TECHNOLOGY ADVANCES IN SATELLITE TRACKING STATIONS

DAVID A. EMANUEL
MANAGER, Network Systems
The Aerospace Corporation
1320 Orleans Drive
Sunnyvale, California 94086

ABSTRACT

This paper addresses the technology advances in S-band remote satellite tracking station hardware which have occurred in the last twenty years. Significant progress has been made in increasing performance, decreasing size, weight and power consumption and greatly improving reliability. Standard remote control interfaces and built-in test/diagnostic features along with readily available control processors can provide automated remote control at modest cost thereby permitting site manning to be reduced significantly and still provide high system availability.

INTRODUCTION

In the early 1960's the U.S. Air Force and NASA deployed several S-band remote tracking station networks. These included the Air Force Satellite Control Facility (AFSCF) to support DoD satellites, the Unified S-band System in support of the early manned space program and the NASA Ground Spaceflight Tracking and Data Network (GSTDN) network to support the current manned space program. Also, the NASA National Oceanic and Atmospheric Administration (NOAA) network was implemented to provide civilian weather and oceanographic services.

In the near future, the Air Force will be upgrading the hardware at its AFSCF remote tracking stations as part of the Automated Remote Tracking Station (ARTS) program. This program will complete the modernization effort started by the current Data System Modernization (DSM) program which is centralizing and automating the control function and upgrading the data processing hardware and software.

This paper presents the results of an industry survey conducted by the System Planning and Engineering Directorate of the Aerospace Corporation in anticipation of the ARTS program. It summarizes the advances made in the various technology areas of hardware required for the tracking station modernization effort.

TECHNOLOGY ADVANCES

ANTENNAS AND ANTENNA CONTROL

There are several companies which offer essentially off-the-shelf antennas suitable for use at S-band. These antennas are primarily geared for the commercial satellite industry in the C and Ku frequency bands. Optional feeds, servo drives, full tracking mounts and tracking systems are offered to adapt such units for S-Band military satellite applications, with sizes available up to 14 meters. Since these units are designed for the higher frequency bands, the available tighter servo control loops and reflector tolerances give increased performance at S-band. Standarization of production allows acquisition and installation on site in a typical 11 - 12 month interval. This was generally the lead time required for metal part fabrication alone in the past. Thus, standardization provides a schedule improvement of four to five months.

When used inside a radome so that the antenna structure itself is not subjected to severe environment, the structure can be lighter, therefore requiring a less complex foundation. The cost of this type of antenna is less than half of the TT&C 46 foot antenna which was designed for SCF application in the early 1970’s.

Dramatic advances have been made in the area of antenna control. Single channel monopulse tracking systems have been developed which give equal or better performance than the old three channel system and greatly reduce system complexity. This approach also allows a reduction in costs of the RF front-end hardware, since a single channel paramp will suffice, rather than a three channel unit.

Digital controllers having powerful capabilities have been developed. Built-in microprocessors allow simplified remote slaving, acquisition pattern generation, through keyhole tracking and built-in test features, along with complete servo remote status monitoring and control. Fig 1 depicts a typical unit consisting of one 10.5 inch chassis which has essentially replaced a rack of hardware in early 1970’s technology. This unit also contains a set of antenna controls and monitors which were previously located on an additional console mounted panel.

RF FRONT-END HARDWARE

Perhaps the most dramatic technology advances have been made in this area. The old cryogenic cooled parametric amplifier that required constant purging, compressor mechanical maintenance and adjustment to maintain an acceptable gain-phase characteristic, which varied widely with temperature, has been replaced by a single GaA_s FET module. Performance is within 20^0K of the old cryogenic units; 70^0K over the 2.2 - 2.3 GHz band being typically available. These small units, which can be held in one hand, can be mounted directly on the feed reducing cable losses. Mean-Time-Between-Failures (MTBF's) are typically 80,000 hours. Thermoelectrically cooled units offer even better performance. The cost of these units is less than one tenth of the old cryogenic units and are maintenance free. Fig 2 depicts one of these units comparing it to its ancestor which weighed approximately one hundred pounds.

HIGH POWER TRANSMITTERS

Up to this time transmitter power has been supplied by either a Traveling Wave Tube (TWT) amplifier or Klystron type amplifier. Power ranges from 2-10 Kw have been in wide use. These transmitters have also been a troublesome area, since both require a high voltage power supply (about 20 KV), which typically had poor reliability. In addition, the tubes had limited life and often failed catastrophically. This would cause a complete loss of command capability to a spacecraft for a significant period, since tube replacement usually took several hours.

