HDTV MUSE Signals on Cables and Optical Fibers

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ABSTRACT

We performed a MUSE (Multiple Sub-Nyquist Sampling Encoding) transmission experiment through two transmission systems in cascade, comprising a communications satellite and coaxial cable facilities, with the cooperation of NCTA and HBO in April 1989. At that time, the MUSE-FM signal was uplinked at the HBO Communications Center in Long Island, New York, to SATCOM K1 and downlinked to two cable headends in the Washington suburbs. At the cable headends, this signal was transformed into the MUSE-VSB•AM signal, and transmitted to remote subscriber locations. Typical results of this experiment were as follows: the unweighted SN ratio is greater than 39 dB and the picture quality is better than 4 on a 5-grade subjective evaluation.

We also developed a demand access optical fiber CATV system for HDTV MUSE signals. On a trunk line, 34 MUSE-FM signals can be transmitted over about 20 km, and at the hub, any 4 MUSE-FM signals can be selected by channel request signals from an individual subscriber, and are transmitted on each subscriber line of about 2 km. The CN ratio through this total system is greater than 17.5 dB, which is the perceptible noise limit of MUSE-FM transmission, whose bandwidth is 27 MHz.

INTRODUCTION

The 1125 scan line/60 field rate HDTV system has demonstrated its capability of producing high quality pictures and sound. In fact, television programs have already been produced in many countries utilizing 1125/60 cameras and equipments. NHK has been broadcasting HDTV experimental programs for an hour per day via broadcasting satellite BS-2 since last June, and plans to start full-fledged HDTV satellite broadcasting via BS-3 in 1990 by using the MUSE system.

In addition, the MUSE system has been successfully tested over communications satellites under the auspices of INTELSAT and other organizations, for cable television transmission, and for optical fiber transmission. In Japan, a space-cable-net. project demonstrated MUSE-FM and MUSE-VSB • AM transmission on cable facilities via communications satellite in October 1989. These experiments have proved the system's feasibility and versatility for a variety of distribution modes. Thus, HDTV has extensive applications to video media.

Presently, there are growing expectations in the United States as to the potential of HDTV services via cable networks and cable television systems. In May of 1988, NHK performed an initial demonstration of HDTV over a cable system in Los Angeles during the NCTA Convention. Additional testing was performed in January of 1989 over two Washington D.C. area cable systems: a 120-channel, state-of-the-art system owned by Media General, and a smaller, more conventional system owned by Jones Intercable. These tests demonstrated that an HDTV picture can be provided today through a typical coaxial cable system without significant impairment due to cable propagation characteristics.

In order to further evaluate the feasibility of HDTV services on cable, the MUSE-VSB•AM transmission including the satellite link in the cable distribution network, was tested in April 1989.(1) The first half of this paper describes the outline and experimental results of this transmission test.

In addition, remarkable progress has been achieved in FM-FDM transmission of video signals for optical fiber CATV systems.(2),(3)

We recently developed an HDTV optical fiber CATV system employing a demand access technique. It can be used by low cost systems, because it does not need expensive wideband optical receivers at the subscribers. Any 4 MUSE-FM signals can be selected among 34 MUSE-FM signals transmitted on trunk lines, at the hubs without demodulating. A compact and inexpensive hub system can be realized by using a heterodyne technique. We adopted commercial low cost LDs developed for compact disk players. Moreover, we utilized conventional BS receivers for Japanese satellite broadcasting at the receiving ends. The second half of this paper describes the outline and experimental results of this demand access optical fiber CATV system for HDTV.

HDTV CABLE TRANSMISSION EXPERIMENT VIA SATELLITE

MUSE-VSB•AM Transmission on Coaxial Cable

A MUSE transmission system compresses the baseband bandwidth of HDTV signals, which have five times as much information as current TV signals, to just double, without deteriorating picture quality. This means an HDTV picture can be transmitted through a narrow bandwidth, and therefore MUSE can be effectively applied to CATV systems.

