NASA Contractor Report 177622

IN-17

186140

Application of New Electro-Optic Technology to Space Station Freedom Data Management System

75P

C. R. Husbands and M. M. Girard

(NASA-CR-177622) APPLICATION OF NEW ELECTRO-OPTIC TECHNOLOGY TO SPACE STATION FREEDOM DATA MANAGEMENT SYSTEM (Mitre Corp.) 75 p

N94-13257

Unclas

G3/17 0186140

CONTRACT NASW-4358
August 1993

NASA

National Aeronautics and
Space Administration

NASA Contractor Report 177622

Application of New Electro-Optic Technology to Space Station Freedom Data Management System

C. R. Husbands and M. M. Girard

The MITRE Corporation
Burlington Road
Bedford, MA 01730

Prepared for
Ames Research Center
CONTRACT NASW-4358
August 1993

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035-1000

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE		PAGE

LIST OF TABLES

SECTION 1

INTRODUCTION

Space Station Freedom has a Data Management System (DMS) which is the key integrating data system for onboard communications and data processing. This design must support the initial operations during the early years of assembly, yet evolve with the station to support data system functionality over the Space Station's projected lifetime. Future subsystem and payload processing requirements are likely to exceed the capabilities of the current baseline architecture of the DMS. This study was designed to define a low risk methodology for inserting new electro-optic technology into the DMS global network and local bus networks to increase their data carrying capacities and to speed messages and data flow between nodes or stations within the DMS in anticipation of growing requirements.

1.1 THE ROLE OF THE DATA MANAGEMENT SYSTEM

The Data Management System is the infrastructure on Space Station Freedom responsible for integrating information onboard into a cooperative whole. It allows integrated data processing and communications for both the core functions and the payloads. The DMS accommodates crew visibility and control over the subsystem and provides application software processing capability for all onboard subsystems. The DMS interfaces with the Communications & Tracking System (CTS) which permits access to the RF digital data links extending DMS data support to the ground. The DMS concept is based on a local area network of loosely coupled data processing stations. Each data processing station is called a Standard Data Processor (SDP) and is based on a microprocessor class PC computer. SDP's are connected to one or more local busses that permit monitoring and control of sensors and effectors used to create a unique subsystem functional entity. Access between SDP's is accomplished through a global network. The global network is an FDDI optical ring network designed to permit substantial increases in subsystem data flow as the Space Station evolves.

1.2 PURPOSE AND SCOPE OF THE STUDY

The purpose of this report is to provide recommendations on the insertion of new electro-optical technology into the DMS global and local bus structure to increase their data carrying capacities and speed messages and data flow between nodes or stations in anticipation of growing requirements. The study described in this report had two objectives: To recommend a low risk technique for increasing the data carrying capacity and speed message flow in the local bus structure, and to examine and recommend techniques for applying wavelength division multiplexing to local and global data bus systems to support higher capacity transmission requirements.

The first portion of the study examines the local bus structure currently employed in the core and payload segments of the Space Station. The existing baseline system is described and some of the limitations imposed by this network design are reviewed. A recommended network solution to overcome the limitations imposed by the existing local data bus design is presented. This recommendation employs a supplementary high speed collateral fiber optic network to augment the current DMS local bus design. A collateral pipeline standard, currently under development for the European Fighter Aircraft Program, permits aircraft originally designed to support MIL-STD-1553B data busses to simultaneously support high data rate transfers over a parallel fiber optic network. A detailed description of this standard, STANAG 3910, is presented. A proposed network implementation applying this standard to the SSF local data topology will then be described. Hardware, designed to support this avionic standards is currently being produced in the United States and Europe. A section of this report will review this available hardware and describe some of the implementation considerations associated with applying this hardware to the Space Station. The local bus study will conclude with an example, which uses this improved local data bus network concept to support increased Payload downlink telemetry capabilities.

The second portion of this study examines the use of Wavelength Division Multiplexing (WDM) technology to support fiber optic data bus structures within the core and payload components of the Space Station. A portion of this study is devoted to developing a dual wavelength approach to provide simultaneous optical transmission channel communications over the improved local data bus structure. This application permits the improved local bus infrastructure to support higher data rate communications on the DMS. In a second portion of this WDM study a concept called spectral slicing is employed to permit the existing global data bus structure to support four times its current capacity. Both of these WDM applications are documented in this study.

The paper concludes with a summary of the results developed from this study and how these results can provide a evolutionary growth path for improved data communications within the DMS structure over the lifetime of the Space Station. Recommendations are also presented in this report. These recommendations are designed to permit an orderly evaluation of the design improvements presented in this paper.

SECTION 2

DMS LOCAL DATA BUS ENHANCEMENTS

2.1 EXISTING LOCAL BUS IMPLEMENTATION

The DMS local data bus is the interconnect structure designed to provide connectivity between the high data rate ring network and the effectors, sensors and other special interfaces [1]. The basic structure of the local bus is shown in figure 1. This figure shows that the high data rate end of the local bus structure is supported by the Standard Data Processor (SDP) unit. The other end of the local bus structure is interfaced to either a Controller multiplexer/demultiplexer (MDM) or a Firmware Controller (F/W Controller). The local bus structure is designed to conform with MIL-STD-1553B. MIL-STD-1553B is an avionic standard developed to provide short word length , low data rate messages communications using a command/response protocol. The MIL-STD-1553B protocol is very deterministic and the requirement for a status response at the conclusion of each message transfer provides a rapid means of fault detection.

2.1.1 Local Bus Topology

The local bus topology implemented in Space Station Freedom provides redundant communication paths to provide fault tolerance against single point failures. Figure 1 indicates that Local Bus A can be controlled from either of the two SDP's assigned to this bus. The other SDP can be used as a remote terminal when not acting as the bus controller. The figure also shows that Local Bus B is also supported by at least two SDP's which have bus control capabilities.

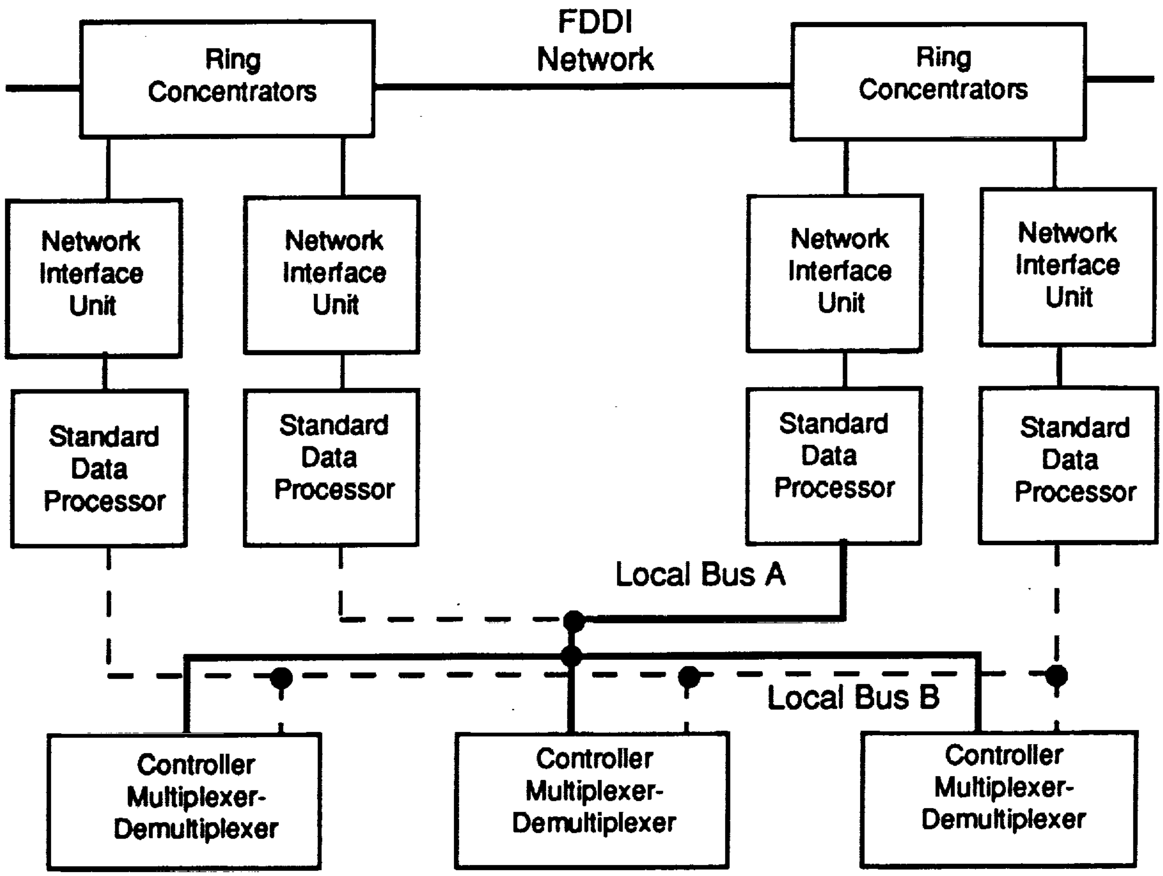


Figure 1. DMS Local Bus Structure

2.1.2 Standard Data Processor Design

The Standard Data Processor acts as a gateway between the high speed data network associated with the FDDI global bus network and the MIL-STD-1553B low speed local bus network. Figure 2 describes the general structure of the SDP design. High speed traffic designated for this specific SDP is moved from the global bus to the SDP's Multibus II backplane through the Network Interface Adapter (NIA). The SDP is supported by a 386-Based data processor capable of operating at 3.1 MIPS. This processor is supported in the SDP with 4 to 16 Mbytes of RAM. Software is provided in the SDP to support standard services and application programs. The interface to the local bus is supported by multiple 1553B Bus Interface Units (BIU's) and associated Bus Interface Adapters (BIA's). The current recommended design permits a single SDP to support up to 18 local busses.

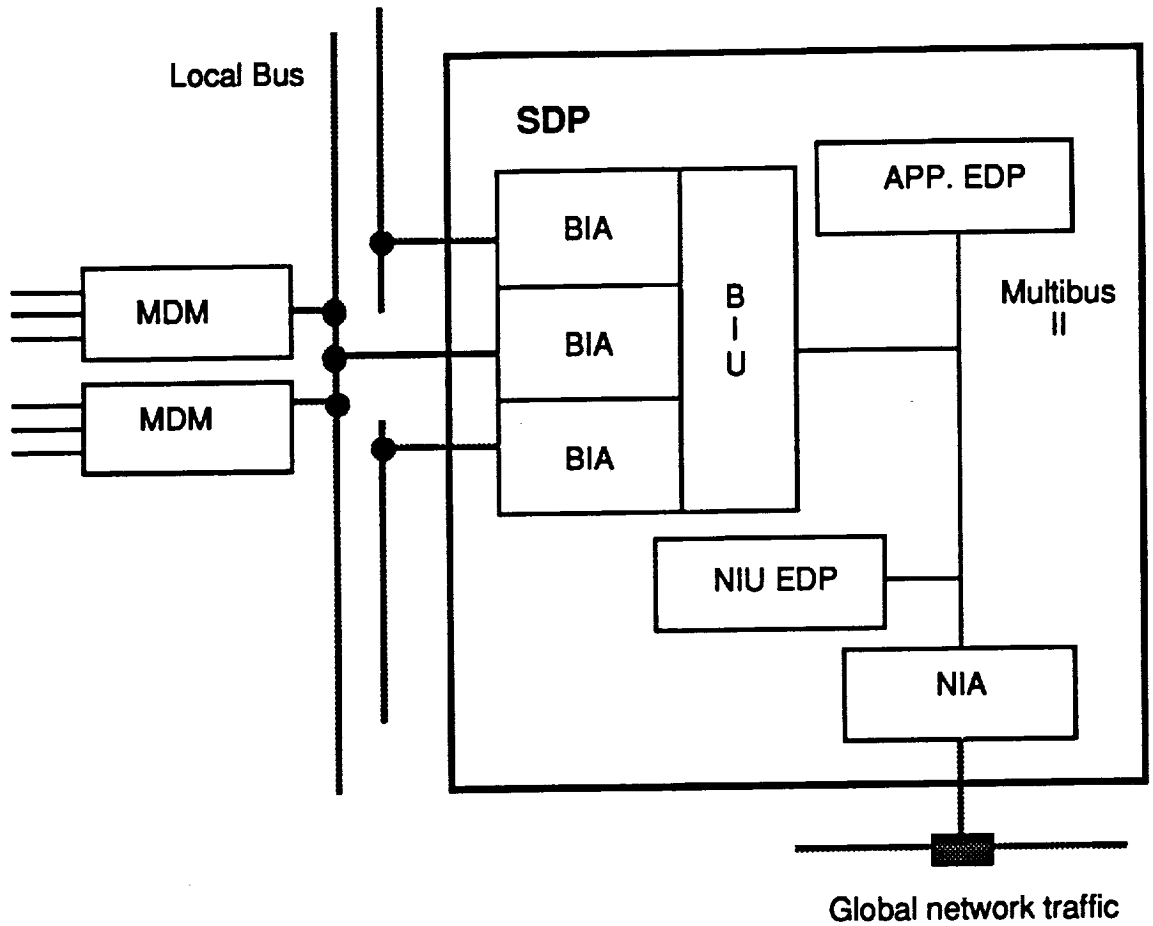


Figure 2. Standard Data Processor (SDP) Design

2.1.3 Controller Multiplexer-Demultiplexer Design

The other end of the local bus structure is supported by the Controller Multiplexer-Demultiplexer (MDM) Units. A diagram of the basic design structure of the MDM is shown in figure 3. The MDM accepts commands and data from the local bus network. These messages are decoded, and if a data request was made, sensor information is sent from the MDM to the appropriate designation. Information can also be sent to effectors on the Spacecraft through the MDM by means of the local bus network.

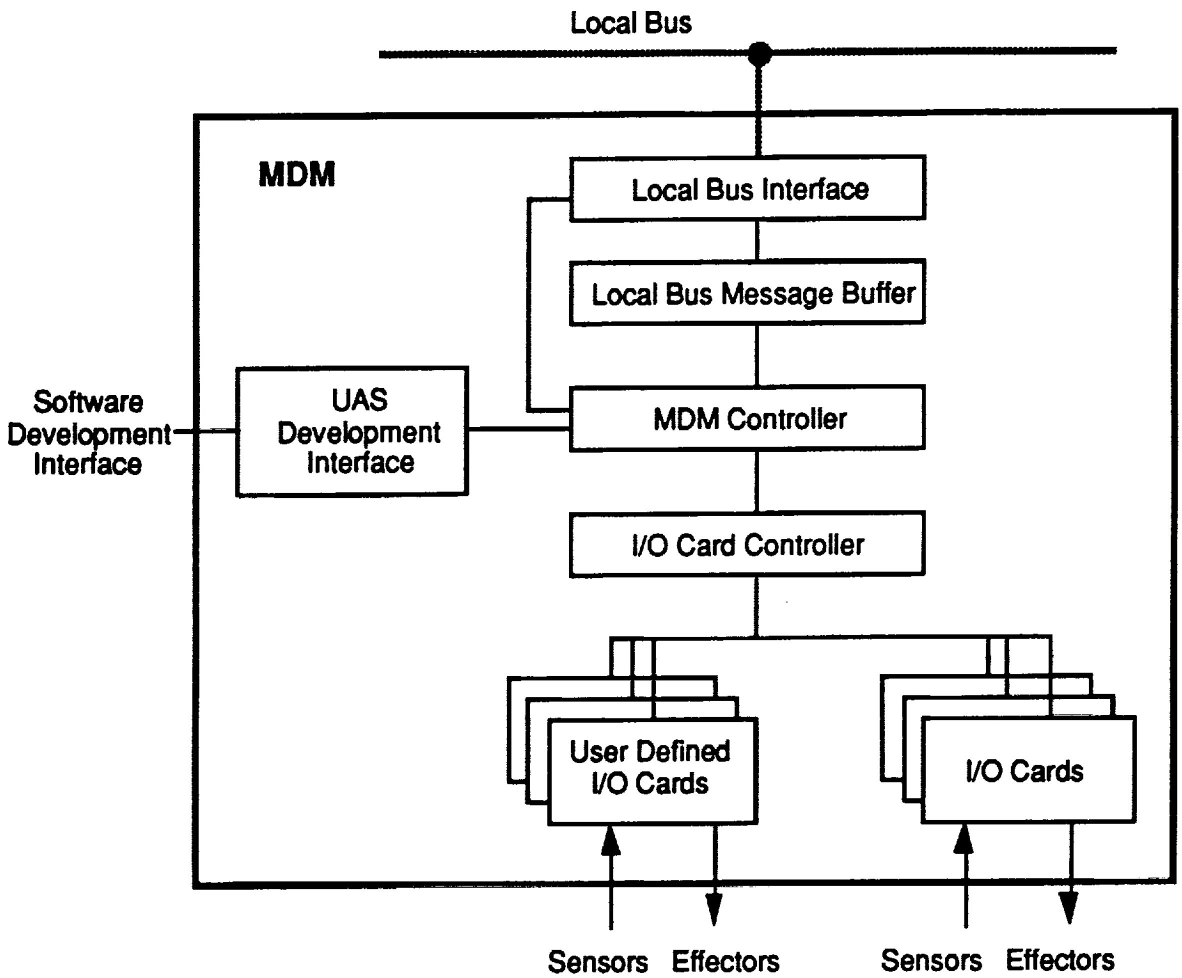


Figure 3. Controller Multiplexer-Demultiplexer (MDM) Design

The packing and unpacking of local data traffic is accomplished by a 386sx data processor. This processor also supports user applications with 0.7 MIPS, 1.25 Mbytes of RAM and 0.5 Mbytes of EEPROM. All interface communications with the local bus is performed through a 1553B Bus Interface.

2.1.4 Local Bus Characteristics

The local bus characteristics conform to MIL-STD-1553B an avionic data bus standard [2,3,4]. This standard calls for a serial multi-drop transmission configuration constructed with shielded twisted-pair cable. Components interfaced to this bus must be transformer coupled to permit terminal failures from disrupting bus operations and to provide a good impedance match between the terminal electronics and the transmission medium.

The data rate on the bus is 1 Mbps, and the data is modulated on the bus using a self-clocked Manchester II encoding technique. Three types of entities may exist on a local bus: Bus Controllers, Remote Terminals, and Bus Monitors. Only one active bus controller can appear on a bus at any time. The bus protocol is command/response, with only the Bus Controller able to initiate bus commands. The maximum throughput data rate on the bus is 748 kbps assuming 32 word (64 byte) messages. For shorter length messages the throughput rate decreases due to penalties associated with increasing overhead. The throughput rate for one word message transmissions is 210 kbps.

2.1.5 MIL-STD-1553B Protocol

The types of message transfers and the command and data words associated with these transfers is shown in figure 4. Three type of data transfer modes are possible under this protocol: Bus Controller-to Remote Terminal Transfers, Remote Terminal to Bus Controller Transfers, and Remote Terminal to Remote Terminal Transfers.

Information can be transferred from the Bus Controller to a specific Remote Terminal by having the Bus Controller place a command word on the data bus designating, the type of transfer, the remote terminal address and the number of words being transferred. The associated data words are then placed on the bus in a sequential fashion. At the end of the transfer, the remote terminal verifies that the proper number of words have been successfully received and responds with a status word. This confirmation of the successful completion of each order is a key feature of the command/response protocol.

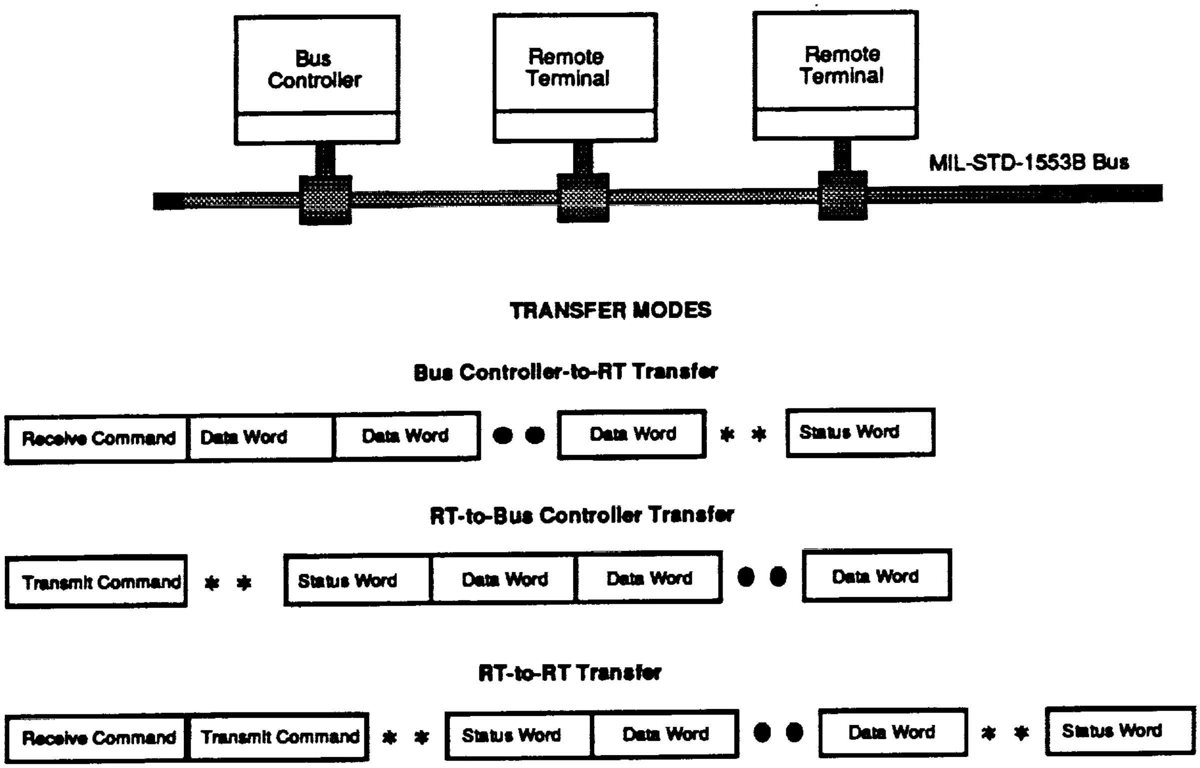


Figure 4. MIL-STDS-1553B Command Structure

To retrieve a series of data words from a specific remote terminal the bus controller must invoke a Remote Terminal to Bus Controller Transfer. In this operation the bus controller places a command word on the data bus designating this type of transfer, specifying the remote terminal address, and the number of data words requested in the transfer. After the transmission of the data word there is a short pause before the requesting remote terminal response with a status word. This status word indicates that the command has been received and the remote terminal is responding to the request. The status word is immediately followed by the number of data words requested by the bus controller.

