A WIDEBAND DATA TRANSMISSION LINK UTILIZING EXISTING CATV AND MICROWAVE FACILITIES

Edward J. Callahan, Jr.
American Television and Communications Corp.
Englewood, Colorado

William J. Deerhake
International Business Machines Corp.
Research Triangle Park, North Carolina

ABSTRACT

An experimental wideband data communications network has been installed at IBM's Systems Communications Division facility at Research Triangle Park (RTP), N.C. The network connects display terminals and other devices with a central computing facility. The network is a dual cable, full duplex, 5-30 MHz and 50-300 MHz system.

Connection of terminals to two other IBM locations in Raleigh, N.C., about 22 land miles from RTP, is also provided. These signals are transmitted from RTP to American Television and Communications' (ATC) microwave tower in Durham, via ATC's Durham cable system.

Then the signals are carried by a one-hop ATC common carrier microwave system to ATC's Raleigh tower. And then, via ATC's Raleigh cable system, the signals are carried to the IBM Raleigh facilities.

INTRODUCTION

In late 1976, IBM approached ATC about a data transmission requirement between IBM facilities at RTP and their facilities at Raleigh.

Because of the nature of the modulation used, a requirement for the communications service was the IBM signals could not be demodulated and remodulated. Instead, the nature of the signals suggested the spectrum occupied by them should simply be translated up and down in frequency, as might be required at any of the interface points between segments of the proposed network. This requirement would obviously be easier to accomplish if the number of interface points were kept to a minimum.

The experimental in-plant cable system and the microwave link described here were installed as part of an IBM Advanced Communications Technology program at RTP. The primary purpose of the installation was to gain experience in the transmission of data over CATV and microwave networks.

Another major objective was to uncover related practical problems, such as specifying the electrical parameters of such networks, procuring vendor services for system design, and coordinating vendor installation of CATV cable in laboratory, office and manufacturing environments.

Also, network performance measuring techniques had to be devised and routine preventive maintenance procedures established. The application chosen to be implemented on the cable system was the connection of display terminals to a central computing facility. At present, about 500 such terminals are distributed throughout the approximate two million square feet of building space at the IBM RTP complex.

At this time, ATC was already operating a CATV system in Raleigh, and ATC's Microwave Mid-Atlantic System was operating common carrier facilities between Durham and Raleigh, and was preparing to start construction of the Durham CATV system.

Several methods of establishing the proposed network were discussed. The one finally chosen used the CATV systems at both ends of a one-hop microwave system (Fig. 1). This, however, required interfaces to be designed for both ends of each CATV segment of the system.

The result was four separate interfaces. This alternative added two additional interface points compared, for instance, to an all-microwave approach. But the consensus was that this was a fair trade-off for the experience we hoped to gain.

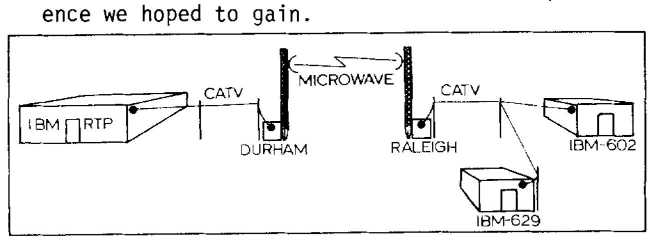

FIG. 1 RTP TO RALEIGH DATA NETWORK

There were several more discussions with IBM about end-to-end signal transmissions requirements. Then Farinon Video and the CATEL division of United Scientific Corp. were contacted about hardware requirements. Both vendors wanted to participate in the project. Subsequent technical meetings were held among the participants, to determine interface parameters, system operating levels, and other system requirements.

For instance, IBM requested that two high-rate 1.2 M b/s data signals 3 MHz apart should be centered in a 6 MHz channel and should be carried at equal amplitudes throughout the network. This meant the signals would have to interface with the microwave radios at baseband rather than at 70 MHz IF. The nature of FM signal processing dictated this.

If an attempt was made to interface two equal amplitude carriers at IF, the FM limiting action in the IF amplifier would cause intolerable IM products to occur. However, with a baseband interface, both signals would be accepted as baseband modulation. However, the total power loading on the radio should be no greater than would be the case with 1 volt peak-to-peak of video measured at 75 ohms.

Then IBM requested two more signals be carried through the network. The first was a 230.4 K b/s full-duplex data-service signal. The second was a tone-activated loop-back test system, to aid in fault location throughout the network. It was decided to carry these additional signals as subcarriers. Therefore the equivalent power loadings on the radios were re-adjusted accordingly.

Close cooperation by everyone resulted in prototype interface hardware being quickly developed. The initial bench testing of the IBM modems through the CATEL interface equipment provided satisfactory results. And thus the final system hardware was fabricated.

