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Lewis Information Network (LINK): Background and Overview

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LEWIS INFORMATION NETWORK (LINK):

BACKGROUND AND OVERVIEW

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SUMMARY

The NASA Lewis Research Center supports a wide variety of research facilities with many isolated buildings, including wind tunnels, test cells, and research laboratories, as well as large office buildings.

These facilities are all located on a 350 acre campus-type environment adjacent to the Cleveland Hopkins Airport. The function of NASA Lewis is to do basic and applied research in all areas of aeronautics, fluid mechanics, materials and structures, space propulsion, and energy systems. These functions require a great variety of remote high-speed, high-volume data communications for computing and interactive graphic capabilities. In addition, new requirements for local distribution of intercenter video teleconferencing and data communications via satellite have developed.

To address these and future communications requirements for the next 15 years, a project team was organized to design and implement a new high-speed communication system that would handle both data and video information in a common lab-wide Local Area Network.

The project team selected cable television broadband coaxial cable technology as the communications medium and first installation of in-ground cable began in the summer of 1980. The Lewis Information Network (LINK) became operational in August 1982 and has become the backbone of all data communications and video at the center.

INTRODUCTION

In the fall of 1977 the Computer Services Division of NASA Lewis formed a committee to study network requirements at NASA Lewis and to recommend a future direction. The committee was comprised of representatives of NASA Lewis' Computer Services Division, and Roger Schulte served as the committee's chairman.

The need for growth in many areas of data communications at NASA Lewis was the impetus for the committee. The existing twisted-pair data cables were inadequate in terms of data rates and number of pairs available, and the switching capacity of this network had been exceeded. Demands for high-speed data acquisition from remote test facilities for processing on the central computers were increasing. The number of computer terminals was growing rapidly, and the newer interactive terminals supported higher data rates than the previous terminals. Another major concern was the introduction of remote interactive graphics systems requiring bandwidths of up to 1.5 MHz.

By early 1977, the growing requirements for high-volume, high-speed access to multiple processors from all points of the facility made it obvious that a high-speed common bus network was necessary. The term bus implies a communications path that provides a way for data to get from any point on the cable to any other point on the cable.

All these areas of concern were represented on the Network Committee. Those concerns also included data acquisition, computer terminal communications, and computer graphics. The primary tasks of the committee were the determination of current and future network requirements at NASA Lewis and the selection of technology that could meet or exceed the requirements for the next 15 years.

INITIAL REQUIREMENTS

When the Network Committee completed its work, a project team was formed, and the implementation of the Lewis Information Network (LINK) began. The initial requirements for the LINK system are described in the following sections and are shown in figure 1.

Low-Speed (Escort II) Data Acquisition

Thirty Digital Equipment Corp. (DEC) minicomputers in the PDP/11 family serve as centralized data-reduction machines for experiments conducted throughout the facility. Data sent to these machines is then forwarded to two PDP 11/34 minicomputers serving as data collectors and to the large IBM 3033 (S/370) host computer. This interfacing required a common bus system such that any given computer could exchange information with any other computer, large or small, and store data in either data collector computer or the large host computer. The data transfer was asynchronous and at 9600 bits/sec.

High-Speed (Escort III) Data Acquisition

The DEC minicomputers, located remotely in test cell areas, needed high-speed access to several DEC VAX computers located in the central computer area. There was a large volume of data traffic, since real-time calculations and graphics were needed. The data rates desired were at least 1 megabit/sec, synchronous.

Computer Terminal Support

Prior to the LINK system, the computer terminal population at NASA Lewis was constrained by the capabilities of the Gandalf electronic switch which connected these terminals to the large host computers. The Gandalf switch was limited in capacity to 256 terminal connections to 128 various computer ports. The computer terminal requirements for the Local Area Network (LAN) were defined as the capability of supporting up to 2000 terminals with character rates of from 120 to 960 characters/sec (1200 to 9600 bits/sec).

An additional requirement was that any computer terminal at NASA Lewis could select any of the host computers, a gateway to external networks, or any other computer terminal at NASA Lewis as its destination. In this estimate, computer terminals included not only the typical video display terminal (VDT), but also hardcopy terminals, asynchronous printers, personal computers, word processors, and similar devices.

Interactive Graphics

Some 60 Tektronics storage tube graphics terminals (similar to VDTs) also required asynchronous communications at data rates of up to 9600 bits/sec. In addition, the Interactive Computer Aided Research (ICARE) office was established for the development of interactive graphics to support analytical studies, mathematical modeling, and computer-aided design and computer-aided engineering (CAD/CAE).

The graphics equipment had to be located in the building with the test facilities and the user offices; this was a prime requirement. High data rates of 1 megabit/sec over a 2-mile radius were mandatory in order to provide true local-connection responsiveness with complete interactivity and the ability to continuously update screens.

Video Support

Although video support was not an initial requirement of the LINK system, the final selection of coaxial cable as the communication medium made it evident that many video applications could develop once the LINK system was in place. Staff presentations by the Director of Lewis, as well as by visiting dignitaries, could be given once instead of several times through remote TV monitors. Instructional offerings and mission coverage could be broadcast throughout the facility, and the system could also be used for video monitoring by security.

Selection of Technology

After much careful study and many site visits, broadband coaxial cable technology was selected for NASA Lewis' LAN. Primary consideration was given to three characteristics of this technology:

(1) wide bandwidth (40 to 300 MHz) available through the network

(2) simultaneous use of selected channels for many different functions

(3) industry-proven, cost-effective technology

LINK SYSTEM ARCHITECTURE AND DESIGN

The LINK system is classified as a dual coaxial cable broadband network. The network serves the NASA Lewis campus as a common information bus. All information in the system is available to any user anywhere in the facility who has the appropriate bus interface device.

Data moves within the cable system as modulated radio frequency (RF) waves. Each device connects through its interface unit to cables for outbound data traffic (data to be received by devices attached to the network) and for inbound data traffic (data transmitted by devices attached to the network).

The inbound cable and outbound cable connect at the headend. It is at the headend that inbound data is exchanged for outbound data and vice versa. Each device on the information bus can both receive and transmit data.

The network is broadband, and it makes use of the capability of the coaxial cable to transmit a wide range of electromagnetic frequencies. The LINK system uses frequencies from 40 to 300 MHz. That is roughly the range used by VHF television, FM radio, and fixed and mobile government communications (the equivalent of 42 television channels).

Various groups of devices on the network are assigned specific ranges of frequencies, or channels, for their use. This allows the LINK system to support multiple distinct subnetworks on one common cable system. Subnetworks operating on different channels may also be connected to each other through the use of devices called bridges.

Some subnetworks require the use of a different channel for inbound and outbound traffic; they transmit on one frequency and receive on another. For these subnetworks, the headend must shift frequencies and not just connect cables. Currently, the LINK system assigns different ranges of frequencies to computer terminal support, data acquisition, graphics, and video. The frequency band allocated to each use is roughly proportional to the rate of data transfer required for that application.

Network Media and Interface Devices

The physical cable network is based on the standards and practices of commercial cable television (CATV) technology. The coaxial cable, connectors, taps, amplifiers, and power sources used in the LINK system are the type used in the CATV industry today. The division of the cable's range of transmittable frequencies into bands for specific uses was also evolved from the CATV industry. CATV standards, including those for signal strength and noise level, also apply to the LINK system. The applicable standards are included in the appendix of this document.

From the headend in the Lewis Research Analysis Center, the interbuilding trunk network stretches out to loop through and interconnect 47 buildings at NASA Lewis. There are three major legs of the cable system. Underground ducts connecting the north, south, and west legs run between the buildings and house trunk cables. The trunk cables terminate at service entrances in each of the buildings. Power supplies and unidirectional amplifiers, which are the active components of the network, are also located in the service entrances. Figure 2 shows the geographic and logical layout of the cable.

The service entrance is the point at which branches split from the trunk cables. These branches may extend on to another group of buildings or they may provide the distribution for the network through that building. Within the buildings, the cables are tapped using standard, multiconnection CATV taps--one each on the inbound and outbound cables. From the taps, pairs of smaller cables service wall outlets.

Two sizes of cable are used. A 1/2-in. hard-line is used for the trunk cables, and a 1/4-in. RG-6 is used at the wall outlets. Each wall outlet has a separate cable jack for both inbound and outbound use. When the outlets are not attached to an interface unit, they are capped to protect the network from spurious signals and to provide proper termination.

The interface devices connect data terminal equipment to the distribution network and parallel the functions of modems in other data communication circumstances. These devices include digital communication bus interface units, called either bus interface units (BIU) or network interface units (NIU); high-speed digital modems using T1 or V.35 protocols that handle data transfer on a dedicated point-to-point basis; and television channel modulators that interface video cameras and other signal sources.

Frequency Allocation Within the LINK System

The current frequency allocation within the LINK system is shown in figure 3. The broadband network supports channels for computer terminal support (SYTEK), data acquisition (Escort II and III), graphics (ADAGE), television, and generic office automation (Lewis Information Management System). Frequencies are available for other subnetworks, such as that for Wang office equipment. Currently, consideration is being given to adding assignments for other network protocols, such as DEC's DECNET/Ethernet and IBM's SNA/SDLC.