The transmission spectrum for MUSE-VSB•AM is shown in Figure 1, and a VSB filter is used on the transmitting side and a Nyquist filter on the receiving side. It has 12MHz bandwidth, and can be transmitted in a channel adjacent to current TV channels as shown in Figure 2.

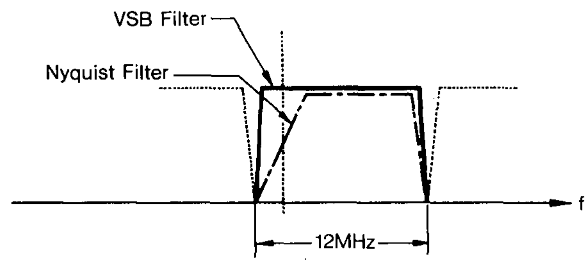

Figure 1 MUSE-VSB•AM Transmission Spectrum

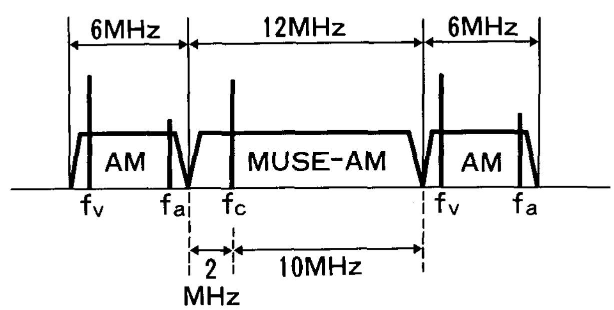

Figure 2 Example of MUSE-VSB•AM Adjacent Transmission

The required CN and CTB (Composite Triple Beat) ratios are the main factors in limiting the number of cascaded amplifiers for coaxial cable systems. The relationship between the number of amplifiers and the required CN (4MHz bandwidth) and CTB ratios for VSB•AM transmission of MUSE and NTSC signals are shown in Figures 3 and 4.

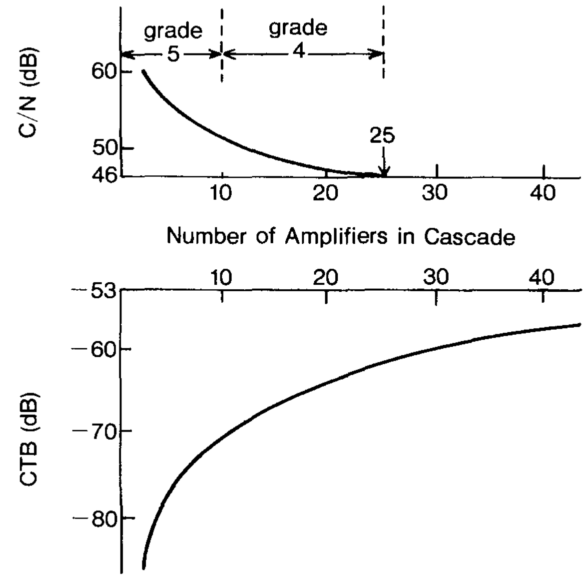

Figure 3 CN and CTB Ratios in a Cascade (MUSE-VSB•AM)

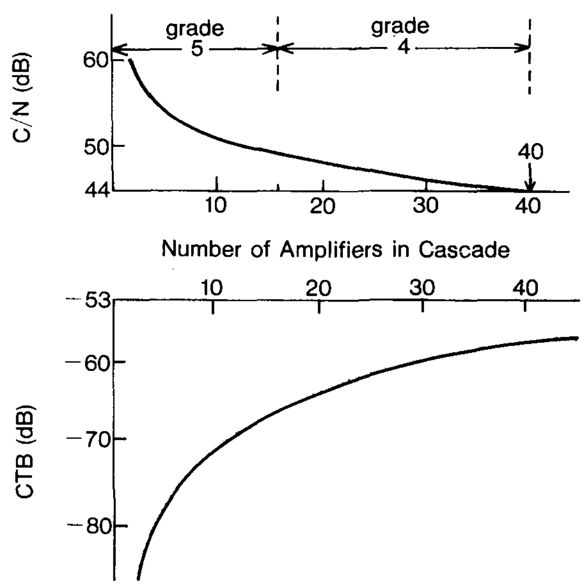

Figure 4 CN and CTB Ratios in a Cascade (NTSC-VSB•AM)