Spurred by the demand in the phased array radar field, solid state transmitters of one kilowatt and higher are now achievable. A 1.0 Kw unit is to be delivered shortly to the SCF for a transportable application and procurement activity is about to begin for a 2 Kw unit. The main advantage offered by the solid-state types is graceful degradation, rather than a complete loss of output power, in the event of a device failure. Since low voltage devices are utilized, greatly improved power supply reliability is possible. This, along with proper device derating can result in much greater MTBF's, 25,000 hours being achievable versus 2500 for a tube type. Solid state devices also permit easily obtained wide bandwidths and do not exhibit am/pm conversion and other tube related degradations which limited performance. Cost of the solid state units is comparable to tube units and will probably decrease as the demand forces higher production quantities. Fig 3 compares today's solid state unit with the 10 kw transmitter design for the AFSCF of the mid 1960's.

TRACKING AND TELEMETRY RECEIVERS

The Ground Receiving and Ranging Equipment (GRARE) receiver and telemetry demodulators designed for SCF application in the mid 1960's consisted of two full equipment racks of hardware. Microminiturization and microprocessor technology now permit the same function to be provided in two 7 inch chasses. In addition, these units are capable of full remote control via a standard control bus and also provide the tracking error demodulation function. Cost of these units is a fraction of the Space Ground Link System (SGLS) receiver unit cost. Fig 4 shows a comparison of today and past technology.

RANGING EQUIPMENT

The SGLS ranging unit occupied a whole rack of hardware. Today's technology again would permit the ranging function to be performed with a single chassis of hardware. Fig 5 depicts the comparison.

TRACKING STATION CONTROL

The early tracking stations required manual equipment operation according to voice commands issued from the control center. A typical tracking station in the SCF requires 13 operations personnel to conduct prepass checkout, configure equipment and monitor data acquisition during active satellite contact. In addition, there are 22 maintenance, logistic support and administrative personnel on site.

In the early 1970's, remote control interface standards were established and hardware implementing these became available. By the mid 1970's, remote tracking stations were implemented with automated remote control of a majority of station functions. The relative low cost of minicomputers has also been an important factor in implementation. Automated remote control has greatly reduced the required number of operations and maintenance personnel.

Development of networks and switching systems has been rapid during the past few years, due to advancements in development of solid state technology. Star, loop, mesh, tree and combinations of these and other network configurations are being utilized to obtain optimum efficiency. Electro-mechanical devices for switching are being replaced by solid state units for lower cost, increased reliability, and more efficient utilization of time. (See Fig 6). The Institute of Electrical and Electronic Engineers (IEEE) published standards for the General Purpose Interface Bus in 1975. It has been updated twice since. The GPIB provides an interface between controllers and instruments resulting in an efficient functional network. The network can be synchronous or asynchronous, with multiple access, as requirements dictate. Today, the majority of the equipment has remote control interfacing capability available as a standard feature. The most popular type of interface is the IEEE-488 which is a parallel control bus structure.

A controller to perform control and status functions for an ARTS Station must interface with about 55 electronic rack-mounted units. In addition, the controller will be required to control various switch matrices for operational configuration and test switching. The controller also provides control for automated test sequencing, initiated locally or from a remote control center.

Software requirements for the ARTS design will include compatibility with the DSM interface, diagnostic testing, and switching configuration control. These requirements may lead to the selection and use of different languages. Most off-the-shelf automated testing systems utilize BASIC. Selection of the controller should be based on multiple language capability, standard software support availability, applications software availability, and DSM requirements.

Manufacturers of equipment suitable for the ARTS controller generally offer standard software which will assist in overall software development. For example, Hewlett Packard offers the “Value Pack,” which includes FORTRAN 77 and Pascal compilers, graphics, and other software packages. Communications software is also standard. The Hewlett Packard price schedule for the HP 1000 series of computer systems includes some 10 pages of standard software items from which an appropriate selection can be made. They also offer a compiler for Atlas, the IEEE 416 standard.

