DIGITAL COMPRESSION IN TODAYS ADDRESSABLE ENVIRONMENT

by

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ABSTRACT

The introduction of digital compression technology to today's addressable system presents a host of new challenges to the industry. With the ability to deliver a vast array of information and entertainment, operators will be faced with the need to easily and seamlessly integrate the digital signal access control within the confines of a relatively mature addressable system environment. While much of the navigating and control will be defined by the user interface in the home terminal, the overall integration of the digital system will also be important to avoid confusion by the consumer.

This paper will address the control system architecture required to enable the variety of services possible, while maintaining the simplicity consumers have become accustomed to in today's addressable environment. The focus will be on the headend and system implications, but will briefly touch on the in-home terminal user interface issues. All aspects of the interface, including video, audio, and data, will be covered.

INTRODUCTION

The cable headend has changed a great deal over the past twenty years. Initially, the headend served nothing more than to receive signals from off air broadcasts and then process the signal for transmission through a cable plant to subscribers who were unable to receive the broadcast signal. Over the course of time, the complexity of the headend has increased as signals are received from off-air antennas, satellites, microwaves, and fiber links, as well as locally originated signals. With 50+ channels of analog video in many of these systems, coupled with scrambling technology and addressability, the need for clean and simple headend interfaces has become critical.

The advent of digital compression will bring about a whole new landscape for the system operator. 500+ channels of video, along with a multitude of data services, will become the norm in the late 1990's. Some of these interfaces will be completely within the control of the operator, while others are likely to be passed through without requiring any intervention. As this convergence of video, voice and data through the headend is inevitable, it is important to step back and review the fundamentals of digital video, the element enabling the convergence, before analyzing the impact on headend and system architecture.

DIGITAL COMPRESSION

Digital compression allows for the carriage of more than one video signal in a standard 6MHz NTSC bandwidth channel. This process was first studied by the video entertainment industry as part of the research toward High Definition Television (HDTV). With an HDTV signal containing at least four times as much information as a standard NTSC signal, compression was all but a necessity for carriage within 6MHz. By applying the same technique to NTSC signals, multiple NTSC signals can be carried within the bandwidth of one NTSC analog signal.

The process of video compression involves several phases. To begin with, the analog signal is divided up into a large number of video pixels. Each pixel is then converted into a numeric value resulting in a signal approaching 100Mbps of information (audio and data packets are included). Transmission of this signal, even using a very robust modulation technique, would require about four standard NTSC signal bandwidths. Therefore, compression is required even to achieve signal transmission of 1:1.

Various techniques of compression are available, with the most promising being discrete cosine transform (DCT). In the DCT process, small areas of information within each frame are compared for similarities. These redundant similarities are then eliminated, leaving only the differential information. By further applying color and motion compensation techniques, the amount of information required to represent similar portions of successive picture frames is reduced.

With only the differential information remaining, a further reduction in the amount of data required is achievable through various mathematical techniques. One such process, Huffman coding, assigns short data codes to frequently repeated data and long data codes to infrequent information. After applying this process, error correction is added to the signal to ensure operation of the system at low carrier-to-noise (C/N). The level of sophistication of the required detection and correction circuitry varies between the cable and satellite environments due to the nature of the transmission media (cable is more rugged since it is a closed environment).

The net result of the completed compression process is a signal with a data rate as low as 2Mbps (2% of original signal). The actual data rate will vary over time, depending upon the source of the material, film versus live motion, and the degree of redundancy in the video. Because the system allows for statistical multiplexing of the combined signal, this data rate will vary over time on a real-time basis.

The complete compressed signal in the General Instrument DigiCipher™ system consists of approximately 30Mbps of information. In the cable environment, the error detection and correction requires about 3Mbps of the data, leaving approximately 27Mbps for the compressed video, audio and data. Access control and encryption is embedded within the signal in the compression process. User feature control can be included in the data, or may be it video, audio, or data. Block A represents the process at the satellite uplink facility, while block B contains the satellite receiver and transcoding equipment required at each cable headend. "C" is the converter in the home. Each of these areas will be expanded upon below.

