ADVANCED DIGITAL HDTV

SUMMARY OF PROTOTYPE HARDWARE IMPROVEMENTS

NOVEMBER 24, 1992

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1. CURRENT HARDWARE IMPROVEMENTS

1.1 RECEIVER CARRIER RECOVERY PULL-IN RANGE

During ATTC testing, we discovered that the frequency pull-in range of our prototype receiver did not meet the full range specified for UHF NTSC practice. The frequency tolerance that will actually be required for UHF HDTV may, of course, reflect modern technology and place considerably tighter tolerances on UHF frequencies. In the event that the current NTSC UHF practices might be maintained for HDTV, the AD-HDTV system was certified with a second-order carrier recovery circuit for its receiver, in order to provide a large frequency tuning pull-in range. Since our implementation of second-order carrier recovery was not complete in time for ATTC testing, the prototype hardware that was tested at ATTC used a first-order carrier recovery circuit. This simpler circuit had a smaller pull-in range that readily accommodated the frequency tolerances of our laboratory equipment, which were similar to VHF practice. This attribute of the prototype hardware was duely reported to PS-WP2, and a technical description of the differences between first and second-order carrier recovery was provided in our submission to PS-WP2[1].

Carrier recovery techniques are not a system attribute, but purely a matter of receiver design, and their effect is limited to the issue of pull-in range. AD-HDTV prototype hardware has been upgraded to second-order carrier recovery with an increased pull-in range.

1.2 QUALITY OF THE HIGH-PRIORITY SAFETY NET

The AD-HDTV system was certified with MPEG++ prioritization and two-tier packetization and transmission intended to provide a safety net that would take effect under severely impaired transmission conditions. Since MPEG++ prioritization is performed on an MPEG codeword stream after compression, changes in prioritization do not affect compression or overall picture quality in any way. Prioritization is simply a step that divides the compressed MPEG codewords into one subset that is packaged in High Priority cells and transmitted on the HP carrier, and the remaining portion of compressed codewords that are packaged in Standard Priority cells and

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1 letter to Mark Richer, July 24, 1992 (SSWP2-0978)

transmitted on the SP carrier. AD-HDTV's prioritization approach was designed to be flexible (varying by program material or scene type), and to evolve and improve over time[2].

The true performance and value of the High Priority safety net has been demonstrated during a series of demonstrations to the industry[3]. We do not believe that the ATTC and ATEL test results fully reflect the value of this transmission robustness safety net in AD-HDTV. We believe that this can be attributed to several factors, including the test procedures and material that were used, and some malfunctions in our compression hardware during testing.

Subjectively, the quality of the HP-only safety net can be highly dependent on program content. The picture quality of the safety net is significantly enhanced by the full quality program audio that is maintained under such conditions. In practice, the effectiveness of AD-HDTV's safety net is provided by the fact that an interested viewer can continue to see and hear a program during temporarily impaired transmission conditions that would otherwise result in a total loss of service. The test procedures were not designed to reflect these real-life subjective effects. The tests were conducted using test material rather than an actual program of interest to the viewer, and audio performance was not considered in the ATEL results.

Several improvements have been made to the prototype hardware to correct difficulties that were noticed during testing:

1) During ATTC testing, occasional difficulties were experienced with our motion compensation hardware, which did not perform with full accuracy in the left third of the picture[4]. The result of this was a slight inefficiency in compression coding that occurred during some tests, which produced slightly more spatially coded information than should have been required. While this had a negligible effect on the overall picture quality, it had a more detrimental effect on the prioritized High Priority subset of the MPEG data. The information that was unnecessarily spatially coded by our malfunctioning hardware occupied valuable High Priority data capacity that would otherwise have produced better picture quality in the High-Priority safety net regime of impaired transmission. The motion compensation hardware has been repaired.