The inbound and outbound allocations differ for several reasons. Some devices, such as the System 370 monitor video channel, are output only. Other subnetworks are essentially point-to-point and require paired originate and answer frequencies for their modems to function.

Computer Terminal Support

NASA Lewis has several host computers which can be reached through the LINK system. Those host computers include an IBM 3033, an IBM 4341, and Amdahl 5840 (VM), an Amdahl 5840 (MVS), and a cluster of DEC VAX's. NASA Lewis' Cray X-MP is accessed through the IBM 3033 and the Amdahls. Any terminal, or computer, capable of asynchronous ASCII communications can be used to access any, or all, of these hosts.

The terminals and host computers attach to the LINK system through a BIU--in this case a SYTEK LocalNet packet communication unit (PCU). These PCU's are intelligent, frequency-agile, radio frequency modems. They are software-configured to support the data handling and flow control options required by the diverse terminal types supported within the LINK system.

Each modem has a unique address and two or more ports for terminal attachment. A terminal has a unique address comprised of its modem's address and the modem port number to which it is attached.

The SYTEK frequency allocation is a 6-MHz band divided into 15, 400-kHz channels. Each host is accessed on a particular channel. Terminals located on different channels can communicate with each other through a SYTEK bridge. The SYTEK bridge receives a message on one channel and retransmits it on another, bridging the gap between two channels.

If necessary, host access may also include protocol conversion. For example, users can call a port on an IBM Series-1 font end, which converts their terminal's asynchronous ASCII protocol to IBM 3270 SNA/SDLC protocol and passes the converted transmission to the IBM or Amdahl host.

Other devices facilitate the operation of the computer terminal support portions of the LINK system. A logical headend converts inbound data on one frequency to outbound data on another frequency. A network control center provides a way to configure and control the network and, in conjunction with a statistical monitor, assists in the management and optimization of the network. All of these devices, as well as the PCU, are versatile, microcomputer-controlled tools.

A terminal user can call a remote device using that device's unit identifier. The unit I.D.s of the host computers are published, while the addresses of other units are exchanged or made available on a need-to-know basis. The SYTEK modems establish a connection through the LINK system, and data can flow bidirectionally between the calling and called devices, using asynchronous ASCII transmissions with conventional EIA or XON/XOFF flow control.

Currently the LINK SYTEK subsystem supports 800 terminals, including approximately 400 personal computer workstations. Newer uses of the LINK system include personal computer-to-personal computer file transfer and LINK-wide bulletin boards.

A big advantage of the LINK system common bus network is workstation mobility. In point-to-point communications such as the Gandalf or IBM 3270 support, miles of direct, dedicated wiring must be run back to the data switch, controller, or computer.

With a common bus system, the relocating of a workstation requires nothing more than disconnection from the LINK wall outlet in one location and reconnection in another location. This applies for all LINK services, e.g., terminal support, graphics, data acquisition, and video. To achieve this capability, the LINK system has full connectivity: there is at least one LINK wall outlet in every office of every staffed building.

Gateway Interfacing

A major component of the NASA Lewis LINK Local Area Network is a common gateway interface to external communication facilities. This gateway interface provides both inbound and outbound links with remote computers via direct-distance dial telephone lines, commercial networking services, and, eventually, NASA's Program Support Communications Network (PSCN) for intercenter satellite communications.

The LINK system architecture is suitable for use with gateways. The gateway concept is also used to provide a connection between the LINK system and its predecessor network, twisted-pair wiring, modems, and an associated Gandalf data switch. The relation of computer terminal users to the gateway is shown in figure 4.

The first implementation of an external gateway interface as a part of the LINK system was in June 1983. A data connection can be made from any NASA Lewis computer terminal to a remote host computer by using local or long-distance telephone lines or by accessing NASA Lewis' Telenet TP 4052 processor to get into the commercial Telenet network.

Remote computer terminal users can access NASA Lewis' computers and have the same capabilities as a local computer terminal user, using either inbound telephone lines or the Telenet network. However, inbound access to the LINK system has been restricted pending installation of an intelligent front-end device to ensure security.

A terminal user accesses the gateways by calling a specific SYTEK unit in the network. Depending on the desired destination, this is connected to either the Telenet TP 4052 telecommunications processor, one of a bank of Rixon auto-dial modems, or the Gandalf data switch that controls what still exists of the twisted-pair data network. The accessed gateway device then allows the user to select the desired system. Users on a Gandalf network terminal use a similar procedure to access the lines that provide them with a gateway into the LINK system.

The Telenet gateway provides direct connections to Marshall Space Flight Center in Huntsville, Alabama, and to NASA Headquarters in Washington, D.C., as well as access to remote services through the Telenet X.25 packet network. Other NASA and contractor sites are common destinations, as is the Telemail network system in Vienna, Virginia. The Rixon gateway provides access through Ohio Bell to other systems not on Telenet.

Data Acquisition

The LINK system provides communication services for two Lewis-wide data-acquisition systems--Escort II and Escort III. Escort II provides centralized, on-line data reduction/collection and storage of information generated during tests and experiments conducted at numerous sites at NASA Lewis. Escort III performs similar functions for test sites that create larger amounts of data and generally require some real-time analysis of the data. Figure 1 graphically demonstrates how these data acquisition systems make use of the LINK system.

Escort II data originates at remote test sites as the analog output of various sensors. After processing by analog-to-digital convertors, the raw, digitalized data passes through a network of twisted-pair wiring and the Gandalf data switch to one of a group of 30 PDP 11/34 processors in the Lewis Research Analysis Center. These machines perform centralized data reduction, using programs personalized for the particular type of experiment being conducted.

Data rates between the remote sites and the PDP 11/34 processors are 9600 baud or less. Two of the Escort II test sites are connected to the PDP 11/34 processors via the LINK system, using Digital Communications Corporation (DCC) BIUs.

Each PDP 11/34 data-reduction computer is also connected to the LINK system through a BIU. This LINK system access is used to pass data to two PDP 11/44 data-collection computers. Data is passed to the IBM 3033 by way of another LINK system BIU connection and a direct 9600-baud, IBM bisynchronous link. Another associated device, the clock/barometer unit, also interfaces via the LINK system to both the data-collection and data-reduction computers.

The DCC BIU is similar to the SYTEK PCU and is addressable and supports a data rate of 9600 baud. It uses a different frequency band than the SYTEK subnetwork and supports a larger block size than NASA Lewis' SYTEK subnetwork currently allows. It is the later characteristic that precludes the use of the SYTEK subnetwork for this purpose.

The Escort III test sites include PDP 11/34 processors which provide on-site computational support. These remote PDP 11/34 processors are connected to the LINK system through Comtech 1-megabit rate V.35 Frequency Division Multiplex modems and through ports of SYTEK PCUs. Several VAX 11/780 processors receive the partially reduced data from the LINK system by way of the V.35 modems and the SYTEK subnetwork. These processors perform personalized real-time analysis, as required by a particular test, and transmit the results of this analysis back to the test site computer and terminals via the LINK system.

The VAX 11/780 processors also forward the data to PDP 11/44 data-collection processors and to the IBM 3033 through DCC BIUs and the LINK system, using the same methods as Escort II. The VAX 11/780 also has access to the same clock/barometer unit used by Escort II.

The DCC BIU connections use the same frequency band as Escort II. The Escort III V.35 modems operate in a point-to-point mode, using specific, paired frequencies for transmission and reception. These frequencies appear on the Frequency Allocation Chart (fig. 3) as narrow lines rather than the bands representing the channels used by the SYTEK PCUs and the DCC BIUs.

Graphics Support

Graphics users at NASA Lewis utilize several types of terminals, but primarily use ADAGE and Tektronix terminals. The facility's graphic services on the IBM 3033 and Cray X-MP are accessible by terminal users through direct commands or through FORTRAN subroutines. The method by which the graphic services are accessed varies with the type of terminal used.

Tektronix users access the hosts over the LINK system through the SYTEK subnetwork or, where the LINK system cables have not been activated, through twisted-pair cables and modems routed via the Gandalf switch with maximum data rates of 9600 or 19200 bits/sec.

The ADAGE equipment requires much higher data rates. ADAGE 4201 control units attach directly to an IBM byte-multiplexor channel. All control units at NASA Lewis are in the Research Analysis Center. Each control unit can support one to four local or remote terminal clusters. Clusters consist of a control station and up to three other display stations. Various models of these stations support either two-dimensional or three-dimensional graphics presentations.

The data rate between the ADAGE control units and remote clusters is 1.544 megabits/sec which is the T-1 data rate. The local cluster is attached to the control unit by coaxial cable, while the remote clusters communicate with the control unit over the LINK system, using Comtech T-1-rate modems. The display stations are connected to the control station through coaxial cable, so that each cluster shares one access point to the LINK system. Figure 5 shows the connection of the ADAGE clusters to their central control units through the LINK system.

