Interference Potential of Hybrid Digital Transmission: An IBOC Occupied Bandwidth Case Study

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ABSTRACT

As stations deploy In Band, On Channel (IBOC)[1] digital signals, new issues arise in the measurement of these complex waveforms. Many measurement questions arise in the RF domain. How will engineers know that the analog-to-digital power ratio is correct? What are the consequences of digital sideband splatter ("spectral regrowth") on adjacent channels? This paper offers a discussion of these issues in the regulatory context of IBOC broadcasting, which is not yet cast in stone. Experience with one IBOC facility in the Boston area will be employed to illustrate the issues.

BACKGROUND

In mid 2003 Broadcast Signal Lab was alerted to complaints of possible interference to the reception of fourth-adjacent channel FM stations in the vicinity of a new Hybrid IBOC FM station. We took a look at the occupied spectrum of the analog signal and the hybrid[2] digital signal of the newly-installed IBOC FM station. The station is a Class B facility near Boston. Of particular interest is the fourth-adjacent channel stations, also Class B facilities, in the same market, but some 15 to 20 miles away. As will be shown, fourth adjacent FM channels are at risk from sideband energy from IBOC waveforms.

In addition to considering the out-of-channel energy of the hybrid IBOC waveform, we undertook to assess the power ratio between the IBOC digital signal and the "host" analog FM carrier.

The specifications and measurement methods of these characteristics are not yet finalized in a standard or regulatory rule.

We determined that there was borderline occupied bandwidth of the IBOC station hybrid transmission, depending on how the emission is evaluated. Also, interference to reception of the fourth adjacent stations, Station A and Station B, in the immediate vicinity of the Hybrid IBOC Station tower may exist even with fully compliant IBOC out of band emissions.

Hybrid IBOC Spectrum

A brief review of the hybrid FM signal may be helpful. The digital signal surrounding the host FM analog signal consists of hundreds of Orthogonal Frequency Division Multiplex (OFDM) carriers, often referred to in IBOC literature as subcarriers.[3] These subcarriers are grouped in two ways. First, there are two fundamental groups, located on the upper and lower sidebands (USB and LSB) of the analog FM carrier. Second, these sideband groups consist of Primary Main subcarriers and some optional Extended subcarriers. The Extended subcarriers are not considered in this paper. Below, Figure 1 is a simplified image of the hybrid spectrum taken from the National Radio Systems Committee FM IBOC evaluation report.[4]

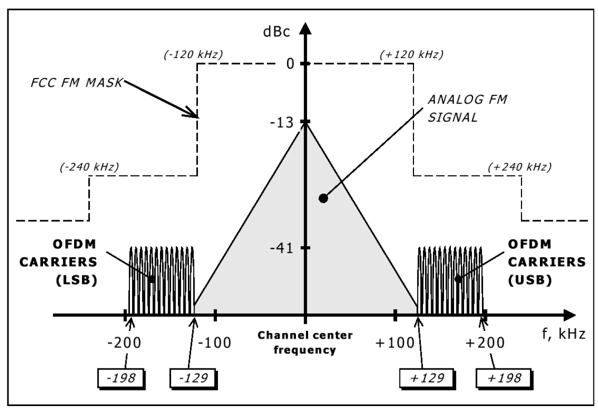

Figure 1. iBiquity FM IBOC system signal spectral power density

The power in a 1-kHz sample of each PM sideband is approximately 41 dB below the power of the analog FM carrier. Each individual subcarrier is about 46 dB below the analog FM carrier. With 191 subcarriers in

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[1] This document uses the generic term, IBOC, to refer to the digital transmission system that is employed by iBiquity Digital Corporation under the brand name "HDRadio."™

[2] A hybrid IBOC signal is one that contains the host station's analog signal sandwiched between digital waveforms.

[3] It is important to distinguish between the digital subcarriers, which are independent RF signals, and the classic FM subcarriers, which are transmitted on the composite baseband of the analog FM signal.

[4] NRSC, DAB Subcommittee, Evaluation Working Group, Dr. H. Donald Messer, Chairman, *Evaluation Of The IBiquity Digital Corporation IBOC System Part 1 – FM IBOC (as adopted by the Subcommittee on November 29, 2001)*

each PM sideband, the total power in a PM sideband is 23 dB below the analog FM carrier.

The sum of the upper and lower PM digital carriers will be twice the power of one set, or about 3 dB higher, yielding a total hybrid digital power that is 20 dB below the analog FM signal power.[5] These ratios were carefully derived by iBiquity and tested for the National Radio Systems Committee when it was deliberating the potential benefits and detriments of hybrid IBOC operation. All receiver compatibility testing for the NRSC is based on this FM-to-digital power ratio. Consequently, NRSC's finding that IBOC is, on the whole, an improvement over analog FM performance is based on this 20 dB analog-to-digital ratio.

