HD Radio™ AM Transmission

System Specifications

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TRADEMARKS

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Table of Contents

Contents

List of Figures

List of Tables

1 Scope

1.1 System Overview

The iBiquity Digital Corporation HD Radio™ system is designed to permit a smooth evolution from current analog amplitude modulation (AM) and frequency modulation (FM) radio to a fully digital in-band on-channel (IBOC) system. This system delivers digital audio and data services to mobile, portable, and fixed receivers from terrestrial transmitters in the existing medium frequency (MF) and very high frequency (VHF) radio bands. Broadcasters may continue to transmit analog AM and FM simultaneously with the new, higher-quality, and more robust digital signals, allowing themselves and their listeners to convert from analog to digital radio while maintaining their current frequency allocations.

1.2 Document Overview

This document details specifications of the iBiquity Digital Corporation HD Radio AM IBOC system. Included in this document are specifications that ensure reliable reception of the digital audio and data, provide precise digital-analog synchronization, define subcarrier power levels, and minimize harmful spectral emissions.

2 Reference Documents

STATEMENT
Each referenced document that is mentioned in this document shall be listed in the following iBiquity document:

- Reference Documents for the NRSC In-Band/On-Channel Digital Radio Broadcasting Standard Document Number: SY_REF_2690s

3 Abbreviations, Acronyms, and Conventions

3.1 Abbreviations and Acronyms

AM	Amplitude Modulation
BPSK	Binary Phase Shift Keying
FCC	Federal Communications Commission
FM	Frequency Modulation
GPS	Global Positioning System
IBOC	In-Band On-Channel
kbit/s	kilobits per second (thousand bits per second)
L1	Layer 1
L2	Layer 2
MER	Modulation Error Ratio
MF	Medium Frequency
MA1	Primary AM Hybrid Service Mode
MA3	Primary AM All Digital Service Mode
N/A	Not Applicable
NRSC	National Radio Systems Committee
OFDM	Orthogonal Frequency Division Multiplexing
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SSB	Single Side Band
VHF	Very High Frequency

3.2 Presentation Conventions

Unless otherwise noted, the following conventions apply to this document:

- All vectors are indexed starting with 0.
- The element of a vector with the lowest index is considered to be first.
- In drawings and tables, the leftmost bit is considered to occur first.
- Bit 0 of a byte or word is considered the least significant bit.
- In representations of binary numbers, the least significant bit is on the right.
- When presenting the dimensions of a matrix, the number of rows is given first (e.g., an n x m matrix has n rows and m columns).
- In timing diagrams, earliest time is on the left.

3.3 Arithmetic Operators

The arithmetic operators used throughout this document are defined below:

Category	Definition	Examples
| x |	Indicates the absolute value of x	| -5 | = 5 | 3 - 4 | = 1

4 AM Transmission Specifications

4.1 Introduction

This document presents the key transmission specifications for the AM HD Radio system.

4.2 Carrier Frequency and Channel Spacing

The HD Radio system operates in-band and on-channel, within the existing allocations and channel spacing as authorized by the FCC in accordance with [12]. The Hybrid and All Digital HD Radio waveforms are centered on the assigned AM band channel frequency.

4.3 Synchronization Tolerances

The system supports two levels of synchronization for broadcasters:

Level I: Network Synchronized (assumed using Global Positioning System (GPS) locked transmission facilities)

Level II: Non-networked Synchronized (non-GPS-locked transmission facilities)

It is recommended that transmission facilities operate as Level I facilities in order to support numerous advanced system features.

4.3.1 Analog Diversity Delay

The absolute accuracy of the analog diversity delay as defined in [2] in the transmission signal shall be within ±68 microseconds (μs) for both Synchronization Level I and Level II transmission facilities. This is equivalent to ±3 audio samples at a sampling rate of 44.1 kHz.

4.3.2 Time and Frequency Accuracy and Stability

The total modulation symbol-clock frequency absolute error of an HD Radio broadcast system shall meet the following requirements:

±0.01 ppm maximum for Synchronization Level I facilities

±1.0 ppm maximum for Synchronization Level II facilities

The total carrier frequency absolute error shall meet the following requirements:

The total (analog and digital) carrier frequency absolute error of a Synchronization Level I broadcast system as observed at the RF output shall be ±0.02 Hz maximum.

The total (analog and digital) carrier frequency absolute error of a Synchronization Level II broadcast system as observed at the RF output shall be ±2.0 Hz maximum.

4.3.3 L1 Frame Timing Phase

For Level I transmission facilities, all transmissions shall phase lock their L1 frame timing (and the timing of all OFDM symbols) to absolute GPS time within ±1 μs.

If the above specification in Synchronization Level I transmission facility is violated, due to a GPS outage or other occurrence, it shall be classified as a Synchronization Level II transmission facility until the above specification is again met.

4.4 AM Analog Host Performance (Hybrid Transmissions)

Hybrid service mode MA1 may be broadcast in one of several configurations. Normally, all of the primary, secondary, and tertiary subcarriers are enabled. In this case, some of the digital sidebands are superimposed in the same spectrum as the analog host signal. There are two different configurations available for this case. In the 5 kHz analog audio bandwidth configuration, the analog host shares the same spectrum as the tertiary subcarriers. In the 8 kHz analog audio bandwidth configuration, the analog host also shares its spectrum with a portion of the secondary subcarriers.

In addition, there is a reduced digital bandwidth configuration where the secondary and tertiary subcarriers are shut off. This configuration is selected by setting the RDB control signal to 1 as explained in [2]. In the reduced digital bandwidth configuration, it is possible to extend the analog audio bandwidth up to 9.4 kHz since there is no potential interference to the secondary or tertiary subcarriers. However, as explained in [30], there are various reasons why extending the analog audio bandwidth beyond 5 kHz is not recommended.

For each of the three configurations just described, the following information applies:

The analog signal shall meet the FCC emissions mask specifications contained in 47 CFR §73.44.

It is recommended that the host analog audio source be filtered according to the guidelines in [13]. In addition, the following RF performance specifications shall be met:

For Hybrid transmissions configured for the 5 kHz analog audio bandwidth configuration, the power spectral density of the modulated AM carrier measured with the HD Radio digital component disabled, at frequencies removed from the carrier frequency by more than 5 kHz and up to 20 kHz shall not exceed -65 dBc/300 Hz.

For Hybrid transmissions configured for the 8 kHz analog audio bandwidth configuration, the power spectral density of the modulated AM carrier measured with the HD Radio digital component disabled, at frequencies removed from the carrier frequency by more than 8 kHz and up to 20 kHz shall not exceed -65 dBc/300 Hz.

For Hybrid transmissions configured for the reduced digital bandwidth configuration (RDB=1), the power spectral density of the modulated AM carrier measured with the HD Radio digital component disabled, at frequencies removed from the carrier frequency by more than 9.4 kHz and up to 20 kHz shall not exceed -65 dBc/300 Hz.

Zero dBc is defined as the total power of the unmodulated AM carrier.

4.5 AM Spectral Emissions Limits

The spectral emissions limits for Hybrid transmissions are given in Subsections 4.5.1, 4.5.2, and 4.5.3.

The spectral emissions limits for All Digital transmissions are given in Subsection 4.5.4.

4.5.1 Spectral Emissions Limits for Hybrid Transmissions with 5 kHz Analog Bandwidth Configuration

For Hybrid transmissions, measurements of the combined analog and digital signals shall be made by averaging the power spectral density of the signal in a 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps. The measurement point and the test configuration shall be as described in Reference [26].

Zero dBc is defined as the total power of the unmodulated analog AM carrier.

Under normal operation with analog modulation present, the secondary and tertiary subcarriers enabled (RDB=0), and the analog audio bandwidth limited to 5 kHz, the following requirements shall be met at all times. These requirements are applicable for all states of the High Power PIDS (HPP) and Power Level (PL) controls described in [2].

Noise and spuriously generated signals from all sources, including phase noise and intermodulation products, shall conform to the limits as described in the following paragraph and shown in Figure 4-1 and Table 4-1*. These limits are applicable for all permissible power levels of the upper and lower sidebands, as defined in Subsection 4.6.

The measured power spectral density at frequencies greater than 5 kHz, up to and including 9.4 kHz, from the carrier frequency shall not exceed -34.3 dBc/300 Hz.

The measured power spectral density at frequencies greater than 9.4 kHz, up to and including 15 kHz, from the carrier frequency shall not exceed -26.8 dBc/300 Hz.

The measured power spectral density at frequencies greater than 15 kHz, up to and including 15.2 kHz, from the carrier frequency shall not exceed -28 dBc/300 Hz.

The measured power spectral density of the Hybrid signal at frequencies removed from the carrier frequency by more than 15.2 kHz, up to and including 15.8 kHz shall not exceed -39 - (|offset frequency in kHz| - 15.2) • 43.3 dBc/300 Hz.

The measured power spectral density of the Hybrid signal at frequencies removed from the carrier frequency by more than 15.8 kHz, up to and including 25 kHz shall not exceed -65 dBc/300 Hz.

The measured power spectral density of the Hybrid signal at frequencies removed from the carrier frequency by more than 25 kHz, up to and including 30.5 kHz shall not exceed -65 - (|offset frequency in kHz| - 25) • 1.273 dBc/300 Hz.

The measured power spectral density of the Hybrid signal at frequencies removed from the carrier frequency by more than 30.5 kHz, up to and including 75 kHz shall not exceed -72 - (|offset frequency in kHz| - 30.5) • 0.292 dBc/300 Hz.

The measured power spectral density of the Hybrid signal at frequencies removed from the carrier frequency by more than 75 kHz, shall not exceed -85 dBc/300 Hz.

If discrete components exceed the limits established in Table 4-1 and in Figure 4-1, the following conditions shall be met when averaging the power spectral density of the signal in each 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps.

1. No more than two discrete components within 75 kHz of the carrier frequency shall exceed the spectral emission limits by more than 10 dB.
2. No more than four discrete components removed from the carrier frequency by more than 75 kHz shall exceed the spectral emission limits by more than 5 dB.

