Field Report
AM IBOC Nighttime Compatibility

October 31, 2003

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This report contains results from field tests designed to assess the analog compatibility of nighttime operation of iBiquity Digital Corporation's AM HD Radio™ system. Earlier this year, iBiquity completed an analytical study of AM HD Radio compatibility with existing analog AM broadcasting. The results of that study were presented in a previous report. This report contains the results of field tests conducted to corroborate the results of the analytical study and to provide real world evidence of the compatibility of the AM HD Radio system with analog AM broadcasts at night.[1]

1 Summary

These compatibility assessments were initiated in response to concerns raised by the National Radio Systems Committee and the Federal Communications Commission questioning whether the AM HD Radio system would cause severe disruptions to analog AM nighttime broadcasts. Contrary to the concerns expressed by broadcasters, listeners and regulators, this report, in combination with iBiquity's previous report on the analytical study, demonstrates that the AM HD Radio system will not have a significant impact on most AM stations' existing analog listeners. The conclusions from this report can be summarized as follows:

- This report confirms the conclusion from the analytical study that the introduction of nighttime AM HD Radio broadcasts should not increase interference to AM stations' analog groundwave signals, except at the edge of analog coverage.
- The field tests discussed herein indicate that the AM HD Radio system has a lower potential to impact analog skywave broadcasts than had been assumed.
- An undesired HD Radio groundwave signal has the potential to impact a desired first adjacent skywave signal in a narrow ring around each undesired IBOC station. Inside of this region, most receivers would not be able to receive a desired skywave signal due to interference from the undesired analog groundwave signal. Outside of this region, groundwave IBOC has less impact on the desired skywave signal than existing analog groundwave and skywave interference.
- Undesired skywave IBOC signals have a greater potential to impact desired analog skywave signals. In this case, the introduction of IBOC will not interfere with skywave in a particular geographic area. Instead, the undesired skywave IBOC signal will decrease the amount of time that a listener will be able to receive the already unreliable analog skywave signal. Because this type of IBOC interference occurs in areas with severe levels of analog interference, the number of listeners to skywave broadcasts in these areas is extremely limited.

Based on these conclusions from the field tests, iBiquity has determined the introduction of IBOC, even if it does increase skywave interference, will have an impact on very few listeners.

[1] A separate report on AM IBOC nighttime digital coverage is being presented concurrently with this submission.

2 Overview of Field Tests

iBiquity's internal analysis indicated the introduction of nighttime AM HD Radio would present different interference risks depending on the characteristics of the existing analog stations. For example, channels characterized by many local stations tend to suffer from high levels of co-channel analog interference and already have relatively small service areas. This would mask any negative effects from the introduction of HD Radio. In contrast, clear channel stations generally are relatively free from co-channel interference and have more extensive service areas. Thus, clear channel stations have a greater risk of interference from HD Radio. In order to concentrate on the area with the greatest risk of interference, this nighttime field test program focused on two first adjacent stations: WOR, New York, 710 kHz, and WLW, Cincinnati, 700 kHz. Each of these stations transmits 50 kW at night and is at the low end of the band and thus has excellent primary ground coverage. Each station also has secondary skywave coverage.

The field tests described in this report were conducted in two separate phases. Phase 1 was conducted during August 2002. Phase 2 was conducted during December 2002. The testing was divided into two phases to account for the different nighttime propagation conditions that exist in the AM band between summer and winter. As is described in greater detail in Section 3 below, the tests were designed to consider the HD Radio system's impact on both analog groundwave and analog skywave broadcasts.

As Figure 1 demonstrates, existing allocations in the AM band result in a pattern with adjacent channels interlaced and overlapping. 20 kHz analog bandwidth signals are assigned every 10 kHz. The introduction of AM HD Radio signals will place digital energy in the sidebands of the first adjacent analog signal. This increases the risk of interface to AM analog broadcasts and was the focus of this field testing.

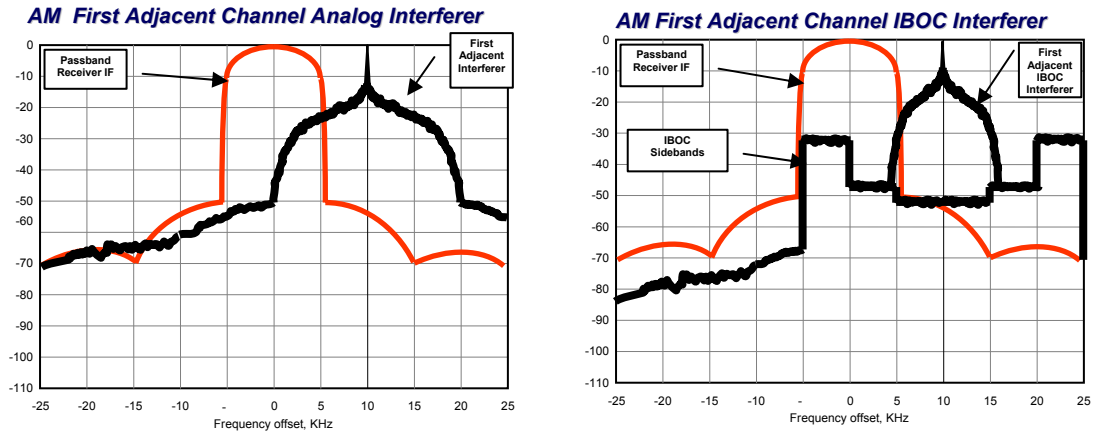

Figure 1: AM Signals with Analog and Digital Interferers

3 Test Methodology

3.1 Field Testing

The nighttime field tests were designed to evaluate the potential impact of the AM HD Radio system for three types of listening conditions:

1. *Effects of Undesired Digital Skywave Interference to Desired Groundwave Analog Reception (S2G)*:
   This type of interference occurs when the receiver is located close to the desired station, within its groundwave signal area, and the interferers are the skywave component of a distant undesired station.
2. *Effects Of Undesired Digital Groundwave Interference On Desired Skywave Analog Reception (G2S)*:
   This type of interference occurs when the receiver is located distant from the desired station, within its skywave signal area, and the interferers are the groundwave component of a local undesired station.
3. *Effects Of Undesired Digital Skywave Interference On Desired Skywave Analog Reception (S2S)*:
   This type of interference occurs when the receiver is located distant from the desired station, within its skywave signal area, and the interferers are also distant skywave stations.

Audio recordings of analog broadcasts with and without HD Radio interferers were made at specified locations intended to capture the effects of S2S, S2G and G2S interference. Propagation modeling software was used to locate geographic locations where these effects could be observed over a sufficient range of D/Us to create recordings where IBOC interference was expected to be inaudible (+10 D/U) to clearly audible (-10 D/U) for the three specified interference scenarios. To test the effects of the automotive omni directional whip antenna versus the common directional ferrite loop antenna employed in home Hi-Fi, portable and boombox receivers, additional off-axis testing locations were chosen where recordings could be made to show the benefits of the directional characteristic of the AM loop antennas. The benefits of a directional loop type AM antenna apply to all locations except those in a direct line between the desired and undesired stations. These recordings were subjectively evaluated to determine the effects of both analog and IBOC interference.

Table 1 below details the receivers considered for this test:[2]

Class of Receiver	Manufacturer	Model No.
Auto OEM	Delphi Corporation	09394139
Auto Aftermarket	Pioneer	KEH-1900
Home Hi-Fi	Technics	SA-EX110
Moderately Priced Boombox	Sony Corporation	CFS-522
High End Portable	G.E.	SUPERADIO7-2887A

[2] The first four receivers are the same units used previously in NRSC sponsored testing.

The two automotive receivers represent a widely used Original Equipment Manufacturers (OEM) receiver and a top selling aftermarket receiver. Both of these receivers employ highly selective IF filters, thus minimizing adjacent channel analog interference and sensitivity to the HD Radio system's digital carriers. The Boombox, Home Hi-Fi, and G.E. SUPERADIO receivers are a class of receivers with less selective IF filtration and directional loop antennas. Together, these five receivers typify the general population of receivers in use.

Ultimately, in the subjective testing program the number of receivers evaluated was reduced to three. The Home Hi-Fi receiver and the aftermarket auto receivers were not used as the performance and design characteristics of these receivers were met with the OEM auto radio, the boombox and the high end portable.

Figure 2 shows all the test locations (Undesired → Desired). Field tests were conducted during summer (August) and winter (December) 2002 to determine whether seasonal variances in skywave effects on the AM band would influence the results. In particular, it was felt that less favorable nighttime skywave propagation conditions in the summer months might mask some level of IBOC impact on analog skywave listening. As is detailed below, the field tests indicated that the determining factor for IBOC interference is the level of analog interference for the desired and undesired stations. The change in season does not change the interference levels where IBOC has a potential to impact analog skywave, but it might change the frequency of finding and location of areas with the greatest potential for an impact.[3]

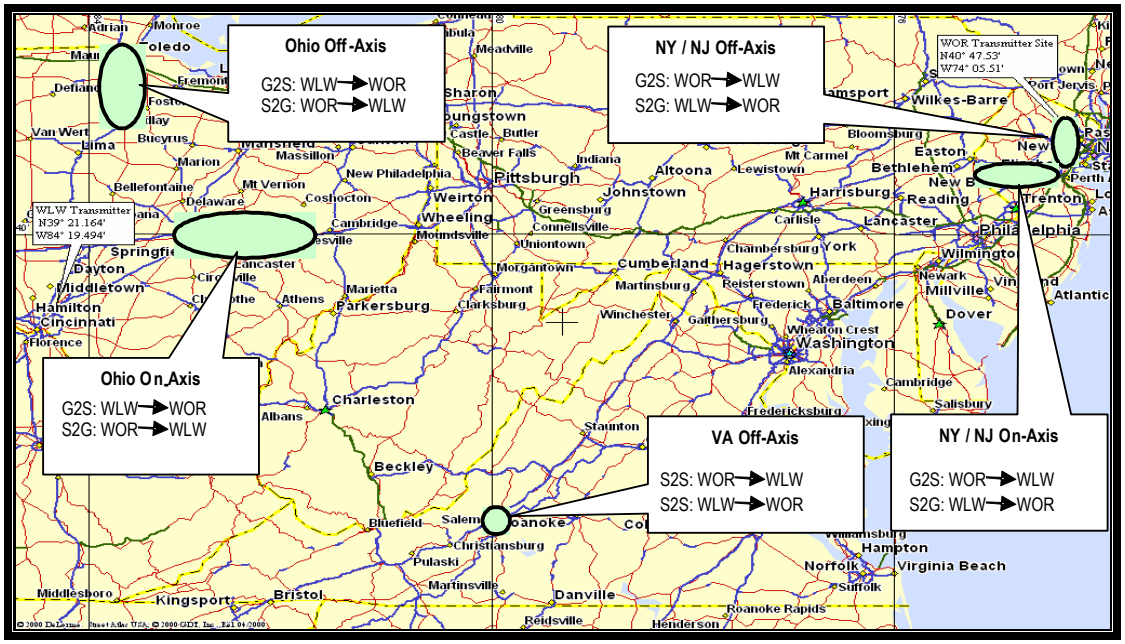

Figure 2 Nighttime Test Location Map

[3] Details on the compatibility field test procedures are in Appendix A.

3.1.1 Skywave to Groundwave Tests

Field test locations for S2G interference were selected to investigate areas where both analog and IBOC interference were expected to impact listening. These areas were located on the fringe of the primary groundwave coverage area for both WOR and WLW. This region looks like a "ring" around each station's primary groundwave coverage area in which the desired groundwave to undesired skywave interference (D/U) ratio is between -10 dB and +10 dB.

3.1.2 Groundwave to Skywave Tests

In the case of G2S interference the field tests were located close to the undesired station in order to be within the groundwave service area. The test receivers were tuned to the distant skywave desired signal.

3.1.3 Skywave to Skywave Tests

S2S testing was conducted in southwestern Virginia where it was predicted that both WOR and WLW would have good skywave coverage. The location was selected to minimize any effects from 720 kHz WGN, Chicago and 690 kHz CBF, Montreal. It had the added benefit of being located off the axis between the stations, thus providing in one location off axis directional results for the portable and boom box and non-directional results of the automotive receivers.

Figure 3 shows the location of the S2S measurement point in Virginia overlaid on a map that predicts the D/U ratio between WLW (Desired) and WOR (Undesired). The red color near WLW shows where the D/U ratio for WLW is greater than 20 dB. The S2S measurement point, located in an area shown in a lighter shade of blue, is predicted to have a positive D/U for WLW of 2 dB.

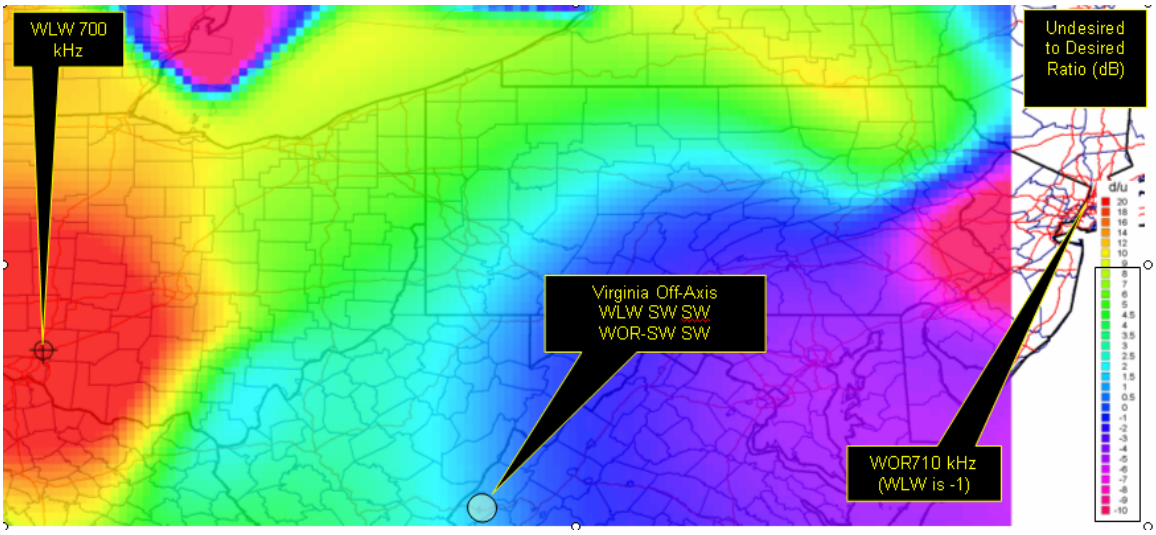

Figure 3: S2S Measurement location overlaid on a map depicting the D/U ratio between WLW (D) and WOR (U)

3.2 Subjective Listening Tests

On axis and off axis field recordings of S2G, G2S, and S2S interference were subjectively evaluated with IBOC off and IBOC on. The evaluations were conducted

using automotive grade speakers in a sound treated listening facility. Because the nature of these nighttime AM tests was fundamentally different than previous subjective evaluations iBiquity has conducted, the subjective evaluation methodology was significantly modified. The subjective evaluation of these nighttime AM audio samples presented two challenges. First, due to the low audio quality of analog AM, the standard ACR MOS methodology would have resulted in all scores being compressed in a narrow range. Second, the standard ACR MOS methodology looks for changes in audio quality but does not provide any information on the motivation of the listener. The modifications to the methodology that were undertaken were designed to address both these concerns.

With regard to the issue of listener motivation, it is important to consider that in the case of FM analog and, to some extent, daytime AM, listeners are motivated by a desire to hear certain content but also by a desire for appropriate levels of audio quality. This is significantly different than AM analog nighttime service, which is characterized by fairly marginal audio quality. Nighttime analog AM listeners are motivated by a desire to hear certain content rather than by an expectation of quality. Under these circumstances, it can be expected that listeners will accept reduced audio quality until a point at which listeners will turn off the radio. Based on these observations, the subjective evaluation program was structured to identify that threshold when reduced audio quality would cause listeners to tune out rather than to identify subtle changes in audio quality.

In order to focus on thresholds for tuning out the programming rather than changes in audio quality, the ACR-MOS scale was modified. The ACR-MOS rating scale used in previous iBiquity tests asks participants to focus solely on one dimension, sound quality, while making their decision. The categories (Excellent, Good, Fair, Poor and Bad) were designed to be evenly spaced. The rating scales used for this AM nighttime study, however, asked participants to consider two dimensions simultaneously: (a) the extent to which impairments are heard (5 = No impairments heard; 4 = Impairments heard, but not bothersome; 3 = Significant impairments heard; 2 = Significant, disruptive impairments; 1 = complete failure) and (b) whether they would continue to listen to the sound sample depending on their perceived motivation. In this test the categories were not chosen to be evenly spaced. They are, instead, distinct decision points. Participants needed to choose between them considering their “state of mind” as well as the level of impairment heard in the sample.[4]

To better interpret the subjective results, an analysis of the data was undertaken to determine the critical point at which a majority of listeners would no longer choose to listen, even when motivated to do so. Because listeners of nighttime AM radio have a high tolerance for interference, understanding the level of interference that will cause the listener to turn off the radio or change the channel is extremely relevant to the analysis of the impact of IBOC service. The analysis of the subjective results indicated that at the 2.6 level, approximately 50% of listeners would keep the radio on. Below that 2.6 point, a majority of listeners claim they would turn off the program. Based on this

[4] Details on the subjective methodology are contained in a report titled “Subjective Methodology and Results of AM Nighttime Transmission Testing” submitted by Ellyn Sheffield, PhD (Subjective Report) and attached hereto as Appendix B.

finding, the results presented herein include a reference to this 2.6 threshold or “tune out” point.

4 Test Results

On balance, the subjective evaluations produced results that were more favorable than had been anticipated. Prior to the tests, there had been concern among some broadcasters and listeners that the introduction of nighttime AM IBOC would create widespread interference to analog AM. As is described in greater detail throughout this section, the subjective evaluation program demonstrated that the introduction of nighttime AM IBOC will have little or no impact on analog listening in the majority of cases.

The test results demonstrate that the existing analog D/U ratio is the best indicator of the areas where IBOC may impact analog listening and that IBOC has the greatest potential to impact analog listening in areas of moderate analog interference. Generally, areas with weak analog interference, +10 dB D/U or less interference (+10 dB or higher), receive acceptable analog reception today. The introduction of IBOC does not have a significant impact in these areas. In areas of strong analog interference (-10 dB D/U or lower) analog reception is already compromised, and subjective evaluations indicated most listeners would no longer listen to a station under those conditions. As a result, the introduction of IBOC cannot be expected to have any meaningful impact in these areas. iBiquity has focused its analysis on the mid range to identify areas where analog listening may be acceptable and where the introduction of IBOC has a potential to impact those broadcasts. Overall, the evaluations indicate the introduction of IBOC in the areas with moderate analog interference will have a minor, but likely acceptable, impact on analog listeners. Even in those situations where the introduction of IBOC reduces listener perception of the analog audio, the subjective evaluations indicate most listeners will continue to listen to the existing analog broadcast.

When analyzing the results, it is important to consider the type of receiver used. The tests demonstrated that the introduction of nighttime AM IBOC will have a different impact on different analog receivers. In certain scenarios, narrowband analog receivers designed to filter out significant levels of analog interference will also provide greater resistance to IBOC interference. At the same time, receivers with directional antennas have the ability to overcome a significant amount of IBOC interference for off axis listening, even if the receiver has a wideband filter.

A complete report on the results of the subjective evaluation is presented in Appendix B. The following sections discuss the results of the subjective evaluation for all three test scenarios (G2S, S2G and S2S). After identifying the analog D/U ratios that are most likely to be susceptible to IBOC interference, these sections also discuss where these interference levels are expected to be found. By identifying the frequency and location of these potentially problematic interference levels, this report helps quantify the impact on actual listeners. At the same time, this analysis helps correlate the subjective results with iBiquity’s previous analytical study. The subjective results were used to identify the interference levels most likely to result in IBOC interference to analog broadcasts. When these interference levels from the subjective evaluations were plotted on the

maps used for the analytical study, they correlated with the areas of potential interference identified in that study.

4.1 Sky-to-Ground

Figure 4 summarizes the results for the sky-to-ground tests.[5] As would be expected, in the case of weak interference, the introduction of IBOC does not impact the analog signal. In the mid range, the introduction of IBOC reduces the subjective evaluation score, but it remains above the tune out threshold. In areas of strong interference, however, there was a degradation in audio quality that went from an acceptable level to below the threshold for tune out. As is explained in greater detail below, however, these strong interference levels would be found at or beyond the desired station's NIF.[6] As a result, the impact from the introduction of IBOC would be felt only in fringe areas outside the station's primary service area.

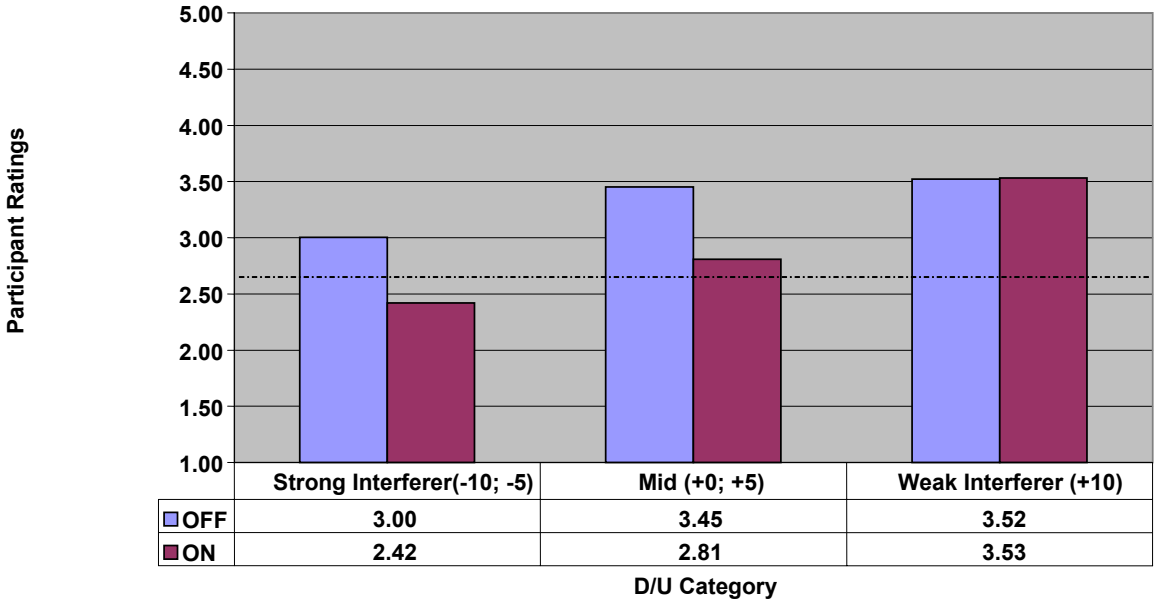

Figure 4: Sky-to-Ground

When testing the impact of WOR's digital skywave signal on WLW's groundwave analog service, it was necessary to go outside the WLW NIF to obtain the required D/U ratios. This field work confirmed potentially problematic interference levels will not be found inside a station's primary service area. The strong, desired groundwave signal is not impacted by undesired skywave interference except in fringe coverage areas. Figure 5 shows WLW's signal strength plot with the theoretical NIF overlaid at 2.7 mV/m

[5] Figures 4, 9 and 11 graphically depict the effect of IBOC on existing analog signals. The audio samples were placed into 3 groups, depending on their signal strength: (a) "strong interferer", including D/U ratios of -10 and -5 dB; (b) "mid", including D/U ratios of +0 and +5 dB, and (c) "weak interferer", or a D/U ratio of +10 dB. The dotted line added to the figures is the 2.6 demarcation point: above the line, the majority of listeners would keep the program on. Below the line, the majority would turn it off.

[6] Although Class A stations do not have a defined NIF, iBiquity has calculated NIF for these Class A stations using the same methodology used for Class B and Class C stations.

(25% exclusion rule) and the locations of the field test recordings. Even at these locations, a positive D/U ratio was recorded for a vast majority of the time. It can be expected that recordings made with those positive D/U ratios would have been above the ACR cutoff point.

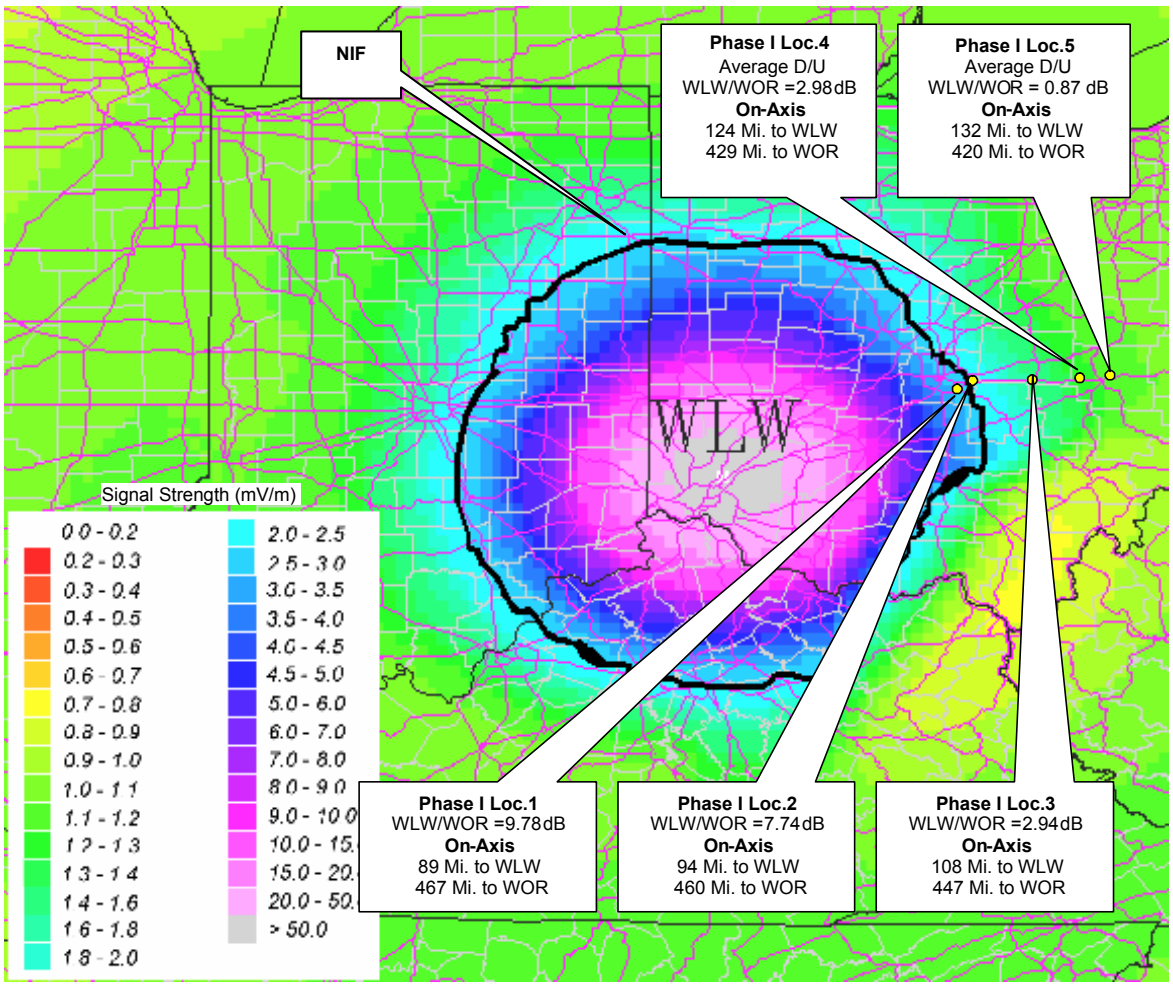

Figure 5: WLW Nighttime Signal Strength Map with NIF of 2.7 mV/m and Field Test Recording Locations overlaid

These conclusions from the field are consistent with the results of the analytical study previously present. Figure 6 shows the predicted differential analog MOS rating for WLW from the previous study. The field test locations are added to this map. As can be seen the required interference levels were found in the yellow color area where impact is predicted to be the greatest (changes in MOS score of 0.4 to 0.48 points).

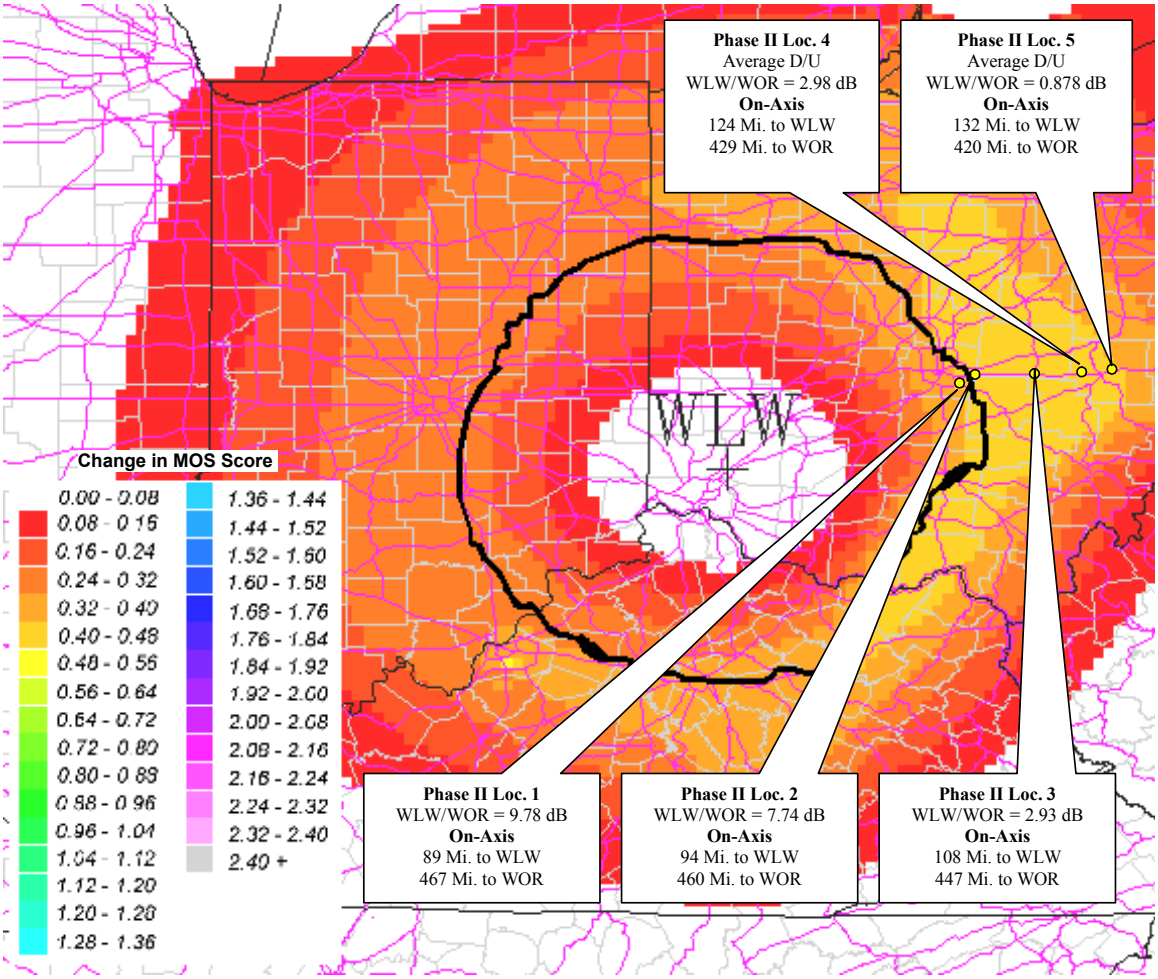

Figure 6: Predicated Change in WLW Nighttime (based on Delphi Receiver) MOS due to IBOC with NIF and Field test Recording Locations overlaid

The results of tests conducted in New York and New Jersey to assess the impact of WLW's digital skywave on WOR's analog groundwave signal further confirm these conclusions. The WOR test points are shown in Figure 7 plotted against the WOR signal strength and theoretical NIF. The test points for WOR also are near or outside the NIF, except for Phase I location 5 which had a D/U on average above +20 dB. At that level, it would be expected that IBOC would have no impact. The rest of the field test points had positive or slightly positive D/Us, except for a few instances where the WLW skywave peaked and WOR groundwave experienced interference from its own skywave, such as at location 2, the furthest point out. Since the D/U remained positive and thus above the affected D/U region inside the NIF, WOR's primary groundwave coverage area would not have been impacted.

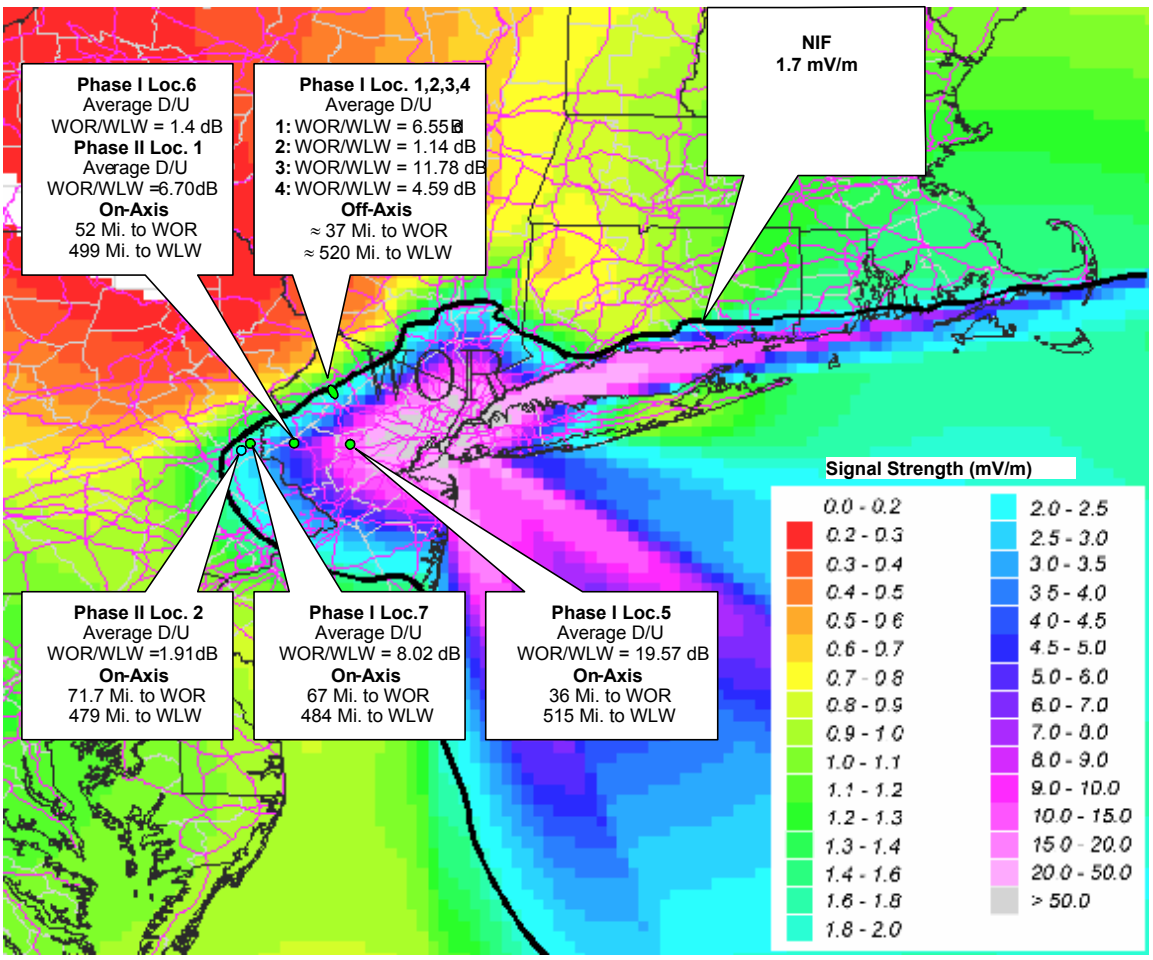

Figure 7: WOR's Nighttime Signal Strength mV/m Map with NIF of 1.7 mV/m and Field Test Recording Locations overlaid

As was the case for WLW, the WOR field tests were conducted near the region where the audio quality scores were predicted to be the most impacted. Figure 8 shows the predicted impact of IBOC from iBiquity's previous analytical study. The areas of greatest impact are indicated in yellow and green. Nearly the entire region predicted to be impacted by a change in MOS of 0.55-0.64 (green color) is outside WOR's NIF.

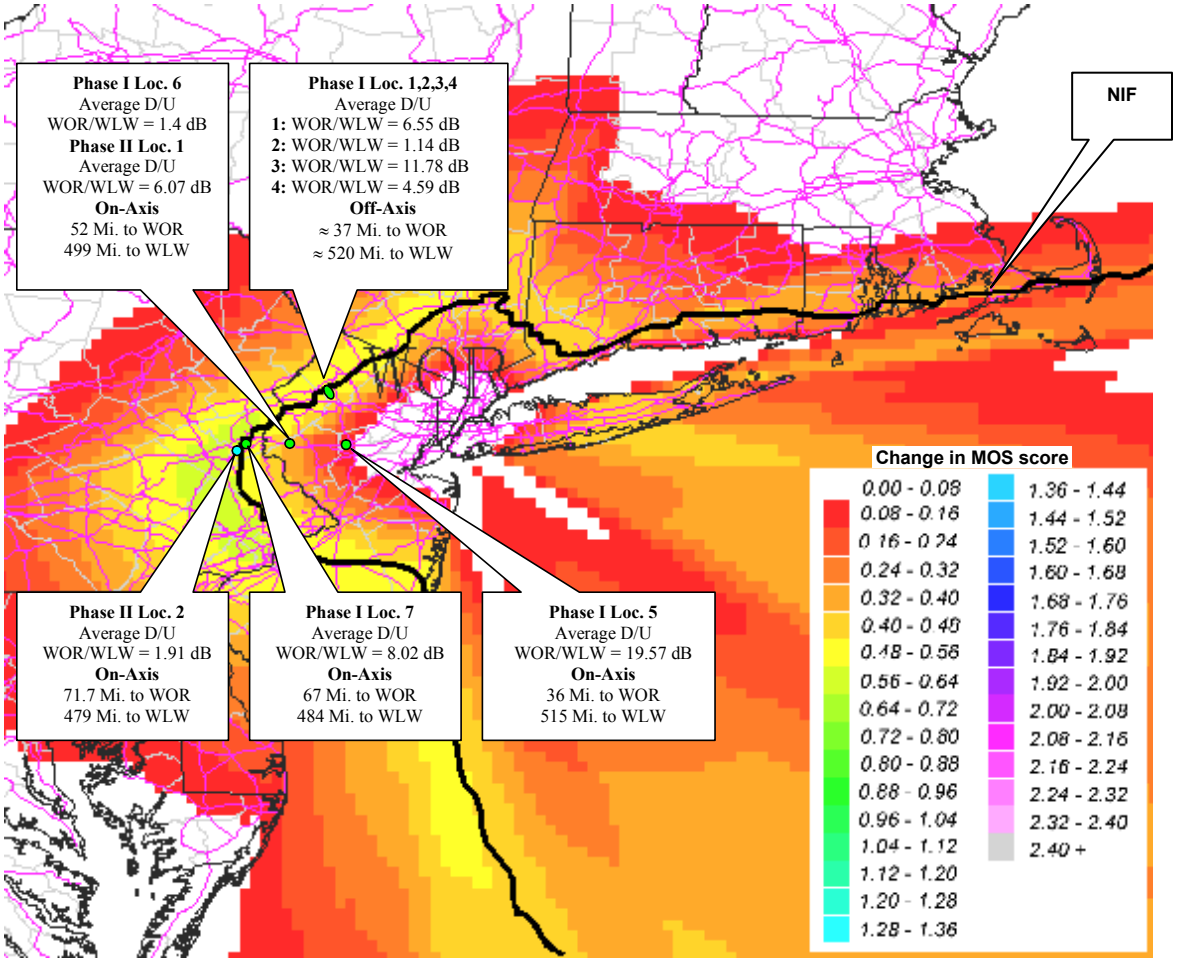

Figure 8: Predicted Change in WOR Nighttime (based on Delphi Receiver) MOS due to IBOC with NIF and Field test Recording Locations overlaid

4.2 Groundwave Interference to Skywave

Because weak skywave signals are unstable and unpredictable, it is difficult to assess the impact of AM IBOC groundwave on skywave reception. Figure 9 presents the subjective evaluation results for ground-to-sky interference. The results indicate the introduction of groundwave IBOC signals will not have a meaningful impact on analog skywave service. The subjective evaluation confirmed that the introduction of IBOC will have the largest impact in the mid range. Even at this level, however, the introduction of IBOC will not cause listeners to tune out. With strong analog interference, the skywave signal is so degraded that it is at the tune out threshold. At this point, the additional degradation resulting from the introduction of IBOC is not meaningful. iBiquity believes the results for weak interferer represent an anomaly in the data. It would have been expected that the weaker interference would have resulted in higher scores for both IBOC OFF and IBOC ON conditions but this was not the case. iBiquity assumes that either the programmatic content or the unusual quality of these particular audio samples resulted in an unusually low score.

