Off-Air Reception of 8VSB signal for CATV Head-Ends

by

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Abstract: In today's analog and DTV simulcast broadcast environment, there is an increasing demand for reception of Off-Air 8VSB signals by CATV Head-End users. The improved digital signal can replace Cable's Analog tier signals. In addition, due to increased demand by CATV customer's reception of HDTV services, there is an increased need to launch HDTV services by CATV operators. This paper describes details about 8VSB reception, channel characteristics, and receiver performance requirements. Understanding of multipath channel and understanding of 8VSB reception is a key for a successful deployment of HDTV service by CATV Head-Ends. As for DTV Broadcasters, it is also important to understand and let CATV Head-Ends know what to expect and how to install an Off-Air 8VSB receiver.

Introduction

Statistics show that more and more DTV Stations are being launched in the USA and provide simulcast of analog and digital broadcast services today. For example, 80% of U.S. TV households are in markets with five or more broadcasters airing DTV, and 52% are in markets with eight or more broadcasters sending digital signals, [1]. In addition, there is work being done to increase this DTV signal coverage by Digital On-Channel Boosters, [3] [4], [5].

Since DTV signals transmitted over-the-air using 8VSB technology, there is a tremendous advantage in the signal video and audio quality, if the signal can be received properly. Furthermore, if the broadcaster is sending an original HDTV content in 1080i or 720p, then the improvement observed by a CATV Head-End will be significant over the analog NTSC reception. But, at minimum, NTSC is prone to ghost errors, while DTV 8VSB operates in the multi-path channel environment and, in most cases, show a perfect picture.

As for HDTV services by CATV Head-Ends, proper reception of HDTV Off-Air signal is critical to maintain proper service quality and injection of the signal in its Digital Tier. As QAM tuners are being built into the latest DTV Television sets, also known as "Plug-N-Play" HDTV sets [2], customers will be demanding basic services from CABLE without having to rent cable Set-Top-Boxes. This has been mandated by the FCC, starting July, 2004. The 8VSB Off-Air signals must be converted to QAM and sent in the clear, i.e., Clear-QAM. Thus, CATV Head-Ends and DTV Broadcasters must understand and check each other for proper signal reception and distribution of the digital signal to the general public.

Therefore, the Off-Air 8VSB signal can be used by CATV Head-Ends for following purposes:

1) Convert to NTSC for Analog Tier
- Provide clear reception
2) Convert to QAM for Digital Tier w EPG
- Provide Clear-QAM signals

Channel Multi-path Interference

Most of broadcast and CATV engineers are used to channel multi-path interference. As for NTSC, this is often referred to as "ghosts" since it makes the received NTSC pictures show multiple and snowy images. The DTV signal also suffers from channel multi-path effects.

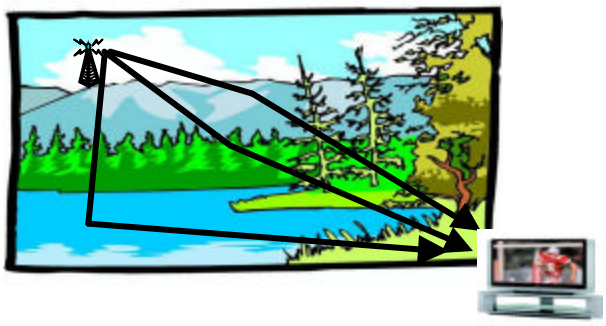

Figure 1 Channel Multi-Path Affects Reception

As can be seen in Figure 1, the RF signal transmitted over-the-air in 8VSB still experiences the same channel multi-path effects as the NTSC signal did. Lake water, near-by trees, and mountains are good signal reflectors. If such reflected signals combined with other reflected or direct-path signals, then a difference in time-delay causes phase cancellation and produce multi-path interference.

Fortunately, an 8VSB signal is designed with such channel impairments in mind. Most of the channel multi-path errors can be corrected using an equalization technique. In addition to the equalization, the receiver performs a multitude of other digital signal processing functions, such as Reed-Solomon Error Correction, Trellis Decoder, and others. From a user's point of view, it is not easy to appreciate the amount of digital signal processing that occurs in the DTV 8VSB receiver. The received DTV signal will present either a perfect image on screen, when the signal is received properly, or a black screen, when the signal is received improperly. Such ON/OFF like nature of the DTV signal requires that broadcasters and CATV engineers understand the nature of the over-the-air 8VSB signal reception and receiving equipment capabilities.

