MINI-HUB ADDRESSABLE DISTRIBUTION SYSTEM FOR HI-RISE APPLICATION

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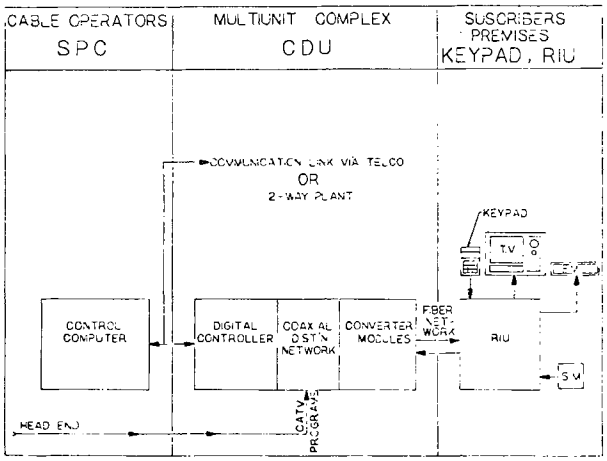
INTRODUCTION

Mini-Hub is a micro-computer controlled local distribution system to provide cable television and other services for urban high-rise environment in major metropolitan areas. The system is fully addressable and uses state-of-the-art fiber optic technology to provide improved security and signal quality.

The block diagram of the basic Mini-Hub system is shown in Figure 1. It consists of five major components:

1. Keypad
2. Residential Interface Unit (RIU)
3. Central Distribution Unit (CDU)
4. Fiber Network
5. Subscriber Program Controller (SPC)



Block Diagram of the Mini-Hub System
Figure 1

In operation, the subscriber selects a channel. A digital signal is generated at the keypad which corresponds to the selected channel and is transmitted optically by the RIU via the fiber network to CDU. The CDU is the central node of communication and signal distribution for the star network architecture used in the present system. It determines service authorization in response to a channel change request, and if valid, just that channel is sent to the subscriber.

Addressability can be achieved locally by using a Field Programming and Diagnostic Unit (FPD). Alternatively, the CDU can be addressed from the operator's office using the SPC. The cable system operator has the capability to enter or request information from the CDU. The interface allows the operator to update/reduce the service menu; enable or disable service; run diagnostics; carry instantaneous polling and other services.

The organization of the paper is as follows: Section 2 summarizes the performance and system design objectives which guided the development of the Mini-Hub system. The key features of the subscriber's keypad are described in Section 3. In Section 4, the RIU is described. Section 5 gives a description of the CDU. The optical fiber network is described in Section 6. The SPC and system's communication network that provides full addressability to the cable operator are considered in Section 7. Section 8 concludes the paper by outlining the advantages of the Mini-Hub System from the cable operator's point of view.

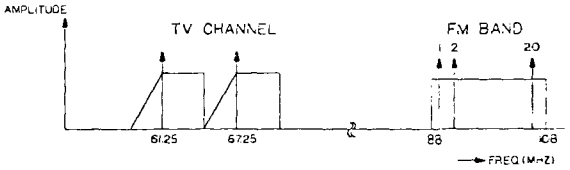
SECTION 2. SYSTEM DESIGN OBJECTIVES

The following objectives guided the development of the Mini-Hub system:

Transmission Format. One TV channel assigned either on channel 3 or 4 and FM band consisting of 20 carriers in 88-108 MHz range are transmitted to the subscriber on uplink fiber. The digital data from subscriber's Keypad or Sensor Interface Module (SIM) is transmitted

downstream at 9.6 kb/s using NRZ code. The frequency plan for the uplink is shown in Figure 2.

Addressable Control. The cable operator exercises total control over the service delivered to each subscriber from the SPC at his central office. The CDU not only operates under the software control of the SPC, but also sends clear confirmation of the commands being executed. The cable operator, as part of routine operational procedure, can confirm the integrity of the control mechanism by verifying the service status of each subscriber.



Frequency Assignment of Uplink
Figure 2

Performance. The performance requirements adopted for delivery to the subscriber are as follows:

TV	
Level	10 dBmV, typical
CNR	43 dB, minimum
FM	
Level	-8 dBmV, typical
SNR (mono)	65 dB, minimum
(stereo)	55 dB, minimum

The guaranteed performance, of course, sets certain minimum requirements on quality of the drop acceptable from cable system.

