WBCN All-digital AM IBOC Field Test Project

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Abstract – *CBS Radio AM station WBCN, 1660 kHz, Charlotte, NC, obtained an experimental license from the FCC in late 2012 for operation in the iBiquity in-band/on-channel (IBOC) HD Radio all-digital MA3 mode. A project team consisting of NAB Labs, CBS Radio and iBiquity calibrated this all-digital transmission and then made daytime and nighttime digital coverage measurements for both indoor and outdoor reception. This paper describes the test procedures used and the preliminary results obtained from this field test project.*

Introduction

The HD Radio in-band/on-channel (IBOC) digital radio system, developed by iBiquity Digital Corporation and standardized by the National Radio Systems Committee (NRSC) [1], can operate in two fundamental modes – hybrid and all-digital. The hybrid mode, which utilizes a radio signal consisting of the legacy analog signal (AM or FM), was authorized for use in the U.S. by the FCC in 2002, and at present over 2,200 radio stations are broadcasting a hybrid HD Radio signal.

iBiquity and others have contemplated that the transition to digital radio using the HD Radio system could encompass two phases: the introduction of digital radio services using the hybrid signal (spectrum shown in Figure 1), which would continue to allow for reception of the main channel audio portion of the signal on legacy analog receivers, and an eventual transition from the hybrid signal to the all-digital signal (spectrum shown in Figure 2), when there was sufficient penetration of HD Radio receivers in the marketplace so as not to disenfranchise listeners (on the order of 85% of listeners). Use of the all-digital signal would be advantageous because of its increased payload capacity and robustness, however, these advantages must be traded off against the loss of reception by analog receivers, which are numerous.

Unlike the hybrid AM IBOC system, the all-digital system has undergone very little testing (outside of that conducted by iBiquity when designing the system), and it has not been evaluated by the National Radio Systems Committee (NRSC).[1] The only publicly released test report by iBiquity on the all-digital AM IBOC system, from 2002 [4], documents field testing and "…highlights the improved performance that will be achieved by converting from the IBOC hybrid mode to all-digital broadcasting." [2]

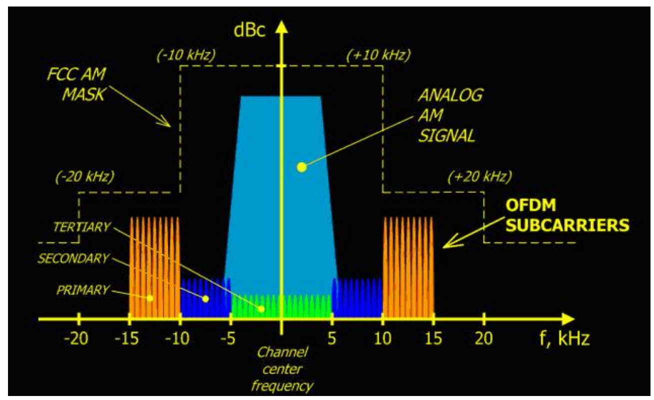

FIGURE 1. HYBRID AM IBOC SIGNAL SPECTRUM

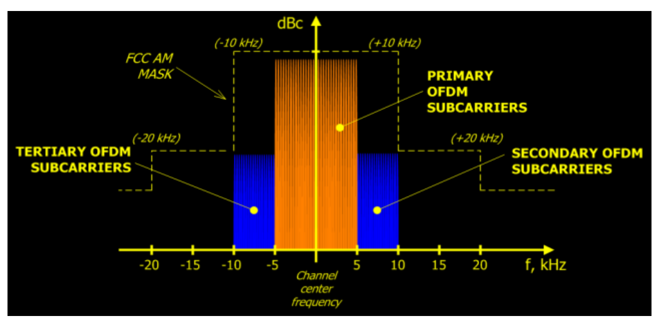

FIGURE 2. ALL-DIGITAL AM IBOC SIGNAL SPECTRUM

Currently (January 2013), with approximately 10 million HD Radio receivers deployed, there is no known effort on behalf of consumers or anyone in the broadcasting industry to advocate for a transition to all-digital HD Radio services, and in fact, all-digital broadcast radio transmissions are not currently allowed by the FCC except under experimental authorization. However, as the number of HD Radio receivers in use increases and even accelerates, it is

[1] iBiquity submitted a detailed test report on the hybrid AM IBOC system to the NRSC in January 2002 [2] which was evaluated by the NRSC's Digital Audio Broadcasting (DAB, now Digital Radio Broadcasting, DRB) Subcommittee [3].

[2] See [4] at page 2.

conceivable that at some point broadcasters will be interested in considering a transition to the all-digital mode of operation. This may be true more so for the AM-band version of HD Radio than the FM-band version, since the hybrid AM IBOC system has not been as widely accepted by the industry as has been the FM IBOC system.[3]

Deployment of all-digital IBOC services would require a change to the FCC rules, but to-date very little technical information on all-digital operation has been entered into the public record which is an impediment to FCC action in this regard.[4] In 2012, CBS Radio approached NAB Labs and iBiquity, offering to make AM station WBCN (1660 kHz, Charlotte, NC) available on a limited basis for all-digital AM IBOC testing, providing an opportunity to begin developing a contemporary test record that would help educate the industry as to the capabilities of all-digital operation, develop all-digital operational parameters, and provide information which could be eventually submitted to the FCC for the purposes of obtaining permanent authorization for all-digital service. The test plan and results described below were developed and obtained to take advantage of this limited opportunity.

Description of Facilities

WBCN is a 10 kW daytime, 1 kW nighttime non-directional facility that typically operates in HD Radio MA1 mode (hybrid AM IBOC); station information is given in Table 1. The antenna and transmitter building are shown in Figure 3.

WBCN's main transmitter is a Harris DX-10 fed by a Harris Dexstar exciter. Under normal operating conditions the DX-10 is used for both day and night operation, however, WBCN also has a 1 kW Nautel transmitter available as a backup. A photograph of the equipment room is shown in Figure 4.

Test Plan

A relatively simple test plan was established for this project, reflecting the limited timeframe available for all-digital testing,[5] and designed to satisfy two principal goals:

1) Develop a procedure for establishing the correct (*i.e.*, licensed) transmit power for the all-digital AM IBOC signal, for both 10 kW (daytime) and 1 kW (nighttime) operation. This was necessary because industry standard procedures (and equipment) used for establishing AM radio station transmit power rely upon the presence of an analog AM signal which, of course, is not present in an all-digital transmission. Described in the sections below is a procedure developed under this test project to establish a 10 kW and 1 kW all-digital MA3 mode AM IBOC transmission. As part of this power calibration procedure, attention was also paid to optimization of the all-digital AM IBOC exciter parameters so as to achieve good compliance with the RF mask for MA3 mode operation that is included in the NRSC-5 Standard.[6]

Table 1. WBCN station information

Call sign	WBCN
Frequency	1660 kHz
Station class	B
Community of license	Charlotte, NC
FCC Facility ID	87037
Digital status	Hybrid
Daytime power	10 kW
Nighttime power	1 kW
Location	35° 14' 56.00" N latitude 80° 51' 44.00" W longitude
Configuration	ND1 (non-directional antenna)
Antenna	Guyed, uniform cross section radiator, electrical height of 90.7°

Figure 3. WBCN transmission facility showing antenna and transmitter building. Note the presence of a 6" grid dish mounted near the top of the tower which is used for a 950 MHz STL (and isolated from the tower using an isocoupler).