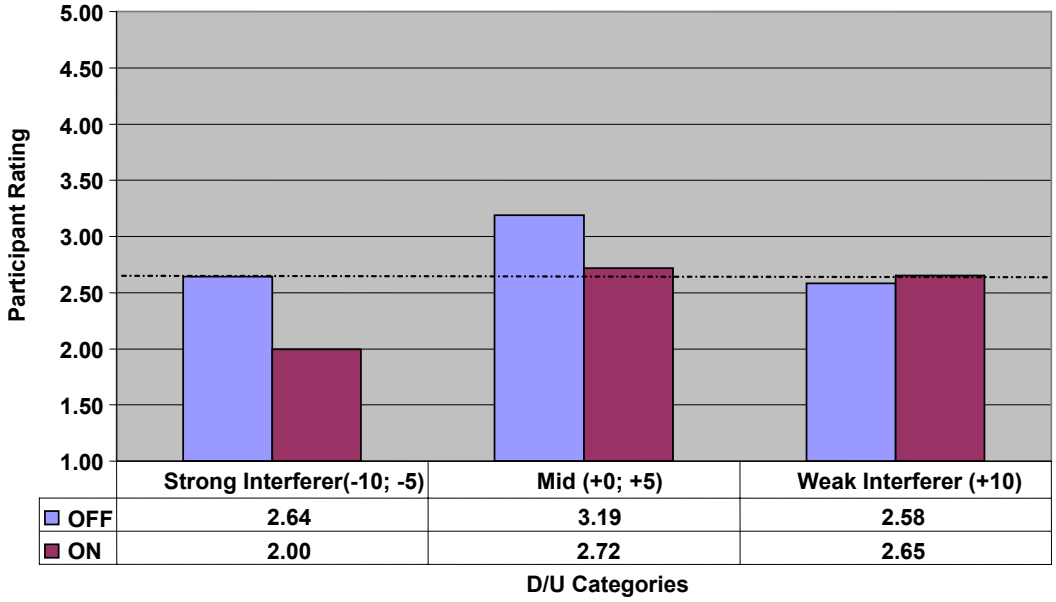

Figure 9: Ground-to-Sky

The field tests indicated any potentially problematic interference levels are found far from the desired skywave station transmitter and inside the service area of the undesired station. The measurement points for the desired WLW skywave signal were located inside WOR's NIF. Outside the WOR NIF there was insufficient impact from the undesired WOR signal. Similarly, it was necessary to approach the Cincinatti service area before undesired WLW groundwave impacted a desired WOR skywave signal. iBiquity's analysis indicates, and as is illustrated in Figure 10, G2S interference creates a ring around the undesired station where the D/U ratios become increasingly negative. This increases crosstalk to the weaker, desired skywave signal. Inside the ring, analog groundwave masks the desired skywave signal. Outside the ring, the desired skywave signal remains listenable, even after the introduction of IBOC on the undesired first adjacent channel. The width and location of this ring of impact depends on each receiver's ability to filter the overlapping first adjacent analog signal.[7]

[7] See Section 3.4 below for a more detailed discussion of the impact of receivers and antennas on skywave reception.

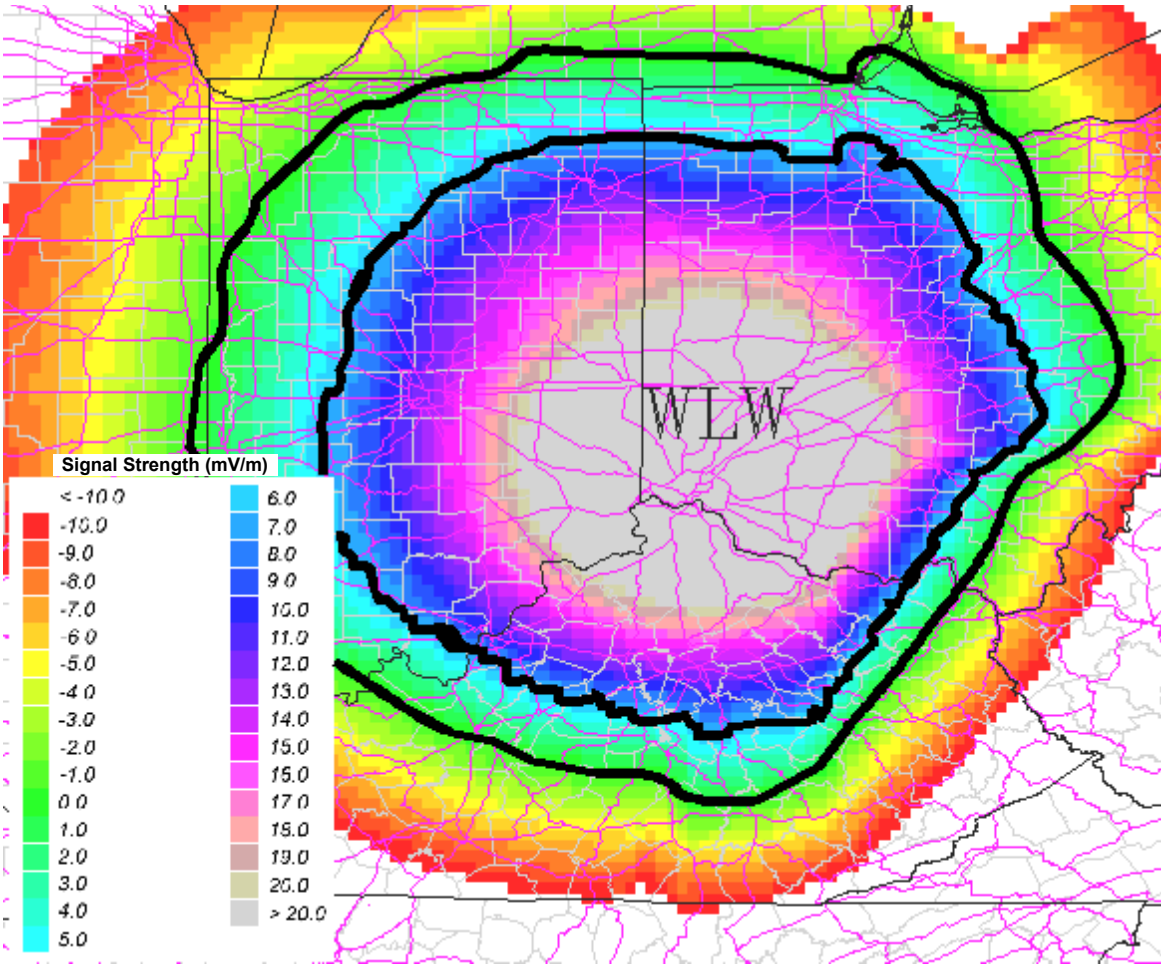

Figure 10: 1st adjacent D/U map and G2S overlays for WLW in Ohio showing added Region where WOR is affected by WLW IBOC between the black lines.

4.3 Skywave Interference into Skywave Desired Signal (S2S):

Figure 11 summarizes the subjective evaluation results for sky to sky interference. Again, for both weak and moderate levels of interference, the subjective evaluations confirmed that any degradation IBOC causes will not reduce audio quality below the tune out threshold. In the case of strong interference, the analog signal is so impaired that the introduction of IBOC does not have a meaningful impact. Notwithstanding the extremely low audio quality of the skywave signal in severe interference conditions, iBiquity recognizes that dedicated distance listeners continue to listen even in those conditions. In those cases, the introduction of IBOC may render an already marginal service unlistenable for some skywave listeners. However, because distance listeners are highly motivated to listen, even under extremely adverse analog interference conditions, they may be more tolerant of the additional IBOC interference than a typical listener would be.

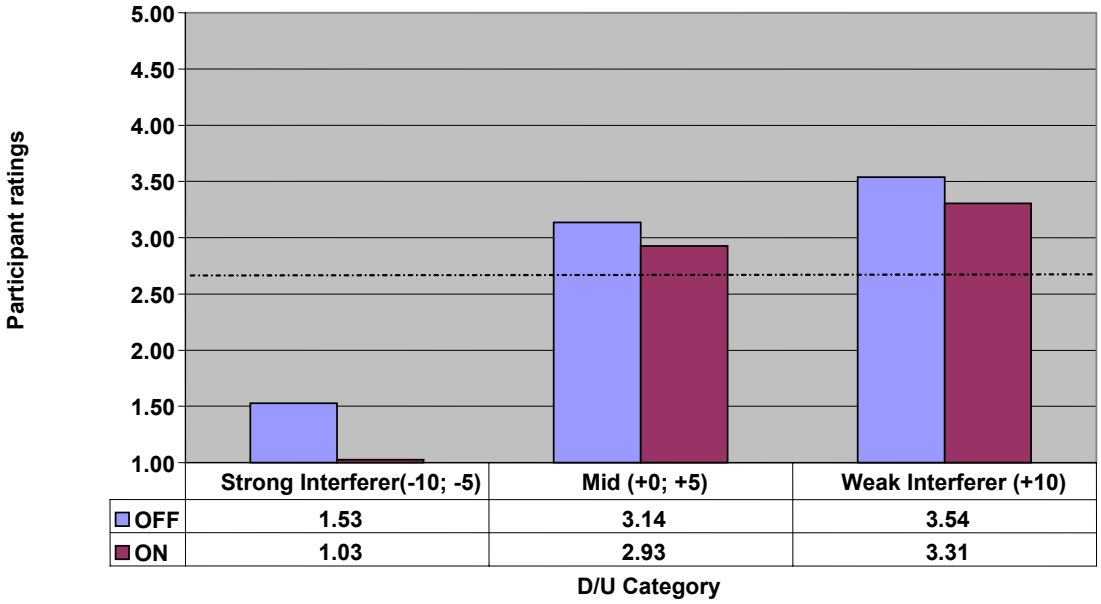

Figure 11: Sky-to-Sky

In the S2S measurements in Virginia, where WOR was the desired signal, the average D/U was positive for WLW and negative for WOR although the variance during the recording times was quite high and changed dramatically over short periods of time. A listener at this location would have to be very determined to continue listening for periods of time greater than 30 seconds as there were periods of time where the signal was unavailable or was replaced with a distant undesired co-channel interferer. Several times, WAQI, 710, Miami was heard instead of the desired WOR signal, creating an Undesired to Undesired (U/U) condition. Assuming the desired signal has sufficient signal strength to overcome the noise and it is not displaced with a second undesired co-channel, the impact of IBOC on existing analog reception in the S2S condition is highly dependent on first adjacent channel D/U. Skywave to skywave field tests were conducted near Roanoke, Virginia with both WLW and WOR used separately as desired stations.

The subjective evaluation results indicate the introduction of IBOC in this situation will impact skywave signals at -5 dB or strong interference levels.[8] Because skywave signal levels vary by time rather than geography, it is difficult to map areas of impact from the introduction of IBOC. Instead, iBiquity analyzed the impact of IBOC in terms of reduced availability of skywave signal.

For example, in a situation where atmosphere conditions are very positive, a skywave signal may be available 95% of the time in a selected area. The addition of IBOC first adjacent skywave interference might reduce the availability to 80%. In other situations,

[8] It is important to note a reduction in subjective score from 1.5 to 1.0 will not have any meaningful impact on listeners. It only represents an even larger population of people who would never listen in the first place.

however, less favorable conditions may limit skywave availability without IBOC to 50%. In that situation, the addition of IBOC interference might reduce skywave availability to 25%. In this situation, however, it would be relevant to consider the viability of a service that is already degraded below the point of acceptability at least 50% of the time.

4.4 Impact of Receivers and Antennas

The subjective evaluations demonstrate a variation in impact from IBOC depending on the type of receiver and the type of antenna used. The narrow IF filtering of the automobile receiver increases its ability to withstand any potential IBOC interference.

Moreover, the narrow IF filtering makes these receivers more effective for receiving distant signals. At the same time, the common directional ferrite loop antenna employed in home Hi-Fis, boomboxes, and portable receivers offers benefits in all locations except those in a direct line between the desired and undesired stations. During the subjective test program, off axis scores for non-automotive receivers showed greater resistance to IBOC interference than auto receivers. Because the vast majority of receivers will operate off axis rather than directly between stations, directional antennas may help mitigate IBOC interference in many situations.

5 Conclusions

Based on the data collected the following conclusions can be drawn from the field tests:

- Interference from IBOC is D/U dependent and is expected to have its greatest impact below 0 dB D/U ratio.
- The primary service area of the station should not be affected by IBOC. The IBOC skywave signal impacts first adjacent groundwave service outside of the NIF, even for clear channel stations with low NIF values. The interference is a ring between where the desired groundwave is strong and where analog is poor, and thus the impact from IBOC is very limited.
- The IBOC groundwave signal impacts first adjacent skywave service in a ring around each undesired IBOC station. Inside of this region, most receivers are impacted from the undesired analog groundwave signal. Outside of this region, groundwave is not dominant.
- Given the time varying nature of skywave to skywave interference the ability to receive skywave signals in the presence of analog or IBOC interference is more a matter of time (signal availability) than geographic location. IBOC introduction is expected to reduce the amount of time skywave service is available, but not disastrously so.
- Boom box and portable receivers have directional antennas and can null-out most of the affects of the 1st adjacent undesired IBOC signal in most locations outside of the axis between the stations.

Appendix A

Analog Compatibility

Field Test Procedures

WLW, Cincinnati, OH
WOR, New York, NY

August 12 thru 16, 2002
&
December 02 thru 05, 2002

iBiquity Digital Corporation
Columbia, MD—Warren, New Jersey

A1 Scope

This document describes the procedure executed during the field test component of iBiquity Digital Corporation's program evaluating HD Radio™ transmission compatibility with existing AM station transmissions during nighttime broadcasts. iBiquity and the National Association of Broadcasters designed this field testing program to address compatibility issues unresolved by the NRSC's AM HD Radio ("IBOC") test program. iBiquity engineers performed the tests under the observation of following witnesses:

Phase I - (New York City Area):

Milford Smith – Vice-President, Engineering, Greater Media Corp (Member, NAB Ad-Hoc Committee)

Phase II - (New York City Area):

Thomas Ray – Corporate Director of Engineering, Buckley Broadcasting (Approved by NAB Committee)

Phase II - (Roanoke, VA):

Jeff Littlejohn – Corporate Director of Engineering, Clear Channel Communications

Randy Michaels – VP, New Technology, Clear Channel Communications

This report reviews test methodologies and the primary data collected.

A1.1 Test Summary

The tests were designed to record representative consumer analog consumer radios with and without a first adjacent HD Radio interferer present. Various audio recordings of analog AM receiver audio were made in different reception scenarios over a range of first adjacent interference conditions. Each interference condition was recorded with and without HD Radio digital carriers present. Each audio sample was categorized by the conditions under which it was recorded and prepared for subsequent subjective evaluation.

Two, appropriately spaced first adjacent Class A 50 kW stations were used:

- WLW, Cincinnati, OH (700 kHz)
- WOR, New York, NY (710 kHz)

The test program measured the effects of all significant modes of HD Radio-to-analog AM interference between these first adjacent stations during nighttime transmissions:

1. Undesired HD Radio Interferer by Skywave ⟶ Desired Analog Station by Groundwave
2. Undesired HD Radio Interferer by Groundwave ⟶ Desired Analog Station by Skywave
3. Undesired HD Radio Interferer by Skywave ⟶ Desired Analog Station by Skywave

For each condition, iBiquity used propagation prediction software to determine prospective test locations expected to produce desired-to-undesired (D/U) signal ratios from -10 to +10 dB. This D/U range provides a wide range of audio quality in typical consumer receivers, both with and without a first adjacent HD radio interferer present.

At each test location, iBiquity engineers made audio recordings of various representative consumer receivers, each tuned to the desired analog station, in the presence and absence of the first adjacent interfering station's HD Radio carriers. To properly correlate the current signal levels and corresponding desired-to-undesired field intensity ratios, spectral data were collected coincident with the audio recordings.

The tests were conducted in two phases as follows:

- Phase 1 – August, 2002 (Single Skywave / Groundwave Interferer)
    - WLW as HD Radio Interferer / WOR as Analog Desired
- Phase 2 – December, 2002 (Alternating Skywave / Groundwave Interferer)
    - WLW as HD Radio Interferer / WOR as Analog Desired
    - WOR as HD Radio Interferer / WLW as Analog Desired

These two phases characterized compatibility across the seasonal variation in ground conductivity.

A2 Test Description

A2.1 Transmission Site Configuration - WLW

WLW is a Class "A" clear channel station serving the greater Cincinnati, Ohio area with a power output of 50 kW, unlimited, on 700 kHz. The antenna system consists of a single 189.3° series-excited vertical radiator, which produces an essentially circular azimuth pattern as shown in Figure A2-1. The transmitter site is located at 39°-21'-11" North Latitude / 84°-19'-30" West Longitude as shown in Exhibit M8, Page A-22.

During Phase I and Phase II testing, iBiquity engineers configured the WLW transmitter site to transmit the hybrid AM IBOC signal as shown in Figure A2-2.

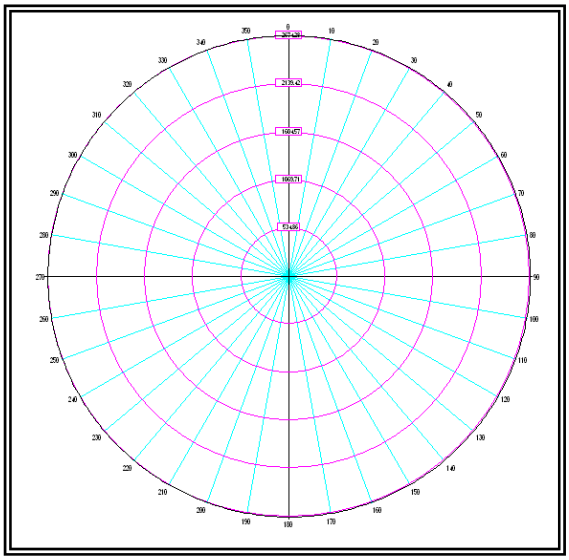

Figure A2-1

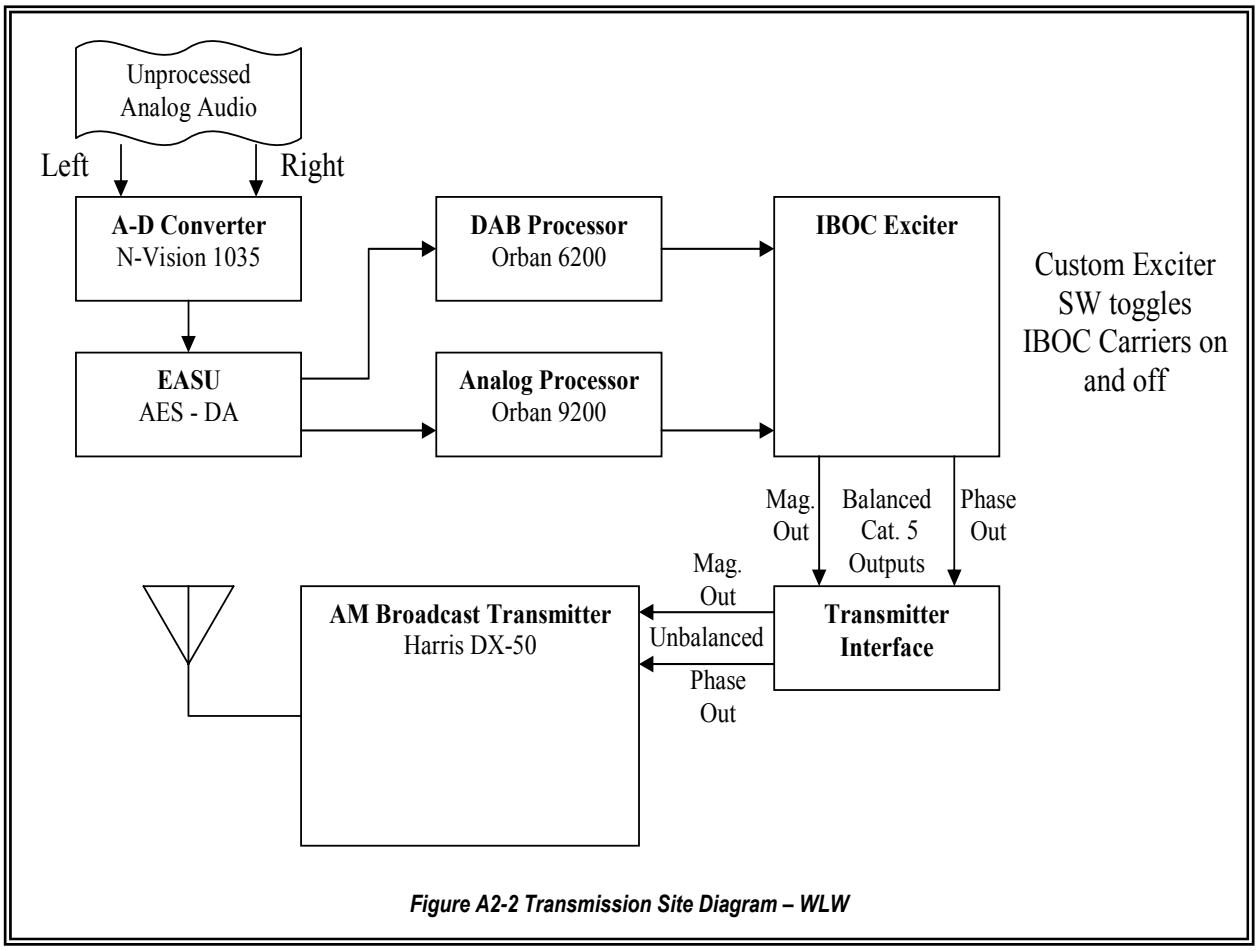

Figure A2-2 Transmission Site Diagram – WLW

A2.2 Transmission Site Configuration - WOR

WOR is a Class "A" clear channel station serving the greater New York City, New York area with a power output of 50 kW, unlimited, on 710 kHz. The directional antenna system consists of three 177° series-excited vertical radiators, arranged in a "dog-leg" configuration, producing the oblong pattern shown in Figure A2-3. The transmitter site is located at 40°-47'-30" North Latitude / 74°-05'-38" West Longitude as shown in Exhibit M1, Page A-15.

During Phase II testing, iBiquity engineers configured the WOR transmitter site to transmit the hybrid AM IBOC signal as shown in Figure A2-4.

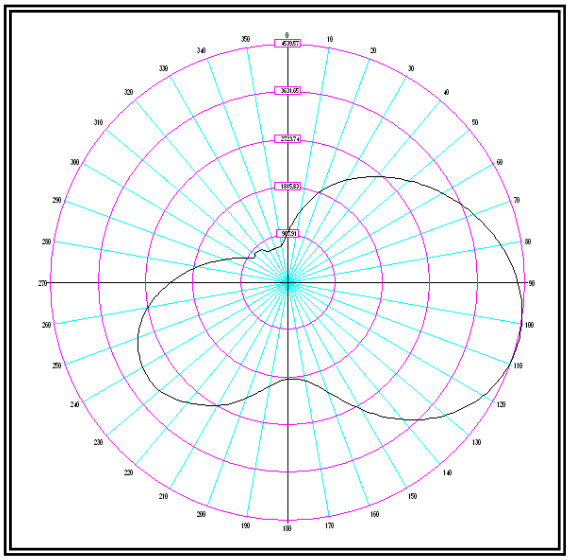

Figure A2-3

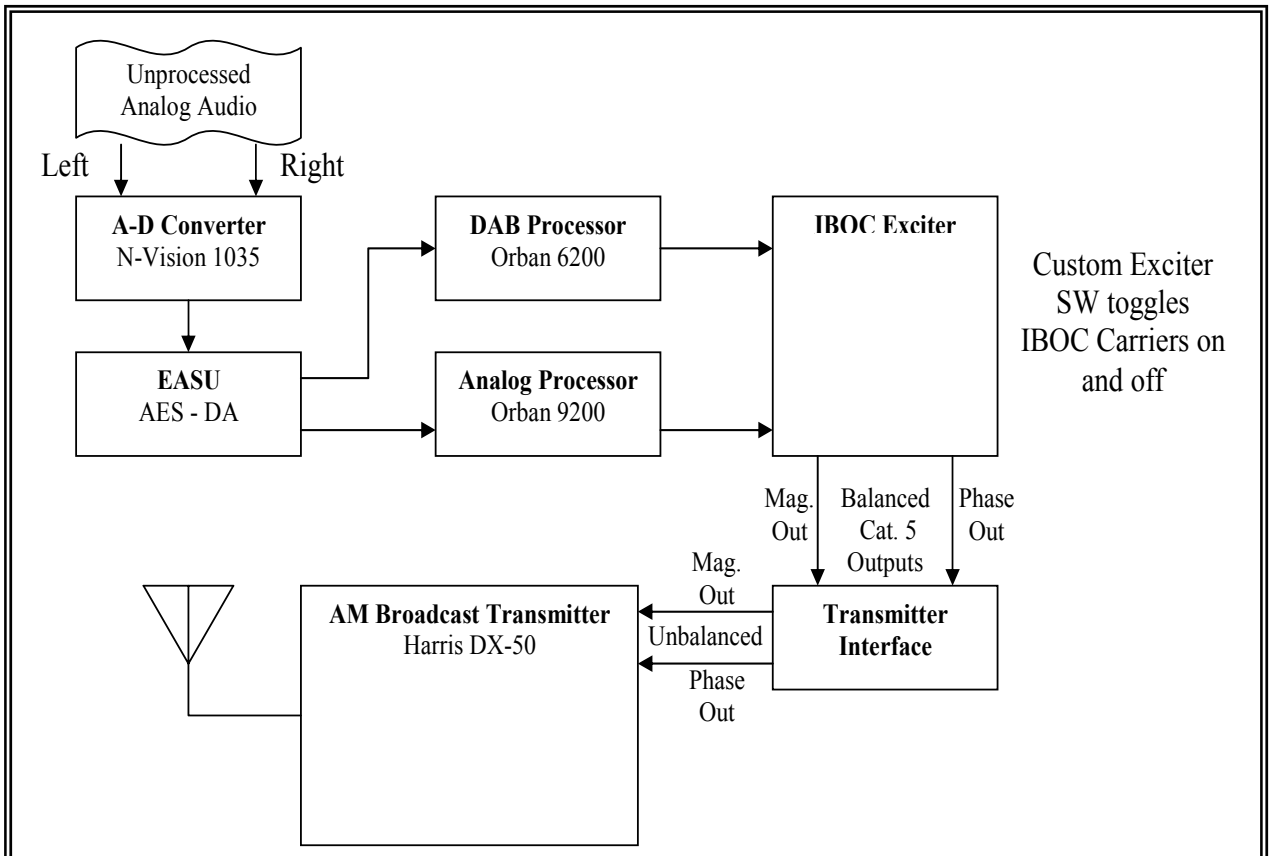

Figure A2-4 Transmission Site Diagram – WOR

A2.3 HD Radio Waveform & Carrier Levels

Both station's exciters were configured to transmit the HD Radio Hybrid waveform depicted in Figure A2-5.

A2.4 Transmission Test Procedure

When acting as the HD Radio interferer, the DAB carriers of the station designated as the interferer were toggled on and off during alternate minutes. This process was synchronized to WWVB to facilititate correlation of data among the receiving test vehicles located in New York, New Jersey, Ohio and Virginia.

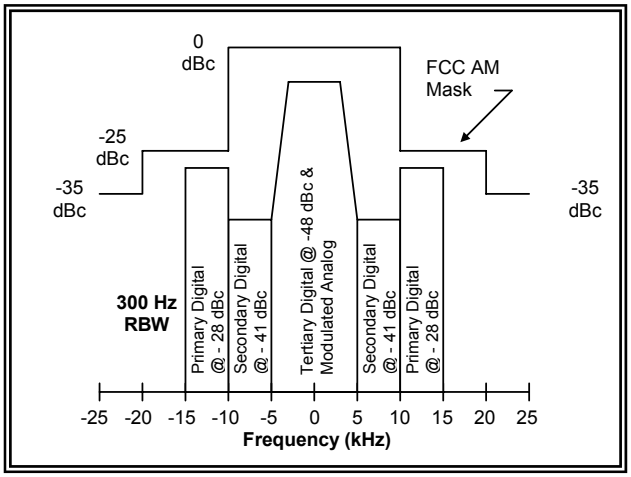

Figure A2-5

A2.5 Reception Sites

Three modes of reception with interfererence were characterized:

1. Undesired HD Radio 1st Adjacent Channel Skywave into Desired Analog Groundwave
2. Undesired HD Radio 1st Adjacent Channel Groundwave into Desired Analog Skywave
3. Undesired HD Radio 1st Adjacent Channel Skywave into Desired Analog Skywave

Engineers selected test regions representing each reception mode using propagation-modeling software and laboratory testing to target significant desired-to-undesired (D/U) field intensity ratios. The test locations in New York/New Jersey, Ohio and Virginia appear in Table A2-1 and Figure A2-6. For Phase I, the Ohio and New York Regions were further subdivided into on-axis and off-axis areas. On-axis locations lie on or nearly on an imaginary line connecting the test stations. Off-axis locations lie significantly "off" that imaginary line. This is significant because many portable consumer radios have directional ferrite loop antennas which can take advantage of off-axis reception to reject interference . Phase I locations provided +10, +5, 0 and -5 dB desired-to-undesired field intensity ratios. Phase II tests included an additional -10 dB D/U point.

Table A2-1 Compatibility Test Locations

Phase	Region	On/Off Axis	Propagation Type: Desired/Undesired	Station: Desired / Undesired	Desired to Undesired Field Intensity Ratio (dB)	Exhibit Reference (Pages 15-39)
Phase I	New York	Off	Groundwave / Skywave	WOR/WLW	-5, 0, +5 +10	M-1 to M-4
	New York	On	Groundwave / Skywave	WOR/WLW	-5, 0, +5 +10	M-5 to M-7
	Ohio	Off	Skywave / Groundwave	WOR/WLW	-5, 0, +5 +10	M-8 to M-10
	Ohio	On	Skywave / Groundwave	WOR/WLW	-5, 0, +5 +10	M-11 to M-13
	Virginia	Off	Skywave / Skywave	WOR/WLW	-5, 0, +5 +10	M-14 to M-15
Phase II	New York	On	Groundwave / Skywave	WOR/WLW	-10, -5, 0, +5 +10	M-16 to M-18
	New York	On	Skywave / Groundwave	WLW/WOR	-10, -5, 0, +5 +10	M-16 to M-18
	Ohio	On	Groundwave / Skywave	WOR/WLW	-10, -5, 0, +5 +10	M-19 to M-23
	Ohio	On	Skywave / Groundwave	WLW/WOR	-10, -5, 0, +5 +10	M-19 to M-23
	Virginia	Off	Skywave / Skywave	WOR/WLW	-10, -5, 0, +5 +10	M-24 to M-25
	Virginia	Off	Skywave / Skywave	WLW/WOR	-10, -5, 0, +5 +10	M-24 to M-25

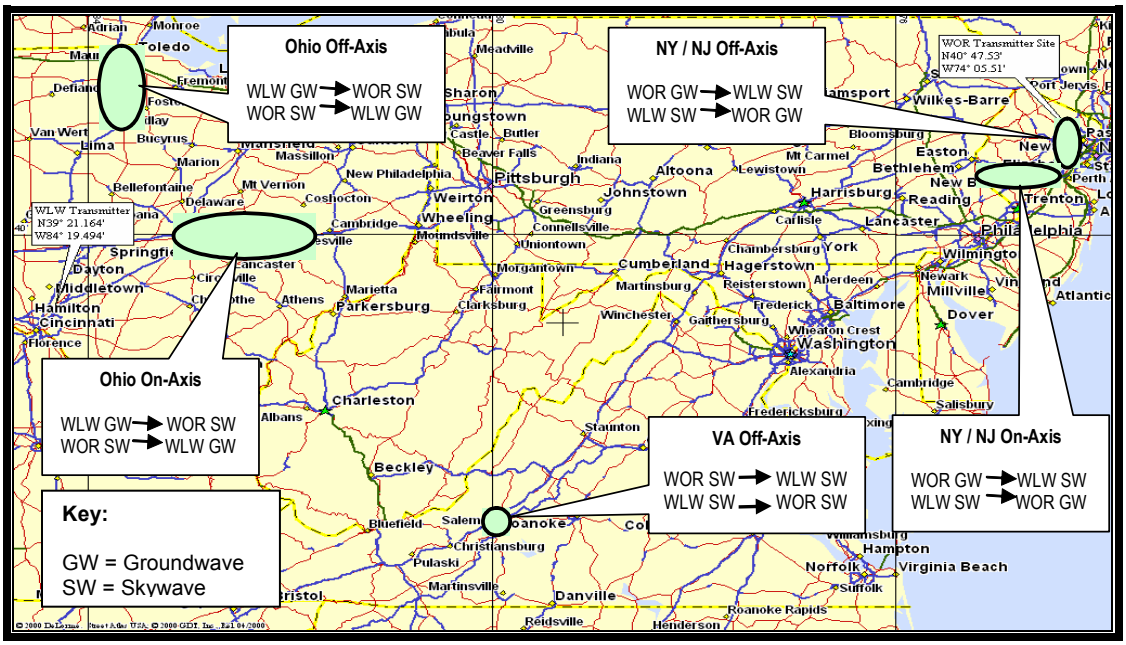

Figure A2-6 Test Region Map

A2.6 Reception Test Platforms

A2.6.1 Receivers:

Table A2-2 lists the 5 sample consumer receivers used for compatibility testing. The models include those chosen for the NRSC 2001 IBOC testing program, plus a GE Super Radio. The table also outlines each receiver's selectivity and sensitivity characteristics. Altogether, these receivers represent the majority of types and performances of those receivers available in the mass marketplace.

Table A2-2 Compatibility Test Receivers

Make	Model	Type	Characteristics
Technics	SA-EX140	Home Hi-Fi	Mid-level home hi-fi receiver - 50 Ohm input impedance for ext. ant. (Installed in test vehicle).
Pioneer	KEH1900	Auto	Wider IF bandwidth auto radio. Has Hi-Z input impedance tuned to 5 ft. length of RG-62 coax. (Installed in test vehicle).
Delphi	09394139	Auto	Narrow IF bandwidth auto radio. Has Hi-Z input impedance tuned to 5 ft. length of RG-62 coax. (Installed in test vehicle).
GE Super Radio	7-2887A	Portable	Non-PLL slide-rule tuned portable radio. Has internal ferrite-loop antenna (Removed from vehicle, oriented for best reception, and supported on non-conductive, non-ferrous box.)
Sony	CFD-S22	"Boom Box"	PLL synthesized portable radio. Has internal ferrite-loop antenna (Removed from vehicle, oriented for best reception, and supported on non-conductive, non-ferrous box.)

A2.6.2 Test Platform System Diagram

Figure A2-7 shows the test platform design. Care was taken to ensure that each receiver was connected in the same manner as it would for consumer use. Hi-Z to 50 Ohm transformers coupled the 31-inch receiving whip antennas to the Technics Receiver and Agilent 8591E Spectrum Analyzer.

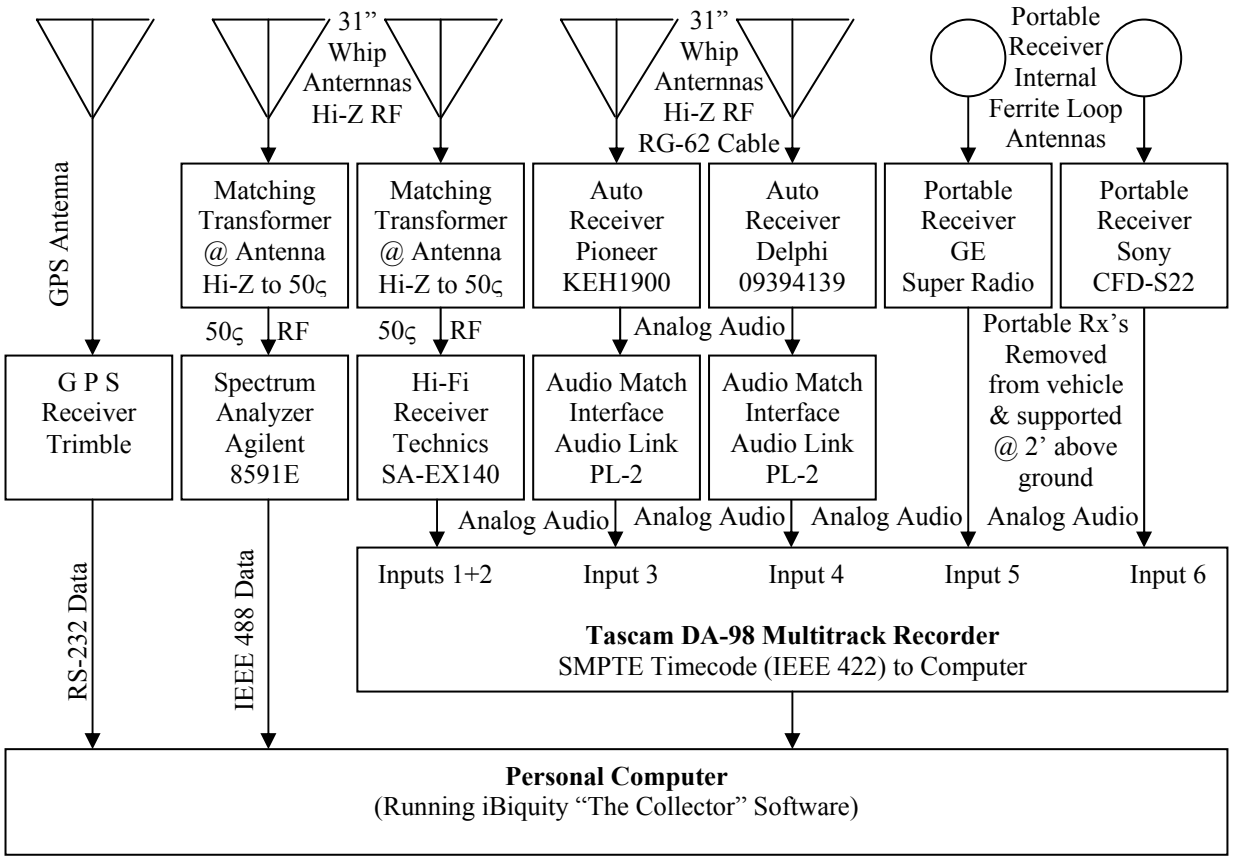

Figure A2-7

During the testing, iBiquity's *The Collector* test automation application (See Section A2.6.3) controlled the Agilent 8591E Spectrum Analyzer, configuring it as shown in Table A2-3

Table A2-3

Center Frequency (kHz)	Span (kHz)	RBW (kHz)	VBW (kHz)	Video Averaging	Number of Averages
700	100	3	3	ON	10
710					

This spectrum analyzer configuration provided sufficient bandwidth and resolution to accurately reflect the current field intensities of WLW and WOR. The dynamic nature of nighttime signals dictated the need for averaging. Ten sweep power averaging provided a balance between signal power and time measurement accuracies.

Audio from the van-mounted receivers fed the multi-track digital audio recorder as shown in Figure A2-7. During measurements, the portable radios were positioned outside the test vehicle, supported on a 2 foot high non-conductive box, each connected via its headphone output directly to the recorder.

A2.6.3 Data Acquisition Software (*The Collector*)

iBiquity Digital's test vans are all equipped with data acquisition and storage computers that accumulate data from multiple peripherals using custom *The Collector* software. Table A2-4 shows the data acquisition system inputs. Figure A2-8 shows a sample *The Collector* screen.

Table A2-4 "The Collector" Data Acquisition System Inputs

Device	Make	Model	Data Type	Use
Multi-Track Digital Audio Recorder	Tascam	DA-98	SMPTE Timecode	Correlation of data with location of recorded audio on tape
GPS Receiver	Trimble	Placer 455	Serial Latitude, Longitude and Altitude Data	Correlation of data with geographic location
Spectrum Analyzer	Agilent	8591E	Spectral Data	Characterization of spectral conditions for each sample.