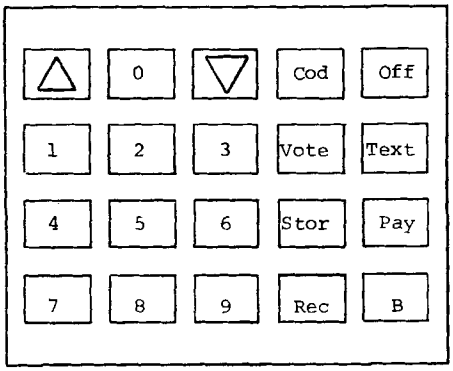
Modular Expandability. One of the major design goals in developing the Mini-Hub system architecture was to incorporate flexibility to provide subscriber access to new cable services as they develop without making the current hardware obsolete. Whereas the basic Mini-Hub system features full addressability (including opinion polling), it is possible to expand to other interactive services, such as

Impulse Pay-per-view
Catalog Shopping
Fire/Medical/Panic/Intrusion Alarm
Videotext

This can be accomplished by adding plug-in services modules and/or firmware changes.

SECTION 3
KEYPAD

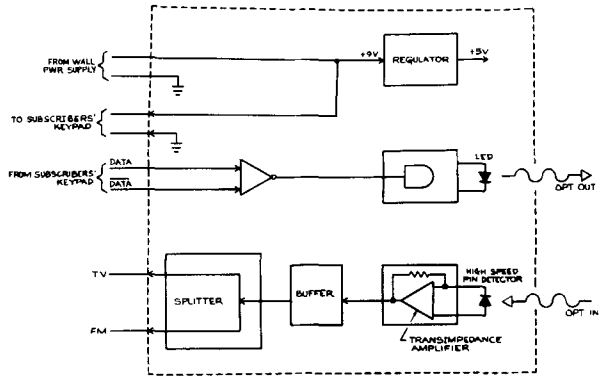
The Keypad provides the necessary interface between the subscriber and the CDU to furnish two-way interactive cable TV service. Included in the Keypad is an 8-bit microcomputer which, in addition to performing the necessary local control and diagnostic functions, receives (from remote IR unit) and encodes 6he data in serial format. The Keypad allows tiered access to over 100 channels, opinion polling, pay-per-view parental authorization codes plus other interactive services. The layout of the push-button keyboard is shown in Figure 3.



Block Diagram of the Keyboard
Figure 3

SECTION 4.
RESIDENTIAL INTERFACE UNIT (RIU)

The RIU is a permanently mounted wall unit which acts as an interface between the subscriber and the CDU via the fiber network. The block diagram of the RIU is shown in Figure 4. It contains a highly reliable digital LED transmitter and a low-noise wideband optical receiver. The transmitter converts the digital command words from the Keypad into a stream of on-off optical pulses. The optical receiver uses a low voltage, high speed PIN detector packaged to provide optimum coupling to 200 um core fiber without using any pigtail. A low-noise, wide band transimpedance amplifier performs the necessary current-to-voltage transformation. TV and FM signals are then made available at separate F connectors via a buffer stage and power splitter.



Block Diagram of the RIU
Figure 4

SECTION 5.
CENTRAL DISTRIBUTION UNIT (CDU)

The CDU is the focal point for all communications and signal distribution. It consists of three main sections:

1. Coaxial Distribution Network
2. Digital Controller
3. Converter Modules

Coaxial Distribution Network

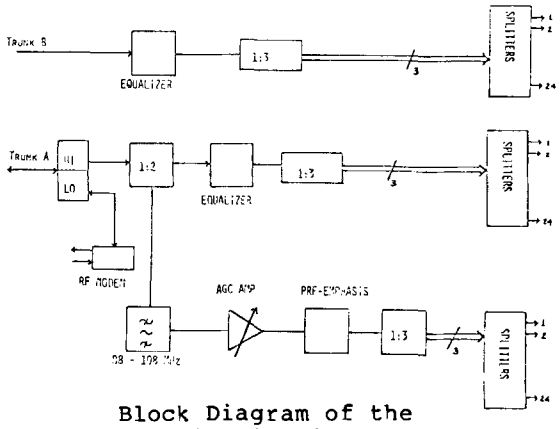
The coaxial distribution network interfaces with 2-way cable distribution plant to perform the following functions: (i) Condition and distribute TV signals on A and B trunks to all converter modules; (ii) Extract, AGC, pre-emphasize, and distribute FM carriers in 88-108 MHz band to all converter modules; (iii) Combine RF modem's response signal with the return trunkline signals.