[3] For example, according to iBiquity, in 2011 there were 269 AM IBOC stations (out of 4,763 AM stations, approximately 6%) while there were 1,762 FM IBOC stations (out of 10,102, approximately 17%).

[4] FCC rules for digital radio are included in CFR 47 Section 73, Subpart C – Digital Audio Broadcasting.

[5] WBCN was made available for all-digital daytime testing for three weekends in late November and December 2012, and on a limited basis for all-digital nighttime testing during the same timeframe. At this time of year, approximately 10 hours were available each weekend day for testing (from 7AM to 5PM).

[6] See [1], Normative Reference [8] (iBiquity reference document 1082s, rev. F), Table 4-4 and Figure 4-4.

FIGURE 4. WBCN TRANSMISSION EQUIPMENT – FROM LEFT TO RIGHT, NAUTEL 1 KW BACKUP TRANSMITTER (AT VERY EDGE OF PHOTO), HARRIS DX-10 10 KW TRANSMITTER, RACK WITH RF SWITCH, RACK WITH HARRIS DEXSTAR EXCITER, AUDIO PROCESSORS, AND STL EQUIPMENT.

2) Characterize the reception coverage of the all-digital AM IBOC signal for both mobile (in-vehicle) reception as well as for indoor reception. For the mobile testing, eight test routes were defined, each starting at the transmitter location and proceeding away from the transmitter, in directions corresponding roughly to the eight cardinal directions of N, NE, E, SE, S, SW, W, and NW. Under the test plan, a test vehicle was to be driven along each route to determine the point-of-failure (POF) of the all-digital AM IBOC signal, for both daytime and nighttime reception conditions, with POF being the point at which reliable reception of the all-digital signal was lost.[7] As part of this process, reception information including vehicle speed and location and received signal strength were to be recorded.

For indoor testing, the test plan called for going to a variety of locations dispersed throughout the station's coverage area and assessing the indoor reception quality of the all-digital AM IBOC signal using an Insignia Narrator tabletop radio, for a variety of building types. Signal strength readings were collected for these indoor measurements, as well, using a Scott LP-3 shielded loop antenna connected to a Rhode & Schwarz spectrum analyzer.

Of significant interest was the audio quality of WBCN's AM analog signal at the locations where the all-digital AM IBOC signal fails. To establish this for the mobile tests, the geographic coordinates of the digital POF were recorded, then when the WBCN transmitter was re-configured for analog transmission (usually on the subsequent day or night), these coordinates were re-visited and an audio recording of the analog signal was made. For the indoor tests, audio recordings and signal strength measurements were obtained under four test conditions at each indoor location: analog daytime and nighttime, and digital daytime and nighttime.

WBCN'S ANTENNA SYSTEM

The WBCN antenna utilizes a guyed, series fed, 24-inch facewidth, triangular tower having an electrical height of 90.7 electrical degrees(45.5m). The antenna system was designed for AM HD Radio hybrid IBOC operation taking into consideration the -45° phase shift of the output network of the Harris Model DX-10 transmitter, 17 feet of Myat 1-5/8" rigid line between the transmitter output and the RF switch, 150 feet of Andrew Type LDF7-50A 1-5/8" foam heliax between the RF switch and the antenna tuning unit (ATU), the phase shift of the Kintronic Labs ATU and the measured drive impedance of the tower while taking into consideration the effects of the LBA STL isocoupler across the base of the tower. A diagram of the complete transmission system with the associated phase shifts for each component as output from the Kintronic Labs CKTNET program is shown in Figure 5.

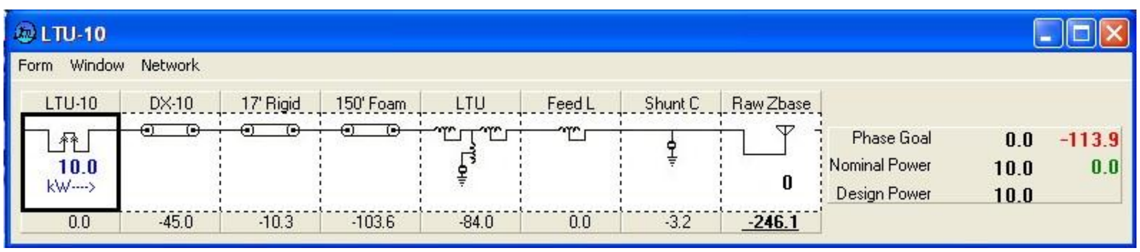

FIGURE 5. CKTNET DESCRIPTION OF THE WBCN TRANSMISSION SYSTEM SHOWING THE ASSOCIATED PHASE SHIFTS FOR EACH COMPONENT. NOTE THAT THE ATU IS DESIGNATED "LTU" (WHICH IS AN ACRONYM FOR "LINE TERMINATING UNIT").

The components denoted as "Shunt C" and "Feed L" in Figure 5 represent the shunt capacitance presented by the STL isocoupler and the series inductance presented by the RF buss between the ATU output and the tower, respectively. The measured drive impedance of the tower, not including the effects of the isocoupler or the RF buss, is shown as Zload in Figure 6. Note that the impedance seen by the ATU is shown as Zout in this figure.

The goal of the ATU design was to yield Hermitian symmetry at the combined final RF amplifier output of the Harris DX-10 transmitter with a VSWR of less than 1.4:1 at the +/-20 kHz sidebands based on the load impedance presented at the output bowl of the ATU, which is shown as Zout in Figure 6. The Zin and VSWR shown in Figure 6 are the carrier and sideband impedance and VSWR at the input

[7] Unlike the hybrid AM IBOC signal, which "blends" to the analog signal at the point of digital failure, when the all-digital AM IBOC signal fails the receiver simply mutes.

