DELIVERING DIGITAL AUDIO

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ABSTRACT

Cable television has grown to service 60 percent of United States television households. Additional growth will require additional services. Audio is the second largest consumer communications market following video. Cable television has the only pipe presently capable of capitalizing on the audio market. Digital audio is necessary to control and provide premium quality programming. This paper presents an integrated system for digital audio delivery which is compatible with existing cable television methods of operation. Room for future growth in audio programming services is designed into the system.

CABLE INDUSTRY GROWTH

Cable television has grown over the past 40 years by providing television programing not available via local broadcast reception. The first stage of cable television growth came from importing distant broadcast signals. Cable developed during this period primarily in small communities. The second stage of growth was driven by satellite delivered signals which provided programing not available from terrestrial broadcasters. This additional programing allowed growth in both small and large population centers. As cable operators now look toward deriving more revenue from existing systems, it is useful to consider that a cable system is really a communication system capable of delivering other services in addition to television.

THE AUDIO MARKET

After television, the next largest available market is audio.

To put audio into perspective, U.S. television sales in 1988 were 6 Billion dollars. U.S. Consumer Audio Equipment Sales were 2 Billion dollars. The audio recording industry sales in 1988 were 6.3 billion dollars according to the RIAA.

Since the advent of compact disc players, the audio hardware industries' sales on an annual basis have doubled. The recording industry has seen a rebirth. Compact discs offer convenience and quality and are achieving widespread acceptance (over 40 million CD players are in use worldwide). Cable systems can be used to deliver compact disc quality audio directly to the home.

DIGITAL AUDIO

Cable systems can deliver digital audio to the home free of commercial interruptions. Broadcast radio can not deliver commercial free digital audio because of transmission regulations, backward compatibility problems and the inability to derive revenue other than by commercial messages. Cable system operators have an opportunity to provide the first direct digital audio link into the home. Digital transmission is necessary for control and consistent quality. Although some analog methods can yield high quality, encryption is difficult and expensive. Digital encryption is inexpensive and does not affect quality.

Digital audio is audio represented as a series of numbers. There are numerous methods of converting audio from a continuous analog form to a discreet digital form. 16 Bit linear pulse code modulation (PCM)is used in compact disc recordings. This system provides excellent audio quality, but uses excessive amounts of information space or bandwidth. For transmission, PCM is usually companded whereby inaudible information is discarded. The resulting audio quality is dependent on the particular companding implementation used. The interested reader is referred to references 1 and 2 for additional information on digital techniques.

Digital (or analog) companding does have measureable affects on audio performance parameters, the claims of some system proponents not withstanding. The parameters affected are typically harmonic distortion and noise in the presence of large signals (instantaneous S/N). The change in these parameters is not necessarily the important issue but whether the change is audible or not.

The method which must be used to determine transparency of a companding system is to have independent scientifically controlled blind listening testing performed. The source material must be of excellent quality and varied in content. The listening system and environment must also be controlled and of excellent quality. If blind testing done in this fashion shows no statistical preference on any program material for the disk source or the compact disc source processed through the companding system, then the system is proven to be transparent.

Another method of digital audio sampling is Dolby TM Adaptive Delta Modulation (ADM). This system developed by the leaders in both professional and consumer recording technology offers certain advantages over PCM systems. It offers audio transparency at a low bit rate (narrow bandwidth) and low cost decoding.

Another advantage of ADM is the ability to withstand a low level of bit errors (i.e. 10-6 BER) without a significant reduction in audio quality. All PCM systems must be error corrected throughout all transmissions, as severe cracks and pops will result when the most significant bits are in error. The need for error correction translates into increased receiver complexity and cost as well as additional transmission bandwidth.

The goal of a transmitted digital audio system is to be audibly transparent while minimizing receiver cost and transmission bandwidth (data rate). Once a signal is in a digital form, its quality is determined. The sampling and companding system determines the quality, not the transmission process (providing that bit errors are corrected). This is the key difference between analog and digital signals; analog signal quality is primarily determined by the transmission or storage medium. Digital signal transmission and storage (both audio and video) are certain to play major roles in the future of cable.

