Airport Fiber Optic Communication System Standards

1. SCOPE

1.1 **Scope**. This document establishes the standards for design and implementation of fiber optics based communication systems at Level III, IV, and V airports in accordance with the requirements of FAA-ORDER-6000.36, *Communications Diversity*, and FAA-ORDER-6950.23, *Cable Loop Systems at Airport Facilities*, and the guidance of FAA-ORDER-6650.8, *Airport Fiber Optic Design Guidelines*.

1.2 **Purpose**. The purpose of this standard is to establish a FAA-wide standard design and FAA-wide standard implementation of a Fiber Optic Communication System (FOCS):

(a) Provides a design of proven performance, reliability, maintainability, and availability;

(b) Provides a design based on a limited set of system components and a limited set of manufacturers/models in order to facilitate the cost-control management of the National Airspace Integrated Logistics Support (NAILS);

(c) Promulgates an implementation based on a standard documentation set.

2. REFERENCED DOCUMENTS.

2.1 General. The following documents of the current issue are a part of this standard but, are applicable only to the extent specified herein.

2.2 FAA Documents.

FAA-C-1391	Installation and Splicing of Underground Cables
FAA-E-2761	Cable, Fiber Optic, Multi-mode, and Single-Mode, Multi-fiber
FAA-E-2789	Controller, Programmable, Monitor and Control
FAA-E-2810	Radar Transmission System, Fiber Optic
FAA-E-2820	Multiplexer-Demultiplexer (MULDEM) Optical Transceiver, Drop-and-Insert
FAA-ORDER-6000.30	Policy for the Maintenance of National Airspace System (NAS) Through the Year 2000
FAA-ORDER-6000.36	Communications Diversity
FAA-NOTICE-6000.183	Remote Maintenance Monitoring Interfaces
FAA-ORDER-6090.1	Development and Implementation of Remote Monitoring Subsystems (RMS) within the National Airspace System (NAS)
FAA-ORDER-6650.8	Airport Fiber Optic Design Guidelines
FAA-ORDER-6650.10	Maintenance of Fiber Optic Communications Equipment
FAA-ORDER-6950.23	Cable Loop Systems at Airport Facilities
FAA-ORDER-6950.27	Short Circuit Analysis and Protective Device Coordination Study
FAA-STD-019	Lightning Protection, Grounding, Bonding, and Shielding Requirements for Facilities and Equipment
NAS-SS-1000	National Airspace System (NAS) System Specification

2.3 National Fire Protection Association.

NFPA 70	National Electric Code

3. REQUIREMENTS.

3.1 General.

3.1.1 **Network configuration**. To limit the impact of failures upon the National Airspace System (NAS), facilities which are functionally independent of one another from a providing-a-service perspective shall not be included in a common network within which they would be subject to sharing a common failure. Because the availability of any network is related to the number of included nodes, the number of nodes per network shall be limited. In the case of RTs, RRs, ASRs, and a Tower network that would interconnect the base building and subjunction level equipment rooms, the number is limited to two. In the case of the network provided for runway associated facilities, in which all included facilities are required to provide the service, the actual number will be dictated both by cost effectiveness and the requirement to provide circuit and path diversity for the most critical services. At most a Runway network would include a node at the ATCT and nodes at the opposing glide slopes and at the opposing localizers. Figure 1 depicts a representative configuration.

3.1.2 **Network architecture**. To ensure optimum availability of a NAS service, the network providing its communication requirements shall incorporate maintainable and inherently reliable system components and features associated with dependable systems[1]:

(a) In accordance with FAA-ORDER-6090.1, *Development and Implementation of Remote Monitoring Subsystems (RMS) within the National Airspace System (NAS),* Remote Monitoring Subsystem (RMS) functionality shall be provided for each network/component;

(b) A back-up system is an integral component of any system specified to have a high degree of dependability:

(1) The back-up system shall include demarcation-to-demarcation redundancy to limit the common points of failure. In general, common points of failure shall be limited to magnetically-latching relay-based transfer switches at the point of demarcation.

(2) Effective physical separation/isolation of the cables servicing the back-up system from the cables servicing the primary system.

(3) The availability of the back-up system shall be continually validated to preclude the possibility of an undetected failure in its common equipment.

[1] In general, the extent to which the implementation shall include features that ensure both reliability and maintainability shall be commensurate with the importance of the service being provided to the NAS and airport operations.

(c) The RMS shall effect switching automatically upon failure or by command from the Maintenance Processor Subsystem (MPS).

3.2 **Implementation/Planning**. The project implementation process is defined by four discernible phases: coordination, site survey/assessment, site adaptation, and installation/test.

3.2.1 **Coordination.** Effective coordination with affected parties both internal and external to the FAA is required.

3.2.1.1 **Internal to the FAA**. Coordination and effective communication is required with System Support Center (SSC) and System Management Office (SMO) personnel, the Air Traffic System Requirements Service, the NAS Implementation Center, the NAS Engineering Center, and assigned NAILS personnel.

3.2.1.2 **External to the FAA.** Coordination will be required with the utilities, any non-government property owners which would sell or lease necessary assets, state and/or municipal government with which any agreements for property use will be required, and any agencies which will issue any required permits and/or waivers.

3.2.2 **Site assessment/survey.** A comprehensive site survey/assessment, including a survey for the presence of hazardous materials, and review of the Airport Master Plan (AMP) shall be conducted to identify future requirements in order to facilitate a cost effective adaptation of the standard FOCS to a specific site.

FAA and Airport Authority/Sponsor utility plan drawings shall be reviewed to assess the availability of conduit. Facilities where FOCS equipment is to be installed shall be inspected and documented with respect to the impact of its installation on space, power, heating, ventilation, and air conditioning (HVAC).

3.2.3 **Site adaptation.**

3.2.3.1 **Loop implementation.** The loop routing shall minimize the cost associated with installing the cable infrastructure without compromising the integrity of the cable loop concept.

3.2.3.1.1 **Duct installation requirements**. It is generally recommended herein, and it is becoming increasingly common at Level IV and Level V airports for it to be required by the airport sponsor, that the cable be installed in concrete encased duct bank. However, when concrete encasement is not required by the airport sponsor, duct (duct bank) shall be installed in accordance with, FAA-C-1391, *Installation and Splicing of Underground Cables,* within the Airport Operations Area (AOA). Outside of the AOA, only rigid steel or concrete encased duct bank shall be acceptable.

A magnetically-detectable marker-ribbon or copper wire shall be included in the duct installation. If copper wire is used, it shall be in accordance with FAA-C-1391, *Installation and Splicing of Underground Cables,* paragraph 3.4.6.

All new duct installation shall be specified to be filled to capacity with inner duct.

