

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

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3.1 Project Description

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The purpose of this project is to develop a high-definition television (HDTV) system for terrestrial broadcasting. Under decisions previously made by the Federal Communications Commission, each current broadcaster will be given a second channel. This channel is to be used for HDTV, transmitting the same program as the standard NTSC channel in a procedure called simulcasting. Fifteen years after the commencement of high-definition broadcasting, NTSC is to go off the air, the original channels being returned to the FCC for reassignment. In many cases, the new assignments will be taboo channels not usable for NTSC because of interference. This obviously requires that the HDTV transmissions have excellent interference performance. Coverage must be comparable to what is now achieved with NTSC.

The system being developed in this project is intended to be more useful than the all-digital scheme that has evolved from the FCC process [the Grand Alliance (GA) system]. Its features have been chosen specifically to be acceptable to the various stakeholders including broadcasters, equipment manufacturers, program producers, regulatory authorities, and viewers. The most important performance factors are efficient use of spectrum, coverage versus quality, cost, and interoperability. In

addition, it must have a feasible transition scenario. We have concluded that all receivers need not have the same picture quality and that low-cost receivers must be available for less-critical applications. We have therefore designed a multiresolution (MR) system, in which a hierarchy of encoders of different price/performance can communicate with a hierarchy of decoders, also of varying cost and quality. As compared with the Grand Alliance system, the new scheme features:

1. Extended coverage, albeit at lower quality in the extra area,
2. Higher quality, albeit only in the central portion of the service area,
3. Comparable quality in a large portion of the service area,
4. Support for single-frequency networks (SFNs), which make the most efficient use of spectrum,¹
5. Support for less expensive receivers for less demanding applications, and
6. Automatic optimization of image quality as a function of signal quality and receiver complexity.

(The cost for features 1-3 is somewhat lower quality in a part of the service area.)

The multiresolution (MR) feature makes possible the design of cheaper receivers for small sizes and other noncritical applications. It also permits higher performance receivers to optimize their image

¹ SFNs make the signal level more uniform across the population of receivers by utilizing a cellular network of low-power transmitters, all operating in the same channel. The several signals sensed at each receiver appear to be ghosts, so very good ghost suppression is required.

quality as a function of received signal quality, thus improving spectrum utilization.

The MR feature is achieved using combined source and channel coding employing a pyramid technique. The coded video and audio data is divided into a number (typically 3 or 4) of data streams. The quality of the reconstructed video depends on the number of streams recovered and their signal-to-noise ratio. Thus the lowest stream provides a picture somewhat better than studio-quality NTSC to the least-expensive receivers and/or under poor reception conditions. The higher streams are used to enhance image quality. The streams are packaged by the channel coder so that the number recovered depends on the signal strength and receiver performance. The lowest quality level features standard MPEG-2 coding so that the cheapest receivers can use single-chip MPEG decoders.²

3.2 Technology

In the GA system, digital source coding is used to get very high compression, which is needed, in part, because all-digital channel coding does not make the best use of the analog channel capacity. Our system uses multiresolution hybrid analog/digital coding, which permits both high compression and efficient use of spectrum.

The source coder uses some MPEG features, but produces data in a form suitable for hybrid channel coding. This data is not all of one kind; some require essentially perfect transmission, and some can tolerate a certain amount of noise and distortion.

The channel coder uses spread spectrum and orthogonal frequency-division multiplex (OFDM),³ which, in combination, give good resistance to analog channel impairments and facilitate multiresolution operation. The coder transmits the more sensitive data digitally and the less sensitive data in analog form. The received signal "looks" simple to a low-performance receiver, while a high-performance receiver, with its more powerful decoder, "knows" where to look in the signal for the higher streams of data. These are recoverable at locations where the signal strength is higher and/or where the receiver is of better quality. Digital per-

formance is enhanced by extensive forward error correction. The simpler receivers are expected to be substantially cheaper than those used in the GA system, while the higher-performance receivers will be of comparable complexity and cost.

3.3 Current Status

By the end of 1995, the system simulation was nearly complete. Output sequences can be demonstrated after transmission through a simulated terrestrial channel showing the effect of noise and echoes on the digital and analog components of the signal. Three levels of resolution are attained at three different receiver CNRs. For details, see our chapter in *RLE Progress Report No. 137 (1994)*, including the first paper referenced at the end of the chapter. A small amount of work needs to be done on the source coder.

The channel coder work is complete and fulfills all our expectations for the system. One of the most important of these is the performance in the presence of echoes. Figure 1 shows the BER with several levels of echo as a function of CNR for a very simplified version of the channel coder. As can be seen, in distinction to the performance of conventional systems such as the Grand Alliance System, the performance of the new system actually *improves with large echoes*.

The echo performance of this system makes it suitable for use in SFNs without the use of directional antennas. In these systems, the conventional centralized transmitter is replaced by a cellular network of low-power transmitters, all emitting the same signal. Receivers, particularly with omnidirectional antennas, see a number of very strong "echoes." The channel coder that we have developed is the first, in my opinion, that is both practical in terms of computation and that performs well enough to be used in this way. SFNs permit much more efficient use of spectrum than conventional terrestrial broadcast systems because they effectively eliminate the effect of co-channel interference. The service area of each station is delimited by the location of the cellular transmitters, and it is only in a narrow region around the edge of the service area that two stations must compete for the same receivers.