Traffic through the LINK system from control unit to remote cluster is point-to-point, using a pair of originate and answer frequencies for each remote cluster. Thus, the ADAGE graphics frequencies appear as pairs of lines on the inbound and outbound cable frequency allocations.

Video Services

Video is input to the LINK system from several sources, including Lewis-originated broadcasts and satellite broadcasts. The video headend room has the capability of patching any of these signals or computer-generated images into the LINK system output cable.

The LINK video system uses currently include distribution of such Lewis-originated programs as messages from the Director and visiting dignitaries and external programming received by satellite. Satellite programming includes teleconferences, shuttle flights, and NASA-originated classes. The NASA Lewis NASCOM TOMA uplink facility permits origination of teleconferences with other NASA centers.

One outbound channel, channel 9, is used to display computer-generated graphics of current computer availability and performance statistics. Another LINK system frequency has been used experimentally for security television. The video uses of the network are represented in figure 3.

Installation

Installation of the LINK system began in July 1980 when the first length of in-ground coaxial cable connected building 86, which houses NASA Lewis' largest wind tunnel, and the Research Analysis Center, building 142.

The actual installation of the cable was done by contractor, personnel following the design developed by the LINK project team and personnel from MITRE Corporation. Both worked closely with NASA Lewis' Facilities Engineering Division. Phase I of the in-ground installation was finished in 1981, and the total in-ground cable plant was completed by September 1983.

At the same time that the in-ground trunk system was being completed, other work teams connected branches within NASA Lewis buildings to the trunk system. The Research Analysis Center subsystem was the first completed. By the spring of 1982, the subsystems in building 86 and the Materials and Structures Building, building 49, were finished. Along with the building subsystem effort, the project team supervised the procurement and installation of the hardware and software necessary to operate the cable system.

The first operational use of the LINK system was in August 1982, and the gateways to external systems opened in July 1983. In 1984, other major facilities were attached to the system, satellite video reception became common, and various hardware upgrades were accomplished. Currently, 100 percent of NASA Lewis buildings are served by a trunk system connection while there are subsystems in 90 percent of the buildings.

The installation was not without both technical and administrative challenges. Just finding room for the cable in crowded, underground ducts was sometimes a problem, as was the task of ensuring proper installation of cables, amplifiers, taps, and other equipment in such an extensive and wide-spread endeavor.

Numerous pieces of test equipment, including signal generators and detectors, were acquired for this effort. Some of the amplifiers originally specified were inadequate for the inter-building cable lengths required in some locations and had to be replaced. There were also problems with backup power systems for the LINK system.

Initial budgeting for the subsystem project was an administrative problem that helped cause a logistical problem. The costs of installing taps and outlets for end-users were charged to individual NASA Lewis organizations. To control costs, organizations had a minimum of connections made in their buildings. When more connections became necessary as the user base increased, contractors would have to return to buildings, causing installation delays, additional costs, and inconvenience. Eventually, budget-allocation problems were resolved, and subsequent buildings were initially equipped with complete subsystems.

System Operation, Support, and Management

Since the LINK system is primarily a medium for communications, no daily, central operating procedure is necessary. The LINK system operates 24 hr a day, 7 days a week, except during periodic maintenance. Downtime caused by problems can usually be limited to a single branch or building within the system. Isolated downtime averages less than 10 min/month.

The Telecommunications and Networking Branch is responsible for the maintenance of the LINK system, assurance of signal quality, and proper operation of the cable network. This Branch was previously in charge of procurement of end equipment for attachment to the LINK system, but now standard workstations and RF modems can be obtained through the NASA Lewis Computer Store.

The configuration of SYTEK modems to meet the needs of terminal users and the handling of trouble calls (usually the trouble is that the configuration parameter of a particular interface unit have been inadvertently changed) is a daily job for the Telecommunications and Networking Branch. The Branch maintains an inventory of SYTEK PCUs and other interface equipment by location.

When terminals need to be moved, the Telecommunications and Networking Branch ensures that the equipment location is known and makes sure cable outlets are properly terminated. The Branch also handles any other operational problems, including determining when it is necessary to bring in equipment for maintenance and the resolution of system-wide difficulties.

Training is also an on-going support function for the Telecommunications and Networking Branch. Training classes which include demonstrations and slide presentations are also the responsibility of Telecommunications and Networking Branch personnel. As a supplement to the current user manual, a video tape for computer terminal users is being developed.

CONCLUDING REMARKS

The LINK system usage is currently growing in all applications. Terminal use is expanding, as are the number of hosts supported. To date, the SYTEK user base has grown to nearly 1000. A statistical monitor program has been developed and placed in operation to assist in planning for and controlling this growth.

The acquisition of personal computers and office automation equipment is increasing the demand for file-transfer services--both host-to-micro and micro-to-micro.

Two applications of broadband ethernet now exist on the LINK system. The LIMS office automation project currently uses channels S and T as an interbuilding backbone for intrabuilding workstation ethernets.

The second application has several distributed research area ethernets utilizing LINK channel 3 as a common backbone, throughout the Center, for very high speed (10 mb) data acquisition and distribution systems.

Inbound gateways are now available, following the installation of front-end intelligent switching equipment with sufficient security-checking capability. Data-acquisition equipment continually improves and expands the data-communications requirements for test sites. New graphics terminals are being continually added.

The NASA-wide Program Support Communications Network (PSCN) is now connected to the LINK system, allowing telenet/telemail functions for all on-site and off-site users.

The LINK system has proven itself a convenient, flexible media which provides rapid, facility-wide responses to the changing data-communications and video requirements of NASA Lewis. It has also proved to be very cost effective in terms of new applications and versatility. This adaptability is a critical asset as NASA Lewis moves ahead to meet challenges in an environment of distributed research and development.

LINK STATISTICS

Backbone Cable	System Total
Primary Backbone Cable (Interbuilding only)	59700'
Backup Backbone Cable (Interbuilding only)	59700'
TOTAL MILES (including backup cable)	115800' or 21.9 miles

System Amplifiers	
Inbound (User Transmit)	60
Outbound (User Receive)	28
Longest Cascade	(14)
Distribution Amplifiers	33
TOTAL Amplifiers	121

CONSTRUCTION COSTS

Work Completed (FY81 through FY86)	
Number of Buildings Completed	22
Total Floor Area (All Completed Buildings):	1,273,198 sq ft
Total Construction Costs:	$924,100
Estimated Average Cost Per Square Foot	$0.74
Number of Outlets:	2,026
Calculated Average Cost Per Outlet	$456

SERVICES AVAILABLE

5 TV Channels (Includes Video Bulletin Board)
32 High Speed T1 Links (CAD/CAM and Experience Facility Applications)
Wang Office Automation (O.A.) Network
Distributed O.A. and Scientific/Engineering Ethernets
700 Asynchronous Terminal to Host Connections
Broadband Monitoring System

APPENDIX - LEWIS INFORMATION NETWORK

The broadband coaxial cable system designed for NASA Lewis is a dual, 75-L coaxial cable network with each cable covering the 50 to 300-MHz frequency spectrum. The LINK system is used to support computer terminal communications, data acquisition, video, and networking at NASA Lewis.

The backbone cable system consists of two parallel, unidirectional cables; one cable (inbound) conveys information toward the central node or headend; the other cable (outbound) conveys information in the opposite direction, away from the head end. At the headend, signals are coupled from the inbound to the outbound to permit two-way communication.

The design of the distribution networks is based on the use of cable television (CATV) techniques. The networks have trunk lines and subsystems that include amplifiers, taps for device access to the coaxial cables, and splitters to serve the various branches of the coaxial cable network.

LINK SYSTEM PERFORMANCE REQUIREMENTS

Table I summarizes the specifications and performance requirements of the LINK system. All signal levels are referred to the 6-MHz video carrier level over a coaxial cable network with an impedance level of 75 L.

FAA RESERVED FREQUENCIES

All radio frequency signals appearing on the LINK system comply with Federal Aviation Administration specifications.

Offset Rules

LINK carrier signals and associated major signal components are a minimum of 200 kHz plus the absolute value of the tolerance of the carrier generating devices removed, i.e., offset from the nominal carrier frequencies of all aeronautical radio services to be protected.

Signal components on the LINK system at frequencies within 200 kHz of any aeronautical frequency are 46 dB below the LINK system nominal operating levels.

Aeronautical radio service frequencies that are protected in accordance with this specification include all frequencies listed in table II and all other frequencies used for aeronautical radio service within 60 n mi of the LINK system.

COMPONENT SPECIFICATIONS

All of the parts, equipment, and components integrated into the LINK system meet or exceed the specifications contained in this appendix. Included with each specification is an example of a particular component that meets the defined specification.

Line Extender Amplifier, One-Way, Manual Gain Control

Push-pull line extender amplifiers are of modular construction and housed in a rugged cast-aluminum enclosure. The unit is adequately weatherproofed to permit outdoor installation without additional protection. The housing cover is hinged. Connections to the amplifier are made with standard 5/8 by 24-in. threaded connectors.

