SYSTEM OVERVIEW AND TECHNICAL DATA RESULTS AND ANALYSIS FROM HBO'S FIELD TEST OF DVB-S2 AND MPEG-4 HD DEPLOYMENT

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Abstract

On June 12, 2007, Home Box Office announced it would make all 26 HBO and Cinemax channels available to HBO distributors in high definition using MPEG-4 compression technology by the end of the second quarter of 2008. The HBO engineering team was tasked with finding a system that would meet HBO's aggressive time frame for deployment. The system would have to be capable of high quality encoding, and robust enough to be able to meet all of HBO's technical requirements. Taking advantage of the newest MPEG-4 (AVC) compression and DVB-S2 satellite modulation, HBO felt it would be able to deploy an efficient and cost effective way to make the 26 HD feeds available.

This paper will describe the technical architecture of the MPEG-4 compression system that HBO has chosen to implement. It will also outline the field test plan that HBO developed for the system, as well as the results of that field testing. The field test results and observations will show that this system is a viable alternative to traditional MPEG-2 compression with QPSK modulation.

INTRODUCTION

In order to meet the aggressive time line for deployment, HBO needed to move rapidly in its selection of a new system. HBO solicited equipment from several vendors for testing at the HBO satellite uplink facility. Once the equipment selection was made, an engineering field test plan was written and implemented so "real world" scenarios could be simulated and observed. The engineering field test provided valuable information and validated the performance of the new system.

SYSTEM SUMMARY

HBO will have three C-band, 36 MHz transponders carrying the 26 HD MPEG-4 channels.

HBO selected Motorola as its MPEG-4 encoding, multiplexer, encryption and satellite modulation vendor. HBO tested several AVC encoders from several vendors, most of which produced good results, but ultimately Motorola was chosen for its ability to provide a complete system including MPEG-4 satellite receivers that would be available for HBO affiliates in early 2008. HBO has a successful history with Motorola as its provider of analog encryption (VideoCipher) and MPEG-2 compression and encryption (DigiCipher II) equipment.

HBO will employ Motorola branded Modulus encoders to perform the MPEG-4 compression.

