UNDERSTANDING THE INSTALLATION REQUIREMENTS OF THE CD-X DIGITAL AUDIO SYSTEM

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ABSTRACT

The following paper describes some of the installation considerations necessary in implementing a satellite-delivered digital audio system into an existing cable system. Areas of discussion include satellite reception, headend configuration, signal carriage, distribution architecture, and input requirements at the subscriber locations. It is important to the cable operator that a system provide the flexibility to adapt within the overall architecture of the system. Systems typically want to preserve bandwidth or simply have very little bandwidth in which to work. The digital audio service must operate well in spectrum not necessarily suitable for video channels. Therefore, the challenge for a digital audio service is to find available spectrum that will provide quality signals throughout the system.

INTRODUCTION

Since the introduction of satellite digital audio to the cable industry, digital audio systems have been installed at an accelerated rate. While the actual implementation of a digital audio system is fairly straightforward, the different types of system architectures and the limited availability of bandwidth is cause for some consideration prior to installation. The first consideration for the cable operator is how the service is to be received from the transmitting satellite. The antenna size and the type of low noise device depends on which satellite the service is carried and the input requirements of the satellite receiver. Once the service is received at the headend, the operator must determine where the system is able to carry the service. Typically, most systems place the service in one or more of the following areas:

- The guard band from 72 MHz to 76 MHz
- The FM band from 88 MHz to 108 MHz
- The roll-off region above the highest video channel

Once the system has determined the placement of the digital audio service, can the service serve the entire distribution network? Since there are a number of distribution architectures in today's CATV environments, the digital audio signal must also be transmitted by these existing means to all subscribers while maintaining a low up-front capital expense. Current architectures range from direct coaxial tree and branch to AML hubs, to more recent AM fiber nodes. In addition, FM fiber and FM supertrunk applications allow operators to transport services to other remote headends for re-processing and distribution. While maintaining compatibility with system architectures, the service must also maintain all minimum input requirements at the terminal device in the subscribers home to insure optimum performance.

SATELLITE RECEPTION

While the digital modulation techniques used in digital audio systems may vary depending on the actual design criteria, Quadrature Phase Shift Keying (QPSK) is a common modulation technique used for transmitting broadband digital audio signals over the satellite link. QPSK transmission allows the satellite transponder to reach saturation providing maximum power on the output. Since the link is power and noise limited but has sufficient bandwidth (36 MHz per transponder), QPSK is the best compromise.

Multiple audio formats are time division multiplexed (TDM) at the studio and then fed to a QPSK satellite modulator. TDM multiplexes multiple data channels together into a single serial data stream which provides both an economical and bandwidth efficient means of transmitting large amounts of data over satellite. The signal is then uplinked to the satellite for transmission to the cable systems. The satellite receiving equipment at the headend must process the QPSK signal while maintaining the integrity of the digital data.

In order to receive the digital signal from the satellite, a cable system requires a low noise device to block convert the signal from C-band to the band necessary for the digital satellite receiver. Important specifications when considering a low noise device (LND) for digital audio are the frequency stability and phase noise of the local oscillator as well as its effective noise temperature. Minimum phase noise needs to be achieved since QPSK is a Phase Modulation (PM) technique with four phase states. The phase noise requirements for an LND in a digital audio application is typically -85 dBc/Hz when measured 10 kHz from the carrier frequency compared to -75 dBc requirement for analog video. The frequency stability of the local oscillator depends on the frequency uncertainty of the satellite receiver. The cable operator should request prior to installation that the vendor recommend an LND that is suitable for the application. Recommendations may also be necessary for systems that have a receiving antenna that is being occupied by an LND having an output frequency range other than that required by the digital satellite receiver. If block-up or block-down converters are required, they also must meet the same specifications.

With analog video signals, the video receiver must maintain a minimum carrier-to-noise (C/N) to ensure the signal is free of impulse noise or "sparklies." For digital audio reception, the digital broadcast receiver requires a minimum specified Eb/No to ensure a quality link. This quantity is the energy in one bit divided by the noise power density. It is equal to the C/N multiplied by the bandwidth divided by the bit rate. In some cases, a larger antenna than what is available for the service may be required to achieve minimum input requirements. To determine if an existing link is adequate, the cable operator should consult the vendor prior to installing a digital audio system. the satellite link is perhaps the most critical aspect of the installation.