All inner duct shall include a pull-tape/rope; and all duct and/or inner duct shall be sealed to prevent entry of water, rodents, and/or insects.

3.2.3.1.2 **Manholes/hand-holes requirements.** When only fiber optic cable is to be installed, the recommended spacing of manholes or hand holes is 600 feet; however spacings of up to 2,000 feet may be feasible. Marking of manholes, hand holes, cable, and cable routing shall be in accordance with FAA-C-1391, *Installation and Splicing of Underground Cables.*

3.2.3.1.3 **Cable**. The cable shall satisfy FAA specification FAA-E-2761, *Cable, Fiber Optic, Multi-mode, Single-mode, Multi-fiber*. The following additional requirements shall be adhered to with respect to the installation of the cable infrastructure:

(a) Installation within facilities shall be in accordance with the *National Electric Code.*

(b) If the cable is to be installed in duct/man-holes where exposure to aircraft fuel is probable, Type B cable shall be specified.

(c) The number of spare fibers to be specified shall be 50% of the number necessary for existing requirements, plus 50% of the number projected for requirements from the five year plan.

(d) The bi-directional attenuation profile of all fibers shall be measured before and after installation in accordance with FAA-ORDER-6650.10, *Maintenance of Fiber-Optic Communications Equipment*, to verify that the fibers were not adversely affected by installation induced stresses.

(e) All splices shall be specified to be fusion type. Mid-field splicing of cables, although not specifically prohibited, should be avoided. Due to the concern of splice enclosures being immersed in water subject to freezing, in-manhole splicing is acceptable only if freezing and flooding due to poor drainage (or a high water table) is not an issue. If freezing is an issue, the cable installation plan shall be revised, if necessary, to allow for the installation of an above-the-ground pedestal mounted splice enclosure. Non-fusion splices shall be used for emergency repairs only, and shall be replaced with fusion type splices as soon as practical.

(d) Within a shelter and within practical limits, the requirement to provide cable diversity shall be addressed throughout its routing.

3.2.3.2 **Equipment adaptation**. Site-specific equipment adaptation shall be limited to interface module selection. Only simple passive signal conditioning such as providing a diode, capacitor, or resistor at an input or an output terminal block demarcation shall be allowed. Commercially acquired modules or circuit boards shall not be modified in any way.

3.2.3.3 **Software adaptation**. Site-specific software adaptations shall be effected by selecting the appropriate FOCS standard sub-routines to operate with the FOCS standard executive routine.

Site-specific software adaptations of the FOCS standard graphics-based maintenance subsystem software shall be limited to the development of site-specific graphics.

3.2.3.4 **Deviations**. All proposed deviations from the FOCS standard shall be submitted to the EC for review and configuration approval. The FOCS standard design and installation documentation shall be revised to reflect all approved site-specific adaptation. All site-specific revisions of the standard shall be indicated in the documentation as having been approved changes.

3.2.4 **Installation and test**.

3.1.4.1 **Racks and equipment**. The wiring and installation of racks and equipment shall be in accordance with FAA-ORDER 6950.019, *Lightning Protection, Grounding, Bonding, and Shielding Requirements for Facilities and Equipment*. The fastening of equipment enclosures/racks to floors and walls shall comply with local building codes.

3.2.4.2 **Short circuit analysis**. A short circuit analysis shall be conducted in accordance with FAA-ORDER-6950.27, *Short Circuit Analysis and Protective Device Coordination Study.*

3.2.4.3 **Uninterruptible Power Supply (UPS) requirements**. UPSs shall be furnished in accordance with requirements stipulated in section 3.4.1.1(c), 3.4.2.1 (c), and 3.4.3.3 (d).

3.2.4.4 **Testing.** The FOCS shall be tested in accordance with FAA-ORDER-6650.10, *Maintenance of Fiber-Optic Communications Equipment*, and site-specific end-to-end testing of circuits, and site-specific validation of alarm/alert detection.

3.3 **Remote Monitoring Subsystem (RMS).** Programmable Logic Controllers (PLCs) shall provide RMS functionality for each of the FOCS networks. At nodes that provide both MAIN and STANDBY equipment, the MAIN PLC shall interface to the STANDBY FOCS components and, conversely, the STANDBY PLC shall interface to the MAIN FOCS components. The PLCs of each of the FOCS networks at the ATCT/TRACON shall interface to a FOCS Graphics-based Display Terminal System (GDTS):

(a) The GDTS shall function as the FOCS-wide RMS concentrator. It shall provide on-airport graphical depictions of each of FOCS networks based on RMS data and shall interface to the MPS using Simple Network Management Protocol (SNMP) per FAA-NOTICE-6000.183, *Remote Maintenance Monitoring Interfaces*.

(b) The PLC shall be programmed to provide a common response to the MPS for each of the functional module types which comprise a FOCS regardless of manufacturer.

(c) Switching between FOCS MAIN and FOCS STANDBY interface equipment, when specified, shall occur within one second of a causative failure.

(1) The RMS shall prevent the FOCS from switching to a failed subsystem.

(2) The RMS shall ensure that the transfer switch at all nodes of a given FOCS network are synchronized to within 250 milliseconds.

(3) The RMS shall ensure that the transfer switch at all nodes of a given FOCS network are selected for the same position.

3.4 **Standard networks**.– Four basic types of networks comprise the FOCS: RT(R); ASR-9; Runway; and Tower.

3.4.1 **RT(R).** As depicted in Figure 2, the RT(R) FOCS network shall be a two node network comprised of three basic elements:

(a) Telephone-industry-standard channel bank.

(b) Telephone-industry-standard fiber optic transmission equipment.

(c) PLC

3.4.1.1 **MAIN and STANDBY FAA equipment**. Both the MAIN and STANDBY FAA equipment shall be provided independent fiber optic transmission and interface equipment.

(a) The FOCS associated with MAIN and the FOCS associated with STANDBY shall be installed in separate equipment racks.

(b) MAIN and STANDBY FAA equipment precludes the requirement to provide redundancy at the interface level. However, the optical transmission subsystem, due to the potentially indeterminate restoration time, shall be redundant in order to minimize the impact of transmission path related failures upon the calculated value of transmitter/receiver system availability.

(c) Power shall be furnished from if not separate panels, separate circuit breakers; and, if available, different phases. The FOCS shall be provided power from the same primary and same back-up sources as the RT(R). The MAIN or STANDBY FOCS, but not necessarily both, shall include a UPS having a nominal fifteen-minute capacity, which would allow the RMS sufficient time to report to the MPS that there has been a catastrophic loss of both the primary and back-up power sources of the facility.

