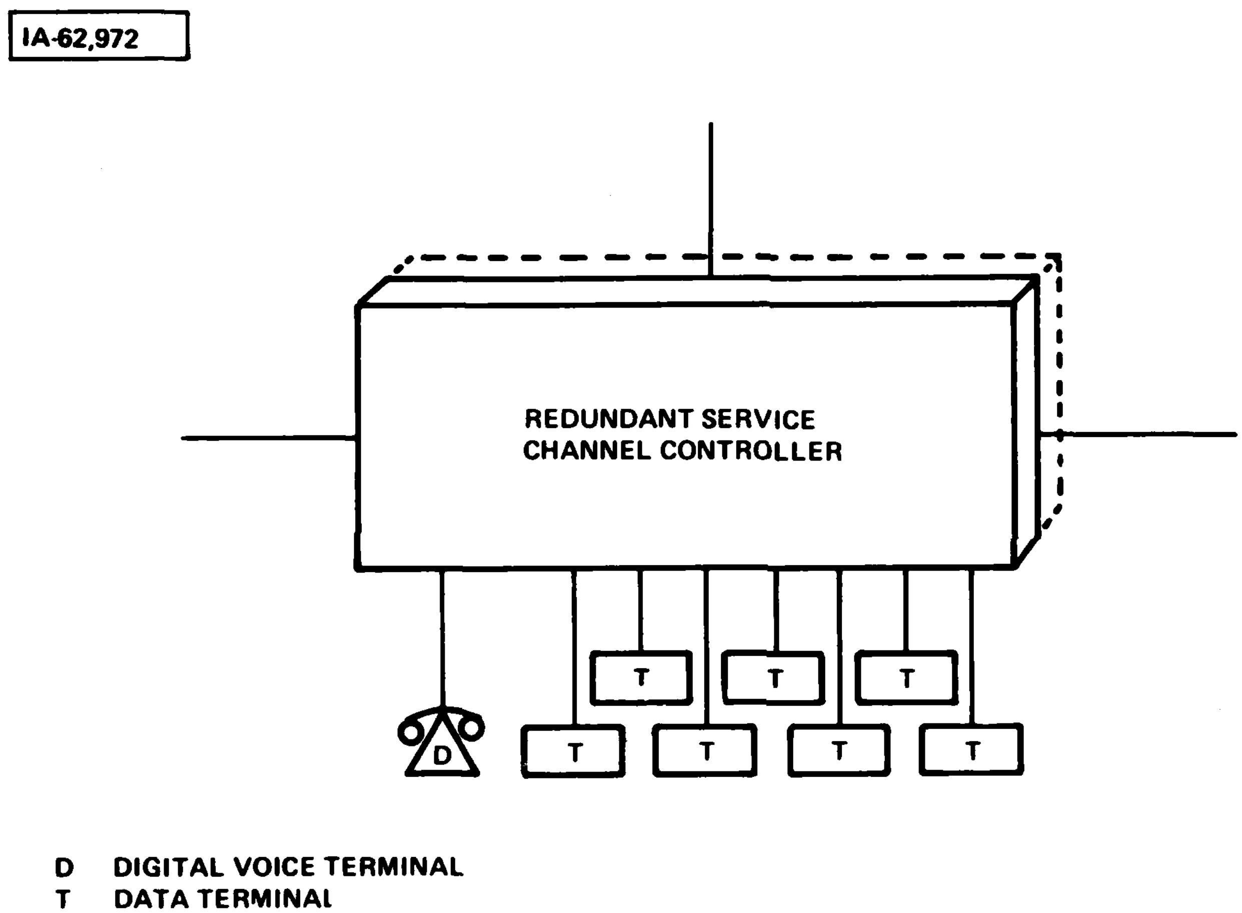

Figure 14. SERVICE CHANNEL CONTROLLER

different from networks that can be implemented with multiplexers such as the AN/FCC-98 or LSTDM. The configuration presented here is based on the grid topology. Virtual circuits are used to achieve adaptive routing.

The SCC implementation presented herein is "pure" in the sense that no other multiplexers are required to access the service channel. A hybrid implementation is possible using a multiplexer similar to the LSTDM. The SCC would connect to one port of the multiplexer. The other multiplexer ports could be used with a digital conference bridge to provide party-line configurations. The VOW is one possible use for the party-line communications. A separate multiplexer is required for each radio. The multiplexers should be redundant to achieve high communications for the service channel network.

