PREFACE

This document has been prepared in response to the Advisory Committee's request for information concerning: 1) improvements to Advanced Digital HDTV hardware and 2) meeting the recommendations of ATSC T3/S3. The ATRC strongly supports the Advisory Committee position that no system changes will be allowed after certification and testing. System changes effecting data compression, data format or signal format are so fundamental that allowing such changes would likely invalidate the entire testing process. Consequently, the ATRC does not contemplate any system changes to Advanced Digital HDTV.

Extensive effort was made in the development of Advanced Digital HDTV to design a system that powerfully exploits the full range of flexibilities offered by digital technology. By virtue of its design, AD-HDTV will compatibly accommodate a wide range of evolutionary improvements to both encoders and receivers, without requiring any changes to the transmission standard and without affecting older receivers. This approach will allow AD-HDTV to be an effective standard that will serve a wide variety of applications over many decades. Therefore, this submission discusses improvements that will be made to the prototype hardware, and describes how the recommendations of T3/S3 have already been addressed by AD-HDTV. All fundamental aspects of the system will remain as they were certified by SS-WP1 and tested at the ATTC.

PROTOTYPE HARDWARE IMPROVEMENTS

The AD-HDTV prototype hardware tested at the ATTC implemented all of the fundamental aspects of the AD-HDTV system. Unfortunately, the schedule did not allow the prototype hardware to demonstrate the full performance capabilities of the AD-HDTV system. Through straightforward engineering, the performance of the prototype hardware is currently being improved to meet the capabilities that were stated in the AD-HDTV System Description that was submitted to SS-WP1. These improvements include:

- Trellis Coding
- Receiver Carrier Recovery Pull-in Range
- Quality of the High-Priority Safety Net
- Adjustment of HP/SP Power Ratio
- Upper and Lower Adjacent Channel Rejection
- Receiver Adaptive Equalizer Range
- QAM for Cable
- Encoder Motion Search Range

Consistent with the published schedules of the Advisory Committee, many of these hardware performance improvements have been scheduled to be completed by the time of field testing.

T3/S3 RECOMMENDATIONS

As certified and tested, AD-HDTV readily accommodates the ATSC T3/S3 recommendations.

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1. AD-HDTV HARDWARE IMPROVEMENTS

1.1 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[1]. 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[2]. We are currently in the process of improving the prototype hardware to provide the full 3 dB of coding gain. 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.

All coding rates, data rates and signal format attributes of the improved hardware will remain identical to what was tested at ATTC. The trellis code improvement simply constitutes the use of a different technique to generate the 1 bit in every 10 that represents the trellis code redundancy (i.e., a 0.9 rate code) used in conjunction with a similarly improved decoder that takes greater advantage of the redundancy. Published ATTC test results show that the DigiCipher system's 0.8 rate trellis code achieved about a 3 dB coding gain in their prototype hardware. Therefore, ATRC is confident that we will successfully achieve full 3 dB trellis coding gain in our AD-HDTV prototype hardware by the time of field testing.

1.2 RECEIVER CARRIER RECOVERY PULL-IN RANGE

During ATTC testing, we discovered that the frequency pull-in range of our AD-HDTV prototype receiver did not meet the full range specified by the FCC for UHF transmission of NTSC. When established in the late 1950's, FCC specifications for UHF channels required receivers to have a significantly larger pull-in range than that used for VHF channels. This

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

[2] letter to Mark Richer, July 28, 1992 (SSWP2-0960)

requirement stemmed from the difficulty of making highly stable oscillators at UHF frequencies in transmitters several decades ago. Today, of course, due to the availability of highly accurate frequency synthesizers, UHF transmitters typically operate with much higher tolerance than required by the FCC. The frequency tolerance that will actually be established for UHF transmission of HDTV may, of course, reflect modern technology and place considerably tighter tolerances on UHF frequencies than are allowed for NTSC transmission.

In the event that the current NTSC UHF frequency tolerances might be maintained for HDTV transmission, 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[3].