3.4.1.2 **FOCS equipment**. Only equipment from the qualified list of manufacturers/models of channel banks, telephone industry standard fiber optic transmission equipment, and PLCs shall be provided NAILS support. The qualified equipment is listed in Appendix II.

3.4.1.3 **Transmitter keying, and antenna changeover.** Transmitter keying and antenna changeover, when required, shall be effected via the E&M signaling provided by the channel bank interface modules.

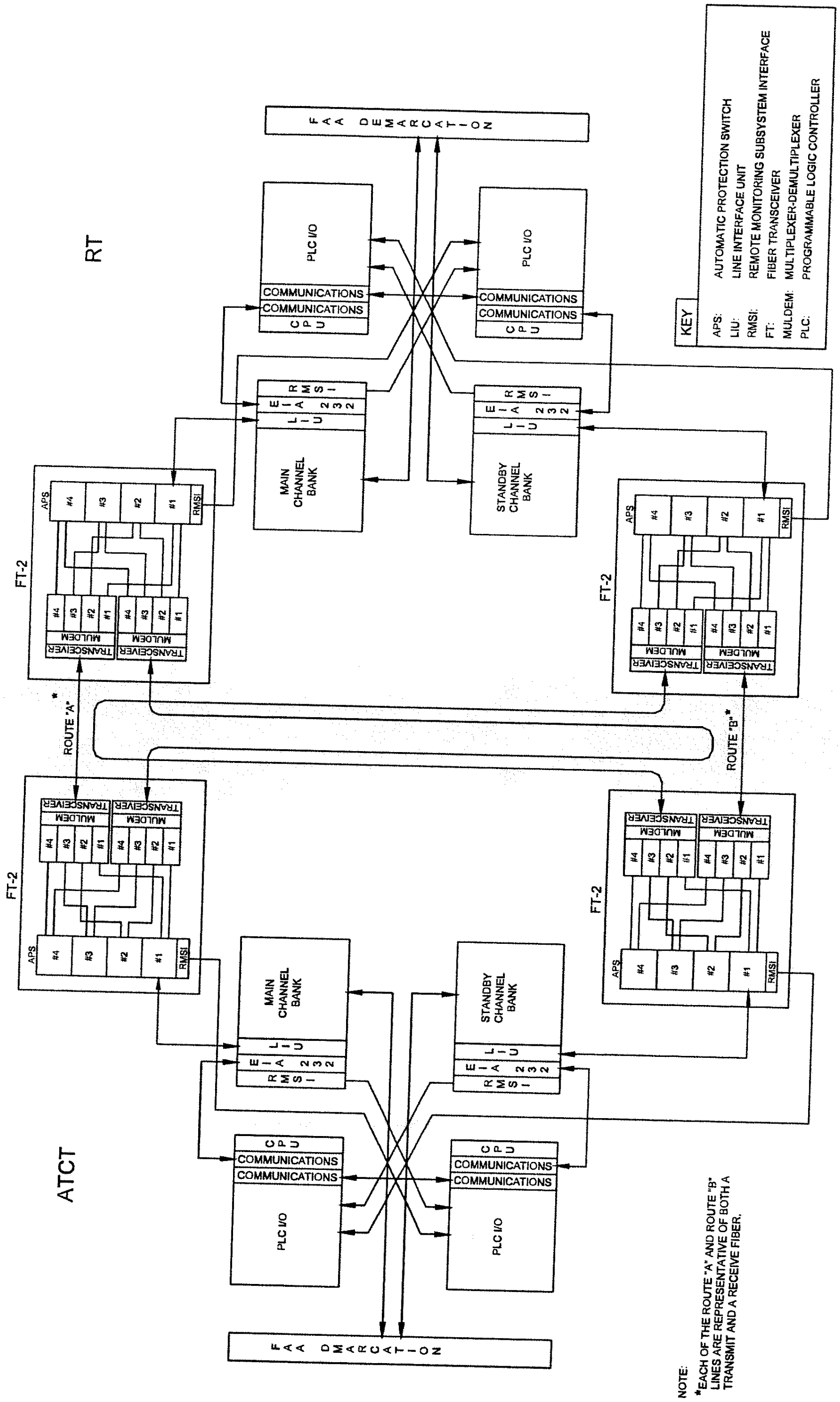


Figure 2. RT(R) Network

3.4.2 **ASR-9.** As depicted in Figure 3, the ASR-9 FOCS network shall be a two node network comprised of four basic components, three of which shall be the same as the RT(R) FOCS network. The fourth component is a RMS-monitored-and-controlled transfer switch.

3.4.2.1 **MAIN and STANDBY FAA equipment**. Both the MAIN and the STANDBY FAA equipment will be provided independent fiber optic transmission and interface equipment.

(a) FOCS. The FOCS associated with MAIN and the FOCS associated with STANDBY are to be installed in separate equipment racks.

(b) The transfer switch shall be monitored and controlled by both RMSs, and by logical extension the GDTS and the MPS.

(c) Power shall be furnished from, if not separate panels, separate circuit breakers; and, if available, different phases. The FOCS shall be provided power from the same primary and same back-up sources as the ASR-9. The MAIN or STANDBY FOCS, but not necessarily both, shall include a UPS having a nominal fifteen-minute capacity, which would allow the RMS sufficient time to report to the MPS that there has been a catastrophic loss of both the primary and back-up power sources of the facility.

3.4.2.2 **FOCS equipment**. Only equipment from the qualified list of manufacturers/models of channel banks, telephone industry standard fiber optic transmission equipment, PLCs, and transfer switches shall be provided NAILS support. The qualified equipment is listed in Appendix II.