² The Motion Picture Experts Group has promulgated an international all-digital standard for TV source coding, which has been adopted by many groups. Inexpensive coder and decoder chips are becoming available, which makes the use of MPEG coding very attractive.

³ OFDM was invented in the United States, but in recent years has been developed in Europe for digital audio broadcasting. It is also intended for use in digital TV terrestrial broadcasting in Europe. The coded form is referred to as COFDM.

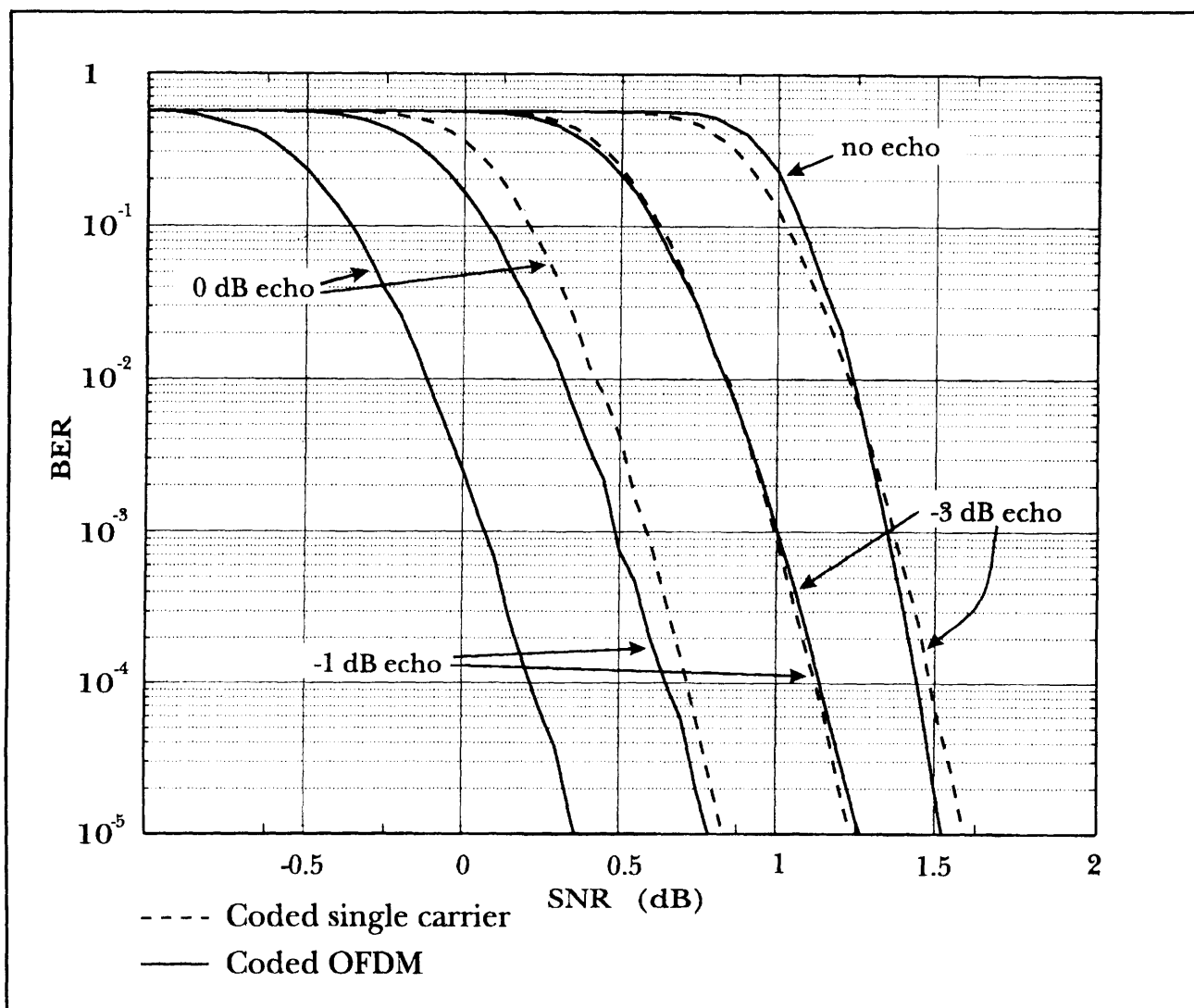


Figure 1. Comparison of single-carrier and OFDM concatenated coder performance for a single-echo channel as the echo power increases.

3.4 Publications

Polley, M.O., W.F. Schreiber, and S.J. Wee. "Comments on Transmission Techniques for Digital Terrestrial TV Broadcasting." *IEEE Commun. Mag.* 33(11): 22-25 (1995).

Schreiber, W.F. "A Unified Approach to Moving Image Coding for Most Media and Most Applications." *Sig. Proc.* 43: 305-321 (1995).

Schreiber, W.F. "Advanced Television Systems for Terrestrial Broadcasting: Some Problems and Some Proposed Solutions." *Proc. IEEE.* 83(6): 958-981 (1995).

Wee, S.J., M.O. Polley, and W.F. Schreiber. "A Scalable Source Coder for a Hybrid Transmission HDTV System." Paper published in the *Proceedings of the International Symposium on Multimedia Communications and Video Coding*, Brooklyn, New York, October 1995.