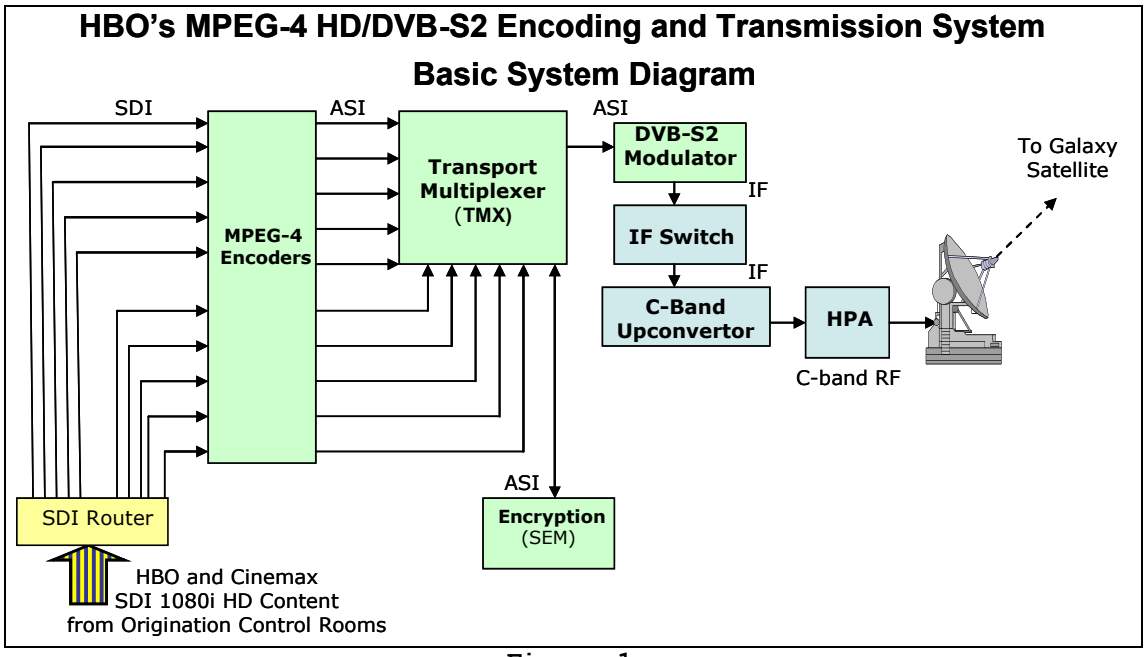

Figure 1

SYSTEM ARCHITECTURE

The MPEG-4 encoding system comprises one rack-unit encoders for each channel of video. The system is very scalable and space efficient. The single channel encoders are easily cascaded and muxed. An identical redundant (back-up) system is configured for each transponder multiplex. HBO has decided to encode the MPEG-4 channels initially at 8 Mbps and determined that this encode rate was the "sweet spot" since quality is very important in addition to optimizing transponder bandwidth as much as possible. It should be noted that 8 Mbps is about half the bit rate of typical broadcast and cable MPEG-2 HD program feeds. With future encoder improvements and MPEG-4 tool enhancements, it may be possible to encode HD lower with no loss in quality. All the MPEG-4 HD services have a single AC-3 English audio program encoded with the video. The audio is 2.0 stereo or 5.1 surround depending on the original source material.

HBO's originated HD programming will feed the MPEG-4 encoders (via SDI) which outputs an ASI stream to feed a Transport Multiplexer (TMX). The TMX muxes the individual ASI streams together, and outputs a single MPEG-4 ASI steam which feeds a SmartStream Encryptor Modulator (SEM). The SEM will encrypt the ASI stream and the TMX will feed ASI to a Newtec DVB-S2 satellite modulator. The last link in the MPEG-4 compression chain is the modulator output to an IF switcher. The IF switcher provides a 70 MHz output which feeds HBO's C-band satellite upconvertors and transmitters. The switcher also provides IF monitoring points prior to satellite uplink.

HBO has chosen to use DVB-S2 satellite modulation. DVB-S2 modulators increase spectral efficiency by using new and advanced high-level coding techniques.

As defined by the DVB organization's DVB-S2 fact sheet, DVB-S2 makes use of the most current modulation and coding techniques to deliver performance that comes close to the Shannon limit, the theoretical maximum

information transfer rate in a channel for a given noise level. DVB-S2 uses a very powerful FEC scheme which is a key factor in allowing the achievement of excellent performance in the presence of high levels of noise and interference. The FEC system is based on the concatenation of BCH (Bose-Chaudhuri-Hocquengham) with LDPC (Low Density Parity Check) inner coding. [1]

The DVB-S2 modulation scheme is not yet widely used in the U.S for satellite distribution feeds. It is, however, quite popular in Europe and Asia and has been proven to be successful domestically with contribution feed users. Extensive testing performed by HBO and Motorola with different FEC (forward error correction) rates led to very positive results. Using a FEC rate of 5/6 yields an available transponder payload of 72 Mbps. Using more aggressive FEC rates vs. required power, the modulation could be traded off to yield more throughput, but 72 Mbps met HBO's payload requirements. 72 Mbps is almost double the transponder payload that most providers currently have with MPEG-2 compression and common QPSK modulation.

HBO utilizes Motorola's Broadcast Network Controller (BNC) software as the interface to control and monitor the modular system, including the TMX and SEM units. The BNC software communicates with HBO's current in-house custom authorization
system, so that no major changes or additional software applications are needed to authorize the new MPEG-4 services. Because no major modifications will be necessary, the HBO authorization hotline will be able to easily authorize services and input pertinent affiliate data just as they currently do for HBO's MPEG-2 linear and HBO On Demand/Cinemax On Demand customers.