4.3.1 Voice Orderwire

The SCC provides the interconnection and bridging functions for the VOW. A party-line configuration is not inherent with the SCC implementation. The SCC establishes a virtual circuit (VC) between a pair of terminals. For conference calls, multiple VCs are established. The service channel network can support simultaneous independent VOW communications as illustrated in Figure 15. Three users (A) are conferencing while two others users (B) have a private circuit. Although the same physical links are used for part of each path, the two virtual circuits are independent.

The VOW terminal must support selective signalling in a digital format that can be interpreted by the SCC. The TRI-TAC DNVT appears to operate in a fashion compatible with the SCC. The DNVT uses CVSD voice encoding at transmission speeds of 16 or 32 kb/s.

The transmission speed of the VOW terminal should be as low as feasible. The VOW communications compete with data communications for the service channel bit stream. If a large number of high speed VOW circuits were attempted, the network could be blocked. For example, three 50 kb/s voice circuits would overload a link. The SCC must include protocols to restrict access if overloading is imminent and to permit pre-emption of routine voice conversations. If low speed (e.g., 2400 b/s) voice terminals are used, the probability of blockage is small and a need for pre-emption is remote.

4.3.2 Data Terminals

The SCC provides the logical interconnection of terminals into user groups. The user interface can be asynchronous or synchronous