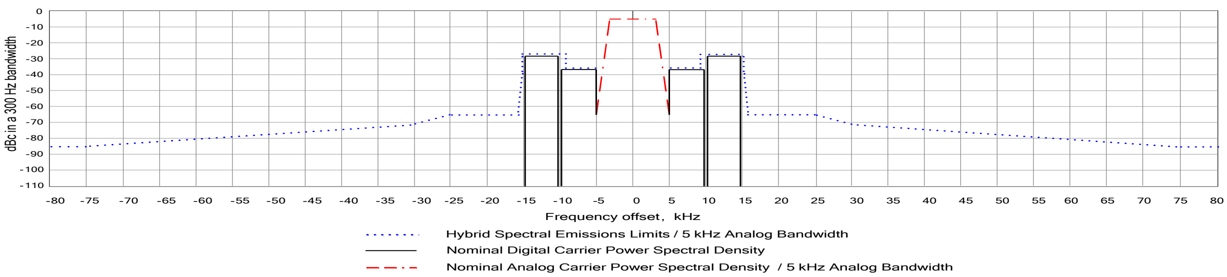

Figure 4-1: HD Radio AM Hybrid Waveform Spectral Emissions Limits for 5 kHz Analog Bandwidth Configuration

Table 4-1: HD Radio AM Hybrid Waveform Spectral Emissions Limits for 5 kHz Analog Bandwidth Configuration*

Frequency Offset Relative to Carrier	**Level Relative to Unmodulated Carrier (dBc per 300 Hz)**
5 to 9.4 kHz offset	-34.3
9.4 to 15 kHz offset	-26.8
15 to 15.2 kHz offset	-28
15.2 to 15.8 kHz offset	-39 - (|frequency offset in kHz| - 15.2) · 43.3
15.8 to 25 kHz offset	-65
25 kHz to 30.5 kHz offset	-65 - (|frequency offset in kHz| - 25) · 1.273
30.5 kHz to 75 kHz offset	-72 - (|frequency offset in kHz| - 30.5) · 0.292
> 75 kHz offset	-85

* The requirements for noise and spurious emission limits defined in this subsection reflect acceptable performance criteria. In certain circumstances, additional measures may be needed to reduce the spectral emissions below the limits given in this subsection in order to reduce mutual interference between broadcast stations.

4.5.2 Spectral Emissions Limits for Hybrid Transmissions with 8 kHz Analog Bandwidth Configuration

For hybrid transmissions, measurements of the combined analog and digital signals shall be made by averaging the power spectral density of the signal in a 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps. The measurement point and the test configuration shall be as described in Reference [26].

Zero dBc is defined as the total power of the unmodulated analog AM carrier.

Under normal operation with analog modulation present, the secondary and tertiary subcarriers enabled (RDB=0), and the analog audio bandwidth limited to 8 kHz, the following requirements shall be met at all times. These requirements are applicable for all states of the High Power PIDS (HPP) and Power Level (PL) controls described in [2].

Noise and spuriously generated signals from all sources, including phase noise and intermodulation products, shall conform to the limits as described in the following paragraph and shown in Figure 4-2 and Table 4-2†. These limits are applicable for all permissible power levels of the upper and lower sidebands, as defined in Subsection 4.6.

The measured power spectral density at frequencies greater than 8 kHz, up to and including 9.4 kHz, from the carrier frequency shall not exceed -34.3 dBc/300 Hz.

The measured power spectral density at frequencies greater than 9.4 kHz, up to and including 15 kHz, from the carrier frequency shall not exceed -26.8 dBc/300 Hz.

The measured power spectral density at frequencies greater than 15 kHz, up to and including 15.2 kHz, from the carrier frequency shall not exceed -28 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 15.2 kHz, up to and including 15.8 kHz shall not exceed -39 - (|offset frequency in kHz| - 15.2) • 43.3 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 15.8 kHz, up to and including 25 kHz shall not exceed -65 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 25 kHz, up to and including 30.5 kHz shall not exceed -65 - (|offset frequency in kHz| - 25) • 1.273 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 30.5 kHz, up to and including 75 kHz shall not exceed -72 - (|offset frequency in kHz| - 30.5) • 0.292 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 75 kHz, shall not exceed -85 dBc/300 Hz.

If discrete components exceed the limits established in Table 4-2 and in Figure 4-2, the following conditions shall be met when averaging the power spectral density of the signal in each 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps:

1. No more than two discrete components within 75 kHz of the carrier frequency shall exceed the spectral emission limits by more than 10 dB.
2. No more than four discrete components removed from the carrier frequency by more than 75 kHz shall exceed the spectral emission limits by more than 5 dB.

When a station operates in the Hybrid 8 kHz configuration, an HD Radio receiver will treat the enhanced carriers as complimentary. Complimentary carriers require that both the upper and lower sidebands be recovered for demodulation. Therefore, in the 8 kHz configuration, digital coverage of a Hybrid station may be adversely impacted by adjacent transmission. The severity of the impact will be dependent upon whether the interference is from a first or second adjacent and if it is an Analog, Hybrid or All Digital transmission.

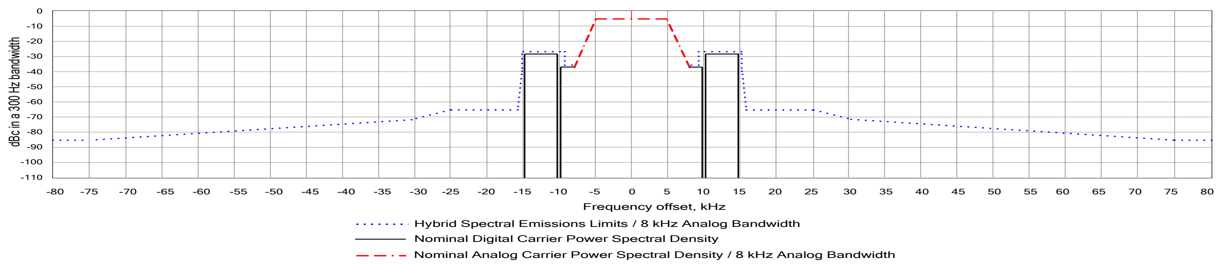

Figure 4-2: HD Radio AM Hybrid Waveform Spectral Emissions Limits for 8 kHz Analog Bandwidth Configuration

Table 4-2: HD Radio AM Hybrid Waveform Spectral Emissions Limits for 8 kHz Analog Bandwidth Configuration†

Frequency Offset Relative to Carrier	**Level Relative to Unmodulated Carrier (dBc per 300 Hz)**
8 to 9.4 kHz offset	-34.3
9.4 to 15 kHz offset	-26.8
15 to 15.2 kHz offset	-28
15.2 to 15.8 kHz offset	-39 - (|frequency offset in kHz| - 15.2) · 43.3
15.8 to 25 kHz offset	-65
25 kHz to 30.5 kHz offset	-65 - (|frequency offset in kHz| - 25) · 1.273
30.5 kHz to 75 kHz offset	-72 - (|frequency offset in kHz| - 30.5) · 0.292
> 75 kHz offset	-85

† The requirements for noise and spurious emission limits defined in this subsection reflect acceptable performance criteria. In certain circumstances, additional measures may be needed to reduce the spectral emissions below the limits given in this subsection in order to reduce mutual interference between broadcast stations.

4.5.3 Spectral Emissions Limits for Hybrid Transmissions with Reduced Digital Bandwidth Configuration

As described in [2], the system provides for a reduced digital bandwidth configuration where the secondary and tertiary subcarriers are disabled. This configuration is selected by setting the control signal RDB to 1. This subsection discusses the spectral emissions limits for such a configuration.

For hybrid transmissions, measurements of the combined analog and digital signals shall be made by averaging the power spectral density of the signal in a 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps. The measurement point and the test configuration shall be as described in Reference [26].

Zero dBc is defined as the total power of the unmodulated analog AM carrier.

In the reduced digital bandwidth configuration, under normal operation with analog modulation present and the analog audio bandwidth limited to no more than 9.4 kHz, the following requirements shall be met at all times:

Noise and spuriously generated signals from all sources, including phase noise and intermodulation products, shall conform to the limits as described in the following paragraph and shown in Figure 4-4 and Table 4-4†. These limits are applicable for all permissible power levels of the upper and lower sidebands, as defined in Subsection 4.6.

The measured power spectral density at frequencies greater than 9.4 kHz, up to and including 15 kHz, from the carrier frequency shall not exceed -26.8 dBc/300 Hz.

The measured power spectral density at frequencies greater than 15 kHz, up to and including 15.2 kHz, from the carrier frequency shall not exceed -28 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 15.2 kHz, up to and including 15.8 kHz shall not exceed -39 - (|offset frequency in kHz| - 15.2) • 43.3 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 15.8 kHz, up to and including 25 kHz shall not exceed -65 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 25 kHz, up to and including 30.5 kHz shall not exceed -65 - (|offset frequency in kHz| - 25) • 1.273 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 30.5 kHz, up to and including 75 kHz shall not exceed -72 - (|offset frequency in kHz| - 30.5) • 0.292 dBc/300 Hz.

The measured power spectral density of the hybrid signal at frequencies removed from the carrier frequency by more than 75 kHz, shall not exceed -85 dBc/300 Hz.

If discrete components exceed the limits established in Table 4-2 and in Figure 4-2, the following conditions shall be met when averaging the power spectral density of the signal in each 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps:

1. No more than two discrete components within 75 kHz of the carrier frequency shall exceed the spectral emission limits by more than 10 dB.
2. No more than four discrete components removed from the carrier frequency by more than 75 kHz shall exceed the spectral emission limits by more than 5 dB.

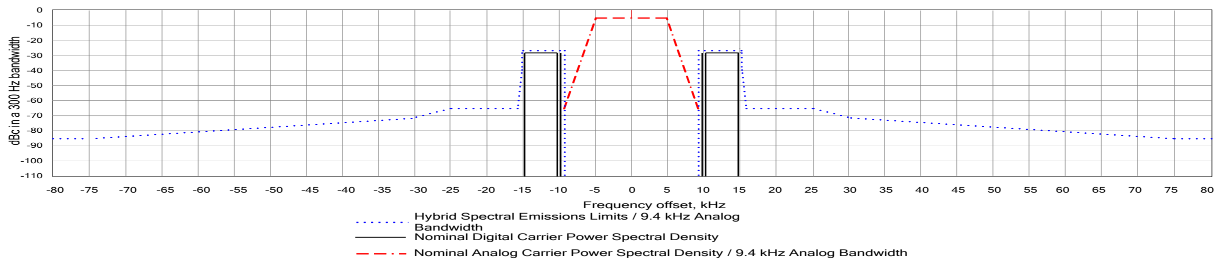

Figure 4-3: HD Radio AM Hybrid Waveform Spectral Emissions Limits for RDB=1 Configuration

Table 4-3: HD Radio AM Hybrid Waveform Spectral Emissions Limits for RDB=1 Configuration†

Frequency Offset Relative to Carrier	Level Relative to Unmodulated Carrier (dBc per 300 Hz)
9.4 to 15 kHz offset	-26.8
15 to 15.2 kHz offset	-28
15.2 to 15.8 kHz offset	-39 - (|frequency offset in kHz| - 15.2) · 43.3
15.8 to 25 kHz offset	-65
25 kHz to 30.5 kHz offset	-65 - (|frequency offset in kHz| - 25) · 1.273
30.5 kHz to 75 kHz offset	-72 - (|frequency offset in kHz| - 30.5) · 0.292
> 75 kHz offset	-85

† The requirements for noise and spurious emission limits defined in this subsection reflect acceptable performance criteria. In certain circumstances, additional measures may be needed to reduce the spectral emissions below the limits given in this subsection in order to reduce mutual interference between broadcast stations.

4.5.4 Spectral Emissions Limits for All Digital Transmissions

For All Digital transmissions, measurements of the All Digital signal shall be made by averaging the power spectral density in a 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps. The measurement point and the test configuration shall be as described in Reference [26].

Zero dBc is defined as the allocated power of the unmodulated analog AM carrier and is equal to the reference level used in Subsection 4.5.1.

