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**RADIOCOMMUNICATION STUDY GROUPS**

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# DIGITAL SYSTEM C FIELD TEST RESULTS

## 1 Overview

This report documents field test results for Digital System C. These results are important because they verify the performance of a physical implementation of the design under real world conditions. Three sets of tests were performed on the system. The Digital Coverage tests illustrate that the DSB audio quality exceeds that of an existing analogue FM signal and show that IBOC DSB offers coverage comparable to existing analogue service. The First Adjacent Compatibility test verifies that the DSB signal does not interfere with the reception of first adjacent analogue FM signals. Finally, the Host Compatibility test shows that the digital portion of the hybrid IBOC DSB signal does not interfere with its analogue host.

## 2 Test Setup

### 2.1 Station Configuration

The test stations were modified, as shown in Figure 1, to generate the FM hybrid IBOC DSB signal. Figure 1 shows that, when the source audio enters the DSB exciter, it is split into two paths.

The first path routes the audio out of the DSB exciter to the DSB audio processor. The processed audio is then returned to the DSB exciter, where audio encoding and DSB modulation is applied to produce the digital portion of the hybrid signal. The output of the DSB exciter is then amplified by a linear HPA, before being routed to the high-power combiner.

The second path routes the audio to the diversity delay for blend before sending it to the analogue audio processor. The processed analogue audio is then input to the analogue FM exciter and FM transmitter to produce the host portion of the hybrid signal. Finally, the analogue host portion is combined with the DSB to produce the final IBOC FM hybrid signal.

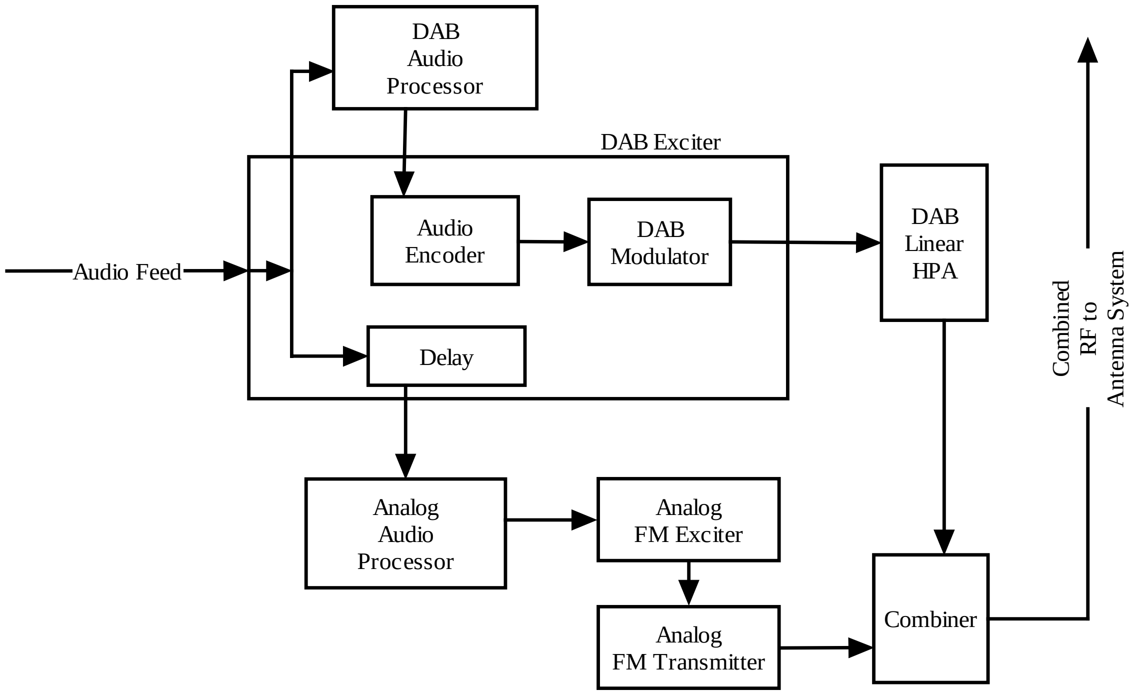



FIGURE 1

**Diagram of Typical FM Transmitter Setup**

## 2.2 Van Configuration

Mobile test platforms were created to collect data while performing field tests. Test vans were modified to support the equipment and interfaces shown in Figure 2. Test data was acquired and stored using a proprietary Field Test PC application. Table 1 describes the manufacturer and model number of the test equipment in the van.