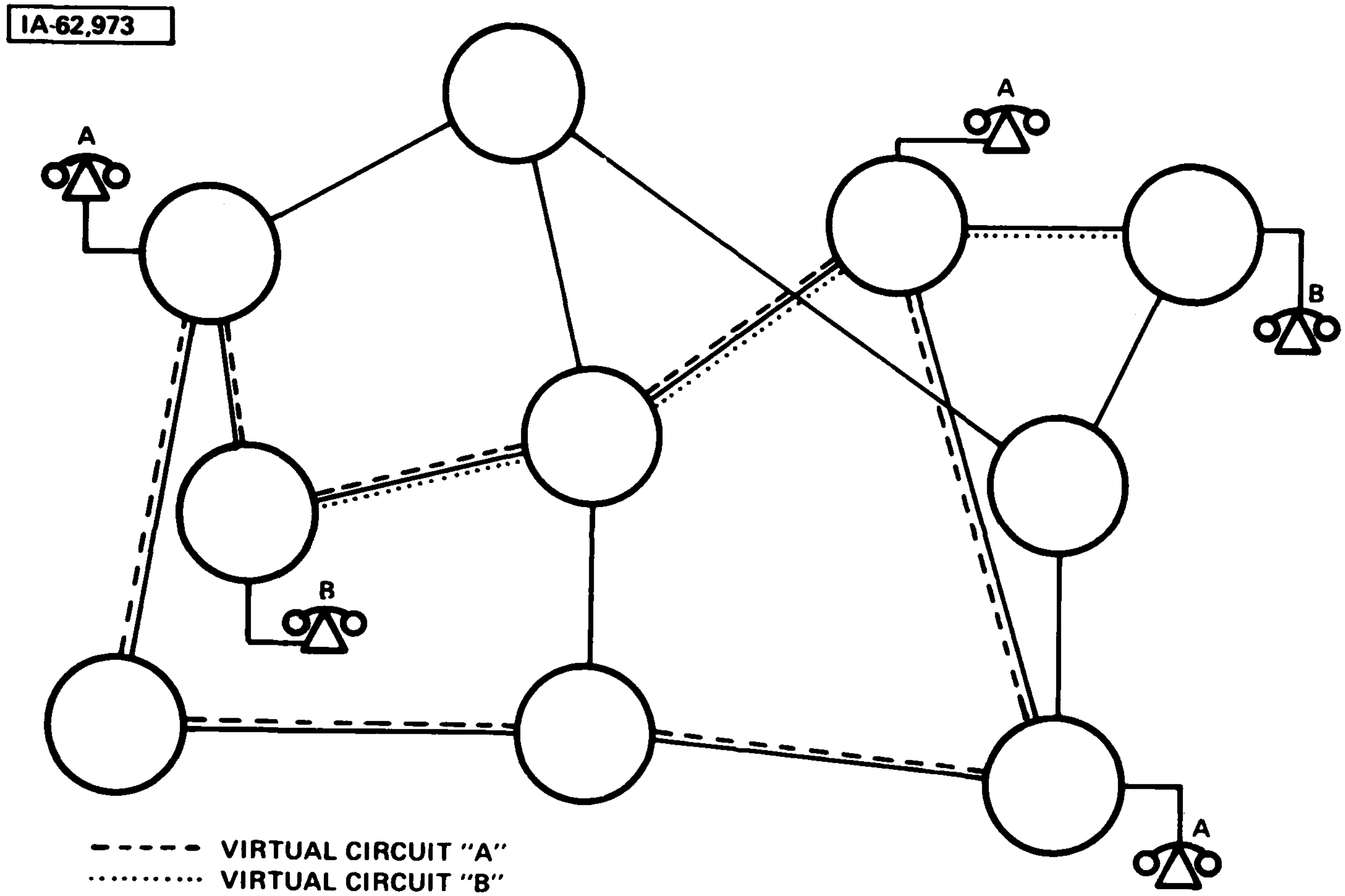

Figure 15. SERVICE CHANNEL NETWORK ILLUSTRATING SIMULTANEOUS INDEPENDENT VOICE COMMUNICATIONS

at a specified standard transmission speed. The SCC can interconnect two users who operate with different data transmission speeds. The interconnection among terminals is implemented with virtual circuits.

The connectivity of the user group is maintained by the SCC. When a VC is established, a route is selected for the messages. If a link along this route should fail, the SCC will reset the virtual along a different route. This resetting is illustrated in Figure 16. The VC will be maintained as long as any connectivity exists between the users. The routing is transparent to the user terminals.

The virtual circuits may be switched (SVC) or permanent (PVC). A SVC can be established or disconnected whenever requested by a terminal. A PVC is established when the terminal is implemented as a member of a user group and remains connected unless the terminal is deleted from the user group. Most of the service channel data users, particularly TRAMCON and SYSCON, will establish PVCs.

A message from a terminal can be delivered to any selected users within a group. Protocols are implemented in the SCC and/or the terminal to determine the destination of a message. A terminal may be a member of more than one user group. In this case, the protocols must identify the user group within which the terminal is communicating.