The amplifier has a minimum full gain without equalizer, of 28 dB at 30 MHz with a minimal manual gain control range of 8 dB and is equipped with a slope control. For cross-modulation not exceeding -57 dB, the output capability is 50 dBmV for each of 35 channels. The cross-modulation does not exceed -63 dB with 35 channels with 46 dBmV output at 320 MHz and 6 dB slope; the second order intermodulation is -70 dB or better. Under is these conditions the triple beat shall be -75 dB or less. Frequency response is 20 to 320 MHz %0.5 dB. The noise figure does not exceed 11.5 dB at 320 MHz without equalizer at full gain. Amplifiers used to upgrade or extend the existing cable system are not equipped with mid-split or sub-split filters.

The amplifier is cable powered from ac input voltages of 46 to 60 V at 800 mA maximum. The amplifier incorporates built-in surge protection and a power disposition switch.

Example: Jerrold SLR-300 or equal.
Example: Jerrold JLE-6-450 (frequencies to 400 MHz).

Note: The specifications for the model JLR-6-450 differ slightly from the JLE-SLR-300 specifications listed above.

Attenuation Pad for LE Amplifier

Plug-in attenuation pads designed for installation inside the line extender housing are provided in nominal values of 3, 6, 9, and 12 dB.

Example: Jerrold SXP-X or equal.

Trunk Amplifier, One-Way, Manual Gain Control

Push-pull trunk amplifiers are of modular construction and housed in a rugged cast-aluminum enclosure. The unit is adequately weatherproofed to permit installation underground in manholes which may contain high water levels. Connections to the trunk amplifier are made with standard 5/8 by 24-in. threaded connectors.

The trunk amplifier has a minimum full gain of 28 dB without equalizers, with a minimum manual gain control range of 9 dB. For cross-modulation not exceeding -57 dB, the output capability is to be 48 dBmV for each 35 channels. The cross-modulation does not exceed -87 dB with 35 channels with 33 dBmV output at 300 MHz. The second order intermodulation is -83 dB or better. Under these conditions--the triple beat is -87 dB or better. Frequency response is 20 to 300 MHz %0.75 dB. The noise figure does not exceed 7 dB at 300 MHz without equalizers at full gain.

The amplifier is cable powered from ac input voltages from 46 to 60 V. The amplifier incorporates built-in surge protection and a power disposition switch.

Example: Jerrold Model SJ-4A or equal.
Example: Jerrold Model SJ-2SS/450 (frequencies to 400 MHz).

Note: The specifications for the model SJ-2SS/450 differ slightly from the SJ-4A specifications listed above.

Attenuation Pad for Trunk Amplifier

Plug-in attenuation pads designed for installation inside the trunk amplifier housing provide for nominal values of 3, 6, 9, 12, and 15 dBs.

Example: Jerrold Model SXP or equal.

Power Passing Splitter and Direction Coupler

Signal splitters are housed in a rugged cast-aluminum housing, which is weather and radiation shielded. Connection to the unit is by aluminum cable connectors with standard 5/8 by 24-in. threads.

Signal splitters can accept a maximum current of 10 A. Units incorporate separate fuses for power distribution to each leg. Removal of the fuses does not interrupt the flow of RF signal. Terminal match at any port is to be 18 dB or better. Frequency passband is 5 to 400 MHz. Units are available in both the symmetrical signal splitter and directional coupler configuration.

The symmetrical signal splitter has a maximum insertion loss of 4.4 dB and an isolation between output ports of 20 dB or greater.

The 7-dB directional coupler has a maximum insertion loss of 2.5 dB and a maximum tap loss of 7.8 dB. Isolation between output ports shall be 20 dB or greater.

The 12-dB directional coupler has a maximum insertion loss of 1.5 dB and a maximum tap loss of 12.8 dB. Isolation between output ports is 20 dB or greater.

The three-output directional coupler has one output with a maximum insertion loss of 4.4 dB and two outputs with a maximum tap loss of 7.9 dB Nominal isolation between output ports is 20 dB or greater.

Example: Jerrold Model SSP-3 Splitter or equal.

(1) Jerrold Model SSP-7 Directional Coupler or equal.

(2) Jerrold Model SSP-9 Directional Coupler or equal.

(3) Jerrold Model SSP-12 Directional Coupler or equal.

(4) Jerrold Model SSP-3-636 Splitter or equal.

Interchangeable Broadband Directional Coupler Multitap

Multitaps are the eight-output directional coupler type. Taps are contained in a rugged cast-aluminum housing.

Feeder line connections are made by aluminum cable connectors with 5/8 by 24-in. threads. The center conductor connections are made by seizing with a screw. Tap connections are made by standard "F" connectors. Additionally, terminating taps with 10-dB nominal isolation are supplied. Eight output taps have nominal isolation values of 35, 32, 29, 26, 23, 20, 17, and 14, and have nominal insertion losses of 0.8, 0.8, 0.8, 0.8, 0.9, 1.0, 1.6, and 4.0 dB respectively. An additional terminating tap shall be furnished with 10-dB isolation. Frequency response of all multitaps is from 5 to 450 MHz. Port-to-port isolation within the same unit is 20 dB from 5 to 300 MHz and greater than 30 dB from 20 to 300 MHz. Taps are power-passing except at any of the tap ports and are rated for at least 5 A. Return loss at the input and output ports is 20 dB or greater. Return loss of the tap ports is in excess of 20 dB from 5 to 300 MHz.

Example: Jerrold FFT-8-Isolation or equal.

Terminating Resistor

Terminating resistors with 75 L impedance were installed at unused ports and feeder line ends. Termination resistors were designated to cover the frequency range from 5 to 300 MHz with a minimum return loss of 30 dB over the VHF band.

Example:

(1) Jerrold Model TR-75F ("F" Connector) or equal.

(2) Jerrold Model STR-75C or equal.

(3) Jerrold Model TR-75-FCW or equal.

Amplifier Power Supply

A remote/standby power supply for cable powering of amplifiers is provided. The power supply is enclosed in a rugged, metal housing.

Regulations of 2 percent are typical for input voltage changes of +10 percent and load changes of 75 percent. Output voltage shall be 60 VAC with maximum current of 12 A or greater. Surge protection shall be provided with a striking voltage of 145 V, nonpolarized.

The unit incorporates a time-delay relay to delay the powering of the unit to protect the CATV system from transient voltage surges generated by the initial turn on. The standby feature is designed to convert 21 to 30 V dc power from a set of batteries to a 60-V, square-wave output. This operational procedure will remain present until the batteries are discharged or until the ac input returns to the "on" cycle.

Example: RMS Electronics Model PS-60/30 or equal.

Power Combiner

Power combiners are housed in a rugged cast-aluminum case which is adequately weatherproof to permit outdoor installation and shielded against radiation. The unit shall insert 60 V ac from a power supply into a coaxial cable for remote powering of amplifiers. The power combiner shall have an RF bandpass from 5 to 400 MHz with an impedance of 75 L at all terminals. RF insertion loss does not exceed 0.4 dB. The unit is rated to carry 10 A on each leg with a maximum current of 14 A on the common leg. The unit shall be fused on each of the two output legs.

Example: RMS Electronics Model CA-3700 or equal.

COAXIAL CABLE

Trunk Cable Construction

The trunk cable has a solid copper center conductor with a 0.111-in. O.D. and foam polyethylene dielectric. It has a solid aluminum sheath, which is protected against flooding by a black polyethylene jacket.

With a nominal outside cable diameter of 0.006 in., the trunk cable has a maximum pulling force of 200 lb and a minimum bending radius of 10 in.

The nominal cable attenuation is 1.31 db/100 ft at 300 MHz, the nominal D.C. loop resistance is 1.23 L/1000 ft, and there is a nominal impedance of 75 L.

Example: Comm/Scope Parameter III No. P-375-500J or equal.

Flooded Trunk Cable Construction

The flooded trunk cable has a solid center conductor with a 0.111-in. O.D. and foam polyethylene dielectric. It has a solid aluminum sheath and a black polyethylene jacket.

With a nominal outside cable diameter of 0.006 in., the flooded trunk cable has a maximum pulling force of 200 lb and a minimum bending radius of 10 in.

The nominal cable attenuation is 1.31 dB/100 ft at 300 MHz, the nominal D.C. loop resistance is 1.23 L/1000 ft, and there is a nominal impedance of 75 L.

Example: Comm/Scope Parameter III No. P-375-500Jss or equal.

Plenum Trunk Cable Construction

The plenum trunk cable has a solid copper center conductor with a 0.109-in. O.D. and foam teflon dielectric. It has a solid aluminum sheath and no jacket.

With a nominal outside cable diameter of 0.006 in., the cable's nominal attenuation is 2.0 dB/100 ft at 400 MHz. There is a nominal impedance of 75 L.

Example: Comm/Scope No. 2311 or equal.