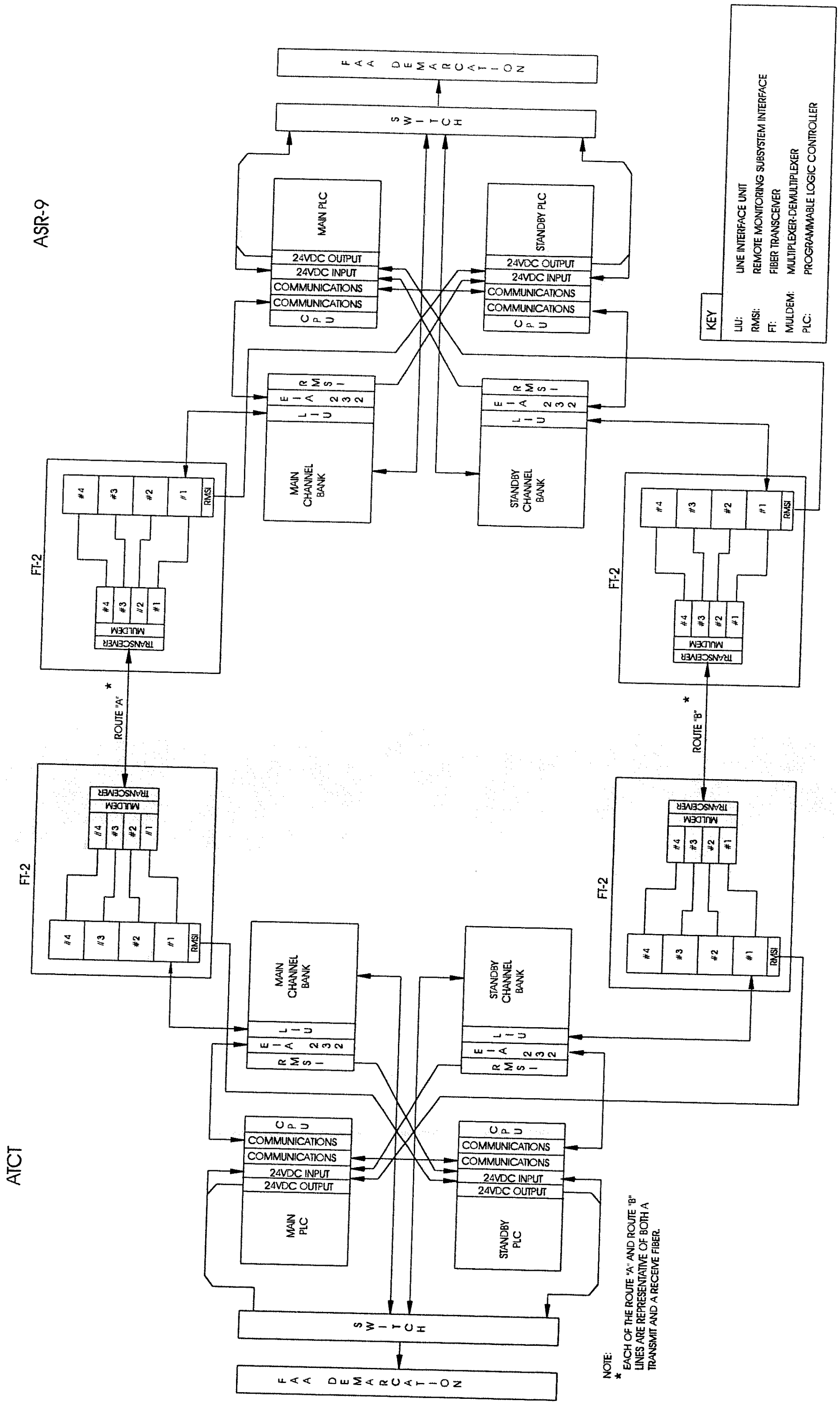


Figure 3. ASR-9 Network

3.4.3 **Runway**. The Runway network implementation shall be five dual-equipped nodes located at the ATCT/TRACON and at the opposing localizers and glide slopes of a runway as illustrated in Figure 4.

3.4.3.1 **Configurations**. Table 1 indicates all approved configurations of a Runway FOCS network. In general, configuration #1, #2, or #3 shall be implemented for Category II/III runways. Configuration #1, #2, and #3 provide absolute independence of the on-line component of the FOCS from its back-up. Configurations #1 and #2 provide sub-second automatic reconfiguration of the optical communication paths in the event of either a complete power failure at a shelter or a catastrophic cable-loop link break, whereas configuration #3 would require the installation of jumpers to restore service. Site specific determinants may warrant configurations having less than five nodes and not including dual equipment. There are, for example, Category II/III runways for which a loss of availability would not result in a significant impact upon the NAS and/or airport operations. Also, Category I runways for which the facilities are not required to be monitored in the cab or TRACON in order to maintain typical Category I operations do not warrant a configuration #1, #2, or #3 level of redundancy.

3.4.3.2 **FOCS equipment**. Only equipment from the qualified list of manufacturers/models of Fiber Optic Communication System Multiplexers (FOCSM), PLCs, two-wire-to-four-wire converters (not required for FOCSMs which provide both two-wire and four-wire interface modules), and transfer switches shall provide NAILS support. The qualified equipment is listed in Appendix II.

3.4.3.3 **Baseline node**. The baseline configuration of a node is shown in Figure 5. This configuration includes two Fiber Optic Communication System Multiplexers (FOCSM), two PLCs, and a transfer switch:

(a) Power to the MAIN and STANDBY nodes of the FOCS shall be furnished from separate circuit breakers.

(b) In general, the MAIN nodes of the FOCS shall be powered from a UPS. However, when dual FOCSM power supplies are furnished, one supply shall be serviced by the UPS and the second by the critical AC source.

(c) In general, the STANDBY nodes of the FOCS shall be powered directly from the AC line.

(d) A runway network node shall be furnished UPS battery capacity consistent with that being furnished to the Instrument Landing System (ILS).

(e) The FOCS associated with MAIN and the FOCS associated with STANDBY shall be installed in separate equipment racks at the ATCT/TRACON.

(f) At each node the transfer switch shall be monitored and controlled by both RMSs and by logical extension the GDTS and MPS.

Table I.

Configuration Number	Dual node	Transceivers per FOCSM[2]	Automatic switch	Power Supplies
1[3]	yes	2	yes	2
2	yes	1	yes	2
3	yes	1	yes	1
4[4]	no	2	n/a	2
5	no	2	n/a	1

[2] Fiber Optic Communication System Multiplexer (FOCSM)
[3] Configuration #1, which incorporates more fault tolerant features, is recommended for Level V Category II/III runways; however, Configurations #2 and #3 are acceptable.
[4] Configurations #4 and #5 are recommended for Category I runways.