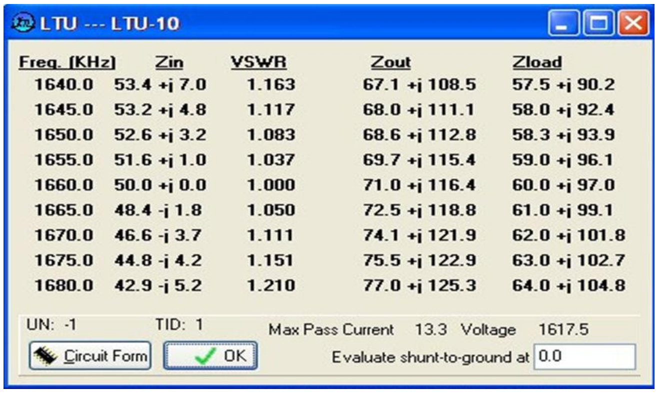

FIGURE 6. WBCN MEASURED TOWER DRIVE IMPEDANCE. NOTE THAT ZLOAD DOES NOT INCLUDE THE EFFECTS OF THE ISOCOUPLER OR THE RF BUSS FROM THE ATU TO THE TOWER.

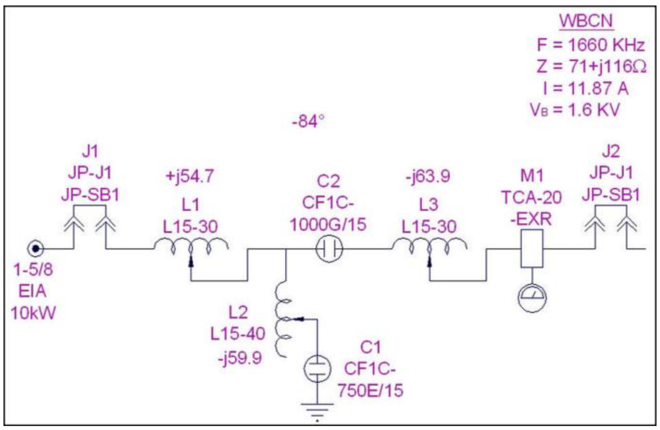

FIGURE 7. SCHEMATIC FOR THE WBCN ANTENNA TUNING UNIT (ATU).

j-plug of the ATU. The optimized ATU design is shown in Figure 7.

Figure 8 shows a Smith chart of the final impedance locus that was presented to the final combined amplifier output of the Harris DX-10 transmitter, which yields the desired +/-20 kHz sideband VSWR of < 1.4:1 with Hermitian symmetry that is required for HD Radio hybrid AM IBOC mask-compliant operation. The dashed circle represents a VSWR of 1.4:1.

Note that in general, an AM antenna that is optimized for HD Radio hybrid AM IBOC (such as the one at WBCN) is also optimized for all-digital AM IBOC, given that the all-digital signal bandwidth is actually less (+/- 10 kHz) than that of the hybrid signal (+/- 15 kHz), as shown above in Figure 1 and Figure 2.

TRANSMITTER CALIBRATION

As discussed above, it was necessary under this project to develop a procedure for setting the correct all-digital AM IBOC transmitter RF output level. Due to the limited peak capability of the DX-10 transmitter, an adjustment of power

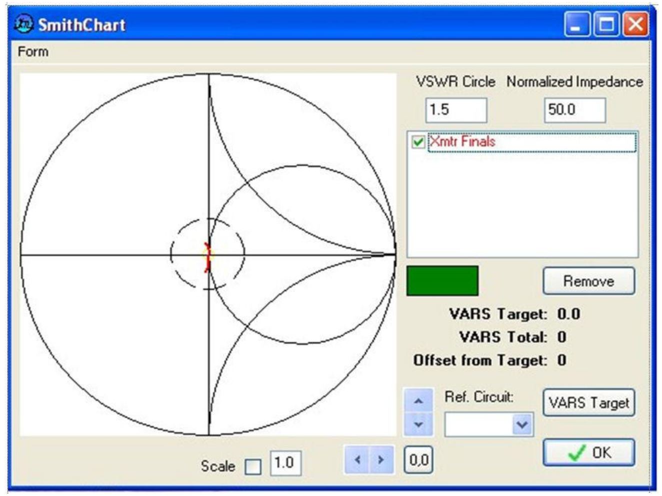

FIGURE 8. SMITH CHART OF NORMALIZED IMPEDANCE PRESENT AT THE FINAL COMBINED RF AMPLIFIER OUTPUT OF THE DX-10 TRANSMITTER.

output was necessary to maintain maximum peak-to-average ratio (PAR) while avoiding clipping of the modulation peaks. Clipping results in excessive intermodulation distortion (IMD) products and potential non-compliance with the iBiquity MA3 mask.

Prior to determining the proper RF output operating point for the system, the base impedance of the tower was verified as 71 +j116 ohms at the carrier frequency. A Delta Electronics TCA-20 ammeter was used as the reference to determine actual power output.

In order to enable the all-digital AM mode (MA3), Harris supplied updated Dexstar software, IRSS version 4.4.7 (this was "pre-release" software developed especially for this project). The DX-10 transmitter was used for essentially all analog and digital testing modes to obtain the data for this project. A backup Nautel 1 kW transmitter, fed directly by an Orban Optimod audio processor, was used in some instances to provide the 1 kW analog signal. Setting the proper RF output to achieve maximum RMS power and MA3 mask compliance is described below.

The RF power measurement was obtained by first setting the reference level for the RF spectrum analyzer (an Agilent E4402B). The DX-10 transmitter was set to the HIGH power level and the Dexstar exciter was placed in the "AM ALL DIGITAL" mode, then in CW analog AM mode by turning the digital carrier off (see Dexstar user interface shown in Figure 9). The transmitter was adjusted as necessary for an indication of 10 kW forward power on the transmitter output power meter. An antenna base current of 11.8 A was observed (Figure 10). This verified the accuracy of the transmitter's RF output power meter.

The spectrum analyzer was connected through a 30 dB pad to the transmitter's output monitor board which, at the HIGH power setting, provides an adjustable sample using an on-board rheostat. The spectrum analyzer was set to the carrier frequency with 10 kHz resolution bandwidth, RMS