The block diagram of coaxial distribution network is shown in Figure 5.

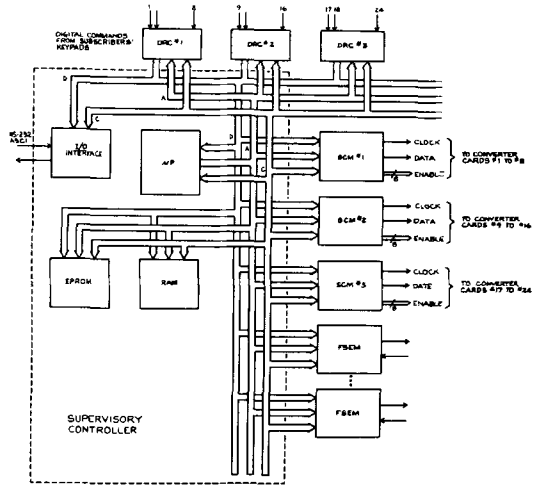
Digital Controller

The digital controller communicates with subscribers as well as cable operator's SPC to exercise necessary control towards delivery of authorized levels of TV and other services. The functional diagram of the digital controller is shown in Figure 6. The major components of the digital controller are

(i) Supervisory Controller
(ii) Data Receiver
(iii) Subscriber Control Module



Block Diagram of the
Coaxial Distribution Network
Figure 5



Block Diagram of the Digital Controller
Figure 6

The Supervisory Controller provides the necessary control over data flow to implement various services as well as supporting the many diagnostic functions designed into most areas of the system.

The Data Receiver is used to receive serial data from the subscriber's Keypad or Sensor Interface Module (SIM). Each data receiver card supports 8 subscribers and up to 3 cards may be installed in a CDU, therefore allowing up to 24 subscribers to be serviced. Each subscriber's receiver IC is individually addressed by the supervisory controller and data placed on bus for further processing by either respective Subscriber Control Module (SCM) or one of the Future Services Expansion (FSE) modules.

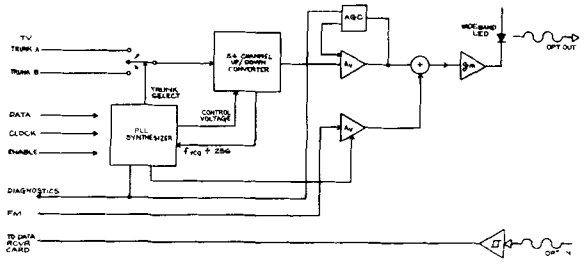
The Subscriber Control Module is a microcomputer based channel selection control unit. One module services up to 8 subscribers and acts upon commands which are routed to it by the Supervisory Controller. Commands include channel change requests from subscribers and SPC's tier enable/disable authorizations.

Following receipt of a channel change command, the microcomputer in the SCM compares the command word to those stored in Electrically Alterable Read Only Memory (EAROM) to determine subscriber's status. If the service has been made available, the SCM sends the appropriate data word to phase locked loop (PLL) circuitry in the converter module to change channel. The contents of the EAROM are remotely alterable by the cable operator using the SPC, thus providing complete control over tier enable/disable functions.

The Converter Module

The Converter Module is a programmable channel selection unit which delivers one subscriber requested cable channel as well as FM band to the uplink optical fiber. One module is required per subscriber. The up/downconverter is switched between trunks A and B on command from subscriber's Keypad. Channel select and other commands to the module originate from the SCM and are sent in serial form. The converter module also regulates delivery of FM service upstream under the control of cable operator's SPC.

The block diagram of the Converter Module is shown in Figure 7. The PLL synthesizer generates the necessary control voltage to set up/down converter's VCO frequency in response to channel select command on its data input line. The up/down converter used in the present system is of improved design as evident from key specifications summarized in Table I.