The third type of data transfer - Remote Terminal to Remote Terminal is a composite action made up of the two previously described commands. The bus controller orders this transfer by transmitting two command words back to back. The first command word is a Bus Controller to Remote Terminal command word and indicates to the selected receiving remote terminal the type of transfer, and the number of words that should be received by that terminal. This command basically tells the receiving remote terminal to "listen". The second command word is designated for the remote terminal that is sending the information. This word indicates the type of transfer and tells the addressed remote terminal to "send". The sending remote terminal responds after a short pause with a status word indicating that it has received the command and is preparing to transmit the designated number of words. This status message is followed directly with the requested number of data words. At the end of the transmission there is another short pause and then the "listening" remote terminal responds to the bus controller with a status word. This status word indicates that the number of words requested were successfully received.

This form of command/response protocol not only provides confirmation of successful results at the conclusion of each data transfer but it also provides transmission faults and faults in remote terminal hardware to rapidly spotted. This function is very valuable in recognizing and isolating system faults. As each local bus has both a backup transmission network and a backup controller rapid identification of faulty transmissions allow utilization of the backup hardware to minimize network downtime.

2.1.6 Rationale for Examining Local Bus Improvements

The low data rate transmission restrictions imposed by the MIL-STD-1553B protocol creates a number of problems for local bus applications in the Space Station. Existing local bus transmission capacity between the Standard Data Processors and the core Multiplexer/Demultiplexer (MDM) units leave little margin for growth. The MDM's represent a large pool of programmable processing power, but limitations imposed by the current local bus structure provides minimum connectivity between devices and between these units and the crew or ground. The current local bus protocol was optimized for the short message length traffic associated with avionic applications. Longer message length capability and a higher speed interconnect infrastructure is necessary to support increasing data requirements. The existing local bus design limitations reduces the flexibility to accommodate changes in functionality and performance over the lifetime of Space Station Freedom.

2.2 EVOLUTION OF MULTIPLE SPEED DATA BUS DESIGNS

The existing Space Station Freedom local bus network employs the MIL-STD-1553B avionics standard. This standard evolved into an accepted military avionic standard in the mid 1970's. MIL-STD-1553B was designed to provided a flexible interconnect mechanism for avionic electronics. When it was initially developed processing power was very expensive and the number of processors employed in avionics was severely limited. The command/response protocol associated with this standard envisioned one smart controller and a number of dumb terminals. Much of communications associated with the early development of this standard required only slow data rate transfers and were associated with short data word messages. As data requirements increased, the data rate was maintained and multiple data busses were employed to support the increasing avionic workload.

With the increased use of composite material in aircraft the application of fiber optics as the transmission medium to support the MIL-STD-1553 protocol became a popular subject. A fiber optic companion standard to MIL-STD-1553 was developed as MIL-STD-1773 [5]. This fiber optic standard maintained the same data rate and same data word structure as the wire-standard. This was done to provide component compatibility with avionic hardware already in the system while decreasing vulnerability to EMP, EMC and grounding problems. MIL-STD-1773 has been installed in a series of avionic applications such as the AV8B but has not been used in an operationally sensitive area. This standard has also been used in very noisy electronic environments such as helicopter control system applications. NASA recently deployed a Small Explorer Satellite which employed MIL-STD-1773 as its data bus system [6].

As the network processing requirements increased more processing power was implemented in the avionic terminal units. To take advantage of this increased capability it was necessary to examine protocol changes which could support higher data transfer rates and longer message lengths. With the availability of fiber optics as the transmission medium, the data rate restrictions imposed by the limited bandwidth of the twisted shielded pair wire no longer applied. In the early 1980's a concept employing variable data rate transmission was developed, at MITRE, based on the extended bandwidth capabilities of fiber optic transmission medium [7]. A modification to MIL-STD-1773 was proposed, using this concept, to support increased data rate transfers while providing backward capability with existing 1 Mbps avionic hardware [8]. This implementation has become known as dual speed MIL-STD-1773. In the dual speed process the bus controller operates at 1 Mbps and supports existing 1 Mbps avionic hardware. When two terminals capable of supporting higher speed transfers are requested to pass information, the interconnect is established at 1 Mbps and the associated status words are returned at the low data rate. The high speed terminals then shift gears and exchange data at a higher rate such as 20 Mbps. In the same time frame that would normally permit the transmission of 32 sixteen bit words, these terminals can transfer 640 sixteen bit words. Work on dual speed MIL-STD-1773 network implementations have been prototyped and ongoing research continues under government sponsorship. However, this implementation requires replacing the twisted shielded pair cable networks, currently installed on production avionics, with fiber optic transmission medium.

In the mid 1980's the United States was providing aircraft to our NATO partners equipped with MIL-STD-1553B avionic data busses. Some of the NATO requirements for avionic terminal hardware exceeded the 1 Mbps data transfer rate supported by MIL-STD-1553B. At that time, several of the European members requested NATO's permission to develop a standard to support multiple speed data rate transmission. As the aircraft already had MIL-STD-1553B data busses installed, which would adequately support low speed traffic, they proposed the use of a fiber optic collateral pipeline design to permit parallel high speed data transfers under low speed control. The standard developed from this effort was designated as STANAG 3910 (NATO standardization agreement 3910). This is the standard that is being recommended for implementation to augment the existing local bus structure of the Space Station. This implementation can support higher data rates and longer message length capability where required.

2.3 ENHANCED LOCAL BUS IMPLEMENTATION CONCEPT

The suggested solution for providing an evolutionary growth path for local data bus design is to overlay a STANAG 3910 network over the existing MIL-STD-1553B cable plant. The STANAG 3910 standard was conceived as a method of eliminating just the form of data bus growth limitations being recognized in local bus network of Space Station Freedom. The standard was designed to maintain the deterministic nature of the command/response protocol and provide compatibility with all of the terminal hardware designed for operation with MIL-STD-1553B word lengths and data rates. However, the introduction of the high speed parallel transmission network permits selective equipments to operate at much higher data rate and support longer data messages. These high speed parameters provide the flexibility necessary to support new media transfers such as digitized compressed video and additional future services.

2.3.1 Characteristics of STANAG 3910 Networks

STANAG 3910 is a standard describing a high speed data transmission network supported under MIL-STD-1553B control [9, 10]. This improved data bus system offers high speed transmission capability over a parallel fiber optic network, but maintains full compliance with the existing MIL-STD-1553B data bus standard.

2.3.1.1 Topologies

A comparison of local bus architectures supporting MIL-STD-1553B and STANAG 3910 standards are shown in figure 5. The upper diagram in figure 5 illustrates the standard implementation of the low speed linear bus network associated with MIL-STD-1553B.

The middle illustration in figure 5 shows the high speed network implemented as a linear bus using "T" couplers. The bidirectional "T" coupled configuration has a topology that is very similar to that of the low speed network. However, "T" coupled optical data busses suffer from a number of problem associated with optical power distribution.

The bottom diagram in figure 5 shows the high speed network configured in a star centered topology. Two types of star centered networks are possible depending on the type of star coupler employed. If a transmissive passive star element is used a pair of fibers must be run from each terminal device to the star element. One of these fibers is used for transmission and one fiber for reception. If a reflective passive star element is used only one fiber must be deployed between each terminal unit and the star element. In the reflective star configuration a second optical power splitting element must be used to permit the terminal's source and receiver elements to share the same fiber. The passive reflective star requires only half the installed fiber cable plant of the transmissive star topology but this advantage is obtained at the cost of additional required optical power.

Figure 5 also illustrates that the network interfaces, in the bus controller and remote terminal units, must be modified to convert the existing MIL-STD-1553B local busses to a STANAG 3910 configuration. This modification includes the addition of a high speed fiber optic transceiver to support the optical bus interface and a STANAG 3910 integrated protocol chip set to service this new high speed network.

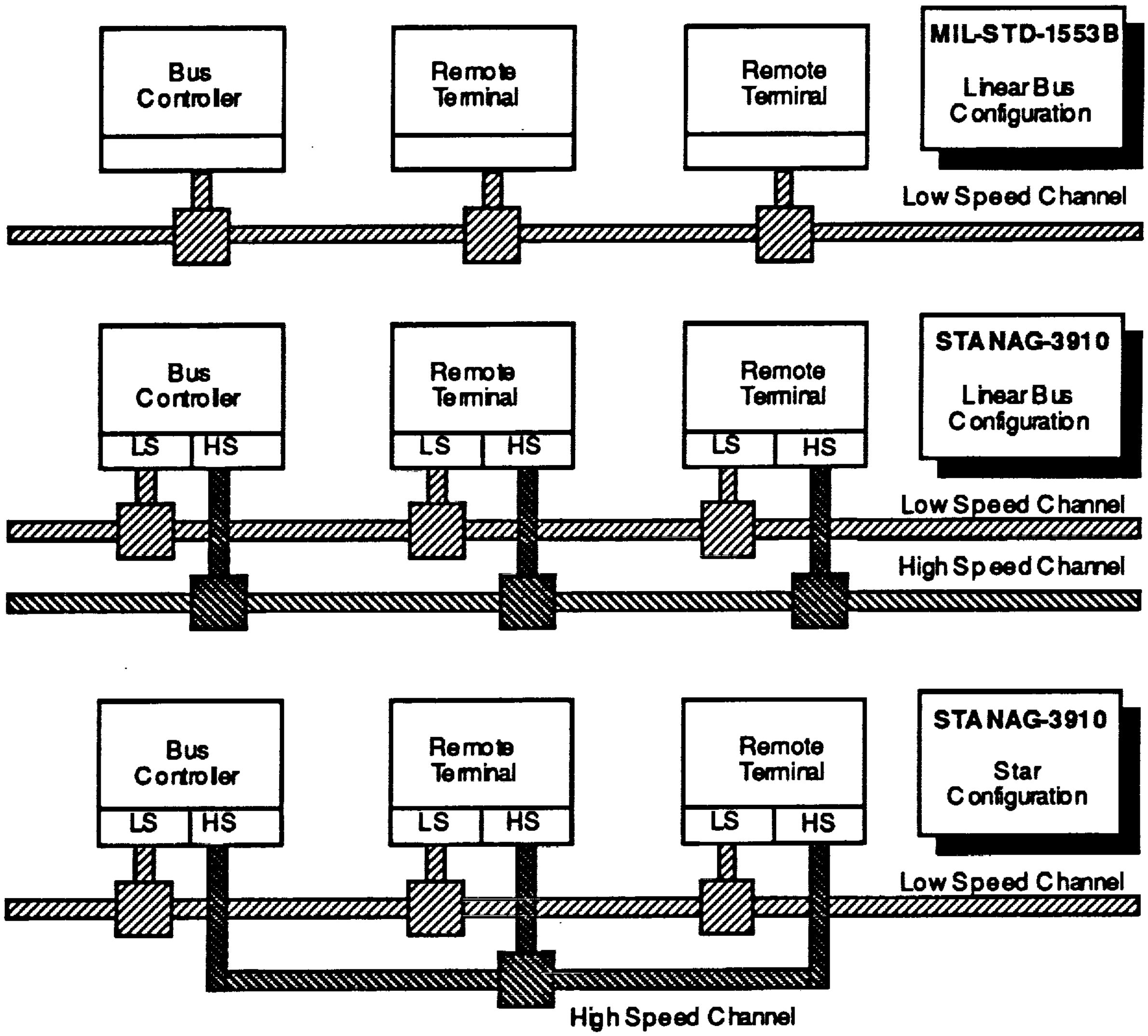


Figure 5. Comparison of Local Bus Architectures

2.3.1.2 STANAG 3910 Command Structure

The command structure used in STANAG 3910 is shown in figure 6. The STANAG 3910 command structure closely follows the MIL-STD-1553B command/response command structure described earlier. However in each command series an additional word is employed to indicate the requirements for a high speed transfer.

In requesting a high speed data transfer of information from the bus controller to a remote terminal a command word is initiated on the low speed channel. The command word is issued, with a unique subaddress, followed by a single data word. Through the unique subaddress, called the High Speed Subaddress, the following data word is recognized as a High Speed Action Word, containing all of the information required to control the high speed data traffic. Upon receipt of the command word the receiving remote terminal responses with the appropriate status word on the low speed channel. Some finite time later the high speed data frame is transmitted from the bus controller to the remote terminal over the fiber optic network.

In a similar manner a high speed data transfer request for information from a remote terminal is initiated, by the bus controller, with a normal command word over the low speed bus. As in the previous case the command word contains a unique subaddress indicating that a high speed data transfer will occur. The command word is followed by a High Speed Action Word. The terminal designated to transfer information to the bus controller response with a status word indicating proper receipt of the command over the low speed channel. Some finite time later the requested data is transferred from the designated remote terminal to the bus controller over the high speed fiber optic channel.

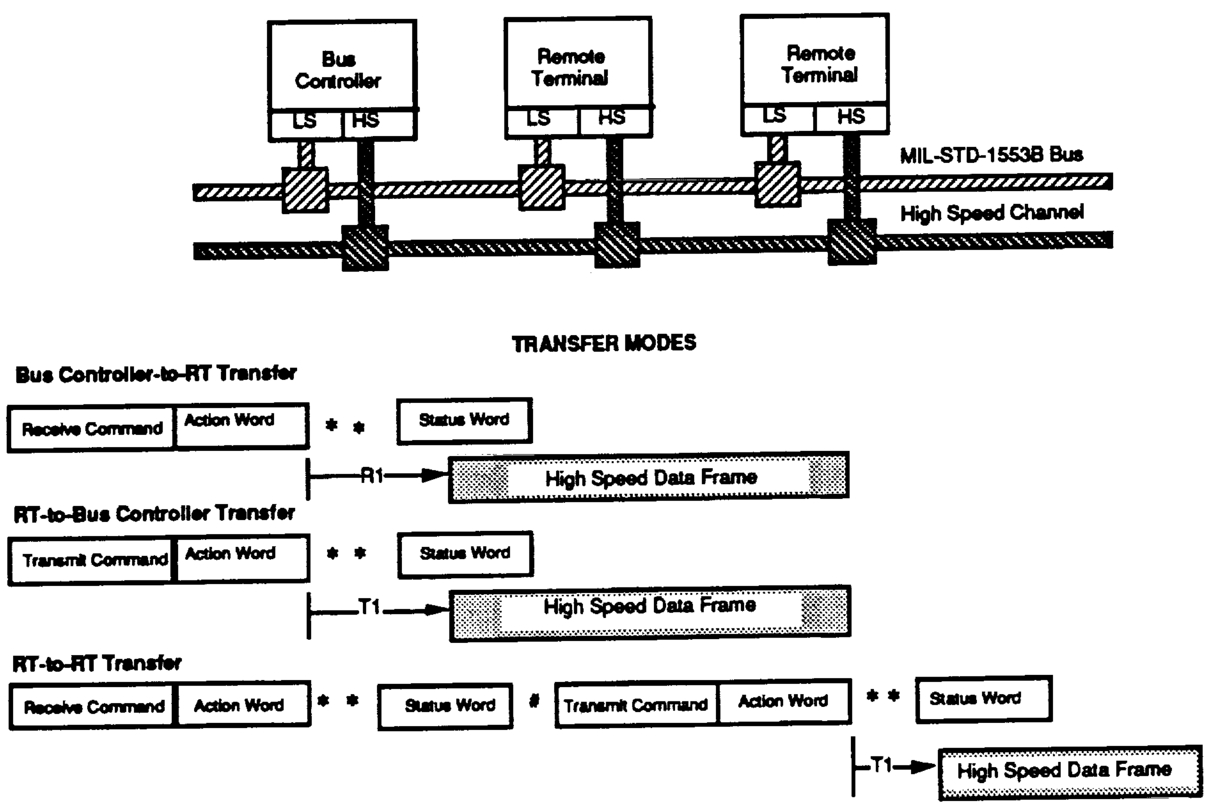


Figure 6. STANAG-3910 Command Structure

To initiate a remote terminal to remote terminal data transfer on the high speed fiber optic network a composite series of commands described above are executed on the low speed channel. A command word is issued, on the low speed channel by the bus controller to the remote terminal designated to receive the message. This command word incorporates the unique high speed subaddress. The command word is followed by a High Speed Action Word. The receiving remote terminal then responses, over the low speed channel, with a status word indicating receipt of the receive command. The bus controller then issues a command, on the low speed channel, to the remote terminal designated to transmit the high speed data message. This command also contains the unique subaddress indicating response on the high speed network. A High Speed Action Word is also transmitted after this command word. The remote terminal designated as the transmitting terminal responses with a status word, on the low speed channel, followed a short time later with a transmission of a remote terminal to remote terminal transfer over the high speed channel.

2.3.1.3 Comparison of Data Throughput Rates

A comparison of the throughput data rates associated with MIL-STD-1553B local bus network and STANAG 3910 network is shown in figure 7 [11]. This diagram describes the effective data throughput rate as a function of packet size. In this diagram it can be seen that the MIL-STD-1553B network approaches a throughput rate of 748 kbps for a transmission packet of thirty-two 16 bit words. After thirty-two words the data throughput rate remains constant for increasing packet length transmissions.

The STANAG 3910 data throughput rate continues to increase with packet size. At the maximum packet size of 4096 sixteen bit words (8192 bytes) the effective data rate is approximately 19.2 Mbps. This shows that the increase in data throughput varies between a factor of 10 for packet lengths longer than 64 sixteen bit data words to a factor of 25 for packet lengths longer than 1000 sixteen bit words.

The results of this analysis indicate that the use of STANAG 3910 provides an excellent vehicle for both short message length/low data rate performance and long message length/ high data rate performance. Short packet length traffic can continue to operate on the low speed twisted shielded pair medium while high speed, longer packet length messages can be efficiently moved on the fiber optic network. As the low speed network is only required to set up the high speed transfer, other low speed traffic can be handled on the low speed channel concurrently with the high speed communications.

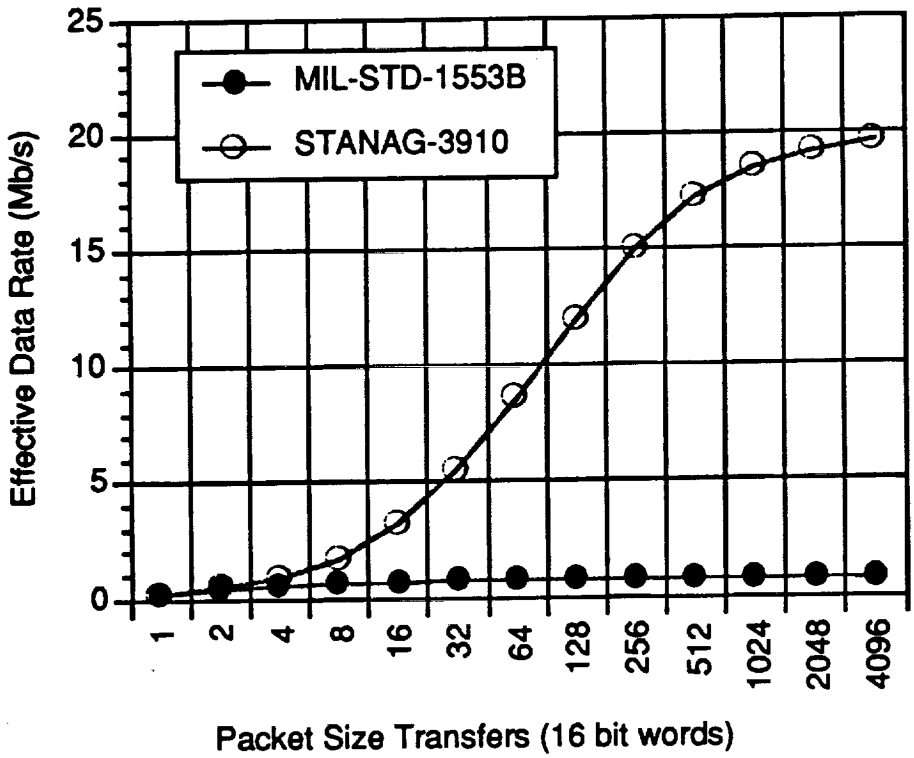


Figure 7. Comparison of Effective Transfer Data Rates

2.3.1.4 STANAG 3910 Network Structure

The suggested topology for implementing STANAG 3910 as a supplement to the current local bus design, for Space Station Freedom, is shown in figure 8. This diagram shows a fully redundant reflective star based network. Busses A and B designate the dual redundant local bus networks that currently exist on Space Station. The MIL-STD-1553B chips shown in this diagram are the current devices presently installed in the SDP, MDM and F/W controller devices to process information on the local bus network.