DIGITAL TRANSMISSION

There are many options available for transmitting digital signals. The choice of modulation format is based on maximizing signal robustness (least received bit errors) while minimizing occupied bandwidth and receiver cost. The more complex the modulation (i.e. number of data levels) the less bandwidth used, but the more complex the receiver is and the more susceptible the signal is to noise, reflections and interference.

A popular modulation choice for digital transmission is quadrature phase shift keying (QPSK) which uses two data levels on each of two carrier phases. Two data levels minimizes the sensitivity of the signal to interferences, as well as the receiver complexity. Two phases doubles the bit rate in a given bandwidth. Using more data levels (4, 8, 16, 32, etc.)will reduce occupied bandwidth by the power of two used, but a 6dB increase in susceptibility to interferences is taken with each power of two increase in data levels. Figure 1 shows C/N vs BER for QPSK signals. An informative text on digital modulation techniques is Reference 3.

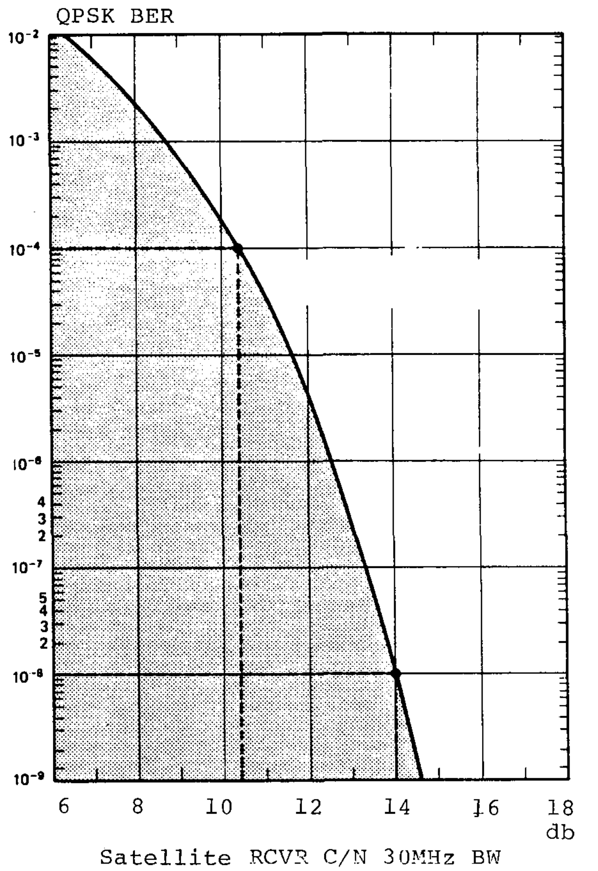

FIGURE 1

DIGITAL AUDIO SERVICE

Commercial free digital audio in numerous musical formats (i.e. rock, country, classical, jazz, etc.) has been proven to be a viable pay service, both in market surveys and market tests. It does not cannibalize video services and has achieved a high level of customer satisfaction due to convenience and quality.

DIGITAL AUDIO SYSTEM

In order to achieve success on a national level, a digital audio system should include the following:

1. A proven addressable control system with major billing system interfaces.

2. A satellite transmission system with no more stringent requirements than those which are required for video reception including immunity to terrestrial interference.

3. A cable transmission system which does not displace present or future video services. The transmission system should also operate to the point of unacceptable video services and not contribute to video distortions.

4. Enough channel capacity to accommodate growth in future audio services. A guideline for the number of audio channels might be comparable to the number of video channels expected in the future.

5. Equipment payback time should be favorable in comparison with other possible service investments.

A system block diagram for nation-wide delivery of pay digital audio services to the home is shown in Figure 2. Key points to consider for each of the blocks follow.