Applicable Emissions Standards

Based on these fundamental characteristics of the hybrid FM IBOC waveform, the question of occupied bandwidth and spurious emission limits can be

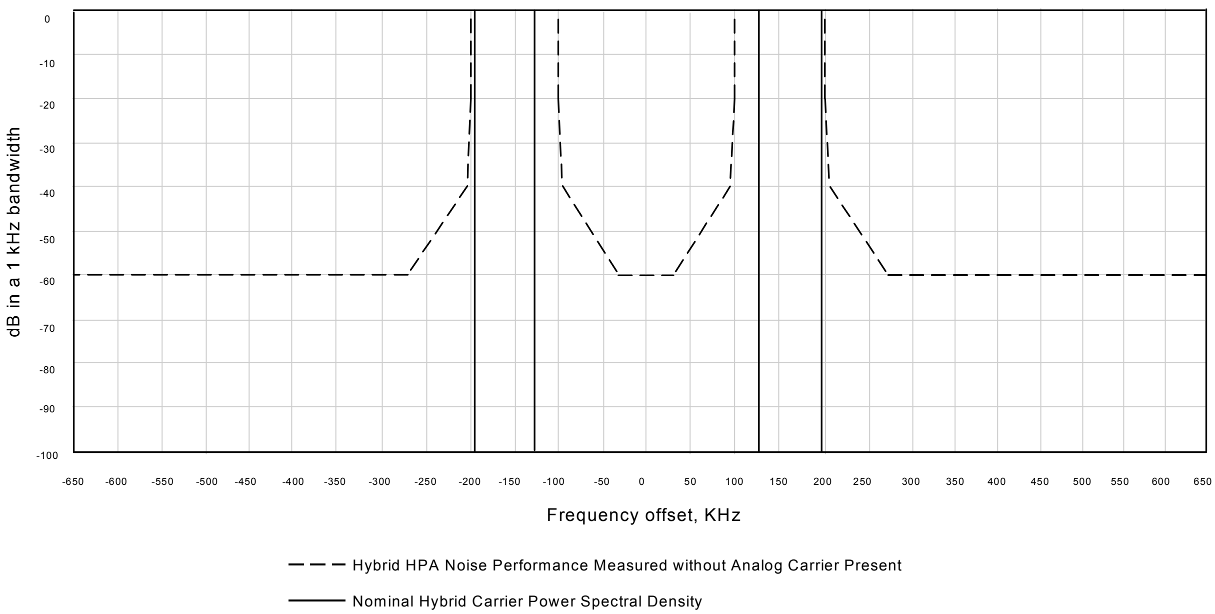

Figure 2: iBiquity's Figure A-1 IBOC FM HPA Hybrid Mode Signal and Noise Emission Limits – FCC Interim Specification

Frequency, F, Offset Relative to Carrier	Level, dB/kHz
0-30 kHz offset	-60 dB
30-95 kHz offset	[-60 + (|frequency in kHz|-30 kHz) * 0.3077] dB
95-100 kHz offset	[-20 + (|frequency in kHz|-100 kHz) * 4.0] dB
200-205 kHz offset	[-20 - (|frequency in kHz|-200 kHz) * 4.0] dB
205-270 kHz offset	[-40 – (|frequency in kHz|-205 kHz) * 0.3077] dB
>270 kHz offset	-60 dB

Table 1: iBiquity's Table A-1 IBOC FM HPA Hybrid Mode Signal and Noise Emission Limits

[5] iBiquity specifies 1 kHz bandwidth measurement over a ten-second interval to obtain an average power reading. *IBOC FM Test Data Report, Appendix A, FM Transmission Specification,* February 28, 2001

addressed. FCC First Report and Order 02-286, Oct 10, 2002, in MM Docket 99-325, states, in part:

E. Interim IBOC Operations

As of the release of this Report and Order, stations may request authority to operate on an interim basis with the hybrid IBOC facilities described in Appendices B and C herein. (See Appendix B, FM IBOC Specification; see also Appendix C, AM IBOC Specification.)

Appendix B is a submittal to the FCC from iBiquity covering the FM IBOC specification. In A.3 of that document it states:

Hybrid and Extended Hybrid Waveforms

Hybrid and Extended Hybrid waveform transmissions including noise and spuriously generated signals from all sources, including phase noise of the IBOC exciter and intermodulation products will remain within the Noise and Emissions Limit as depicted in Figure A-1 and summarized in Table A-1. Measurements of the digitally-modulated signals are relative to the PM sidebands of the digital carriers spectral density in a 1 kHz bandwidth.

This method is interpreted as meaning that the PM (Primary Main) sidebands of the digital signal[6] may be measured directly with a 1kHz resolution bandwidth on a spectrum analyzer. Likewise, any spurious digital emissions may be measured with a 1 kHz bandwidth, and are to be referenced to the emission mask. The emission mask uses the 1kHz bandwidth power of the PM digital carriers as the 0 dB reference. (Table 1 and Figure 2 above)

However, when measuring noise and spurious emissions with respect to the FM analog carrier power instead of the PM digital power, normalization must be made to the specified limits. As discussed above, the 1kHz PM sideband power is about 41 dB below the analog FM power, if the station is set up to specification.

[6] The terminology can be confusing because in this context, when the digital OFDM carriers that constitute the digital signal are discussed as a group, they are called "sidebands" because they reside on either side of the analog FM carrier and among the analog FM sidebands. However, the PM digital carriers also produce their own sidebands. This paper will use the term "PM sidebands" to refer to the groups of OFDM digital carriers on either side of the FM analog carrier, and will refer to unwanted digital energy as spurious digital emissions.

For instance, consider the noise limit in Figure 2 above at 400 kHz offset from carrier. It is –60 dB in a 1kHz bandwidth with respect to the PM power in a 1 kHz bandwidth. Using the normalization of 41 dB with respect to the FM carrier, the specification for hybrid noise at 400 kHz offset is 101 dB below the FM analog carrier power.

Based on the foregoing, the limit for all emissions greater than 270 kHz offset from center frequency is the 60 dB specification (from the table above) plus the 41 dB normalization to the FM carrier level, which totals -101 dBc_{FM} (FM analog carrier power reference).

The above computation is based on the specifications adopted by the FCC in Report and Order 02-286. It is a mask specifically for the hybrid digital transmission system, as the analog signal is still subject to the standard occupied spectrum mask for analog FM (47 CFR §73.317 shown in Table 2 below). The realities of cost-effective equipment design have rendered the specifications in the FCC/iBiquity Figure A-1 (Fig. 2 above) impracticable even for digital transmitters.

Offset from Carrier	Attenuation below carrier
120 to 240 kHz	25 dB
240 to 600 kHz	35 dB
> 600 kHz	80 dB, or 43 +10 log(power in W) whichever is the lesser attenuation

Table 2 47 CFR 73.317 FM Emissions Mask
[See also Figure 1, above]

A different specification is available that is unofficial at this time, but is employed as a working reference by iBiquity and equipment manufacturers. Since the FCC adoption of the interim specification containing the mask in Figure 2 above, the NRSC DAB Subcommittee has been deliberating standards proposed by iBiquity. The FM specification in the proposed NRSC standard[7] is stated differently than the interim specification above. This proposed NRSC specification corresponds to another contained in the iBiquity specifications upon which licensed transmitter manufacturers rely.[8] (Figure 3 and Table 3 below)

[7] HD Radio™ FM Transmission System Specifications, Rev B, March 7, 2003, iBiquity document SY_SSS_1026s
[8] iBiquity specification TX_SSS_1038, Rev. C, March 22, 2002

This working specification considers the combination of both the analog and digital signals in the hybrid mode. It directly references the FM analog carrier power and has different spectral break points than those adopted by the FCC in its interim ruling on IBOC. At 270 kHz this specification calls for spurious energy to be –74.4 dBc_{FM}, compared with the –101 dBc_{FM} calculated above.

consistent peak-to-average ratio because of the nature of digital transmissions. If necessary, one can use this ratio to make further judgments about the measurements.

Follow-on measurements were taken off the air and included two measurement techniques: Max Hold and Average of Mean values. The analyzer offers several

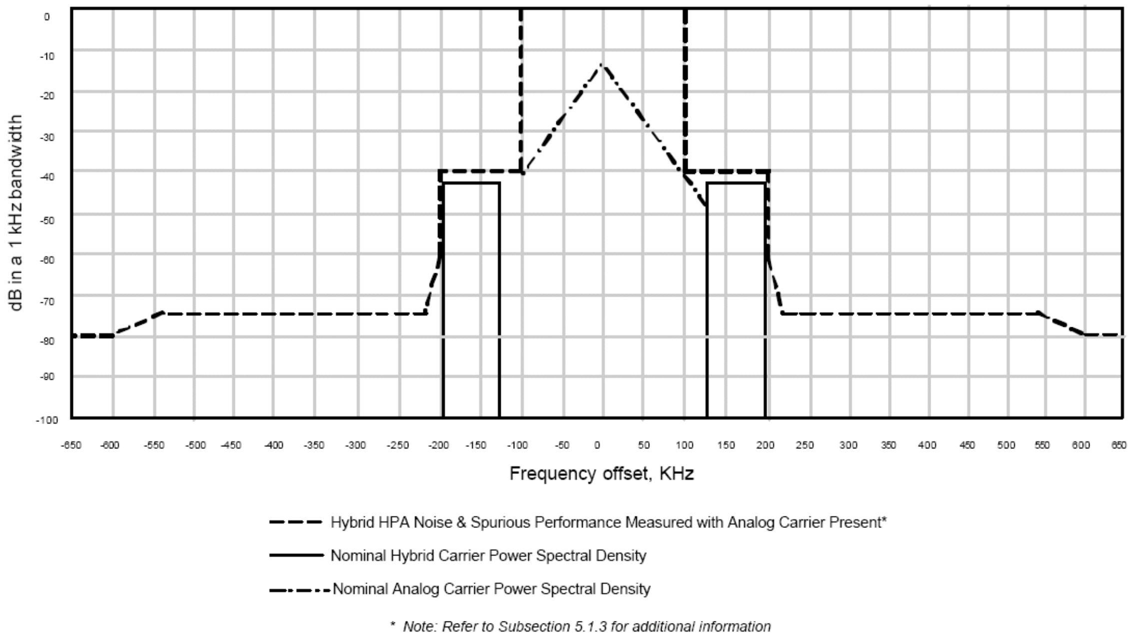

Figure 3: iBiquity FM Hybrid Mode Noise and Spurious Emission Limits

Frequency, F, Offset Relative to Carrier	Level, dB/kHz
200-215 kHz offset	[-61.4 - (|frequency in kHz|-200 kHz) · 0.867] dB
215-540 kHz offset	-74.4 dB
540-600 kHz offset	[-74.4 - (|frequency in kHz|-540 kHz) · 0.093] dB
>600 kHz offset	-80 dB

Table 3: iBiquity FM Hybrid Mode Noise and Spurious Emission Limits

MEASUREMENTS

The Hybrid IBOC station was equipped with separate amplification and a 10 dB combining system with a reject load dumping 90% of the hybrid digital power. At the time of this examination, there was no sample on the antenna side of the combiner, so the combined hybrid signal with analog carrier was sampled off the air at the transmitter site. Measurements consisted of taking multiple sweeps with the spectrum analyzer. On an initial visit, all measurements were Max Hold accumulations of peak energy values. They are sufficient for making comparative judgments about the emissions sampled in each of three locations: Digital transmission line, Digital exciter, and off-air. Also, accumulated samples of peak energy will exhibit a

measuring options. Maximum is the value of the peaks in each sweep of the analyzer. The maximum value of each frequency bin can be accumulated over a number of sweeps. This is the Max Hold function employed in peak measurements.

The second method takes advantage of the digital analyzer's method of viewing a sample for a period of time. Instead of taking the highest or the lowest level that occurs during the sampling time window, the analyzer is instructed to take the value at the end of the sampling time. This would be representative of a random sample in each frequency bin. When averaged over a series of sweeps, the analyzer displays what should be the closest to an average power level for each frequency bin. This method is the Mean Average and seems to be most comparable to the “average” method specified in the iBiquity documents.

The instrument employed was a Tektronix 2712 Tektronix literature explains that this analyzer family can make a 2.5 dB understatement of the power of a noise-like waveform due to its detection circuitry, so there is likely some inherent error in utilizing this averaging function on a digital waveform.

The instrument is equipped with resolution bandwidths (RBW) in decades that are multiples of three: 300 Hz, 3 kHz, etc. iBiquity methodology calls for 1 kHz RBW and we used 3 kHz. Assuming a perfect 3:1 correspondence between the measured 3 kHz RBW and the ideal 1 kHz RBW, the instrument will over-report the 1 kHz bandwidth power by an approximate factor of three, or about 4.8 dB. Additional error may be introduced by the fact that RBW filters are not perfectly square, containing energy sidebands that may overstate the measured power levels in different proportions, depending o the bandwidth.

These two errors in reporting the 1 kHz bandwidth power spectral density by measuring the 3 kHz average power are corrected approximately with a –4.8 + 2.5 = -2.3 dB adjustment.

Multichannel Sweep

Finally, the FM carrier power reference (top of display in Figure 4 below) was made with a 300 kHz resolution bandwidth to integrate the total FM power level at the center frequency. Additional IBOC energy was also integrated in some of the setups, but such power represents only 1% of the total and should not materially affect the results. (Narrower bandwidths were employed to take the actual measurements.) The energy of fourth-adjacent channel stations is sufficiently removed from center frequency that it would not affect the carrier reference.

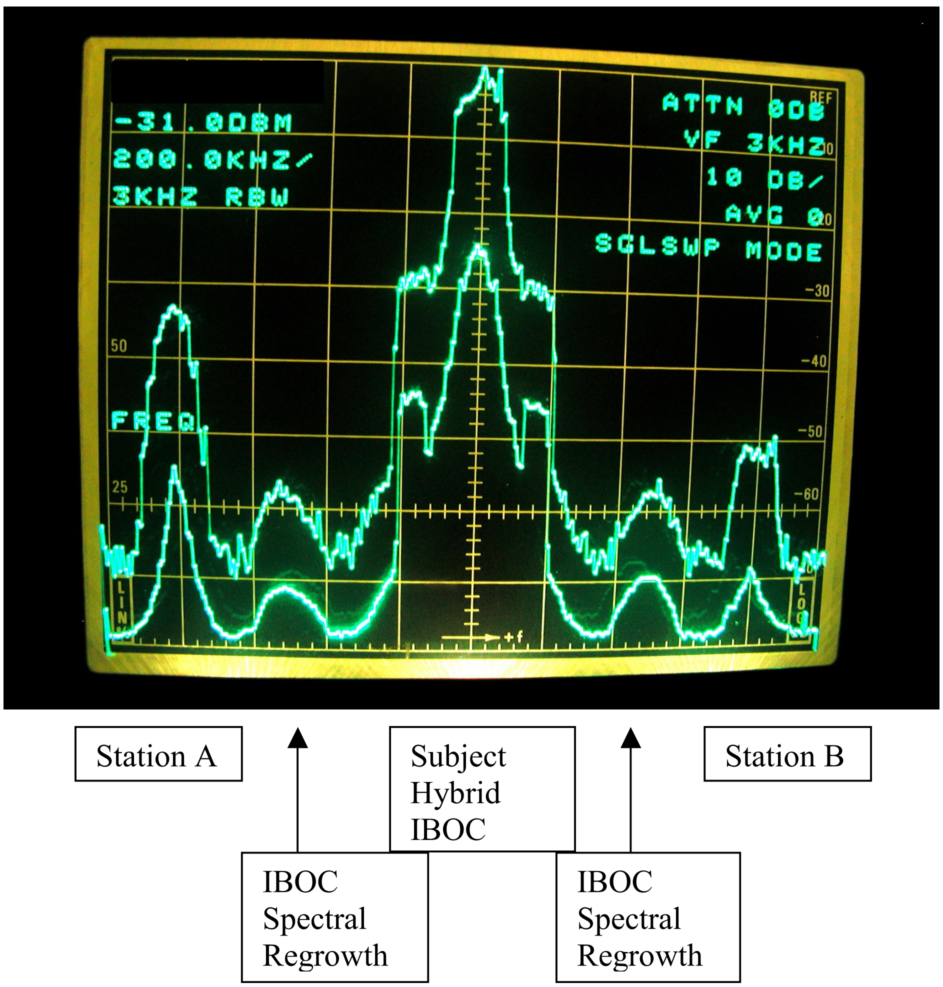

Figure 4 Max Hold and Mean Average Traces From 1/3 Mile

The above image shows the occupied bandwidth of the station taken over the air about 1/3 mile away. It shows the Max Hold value (upper trace) and the Mean Average value (lower) recorded on the analyzer.

IBOC to Analog Power Ratio

The primary main digital sidebands are characterized by a flat-top spectral form. Note how the PM digital sidebands are approximately –30 dBc_{FM} (max hold trace) and –45 dBc_{FM} (average trace) at this resolution bandwidth. Compensating for the specified 1 kHz measurement RBW and the detection error, we could expect this image to be about 2.3 dB lower on the sidebands than shown above, at –47 average. This is lower than the –41.4 dBc per 1 kHz bandwidth specified for the Primary Main sideband. Assuming the mean average method, with correction, is relatively close to actual power spectral density of the PM sideband, the station is emitting a digital signal that is about 6 dB low with respect to the analog carrier. This is not a definitive result, due to the lack of well-specified measurement methods.

The transmitter manufacturer examined this ratio using its instruments set at 1 kHz resolution bandwidth and indicates that the setup is satisfactory. The manufacturer did not report the specific analyzer settings.

There must be a difference in measurement methods, as we have reasonably accounted for the difference between 3 kHz and 1 Hz resolution bandwidths. In a future visit we will employ a narrower resolution bandwidth and will separately use a power meter to more definitively answer the question of how best to assure the analog-to-digital power ratio is as specified.

Out of Channel Emissions

The analog-to-digital ratio is primarily a quality of service issue for the broadcaster, likely affecting either analog or digital listeners to the host station depending on whether the digital signal is too high or too low. On the other hand, out of band emissions may be problematic for other stations' listeners. In other words, mis-set ratios primarily cause self-interference while high out of band energy may cause interference to the reception of other stations within a radius of the IBOC station.

A common characteristic of densely modulated digital waveforms is their tendency to intermodulate due to nonlinearities in the transmission system. This characteristic is called "spectral regrowth" and manifests in "shoulders" of elevated energy around the digital waveform. In the special case of a hybrid IBOC signal, intermodulation can also produce harmonically related independent noise sidebands. Spectral regrowth sidebands are visible at about $\pm$ 500 kHz from the center frequency of the channel.

Recall that the PM digital sidebands extend from 129 to 198 kHz offset from center frequency. The centers of the PM sidebands are therefore at 164 kHz offset. Three times 164 is 492 kHz, or about the 500 kHz shown on Figure 4. If the intermodulation mechanism yields odd harmonic products, then there would also be sidebands, at five times 164 kHz, or 820 kHz offsets. These sidebands are not particularly visible on Figure 4 because of the presence of fourth adjacent channel stations on these frequencies, but can be seen on the next image, Figure 5.

The spectral regrowth sidebands at 500 kHz, when averaged over 16 sample sweeps, rise to about –70 $dBc_{FM,}$ where c_{FM} is the host FM analog carrier power. The current working limit for this offset from center frequency (approximately $\pm$500 kHz) is, –74.4 dBc_{FM}. This limit is based on a 1 kHz bandwidth measurement. To normalize the measured value to 1 kHz RBW and correct for analyzer response, we deduct the 2.3 dB adjustment discussed above. –70 dBc_{FM} at 3 kHz resolution less 2.3 dB would be –72.3 dBc_{FM} at 1 kHz. This is barely non-compliant with the proposed -74.4 dB figure the manufacturers are using, but considering the degree of uncertainty in the measurement specifications and methods, it is probably close enough in the interim. [9] This figure fails by far the interim specification adopted by the FCC. The larger question is whether the working specification, with 1 kHz bandwidth power, is sufficient for such a wide spectral block of energy occupying possibly a hundred kHz.

Based on this analysis, the new IBOC station in the hybrid digital mode barely misses the present working IBOC emissions standard, and is orders of magnitude above the specification in the FCC Report and Order.

Measurements in Transmission Chain: Exciter

Further measurements reveal the progression of the digital signal through the air chain. Figure 5 below is a single sweep image from the analyzer as it looks at the RF sample on the digital exciter. No reference level was set on the display, other than setting the input to produce peaks near the top of the display. This is sufficient to consider the attenuation of the out of band sidebands, which are about 50 dB below the Primary Main sidebands.

Figure 5 below compares the 3 kHz bandwidth power of the Primary Main with the 3 kHz bandwidth of the out of band noise. It measures peak values. There is no FM carrier power reference.

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[9] Note that if the IBOC-to-FM ratio is off by 6 dB as surmised above, increasing the IBOC power could lead to a 6 dB increase in the noise power, rendering it out even the working specification.

The ratio of 3 kHz RBW peak measurements on PM sidebands and 500 kHz noise sidebands in Figure 5 is about 50 dB. In comparison, the ratio of the same components in Figure 4 (the off-air measurement) is about 25 dB. This represents about a 25 dB increase in the 500 kHz spectral regrowth energy from source (exciter) to air. At the exciter, the 50 dB ratio between PM sidebands and the 500 kHz noise spectra should be sufficient to meet the current working emissions specification.

Digital Transmitter

The next image, Figure 6, is of a forward sample from the digital transmission line between the digital transmitter and the 10 dB combiner. This image is a Max Hold sampling multiple sweeps. In this image, the first out of band sidebands are now only ~25 dB below the primary main sidebands. This is a 25 dB increase over the exciter output figures. (To confirm the instrument was not causing the artifact, the input power level was verified to be within the linear range of the instrument.) The –25 dB level is comparable to the peak hold ratios taken off air and shown in Figure 4. It can be concluded the power amplification stage of the digital transmitter is the primary source of spectral regrowth. The dilemma of a manufacturer is to keep the cost of the power amplifier down, while reigning in the impact of its non-linearities to comply with the noise limits.

The 800 kHz offset noise waveform of the high power hybrid digital signal is about 45 dB below the PM digital sideband. This is twenty dB less than the 500 kHz offset power, but may be more problematic because the 800 kHz offset is directly on the fourth adjacent channel. The working specification for 800 kHz offset noise power is -80 dBc_{FM} per kHz. This is the same limit as the traditional FCC mask for analog emissions. It appears that at this level, the 800 kHz noise is within the limits of (but close to) the working noise specification.

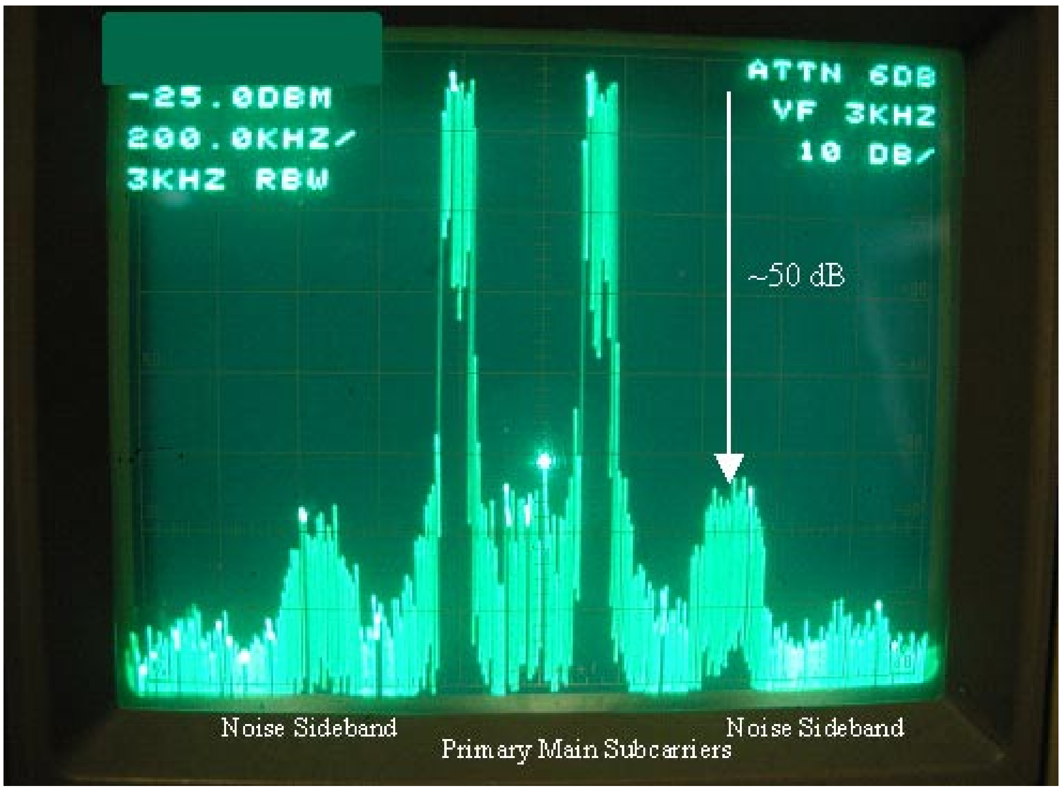

Figure 5 Output Sample of Digital Exciter Showing Sideband Energy at ± 500 and 800 kHz