The heart of the modification that converts the existing MIL-STD-1553B local network into a STANAG 3910 network is the STANAG 3910 Protocol Chip. This chip interfaces with the existing MIL-STD-1553B chip and to the subsystem backplane. A high speed memory is employed with this protocol chip to permit buffering between the high speed fiber optic network and the subsystem backplane. In some versions of the STANAG 3910 system design a CMOS to positive ECL translator chip is employed between the STANAG 3910 Protocol Device and the fiber optic transceivers. This chip permits the proper voltage level transitions to occur between the ECL technology in the fiber optic transceivers and the CMOS technology used in the integrated circuits of the protocol chip.

The fiber optic transceiver contains an LED transmitter, a PIN receiver, a 50/50 internal optical splitter, and a clock recovery circuit. Data to be transmitted on the high speed network is sent from the protocol device to the optical transmitter in the transceiver unit. A portion of the optical signal developed by the LED transmitter is coupled to the transmission network through the built-in 3 dB coupler. In receiving information a portion of the optical signals, from the reflective star, is coupled to the PIN receiver through the built-in 3 dB coupler. The receiver converts this information from optical to electrical format. A built-in clock recovery unit recovers the clock from the received signal, and the recovered clock and data information is passed on to the STANAG 3910 Protocol Device through the level translation logic. The data rate on the optical network is 20 Mbps, and the data is modulated on the bus using a self-clocked Manchester II encoding technique.

The fiber optic network is designed around a passive reflective star element. This element mixes the optical information from each input and then reflects the composite optical signal proportionally back into each fiber. With this device and the 3 dB splitters installed in each fiber optic transceiver only one fiber is required between each optical transceiver and the star element. Figure 8 shows a fully redundant configuration which requires two transceivers at each terminal device and two reflective stares in the network. This configuration is fully compatible with the 3910 standard and matches the dual redundant requirements imposed in the Space Stations local bus network design.

The fiber optic network characteristics established by the standard change with the type of fiber employed. STANAG 3910 fiber optic interface characteristics have been established for both 100/140 micron step index fiber and 200/280 micron step index fiber. These characteristics are documented in Tables 1 and 2 [12]. Step index fiber have traditionally been the fiber of choice for avionic applications, as these fibers are less susceptible to darkening from extended exposure to gamma radiation. However, they tend to have a lower numerical aperture than their graded index counterparts which results in lower values of couple power. Special 100/140 micron graded index fibers are currently under development to support the global data bus in Space Station Freedom but detailed technical information on this effort were not available at the time of this study. In the Small Explorer Satellite recently developed by NASA GSFC a graded index 100/140 micron Corning ISDF-1508 fiber was used. The numerical aperture of this fiber is 0.29.

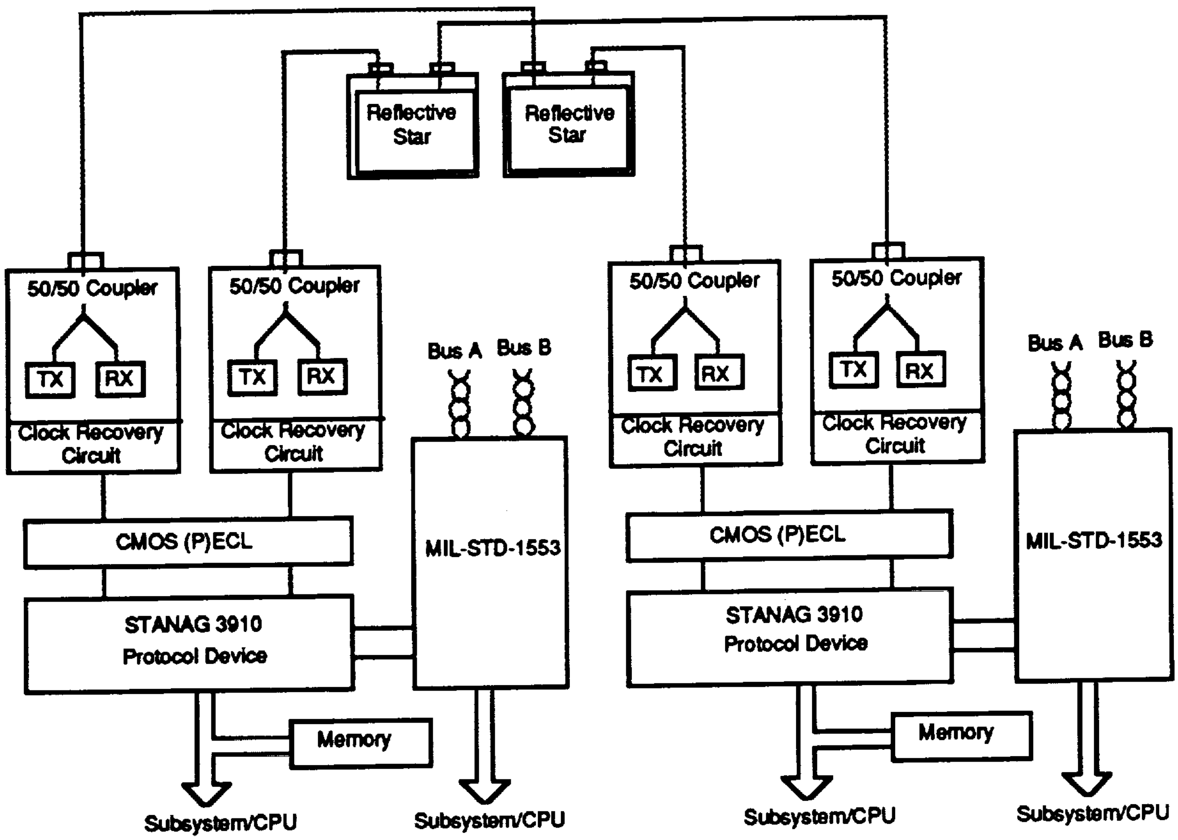


Figure 8. STANAG-3910 Dual Redundant Reflective Star Coupled Bus

2.3.2 Proposed Enhanced Local Bus Implementation

As an example of how the 3910 standard might be implemented in the Space Station the topology associated with core local buses was examined. Figure 9 shows the topology associated with local bus 1 (LB1) and local bus 2 (LB2) as developed from the DMS Architectural Overview. This figure shows four Standard Data Processors interconnected over the SDP1 local bus. Two local busses emanate from the SDP's, with local bus 1 (LB1) servicing 8 Controller Multiplexer/Demultiplexers (MDM's) and one firmware controller and local bus 2 (LB2) servicing 8 MDM's and 10 firmware controllers. This network configuration permits any of the four SDP's, associated with LB1 &LB2, to act as a bus controller or remote terminals on this network. This network is duplicated as each of the SDP's, MDM's and F/W Controllers are connected to both an "A" Bus and a "B" Bus (not shown on figure 9). This redundant connectivity eliminates total network failures due to the loss of one of twisted shielded pair cable networks. One of the SDP's is usually designated as a backup bus controller so that data communications can continue with the loss of the SDP functioning as the primary bus controller.

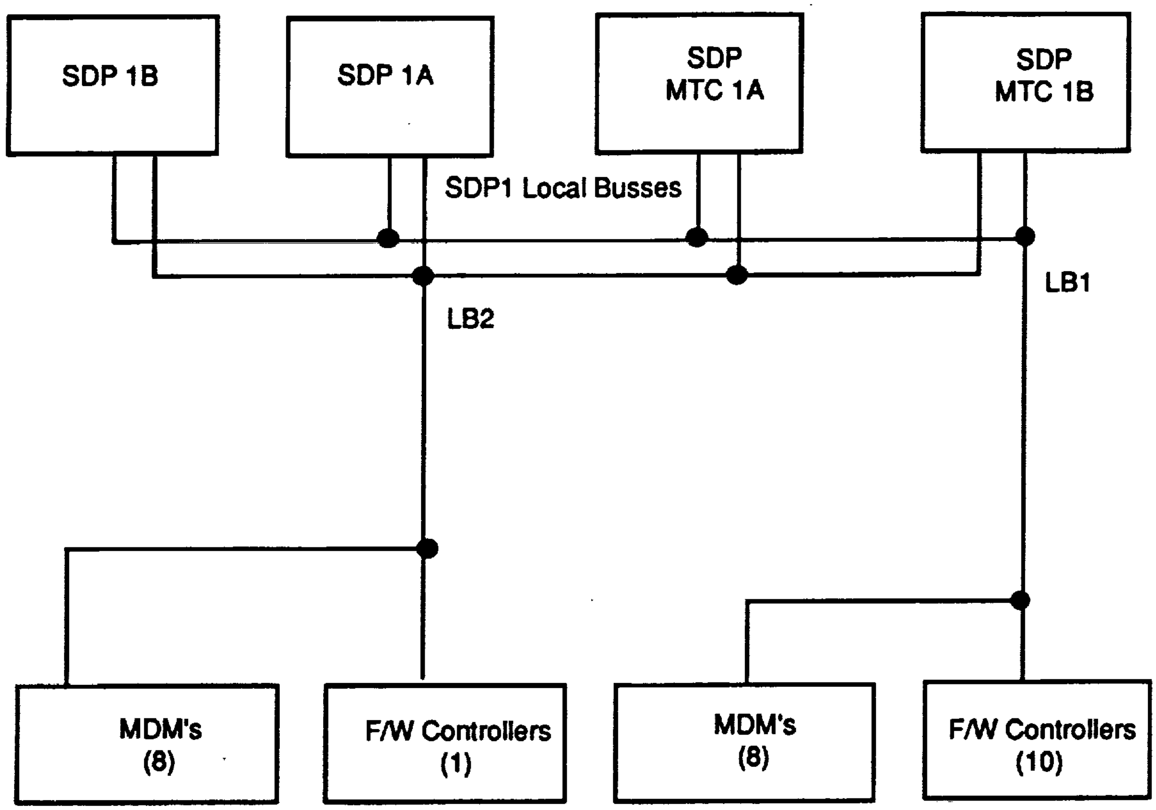


Figure 9. Twisted Pair Cable Topology for SDP1 Local Bus

To apply the 3910 standard to the local bus structure shown in figure 9 a fiber optic collateral network must be installed. Figure 10 shows the same local bus configuration designed to support both low data rate and high data rate traffic. In this configuration a passive reflective star element forms the hub of the fiber optic high speed network while the low speed MIL-STD-1553B network remains untouched. Fiber optic cables are deployed between each of the SDP's and the reflective star. In a similar manner fiber optic cable is installed from each of the MDM's to the reflective star element. The firmware controllers are not connected into the high speed data network as their data transfer rate requirements can be satisfied by the twisted shielded pair transmission medium. The termination ports on the SDP's and MDM's, connected to the fiber optic network, must be modified to accept the STANAG 3910 components. As indicated earlier this modification requires the installation of a fiber optic transceiver, a STANAG 3910 Protocol integrated circuit chip and a high speed random access memory module.

The reflective star element in figure 10 must support 20 fiber optic ports. One from each of the 16 MDM's and one from each of the four SDP's. If a 24 port reflective star is employed and standard EFA sources and receivers are employed 14 dB of optical budget should be available to compensate for cable and connector losses from any terminal unit to any other terminal unit. This loss budget appears adequate for the multiple connector configurations associated with the modular construction techniques required in the Space

Station. Modular construction techniques insure that large numbers of connectors will be encountered in the optical network.

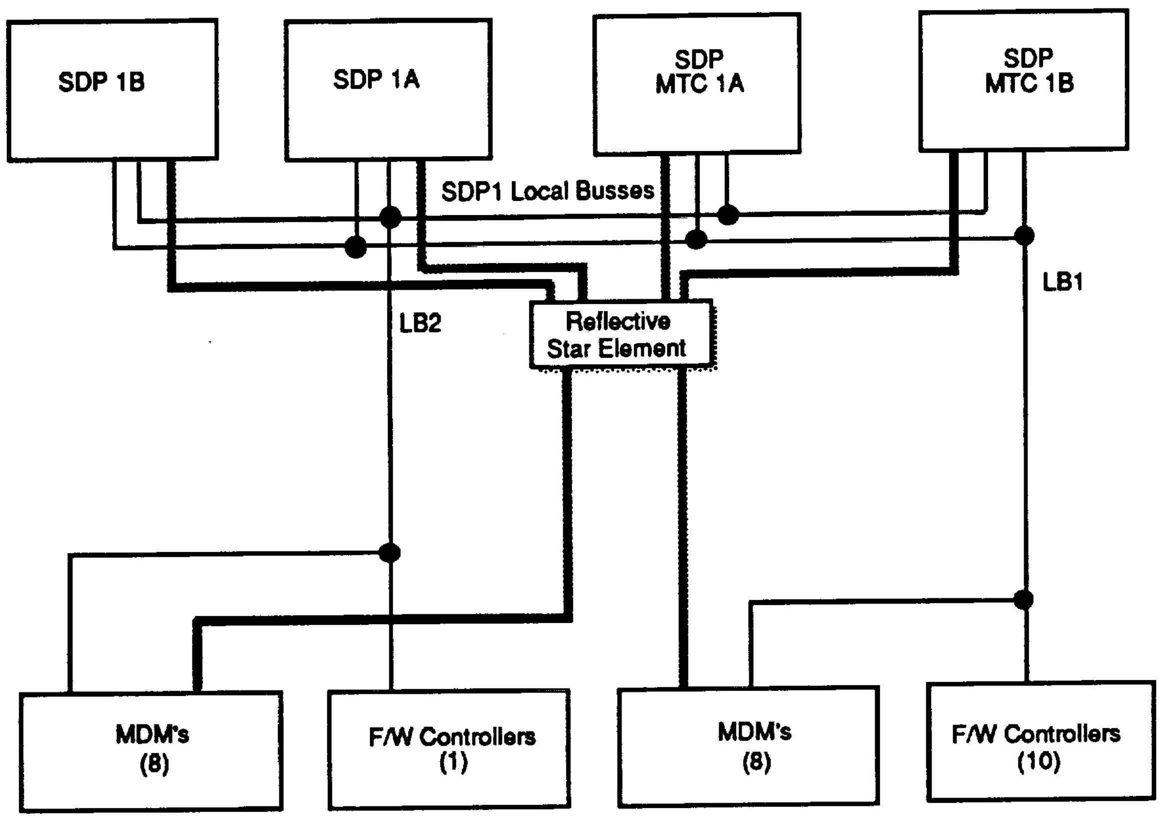


Figure 10. SDP1 Local Bus Connectivity using STANAG-3910

(Single Redundancy)

For completeness a dual redundant implementation of the local bus configuration designed to support STANAG 3910 is shown in figure 11. This configuration includes the use of two reflective stars and requires an optical interface from each star to each SDP and MDM. In a similar manner it can be seen that each SDP and MDM are connected to each of the redundant local twisted shielded pair busses (LB1 A&B or LB2 A&B). This implementation will insure that a single point failures of either transmission medium will not adversely effect network performance. When a transmission failure is detected data transfers are shifted from the active bus to the standby bus. To prevent one cable accident from severing both transmission cables the active and standby cables are usually run over diverse routes.

This example covers only a fraction of the local busses designed to support the Data Management System at PMC. These local busses support 66 MDM's and 154 firmware controllers. The fiber optic collateral pipelines do not have to support the firmware controllers as these devices operate at data rates that can be supported over the current twisted shielded pair transmission system.

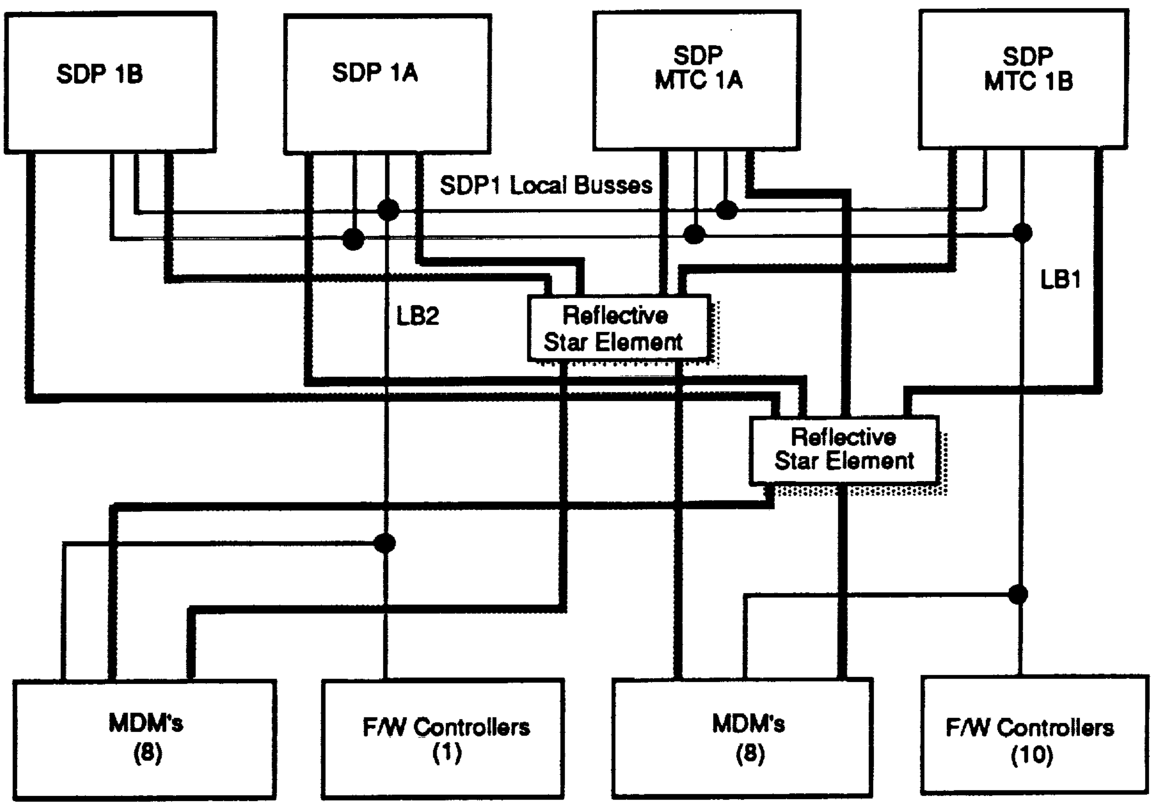


Figure 11. SDP1 Local Bus Connectivity using STANAG-3910

(Dual Redundancy)

2.4 AVAILABLE HARDWARE AND IMPLEMENTATION CONSIDERATIONS

With the development of the European Fighter Aircraft (EFA) a unique configuration for STANAG 3910 was selected. This design chose fiber optics as the transmission medium and a reflective star centered topology for the network configuration. The design employed large scale semiconductor technology to limit the number of components necessary to add the high speed capability to the existing low data rate bus design. In addition, the system was designed to support dual redundancy to permit either a twisted shielded pair or fiber bus to be switched to a back-up medium if network problems are detected.

2.4.1 EFA Terminal Architecture

An example of the terminal hardware built for the EFA program is shown in figure 12. The MIL-STD-1553B Remote terminal chip is the same type of chip developed for military aircraft applications and currently used as the remote terminal chip for the Space Station Freedom's local busses. The chip is transformer coupled to the twisted pair transmission medium to provide impedance matching and isolate the terminal from the data bus in case of terminal failure. Like the MIL-STD-1553B remote terminal chip these transformers are universal components. The MIL-STD-1553B remote terminal is also connected to the equipment subsystem bus to allow information to be loaded and removed from the remote terminal for communications with other components on the local bus.