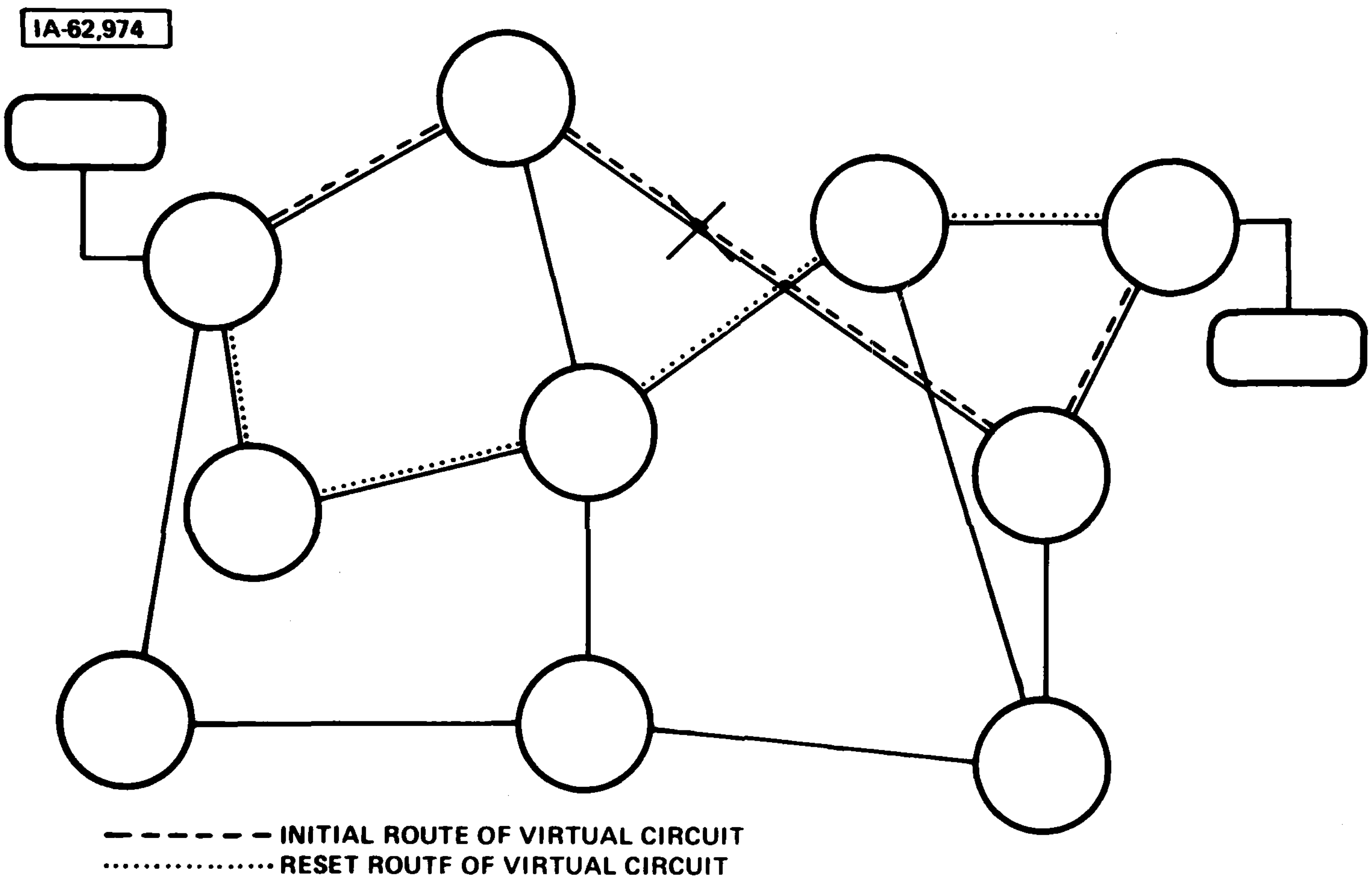

Figure 16. REROUTING OF VIRTUAL CIRCUIT FOLLOWING FAILURE OF LINK

5.0 RECOMMENDATIONS

The service channel network supplies communications circuits for a variety of functions. The scheduled implementation, using the analog interface modules of the AN/FCC-98[3], cannot supply sufficient capacity to satisfy the known requirements.

Alternative implementations of the service channel network have been examined. The alternatives are based on using one of three devices to interface the DRAMA service channel: (1) the analog and digital interface modules of the AN/FCC-98; (2) the low speed time division multiplexer (LSTDM) that is being developed under the DRAMA program; or (3) a communication processor configured as a service channel controller.

Several implementations are capable of satisfying the user requirements. The implementations using the service channel controller are shown to provide the greatest reliability, to require the least logistics support, and to furnish the most flexibility for interconnection of users. However, the service channel controller will require software development and may require hardware development.

The superior performance indicates the desirability of developing a service channel controller. The logical steps in the development are:

- Identify communications processors that will satisfy the SCC requirements; and, if necessary, identify required hardware modifications.
- Implement the SCC in a test bed and develop software.
- Implement the SCC in a pilot system to refine operational concepts.
- Prepare procurement specifications.

APPENDIX

Functional Description of a Service Channel Controller

This appendix presents a brief description of the essential functions of a service channel controller (SCC). The basic SCC features must support communications over the DRAMA service channel. Features that would permit utilization of the SCC with other communications media are indicated by a #. These additional features are not required for the DRAMA implementation. Explanatory comments are delimited by asterisks (e.g., **...**).

A.1 Application

The service channel controller is a special purpose communications processor. It is used as a nodal controller to configure a communications network from the DCS service channel. The SCC will operate with the DRAMA 192 kb/s service channel. #It may also be used with other communications media, such as the DEB I service channel.#

The SCC will interconnect with user terminals at each node. The types of terminals include digital voice, minicomputers and keyboard/displays. The service channel network (SCN) will provide virtual circuits between selected pairs of terminals. Except for the selection of the message destination, the SCN will be transparent to the user terminals.

A.2 Electrical Interface

The SCC will provide standard electrical interfaces for the network trunks and user terminals. A network trunk is the DRAMA service channel #or other DCS digital communications media#.

A.2.1 Network Trunk Interface

A.2.1.1 Network Trunk Signal Levels

DRAMA radio NRZ interface

Transmit level	± (1.8 to 2.2) volts.
Receive sensitivity	± (0.2 to 7.0) volts.
Impedance	78 ohms balanced.
Signal circuits	Receive data, receive clock, transmit data, transmit clock, transmit source clock.

** The primary network trunk interface is defined by the service channel bit stream (SCBS) part specification of the DRAMA radio. The interface is compatible with MIL-STD-188-114 (balanced) except for the impedance.**

#Other Interface Signal Levels.#

#MIL-STD-188-114 (balanced and unbalanced).#

#MIL-STD-188-100.#

#20 ma current loop.#

These interfaces will permit the use of media other than the DRAMA 192 kb/s service channel. Possible other media that may be used include a DCS digital mission channel, the DEB I service channel, an FDM group channel, or an analog voice channel.