8VSB Off-Air Receiver

At minimum, an 8VSB Off-Air receiver must have the following signal requirements:

✍-65 dBm ~ -10 dBm Rec Power for UHF

Typically, an 8VSB Off-Air receiver will require a received power range of –65dBm ~ –10dBm. This power is measured in the 6MHZ RF channel bandwidth. Care must be taken to set up a spectrum analyzer properly and measure the "flat-noise-like" spectrum of an 8VSB signal. Unlike sinusoidal tones in NTSC, the 8VSB DTV signal occupies the entire 6MHZ bandwidth of an RF channel. Thus, a measure of the power must be made within the 6MHZ bandwidth. Most of today's spectrum analyzer's provide such power measurement utilities.

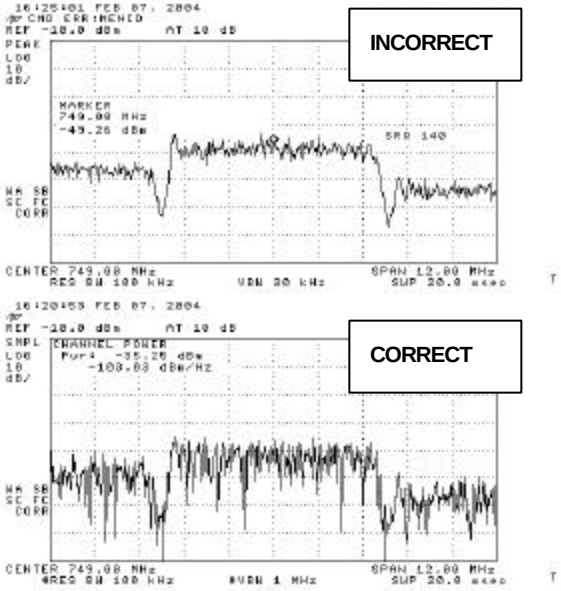

Figure 2 Off-Air Signal on Spectrum Analyzer

As can be seen in Figure 2, the RF received power of an 8VSB signal can be measured using a spectrum analyzer. Here, -49.26dBm is incorrect since it is measured at a single point by the marker, and -35.25 dBm is the correct power since it is measured in the 6MHZ bandwidth using the unit's power measurement utility.

In the case that –65dBm power is not obtainable from the current RF environment, one may consider the use of a directional parabolic or a Log-Periodic antenna. A high gain antenna also reduces multi-path interference signals that may arrive from off-angle axis relative to the desired signal. In addition to a high gain antenna, a Low Noise Amplifier (LNA) may also help increase the

signal power level. However, the use of an LNA may also increase noise levels and interference. Thus, one must understand if the issue is due to noise, adjacent channel interference, or co-channel interference. In the case of a noise limited RF environment, locating the 8VSB Off-Air receiver unit closer to the antenna may solve the issue. Another solution is to use a receiver with improved sensitivity. It is possible to add a special RF front-end and obtain –80dBm sensitivity for an Off-Air 8VSB Receiver.

If the issue is related to adjacent or co-channel interference, then users must be aware that the performance is different depending upon actual Off-Air Receiver hardware used. Although most receivers will perform similarly in this regard, each user experience will depend upon the actual 8VSB Off-Air receiver unit, physical and RF receiving system, and channel interference being actually present at the receiving site.

Figure 3 Off-Air Signal Diagnostics

Some diagnostics tools built into the 8VSB Off-Air receivers are very useful during installation and operation. As can be seen in Figure 3, a Bit Error Rate (BER) display, Signal-to-Noise Ratio (SNR) Display, and RF Power Level Display will indicate the current RF and 8VSB Off-Air receiver status. Typically, a good signal characteristic will show that BER is 0.0E-6, SNR is 30 dB, and RF power is indicated as 5 bars. These indicate that no bit error is being detected, that high level of received SNR is present, and that a good RF power level is being received, respectively. Typically, BER of 1E-3 or higher is considered bad. An SNR of 16 dB or lower is considered bad. And RF power level of less than 2 bars is considered bad.

In some cases, BER and SNR will show bad while the RF power level is good. This will indicate that there may be strong co-channel or adjacent channel interference conditions.

In most cases, BER, SNR, and Power level indicators will show good, and this is considered the normal operation for good reception of an 8VSB Off-Air signal.

Another important consideration of an 8VSB Off-Air receiver is its firmware upgradeability and modularity. Some CATV operators have employed the use of a commercial DTV Set-Top-Boxes to receive the 8VSB Off-Air signal. However, this is typically a one-time solution and does not help if there are any specification changes or the need to add new features for proper reception or operation such as Closed Captioning. The modularity of an 8VSB Off-Air receiver is also important since it allows users to add or delete functions and features based on actual needs. This is a cost effective solution.

8VSB Off-Air Conversion for CATV Analog

Once the signal is received properly, most 8VSB Off-Air receivers will provide a decoded and down-converted NTSC picture. For CATV Analog Tier, this DTV-signal-converted-to-NTSC will present an improved picture quality over an NTSC signal.

