

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

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## 3.1 Project Description

### Sponsor

Scitex America Corporation

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,<sup>1</sup>
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 price 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 quality as a function of received signal quality, thus improving spectrum utilization.

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<sup>1</sup> 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.

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.<sup>2</sup>

### 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 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),<sup>3</sup> 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 performance 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

All the novel elements of the system have been simulated and picture quality at the first three levels has been demonstrated. These have resolutions of 384 x 640 (better than NTSC), 576 x 960, and 768 x 1280, all 60 frames/sec progressively scanned compared to 720 x 1280 for the GA system. It is believed that further system optimization will permit substantially higher resolution for all levels above the first.

### 3.4 Future Plans

One small coding job remains, which is the coding of the coefficient identification data. Based on previous work, we expect no problem with this. We shall continue to improve the system. There is little doubt that the quality at the middle and highest levels will become better. (It is already very good.) These levels, at present, must cope with distortions introduced by MPEG at the lowest level. Although the MPEG pictures are good when displayed at 60 fps, there are significant frame-to-frame errors that place a burden on the motion compensation at levels two and three. This is so much the case that we can get nearly as good results using intraframe coding only at these levels.

If we retain motion compensation at levels two and three, we plan to go to a scheme in which the motion vectors will be calculated for all three levels from the original high-resolution sequence. This may well solve some of the problems we are now having at the lowest level, and it also will facilitate the coding of the vectors for levels two and three.

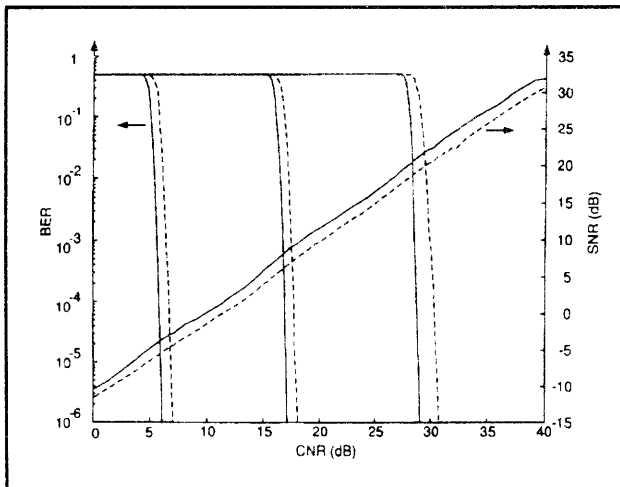
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<sup>2</sup> The Motion Picture Experts Group has promulgated an international all-digital standard for TV source coding, which has been adopted by many groups. Inexpensive coder and decoder chips are becoming available, which makes the use of MPEG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

<sup>3</sup> OFDM was invented in the US, 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.

**Table 1. Composition, Rates, and Thresholds of the MR Data Streams.** This table shows details of the three levels of performance. Note that it is possible to transmit only the lowest level, or only the lowest two levels, in which case the threshold is reduced and coverage increased.

Class	Composition		Incremental Rate	Total Rate	Threshold
low-res 384 x 640	MPEG stream audio ancillary data	digital	4 Mb/s	4 Mb/s	6 dB CNR
medium-res 576 x 960	enhanced motion vectors, selection infor- mation, additional audio	digital	4 Mb/s	8 Mb/s	17 dB CNR
	selected residual coeffs.	analog	2.5 Ms/s	2.5 Ms/s	
high-res 768 x 1280	enhanced motion vectors, selection infor- mation, additional audio	digital	4 Mb/s	12 Mb/s	29 dB CNR
	selected residual coeffs.	analog	2.5 Ms/s	5 Ms/s	



**Figure 1. Noise Performance With and Without Echoes.** This figure shows the performance of both the digital and the analog data streams as a function of the receiver CNR. (We use CNR to mean the signal/noise ratio of the radio-frequency carrier and SNR to apply to the recovered baseband signal representing the analog data.) The solid lines represent the no-echo situation, while the dotted lines represent the performance in the presence of five echoes ranging from -10 to -20 dB.

### 3.5 Publications

Polley, M.O., S.J. Wee, and W.F. Schreiber. "Hybrid Channel Coding for Multiresolution HDTV Terrestrial Broadcasting." *Proceedings of the IEEE International Conference on Image Processing*. November 1994.

Schreiber, W.F. "A Unified Approach to Moving Image Coding for Most Media and Most Applications." *Sig. Proc.* Forthcoming.

Schreiber, W.F. "Advanced Television Systems for Terrestrial Broadcasting: Some problems and some proposed solutions." *Proc. IEEE*. Forthcoming.

Wee, S.J., M.O. Polley, and W.F. Schreiber. "A Scalable Source Coder for a Hybrid Transmission HDTV System." *Proceedings of the IEEE International Conference on Image Processing*. November 1994.