The Field Test PC provides a graphical user interface ("GUI"), as shown in Figure 3. This application controls and collects data from three sources:

- GPS receiver;
- Spectrum analyser;
- DSB receiver.

### 2.2.1 GPS Receiver Data and Processing

The following data is collected by the GPS receiver over an RS-232 interface:

- GPS time;
- GPS position (latitude and longitude).

During setup, the operator enters the position of the transmitter. Current latitude and longitude are then taken directly from the GPS receiver and displayed. The application uses this information to compute and display the current distance from the transmitter.

### 2.2.2 Spectral Data and Processing

The following data is collected by the spectrum analyser over a GPIB interface:

- lower first adjacent signal level;
- upper first adjacent signal level;
- lower second-adjacent signal level;
- upper second-adjacent signal level;
- desired signal level.

This data is then displayed directly by the Field Test PC application.

### 2.2.3 DSB Receiver Data and Processing

The following data is collected from the DSB receiver over an RS-232 interface:

- desired signal strength;
- DSB receiver audio mode (digital or analogue);
- cumulative blend counter, which increments whenever the receiver changes its blend status.

### 2.2.4 PC Application

This application displays new data from each device every eight seconds. All data shown on the display is also stored to a file. The data stored in this file is then re-formatted to generate a strip-chart recording, which plots the variation of select parameters with time over the length of the test.

### 2.2.5 Video Processing and Storage

Video cameras are mounted on the front and back of each test van. The outputs from each camera, along with the video display from the spectrum analyser, are multiplexed into one image by a quad-screen controller, and recorded on videotape. The operator keeps logs to coordinate the stored images with the data collected by the Field Test PC application.

### 2.2.6 Audio Processing and Storage

During Digital Coverage Testing, the Akai DR8 digital audio recorder simultaneously records audio from the Delco and IBOC receivers. During First Adjacent and Host Compatibility Testing, the digital audio recorder simultaneously records audio from all test receivers: the Delco car stereo, Yamaha home HiFi, and Philips boombox (host compatibility test only). All audio and video equipment is controlled manually.

TABLE 1

**Test Equipment Manufacturer and Model Numbers**

| Type | Manufacturer | Model |
|---|---|---|
| Spectrum Analyser | Hewlett Packard | HP-8591 |
| Video Multiplexer | Capture | CPT-MQ4 |
| VCR | AVE | RT195 |
| Video Camera(s) | Marshall | V1212BNC |
| GPS Receiver | Garmin | GPS II |
| Digital Recorder | Akai | DR8 Hard Disk |
| Car Stereo | Delco | 16195167 |
| Home HiFi | Yamaha | HTR-5130 |
| Boombox | Philips Magnavox | AZ1020 |