RG 6/U Drop Cable Construction

The RG 6/U drop cable has a copper clad steel center conductor with 0.040-in. O.D. and T4 foam polyethylene dielectric. It has a sheath made of aluminum, polypropylene, and aluminum foil with an overlap, as well as an aluminum braid wire sheath. The cable is jacketed with black polyvinyl chloride.

With a nominal outside cable diameter of 0.272 in., the RG 6/U drop cable has a nominal attenuation of 3.46 dB/100 ft at 300 MHz, a nominal D.C. loop resistance of 46.1 L/1000 ft, and a nominal impedance of 75 L.

Example: Comm/Scope No. 2275 or equal.

Coaxial Cable Connector Construction

The coaxial cable connectors are solderless with a 75-L impedance. They were designed for the specific type of cable used in the LINK system. Splices are acceptable unless splice connectors specifically designed for the purpose are available. Connectors for 0.500-in. cable do not have an integral radiation sleeve, and RG 6/U cables are not spliced.

Example: Jerrold Model No. VSF-500SS, SC-500SS, F-500SS 0.500-in.
Cable Type: aluminum-sheath cable.

LINK INTERFACE EQUIPMENT

Interface equipment connected to the LINK system must conform to the following specifications:

(1) Interfaces demonstrate satisfactory operation with receive level variations of -5 to +15 dBmV. Satisfactory operation is defined as equipment yielding bit error rates of 1×10^{-8}.

(2) Transmitter spurious output is to be 46 dBmV below the LINK system nominal operating level for each direction on the system.

CATV NETWORK INSTALLATION REQUIREMENTS

Codes, Standards, and Specifications

In addition to meeting the requirements of the contract specifications, all material and equipment furnished and all work performed must conform to the applicable portions of the following standards, codes, and specifications:

(1) National Fire Protection Association: (NFPA):
NFPA No. 70-1981 National Electrical Code

(2) American National Standards Institute:
C2-National Electrical Safety Code (1981)

(3) Federal Communications Commission:
Part 76, Subpart K

Federal Specifications

All work was performed in accordance with federal and municipal laws, codes, regulations, and all other codes and ordinances applicable. Therefore the stated codes, regulations, and ordinances took precedence over other specifications in the event of a conflict.

Grounding

Neutral conductors, cable troughs, conduit, system components, cabinets, and all noncurrent-carrying metallic parts of the equipment are grounded in accordance with NFPA 70-1981. In the underground system, grounding was accomplished by using the existing ground rod or ground conductor located in each manhole in accordance with NFPA 70-1981.

Terminators

All branches of 0.500-in. O.D. cable which do not incorporate a terminating multitap at their end were terminated with a suitable terminating resistor incorporating ac power blocking capability. All multitap ports were terminated with 75-L terminators using integral "F" fittings.

Conduit System

Any new conduit system which may be necessary will be separate and independent of all other systems.

In those buildings where flush mounted systems exist, all new work will be flush-mounted. In those buildings where surface-mounted systems exist, all new work will be surface-mounted. The type of flush or surface-mounted system used (conduit, metal surface raceway, etc.) will depend on the existing system.

Cable Mounting

All distribution cables not installed in conduit, cable trays, or on messenger cable are supported with approved-type straps or cable hangers. The bending radius of the distribution cables is not to be less than 10 in. All bends were made using a tubing bender and care was taken to avoid repeatedly bending the cable at any point. Caution was also exercised in order to prevent excessive flexing of distribution cables when they were pulled through conduits. All penetrations of firewalls were sealed with compounds approved for this purpose.

Messenger Cable

Messenger cable used for cable support is 3/8 in. in diameter; are seven-strand, 0.273 lb/ft galvanized steel, and have a breaking strength of 11 500 lb.

Coaxial Cable--One-Half Inch

The 0.5-in. coaxial cable was installed according to the following specifications:

(1) The radius of the cable was maintained throughout its entire length.

(2) The cable was not kinked or dimpled.

(3) The cable was securely fastened to a reel until it was ready to be installed.

(4) The cable reel was placed so that the cable pulled straight from the center of the reel and not an angle to reduce the possibility of damage or kinking caused by the cable contacting the flange of the reel.

(5) The cable was paid off from reels so that the natural curve of the cable was maintained.

(6) The maximum pull force did not exceed 200 lb.

(7) The minimum inside cable bending radius was 10 in.

(8) Cable pulleys were used to insure that a radius no smaller than the manufacturer's recommended minimum bending radius for the cable is maintained.

(9) The cable was inspected for defects while it was being installed.

Splices

Excessive splicing of cables was avoided, but when cable splicing was required, splice connectors designed specifically for that purpose were used. In manholes, heat shrink tubing was placed over the splice connection. Splices were not permitted on drop cables.

Cable Identification

At the outlet box and tap, tags were installed on the RG 6/U drop cable. With a heated air gun, clear, shrinkable, nonflammable tubing was placed over these tags. The tags identify the cable as inbound or outbound and show the room number that the cabled serves. For identification, a green tag was used to mark the outbound cable and a yellow tag was used for the inbound cable.

Directional arrows were installed on the 0.5-in. primary inbound and outbound cables. The arrows were placed on both sides of all components through which the cables pass. Yellow tags indicated the inbound cable, and green tags indicated the outbound cable. The outbound cable connector was placed on the top or left side of each outlet box.

Electronic Components

Ports on taps were installed vertically perpendicular to the finished floor. Electronic components were attached to the messenger cable with a bracket, (e.g., Aberdeen 1020A or equal).

Receptacles

Receptacles were installed at power supply locations as needed. Except where codes or regulations dictated otherwise, 120-V power receptacles of the standard National Electric Manufacturers' Association (NEMA) parallel U-blade grounding type were used. All wiring was installed in accordance with the specifications of the National Electric Code. Where receptacles are located in areas subject to dampness, approved ground fault interrupting receptacles were used. Installed receptacles shall be fed from dedicated, independently protected circuits originating from the nearest lighting panel.

Outside Cable Plant

The outside cable plant included all wire and cable required to extend cable from the underground cable system in manholes to the first entrance cabinet in a building.

Conduit Preparation

Empty ducts were cleaned prior to the installation of new cable. Ducts found to be obstructed by foreign material which cannot be removed shall be reported to the Government without delay.

Damage

Any existing cable damaged during installation was repaired or replaced. Some duct cable was under pressure and extreme care was exercised when work was done around or near them.

Cable Installation

Careful control was exercised in the movement of cable reels. Where it was necessary to roll a reel to a desired location, it was rolled in the direction indicated by the arrows painted on the reel flanges. The reel was not permitted to tilt. A substantial runway of heavy planks was employed where uneven ground conditions might have caused the reel to tilt. Where it was necessary to move a reel of cable with a construction truck, a cable reel sling or its equal was used.

Cable reels were set up on the same side of the manhole as the conduit section in which the cable was to be placed. The reel was leveled and properly aligned with the conduit section so that the cable could be passed from the top of the reel in a long smooth bend into the duct without being twisted. Under no circumstances was the cable pulled from the bottom of a reel.

A cable feeder guide of suitable dimensions was used between the cable reel and the face of the duct to protect the cable and guide it into the duct as it came off of the reel.

Cables were lubricated as they came off of the reel into the cable feeder. The lubricant was approved for use with the type of insulation on the cable being pulled. A cable lubricator was placed around the cable just ahead of the cable feeder to facilitate proper lubrication.

Soap lubricants or lubricants containing soap are definitely harmful to polyethylene sheathed cable. After the cable was placed, the exposed cable in the manholes was wiped clean of cable lubricant with a cloth.

The ends of all ducts into buildings were sealed to prevent the entrance of foreign material, water, or gas.

Manhole Access Requirements

Open flames, torches, lighted cigars, cigarettes, or pipes were not permitted near open manholes, into a cover or tent over a manhole opening, nor into a manhole even though tests indicated that combustible gases are not present. Only government approved lighting and heating equipment was used.

The connection and disconnection of electric lighting equipment is not permitted in a manhole.

Every manhole opened for the first time during the day will be tested by the government to determine whether combustible gases are present. Additional tests were performed when required by the Contracting Officer's Representative (COR). Manholes were also tested after the removal of water or duct plugs which could possibly have permitted the flow of gas into a manhole. Where gases were detected or suspected, the manhole shall be ventilated by forced fresh air equipment.

Care was taken to prevent damage to the existing cables while setting up the pulling apparatus or while placing tools of any kind. Cable was not stepped on by workers when they were entering or leaving a manhole. Special care was taken with the filled-type cables when the temperature was below approximately 35 °F. This type cable becomes more difficult to work with as temperatures decrease, and there is a possibility of cable damage at temperatures near 0 °F.

Water was removed from manholes before work began and kept out until work was completed.

Cable Support in Manholes

All cable and stubs shall be supported on cable racks with hooks and insulators using existing or new "T" slats and racks. Cables and stubs were arranged in the manholes to follow accessibility to the cable splices.