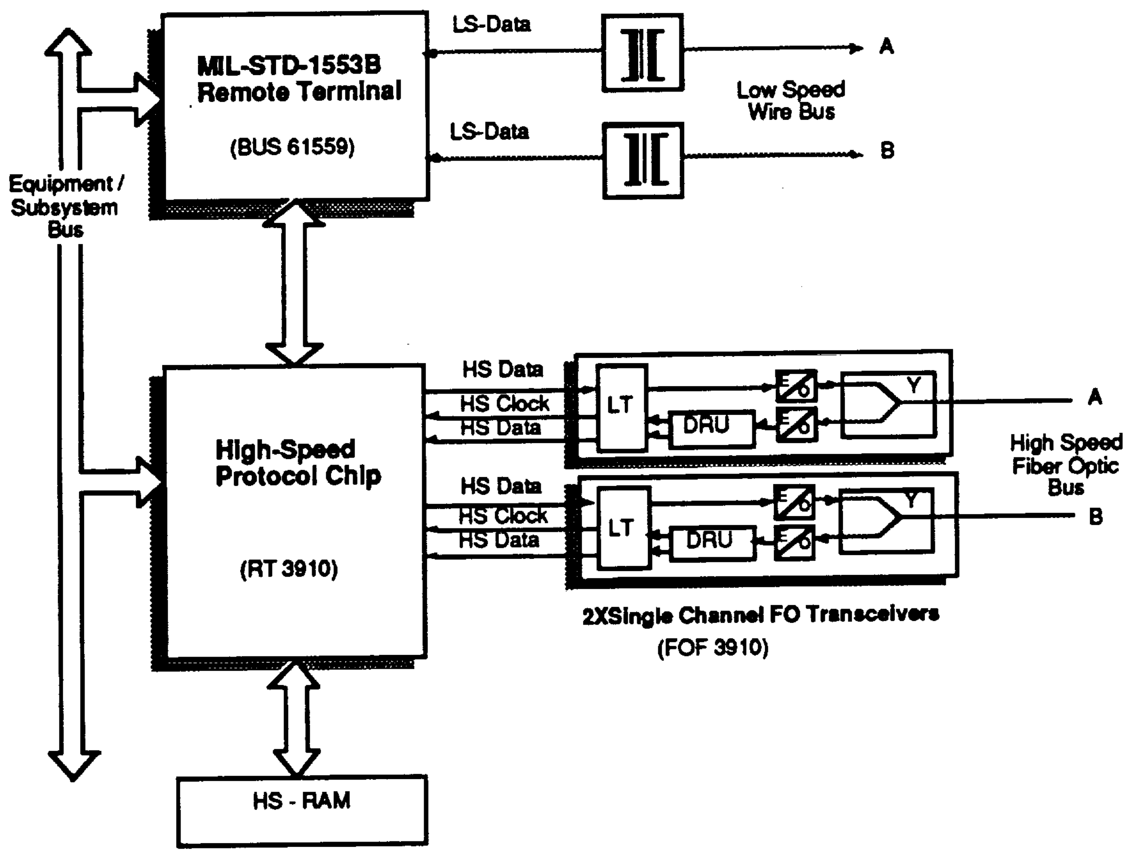


Figure 12. EFA Terminal Architecture

The heart of the EFA STANAG 3910 high speed design is the High-Speed Protocol Chip [13]. This device also connects to the equipment subsystem bus to allow information on the high speed data network to be loaded or extracted. The High-Speed Protocol Chip can also be interconnected directly to the MIL-STD-1553B remote terminal chip. This interface is available if the MIL-STD-1553B chip has the capability to support external extended memory. If this facility is not available on the remote terminal chip selected, all hand-shaking between the remote terminal chip and High-

Speed Protocol Chip will take place over the subsystem bus. If the remote terminal has the capability to support external memory this facility can be used to directly hand-shake with the High-Speed Protocol Chip. The High-Speed Protocol Chip is also interconnected to a high speed RAM module. This module acts as a high speed buffer permitting data to be moved to and from the subsystem bus at that facilities convenience. The High Speed Protocol Chip interconnects to the Fiber Optic Transceiver through a data and clock interface. This interface sends high speed data to the optical transmitter during transmission, and receives recovered clock and high speed data during the receive process.

The current EFA design employs two single channel fiber optic transceivers. Each transceiver consists of a CMOS to ECL level converter a fiber optic LED transmitter unit, a PIN fiber optic receiver unit, a data recovery unit and a "Y" coupler. The "Y" coupler permits the single fiber optic line interfaced to the fiber optic transceiver to operate in a bidirection manner. The EFA fiber optic transceivers are designed to interface with either 200/280 micron or 100/140 micron fiber.

2.4.2 EFA Fiber Optic Bus Characteristics

The EFA version of STANAG 3910 employs a Manchester II encoding scheme with a 20 Mbps data rate and a 40 M Baud signaling rate. The fiber specified for the EFA Program is a step index, multimode (200/280 micron) fiber with a 0.24 numerical aperture. This fiber has a core of pure fused silica and a doped fused silica cladding. This combination reduces the number of color centers in the fiber generated by gamma radiation. The fiber has a minimum attenuation of 3.0 dB/km and a maximum attenuation of 15.0 dB/km.

The optical transmitters in the fiber optic transceiver are specified to couple -0.5 ± 3.5 dBm into the 200/280 micron transmission fiber. At the present time production transceivers are being manufactured which provide -0.2 dBm of coupled power. The optical receivers in the transceiver units are designed to provide a BER of 10^{-10} with a minimum input power level of -37.0 dBm. At the present time production receivers are available with receiver sensitivity levels of -35 dBm.

The principal component in the EFA fiber optic network is a passive star component. This component is designed into a reflective star topology. The star element is designed using mixing rods with mirrored end faces. Stars are available in sizes ranging from 24 to 32 ports. The current production reflective stars have 24 ports and impose 17 dB of losses due to power splitting and excess losses. The "Y" couplers, permitting bidirectional operation are designed into the optical transceiver and produce a 50/50 power split. The network employs a connector designed specifically for this program. This connector is a ruggedized form of the standard FC/PC connector designed to fit the 280 micron dimension of the EFA step index fiber.

The fiber optic media interface characteristics of the reflective star coupled bus using 100/140 micron fiber is given in table 1. The same characteristics for a reflective star coupled bus using 200/280 micron fibers is shown in table 2.

Table 1. Fiber Optic Media Interface Characteristics:

Type F-4 (Reflective Star Coupled Bus with 100/140μm Fiber)
(Y Coupler internal to the Optical Transceiver)

Parameter	Description	Requirement	Units
COMMON CHARACTERISTICS			
	Encoding Method	Manchester	
R_d	Data Rate	20	Mbps
R_s	Signaling Rate	40	MBaud
T_o	Nominal Bit Time	50	ns
T_m	Signaling Time	25	ns
R_{sts}	Short Term Stability	0.01	%
R_{lts}	Long Term Stability	0.03	%
S_p	Preamble Size	40	Bit
S_{itg}	Minimum Intertransmission Gap	2.0 + Sp•To	μs
W_1	Optical Wavelength Lower	800	nm
W_2	Optical Wavelength Upper	880	nm
BW	Spectral Bandwidth	<60	nm
TRANSMITTER CHARACTERISTICS			
T_{po}	TX Optical Power (Signal High)	-3.5 ±3.5	dBm
T_{pr}	TX Residual Power (Signal Low)	Tpo - 14.0	dBm
T_{pl}	TX Leakage Power (TX Off)	-40.0	dBm
T_{plr}	TX Leakage Power Ripple RMS	-60.0	dBm
T_r	TX Maximum Rise Time	10.0	ns
T_f	TX Maximum Fall Time	10.0	ns
T_{dpw}	TX Maximum Pulse Width Distortion	2.5	ns
T_{ous}	TX Combined Over/Under-Shoot	5.0	%
T_I	TX Initialize Time	24.0 to 32.0	μs
T_{ds}	Data Streaming Timeout	4.15 ±20%	ms

Table 1. (Continued)

Fiber Optic Media Interface Characteristics:
(Reflective Star Coupled Bus with 100/140μm Fiber)

RECEIVER CHARACTERISTICS			
R_{po}	RX Maximum Optical Power Input	+5.0	dBm
R_{rec}	RX Recovery Time after R_{po} dBm Input	100	μs
R_{or}	RX Operating Range	TBD	dB
R_{idr}	RX Intertransmission Dynamic Range	TBD	dB
R_{pm}	RX Minimum Optical Power Input	-39.0	dBm
R_{ous}	RX Combined Over/Under-Shoot	10.0	%
R_r	RX Input Maximum Rise Time	12.5	ns
R_f	RX Input Maximum Fall Time	14.5	ns
R_I	RX Initialize Time	24.0	μs
R_{Iout}	RX Initialize Timeout	185 ± 15.0	μs
R_{dpw}	RX Maximum Pulse Width Distortion	5.0	ns
R_{ber}	Maximum Bit Error Rate	10^{-10}	
TRANSMISSION MEDIA CHARACTERISTICS			
	Fiber Type	Step index, multimode	
	Fiber Material	Core: doped fused silica Cladding: doped fused silica	
D_{core}	Fiber Core Diameter	100 ± 6.0	μm
D_{clad}	Fiber Cladding Diameter	140 ± 8.0	μm
N_{core}	Non Circularity of Core	≤4.0	%
N_{clad}	Non Circularity of Cladding	≤ 4.0	%
$E_{co/cl}$	Concentricity Error Core/Cladding	≤4.0	μm
N_{Ath}	Fiber Numerical Aperture	0.26 ± 0.03	
n_{co}-n_{cl}	Refractive Index Difference (Core/Cladding)	TBD	
D_{cm}	Maximum Net Distortion	3.0	ns
A_{min}	Minimum Transmission Media Attenuation	TBD	dB
A_{max}	Maximum Transmission Media Attenuation	TBD	dB
R_{iso}	FO Jacketing Ambient Light Coupling	-60.0	dBm

Table 2.

Fiber Optic Media Interface Characteristics: Type F-3.2
(Reflective Star Coupled Bus with 200/280 μm Fiber)
(Y Coupler internal to the Optical Transceiver)

Parameter	Description	Requirement	Units
COMMON CHARACTERISTICS			
	Encoding Method	Manchester II	
R_d	Data Rate	20	Mbps
R_s	Signaling Rate	40	MBau d
T_o	Nominal Bit Time	50	ns
T_m	Signaling Time	25	ns
R_{sts}	Short Term Stability	0.01	%
R_{lts}	Long Term Stability	0.03	%
S_p	Preamble Size	40	Bit
S_{itg}	Minimum Intertransmission Gap	$2.0 + S_p \cdot T_o$	μs
W_1	Optical Wavelength Lower	770	nm
W_2	Optical Wavelength Upper	850	nm
B_W	Spectral Bandwidth	<60	nm
TRANSMISSION CHARACTERISTICS			
T_{po}	TX Optical Power (Signal High)	-0.5 ± 3.5	dBm
T_{pr}	TX Residual Power (Signal Low)	$T_{po} - 14.0$	dBm
T_{pl}	TX Leakage Power (TX Off)	-42.0	dBm
T_{plr}	TX Leakage Power Ripple RMS	-60.0	dBm
T_r	TX Maximum Rise Time	10.0	ns
T_f	TX Maximum Fall Time	10.0	ns
T_{dpw}	TX Maximum Pulse Width Distortion	2.5	ns
T_{ous}	TX Combined Over/Under-Shoot	5.0	%
T_I	TX Initialize Time	24.0 to 32.0	μs
T_{ds}	Data Streaming Timeout	$4.15 \pm 20\%$	ms

Table 2. (Continued)

Fiber Optic Media Interface Characteristics:
(Reflective Star Coupled Bus with 200/280 μm Fiber)

RECEIVER CHARACTERISTICS			
R_{po}	RX Maximum Optical Power Input	+7.0	dBm
R_{rec}	RX Recovery Time after R_{po} dBm Input	100	μs
R_{or}	RX Operating Range	25.0	dB
R_{idr}	RX Intertransmission Dynamic Range	23.0	dB
R_{pm}	RX Minimum Optical Power Input	-37.0	dBm
R_{ous}	RX Combined Over/Under-Shoot	10.0	%
R_r	RX Input Maximum Rise Time	12.5	ns
R_f	RX Input Maximum Fall Time	14.5	ns
R_I	RX Initialize Time	24.0	μs
R_{Iout}	RX Initialize Timeout	185 ± 15.0	μs
R_{dpw}	RX Maximum Pulse Width Distortion	5.0	ns
R_{ber}	Maximum Bit Error Rate	10^{-10}	
TRANSMISSION MEDIA CHARACTERISTICS			
	Fiber Type	Step index, multimode	
	Fiber Material	Core: pure fused silica Cladding: doped fused silica	
D_{core}	Fiber Core Diameter	200 ± 3.0	μm
D_{clad}	Fiber Cladding Diameter	278 ± 2.0	μm
N_{core}	Non Circularity of Core	≤2.5	μm
N_{clad}	Non Circularity of Cladding	≤2.0	μm
$E_{co/cl}$	Concentricity Error Core/Cladding	≤1.0	μm
NA_{th}	Fiber Numerical Aperture	0.24	
$n_{co}-n_{cl}$	Refractive Index Difference (core/Cladding)	$(20 \pm 1.2) \cdot 10^{-3}$	
D_{cm}	Maximum Net Distortion	3.0	ns
A_{min}	Minimum Transmission Media Attenuation	15.0	dB
A_{max}	Maximum Transmission Media Attenuation	33.0	dB
R_{iso}	FO Jacketing Ambient Light Coupling	-60.0	dBm

2.4.3 EFA Component Suppliers

A number of companies are currently involved in developing production hardware to the EFA specifications. Listed below are some of the companies associated with the EFA program and the products that they produce:

C-MAC Microcircuits Limited, Norfolk, United Kingdom

Terminal Chip Sets

Fiber Optic Transceivers

Reflective Star Elements

GEC, Rochester, Kent, United Kingdom

Terminal Chip Sets

Litton Scientific, Blacksburg, Virginia, U.S.A.

Fiber Optic Transceivers

Test Boards

Alcatel (SEL) Stuggart, Germany

Terminal Chip Sets

Fiber Optic Transceivers

Reflective Star Elements

Test Boards

Dassault Electronique, Paris, France

Terminal Chip Sets

DDC, Bohemia, New York

MIL-STD-1553B Remote Terminal Chip Sets

Marketing Agent for STANAG 3910 Components

In addition to this list of components a testbed exists at Messerschmitt-Bölkow-Blohm GmbH (MBB) in Munich, Germany. The purpose of this testbed is to insure that all of the system components developed for the EFA Program function as advertised, and are compatible with products from other sources. British Aerospace also has a testbed facility at Bough, UK, where component level compatibility can be tested.

Table 3 presents some of the physical properties of the 3910 components. These factors include physical size and power. The chip set characteristic shown in table 3 are from the CMAC 3910 Optical Kit produced C-MAC Microcircuits Limited, South Denes, Norfolk England. The chip components are produced by C-MAC and the optical transceivers are produced by Litton Scientific, Blacksburg, VA. This chip set includes a separate level converter to match the integrated circuit technology in High Speed Protocol to the circuit technology used in the optical transceivers.

Table 3. Physical Characteristics of STANAG 3910 Components

Component	Power Consumption	Size
Fiber Optic Transceiver	Standby -1.5 watts 50% Transmit - 2.45 watts	50 mm x 30 mm x 14 mm Connector Extension 14 mm
Level Translator	1.1 watts	44 Pin JEDEC LCC
High Speed Protocol (HSP 3910)	1.4 watts Leaded Chip Carrier (LCC)	19.05 mm x 19.02 mm
MIL-STD-1553B chip	Standby-1.2 watts 50% Transmit - 2.4 watts	53 mm x 47.5 mm

It can be seen from this information that a number of sources of hardware capable of supporting a STANAG 3910 overlay of the Space Stations local bus network is available. These components were not designed for the Space environment but have been built to avionic standards where temperature, shock, vibration, vacuum and radiation are design concerns.

2.5 EXAMPLE APPLICATION OF IMPROVED LOCAL DATA BUS NETWORK

As part of this study several potential applications involving the insertion of electro-optic technology into the DMS local bus structure were examined. These studies centered around the addition of STANAG 3910 processing and transmission hardware to existing local bus networks to increase data carrying capacities and speed message and data flow between nodes in anticipation of growing requirements. This section will describe the use of collateral fiber optic pipeline technology to increase downlink data transmission capability for payload module users.

2.5.1 Baseline Payload Module Topology

Payload facilities are designed as a platform for conducting experiments on-board Space Station Freedom. Figure 13 shows a Data Management System view of the data connectivity associated with a typical payload facility. The payload DMS structure is built around a payload FDDI network interconnecting a series of ring concentrators units (RC's). The payload FDDI is interconnected to the Space Station Freedom's core FDDI network through a pair of bridge units (BR's) using ring concentrators. The payload FDDI network is connected to the experimental packages through a ring concentrator and a Standard Data Processor. In this application the SDP has been labeled as PEP, the Payload Executive Processor. The PEP acts as a data bus controller to distribute commands and data, and collect data from the experiments over a series of MIL-STD-1553B local busses. The other end of these local busses interface to Multiplexer/Demultiplexer Units (MDM's) which decode the communications from the SDP and transfer information to the experimental packages through the appropriate effectors. In the same manner data collected by the sensors on the experimental packages are multiplexed together in the MDM's and sent, on command, to the PEP for routing to the crew for on-board monitoring or recording, or to the ground through the appropriate downlink telemetry channels.

Uplink telemetry or commands are provided to the payload facilities from the ground over S-Band radio links via the core FDDI network to the payload FDDI network by means of bridges and ring concentrators on the payload high speed network. A pair of bridges and associated ring concentrators are used between the two ring networks to provide a dual redundant path.

In the current configuration downlink telemetry is provided to the intermediate rate gateway (IRGW) through the ring concentrator, associated with the PEP, the payload FDDI ring network and the ring concentrator associated with the IRGW. Communications is also provided to the Japanese Experimental Module (JEM) through the payload ring network, ring concentrators and the JEM gateway (JEM GW1). Additional communication paths are provided to Columbus through the European Space Agency Gateway (ESA GW2). The IRGW is connected to the high rate data link patch panel (HRDL patch panel) by means of a fiber optic link. The HRDL patch panel acts as a fusion point permitting individual fiber optic lines from the IRGW, fiber optic point-to-point links from the US payload laboratory racks and fiber optic information from the international high data rate payloads to be formed into an 8 fiber optical cable. This cable is used to interconnect the HRDL patch panel with the communications and tracking high rate frame multiplexer (C&T HRFM). The C&T HRFM converts the optical information to electrical format and then multiplexes the input data streams into a composite 42 Mbps data stream for transmission to the ground over the Kμ-Band downlink telemetry system.

2.5.2 Data Communications Constraints

The existing DMS interconnect system associated with the payload module has several data constraints. The payload FDDI network has the potential of supporting data rates of 100 Mbps. However, the network interface adapter between the ring concentrator and the PEP reduces this throughput rate to 10 Mbps at the PEP. The PEP is then interconnected to the experimental packages in the associated payload to the MDM's through a series of standard avionic MIL-STD-1553B data busses. The MIL-STD-1553B data busses are implemented in twisted-shielded pair cabling and each bus is designed to support a 1 Mbps data rate. The maximum throughput rate of this bus design, after removal of the overhead support structure is 748 Kbps. This data transmission rate is sufficient for uplink performance but may inhibit the downlink telemetry of real time experiments, or the support of digitized compressed video. Each of the MIL-STD-1553B data busses must support both the transmission of data to the experimental packages and extraction of data from the experimental packages unless the package has its own interface to the payload network or the HRDL patch panel.

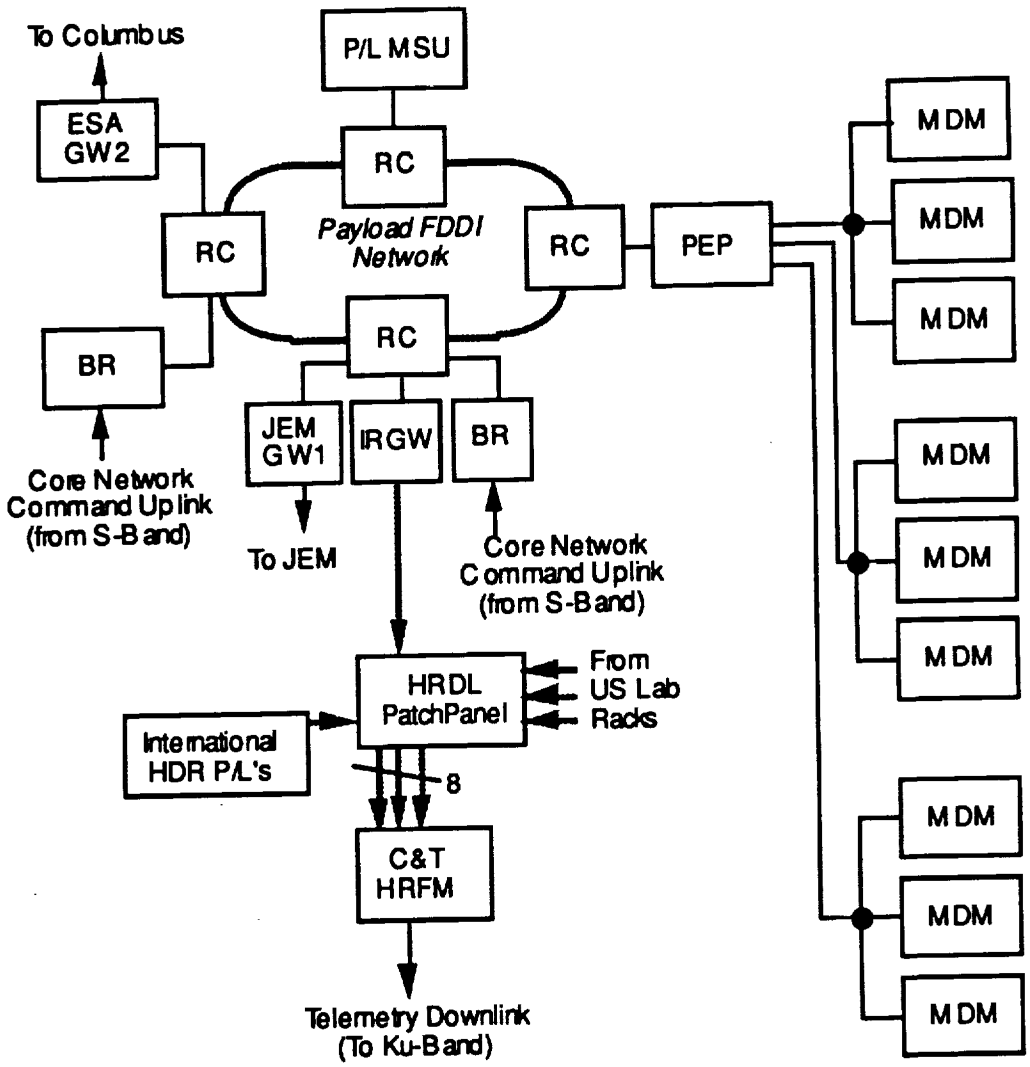


Figure 13. Existing Payload Connectivity to DMS and Telemetry System

2.5.3 Proposed Solution to Increase Payload Downlink Capacity

The proposed solution for increasing the downlink data transmission capability involves the use of a collateral fiber optic pipeline to overlay a portion of the DMS payload. An implementation augmenting the existing payload local bus structure with this fiber optic mechanization is shown in figure 14. On the right side of this figure it can be seen that the MDM's in each experimental group are interconnected together with a passive reflective fiber optic star to form a high speed optical transmission network. The MDM's are interconnected to this fiber optic network through a STANAG 3910 communications chip and a fiber optic transceiver. One port on each optical transmission network is terminated in a device called the Downlink Interface Unit. In a similar manner, a port on each of the MIL-STD-1553B local data busses is also interconnected to the Downlink Interface Unit. Each of the fiber optic and twisted shielded pair lines are terminated in an STANAG 3910 card. This card contains a MIL-STD-1553 transceiver, a STANAG 3910 communications chip and a fiber optic transceiver. The Downlink Interface Unit integrates the STANAG 3910 cards into a data processing backplane together with a TAXI chip, local data processing capability, and perhaps a zone of exclusion recorder.