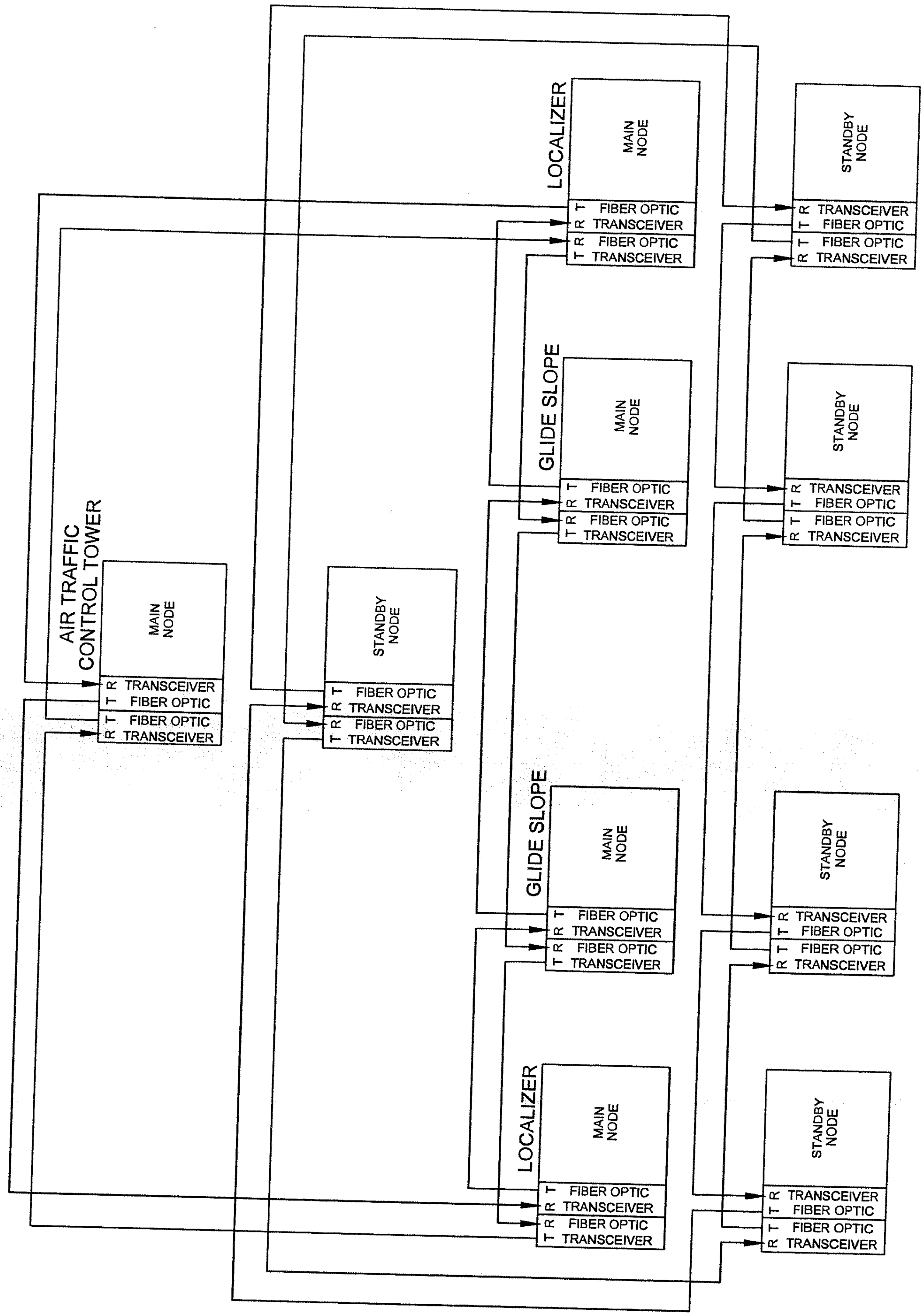


Figure 4. Runway Network

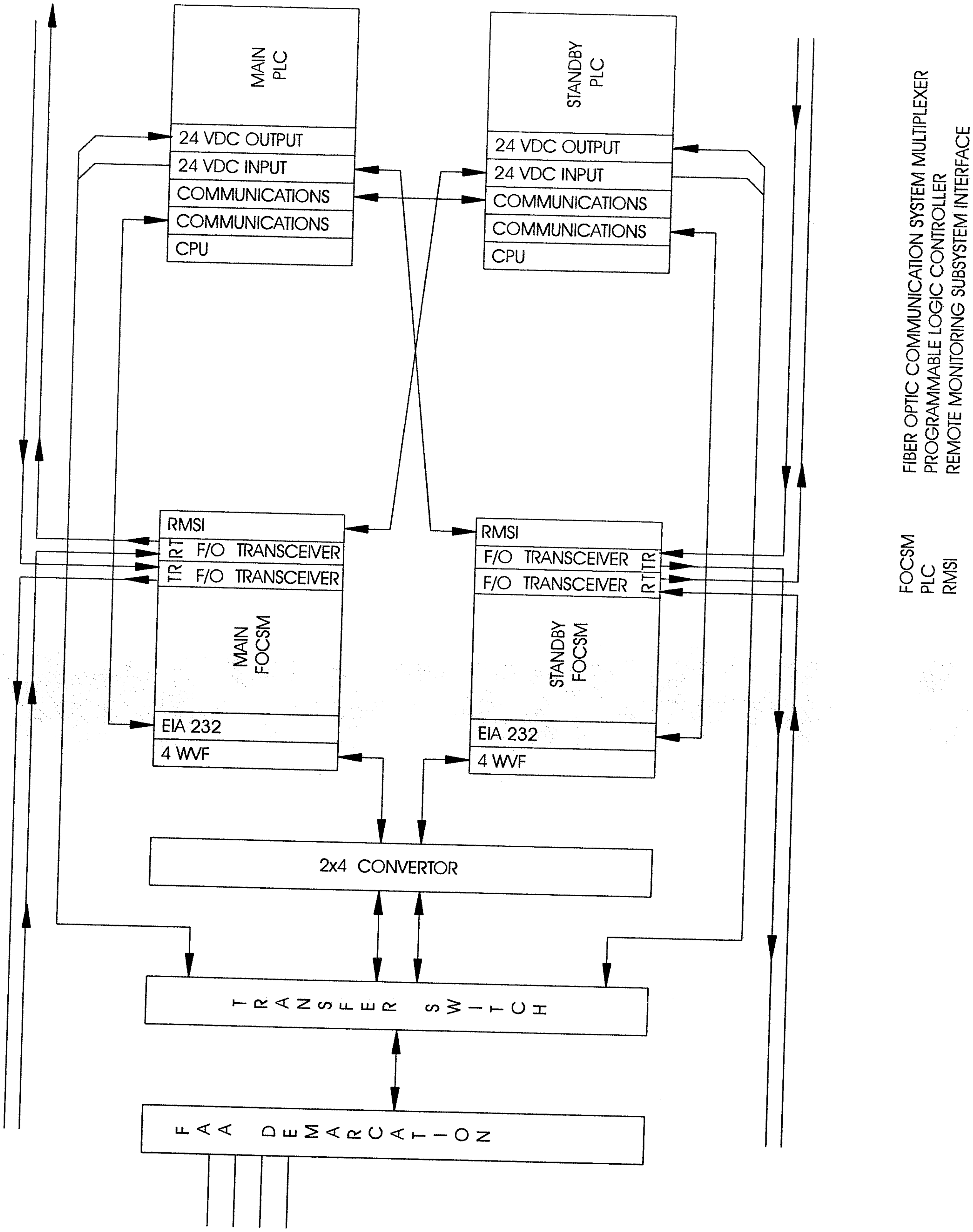


Figure 5. Typical Runway Network Node

3.4.4 **Tower**. The Tower network configuration shall be a two node network consisting of MAIN and STANDBY equipment. A simplified depiction is illustrated in Figures 6a through 6d. The Tower network, to the extent that it is possible, shall be configured of the same equipment as the other FOCS networks. Where both MAIN and STANDBY FAA signals exist the FOCS will provide diverse routing of the FAA MAIN and the FAA STANDBY signals; it will not provide a second level of circuit diversity. The MAIN signal cables shall be routed along Route A and the STANDBY signal cables routed along Route B.