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. Furthermore, we note that even if current UHF frequency tolerances are allowed for UHF HDTV transmission, AD-HDTV receivers may be designed to use more advanced approaches (e.g., first-order carrier recovery in conjunction with a microprocessor controlled tuning search algorithm) as an alternative to second-order carrier recovery. Nevertheless, second-order carrier recovery with an increased pull-in range will be completed by the time of field testing, and can be demonstrated by that time.

1.3 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

[3] 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[4].

We do not believe that the ATTC and ATEL test results will adequately verify the importance 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.

First, the quality of the HP-only safety net is 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. ATTC and ATEL 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.

Second, 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[5]. 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.

Third, 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 during severely impaired transmission conditions was not working optimally during ATTC testing. Improvements to this circuit will improve the picture quality that is obtained around the threshold of the Standard Priority carrier. These improvements will be implemented in the AD-HDTV prototype hardware prior to field testing. 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

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

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

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.

Fourth, 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. Improved prioritization approaches are currently under development. Since prioritization splits the compressed data into two streams that are put back together at the receiver, the AD-HDTV system definition allows prioritization improvements to be made in encoders without any change to receivers or the transmission standard. The result of 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-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.

The true performance and value of the High Priority safety net has been demonstrated during a series of demonstrations to the industry[6]. In order to officially incorporate this into the Advisory Committee process, we suggest that the System Specific testing Task Force (or another appropriate group) visit our laboratory and evaluate system performance with additional test material. Prior to field testing, some improved prioritization approaches will be implemented in our prototype hardware, while other more advanced approaches will be demonstrated through simulation. We intend to implement such advanced approaches in a second generation prototype hardware system. 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.

1.4 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 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

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

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. System specific tests of AD-HDTV were conducted at the ATTC to measure the effects of a slight increase in High Priority carrier power (to 7 dB).

The ATRC proposes to fine tune the precise adjustment of the HP/SP power ratio during field tests, when an opportunity exists to observe terrestrial transmissions for an extended period of time. 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. Since these transmission robustness adjustments are a unique capability of AD-HDTV, we believe that this is an important aspect of the system that should be explored during field tests. Hardware capable of testing different HP/SP power ratios was provided to ATTC, and will available again for field testing.

1.5 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.

It is important to understand that tuner adjacent channel performance is a receiver design issue rather than a system attribute. Therefore, ATRC will continue to make ongoing improvements to our tuner. For example, a custom SAW filter is currently being designed that will result in additional improvements to both lower adjacent and upper adjacent channel rejection. Thus, a tuner with significantly improved performance characteristics will be provided for field tests.

1.6 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[7]. The hardware tested at ATTC generally achieved excellent results over its intended range. It is important to note that adaptive equalizer range is a receiver design option rather than a system attribute. Since consumer receivers will have to deal with longer equalizer ranges, at least in some models, ATRC has an ongoing effort to improve receiver equalizer performance. A first improvement step will double the equalizer range to ±8 μsec, followed by a later improvement to ±16 μsec. An adaptive equalizer with at least a ±8 μsec range will be provided for field tests.

1.7 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.

[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

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

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

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.

1.8 ENCODER MOTION SEARCH RANGE

The AD-HDTV system was certified with MPEG compression. As explained in our certification documents, MPEG supports a [-1024,+1023] pixel motion compensation range[10]. 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. Spatially coded portions of a scene generally require more bits to encode with high fidelity, and if there are too many of them, compression artifacts may result. While the prototype hardware implementation was in full compliance with our system certification, improved motion compensation range is anticipated in our system design and description.

We anticipate that market needs will result in the development of encoders for different applications that have various amounts of motion search range. For example, encoders for sporting events will require a large motion search range. Less expensive encoders with a smaller motion search range will likely be developed for newsroom and drama programming, and for industrial and educational use. Thus, AD-HDTV has tremendous potential for cost-effectively accommodating a wide variety of applications, as well as providing for evolutionary encoder improvements that do not require any changes to receivers or transmission standards.

Prior to field testing, ATRC will submit computer simulations that demonstrate the picture quality improvements (on scenes containing fast motion) that result from increased motion search range. We also intend to implement these advanced approaches in a second generation prototype hardware system.