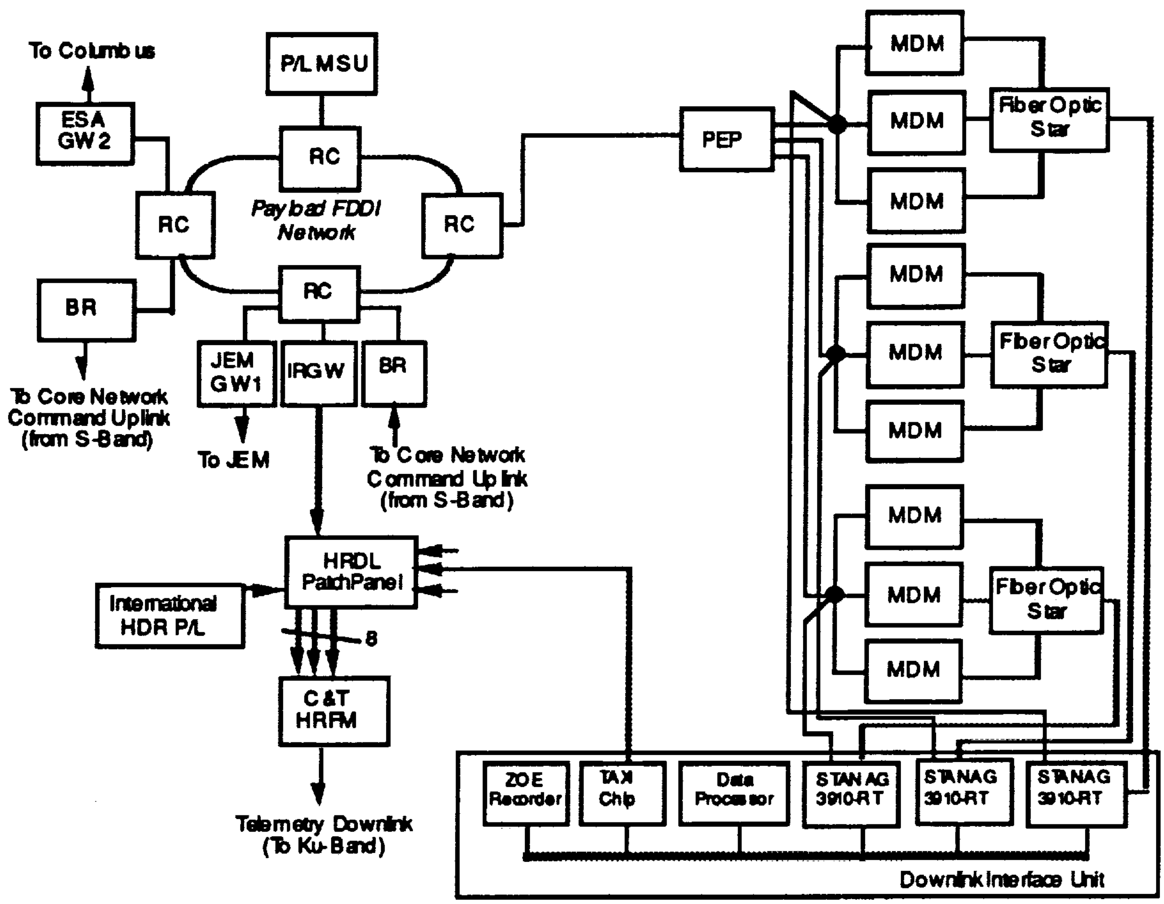


Figure 14. Payload Connectivity of DMS with Improved Downlink Telemetry Capability

When high speed output data is scheduled to be communicated with the ground the PEP sends a series of commands to a selected MDM, associated with experimental data being collected, and STANAG-3910 chip set in the downlink interface unit associated with that downlink data. This action moves the downlink data from an experimental package to be sent to the Downlink Interface Unit through the MDM and fiber optic network. High speed RAM memory is provided on the STANAG 3910 communication card to permit limited buffering of the downlink data. The local processor in the Downlink Interface Unit then reads the data from the STANAG 3910 communications card, reformats the data and presents the data to the TAXI chip in the proper format for downlink transmission via the C&T HRFM. With a high speed backbone, and a high performance local processor, this downlink communications link concept should be capable of supporting data rates approaching the bandwidth limits of the Kμ-Band channel. By providing selection of the experiment to downlink telemetry path, under the PEP control, the Downlink Interface Unit provides a high speed switching function. This switching function can replace the manual point-to-point patching concept currently being proposed. It has been suggested that a zone of exclusion recorder be provided within the Downlink Interface Unit to permit data to stored and then forwarded when the Space Station is out of telemetry range of the designated Kμ-Band receiving stations.

This implementation increases the maximum sustained downlink throughput rate from any experimental package from 0.78 Mbps to 19.2 Mbps. This application can be implemented with transmission hardware which is currently available and has been qualified to operate in an avionics environment. The suggested application augments, and does not replace the current DMS architecture, so that it can be incrementally applied where downlink data rates beyond the capacity of the existing system must be supported.

SECTION 3

APPLICATION OF WDM TO LOCAL AND GLOBAL BUS NETWORK IMPROVEMENTS

This section of the report discusses the use of wavelength division multiplexing (WDM) to improve the throughput and capacity of the local bus and global bus in the DMS. WDM is introduced and then applied to the 3910 improved local bus discussed in the previous section. The concept of spectral sliced WDM is described and then applied to the global bus resulting in a four channel WDM global bus.

The SSF DMS must support on-board communications and data processing functions over the lifetime of the platform. The two topics discussed here indicate that the DMS local and global busses can be easily upgraded providing reserve for unanticipated mission requirements. The global bus can be easily upgraded to a four channel optical FDDI ring on the same fiber by additional optical transmission units. This new technology can be added without altering the global bus fiber plant.

Wavelength division multiplexing was evaluated in this study because it uses the wide band-width of optical fiber to provide simultaneous parallel communication paths in a network that do not interfere with each other. In a WDMA network, the band-width of the fiber is split into a set of discrete bands (wavelengths), and each communication path is assigned a separate wavelength. Each wavelength is used to simultaneously carry data throughout the interconnect network. The salient feature of WDMA networks is the formation of an orthogonal set of discrete wavelength carriers that can be separated, routed, and switched without interfering with each other.

A WDM network has advantages over a single channel high speed network in that the speed of the network interface components operates at the individual channel rate rather than the extremely high data rates required by a time division shared network. With a WDMA network, the electronics for each node need run no faster than the burst rate of that node, unlike conventional single-channel networks, where the electronics operate at the aggregate burst bit rate of all the nodes. Another feature of WDMA networks is their protocol heterogeneity. With WDM, once a connection is set up, there is complete protocol transparency; the network imposes no designated bit rate, framing, coding, error correction, or any of the other functions making up the protocol stack. Pairs of connected ports need only adhere to each other's protocols, and the network can support different kinds of traffic concurrently.

3.1 APPLICATION OF DUAL WAVELENGTH WDM TO IMPROVED LOCAL BUS NETWORK

An enhancement to the 3910 improvements to the local bus discussed in section 2.2 is to add a dual wavelength capability to the 3910 fiber-optic bus. This would result in doubling the throughput and capacity of the fiber bus. The technical feasibility of this approach was examined during this study. The WDM approach makes use of the fiber cable plant that would serve the high speed data path for the 3910 bus discussed in section 2.2.2.

Standard commercial 3910 components operate at the 850 nm wavelength. Operation at the 1310 nm wavelength in addition to 850 nm was evaluated as a part of this study. Figure 15 illustrates the implementation of 3910 using the dual wavelength approach in a dual redundant transmissive star topology. The dual redundant transmissive star architecture was chosen for this evaluation based on the information presented in section 2.2.1. As shown in the figure, each node on the network connects to both the low speed bus and both wavelengths of the high speed bus. Each wavelength shares the low speed 1553 bus for control and requires its own 3910 protocol processor integrated circuit controller. The architecture requires the addition of a 50/50 optical coupler that combines the output bus fibers of each wavelength and couples the optical signals onto the 3910 high speed fiber bus. This coupler is in addition to the standard Y-couplers internal to the individual network transmitter in the transmissive architecture.

The main issues of concern with this approach is the potential for cross talk between the two wavelengths, the optical power budget required to insure reliable data transmission, and the protocol requirements when adding a second high speed data path to each remote terminal address. Each of these issues was evaluated and is described in the following sections.

3.1.1 Optical Cross-talk

The cross-talk between the two wavelengths is a concern in this application because the sensitivity of 1300 nm optical receiver PIN photo diodes at 850 nm is only slightly decreased compared to their sensitivity at 1300 nm. The manufacturer[1] of 3910 transceivers has reported that 850 nm receivers will not be sensitive to 1300 nm signals, but that the 1300 nm receivers will only be approximately 10 dB down at 850 nm [14]. Since the desired cross-talk level is approximately 30 dB down, the incorporation of a long wavelength pass filter in the 1300 nm receiver is required. Figure 16 illustrates the characteristics of the filter from reference [14]. The filter consists of a glass substrate with a multi-layer dielectric coating deposited on one side. The coating causes an interference of light and can reflect some wavelengths and transmit others. The filter is inserted into the pin diode package by the manufacturer. As shown in figure 16, the filter will pass wavelengths above 1100 nm and will solve the cross-talk concerns in the design.

[1] Litton Poly Scientific Inc.

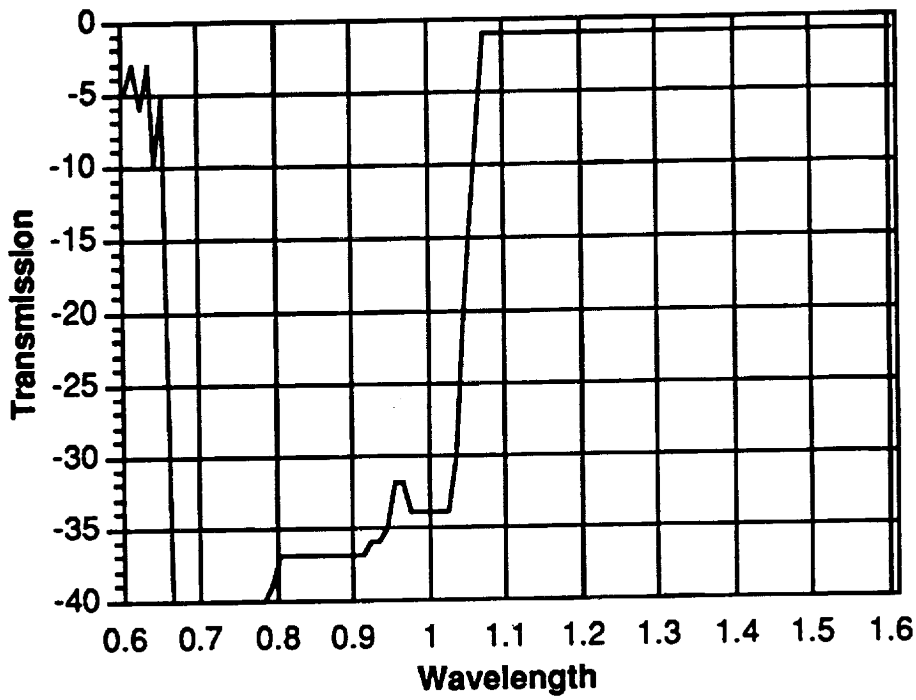


Figure 16. Long Wavelength Filter Characteristic

3.1.2 Optical Power Budget

The second technology issue is the availability of 1300 nm light emitting diodes that will meet the optical power required in the 3910 transmissive star architecture. The 3910 transceivers can be readily modified by the manufacturer[1] replacing the 850 nm LEDs with 1310 nm LEDs. The optical output power is predicted to be -15 dBm and includes the losses in the integral coupler that is standard in these transceivers. This value is 11 dBm lower than the output power of the 850 nm 3910 transceivers. The data presented in table 4 illustrates the power budget for the two wavelengths in the dual wavelength dual redundant transmissive star architecture. The data indicates that a 24 port dual wavelength architecture would just barely meet optical power margin considerations using the Litton LED. Alternative 1300 nm LEDs with higher optical power are available [18] which is a higher power version of the FDDI device[2] currently used in the SSF ring concentrator. The typical output power is -7.8 dBm at 25°C into a 100/140 optical fiber, raising the optical power margin 10.2 dB. These devices are recommended in the dual wavelength design.

---

[1] Litton Poly Scientific Inc.

[2] Fibercom Inc.

Table 4. Dual Wavelength Dual Redundant Transmissive Star 3910 Optical Power Budget

	850 nm	1300 nm
Launch power: (includes integral coupler)	-4 dBm	-15 dBm
810/1300 50/50 coupler losses:	3 dB	3 dB
Star coupler splitting loss (24 port):	13.8 dB	13.8 dB
Star coupler excess loss:	3 dB	3 dB
Receiver sensitivity:	-37 dBm	-38 dBm (includes filter)
Optical Power Margin:	13.2 dB	3.2 dB

3.1.3 3910 Protocol Analysis

As discussed in section 2.2.2.2, the communication takes place on 3910 in a command/response manner. All high speed data transfers are initiated by a message sequence on the low speed bus from the bus controller (BC) to every remote terminal (RT). The protocol was analyzed in this study to determine a method to distinguish message requests for the 850 nm bus from message requests for the 1310 nm bus.

The first word transmitted on the low speed bus to initialize the high speed (HS) data transfer between a particular RT transmitter and the particular RT receiver is a Command Word. A single Data Word follows the Command Word. Figure 17 illustrates the format of the Command Word. The particular RT is addressed using the first five bits. One bit is used to distinguish between transmitting and receiving, the R/T bit. The five bit sub-address field is used to distinguish between commands for the low speed bus and the high speed bus. In a typical 3910 system a single sub-address value, i.e. 26, is used to distinguish data transfer commands for the HS data transfers. The Data Word that follows a Command Word which has its sub-address field set word is known as the HS Action Word and specifies the type of command for the HS bus.

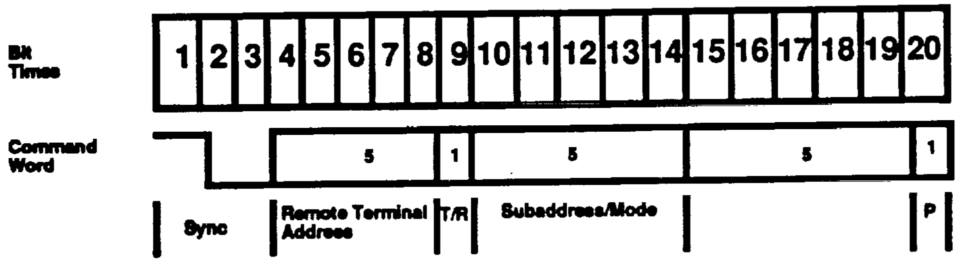


Figure 17. 3910 HS Command Word Definition

Commands for the second wavelength can be distinguished from the first wavelength by using a different sub-address value in the sub-address field. 3910 specifies that the sub-addresses may be assigned under control of the system manager. Each of the two wavelengths will require a 3910 protocol processor chip,. This is because although the chip set sub-address field is programmable, the chip set was designed to process only one address at a time.

3.1.4 Hardware Availability

As a part of this study Litton Poly Scientific, the manufacturer of 3910 interface cards, was contacted [14] for pricing and availability of 810 and 1300 nm 3910 transmission equipment. Fiber optic transceivers are commercially available that meet the 3910 reflective star topology at 810 nm. The devices cost $2230 in small quantities, weight 62-65 grams, and consume 3.02 watts. A similar transceiver at 1300 nm is available and costs $2530 in small quantities. These devices have an integral coupler for the reflective star topology included. A lower power version that consumes 2.07 watts is under development and will be available in the summer of 1993.

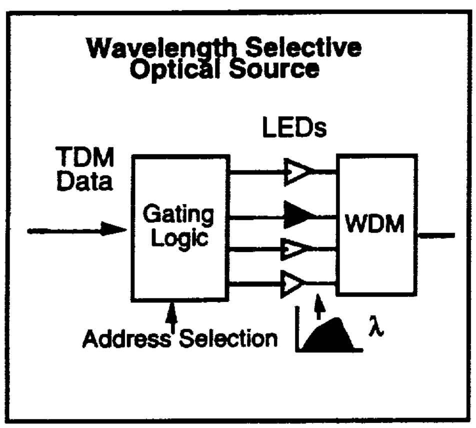
An additional pair of circuit cards are available [14] that can be used in a test-bed for 3910 810 and 1300 nm system transmission tests. Section 4 discusses test-bed options in more detail.

3.2 APPLICATION OF SPECTRAL SLICED TECHNOLOGY TO THE DMS GLOBAL BUS NETWORK

The process of selecting segments of the LED spectrum through filtering is known as spectral slicing and has previously been examined for a number of point-to-point wavelength multiplexing/demultiplexing applications [15,16,17]. The spectral-sliced process employs the broad optical spectrum of LEDs and the bandpass filtering characteristics of a wavelength division multiplexer (WDM) to establish unique output wavelength channels. Each output wavelength is used to simultaneously carry data throughout the interconnect network. Spectral slicing was chosen for this study because it provides a low-cost WDM approach using reliable devices that are reasonably insensitive to temperature variations.

3.2.1 Optical Spectral Slicing Concept

Figure 18 illustrates the spectral slicing concept for a four channel WDM approach. Each of the LED sources shown in the figure has an identical optical output emission spectrum. The output of each source is connected to a WDM input. Gating logic is included to select the LED source used to transmit the serial TDM data stream. As each source is enabled, the filtering characteristics of the WDM device produces a slice of that source's spectrum on the WDM output fiber. The figure illustrates transmission using only the second LED. The corresponding "slice" is shown shaded on the right side of the figure. Simply by selecting the first, second, third, or fourth LEDs to transmit the data, the first, second, third, or fourth slices are produced at the output of the transmit module. In the case where the data is transmitted on each slice simultaneously (multi-cast mode), all four peaks would be shown shaded.



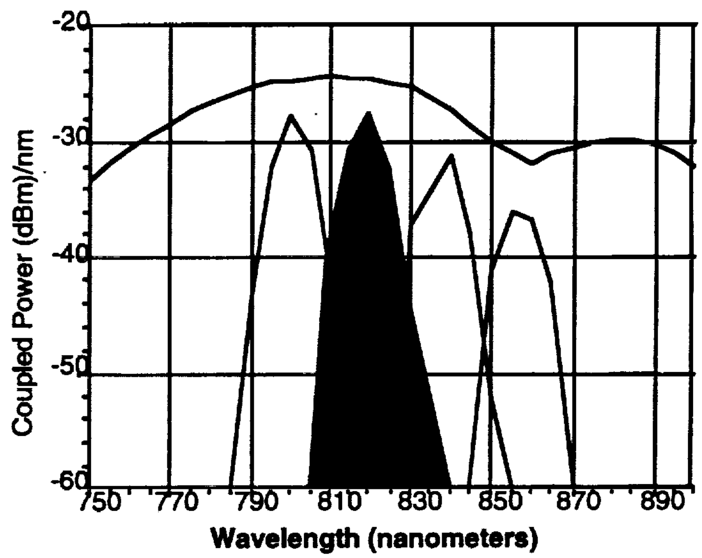


Figure 18. Spectral Sliced Wavelength Division Multiplexing Concept

Figure 19 illustrates the GRIN rod lens and grating used in the WDM device. The WDM is a standard off-the-shelf Littrow device[1] employing a grin rod lens, prism, and blazed grating [19,20]. A multi-wavelength signal on the upper fiber will be collimated by the GRIN rod lens and strike the grating. Different wavelengths are reflected back through the lens and are focused on separate output fibers. The device parameters determine the width and center wavelength of each channel.