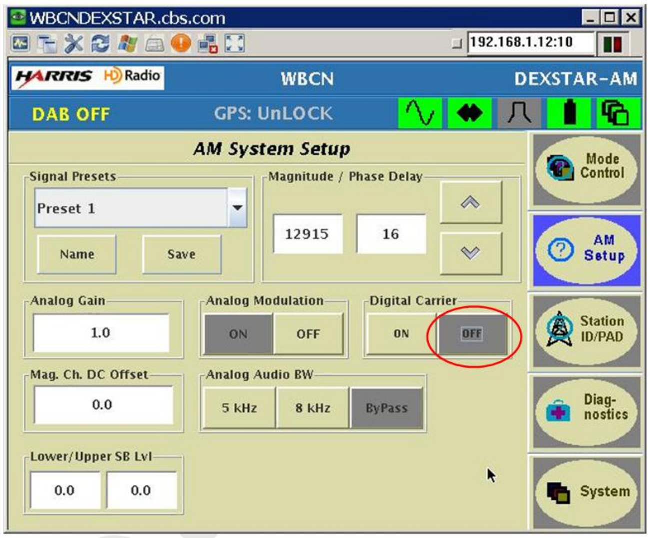

FIGURE 9. DEXSTAR GRAPHICAL USER INTERFACE (GUI) IN CW AM MODE

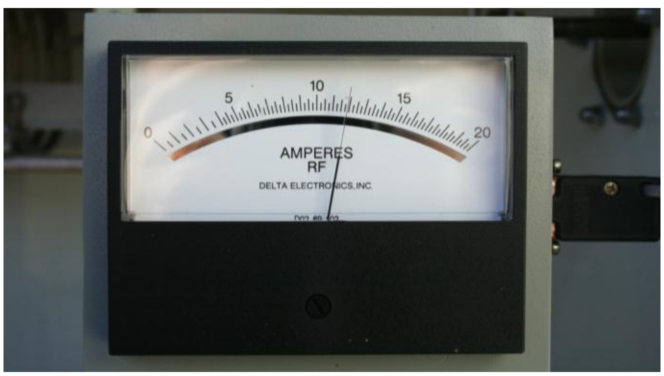

FIGURE 10. BASE CURRENT AMMETER IN AM CW MODE

power averaging, detector mode to Sample, and averaging turned on (10 averages). The output monitor board was then adjusted to produce a 0 dBm reference level on the spectrum analyzer (Figure 11).

A Rohde & Schwartz NRP-Z92 average power sensor was further used to calibrate transmitter output power. Once the spectrum analyzer reference was determined, the transmitter RF sample was connected directly to the power sensor. The NRP Toolkit PC software used with the power sensor was launched and the sensor was connected to the PC via USB interface. The carrier frequency and offset value were adjusted in the PC software to indicate 10 kW power (Figure 12). An offset value of 40.2 dB was used.

Next, the digital carrier was set to ON in the Dexstar exciter. The DX-10 transmitter power output was adjusted with the front panel RAISE and LOWER controls to indicate 10 kW average power on the power sensor software display. This resulted in an indication of 7.8 kW forward power on the transmitter output power meter (Figure 13). Approximately 51 A of PA current was noted (Figure 14).

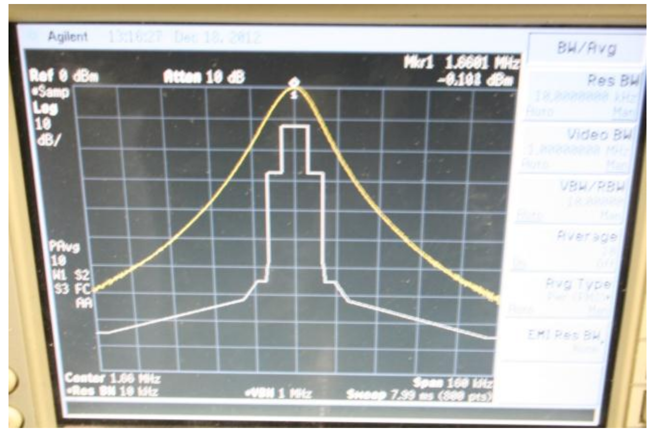

FIGURE 11. SPECTRUM ANALYZER REFERENCE LEVEL

FIGURE 12. POWER SENSOR CALIBRATION IN AM CW MODE

Finally, the RF sample was connected to the spectrum analyzer. Again, 30 dB of attenuation at the analyzer input was used. The analyzer settings were changed to a resolution bandwidth of 300 Hz and 100 averages. The NRSC-5-C MA3 mask limit file was loaded into the analyzer.[8] The I/Q Scale Factor and Magnitude/Phase Delay were adjusted with the Dexstar GUI in small increments while observing the spectrum analyzer so as to achieve maximum mask compliance.

The final output spectrum resulting from this procedure vs. the MA3 mask is shown in Figure 15. The settings obtained were used for all digital daytime measurements. The I/Q Scale Factor was 8000 and the Magnitude/Phase Delay was 12915 (Figure 16). Note that it was not possible to bring the spectrum entirely within the MA3 mode mask. This may be because this mask is in some sense "theoretical" and does not take into consideration what may be realizable with real-world transmission equipment. One of the likely consequences of this (and future) all-digital AM IBOC test projects is that this mask may be modified to

[8] See footnote 6.

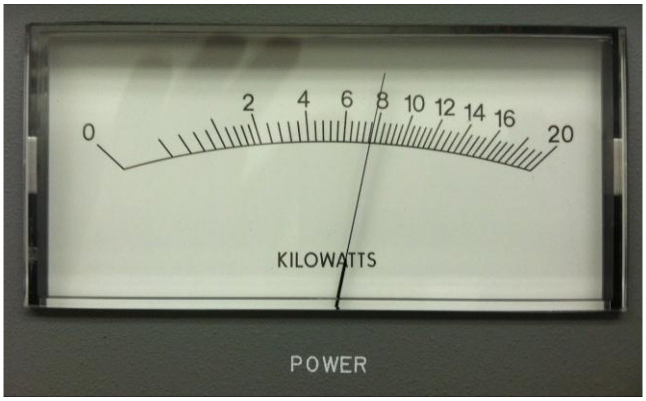

FIGURE 13. TRANSMITTER FORWARD POWER AT 10 KW IN MA3 MODE

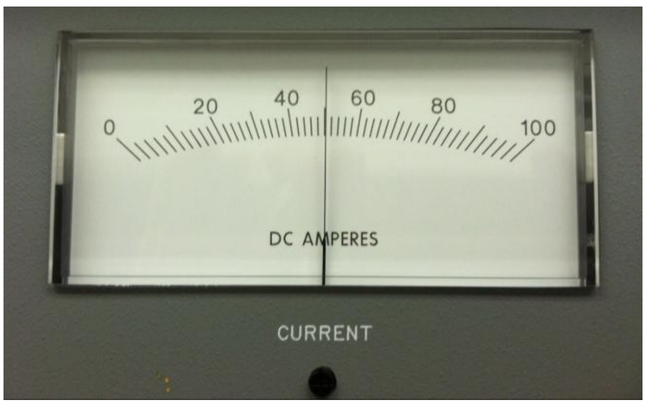

FIGURE 14. TRANSMITTER PA CURRENT AT 10 KW IN MA3 MODE

reflect real-world implementations, as has been the case for other IBOC implementation modes (for example, the hybrid FM IBOC mask was modified in a similar fashion after sufficient field experience with the hybrid FM IBOC system had been obtained – see [5]).