Under normal operation, the following requirements shall be met at all times. These requirements apply regardless of the waveform configuration; i.e., the spectral emissions limits are applicable for all states of the High Power PIDS (HPP) and Power Level (PL) controls.

Noise and spuriously generated signals from all sources including phase noise and intermodulation products, shall conform to the limits as described in the following paragraph and as shown in Figure 4-4 and Table 4-4‡.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 0.3 kHz, up to and including 5.0 kHz shall not exceed -12.3 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 5.0 kHz, up to and including 5.9 kHz shall not exceed -12.3 - (|frequency offset in kHz| - 5.0) · 16.67 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 5.9 kHz, up to and including 10.0 kHz shall not exceed -27.3 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 10.0 kHz, up to and including 11.2 kHz shall not exceed -27.3 - (|frequency offset in kHz| - 10.0) · 23.08 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 11.2 kHz, up to and including 20.0 kHz shall not exceed -55 - (|frequency offset in kHz| - 11.2) · 1.25 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 20.0 kHz, up to and including 30.0 kHz shall not exceed -66 - (|frequency offset in kHz| - 20.0) · 0.6 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 30.0 kHz, up to and including 60.0 kHz shall not exceed -72 - (|frequency offset in kHz| - 30) · 0.27 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 60 kHz, shall not exceed -80 dBc/300 Hz.

If discrete components exceed the limits established in Table 4-4 and in Figure 4-4, the following conditions shall be met when averaging the power spectral density of the signal in each 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps:

1. No more than two discrete components within 75 kHz of the carrier frequency shall exceed the spectral emission limits by more than 10 dB.
2. No more than four discrete components removed from the carrier frequency by more than 75 kHz shall exceed the spectral emission limits by more than 5 dB.

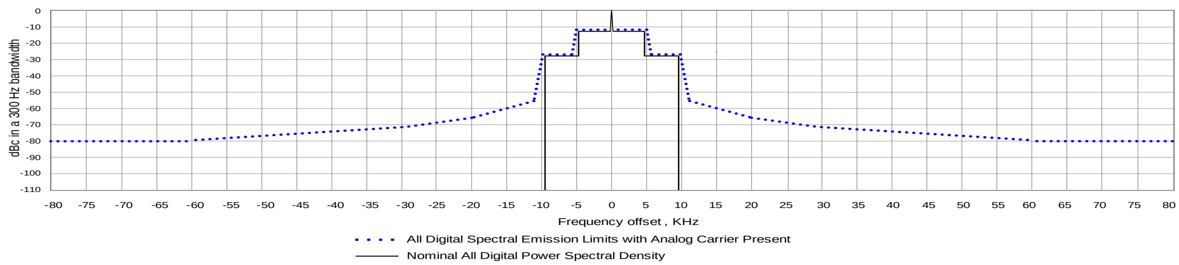

Figure 4-4: HD Radio AM All Digital Waveform Spectral Emissions Limits

Table 4-4: HD Radio AM All Digital Waveform Spectral Emissions Limits‡

Frequency Offset Relative to Carrier	**Level Relative to Unmodulated Carrier (dBc per 300 Hz)**
0.3 kHz to 5.0 kHz offset	-12.3
5.0 kHz to 5.9 kHz offset	-12.3 - (|frequency offset in kHz| - 5.0) · 16.67
5.9 kHz to 10.0 kHz offset	-27.3
10.0 to 11.2 kHz offset	-27.3 - (|frequency offset in kHz| - 10.0) · 23.08
11.2 to 20.0 kHz offset	-55 - (|frequency offset in kHz| - 11.2) · 1.25
20.0 to 30.0 kHz offset	-66 - (|frequency offset in kHz| - 20.0) · 0.6
30.0 to 60.0 kHz offset	-72 - (|frequency offset in kHz| - 30) · 0.27
> 60 kHz offset	-80

‡ The requirements for noise and spurious emission limits defined in this subsection reflect acceptable performance criteria. In certain circumstances, additional measures may be needed to reduce the spectral emissions below the limits given in this subsection in order to reduce mutual interference between broadcast stations.

4.5.5 Spectral Emissions Limits for All Digital Transmissions with Reduced Digital Bandwidth Configuration

As described in [2], the system provides for a reduced digital bandwidth configuration where the secondary and tertiary subcarriers are disabled. This configuration is selected by setting the control signal RDB to 1. This subsection discusses the spectral emissions limits for such a configuration.

For All Digital transmissions in the reduced digital bandwidth configuration, measurements of the All Digital signal shall be made by averaging the power spectral density in a 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps. The measurement point and the test configuration shall be as described in Reference [26].

Zero dBc is defined as the allocated power of the unmodulated analog AM carrier and is equal to the reference level used in Subsection 4.5.1.

Under normal operation, the following requirements shall be met at all times. These requirements apply regardless of the waveform configuration; i.e., the spectral emissions limits are applicable for all states of the High Power PIDS (HPP) and Power Level (PL) controls.

Noise and spuriously generated signals from all sources including phase noise and intermodulation products, shall conform to the limits as described in the following paragraph and as shown in Figure 4-5 and Table 4-5‡.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 0.3 kHz, up to and including 5.0 kHz shall not exceed -12.3 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 5.0 kHz, up to and including 7.0 kHz shall not exceed -12.3 - (|frequency offset in kHz| - 5.0) · 17.35 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 7.0 kHz, up to and including 10.4 kHz shall not exceed -47 - (|frequency offset in kHz| - 7.0) · 2.06 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 10.4 kHz, up to and including 20.0 kHz shall not exceed -54 - (|frequency offset in kHz| - 10.4) · 1.25 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 20.0 kHz, up to and including 30.0 kHz shall not exceed -66 - (|frequency offset in kHz| - 20.0) · 0.60 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 30.0 kHz, up to and including 60.0 kHz shall not exceed -72 - (|frequency offset in kHz| - 30.0) · 0.27 dBc/300 Hz.

The measured power spectral density of the All Digital signal at frequencies removed from the carrier frequency by more than 60 kHz, shall not exceed -80 dBc/300 Hz.

If discrete components exceed the limits established in Table 4-5 and in Figure 4-5, the following conditions shall be met when averaging the power spectral density of the signal in each 300-Hz bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps:

1. No more than two discrete components within 75 kHz of the carrier frequency shall exceed the spectral emission limits by more than 10 dB.
2. No more than four discrete components removed from the carrier frequency by more than 75 kHz shall exceed the spectral emission limits by more than 5 dB.

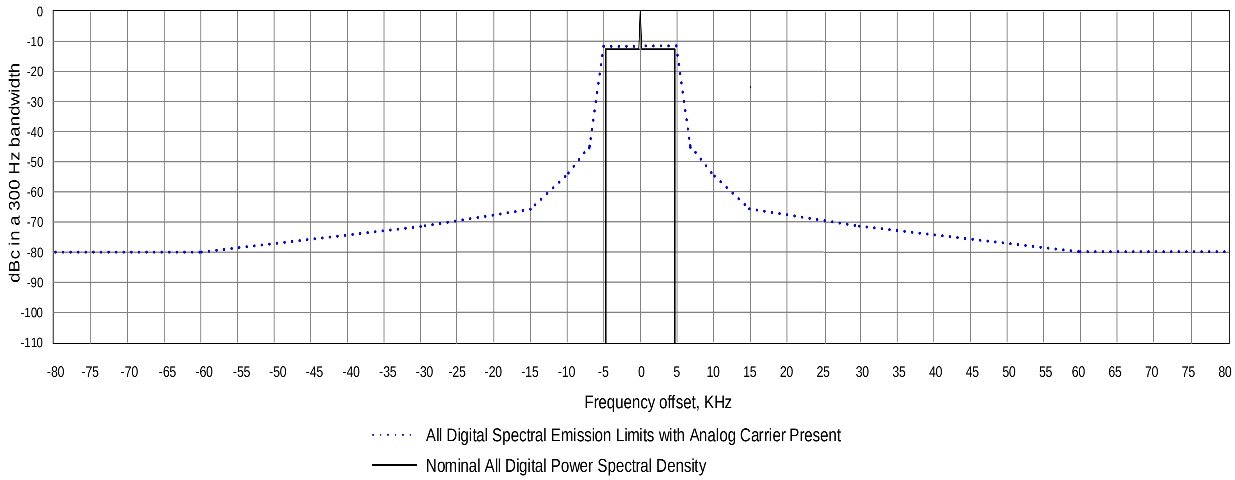

Figure 4-5: HD Radio AM All Digital Waveform Spectral Emissions Limits for RDB=1 Configuration

Table 4-5: HD Radio AM All Digital Waveform Spectral Emissions Limits for RDB=1 Configuration ‡

Frequency Offset Relative to Carrier	Level Relative to Unmodulated Carrier (dBc per 300 Hz)
0.3 Hz to 5.0 Hz offset	-12.3
5.0 Hz to 7.0 kHz offset	-12.3 - (|frequency offset in kHz| - 5.0) · 17.35
7.0 to 10.4 kHz offset	-47 - (|frequency offset in kHz| - 7.0) · 2.06
10.4 to 20.0 kHz offset	-54 - (|frequency offset in kHz| - 10.4) · 1.25
20.0 to 30.0 kHz offset	-66 - (|frequency offset in kHz| - 20.0) · 0.60
30.0 to 60.0 kHz offset	-72 - (|frequency offset in kHz| - 30.0) · 0.27
> 60 kHz offset	-80

‡ The requirements for noise and spurious emission limits defined in this subsection reflect acceptable performance criteria. In certain circumstances, additional measures may be needed to reduce the spectral emissions below the limits given in this subsection in order to reduce mutual interference between broadcast stations.

4.6 Digital Sideband Levels

The amplitude scaling of each OFDM subcarrier within each digital sideband is given in Table 4-6 for the Hybrid and All Digital waveforms. The amplitude scale factors are such that the average power in the constellation for that subcarrier meets the average per subcarrier power spectral density shown in dB.

For both the Hybrid and All Digital waveforms, the subcarrier levels are specified relative to the total power of the unmodulated analog AM carrier (assumed equal to 1).

Refer to [2] for a description of how the various scale factors are selected and applied to the various waveforms.

In service mode MA1, the power of one primary sideband may be scaled downward if necessary to reduce potential interference to another broadcast on an adjacent channel. However, all of the other sidebands must maintain the levels shown in Table 4-6.

In service mode MA3, asymmetric sideband operation is not permitted.

Refer to Figure 4-6 through Figure 4-10 for illustrations of how the scale factors are applied for each of the service mode MA1 configurations. In each of these figures, the typical case of symmetric sideband operation is shown.

Optionally, asymmetric sideband operation is permissible for each of the MA1 configurations. Refer to Figure 4-11 for an illustration of asymmetric sideband operation. Such operation is possible in all MA1 configurations. However, only the configuration of RDB=0, PL-0, and HPP=0 is shown. Note that the outer PIDS subcarriers are scaled according to the individual primary sideband levels.

Refer to Figure 4-12 through Figure 4-14 for illustrations of how the scale factors are applied for each of the service mode MA3 configurations.