2) During ATTC testing, the "squelching" circuit that manages the transition between full use of both High Priority and Standard Priority data and the use of only the High Priority data

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2 AD-HDTV System Description, Jan. 20, 1992 submission to SS-WP1, p.50

3 AD-HDTV demonstrations held at the Park Hyatt, Washington, D.C. from Sept 30 -- October 9, 1992

during severely impaired transmission conditions was not working optimally. This circuit has been modified to improve the picture quality that is obtained around the threshold of the Standard Priority carrier. Furthermore, the design and performance of this circuit is a receiver issue rather than a system attribute. Ongoing development and future receiver designs can be anticipated that will offer continuing improvement of performance in this impairment regime. Of course, such receiver improvements will require absolutely no change to the transmission standard.

3) While the implementation that was delivered for testing was in full compliance with our system certification, a relatively simple prioritization approach was used. The tested prototype hardware selected high spatial resolution (but low temporal resolution) codewords for transmission on the HP carrier. Improvements to the tested prioritization approach have already been developed.

These improvements will not affect overall picture quality or data rate in any way, since prioritization is simply a splitting of the data that is performed after compression. It is important to reiterate that the AD-HDTV system allows ongoing prioritization improvements to be made in encoders without requiring any changes to receivers or transmission standards.

1.3 Upper and Lower Adjacent Channel Rejection

While the ATTC test results of adjacent channel performance appear quite adequate to allow an AD-HDTV transmitter to be co-sited with transmitters for adjacent NTSC channels, the AD-HDTV prototype hardware did not attain our fully desired amount of upper adjacent channel immunity. Internal tuner adjustments have be made to our tested prototype hardware that improve the upper adjacent channel rejection by several dB. Lower adjacent channel performance is not affected by these changes.

1.4 Receiver Adaptive Equalizer Range

As explained in our certification documents, the prototype hardware delivered for testing at ATTC was limited to an equalization range of ±4 μsec[5]. The hardware tested at ATTC generally achieved excellent results over its intended range. Adaptive equalizer range is a receiver design consideration rather than a system attribute, and the ATRC has an ongoing effort to improve

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4 This also caused the visible Macroblock errors in the left third of the picture that were noticed on some tests.

5 AD-HDTV System Description, Jan. 20, 1992 submission to SS-WP1, p.35

receiver equalizer performance. A current improvement doubles the equalizer range to ±8 μsec. No other system performance attributes will be effected.

2. HARDWARE IMPROVEMENTS FOR FIELD TESTING

2.1 TRELLIS CODING

The AD-HDTV system was certified with a trellis code that had a 3 dB coding gain. (Coding gain is the improvement in carrier-to-noise ratio that results in a threshold bit error rate, compared to an uncoded QAM signal.) Since our full implementation of trellis coding hardware was not complete in time for ATTC testing, the prototype hardware that was tested at ATTC used a relatively simple member of the trellis coding family, called a set partition code. A description of the general family of trellis codes can be found in the technical literature[6]. The simpler code used during ATTC testing had a coding gain of about 1.5 dB, and this variance was duly reported to PS-WP2[7]. We are currently in the process of improving the prototype hardware to provide the full 3 dB of coding gain. All coding rates, data rates and signal format attributes of the improved hardware will remain identical to what was tested at ATTC. This will improve the random noise and ATV-ATV co-channel performance of the prototype hardware by 1.5 to 2 dB. Performance in the presence of other noise, interference and impairments will also improve.

2.2 UPPER AND LOWER ADJACENT CHANNEL REJECTION

Tuner adjacent channel performance is a receiver design issue rather than a system attribute. In addition to the current improvements that were previously described, a custom SAW filter is being designed that will result in additional improvements to both lower adjacent and upper adjacent channel rejection. This can be expected to improve adjacent channel rejection by at least 10 dB.