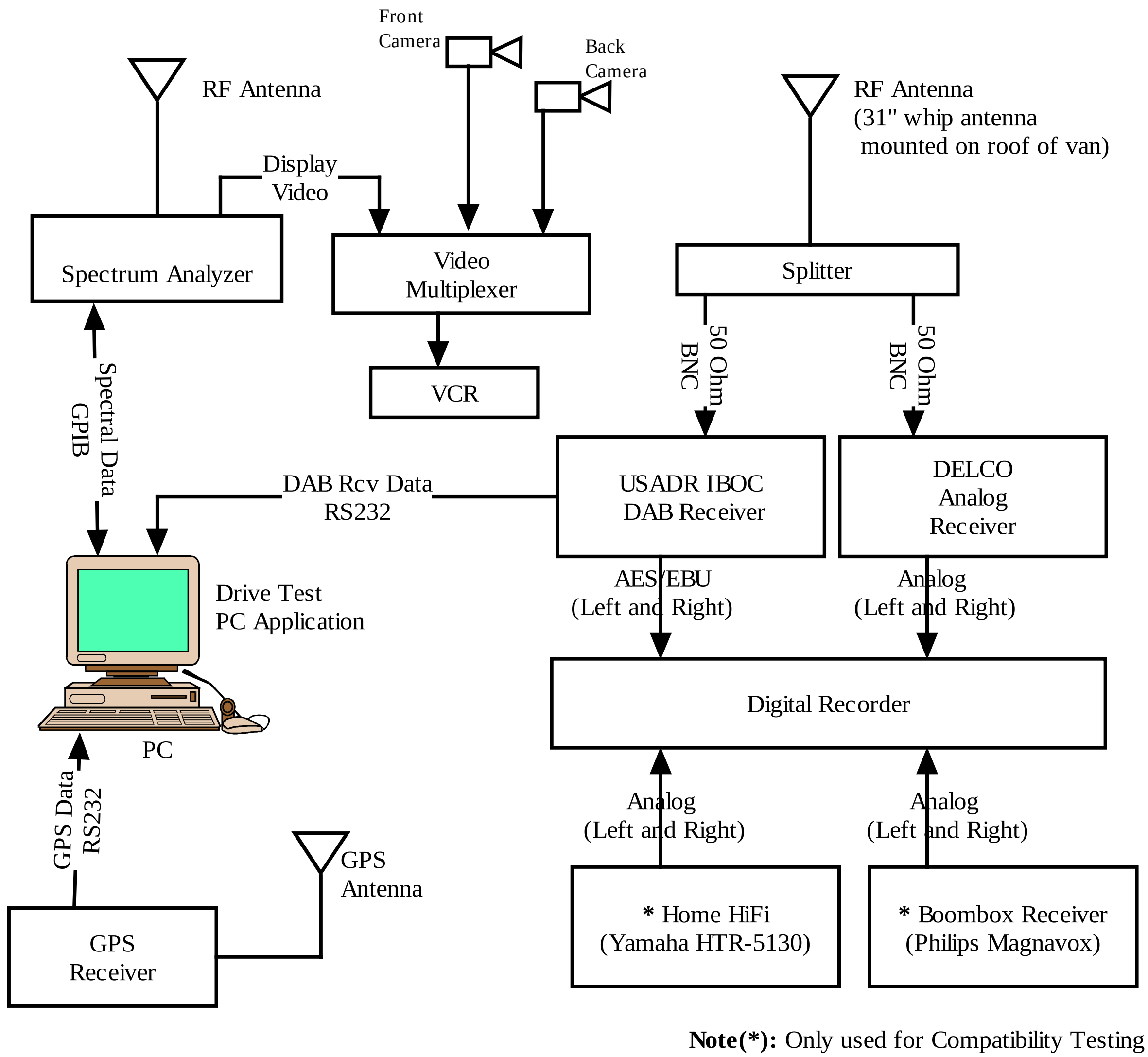



FIGURE 2

**Test Van Equipment Setup**

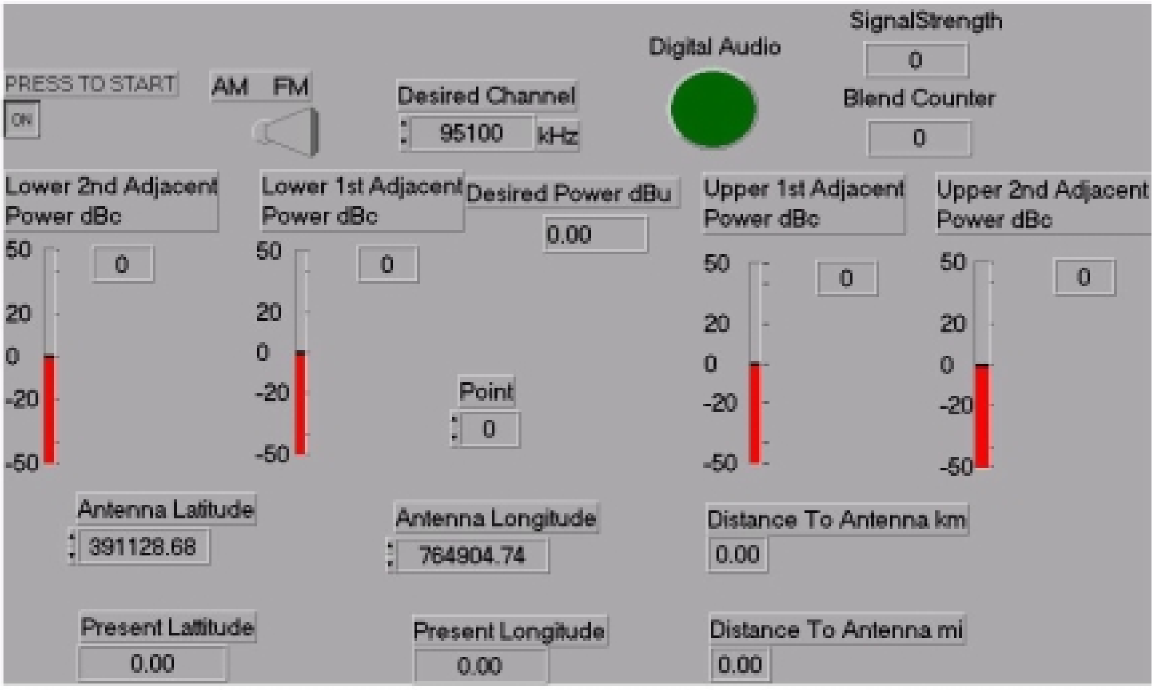



FIGURE 3

**Field Test PC Application Display (GUI)**

## 3 Digital Coverage Tests

### 3.1 Overview

This test measures the digital coverage of the hybrid IBOC signal. During the testing the following information was stored:

- data from the Field Test PC application;
- video from the spectrum analyser;
- video from the front and back cameras;
- audio from the Delco and IBOC receivers.

### 3.2 Route Selection

The following steps were followed to create the routes travelled by the test vans:

- Radials were plotted for at least six azimuth lines from the transmitter site.
- The shortest driving routes were selected to approximate the desired radials.
- Driving instructions from commercial mapping software were obtained for each route.
- Efforts were made to route the van through areas of varying terrain, with urban and suburban population densities.

### 3.3 Test Procedure

a) At the starting location, tune the PC, the IBOC receiver, and the Delco receiver to the desired operating frequency. Enter the GPS coordinates of the transmitter site into the PC. Load the recording media into the Digital Audio Recorder, set the analogue audio levels, and label the audio cut. Place a tape into the VCR and setup to record.

b) All notes, tapes, and data should have the same time reference, which is derived from the GPS. Be sure all clocks are synchronized.

c) Simultaneously begin recording on the VCR, Digital Audio Recorder, and PC.