The temperature sensitivity studies of these devices have been examined in [21]. Two manufacturing techniques exist for GRIN rods lens fabrication: temperature dependent ion exchange/diffusion and a Sol-Gel process that uses an acid etch during gel phase prior to consolidation of the rod at over 1250 °C. Both devices have been tested from -5 °C to ≈550 °C. Below 250 °C both devices showed no variations in spot size and

[1] Litton Poly Scientific Inc.

shifting in position, but above 250 °C the devices manufactured using the ion exchange fabrication process exhibited variations in spot size and shifting in position. Sandia National Laboratories have tested [21] both devices for radiation resistance and showed the Sol-Gel GRIN rod lens have an order of magnitude more radiation resistance than ion exchange GRIN rod lens.

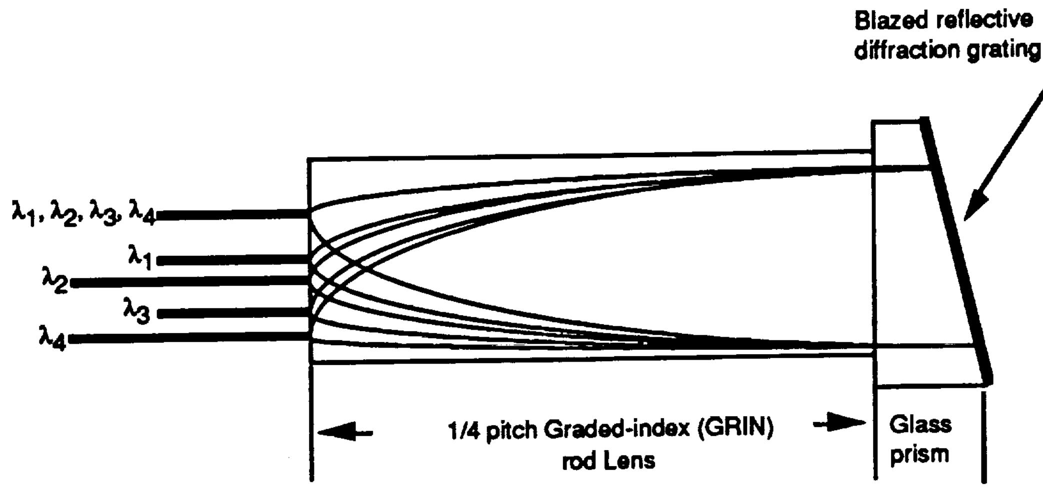


Figure 19. Wavelength Division Multiplexer and Demultiplexer, Littrow Design

A four channel WDM and a set of four FDDI LEDs were used to evaluate a four channel FDDI global bus architecture in this study for the DMS. The architecture of the DMS was evaluated in order to determine if it would support the components required to implement a four channel WDM system. The assumptions made during this architecture analysis were that the existing DMS interfaces between the ring concentrators and the SDP units would remain identical and that the existing FDDI protocol and cable plant would be retained. In order to retain the interfaces, a front end filter is required at every node that will provide a connection for up to four users, one per wavelength channel. The DMS ring concentrators, when used in the multi-wavelength architecture, will have to be redesigned to accommodate simultaneous regeneration of each of the four wavelength channels. Figure 20 illustrates the four wavelength WDM system applied to the core FDDI DMS global bus including the front end node filter units and redesigned ring concentrator.

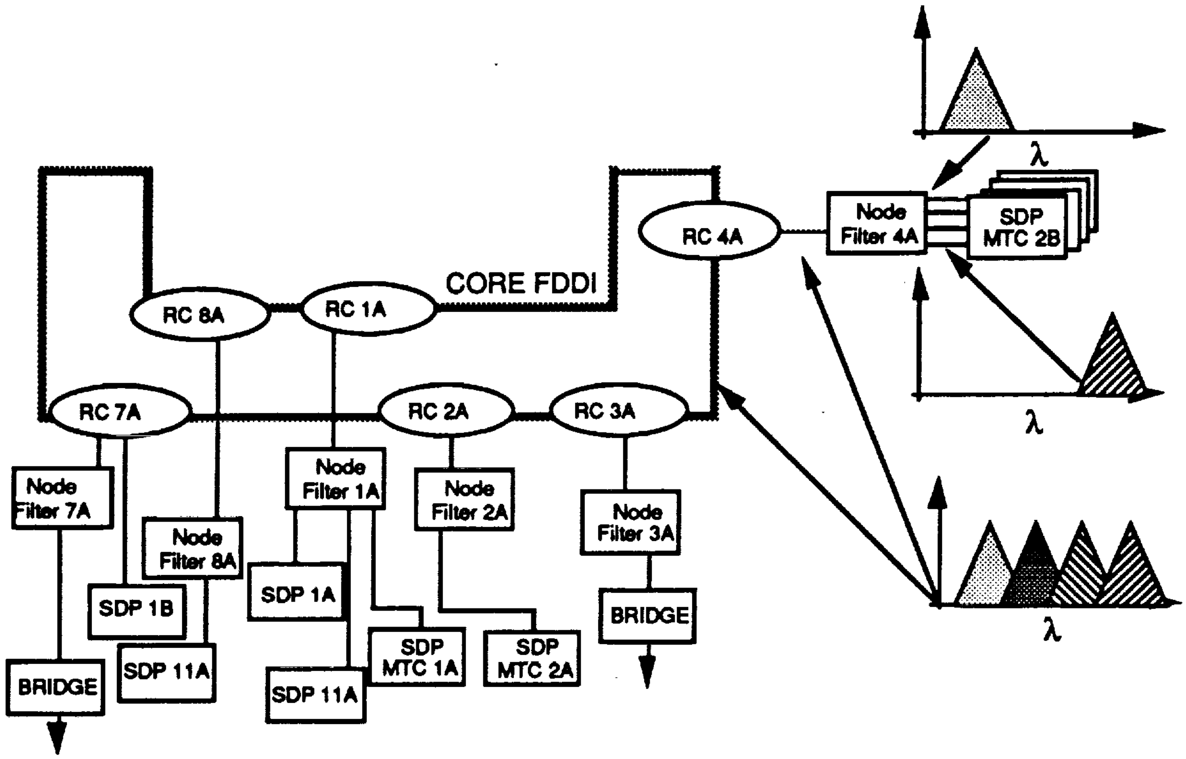


Figure 20. Spectral Sliced Four-wavelength FDDI DMS Global Bus

The DMS ring concentrator as currently designed is illustrated in figure 21. The DMS ring concentrator includes an optical signal regeneration function for user ports 1, 4 and 8. When the device attach signal from a user port is absent, the optical signal regenerator receives and re-transmits the signal. In the case where a user is attached to the port, the optical signal regenerator is bypassed.

The optical signal regeneration function in the redesigned ring concentrator is illustrated in figure 22. The optical signal regenerators divide the composite WDM signal into its appropriate slices prior to optical reception and re-transmission. The re-transmitted signals are combined into the composite WDM signal for transmission to the optical bypass switch in the FDDI ring.

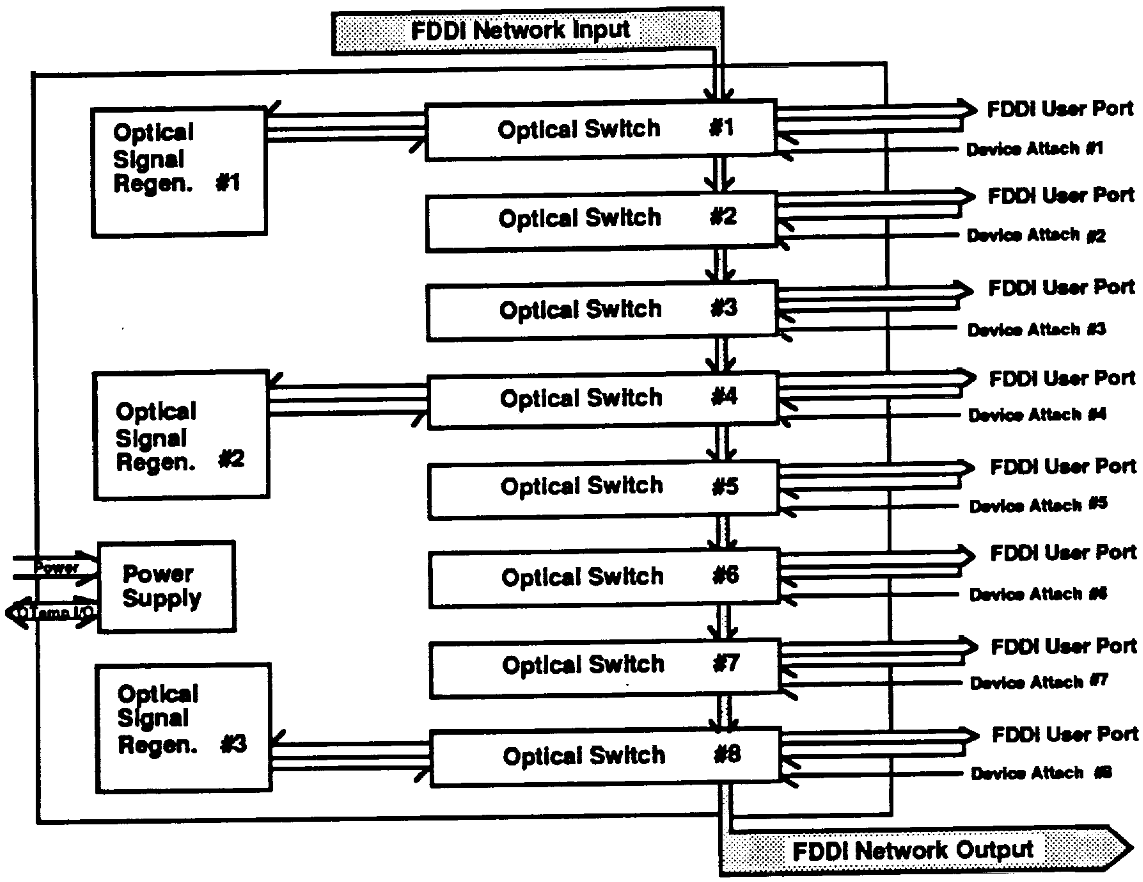


Figure 21. DMS Ring Concentrator

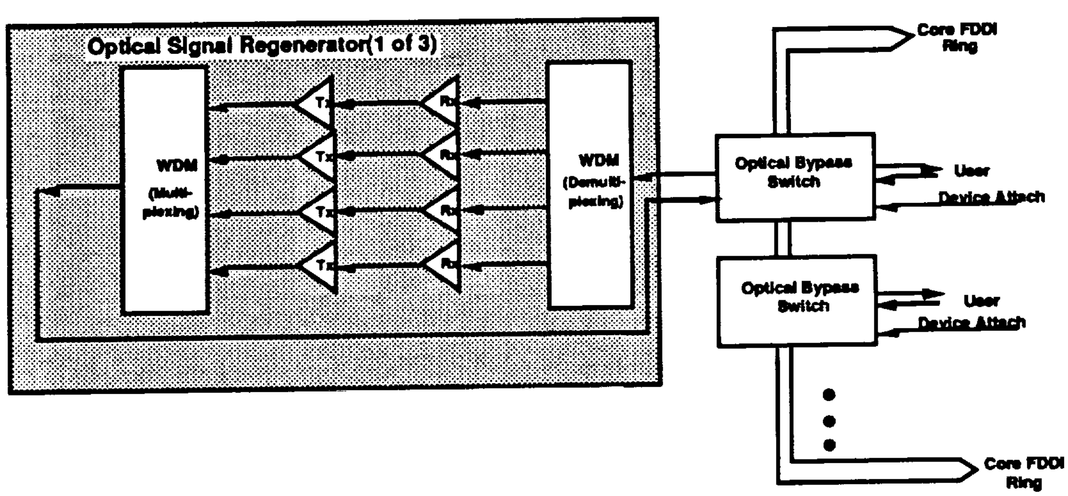


Figure 22. Redesigned Ring Concentrator

The node filter block diagram is illustrated in figure 23. In a similar manner to the optical signal regenerators in the redesigned ring concentrator, the node filter units divide the composite WDM signal into its appropriate slices prior to optical reception. The four electrical switches are controlled by the appropriate user device attach signal. When the device attach signal from a user port is absent, the node filter unit re-transmits the signal. In the case where a user is attached to a port, the signal is re-transmitted to the user. Signals received from the users are received and re-transmitted. The re-transmitted signals are combined into the composite WDM signal for transmission to the ring concentrator in the FDDI ring. Note that the functions included in the node filter units could be combined with the redesigned ring concentrator functions which will result in decreasing the amount of new hardware and power required in the SSF DMS. The architecture is shown broken up into two units for ease of understanding.

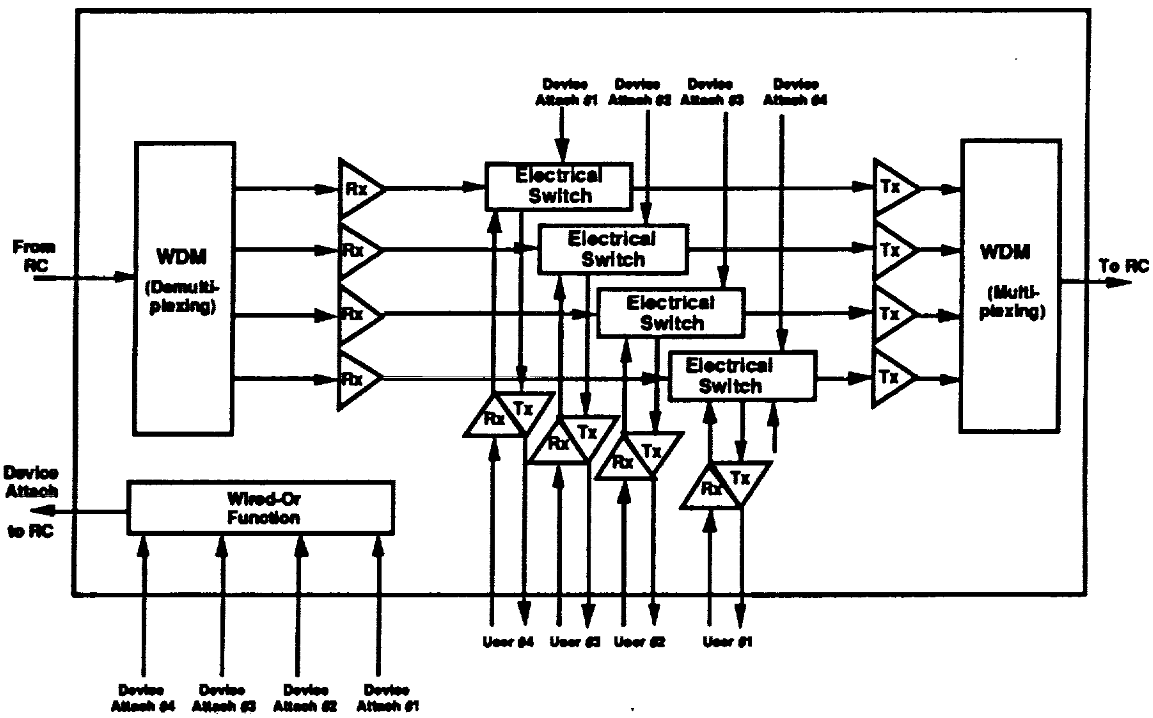


Figure 23. Four Wavelength Filter/regenerator

3.2.2 Optical Power Budget

This section describes a series of measurements and simulation results using several LEDS and a WDM device from Litton Poly-Scientific in the four-channel FDDI system. The simulations are used to examine the optical power margin that can be achieved using the WDM technique in the FDDI ring.

Four LED sources were examined as candidates for spectral slicing in the DMS. These devices are the ELED used in the Fibercom FDDI transmitter currently produced for the U. S. Navy SAFENET program and ARINC 636, the 1A248 and the 1A275 produced by ABB HAFO Inc. of Sweden and the BT&D 1040 produced by BT&D Technologies. The characteristics of the latter three devices were measured in the MITRE Optical Communications Laboratory. The Fibercom device data was estimated from reference [18]. Figures 24, 25, 26, and 27 describe the coupled power versus wavelength characteristics of these devices.