2.3 ADJUSTMENT OF HP/SP POWER RATIO

The High Priority (HP) carrier in AD-HDTV nominally has a 5 dB higher power spectral density than its Standard Priority (SP) carrier. This value was selected based on field strength statistics that show that a 5 dB difference in threshold increases the time availability at the

6 Trellis-Coded Modulation with Redundant Signal Sets, Part I: Introduction and Part II: State of the Art; G. Ungerboeck, IEEE Communications Magazine, Feb. 1987

7 letter to Mark Richer, July 28, 1992 (SSWP2-0960)

coverage contour by 7.5%. Thus, AD-HDTV was designed to provide a 97.5% time availability of the HP carrier at the fringe of the service contour, in order to provide a safety net for the 90% time availability of the SP carrier that is needed to achieve full quality HDTV pictures. Since AD-HDTV has two separate 32-QAM carriers, the amount of power in each can be easily varied.

AD-HDTV is the only system that has the capability to make such an adjustment. Performing this optimization is crucial, so that the power levels used in the final FCC standard reflect true field experience in addition to statistical data. AD-HDTV's flexibility even allows the HP/SP power ratio to be either increased or decreased at a given broadcast station, depending upon the precise terrain and the co-channel and interference environment that are involved. Realizing this capability simply requires the use of two separate automatic gain control (AGC) circuits in receivers, which are standard circuits that have been used for decades.

2.4 RECEIVER ADAPTIVE EQUALIZER RANGE

Adaptive equalizer range is a receiver design issue rather than a system attribute. In addition to the current increase in equalizer range (to ±8 μsec) that was previously described, a further increase to ±16 μsec range is underway, and is expected to be available for field tests.

2.5 QAM FOR CABLE

AD-HDTV was designed to provide both SS-QAM and QAM transmission options for the cable operator[8]. Which signal form is preferred for use on cable will likely depend upon the operator's method of acquiring the video signal. For broadcast-originated programming, the SS-QAM signal will be received through an antenna (or as a direct feed from the broadcast station) and directly transmitted over cable. This method of AD-HDTV cable operation was tested at the ATTC, since test procedures would only allow one signal form.

Since cable transmission does not have the co-channel requirements that are essential for terrestrial simulcast, AD-HDTV also provides for a conventional QAM transmission over cable. This is a sensible option in the case of satellite-based distribution of programming to cable headends, since the satellite QPSK signal can be simply remodulated as a QAM signal.

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8 AD-HDTV System Description, Jan. 20, 1992 submission to SS-WP1, p.18; p.120

[Note: conversion of QPSK satellite-distributed programming to SS-QAM for terrestrial broadcasting is also quite simple. It requires one small additional step to synchronize and demultiplex the HP and SP packets for transmission on the two carriers of SS-QAM. This topic is discussed in our recent submission to PS-WP4[9].]

AD-HDTV receivers can readily be designed to receive terrestrial SS-QAM signals, cable QAM signals and satellite QPSK signals. Closely related signal forms and data rates make such designs both feasible and economical. In order to demonstrate and test QAM cable transmission, the “cable remodulator” that will be supplied for field tests will receive an SS-QAM broadcast signal, and will perform demodulation and error correction, as requested by the Field Test Task Force. The cable remodulator will then remodulate the data in either SS-QAM or QAM form. The AD-HDTV receiver supplied for cable testing will be capable of receiving either signal form.

2.6 MULTI-CHANNEL AUDIO

As certified and tested, Advanced Digital HDTV’s unique packet format (Prioritized Data Transport) provides the means to implement the recommendations of ATSC T3/S3, which relate to flexible audio and ancillary data services. AD-HDTV generally supports all of the major principles embodied in the T3/S3 recommendations (T3/S3 document 186). The addition of multi-channel audio will allow AD-HDTV to fully comply with these recommendations. A description of AD-HDTV capabilities may be found in the system improvements description that was submitted to the Technical Sub-Group of the Special Panel[10] and the Scope of Services and Extensibilty chapters of our recent submission to PS-WP4[11].