Headend Requirements

In addition to a digital satellite receiver, the digital audio system requires a device to demultiplex the demodulated output of the receiver. The demultiplexer separates the data stream into smaller channel groups for carriage over the distribution plant. Each demultiplexed output is sent to a headend digital audio modulator. Each modulator output is then combined with the existing video services for normal distribution. The bandwidth requirement for each modulator depends on the number of data channels being modulated and the amount of data included in each channel. If TDM is used, a time division demultiplexer will divide the multiple data channels received from the satellite receiver into smaller channel groups. If frequency division multiplexing (FDM) is used, the multiple data channels received from the satellite receiver will be divided into single data channels.

While TDM provides bandwidth efficiency and is more economical in the number of individual modulators that are required to deliver the service, both methods provide flexibility in the placement of the signal.

The most common digital modulation techniques for carriage of digital audio data in cable systems are Quadrature Partial Response (QPR) and QPSK. Both of these techniques consist of suppressed carrier modulation. The RF carrier is digitally modulated at a particular amplitute and phase state which prepresents two bits of information. QPSK consists of four phase states which are 90 degrees apart. This modulation technique is made up of two signal components knows as in-phase (I) and quadrature (Q), each having two amplitude states. With QPR, a third level is generated between the (I) and (Q) axis to produce a total of nine states. While QPSK provides a better noise performance, QPR is more bandwidth efficient.

Simulcast audio as well as FM broadcasts can be digitally encoded to enhance the digital audio service. While some digital audio services provide audio simulcasts and radio formats as part of the satellite package, others give the operator the flexibility to choose the additional services the system wants to carry on a local level. The S/N and stereo separation at the output of a video satellite receiver/decoder is typically better than 60 dB and provides a quality signal for digital encoding. In order to encode the audio from a satellite receiver or other audio sources, the headend requires additional hardware. Analog to digital encoder are required for analog audio sources while digital to digital encoders are required for digital audio sources.

Also required in the headend is some means of communicating addressable commands to the digital audio terminals. Depending on the system, this can be accomplished with a local addressable controller or via a addressable link from the uplink studio. As with any addressable control system, the billing computer must implement the necessary host transactions to update the database of the digital audio control computer. It is important that the cable operator understand the requirements of the interface and whether or not the billing computer can fully support the system. The operator should consult both the product vendor as well as the billing vendor prior to launching a digital audio service.

Additional hardware may also be required for headends with microwave or fiber hubs. With channelized AML, microwave upconverters convert RF frequencies to microwave frequencies. If the cable system requires the digital audio service to operate in a spectrum that is not active over the microwave, additional microwave hardware as well as channel licensing may be required prior to launching the service. With FM fiber and FM supertrunk applications, services are combined with FM video, transported, demodulated and then modulated at the remote headend location. The same requirements are necessary for a digital audio service except that the demodulators and modulators are unique for the digital audio application.

The actual headend configuration will depend on the needs of the operator. The digital audio system must be tailored to serve all service areas and have upgrade potential to support any future demands. Figure (1) shows a simplified block diagram of a full function digital audio system.

Bandwidth Availability

In many cable systems, available bandwidth is very limited and is generally preserved for expanded video services. Therefore, digital audio services must operate well where analog video signals cannot. Digital audio services are typically carried in either the FM band or in the spectrum above the highest active video channel. Many operators will eliminate FM services that are currently occupying the FM band for a digital audio service since the revenue potential for a premium audio service is much greater. The number of digital audio services that can be carried in a particular spectrum depends on the amount of available bandwidth and the bandwidth requirements of the digital audio system. The number of services that can be carried in the "roll-off" region of the distribution plant depends on the frequency response at the end of the amplifier cascade. When selecting a frequency for carriage of

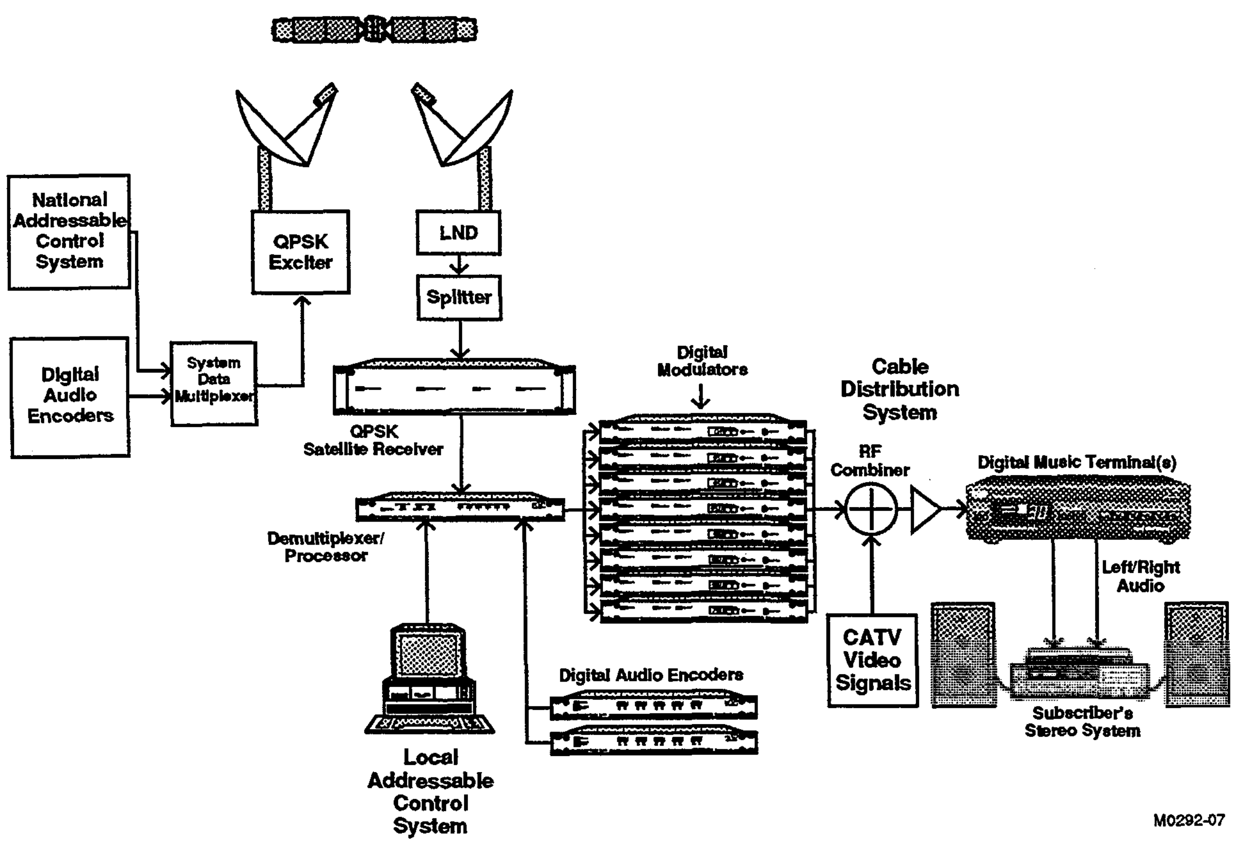

Figure 1. Digital Audio Configuration

the digital audio signal over the entire distribution plant, the most important specifications to consider are carrier-to-noise, signal level, and tilt response. These specifications are important to the operation of the digital music terminal.

Digitally modulated signals are more robust than are analog video signals, requiring a lower C/N. Analog signals are also more susceptible to interfering carriers and reflections. Since the interfering source is summed with an AM signal, the receiver has no way to distinguish between the interference and the desired signal. With digital transmission, the receiver only has to determine whether a bit is a "1" or a "0". Therefore, it is easier to reject undesired signals. The result is that available spectrum may be desirable for carriage of digital signals even if it is undesirable for analog video channels.

Smaller portions of a broadband spectrum may also be available. Standard systems have 4 Mhz between channels 4 and 5. This band covers 72 MHz to 76 MHz and is often occupied by a pilot carrier for AML transmission. There is also spectrum below channel 2 (48 MHz-54 MHz) assuming the distribution plant will pass signals in this frequency range. Channel A-1 (114 MHz to 120 MHz) and channel A-2 (108 MHz to 114 MHz) may be available in some systems as well, although both are often used for video channels. Channel A-2 is also used for addressable data carriers and carriers used to detect signal leakage. Since digital audio signals require less bandwidth than analog video channels, they can co-exist with other signals in the same spectrum.

Signal Level

As previously mentioned, both QPR and QPSK are suppressed carrier modulation techniques. Therefore, when modulated, the power is distributed over the entire operating bandwidth. With distributed signals, the level will vary depending on the measurement bandwidth. This is important when notifying the FCC for signals that fall in the FAA navigation and communication bands. The FCC requires offsets if the signal exceeds 38.75 dBmV when measured in a 25 kHz bandwidth and averaged over 160 usec. Since the level of the digital audio signal is typically 5 dB to 10 dB below the video carrier level, the signal level measured in a 25 kHz bandwidth will be much lower than the level of the video carriers and therefore does not require offsets.

The actual signal level may vary depending on where the service is carried. If the roll-off region is used, the actual level may need to be increased to insure that the proper input level and C/N ratio is met at the input of the digital music terminal.

Distribution Architectures

There are a variety of distribution architectures that make up a distribution plant. While conventional tree and branch does well to serve immediate distribution areas, other architectures such as AM fiber and AM microwave allows systems to deliver high quality services to other remote service areas. In addition, FM fiber, FM microwave, and FM supertrunk architectures allow cable systems to transmit signals to remote headends for re-processing and carriage to those service areas as well. Cable systems will use a combination of the above mentioned architectures to deliver cable services throughout the system. It is important that the digital audio service work well under all possible conditions to ensure that the service can reach all service areas.

Conventional tree and branch consists of trunk amplifiers which carry broadband signals to bridger amplifiers, which in turn provide a high level signal to feeder amplifiers. The feeder provides a signal to a series of line extenders, taps, and directional couplers, which provide the proper signal level to the subscriber's home. As mentioned earlier, digital signals are more robust than are analog video signals. Therefore, a digital audio service can survive where video services cannot. With tree and branch, no additional hardware is required for digital audio. The same can also be said for AM fiber. AM fiber improves C/N in a distribution plant by reducing the amplifier cascades. The optoelectronic transmitter takes a broadband input and transmits the broadband spectrum via fiber to an optoelectronic receiver, which provides the same broadband output to the distribution amplifier. Therefore, the digital audio service can be combined in the headend with the video services and fed to the transmitter without any additional hardware.

There are a number of applications consisting of channelized and broadband AML. Channelized AML is made up of individual microwave upconverters that convert the video channel from RF to microwave frequencies. Adding a channel requires an additional upconverter as well as getting licensing for the frequency. The same is true for adding a channel for carriage of digital audio. The hardware and licensing requirements should be discussed prior to installation to insure the service can be transmitted over the microwave link. Alternatives may be to carry the service in existing spectrum that is being carried by the AML. No additional hardware is required for broadband AML since the low power AML transmitter accepts a combined broadband input. This assumes however, that the transmitter has a bandpass that will accept the frequency assignments for the digital audio service.

FM fiber and FM supertrunk require additional hardware considerations as well. Baseband video and audio are typically FM modulated at the origination headend and FM demodulated at the receive headend prior to being AM modulated for distribution. Each FM modulated channel requires 14 MHz of bandwidth. The cable system must find available spectrum to carry the digital audio service over the fiber or supertrunk. At the receive headend, the digital audio signal must be demodulated or reprocessed to filter out other FM modulated services. The signals are then remodulated and combined in the headend for general distribution.

Digital Music Terminal Requirements

It is important for the cable operator to maintain minimum input requirements to the digital music terminal as previously mentioned. The most important input requirements are input level, C/N and tilt response. These specifications are vital to the performance of digital audio service. Once these input requirements are established at the drop location, the installation should insure that the signal quality for the existing video services is maintained. A directional coupler should provide the recommended isolation between ports and have minimal insertion loss. Since the digital music terminal typically requires a lower input level than cable converters, a 6 dB or 9 dB directional coupler is recommended.

The output of the digital music terminal should include a digital output in addition to the left/right analog output. A loop-through option should also be available on the terminal to preserve auxiliary inputs on the stereo amplifier or receiver. The digital output must be compatible with digital audio tape (DAT) recorders, compact disc players and other digital interfaces which use the Sony Philips Digital Interface (SPDIF). A typical subscriber installation is shown in figure (2).

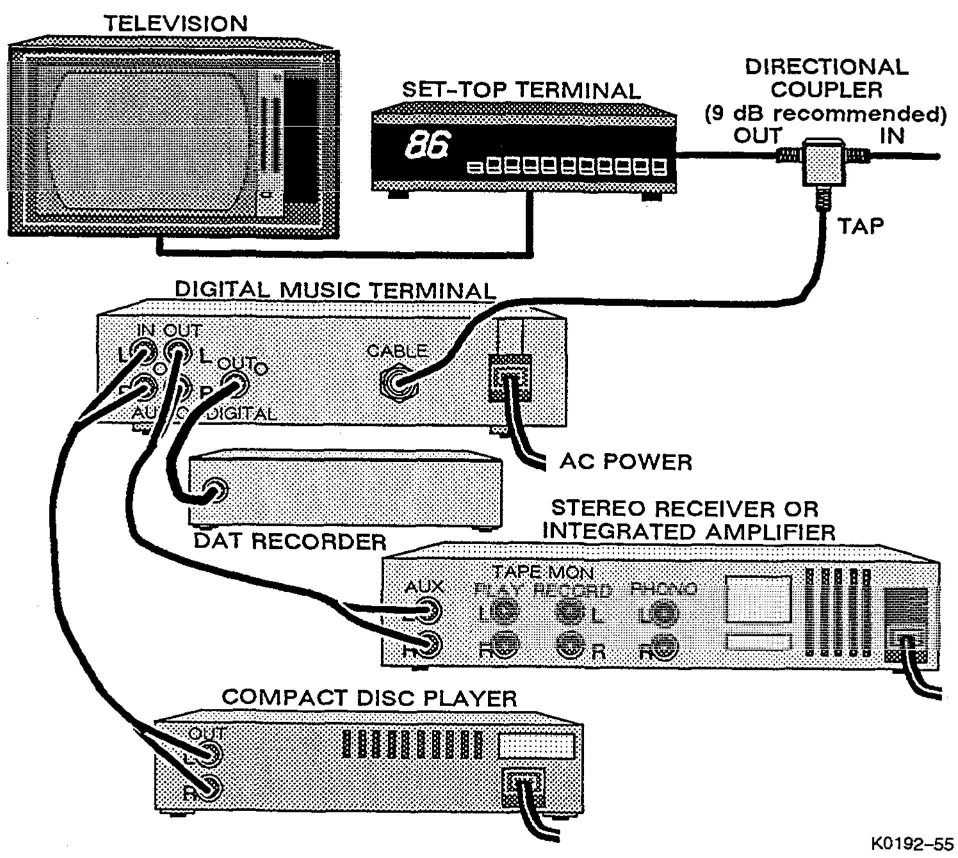

Figure 2. Digital Audio System Wiring Diagram– Subscriber's Home

CONCLUSION

In conclusion, the digital audio system must be extremely rugged while providing near CD quality audio to subscribers. The system must adapt to existing architectures and be easy to implement. The cable operator demands a system that is bandwidth efficient, reliable and user friendly.

REFERENCE

Leo Montreuil and William Wall-"Performance of Digital Modulation Methods in Cable Systems," 1991 NCTA Papers, pp. 204-214.