Splicing

Splices were not placed or pulled into the duct (duct splices), but were positioned within the manholes. When it was necessary to leave a splice open for a short period or when a temporary splice was made, the splice was sealed and treated in a manner which protected the splice from moisture and damage. Cable ends were kept sealed at all times.

Identification in Manholes

Cables were permanently identified with lead, stainless steel, or brass tags. Tags were placed on each cable as they entered and left the assigned duct in each manhole and cabinet. Tags were stamped with the cable identification in 1/2-in. characters. Identification included cable number and pair count.

SYSTEM TESTING

Test Equipment

The following test equipment was used to perform the operational tests described in this appendix.

(1) Sweep generator (transmitter)

- Range: 1 to 450 in 200 kHz steps; maximum sweep width--400 MHz
- Frequency control: Sweep F1 to F2 or CW
- Accuracy: (Sweep or CW) 1 percent of swept band %25 kHz
- Output amplitude: Adjustable from +50 to +60 dBmV in 0.1 dB increments

- Output flatness: %0.25 dB over frequency range
- Model: Wavetek 1855B or equal

(2) Sweep generator (receiver)

- Sensitivity: -10 to 60 dBmV
- Impedance: 75 L
- Display: 5-in. diagonal, electromagnetic; Type: raster scan, refreshed; Graticule: 8 div by 10 div
- Frequency accuracy: %25 kHz over a single channel; 1 percent of swept band
- Level accuracy: %0.5 dB
- Resolution: 0.01 dB
- Model: Wavetek, 1865B or equal

(3) Signal level meter

- Range: 54 to 216 MHz (VHF), 216 to 450 MHz (Super)
- Accuracy: %1 dB (VHF and Super)
- Frequency calibration: %1.0 percent (VHF); /61.5 percent (Super)
- Input impedance: 75 L
- Model: Sadelco FS-3DVS or equal

(4) Signal generator

- Frequency range: 1 to 500 MHz
- Frequency dial calibration: 10 MHz/div
- Frequency accuracy: 10 MHz or 2 percent of frequency selected
- Output impedance: 75 L
- Output flatness: %0.25 dB
- Output accuracy: %0.50 dB
- Output amplitude: +57 dBmV, 0.7 Vrms (maximum)
- Output attenuation: adjustable from +57 to -33 dBmV
- Sweep time: variable 10 to 100 msec; 1 to 100 sec
- Model: Wavetek 1801 or equal

(5) Camera/Bezel

- Type: Polaroid
- Shutter speed range: manual set to 1/125 sec
- F-Stop range: 3.5 to 32
- Hood: sized to fit 5-in. CRT
- Model: Wavetek C1 or equal

(6) Calibrated antenna with preamplification Wavetek RD-1 or equal

(7) Film

Operational Tests

Tap, outlet, system integrity, and radiation tests were performed to verify the performance requirements listed in section 1.0 of this appendix.

After the coaxial cable/electronic component installation was complete, and prior to testing, all amplifiers were set up and aligned in accordance with the cable system design.

System testing was performed in the presence of the COR and/or a representative of the Telecommunications and Networking Branch. No system testing was done without prior approval of the COR.

Tap Test

A sweep generator transmitter, receiver, camera, and film were provided to perform the tap test.

Outbound

The sweep generator transmitter was connected to the output of the outbound line extender amplifier (JLE model). The transmitter was set to sweep between 50 and 300 MHz, or the highest system frequency supported by the LINK with an output of 48 dBmV.

The frequency response at the last tap on each outbound leg of the distribution cable was measured with the sweep generator receiver and recorded on film.

Inbound

The transmitter was connected to the last tap on each inbound leg of the distribution cable and the transmitter was set between 50 and 300 MHz, (or the highest frequency supported by the LINK system), with an output of 55 dBmV.

The corresponding frequency response at the inbound test port of the inbound amplifier was measured with the receiver and recorded on film.

After a tap was tested, the record picture was scaled, and the building number, tap number, inbound/outbound, and date placed on the back. The pictures were turned over to the COR and/or a representative of the Telecommunications and Networking Branch. The government reviewed the record pictures at the job site. Outlet testing did not begin until the results of the tap tests were acceptable to the government.

Outlet Test

A sweep generator transmitter, receiver, camera, and film were provided to perform the outlet test.

Outbound

The sweep generator transmitter was connected to the output of the outbound JLE. The sweep generator was set to sweep between 50 and 300 MHz (or highest frequency supported by the LINK system) with an output of 48 dBmV.

The receiver was connected to the farthest outlet on each leg to record the frequency response at that point.

Inbound

A similar measurement was made for the primary inbound cable. The sweep generator transmitter was connected into the last outlet on each inbound leg of the distribution cable and set to sweep between 50 and 300 MHz (or highest frequency supported by the LINK) with an output of 56 dBmV.

The corresponding frequency response at the inbound test port of the inbound amplifier was measured and recorded on film. All results were turned over to the COR and/or a representative of the Telecommunications and Networking Branch.

System Integrity Test

A sweep generator transmitter and receiver were provided to test each installed CATV outlet to verify total system integrity.

Outbound

The transmitter was set to the corresponding level of the outbound amplifier and connected to the outbound amplifier output port. The transmitter was set to sweep between 50 and 300 MHz, (or the highest frequency supported by the LINK system). The receiver was connected to each CATV outlet and the highest and lowest signal level readings were recorded.

Inbound

The transmitter level was set to 56 dBmV and the sweep was set between 50 and 300 MHz (or highest frequency supported by the LINK system). The transmitter was connected to the inbound port of the CATV outlet. The receiver was connected at the input of the inbound trunk amplifier; the lowest and highest signal readings were recorded and turned over to the COR and/or a representative of the Telecommunications and Networking Branch.

Radiation Leakage Test

Measurements were made to determine the field strength of radio frequency energy radiated by the LINK system. The signal level meter specified in this appendix was used in combination with the calibrated dipole antenna also specified in this appendix to provide field strength measurements in the 0 to 20 uV range at the specified frequency ranges of table I.

A set of three marker CW signals were introduced into the LINK system using the techniques and levels specified for the System Integrity Test. Frequencies were chosen that were approximately centered on the bands to be tested in table I while protecting the reserved aeronautical frequencies in table II.

The center of the dipole antenna was placed at a distance of 10 ft from each system component. The horizontal dipole was rotated about a vertical axis and the maximum reading was used to determine system compliance. The LINK system was brought into compliance with the specifications of table I.

Sample Termination

Prior to starting work, each individual involved in the actual CATV installation had to demonstrate to the COR and/or a representative of the Telecommunications and Networking Branch the technical capability to make acceptable CATV cable terminations consisting of straight-pin, direct-entry, angle, and cable-to-cable type connectors.

TABLE I. - LINK BROADBAND COMMUNICATION SPECIFICATIONS

Carrier-to-noise ratio, forward	≥43 dB
Carrier-to-noise ratio, return	≥40 dB
P-P hum to peak carrier ratio	<3 percent
Peak-to-valley response, full system	±3.5 dB
Peak-to-valley response, n-amplifier	1 + n/10 dB
Peak-to-valley response, any 6 MHz channel	±1 dB
Carrier-to second order beat ratio	56 dB below Ref carrier
Carrier-to-composite triple beat ratio	48 dB below Ref carrier
Outlet receive level, nominal	+6 dBmV ±3 dB
Tap receive level, min.	+8 dBmV ±3 dB
(This assumes a 2 dB drop cable loss.)	
Radiation (measured with a tuned dipole)	
5 to 54 MHz (measured at 100 ft)	≤15 μV/m
54 to 216 MHz (measured at 100 ft)	≤20 μV/m
216 to 400 MHz (measured at 100 ft)	≤15 μV/m
Forward path loss, nominal	50 dB
Return path loss, nominal	46 dB
Headend processor transmit level, nominal	+56 dBmV ±1 dB
Headend processor receive level, nominal	+10 dBmV ±3 dB
Outlet transmit level (TV visual carrier level-VCL)	+56 dBmV ±1 dB
Outlet transmit level (Data carrier level-DCL)	DCL = VCL - 10 Log N
(Where N = number of subcarriers.)	

TABLE II. - FAA RESERVED FREQUENCIES FOR CLEVELAND HOPKINS AREA

[The restricted frequencies which follow are valid for both the inbound and outbound cables of the LINK system. Under no circumstances are RF signals transmitted within this group of selected frequencies.]