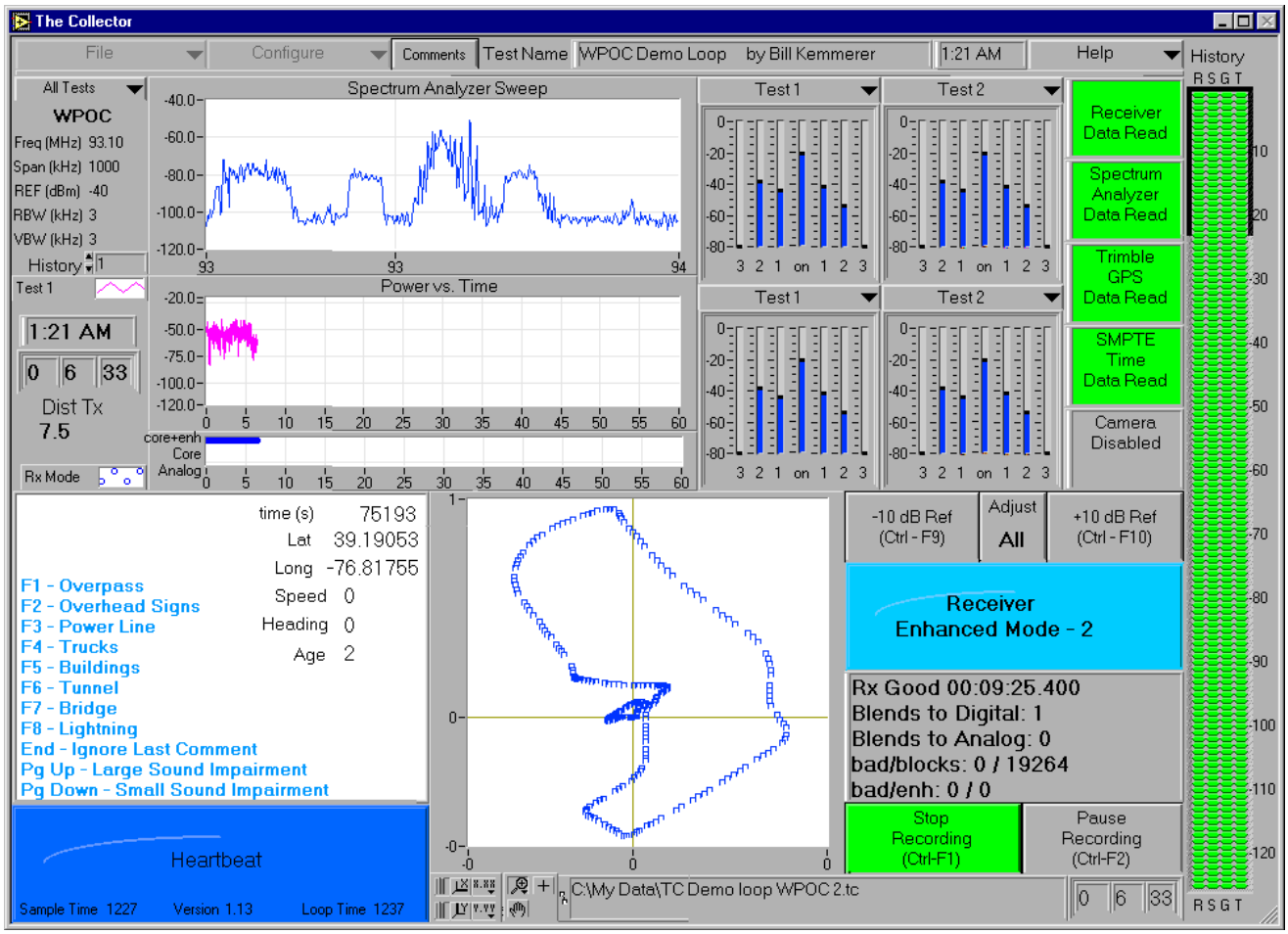

Figure A2-8

A2.7 Test Procedure - General

In the New York and Ohio test regions, the test team selected each test location by driving the test vehicle away from the groundwave transmitter along a prescribed route until the spectrum analyzer indicated one of the target desired-to undesired-ratios. In Roanoke, VA, a single location was selected. All test sites were clear of obvious re-radiating grounded conductive structures and electromagnetic interference. At each test site:

- iBiquity test personnel removed the portable radios from the vehicle and placed them on a 2 foot high non-conductive, non-ferrous support.
- The portable radios were then rotated to maximize the quality of the received signal.
- The portable radio headphone audio outputs were connected to inputs of a Tascam DA-98 multitrack recorder.
- The auto and home receivers were permanently connected to the recorder as in Figure A2-7.

The Tascam recorder, spectrum analyzer, and GPS receiver supplied timecode, spectrum and location data, respectively, to *The Collector* software in the computer. (See Section A2.6.3). *The Collector* controlled the spectrum analyzer, configuring it with the parameters shown in test setup Table A2-3.

The field intensities of both the desired and interfering stations as measured on the spectrum analyzer were corroborated with simultaneous readings from a Potomac FIM-41 field intensity meter. Later analysis established a signal strength calibration factor using measurement data from both devices. This factor was used to scale the field intensity plots in the exhibits.

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A2.7.1 Compatibility – Phase I

For Phase I, iBiquity engineers tuned the five representative consumer radios to the desired analog station, WOR. WLW was the HD Radio interferer, it's digital carriers automatically toggled *on* and *off* every other minute, as described in Section A2.4.

- Test vans were located in the three test regions as outlined in section A2.5.
- Specific test locations within each test region were selected as described in Section A2.7.
- At 15 seconds before a ten minute absolute time interval (as monitored by a WWVB corrected clock), *The Collector* was started.
- 15 seconds later, at the top of the minute, the multitrack tape started recording.

The points of on/off transition for the WLW HD Radio carriers were synchronized to the multitrack recorder's SMPTE timecode, which was recorded by *The Collector* software. Specific dates, times and locations for each of the Phase I Compatibility data collections appear in Table A2-5.

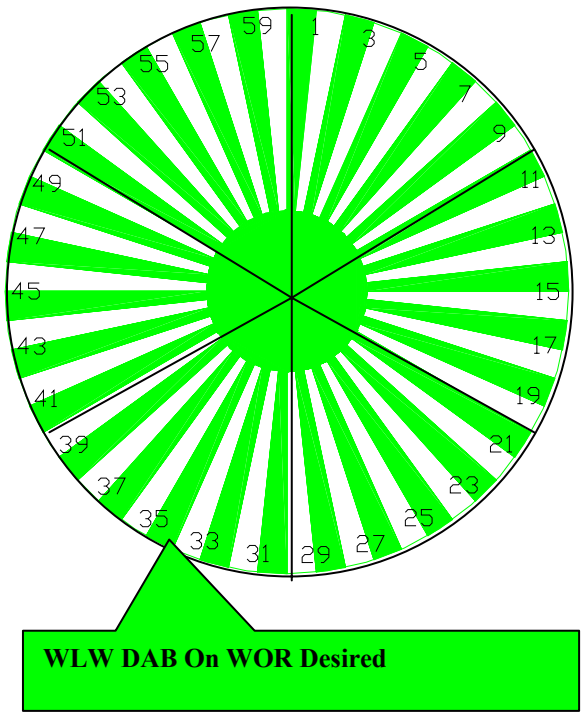


Figure A2-9 WLW IBOC Carrier Toggling Diagram – Phase I

Table A2-5 Compatibility Test Locations – Phase I

Area	Date (2002)	Time	Location	Reception Mode & Desired to Undesired Ratio	Exhibit No. (Pages 15-39)
New York City	8/12	11:00 PM to 02:00 AM	Various locations on Route 206 (North of I-80) – New Jersey	WLW (Skywave) into WOR (Groundwave) – Off-Axis @ +10, +5, 0 and -5 dB Desired (WOR) to Undesired (WLW) ratio	M-1 thru M-4
	8/13	02:00 AM to 04:00 AM	Various locations on Route 78 West of Warren, New Jersey	WLW (Skywave) into WOR (Groundwave) – On-Axis @ +10, +5, 0 and -5 dB Desired (WOR) to Undesired (WLW) ratio	M-5 thru M-7
Cincinnati, OH	8/13	00:40 AM to 03:00 AM	Various locations on Route I-70 East of Columbus, Ohio	WOR (Skywave) into WLW (Groundwave) – On-Axis @ +10, +5, 0 and -5 dB Desired (WOR) to Undesired (WLW) ratio	M-8 thru M-10
	8/13	11:50 PM to 02:30 AM	Various locations on Route I-70 South of Toledo, Ohio	WOR (Skywave) into WLW (Groundwave) – Off-Axis @ +10, +5, 0 and -5 dB Desired (WOR) to Undesired (WLW) ratio	M-11 thru M-13
Roanoke, VA	8/16	02:00 AM to 03:00 AM	Single Location on I-81 West of Roanoke, VA	WOR (Skywave) into WLW (Skywave) – Off-Axis @ Desired to Undesired ratio determined by propagation.	M-14 thru M-15

A2.7.2 Compatibility – Phase II

The Phase II compatibility procedure was similar to that of Phase I, except that WOR and WLW alternated roles as the desired and the undesired stations every ten minutes: During the first ten-minute interval, WLW remained in analog mode (desired) while WOR's HD Radio carriers turned *on* and *off* on alternate minutes. In the following ten-minute interval, WOR remained in analog mode (desired) while WLW's HD Radio carriers turned *on* and *off* on alternate minutes. Figure A2-10 depicts one hour of this test cycle. For each ten-minute transition, the radios were retuned to whichever was the designated desired station.

Specific dates, times and locations for each of the Phase II Compatibility data collections are listed in Table A2-6.

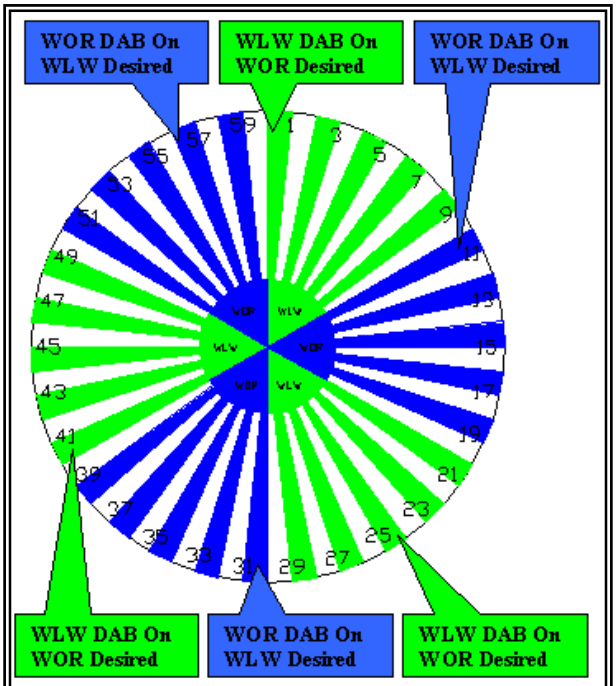


Figure A2-10 WLW IBOC Carrier Toggling Diagram – Phase II

Table A2-6

Area	Date 2002	Time	Location	Reception Mode & Desired to Undesired Ratio	Exhibit # P. 15-39
NY / NJ	12/2	10:00 PM to 11:00 PM	Route I-78 and Route 1-73 52 miles from WOR Transmitter	WLW (Skywave) into WOR - Desired (Groundwave) WOR (Groundwave) into WLW - Desired (Skywave) On-Axis @ +10, +5, 0, -5 and -10 dB Desired to Undesired ratio	M-16 thru M-18
	12/2 12/3	11:50 PM to 12:50 AM	72 miles from WOR Transmitter	WLW (Skywave) into WOR - Desired (Groundwave) WOR (Groundwave) into WLW - Desired (Skywave) On-Axis @ +10, +5, 0, -5 and -10 dB Desired to Undesired ratio	M-16 thru M-18
OH	12/2	00:40 AM to 03:00 AM	Various locations on Route I-70 East of Columbus, OH	WOR (Skywave) into WLW - Desired (Groundwave) WLW (Groundwave) into WOR - Desired (Skywave) On-Axis @ +10, +5, 0, -5 and -10 dB Desired to Undesired ratio	M-19 thru M-23
	12/3	11:50 PM to 02:30 AM	Various locations on Route I-70 South of Toledo, Ohio	WOR (Skywave) into WLW - Desired (Groundwave) WLW (Groundwave) into WOR - Desired (Skywave) On-Axis @ +10, +5, 0, -5 and -10 dB Desired to Undesired ratio	M-19 thru M-23
VA	12/2	02:00 AM to 03:00 AM	Single Location on I-81 West of Roanoke, VA	WOR (Skywave) into WLW - Desired (Groundwave) WLW (Groundwave) into WOR - Desired (Skywave) On-Axis @ +10, +5, 0, -5 and -10 dB Desired to Undesired ratio	M-24 thru M-25

A3 Data Preparation

A3.1 Spectral Data ("*The Collector*" Files)

The Collector data files were labeled descriptively during each test to permit reliable association with the recorded audio. The analyzing engineer used *The Collector's* spectral data to identify audio segments recorded at the target desired-to-undesired field intensities.

The Desired to Undesired Ratio at the top of each minute (point of HD Radio interferer Off/On transition) was extacted from the Collector Data. This ratio was characteristic of the time period from which the audio samples were selected (30 seconds before the top of the minute to 30 seconds after). The modes and D/U ratios were sorted into bins as shown in Table A3-1.

In order to prepare a representative sample of the real-world nighttime listening environment, the percentage of total samples in each bin was applied to the total number of samples in the test.

Table 3-1 D/U Bins

	D/U Bins: Number of Audio Sample D/U Ratios Meeting Criteria				
MODE	**<-7.5 dB**	**-7.5 to -2.5 dB**	**-2.5 to 2.5 dB**	**2.5 to 7.5 dB**	**> 7.5 dB**
Ground to Sky Off-Axis	1	13	7	7	2
Ground to Sky On-Axis	40	37	28	14	8
Sky to Ground Off-Axis	0	3	6	16	15
Sky to Ground On-Axis	2	6	31	34	56
Sky to Sky Off-Axis	22	12	23	16	23

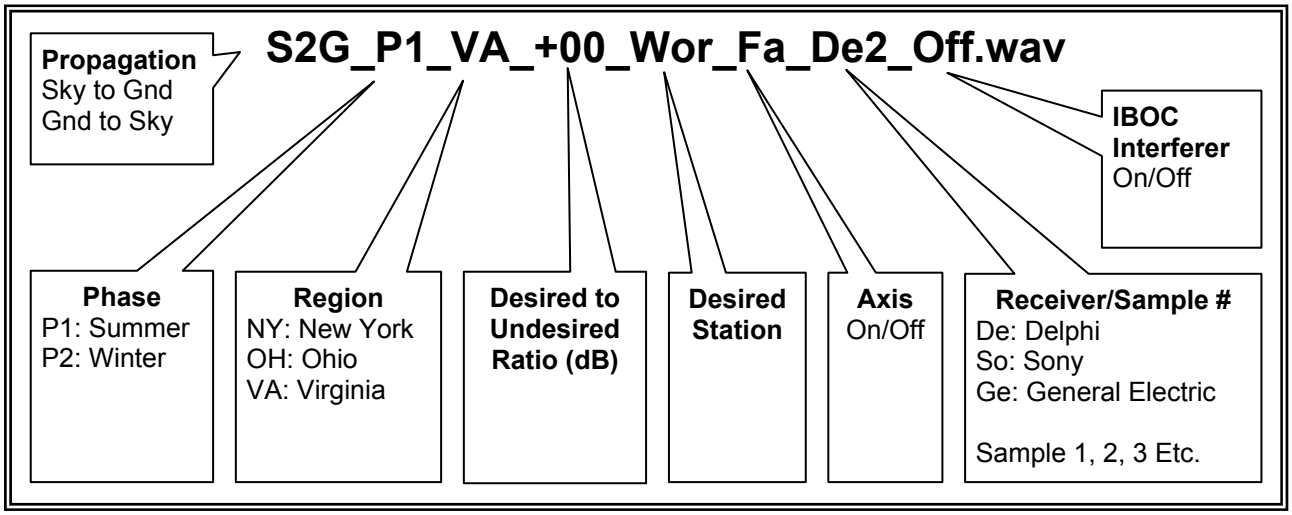
A3.2 Audio Data

Tascam DA-98 multitrack audio recordings made at each compatibility test location were labeled descriptively and correlated with the Collector D/U data to target prospective test samples. Each 5 to 10 second selection was taken from a larger 1 minute sample beginning at 30 seconds before to 30 seconds after the top of the minute. Each sample was reviewed to ensure that it accurately represented the target D/U and mode.

Selected audio files were named according to the convention in Figure A3-2.

Table 3-2 indexes the sample audio files and their corresponding D/U plots and maps.

Table A3-2

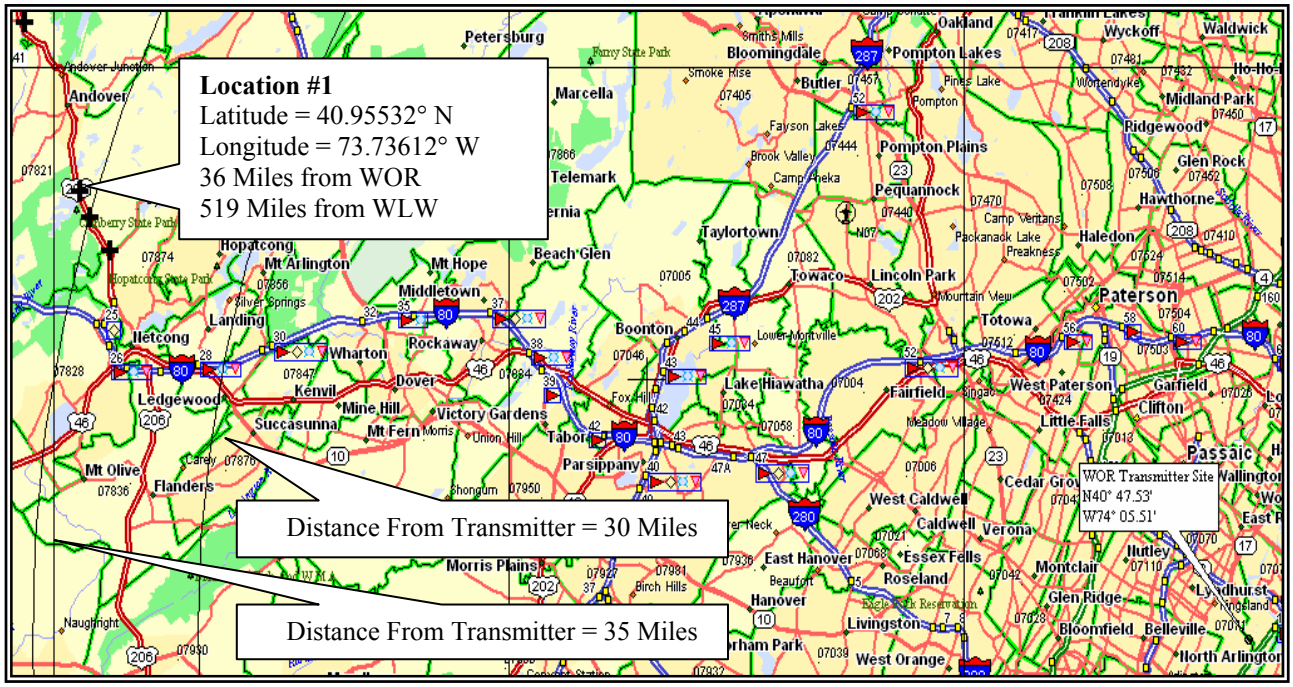


Audio Sample #	FileName	Tape #	Minute	Exhibit #	Page
1	G2S_P1_OH_-05_Wor_Fa_RX1_OffOrOn.wav	5	11	M8	A-22
2	G2S_P1_OH_+00_Wor_Fa_RX1_OffOrOn.wav	5	18	M8	A-22
3	G2S_P1_OH_+05_Wor_Fa_RX1_OffOrOn.wav	5	52	M10	A-24
4	G2S_P2_OH_-10_Wor_Na_RX1_OffOrOn.wav	9	07	M19	A-33
5	G2S_P2_OH_-05_Wor_Na_RX2_OffOrOn.wav	9	27	M20	A-34
6	G2S_P2_OH_-10_Wor_Na_RX4_OffOrOn.wav	10	17	M22	A-36
7	G2S_P2_OH_-05_Wor_Na_RX2_OffOrOn.wav	9	24	M20	A-34
8	G2S_P2_OH_-05_Wor_Na_RX3_OffOrOn.wav	9	41	M21	A-35
9	G2S_P2_OH_-05_Wor_Na_RX4_OffOrOn.wav	10	18	M22	A-36
10	G2S_P2_OH_-05_Wor_Na_RX5_OffOrOn.wav	10	23	M23	A-37
11	G2S_P2_OH_+00_Wor_Na_RX1_OffOrOn.wav	10	24	M23	A-37
12	G2S_P2_OH_+00_Wor_Na_RX2_OffOrOn.wav	10	16	M22	A-36
13	G2S_P2_OH_+00_Wor_Na_RX3_OffOrOn.wav	10	28	M23	A-37
14	G2S_P1_OH_+10_Wor_Na_RX1_OffOrOn.wav	4	58	M13	A-27
15	G2S_P2_OH_+10_Wor_Na_RX1_OffOrOn.wav	10	26	M23	A-37
16	S2G_P1_NY_-05_Wor_Fa_RX1_OffOrOn.wav	1	33	M2	A-16
17	S2G_P1_NY_+00_Wor_Fa_RX1_OffOrOn.wav	2	13	M4	A-18
18	S2G_P1_NY_+05_Wor_Fa_RX2_OffOrOn.wav	2	14	M4	A-18
19	S2G_P1_NY_+10_Wor_Fa_RX1_OffOrOn.wav	2	18	M4	A-18
20	S2G_P2_OH_-10_Wlw_Na_RX1_OffOrOn.wav	10	35	M23	A-37
21	S2G_P2_OH_-05_Wlw_Na_RX1_OffOrOn.wav	10	05	M22	A-36
22	S2G_P2_OH_+05_Wlw_Na_RX1_OffOrOn.wav	9	38	M20	A-34
23	S2G_P2_OH_+00_Wlw_Na_RX2_OffOrOn.wav	10	33	M23	A-37
24	S2G_P2_OH_+05_Wlw_Na_RX3_OffOrOn.wav	9	39	M20	A-34
25	S2G_P2_OH_+05_Wlw_Na_RX2_OffOrOn.wav	9	15	M19	A-33
26	S2G_P2_OH_+05_Wlw_Na_RX3_OffOrOn.wav	9	31	M20	A-34
27	S2G_P2_OH_+00_Wlw_Na_RX4_OffOrOn.wav	9	51	M21	A-35
28	S2G_P2_OH_+10_Wlw_Na_RX2_OffOrOn.wav	9	12	M19	A-33
29	S2G_P2_OH_+10_Wlw_Na_RX3_OffOrOn.wav	9	37	M20	A-34
30	S2G_P2_OH_+10_Wlw_Na_RX5_OffOrOn.wav	9	33	M20	A-34
31	S2S_P2_VA_-10_Wlw_Fa_RX1_OffOrOn.wav	11	33	M24	A-38
32	S2S_P2_VA_-10_Wor_Fa_RX2_OffOrOn.wav	12	04	M25	A-39
33	S2S_P2_VA_+00_Wlw_Fa_RX2_OffOrOn.wav	11	15	M24	A-38
34	S2S_P2_VA_+00_Wor_Fa_RX2_OffOrOn.wav	11	03	M24	A-38
35	S2S_P2_VA_+00_Wor_Fa_RX3_OffOrOn.wav	11	07	M24	A-38
36	S2S_P2_VA_+05_Wor_Fa_RX2_OffOrOn.wav	11	21	M24	A-38
37	S2S_P2_VA_+05_Wor_Fa_RX3_OffOrOn.wav	11	22	M24	A-38
38	S2S_P2_VA_+10_Wor_Fa_RX3_OffOrOn.wav	11	28	M24	A-38
39	S2S_P2_VA_+10_Wor_Fa_RX4_OffOrOn.wav	12	14	M25	A-39

Table 3- 2 Multitrack Tape Sample SMPTE TimeCode & .wav File Names

Exhibit M – Compatibility Maps & Charts

Exhibit M1 – Phase I – WOR / WLW Night Compatibility Map & Chart – NYC (Off Axis / Loc. #1)



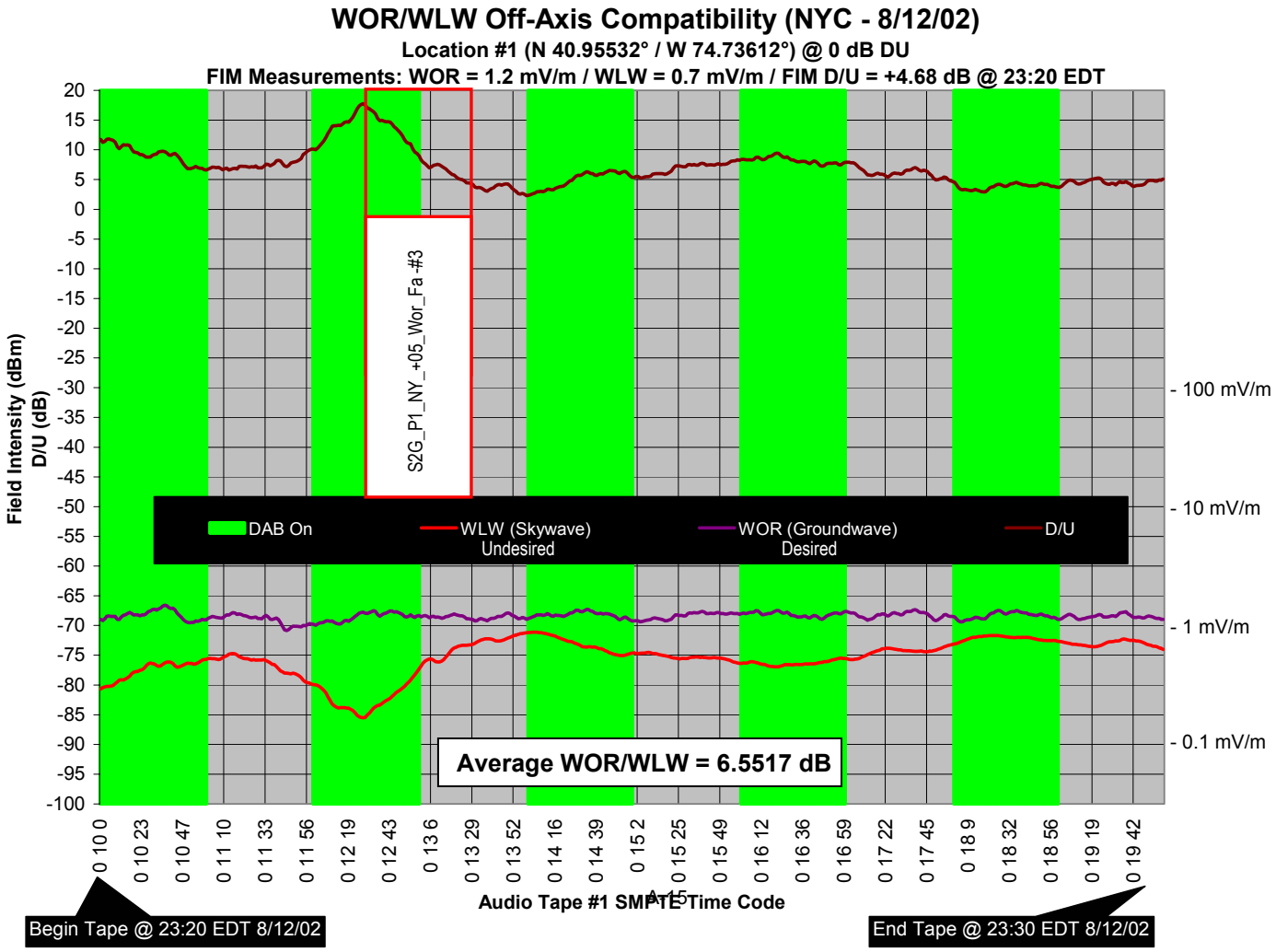
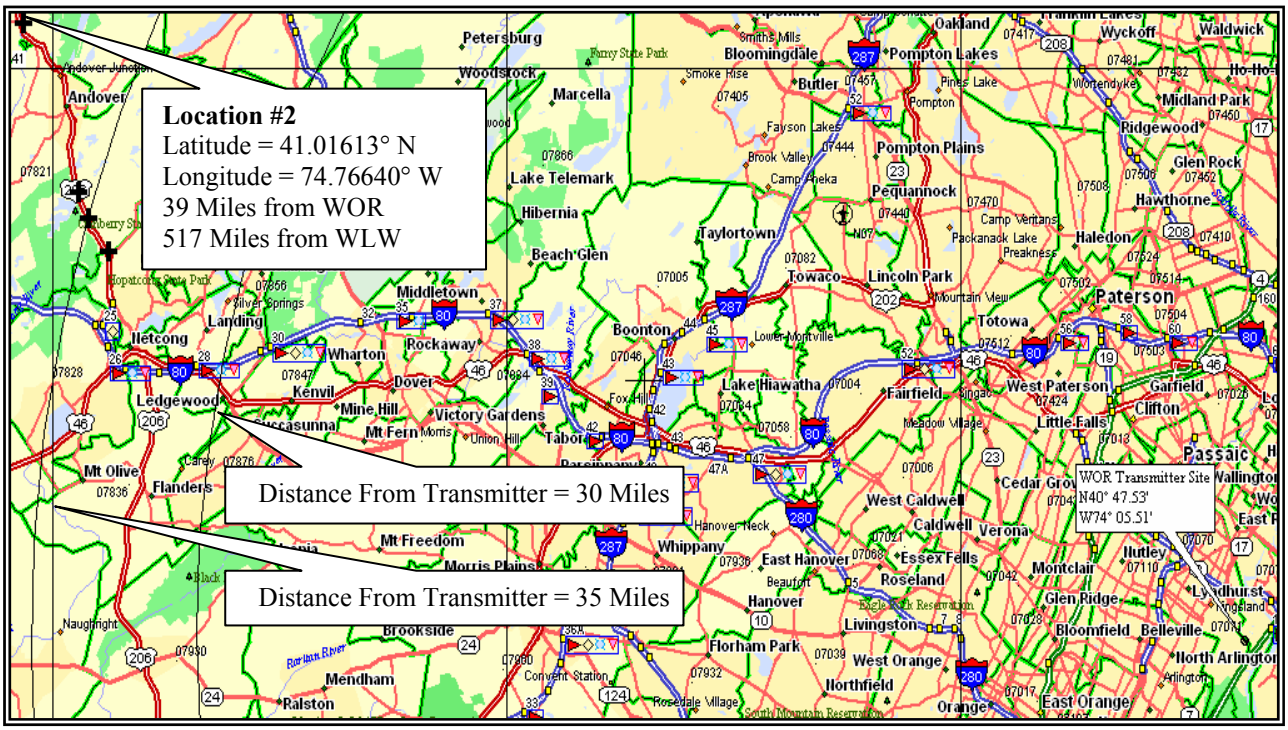


Exhibit M2 – Phase I - WOR / WLW Night Compatibility Map & Chart – NYC (Off Axis / Loc. #2)



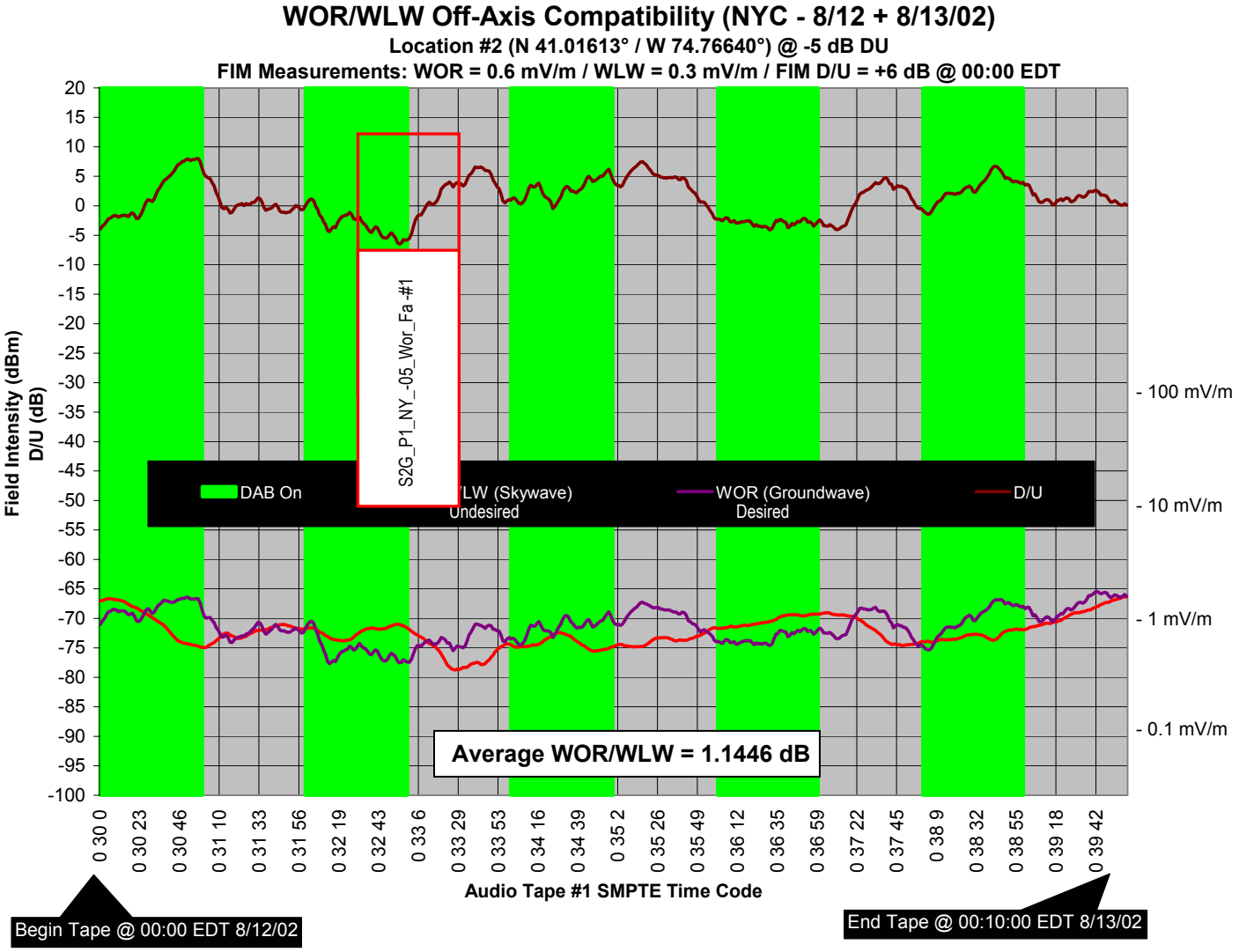
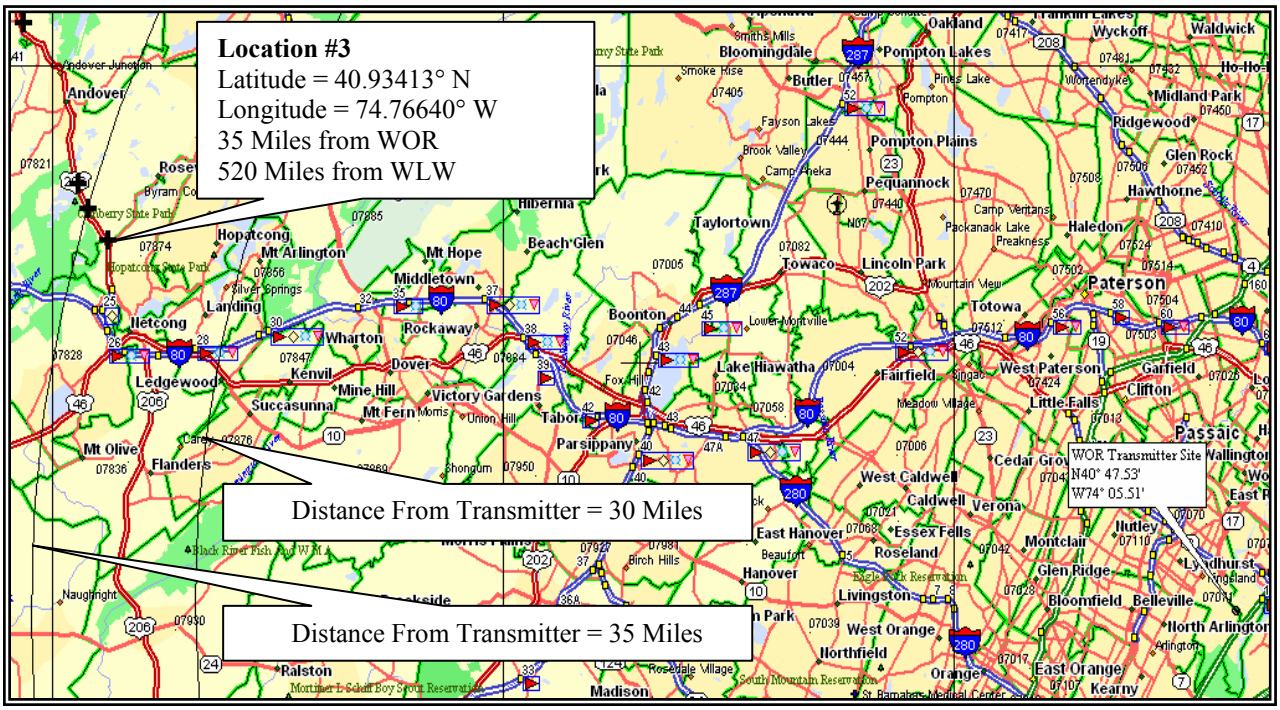


Exhibit M3 – Phase I - WOR / WLW Night Compatibility Map & Chart – NYC (Off Axis / Loc. #3)



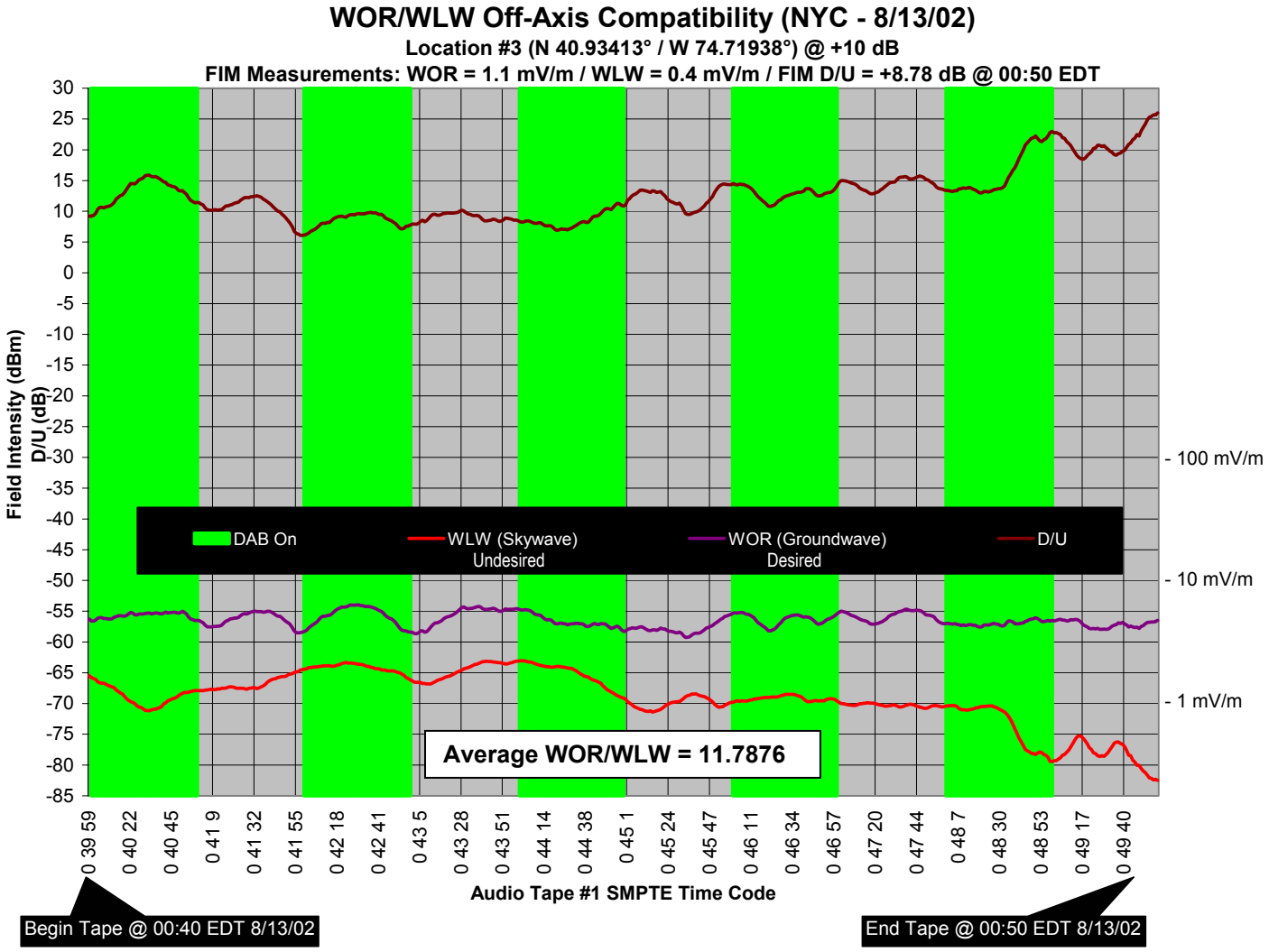
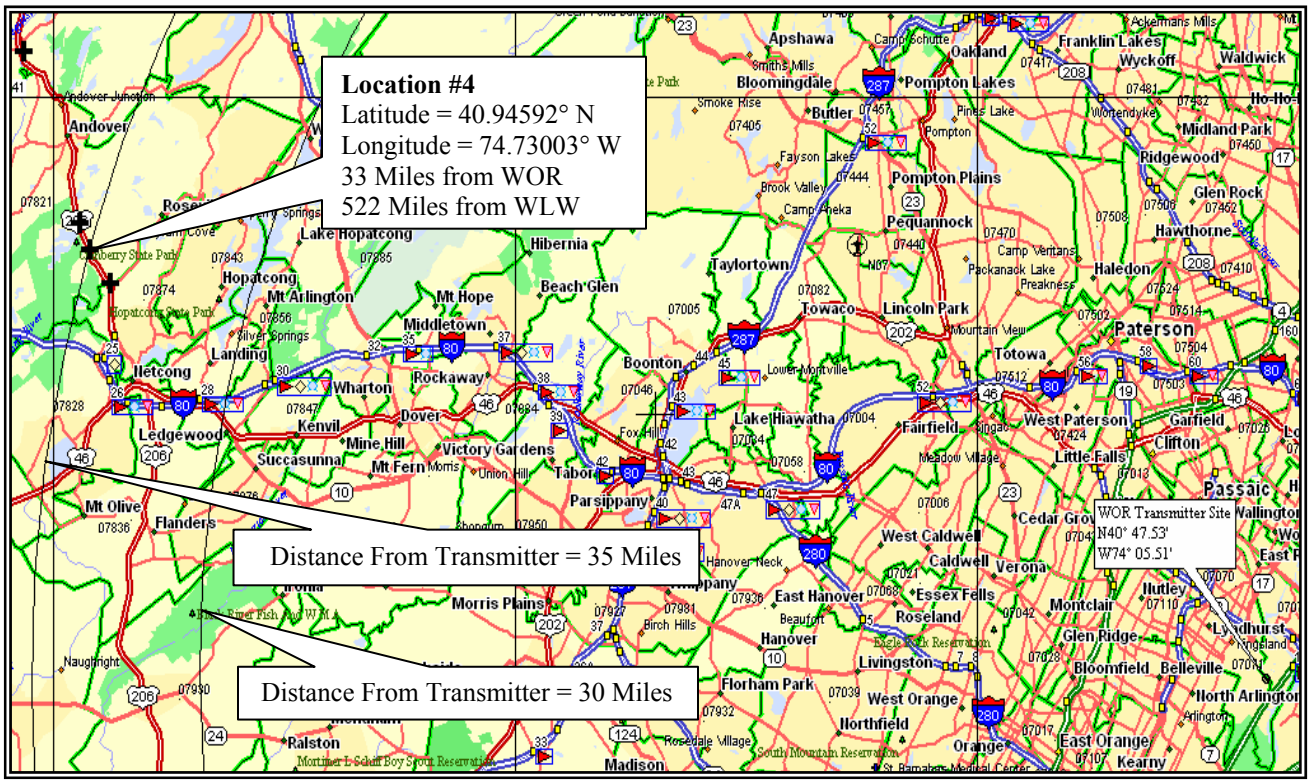