One of the most important of HBO's requirements was to have high quality satellite receivers available by early 2008 so that all of HBO's distributors could downlink and process the new HD feeds without having to integrate additional and/or complex gear to their existing headend infrastructure. Working closely with HBO's engineers, Motorola was able to develop two receiver solutions to complete their AVC system.

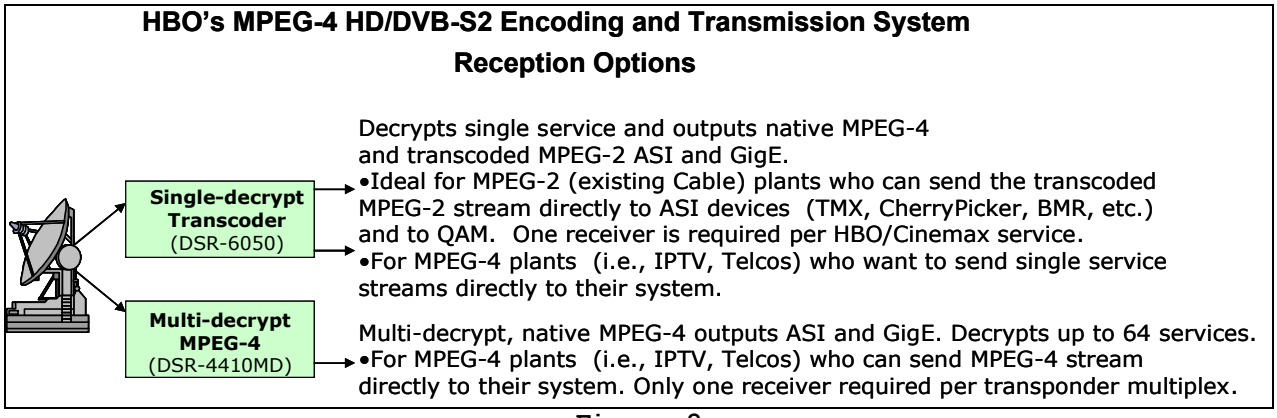

Figure 2

The first is a native MPEG-4 multi-decrypt receiver, the DSR-4410MD. This unit is capable of decrypting up to 64 services using a single one rack-unit box.

The receiver will decrypt all streams on one of HBO's MPEG-4 transponders and output MPEG-4 via ASI and/or Gigabit Ethernet. This will be beneficial to newer MPEG-4 plants who

will be able to send the native MPEG-4 channels through their system without the need for conversions or additional processing equipment. HBO has conducted extensive field testing of this receiver and DVB-S2 modulation with several MSO headends and affiliate labs. The results have been excellent in all parameters, including successful reception links with low power levels in a wide variety of geographical areas and varying weather conditions.

Motorola will also make available an MPEG-4 – to – MPEG-2 single channel transcoding IRD, the DSR-6050, which will output MPEG-4 and/or MPEG-2 via ASI and/or Gigabit Ethernet. This unit will be ideal for conventional cable distributors who have extensive MPEG-2 plants and have numerous field deployed MPEG-2 set tops. This will allow existing HBO/Cinemax affiliates to be able to immediately take advantage of the new HD MPEG-4 channels.

The IRD will decode the HBO MPEG-4 stream, and re-encode it to MPEG-2 all within a single rack-unit device. HBO will set the transcoded MPEG-2 output bit rate to ensure appropriate quality.