An ARTS will interface to the DSM software either through the 19.2 kbps Future Interface of the Remote Control and Status Element (RCSE) or directly with the Defense Communications System/Satellite Control Facility Interface System (DSIS) communication terminal. The DSM will utilize Advanced Data Command and Control Procedure (ADCCP) and Synchronous Data Link Control (SDLC). Therefore, the ARTS controller software must be structured to match these protocols. Provisions for interface development must be made to recognize station status, link connect/disconnect, data transfer, data acknowledgment, and link testing capability.

Local Areas Networks (LAN) are emerging as one of the new technologies in the data communications area. These systems offer an alternate method of controller to equipment interface and network protocol. A LAN might be effectively used in a control and status system such as the one for ARTS.

While network definitions vary widely, most experts consider a LAN to be one which is used to link together different kinds of computer based equipment located within a limited area, such as a large office building, factory complex or tracking station. LANs usually run at a data rate ranging from 100 kilobits-per-second to 20 megabits-per-second. They link individual work stations to data bases, host computers and peripherals, to create a resource-sharing environment. A LAN can provide a logical and efficient means to connect digital equipment across distances ranging from dozens of yards to miles.

LANs come in a variety of configurations, or “topologies,” and use a number of different control methods. Potential LAN users must choose from these options. The options that exist can be subdivided into the following categories of network design: Architecture, Protocol, and Media. (See Table 1-Basic Local Network Architectures and Table-2 Media for Local Networks).

Of all the current LANs systems, the Ungermann/Bass NetOne appears to be a suitable best candidate for the ARTS design. The NetOne is a general purpose system for interconnecting normally incompatible equipment. In addition, NetOne can be media and transceiver-transparent, thanks to its network interface units, which can be programmed by the user to handle different media in the future, i.e., broadband coax or fiber-optic cables. (See Table 2 - Media for Local Networks)

CONCLUSION

Great strides have been made in technology relating to S-band satellite remote tracking stations. An abundance of hardware is essentially available off-the-shelf to provide low cost, highly reliable system designs. The broad availability of hardware with remote control capability, along with a wide variety of switching matrices, low cost processors and software, will allow an automated remote controlled design to be implemented at moderate cost. Projected manpower savings in the number operations and maintenance personnel due to automation and the greater reliability of today's hardware indicates a 50% reduction in manpower may be possible.

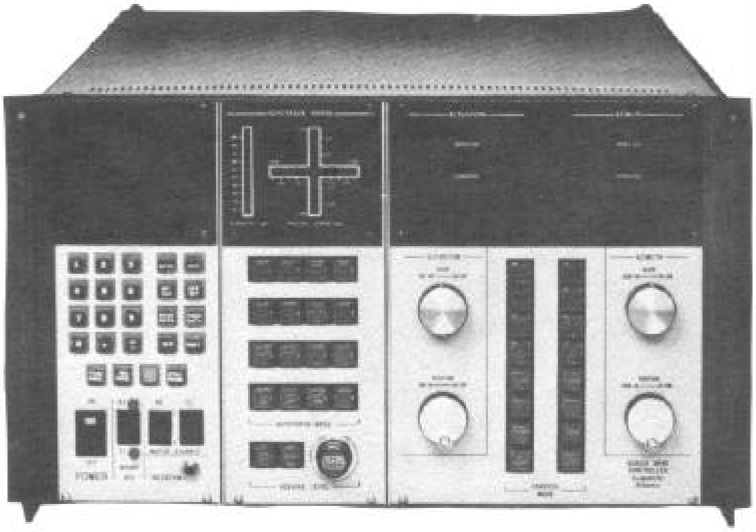
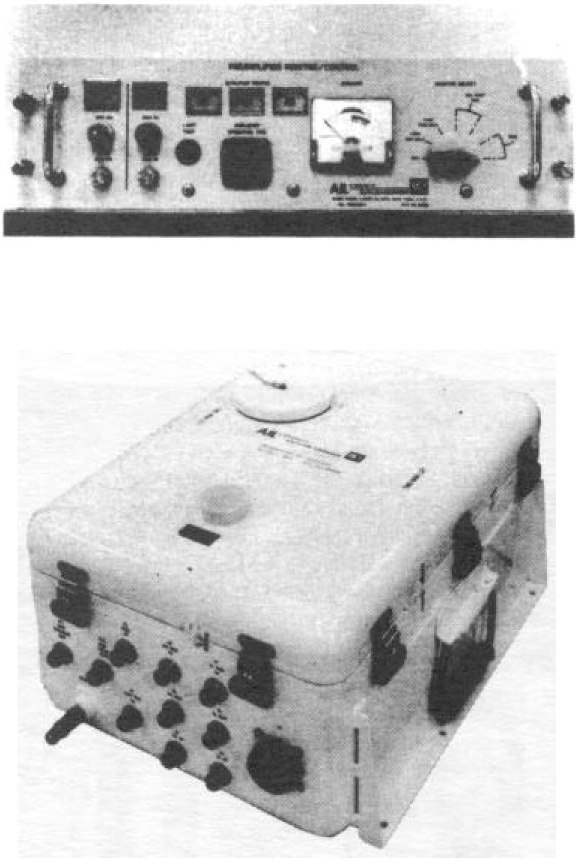
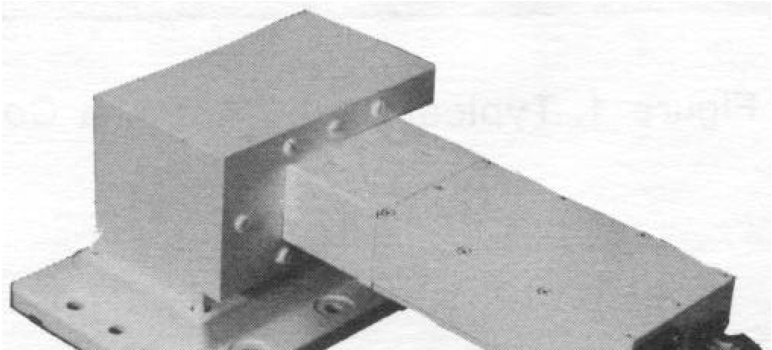