Exhibit M4 – Phase I - WOR / WLW Night Compatibility Map & Chart – NYC (Off Axis / Loc. #4)



WOR/WLW Off-Axis Compatibility (NYC - 8/13/02)

Location #4 (N 40.94592° / W 74.73003°) @ +5 dB

FIM Measurements: WOR = 1.4 mV/m / WLW = 0.8 mV/m / FIM D/U = +4.86 dB @ 01:20 EDT

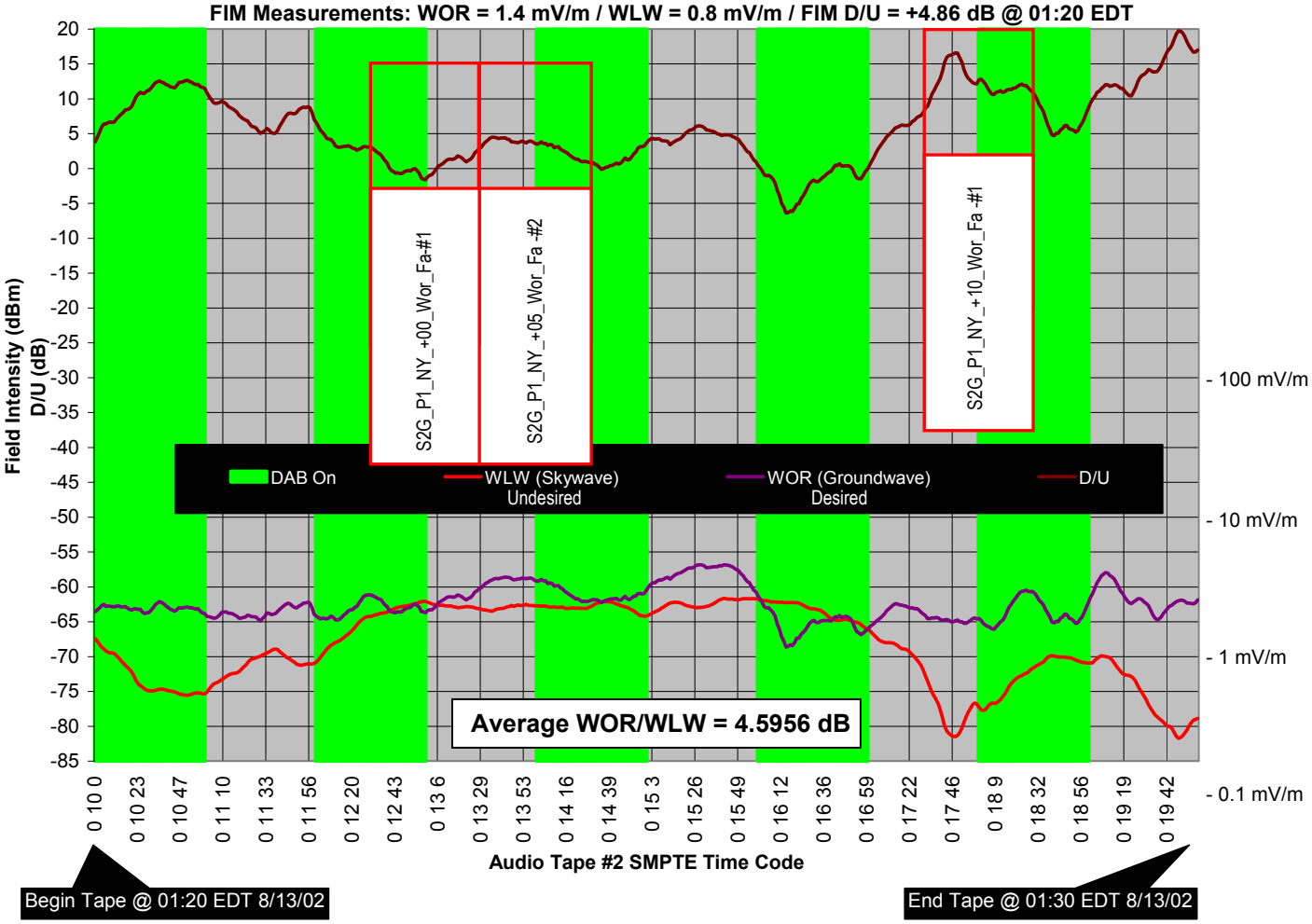
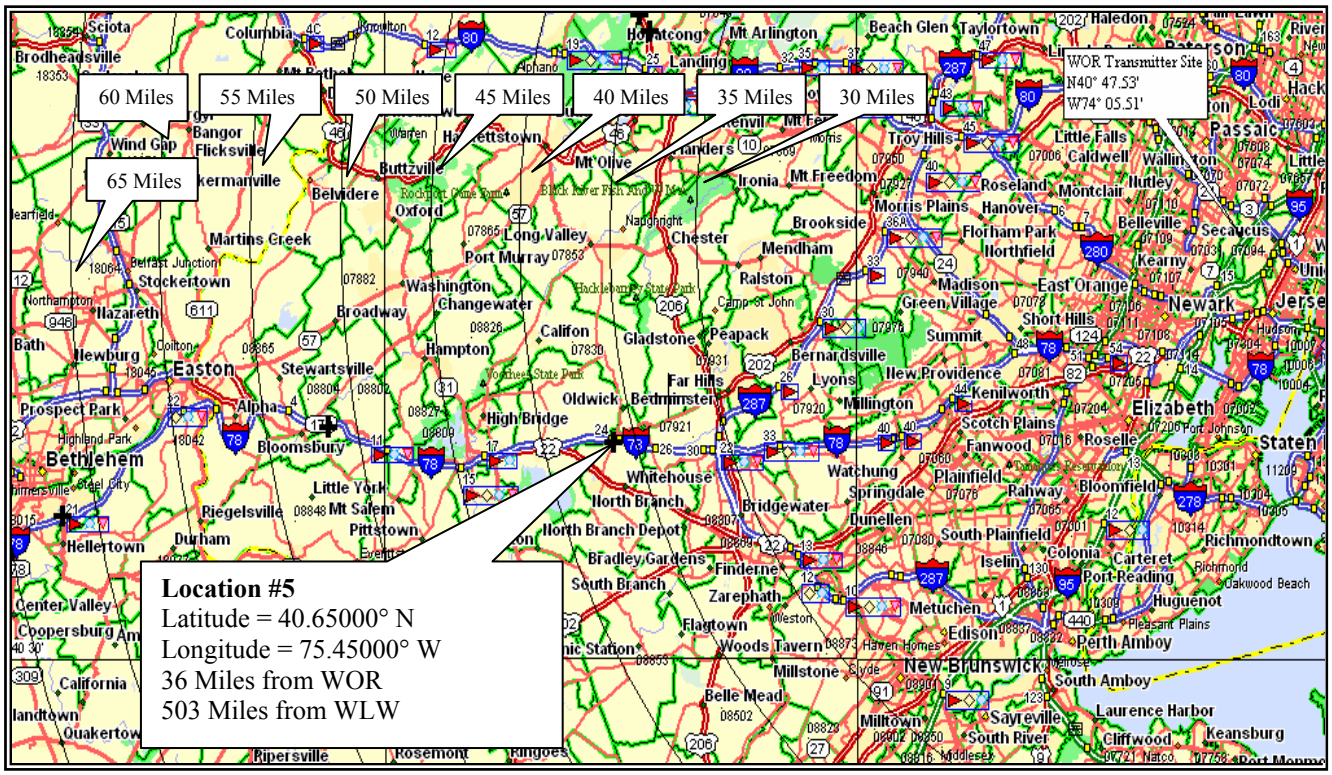


Exhibit M5 – Phase I - WOR / WLW Night Compatibility Map & Chart – NYC (On Axis / Loc. #5)



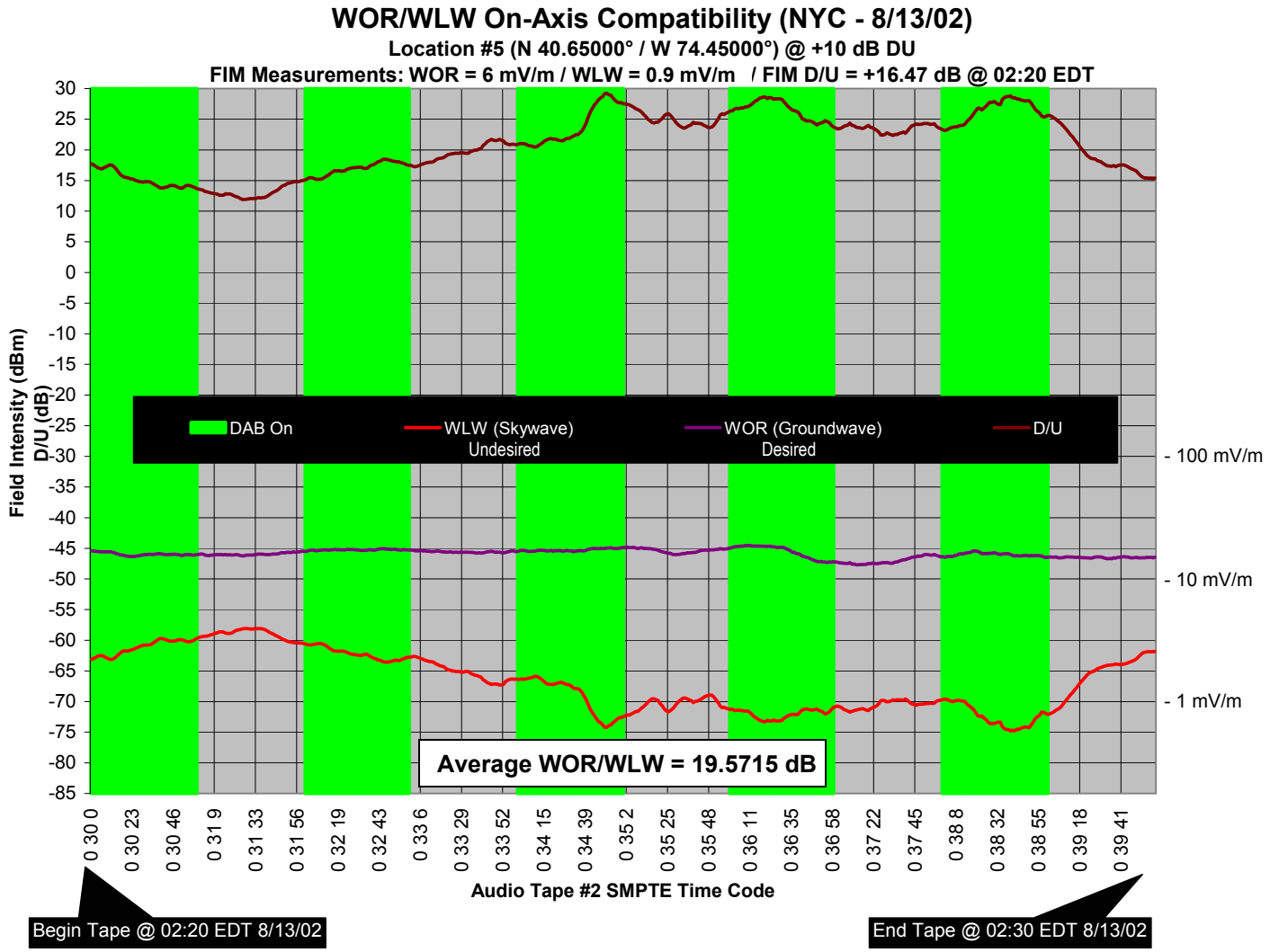
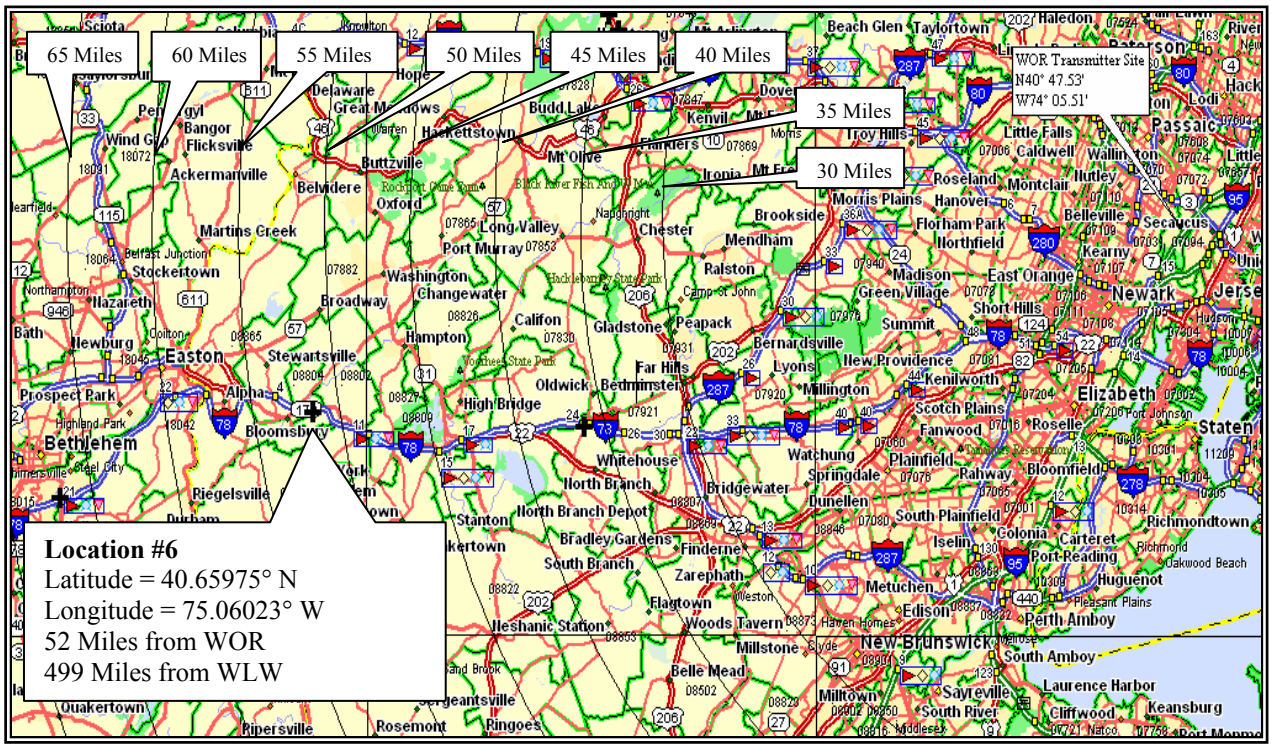


Exhibit M6 – Phase I - WOR / WLW Night Compatibility Map & Chart – NYC (On Axis / Loc. #6)



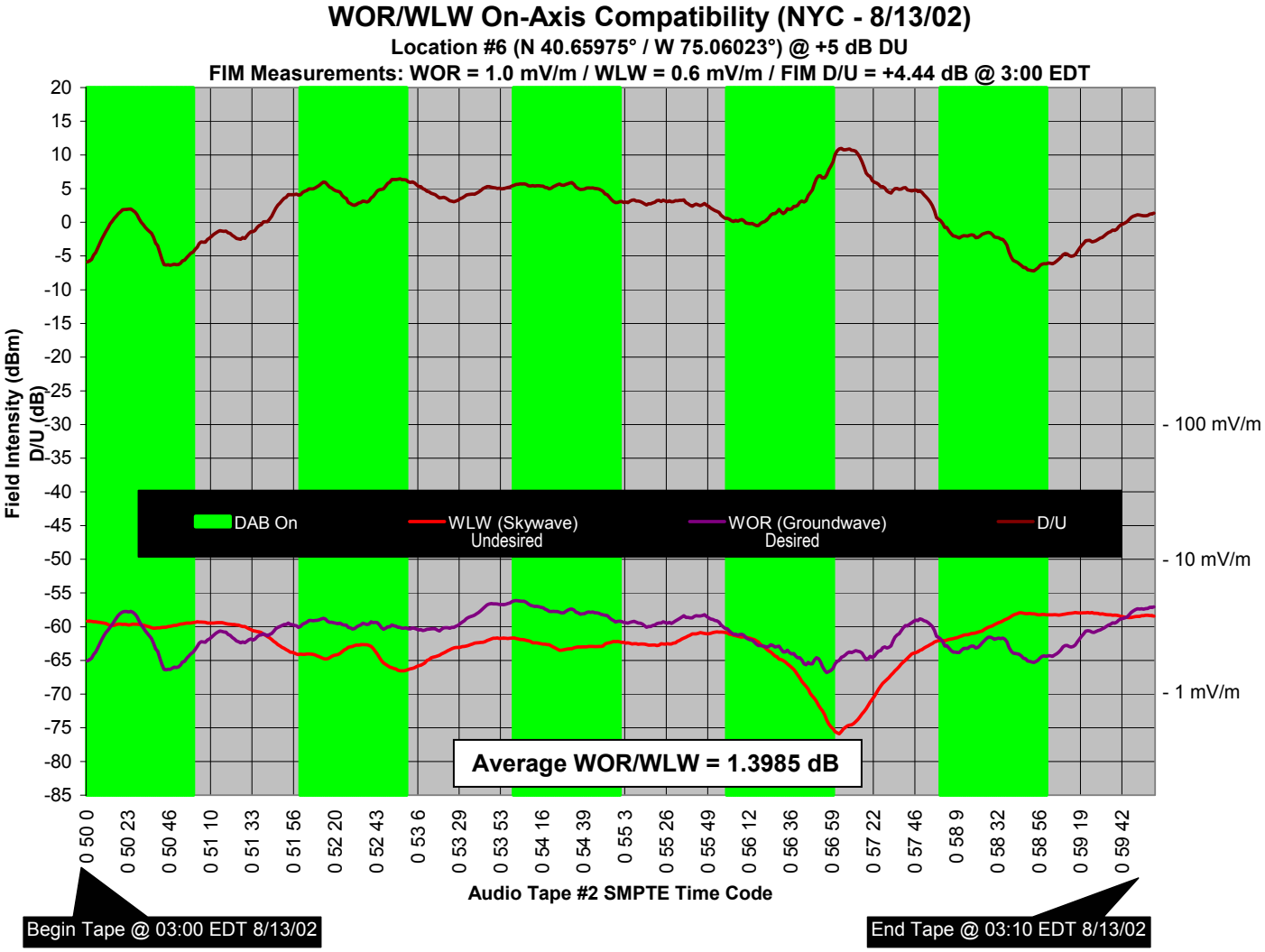
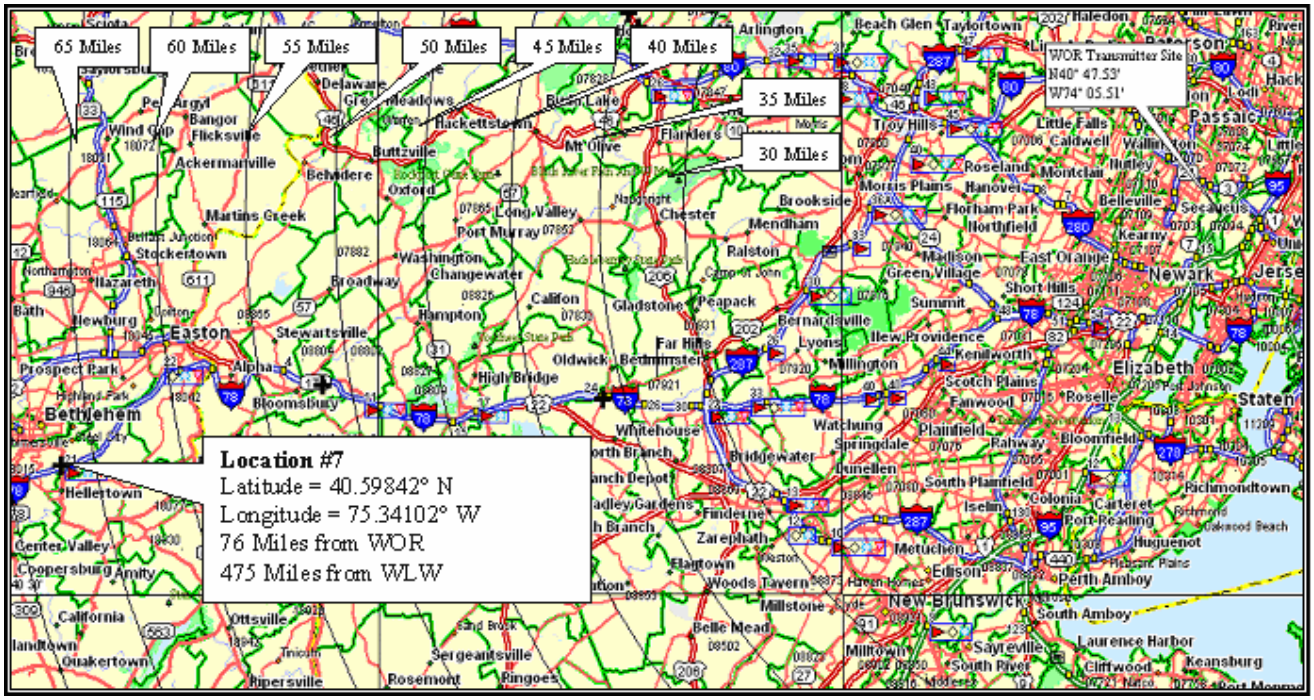


Exhibit M7 – Phase I - WOR / WLW Night Compatibility Map & Chart – NYC (On Axis / Loc. #7)



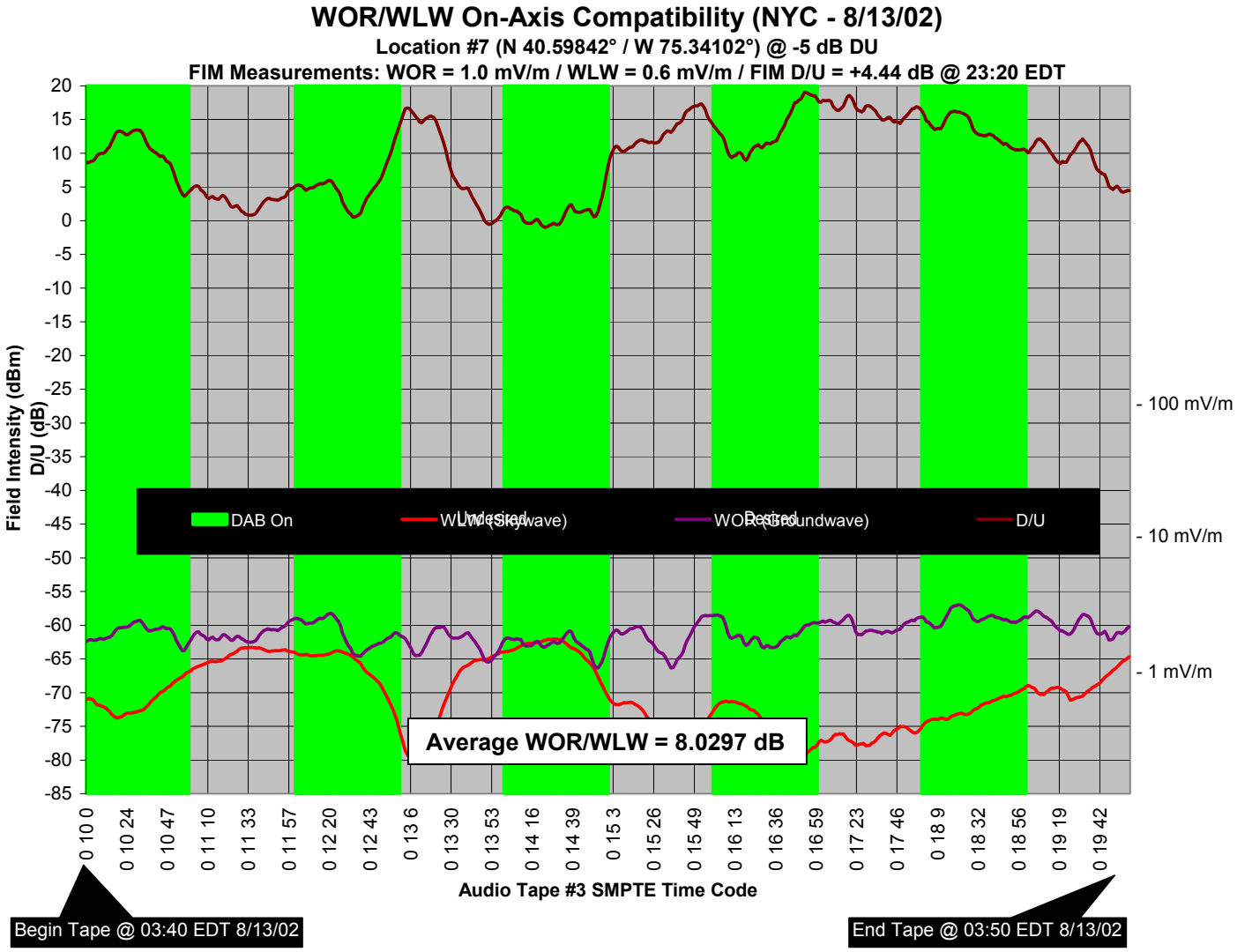
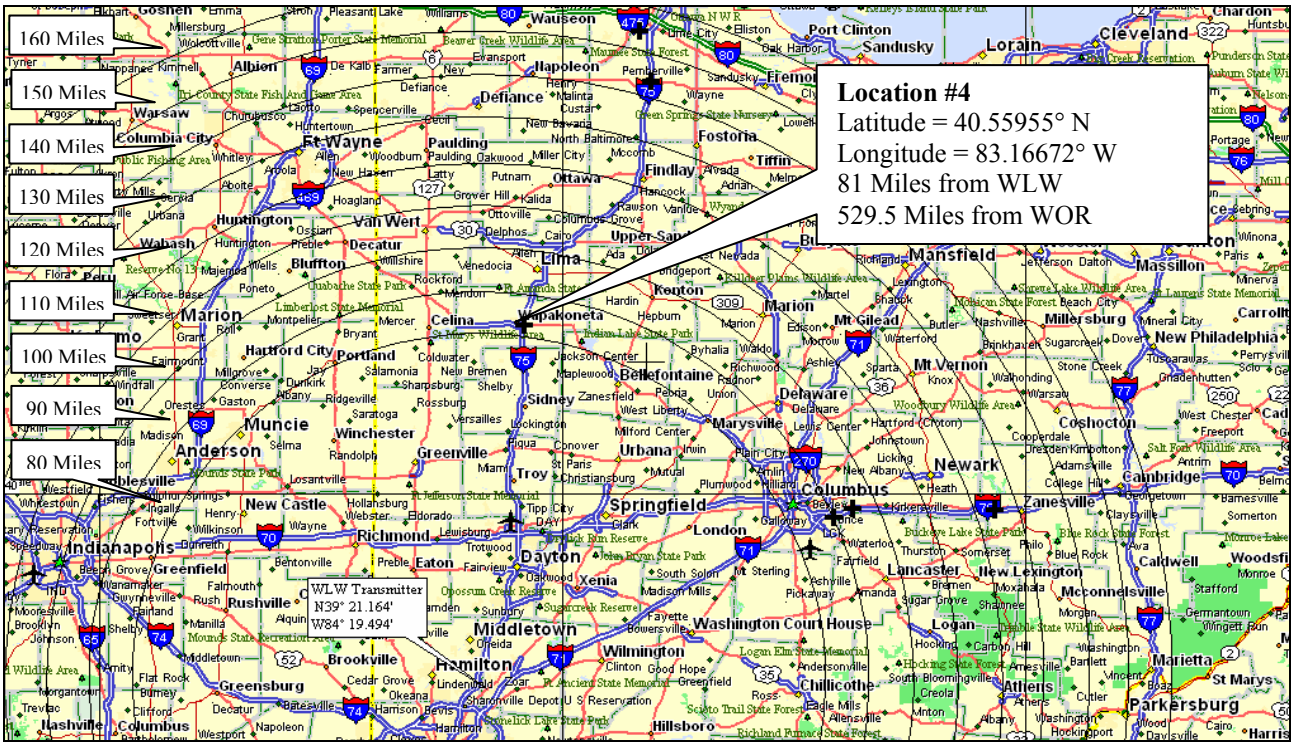


Exhibit M8 – Phase I - WOR / WLW Night Compatibility Map & Chart – Ohio (Off Axis / Loc. #4)



WOR/WLW Off-Axis Compatibility (Cincinnati) - 8/13 + 8/14/02)

Location #4 (N 40.55955° / W 84.16672°) @ -5 dB

FIM Measurements: WOR = 0.9 mV/m / WLW = 2.45 mV/m / FIM D/U = -8.7 dB @ 01:30 EDT

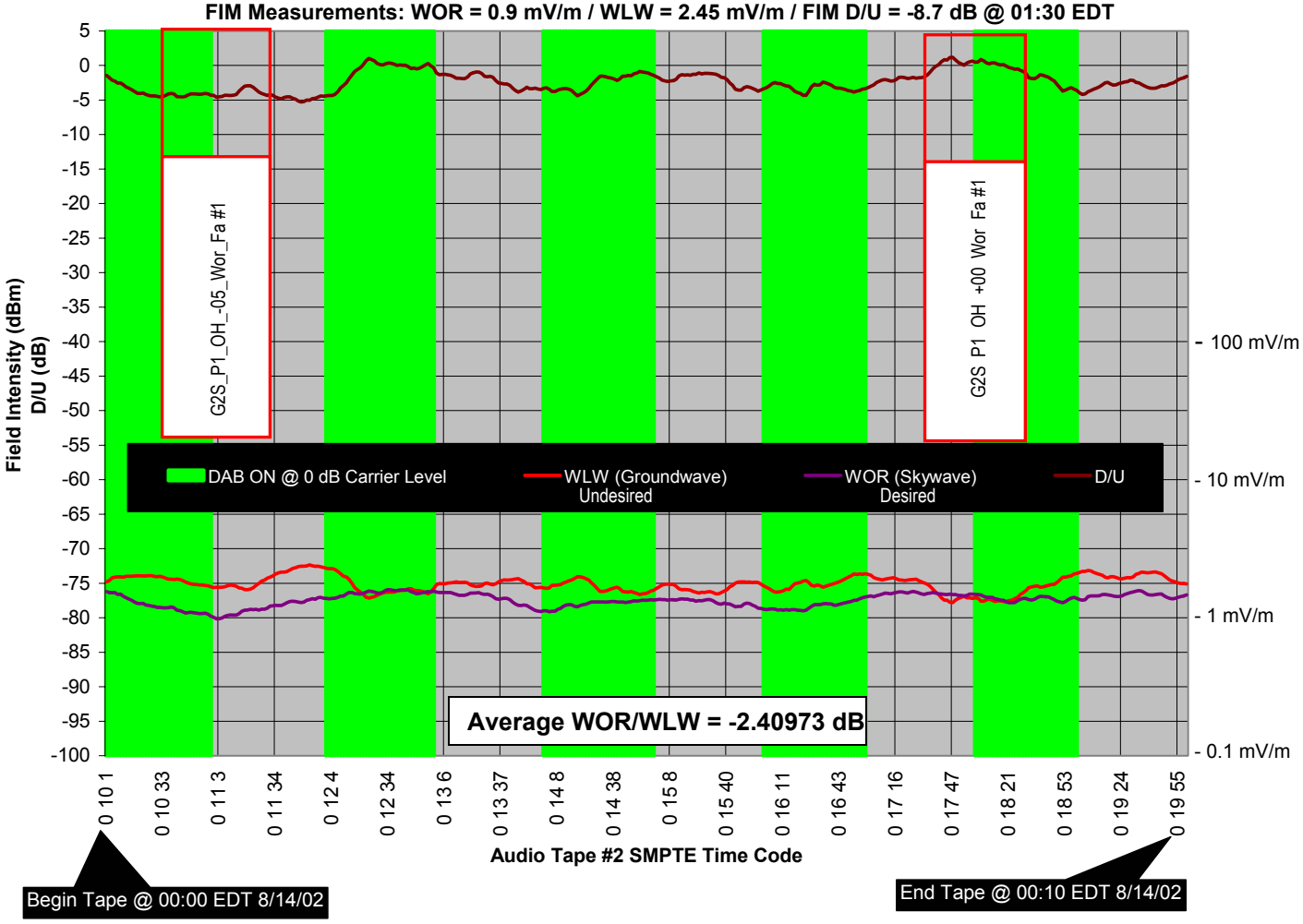


Exhibit M9 – Phase I - WOR / WLW Night Compatibility Map & Chart – Ohio (Off Axis / Loc. #5)

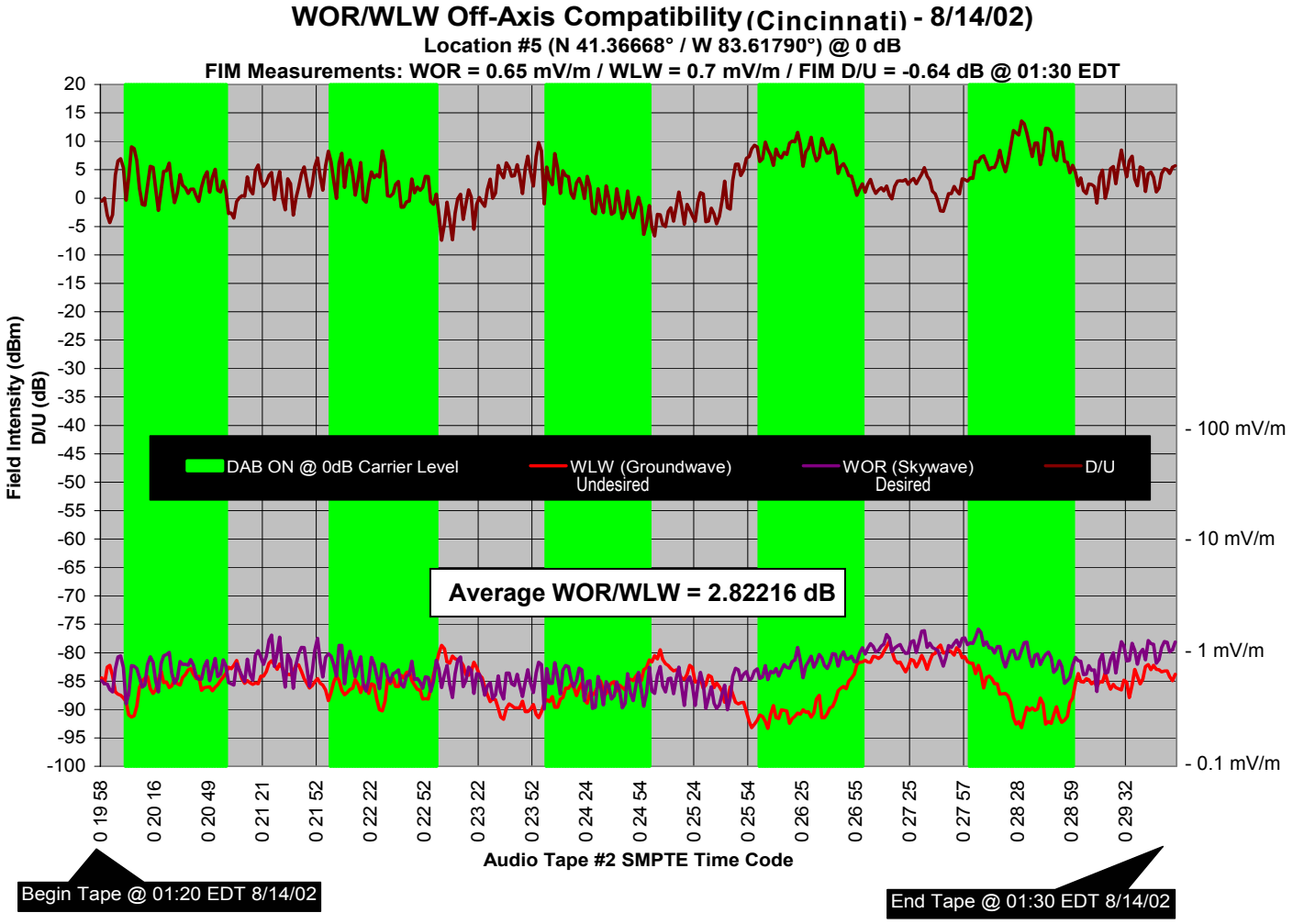
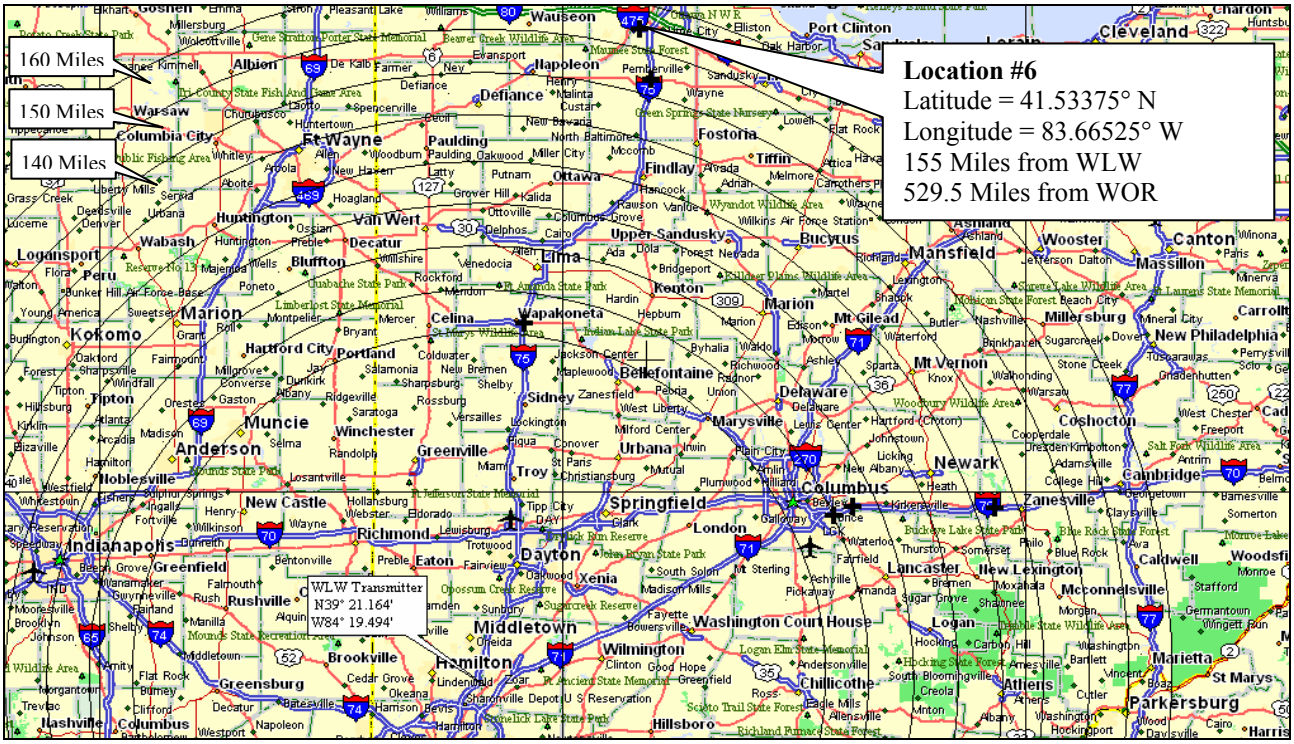