MPEG-4 FIELD TEST PLAN

HBO developed a four-phase test plan that encompassed approximately eight weeks. MPEG-4 receivers were sent to 18 test locations consisting of various cable and telco operators and vendor labs. The test locations were chosen based on their ability to process and report on the MPEG-4 signals. It was important to HBO to select a diverse group of test sites (both in location and technical infrastructure), as this would represent several "real world" scenarios which would simulate conditions at HBO's various distributors. HBO specified test site technical requirements that included the following:

1) 3.5m diameter or larger antenna (or equivalent gain and noise temp)
2) C-Band Digital PLL LNB,
Recommended Specifications:
a) Noise Temp 20°K or better
b) Avg gain 60dB
c) LO Stability ±12 kHz or better
d) Extremely low phase noise

HBO provided a testing matrix spreadsheet to all test sites. This matrix document allowed the test sites to record their findings/measurements during the various test phases. Weekly conference calls were held with the test sites, and e-mail alerts were generated to brief test sites on any new developments and/or procedures.

Phase I "Out of Box" Experience and Baseline Measurements. (two week duration)

The first phase of the field test consisted of install, set-up and reporting on the "out of the box" experience. Test sites were instructed to configure the receivers as per the Motorola Operator Guide using satellite transmission and service parameters that were provided in HBO's test schedule. Test sites were instructed to call HBO's authorization hotline (just as they would in a real world scenario) once the receiver was set up and had signal lock on the test satellite coordinates. Test sites were asked to provide anecdotal feedback to HBO in regard to ease of installation and configuration. Once confirmed authorized for service, the test sites were asked to record the following initial baseline measurements:

1) Satellite C+N/No at L-Band (if available)
2) L-Band input signal level at IDR/MRD RF Port
3) Front Panel IRD LED indicators, any alarms present
4) Status Menu/OSD Diagnostics
   a) Signal Strength
   b) "Signal Quality"

c) Eb/No (Energy per bit to noise power spectral density ratio)
d) VCT (Virtual Channel Table number)
e) VCN (Virtual Channel Number)
f) Authorization Status
g) BER (Bit Error Rate)

5) Initial ASI or GbE stream analysis (high level)

Phase II Transmission Performance (one week duration)

The second phase of the field test allowed HBO to vary uplink parameters while the test sites recorded changes to signal lock and Eb/No levels on their receivers. This testing helped HBO to determine the optimal transmission parameters for best real-world link performance with minimal sacrifice of data throughput, while maintaining appropriate downlink margins. HBO used an FEC modulation rate of 5/6.

Specifically, HBO attenuated the uplink transmitter power by -1dB increments every 10 minutes until -6dB was reached. At that point the power was brought back up in -1dB increments every 10 minutes until full power was restored. The total test duration was 80 minutes. The field test sites were asked to record the receiver's Eb/No level at the 10 minute intervals, and also note if the receiver lost signal lock at any time. The identical test was repeated at the same time the next day to ensure all test sites were able to observe the receivers.

Eb/No (or E_b/N_o) is defined as Energy per bit to noise power spectral density ratio, and is considered the measure of signal to noise for a digital satellite/communication or data system. It is normally measured at the input to the satellite receiver and is used as the basic measure of how strong the signal is. It is a normalized signal to noise ration (SNR) measure, also known as the "SNR per bit". It is especially useful when comparing the bit error rate (BER) performance of different digital modulation without taking bandwidth into account. [2]

Phase III Decoder Output Interfaces (one week duration)

In this phase of the testing, field sites were asked to measure, observe and document the various outputs of the decoders in the HBO test schedule. This included taking empirical measurements and recording the responses of terminal equipment (subject to test site capability) including adherence to the following standards as applicable:

- DVB ETSI TR 101-290
- ETSI TR 102-034
- IEEE 488.1-1987
- ITU-T H.264
- ATIS
- SMPTE-292M (HD-SDI Output via external decoder)
- SCTE 40, SCTE 20 and other applicable standards

Phase IV Long Term Stability (four week duration)

HBO transmitted continuous program services to the field test equipment at the test sites during this phase of testing. Test sites were asked to perform qualitative observations of the decoded services at the video and audio outputs of a set top box or other decoding devices (e.g., Sencore/Motorola MRD-3187). Test sites were asked to observe and record (at regular intervals) the picture and aural quality of the signals. Test sites were requested to maintain reception of "existing" MPEG-2 feeds from HBO and compare the feeds "under test" to the existing feeds. No visual differences should be observed in either the decoded MPEG-4 or the transcoded MPEG-2 output. The following items would be monitored:

- Eb/No levels should be steady/consistent. Any variations should be documented.
- Receiver signal status should be "locked." Any variations should be documented.
- Integrity and any irregularities of ASI output stream
- Decoded Picture quality (color, motion, detail, artifacts, disturbances, etc.)
- Decoded Aural quality (levels, dynamics, response, distortion, separation)
- Lip Sync within one frame (30-mSec)
- Closed Captioning (CEA-608 and CEA-708)

Test Completion

At the end of Phase IV, HBO collected and compiled all spreadsheet data as well as all of the field sites' subjective comments and opinions. After several weeks of test data analysis and interpretation, HBO's engineering team made their recommendations to Motorola as to the success of the field-deployed receivers performance.

MPEG-4 FIELD TEST RESULTS

Phase I "Out of Box" Experience and Baseline Measurements

Out of the 18 MPEG-4 (DSR-4410MD) receivers delivered to the test sites, one receiver was DOA (would not power up) and had to be replaced.

Phase I revealed to HBO that there were some "growing pains" to be expected with this new technology. Several sites were not familiar with the MPEG-4 receivers and how to set them up and obtain transponder signal lock. HBO's engineering team and Motorola's IRD product team addressed these issues directly with the test sites. One example of this was whether to set the multi-decrypt MPEG-4 receivers to manual or automatic mode. The difference being, the ACP (Access Control Processor) addresses would be manually assigned by the end user or automatically populated when the anchor (or "in care of") unit address number was authorized. HBO found that it's easier to have the end user set the receiver to automatic mode. This works especially well when the end user is receiving all the channels on the same transponder multiplex.

Another issue (affecting the MPEG-4 receivers) discovered during Phase I testing was a setup step not clearly explained in the operator guide. It seems that after selecting an ACP number, the menu curser must be moved to the corresponding program number and entered by using the up/down arrows for each ACP number that is used. If the program number is not entered, the receiver will not authorize that ACP.

Despite these minor issues, it seemed to be fairly easy for the test sites to set up and have their receivers authorized for the MPEG-4 signals. The following chart includes the receiver's measured signal quality and Eb/No for the 11 field test sites that submitted Phase I data.

DSR-4410 Phase I Results Summary Data

Test Site	Antenna Size	Date	L-Band Sig. Level at RF Input Port	Front Panel LED Signal Lock	Front Panel LED Auth.	Signal Quality	Eb/No
A	4.5m	10/29/07	not available	OK	OK	94	11.6
B	5m	11/1/07	-29.6 dBm	OK	OK	98	14.3
C	7m	10/30/07	-15.6 dBm	OK	OK	99	14.2
D	5m	10/22/07	-47.1 dBm	OK	OK	98	14.8
E	9m	10/25/07	-38.6 dBm	OK	OK	100	10.9
F	4.5m	10/16/07	not available	OK	OK	100	15.0
G	3.8m	10/24/07	-25.3 dBm	OK	OK	92	10.7
H	5m	10/25/07	-22.8 dBm	OK	OK	93	11.2
I	3.8m	10/24/07	-48.2 dBm	OK	OK	100	12.4
J	5m	10/19/07	-47.0 dBm	OK	OK	95	12.4
K	5m	11/5/07	-20.8 dBm	OK	OK	100	14.2
Avg.*	**5.24m**		**-32.8 dBm**			**97.2**	**12.9**

Figure 3

*The calculated averages in figure 3 indicate that with a standard (or common) headend antenna, excellent downlink performance is achieved.

