Chapter 3. Combined Source and Channel Coding for High-Definition Television

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3.1 Introduction

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The purpose of this project is to develop a high-definition television (HDTV) system for terrestrial broadcasting. In accordance with ground rules set up by the Federal Communications System, each TV licensee will be given a second channel within the current spectrum allocation. This new channel, to be awarded without competition, must be used for HDTV broadcasting. The existing channels will continue to be used for standard broadcasting. For much of the day, the same program must be sent on both channels, a procedure called simulcasting. In many cases, the new channels will be so-called *taboo* channels—those that cannot be used today for standard broadcasting because of interference. However, coverage on the new channels must be about the same as coverage on existing channels. Obviously, the HDTV format must have much better interference performance than the current format.

Two additional requirements for this new system are: (1) the picture must be the highest quality possible and (2) the system must operate satisfactorily in spite of noise, ghosts, interference, and frequency distortion. In addition, the system must have good interoperability with other media, and nondisruptive improvement over a period of time must be possible.

3.2 System Development

As discussed in *RLE Progress Reports Numbers 134 and 135*, in our initial plan we had intended to use a two-stage spread-spectrum (SS) system. In this scheme, the video bandwidth is divided into a large number of narrow-band signals. Then each signal is spread to full (6 MHz) channel bandwidth by a unique spreading sequence with all the spread signals added. However, we found that this method did not have adequate ghost (multipath) suppression. As discussed in last year's *Progress Report*, we combined the spread-spectrum method with the orthogonal frequency-division multiplex (OFDM) method to improve ghost performance.

In both the OFDM and the SS methods, the signal is divided into many channels so that the symbol length in each channel is substantially longer than the temporal spread of the multipath. A guard interval is added to each symbol in which a portion of the symbol is repeated. By integrating over exactly one symbol length at the receiver, multipath up to the length of the guard interval is entirely eliminated. This performance has been verified in the simulation exercise.

3.2.1 Current Status

The system shown in figure 1 is under simulation. As in our earlier system, this system uses hybrid analog/digital source coding and channel coding. This gives higher spectrum efficiency than all-digital channel coding while having just as good compression performance in the source coder.

The source coder generates both analog and digital data. The analog data consists of selected Fourier coefficients. The digital data comprises DC and very low-frequency data, audio, ancillary data, and adaptive selection information for identifying the selected coefficients. As in our earlier system, analog data is subjected to a spread-spectrum operation. After forward error correction (FEC) has been added to the digital data, the analog data is added to it.