Frequency, MHz	CATV channel	Function
109.900	A2 Block 2	Localizer
110.400	A2 Block 3	Vot
110.700	A2 Block 3	Localizer
111.900	A2 Block 4	Localizer
118.150	A1 Block 5	Communications
118.900	A1 Block 5	Communications
120.900	A Block 1	Communications
121.900	A Block 2	Maximum reserve
121.700	A Block 2	Communications
121.800	A Block 2	Communications
122.100	A Block 3	Communications
122.200	A Block 3	Communications
122.350	A Block 4	Communications
124.000	A Block 5	Communications
124.300	A Block 5	Communications
124.350	A Block 5	Communications
124.500	A Block 5	Communications
125.050	A Block 6	Communications
125.200	A Block 6	Communications
125.359	A Block 6	Communications
125.700	A Block 6	Communications
125.850	A Block 6	Communications
126.550	B Block 1	Communications
127.500	B Block 2	Communications
127.850	B Block 3	Communications
132.250	C Block 1	Communications
132.400	C Block 1	Communications
133.375	C Block 2	Communications
134.900	C Block 3	Communications
135.100	C Block 4	Communications
156.800	G Block 1	Communications
243.000	N Block 4	Communications
255.400	P Block 4	Communications
257.800	P Block 6	Communications
330.200		Glide slope
331.100		Glide slope
333.800		Glide slope
335.000		Glide slope
360.600		Communications

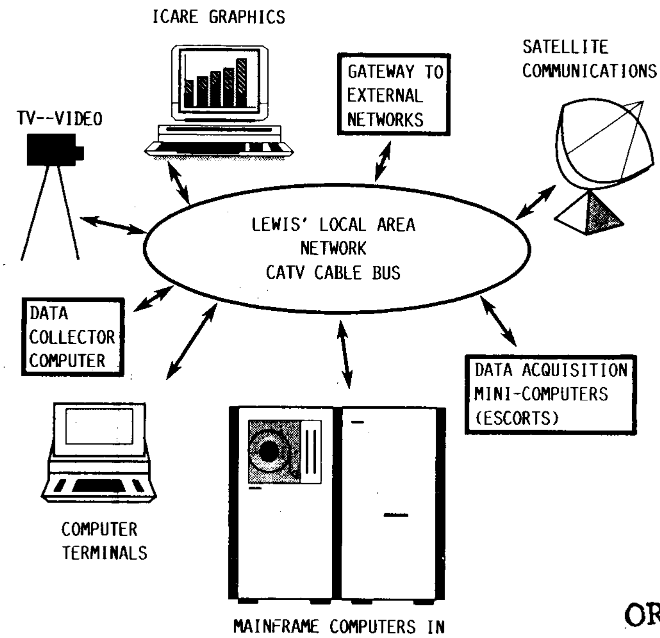

FIGURE 1.

ORIGINAL PAGE IS OF POOR QUALITY

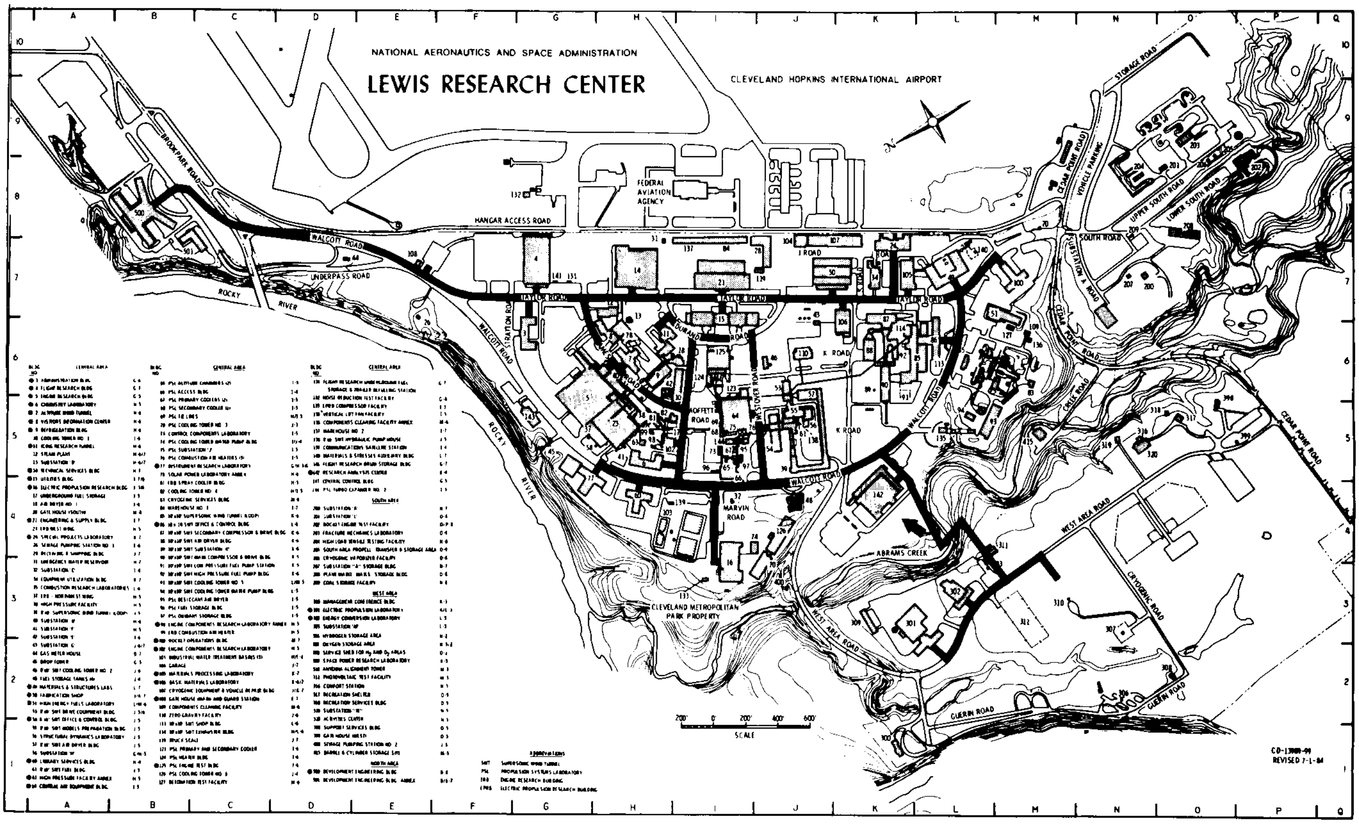

FIGURE 2.

LEWIS INFORMATION NETWORK (LINK)

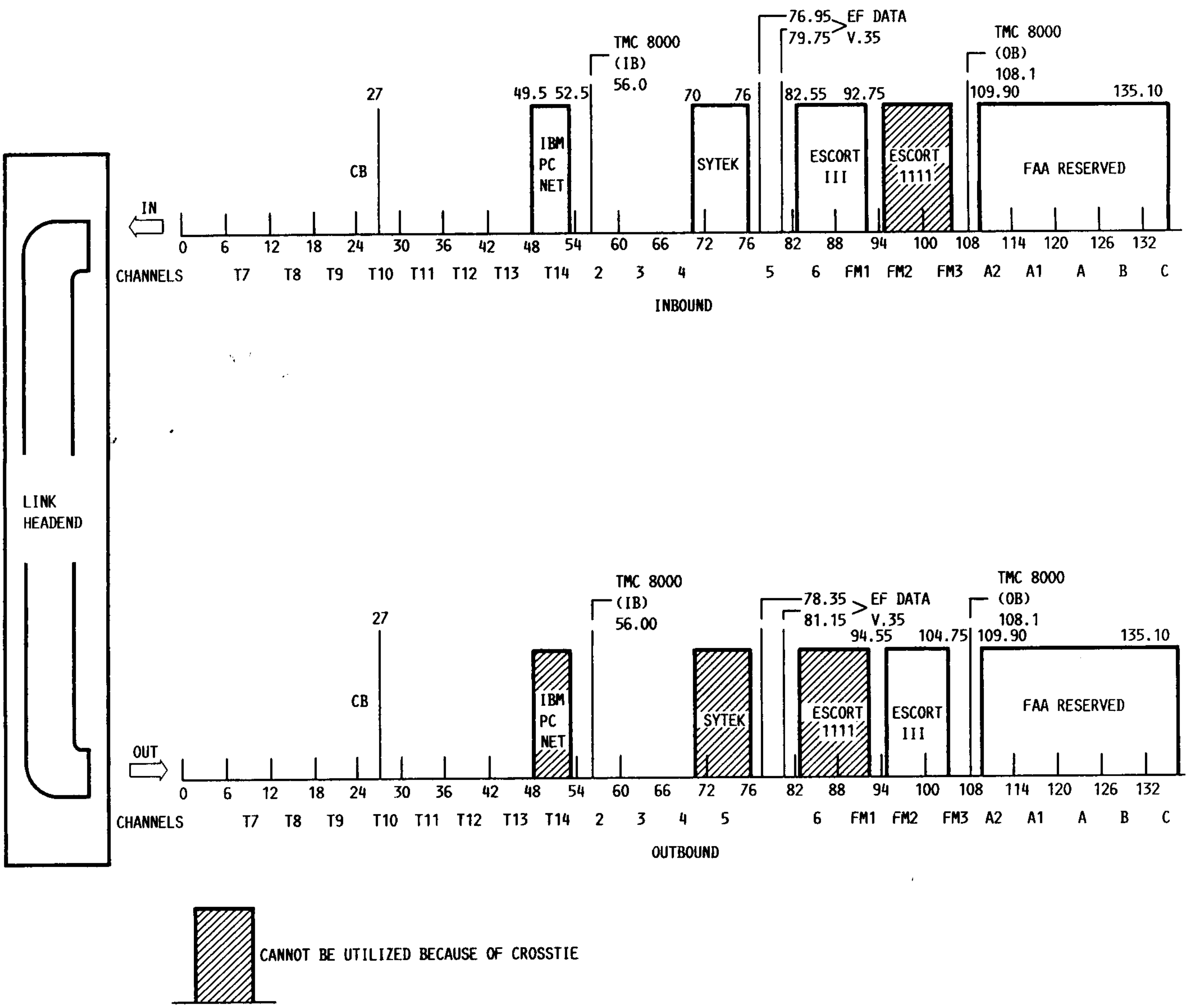

FIGURE 3.