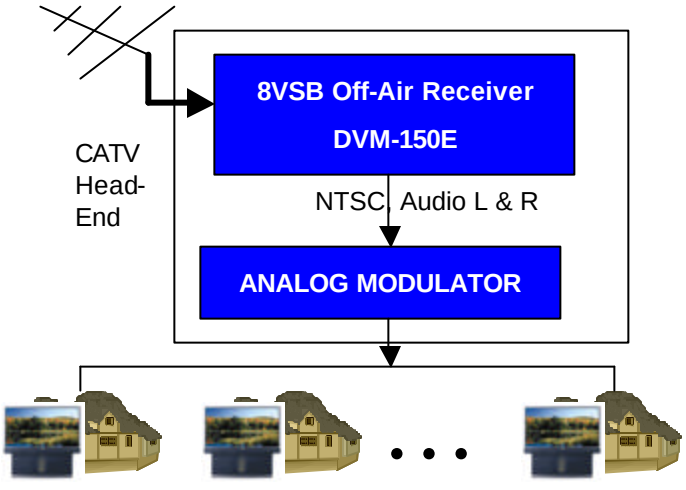

Figure 4 CATV Analog Tier

Most broadcasters typically switch between SD and HD programming contents during a 24-hour period. Typically, 8VSB Off-Air receivers provide several options to select programs in such a way that only the intended DTV programs are received properly. There can be several modes for this purpose:

Mode A may be that any one program out of multiple programs being transmitted by a broadcaster is always decoded by the 8VSB Off-Air receiver. This mode is designed to pick up any one program in the Transport Stream to make certain that a DTV signal is always being decoded.

Mode B may be that the 8VSB Off-Air receiver is always tuned to a specific program number. This will allow the unit to always come back to this selected program number even after a power cycle due to power interruption. For example, a broadcaster may transmit ABC content on program number 1 and transmit NBC content on program number 2. If a receiver always came back to program 1 after a power interruption, this may not be the desired operation. Thus, with Mode B, the unit will always return to its intended program even after a power cycle.

Mode C may be that the 8VSB Off-Air receiver will follow the order in which the program number is listed in the PAT table of the MPEG2 transport stream. A PAT table lists all of the program numbers and contents. Thus, having the 8VSB Off-Air receiver to follow this PAT table may be useful in the event of missing contents. For example, in the event that the broadcaster's signal is 5 SD most of the day, and except during the prime time, the signal is switched to 1 HD and 1 SD only. In Mode C, the unit will select the first SD and switch to the HD when it appears. When the HD goes away, then the unit will pick up the first SD program from the multiple programs.

As for Closed Captioning, there are two standards, e.g., EIA-608 and EIA-708. Both of these signals must be passed and presented properly. As for Analog Tier at CATV Head-End, one must check for presence of Line 21 information. If an SDI SMPTE-259 interface is being employed, then embedded audio for both primary and secondary audio is desired. In addition to analog EIA-608 Closed Caption information present on line 21, it may be desired to have SMPTE-291 and SMPTE-334 capability for ancillary data services and embedded Closed Caption data on the SDI signal.

For an HDSDI SMPTE-292 interface, the same is true. It is desired to have the capability of embedded audio and closed caption information.

8VSB Off-Air Conversion for CATV Digital Tier

For launch of an HDTV service by CATV Head-Ends, the Off-Air Terrestrial signals represent a unique service offering to CATV customers. Figure 5 shows the equipment connection for this implementation.

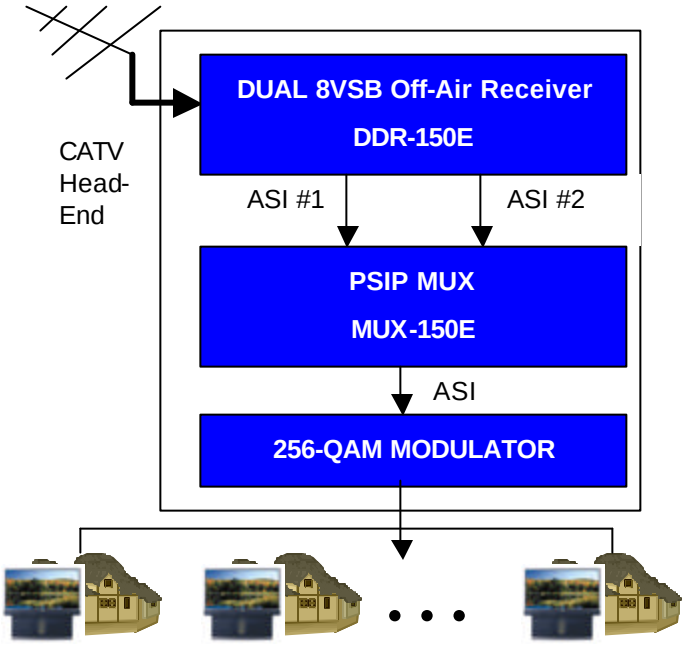

Figure 5 CATV Digital Tier for 8VSB Off-Air

Simple arithmetic will show that 2 Off-Air signals at 19.39MBPS each will fit in one 256QAM signal and occupy one 6MHZ RF channel bandwidth for the CATV Digital Tier. Thus, the 8VSB Off-Air signal is most effectively carried on 256QAM Digital CATV Tier.