d) Follow driving instructions for the selected radial. Proceed to the end of the planned route, or to a point several miles beyond the edge of digital coverage.

e) Close all files, and remove and mark all tapes.

f) Repeat steps a) through e) for all radials.

### 3.4 Presentation of Test Results

The field test results are summarized using maps illustrating the extent of IBOC coverage. The maps, using data recorded by the Field Test PC application, colour code the audio mode of the IBOC receiver along each of the field test radials. The colours signify three main regions of IBOC coverage:

- Region 1 (black) indicates the portion of the radial where digital audio is uninterrupted.
- Region 2 (yellow) indicates the portion of the radial where the audio is blending between analogue and digital.
- Region 3 (red) indicates the portion of the radial where digital audio is no longer available, and the receiver has blended to analogue.

IBOC field performance may be further illustrated by analyzing the full suite of test data recorded along each of the radials.

The suite of test data is presented via strip-chart recording, comprised of data logged by the Field Test PC application. The strip chart displays the variation of select parameters with time over the entire length of the radial. The following parameters are included on the strip chart:

- desired signal strength, in dBu (red);
- upper (blue) and lower (yellow) first adjacent signal strength, in dBu;
- upper (black) and lower (magenta) second-adjacent signal strength, in dBu;
- distance from the transmitter, in km (orange);
- receiver audio mode, digital or analogue (green).