Figure 1. Typical Digital Antenna Controller

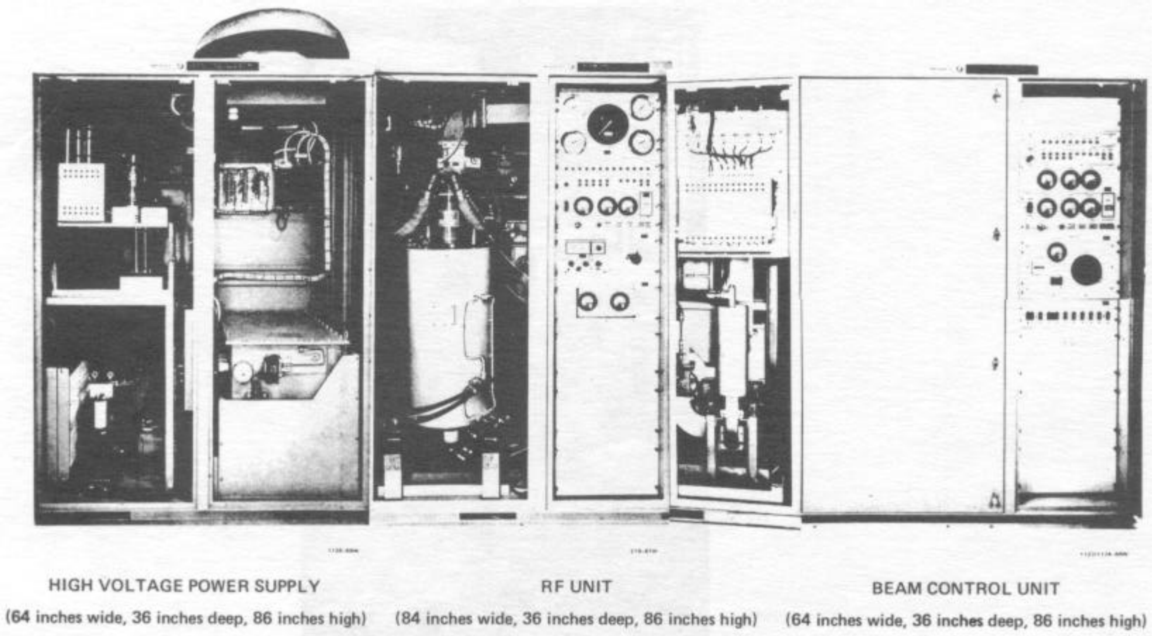


Old S-Band Equipment

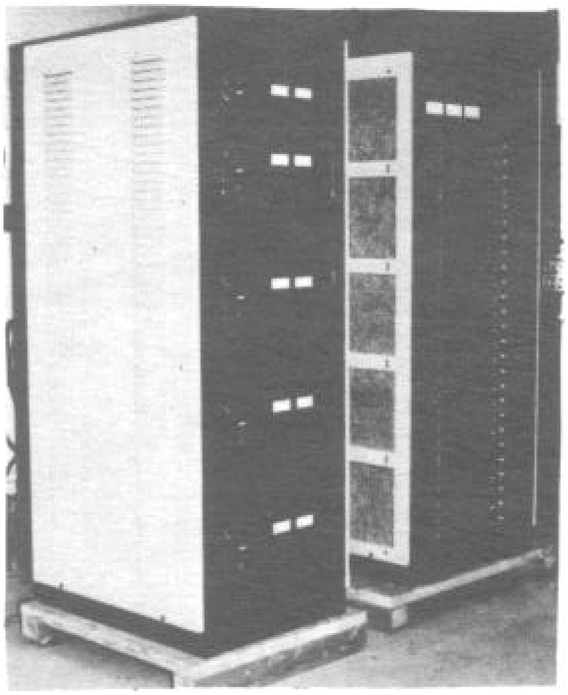


Typical S-Band GaAs FET LNA

Figure 2. LNA Comparison

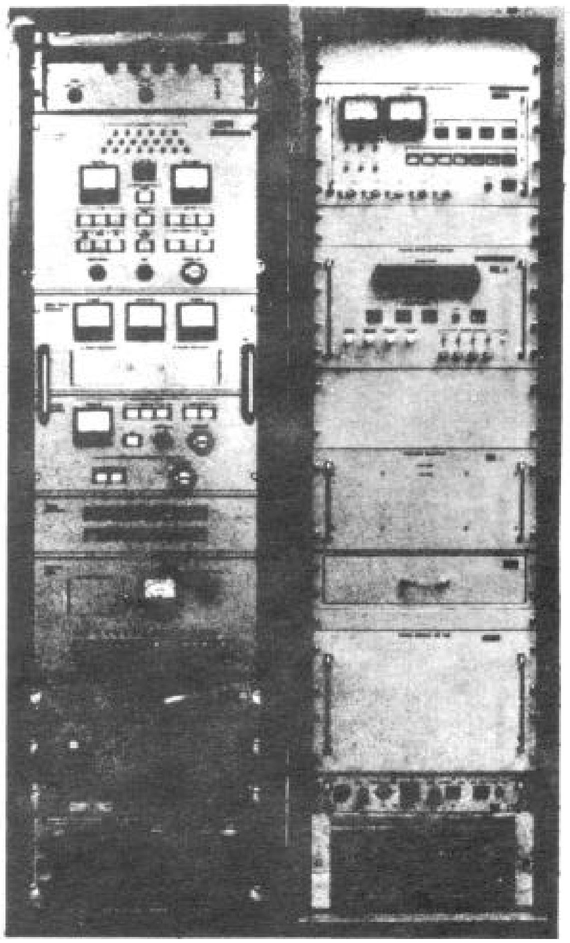


Old Water Cooled Unit

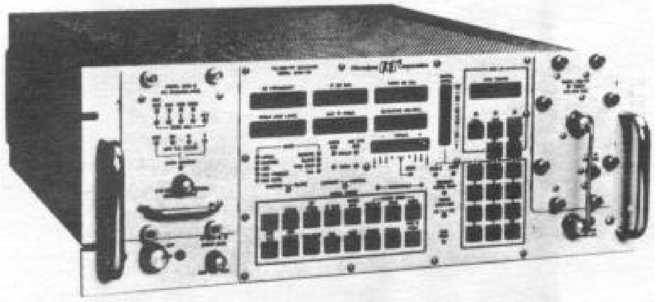


New Solid-State Air Cooled Unit

Figure 3. Transmitter Comparison

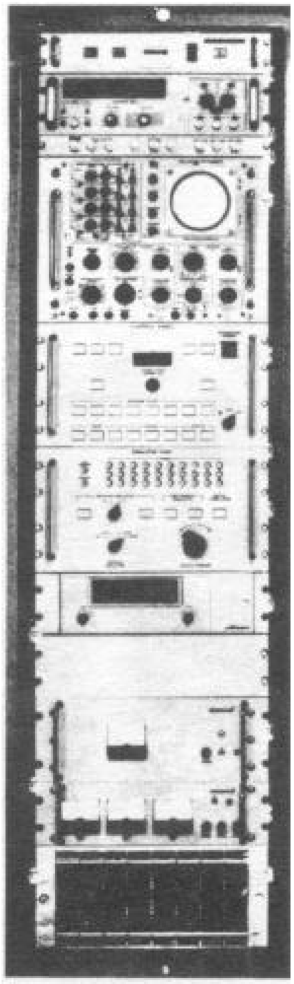


GRARE DEMODULATOR

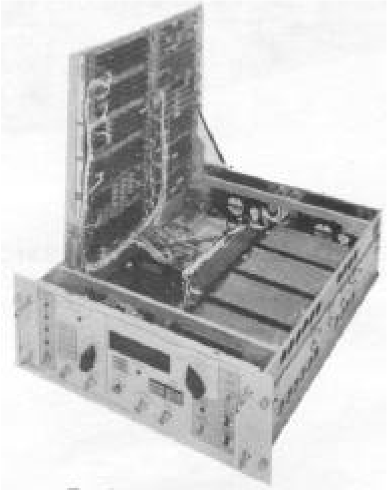


Typical New Receiver Unit

Figure 4. Telemetry Receiver Comparison



OLD Digital Ranging Equipment



Typical New Ranging Equipment

Figure 5.   Ranging Equipment Comparison

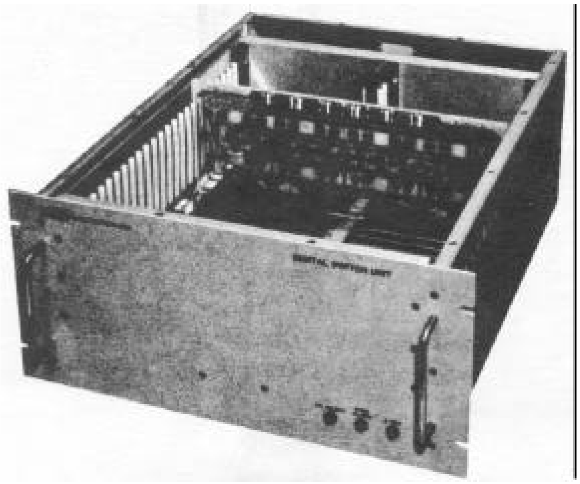
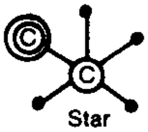
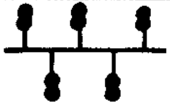