Exhibit M10 – Phase I - WOR / WLW Night Compatibility Map & Chart – Ohio (Off Axis / Loc. #6)



WOR/WLW Off-Axis Compatibility (Cincinnati) - 8/14/02)

Location #6 (N 41.53375° / W 83.66525°) @ +5 dB

FIM Measurements: WOR = 0.85 mV/m / WLW = 1.8 mV/m / FIM D/U = -6.51 dB @ 02:20 EDT

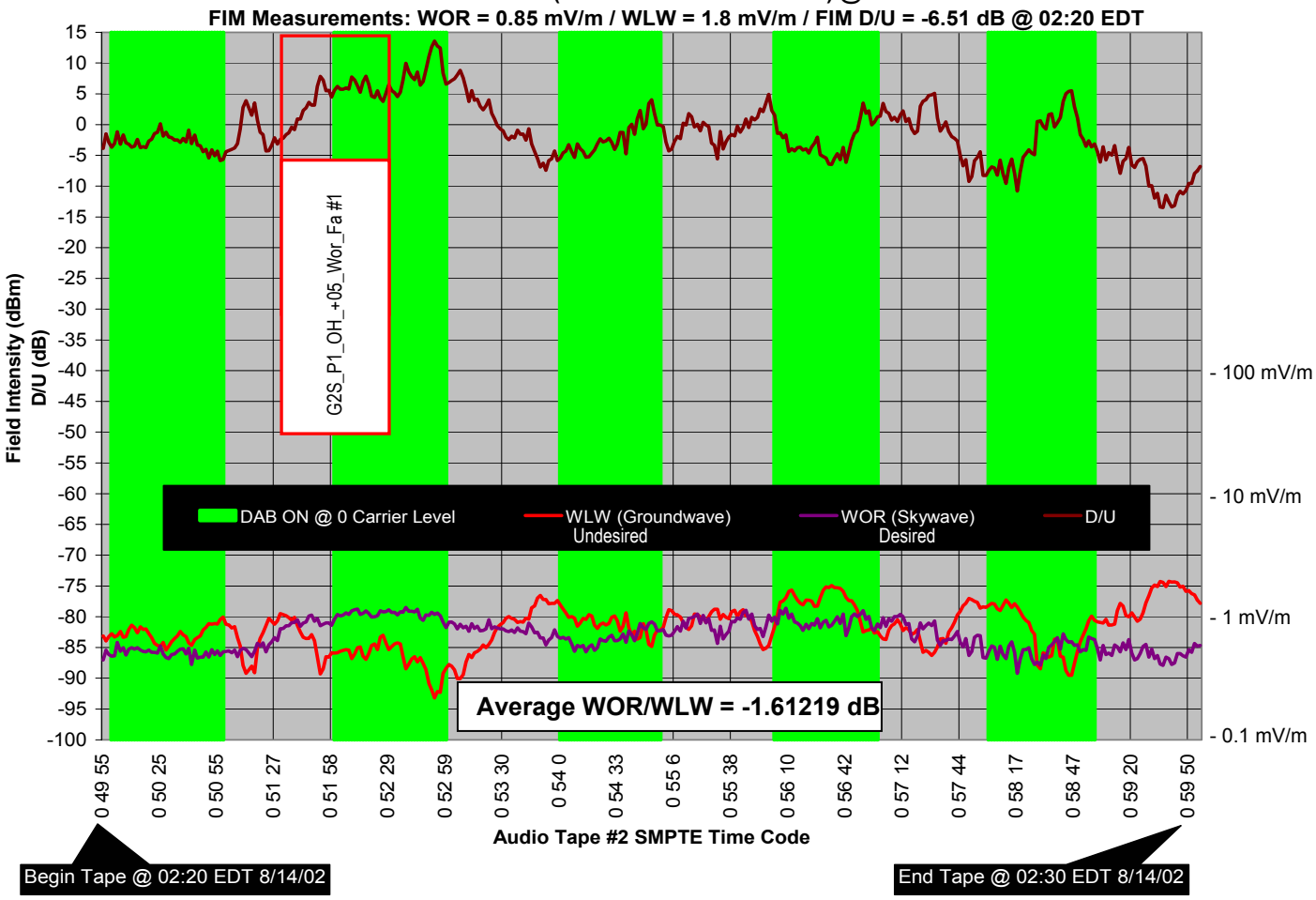
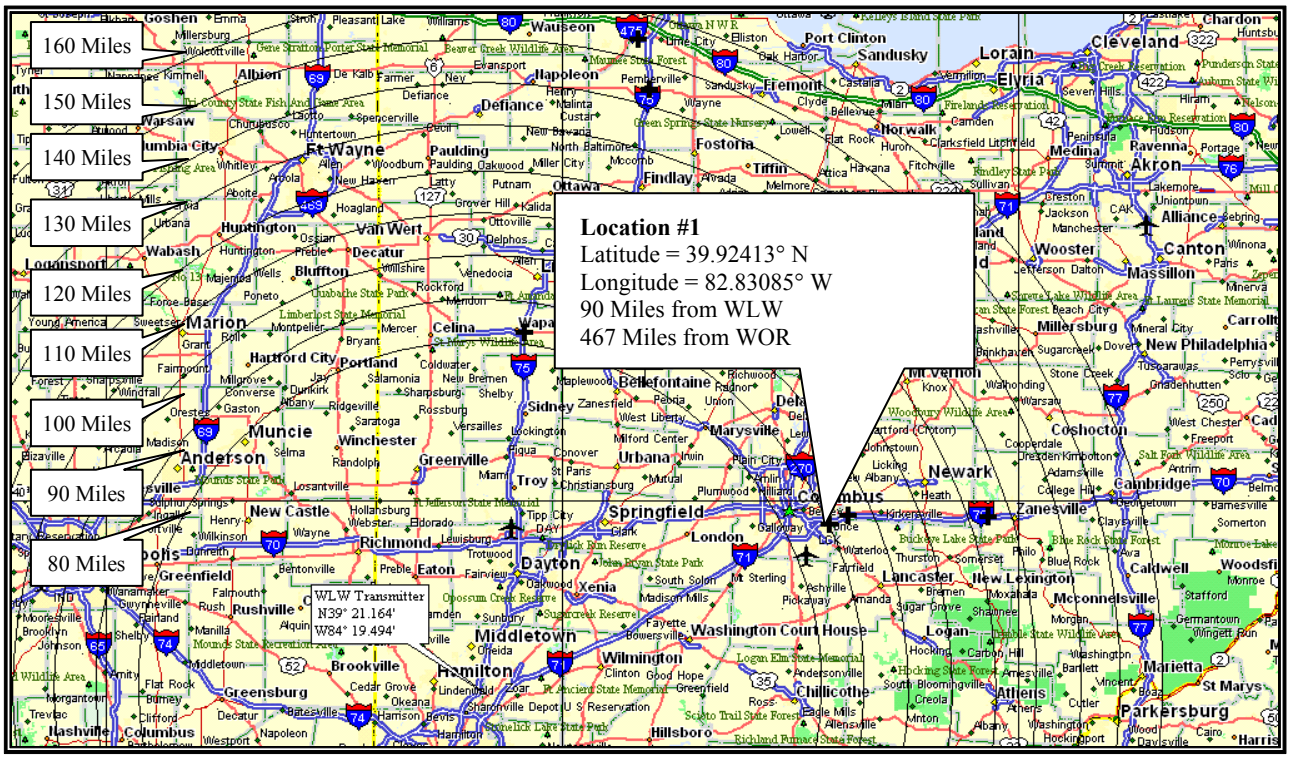


Exhibit M11 - Phase I - WOR / WLW Night Compatibility Map & Chart – Ohio (On Axis / Loc. #1)



WOR/WLW On-Axis Compatibility (Cincinnati) - 8/13/02)

Location #1 (N39.92413 ° / W82.83085 °) @ -5 dB

FIM Measurements: WOR = 0.95 mV/m / WLW = 1.95 mV/m / FIM D/U = -6.24 dB @ 00:50 EDT

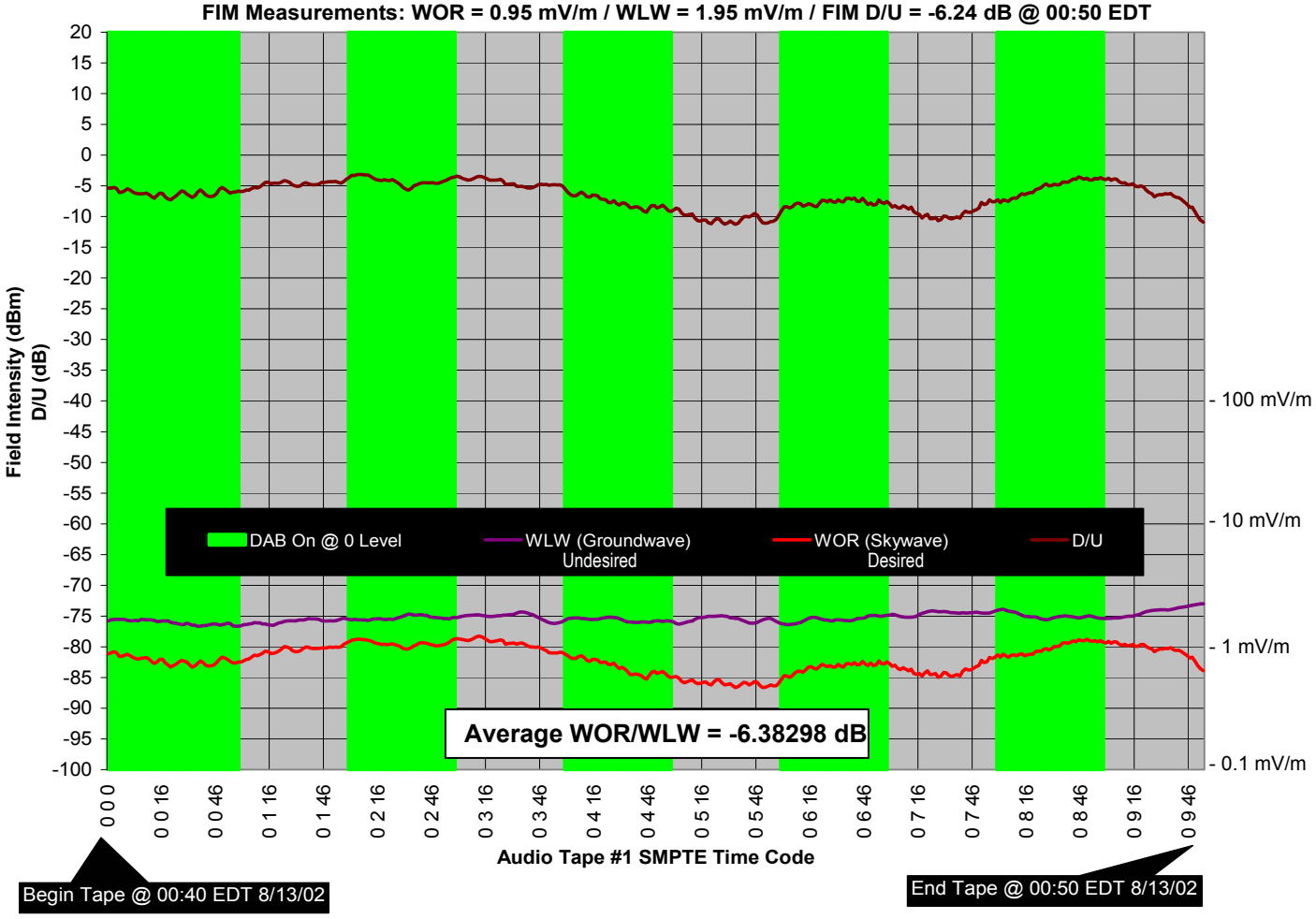
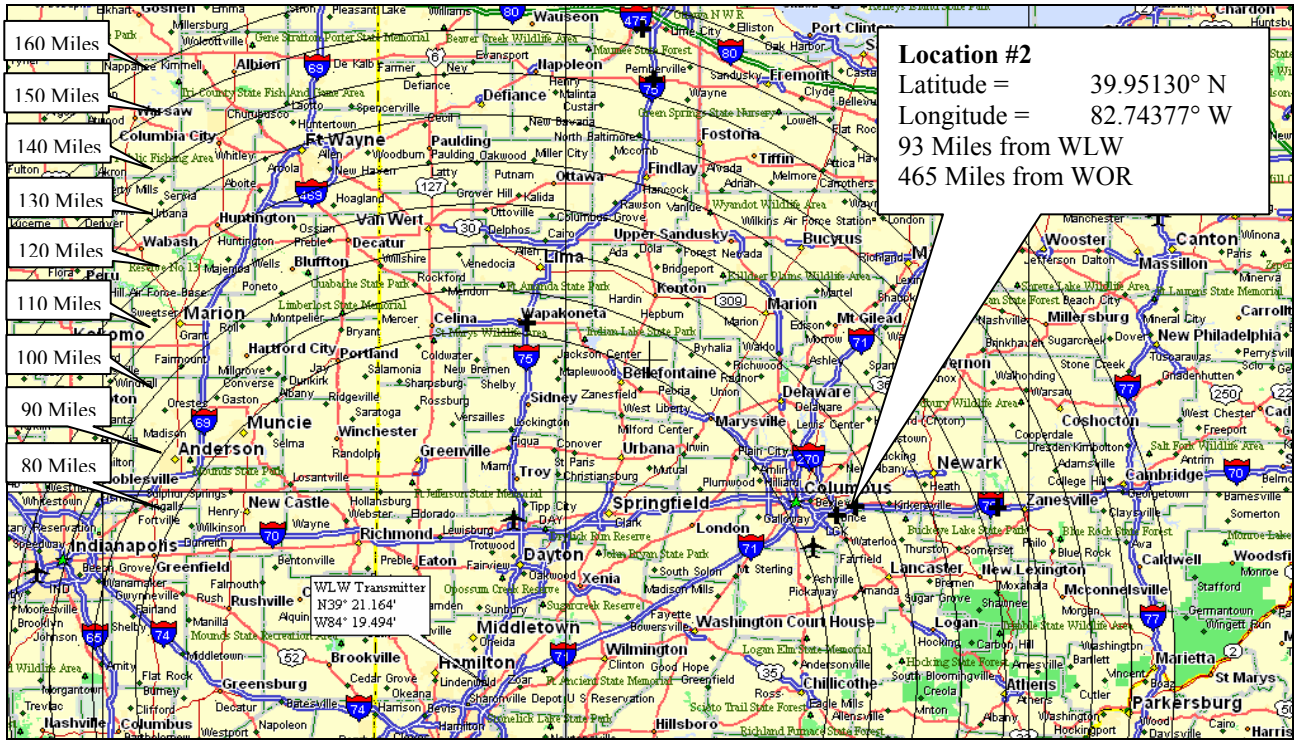


Exhibit M12 – Phase I - WOR / WLW Night Compatibility Map & Chart – Ohio (On Axis / Loc. #2)



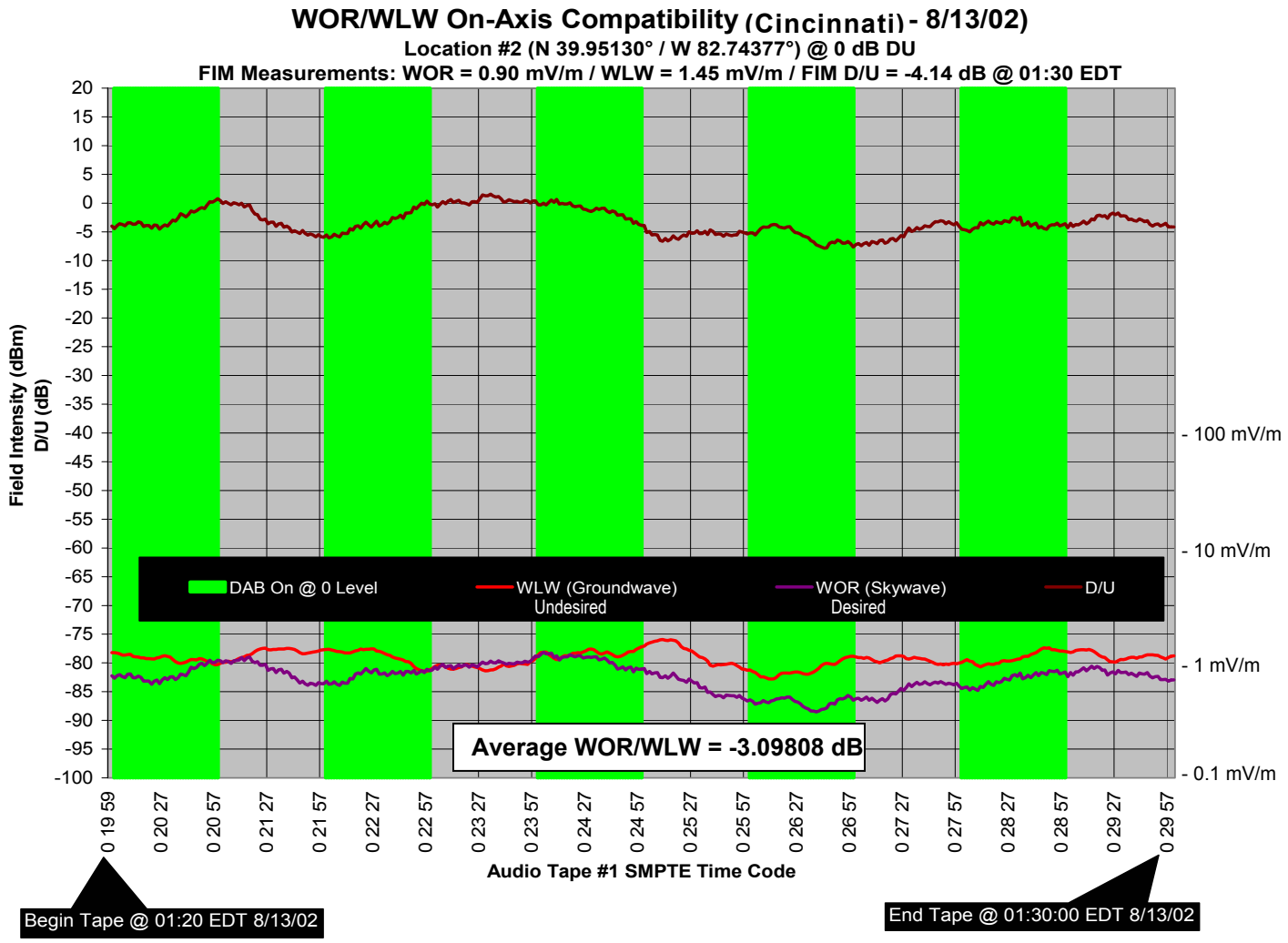
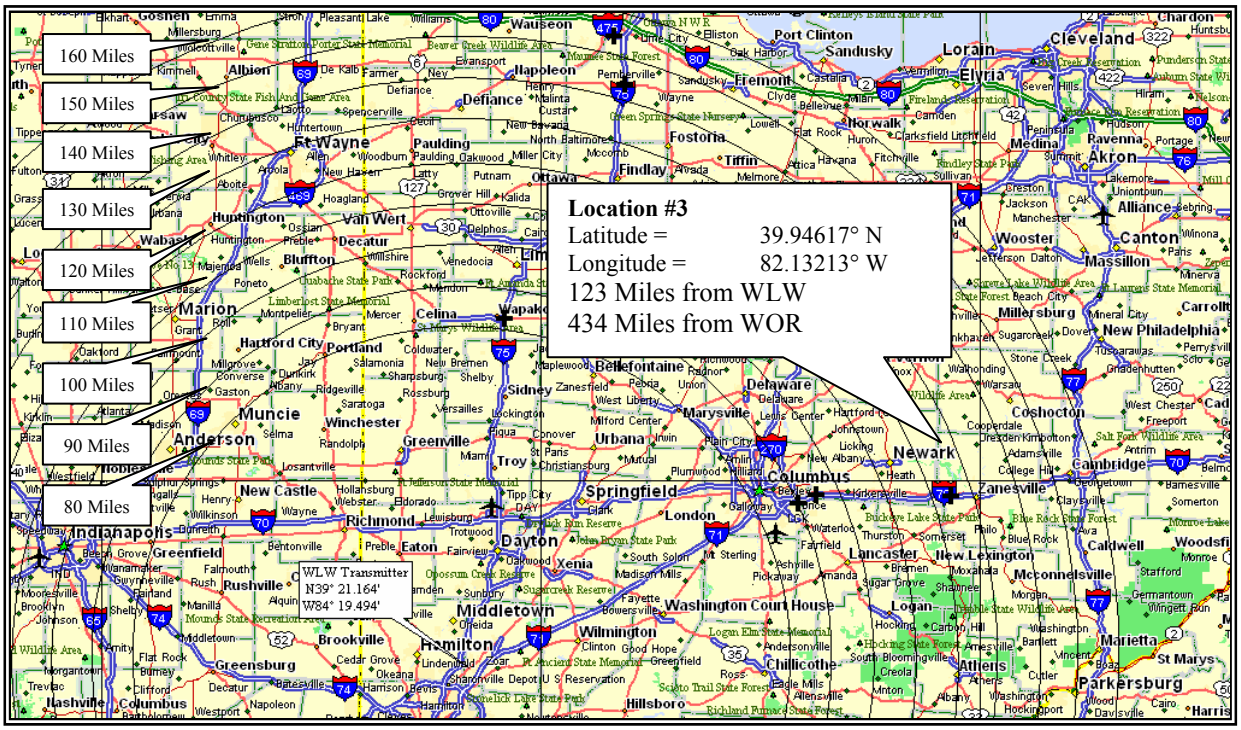


Exhibit M13 – Phase I - WOR / WLW Night Compatibility Map & Chart – Ohio (On Axis / Loc. #3)



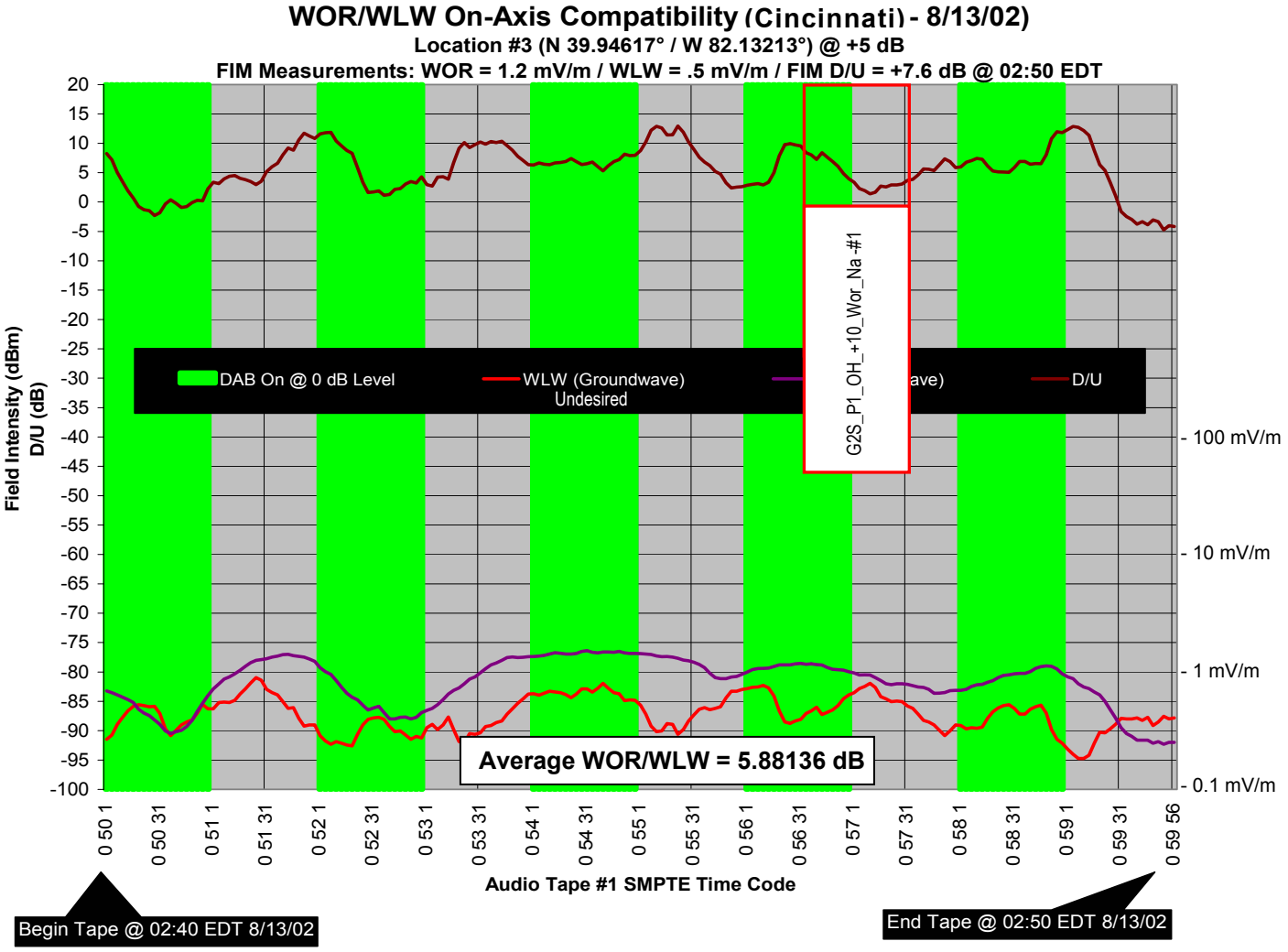
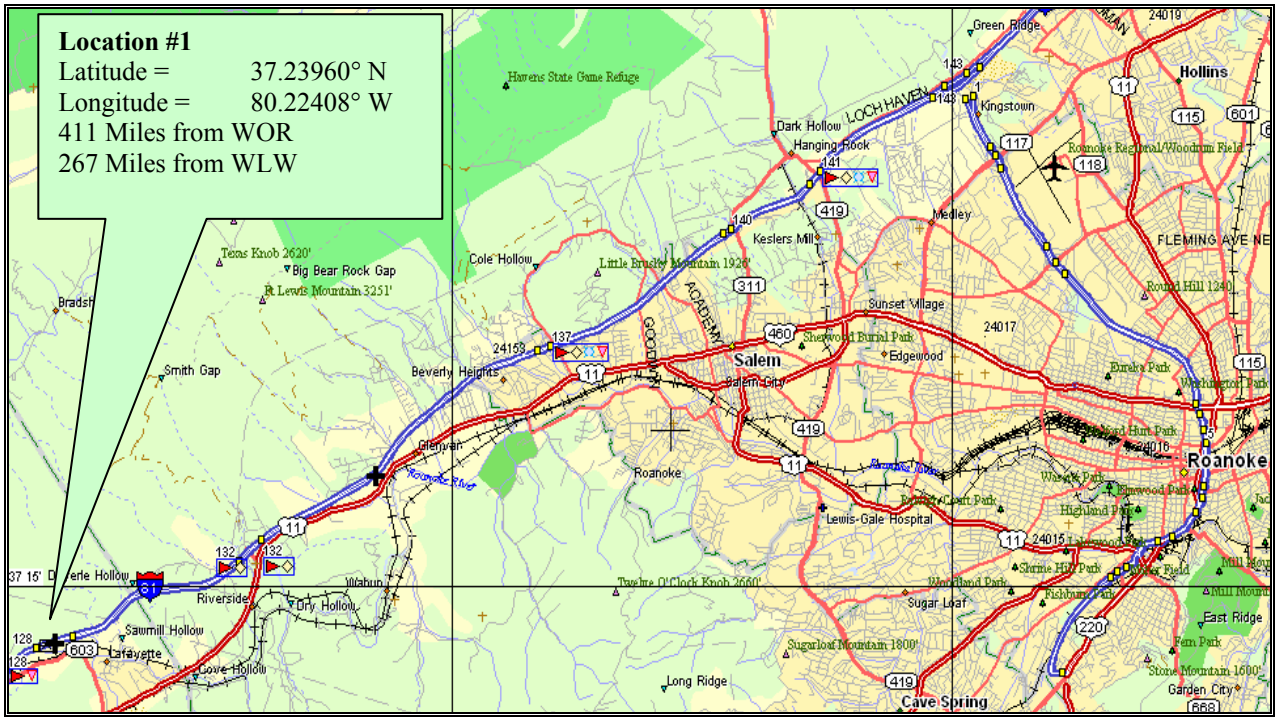


Exhibit M14 – Phase I - WOR / WLW Night Compatibility Map & Chart – Virginia (Off Axis / Loc. #1)



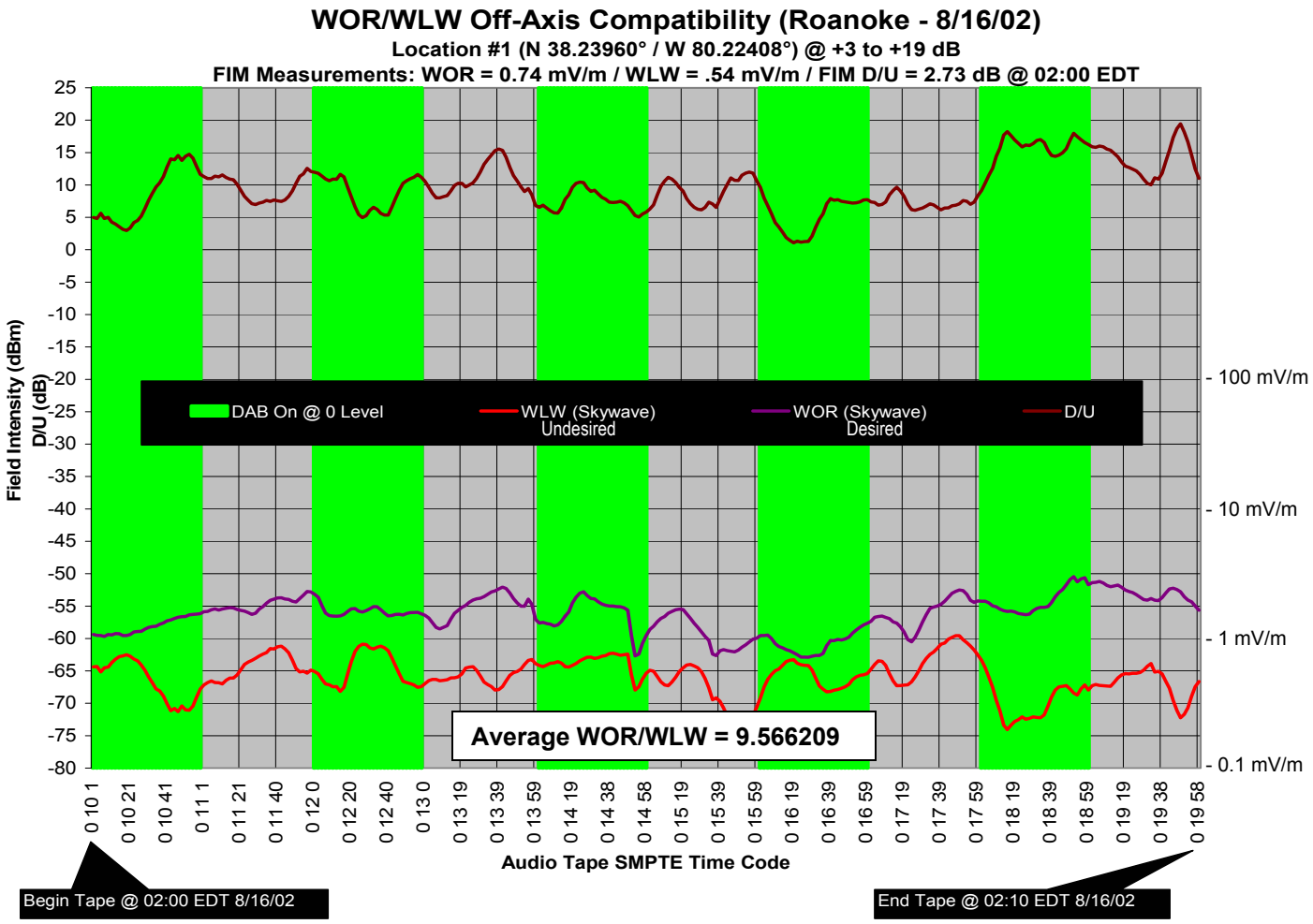
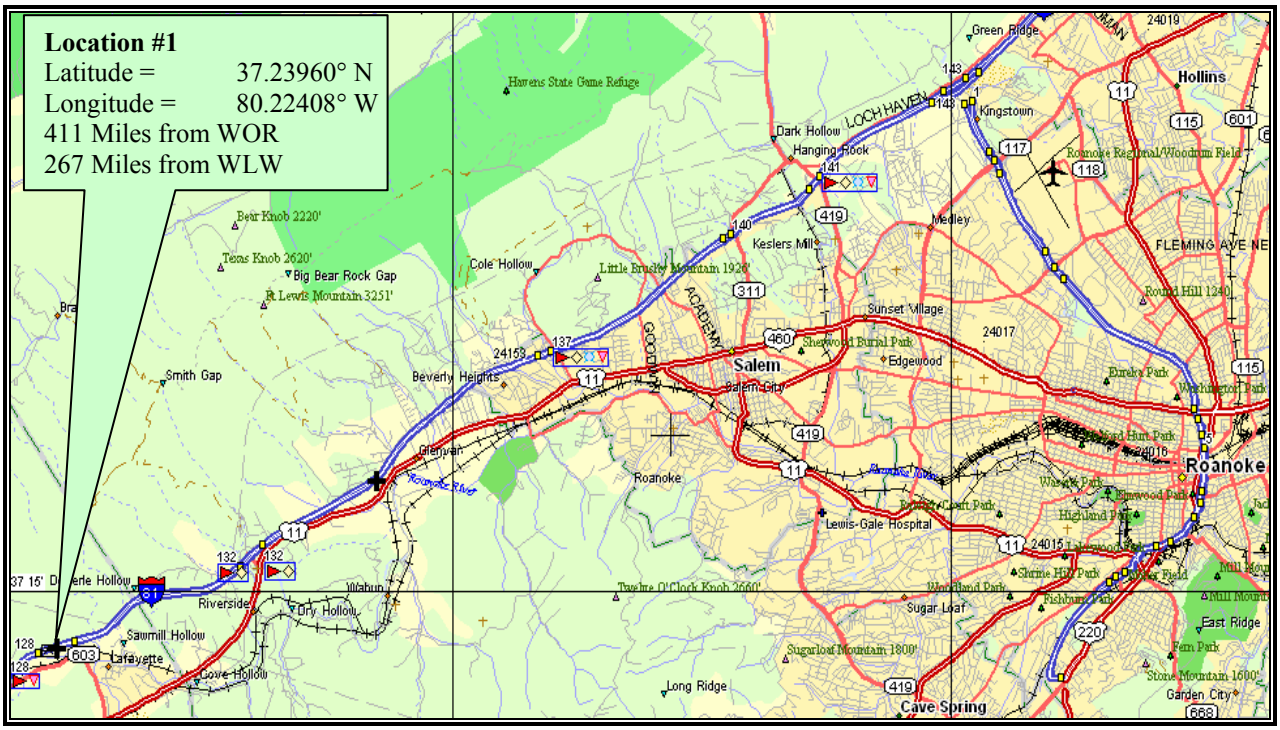


Exhibit M15 – Phase I - WOR / WLW Night Compatibility Map & Chart – Virginia (Off Axis / Loc. #1)



WOR/WLW Off-Axis Compatibility (Roanoke - 8/16/02)

Location #1 (N 38.23960° / W 80.22408°) @ +2 to +21 dB

FIM Measurements: WOR = 0.74 mV/m / WLW = .54 mV/m / FIM D/U = 2.73 dB @ 02:00 EDT

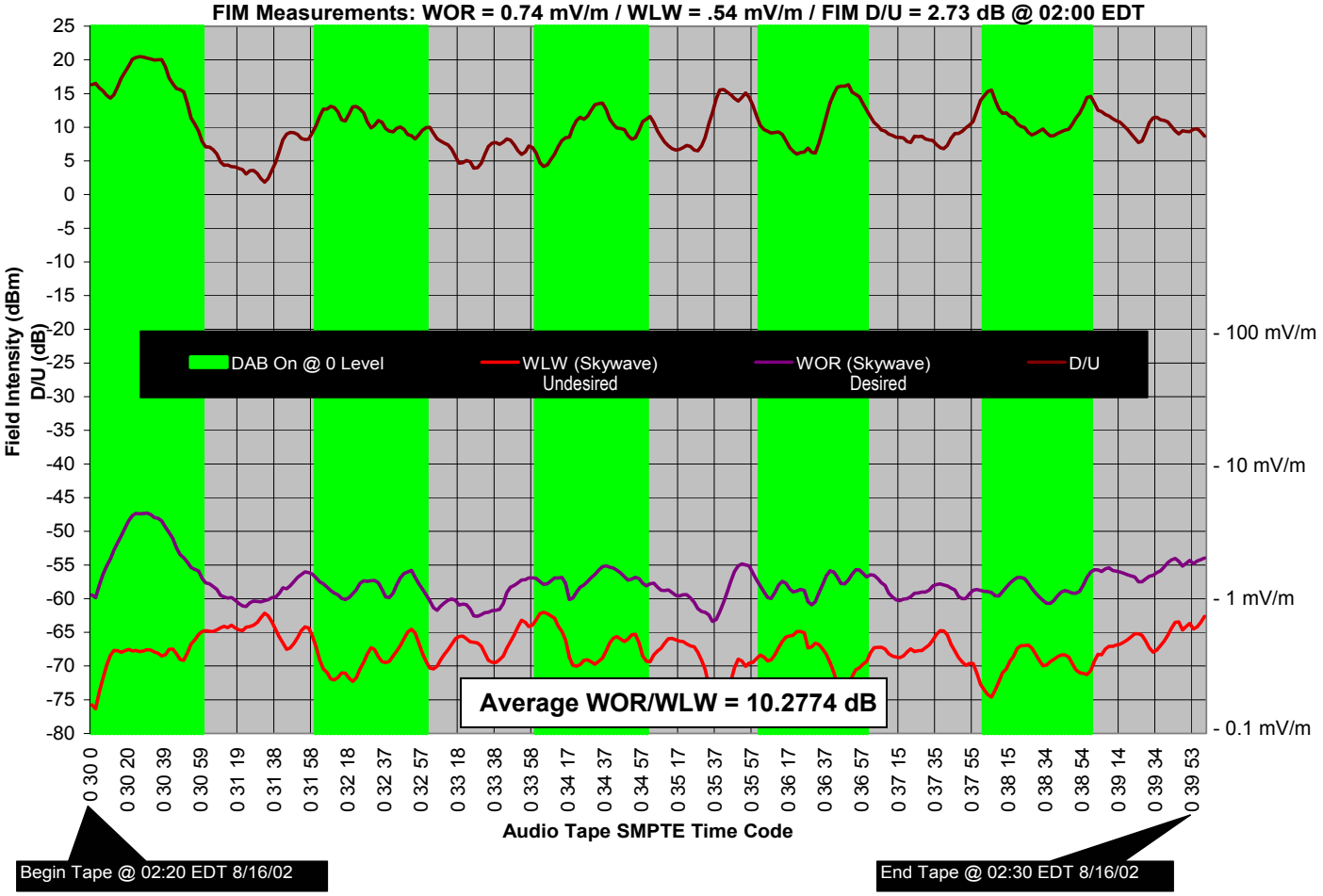
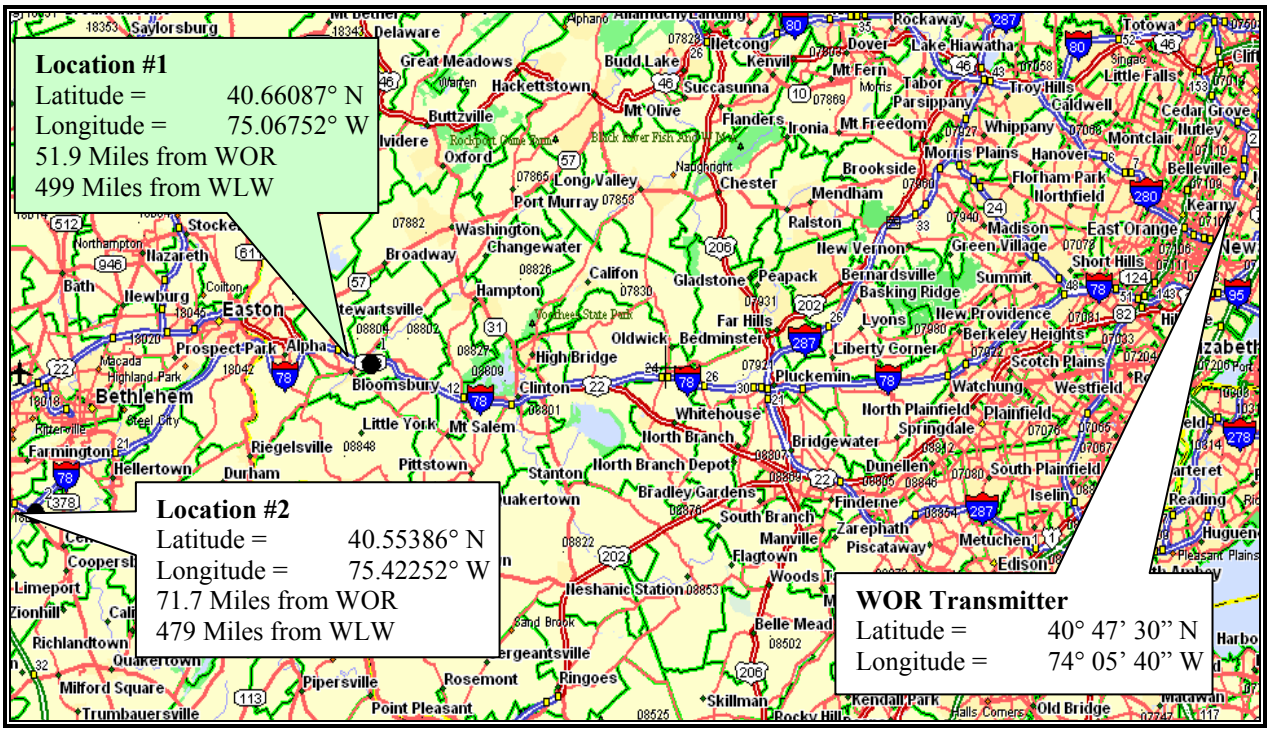