Table 4-6: OFDM Subcarrier Amplitude Scaling

Waveform	Service Mode	Sidebands	Amplitude Scale Factor Notation	Modulation Type	Nominal Power Spectral Density, dBc/Subcarrier	Nominal Power Spectral Density in a 300 Hz Bandwidth, dBc
Hybrid	MA1	Primary Upper	CH_{PU}	64-QAM	-30 (Note 1, 2)	-27.8
		Primary Lower	CH_{PL}	64-QAM	-30 (Note 1, 2)	-27.8
		Secondary Upper	CH_{S1}	16-QAM	-43	-40.8
			CH_{S2}	16-QAM	-37	-34.8
		Secondary Lower	CH_{S1}	16-QAM	-43	-40.8
			CH_{S2}	16-QAM	-37	-34.8
		Tertiary Upper	$\underline{CH}_{T1}[0]$	QPSK	-44	-41.8
			$\underline{CH}_{T1}[1]$	QPSK	-44.5	-42.8
			$\underline{CH}_{T1}[2]$	QPSK	-45	-42.8
			$\underline{CH}_{T1}[3]$	QPSK	-45.5	-43.3
			$\underline{CH}_{T1}[4]$	QPSK	-46	-43.8
			$\underline{CH}_{T1}[5]$	QPSK	-46.5	-44.3
			$\underline{CH}_{T1}[6]$	QPSK	-47	-44.8

Waveform	**Service Mode**	**Sidebands**	**Amplitude Scale Factor Notation**	**Modulation Type**	**Nominal Power Spectral Density, dBc/Subcarrier**	**Nominal Power Spectral Density in a 300 Hz Bandwidth, dBc**
			$\underline{CH}_{T1}$ [7]	QPSK	-47.5	-45.3
			$\underline{CH}_{T1}$ [8]	QPSK	-48	-45.8
			$\underline{CH}_{T1}$ [9]	QPSK	-48.5	-46.3
			$\underline{CH}_{T1}$ [10]	QPSK	-49	-46.8
			$\underline{CH}_{T1}$ [11]	QPSK	-49.5	-47.3
			$\underline{CH}_{T1}$ [12:24]	QPSK	-50	-47.8
			$\underline{CH}_{T2}$ [0:24]	QPSK	-44	-41.8
		Tertiary Lower	$\underline{CH}_{T1}$ [0]	QPSK	-44	-41.8
			$\underline{CH}_{T1}$ [1]	QPSK	-44.5	-42.8
			$\underline{CH}_{T1}$ [2]	QPSK	-45	-42.8
			$\underline{CH}_{T1}$ [3]	QPSK	-45.5	-43.3
			$\underline{CH}_{T1}$ [4]	QPSK	-46	-43.8
			$\underline{CH}_{T1}$ [5]	QPSK	-46.5	-44.3
			$\underline{CH}_{T1}$ [6]	QPSK	-47	-44.8
			$\underline{CH}_{T1}$ [7]	QPSK	-47.5	-45.3
			$\underline{CH}_{T1}$ [8]	QPSK	-48	-45.8
			$\underline{CH}_{T1}$ [9]	QPSK	-48.5	-46.3
			$\underline{CH}_{T1}$ [10]	QPSK	-49	-46.8
			$\underline{CH}_{T1}$ [11]	QPSK	-49.5	-47.3
			$\underline{CH}_{T1}$ [12:24]	QPSK	-50	-47.8
			$\underline{CH}_{T2}$ [0:24]	QPSK	-44	-41.8
Hybrid	MA1	Reference Upper	CH_B	BPSK	-26	-23.8
		Reference Lower	CH_B	BPSK	-26	-23.8
		PIDS1	CH_{I1}	16-QAM	-43	-40.8
			CH_{I2}	16-QAM	-37	-34.8
		PIDS2	$CH_{PU} \cdot CH_{I3}$	16-QAM	-13 dB_{PU} (Note 3)	-13 dB_{PU} (Note 4)
			$CH_{PU} \cdot CH_{I4}$	16-QAM	-7 dB_{PU} (Note 3)	-7 dB_{PU} (Note 4)
			$CH_{PU} \cdot CH_{I5}$	16-QAM	0 dB_{PU} (Note 3)	0 dB_{PU} (Note 4)
		PIDS1*	CH_{I1}	16-QAM	-43	-40.8
			CH_{I2}	16-QAM	-37	-34.8
		PIDS2*	$CH_{PL} \cdot CH_{I3}$	16-QAM	-13 dB_{PL} (Note 5)	-13 dB_{PL} (Note 6)
			$CH_{PL} \cdot CH_{I4}$	16-QAM	-7 dB_{PL} (Note 5)	-7 dB_{PL} (Note 6)
			$CH_{PL} \cdot CH_{I5}$	16-QAM	0 dB_{PL} (Note 5)	0 dB_{PL} (Note 6)

Waveform	Service Mode	Sidebands	Amplitude Scale Factor Notation	Modulation Type	Nominal Power Spectral Density, dBc/Subcarrier	Nominal Power Spectral Density in a 300 Hz Bandwidth, dBc
All Digital	MA3	Primary Upper	CD_P	64-QAM	-15 (Note 7)	-12.8 (Note 7)
		Primary Lower	CD_P	64-QAM	-15 (Note 7)	-12.8 (Note 7)
		Secondary	CD_E	64-QAM	-30	-27.8
		Tertiary	CD_E	64-QAM	-30	-27.8
		Reference Upper	CD_B	BPSK	-15	-12.8
		Reference Lower	CD_B	BPSK	-15	-12.8
		PIDS1	$CD_P \cdot CH_{I1}$	16-QAM	-15 dB_{PU} (Note 8)	-15 dB_{PU} (Note 9)
			$CD_P \cdot CH_{I2}$	16-QAM	0 dB_{PU} (Note 8)	0 dB_{PU} (Note 9)
		PIDS2	$CD_P \cdot CH_{I1}$	16-QAM	-15 dB_{PL} (Note 10)	-15 dB_{PL} (Note 11)
			$CD_P \cdot CH_{I2}$	16-QAM	0 dB_{PL} (Note 10)	0 dB_{PL} (Note 11)

Notes:

1. In service mode MA1, the power spectral density of either the primary upper or primary lower sideband may be adjusted downward to any value provided that none of the specifications in Subsection 4.10 are violated.
2. In service mode MA1, only one primary sideband may be adjusted downward in power. The other sideband shall maintain its maximum power level.
3. The unit dB_{PU} refers to the power relative to the Primary Upper sideband. CH_{I3}, CH_{I4}, and CH_{I5} are adjusted so that the power spectral density (dBc per subcarrier) of the PIDS2 subcarrier has the value shown relative to the power spectral density of the Primary Upper sideband. For example, CH_{I3} is adjusted so that the power spectral density of the PIDS2 subcarrier is 13 dB below that of the Primary Upper sideband.
4. The unit dB_{PU} refers to the power relative to the Primary Upper sideband. CH_{I3}, CH_{I4}, and CH_{I5} are adjusted so that the power spectral density (in a 300-Hz bandwidth) of the PIDS2 subcarrier has the value shown relative to the power spectral density (in a 300-Hz bandwidth) of the Primary Upper sideband. For example, CH_{I3} is adjusted so that the power spectral density (in a 300-Hz bandwidth) of the PIDS2 subcarrier is 13 dB below that of the Primary Upper sideband.
5. The unit dB_{PL} refers to the power relative to the Primary Lower sideband. CH_{I3}, CH_{I4}, and CH_{I5} are adjusted so that the power spectral density (dBc per subcarrier) of the PIDS2* subcarrier has the value shown relative to the power spectral density of the Primary Lower sideband. For example, CH_{I3} is adjusted so that the power spectral density of the PIDS2* subcarrier is 13 dB below that of the Primary Lower sideband.

6. The unit dB_{PL} refers to the power relative to the Primary Lower sideband. CH_{I3}, CH_{I4}, and CH_{I5} are adjusted so that the power spectral density (in a 300-Hz bandwidth) of the PIDS2* subcarrier has the value shown relative to the power spectral density (in a 300-Hz bandwidth) of the Primary Lower sideband. For example, CHI3 is adjusted so that the power spectral density (in a 300-Hz bandwidth) of the PIDS2* subcarrier is 13 dB below that of the Primary Lower sideband.
7. In service mode MA3, both primary sidebands shall be set to the maximum power spectral density values shown. The level is not adjustable.
8. The unit dB_{PU} refers to the power relative to the Primary Upper sideband. CD_{I1} and CD_{I2} are adjusted so that the power spectral density (dBc per subcarrier) of the PIDS1 subcarrier has the value shown relative to the power spectral density of the Primary Upper sideband. For example, CD_{I1} is adjusted so that the power spectral density of the PIDS1 subcarrier is 15 dB below that of the Primary Upper sideband.
9. The unit dB_{PU} refers to the power relative to the Primary Upper sideband. CD_{I1} and CD*I2* are adjusted so that the power spectral density (in a 300-Hz bandwidth) of the PIDS1 subcarrier has the value shown relative to the power spectral density (in a 300-Hz bandwidth) of the Primary Upper sideband. For example, CD_{I1} is adjusted so that the power spectral density (in a 300-Hz bandwidth) of the PIDS1 subcarrier is 15 dB below that of the Primary Upper sideband.
10. The unit dB_{PL} refers to the power relative to the Primary Lower sideband. CD_{I1} and CD_{I2} are adjusted so that the power spectral density (dBc per subcarrier) of the PIDS2 subcarrier has the value shown relative to the power spectral density of the Primary Lower sideband. For example, CD_{I1} is adjusted so that the power spectral density of the PIDS2 subcarrier is 15 dB below that of the Primary Lower sideband.
11. The unit dB_{PL} refers to the power relative to the Primary Lower sideband. CD_{I1} and CD_{I2} are adjusted so that the power spectral density (in a 300-Hz bandwidth) of the PIDS2 subcarrier has the value shown relative to the power spectral density (in a 300-Hz bandwidth) of the Primary Lower sideband. For example, CD_{I1} is adjusted so that the power spectral density (in a 300-Hz bandwidth) of the PIDS2 subcarrier is 15 dB below that of the Primary Lower sideband.

MA1, RDB=0, HPP=0, PL=0

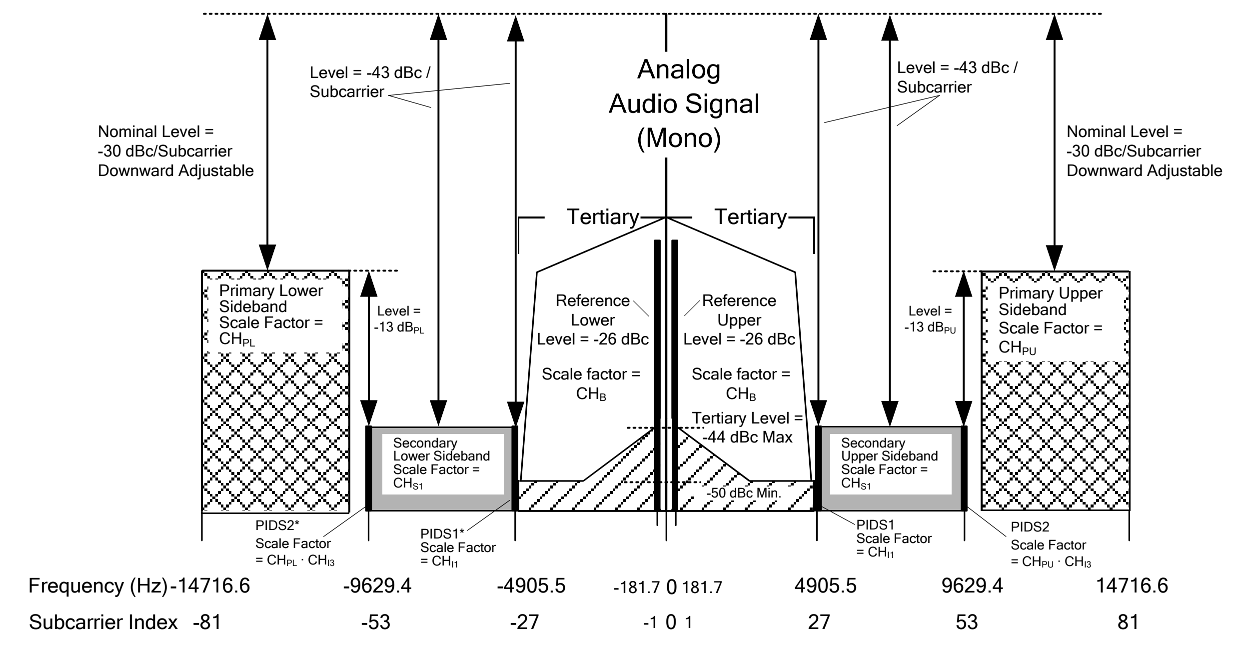

Figure 4-6: MA1, RDB=0, HPP=0, PL-0 – Symmetrical Sidebands

MA1, RDB=0, HPP=0, PL=1

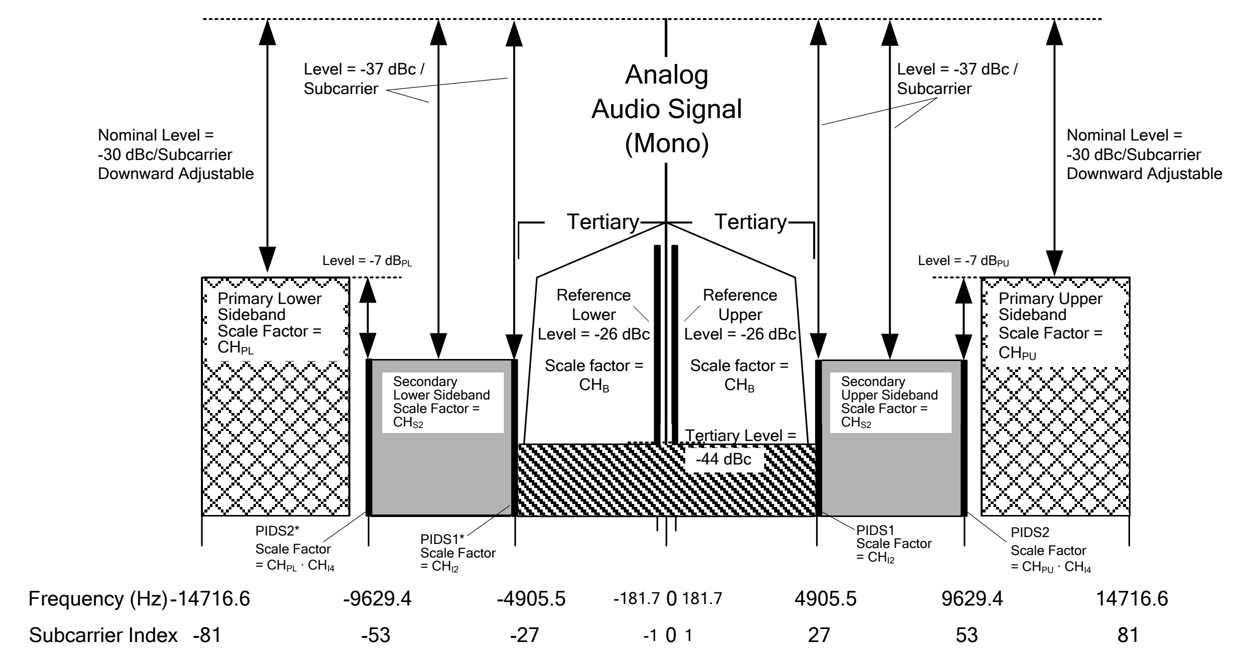

Figure 4-7: MA1, RDB=0, HPP=0, PL=1 – Symmetrical Sidebands

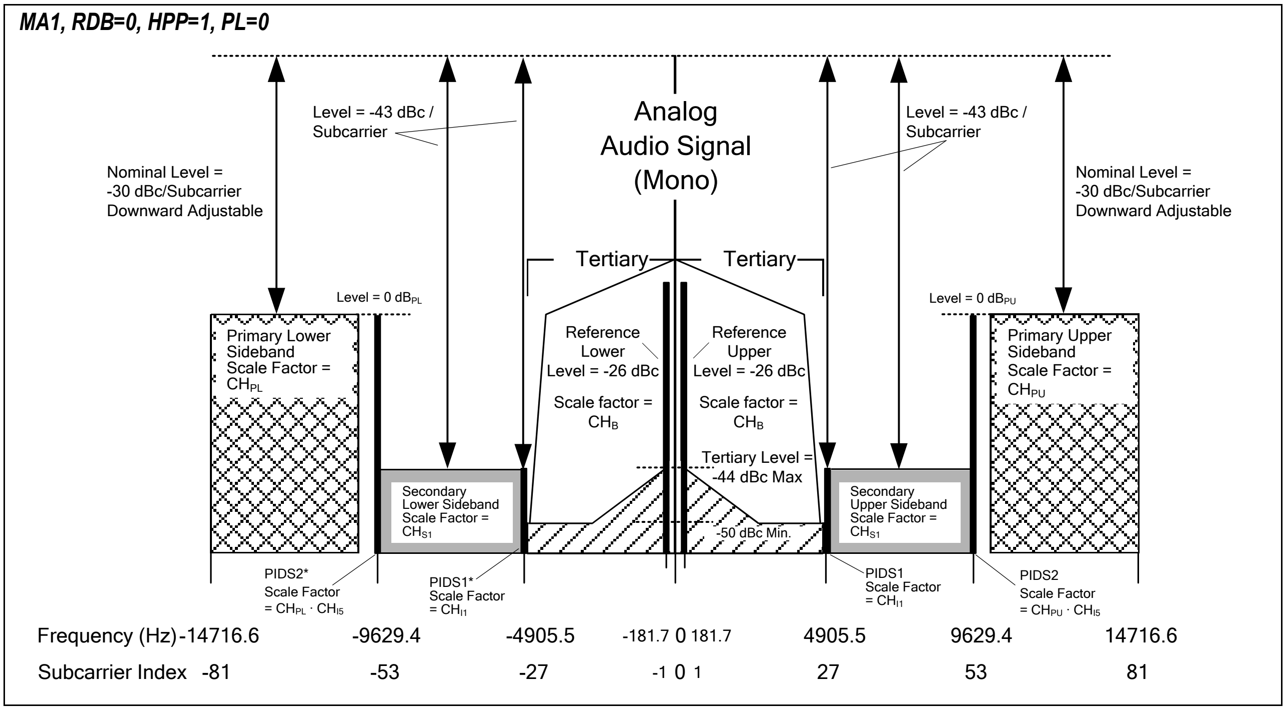

Figure 4-8: MA1, RDB=0, HPP=1, PL=0 – Symmetrical Sidebands

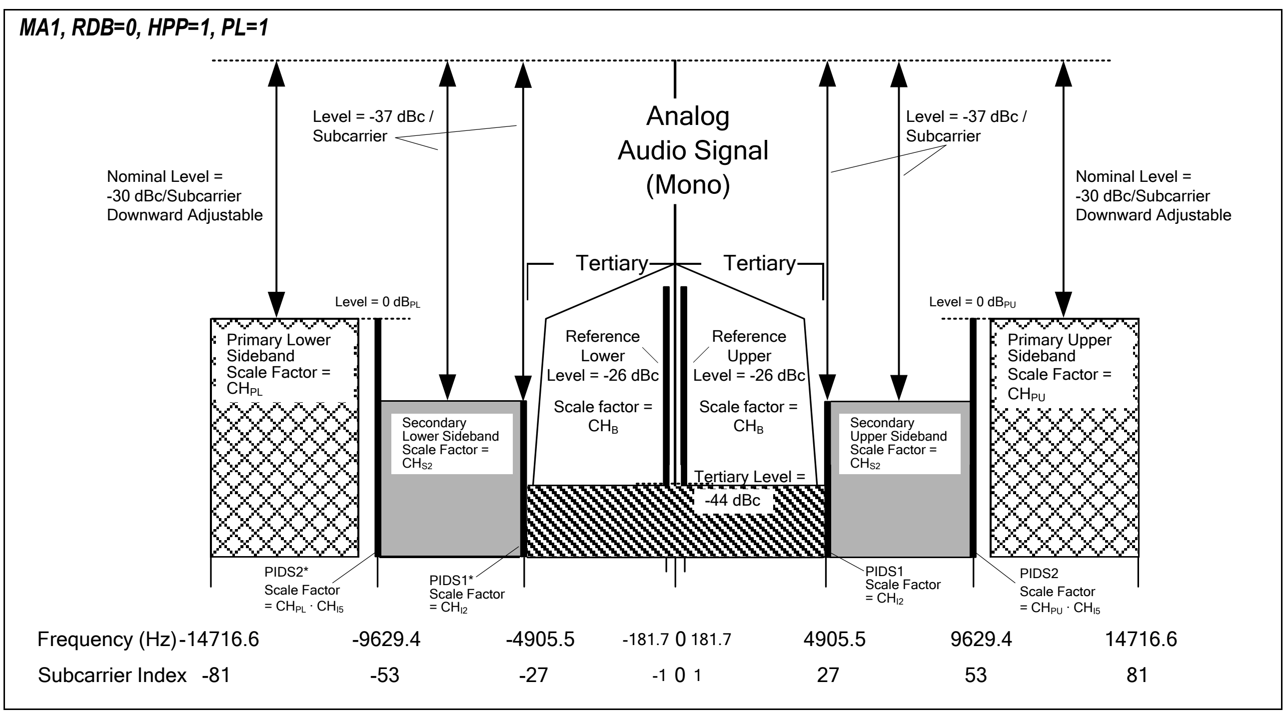

Figure 4-9: MA1, RDB=0, HPP=1, PL=1 – Symmetrical Sidebands

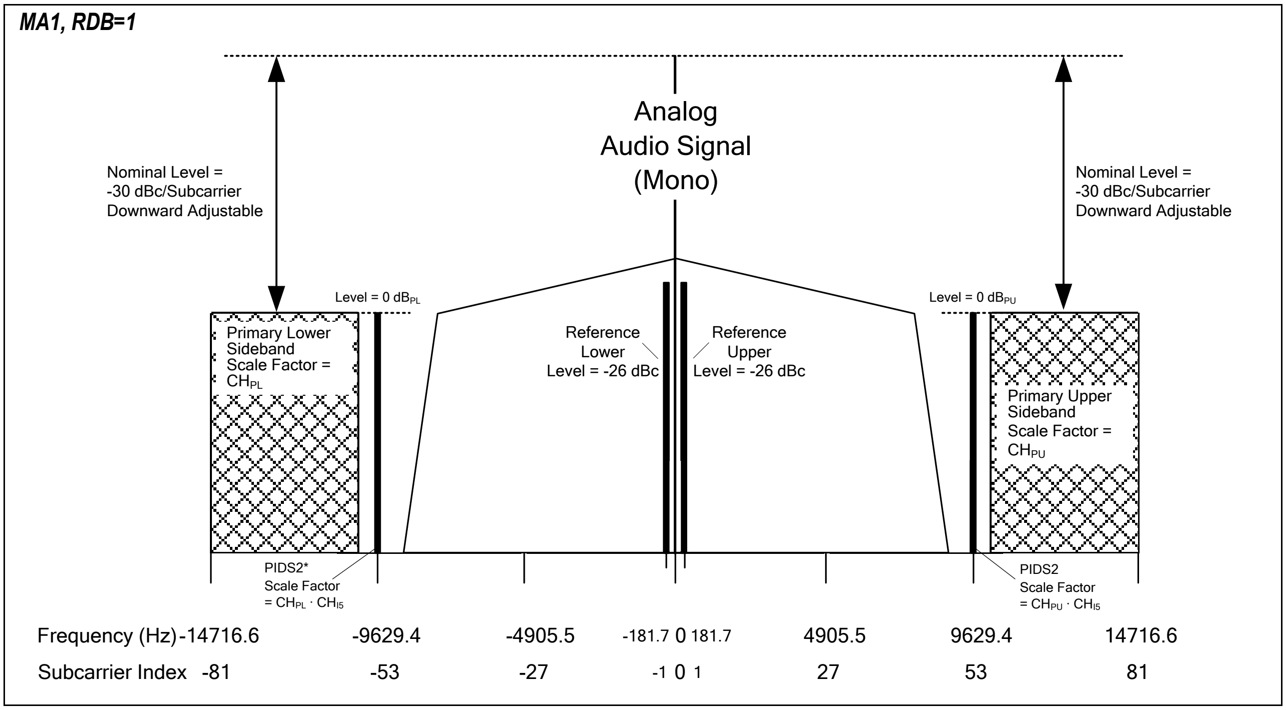

Figure 4-10: MA1, RDB=1 – Symmetrical Sidebands

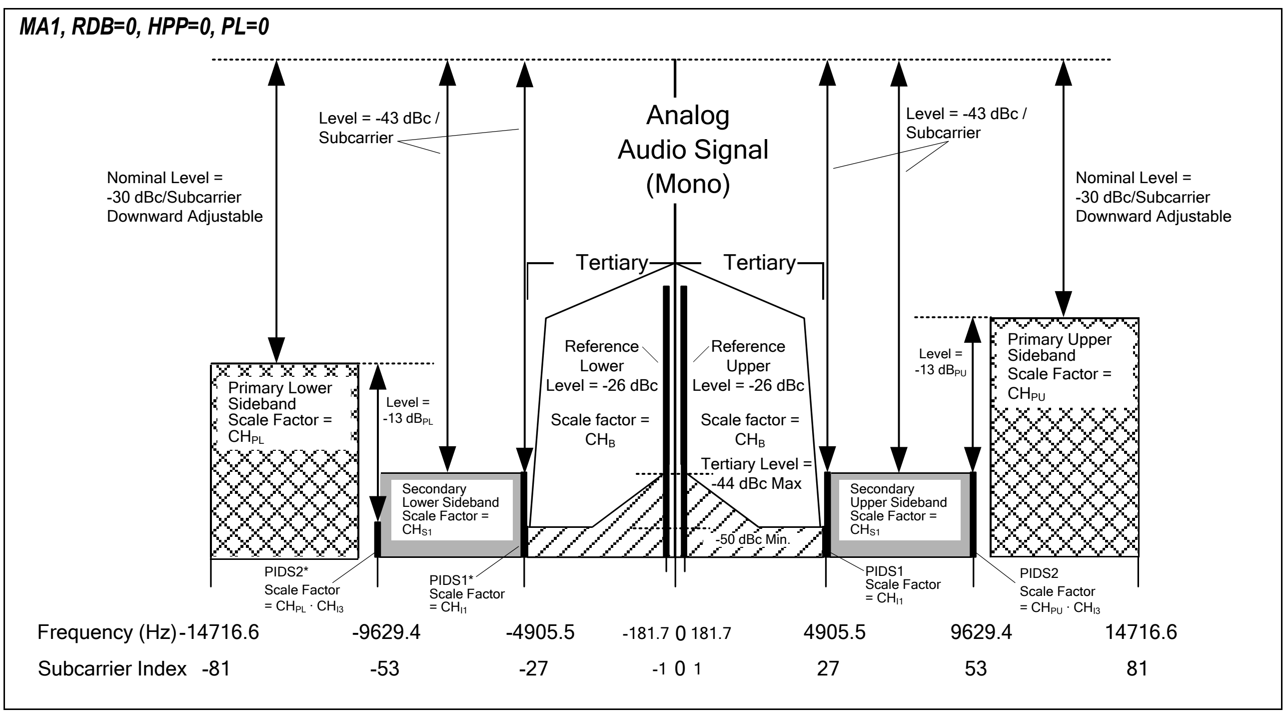

Figure 4-11: MA1, RDB=0, HPP=0, PL-0 – Asymmetrical Sidebands

NOTE

In Figure 4-11, the Primary Upper and Lower Sidebands are shown to have different power levels to illustrate an asymmetrical sideband configuration. Normally the two sidebands are equal, but may be different under special operational scenarios.

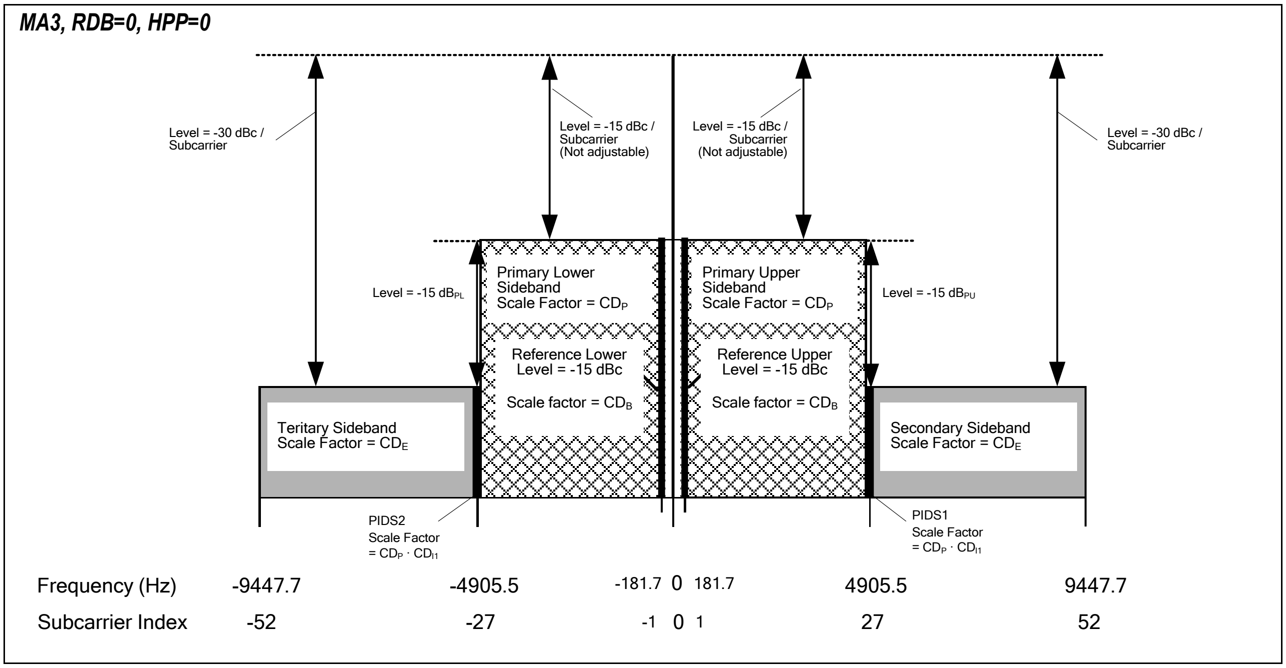

Figure 4-12: MA3, RDB=0, HPP=0

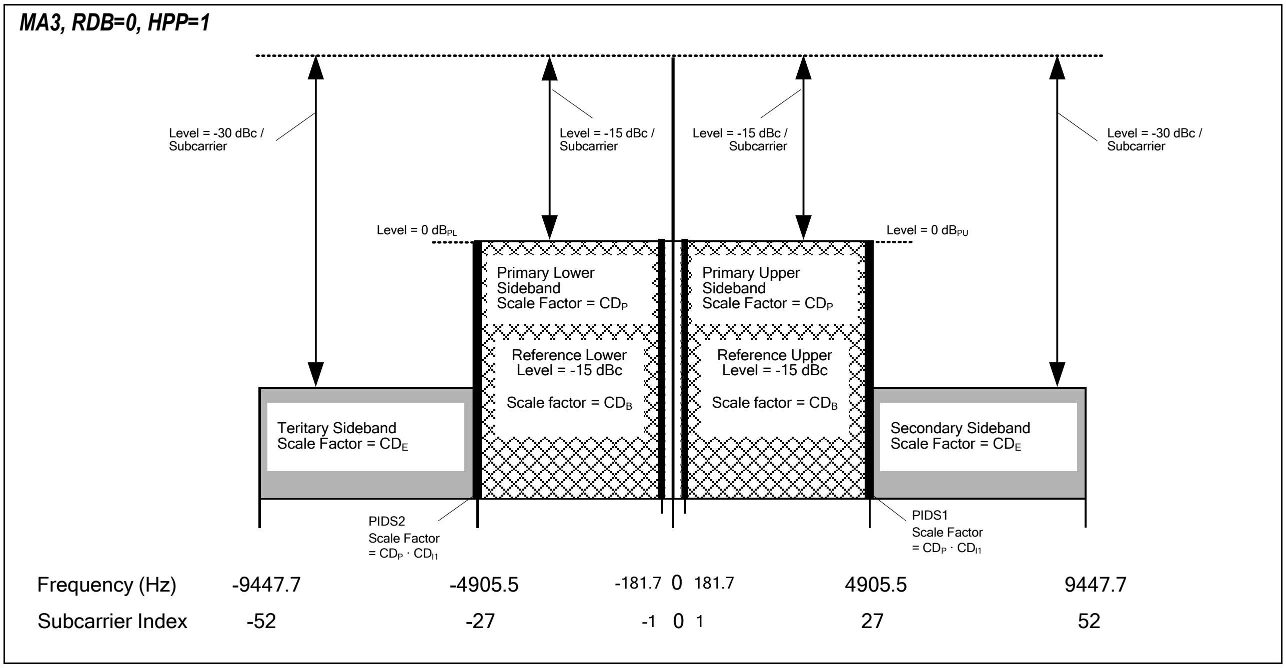

Figure 4-13: MA3, RDB=0, HPP=1

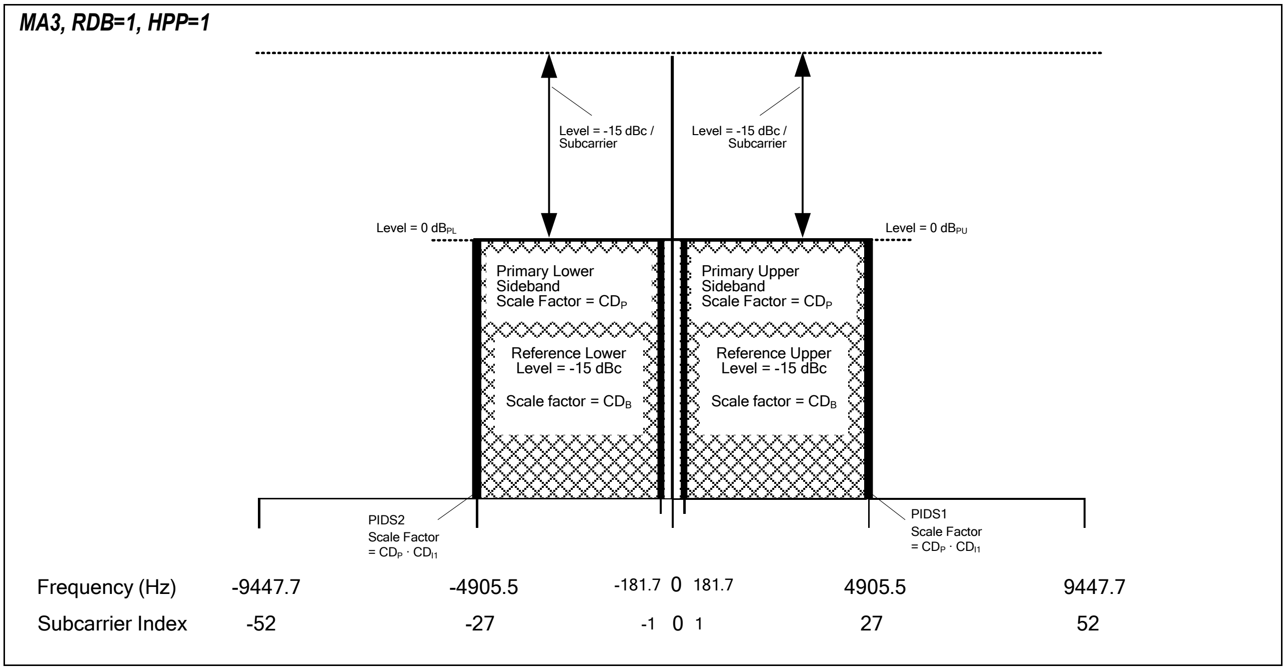

Figure 4-14: MA3, RDB=1, HPP=1

4.6.1 AM Digital Carrier Power

4.6.1.1 Hybrid MA1 Digital Carrier Power

Table 4-7 characterizes the total (nominal) integrated digital power for the various Hybrid MA1 waveform configurations. The nominal digital-to-analog power ratio is derived from Table 4-6, where 0 dBc equals the total power of the unmodulated analog AM carrier.

In addition, the total integrated digital power with one of the primary digital sidebands removed is shown. This represents a lower power limit for asymmetric sideband operation (for calculation purposes only; it is not expected that a sideband will be completely shut off). This value, in combination with the total digital power of just one of the primary sidebands alone is useful to calculate the exact power level for asymmetric sideband operation, as explained in the next subsection.

Table 4-7: Hybrid MA1 Digital to Analog Power Ratios

Subcarrier Scaling Control Signal State			Total Digital Power of All Sidebands (Nominal)	Total Digital Power with One Primary Sideband Removed (Nominal)	Total Digital Power of One Primary Sideband Alone (Nominal)
RDB	HPP	PL			
0	0	0	-12.33 dBc	-14.74 dBc	-16.02 dBc
0	0	1	-11.69 dBc	-13.69 dBc	-16.02 dBc
0	1	0	-12.19 dBc	-14.51 dBc	-16.02 dBc
0	1	1	-11.59 dBc	-13.53 dBc	-16.02 dBc
1	X	X	-12.44 dBc	-14.95 dBc	-16.02 dBc

4.6.1.2 Power Limits for MA1 Asymmetrical Sideband Operation

If asymmetrical sideband operation is desired, the last two columns of Table 4-7 can be used to help calculate the total integrated power, but the total digital power of one primary sideband is reduced by the desired power reduction in dB. For example, for RDB=0, HPP=0, and PL=0 and it is desired to reduce the Primary Lower sideband power level by 12 dB, the total integrated power will be:

$$= 10\ \mathrm{Log}_{10}\left(\mathrm{Log}_{10}^{\ -1}(\mathrm{PWR1}/10) + \mathrm{Log}_{10}^{\ -1}([\mathrm{Pwr2} - \text{Sideband Reduction Value}]/10)\right)$$

Where

PWR1 = Total Digital Power with One Primary Sideband Removed

PWR2 = Total Digital Power of One Primary Sideband Alone

$$= 10\ \mathrm{Log}_{10}\left(\mathrm{Log}_{10}^{\ -1}(-14.74/10) + \mathrm{Log}_{10}^{\ -1}([-16.02 - 12]/10)\right)$$

$$= 10\ \mathrm{Log}_{10}(0.03357 + 0.001578)$$

$$= 10\ \mathrm{Log}_{10}(0.03515)$$

$$= -14.54\ \mathrm{dBc}$$

4.6.1.3 All Digital MA3 Carrier Power

Table 4-8 characterizes the total integrated digital for the various Hybrid MA3 waveform configurations. The nominal digital-to-unmodulated AM carrier power ratio is derived from Table 4-6, where 0 dBc equals the total power of the unmodulated analog AM carrier.

Table 4-8: All Digital MA3 Carrier Power

Subcarrier Scaling Control Signal State			Total Digital Power of All Sidebands
RDB	HPP	PL	
0	0	X	+2.30 dBc
0	1	X	+2.45 dBc
1	X	X	+2.32 dBc

4.7 Analog Audio Source

The analog signal shall not exceed the modulation levels specified in Title 47 CFR §73.1570.

The HD Radio system is not compatible with existing analog AM stereophonic broadcasts. The input analog signal shall be a monophonic signal.

4.8 Phase Noise

The phase noise mask for the broadcast system is illustrated in Figure 4-15 and Figure 4-16 and specified in Table 4-9. As can be seen in the figures, the response is linear (on the dB scale) between every pair of points drawn on the curve.

Zero dBc is defined as the total power of the subcarrier being measured. The phase noise mask is applicable for all permissible power levels of the upper and lower sidebands, as defined in Subsection 4.6.

The total single sideband phase noise at the transmitter RF output as measured in a 1-Hz bandwidth shall be within the mask specified in Table 4-9. This shall be verified by transmitting a single unmodulated digital subcarrier. In addition, for the Hybrid waveform, the unmodulated AM carrier shall be separately verified.

Table 4-9: AM Broadcast System Phase Noise Specifications

Frequency, F, Offset Relative to Carrier	Level, dBc/Hz
1 Hz to 10 Hz	$-1.11F - 38.9$
10 Hz to 100 Hz	$-4.44 \cdot 10^{-1}F - 45.6$
100 Hz to 1000 Hz	$-5.56 \cdot 10^{-3}F - 89.4$
1 kHz to 10 kHz	$-1.67 \cdot 10^{-3}F - 93.3$
10 kHz to 100 kHz	$-1.11 \cdot 10^{-4}F - 108.9$
> 100 kHz	-120.0