A.2.1.2 Data Transmission Speed

The network trunks will operate synchronously at the following speeds:

192 kb/s, #153 kb/s, 128 kb/s, 64 kb/s, 56 kb/s, 50 kb/s, 32 kb/s, 19.2 kb/s, 16 kb/s, 9600 b/s, 8000 b/s, 4800 b/s, 2400 b/s, and 1200 b/s.#

The alternative transmission speeds will permit the use of DCS digital channels and analog channels (with modems).

A.2.2 User Terminal Interface

The SCC must be able to support all of the types of interfaces described herein. Separate ports may be used for different types of interfaces.

A.2.2.1 Data Signal Levels

The user terminal signals will correspond to one of the following standard interfaces:

MIL-STD-188-100.
MIL-STD-188-114 balanced.
MIL-STD-188-114 unbalanced.
#20 ma current loop#.

A.2.2.2 <u>Data Transmission Speed</u>

The user terminal interface will operate at one of the following speeds:

19.2 kb/s synchronous or asynchronous.
16 kb/s synchronous.
9600 b/s synchronous or asynchronous.
#8000 b/s synchronous.#
#7200 b/s synchronous.#
4800 b/s synchronous or asynchronous.
2400 b/s synchronous or asynchronous.
1200 b/s synchronous or asynchronous.
600 b/s #synchronous or# asynchronous.
300 b/s asynchronous.
150 b/s asynchronous.
110 b/s asynchronous.
75 b/s asynchronous.
#50 b/s asynchronous.#
#45 b/s asynchronous.#
#35 b/s asynchronous.#

A.2.2.3 <u>Data Formats</u>

The SCC user interface will support the following data formats:

HDLC, #ADCCP#, #BSC (IBM 2780, 3780, 3740, 2740, 3770)#, and start/stop (5, 6, 7 or 8 data bits; with or without parity).

A.2.2.4 <u>Voice Orderwire Terminal</u>

The SCC will support an interface for a digital voice orderwire terminal. **The characteristics of the digital voice orderwire must be developed. The Tri-Tac DNVT terminal operating at 16 Kb/s is assumed for initial planning.**

A.3 Protocols

The SCC will implement protocols to control the flow of messages through the network and to permit the user terminals to access the network.

A.3.1 Network Protocols

A.3.1.1 Link Level

The link level protocols will incorporate HDLC. The ADCCP, X.25 or X.75 versions of HDLC are appropriate. The link protocols will control the following functions:

Link setup and disconnect.
Error control.
Flow control.
Message frame format.

A.3.1.2 End-to-End Level

The network end-to-end protocols govern the establishment of virtual circuits (VC) and the flow of messages over these circuits. Permanent VCs are established on implementation. Switched VCs are established on request by a user.

The circuit establishment protocols include procedures for requesting circuits, accepting or refusing circuits, clearing circuits, and resetting circuits to another link. Resetting is initiated by the network. The other procedures are initiated by the network or the user. All procedures include acknowledgement.

Message flow is controlled by window rotation and message acknowledgement. Acknowledging a message rotates the window and authorizes the sending node to transmit additional messages.

A.3.2 User Access Protocols

The users may access the network using synchronous or start/stop terminals. The access protocols are fixed when a terminal is connected to the SCC.

A.3.2.1 Synchronous Terminals

Synchronous terminals will use HDLC #or byte synchronous (BSC)# framing and link protocols. #The SCC will translate BSC protocols into HDLC protocols for transmission through the network.# The terminal protocols will support the same functions as the network protocols. Each terminal may establish up to 63 virtual circuits.

A.3.2.2 Start/Stop Terminals

The SCC user access protocols will support interactive start/stop terminals. Continuous messages from the start/stop terminal will be segmented into lengths compatible with the network protocols. The SCC will convert the start/stop protocols into functionally equivalent network protocols. Each start/stop terminal may establish up to 7 virtual circuits. **The start/stop protocols are based on a subset of the CCITT Recommendations X.3 and X.28. The use of multiple virtual circuits by start/stop terminals is not defined by those recommendations.**

A.3.3 User Groups

The SCC protocols will permit configuration of terminals into closed user groups. A VC cannot be established between terminals in different groups. However, a terminal may be included in more than one group. Within a group, a terminal may be defined to establish the following types of virtual circuits:

- o Permanent.
- o Outgoing (requests only).
- o Incoming (accepts only).
- o Incoming or outgoing.

The SCC protocols will enforce these procedures.

END

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