Block Diagram of the Converter Module
Figure 7

TABLE I

Noise Figure		10dB, max.
Return Loss -	Input	14 dB, min.
	Output	14 dB, min.
Flatness		±0.5 dB
Output Frequency -	Accuracy	±5 kHz
	Drift	±50 kHz
Cross Modulation (at 13 dBmV input/channel)		-56 dB, max.
Adjacent Carrier Rejection		30 dB, min.
Temperature Range		0° to 50°C

AGC control of LED drive assures specified modulation depth and performance level in spite of certain extent of channel-to-channel level variation. The LED used to transmit multiplexed TV and FM signal on frequency upstream is state-of-the-art performance device. It has excellent linearity and coupled power-bandwidth product. In addition, the inexpensive GaAlAs surface emitter has proven reliability in excess of 10^5 hours.

The converter module uses a schmitt trigger detector to perform optical to electrical conversion of downlink data headed for the Data Receiver.

SECTION 6.
FIBER AND CABLE NETWORK

The fiber developed for Mini-Hub is of a special large core design to efficiently collect light emitted from an LED. The core diameter at 200 um makes the cross-sectional area 16 times greater than that of the 50 um diameter international standard fiber used in telecommunications. Light collection from an LED is directly proportional to the core area. Another advantage of the large core is that it substantially reduces the tight tolerances and thus the cost associated with optical connectors. The fiber is made with a pure silica core and a binary borosilicate cladding. The low cost of the silicon and boron starting materials makes this fiber particularly attractive for consumer applications.

A star network of large core glass-clad-glass step index dual fiber optic cable links the subscriber's RIU with the CDU. The downlink fiber carries digital signals from the RIU to the CDU. The uplink fiber transports TV and FM optical signals from the CDU to the RIU. The major segments of the fiber network are

1. Distribution Box
2. Vertical Riser
3. Junction Box
4. Horizontal Home Runs

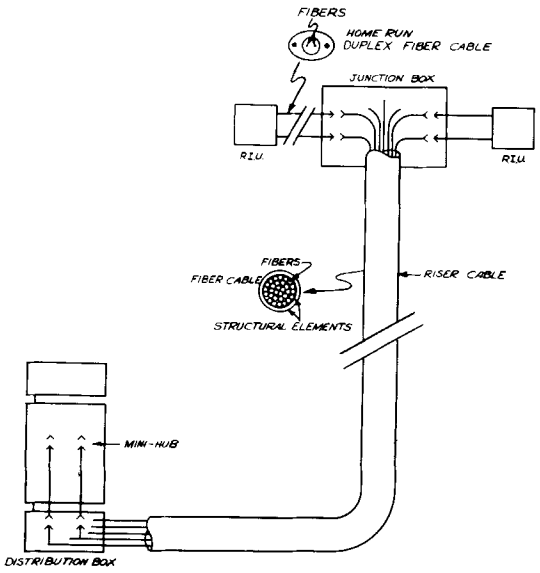
Figure 8 shows the fiber optic network configuration for high-rise application. The optical fiber jumpers from each converter module terminate on the optical connectors in the distribution box. Vertical Riser cable originates at the distribution box and terminates on the junction box at each floor. The Riser uses multiple-fiber cable design and may contain 8, 12, 16 and up to 24 fibers. The overall dimensions of this cable are on the order of 1/4". Thus, a single riser cable, with dimensions comparable to RG-59 coax, can serve up to 12 subscribers. This multifiber cable is available with a polymer outer sheath or in a seamless aluminum jacket where re- quired by fire codes. The home runs to each subscriber begin at the junction box and terminate in the RIU. The dedicated fiber pair cable used in these runs is packaged in single oval element reinforced with two steel wires. The characteristics of optical fiber used in the network are summaried in Table II.

TABLE II

Fiber Dimensions	200 um core dia. 250 um clad dia.
Type	Step index
NA	0.15
Bandwidth	45 MHz-km
Attenuation	8 dB/km
Home Run Cable Dimensions	Oval, 0.100 in. x 0.150 in.

This cable is particularly well-suited for termination with optical connectors. The first step in terminating the cable is to use a knife or razor blade to cut into the jacket about 6 to 8 inches from the end. The blade is then glided along steel reinforcing wires to strip away the polymer and expose the fibers. In completing the connector assembly, the steel wires are fastened to the backshell of the connector so that axial pull forces are not directly transmitted to the fibers. The fiber can be terminated with a rugged connector assembly in less than 5 minutes under field conditions.