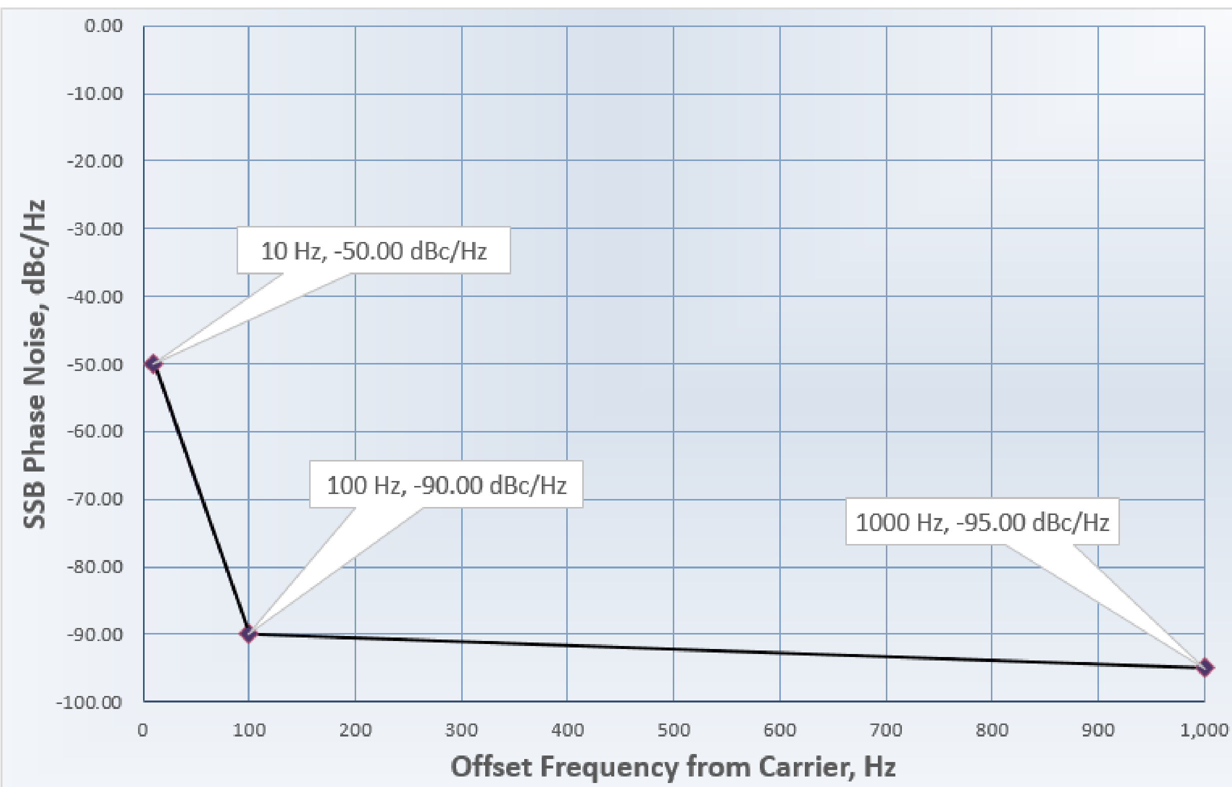

Figure 4-15: AM SSB Phase Noise Mask | 10 Hz to 1000 Hz

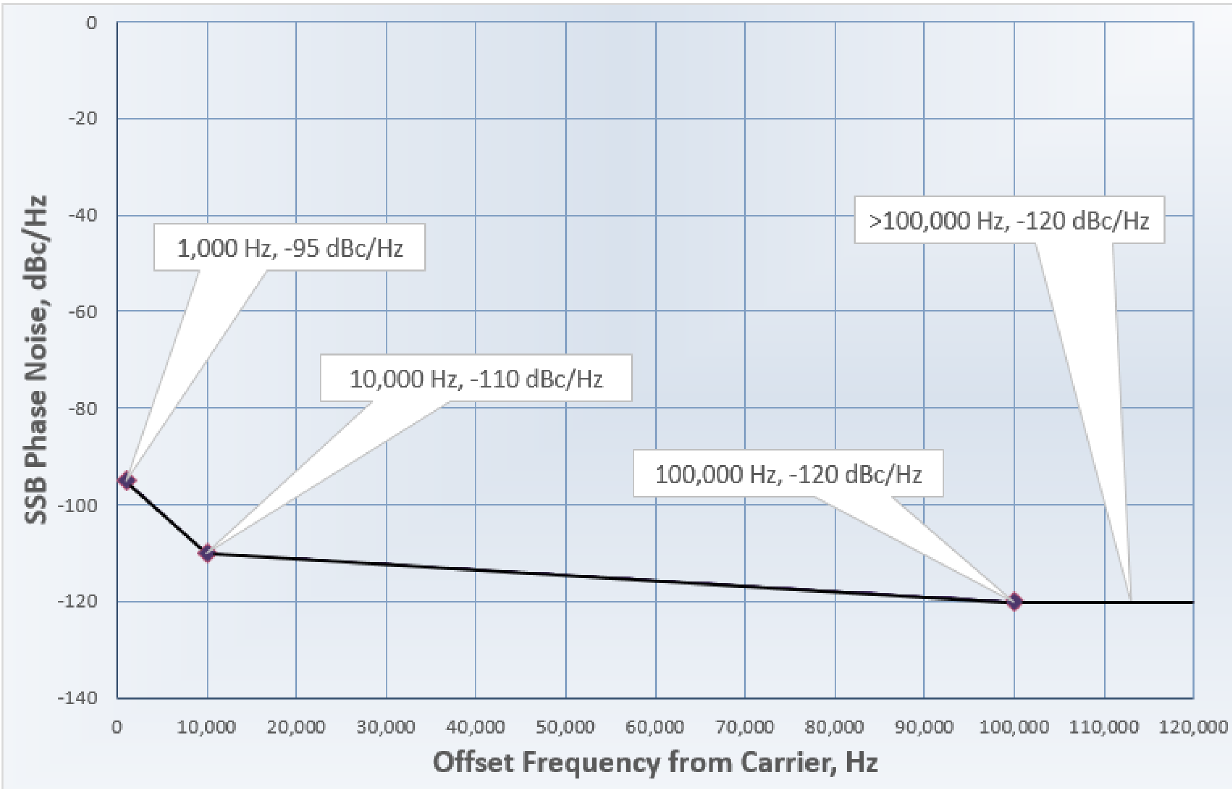

Figure 4-16 : AM SSB Phase Noise Mask | 1 kHz to 100 kHz

4.9 Discrete Phase Noise

For the broadcast system, the spectrum from (F_c – 15 kHz) to (F_c + 15 kHz) shall be considered to consist of multiple non-overlapping sub-bands, each with a bandwidth of 100 Hz, where F_c is the carrier frequency. Discrete phase noise components measured at the transmitter RF output shall be permitted to exceed the mask specified in Table 4-6 provided that for each sub-band, the measured total integrated phase noise does not exceed the total integrated phase noise calculated from Table 4-9.

If the upper and lower sidebands have different power levels, as permitted in Subsection 4.6, the measurement must account for the fact that the 0-dBc reference level will be different for each sideband.

4.10 Modulation Error Ratio (MER)

AM MER is defined as the ratio of the signal power to the error power as defined in Equation 1. The ratio shall be computed for each subcarrier type independently as explained in the following subsections.

Equation 1: Classical MER Computation

$$\mathrm{MER(dB)} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{error}}}\right)$$

where P_{error} is the RMS power of the error vector, and P_{signal} is the RMS power of the ideal transmitted signal

4.10.1 Detailed MER Specifications

The following specifications shall be met, using the test configuration described in Reference [26].

4.10.1.1 MA1 and MA3 Reference Subcarriers

The instantaneous MER for each and every Binary Phase Shift Keying (BPSK) reference subcarrier, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 11 dB, as computed by Equation 1.

The average MER of all the Binary Phase Shift Keying (BPSK) reference subcarrier in the upper sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 14 dB, as computed by Equation 1. This computation shall be based on a block of N = 128 contiguous symbols.

The average MER of all the Binary Phase Shift Keying (BPSK) reference subcarrier in the lower sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 14 dB, as computed by Equation 1. This computation shall be based on a block of N = 128 contiguous symbols.

4.10.1.2 MA1 Tertiary Subcarriers

The instantaneous MER for each and every Quadrature Phase Shift Keying (QPSK) subcarrier, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 11 dB, as computed by Equation 1.

The average MER of all the Quadrature Phase Shift Keying (QPSK) subcarriers in the upper sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 14 dB, as computed by Equation 1, averaged across all tertiary upper QPSK subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

The average MER of all the Quadrature Phase Shift Keying (QPSK) subcarriers in the lower sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 14 dB, as computed by Equation 1, averaged across all tertiary lower QPSK subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

4.10.1.3 MA1 Secondary, MA1 PIDS, and MA3 PIDS Subcarriers

The instantaneous MER for each and every 16-QAM signal subcarrier, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 18 dB, as computed by Equation 1.

The average MER of all the 16-QAM subcarriers in the upper sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 21 dB, as computed by Equation 1, averaged across all upper sideband 16-QAM subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

The average MER of all the 16-QAM subcarriers in the lower sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 21 dB, as computed by Equation 1, averaged across all lower sideband 16-QAM subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

4.10.1.4 MA3 Secondary and Tertiary Subcarriers

The instantaneous MER for each and every MA3 Secondary and Tertiary 64-QAM signal subcarrier, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 22 dB, as computed by Equation 1.

The average MER of all the MA3 Secondary and Tertiary 64-QAM subcarriers in the upper sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 25 dB, as computed by Equation 1, averaged across all upper sideband 64-QAM subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

The average MER of all the MA3 Secondary and Tertiary 64-QAM subcarriers in the lower sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 25 dB, as computed by Equation 1, averaged across all lower sideband 64-QAM subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

4.10.1.5 MA1 Primary Subcarriers

The instantaneous MER for each and every MA1 Primary 64-QAM signal subcarrier, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 22 dB, as computed by Equation 1.

The average MER of all the MA1 Primary 64-QAM subcarriers in the upper sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 25 dB, as computed by Equation 1, averaged across all upper sideband 64-QAM subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

The average MER of all the MA1 Primary 64-QAM subcarriers in the lower sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 25 dB, as computed by Equation 1, averaged across all lower sideband 64-QAM subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

4.10.1.6 MA3 Primary Subcarriers

The instantaneous MER for each and every MA3 Primary 64-QAM signal subcarrier, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 22 dB, as computed by Equation 1.

The average MER of all the MA3 Primary 64-QAM subcarriers in the upper sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 25 dB, as computed by Equation 1, averaged across all upper sideband 64-QAM subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

The average MER of all the MA3 Primary 64-QAM subcarriers in the lower sideband, measured at the RF output of the transmission system at the connection point to the antenna system (including any RF filters), shall be greater than or equal to 25 dB, as computed by Equation 1, averaged across all lower sideband 64-QAM subcarriers. This computation shall be based on a block of N = 128 contiguous symbols.

4.11 Gain Flatness

The total gain of the transmission signal path as verified at the transmitter output into a 50-ohm, non-reactive load, shall be flat to within ±0.5 dB for all frequencies between (F_c – 10 kHz) to (F_c + 10 kHz), where F_c is the RF channel frequency. For frequencies removed from F_c by more than 10 kHz and less than 15 kHz, the gain shall be flat to within ±1.0 dB. It is assumed that the source data consists of scrambled binary ones and the power of each subcarrier is an average value.

For the case where the upper and lower digital sideband power levels are intended to be different, as defined in Subsection 4.6, the gain flatness specification shall be interpreted as follows:

> Gain flatness is the difference between the measured power spectral density in a 300-Hz bandwidth of each subcarrier frequency, and the power spectral density of the applicable digital sideband, normalized to a 300-Hz bandwidth.

For optimal HD Radio digital performance it is recommended that the transmission system, including the antenna, adheres as closely as is practicable to the Gain Flatness specification. Performance may be verified using a suitable sample loop on the reference or main tower. In addition to antenna component selection and adjustment, active pre-compensation of the HD Radio waveform may be employed to improve the effective gain flatness.

4.12 Amplitude and Phase Symmetry

The amplitude and phase symmetry of the transmission signal path shall be verified at the transmitter output into a 50-ohm, non-reactive load. For Hybrid transmissions, for any frequency, F, between 0 and 5 kHz, removed from the carrier frequency, F_c, the RF digital transmission must maintain symmetry within the following limits:

i. The average RF signal power at a frequency (F_c + F) shall be within ±0.25 dB of the RF signal power at the corresponding frequency (F_c – F), where the power is measured in a 300-Hz bandwidth averaged over an interval of at least 30 seconds of time and for at least 100 averages.

ii. The phase of the signal at a frequency (F_c + F) shall be equal to the negative of the signal phase at a frequency (F_c – F) within ±2 degrees rms.

For optimal HD Radio digital performance it is recommended that the transmission system, including the antenna, adheres as closely as is practicable to the Amplitude and Phase Symmetry specification. This may be verified using a suitable sample loop on the reference or main tower. In addition to antenna component selection and adjustment, active pre-compensation of the HD Radio waveform may be employed to improve the amplitude and phase symmetry.

The above specifications assume that the upper and lower digital sidebands are transmitted with equal power levels. If this is not the case, the appropriate power level offset shall be applied to the amplitude symmetry specification listed above.

4.13 Group Delay Flatness

Group delay of the transmission signal path shall be verified at the transmitter output into a 50-ohm, non-reactive load. The group delay of the entire transmission signal path (excluding the RF channel) as measured at the RF channel frequency (F_c) shall be flat to within ±3 μs from (F_c – 15 kHz) to (F_c + 15 kHz).

For optimal HD Radio digital performance it is recommended that the transmission system, including the antenna, adheres as closely as is practicable to the Group Delay specification. This may be verified using a suitable sample loop on the reference or main tower. In addition to antenna component selection and adjustment, active pre-compensation of the HD Radio waveform may be employed to improve group delay.