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

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

2. T3/S3 RECOMMENDATIONS

2.1 INTRODUCTION

Advanced Digital HDTV's unique packet format (Prioritized Data Transport) provides the means to implement the recommendations of ATSC T3/S3. A brief overview will be followed by a discussion of the various T3/S3 recommendations. A more complete description of these capabilities may be found in the Scope of Services and Extensibilty chapters of our recent submission to PS-WP4[11].

2.2 PRIORITIZED DATA TRANSPORT OVERVIEW

AD-HDTV's Prioritized Data Transport format is specifically designed to carry, synchronize and protect MPEG++ high-priority and standard-priority data through AD-HDTV's two-tier (prioritized) transmission system that has two separate data channels. AD-HDTV's Prioritized Data Transport format separately packages MPEG++ high-priority and standard-priority data streams into separate (but related) sequences of fixed-size cells. Each cell is a self-contained data unit of 148 bytes. The transport cell provides several layers of "safety nets" in the form of error correction, error detection, and error recovery capabilities that allow AD-HDTV receivers to continue decoding useful video data even under very high bit error rate conditions.

Prioritized Data Transport forms the basis for AD-HDTV's service flexibility. Although digital systems are generally described as flexible, many of them use a fixed format that carries different types of data (e.g., video, audio and auxiliary data) with a pre-determined capacity. AD-HDTV offers complete flexibility to allocate its capacity among video, audio and auxiliary data services, which is accomplished entirely within the scope of its system definition. AD-HDTV's Prioritized Data Transport format includes a special *service type* header/descriptor. This service type indicates whether the cell's data are high priority video, standard priority video, audio program 1, audio program 2, auxiliary data, or other service types. Thus, an AD-HDTV data stream simply consists of a sequence of cells, as shown in Figure 2.1, and it allows many different types of data to be delivered asynchronously.

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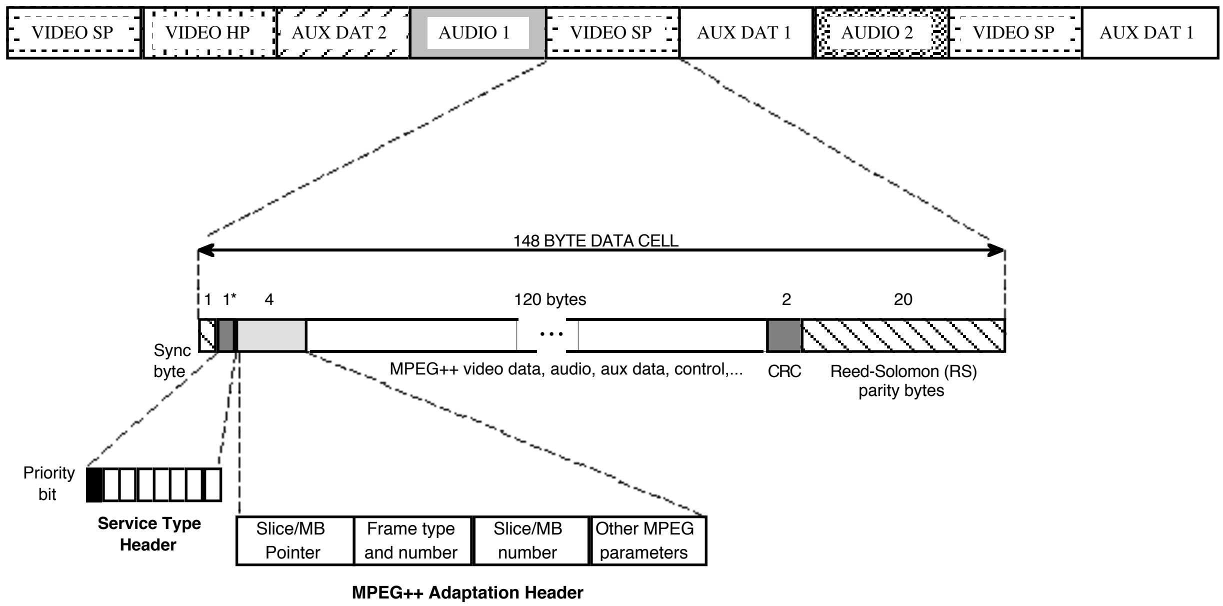
11 Interoperability, Scope of Services and Extensibility Features of AD-HDTV, Sept.18, 1992



An AD-HDTV data stream consists of a flow of cells, each containing a single type of data. The order and type of cells is arbitrary, allowing complete flexibility in the mix of services that can be provided.