Exhibit M16 – Phase II - WOR / WLW Night Compatibility Map & Chart – New York (On Axis / Loc. #1)



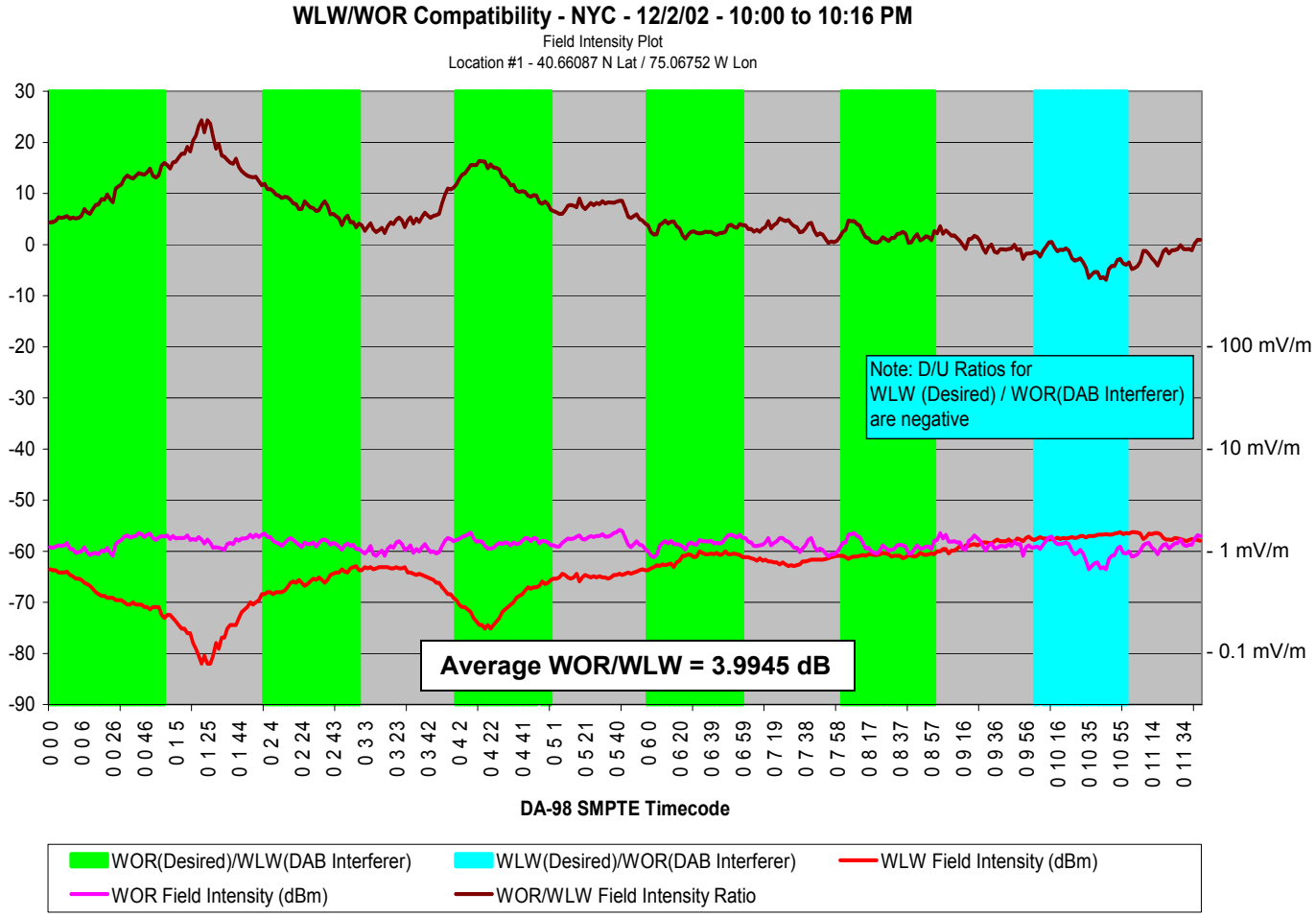
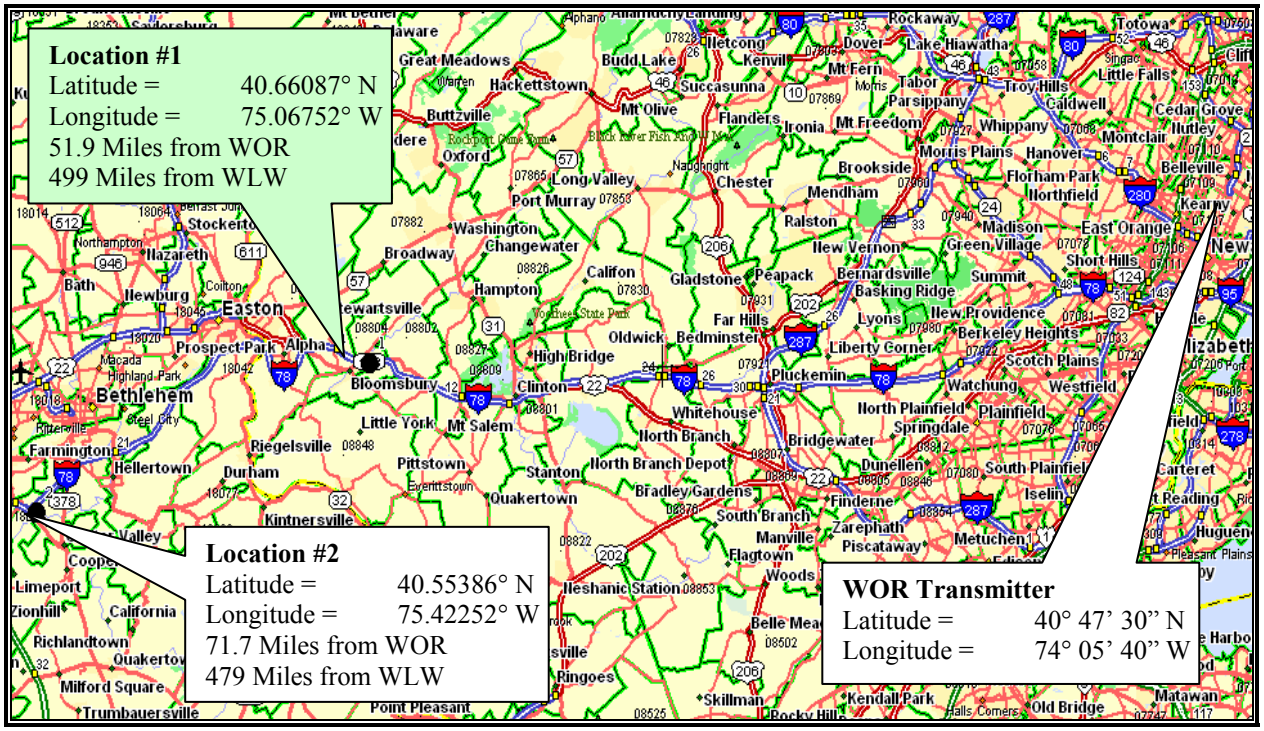


Exhibit M17 – Phase II - WOR / WLW Night Compatibility Map & Chart – New York (On Axis / Loc. #1)



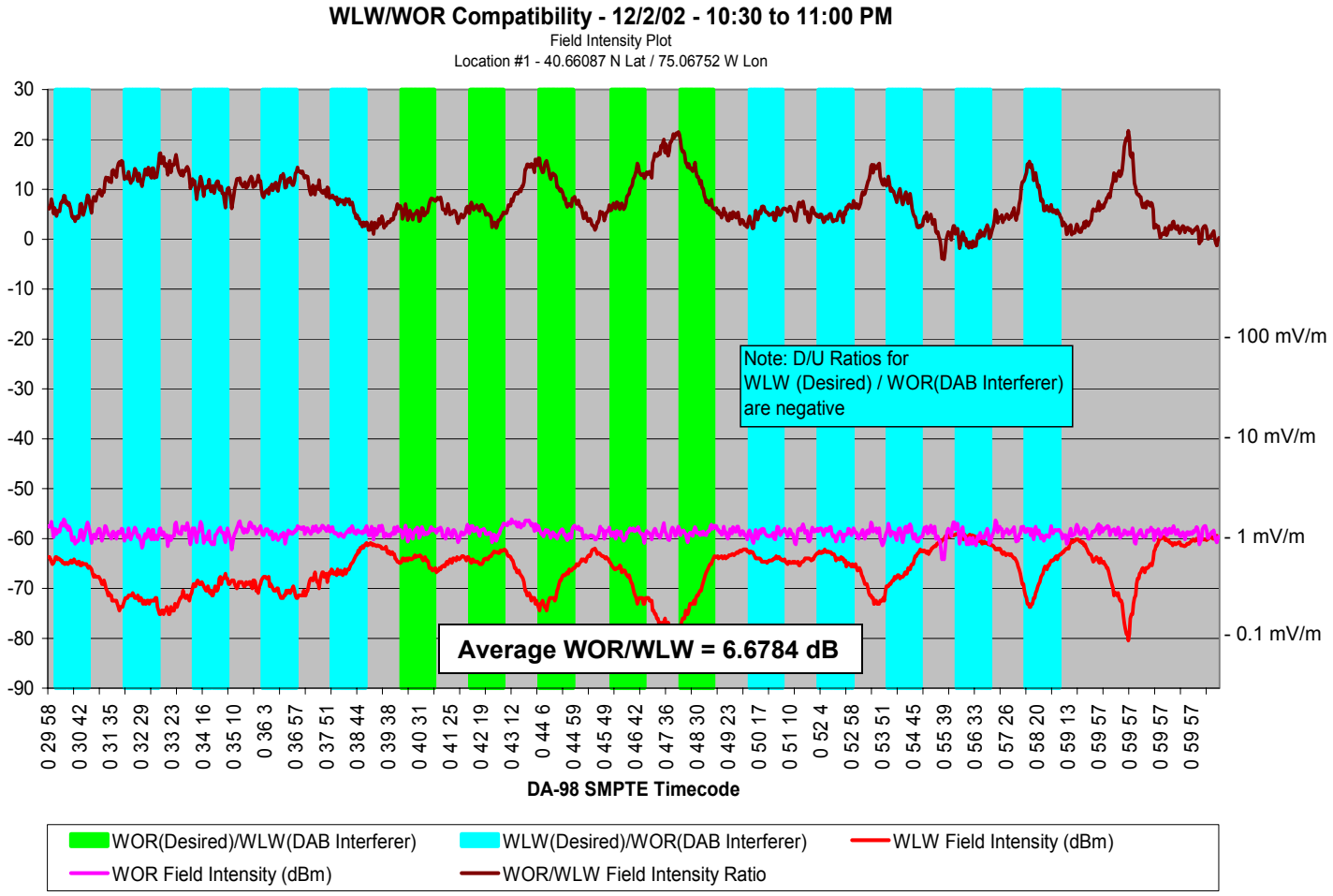
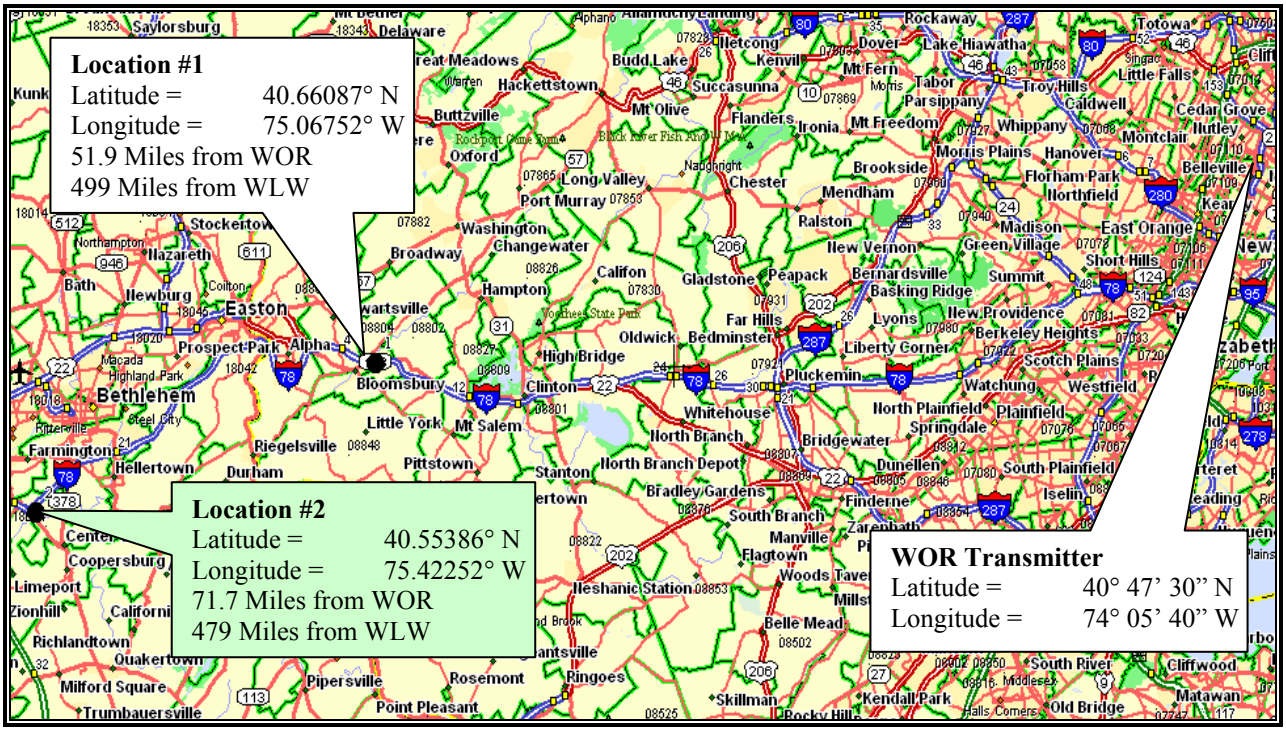


Exhibit M18 – Phase II - WOR / WLW Night Compatibility Map & Chart – New York (On Axis / Loc. #1)



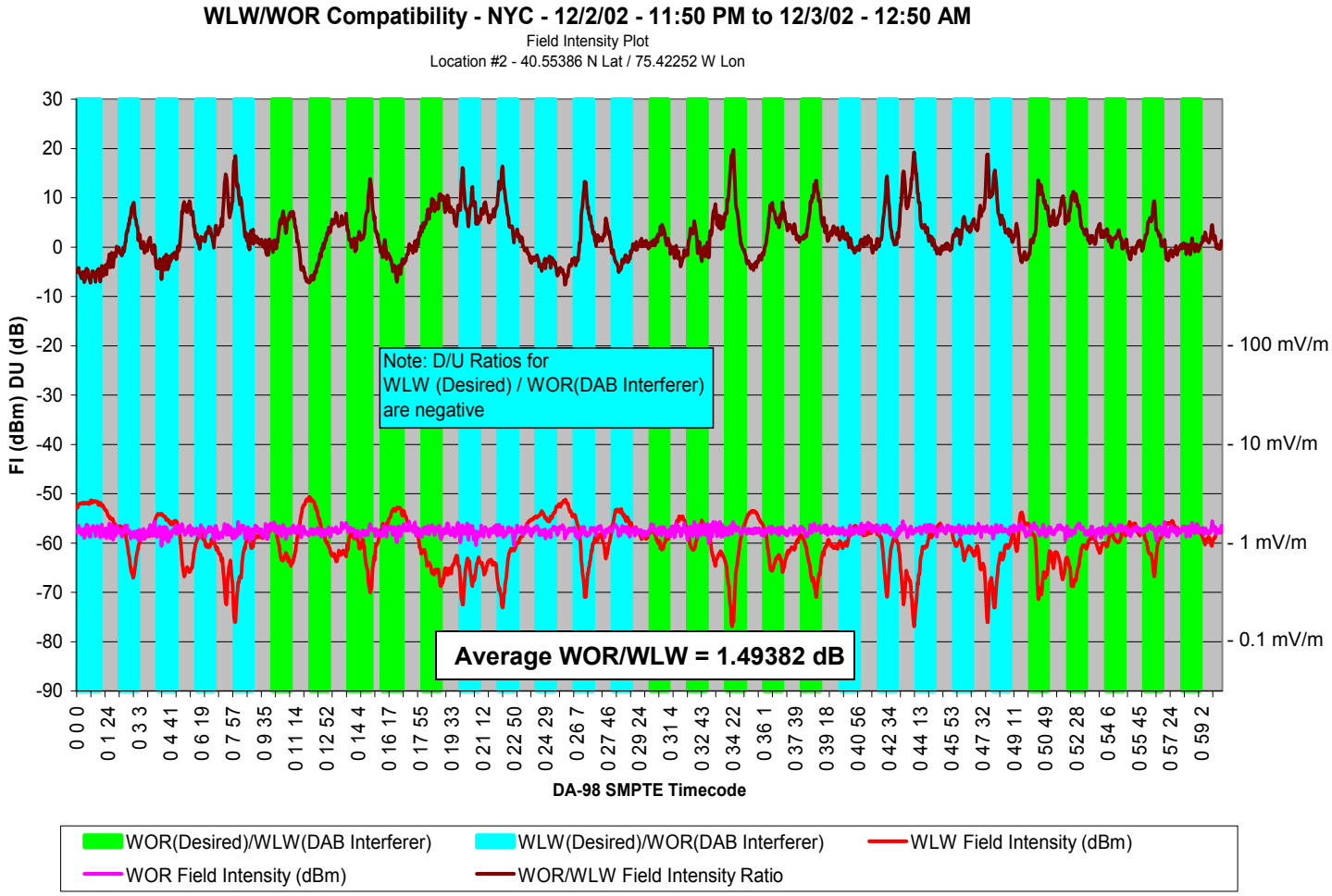
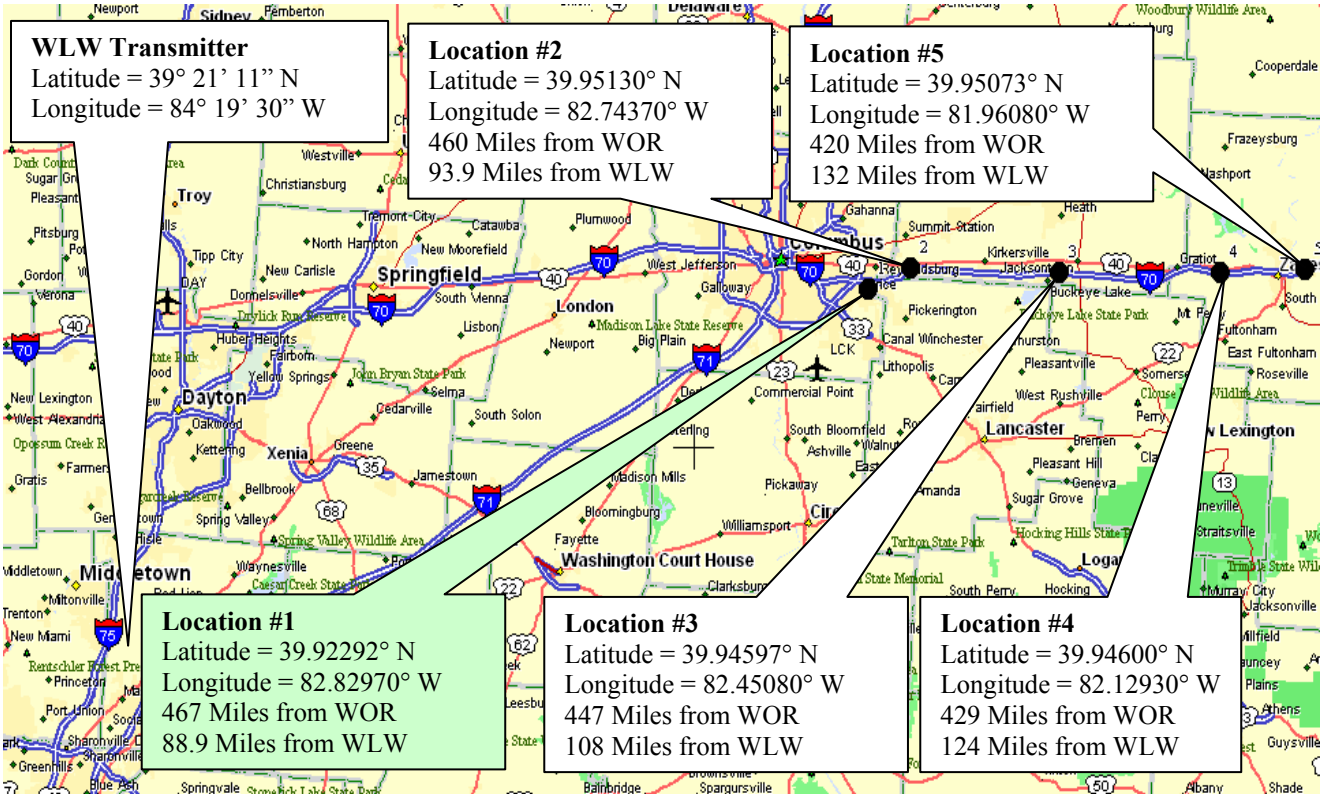


Exhibit M19 – Phase II - WOR / WLW Night Compatibility Map & Chart – Ohio (On Axis / Loc. #1)



WLW/WOR Compatibility - Cincinnati - 12/3/02 - 12:00 AM to 12:20 AM

Field Intensity Plot

Location #1 - 39.92292 N Lat / 82.8298 W Lon

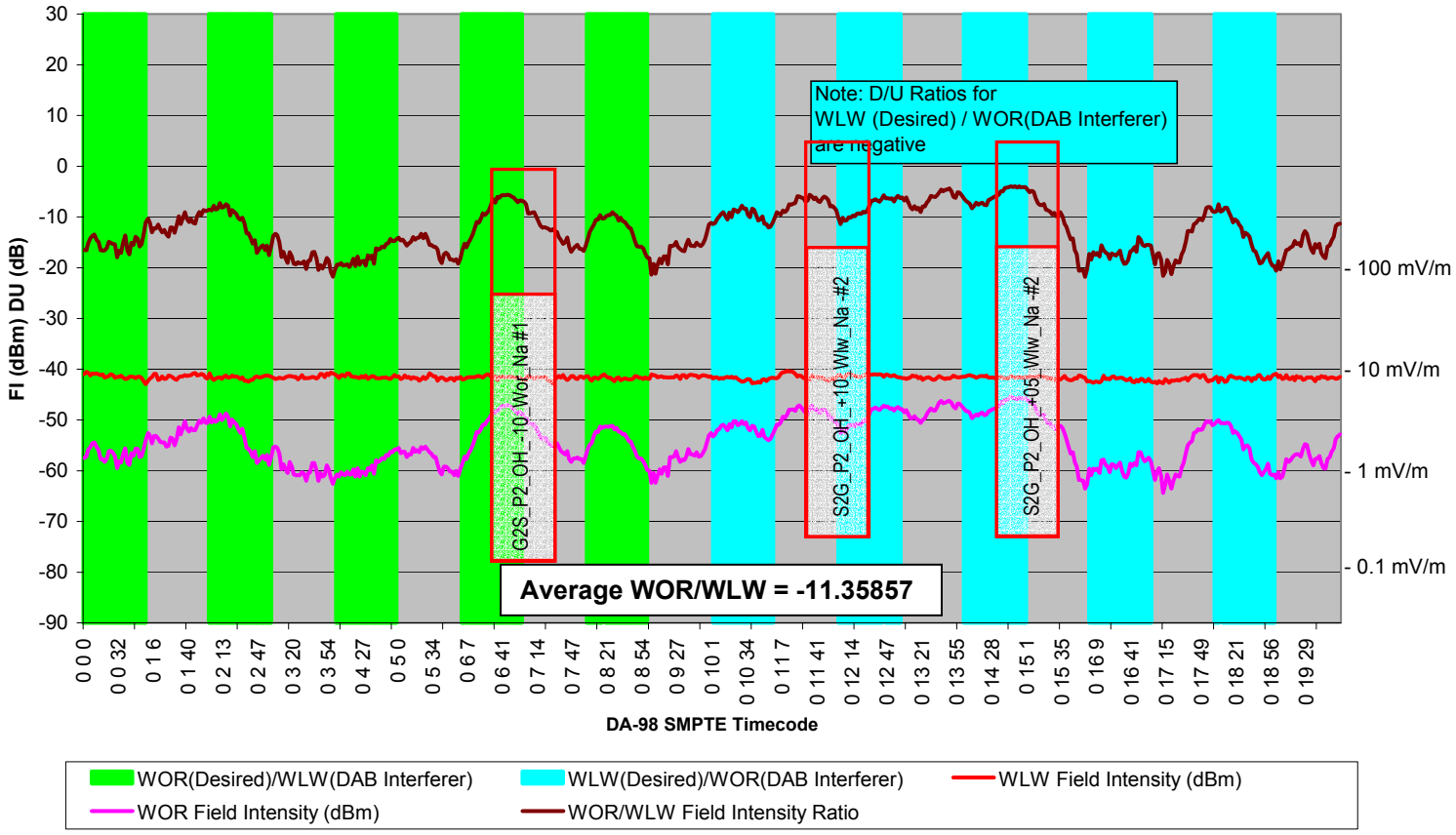
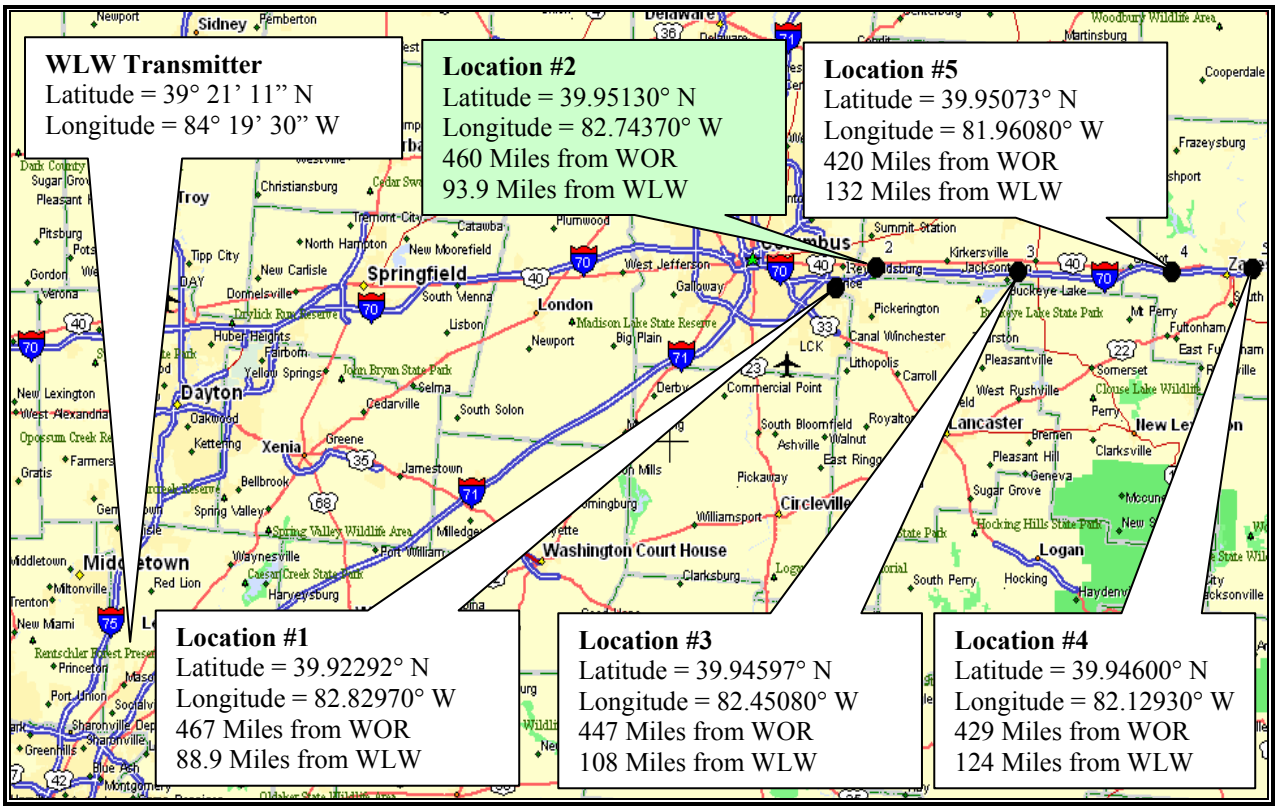


Exhibit M20 – Phase II - WOR / WLW Night Compatibility Map & Chart – Ohio (On Axis / Loc. #2)



WLW/WOR Compatibility - Cincinnati - 12/3/02 - 12:40 AM to 1:00 AM

Field Intensity Plot

Location #2 - 39.95130 N Lat / 82.74370 W Lon

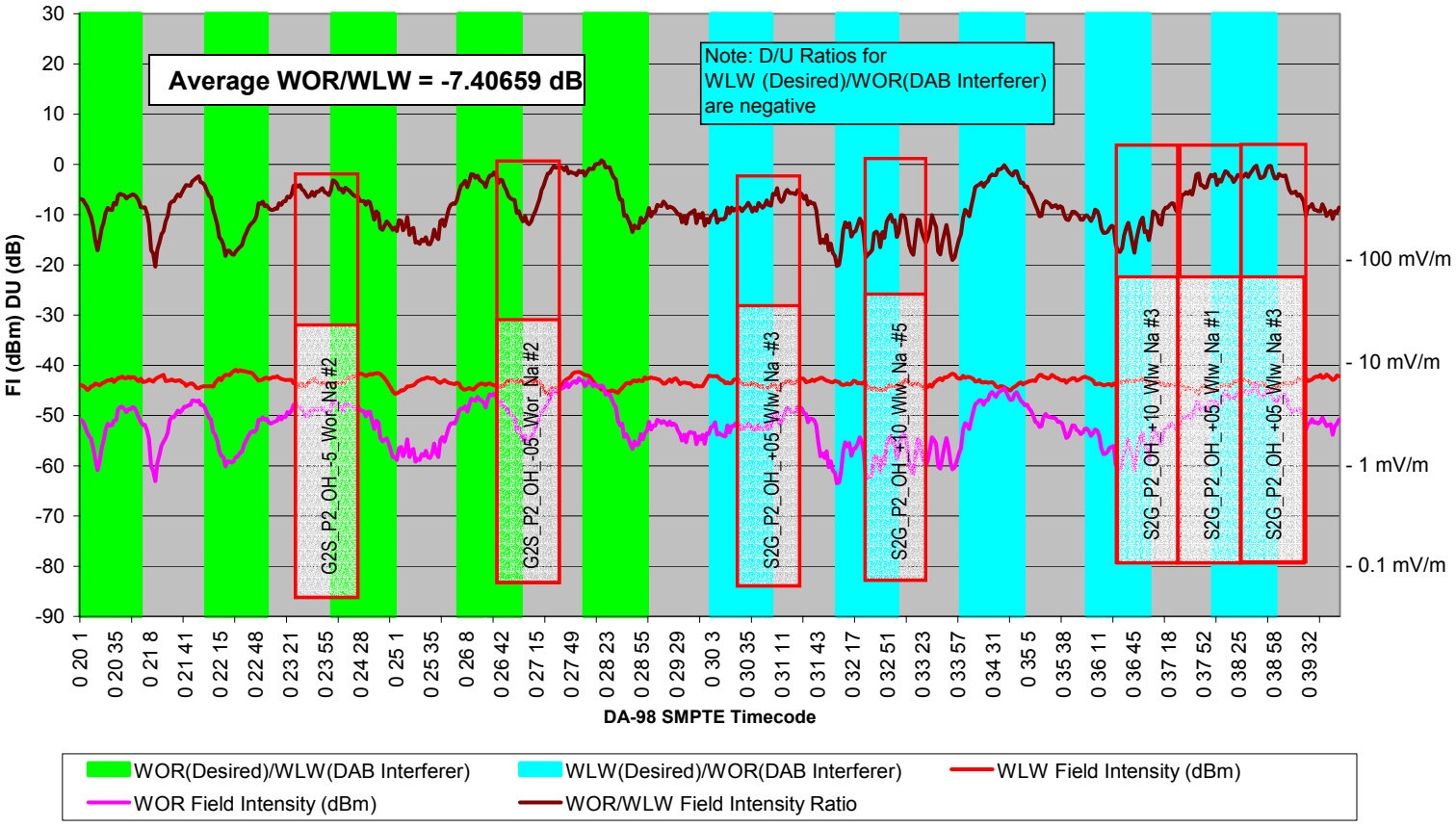
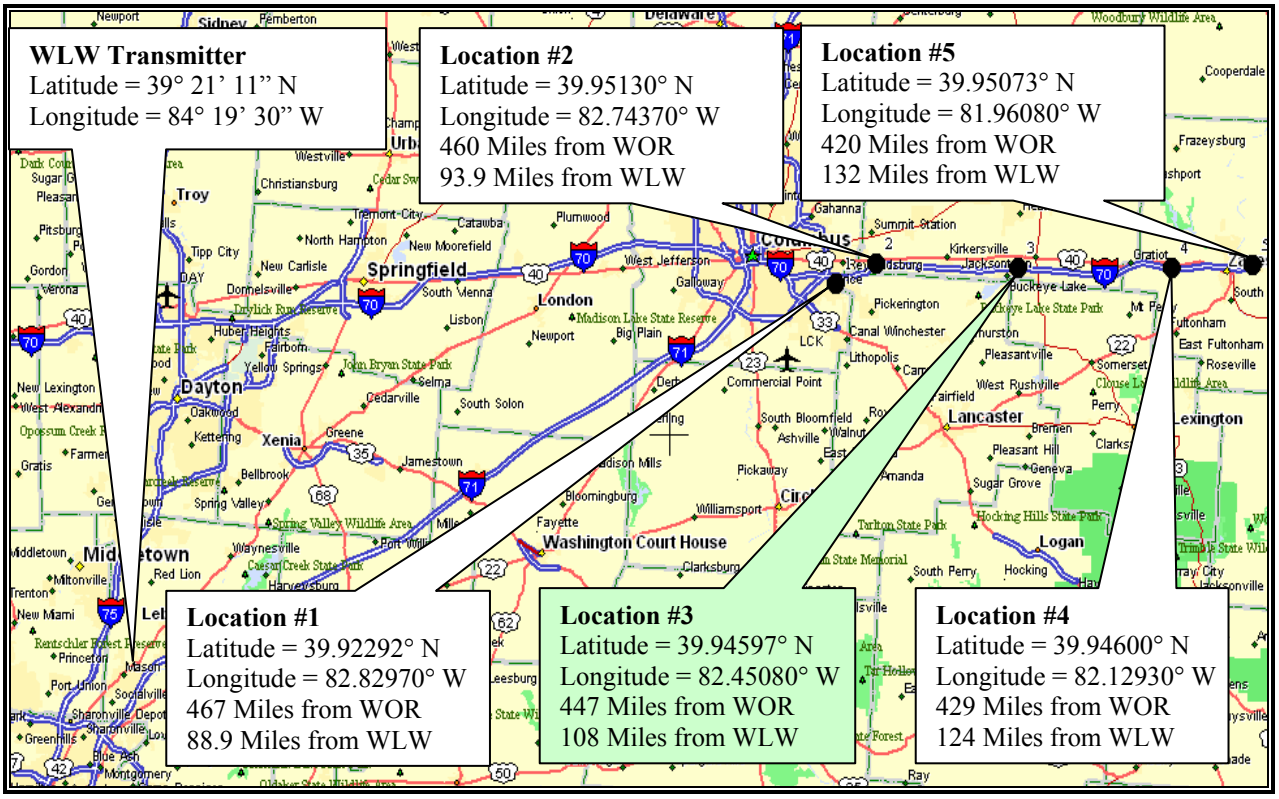


Exhibit M21 – Phase II - WOR / WLW Night Compatibility Map & Chart – Ohio (On Axis / Loc. #3)



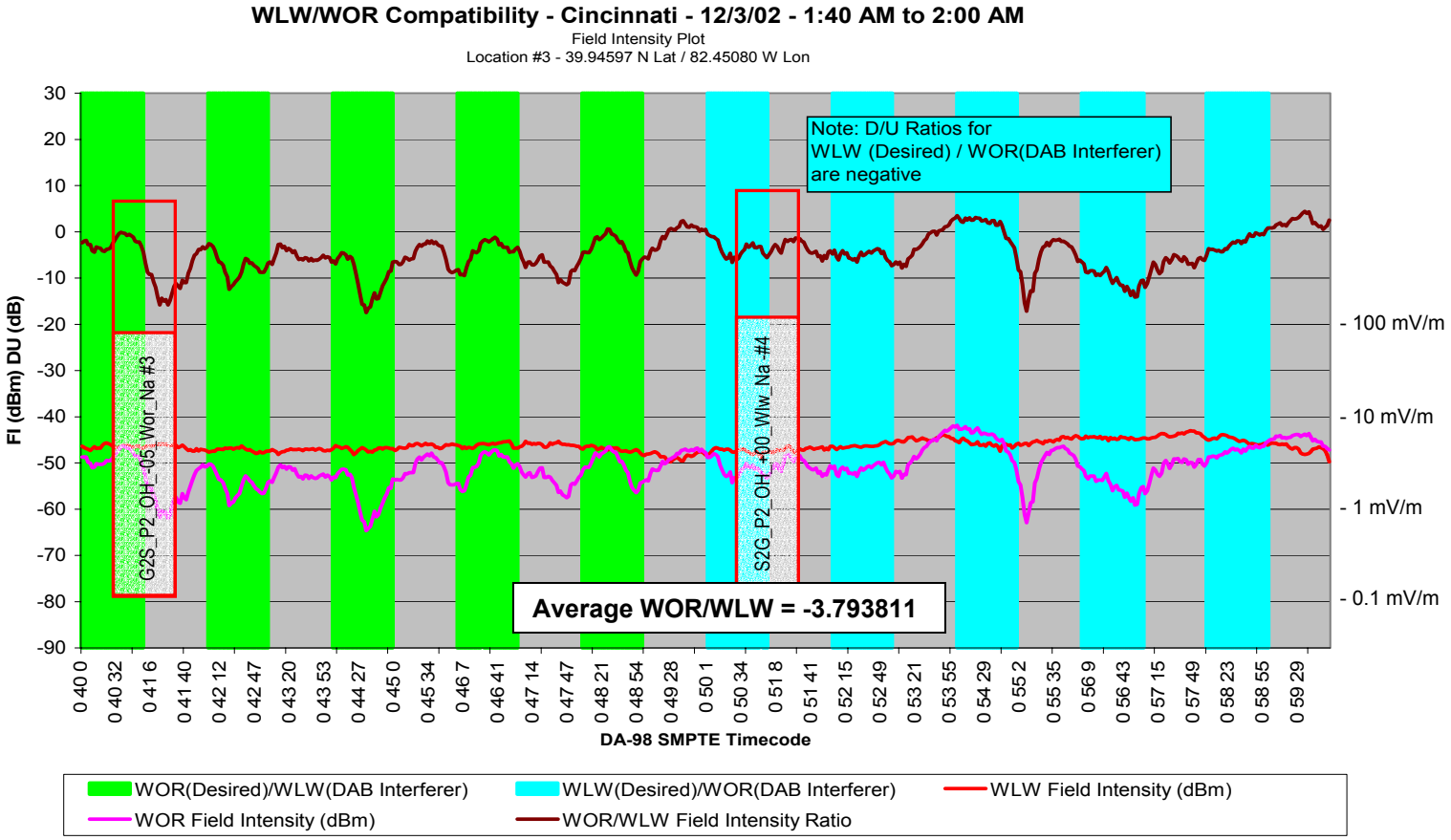
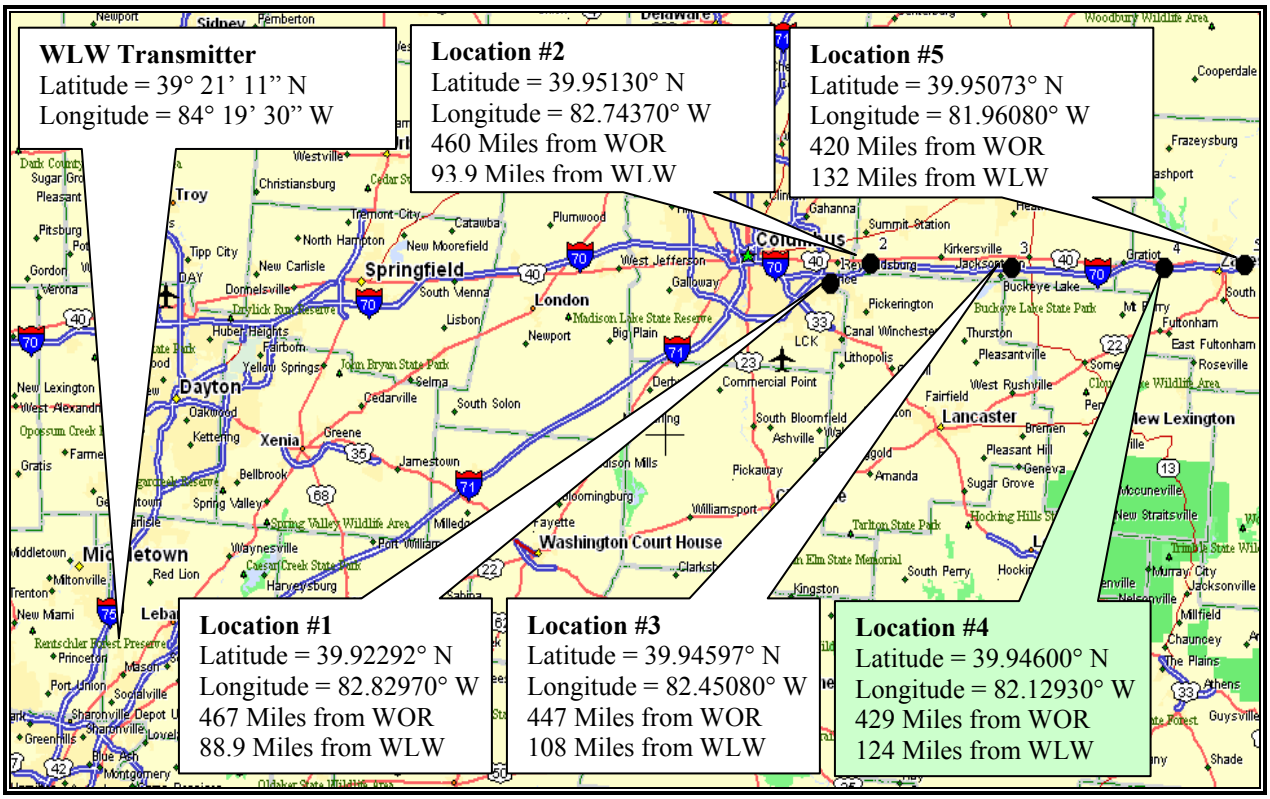


Exhibit M22 – Phase II - WOR / WLW Night Compatibility Map & Chart – Ohio (On Axis / Loc. #4)



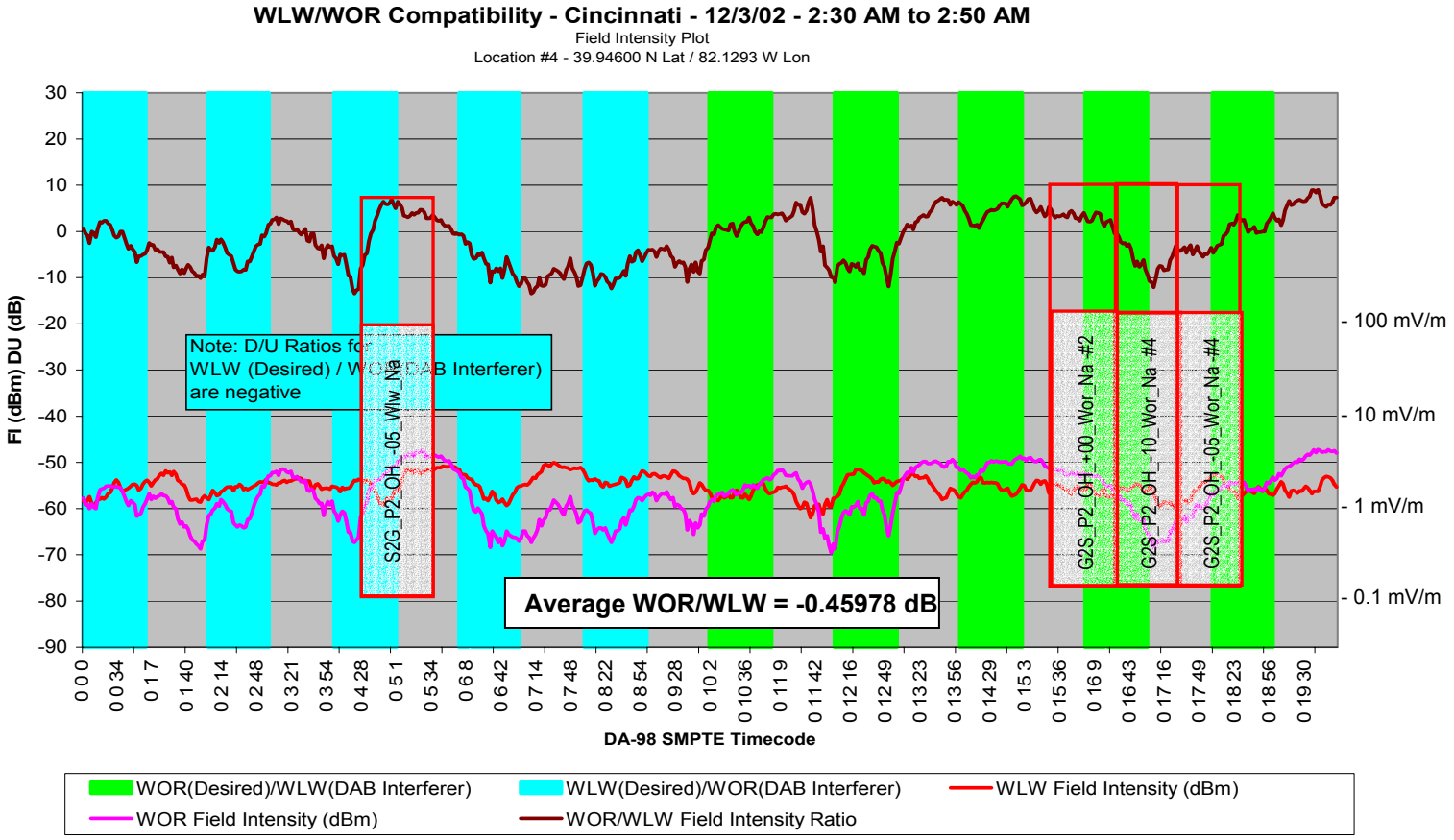
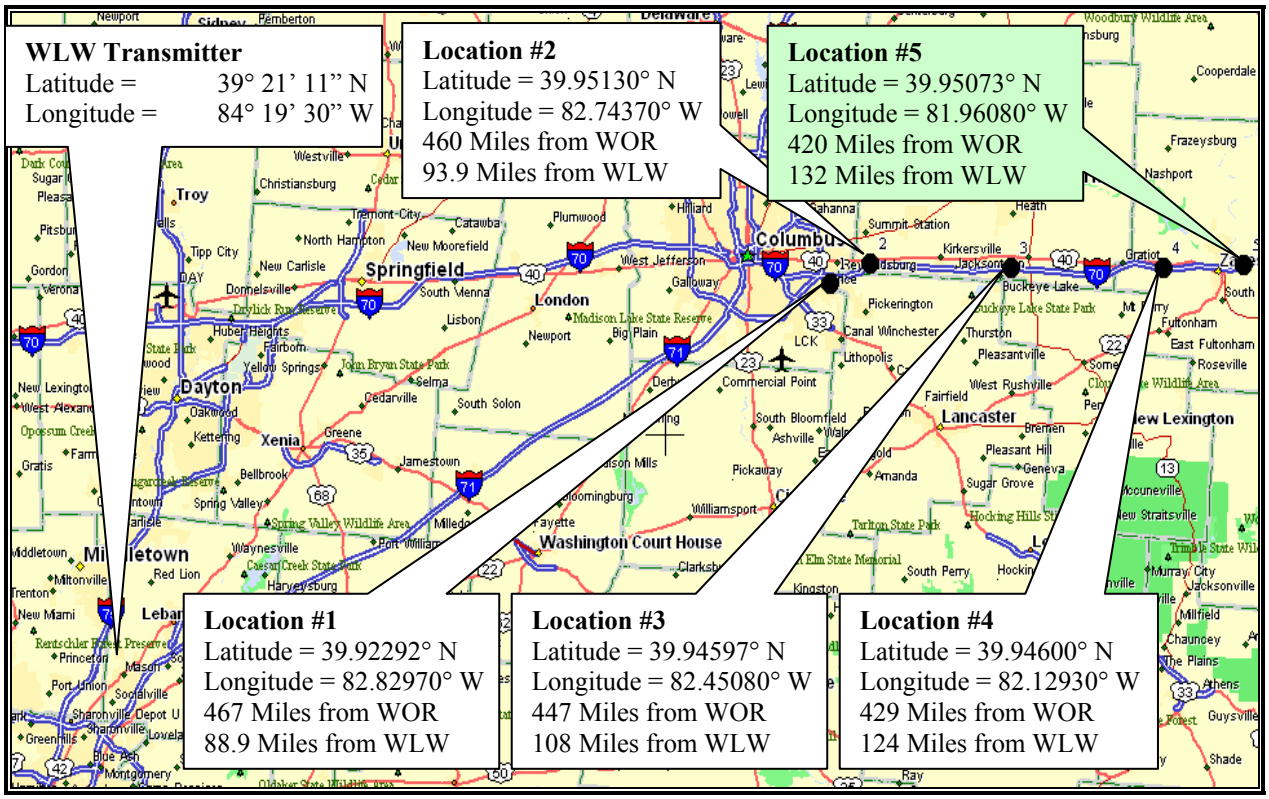


Exhibit M23 – Phase II - WOR / WLW Night Compatibility Map & Chart – Ohio (On Axis / Loc. #5)



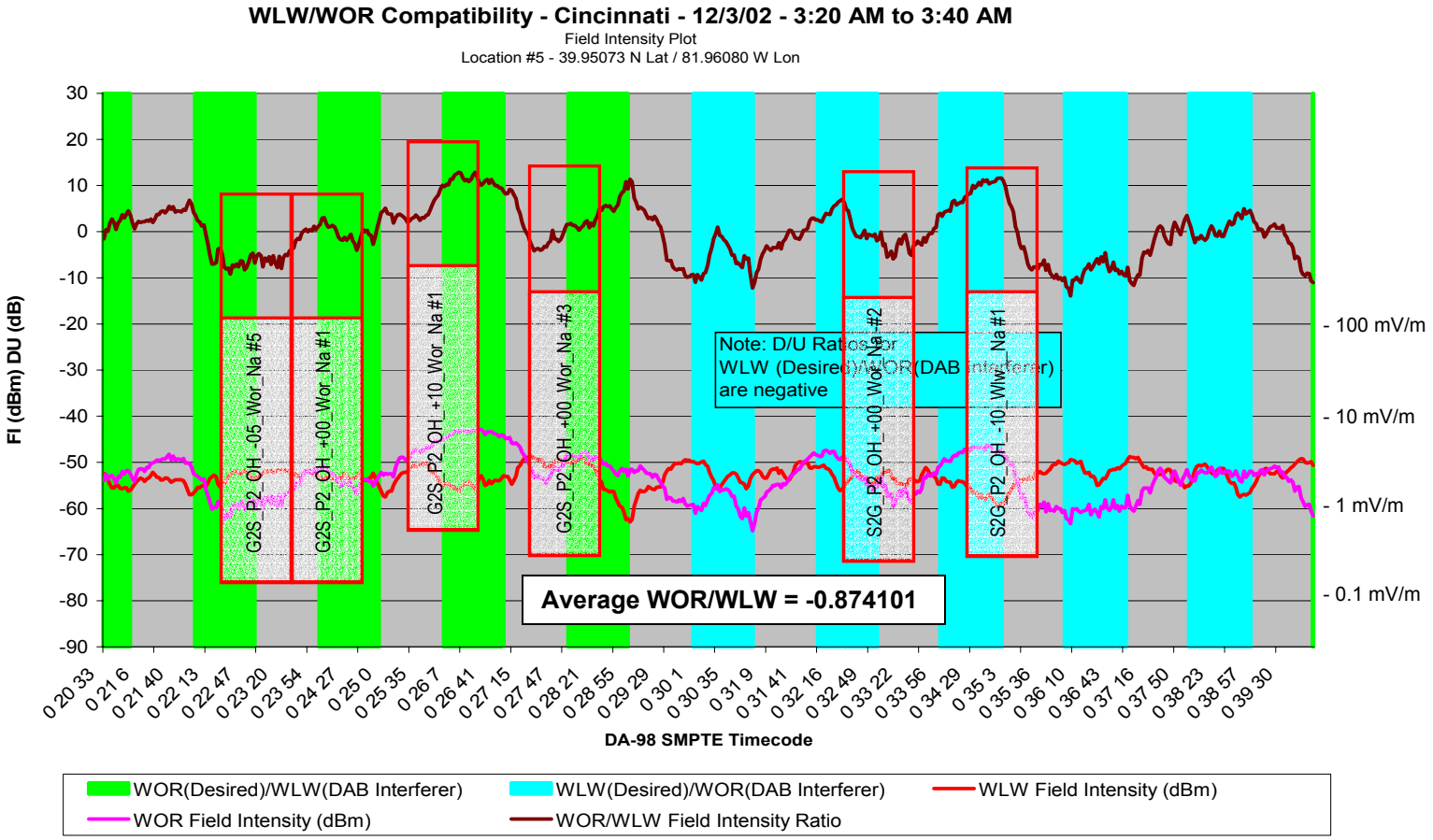
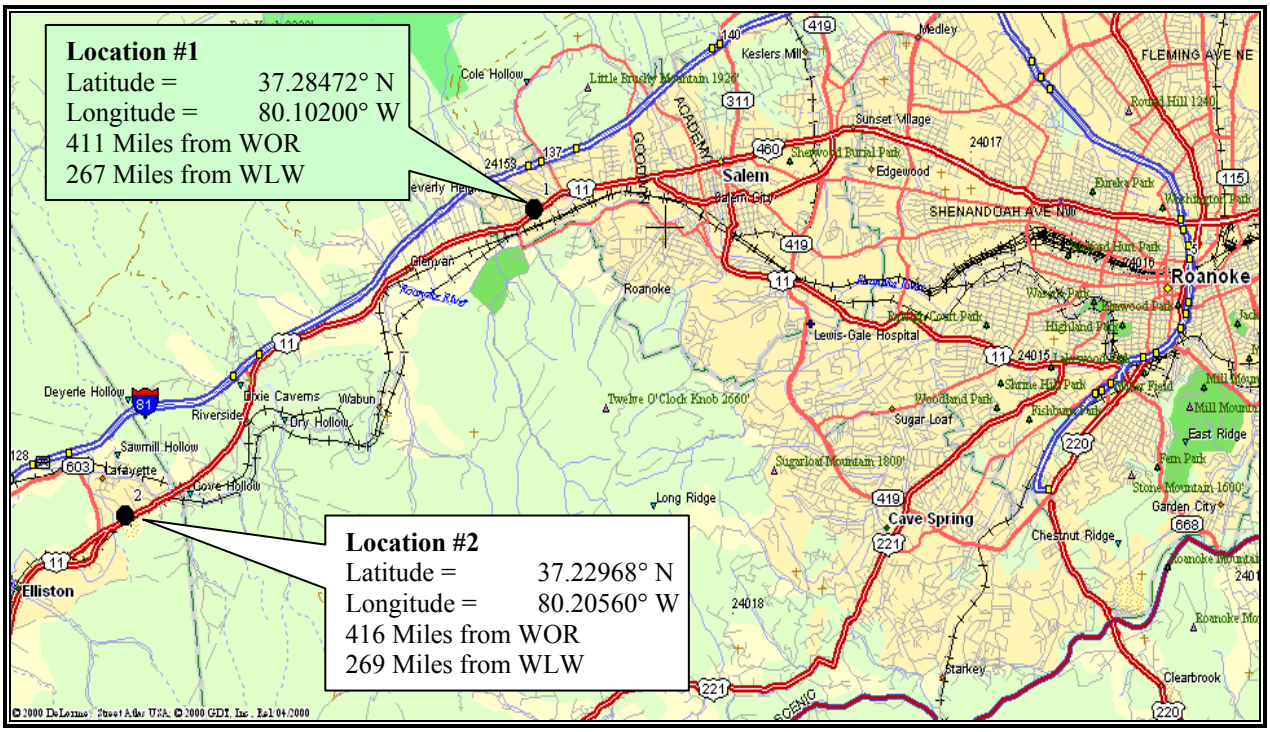


Exhibit M24 – Phase II - WOR / WLW Night Compatibility Map & Chart – Virginia (Off Axis / Loc. #1)



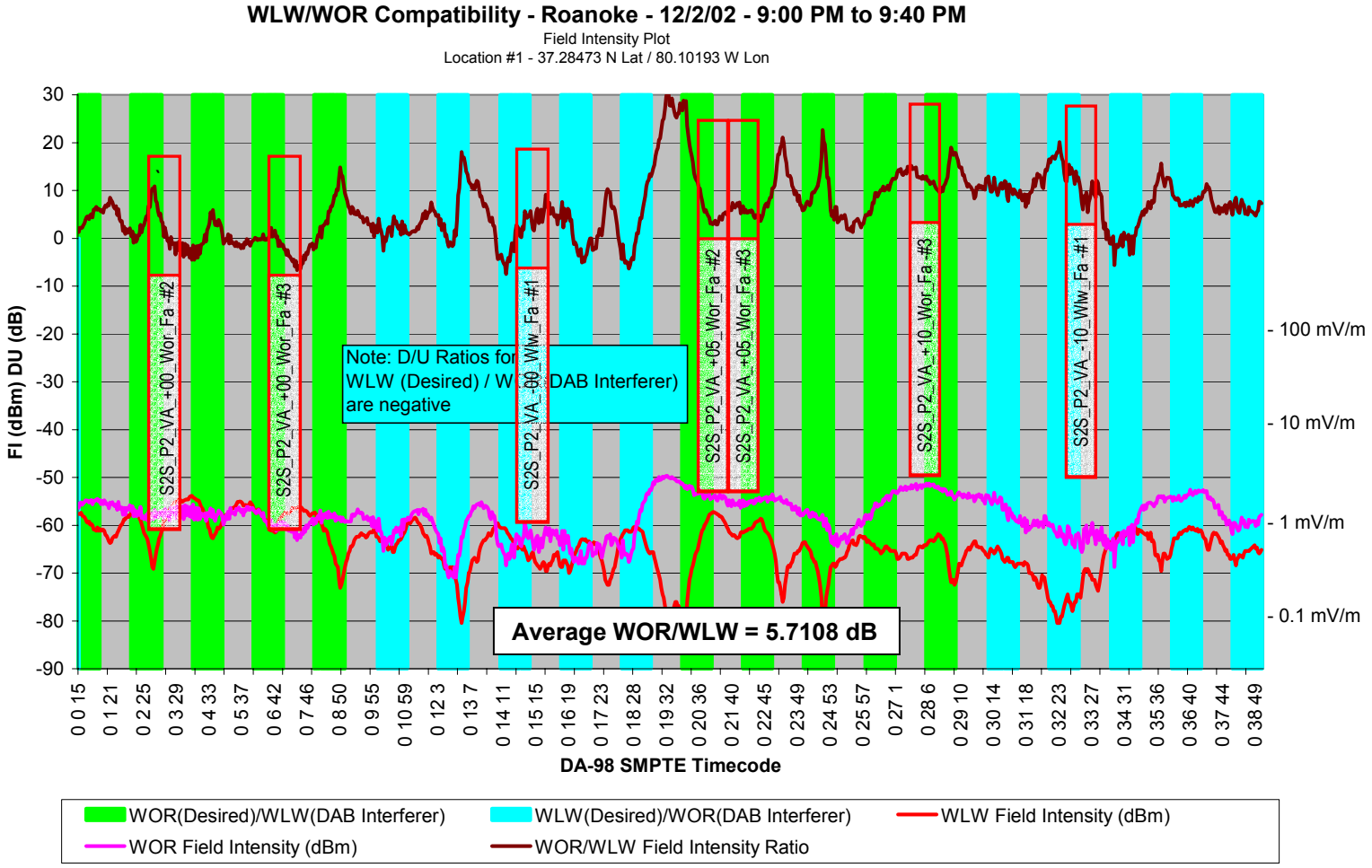
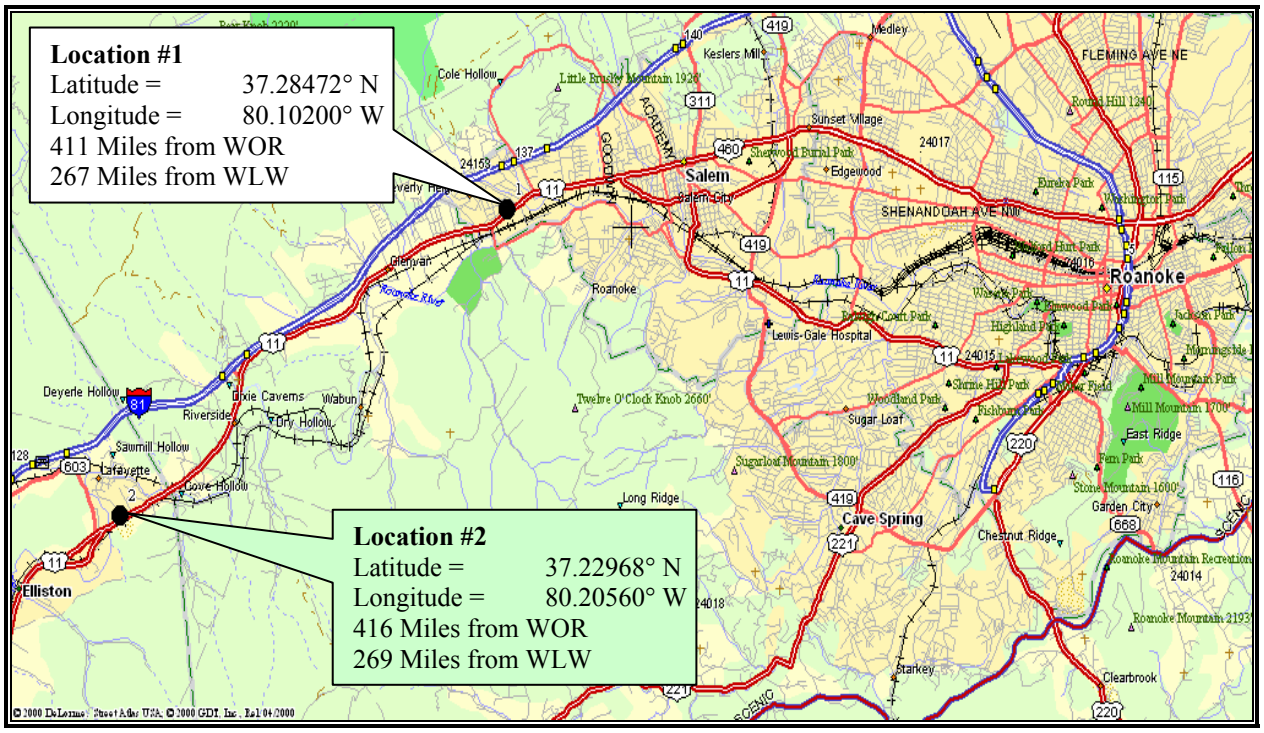
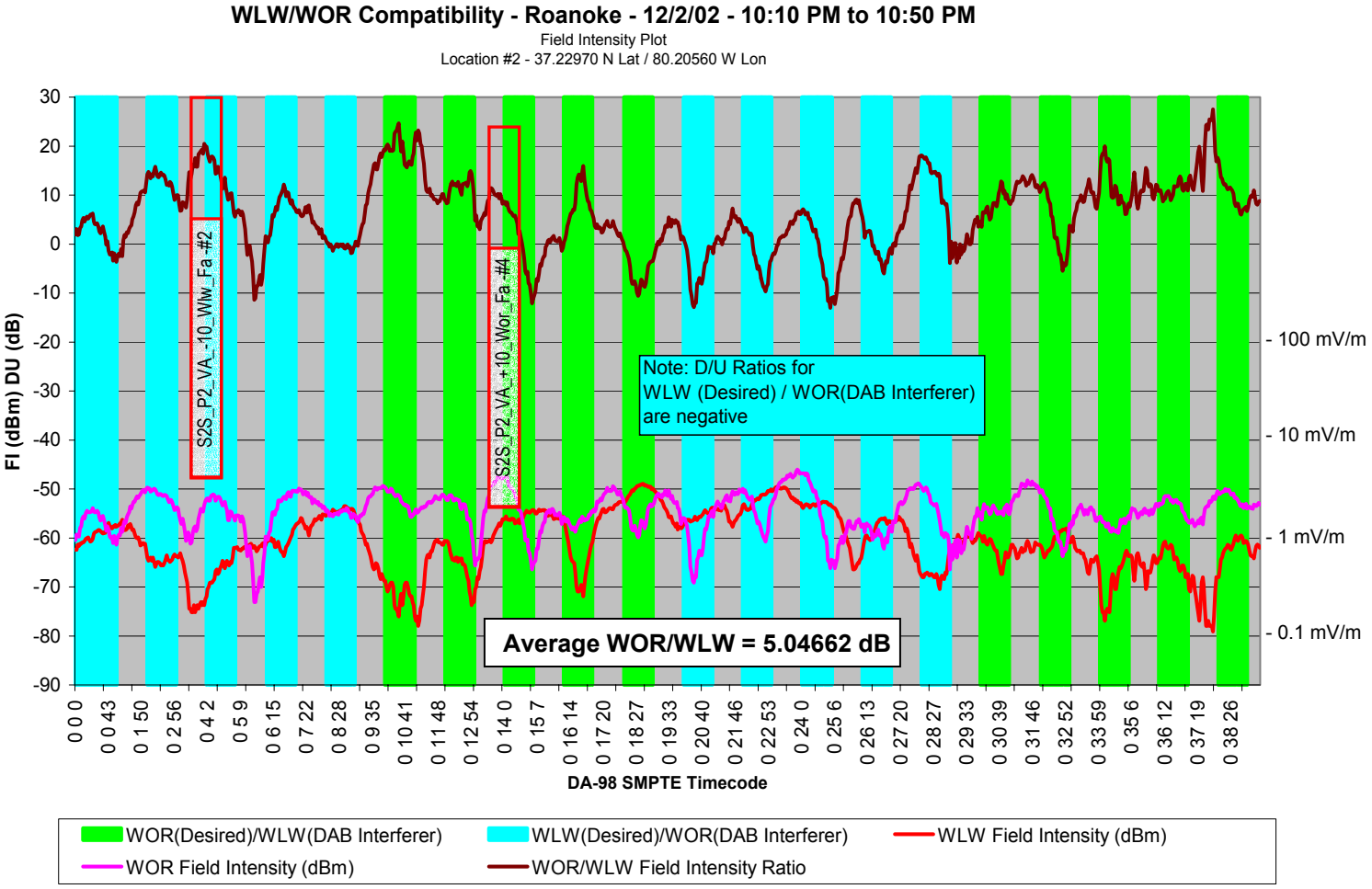


Exhibit M25 – Phase II - WOR / WLW Night Compatibility Map & Chart – Virginia (Off Axis / Loc. #2)





Subjective Methodology and Results of AM Nighttime Transmission Testing

July 1, 2003

Prepared for iBiquity Digital Corporation by:

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Subjective Test Methodology

This subjective test methodology evaluated the impact of IBOC on AM analog nighttime transmission. In order to realistically assess consumer reaction to nighttime transmissions (with and without IBOC), a new Absolute Category Rating (ACR) 5-point scale was developed. Designing this new scale was necessary for two reasons. First, AM nighttime listeners do not fit the profile of typical radio consumers in that they are highly motivated to listen to the program that they have selected, and will endure worse transmission conditions than casual radio consumers. Because they are highly motivated to listen, the importance of overall quality (i.e. attractiveness of sound) is less likely to impact their behavior than other factors, such as intelligibility, annoying interference, sustained loss of signal, etc. Second, the quality of typical AM nighttime transmission would likely be considered either "fair" or worse by the average consumer and therefore the standard quality ratings (i.e. Excellent, Good, Fair, Poor, and Bad) would be overly compressed, providing little insight into the differences between IBOC-off and IBOC-on transmissions. For these reasons, the adapted scale asked participants to rate samples on the basis of whether they would continue to listen to the program or switch to another, depending on how motivated they were when listening to the transmission. Results from this question provided relational information, consistent with typical ITU recommended MOS scales, but also provided **threshold** information which exposed the point at which consumers would no longer listen to the broadcast.

1.1 Adapted 5-point scale

Table 1.1 describes the scale that participants used to judge all transmissions. Notice that threshold information is obtained at two places, "3.0" (i.e., the participant would continue to listen *only when they were motivated*) and "1.0" (the participant would always turn off the broadcast).

Table 1.1: Adapted 5-point scale

Rating	Description of Rating (as provided to test subjects)	Numeric Translation for Analysis
Unimpaired (Keep On)	This sample sounded good. I would listen to this audio under all circumstances.	5.0
Somewhat Impaired (Keep On)	This sample sounded good, but I heard some background impairments and noise. Still, I would listen to this audio a majority of the time.	4.0
Noticeably Impaired (Keep on if Motivated)	This sample was intelligible, but the background chatter and noise was noticeable and significant. I would continue to listen to this audio a majority of the time only if I was extremely interested in the program.	3.0
Severely impaired (Keep on only sometimes if extremely motivated)	This sample was mostly intelligible but the background chatter and noise was very annoying. I would continue to listen some of the time only if I was extremely interested in the program.	2.0
Failed (Turn off)	This sample is unintelligible. I would not listen to this audio under any circumstance.	1.0

1.2 Audio samples

Due to the nature of nighttime transmission, samples at the same or similar D/U signal levels varied widely in both overall quality and size of impairment. This variation made it difficult to characterize an entire listening experience based only on one sample-pair[1]. Therefore, where possible, the test included several sample-pairs at the same D/U level. The number of sample-pairs chosen to be included at each D/U levels was based on the total number of samples collected during field recordings divided by the number of samples recorded at that D/U level. Thus, each D/U level listed in "Table 2.1 - Experimental Conditions", contains at least 1 on-off sample pair, and potentially contains up to 4 sample-pairs, depending on how many recordings were made in the field at that D/U level, and how many samples met the sample selection criteria (see section 1.2.2 for details on selection of samples).

In total, 262[2] audio samples were presented to participants for rating, 248 field recordings (from 124 sample-pairs), and 14 laboratory generated samples. Field samples included Sky-to Ground, Ground-to-Sky and Sky-to-Sky transmissions between -10 and +10 D/U. Samples were either considered "on-axis" if there were on or near the direct line between the two stations (WLW and WOR) or "off-axis" if they were not on a direct line between the two stations. High quality, unimpaired laboratory-generated samples were included to provide participants the opportunity to hear transmissions they would rate highly (i.e., 4 or 5). They were also intended to help alleviate the monotony resulting from presenting the same field samples to participants multiple times. All participants heard both IBOC-Off and IBOC-On samples for all conditions.

Transmissions recorded over three receivers were included in this test. These include the Delphi, Sony, and GE Superadio receivers. Table 1.2 lists the receiver, model number and type.

Table 1.2: Description of Receivers

Manufacturer	Model Number	Type
Delphi	09394139	Auto
Sony	CFD-S22	Boom-Box
GE	7-2887A	Portable

1.2.1 Receiver Selection Criteria

The Delphi was chosen since it is widely available, has excellent front-end performance and has narrowband filtering. The Sony was chosen to represent the semi-portable "boombox" class of receivers. It is battery-powered and is often used outdoors. Both the Delphi and Sony receivers were included in prior AM and FM interference tests. The GE Superadio receiver was selected because it represents the higher end of the portable receiver market. It also can be powered by

[1] A sample-pair consists of two samples taken from a one-minute recording segment, one being IBOC-on, the other being IBOC-off.

[2] Not all 262 recordings were used in data analysis. Some sample-pairs were omitted because in post-test analysis it was found that the D/U averages for "on" and "off" samples in specific sample-pairs did not match closely enough for comparisons to be made. See Section 4 for a complete discussion on this point.

batteries and taken outdoors. It has a large internal antenna that can pick up distant signals. Thus, all of these receivers are used outdoors by consumers, away from the man-made noise typically generated in office buildings and homes.

Two other receivers were used during the field testing: the Technics home hi-fi receiver and the Pioneer auto receiver. Neither was used for this audio test[3].

1.2.2 Processing Audio Samples (Recording, Selecting, Editing and Leveling)

All field samples were collected under NRSC auspices during August and December, 2002. As with the iBiquity daytime AM field test program, audio was recorded at 30-second intervals, alternating between IBOC-Off and IBOC-On. For each test condition in this study, 2 samples were chosen from "on-off" or "off-on" 60-second segments. All individual sound samples were edited, labeled and leveled for presentation to participants. Resulting samples were 6 to 10 seconds long. Only sample-pairs (IBOC-off, and IBOC-on) that were matched in genre, density and programmatic material were included in this test plan.

Specifically, samples included in this plan were based on the following criteria:

- the IBOC-off and IBOC-on samples were matched for genre (i.e., speech to speech; voiceover to voiceover; commercial to commercial)
- the programmatic content was appropriate (e.g., programming will be included only if it is considered neutral and non-offensive)
- talkers' intelligibility was consistent and clear (heavily accented speech, garbled speech and stuttering was minimized)
- the speech density was equivalent between IBOC-off and IBOC-on samples (i.e., no long pauses in speech for one sample but not the other)
- within a given condition, if there were different announcers for the IBOC-off and IBOC-on samples, the announcers' voices were matched vis-à-vis pitch and rate of speech.

[3] The Technics relies on AC current and is rarely used outdoors. Its performance is severally impacted by background noise generated from TVs, computers, fluorescent lights etc, which are typically found in home and office environments. The signal reaching the antenna is degraded because many homes are sided with aluminum. Therefore, it is not a candidate for nighttime listening in most parts of the country. The Pioneer auto receiver has slightly wider front-end filtering than the Delphi, therefore it is not as good at receiving stations at night as the Delphi. It was eliminated as a test receiver since the differences between IBOC-on and IBOC-off would not be as obvious. Therefore, the Delphi represents a more conservative choice than the Pioneer for this test program.

1.3 Experimental Design

Table 1.3 shows the experimental design of the study. Notice that there varying numbers of sound samples at different D/U levels. Because it was difficult to find multiple sample-pairs at consistent D/U levels that also matched all of the qualifications described in Section 1.2.2, on-off sample-pairs were included at a D/U level if the midpoint between the D/U level for the "on" and "off" samples was within ±2.5 dB of that level[4]. For example, if the average of an "off" sample in a sample-pair was 1.76dB and the average of its corresponding "on" sample was -3.04dB, their span would be 1.76 + 3.04 or 4.8dB, and their midpoint would be 1.76dB - 2.4dB = -.64dB. Since -.64dB is within ±2.5 dB of 0, the pair would be placed in the +0 D/U category. The averages for all samples by sample-pair are included in **Appendices C, D and E.** Although 262 samples were played for participants, only 218 are included in the Experimental Design (see Section 4 for a description of post-hoc D/U analysis of sound samples for a full explanation).

Table 1.3: Experimental Conditions

Condition	D/U Range	Delphi		SONY		GE		Total
		Off	On	Off	On	Off	On	
OFF AXIS								
Sky-to-sky	-10	2	2	2	2	2	2	12
	-5	0	0	0	0	0	0	0
	0	2	2	2	2	2	2	12
	+5	2	2	2	2	2	2	12
	+10	2	2	2	2	2	2	12
Sky-to-ground	-5	1	1	1	1	1	1	6
	0	1	1	1	1	1	1	6
	+5	1	1	1	1	1	1	6
	+10	1	1	1	1	1	1	6
Ground-to-Sky	-5	1	1	1	1	1	1	6
	+0	1	1	1	1	1	1	6
ON AXIS								
Ground-to-Sky	-10	2	2	2	2	2	2	12
	-5	4	4	4	4	4	4	24
	+0	3	3	3	3	3	3	18
	+5	0	0	0	0	0	0	0
	+10	1	1	1	1	1	1	6
Sky-to-Ground	-5	1	1	1	1	1	1	6
	+0	2	2	2	2	2	2	12
	+5	4	4	4	4	4	4	24
	+10	3	3	3	3	3	3	18
Laboratory Samples								14
TOTAL SAMPLES								**218**

[4] Spectral Data was collected approximately every second, and each plot was a rolling average of the previous 10 samples. A figure representing the averaged D/U for each audio test file was obtained by converting all D/U dB measurements taken during the sample to voltage, averaging them and converting that figure back to dB.

1.4 Participants

46 subjects (24 males and 22 females) participated, distributed between 16 and 65 years of age. Forty-three participants were from the general public, 3 participants were representatives from the NAB Ad-Hoc Technical Group. One participant was excluded because she did not finish the test due to computer problems. Two participants were excluded because post-hoc statistical analysis indicated that their pattern of ratings were significantly different from the patterns of ratings for the whole group. In order to demographically characterize the test sample, participants were asked to fill out a questionnaire prior to taking the test, which included their age, gender, and whether they listen to AM radio on a regular basis (see **Appendix A** for a sample questionnaire). Listeners who reported that they listened to AM daily were classified as "Heavy AM listeners"; those who reported that they listened to AM within the last week or month were classified as "Light AM listeners" and those who reported that they listened within the last year or not at all were classified as "No AM listeners". See Tables 1.4-1 and 1.4-2 for the demographic breakdown. Participants who claimed hearing loss due to temporary or chronic problems were excluded from participating.

Table 1.4-1: Participants age and gender

Age	Male	Female
18-29	5	5
30-39	5	6
40-49	5	5
50+	7	5

Table 1.4-2: Number of participants listening to AM

Age	Heavy AM listening		Light AM listening		No AM Listening	
	Male	Female	Male	Female	Male	Female
18-29	1	2	0	3	2	2
30-39	3	2	1	2	1	2
40-49	4	1	0	1	1	3
50+	4	1	2	1	1	3

1.5 Procedure

Participants listened to each sample once. They were encouraged to listen to the sample again if they needed more time to rate it. The order of sample presentation was randomized for each participant. Participants listened to 67 or 66 trials in a listening session, followed by a 5-minute break. The total time for an experiment, including training, testing and breaks was approximately 100 minutes.