Also shown in the figures are the regions where the CN ratio gives a picture quality of grades 4 and 5 using a five-point comment scale. For the calculation, the performance of trunk amplifiers is assumed as follows: CN ratio = 60 dB, CTB ratio = -90 dB. It can be seen from the figures that a picture quality of grade 4 requires a CN ratio of about 46dB for MUSE, and about 44 dB for NTSC; thus, HDTV transmission requires a higher CN ratio.

Experimental Setup

The setup of this transmission experiment is illustrated in Figure 5. In this experiment, a MUSE signal is transmitted through two transmission systems in cascade, comprising a communications satellite and cable facilities.

At the satellite transmitting end of the HBO Communications Center in Long Island, New York, an HDTV studio signal is encoded into the MUSE signal, which is transmitted by frequency modulation to the communications satellite, SATCOM K1.

At the cable headends, the MUSE-FM signal received from the satellite is transformed into the MUSE-VSB • AM signal. This signal is multiplexed with many channels of conventional broadcast waves transmitted via the other satellites and ground microwaves, and these multiplexed signals are transmitted to the cable receiving ends through multistage amplifiers and coaxial cables. The cable systems involved in this transmission experiment were Media General which owns state-of-the-art system in Fairfax, Virginia, and Jones Intercable, which owns more conventional system in Anne Arundel, Maryland.

At the cable receiving ends, the received MUSE signal is decoded and displayed on an HDTV monitor. The MUSE signal is also received by a conventional TV set, with a simple and low cost MUSE-NTSC converter.

