advanced*television*systems*committee*inc

# ATSC Recommended Practice: Transmission Measurement and Compliance for Digital Television

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The Advanced Television Systems Committee, Inc., is an international, non-profit organization developing voluntary standards for digital television. The ATSC member organizations represent the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

Specifically, ATSC is working to coordinate television standards among different communications media focusing on digital television, interactive systems, and broadband multimedia communications. ATSC is also developing digital television implementation strategies and presenting educational seminars on the ATSC standards.

ATSC was formed in 1982 by the member organizations of the Joint Committee on InterSociety Coordination (JCIC): the Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Telecommunications Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). Currently, there are approximately 140 members representing the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

ATSC Digital TV Standards include digital high definition television (HDTV), standard definition television (SDTV), data broadcasting, multichannel surround-sound audio, and satellite direct-to-home broadcasting. Contact information is given below.

| | |
|---|---|
| Mailing address | Advanced Television Systems Commmittee, Inc. |
| | 1776 K Street, N.W. |
| | Washington, D.C. 20006 |
| Telephone | 202-872-9160 (voice) |
| | 202-872-9161 (fax) |
| Web site | http://www.atsc.org |
| E-mail | standards@atsc.org |

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The revision history of this document is given below.

### A/64 Revision History

| | |
|---|---|
| A/64 approved | 17 November 1997 |
| Revision A approved | 30 May 2000 |
| Revision B approved | 26 May 2008 |
| TSG reviewed and revised this document as part of the ongoing 5-year review process specified in "Procedures for Technology Group and Specialist Group Operation," Section 16. TSG decided to change the designation of the document from a Standard to a Recommended Practice. Reaffirmed 11 December 2014. | |

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## 1. FOREWORD

This document was prepared by the Advanced Television Systems Committee (ATSC) Technology and Standards Group (TSG). The document was initially approved by the members of the ATSC on 17 November 1997 as Document A/64. Revision A of A/64, which included the revised FCC DTV emission mask and specified that A/64 and its revisions are for use in the United States and not world-wide, was approved by the members of the ATSC on 30 May 2000. Revision B of A/64 converted the document from a Standard to a Recommended Practice as no element was deemed essential for correct operation; updated references; and made certain editorial changes. Revision B was approved by the members of the ATSC on 26 May 2008.

## 2. SCOPE

This ATSC Recommended Practice describes methods for testing, monitoring, and measurement of the transmission subsystem intended for use in the digital television (DTV) system adopted as the U.S. Standard by the Federal Communications Commission. Both 8-VSB and 16-VSB are described in this document.

Furthermore, this document describes specifications for maximum out-of-channel emissions, parameters affecting the quality of the in-channel signal, symbol error tolerance, phase noise and jitter, power, power measurement, frequency offset and stability. In addition, the condition of the RF symbol stream upon loss of MPEG transport packets is described.

## 3. REFERENCES

The following documents contain provisions which, through reference in this text, also constitute provisions of this Recommended Practice. At the time of publication, the editions indicated were valid. All documents are subject to revision, and parties to agreement based on this Recommended Practice are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

[1] IEEE: "Use of the International Systems of Units (SI): The Modern Metric System", Doc. IEEE/ASTM SI 10-2002, Institute of Electrical and Electronics Engineers, New York, N.Y., 2002.

[2] FCC Rules and Regulations, Parts 73 and 76, Federal Communications Commission, Washington, D.C.

## 4. DEFINITIONS

With respect to definition of terms, abbreviations, and units, the practice of the Institute of Electrical and Electronics Engineers (IEEE) as outlined in the Institute's published standards are used [1].