DIGITAL AUDIO DELIVERY SYSTEM

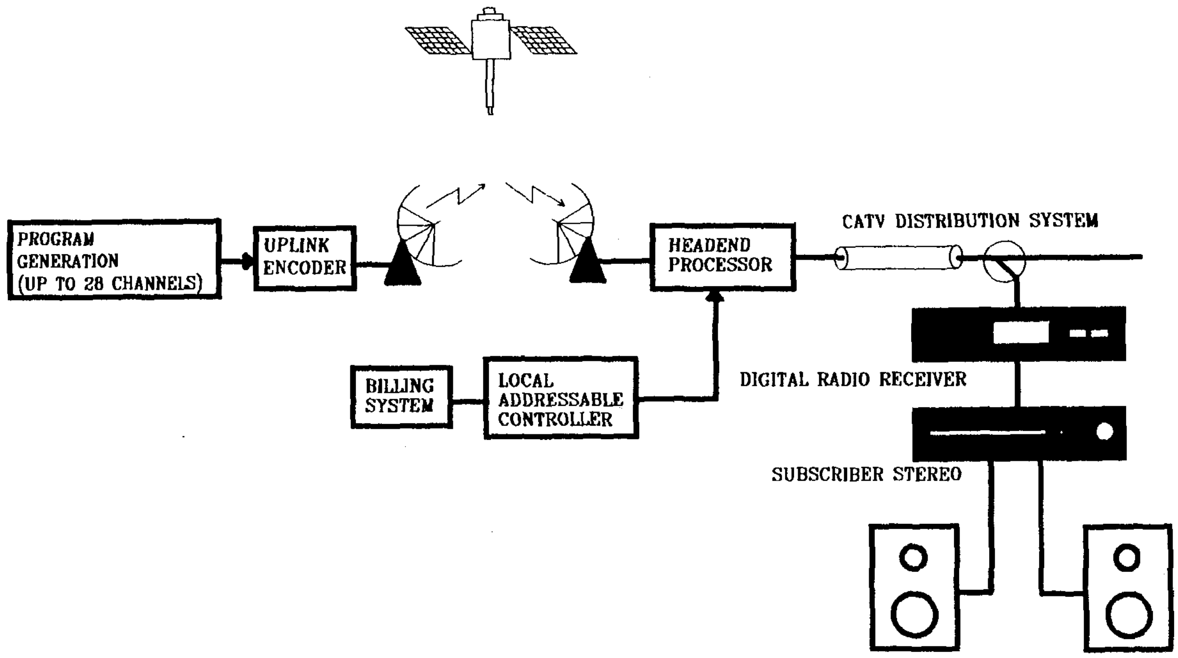

Figure 2.

Program Origination

Each channel of the digital audio service programming is sourced by a computer controlled playback system. The playback system plays from a selection of format dedicated compact discs according to a playlist programmed into the control computer. The playlists for each music format are created by programming experts within that format. The system is capable of continual play, and the playlist and disc stock can be updated as required. See Figure 3.

Satellite Link

Up to 28 stereo audio pairs are converted from analog to digital form by Dolby DP-85 encoders. The uplink encoder encrypts each channel, adds forward error correction and control data before interleaving the channels and framing the multiplexed data. Rather than using a pseudo video signal format and applying it to a standard satellite exciter, the multiplexed data is QPSK modulated at a 70MHz IF frequency and then upconverted to the transponder uplink frequency.

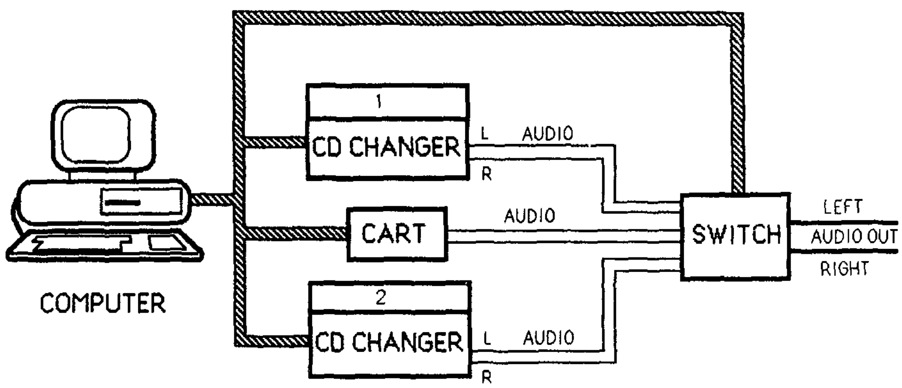

FIGURE 3

This has two key advantages: an improved bit error rate (BER) at the receiver, and a bandwidth narrow enough to allow filtering to reduce terrestrial interference. This system will operate with as little as 10dB C/N. It is desirable to carry the digital audio service on a transponder of a satellite which carries other common cable services. In this case the existing 950 to 1450MHz feed from the existing antenna and LNB is split and fed to the tuner and QPSK demodulator for the digital audio service, as well as to the video service satellite receivers.