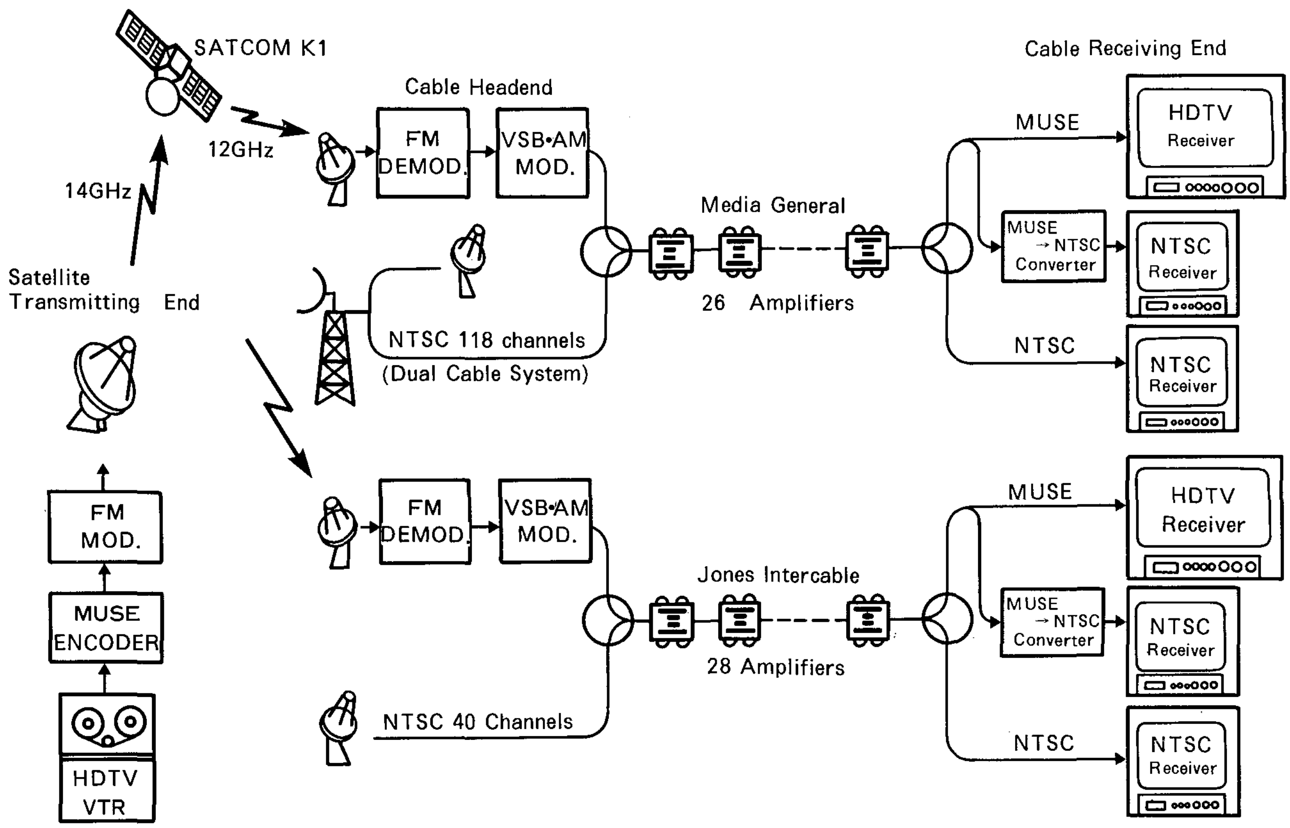

Figure 5 Experimental Setup of HDTV Cable Transmission via Satellite

Items	Data	Comments
Downlink EIRP	50.0 dBW	
Receiving Antenna Gain	49.5 dB	Antenna Diameter 3.1m
Uplink CN Ratio	30.0 dB	
Total CN Ratio	23.7 dB	
Transmission Bandwidth	36 MHz	
Frequency Deviation	17 MHz	Without Energy Dispersion
FM Improvement	17.7 dB	
Emphasis Improvement	9.5 dB	
Received Unweighted SN Ratio	50.9 dB	

Table 1 Transmission Parameters of Satellite Link

Items	State-of-the-art System	Conventional System
Company	Media General	Jones Intercable
Number of NTSC Channels	118(Dual Cables)	40
NTSC Transmission Method	HRC*	Standard
Number of Subscribers	167,000	32,000
Modulation Method	VSB•AM	VSB•AM
Transmission Bandwidth	12 MHz	12 MHz
Video Carrier Frequency	330.30 MHz	331.25 MHz
Channels for HDTV	42, 43	42, 43
Adjacent Channels	41, 44	41
Number of Amplifiers	26	28
Cable Length	13 km	20 km

* Harmonically Related Carrier

Tabel 2 Outline and Transmission Parameters of Cable Facilities

The typical transmission parameters of SATCOM K1 are shown in Table 1. The outline and the typical transmission parameters of cable facilities are shown in Table 2.

Experimental Results

The experimental results of this MUSE cable transmission via satellite are shown in Table 3. The received CN ratios of the satellite link at both cable headends are greater than 23 dB, and the received CN ratios at both cable receiving ends are greater than 44 dB (8.1 MHz). Thus, excellent HDTV pictures whose picture qualities are grade 4 at least, and whose unweighted SN ratios after demodulating are greater than 39 dB, can be obtained.

Thus, this transmission experiment has proved that excellent HDTV pictures can be achieved by MUSE-VSB•AM cascaded transmission comprising a satellite and cable facilities.

Facilities	Satellite System		Cable system				
	Frequency Deviation (MHz)	Received CN Ratio (dB)	Received CN Ratio (dB)	Modulation Depth (%)	Unweighted SN Ratio (dB)	CTB (dB)	Grade of Picture Quality
State-of-the-art System	16.8	23.5	44.5	83.3	41.0	-44	4
Conventional System	16.8	24.0	44.3	70.0	39.1	-53	4

Table 3 Experimental Results

HDTV OPTICAL FIBER CATV SYSTEM EMPLOYING DEMAND ACCESS TECHNIQUE

FM Frequency Allocation and Parameters

The frequency allocation of MUSE-FM signals on the trunk line is shown in Figure 6. At the trunk line, 34 MUSE-FM signals are allocated with the frequency interval, 38.36 MHz, used in Japanese satellite broadcasting. At the subscriber line, any selected 4 channels are transmitted on the BS-IF band (1-1.3 GHz). The FM parameters of HDTV MUSE-FM signals are shown in Table 4.

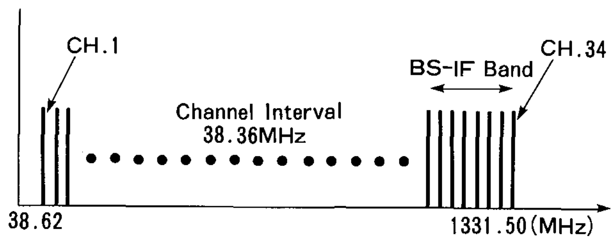

Figure 6 Frequency Allocation of MUSE-FM on Trunk Line

Items	Data
Video Bandwidth	8.1 MHz
Frequency Deviation	10.2 MHz
FM Bandwidth	27 MHz
FM Improvement	11.9 dB
Emphasis Improvement	9.5 dB

Table 4 Transmission Paramenters of MUSE

System Configuration

The system configuration of an optical fiber CATV system for HDTV is shown in Figure 7.

At the CATV headend, MUSE signals are frequency modulated and combined with the rebroadcasting MUSE-FM signals. Thirty four channels of FM signals are transmitted over 20 km to the hub through a single mode fiber by intensity modulation of an LD (1.3 um).

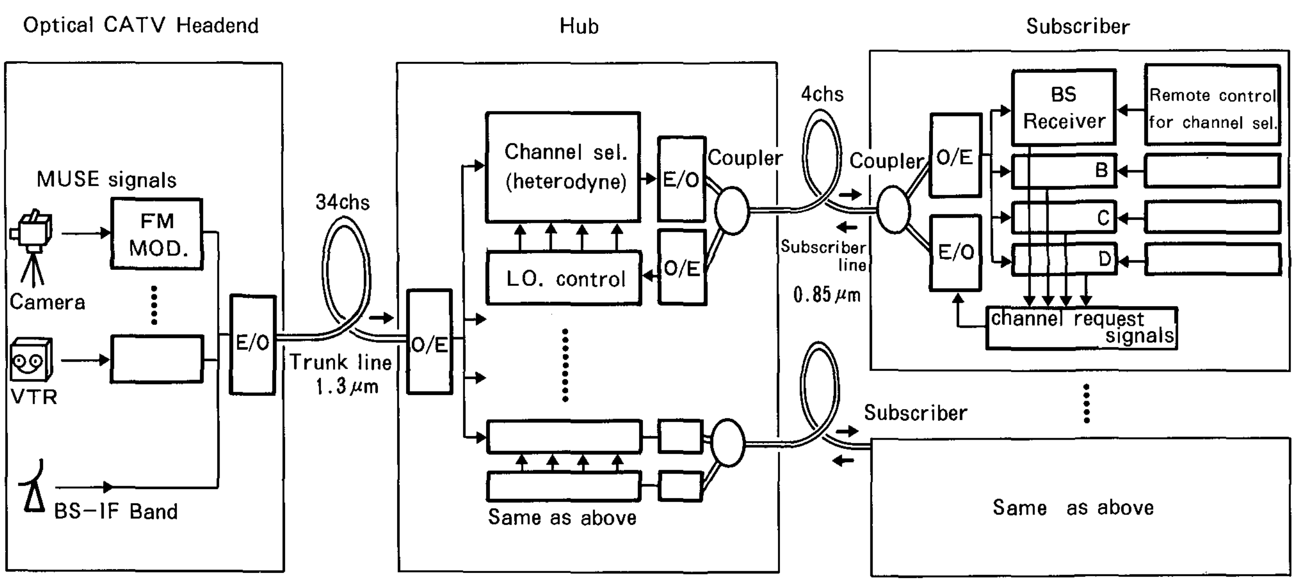

Figure 7 System Configuration of Demand Access Optical Fiber CATV System

At the hub, these signals are transformed into electrical signals. Any 4 signals can be selected by channel request signals from an individual subscriber employing a heterodyne technique. The selected 4 signals allocated in the BS-IF band, modulate a low cost LD (0.85 μm), and are transmitted to each subscriber through an ordinary single mode fiber.

At the subscriber, these signals are transformed into electrical signals, and distributed to 4 conventional home receivers used for satellite broadcasting, and then demodulated. The channel request signals are sent to the hub through the same fiber used for a down stream. The digital signal format of the remote controlled channel selector at the television sets is adopted for the transmission of channel request signals.

The optical transmission parameters are shown in Table 5. Optical fiber couplers with a core diameter of 6 μm, are used at both ends of the subscriber lines to obtain bi-directional transmission. These couplers also eliminate the higher order mode generated in the fibers when an ordinary single mode fiber is used at a short wavelength.

Experimental Results

The relationship between the received CN ratio and the received optical power, P_R, when multiplexing 34 MUSE-FM signals on a trunk line, is shown in Figure 8. In this figure, the dashed line indicates the CN ratio when all channels are not modulated, and the solid line indicates the effective CN ratio including distortion power as noise when all channels except the measured channel are modulated. In the frequency allocation chart shown in Figure 6, we can avoid the second-order distortions, but third-order distortions drop into the FM transmission band. The CN ratio degrades effectively as the optical modulation depth m increases, because many third-order distortions are also frequency modulated and added in random frequency and phase, and behave like random noise. Therefore, the optical modulation depth giving the maximum CN ratio can be determined when P_R is given. In the design for 20 km transmission on the trunk line, P_R is -12 dBm since the output of the optical transmitter is -2 dBm, and the optical loss of the fiber is assumed as 0.5 dB/km. In the case of Figure 8, the maximum CN ratio can be obtained as 28 dB.

Items	Trunk Line	Subscriber Line (Down stream)	Subscriber Line (Up stream)
Optical Source	InGaAsP-LD	GaAlAs-LD	GaAlAs-LD
Wavelength	1.3 μm	0.85 μm	0.85 μm
Threshold Current	5 mA	15 mA	12 mA
Bias Current of LD	40 mA	42 mA	16 mA(Max.)
Optical Power	-2 dBm(10/125)	+2 dBm(6/125)	-10 dBm(6/125)
Optical Isolator	Isolasion: 60 dB	not used	not used
Optical Fiber	10/125 SMF	10/125 SMF	
Optical Coupler	-	2 x 2 type (0.85 μm) 6/125 SMF	
Optical Receiver	InGaAs-APD	Si-APD	Si-PD

Table 5 Optical Transmission Parameters

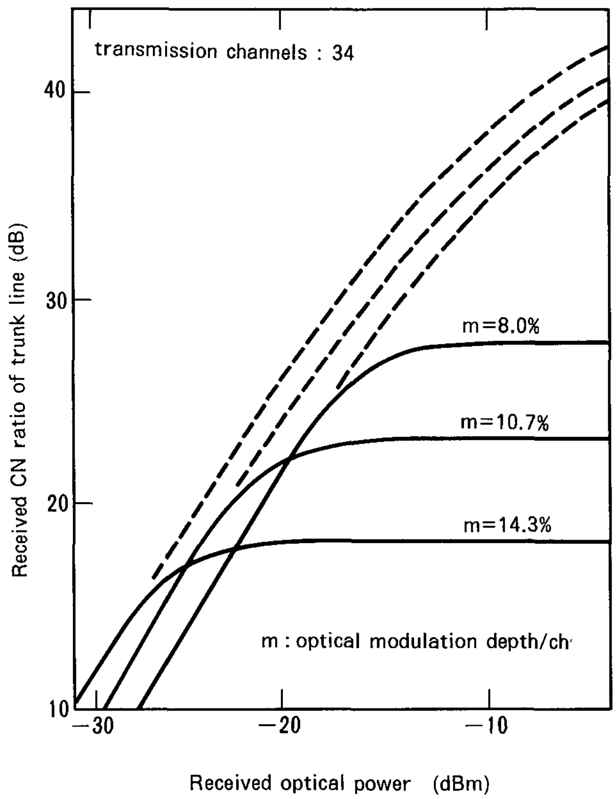

Figure 8 Received CN Ratio on Trunk Line
(dashed line : unmodulated
solid line : modulated)

In the case of rebroadcasting HDTV from a satellite on CATV, the CN ratio at a subscriber, $(C/N)_{total}$ is given by the following equation:

$$\frac{1}{(C/N)_{total}}=\frac{1}{(C/N)_{sat}}+\frac{1}{(C/N)_{trunk}}+\frac{1}{(C/N)_{sub}}$$

, where $(C/N)_{sat}$ is the received CN ratio of the satellite link at the headend, $(C/N)_{trunk}$, $(C/N)_{sub}$ is the CN ratios of the trunk and the subscriber lines, respectively. We obtained $(C/N)_{sat}$ of 25 dB with a parabolic antenna of 1.2 m diameter and a RF converter of 1.3 dB noise figure. If we design the system with $(C/N)_{total}$ of 17.5 dB, which gives the perceptible noise limit, the required CN ratio for the cascaded transmission on the trunk and subscriber systems is greater than 18.4 dB.

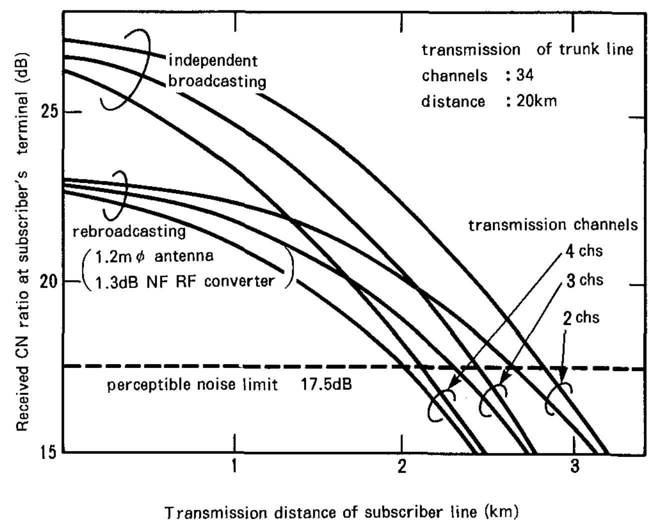

Figure 9 Total CN Ratio of Demand Access Optical Fiber CATV System

The relationship between $(C/N)_{total}$ and the transmission distance of the subscriber line after 20 km transmission of the trunk line, is shown in Figure 9 with the parameters of the number of channels on the subscriber line. Four MUSE-FM signals can be transmitted over more than 2 km, as shown in Figure 9.

CONCLUSION

The feasibility of HDTV services on coaxial cables has been demonstrated by this MUSE-VSB·AM transmission experiment. A demand access optical fiber CATV system for HDTV MUSE signals has been developed, and the possibility of the FTTH (Fiber To The Home) of HDTV has also been recognized.

References

(1) Y.Utsumi, S.Yamazaki, H.Arata, T.Susaki, M.Honda, Y.Iwadate, H.Miyazawa, T.Tokumoto: "HDTV Transmission Tests on Coaxial Cable via Satellite", NHK R&D, No.6, pp.34-47, Aug. 1989.

(2) R.Olshansky, V.Lanzisera, P.Hill: "Subcarrier multiplexed lightwave systems for broadband distribution", IEEE J. Lightwave Technol., LT-7, 9, pp.1329-1342, 1989.

(3) M.Maeda, M.Yamamoto: "FM-FDM optical CATV transmission and system design for MUSE HDTV signals", to be published in IEEE. J. Selected Area of Comm., 1990.