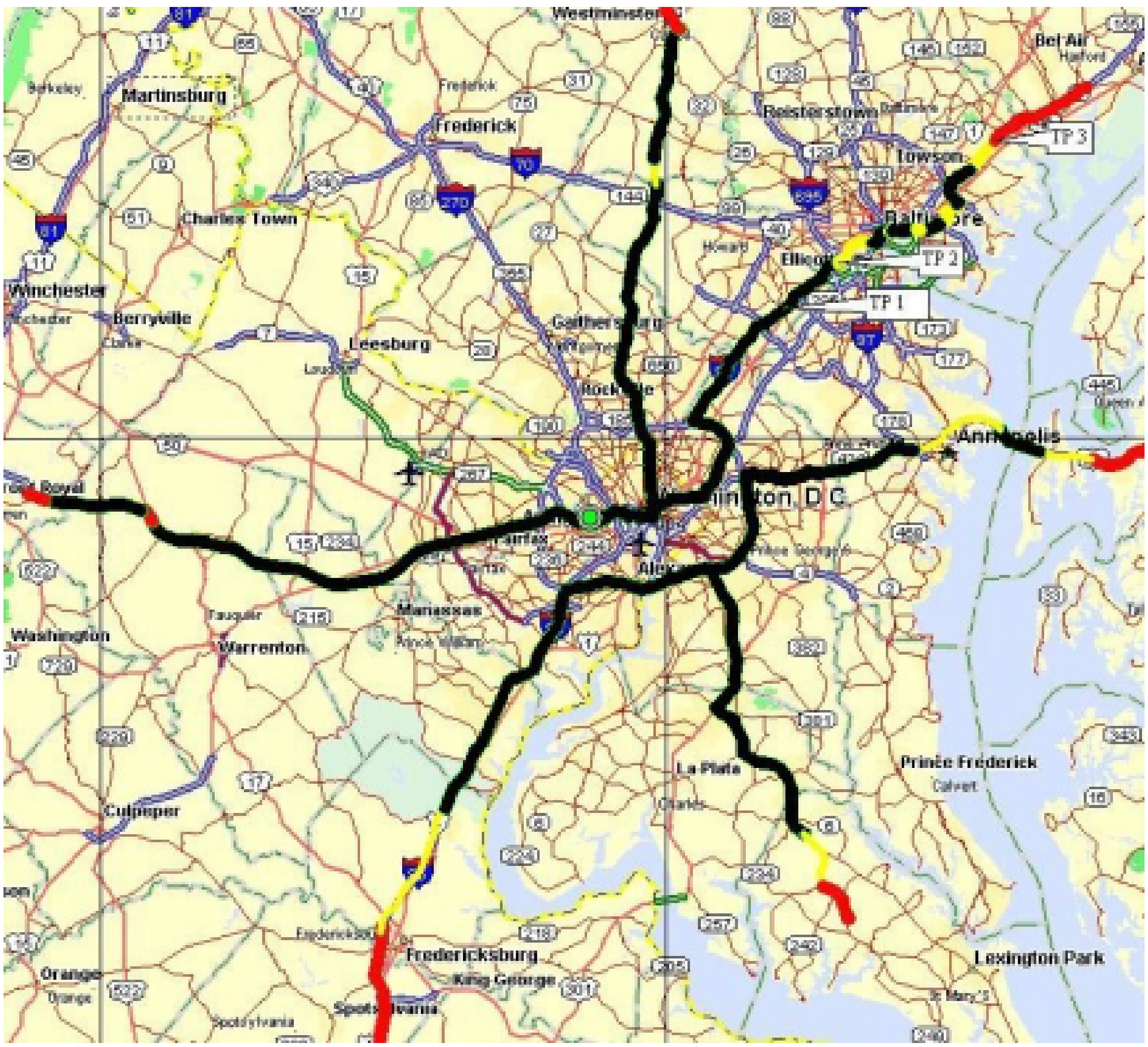
### 3.5 Washington/Baltimore Tests

WETA, a Class B FM public radio station which broadcasts 75.0 kW effective radiated power ("ERP") at 90.9 MHz in the Washington, D.C. metropolitan area, was used for one series of the digital coverage tests. The transmitter is located at $38^{o}$53'30" N latitude and $77^{o}$07'55" W longitude. The power in each of the DSB sidebands was 25 dB below the total power in the analogue host; thus, the total digital power was 473 watts ERP.