3.4.4.1 **Primary interface**. The four basic types of interface shall be provided:

(a) Telephone industry – (encompassing DS-1, DS-0, and ISDN)

(b) Discrete process and control

(c) Ethernet

(d) Video.

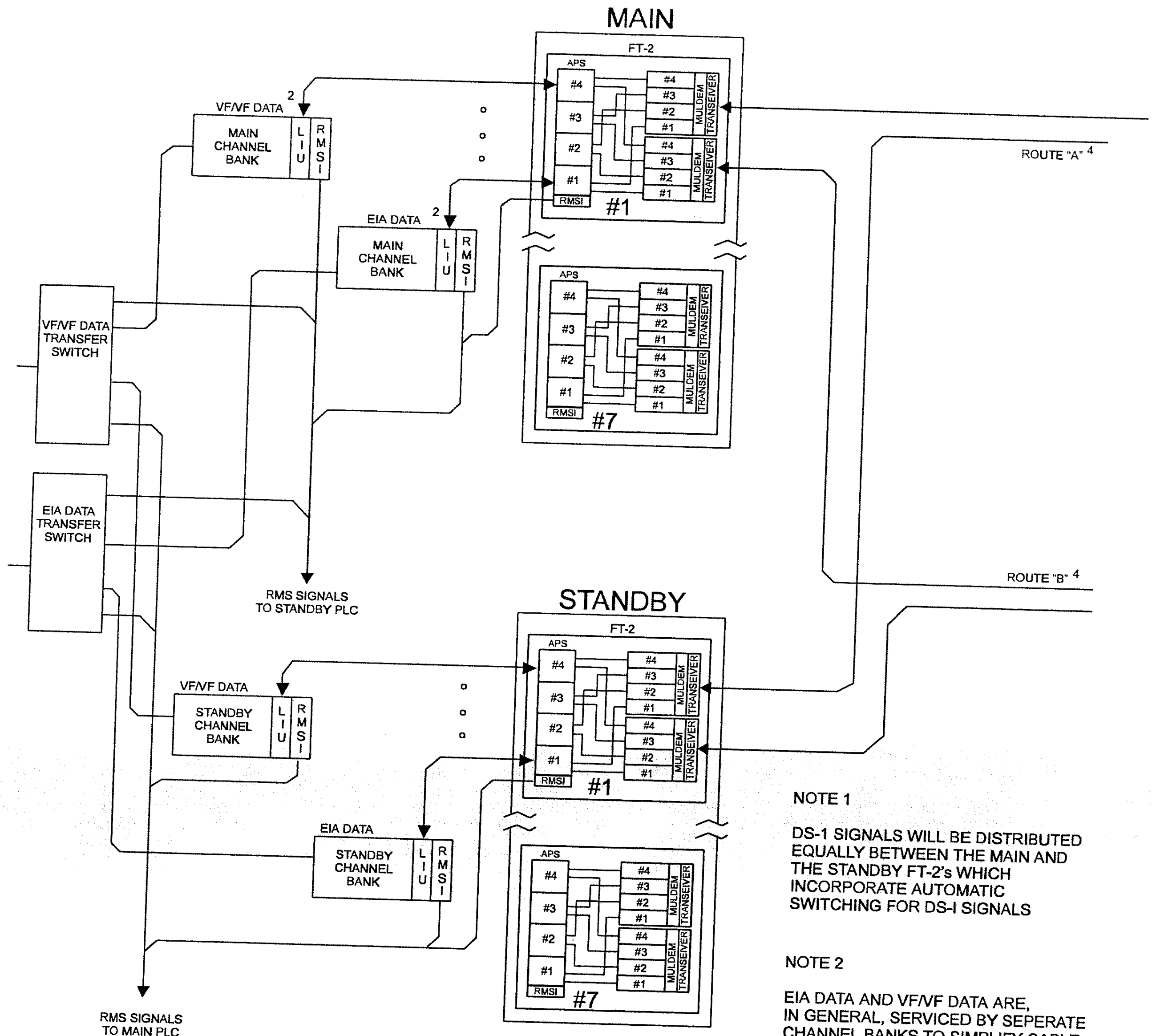
3.4.4.1.1 **Telephone industry**. As depicted in Figure 6a, DS-0 signals (digitized voice/voice frequency data and EIA-232/EIA-422 signals) and Integrated Services Digital Networks (ISDN) signals shall be multiplexed via channel banks to create DS-1 signals. Subsequently groups of four DS-1 signals shall be multiplexed and transmitted by the FT-2 system also depicted in Figure 6a.

3.4.4.1.2 **Discrete process and control**. As depicted in Figure 6b, discrete process and control signals such as the map selects for the DBRITE signals and the Minimum Safe Altitude Warning (MSAW) signal shall be multiplexed/demultiplexed via a PLC in the base-building equipment room which communicates to a correspondingly functioning PLC installed in the subjection-level equipment room via Ethernet links. As depicted in Figures 6a through 6d, the PLC shall also function as the RMS concentrator for the Tower FOCS.

3.4.4.1.3 **Ethernet.** As depicted in Figure 6c and in accordance with 3.4.4, Ethernet signals shall be allocated an optical channel consisting of two transceivers, a transmit fiber, and a receive fiber.

3.4.4.1.4 **Video.** As depicted in Figure 6d and in accordance with 3.4.4, each video signal shall be allocated an optical channel comprised of a transmitter, a receiver, and a single fiber.

3.4.4.2 **Fibers**. The minimum number of fibers to be installed shall be 24 single-mode and 24 multi-mode per each of two spatially diverse routes.