The 1 kW (nighttime) power level was set in the same manner with the following exceptions. The DX-10 transmitter has no easily adjustable RF sample output for the LOW power level. This required an adjustment in reference level and reference offset to be entered in the spectrum analyzer. Power calibration was achieved with the same procedure using the 1 kW base current value as reference. The DX-10 output power achieved was 800 watts for 1 kW average power in MA3 mode. Approximately 9 A of PA current was noted. The Dexstar I/Q Scale Factor was 7800 and Magnitude/Phase Delay was 12935. Figure 17 shows the spectrum in MA3 mode at 1 kW. A summary of the transmitter operational parameters for each mode is provided in Table 2 and Table 3.

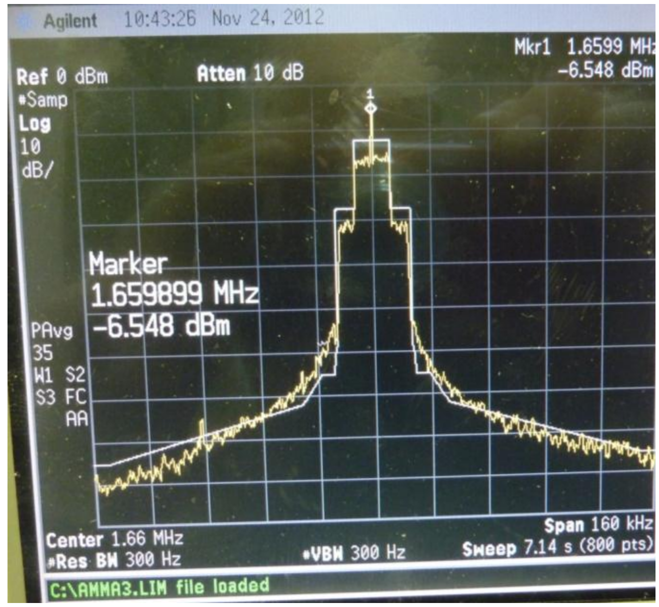

FIGURE 15. OUTPUT SPECTRUM AT 10 KW IN MA3 MODE

FIGURE 16. DEXSTAR FINAL SETTINGS FOR 10 KW MA3 MODE

TEST RESULTS – MOBILE TESTING

Once the transmitter was properly calibrated for operation in MA3 mode, an iBiquity test vehicle was driven along each test route to establish the digital POF (Figure 18). A block diagram of the equipment in the test vehicle is shown in Figure 19 and is described here:

- Principal determination of all-digital signal reception and POF was done using an OEM Ford Sync HD Radio receiver that was factory-installed in a Ford Focus

TABLE 2. SUMMARY OF TRANSMISSION PARAMETERS - DAYTIME

Parameter	Analog	Digital (MA3)
Forward power as indicated on DX-10 (kW)	10.0	7.81
PA current as indicated on DX-10 (A)	54	51
Antenna base current (A)	11.8 (carrier only)	10.6
Dexstar I/Q scale factor	n/a	8000
Dexstar mag / phase delay	n/a	12915

TABLE 3. SUMMARY OF TRANSMISSION PARAMETERS - NIGHTTIME

Parameter	Analog	Digital (MA3)
Forward power as indicated on DX-10 (kW)	1.0	0.8
PA current as indicated on DX-10 (A)	9	9
Antenna base current (A)	3.75	3.4
Dexstar I/Q scale factor	n/a	7800
Dexstar mag / phase delay	n/a	12935

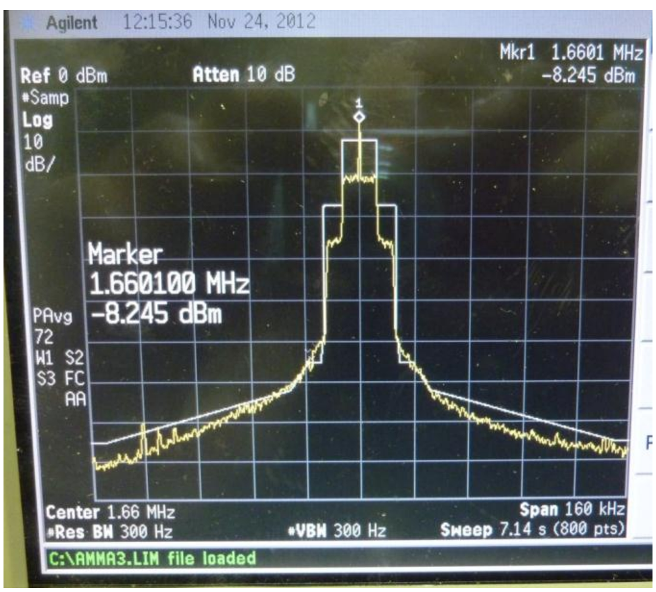

FIGURE 17. OUTPUT SPECTRUM AT 1 KW IN MA3 MODE

automobile and connected to the vehicle's built-in antenna. A custom data interface to this receiver was designed by iBiquity utilizing the auto's "I2C" data bus allowing for connection to a laptop computer ("Laptop #1 in Figure 19). Note that principal determination of all-digital signal reception was done using this receiver/antenna combination since this most accurately represents an actual consumer experience;

FIGURE 18. IBIQUITY TEST VEHICLE SHOWING MILLIMETRICA ANTENNA INSTALLED ON THE ROOF.

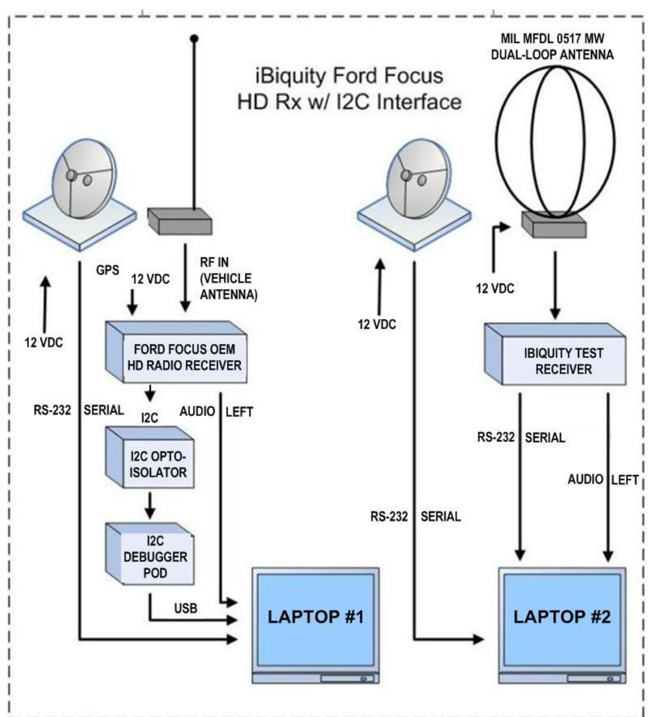

FIGURE 19. MOBILE TEST VEHICLE SETUP.