## 5. TRANSMISSION MEASUREMENT AND COMPLIANCE

### 5.1  8-VSB Modulation (Trellis Coded)

5.1.1   Maximum Out-of-Channel Spectrum Emissions

5.1.1.1    Specification of DTV Out-of-Channel Emission Mask from FCC Memorandum Opinion and Order on Reconsideration of the 6th Report and Order, Released 23 February 1998

The DTV emission mask was adopted in FCC Memorandum Opinion and Order on Reconsideration of the 6th Report and Order, Released 23 February 1998, and codified in Section 73.622(h) of the FCC Rules (47 CFR 73.622). The order requires that:

> 1) *in the first 500 kHz from the authorized channel edge, transmitter emissions must be attenuated no less than 47 dB below the average transmitted power*;
>
> 2) *more than 6 MHz from the channel edge, emissions must be attenuated no less than 110 dB below the average transmitted power; and*
>
> 3) *at any frequency between 0.5 and 6 MHz from the channel edge, emissions must be attenuated no less than the value determined by the following formula:*
>
> *Attenuation in dB = 11.5 ($\Delta f$ + 3.6) where $\Delta f$ = frequency difference in MHz from the edge of the channel.*
>
> *All attenuation limits are based on a measurement bandwidth of 500 kHz. Other measurement bandwidths may be used as long as appropriate correction factors are applied. Measurements need not be made any closer to the band edge than one half of the resolution bandwidth of the measuring instrument. Emissions include sidebands, spurious emissions and radio frequency harmonics. Attenuation is measured at the output terminals of the transmitter (including any filters that may be employed). In the event of interference caused to any service, greater attenuation may be required.*

Figure 5.1 shows the FCC Emission Mask in graphical form.

5.1.1.2    Specification of DTV Out-of-Channel Radiation Using a Weighting Function to Quantify Interference to First Adjacent Channel NTSC Assignments

This section is useful as an analytical tool in cases where the DTV spectral sidelobes meet the requirements of 5.1.1.1 but have different spectral shapes than an exact match specified there, and/or, where the ratio of DTV and NTSC field strengths varies due to transmitting antenna azimuth and elevation pattern (beam tilt), location and terrain differences, or for determining the interference levels to NTSC Services in addition to population affected by DTV power increase or other allocation changes under the FCCs de minimus Standard.

The out-of-channel measurement specification defined in this section is based upon measurements made at the Advanced Television Test Center (ATTC) to determine THE NTSC Threshold of Visibility (TOV) for 500 kHz wide noise sources centered at various points across the NTSC channel. This work determined an appropriate "weighting function," which is rounded to the nearest dB to obtain this specification. A "weighting function" approach allows some flexibility in spectral sidelobe details, while still achieving completely adequate protection of adjacent NTSC channels. This specification is defined in terms of the Desired-to-Undesired ratio
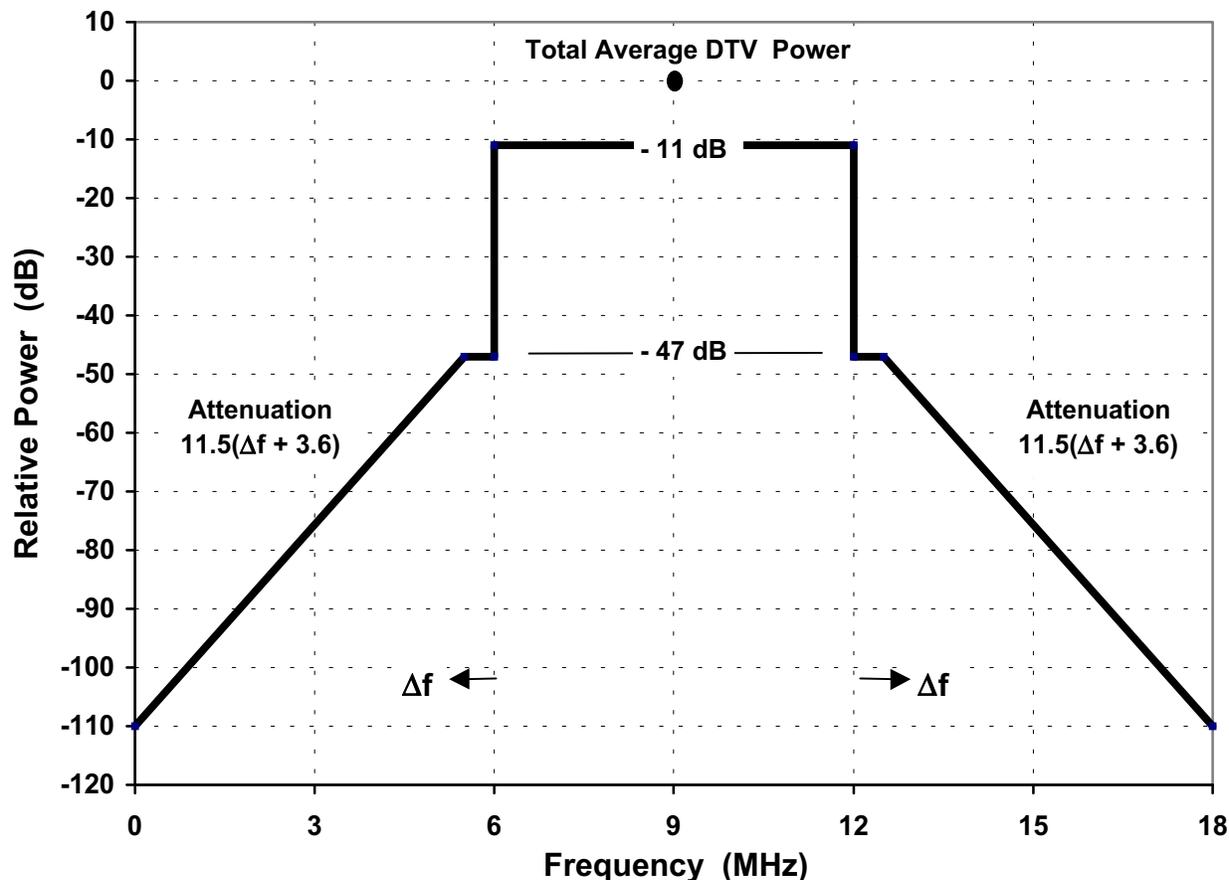
**Figure 5.1** FCC DTV emission mask (based on measurement bandwidth of 500 kHz).