This report illustrates the IBOC DSB coverage for all six test radials. One radial that runs northeast through Washington, D.C. and Baltimore, Maryland was selected for more detailed analysis in this report. This radial was selected because it illustrates the performance of one IBOC station in two major metropolitan areas; the radial passes directly through the center of each city. In particular, the analysis focuses on three critical locations along this radial:

- **Test Point 1**. This test point, indicated on the IBOC coverage map as TP 1, is located in Region 1, where digital audio is continuously available.
- **Test Point 2**. This test point, indicated on the IBOC coverage map as TP 2, is located at the boundary of Region 1 and Region 2, where the audio first blends from digital to analogue.
- **Test Point 3**. This test point, indicated on the IBOC coverage map as TP 3, is located at the boundary of Region 2 and Region 3, where the audio blends from digital to analogue for the last time on this radial.

Figure 4 illustrates the extensive coverage of Digital System C on the six test radials. The northeast radial contains designations for the three test points analysed.




***(scale: 1" = 18.4 km)***

FIGURE 4

**WETA FM IBOC Coverage Map**

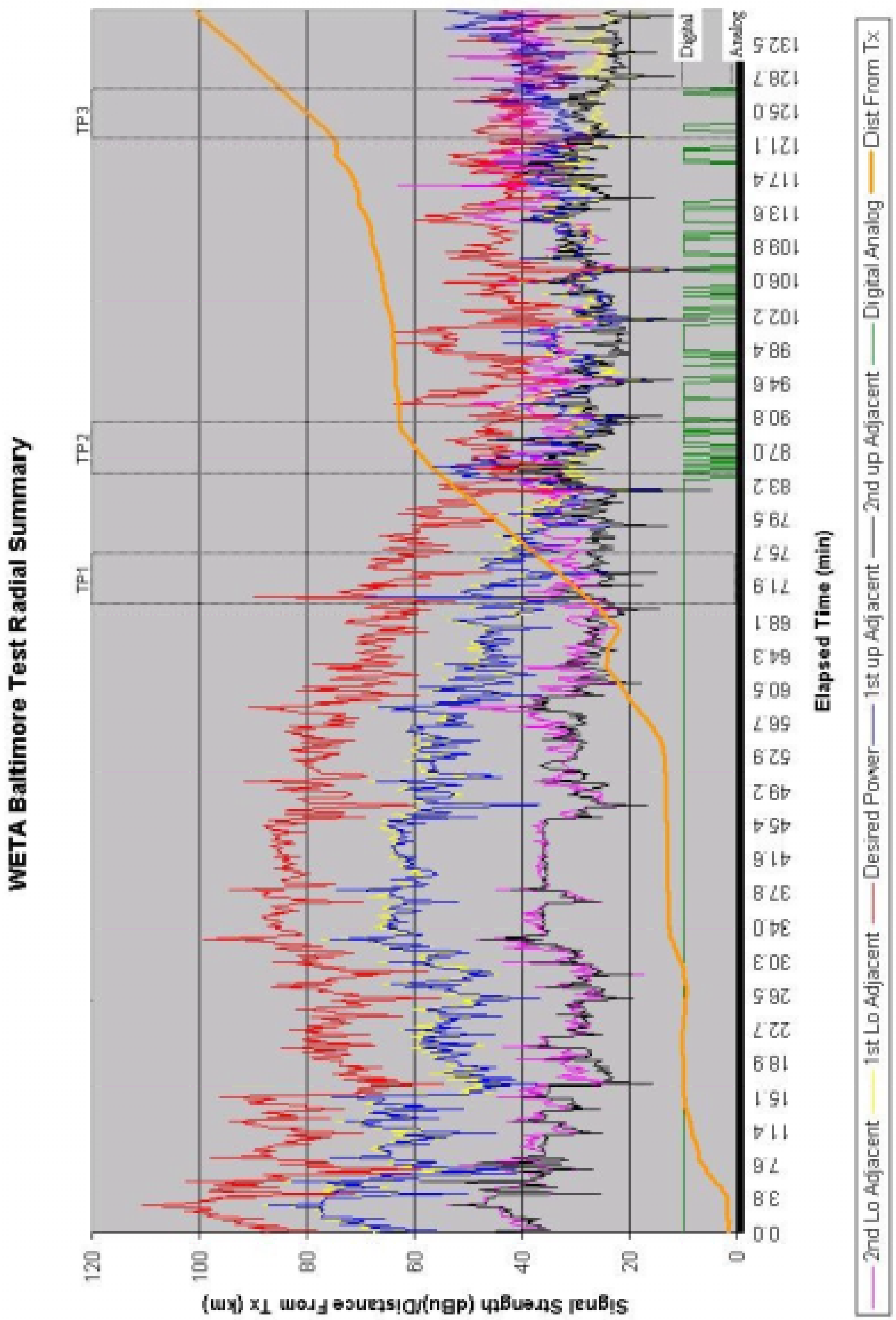



FIGURE 5

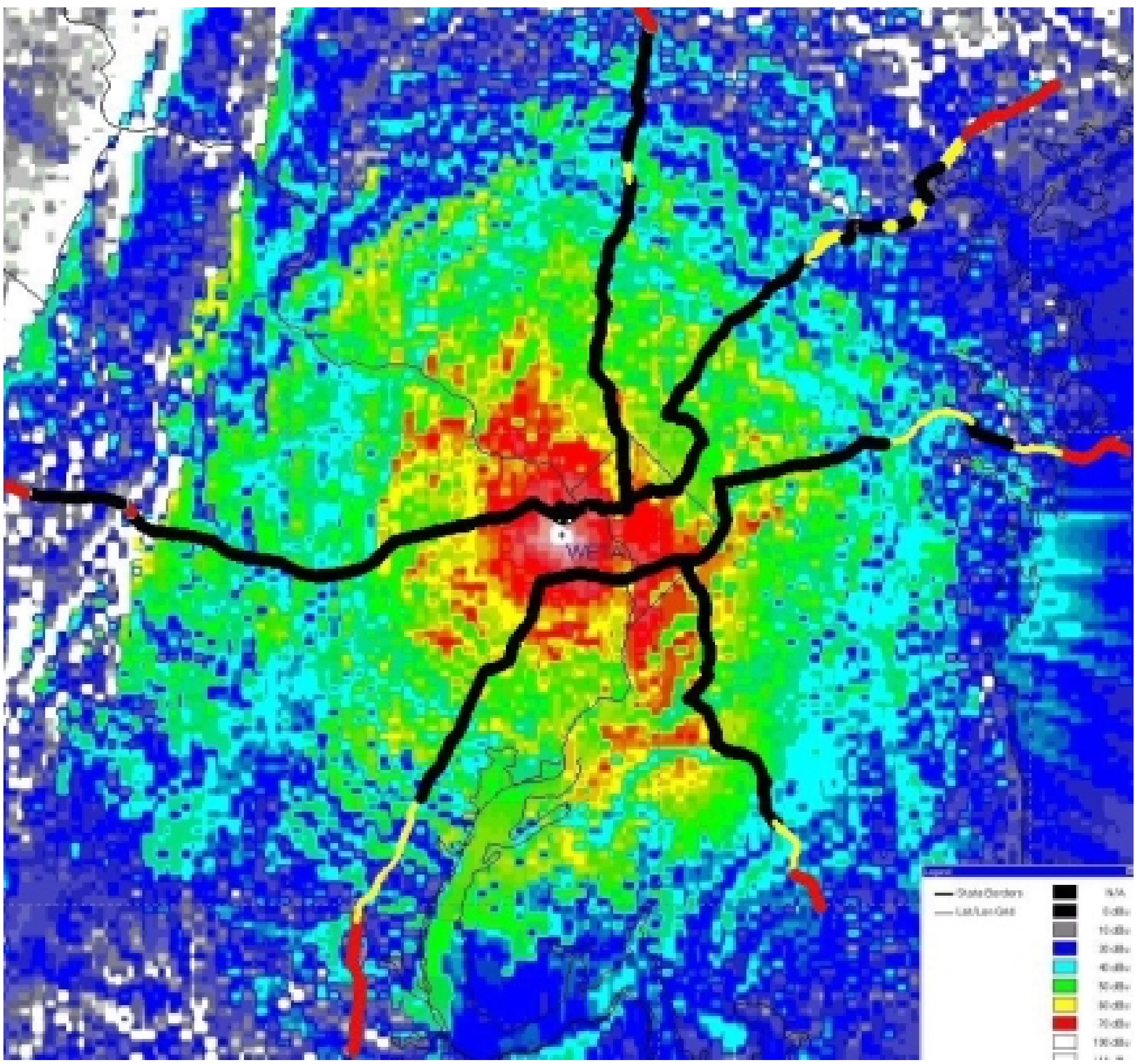
**WETA Strip-Chart Recording for Washington-Baltimore Test Radial**