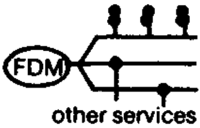


Figure 6. Digital Switch Unit (Basic Building Block).

Table 1. Basic local-network architectures

Topology	Transmission mode	Typical protocols	Typical No. of nodes	Advantages	Typical systems
 Star	Point-to-point via channel switch or computer memory	RS-232C or computer	Tens	Well-known, large base of users	PABX, computer μC clusters
 Loop	Message routing via loop controller	SDLC	Tens	Well-known, large base of users	IBM 3600/3700, μC clusters
 Ring	Packet transmission around rings	HDLC (token passing)	Tens to hundreds per channel	Distributed control, no contention, popular for computer nets	Primenet, Domain, Omnilink μC clusters
 Common Bus	Broadcast along serial bus	CSMA/CD or CSMA with acknowledgment	Tens to hundreds per segment	Distributed control, popular for office networks & computer nets	Ethernet, Net/One, Omninet, Z-Net μC clusters
 Broadband bus	Packet broadcast bus with dedicated or prioritized channels	CSMA/CD RS-232C & others per channel	Two to hundreds per channel	Distributed control, large variety of users and services	Wangnet, Localnet M/A-COM

● Terminal

●● Terminal with distributed controllers and/or multivendor interfaces

Ⓒ Local controller

◎ Hierarchical network

(FDM) Frequency division multiplex

Table 2. Media for local networks

Cable	Typical aggregate data rate	Typical number of nodes	Typical Applications
Shielded twisted pair	1 Mbit/s	Tens	µC cluster
Baseband coaxial cable	10 Mbits/s	Tens to hundreds To	Office equipment
Broadband coaxial cable	300 Mbits/s	hundreds per channel	Office, computer center
Fiber-optic	50 Mbits/s	Two	Trunk, Hi-rel link