Figure 2.1 - An AD-HDTV cell stream.

The use of a service type header in the cell header means that the mix of video, audio and auxiliary data is completely flexible and need not be specified in advance. AD-HDTV enables broadcasters to alter their mix of video, audio and data services to address special market needs or to innovate new service opportunities. An important capability that both meets established needs and creates opportunities for innovative new video production in the future is that AD-HDTV allows its mix of data types to be altered *dynamically*.

AD-HDTV provides open-ended extensibility, since an AD-HDTV receiver will disregard any cell with a service type that it does not recognize or cannot process. This means that new service types can be easily introduced without having to overcome the constraints of maintaining “backward-compatibility” with the installed base of receivers. Although the new services will not be delivered to older AD-HDTV receivers, the freedom from restrictive backward-compatibility constraints ensures that innovative new services can be frequently introduced.

2.3 MAJOR PRINCIPLES OF T3/S3

AD-HDTV generally supports all of the major principles embodied in the T3/S3 recommendations (T3/S3 document 186). Minor improvements will allow AD-HDTV to fully comply with these recommendations.

2.3.1 Flexible Allocation

In its nominal configuration, AD-HDTV provides for HDTV video (17.7 Mbps), two channels of audio (512 kbps) and auxiliary data (256 kbps), which are delivered by a total application capacity of 18.5 Mbps. Beyond this baseline capability, AD-HDTV offers broadcasters and other service providers total flexibility in the mix of video, audio and data services that they provide to appropriately-featured receivers. The key to this capability is AD-HDTV's Prioritized Data Transport format, that includes Service Type header/descriptors at the beginning of every cell. The mix of services may be altered completely at the service provider's discretion, and can be used to meet special market needs or to provide new service opportunities. AD-HDTV can provide either additional channels of video or audio, or increased auxiliary data capacity at the expense of a modest reduction in picture quality.

An important feature of AD-HDTV is that its mix of services is *dynamically* allocatable. The allocation of capacity to each service type may vary from one programmer to another (e.g., allowing certain programmers to broadcast in many languages). An individual programmer may choose to vary the allocation of capacity to each service type on a program-by-program basis (e.g., allowing certain programs to have increased closed-captioning capacity). A particular program may also vary the allocation of capacity to each service type on a second-by-second basis (e.g., to allow high data rate burst-mode delivery of software or other auxiliary data).

The flexible allocation of AD-HDTV is a fundamental attribute of the system, and it can be readily demonstrated in our prototype hardware. Audio and auxiliary data are packetized and inserted in the video packet stream. Removing these sources results in more available bandwidth for video, while loading them heavily reduces the amount of capacity available to video. In fact, during ATTC testing, we were required to load the auxiliary data channel in order to ensure that nominal data allotments were met.

2.3.2 Extensibility

The header/descriptor approach used by AD-HDTV to specify the service type of each transmission cell.also provides extensibility. When introduced, future enhancements and new services will be assigned new service types. This approach eliminates the burden of backward compatibility from future enhancements and new services, since cells with unrecognized services types will simply be discarded by older AD-HDTV receivers that do not recognize or cannot handle the new service type. AD-HDTV's extensibility will foster future growth and new opportunities. AD-HDTV provides for future growth in new receiver features and functions while assuring compatibility with the installed base of AD-HDTV receivers.

2.3.3 Service Identification Data

Service Identification Data is provided directly by AD-HDTV's Prioritized Data Transport format, that includes Service Type header/descriptors at the beginning of every cell.