(D/U) and a 500 kHz measurement bandwidth. This definition specifically recognizes that the required attenuation of DTV spectral sidelobes depends on the relative power levels of the DTV signal and an NTSC signal in the adjacent channel over the NTSC coverage area.

Work done at ATTC showed that noise with a flat spectrum across the 6 MHz NTSC channel which has a power that is at least 51 dB below NTSC peak-of-sync was adequate to avoid TOV interference with the NTSC signal, based on the median of the receivers tested. Weighting such a flat spectrum of noise with the weighting function results in a weighted TOV power level that is 5 dB lower, or at 56 dB below NTSC peak-of-sync power.

For various shaped noise or noise-like distributions across the NTSC channel, it has been verified that as long as the weighted noise is at least 56 dB below NTSC peak-of-sync power, then TOV is avoided. Here, the NTSC noise interference is viewed as arising from the non-flat spectral sidelobes of an adjacent channel DTV transmitter. If the ratio of DTV average power to NTSC peak-of-sync power is

$$\left( \frac{DTV}{NTSC} \right)_{dB} ,$$

then to avoid NTSC TOV the DTV sidelobes in the adjacent NTSC channel, when weighted and summed across the 6 MHz channel, are to be attenuated below average DTV transmitter power by at least

$$\left( 56 + \left( \frac{DTV}{NTSC} \right)_{dB} \right) \text{ dB.}$$

For example, if the DTV average power is 12 dB below the NTSC peak power,

$$\left( \frac{DTV}{NTSC} \right)_{dB} = -12 \text{ dB,}$$

the weighted DTV sidelobe power in an adjacent channel needs to be attenuated at least 56 – 12 = 44 dB below DTV average signal power for this case.

Further work done at the ATTC determined that in order to avoid the Threshold of Audibility (TOA) on the NTSC audio channel, the power measured in the upper 500 kHz segment of the NTSC channel are to be attenuated at least 48 dB below NTSC peak-of-sync power, or

$$48 + \left( \frac{DTV}{NTSC} \right)_{dB} \text{ dB}$$

below the DTV average power. This was for a ratio of visual-to-aural carrier powers of 13 dB. Less attenuation is required for lower visual-to-aural ratios.