Phase II Transmission Performance

Phase II yielded excellent satellite link results. As the following graphs (figures 4 and 5) will illustrate, 12 test sites were able to participate in the uplink attenuation phase. Considering the different geographical locations and different downlink antenna types and sizes, the average Eb/No at full uplink power was 12.1. When the uplink power was attenuated by -6dB all but three sites still had signal lock with an average Eb/No of 7.35. So, 75% of the downlink sites were able to keep signal lock on the transponder at -6dB power attenuation. This proves the strength of the DVB-S2 modulation. Except in the very rare instance of local weather being unusually extreme and/or the HBO satellite link experiencing a major transmission problem, it would be extremely uncommon for real world conditions to come close to -6dB of uplink attenuation.

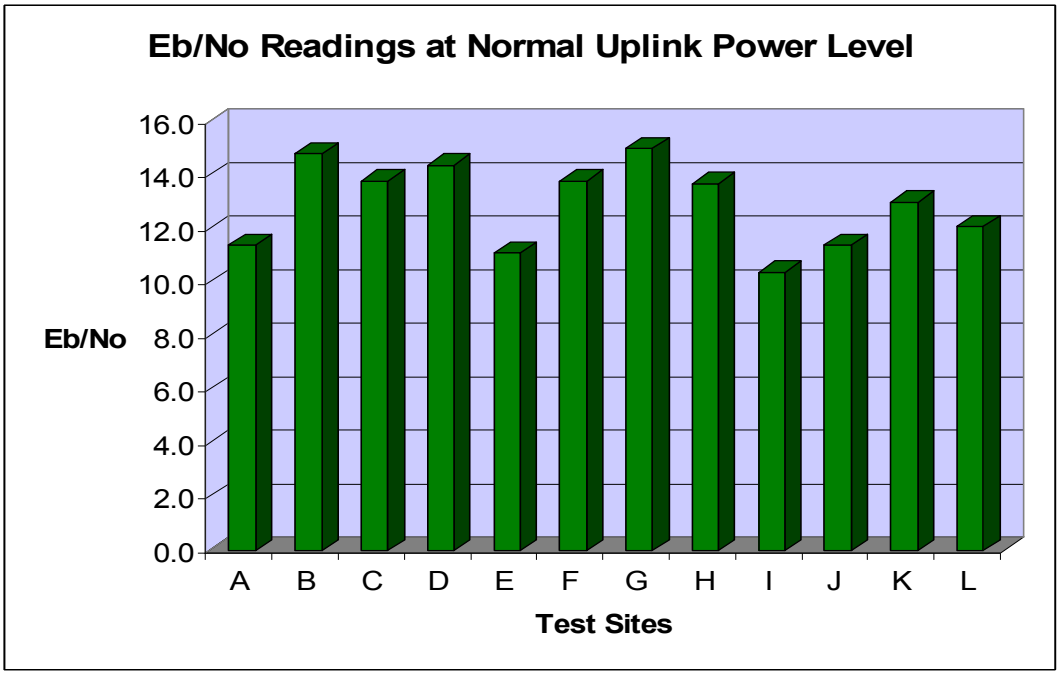

Figure 4

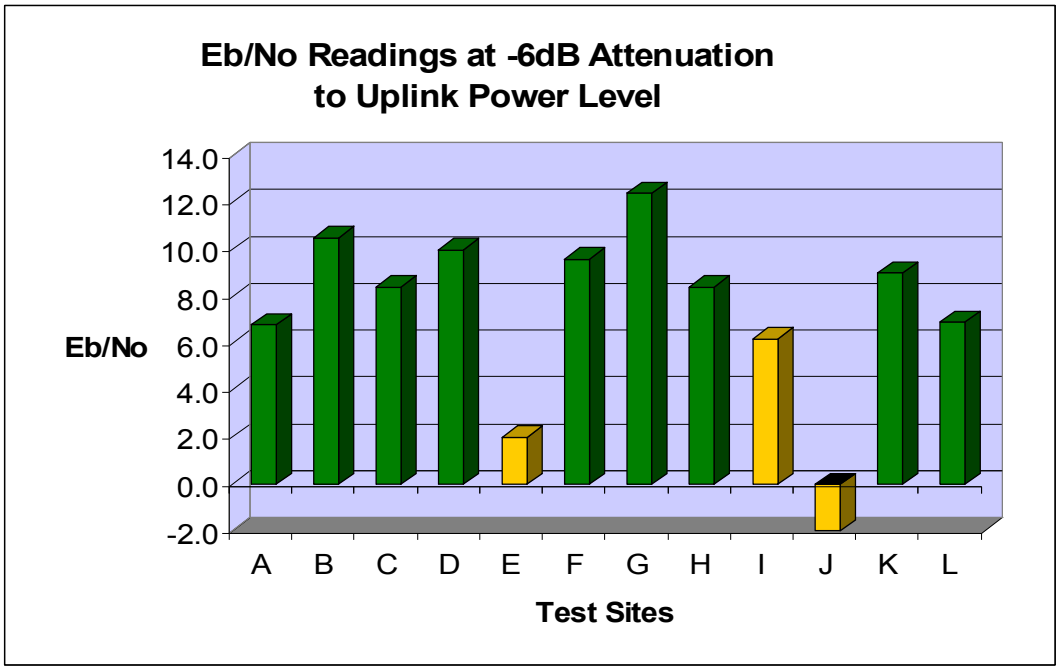

Figure 5

As illustrated in figure 5, only the three test site locations indicated in yellow E, I and J (Eb/No 2.0, 6.2 and -2.0) lost signal lock at-6dB uplink attenuation. The other nine sites were able to maintain transponder signal lock. Site I tested with a small antenna, and this validates that nominal downlink sites can receive DVB-S2 signals with margin.

Phase III Decoder Output Interfaces

In this Phase, the field sites were asked to observe the output quality of the MPEG-4 receivers. Since the test sites all had different

types of measurement equipment (i.e., stream analyzers, etc.), the findings in this phase are somewhat subjective. This actually benefited HBO in determining how the receiver's outputs would perform based on non-consistent readings and stream observations that would vary from site to site. These results again depict “real world" results, as no two headends are exactly the same.

Many of the test sites were not able to look at the MPEG-4 output due to the constraints of having an all MPEG-2 (typical cable plant) infrastructure, but several could and found the outputs to be without any issues or anomalies. Some sites were able to utilize next-generation set top boxes that indicates MPEG-4 technology is rapidly becoming available to cable providers.

The GigE and ASI outputs produced solid MPEG-4 streams. At the time of this testing HBO was broadcasting six HD channels with a total bit rate of about 46 Mbps. One test site fed the ASI output to an active Terayon CherryPicker and logged zero errors. Another site observed legal value video and normal audio as they decoded the ASI stream using a Sencore/Motorola MRD-3187.

The successful Phase III testing indicted the MPEG-4 receiver would be easily deployable in plants that had an MPEG-4 infrastructure, such as IPTV Telco or in plants that would want to employ an external decoding device such as the Sencore/Motorola MRD-3187, or MPEG-4 cable set tops as they become available.

Phase IV Long Term Stability

As with Phase III, many test sites were unable to monitor actual audio and video output of the MPEG-4 receiver, but those that were able to, provided feedback that indicted the receiver was stable and ready for deployment. Some test sites simply observed the Eb/No, signal lock and authorization status during the Phase IV testing.