Sound samples were presented to participants over loudspeakers in acoustically appropriate test environments (see Section 2.0 for details).

1.6 Training Period and Screening

Training included an orientation to the software used to collect data and a description of the scenarios on which participants based their answers. Experimenters described each category in the 5-point scale at length, ensuring the participants understood the difference between listening in a "casual" way and listening with "motivation" (see **Appendix B** for details). Participants were directed to rate samples based on the quality of the transmission and not the programmatic material. Participants were also told that these were AM recordings taken from real radio programs from around the country. In order to minimize the risk of biasing participants, training samples were not played prior to testing, nor was information given about impairments that they might hear. Screening was performed after data collection took place. A post-hoc statistical test was conducted for each participant to ensure that individual participants' vector of rating correlated positively to the vector of ratings found in the group. If a person's pattern of answers were significantly different from the group's, their data was not included in analyses.

2 Audio Playback Setup and Testing Environment

Participants were tested individually using iBiquity software. All audio samples were presented to listeners over loudspeakers. A set of medium quality auto loudspeakers, the Optimus (Tandy – Cat. #12-1773) were used to deliver the audio samples to participants. All manufacturer's suggestions for requirements for optimal performance were followed, including amplification.

Since loudspeakers were used for testing, it was important for the test environment to be quiet, free from aural and visual distractions. Listening rooms were configured for testing with low ambient/background noise and minimal ingress of external sounds. Ambient/background noise did not exceed 43dB(A)[5]. Each test participant was located in a pre-determined position within the room, and was instructed not to move or relocate the chair during the course of the experiment. Loudspeakers were configured in the room for optimal listening performance. Figure 2.1 shows an example of the test set-up.

Figure 2.1: Experimental room 1

[5] Measurements were taken with a TerreSonde Audio Toolbox, A-weighted in slow response mode.

3 Long-sample test

After completing the short sample test, a subset of participants was asked to rate 24 additional samples that were between 24 and 28 seconds in length. This test was designed to examine whether consumers would rate long samples differently than 6-10 second, short samples. It is believed that certain impairments cause "listener fatigue" and that over longer periods of time participants become more critical of samples due to increased exposure to these impairments. Would this be true for AM nighttime transmissions, and would the introduction of IBOC exacerbate this effect? By creating short and long samples from the same source material and presenting them to participants, it was possible to determine whether consumers would judge transmissions more critically merely due to the length of the presentation sample. Long sound samples were parsed and edited identically to short ones except that they lasted approximately four times longer. Thus, for a given condition (e.g., Sky-to-Ground +10 D/U), a long sample included the short sample and 16-18 additional, contiguous seconds taken from the original 30-second transmission segment. Five conditions were tested: Ground-to-Sky -10 and -5 D/U; Sky-to Ground +10 D/U; and Sky-to-Sky +0 and +10.

4 Post-hoc analysis of samples

As was noted in Section 1.2.2. each sample-pair was chosen from 60 continuous seconds of field transmission, resulting in two individual samples (an IBOC-off sample, taken from the first 30 seconds and an IBOC-on sample, taken from the next 30 seconds[6]) The D/U dB level for each resulting sample-pair was taken from a reading of the field intensity at the top of the minute. However, because we presented to participants only 6-10 seconds of the original 30-second recording for each sound sample, it was critical to re-check the average D/U dB level for each shortened sample. Upon re-calculating the dB level for individual samples, we found several cases in which the difference between IBOC-on and IBOC-off was too large for meaningful comparisons to be drawn. Thus, we eliminated those samples where the absolute difference in average dB between IBOC-on and IBOC-off was greater than 7dB.

5 Results

5.1 Interpreting participants results using the 5-point rating scale

When interpreting participants' ratings, it is important to keep in mind that the rating scale used for this study does not follow the same principles as does the ACR-MOS quality rating scale. The ACR-MOS rating scale asks participants to focus solely on one dimension – sound quality – while making their decision. The categories (Excellent, Good, Fair, Poor and Bad) were designed to be evenly spaced. The rating scale used in this study asks participants to focus on two dimensions simultaneously: (a) the extent to which impairments are heard (5 = No impairments heard; 4 = Impairments heard, but not bothersome; 3 = Significant impairments heard; 2 = Significant, disruptive impairments; 1 = complete failure), and (b) whether they would continue to listen to the sound sample depending on their perceived motivation (a rating of 4 or 5 signifies that the participant would listen all the time; 3 – participants would listen only if

[6] In point of fact, some 60-second recordings were actually 30 seconds IBOC-on followed by 30 seconds IBOC-off; others were 30-sec. IBOC-off followed by 30 seconds IBOC-on.

motivated; 2 – participants would listen rarely even if motivated; 1 – participants would never listen). The categories were not chosen to be evenly spaced. They are, instead, distinct decision points. Participants must chose between them considering their "state of mind" as well as the level of impairment heard in the sample. Using a numeric translation of this categorical scale, an individual score of 4.0 (Somewhat impaired – keep on) or 5.0 (Unimpaired – keep on) indicates that a participant would listen to the transmission all of the time, regardless of impairments heard or their level of motivation. 3.0 is a particularly interesting demarcation, because at this score participants claim they would listen a majority of the time *if they were motivated* (which best characterizes nighttime listeners), yet they still claim they hear noticeable impairments. Conversely, at 2.0 participants claim that the sample is severely impaired and that they would listen only very infrequently, when they were extremely motivated. Therefore, somewhere between 3.0 and 2.0 there is critical point at which a *majority of listeners* would no longer choose to listen, even when motivated to do so. In order to determine this point, participants' scores were re-coded using the following conversion: if a participant rated a sample as a 1 (Failure) or a 2 (Would listen only under extraordinary circumstances) , it was re-coded to "0" (meaning that they would almost always turn the broadcast off); if a sample had received a 3, 4 or 5, it was re-coded as a "1" (meaning that they would continue to listen to the broadcast). See Table 5.1 for conversions. The resulting "on-off score" for each sound sample was simply the proportion of participants who would continue to listen to it. The original mean scores were compared to these "on-off scores" to determine the point at which the majority of participants would continue to listen.

Using this translation, at the 3.0 level, approximately 68% of all listeners would keep listening to the sample. Notice that because these are aggregated scores, 100% agreement that the transmission is acceptable (when participants are motivated) is not realized at 3.0. In fact, 100% agreement occurs only at approximately 3.8. At the 2.6 level, approximately 50% of listeners would still keep the radio on. Below 2.6, a majority of listeners claim that they would turn the program off. Thus, 2.6 is a significant cut-off point, as it reflects when the majority of people would still be satisfied with transmission quality, if they were motivated to listen to the program.

Table 5.1: Conversion from mean opinion score to on/off rating

Original Mean Score	On/Off Conversion	Meaning
1 and 2	0	Would not listen
3, 4, and 5	1	Would listen

5.2 Preliminary Analyses

In order to determine whether participants reacted differently to samples because of their age, gender, and experimental room in which they were tested, preliminary analyses of variance (ANOVAs) were conducted. A 2 (Gender) x 2 (IBOC: on/off) ANOVA was performed on participants' ratings. Although this analysis showed a significant effect of IBOC (i.e., IBOC-off was rated significantly higher than IBOC-on) it showed no effect of gender. Thus, females and males rated samples similarly, regardless of whether IBOC was off or on. A 4 (Age) x 2 (IBOC: on/off) analysis of variance was additionally performed. This analysis showed a significant effect of age, although the differences were minor. With the exception of 18-29 year olds, the older the participants were, the more tolerant they were, rating samples significantly higher. However, in this study, 18-29 year-olds were also quite tolerant, rating samples higher than 50-

59 year olds. While interesting, this finding is not corroborated by other tests which have found that younger listeners are generally more critical than older listeners. Again, IBOC did not interact with age, suggesting that IBOC did not play a mediating role in participants' judgments. Finally, a 2 (room A; room B) by 2 (IBOC: on/off) analysis of variance was performed to see whether scores might be affected by the different environments in which people were tested. The average score of all participants combined for all samples for Room 2 was **2.8**; the average for Room 1 was **2.9**. Although these averages are statistically different, the difference is minimal. Table 5.2 shows the means for gender, age, and room placement.

Table 5.2 Participant Ratings by gender, age and room placement

	Female		**Male**	
	Room 1	**Room 2**	**Room 1**	**Room 2**
18-29	2.93	2.79	2.81	3.13
30-39	2.58	2.95	2.71	2.42
40-49	3.29	2.64	2.64	2.80
50+	3.30	2.85	2.85	2.69

5.3 Reference samples (high anchors)

Recall that 14, laboratory generated, unimpaired references were included in this test to ensure that participants heard recordings that they would rate a "5". The mean score of all rated reference samples was 4.84, indicating that participants were well "calibrated" during the testing procedure, that they could easily distinguish impaired and unimpaired samples, and that they were willing to appropriately use all 5 categories in the 5-point scale.

5.4 AM listeners vs. Non-AM listeners

Because this subjective study was designed to evaluate customer satisfaction for AM nighttime transmissions, it was important to evaluate test data in relation to participants' day-to-day listening habits, in order to determine whether listeners who listened to AM regularly would rate transmissions differently from those listeners who claimed they did not listen to AM regularly. It was hypothesized that because regular AM listeners were more familiar with the "AM sound", they would be more likely to have a realistic internal representation of it and, therefore, rate the sound samples more favorably than those listeners with no AM experience. To test this hypothesis, a 3 (Heavy AM; Light AM; No AM) x 2 (IBOC: on/off) ANOVA was conducted on rating scores. There was a significant main effect of listeners, but this difference did not interact with IBOC, indicating that the introduction of IBOC did not have a negative effect on any particular group of listeners. Listeners claiming *more* experience with AM (the Heavy AM and Light AM groups) rated samples significantly *lower* than listeners with no experience. See Table 5.4 for details. This finding was somewhat surprising. Intuitively, it seemed likely that listeners who were exposed to AM on a regular basis would have rated it higher than listeners who had not been exposed to AM. This was not the case. Nevertheless, this finding may be fortunate – because our sample population contained a large number of AM listeners, results are conservative, and will most likely accurately depict the real-world listening experience.

Table 5.4: Mean scores from "Heavy", "Light" or "No AM-listeners

AM Listener	IBOC OFF	IBOC ON
Heavy	3.20	2.94
Light	3.19	2.91
No	3.43	3.21

5.5 Short vs. Long Samples

In order to test whether participants judged short (6-10 second) samples differently than longer (24-26 second) samples, a 2 (Short vs. long) x 3 (AM Heavy, AM light and No AM listener) x 2 (IBOC-on; IBOC-off) ANOVA was conducted. This analysis not only considered whether participants would become more critical over time, but also examined whether there was any difference in the way participants perceived IBOC over time. Additionally, this analysis looked at AM vs. non-AM listeners. There was no effect of short vs. long samples, and no interactions with IBOC or AM vs. non-AM listeners. (See Table 5.5 for a comparison of mean scores.) Therefore, with minor exception[7] whether listeners heard short samples or longer samples, they rated the samples similarly. This is another surprising finding because there is a great deal of speculation that people grow more dissatisfied with impaired audio transmissions as they listen for longer periods of time. It is possible that 24-26 seconds was not a long enough time for this effect to take place. However, when participants were debriefed after this test, no one suggested that the samples were too short to judge appropriately – they claimed that the samples were either too long, or approximately the right length. In fact, there is excellent reason to believe that people actually make decisions about samples within the first 6-10 seconds. Another de-brief question asked participants to think about when they made their final decision concerning their rating. Of the 38 participants, 12 stated they made their decision in the first 3 seconds; 24 within the first 6 seconds, and 2 within the first 10 seconds. Thus, it appears that the reason long and short samples were judged so similarly is a result of people's decision making strategy – listen briefly and decide to continue to listen or to turn the radio off.

Table 5.5: Comparison of Short and Long Samples

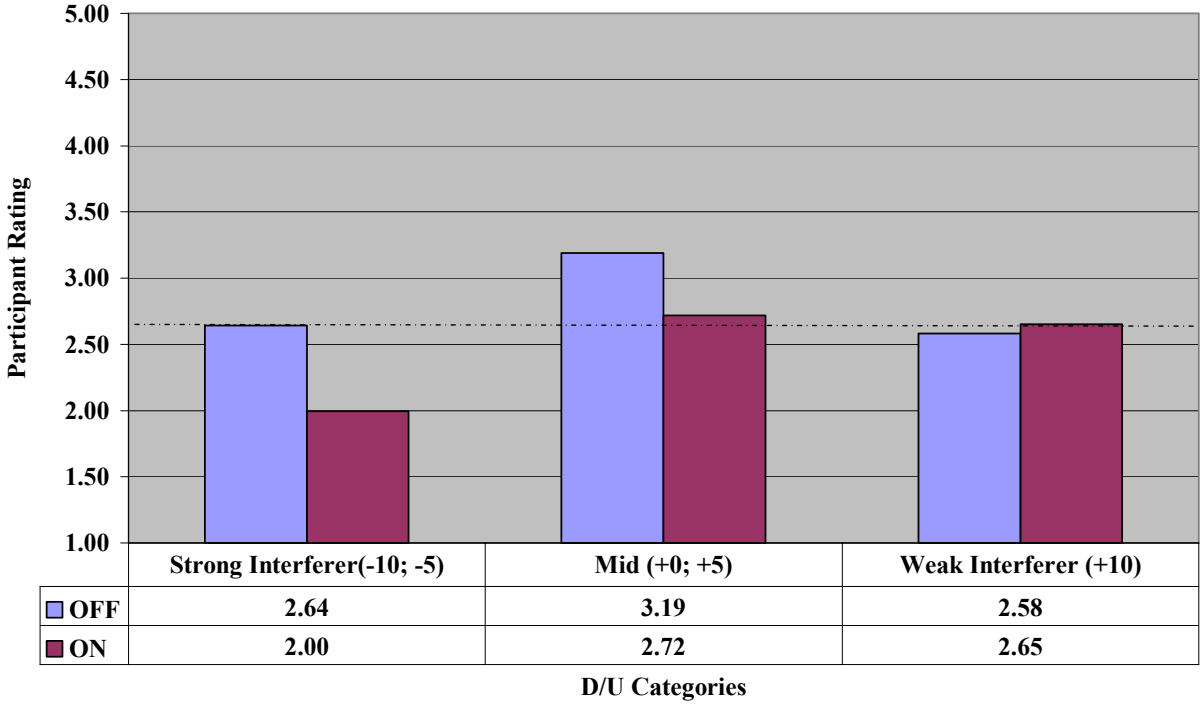
	Ground to Sky				Sky to Ground				Sky to Sky	
	Delphi Cut 4	**GE Cut 1**	**GE Cut 4**	**SONY Cut 1**	**Delphi Cut 2**	**Delphi Cut 5**	**SONY Cut 2**	**SONY Cut 5**	**Delphi Cut 3**	**GE Cut 3**
	D/U-5	**D/U -10**	**D/U -5**	**D/U-10**	**D/U 10**	**D/U 10**	**D/U 10**	**D/U 10**	**D/U 10**	**D/U 10**
IBOC OFF										
LONG	2.8*	2.8	2.6	1.0	4.1	4.6	3.3	3.8	4.2*	3.4*
SHORT	3.1	2.9	2.6	1.1	4.0	4.3	3.2	3.6	4.6	3.8
IBOC ON										
LONG	2.8	1.8	2.7	1.1	3.3	4.1	3.2	3.6	4.3	3.6
SHORT	2.6	1.8	2.7	1.1	3.3	4.2	3.0	3.6	4.3	3.5

[7] In 4 cases, short and long samples were rated differently (greater than .3). These occurred only in IBOC-off conditions. In 3 of these cases, participants rated longer samples lower than shorter samples, suggesting that some of the IBOC-off ratings may be slightly inflated. This anomaly suggests that people are more quickly able to judge the effects of IBOC impairments than when the signal is purely analog.

5.6 Effects of IBOC

Figures 5.6-1, 5.6-2 and 5.6-3 graphically depict the effect of IBOC on the analog transmission. Transmissions were placed into 3 groups, depending on their signal strength: (a) "strong interferer", including D/U ratios of -10 and -5dB; (b) "mid", including D/U ratios of +0 and +5dB, and (c) "weak interferer", or a D/U ratio of +10dB. The dotted line is the demarcation point: above the line, the majority of listeners would keep the program on. Below the line, the majority would turn it off. With the exception of Sky-to-Ground in strong interferer conditions (-10 and -5dB), the majority of motivated listeners would keep listening to their program after IBOC is introduced. Although ratings are generally lower for IBOC-on transmissions, they are nonetheless above or well above the 2.6 demarcation, indicating that the majority of participants would still be willing to listen to the transmission when motivated.

Figure 5.6-1: Ground-to-Sky



	Strong Interferer(-10; -5)	Mid (+0; +5)	Weak Interferer (+10)
OFF	2.64	3.19	2.58
ON	2.00	2.72	2.65

Figure 5.6-2: Sky to Ground

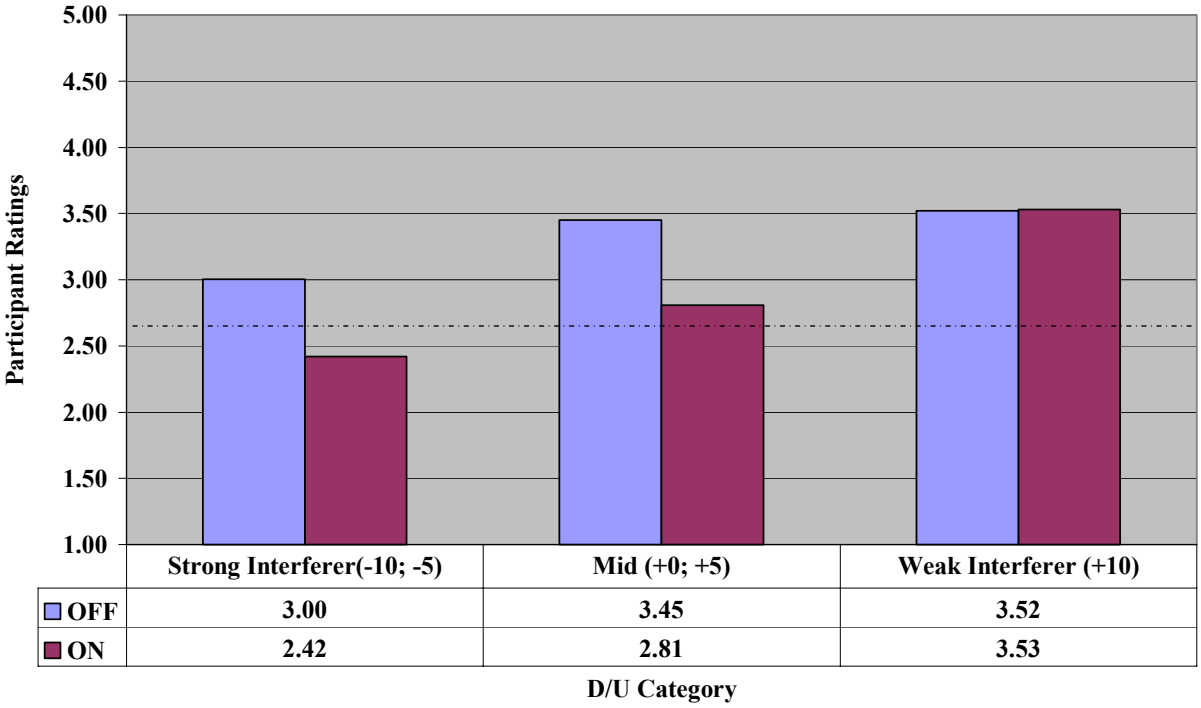
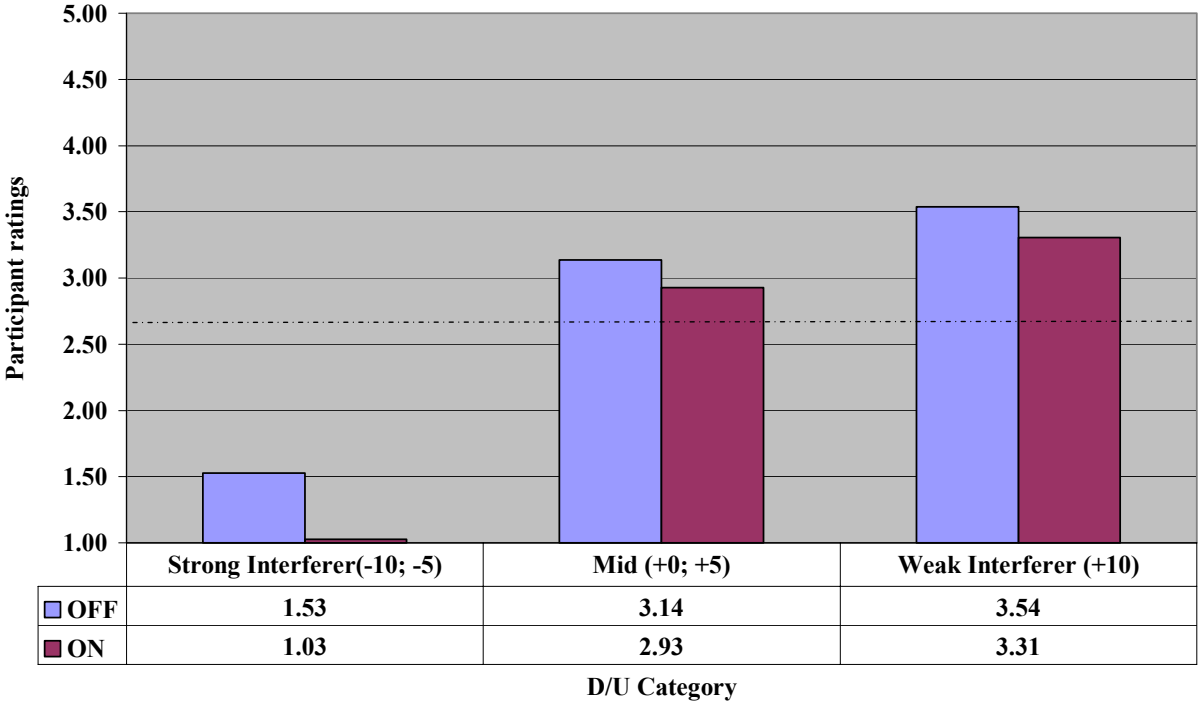


Figure 5.6-3: Sky-to-Sky



Tables 5.6-1 through 5.6-3 show rating scores and confidence intervals for samples aggregated by D/U level. Appendices C through E show individual sample rating scores, confidence intervals and the average D/U level of each 6-10 second sample.

Table 5.6-1: Mean Ratings by D/U: Ground to Sky

			Delphi		GE		SONY		TOTAL	
	D/U		OFF	ON	OFF	ON	OFF	ON	OFF	ON
OFF Axis	-5	Rating	3.7	2.8	3.5	3.1	3.6	3.1	3.6	3.0
		CI (+/-)	0.22	0.19	0.21	0.22	0.20	0.18	0.12	0.12
	0	Rating	3.6	2.7	3.5	3.0	3.6	2.9	3.6	2.9
		CI (+/-)	0.21	0.20	0.21	0.23	0.24	0.21	0.12	0.13
ON Axis	-10	Rating	2.3	1.9	2.3	1.5	1.0	1.0	1.9	1.5
		CI (+/-)	0.21	0.14	0.21	0.12	0.04	0.04	0.12	0.08
	-5	Rating	3.3	2.0	2.6	1.9	2.4	2.0	2.8	2.0
		CI (+/-)	0.14	0.12	0.15	0.13	0.18	0.12	0.10	0.07
	0	Rating	3.5	3.0	2.8	2.5	2.9	2.5	3.1	2.7
		CI (+/-)	0.15	0.11	0.19	0.13	0.17	0.16	0.10	0.08
	10	Rating	3.4	3.1	2.2	2.4	2.1	2.4	2.6	2.7
		CI (+/-)	0.21	0.25	0.22	0.22	0.20	0.19	0.16	0.14

Table 5.6-2: Mean Ratings by D/U: Sky to Ground

			Delphi		GE		SONY		TOTAL	
	D/U		OFF	ON	OFF	ON	OFF	ON	OFF	ON
OFF Axis	-5	Rating	1.9	1.7	3.1	3.4	3.0	2.9	2.7	2.7
		CI (+/-)	0.17	0.19	0.23	0.24	0.21	0.22	0.15	0.18
	0	Rating	2.7	3.4	3.6	2.6	3.4	2.6	3.2	2.9
		CI (+/-)	0.23	0.26	0.26	0.23	0.28	0.23	0.16	0.15
	5	Rating	3.8	2.9	3.6	3.3	3.7	3.5	3.7	3.2
		CI (+/-)	0.25	0.20	0.21	0.22	0.25	0.30	0.14	0.15
	10	Rating	3.4	3.9	3.3	3.6	3.1	3.5	3.3	3.7
		CI (+/-)	0.20	0.21	0.22	0.24	0.26	0.25	0.13	0.14
ON Axis	-5	Rating	3.5	2.5	3.0	1.5	3.6	2.5	3.3	2.2
		CI (+/-)	0.21	0.19	0.26	0.18	0.25	0.21	0.14	0.14
	0	Rating	3.8	2.9	2.3	1.5	2.8	2.2	2.9	2.2
		CI (+/-)	0.16	0.20	0.16	0.13	0.19	0.20	0.12	0.12
	5	Rating	4.3	3.4	3.3	2.6	3.4	3.0	3.7	3.0
		CI (+/-)	0.10	0.11	0.14	0.11	0.12	0.12	0.08	0.07
	10	Rating	4.1	3.8	3.3	3.3	3.4	3.3	3.6	3.5
		CI (+/-)	0.12	0.12	0.15	0.14	0.14	0.13	0.10	0.10

Table 5.6-3: Mean Ratings by D/U: Sky to Sky

			Delphi		GE		SONY		TOTAL	
	D/U		OFF	ON	OFF	ON	OFF	ON	OFF	ON
OFF Axis	-10	Rating	1.9	1.1	1.4	1.0	1.3	1.0	1.5	1.0
		CI (+/-)	0.19	0.09	0.12	0.00	0.11	0.05	0.09	0.03
	0	Rating	3.4	2.8	2.5	2.0	2.7	2.7	2.8	2.5
		CI (+/-)	0.20	0.16	0.23	0.16	0.19	0.18	0.13	0.11
	5	Rating	3.8	3.9	3.3	3.3	3.2	2.9	3.4	3.4
		CI (+/-)	0.18	0.16	0.18	0.16	0.19	0.18	0.11	0.11
	10	Rating	4.3	3.9	2.8	2.6	3.5	3.4	3.5	3.3
		CI (+/-)	0.13	0.18	0.26	0.24	0.16	0.19	0.13	0.13

Appendix A – Test Participant Questions

Participants will be asked a series of questions prior to the start of the test session. These questions are designed to elicit behavioral/preference information that may be incorporated in the final data analysis. The following questions will be posed to each test participant:

*Have you listened to **FM** radio within the last:*

- ❑ *Year*
- ❑ *Month*
- ❑ *Week*
- ❑ *Day*

*IF you listen to **FM** radio on a regular basis (even if only once in a while), Please answer the following questions:*

*How many hours per day do you listen to **FM** radio?*

- ❑ *Less than 30 minutes per day*
- ❑ *30 to 59 minutes per day*
- ❑ *1 to 2 hours per day*
- ❑ *More than 2 hours per day*

*Where do you spend most of your time listening to **FM** radio?*

- □ *In the car (on a car radio)*
- □ *At home (on a stereo)*
- ❑ *At home (on a boombox)*
- ❑ *At home (on a walkman)*
- ❑ *Outdoors (on a boombox)*
- ❑ *Outdoors (on a walkman)*
- ❑ *At work (on a stereo)*
- ❑ *At work (on a boom box)*
- ❑ *At work (on a walkman)*
- ❑ *In public places (i.e., gyms, malls, etc.)*
- ❑ *Other* _____

*Have you listened to **AM** radio within the last:*

- ❑ *Year*
- ❑ *Month*
- ❑ *Week*

- ❑ *Day*

*IF you listen to **AM** radio on a regular basis (even if only once in a while), Please answer the following questions:*

*How many hours per day do you listen to **AM** radio?*

- ❑ *Less than 30 minutes per day*
- ❑ *30 to 59 minutes per day*
- ❑ *1 to 2 hours per day*
- ❑ *More than 2 hours per day*

*Where do you spend most of your time listening to **AM** radio?*

- ❑ *In the car (on a car radio)*
- ❑ *At home (on a stereo)*
- ❑ *At home (on a boombox)*
- ❑ *At home (on a walkman)*
- ❑ *Outdoors (on a boombox)*
- ❑ *Outdoors (on a walkman)*
- ❑ *At work (on a stereo)*
- ❑ *At work (on a boom box)*
- ❑ *At work (on a walkman)*
- ❑ *In public places (i.e., gyms, malls, etc.)*
- ❑ *Other* _____

*For both **AM** and **FM**, which types of radio shows do you listen to? (Check all that apply).*

- ❑ *Sports*
- ❑ *News*
- ❑ *Music*
- ❑ *Talk Shows*
- ❑ *NPR*
- ❑ *Religious*
- ❑ *Other* _____

Which types of music do you listen to? (Check all that apply!)

- ❑ *Alternative*
- ❑ *Classical*
- ❑ *Country*
- ❑ *Jazz/Blues*
- ❑ *New Age*
- ❑ *Pop/Rock*
- ❑ *Gospel*
- ❑ *Oldies*
- ❑ *Ethnic*

- ❑ *Rap*
- ❑ *R&B*
- ❑ *Other*
- ❑ *Classic Rock*

*What stations do you listen to during the day? (list the name or the "call numbers" and the locations they come from, if known)*_____

_____

*What stations do you listen to at night? (list the name or the "call numbers" and the locations they come from, if known)*_____

_____

Do you have favorite radio station(s)? List: _____

What are your favorite radio shows? List: _____

How often do you listen to them? (Check only one)

- ❑ *Daily*
- ❑ *Semi-Weekly*
- ❑ *Weekly*
- ❑ *Semi-Monthly*
- ❑ *Monthly*

Do you ever listen to stations that are outside of the DC/Baltimore area during the day?

- ❑ *Yes*
- ❑ *No*

*If yes, which ones?*_____

_____

Do you listen to far-away stations at night that you may not be able to hear during the day?

- ❑ *Yes*
- ❑ *No*

If "yes", name or list the "call numbers" for those stations (and cities they come from, if known:

_____

_____

*What is your biggest complaint about FM radio?*_____

*What is your biggest complaint about AM radio?*_____

*Do you work in the audio industry?*_____

*Do you work in the radio industry?*_____

*What kind of car do you own?*_____

Do you know what kind of radio is in your car? If yes, what is the brand? _____

_____

Do you have standard or special speakers in your car? _____

Appendix B – Experimenter Script

Welcome to our session! Today you will be participating in an audio test which should last approximately 2 hours. For this test you will hear approximately 250 short AM radio transmissions. Please listen to the clip from start to finish. Please listen only once. At the end of the clip, you will be asked to judge the sample on a 5-point scale. The clips you are going to hear are taken from news, sports and talk shows and from commercials. All of them are taken from real AM radio transmissions from different radio stations around the country. Once you start a session, you should continue until the program tells you to take your break, **but** you are also encouraged to take the test at your own pace. This may mean stopping between samples if you feel you need to "clear your head" for a few seconds.

For each sample, we ask you to keep the following scale in mind *(Experimenter – give participants a copy of the scale now)*:

Rating that you will see on the screen	**Description of Rating (as provided to test subjects)**
Unimpaired (Keep On)	This sample sounded good. I would listen to this audio under all circumstances.
Somewhat Impaired (Keep On)	This sample sounded good, but I heard some background impairments and noise. Still, I would listen to this audio a majority of the time.
Noticeably Impaired (Keep on if Motivated)	This sample was intelligible, but the background chatter and noise was noticeable and significant. I would continue to listen to this audio a majority of the time only if I was extremely interested in the program.
Severely impaired (Keep on only sometimes if extremely motivated)	This sample was mostly intelligible but the background chatter and noise was very annoying. I would continue to listen some of the time only if I was extremely interested in the program.
Failed (Turn off)	This sample is unintelligible. I would not listen to this audio under any circumstance.

You will have this scale with you on paper at all times, even though the screen will only display what is written in the left-hand column. Let's review the scale together. Notice that in a few categories (the top 2) you will be indicating that you would listen to the audio either under all circumstances or a majority of the time.

In other categories (the bottom 3) you will be indicating that you would listen to the audio under special circumstances – when you are motivated to listen. For example: suppose you were in your car listening to your favorite news show or sports broadcast. The program is one that you really are interested in and have been looking forward to hearing. It is unique – you can't get the same program from another channel (example: a college basketball game or a religious show that you know and like). You would use these categories to describe whether you would continue to listen to this special broadcast or whether you would try to find another station to listen to.

In all cases, we want to remind you that we are not asking you to judge the program material, or what's being talked about. We know that you will have various feelings about the sports and sports announcers, talk shows or commercials that you will hear. For this test, we are asking you to try to keep focused on only two things: (a) the quality of the transmission you are listening to and (b) the condition under which you are listening.

Appendix C – Ground to Sky Individual Sound Sample Ratings

				Delphi		GE		SONY		TOTAL		AVERAGE D/U LEVEL	
	D/U Level	Cut Number		OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Off Axis	-5	1	Rating	3.70	2.84	3.47	3.14	3.58	3.07	3.58	3.02	-3.570	-4.140
			CI (+/-)	0.22	0.19	0.21	0.22	0.20	0.18	0.21	0.20		
	0	1	Rating	3.63	2.65	3.51	3.02	3.56	2.91	3.57	2.86	0.273	0.260
			CI (+/-)	0.21	0.20	0.21	0.23	0.24	0.21	0.22	0.22		
On Axis	-10	1	Rating	2.91	2.30	2.93	1.77	1.05	1.09	2.29	1.72	-11.942	-5.897
			CI (+/-)	0.26	0.15	0.25	0.17	0.06	0.09	0.34	0.20		
		4	Rating	1.60	1.58	1.70	1.33	1.02	1.00	1.44	1.30	-11.238	-7.180
			CI (+/-)	0.20	0.17	0.20	0.16	0.05	0.00	0.19	0.15		
	-5	1	Rating	3.74	2.12	3.19	2.14	2.91	2.44	3.28	2.23	-6.370	-4.973
			CI (+/-)	0.20	0.16	0.26	0.19	0.21	0.21	0.25	0.19		
		2	Rating	4.02	2.26	3.05	1.72	3.02	2.05	3.36	2.01	-5.605	-5.611
			CI (+/-)	0.19	0.20	0.26	0.21	0.22	0.17	0.26	0.20		
		4	Rating	2.98	2.60	2.60	2.72	1.14	1.60	2.24	2.31	-4.021	-2.690
			CI (+/-)	0.23	0.21	0.22	0.20	0.10	0.17	0.30	0.24		
		5	Rating	2.60	1.16	1.60	1.00			2.10	1.08	-6.290	-8.047
			CI (+/-)	0.24	0.13	0.20	0.00			0.26	0.09		
	0	1	Rating	3.67	3.00	2.65	2.56	3.77	3.16	3.36	2.91	0.428	1.296
			CI (+/-)	0.18	0.19	0.24	0.25	0.24	0.17	0.27	0.22		
		2	Rating	4.05	2.95	3.86	2.60	2.67	1.58	3.53	2.38	3.138	1.356
			CI (+/-)	0.16	0.20	0.26	0.19	0.22	0.16	0.28	0.25		
		3	Rating	2.72	3.12	1.95	2.44	2.23	2.63	2.30	2.73	-1.750	1.322
			CI (+/-)	0.25	0.16	0.17	0.22	0.17	0.24	0.22	0.23		
	10	2	Rating	3.44	3.14	2.19	2.37	2.12	2.44	2.58	2.65	6.840	12.080
			CI (+/-)	0.21	0.25	0.22	0.22	0.20	0.19	0.27	0.24		

Appendix D – Sky to Ground Individual Sound Sample Ratings

				Delphi		GE		SONY		TOTAL		AVERAGE D/U LEVEL	
	D/U Level	Cut Number		OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
Off Axis	-5	1	Rating	1.88	1.67	3.09	3.42	3.00	2.88	2.66	2.66	0.073	-5.420
			CI (+/-)	0.17	0.19	0.23	0.24	0.21	0.22	0.26	0.31		
	0	1	Rating	2.67	3.37	3.56	2.56	3.42	2.63	3.22	2.85	1.202	0.222
			CI (+/-)	0.23	0.26	0.26	0.23	0.28	0.23	0.28	0.26		
	5	2	Rating	3.84	2.88	3.58	3.33	3.72	3.49	3.71	3.23	3.790	2.528
			CI (+/-)	0.25	0.20	0.21	0.22	0.25	0.30	0.24	0.25		
	10	2	Rating	3.42	3.86	3.33	3.63	3.12	3.53	3.29	3.67	13.062	11.518
			CI (+/-)	0.20	0.21	0.22	0.24	0.26	0.25	0.23	0.24		
On Axis	-5	1	Rating	3.49	2.51	3.00	1.49	3.56	2.53	3.35	2.18	-3.669	-6.059
			CI (+/-)	0.21	0.19	0.26	0.18	0.25	0.21	0.25	0.24		
	0	2	Rating	3.70	2.26	2.16	1.28	2.35	1.47	2.74	1.67	3.620	1.113
			CI (+/-)	0.27	0.22	0.23	0.15	0.20	0.15	0.31	0.21		
		4	Rating	3.84	3.49	2.40	1.63	3.16	2.84	3.13	2.65	6.570	1.215
			CI (+/-)	0.18	0.20	0.21	0.19	0.27	0.22	0.28	0.31		
	5	1	Rating	3.93	3.16	3.09	2.47	3.26	2.98	3.43	2.87	6.160	4.040
			CI (+/-)	0.19	0.20	0.25	0.20	0.21	0.21	0.24	0.22		
		2	Rating	4.05	3.26	2.88	2.40	3.30	2.60	3.41	2.75	5.650	8.006
			CI (+/-)	0.21	0.17	0.30	0.21	0.23	0.21	0.29	0.22		
		3	Rating	4.66	3.57	3.67	2.85	3.62	3.24	3.98	3.22	1.630	3.300
			CI (+/-)	0.16	0.23	0.26	0.23	0.24	0.25	0.26	0.25		
	10	2	Rating	3.95	3.35	2.72	2.74	3.21	3.00	3.29	3.03	6.520	10.337
			CI (+/-)	0.20	0.19	0.25	0.22	0.26	0.21	0.28	0.22		
		3	Rating	3.98	4.05	3.42	3.37	3.44	3.40	3.61	3.60	7.870	11.680
			CI (+/-)	0.20	0.20	0.24	0.21	0.25	0.22	0.24	0.23		
		5	Rating	4.28	4.12	3.77	3.72	3.60	3.58	3.88	3.81	14.310	14.530
			CI (+/-)	0.19	0.16	0.19	0.20	0.20	0.22	0.21	0.20		

Appendix E – Sky to Sky Individual Sound Sample Ratings

			Delphi		GE		SONY		TOTAL		AVERAGE D/U LEVEL	
D/U Level	Cut Number		OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
-10	2	Rating	2.60	1.12	1.65	1.00	1.63	1.00	1.96	1.04	-9.970	-14.150
		CI (+/-)	0.20	0.19	0.17	0.00	0.18	0.00	0.23	0.11		
	3	Rating	1.19	1.00	1.09	1.00	1.00	1.05	1.09	1.02	-19.416	-16.094
		CI (+/-)	0.13	0.00	0.11	0.00	0.00	0.09	0.10	0.05		
0	2	Rating	2.95	2.63	1.63	1.58	2.12	2.16	2.23	2.12	-2.405	-1.622
		CI (+/-)	0.26	0.22	0.17	0.20	0.21	0.21	0.27	0.24		
	3	Rating	3.84	2.95	3.35	2.51	3.19	3.16	3.46	2.88	-2.654	-1.184
		CI (+/-)	0.23	0.23	0.22	0.18	0.23	0.21	0.24	0.22		
5	2	Rating	3.86	4.19	3.35	3.42	3.23	2.93	3.48	3.51	4.900	8.951
		CI (+/-)	0.25	0.22	0.25	0.22	0.27	0.25	0.27	0.28		
	3	Rating	3.81	3.67	3.21	3.12	3.12	2.81	3.38	3.20	6.805	5.070
		CI (+/-)	0.28	0.21	0.26	0.23	0.26	0.25	0.28	0.25		
10	3	Rating	4.49	4.23	3.81	3.49	3.56	3.65	3.95	3.79	12.620	11.695
		CI (+/-)	0.18	0.23	0.22	0.28	0.25	0.29	0.24	0.28		
	4	Rating	4.14	3.60	1.79	1.74	3.44	3.12	3.12	2.82	8.696	6.819
		CI (+/-)	0.18	0.24	0.21	0.16	0.21	0.22	0.35	0.31		