This procedure produces hybrid analog/digital symbols that are fed to the OFDM modulator. (The combination of coding with OFDM is called coded
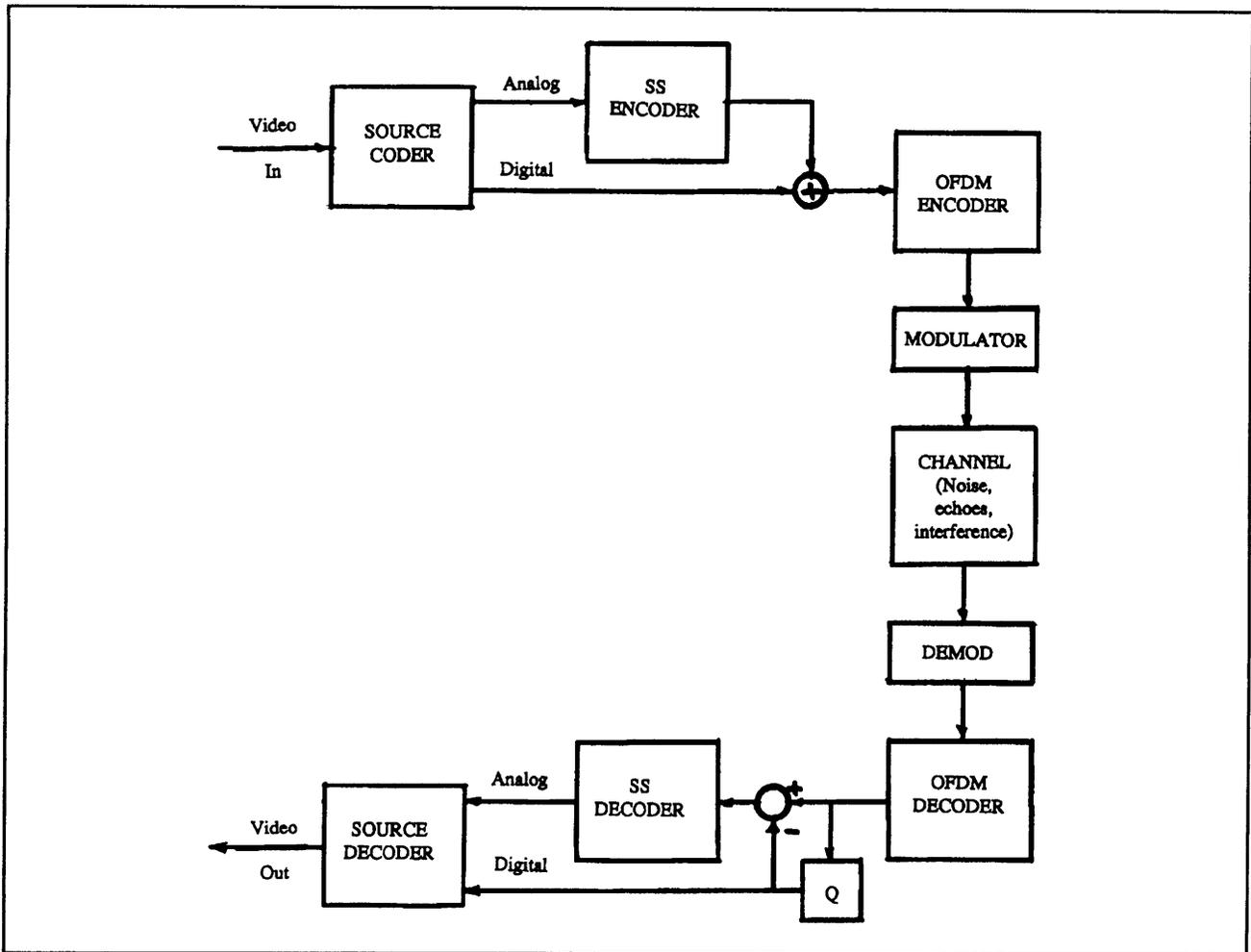
Figure 1.

OFDM or COFDM.) At the receiver, the signal is demodulated into hybrid symbols and decoded, producing error-corrected data. This data is recoded and subtracted from the hybrid symbols to produce analog data, which is then subjected to an inverse SS operation. The source decoder processes analog and digital data streams to produce an approximation to the original video.

3.3 Error Correction

The digital data must be received nearly error-free. We accomplish this by using a concatenated coder consisting of a Reed-Solomon coder (adding check bits to locate errors) and a convolutional coder, which increases the number of levels in the signal to regain channel capacity normally lost by quantization. This combination has proved extremely effective.

3.4 Channel Equalization

One benefit of OFDM is that, since the multipath spread is shorter than the symbol length, demodulation into the separate channels can be done before equalization, thus improving the SNR of the recovered signals. Multipath causes the gain to be nonuniform across the channel. At frequencies where the gain is low, noise is amplified. In this case, there are fewer problems if equalization is done after demodulation.

Since there are so many subcarriers, the channel gain can be described by a single gain and phase for each. These are easily measured by a training signal. Correction is easily implemented since the amplitudes of the various carriers are separated out by the demodulation process.

3.4.1 Current Status

We have fully simulated the channel coder and are now measuring its properties. We are designing the source coder which is a modification of the popular MPEG scheme but, in our scheme, the amplitude and identification of coefficients are transmitted independently. We are also developing a multiresolution version of the system. Pictures of different quality are recovered, depending on receiving conditions. Finally, we are investigating a transmission constellation that separates the digital and analog data streams so that each is recovered without interference from the other.