Eb/No and signal quality readings remained steady as observed for several weeks at different times of day with varying local weather conditions. The observed overall bit rate was consistent with what the HBO uplink was broadcasting for the duration of the testing. All HBO required signal attributes (including closed captions, parental controls/ratings and 5.1 audio) were observed to successfully pass after decoding the MPEG-4 signal. No major MPEG artifacts (including blocking or freezing) were observed during the long term testing. Audio and video quality were said to be very good and there were no instances of receiver failure or need to re-boot or power cycle the units

Transcoding IRD Testing

Directly following the successful testing of the MPEG-4 receiver, HBO (in coordination with Motorola) shipped another receiver to all the field test sites. This unit is a single-decrypt MPEG-4 – to - MPEG-2 transcoding IRD (DSR-6050). This new receiver will enable the end user to provide a transcoded MPEG-2 ASI signal that can be easily put into service in existing MPEG-2 cable plants without the need for any additional equipment. The receiver decodes the MPEG-4 signal and then re-encodes it to MEPG-2. This IRD will output both the native MPEG-4 and the transcoded MPEG-2. The HBO uplink (utilizing Motorola’s BNC software) can control the transcoded output data rate to insure the best possible quality for each HBO/Cinemax service.

The test plan for the transcoding IRD was abbreviated to three phases, with Phase II (uplink attenuation) being eliminated. It was HBO’s feeling that there was no need to duplicate the RF test, since the MPEG-4 receiver performed extremely well. The front end (and RF) portion of the DSR-6050 is identical to the DSR-4410MD, which is based

on Motorola's popular DSR-4400MD (MPEG-2) receiver.

The initial pre-production version of the DSR-6050 had some stability and operational "bugs" which caused the unit to sometimes not enable the MPEG-2 ASI output and also cause the IRD to intermittently "freeze up", requiring a power recycle and/or factory reset. The initial units also did not pass digital closed captions or 5.1 Dolby surround audio. With feedback from HBO and the field test sites, Motorola addressed these problems and issued a firmware upgrade. New DSR-6050s (with the updated firmware code) were sent to the field test sites for evaluation.

Data from the field sites indicates that Motorola successfully corrected all stability and operational issues with the 6050 transcoders. Closed captions and Dolby 5.1 audio pass through the transcoded ASI output without consequence. Many of the test sites reported the overall (video/audio) quality of the transcoded (MPEG-2) output is as good or in some opinions superior to HBO's native MPEG-2 signal. As of this writing, Motorola expects to put the DSR-6050 into full production and make it available to cable distributors by April 2008.

Field Test Conclusions

- The RF transmission link (utilizing DVB-S2 modulation) is extremely stable.
- The Forward Error Correction (FEC) Rate of 5/6 has been chosen and will yield a transponder data payload of 72 Mbps. This FEC rate is sufficient for HBO's MPEG-4 data requirements and is also quite suitable for successful headend reception performance with an average size downlink antenna, and will not cause any downlink reception issues.
- The DSR-4410MD performed well with no major issues and should be recommended to HBO distributors who wish to receive the new HD services with a native MPEG-4 output format.
- Stability and operational issues with the DSR-6050 transcoder have been addressed, and updated (production) firmware proves this receiver should be recommended to HBO cable distributors. This will allow cable MSOs to take advantage of HBO's additional HD channels, without concern about having to alter any existing cable plant infrastructure or incurring the expense of purchasing additional processing equipment.

FINAL THOUGHTS

As HD television is becoming more popular and the related consumer equipment costs are dropping, consumers have a desire for more HD content. HBO has led the charge to increase HD offerings to its distributors and their subscribers. Implementing the Motorola MPEG-4/DVB-S2 solution will address the demand for more HD content by providing a high quality, scalable and cost effective method of providing more HD channels using HBO's existing satellite transponder inventory.

In launching this new system, HBO maintains its presence as a technology leader. HBO was the first programmer to use satellite distribution for its cable affiliates and was the first programmer to use encryption and digital compression. HBO also launched the first satellite-delivered MPEG-2 HD channel and now will be the first programmer to offer all of its channels in HD using advanced DVB-S2 modulation and MPEG-4 compression.

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NOTES

[1] DVB Fact Sheet, August 2007, http://www.dvb.org/technology/fact_sheets/

[2] http://en.wikipedia.org/wiki/EbNo