Transportation

As shown, the cable system operator will receive the digital audio service via earth station downlink from a cable programming satellite. In those cases where the earth station downlink and CATV headend are not co-located, provision must be made to transport the signals. The CATV community presently utilizes two classifications of equipment to transport video services: FM systems and AM systems. Each of these can be compatible with digital audio.

The FM systems currently employed consist of FM supertrunk, FM microwave (FML) and FM fiber optics. In any of these systems, the digital audio signal will be transported by processing the received satellite IF signal (70MHz) as appropriate to the application. In FM supertrunk applications, the IF signal can be converted to a selected output channel, transported via coaxial plant, and converted back to IF at the CATV headend. FM microwave (FML) applications require that the IF signal be up-converted and amplified for microwave broadcast, then received and down-converted at the CATV headend. FM fiber optic systems will make use of available lightwave processing equipment to deliver the IF signal to the CATV headend.

AM systems in use include standard coaxial plant, AM microwave (AML), and AM fiber optic systems. Transportation of digital audio through these will be accomplished by processing the received satellite signal into discreet QPSK channels (as discussed in the following section), and distributing these in a method similar to processed FM analog audio, or modulated video. Interconnection to the addressable controller will be by established data communications products.

Headend Signal Processing

In order to provide a pay digital audio service that does not take up spectrum suitable for video services, the FM band (88 - 108 MHz) is an ideal location. Ingress generally makes picture quality unacceptable in the FM band. This ingress also makes transmission of wideband multiplexed high speed digital signals unreliable in this band. The solution is to demultiplex the high speed satellite delivered signal and generate individual data carriers which can be spaced 600kHz apart.

Not only are the narrow band signals less sensitive to noise and reflections, but the carriers can be placed to avoid frequencies of maximum ingress or desired existing carriers. QPSK modulation is again a desirable modulation form for transmission over the cable system. Operation with only 15dB C/N or C/I is fully acceptable. A cable system with 35dB C/N video carrying digital audio with QPSK carriers 15dB below video still has a 15dB safety margin for the digital audio service. This is due to the noise bandwidth of the QPSK receiver being about 400kHz instead of 4MHz which reduces noise by 10db relative to video.

The headend signal processing includes transponder tuning, QPSK demodulation, data demultiplexing, error detection and correction, control data multiplexing and data framing, digital filtering and QPSK modulation. Controls are provided for transponder selection, audio service selection, output frequency and output level.

Since the QPSK carriers are more robust than AM video, any transmission component suitable for AM video use will be suitable for digital audio use. This includes AML and AM fiber.

Addressable Control System

Addressable authorization control is an important consideration to the success of the digital audio service. Authorization control is accomplished by first encoding each digital service with a "tag" or identification and then authorizing each tuner to play a package of services. This control is equivalent to and compatible with present addressable control methodology. Additionally, the tuner is configured for operating parameters and channel allocation via the addressable control system. This control can be an upgrade to the existing addressable controller or a standalone system.

The distribution of the addressing data requires a family of communication products that can accommodate a wide range of cable system interconnect architectures. These products have been developed for present addressable control systems and a pool of trained resources is in place to assist in their installation. A wide variety of local and remote (both via RF and telephone) applications can be met.

The business system integration of the digital audio services will make use of existing billing system functions; installing a new converter type, and building a new service package (or packages). The billing system will interface to the addressable control system by using the standard wirelink protocol.