The protection of the adjacent NTSC channel against TOV and TOA leads to the following out-of-channel DTV spectral emission specification:

a)  To protect against adjacent channel NTSC TOV, out-of-channel DTV spectral emissions measured in an adjacent 6 MHz wide channel, when weighted by the weighting function, should be attenuated below the DTV average transmitter power by at least

$$56 + \left( \frac{DTV}{NTSC} \right)_{dB} \text{ dB.}$$

b)  Additionally, to protect against adjacent channel NTSC TOA, the power measured in the uppermost 500 kHz segment of an adjacent channel should be attenuated below DTV average power by at least

$$48 + \left( \frac{DTV}{NTSC} \right)_{dB} \text{ dB.}$$

This assumes a visual-to-aural carrier power ratio of 13 dB.

    c) Finally, the unweighted power in any non-adjacent 6 MHz channel should be attenuated below DTV average power by at least 110 dB.

Where:

$$\left(\frac{DTV}{NTSC}\right)dB = 10\log_{10}\left(\frac{\text{Average Power of the DTV Signal in the 6 MHZ channel}}{Peak\,Sync\,Power\,of\,Adj.channel\,NTSC\,Signal}\right)_{MAX}$$

i.e., the maximum ratio of received DTV power compared to an adjacent NTSC channel peak-of-sync power at any location within the DTV coverage area where the NTSC channel's coverage is to be protected. This measured ratio includes any effects of different DTV and NTSC transmitting antenna patterns.

    The algorithm to determine weighted noise power of a spectral density distribution across a 6 MHz NTSC Television channel is as follows:

    The distribution is divided into twelve 500 kHz frequency bands. Beginning with the band at the low frequency end of the channel, the power in each band, in turn, is weighted with the following weighting function sequence: – 27 dB, –13 dB, – 3 dB, – 2 dB, 0 dB, –1 dB, – 4 dB, – 9 dB, –10 dB, – 4 dB, –10 dB, minus infinity dB. The total weighted picture interference is the power sum of all 12 weighted bands. (See Section 5.1.1.2 (a), above.)

    The sound interference is determined by the 12th frequency band only and is weighted by 0 dB. (See Section 5.1.1.2 (b), above.)

    The NTSC weighting function is plotted in Figure 5.2.

### 5.1.1.3    Specification of DTV Out-of-Channel Radiation to Protect Adjacent Channel DTV Assignments

The FCC requires that the out-of-channel radiation from all DTV transmitters comply with the emission mask specified in the FCC Opinion and Order on Reconsideration of the 6th Report and Order, Released 23 February 1998. (See Section 5.1.1.1.) As an analytical tool for various co-located (within 5 km) DTV adjacent channel relative power levels where the DTV splatter side-lobes shape exactly match the FCC DTV emission mask (see Section 5.1.1.1), the following is helpful:

1) For 0.1 dB degradation to the fringe area performance (15 dB SNR threshold) of a DTV channel having DTV adjacent channel assignments, the sum of authorized effective radiated powers of the adjacent channels should not exceed twenty (20) times the authorized effective radiated power of the transmitter of that DTV channel so that an effective signal-to-noise ratio of 31 (44 – 13) is maintained in that channel, and

2) For 0.25 dB degradation to the fringe area performance (15 dB SNR threshold) of a DTV channel having DTV adjacent channel assignments, the sum of authorized effective radiated powers of the adjacent channels should not exceed fifty (50) times the authorized effective radiated power of the transmitter of that DTV channel so that an effective signal-to-noise ratio of 27 dB (44 – 17) is maintained in that channel.