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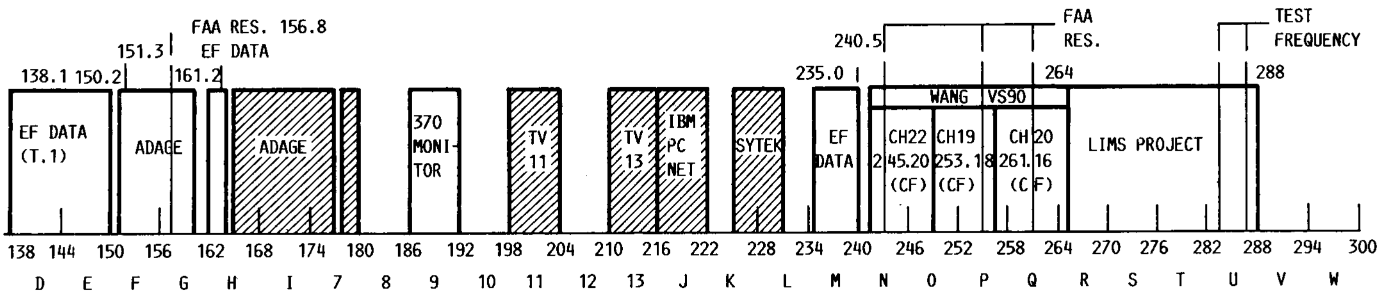
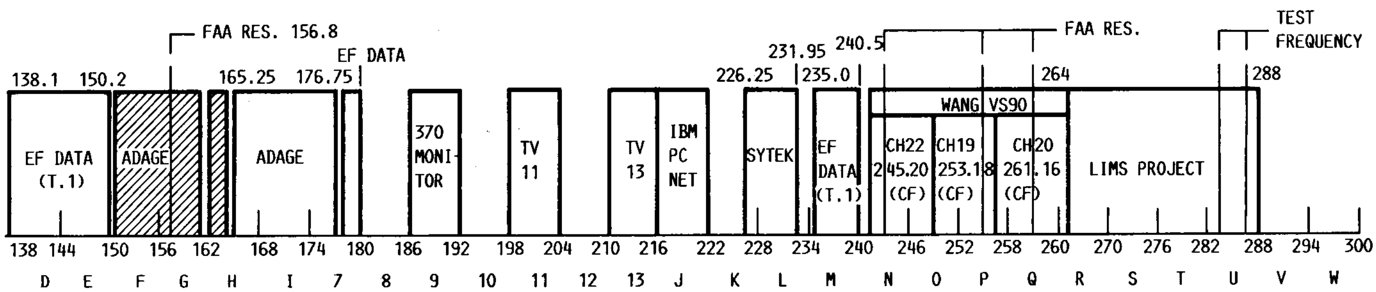
OF POOR QUALITY

LEWIS INFORMATION NETWORK (LINK)



INBOUND



OUTBOUND

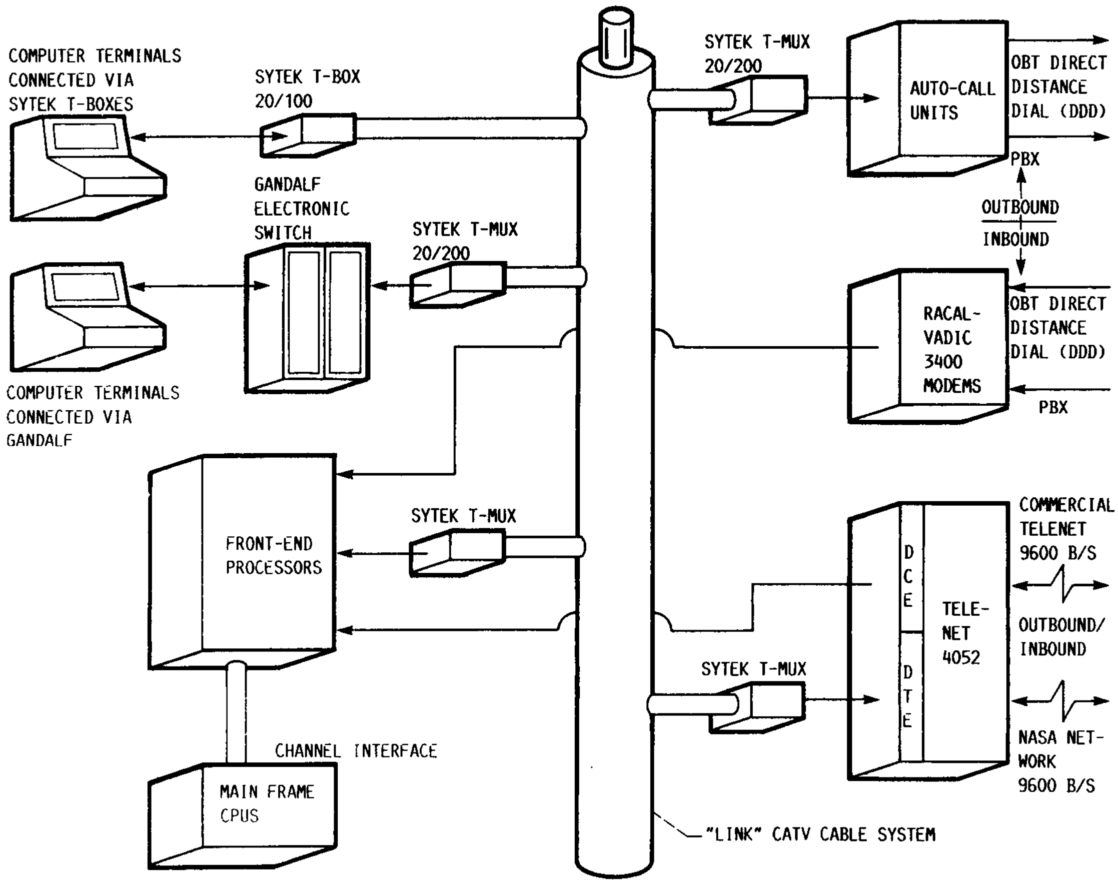

COMPUTER TERMINALS
CONNECTED VIA
SYTEK T-BOXES
SYTEK T-BOX
20/100
GANDALF
ELECTRONIC
SWITCH
SYTEK T-MUX
20/200
COMPUTER TERMINALS
CONNECTED VIA
GANDALF
FRONT-END
PROCESSORS
SYTEK T-MUX
CHANNEL INTERFACE
MAIN FRAME
CPUS
SYTEK T-MUX
20/200
AUTO-CALL
UNITS
OBT DIRECT
DISTANCE
DIAL (DDD)
PBX
OUTBOUND
INBOUND
RACAL-
VADIC
3400
MODEMS
OBT DIRECT
DISTANCE
DIAL (DDD)
PBX
COMMERCIAL
TELENET
9600 B/S
D
C
E
TELE-
NET
4052
D
T
E
OUTBOUND/
INBOUND
SYTEK T-MUX
NASA NET-
WORK
9600 B/S
"LINK" CATV CABLE SYSTEM

FIGURE 4.

NASA
National Aeronautics and Space Administration

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15. Supplementary Notes

16. Abstract

The NASA Lewis Research Center supports a wide variety of research facilities with many isolated buildings, including wind tunnels, test cells, and research laboratories, as well as large office buildings. These facilities are all located on a 350 acre campus-type environment adjacent to the Cleveland Hopkins Airport. The function of NASA Lewis is to do basic and applied research in all areas of aeronautics, fluid mechanics, materials and structures, space propulsion, and energy systems. These functions require a great variety of remote high-speed, high-volume data communications for computing and interactive graphic capabilities. In addition, new requirements for local distribution of intercenter video teleconferencing and data communications via satellite have developed. To address these and future communications requirements for the next 15 years, a project team was organized to design and implement a new high-speed communication system that would handle both data and video information in a common lab-wide Local Area Network. The project team selected cable television broadband coaxial cable technology as the communications medium and first installation of in-ground cable began in the summer of 1980. The Lewis Information Network (LINK) became operational in August 1982 and has become the backbone of all data communications and video at the center.

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