DIGITAL RADIO RECEIVER

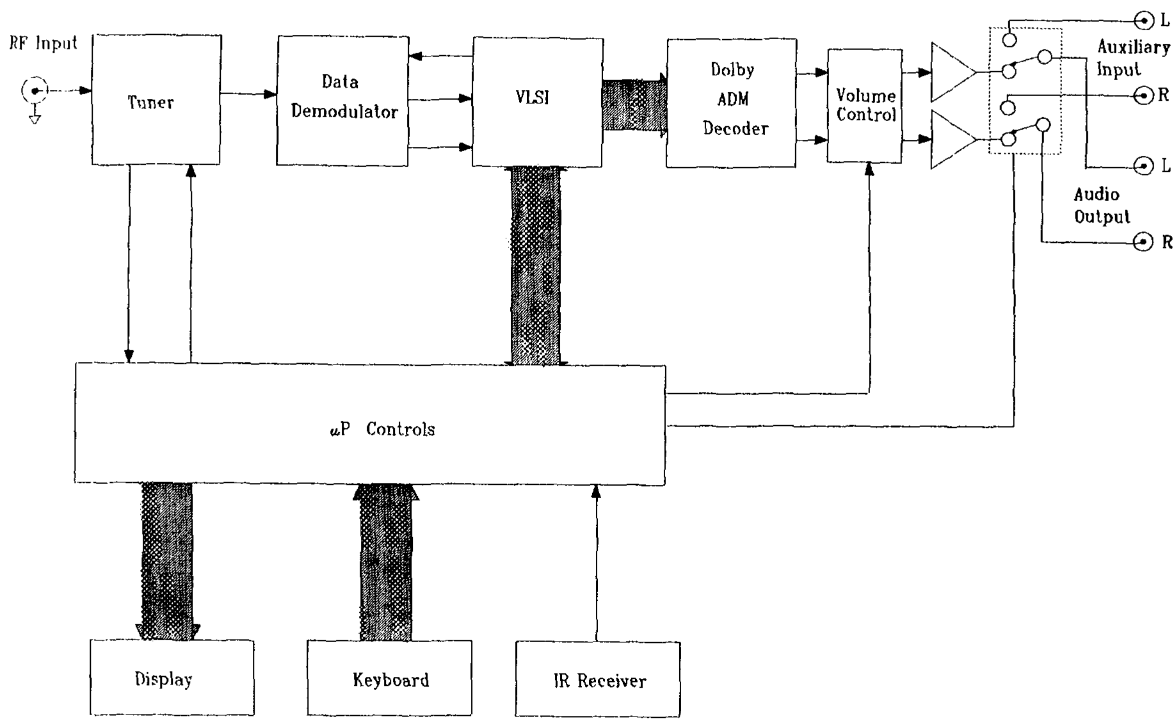

FIGURE 4

Receiving Terminal

The digital radio receiver block diagram is shown in Figure 4. The front end is similar to an FM radio tuner. It is a single conversion tracking tuned RF system. The oscillator is synthesized and operates from a downloaded tuning map. The IF frequency is 10.7MHz allowing the use of wide type ceramic filters for channel selectivity. The 10.7MHz IF QPSK signal is demodulated and fed to a logic LSI which reads and passes control information to a microprocessor.

The microprocessor decrypts control information and in conjunction with the LSI it decrypts the digital audio when authorized. The digital audio data is formatted and provided to the Dolby TM ADM decoder which converts the digital data to analog audio. This audio is then passed through a digitally controlled attenuator to provide the remote volume control function and passed out to the left and right audio output jacks.

Subscriber Installation

The subscriber installation of the digital audio service will be similar to that of an additional outlet. A coaxial feed from the subscriber drop will be routed to the location of the subscriber's home audio system where the tuner will be installed. A wide dynamic range input will facilitate installation on any drop which provides satisfactory video signals using a directional coupler. The tuner will connect to the AUX or CD inputs of the stereo system and connections will be made using standard hardware. The tuner does not require any additional inputs on the subscriber's existing stero amplifier or receiver. Audio inputs are provided on the digital tuner to allow an additional input to the audio system when the tuner is powered off.

CONCLUSION

Delivering digital audio presents the cable system operator with an opportunity to capitalize on the second largest consumer communications market. An integrated system for delivering digital audio to the home can ease the launch of digital audio services into the CATV business environment.

This system can operate on existing cable plant and take advantage of existing business system operations. Finally, the system possesses the flexibility to allow for expansion as the market requires.

REFERENCES

1. Digital Audio for Cable Television
   Clyde Robbins
   1986 NCTA Technical Papers

2. A Digital Audio System for Broadcast Cable and Satellite Delivery Media
   C. C. Todd and K. J. Gundry
   1984 NCTA Technical Papers

3. Digital Communications
   Satellite/Earth Station Engineering
   Dr. Kamilo Feher
   Copyright 1983 Prentice-Hall, Inc.

4. Digital Audio Services
   Clyde Robbins
   Communications Technology
   February 1989