- Information collected on Laptop #1 was obtained from the OEM receiver as well as a GPS receiver (connected via USB) and included time (UTC), position (latitude and longitude), vehicle speed, receive mode (all-digital enhanced, all-digital core, no reception), and signal-to-noise ratio (SNR). The data collection software was custom-designed by iBiquity for AM HD Radio data collection;
- Laptop #2 collected similar information from an iBiquity test receiver located in the rear seat of the

Focus, and ran the same iBiquity custom-designed software as did laptop #1. This receiver was connected to a roof-mounted Millimetrica active dual-loop antenna and was able to provide more precise field strength measurements than the OEM receiver (connected to laptop #1). [6]

The typical experience on each test route was that all-digital reception would be solid, with no "drop-outs," in strong signal areas near the transmit antenna, and it would stay solid with only an occasional drop out until near the all-digital POF, at which point reception would fairly abruptly become intermittent and then be lost completely. Reception data collected from the Ford Sync receiver is illustrated below in Figure 20 for daytime reception and Figure 21 for nighttime reception. Some specific observations on the data in these figures:

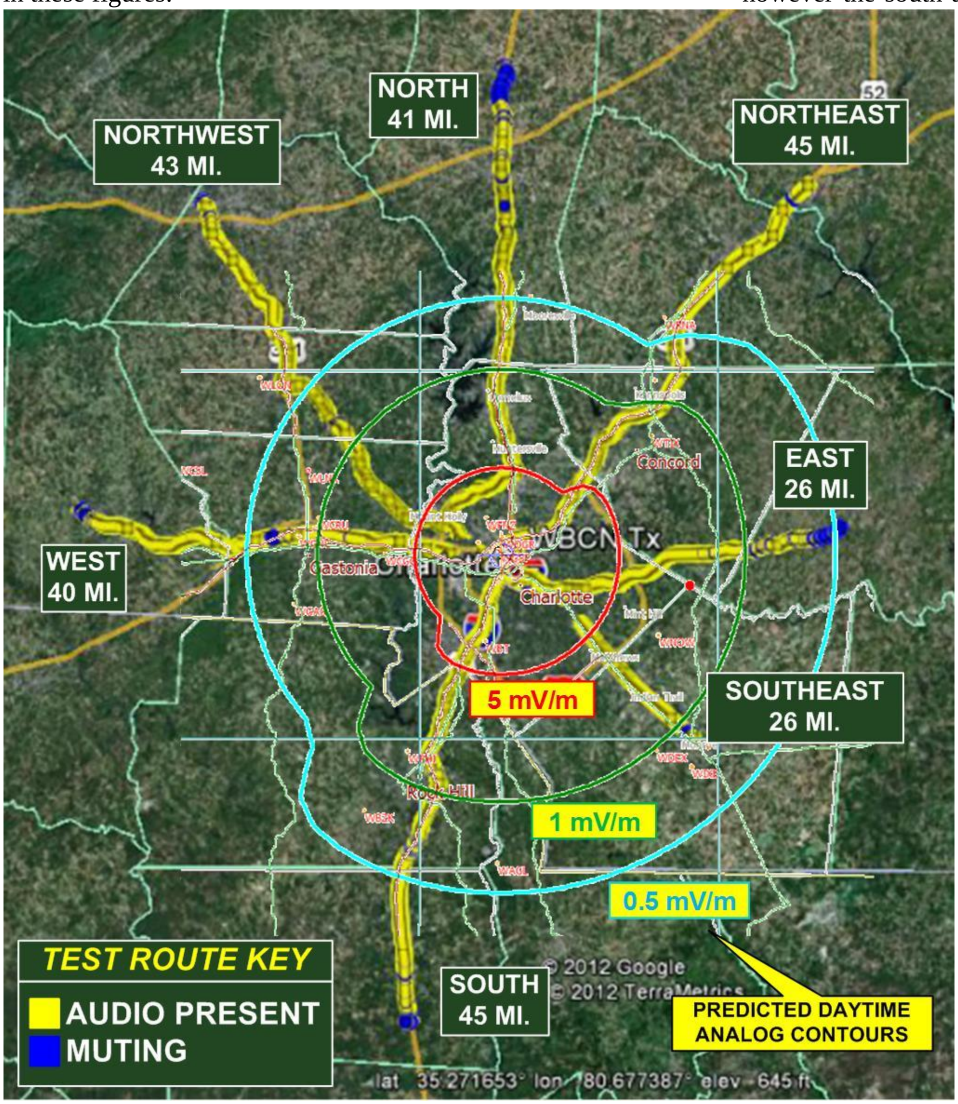

FIGURE 20. ALL-DIGITAL AM IBOC MOBILE TEST RESULTS – DAYTIME. FIGURES FOR EACH ROUTE INDICATE APPROXIMATE DISTANCE FROM TRANSMITTER TO ALL-DIGITAL AM IBOC POINT-OF-FAILURE (POF). OVERLAID ON THE ROUTE MAP ARE PREDICTED DAYTIME ANALOG AM CONTOURS FOR 5, 1, AND 0.5 MV/M.

- Predicted analog signal contours for WBCN are overlaid onto the all-digital mobile test route data, illustrating that for daytime operation, the all-digital signal was solid beyond the 1 mV/m contour, and for nighttime, beyond the 5 mV/m contour;
- Only seven of the eight planned test routes were driven for the daytime tests (no data on the southwest route was obtained). This is because there was just enough time during the first weekend of testing to collect data on the seven routes driven, and this data was deemed adequate for achieving the goals of the test. It was decided to go ahead and return the test vehicle to iBiquity's headquarters in Columbia, MD rather than keep it in Charlotte for an entire week to just do a single test run;
- For nighttime testing, all eight test routes were driven, however the south and southwest routes were the same for the first few miles and since the all-digital POF was encountered on the common part of these two routes, only the south route is shown in Figure 21. Also, portions of Interstate 485 were captured at night as well and are shown in the figure;
- Performance to the east and southeast was noticeably poorer than on the other routes. This is believed to be due in part to a greater amount of environmental noise, especially due to power lines in close proximity to the test routes;
- Surprisingly, nighttime performance appeared to be compromised by the presence of co-channel interference, which was not expected on an expanded-band AM station. It is believed that this was due to a nearby co-channel station may not have been fully powering down for nighttime operation.