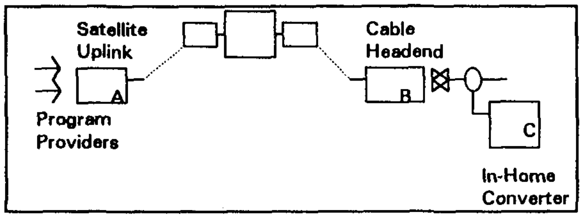

Figure 1 - System Block Diagram

A. Satellite Uplink Facility

The satellite uplink facilities in use today can be readily adapted for digital compression. At these facilities, analog signal will be converted to digital by feeding each signal through the compression process previously outlined. If the plan is to carry six (6) signals within the one transponder all six (6) signals will be fed into the compression system and will be statistically multiplexed with one another, either in total of separately between the I and Q phases. The access control and encryption information is then added to the signal. Each video service within the multiplexed signal can be encrypted with a unique key and can therefore be authorized on an individual basis. If desired, however, the complete multiplexed signal can be encrypted with a single key. Such a process could reduce the cost at the headend and might be viable in certain applications (e.g. NVOD).

Before transmission, forward error detection and correction is added to the signal. As the result of the nature of satellite environment (low C/N, high interference), a complex error correction circuit must be added. The resultant signal is then fed into a QPSK modulator for transmission (FM) over the satellite link.

Figure 2 shows the complexity of the satellite encoder. Due to the real-time requirements, a fully redundant sytem is required. While this significantly increases the cost, on a per subscriber basis the impact is minimal.

B. Headend Facility

The purpose of the cable headend in a digital environment is basically the same as today: receive the signal and process for transmission over the cable network. Instead of analog integrated receiver descramblers (IRD's), digital IRD's capable of decompressing one video signal within each transponder will be used. As compression over satellite will occur before compression over cable, the output of the initial IRD's will be 6MHz analog signals. This signal is basically identical to that from an analog IRD and will be processed similarly at the headend (see figure 3).

With digital compression over the cable plant coming on line in 1994, the utilization of compressed video over satellite for such services as NVOD will explode. With up to ten (10) compressed signals per transponder, the number of individual IRD's and QAM Modulators could become unmanageable. Therefore, a modular approach to the headend system will provide the most cost and space effective solution. This rack-mounted frame with cards, called an Integrated Receiver Transcoder (IRT), will allow for one card per video signal, containing both the functionality of the IRD and a modulator (QAM) as well as acting as an interface to local addressable controllers and cable FEC generator.

Access control for the headend IRD is generated at the uplink facility. The design of the DigiCipher system allows for pass through of the access control signal at the headend or for a new access control signal to be added at the headend. In the first case, only basic transcoding equipment is required at the headend. The basic transcoding cards demodulate the satellite QPSK signal, strip off the satellite error correction and add the lower cost cable error correction, and then modulate the cable QAM signal. This system provides the lowest cost solution for bandwidth efficiencies, but is subject to higher security risks due to lack of segmentation.

The second approach to cable compatibility offers the greatest degree of operator flexibility, growth potential, and security. In this segmentation transcoding approach, the satellite access control is removed from the incoming signal and replaced with system-level access control. This control information can be generated from the addressable control computer resident in virtually every addressable system or could be provided on an individual system level basis over the satellite. With local access control, the same controller which operates the analog converters in the system will drive the digital converters, thereby enabling a smooth transition and not requiring any change in billing operation.

In the future, local system compression will also be an integral part of the overall system. The local compressor will operate similar in nature to the satellite system compressor, multiplexing various analog signals into a single digital data stream. As local ad insertion on digital signals requires the same expensive compression system at the headend (or potentially on a regional basis), it is envisioned that no local insertion will occur in the initial deployment of digital compression. Once this capability becomes cost effective, the segmentation transcoder will be enhanced to enable insertion at a given data rate. As the compression signal maybe statistically multiplexed in many applications and the data rate may vary over time, the local insertion system will need to be designed to operate in a very flexible mode.

Figure 4 shows a typical headend with digital compression signals being received and processed, along with local insertion and access control.

C. <u>In-Home Converter</u>

The in-home converter will receive and demodulate the signal, and decompress the appropriate video. Because of the installed base of analog scrambling systems, the decompression converter will also tune and descramble analog signals. This backward compatibility functionality will enable a smooth transition to digital and permits a single converter solution. Access control will be provided over a single out of band data stream, including authorizations for both analog and digital signals. The user feature set of the converter will expand upon those found in today's analog converters. While the myriad of potential features is beyond the scope of this paper①, it is likely this converter will more appropriately reflect the convergence of a computer into the converter. With the power of digital compression, the need for an operating environment which facilitates navigation and control will be imperative.