INTERFERENCE POTENTIAL OF 500 AND 800-KHZ SPECTRAL SIDEBANDS

The levels of the fourth-adjacent channel stations in the vicinity of the Hybrid IBOC station are visible on Figure 4, approximately 55 to 70 dB below the received level of the Hybrid IBOC station's analog FM power. As can be anticipated, relocation of the instrumentation in the general locus of the Hybrid IBOC station would cause all three stations' signals to vary in absolute level and with respect to one another. Generalizations can be made based upon the FCC interference protection ratios.

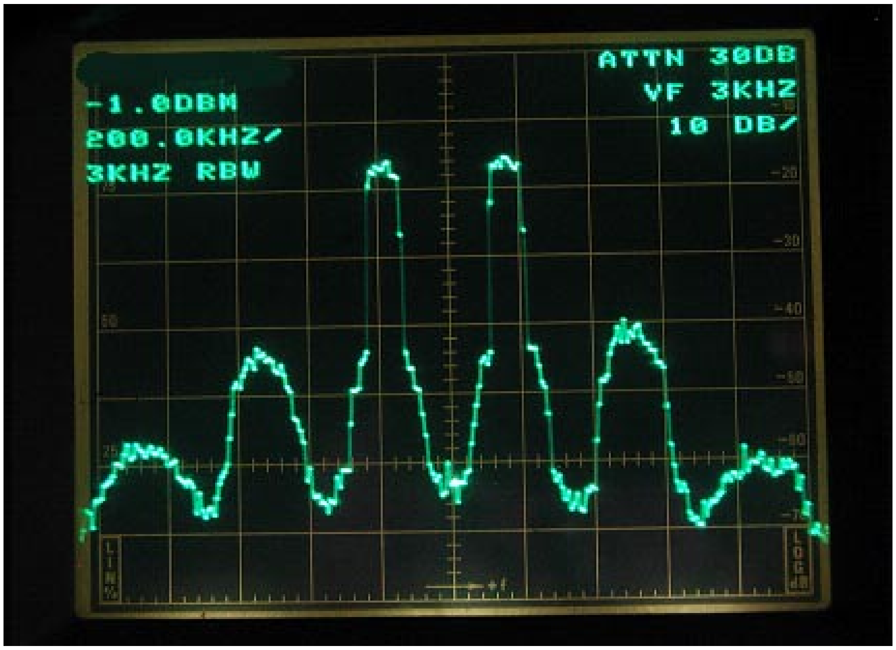

Figure 6 Sample from Digital Transmitter at full TPO prior to High Power Combining

The noise emission that is 500 kHz offset from the Hybrid IBOC station is correspondingly offset 300 kHz from Station B. This spur straddles the line between the first and second adjacent channel of Station B. The FCC frequency assignment rubric assumes interference can occur from a first adjacent channel interferer when the desired station is less than 6 dB stronger than the interferer. Interference protection from a second adjacent station is substantially more relaxed, permitting the interferer to be up to 40 dB stronger than the desired signal. The 500 kHz spur (300 kHz from Station B) may be an issue for a receiver at levels as low as 6 dB below the desired signal, but because the spur is only partly in the fist adjacent channel, it will likely take more than the –6 dB undesired-to-desired ratio to cause consistent problems.

Power of Spur

This discussion is treating the spectral regrowth as if it were a separate FM analog signal, rather than a noise source. A glance at the shape of the spectral regrowth spur reveals a spectral density that is similar to that of the FM analog signal nearby. It is therefore more likely to behave more like a FM interferer than a narrowband noise source or a broadband low density noise source.

The practice of evaluating noise interference may not be applicable to these spurs, because it takes an average value of the noise and compares it to the continuous power of the FM carrier. This would have been sensible when considering the concerns of equipment design and maintenance for analog transmission when the current analog RF mask was originally created. Spurious emissions could be highly transient and/or monotonic, depending on their cause. It is not likely that the FCC was anticipating noise sources with the power spectral density of digital spectral regrowth. Therefore, the use of a 1 kHz bandwidth in verifying RF mask compliance would have been sufficient, but may not be so now.

500 kHz Spur as Interferer

Considering the 500 kHz spur as a noise source, its averaged level (3 kHz bandwidth) is shown on the bottom trace of Figure 4 (and Figure 7 below).