Using state-of-the-art device and fiber network technologies, the system can achieve a transmission distance of 1/2 km. The link budget accounts for not only worst case connector and cable losses, but includes margin for temperature and aging effects.



Fiber Network in Hi-Rise Environment
Figure 8

SECTION 7.
SUBSCRIBER PROGRAM CONTROLLER (SPC)

The SPC is a minicomputer system designed to support the programming of Mini-Hub system CDUs in field installations. The smallest version of SPC supports from 20,000 to 30,000 subscribers. This is determined by a combination of equipment and storage strategies. The SPC utilizes advanced minicomputer technology which can be upgraded to provide greater subscriber capacity and to add real-time processing. Additionally, the SPC supports production of CDU subscriber programming on magnetic media or battery backed RAM. This media can be used with Field Programming and Diagnostic Unit (FPDU) to program the CDU or to execute diagnostics at site. The SPC employs Digital Equipment Corporation's (DEC) PDP-11 system hardware. Software support for SPC includes an RT-11 operating system, a communications controller and Mini-Hub system application software. The application software package includes the following modules:

Service

These programs are used to create Master and Site Files which detail what services subscribers are authorized to receive. The site files are outputted to various field installations via cable operator's plant or telco network. The

functions include addressability operations such as subscriber channel authorization/verification, upgrading/downgrading, and connect/disconnect.

Diagnostics
These programs are used to exercise various diagnostic functions built into the system. The operator selects diagnostic options desired and defines the scope of test.

Transactions
These programs are used to provide "impulse" pay-per-view programming, opinion polling, teleshopping and personal transactions in a batch-store and forward mode. To implement these functions, supervisor controller memory at site is used as temporary storage media. The information is collected by SPC in a polling operation, concurrently clearing site storage for new transactions.

Real Time
These programs support functions such as fire, security, etc. which require two-way real-time processing.

SECTION 8
ADVANTAGES

1. Signal Security. The Mini-Hub system eliminates signal theft completely because it sends only one authorized channel at a time to the subscriber's apartment. Even FM service can be remotely switched on or off. The F/O network is virtually impossible to tap and thus provides an added measure of security.

2. Elimination of Equipment Theft. Since the keypad in the subscriber's apartment is inexpensive, equipment theft is essentially eliminated. Further, the motivation for theft of the keypad does not exist because it cannot provide service unless authorized by the CDU which is remotely located in a secure area of the building.

3. Lower Connect/Disconnect Costs. Disconnect costs can be totally eliminated. Addressable control allows disconnect or back-pay reconnect instantly from the home office. An apartment visit to retrieve the expensive set-top converter is not required.

4. Flexible Control of Premium Programming. With the Mini-Hub system, premium programming can be provided on impulse pay-per-view or regular basis quite flexibly.

5. Expandability to Provide New Services. The system is designed to provide new services such as fire/intrusion alarm, and other enhanced services by adding plug-in modules or replacing the firmware without making the system obsolete.

6. Improved Signal Quality. The system design is performance driven. The improvement in signal quality delivered to the subscriber has been achieved by using state-of-the-art up/down converter, fiber optic and microcomputer technologies.

7. Compatibility with Other Addressable Systems. In a mixed single/multi-unit dwelling environment, the Mini-Hub system can coexist with other addressable converter systems. A modified version of the SPC, acting as a database controller, can provide the necessary interface with cable operator's control computer.

8. Electrical Isolation. The fiber optic network provides electrical isolation between the subscriber and the Mini-Hub. Sheath currents common to coaxial systems are eliminated as well as any potential egress or ingress of RF signals. Static discharge transients cannot enter the Keypad and damage microprocessor circuitry.

Acknowledgments

The Mini-Hub System is the culmination of a major development effort at TFC involving more than 50 people. M.F. Mesiya acknowledges the contributions of J. Barton, T. Batko, N. Bunker, J.Curreri, J. Heath, W. O'Neil and F. Williams.

The development of the SPC represents efforts of S. Westall's team. Development of the fibers and fiber cables was due to the efforts of W. Hanley, J. Lanoue, P. Levin, D. Munson and F. Noble. The connector work represents the efforts of L. Engdahl, R. Strait, and R. Ziltz..

The authors thank J. Herman for critical review of the manuscript and constructive comments.