The field installations of the cable segments and associated interface equipment were done in parallel with the installation of the Farinon microwave radio equipment. The only change required in the Farinon equipment was to replace the 5 MHz baseband filter with an 8 MHz baseband filter. The standard video pre-emphasis and de-emphasis networks were used to maintain an acceptable Signal-to-Noise Ratio (SNR) end-to-end.

DATA NETWORK AND INTERFACES EXPLAINED

To better visualize the end-to-end wideband service provided by the network, please refer to Fig. 2. Starting at the RTP end, the IBM data carriers are injected directly into the end of the cable at 16.5 MHz and 19.5 MHz at the proper level.

The 230.4 K b/s data is impressed on the cable by the transmitter portion of the 230.4 K b/s modem at a frequency of 7.1 MHz. Additionally,

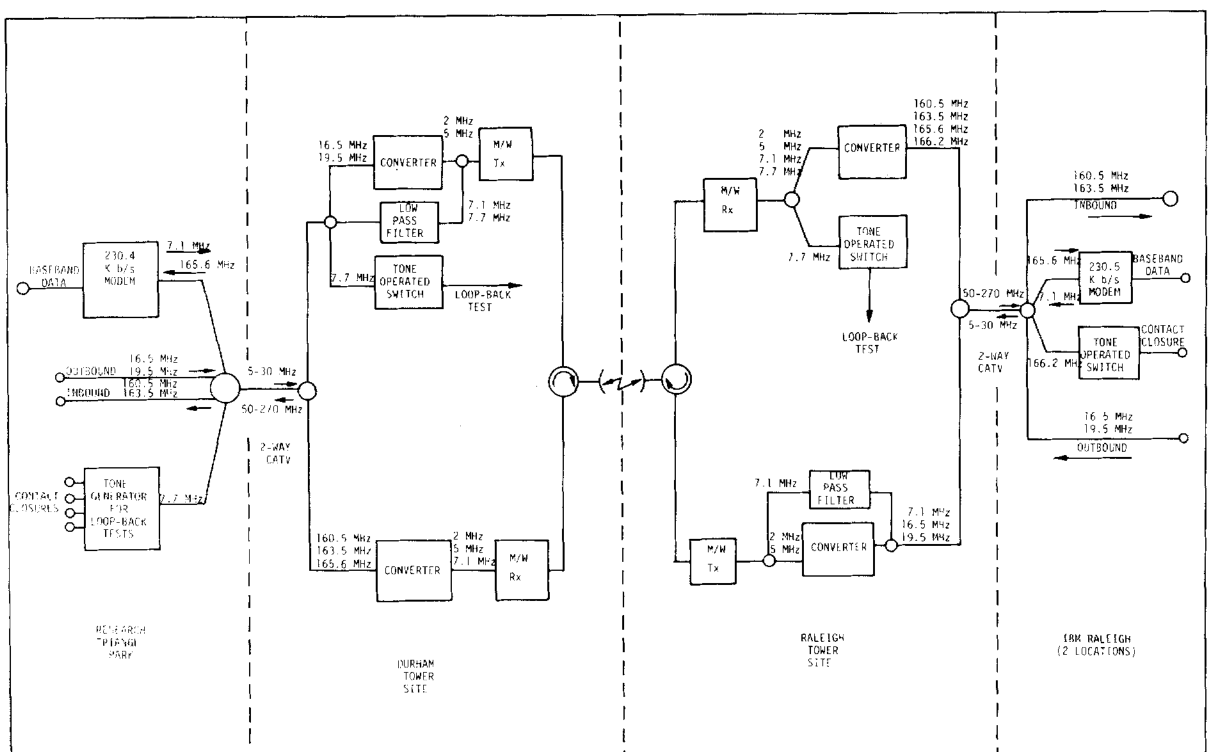

FIG. 2 DATA NETWORK INTERFACE BLOCK DIAGRAM

FSK data is impressed on the cable at 7.7 MHz to activate tone-controlled switches at the remote interface points, to perform loop-back tests.

The signals are carried via ATC's Durham CATV system in a subsplit configuration to the Durham microwave tower site. At this point, the 16.5 MHz and the 19.5 MHz signals are block converted to 2 MHz and 5 MHz, respectively, bandpass filtered, and presented to the baseband input of the microwave transmitter. The 7.1 MHz and 7.7 MHz carriers are low-pass filtered and combined with the 2 MHz and 5 MHz carriers at the baseband input to the transmitter. The 7.7 MHz carrier also feeds a tone decoder and switch, to perform a loop-back test between the microwave transmitter 70 MHz IF output and the microwave receiver 70 MHz IF input.