2.3.4 Multi-Channel Audio

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 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. Decoders will be able to provide either five channel or two channel service, as either delivered by the programmer or determined by the capabilities of the receiver. Prototype hardware construction, testing and demonstration will occur as soon as possible.

(Of course, AD-HDTV can deliver the data for any audio encoding system. For instance, the Dolby audio coding system requires 320 kbps for full 3/2 surround sound, and it is designed to work with 3/0 and 2/0 transmission modes and receivers. AD-HDTV may be demonstrated with other audio encoding approaches by the time of field testing.)

2.3.5 Multiple Languages

In its nominal configuration tested at the ATTC, AD-HDTV provides two stereo pairs of high quality MUSICAM compressed sound (each at 256 kbps). Like all data in AD-HDTV, each audio stream is separately identified as a unique service type and packetized as its own series of cells. This approach allows many additional audio streams for additional languages to be added by the programmer, with a commensurate reduction in picture quality.

2.3.6 Audio Services to the Visually and Hearing Impaired

AD-HDTV can accommodate narrative audio as a service to the visually impaired and dialog audio as a service to the hearing impaired. In each case, the additional audio data is handled as a separate service type that can be decoded by appropriately equipped receivers. (AD-HDTV also supports captioning text streams by transporting them as a unique service type. Captioning is envisioned as a 9.6 kpbs data rate requirement by the National Captioning Institute. AD-HDTV can provide multiple captioning data streams that can accommodate multiple languages that are viewer-selectable at the receiver.)

2.3.7 Uniform Loudness

While the tested prototype hardware does not implement this feature, the MUSICAM system can be adapted at the receiver to provide uniform loudness.

2.3.8 Dynamic Range Control

While the tested prototype hardware does not implement this feature, the MUSICAM system can be adapted at the receiver to provide dynamic range control.

2.3.9 Ancillary Data Services

In its nominal configuration, AD-HDTV assumes an aggregate data rate of 256 kbps for ancillary data services. The only initial use that is currently planned for the nominal 256 kbps ancillary data capacity is closed captioning service at 9.6 kbps. The 256 kbps capacity was picked because we believe that it is sufficient for most traditionally-anticipated uses for ancillary data. More or less ancillary data is automatically accommodated by AD-HDTV. Text and program guide data can easily be delivered to receivers by AD-HDTV. This is accomplished by designating a service type for the delivery of such services. The data is then packaged in its own series of cells which are asynchronously multiplexed into the overall AD-HDTV data stream.

2.3.10 Programmer Control of Audio and Ancillary Data Services

AD-HDTV's approach of separately packetizing each service into its own sequence of cells facilitates programmer control of audio and ancillary data services. Undesired services that are distributed to the programmer may be easily deleted by replacing the cells of that service type with cells having a "null" service type. Alternatively, other services (e.g., locally originated) may be substituted in the vacated portion of the data capacity. Likewise, space for local insertion of data can be reserved by distributing a data stream with a portion of "null" cells that can be replaced by the programmer. The AD-HDTV prototype hardware tested at ATTC actually made use of null cells to fill the channel during buffer underflow conditions.

2.3.11 Error Correction and Concealment for Audio Services

AD-HDTV's approach of separately packetizing each service into its own sequence of cells facilitates error correction and concealment for audio services. Each cell contains 20 bytes of Reed-Solomon error correction code and 2 bytes of CRC error detection code. Uncorrectable errors are identified by the CRC code. The AD-HDTV prototype hardware tested at ATTC performs audio muting when subjected to uncorrectable audio bit errors. In AD-HDTV, programmers also can select which audio services to send as High Priority data, providing these services with an extra 5 dB of transmission robustness.

2.3.12 Monitor Electro-Acoustic Frequency Response

(This is an audio production issue.)

2.3 CONCLUSIONS

The ATRC would like to thank the Advanced Television Systems Committee and its T3/S3 group for their excellent work in producing the T3/S3 recommendations. AD-HDTV was designed to provide flexible capabilities that are now being recognized as practical requirements in an HDTV system. We strongly support the T3/S3 recommendations, and look forward to working with ATSC to implement their recommendations as part of Advanced Digital HDTV.