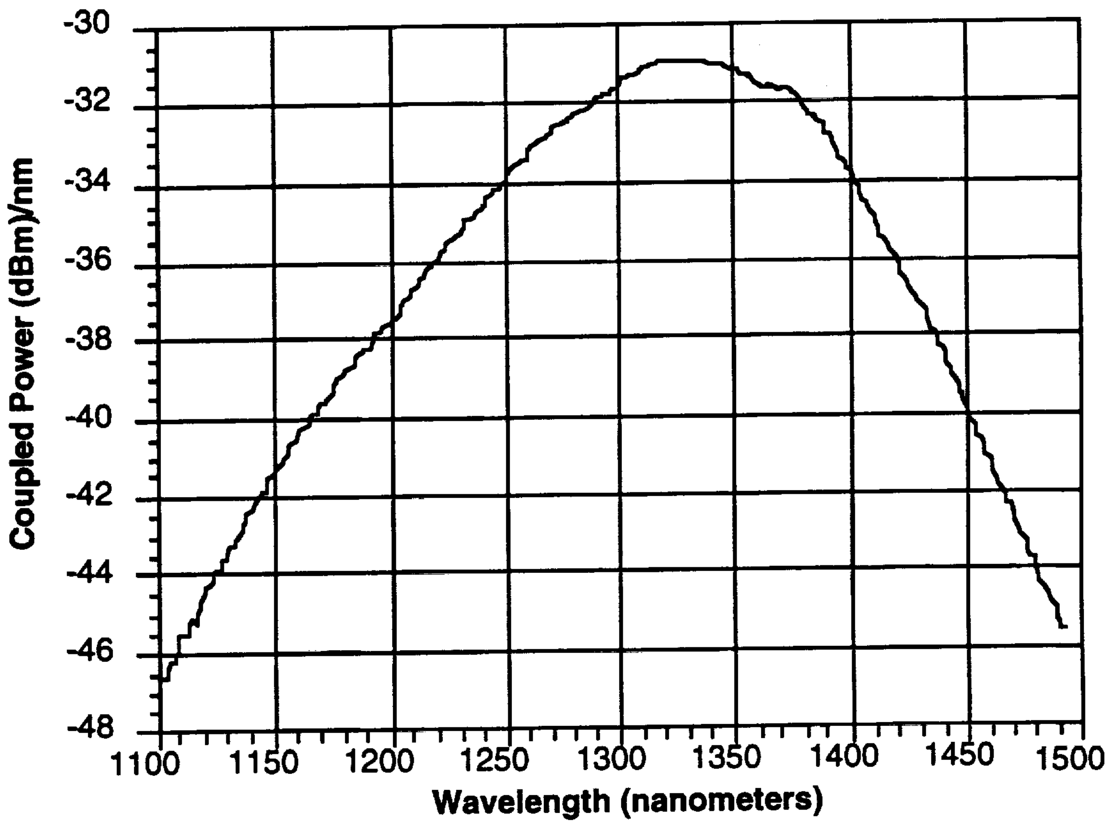


Figure 24. Fibercom FDDI Device Spectrum

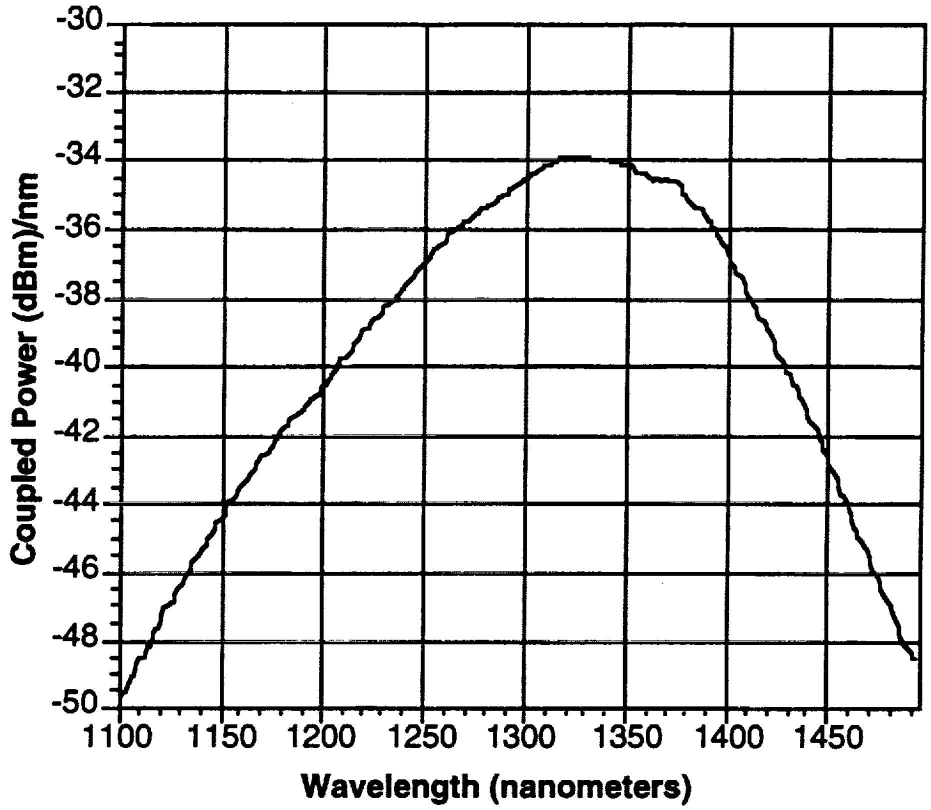


Figure 25. ABB HAFO 1A248 Device Spectrum

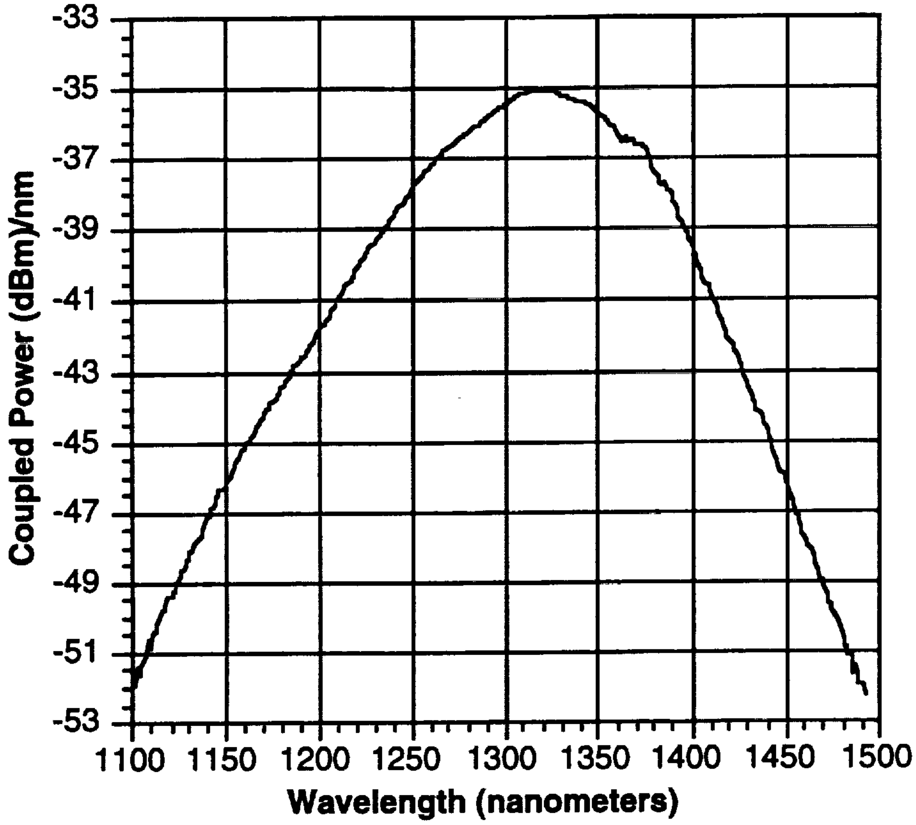


Figure 26. ABB HAFO 1A275 Device Spectrum

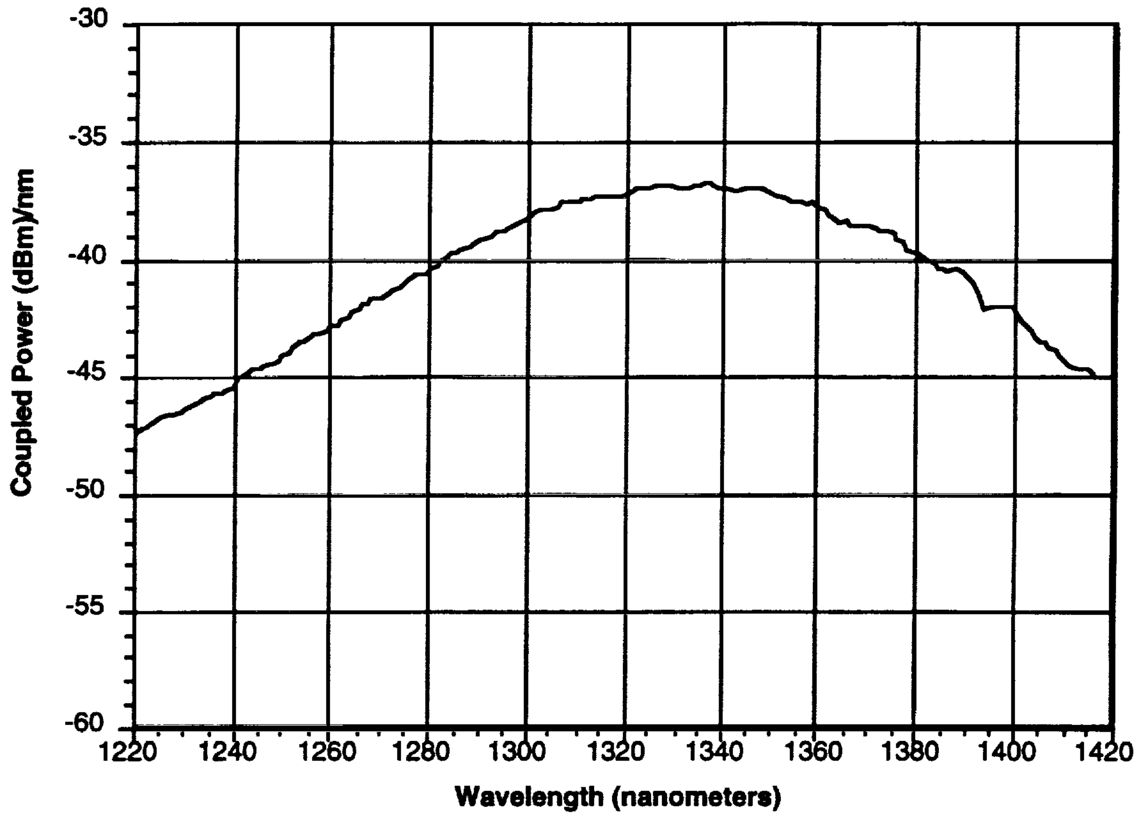


Figure 27. BT&D 1040 Device Spectrum

The Fibercom LED, as shown in figure 24, has a full width half maximum (FWHM) of approximately 149 nanometers [18]. These devices cost about $100 each, in volume greater than 100 units [22]. The measured average output optical power of this device is specified and measured by the manufacturer at -7.8 dBm [18] when coupled into a 100/140 micron fiber at a modulation rate of 125 Mb/s.

The ABB HAFO 1A248, as shown in figure 25, has a full width half maximum (FWHM) of approximately 150 nanometers. These devices cost about $67 each, in volume greater than 100 units. The measured average output optical power of this device was -11.7 dBm when coupled into a 100/140 micron fiber at a modulation rate of 125 Mb/s.

The ABB HAFO 1A275, as shown in figure 26, has a full width half maximum (FWHM) of approximately 150 nanometers. These devices cost about $57 each, in volume greater than 100 units. The measured average output optical power of this device was -13.2 dBm when coupled into a 100/140 micron fiber at a modulation rate of 125 Mb/s.

The fourth LED device measured was a BT&D 1040. This device, as shown in figure 27, has a FWHM of about 100 nanometers. This device was able to couple -13.7

dBm into a 100/140 micron fiber at a modulation rate of 125 Mb/s. These devices cost about $98 each, in volume greater than 100 units.

When the spectrum of the BT&D device and the 1A275 is compared with the Fibercom and the 1A248 device it can be seen that the coupled power, over the entire spectrum of interest, favors the latter two devices.

The WDM device examination undertaken in this study involved measurements of a WDM built by Litton Poly-Scientific of Blacksburg, Virginia. The device was designed to support four channels and was implemented with 62.5/125 micron input fibers and a 62.5/125 micron output fiber. Figure 28 describes the characteristics of the Litton Grin Rod WDM device number 103, as measured in the MITRE Optical Communications Laboratory. This device is designed with a filter FWHM value of 9 nanometers with the wavelength filter peaks on 20 nanometer centers. This device is not suitable for the DMS because it was manufactured for 62.5/125 optical fiber. Since narrow slices were used, the device would incur power losses in excess of optical margins required on SSF. The manufacturer provided measured data from a similar device that could be built using 100/140 optical fiber. Figure 29 describes the characteristics of this device.

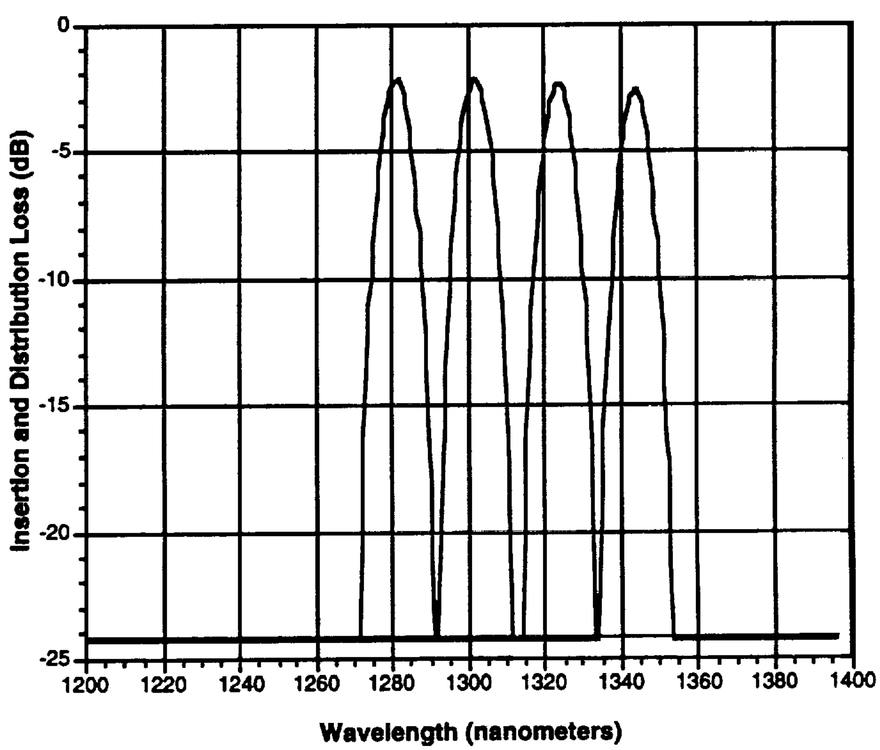


Figure 28. Litton # 103 WDM Device Characteristics

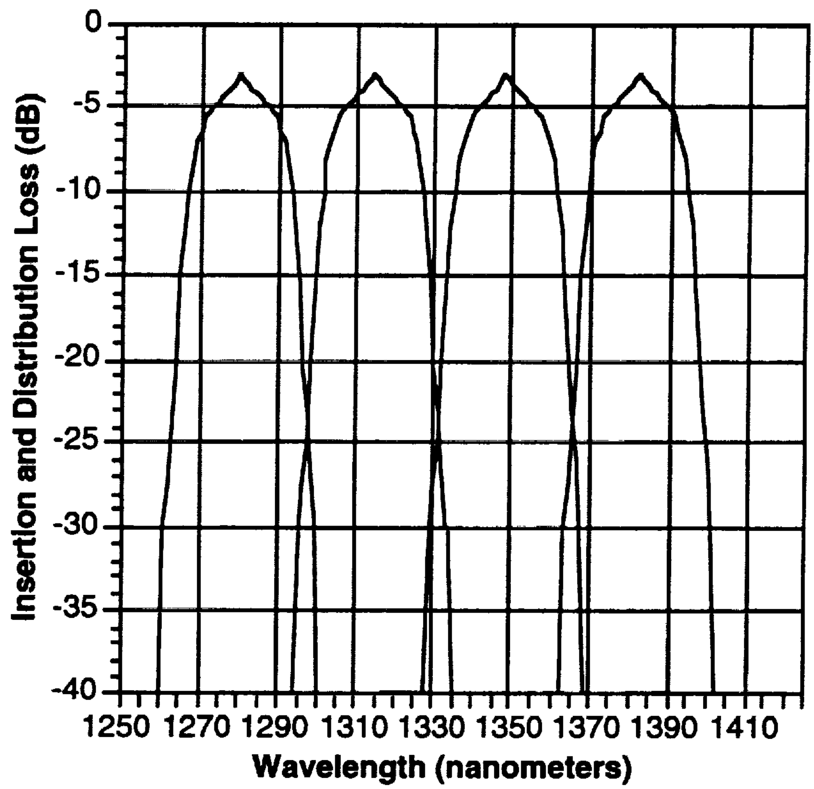


Figure 29. Litton 100/140 WDM Device Characteristics

The analysis of the four wavelength WDM was then extended to examine the application of the four LED sources sliced through two Litton WDM filters. These tests were used to obtain a feel for the cross-talk and distribution loss. The first filter, the multiplexing filter, slices the selected LED input spectrum into the selected optical spectral components. The second filter, the demultiplexer filter, separates the composite signal back into the original optical spectrum components and steers this information to the correct receiver port. The input or multiplex filter is termed the WDM and the demultiplexing or output filter is referred to as the WDDM or demultiplexing WDM filter.

The calculated result of cascading two Litton filters together with the spectrum of a Fibercom LED applied is shown in figure 30. In this diagram the upper curve represents the applied optical spectrum from the LED source. The average applied optical power for this application was -7.8 dBm with a modulated data rate of 125 Mb/s.

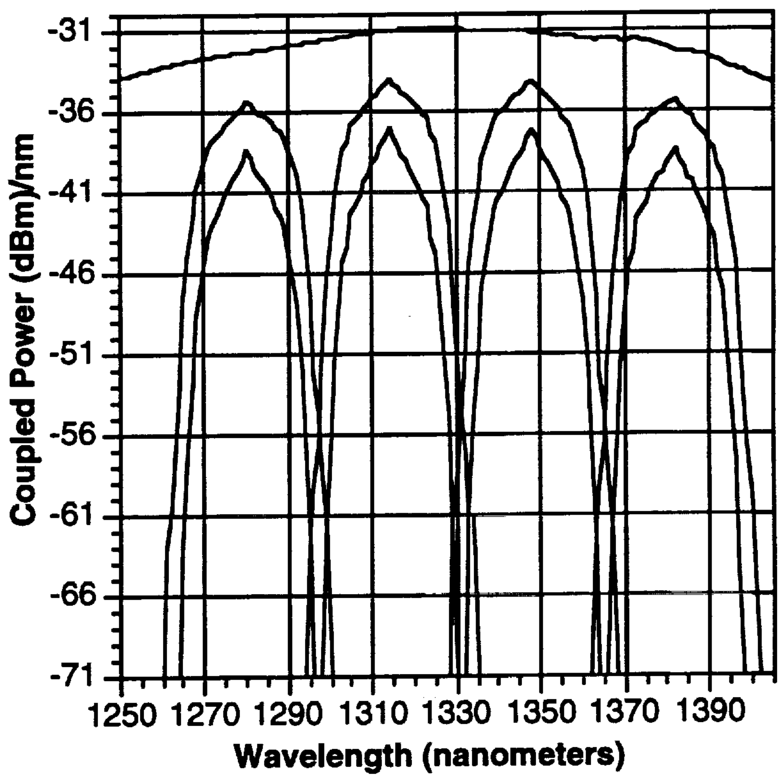


Figure 30. Fibercom/WDM Device Characteristics

The calculated result of cascading two Litton filters together with the spectrum of an ABB HAFO 1A248 LED applied is shown in figure 31. In this diagram the upper curve represents the applied optical spectrum from the LED source. The average applied optical power for this application was -11.7 dBm with a modulated data rate of 125 Mb/s.

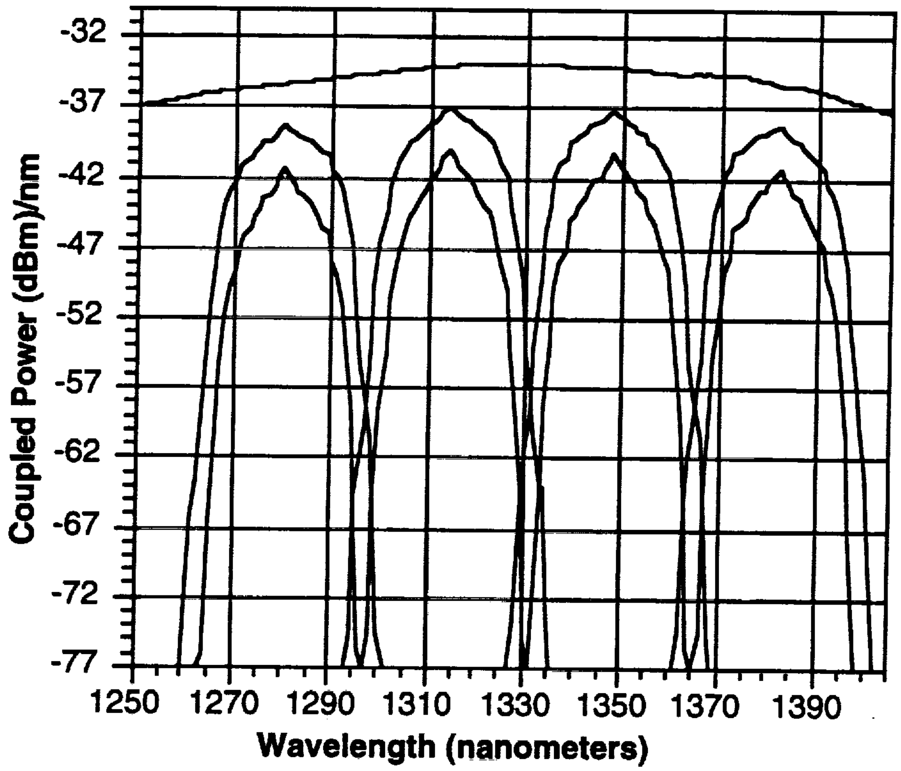


Figure 31. 1A248/WDM Device Characteristics

The calculated result of cascading two Litton filters together with the spectrum of an ABB HAFO 1A275 LED applied is shown in figure 32. In this diagram the upper curve represents the applied optical spectrum from the LED source. The average applied optical power for this application was -13.2 dBm with a modulated data rate of 125 Mb/s.

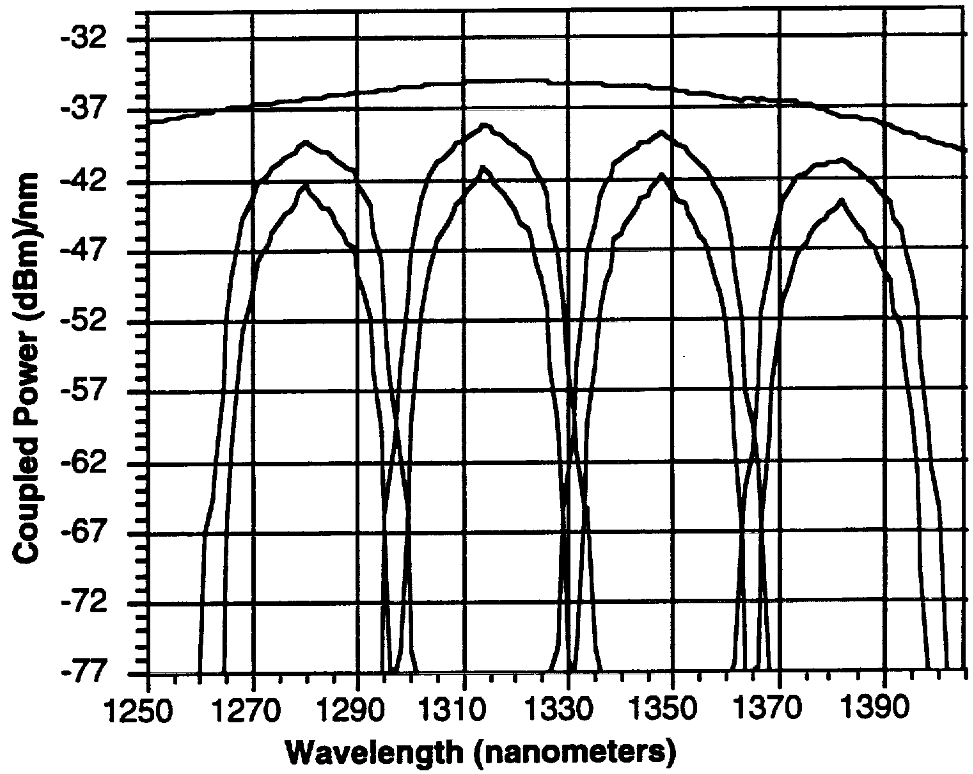


Figure 32. 1A275/WDM Device Characteristics

The calculated result of cascading two Litton filters together with the spectrum of an the BT&D LED applied is shown in figure 33. In this diagram the upper curve represents the applied optical spectrum from the LED source. The average applied optical power for this application was -13.7 dBm with a modulated data rate of 125 Mbps.

As shown in figure 33, the spectral plot of the source is much narrow than any of the three previous LEDs. The rapid narrowing of the LED spectrum along with the low optical output power leads to the worst case power available to the FDDI receiver if this LED were used in a four channel FDDI system. Based on the data shown here, this LED would not be recommended in the design.