AD-HDTV can easily support the data capacities required for multiple audio coding modes, including independent and composite coding. The MUSICAM audio tested at ATTC provided high quality stereo sound (2/0 mode) with a 256 kbps data stream. Full surround sound (3/2 mode) and/or three channel frontal sound (3/0) capabilities can be provided by an appropriate extension of the MUSICAM compression system. Since compatibility with MPEG Layer II audio is an extremely important interoperability and extensibility consideration, the ATRC plans to meet the T3/S3 recommendations by incorporating the MPEG five channel coding approach as part of AD-HDTV. The ISO-MPEG audio committee is currently in the process of defining a

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9 Interoperability, Scope of Services and Extensibility Features of AD-HDTV, Sept.18, 1992, pp.22-23

10 AD-HDTV Prototype Hardware Improvements and T3/S3 Recommendations, Nov. 2, 1992

five channel composite coding extension that is backward-compatible with Layer II two channel coding (i.e., the MUSICAM audio system used in AD-HDTV). This composite coding will require between 320 and 384 kbps to provide high quality five channel service.

In the event that the MUSICAM five channel hardware is not available at the time of field testing, AD-HDTV will incorporate an alternate multichannel audio system.

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[11] Interoperability, Scope of Services and Extensibility Features of AD-HDTV, Sept.18, 1992

3. HARDWARE IMPROVEMENTS AFTER FIELD TESTING

3.1 ENCODER MOTION SEARCH RANGE

The AD-HDTV system was certified and tested with MPEG compression. As explained in our certification documents, MPEG supports a [-1024,+1023] pixel motion compensation range[12]. The prototype hardware tested at ATTC fully implemented this compression syntax (it made room for the full range of motion vectors to be transmitted). However, due to the limited time available to construct and debug prototype hardware for ATTC testing, the prototype encoder hardware that was built had a relatively small [-32,+31] pixel motion search range. Even with this limited motion search range, the AD-HDTV prototype hardware produces outstanding picture quality.

The MPEG standard allows greater motion search range improvements to be made in encoders without any change to receivers or the transmission standard. Greater motion search range will improve overall picture quality on scenes containing fast motion, since the rapidly moving portions of such scenes are currently outside of the encoder's motion search range, and are thus encoded spatially. Thus, AD-HDTV provides for ongoing encoder improvements that do not require any changes to receivers or transmission standards.

3.2 QUALITY OF THE HIGH-PRIORITY SAFETY NET

The AD-HDTV system was certified and tested with MPEG++ prioritization and two-tier packetization and transmission intended to provide a safety net that would take effect under severely impaired transmission conditions. AD-HDTV's prioritization approach was designed to be flexible (varying by program material or scene type), and to evolve and improve over time. Ongoing improvements to encoder prioritization and to receiver error management will offer continuing improvement of picture quality under impaired transmission conditions. Of course, such improvements will require absolutely no change to the transmission standard.

Ongoing prioritization improvements can be made in encoders without any change to receivers or the transmission standard. The result of such encoder prioritization improvements will be better picture quality of the HP-only pictures that provide service robustness under severely impaired transmission conditions. Improved prioritization can adapt on a scene-by-

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[12] AD-HDTV System Description, Jan. 20, 1992 submission to SS-WP1, p.34

scene basis to favor sending either spatial or temporal resolution as high priority data. For slow-action scenes, spatial resolution should be favored, while for fast-action scenes, temporal resolution should be favored. These improvements will not affect overall picture quality or data rate in any way, since prioritization is simply a splitting of the data that is performed after compression. Improvements made to encoders will benefit all receivers.

Similarly, ongoing improvements to receiver error management can also be anticipated. Improved receiver error concealment approaches and "squelching" circuit operation will also improve picture quality under impaired transmission conditions. Such improvements will be a competitive factor for receiver manufacturers.

3.3 OTHER ONGOING IMPROVEMENTS

The AD-HDTV system has been designed to promote the implementation of many other ongoing encoder (e.g., better perceptual weighting and quantization) and receiver (e.g., optional upconversion to 72 fps progressive scan displays) improvements over the lifetime of the HDTV standard. Such improvements are anticipated without the need to alter the transmission standard in any way. In addition to many of the obvious improvements that are possible, the ATRC believes that in the future, the flexibility and extensibility attributes of AD-HDTV will also serve to facilitate the introduction of new services and receiver improvements that benefit from the transmission of additional information to receivers.