NOTE 1

DS-1 SIGNALS WILL BE DISTRIBUTED EQUALLY BETWEEN THE MAIN AND THE STANDBY FT-2's WHICH INCORPORATE AUTOMATIC SWITCHING FOR DS-I SIGNALS

NOTE 2

EIA DATA AND VF/VF DATA ARE, IN GENERAL, SERVICED BY SEPERATE CHANNEL BANKS TO SIMPLIFY CABLE MANAGEMENT

NOTE 3

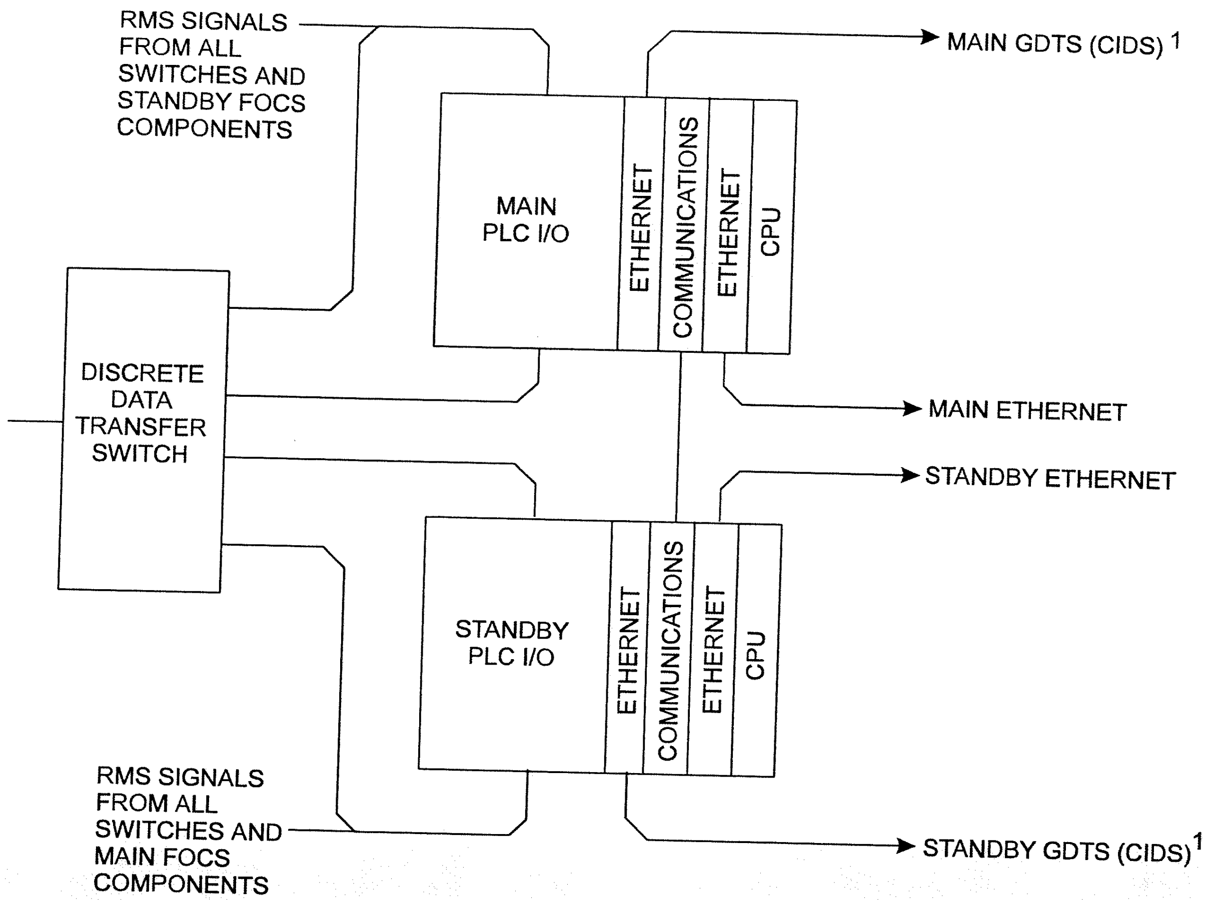
WHERE A MAIN AND A STANDBY FAA SIGNAL ARE PRESENT THE MAIN SIGNAL WILL BE INTERFACED DIRECTLY TO THE MAIN CHANNEL BANK AND THE STANDBY TO THE STANDBY CHANNEL BANK

NOTE 4

EACH LINE IS REPRESENTIVE OF TWO FIBERS - ONE TRANMIT AND ONE RECEIVE

APS	AUTOMATIC PROTECTION SWITCH
DS	DIGITAL SIGNAL
EIA	ELECTRONIC INDUSTRIES ASSOCIATION
FT	FIBER TRANSMISSION
LIU	LINE INTERFACE UNIT
PLC	PROGRAMMABLE LOGIC CONTROLLER
RMS	REMOTE MONITORING SUBSYSTEM
RMSI	REMOTE MONITORING SUBSYSTEM INTERFACE
VF	VOICE FREQUENCY

Figure 6a. DS-1/DS-0 Transmission System



CIDS	CAB INTEGRATED DISPLAY SYSTEM
CPU	CENTRAL PROCESSING UNIT
FOCS	FIBER OPTIC COMMUNICATION SYSTEM
GDTS	GRAPHICS-BASED DISPLAY TERMINAL SYSTEM
I/O	INPUT/OUTPUT
PLC	PROGRAMMABLE LOGIC CONTROLLER
RMS	REMOTE MONITORING SUBSYSTEM

