THE NATIONAL RADIO SYSTEMS COMMITTEE IBOC RF MASK MEASUREMENT GUIDELINE - NRSC-G201

David Maxson
Broadcast Signal Lab, LLP
Medfield, Massachusetts

ABSTRACT

The NRSC-5 Standard for In-Band/On-Channel ("IBOC") hybrid digital radio broadcast transmission is rich with detail on how the system should work. However, since it was largely written before there was collective experience in operating and measuring actual transmissions, the NRSC-5 Standard provides only top-level guidance on measuring IBOC signals. Experience has shown that there is some inconsistency in the results of IBOC spectral measurements due to varying interpretations of methodology on the part of those taking the measurements and due to the various instrument types and settings that are brought to the measurement task. Beginning in 2007, when the NRSC-5-B version of the Standard was being deliberated, the National Radio Systems Committee ("NRSC") Digital Radio Broadcasting ("DRB") Subcommittee began to discuss IBOC measurement issues. The DRB Subcommittee's IBOC Standards Development Working Group ("ISDWG"), under the leadership of Chair Dom Bordonaro, Chief Engineer, Cox Broadcasting Connecticut, has held numerous meetings to discuss and craft an RF measurement guideline for both AM and FM IBOC. The result of the ISDWGs two-year process is expected to be adopted in 2009 as an NRSC guideline, NRSC-G201. This Guideline will clarify RF mask compliance measurement techniques for broadcasters, manufacturers and regulators.

INTRODUCTION

IBOC technology is more familiarly known by the brand name "HD Radio"™ technology, a trade name of iBiquity Digital Corporation which licenses the technology to manufacturers, developers and broadcasters.

As described in reference [1] ,

> *Hybrid IBOC transmissions present waveforms that are moderately challenging to measure. The term "hybrid" applies to the presence of two types of signal modulation in one communications channel: traditional analog modulation (AM or FM) accompanied by a set of OFDM digital waveforms. Orthogonal Frequency Division Multiplex transmission, from which the acronym OFDM derives, simultaneously modulates hundreds of narrow-bandwidth carriers with a series of digital symbols. In hybrid IBOC transmission, the OFDM waveforms are transmitted at a combined power level that is lower than the accompanying analog signal in the same channel. To measure the OFDM signal power levels, the dynamic range of the measurement instrumentation must accommodate the stronger analog signal while providing a clean enough noise floor to discriminate not only the digital signal components, but also the even lower-level unwanted byproducts of the transmission process. Further complicating such measurements, the manner in which digital signals are measured requires different assumptions than the measurement of analog signals.*

Much material has been published on the structure of the hybrid IBOC signals in the AM and FM broadcast bands; this paper does not dwell on these fundamentals. See the National Radio Systems Committee ("NRSC") website for the IBOC transmission standard, which as of this writing is the version called NRSC-5-A. It can be obtained at no charge through www.nrscstandards.org. A detailed explanation of the inner workings of IBOC transmissions is presented in The IBOC Handbook - Understanding HD Radio Technology, written by this author and published by NAB/Focal Press. Further information is available in the NAB Engineering Handbook, 10th edition chapter 4.13 written by Jeff Detweiler of iBiquity Digital Corporation. The IBOC Handbook also contains a bibliography of many papers relating to the technology.

This paper touches on the issues addressed in the creation of guideline NRSC-G201. Where a formally adopted standard, such as NRSC-5-B, defines how a standards-compliant signal is structured, a formally adopted guideline is intended to be practicable information that assists the reader in achieving his or her measurement objective. In the language of standards, the NRSC-5-B Standard is *normative* and the NRSC-G201 Guideline is *informative.* Nevertheless, both types of documents have a similar purpose— to provide uniform and repeatable specifications. The Standard enables standard-compliant devices to be as

interoperable as possible. Interoperability promotes wider adoption of a technology as competitors develop a plurality of transmitter and receiver devices that all work properly with the same IBOC signal. The Guideline promotes repeatable measurement of IBOC signals to the uniform minimum performance required by the Standard. In a way, the Guideline promotes interoperability by creating a basis upon which all IBOC systems can be compared reliably.

THE STANDARD

The NRSC-5-B Standard contains fairly simple descriptions of the measurement of the digital components of hybrid IBOC signals. These can be found in the transmission system specifications that are incorporated in the NRSC-5-B Standard. These documents are available at the NRSC web site, www.nrscstandards.org. Document 1026s rev. E contains the FM transmission system specification and document 1082s rev. E contains the AM transmission system specification. These documents are free to download.

These IBOC transmission system specifications describe numerous parameters for assuring reliable performance of the IBOC signal. Each transmission specification has sections on spectral emissions limits, which have been the focus of the current ISDWG effort to document best measurement practices.

Other specifications relate to the synchronization of analog diversity audio, L1 frame timing, time and frequency accuracy and stability, gain and group delay flatness, phase noise, and error vector magnitude. Most of these specifications are pertinent to the design and manufacture of IBOC transmission equipment.

To date, for broadcasters the spectral emissions limits have been the most useful for evaluating the performance of an IBOC transmission system. They describe the maximum permissible spectral occupancy of the IBOC signal in terms of Power Spectral Density ("PSD"). They define an "RF mask" that can be converted to a pass/fail limit line on a spectrum analyzer. There have been variations, however, in how and where the measurements are taken. Because the methodology is not fully described in the Standard, the variances between measurements of the same signal have sometimes resulted in uncertainty as to whether a specific IBOC broadcast is compliant with its RF mask.

The measurement instructions in the NRSC-5-B transmission system specifications documents say this for FM and (AM) measurements against the RF masks:

> *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 1 kHz [for FM; 300 Hz for AM] bandwidth over a minimum time span of 30 seconds and a minimum of 100 sweeps. Compliance will be determined by measuring the composite power spectral density of the analog and digital waveforms. The measurement point shall be at the air interface, as defined by the NRSC. Zero ("0") dBc is defined as the total power of the analog FM [or unmodulated AM] carrier.*

This wording for the RF mask measurements leaves much to be assumed.

QUESTIONS

Based on these brief technical specifications for RF mask measurements contained in NRSC-5-B, numerous questions have developed and were considered by the ISDWG in the crafting of NRSC-G201. Highlights of these questions are summarized below.

Signal Sample:

- As the transmission system specification states, should there be an NRSC-defined uniform "air interface" point for AM and for FM IBOC measurements?
- Is a transmission line sample of the combined hybrid IBOC signal sufficient for evaluating hybrid FM IBOC broadcasts?
- Where on the transmission line and with what kind of signal sampling probe should an FM IBOC signal be measured?
- What about the stations that do not have both the digital and analog signals on the same transmission line (such as with separate-antenna and dual-feed antenna topologies)—how should they be measured?
- Is it possible to simplify AM IBOC mask measurements by permitting measurements to be taken from the output of the transmitter rather than in the field?

Regulatory Issues:

- What should be the role of the legacy FCC masks (47 CFR §73.44 and §73.317) when hybrid IBOC signals are present?

Normal Modulation? Reference Modulation?

- Spectral regrowth sidebands can vary with the analog modulation; should there be a reference analog modulation scheme for repeatability of testing?

- Are there factory tests of transmitters that may differ from the manner in which an entire transmission system is tested *in situ*?

Instrument Configuration

- Is the measurement specification based on a specific instrument or instrument type?

- How does one compensate for the differences between true averaging detectors and nominally averaging detectors (such as the sample detector)?

- If one can obtain repeatable results with little variation using 100-sweep averaging, is the 30-second criterion necessary?

- What should one do if the instrument is not a swept analyzer or can obtain more repeatable measurements more conveniently with fewer or only one sweep and 30 seconds of data collection?

- The noise bandwidths of various filters available in spectrum analyzers differ to some degree, which causes variations in the measured PSD of a digital waveform. Is one filter type the reference, or should each analyzer's noise bandwidth be taken into account when interpreting that analyzer's measurements?

- If a different resolution bandwidth than the one specified is available, is a measurement valid at a different resolution bandwidth if the necessary level correction is made (*e.g.*, running an FM IBOC measurement at 5 kHz or 1 Hz bandwidth instead of 1 kHz)?

- If the slope of the analyzer's 300 Hz filter combined with the hybrid AM IBOC signal puts the PSD over the limit on the shoulder of the mask, should the signal fail the test, or can it be viewed with a narrower bandwidth to see whether the filter skirt was contributing to the failure (assuming a correction to the reference level is made with the narrower bandwidth)?

CONCLUSION

Manufacturers of transmission equipment and test equipment have been actively participating in the process of developing the NRSC-G201 guideline. Their collective knowledge of the inner workings of transmitters, couplers, antenna systems, and analyzers has informed the discussion process. Broadcast engineers are also active in the dialog sharing their experiences, techniques, and measurement results to develop a common understanding of the challenges and solutions to making uniform measurements.

The NRSC is an association of companies who volunteer their engineers' time to address the technical needs of the radio broadcasting industry. Individuals reading this article may not realize that their participation in the NRSC is not only welcome, but also it is invited. The NRSC is sponsored by the National Association of Broadcasters and the Consumer Electronics Association. Please contact **David Layer** at NAB (202-429-5339) or **Dave Wilson** at CEA (703-907-7421) for more information.

REFERENCE

[1] Maxson, David, *The Role of the Detector in Spectrum Analyzer Measurements of Hybrid Digital Signals*, Proceedings of the 2008 NAB Broadcast Engineering Conference, April 2008.