COMPRESSION IMPLEMENTATION

The implementation of compression in a cable system will be dictated by the services which adopt the technology. While the advantages of digital compression to the system operator are tremendous in terms of picture quality improved bandwidth utilization, and enhanced security, the costs of the compression system will limit its initial applications to those services which dictate these characteristics the most. Multi-channel pay-per-view and near-video-on-demand services are likely to become the first major adopters of compression because they are nationally delivered, do not require local ad insertion, and will require the highest video/audio quality in order to obtain top dollar from the subscriber. A fifty (50) channel NVOD service will require an operator to purchase transcoding equipment for each of the channels. If this service is offered with a club fee to subscribers, only a small percentage of subscribers will require a decompression converter initially. As the service grows in popularity additional converters can be added on an incremental basis without obsoleting the entire installed base. As the cost of the compression technology is reduced over time, additional services will be carried digitally compressed on the cable system. In each case, digital converters can be added incrementally without disrupting the analog system already in place. With local system control and full backward compatibility, introducing new services will be comparable to how analog services are added today.

The digital compression system will also bring about an extremely cost effective means for delivering data services. As each 6MHz bandwidth will contain several 9.6KBps data channels, various "interactive TV" data services, such as electronic program guides and augmented video services, will benefit from the new delivery means. While many unsuccessful attempts have been made to market such services, digital compression coupled with fiber optics, have eliminated these technical obstacles and brought about, an environment which will readily facilitate consumer testing.

VIDEO ON DEMAND

One potential service which has received a great deal of attention lately and which will dramatically change the headend of the future is video on demand (VOD). VOD is a broad category which encompasses not only movies on demand, but a vast array of on demand information and entertainment. By digitizing video signals and using a defined packetized data structure, the opportunity exists to move blocks of digital information, video, audio, or data, amongst various devices. Information can be stored digitally on high capacity disks and then retrieved on a real-time basis with digital file servers. As the information is requested and retrieved from the server, a packet switcher will route the data to the proper subscriber on demand. The introduction of this approach to on-demand information will dramatically impact the interfaces in the headend, from access control to the billing system. The architectural considerations in the client-server concept requires a paper unto itself and will not be addressed here. Needless to say, however, that the choice of such an architecture will require stringent evaluation as it will alter the operation of the system forever.

SUMMARY

The era of digital technology is upon us. Beginning in 1994, digital compression technology will be integrated into today's addressable environment through an evolutionary process. A variety of new services will be developed to expand the on line capabilities in video, audio and data. To facilitate the integration, careful planning must be undertaken to ensure the transition is seamless to customers. Because this is a new technology within the cable environment, all aspects of the delivery system from the uplink facility to the in-home converter will be affected. By utilizing analog backward compatible converters, subscribers will easily transition to the digital technology.

The DigiCipher™ digital compession system enables a variety of headend configurations, from full pass through of the compressed signal to complete local control. It also allows for the addition of new data services to be integrated into the system at the headend, either from a local file server or from a nationally delivered data service. The end result of such capabilities will be a highly flexible environment in which both the operator and the ultimate customers, the subscribers, reap significant benefits.

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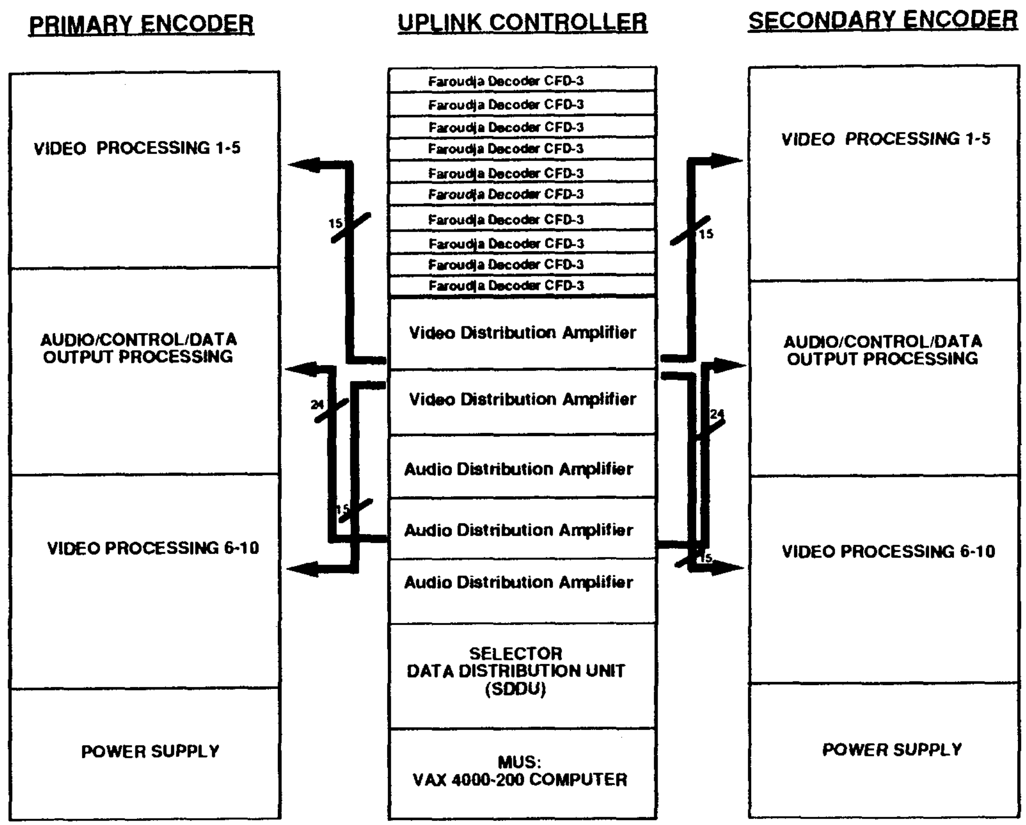