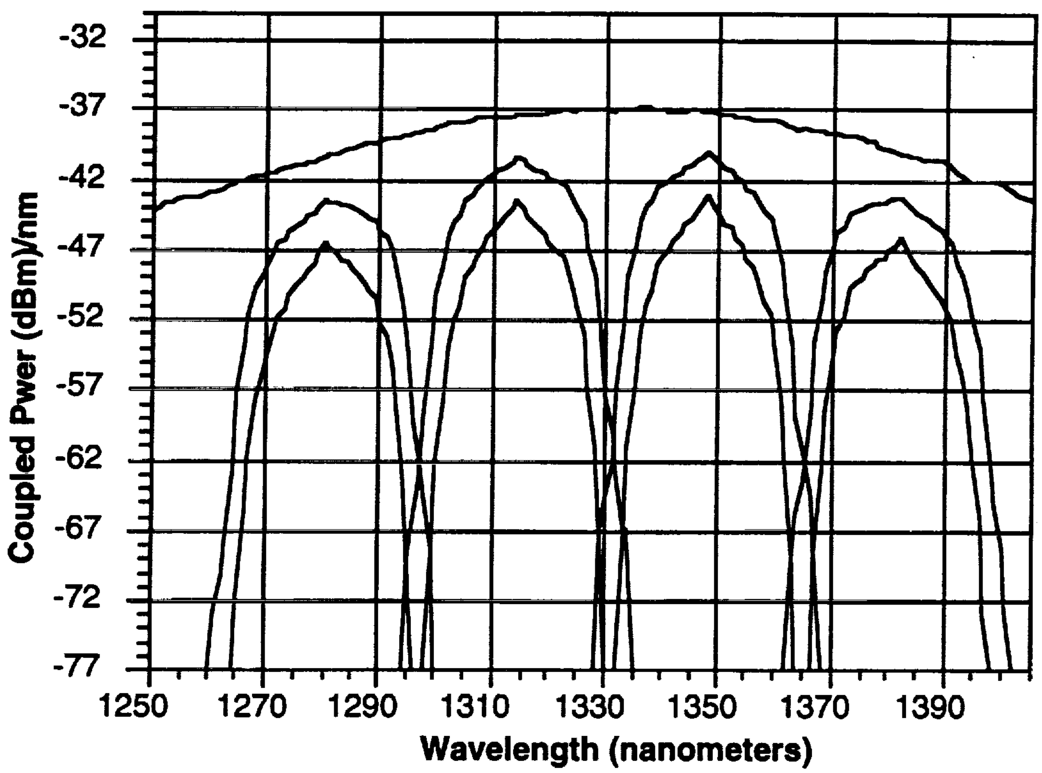


Figure 33. BT&D/WDM Device Characteristics

3.2.3 Optical Cross-talk

Each of the four simulations indicate that the cross-talk as defined by the average optical power of the signal from the adjacent channel, appearing in the channel under examination, is below measurement value. This is due to the spacing of the WDM channels. The WDM devices could be made with wider channels and still have very low cross-talk but this would require a fatter fiber. The very low cross-talk indicates that the 34 nm channel spacing could be decreased and all the channels shifted so that a fifth channel could possibly be accommodated under the LED spectrum, particularly when considering using the Fibercom LED.

3.2.4 Optical Power Budget Analysis

The calculated average optical power at the output of the WDDM for each of the four wavelength channels after losses due to slicing in the WDM and insertion losses in the WDDM are taken into account determines the feasibility of the system. The data presented in table 5 illustrates the power budget for the worst case channel of the four wavelengths for each type of LED. The data indicates that a four wavelength architecture would just barely meet optical power margin considerations using the ABB/HAFO device and the BT&D device but that the higher optical power are available with the Fibercom LED would raise the optical power margin to 7.4 dB. These devices would be recommended in the four wavelength FDDI design.

Table 5. Optical Power Budget for Four Wavelength FDDI Architecture

	Fibercom	1A248	1A275	BT&D
Launch power:	-7.8 dBm	-11.7 dBm	-13.2 dBm	-13.7 dBm
WDM Slicing Loss:	14.4 dB	14.2 dB	14.8 dB	17.2 dB
WDDM Insertion Loss:	4.6 dB	4.6 dB	4.7 dB	4.6 dB
FDDI Receiver Sensitivity:	-34 dBm	-34 dBm	-34 dBm	-34 dBm
Optical Power Margin:	7.4 dB	3.5 dB	2.6 dB	-1.5 dB

SECTION 4

RECOMMENDATIONS

Figure 34 illustrates a test-bed scenario recommended for evaluation of the 3910 applicability to the SSF DMS. The test scenario shown here takes advantage of 3910 test circuit cards available from Litton Poly-Scientific Inc.

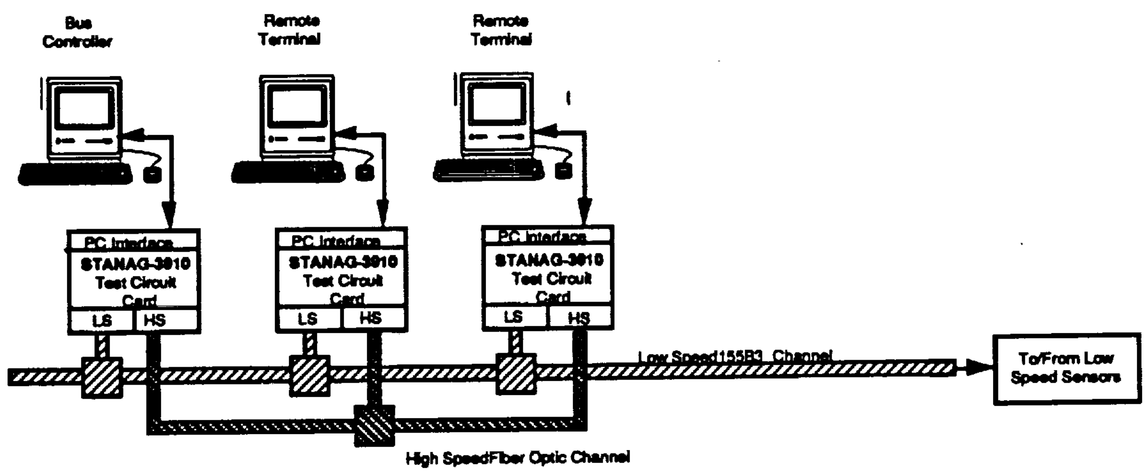


Figure 34. 3910 Recommended Test-Bed

There are two pieces to the Litton test system available for this testbed implementation. Figure 35 illustrates a 3910 test board available from Litton Inc. that could be used to examine the available optical power budget, 3910 protocol issues, and verification of throughput rates for various DMS scenarios. A second test circuit card is inserted into the PC bus to provide an interface between the external 3910 circuit card and the PC. This configuration was initially designed to support temperature and pressure tests of the 3910 components. The circuit cards cost approximately $9200 for the pair. Litton is also able to offer the 3910 test circuit card in a 810 nm and 1300 nm version, permitting testing of the dual wavelength WDM implementation. These circuit cards would cost approximately $9700.

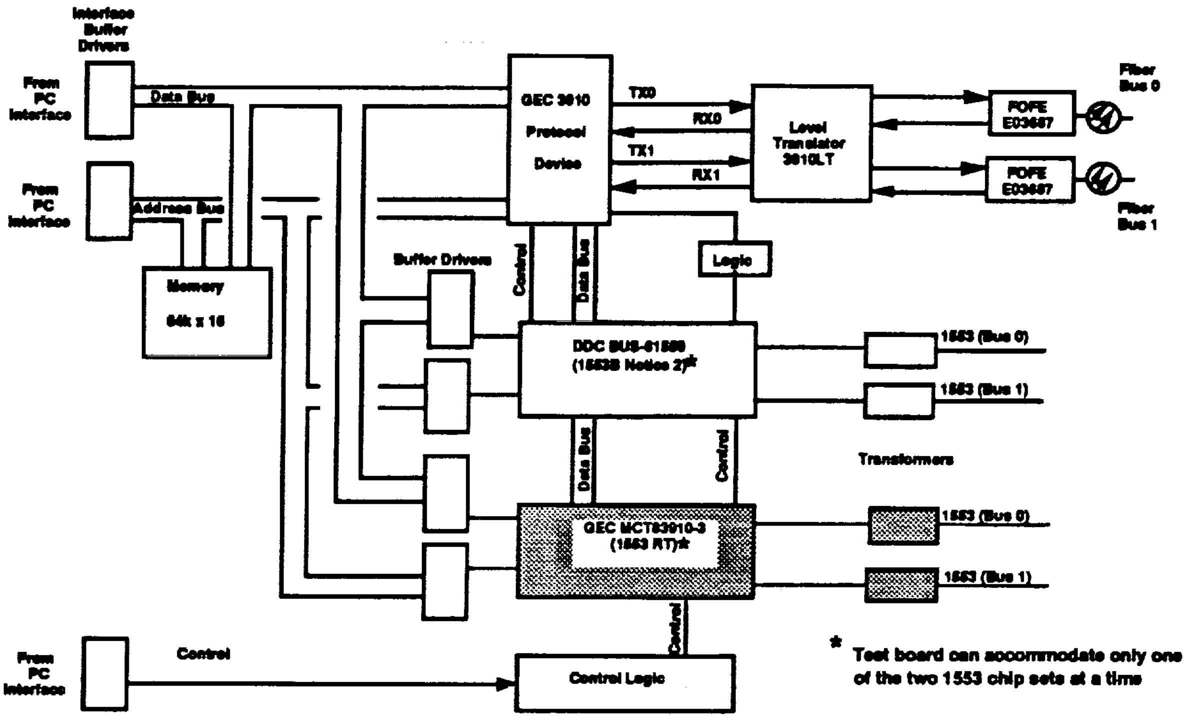


Figure 35. HS 3910 RT PC Test Board

These circuit cards would be adequate to test the 3910 operation and the dual wavelength 3910 operation in the NASA AMES test-bed but since the board does not include recommended 1300 nm LED that is available from Fibercom, a separate board should be procured with the recommended LED device inserted in the high speed channel.

This test-bed would be used to test the effectiveness of 3910 as an augment of the existing DMS local busses. The software hooks that must be placed in the existing DMS software and the hardware scars needed in SSF to support 3910 can be determined using the test-bed. The optical power margins would be examined to determine if the multiple connectors in SSF could be supported. The effect of reducing the system bottlenecks could be examined using the test-bed.

The simulations for the WDM FDDI network discussed in section 3.2 indicated that the optical components exist to support the four channels. It is recommended that prototype hardware be procured to construct a spectral sliced implementation of the four channel FDDI ring network in order to verify the analysis presented in this report. The WDM FDDI network, if proven feasible, could be used to extend the capacity of the DMS FDDI test-bed as well as other NASA installations.

SECTION 5

CONCLUSIONS

This study has evaluated and recommended a low risk design methodology to permit the local bus structures to support increase data carrying capacities and to speed messages and data flow between nodes or stations on the Space Station's Data Management System in anticipation of growing requirements. The recommended design employs a collateral fiber optic technique that follows an avionic standard developed for the European Fighter Aircraft Program. Application of this process will permit a potential 25 fold increase in data transfer performance on the local bus networks used in Space Station Freedom. This concept overlays the current local wire bus network with a fiber optic network, maintaining the functionality of the low speed bus and supporting all of the redundant transmission and fault detection capabilities designed into the existing system.

This study also examined the application of wavelength division multiplexing (WDM) technology to both the local data bus and global data bus segments of the Data Management System to support anticipated additional high speed data transmission requirements. Techniques were examined to provide a dual wavelength implementation of the fiber optic collateral networks. This dual wavelength implementation would permit each local bus to support two simultaneous high speed transfers on the same fiber optic bus structure and operate within the limits of the existing protocol standard. A second WDM study examined the use of spectral sliced technology to provide a four fold increase in the FDDI global bus networks without requiring modifications to the existing installed cable plant. Computer simulations presented in this study indicated that this data rate improvement can be achieved with commercially available optical components.

LIST OF REFERENCES

1. R. Bartlett, G. Davis, T.L. Grant, J. Gibson, R. Hedges, M.J. Johnson, L.K. Liu, A Patterson-Hine, N. Sliwa, H. Sowizral, and J. Yan, "Space Station Freedom Data Management System Growth and Evolution Report," NASA Technical Memorandum 103869, September 1992.

2. "Fiber Optics Mechanization on an Aircraft Intrernal Time Division Command/Response Multiplex Data Bus," MIL-STD-1773, May 20, 1988.

3. "Aircraft Internal Time Division Command/Response Multipex Data Bus," MIL-STD-1553B, September 21, 1978. Notice 1 dated Febuary 12, 1980. Notice 2 dated September 8, 1986.

4. DDC (ILC Data Device Corporation) "MIL-STD-1553 Designer's Guide," 3rd edition, 1990.

5. C. R. Husbands, "Fiber Optic Standards for Avionic Applications," Proceedings of the DoD/ANSI/EIA Fiber Optic Standarization Symposium, pp 70-76, December 1987.

6. Mark Flanegan and Ken LaBel, Small Explorer Data System MIL-STD-1773 Fiber Optic Bus," NASA Technical Paper 3227, June 1992.

7. C. R. Husbands, "The Application of Variable Data Rate Transmission to Local Area Fiber Optic Networks," 6th Conference on Local Computer Networks, pp 102-107, October 1981.

8. C.R. Husbands and R. Katz, "The Application of Multiple Speed Data Rate Transmission to the MIL-STD-1773 Data Bus Structure," 5th AIAA/IEEE Digitial Avionics Systems Conference, pp 12.4-12.6, October 1983.

9. "STANAG 3910 High Speed Data Transmission Under STANAG 3838 or Fiber Optic Equivalent Control," File: STAN3922.DOC, Rev. 1.7, March 1990.

10. H. Birlie, J. Potthaus, W. Steudle, STANAG 3910, High speed Data Transmission under STANAG 3838 (MIL-STD-153) or DoD-STD-1773 Control, Proceedings of the IEEE 1987 National Aeorspace and Electronics Conference (NAECON'87), Vol 1, pp 131-136, June 1987.

11. H. Birli and W. Steudle, The Fiberoptic Databus for Avionic Applications According to Draft Stanag 3910," European Military Fibre Optic and Local Area Network Conference (E-MFOC 88), pp 84-88, June 1988.

12. AECMA (Association Européenne des Constructuerurs de Matériael Aérospatial), "Aerospace Series High Speed Data Transmission under STANAG 3838 or Fiber Optic Equivalent Control," (English Version), prEN 3910, Issue P1, February 1992.

13. H. J. Birili, "STANAG 3910 Terminal Hardware - Overview of the Product Development at the Standard Elektrik Lorenz AG," The Third European Military Fibre Optic and Local Area Network Conference (E-MFOC '90), pp 58-64, June 1990.

14. Norris Lewis, Litton Poly-Scientific, Inc., December 1992, private communication.

15. R. Rund, L. Bersiner, "Experimental Demonstration of Bidirectional WDM Transmission with LED Spectral Slicing," Eighth Annual European Fibre Optic Communications and Local Area Networks Conference (E-FOC 90), Munich, pp 365-368, June 1990.

16. A. Hunwicks, L. Bickers, M. H. Reeves , S. Hornung, "An Optical Transmission System for Single-mode Local Loop Applications Using a Sliced Spectrum Technique," Twelfth International Fiber Optic Communications and Local Area Networks Exposition (FOC/LAN'88), pp. 237-240, September 1988.

17. S. Stuart Wagner, Howard L. Lemberg, "Technology and System Issues for a WDM-Based Fiber Loop Architecture", Journal of Lightwave Technology, Vol. 7, No. 11, pp. 1759-1768, November 1989.

18. Fiber optic hybrid module receiver, Part No. 5211002-01, Specification Control Drawing, Fibercom Inc. November 10, 1992.

19. W. Tomlinson, G. Aumiller, "Optical Multiplexer for Multimode Fiber Transmission Systems," *Appl. Phys. Lett.*, pp. 169-171, Vol. 32, 1977.

20. B. D. Metcalf, J. F. Providakes, "High Capacity Wavelength Demultiplexer with Large Diameter GRIN Rod Lens," *Appl. Opt.*, Vol. 21, p. 794, March 1982.

21. Sol-Gel GRIN Fiber Optic Connectors, Contract #N00019-90-C-0214, Final Technical Report, Gradient Lens Corporation, Rochester, NY, April 30, 1991.

22. Kenneth Ferris, Fibercom Inc. March 19, 1993, private communication.

ACRONYMS

APP	Application
ARC	Ames Research Center
BCU	Bus Control Unit
BIA	Bus Interface Adapter
BIU	Bus Interface Unit
CMOS	Complementary Metal Oxide Semiconductor
CPU	Central Processing Unit
CSA	Canadian Space Agency
C&T	Communications and Tracking
CTS	Communications and Tracking System
DARPA	Defense Advanced Research Project Agency
DMS	Data Management System
DoD	Department of Defense
ECL	Emitter-Coupled Logic
EDP	Embedded Data Processor
EEPROM	Electronically Erasable Programmable Read Only Memory
EFA	European Fighter Aircraft
ESA	European Space Agency
FC/PC	Fiber Connector/Physical Contact

FDDI	Fiber Distributed Data Interface
FDIR	Fault Detection, Isolation, and Recovery
FMEA	Failure Modes and Effects Analysis
FWHM	Full width half maximum (filter bandwidth definition)
F/W	Firmware Controller
GaAs	Gallium Arsenide
GN&C	Guidance, Navigation, and Control System
GPC	General Purpose Computer
GSFC	Goddard Space Flight Center
GW	Gateway
HRDL	High-Rate Data Link
HRFM	High Rate Frame Multiplexer
IEEE	Institute of Electrical and Electronics Engineers
I/O	Inputs and Outputs
IOUC	I/O control unit
IRGW	Intermediate Rate Gateway
ISES	Information Sciences Experimental System
ISO	International Standards Organization
JEM	Japanese Experiment Module
JSC	Johnson Space Center

kbps	Kilobit Per Second=10^3 Bits Per Second
LAN	Local Area Network
LaRC	Langley Research Center
LED	Light Emitting Diode
Mbps	Megabit Per Second-10^6 Bits Per Second
MB	Megabyte
MDM	Multiplexer-Demultipexer
MDSSC	McDonnell Douglas Space Syatems Company
MILSPEC	Military Specification
MIL-STD	Military Standard
MIPS	Million Instructions Per Second
MMU	Memory Management Unit
MPAC	Multippurpose Application Console
MSU	Mass Storage Unit
NATO	North Atlantic Treaty Organization
NIA	Network Interface Unit
NOS	Network Operating System
ORU	Orbital Replaceable Units
OS	Operating System
OSI	Open Systems Interconnection

PC	Personal Computer
PEP	Payload Embedded Processor
PIN	Positive-Instrinic-Negative Photodiode
P/L	Payload
PMC	Permanent Manned Configuration
PWR	Power
RAM	Random Access Memory
RC	Ring Concentrator
RF	Radio Frequency
ROM	Read-Only Memory
RT	Remote Terminal
SDP	Standard Data Processor
SM	System Management
SOS	Silicon on Sapphire
SSF	Space Station Freedom
STANAG	NATO Standard Aggrement
TCP/IP	Transmission Control Protocol/InternetProtocol
TCS	Thermal Control System
TDRSS	Tracking and Dat Relay Satellite System
TGU	Time Generation Unit

WDM	Wavelength Division Multiplexing
WDDM	Wavelength Division DeMultiplexing
ZOE	Zone of Exclusion

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 1993	Contractor Report

4. TITLE AND SUBTITLE

Application of New Electro-Optic Technology to Space Station Freedom Data Management System

5. FUNDING NUMBERS

NASW-4358

6. AUTHOR(S)

C. R. Husbands and M. M. Girard

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

The MITRE Corporation
Burlington Road
Bedford, MA 01730

8. PERFORMING ORGANIZATION REPORT NUMBER

A-93117

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA CR-177622

11. SUPPLEMENTARY NOTES

Point of Contact: Terry L. Grant, Ames Research Center, MS N269-4, Moffett Field, CA 94035-1000; (415) 604-4200

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified — Unlimited
Subject Category 17

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This study has evaluated and recommended a low risk design methodology to permit the local bus structures to support increased data carrying capacities and to speed messages and data flow between nodes or stations on the Space Station Freedom Data Management System in anticipation of growing requirements. The recommended design employs a collateral fiber optic technique that follows a NATO avionic standard that is developed, tested, and available. Application of this process will permit a potential 25 fold increase in data transfer performance on the local wire bus network with a fiber optic network, maintaining the functionality of the low-speed bus and supporting all of the redundant transmission and fault detection capabilities designed into the existing system.

This study also examined the application of wavelength division multiplexing (WDM) technology to both the local data bus and global data bus segments of the Data Management System to support anticipated additional high-speed data transmission requirements. Techniques were examined to provide a dual wavelength implementation of the fiber optic collateral networks. This dual wavelength implementation would permit each local bus to support two simultaneous high-speed transfers on the same fiber optic bus structure and operate within the limits of the existing protocol standard. A second WDM study examined the use of spectral sliced technology to provide a fourfold increase in the Fiber Distributed Data Interface (FDDI) global bus networks without requiring modifications to the existing installed cable plant. Computer simulations presented in this study indicated that this data rate improvement can be achieved with commercially available optical components.

14. SUBJECT TERMS

Fiberoptics, MIL Standard 1553B, Wavelength division multiplexing

15. NUMBER OF PAGES 83

16. PRICE CODE A05

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified		