FIELD TESTING OF A DIGITAL AUDIO SYSTEM

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ABSTRACT

Cable operators are currently presented with multiple vendor options when considering the addition of high quality audio services. Initial product selection by the operator will serve to communicate the minimum acceptable functional and performance requirements to manufacturers. System operators are therefore uniquely positioned to demand the best in quality, performance and economy from future audio products. Technical product field testing provides the operator with preliminary information which may be valuable in determining how to invest capital for a new service.

INTRODUCTION

Laboratory testing of a new digital audio system occurred at the ATC R&D facility during the summer of 1985. After the completion of these tests, an engineering field test began and, as of this writing (1/86), is still in progress. The primary purpose of the field test is to evaluate the performance of the system technically. However, it is expected that valuable information from the consumer's perspective will be received from a second phase of the two phase field test.

The system under evaluation was previously described in the NCTA 1985 technical paper titled "A Digital Audio System for CATV Application". The prototype Toshiba system consists of one hundred terminals and one four channel headend. Field trial activities occurred at American CableVision of Thornton, an ATC system in Thornton, Colorado. During the field trial, participants are both friendly and typical subscribers. Audio programming is provided to subscribers from a variety of high quality sources. In general, technical evaluations have provided positive results. Areas of improvement for the current design have been identified with some modifications deemed essential. However, terminal characteristics which relate to operation in a practical cable environment are acceptable.

SYSTEM COMPONENTS

Subscriber Reception/Decoding Equipment

In both the laboratory and field test, the system component which is the primary focus of attention is the in-home DCAT (Digital Cable Audio Terminal) unit. The terminal's primary functions are the tuning and demodulation of QPSK digital DCAT data, separation of demodulated data into audio and control information, and conversion of digital audio data to high quality analog audio signals. The audio signals are compatible with standard auxiliary inputs on existing commercial audio amplifiers. The terminal also maintains internal RAM tables which contain system channelization and subscriber authorization data. A user interface in the form of a front panel keypad allows selection of headend delivered programs if appropriately authorized.

When used with compatible custom headend equipment, the terminal delivers high quality audio in one of two quality modes:

- "Ultra": 96 dB dynamic range (16 bits)
  20 Hz to 20 kHz frequency response
  Greater than 86 dB signal to noise

- "Super": 86 dB dynamic range (14 bits)
  20 Hz to 15 kHz frequency response
  Greater than 76 dB signal to noise

Operation is permitted from 88 to 120 MHz with any single RF channel capable of being positioned within this spectrum with 100 Khz granularity. Each channel may contain either one 16 bit "ultra" stereo program or two 14 bit (companded to 10 bit) "super" stereo programs.

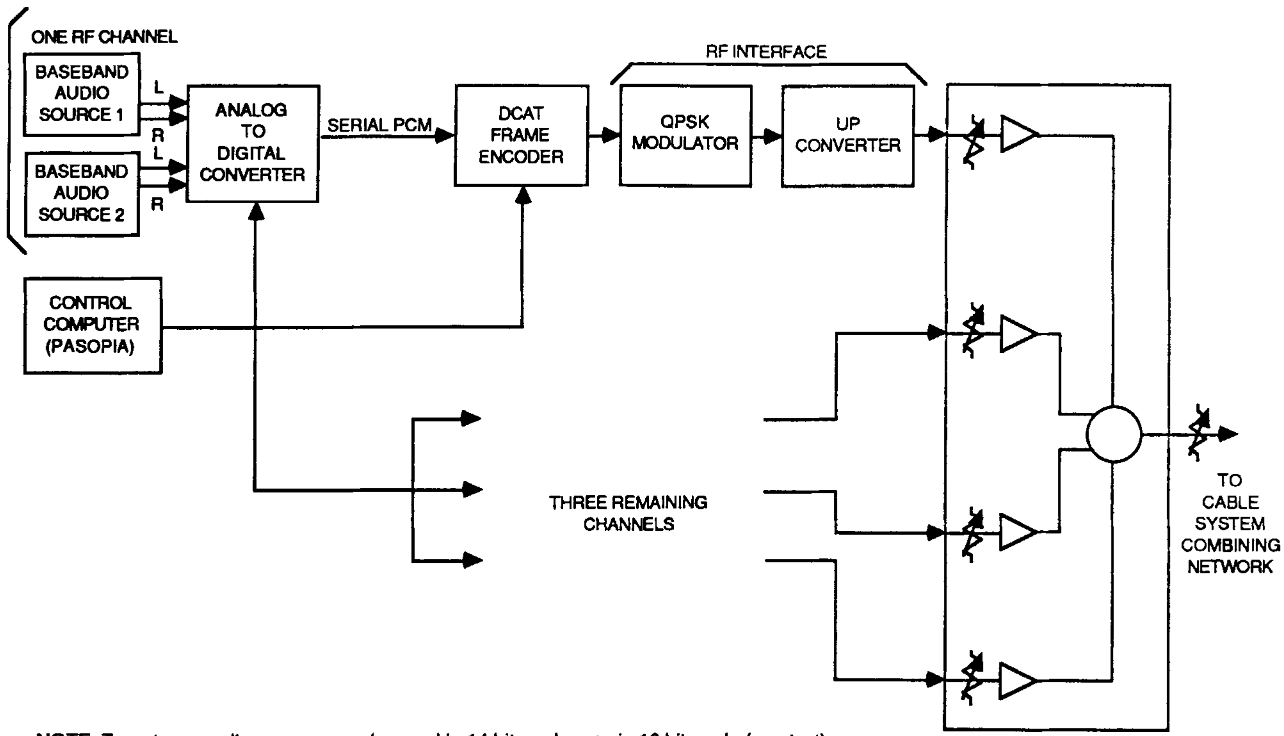
This field test is the first test in the United States of this equipment in an actual cable environment. As a result, some appropriate goals for this test have been verification of initial specifications and evaluation of it's practical application in a typical cable and subscriber environment.

Audio Headend Equipment

The prototype headend equipment used for the initial testing of the DCAT system was designed and constructed by Toshiba. Figure A shows the basic components of the headend equipment and primary cable system interface. The labelled modules shown in the diagram represent one RF channel. All modules are duplicated for the remaining three channels with the exception of the control computer.

The Analog to Digital Converter modules provide an external input interface for connection of the audio programming sources. All inputs are baseband analog audio. The primary functions of this module are filtering and digitization of baseband input audio, generation of subscriber authorization, and serialization of digitized audio data for eventual DCAT transmission frame formatting.

The DCAT Frame Encoder provides two critical functions: the formatting of input serial digitized audio data into a data frame configuration which is compatible with the DCAT in-home terminal, and the insertion of program definition and system channelization data into



NOTE: Two stereo audio sources may be used in 14 bit mode, one in 16 bit mode (see text).

FIGURE A:
FOUR CHANNEL HEADEND FOR TOSHIBA DCAT TERMINALS

the DCAT frame. The Encoder also generates the required error control codes for error detection and correction functions performed by the in-home terminal.

The final encoded baseband bit stream is input to the RF Interface where the digital data is converted to a QPSK (quadrature phase shift keyed) signal and up converted to the final transmission frequencies. At this point, the RF output for each channel is input to a DCAT combining network. The output of this network is input to the cable system's primary combining network.

The control computer provides a user interface for the headend operator which permits definition of program quality options (16 or 14 bit modes), program channelization selections and free tier or encrypted (addressable) modes of operation.

The headend equipment used in this field test is not representative of a final production headend. The headend consists of the same hardware and software which was demonstrated at the Western Cable Show at Anaheim in December 1984.

Audio Programming Sources:

Multiple audio programming sources were used to provide listeners with a sufficient number of alternatives in programming material so as to encourage their participation in the test. (It was intended that subscribers provide ATC technical personnel with descriptions of unusual or improper operating situations which may imply technical problems rather than evaluate the programming material provided by the signal sources.) Additionally, it was desired that experience be gained in connecting headend audio sources to DCAT audio headend equipment in typical CATV situations.

The following audio program sources were used for Phase 1:

A. One Compact Disc (CD) Karaoke player (a CD jukebox which was specially modified by Toshiba for continuous, sequential CD access and play).

B. Audio for MTV, VH-1, HBO and Cinemax.

C. WFMT (satellite delivered "superstation" with classical format).

D. KBCO (an FM broadcaster in Boulder, Colorado featuring unusual and well chosen rock selections, often using CD sources)

All audio source equipment provided analog audio outputs as required for connection to the Toshiba headend equipment.

The following table defines the equipment used to provide each of the audio signals to the Toshiba headend. These sources may be considered to be typical sources in terms of potential interface requirements for future headend equipment.

Source	Equipment
HBO, CINEMAX	M/A-COM Videocipher II
MTV, VH-1	Wegener Dolby Digital Demod (Series 1739)
KBCO	NAD Stereo Tuner
WFMT	Wegener Analog Demod (Series 1620)
CD JUKEBOX	Toshiba/EMI XK-601EMa with custom continuous play modification

System Distribution Equipment

DCAT signals were transmitted on six system trunks. The distribution equipment consisted of Jerrold SJAS-400 trunk amps, SJBN-400 bridger amps and JLE-6-450 line extenders. The longest cascade in the system was "A" trunk which has 25 amps followed by "C" trunk which has 24 amps. The other trunks,B,D,E and F had 15,2,18 and 17 amps, respectively.

The Toshiba headend provided 4 physical (RF) channels for use during the field test. For Phase 1 testing, one channel was configured for the highest quality mode of operation (16 bit, 20 to 20 Khz); the remaining channels were assigned to the lower quality mode (14 bit, 20 to 15 Khz). Operation in the 14 bit mode allows 2 stereo programs of this quality level to exist on one RF channel, effectively doubling the program density relative to the 16 bit mode. The Toshiba CD Jukebox was assigned to the highest quality channel.

The following channel assignments were applicable during Phase 1:

Program	Frequency	Mode	
HBO, CINEMAX	109.2 MHz	14 bit	Stereo
VH-1, MTV	110.6 MHz	14 bit	Stereo
KBCO, WFMT	111.8 MHz	14 bit	Stereo
Jukebox	113.0 MHz	16 bit	Stereo

The first RF channel in the above table (109.2) was spaced 1.4 MHz from the next highest channel (110.6). The remaining 3 channels were separated from each other by 1.2 MHz.

Although the DCAT terminal had a specification of 1.4 MHz for channel spacing, 1.2 MHz spacing was used throughout Phase 1 due to headend limitations.

In Home Configuration

In the Thornton cable system, all friendly subscribers were installed using basically two types of in-home component configurations. Subscribers already had either one or two television sets; the terminal was connected to the system by adding a directional coupler in-line with the appropriate cable. A directional coupler (DC-8) was chosen for terminal feed due to the desire to minimize signal loss to existing television sets and to maximize isolation of the terminal from these sets. The physical configuration for a two-set home is shown in Figure B. For this configuration, isolation averaged 28.8 dB thru the splitter/DC path (20 dB/8.8 dB) and in excess of 30 dB between the DC output and the terminal feed leg. This ensured sufficient margin to prevent spurious output interference to either the terminal from a television or vice versa.

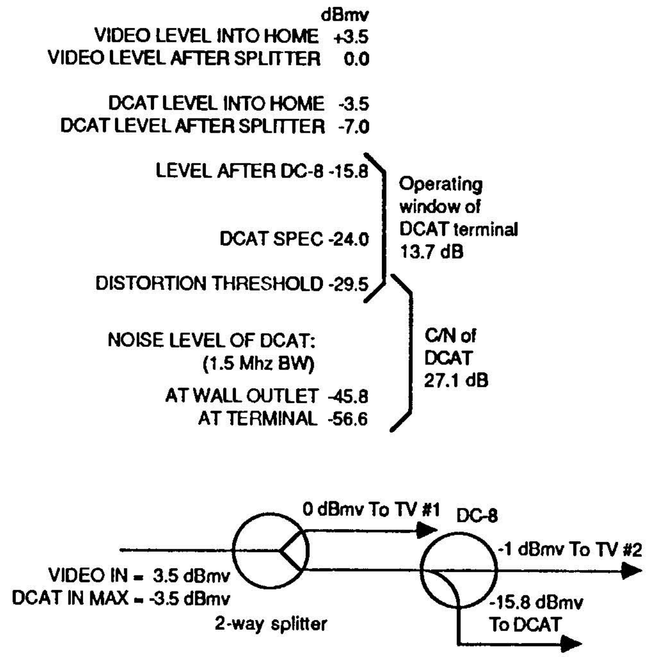


FIGURE B
TWO-SET IN-HOME CONFIGURATION

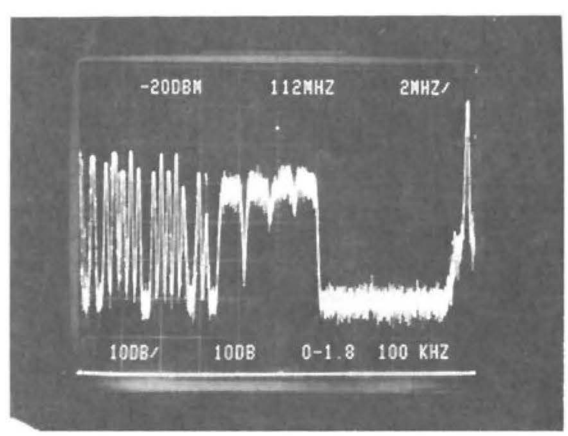
Use of a directional coupler minimized video signal loss to approximately 1 dB.

The one and two-set configurations are considered to be typical for most homes which would eventually receive service. Based on these assumptions, it was possible to define a practical operating window with respect to transmitted and received DCAT signal levels.

TEST RESULTS

Signal Degradation After Cascades

Prior to connecting the friendly DCAT subscribers to the system, the transmitted DCAT signals were visually inspected at various points on selected trunks. A photo of the signals at the end of the "C" trunk (24 amps deep) is shown in figure C.



The effect of the system trunk cable and amplification equipment was minimal. Terminals tested at these positions operated normally. A test point on the terminal PC board permitted measurement of the number of bit errors which were not correctable by the single error correcting, double error detecting BCH code used in this system. No significant increase in uncorrectable errors was detected relative to previous lab measurements.

Operating Window

Practical DCAT system operation when operating in the A-1 and A-2 channels as in this field test was defined based on the following criteria and considerations:

A. Upper limit:

1. FCC restrictions for operation on aeronautical navigation frequencies.

2. The requirement to remain within existing system design guidelines regarding maximum power available from system distribution amplifiers within the spectrum where DCAT operation was intended.

B. Lower limit:

1. The presence of audible distortion in the received audio output caused by limitations in the error correction or digital audio interpolation capability of the terminal. (The primary causes of this effect are excessively low signal input levels or exceeding the carrier to noise capability of the terminal).

Details on Operating Window Estimate: UPPER LIMIT

Signal level restrictions in the A-1 and A-2 bands required that signals be operated below 10^{-5} watts (28.75 dBmv) unless the FCC is notified. American Cablevision of Thornton operates channel A at approximately 38.5 dBmv and provides the FCC with this information on an annual basis. An additional 3 to 4 dB of level fluctuation is expected due to equalizer settings and temperature. For operation during the field test, DCAT signals were transmitted at a carrier level 15 dB below the video carrier of channel A (23.5 dBmv plus temperature tolerances). At this level, signal levels are well below the specified FCC threshold for notification. Future FCC regulations will require that the average level of signals transmitted in the A-1 and A-2 bands not exceed 38.75 dBmv averaged over any 160 microsecond period within a 25 kHz bandwidth at any point in a cable plant (unless the FCC is notified). According to the update to FCC Notice 21006 which describes the above requirements, this limitation will not exist for operation in the 88 to 108 MHz spectrum region.

For the DCAT system, the highest level which would be transmitted within a 25 Khz window occurs when modulation is removed from the transmitted signal. The unmodulated carrier peaks at the center frequency of what was previously the QPSK signal. This situation, in practice, is quite possible, requiring only a failure in the portion of the headend equipment which generates the DCAT bit stream. Potential users of the DCAT system in the A-1 and A-2 channel slots should be aware of these limitations and notification requirements.

A major factor with respect to introducing new signals into a cable system is the requirement to prevent excessive loading of the system amplifiers due to exceeding system design limitations. These limits are based on the ratings of the particular amplifiers in use and on the assumption that video signals are carried throughout the cable spectrum.

Using the bandwidth of a normal 6 MHz video (and in-band audio) signal as the reference, and assuming that DCAT signals are positioned maximally adjacent at 1.2 MHz spacing within this 6 MHz window, 10 log (BW DCAT/BW Video) = -7 dB states that operation of every DCAT signal at 7 dB below video maximum will result in operation at the design specification of the system.

If the minimum video level present at the subscriber television input is zero dBmv, as required by the FCC, then the highest level allowable for DCAT signals based on this limit and the desire to retrofit DCAT into existing systems is -7 dBmv. Any additional signal level at the wall provides additional margin. Using 3.5 dBmv as a minimum video level in a practical system, DCAT signals would arrive at a splitter at -3.5 dBmv and be reduced to approximately -15.8 dBmv by the splitter (3.5 dB loss) and the DC-8 (8.8 dB loss) for the two set configuration. Therefore, a practical upper level limit which recognizes the design limits for the system would be -15.8 dBmv for Thornton.

Operation during Phase 1, however, was done at a level of 15 dB below channel A video (-24 dBmv after two-set losses). This placed DCAT signals at the same amplitude as existing FM carriers and resulted in the received signal levels being at the threshold of the DCAT receiver dynamic range specification (-24 dBmv). These levels provided good results throughout the test, since the terminal's actual lower limit was significantly below this operating level.

Details on Operating Window: LOWER LIMIT

Determination of the practical lower operating limit was done by measuring the absolute peak level of a DCAT signal at the RF input to the terminal at trunk taps while the amplitude of the signal was reduced at the headend. A measurement of received signal was made at a level just prior to detection of audible clicks in the audio output of the terminal. Additionally, the background noise level was measured for carrier to noise performance evaluation. Independent measurements were performed at the end of three separate trunks in the system. The following were the results:

Trunk	Cascade Length	Noise Level (dBmv)	Signal Threshold (dBmv)	Effective C/N (dB)
A	25	-45	-29.5	-15.5
C	24	-45	-29.5	-15.5
E	18	-50	-35.5	-15.5

Note: All DCAT signals were reduced simultaneously with no measurable deviation in signal level between adjacent channel peak amplitudes.

Based on these results, it appeared that the threshold was reached due to C/N limitations of the terminal. In an attempt to confirm this point further, and to gain additional information regarding the degree of uniformity in C/N performance throughout the specified dynamic range window (+5 to -24 dBmv), additional tests were conducted in the Thornton headend. Data was taken on 3 different terminals where C/N was measured as a function of input signal level. The input signal was reduced in 3 dB steps from +5 dBmv and noise increased to the distortion threshold. A C/N measurement was taken at each point until a limit was reached where no attainable C/N prevented objectionable audible clicks.

Two of the terminals provided very consistent results: the C/N requirements remained within 1 dB with an input signal range of +5 to -33 dBmv. The C/N requirement window throughout this input range was from 16 to 17 dB for the first terminal and from 15 to 16 dB on the second. Between -33 and -37 dBmv the C/N required was 25 dB; at -34 dBmv, C/N required was 28 dB with the absolute threshold at -37 dBmv.

When referring to Figure B note that the "C/N of DCAT" is the effective C/N when the input signal to the terminal is -29.5 dBmv at the Thornton cable system. Since the system noise is reduced noticeably by the DC-8, additional margin with respect to C/N exists when the terminal is operated in this configuration based on the 3 terminal test results summarized above. Of course, operation in this signal level region (below -24 dBmv) is not recommended since the inclusion of sensibly defined operating margins is necessary to ensure continued stable operation under adverse system operating conditions. Toshiba's specification of -24 dBmv provides a desirable level of safety. The C/N spec, measured in a 1.5 MHz noise bandwidth is 28 dB and includes approximately 10 dB of margin from various sources.

Level Deviation Between Adjacent DCAT Carriers

A test of the effect of signal level variation of the center DCAT carrier of the triplet with respect to the adjacent carriers was performed in the Thornton headend. This test was similar to laboratory tests with respect to the test environment since the RF signals were not received by a terminal connected to a system trunk, feeder or tap. The test was performed with 1.2 MHz spacing between the 3 RF channels.

The center channel signal level was reduced in 1 dB steps from the 2 adjacent channels which were adjusted to identical levels. No noticeable effect to output audio was detected until the level of the center channel was reduced to 3 dB below the adjacent channel reference. At this point, audible clicks were clearly heard at the output of the terminal and the BCH uncorrectable error rate increased significantly. It is clear from this test that the terminal is sensitive to these level differences, as indicated by a terminal specification published by Toshiba defining 3 dB as the maximum deviation.

It is important to consider that this test was performed at 1.2 MHz channel spacing due to the headend configuration. The deviation specification is applicable to 1.4 MHz spacing. It is expected that this characteristic of the terminal receiver would improve if the spacing were increased to 1.4 MHz.

Testing was not performed to determine the effect of level deviations between non-adjacent channels.

Use of Encryption

After the primary system testing was completed, all channels were switched from non-encrypted to encrypted (tiered) mode. All channels were assigned the same tier. Operation in this mode for a period of 8 weeks resulted in no negative feedback from cable system personnel or subscribers. It was necessary to individually address each terminal from the headend to activate the encrypted service. This field test activity in addition to laboratory testing has empirically confirmed the functionality of the DCAT encryption technique and system implementation.

Interference Issues

DCAT to Normal Cable Operations

Prior to applying DCAT RF to Thornton system trunks, existing video and audio signals were examined for future reference. After applying RF, there were no reports of interference from any of the Thornton technical personnel. System video and audio signals were again inspected with no evidence of interaction with any of the four DCAT RF signals.

Normal Cable Operations to DCAT

--- High Level Sweeps

The Thornton cable system uses a high level sweep for system analysis. The system in use is a Wavetek 1855/65, which sweeps from 1 to 400 MHz in less than 3 milliseconds at a level of 20 dB above the video carriers. The repetition rate used is from 1 to 25 seconds during this operation. Each sweep generates an audible click at the terminal audio output. Based on the characteristics of the sweep, it is possible that 2 subframes of DCAT information could be destroyed for each sweep (approximately 10 microseconds per RF channel at 1.4 MHz). Although the click is not particularly loud to the listener, it is not known whether this event could cause damage to a subscriber's stereo system. A system operator considering the use of this system should assume that the potential for damage exists, and plan on providing a notch filter at the sweeper output.

--- Low Level Sweeps

The pertinent specification for the DCAT terminal with respect to susceptibility to interference from a low level sweep system is the desired to undesired ratio. To prevent interference to transmitted DCAT signals it would be required that the RMS level of the sweep output signal be at least 14 dB below the peak level of the DCAT signals.

Low level sweeps are most often operated at levels of 10 to 20 dB below system video carriers. DCAT signals may be operated as low as 15 dB below video and an additional 14 dB is required to satisfy the D/U requirements of the terminal. Under these conditions interference will occur. It is reasonable to expect that the effect of the interference would be similar to that experienced under high level sweep conditions.

Systems employing low level sweeps with output levels greater than the D/U specification below DCAT (plus reasonable margin) should plan on the use of notch filtering or similar solution to prevent interference.

--- Premium Service Traps

Thornton cable system uses Channels A and C for premium video services. When DCAT terminals were initially installed at some subscriber sites, the effect of two types of traps in use in the system to prevent unauthorized reception were observed on DCAT signals. One type of trap is used to prevent reception of a single service in channel A or C while the other type is used to eliminate channels A, B and C. The attenuation of the multichannel trap from 110 to 120 MHz is quite severe, with 2 dB attenuation at 110 MHz to 40 dB at 120 MHz. The single channel trap attenuation ranges from 1 dB at 110 MHz to 3 dB at 115 MHz with the attenuation increased to 20 dB at 120 MHz.

The terminal specification for level deviation between DCAT carriers does not permit adjacent DCAT channel level deviations from exceeding 3 dB or in-band level deviations between non-adjacent channels in excess of 6 dB.

Assuming this situation is common in existing cable systems, this specification introduces restrictions on cable operators regarding reliable terminal operation and use of cost efficient deauthorization components in non-addressable systems. The operator who is faced with this situation will be required to engage in careful spectrum planning and system analysis before initiating subscriber service. Fortunately, the effect of the traps used in the Thornton system between 88 and 108 MHz was negligible.

Installer Feedback

A questionnaire and information summary sheet was completed for 22 of the 23 friendly subscribers at the time of initial DCAT installation.

The requested information included a description of the customers stereo system, the in-home installation and the general environment in which the terminal was installed. The subscriber's initial comments concerning the installation, terminal or service were also requested.

Very few trends could be determined from the data on stereo system type. A wide range of manufacturers and qualities were represented. The most common type of system was the "rack" system from labels like J.C. Penney, Fisher, and Zenith. None of the subscribers owned Compact Disc players. A few subscribers had no stereo system, using headphones only on the terminal.

Most installations had relatively short (less than 5 ft.) cable runs from the wall plate to the TV and stereo. In one installation the stereo was located in a basement room 30 feet from the nearest cable outlet.

No problems were reported with heat or interference to or from the DCAT unit, although some subscribers mentioned that the terminal remained hotter than expected during power off periods. This is not unusual since the terminal electronics remain active even after the ON/OFF key is pressed. This maintains the internal RAM for previous authorization and channelization data and allows reception of new data to modify previous information.

As might be expected, the most common comment was good sound quality. Also common were requests for remote control units and positive comments regarding the terminal's appearance. Channel tracking and matching channel numbers for video simulcasts were also stated as desirable. A few commented immediately that they would prefer additional program variety. Some subscribers were very pleased with the terminal's ease of use, and suggested a convenience AC outlet on the terminal back panel. The lack of AC outlets was a common problem during the installations.

Subscriber Feedback

After the friendly subscribers had their service in place for approximately four weeks, all were requested to return completed questionnaires regarding their impressions of the service and terminal equipment. Most subscribers commented very positively on the audio quality. The same comments stated on the installation report were restated by additional subscribers after receiving the service. Several subscribers mentioned that the Compact Disc channel seemed to be lower in volume than the others; perhaps this is due to an unfamiliarity with the wide dynamic range of Compact Disc sources. Several of the other sources used in the test were heavily compressed and thus, on the average, sounded much louder as channels were rapidly scanned.

Measurement Techniques

Spectrum Analyzer

To accurately describe the level characteristics of a DCAT signal, the peak unmodulated carrier level must be defined. However, as terminal installations progress, it is undesirable to interrupt previously installed subscribers' service by removing modulation for a measurement. Therefore, amplitude measurements were performed on the actual modulated signals and a calibration factor applied to normalize to the unmodulated carrier level reference.