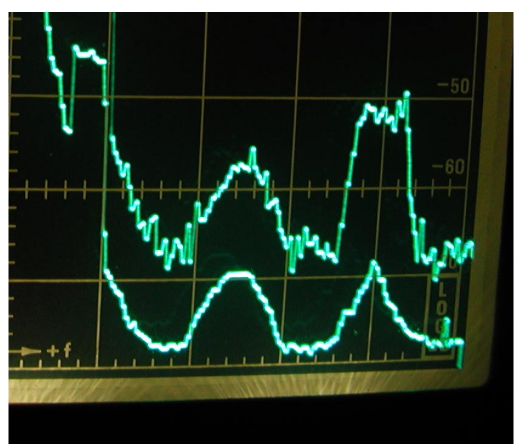

Figure 7 Upper Sidebands (from Fig. 4)

Compare the peak and average values of the 500 kHz spur and the Station B FM signal. The peak value of Station B (3 kHz bandwidth) is visible on the right of the upper trace. This peak value should be close enough to the reference level of its unmodulated FM carrier for the purposes of this discussion.[10] The difference, then, between the total power of Station B and the 3kHz power of the 500 kHz spur is about 20 dB. In contrast, the average power spectral density of the Station B waveform is comparable in both amplitude and enclosed area to that of the 500 kHz spur (bottom trace of Figure 7 for both), suggesting a great similarity between the 500 kHz spur and the FM waveform.

Finally, comparing peaks to peaks, the FM waveform of Station B, as would be expected from a Frequency modulated carrier that has to repeatedly cross center frequency, has 3 kHz bandwidth peak levels that are about 5-7 dB higher at center frequency than the peaks of the 500 kHz spur. Given that the spur's modulation is more noise-like than the FM carrier, its power spectral density takes a more gaussian shape.

These comparisons of the peak and average power levels of the 500 kHz spur and the Station B FM signal hint at the true amount of power in the spur that has the potential for causing interference to the reception of Station B near the site of the Hybrid IBOC station. If a receiver responds to the 500 kHz spur as it would a first adjacent FM signal, the ratios shown in Figure 7 may be enough to interfere with reception of Station B. If the 500 kHz spur's channel-and-a-half offset from Station B puts it more into the range of a second-adjacent interferer, then it would be less problematic for Station B reception. However the same questions would arise in situations where the affected station is second or third adjacent to the Hybrid IBOC signal. In such cases, the 500 kHz spur would be right on top of the affected station.

800 kHz Spur as Interferer

Assuming the 800 kHz spur observed on the transmission line translates to the air at a level that remains about 15 dB below the 500 kHz spur, a co-channel interference problem may exist for Station B reception. This would place the average 800 kHz spur level (3 kHz bandwidth) 15 dB below the average 3 kHz power spectral density of the Station B signal. Using the familiar average-noise-to-full-FM-power assessment method, the 800 kHz spur average power would be 30-35 dB below the Station B FM signal. This would suggest that reception of Station B would not be particularly affected (20 dB desired to undesired ratio is the FCC threshold of co-channel interference). However, based on the discussion above, it seems counter-intuitive that only 1 kHz of the power in the spur should be considered against the desired FM station's total power.

800 kHz Spur at Threshold Level

The power in the 500 kHz spur appears to occupy a bandwidth of approximately 100 kHz. The 800 kHz spur appears to be spread a little more. For the sake of argument, let us assume the bandwidth of the spurs is 100 kHz. Assuming further that an 800 kHz spur is at the threshold level of -80 dBc_{FM} per kHz, its total power is –60 dBc_{FM}.

As is the case of Station B at the site of the Hybrid IBOC station, assume the 70 dBu contour of the desired 4th adjacent channel station is near the Hybrid IBOC station. Co-channel interference from the 800 kHz spur would be likely if the spur were 20 dB or less below the level of the contour, or 50 dBu. Since the total power of the 800 kHz spur is assumed to be –60 dB with respect to the Hybrid IBOC station, 50 dBu + 60 dB = 110 dBu would be the contour of the Hybrid IBOC station within which interference would be likely to the 70 dBu 4th adjacent station.

If the Hybrid IBOC station were near the 60 dBu contour of the 4th adjacent channel station, co-channel interference would likely occur within the 100 dBu contour of the Hybrid IBOC station. These figures represent areas that are somewhat greater than the 115 dBu blanketing area of each FM radio station.

CONCLUSION

Interference to the reception of fourth adjacent channel stations was observed in the vicinity of a new Hybrid IBOC station.[11] The method of ascertaining compliance with transmitted analog-to-digital power ratios and out-of-band emissions ratios is not clearly specified yet. The values selected as working out of band emissions limits are not supported by a rationale that considers the total power of a spectral regrowth spur on or near a receivable FM station's channel.

Follow-on work contemplated by Broadcast Signal Lab includes 1) more precise characterization of power measurement techniques for both the PM sideband power and the spectral regrowth spur power; 2) more detailed analysis of the susceptibility of receivers to IBOC spectral regrowth spurs.

[10] The corresponding behavior of the Hybrid IBOC station's analog carrier is visible with its peaks approaching the top of the display in Figure 4 when the display was calibrated to its full FM power prior to taking the sample, suggesting these peak measurements approximate total FM power.

[11] As a good will gesture, the station has since installed additional filters to reduce these spurs.