Figure 2: Satellite Uplink Encoder

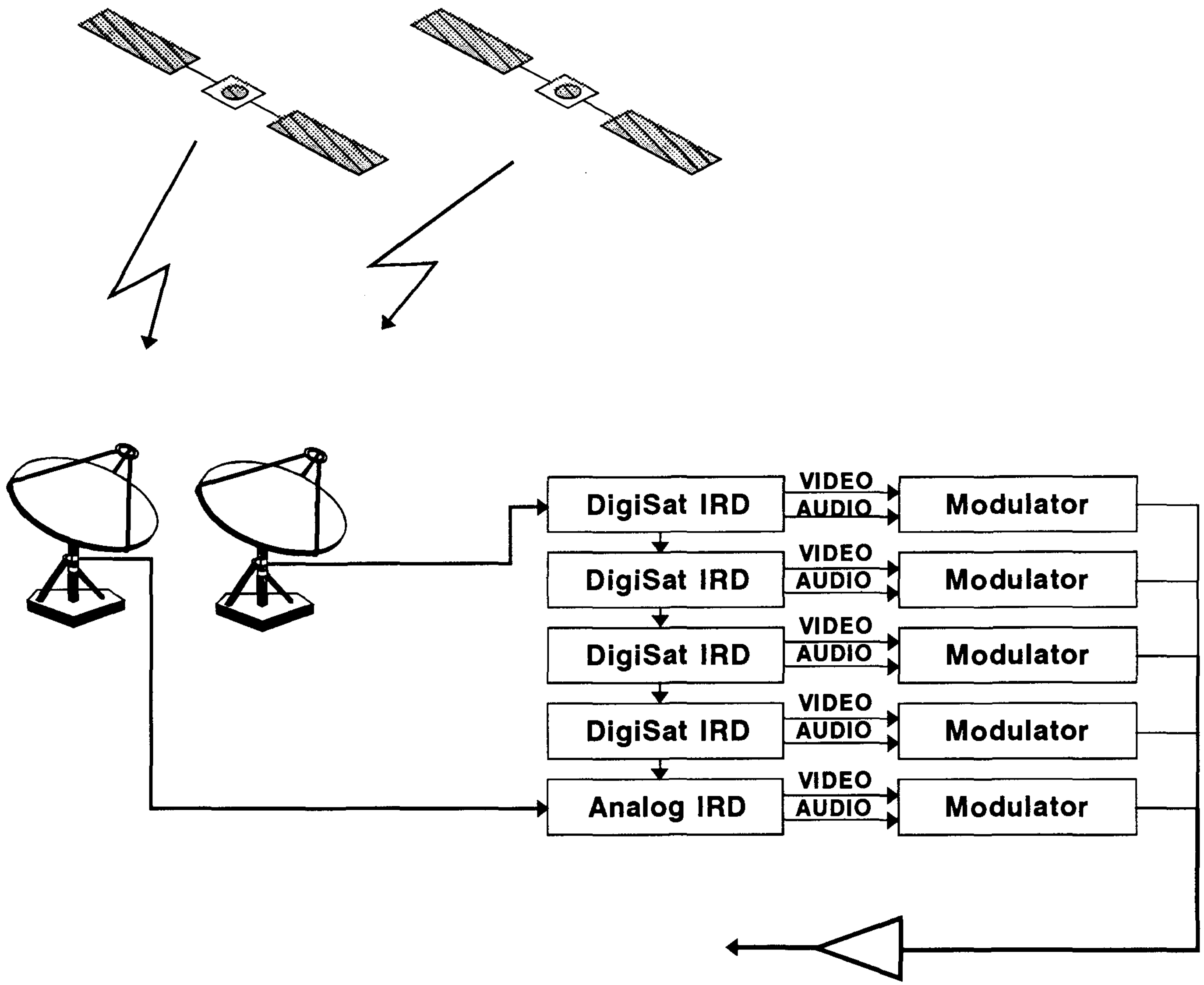

Figure 3: Digital/Analog Headend

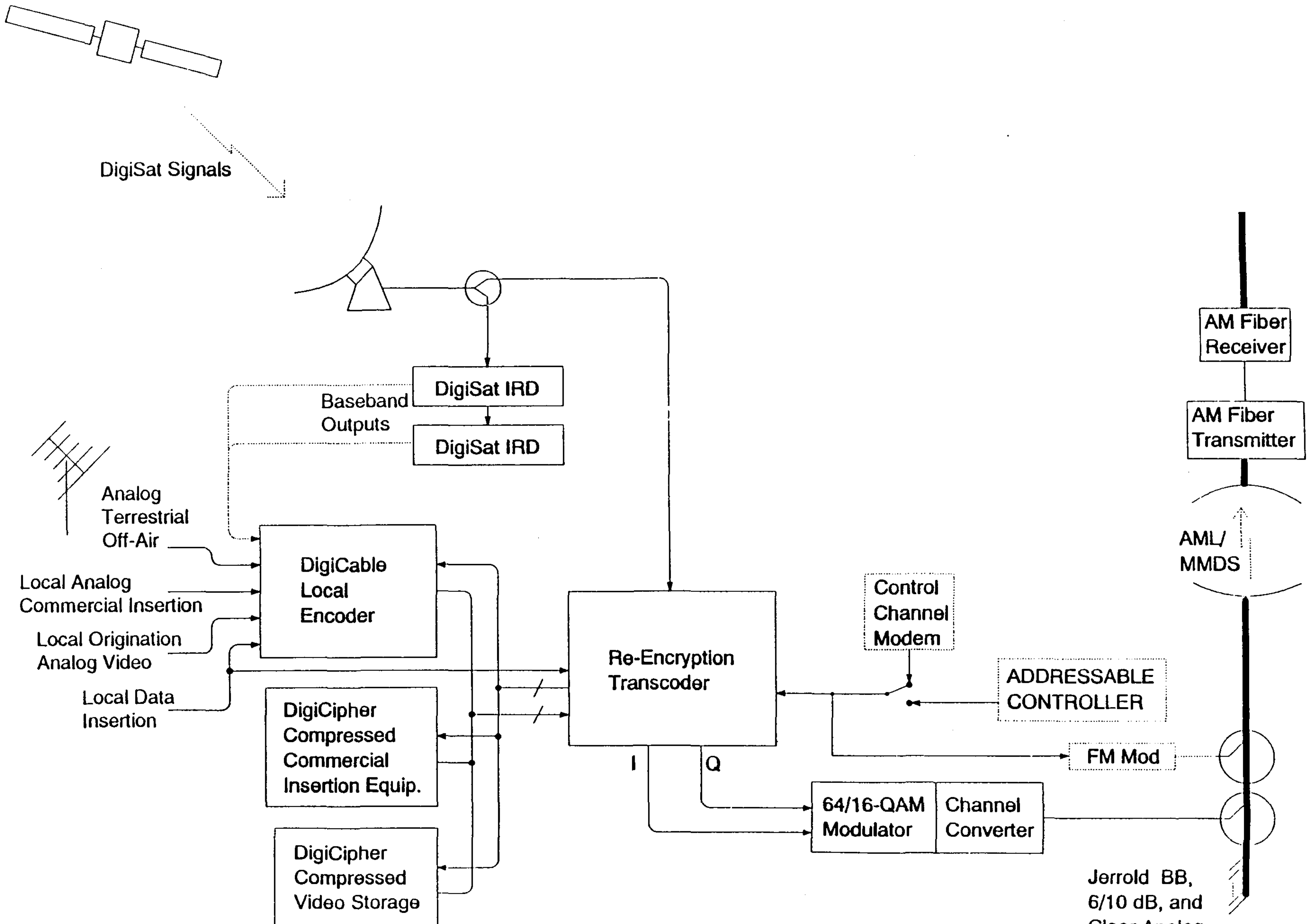

Figure 4: Digital Signal Processing