After establishing the geographic coordinates for the all-digital POF for each test route, WBCN was configured for analog AM (not hybrid AM IBOC) transmission, and a second Ford Focus, this one with a factory-installed, non-HD Radio receiver (*i.e.*, analog only) was driven to each POF location. A recording of the analog receiver audio was made at each POF location with the vehicle parked on the side of the road using a Tascam DR-2d digital audio recorder [7], and signal strength measurements were made

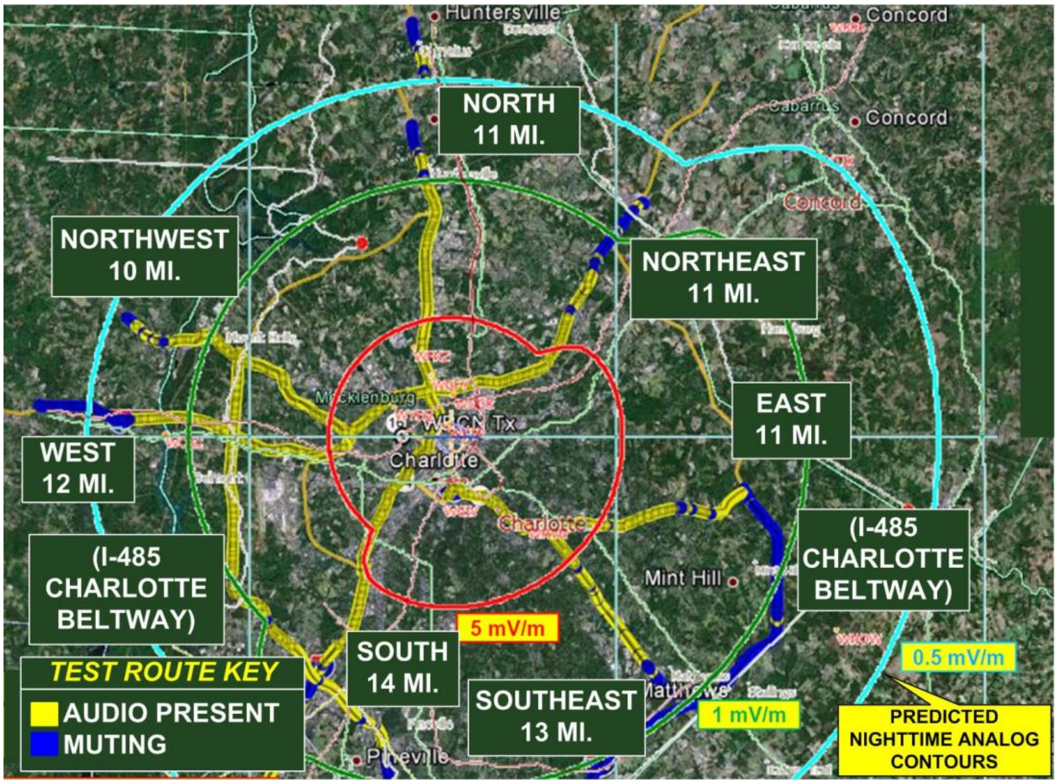

FIGURE 21. ALL-DIGITAL AM IBOC MOBILE TEST RESULTS – NIGHTTIME. FIGURES FOR EACH ROUTE INDICATE APPROXIMATE DISTANCE FROM TRANSMITTER TO ALL-DIGITAL AM IBOC POINT-OF-FAILURE (POF). OVERLAID ON THE ROUTE MAP ARE PREDICTED NIGHTTIME ANALOG AM CONTOURS FOR 5, 1, AND 0.5 MV/M.

using a Scott LP-3 shielded loop antenna connected to a Rhode & Schwarz spectrum analyzer (same equipment used for indoor signal strength measurements). [8] These recording and the signal strength data are currently under analysis and will be described in a future report.

TEST RESULTS – INDOOR TESTING

Indoor reception tests were conducted at fifteen sites within the WBCN coverage area (Figure 22 and Figure 23), under four reception conditions: analog day, analog night, digital day, and digital night. An Insignia Narrator tabletop HD Radio receiver was used for these tests. [9] The Narrator receiver utilizes an AM loop antenna (included with the receiver), and at each site the position of this antenna was adjusted for best reception. The particular receiver and antenna orientation for each site was photographed and this photograph was used to ensure the same orientation for each of the four test conditions at that site. This was necessary since for most sites, four separate visits over the course of a few days were needed to obtain data under all four test conditions.[9]

Also, at each test site, for each reception condition, a signal strength measurement was made using a Scott LP-3 shielded loop antenna connected to a Rhode & Schwarz spectrum analyzer. Figure 24 is a photograph of a typical indoor measurement which was taken at site P, the lobby of a Fairfield Inn and Suites. Once the receiver's antenna was oriented for best reception, if reception was achieved then a two-minute audio recording was made for each site under each test condition by connecting a digital audio recorder (Tascam DR-2d) to the headphone jack of the Narrator receiver.

These indoor sites were representative of a variety of building construction materials including (letters refer to test sites shown in Figure 22 and Figure 23) steel (N, O, P), steel and masonry (B,Q), brick (D, C, F, E, K), and wood with siding or brick (G, H, I, L, M). Table 4 provides a summary of the results of these indoor tests. Some specific observations on the indoor test results include the following:

- Solid all-digital indoor reception was achieved for daytime and nightime locations within approximately 13 and 7 miles, respectively, of the transmit antenna site. As expected, these distances are significantly less than for mobile reception, where solid all-digital reception was achieved out to about 40 miles (daytime) and 11 miles (nighttime);
- One exception to this was the indoor reception experienced at site "C," the CBS Radio Epicentre Studio. Despite close proximity to the transmit site (1.97 mi), analog reception was poor (daytime) or non-existent (nighttime) yet good all-digital reception (daytime) was achieved. All-digital nighttime reception was attempted at this site but not achieved;
- For the last five sites in the table (H, I, Q, L, M) no actual digital nighttime reception was attempted since analog daytime reception was poor and analog nighttime reception was non-existent. This poor performance was attributed to the fact that all of these test sites are relatively far away (16 miles or more) from the transmit site.

[9] Note that for some sites, analog and digital night measurements were made in a single visit to the site, by remotely switching between the Harris DX-10 (set up for all-digital transmission) and the Nautel backup transmitter (set up for analog transmission).