    If the center channel of three DTV assignments is taken as the reference desired channel (N), the spectral spillover from each adjacent channel (N+1, N–1) is power additive as interference to the desired (N) channel. Since the spectral spillover power bears a direct relationship to the authorized power of the channel transmitter causing it, the sum of spectral spillover coming from
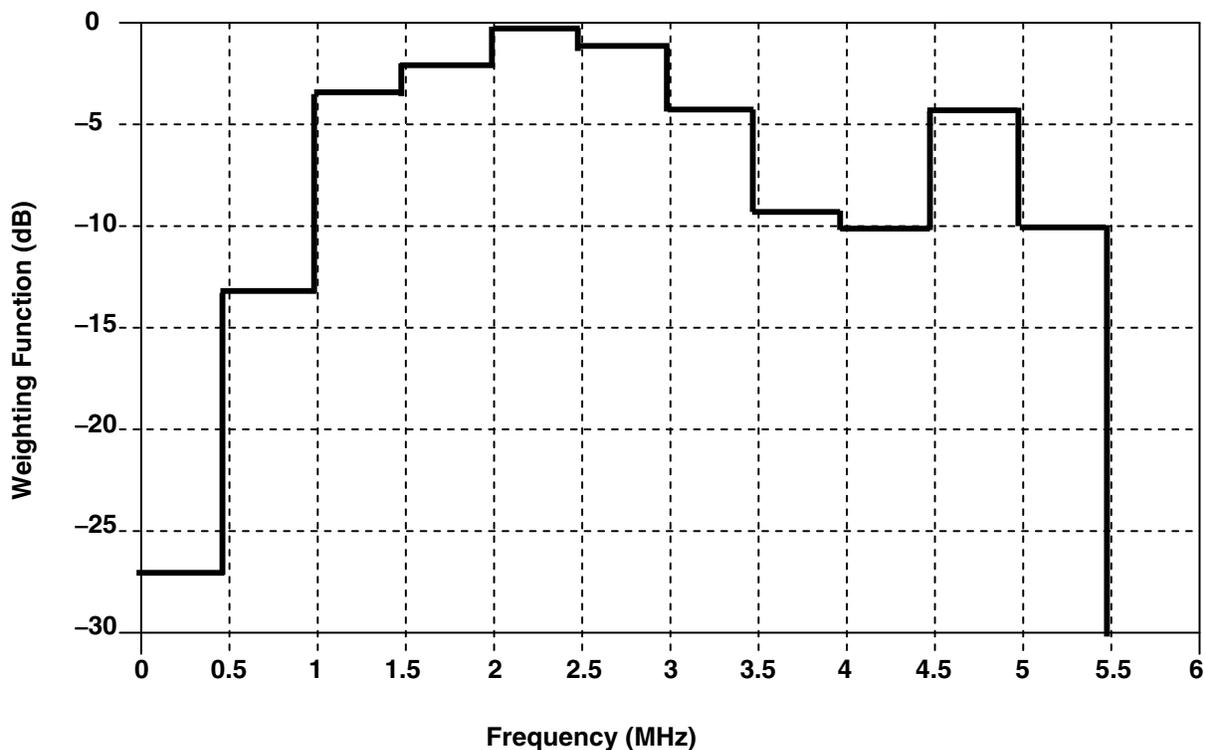
**Figure 5.2** NTSC weighting function.

the channel on both sides; i.e., the interference to the desired channel (N), is directly proportional to the sum of the effective radiated powers in the adjacent channels (N+1, N–1).

The average adjacent channel power in a DTV signal whose splatter exactly matches the FCC Emission Mask is 44 dB below the in-channel average power. Where the transmitter side-lobe interference average power (N+1 or N–1) is lower than minus (–) 44 dB (more dB in the negative direction), interference level to the desired channel (N), due to transmitter filtering and/or improved linearity, the permitted effective radiated power of such a DTV transmitter is increased in direct proportion to that side-lobe power reduction.

### 5.1.2  In-Channel Signal Characterization

The quality of the in-channel emitted signal can be specified and measured by determining the departure from 100 percent "eye" opening (this requires a reference receiver). The departure, or error, has four identifiable components: 1) circuit or "white" noise, 2) intermodulation noise caused by non-linearities, 3) intersymbol interference, and 4) phase noise. The combination of all of these effects can be specified and measured by an error (or noise) magnitude power.

The error magnitude power for a DTV signal should be no greater than – 27 dB relative to the authorized signal power. The signal-to-noise (error-magnitude) power ratio is sometimes referred to as SNR (MER); i.e., signal-to-noise ratio, or modulation error ratio. An error power of this level will increase (worsen) the received DTV error threshold by a maximum value of about 0.25 dB, which for UHF assignments corresponds to a reduction of approximately 1/4 mile in coverage

distance from the transmitter. The error is the total power of all the above errors along the in-phase demodulation axis, and is considered as "noise" when measuring signal-to-noise ratio.

### 5.1.3   Symbol Rate Tolerance

The symbol rate is

$$f_{sym} = 4.5 \cdot \frac{684}{286} \ MHz \ \pm 30 \ Hz \ \approx \ 10{,}762{,}237.8 \ Hz \ (\pm \ 2.79 \ ppm)$$

Notes:

1) The symbol rate f$_{sym}$ is locked to the transport stream data rate $f_{tp}$ in the exact ratio:

$$f_{sym} = \frac{1}{2} \cdot \frac{208}{188} \cdot \frac{313}{312} \cdot f_{tp}$$

The approximate value of $f_{tp}$ is: ~19,392,658.5 ± 54 Hz.

2) The tolerances on $f_{sym}$ and $f_{tp}$ provide a reference suitable for generation of the NTSC color subcarrier frequency in devices which translate the digital signal to NTSC, with a tolerance of ±10 Hz.

### 5.1.4   Pilot Carrier Phase Noise and Jitter

The level of (pilot) carrier phase noise should be no greater than –104 dBc/Hz @ 20 kHz offset from the carrier frequency.

### 5.1.5   Power Specification and Measurement Principles

*Background*: The present NTSC service allows a power variation ranging between 80 percent and 110 percent of authorized power. These values correspond to –1.0 dB and + 0.4 dB, respectively. Because of the so-called "cliff effect" at the fringes of the service coverage area for a digital DTV signal, the allowable lower power value will have a direct effect on the DTV threshold. A reduction of 1.0 dB in transmitted power will change the DTV threshold of 15 dB (which has been determined to cause a $3 \times 10^{-6}$ bit error rate which corresponds to $1.9 \times 10^{-4}$ packet error rate) to 16 dB, or for UHF assignments approximately a one mile reduction in coverage distance from the transmitter.

   Therefore, the average power of the DTV transmitted signal should be specified and measured as follows:

   The lower allowed power value should be 95 percent of authorized power and the upper allowed power value should be 105 percent of authorized power.

   A conventional full-wave rectifier type of power meter will register approximately 1 dB lower than the true power on "white" noise. It has not been determined what the reading will be when measuring DTV power. It is suggested that DTV stations use a calorimeter type true power measurement method to re-calibrate the rectifier type of power meter if used. The power reading

should have an uncertainty no worse than 5 percent, and preferably better, in order to have minimum impact on DTV coverage.

### 5.1.6   Frequency Offsets and Stability

Several interference mechanisms need to be considered in selecting the DTV frequency offsets. These are: 1) DTV-into-DTV co-channel, 2) NTSC-into-DTV co-channel, and 3) DTV-into-NTSC upper adjacent channel. Other interference effects (i.e., lower adjacent, taboos, DTV-into-NTSC co-channel, etc.) are insensitive to frequency offset. In each case, the dominant interference will determine which frequency offset will have precedence. The DTV offsets in each case below track the assigned offsets to the NTSC station (i.e., –10 kHz, 0 kHz, +10 kHz).

These proposed offsets are not modifications to the ATSC Standard. Rather, these offsets are specific solutions that account for interference effects encountered during the actual channel allocation process.

#### 5.1.6.1   Co-channel DTV-to-DTV Offset

In the DTV co-channel interference condition, it has been found that a DTV pilot frequency offset that is an odd multiple of half the DTV segment rate provides improved interference rejection. There are several choices that meet this requirement. An offset of 1.5 times the segment frequency (i.e., 19,403 Hz) appears to provide the best performance. The frequency tolerance of the DTV transmitters should be ±10 Hz.

#### 5.1.6.2   Co-channel NTSC-to-DTV Offset

For the NTSC-to-DTV co-channel interference condition, the best performance is obtained if the DTV signal is aligned such that the NTSC visual carrier is located near the notch of the DTV receiver's NTSC rejection comb filter. Additionally, the DTV receiver clock recovery performance is most robust if the visual carrier location is chosen to be near an odd multiple of half of the segment frequency. The DTV pilot frequency should be below the NTSC visual carrier frequency by 70.5 times the segment frequency (i.e., 911,944 Hz) for best performance. This should be with a tolerance of ±1 kHz.

#### 5.1.6.3   Upper Adjacent Channel DTV-into-NTSC Offset

For interference caused by the upper adjacent DTV-into-NTSC, tests at the ATTC have shown that the DTV pilot carrier may appear as a chrominance beat in the NTSC image on some sets. An improved alignment between the DTV pilot and the NTSC chroma subcarrier is selected to be an odd multiple of half the NTSC line rate. This causes the chrominance beat pattern to alternate at the NTSC scan line rate. This reduces the visibility of the chroma beat interference. The offset proposed by the ATTC is 95.5 times the NTSC horizontal scan rate. This allows a tolerance of ±1 kHz on both the NTSC and DTV transmitters. The frequency of the DTV pilot can be expressed in terms of the frequency of the NTSC visual carrier on the lower channel and the NTSC horizontal scan rate.

$$F_p(n) = F_v(n-1) + \frac{455}{2} F_h + 95.5 F_h$$

It has been found that when this frequency is chosen as the offset, an underlying high-frequency luminance beat of 5.0821678 MHz is also then produced. An additional refinement to

the frequency offset between the DTV and NTSC signals produces an alternating beat pattern at both the NTSC frame and line rates. This proposal specifies a difference between the DTV pilot frequency and the NTSC chroma carrier frequency of 95.5 times the NTSC line rate minus the NTSC frame rate.

$$F_p(n) = F_v(n-1) + \frac{455}{2} F_h + 95.5 F_h - 29.97$$

This additional refinement provides a reduction in visibility of upper adjacent DTV interference into NTSC, but it requires a tighter frequency control on the NTSC transmitter to maintain a frequency difference of $\pm 3$ Hz. This frequency difference specification is required to be met by all DTV stations operating in an adjacent channel above an NTSC channel. The FCC specification for this, contained in the Memorandum Opinion and Order on Reconsideration of the 6th Report and Order, Released 23 February 1998 and codified in Section 73.622 of the FCC Rules (47 CFR 73.622) is:

(g) *DTV stations operating on channels above an analog TV station.*

(1) *DTV stations operating on a channel allotment designed with a "c" in paragraph (b) of this section must maintain the pilot carrier frequency of the DTV signal 5.082138 MHz above the visual carrier frequency of any analog TV broadcast station that operates on the lower adjacent channel and is located within 88 kilometers. This frequency difference must be maintained within a tolerance of $\pm 3$ Hz.*

### 5.1.7   Synchronization Signals

It can be expected that in broadcast operations the transmission modulator will sometimes be fed with corrupted MPEG transport packets, which can result in loss of, or incorrectly timed, sync and clock signals. In such cases, the receiver will go out of lock and thereby prolong the disruption of service.

The transmitted RF VSB symbol stream should retain continuity throughout the time of any loss of MPEG-packets at the VSB modulator input. VSB segment and field syncs are required to be transmitted at all times, with no significant phase discontinuities, and the symbol clock frequency should remain within the $\pm 2.79$ ppm tolerance without significant phase discontinuity. If MPEG-data is determined to be absent or corrupted at any stage before the modulator, a null MPEG transport packet should be inserted into the path. This is prior to the VSB processing (i.e., randomizing, Reed Solomon encoding, interleaving, trellis encoding, etc.) by the exciter.

## 5.2   16-VSB Modulation

### 5.2.1   Emission Mask

The present rules in Section 76.605 of the FCC Rules (47 CFR 76.605), Technical Standards, cover specifications for disturbances such as intermodulation, which are entirely adequate for 16-VSB signal carriage by high data rate media, and no specific emission mask is required [2].