NOTE 1: CONNECTION IS TO THE GDTS IN EQUIPMENT ROOM AND TO THE CIDS AT SUBJUNCTION LEVEL

Figure 6b. Discrete Signal Transmission System

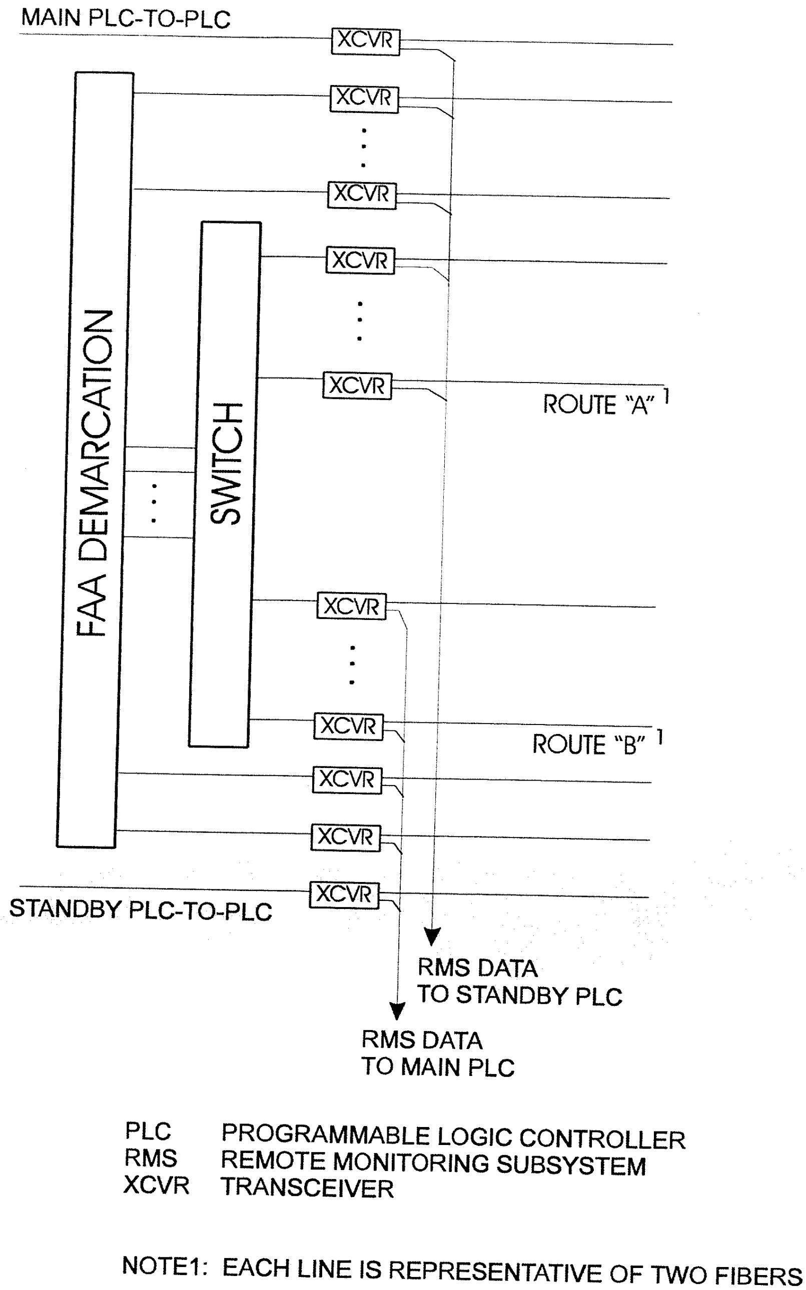
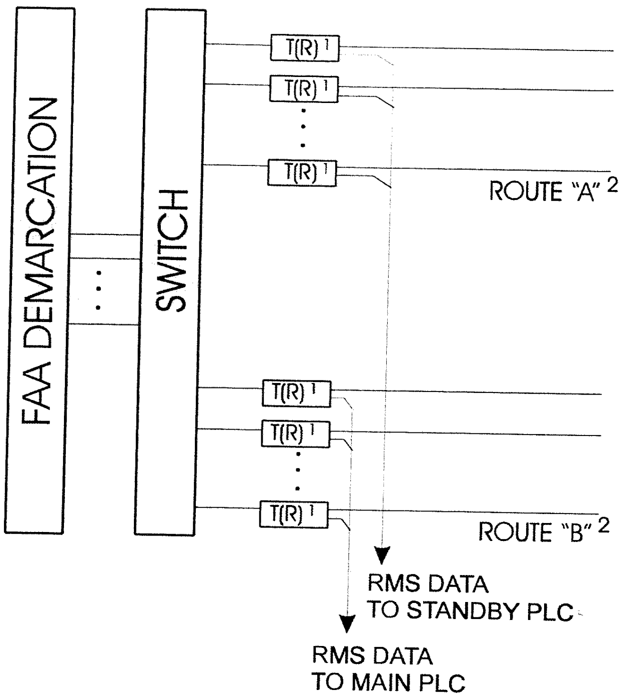


Figure 6c. Ethernet Transmission System



PLC	PROGRAMMABLE LOGIC COMPUTER
RMS	REMOTE MONITORING SUBSYSTEM
R	RECEIVER
T	TRANSMITTER

NOTE1: IN MOST INSTANCES, IN THE EQUIPMENT ROOM THE MODULE IS A TRANSMITTER AND AT THE SUBJUNCTION LEVEL IT IS A RECEIVER; HOWEVER THERE ARE INSTANCES WHERE THE TRANSMITTER WILL BE AT THE SUBJUCTION LEVEL AND THE RECEIVER WILL BE IN THE EQUIPMENT ROOM.

NOTE2: EACH LINE IS REPRESENTATIVE OF ONE FIBER

Figure 6d. Video Transmission System

APPENDIX I
ACRONYMS/ABBREVIATIONS

ALSF	Approach lighting system with sequenced flashers
AMP	Airport master plan
APS	Automatic protection switch
ASR	Airport surveillance radar
ATCT	Air traffic control tower
BRITE	Bright Radar Indicator Tower Equipment
DBRITE	Digital BRITE
DS	Digital signal
EIA	Electronic Industries Association
E&M	Ear and mouth
FAA	Federal Aviation Administration
FFM	Far field monitor
FO	Fiber optic
FOCS	Fiber optic communication system
FOCSM	Fiber optic communication system multiplexer
FS	Field shelter
GDTS	Graphics-based display terminal system
GS	Glide slope
HVAC	Heating ventilation air conditioning
I/O	Input/output
IM	Inner marker
ISDN	Integrated services digital networks
LIU	Line interface unit
LOC	Localizer
MM	Middle marker
MPS	Maintenance processor subsystem
MULDEM	Multiplexer-demultiplexer
NAILS	National airspace integrated logistics support
NAS	National airspace system
NFPA	National fire protection association
OM	Outer marker
PAPI	Precision approach path indicator
PLC	Programmable logic controller
RF	Radio frequency
RMS	Remote monitoring subsystem
RMSI	Remote monitoring subsystem interface
RR	Remote receiver
RT	Remote transmitter
RVR	Runway visual range
SMO	System management office
SNMP	Simple network management protocol
SSC	System service center
TRACON	Terminal radar approach control;

UPS	Uninterruptible power supply
VF	Voice frequency

APPENDIX II
QUALIFIED EQUIPMENT LIST

Telephone industry standard fiber optic transmission equipment:

Larus FT-2 transceiver
ITT/Alcatel ADM-50
Newbridge

Channel banks:

Coastcom
ITT/Alcatel D424
Wescom 360 (LDRCL)
Newbridge

PLC:

GE/Fanuc Series 90

FOCSMs:

Racal PremNet 5000
Newbridge

Switches:

Ways Unlimited SDVX-33, SDVX-4
Dataprobe automatic A/B
Hadax Intelliswitch 2000

Two-wire-to-four-wire converter:

Ways Unlimited CDVX-8, CDVX-16
Tellabs 4024E

Video transmitter/receiver:

Optelecom
American Lightwave Systems
Opticomm

Ethernet:

Canoga Perkins