In Figure 5, it can be seen that an 8VSB Off-Air unit is used to simultaneously demodulate 2 independent 8VSB Off-Air signals. The unit generates 2 independent ASI signal outputs, corresponding to the respective RF channels.

After the conversion of the 8VSB Off-Air signal into an ASI Transport Stream signal, the PSIP-MUX unit performs the following operations: a 2-to-1 multiplex operation, a PSIP-merge and update/modification operation, PID filtering, and generation of one ASI stream at 38.8MBPS. Note here that no bit rate shaping is performed. The original and entire full 19.4MBPS transport stream is converted into 256-QAM signal and occupies one 6MHZ RF channel.

Here, the important fact about PSIP-merge and update/modification operation is that consumer HDTV sets are following the traditions of cable tuners in television sets. Just as analog cable tuners were built into analog television sets in the past, the FCC is mandating that QAM tuners are included in digital HDTV sets for receiving digital cable signals including HDTV.

Both broadcasters and CATV Head-Ends must implement PSIP properly such that consumer HDTV sets equipped with QAM tuners will be able to tune properly and display proper messages such as PSIP-EPG materials.

The EPG Table includes such information as program title, time, authors, content description and other general information about the program being transmitted during the day. The EPG information will be included as part of the broadcaster's 8VSB Off-Air signal. However, it is up to CATV Head-Ends to properly pass the EPG information carried in the Off-Air PSIP into the Clear-QAM signals.

Furthermore, Consumers with QAM tuner enabled HDTV sets will be able to order Digital CATV services without having to rent cable Set-Top-Boxes. In these cases, CATV Head-Ends must provide Clear-QAM signals with proper PSIP and EPG information such that it is properly displayed on consumer "Plug-N-Play" HDTV sets.

Another aspect of HDTV on the CATV Digital Tier is that it is best to leave unchanged the format, bit rate, and video/audio quality of the primary program from a broadcaster. Not only is it an FCC rule to leave it alone, but it is not good practice to bit "Rate Shape" a few mega-bits from the 8VSB Off-Air bit streams. The consumers will ultimately expect a great High-Definition experience from the local broadcaster 8VSB Off-Air signals. Already, consumers equipped with a large HDTV screens such as 42 inch Plasma Displays are demanding better picture quality from CATV operators.

As some CATV Head-Ends use "Rate Shaping" technology to squeeze more 8VSB Off-Air into the 6MHZ RF Bandwidth, the picture quality of the 8VSB Off-Air is also being degrading. Furthermore, this degraded picture quality is more evident and easily seen by those consumers with large HDTV display screen (42 inches or larger). As more consumers watch HDTV broadcasts, they will demand the highest quality picture quality from Cable operators as well.

Conclusions

In this paper, issues related to 8VSB Off-Air receiving equipment are discussed. It is urged that both DTV broadcasters and CATV operators understand the channel issues of receiving 8VSB and properly carry the digital Off-Air signals into CATV Head-Ends.

Since most of today's DTV Broadcasters are simul-casting both analog and digital over-the-air, there is a tremendous advantage of receiving the 8VSB Off-Air signal by CATV operators.

Conversion of the DTV received signal into NTSC will represent an improved picture quality for CATV's analog tier. However, as consumers demand HDTV services from CATV operators, the 8VSB Off-Air is being injected into Digital Tiers. Be aware that FCC has mandated rules related to passing PSIP information properly such that "Plug-N-Play" HDTV sets are able to tune to those digital signals provided by CATV Operators.

References

[1] www.nab.org, Dec, 2003

[2] http://www.fcc.gov/dtv/ , Jan 2004

[3] S. Kuh, "DTV Translator Test Program Report: An 8-VSB Digital On-Channel Booster Technology" National Translator Association, May 3, 2003.

[4] S. Kuh " Digital On-Channel booster for 8-VSB" 53rd Annual IEEE Broadcast Symposium, Oct 15, 2003 Washington DC USA

[5] S. Merrill Weiss, "Distributed Transmission Systems - Overcoming the Limitations of DTV Transmission", Proceedings, NAB 2003