The spectrum analyzer used for most of the measurements was a Hewlett Packard 8558B. After modulation is applied to the zero dB peak unmodulated DCAT signal, the signal was measured using the HP Spectrum Analyzer. The following results were obtained:

Bandwidth	Level
1 MHz	-4 dBmv
300 kHz	-9 dBmv
100 kHz	-14 dBmv

There was a 4 dB difference between the zero dBmv peak level of the unmodulated signal and the same signal within a 1 MHz window after modulation was applied.

Bit Error Rate

Toshiba has specified a bit error rate (BER) of 3 x 10^{-4} as the transmission link bit error limit for satisfactory reception of high quality audio as specified for the DCAT terminal. This BER figure is the absolute reference for defining thresholds for a number of different technical specifications (for example: Carrier to Noise Ratio, Desired to Undesired Ratio, Level deviation between RF channels, etc.).

Although the BER specification provides a technically accurate yardstick for defining many terminal specifications, operation at the specified limit consistently resulted in acceptable performance. As a result, all tested terminals met published specifications, however, very little was learned about the absolute limits of various specification parameters on a more subjective level. For this reason, test thresholds were established in a manner which describes the effect of unsatisfactory system operation to the end user. As each specification parameter was varied towards its most undesirable extreme, (while other parameters were maintained at "normal" settings), a common result occurs in the audio output regardless of which parameter is being varied. As a result of exceeding the error correction capability of the DCAT BCH error correction code and audio interpolation capability of the terminal logic, audible clicks due to an excessive number of uncorrectable bit errors in the received data stream are heard at the audio output. The click rate changes from effectively zero per second to thousands per second (audibly resembling white noise) very quickly for a given parameter range change. This result was also reasonably independent of the parameter under examination. Typically, these two extremes would be seen within a 1 to 3 dB window. The limits for the various specifications were determined by listening for clicks to just be detectable in headphones (with no audio programming) at a very low repetition rate; additional change in the parameter would result in the presence of noise (clicks) which, in our listener's judgement, would be objectionable to a typical subscriber.

The method described above is not intended as one which would replace measurements based on BER, but rather one which provides additional information which is practically useable for quantifying specific DCAT terminal parameter thresholds in a realistic cable environment.

Summary

During Phase 1 of the Engineering Field Test, 23 terminals were installed in the Thornton system. All terminals but one operated normally.

The friendly subscribers who received the service were very pleased with the quality of audio although only one of the seven programs was truly from a high quality source (the Toshiba/EMI CD Jukebox). Other subscriber feedback and suggestions consisted of comments regarding terminal appearance, the desire for remote control, matching channel numbers for video simulcasts and the need for greater variety in audio programming.

It has been determined that the terminal is susceptible to interference from both the low and high level sweep systems commonly used in current cable systems. This is primarily due to the low levels at which DCAT operates. Therefore, it will be required for cable operators using DCAT to include a notch filter at their sweeper output to prevent the occurrence of the low volume click heard by terminal users as the sweeper is active.

Cable systems which have assigned Channels A, B, or C for their premium video services and use negative traps to prevent reception will need to exercise care in providing DCAT service to subscribers who are not authorized for these video channels. This caution applies primarily for systems who transmit DCAT in the upper portion of the 88 to 120 MHz band.

An operating window with respect to input signal level was established based on FCC restrictions, system design constraints and minimum useable signal limitations of the terminal. With the in-home configurations used in Thornton cable system, practically useable windows of approximately 14 dB and 17 dB were determined for two-set and one-set configurations, respectively. These windows extend beyond the low end dynamic range specification published for the terminal by 5.5 dB.

The technical testing which is described in this paper is a small subset of the testing performed to date. The detailed technical testing was done during Phase 1 of the test. The second and last phase of the field test, now in progress, is directed toward evaluating consumer reactions to both the DCAT system and additional premium audio programming sources. Information concerning consumer response to the second phase will be available after completion of focus group activity and data compilation.