At the Raleigh tower site, the 2, 5, 7.1, and 7.7 MHz carriers are block converted to 160.5, 163.5, 165.6, and 166.2 MHz, respectively, and are transmitted via ATC's Raleigh CATV system to two IBM locations in Raleigh. Again, as was the case at the Durham tower site, the 7.7 MHz carrier also feeds a tone-operated switch, to effect a loop-back test from the microwave receiver IF output to the microwave transmitter IF input.

At both of the IBM locations in Raleigh, the 160.5 MHz and 163.5 MHz signals are introduced directly into the in-plant IBM coaxial network. The 165.6 MHz signal is demodulated by the 230.4 K b/s modem which provides baseband data output. The 166.2 MHz signal activates a switch which provides a contact-closure signal to IBM for testing purposes.

The transmission from the two Raleigh locations back to RTP is accomplished in a manner which is an almost exact "mirror-image" of the RTP-to-Raleigh path. However, no loop-back testing is needed. Therefore, no 7.7 MHz carrier or tone-activated switches are required in the Raleigh-to-RTP path.

The end-to-end link was tested to the specifications in Table 1, which are the specifications for IBM's in-plant network. Additionally, the link had to meet an end-to-end frequency offset of no more than $\pm$ 10 KHz. Link tests showed these specifications to be met.

The concept of terminal connections through a wideband coaxial channel is illustrated in Fig. 3. Although a dual cable representation is shown, the technique is also applicable to a single cable system using, for example, a mid-split frequency arrangement. The individual data channels on the cable are separated by Frequency Division Multiplex (FDM) techniques using selective RF digital modems.

Thus the Local Control Unit attached to Computer 1 transmits on carrier frequency f_a to its associated Remote Control Unit whose RF modem receives on frequency f_a. The reverse path data stream is on carrier frequency f_b. The terminals associated with Computer 2 operate on carrier frequencies f_c and f_d. They can therefore operate simultaneously with the terminals associated with Computer 1 over the same cables.

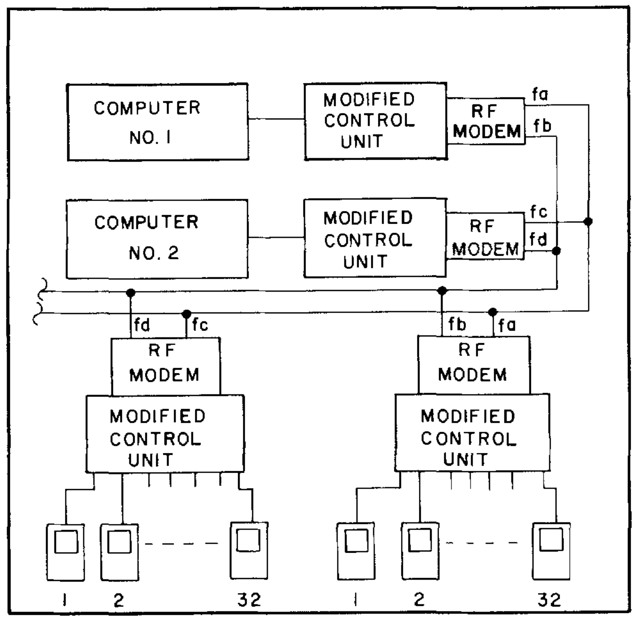

Fig.3 Terminal Connections via FDM Techniques

Table I. In-plant Cable System Specifications

System impedance	75 ohms
Modem transmit carrier level	+50dBmV $\pm$ 2 dB
Modem receive level	+10dBmV $\pm$ 10 dB
Modem carrier (rms)/ rms noise	40 dB over 3 MHz
Echos relative to signal	-40 dB
Cross and inter-modulation full channel loading	-40 dB
Channel flatness	1 dB peak to valley within $\pm$ 1.5 MHz of center frequency
Radiation	Meets all U.S. and foreign standards

Each modem in the system occupies a channel 3 MHz wide. Use of these modems provides a theoretical maximum of approximately 88 channels over the dual-cable system, based on present CATV technology.

In order to implement the experimental system, some IBM terminal control units required modification. In addition, an RF, asynchronous, 1.2 M b/s modem was vendor-procured. Neither the control units nor the modems are available from IBM.

IN-PLANT CABLE SYSTEM

A dual-cable system, with 5-30 MHz and 50-300 MHz bandwidths in each direction, was chosen to be implemented. A vendor design was obtained for a complete network covering four of the major buildings at RTP and two locations in Raleigh. The initial precursor system as installed was a subset of the ultimate-coverage system, to allow orderly system expansion.

The site plan of IBM at RTP (Fig. 4) shows the main truck cabling and a portion of the link which eventually connects to the Raleigh location via the microwave link. The total cable length of the in-plant trunk system is about 22,000'.

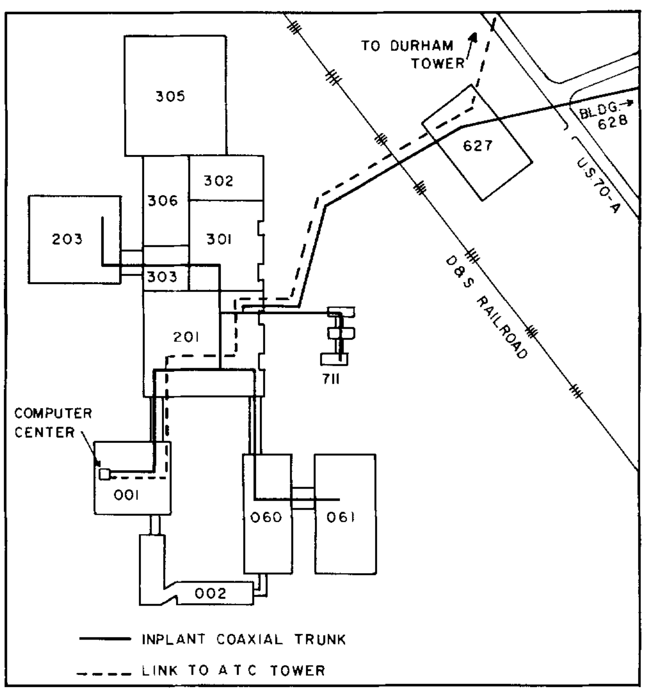

Fig. 4 RTP Coaxial Trunk System

The initial system requirements could have been met with a single cable, mid-split. However, because of the experimental nature of the technology program, it was decided to use dual cables. This provides the maximum bandwidth to accommodate (possible) future applications.

A typical portion of the cable distribution system within a building is shown in Fig. 5.

Standard CATV components are used throughout and the cable is the same as the trunk cable. Only the outbound network from the central computer has been shown. The parallel inbound cable system differs only in the direction of the amplifiers. Components used as splitters in the outbound network function as combiners in the inbound network.

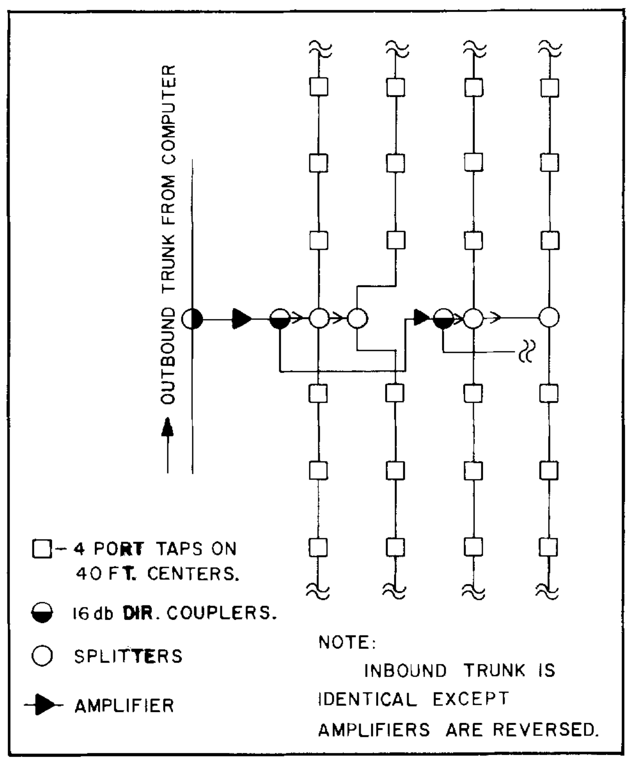

Fig. 5 Inplant Coaxial Distribution Network

The electrical specifications for the in-plant cable system, which also apply to the cable-microwave link, have already been shown in Table 1. These specifications were dictated primarily by the characteristics of the RF modem. Final system tests showed that these specifications were met.

SUMMARY

Both the in-plant and the microwave systems have been used in actual, not simulated, work environments for the past six months. Experience shows that these systems provide useful, reliable media for data transmission. However, there are basic differences between the home entertainment and the business environments which cannot be ignored.

Data applications usually require very high system reliability and availability. The first requirement implies the use of very high quality system components and meticulous construction practices. The second may require special system/maintenance agreements.

The growing use of data processing equipment implies a corresponding increase in the volume of data transmitted. Properly applied, the CATV and microwave technologies can be an important factor in this future business opportunity.