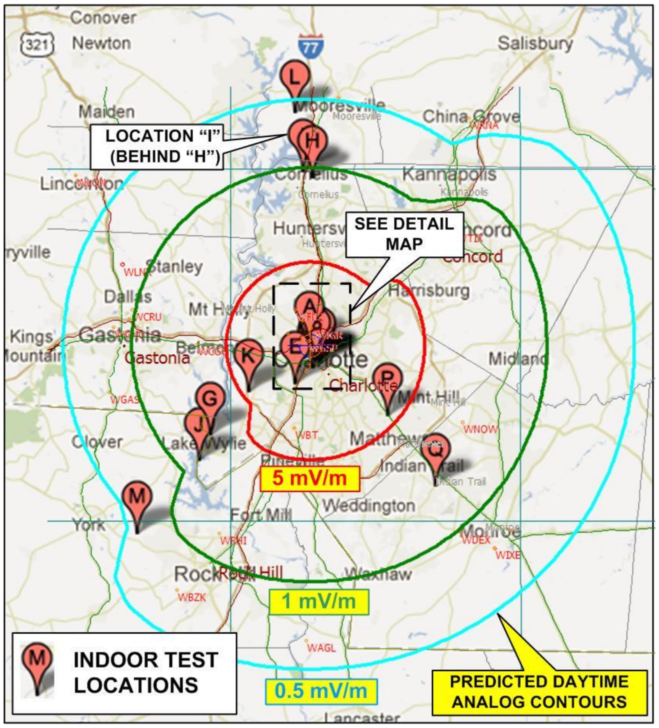

FIGURE 22. INDOOR TEST LOCATIONS ("A" IS THE WBCN TRANSMISSION SITE)

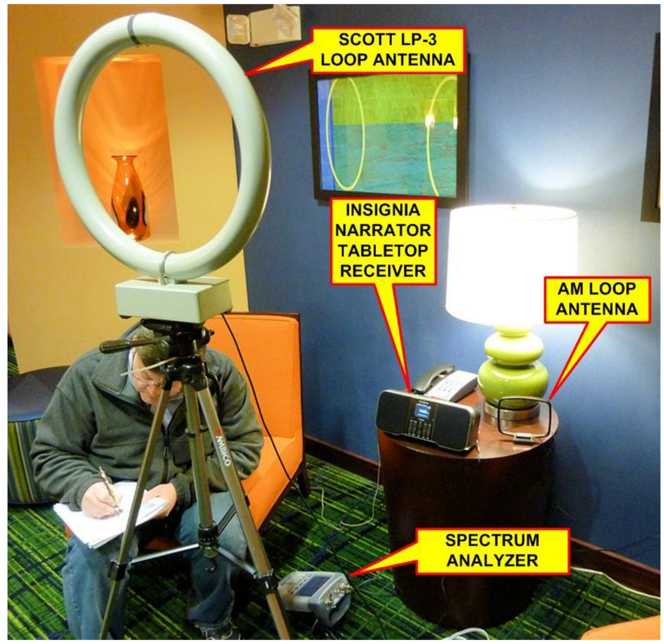

FIGURE 24. INDOOR MEASUREMENT EQUIPMENT SETUP AT SITE P (FAIRFIELD INN & SUITES). NOTICE THAT THE SCOTT AND INSIGNIA NARRATOR LOOP ANTENNAS ARE ORIENTED IN THE SAME DIRECTION; THIS WAS TYPICAL OF ALL MEASUREMENT SITES.

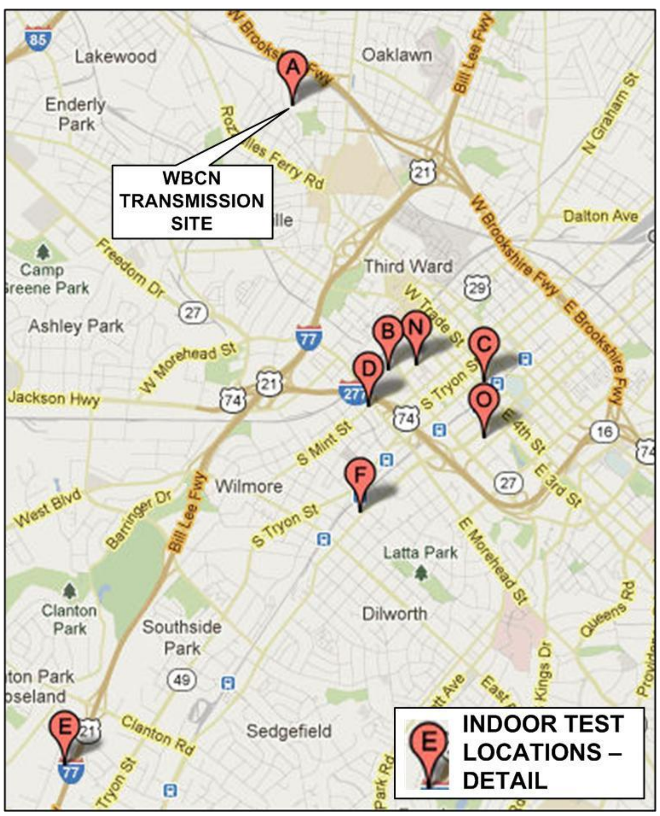

FIGURE 23. INDOOR TEST LOCATIONS – DETAIL

TABLE 4. INDOOR TEST LOCATION RECEPTION RESULTS

KEY: AD – Analog Day, AN – Analog Night, DD – Digital Day, DN – Digital Night

Analog reception: G – Good, F – Fair, P – Poor, n/a – not available

Digital reception: Green – Yes, Red – No, Yellow - Intermittent

Map Key	Distance to TX antenna (mi)	Description	AD	AN	DD	DN
B	1.66	Bank of America Stadium	G	G/F	Green	Green
N	1.69	Residence Inn by Marriott	G	G/F	Green	Green
D	1.83	CBS Radio - "Doghouse"	G	G	Green	Green
C	1.97	CBS Radio - Epicentre studio	P	n/a	Green	Red
O	2.25	Hilton Garden Inn	G/F	F/P	Green	Green
F	2.42	CBS Radio studios	F	F/P	Green	Green
E	4.10	CBS Radio former studios	G/F	F/P	Green	Green
K	7.60	Fred Smith residence	G	F	Green	Green
P	10.40	Fairfield Inn & Suites	P	P	Green	Red
G	13.03	John Dolive residence	F	P	Green	Red
H	16.01	Hair Salon	P	n/a	Red	No service expected
I	16.62	Alan Lane residence	P	n/a	Yellow	No service expected
Q	18.48	McDonald's	P	n/a	Red	No service expected
L	22.45	Joshua Pierce residence	P	n/a	Red	No service expected
M	24.95	Brad Humphries residence	F/P	n/a	Green	No service expected

No service expected (hatched)

SUMMARY AND FUTURE ACTIVITIES

This field test project, facilitated by CBS Radio's decision to allow for limited all-digital AM IBOC testing at WBCN in Charlotte, has resulted in the collection of important information pertaining to the operation of an AM IBOC radio station in the MA3 all-digital mode. Specifically, a procedure was developed for calibration of the transmitter power (in all-digital mode) to the licensed daytime and nighttime power of the station, and mobile and indoor all-digital AM IBOC reception data were obtained.

The project team is continuing to analyze the field strength measurements and audio recordings obtained during these tests, and expects to make this information available to the industry when this analysis is completed. NAB Labs expects to support future all-digital AM IBOC test projects at other stations so as to fully develop a performance record of operation in this mode.

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