### 5.2.2  In-Channel Signal Characterization

The quality of the in-channel signal as received can be specified and measured by determining the departure from 100 percent "eye" opening. The departure, or error, has four components:

1) White noise,

2) Intermodulation disturbances caused by non-linearities,

3) Intersymbol interference, and

4) Phase noise.

The combination of all of these effects can be specified and measured by an error (or noise) magnitude. The first component will be no worse than $-43$ dB relative to peak of NTSC sync as measured in a 4 MHz band. The equivalent in 6 MHz is $-41.2$ dB. The 16-VSB signal level is typically 6 dB lower than the equivalent NTSC sync. Therefore, the maximum noise level relative to the 16-VSB signal average power in a 6 MHz band is $-35.2$ dB. The second component intermodulation disturbances are required to be $-47$ dB relative to NTSC peak of sync or, equivalently, $-41$ dB relative to 16-VSB average power. The third component, intersymbol interference, is best measured and specified at the output of the 16-VSB modulator and phase noise can be measured at the local upconversion oscillator. The power sum of all components along the in-phase axis is the error or noise when measuring signal-to-noise ratio.

The theoretical signal to noise ratio threshold for 16-VSB modulation which produces a bit error rate of 3 x $10^{-6}$ (which corresponds to a packet error rate of 1.9 x $10^{-4}$) is 28.4 dB. Therefore, an intersymbol interference error magnitude for 16-VSB signal no greater than $-32$ dB relative to the 16-VSB power will produce a total error magnitude no greater than $-31.4$ dB which is a margin of 3 dB with respect to the threshold of 28.4 dB.

### 5.2.3  Symbol Rate Tolerance

The symbol rate should be

$$f_{sym} = 4.5 \cdot \frac{684}{286} MHz \pm 30 Hz \approx 10,762,237.8 Hz \ \ (\pm 2.79\, ppm)$$

Notes:

1) The symbol rate $f_{sym}$ is required to be locked to the transport stream date rate $f_{tp}$ in the exact ratio

$$f_{sym} = \frac{1}{4} \cdot \frac{208}{188} \cdot \frac{313}{312} \cdot f_{tp}$$

The approximate value of $f_{tp}$ is: ~38,785,316.9 ±108 Hz.

2) The tolerances on $f_{sym}$ and $f_{tp}$ provide a reference suitable for generation of the NTSC color subcarrier frequency in devices which translate the digital signal to NTSC, with a tolerance of ±10 Hz.

### 5.2.4    Pilot Carrier Phase Noise and Jitter

The level of (pilot) carrier phase noise should be no greater than –104 dBc/Hz @ 20kHz offset from the carrier frequency.

### 5.2.5    Signal Level Specification

The service provider should provide, at the receiver, – 6 dBmV average DTV signal level in 6 MHz. Since the noise and other disturbances are specified with respect to the signal level, there is no effect on 16-VSB threshold and therefore no other signal level specification is required.

### 5.2.6    Frequency Offsets and Stability

The pilot carrier frequency tolerance should be ±1 kHz. Frequency offsets are not needed in a controlled signal level environment where DTV average power is at least 6 dB below adjacent channel NTSC peak-of-sync power.

### 5.2.7    Synchronization Signals

It can be expected that in cable operations the transmission modulator will sometimes be fed with corrupted MPEG transport packets, which can result in loss of, or incorrectly timed, sync and clock signals. In such cases, the receiver will go out of lock and thereby prolong the disruption of service.

The transmitted RF VSB symbol stream should retain continuity throughout the time of loss of MPEG-packets at the VSB modulator input. VSB segment and field syncs should be transmitted at all times, with no significant phase discontinuities, and the symbol clock frequency should remain within the ± 2.79 ppm tolerance without significant phase discontinuity. Once MPEG-data is determined to be absent or corrupted, a null MPEG transport packet should be inserted into the path prior to the VSB processing (i.e., randomizing, Reed Solomon encoding, interleaving, trellis encoding, etc.).