A couple of observations can be made regarding the strip chart of Figure 5. First, the traces of the first adjacents do not accurately represent the actual interference environment over much of the radial, since the DSB sidebands are included in adjacent channel measurements. The upper and lower first adjacent traces are each about 25 dB below the desired signal, because this is the level of each DSB sideband relative to its host. Late in the profile, actual first adjacents begin to dominate the DSB sidebands, as evidenced by the convergence of the desired and adjacent traces.

Second, the transition from region 1 (digital) to region 2 (blend) occurs as a result of a significant drop in received signal strength. When cross-referenced with the coverage map of Figure 4, it became apparent that blending begins just south of the city of Baltimore. The distance trace on Figure 5 indeed verifies that blending commences just prior to a reduction in speed commensurate with entering the city limits. Finally, this signal strength drop-off is the result of shadowing due to terrain, which drops rapidly upon entering the Patapsco River Valley and Baltimore Harbor basin.

### 3.5.1 Comparison of IBOC Coverage to Existing Analogue Signal Levels

To provide context to the measured IBOC coverage shown in Figure 4, the test radials have been superimposed on a map which predicts the analogue signal levels of WETA. This map is shown in Figure 6.



***(scale: 1" = 18.4 km)***

FIGURE 6

**Overlay of IBOC Coverage Radials onto Analogue Signal Strength Prediction Map**

This map, generated using propagation prediction software, displays the predicted analogue signal strength at a given location using colour-coded pixels. For example, green areas correspond to signal levels in the 50 to 59 dBu range; a location on the innermost portion of the green area would have a signal strength of 59 dBu, while a location on the outer edge of the green area would have a signal strength of 50 dBu.

The strip-chart recording of Figure 5 can be used to confirm the validity of the propagation predictions in Figure 6. Figure 5 indicates that the IBOC receiver begins to blend at desired signal levels of about 45 dBu. Figure 6 shows that blends for most radials commence in the center of the light-blue region, which corresponds to a 45 dBu signal level. Therefore, actual field measurements verify that the signal-strength prediction map of Figure 6 is indeed accurate.

### 3.5.2 Comparison of Measured Digital Performance with Existing Analogue Service

Besides showing that the IBOC receiver begins to blend at a signal level of about 45 dBu, Figure 6 illustrates that the edge of digital coverage lies beyond the 40 dBu signal level, and that solid, unperturbed digital coverage extends to the 50 dBu signal level. It can be shown from Figure 6 that IBOC digital coverage is comparable to existing analogue coverage. To further interpret these results, the data collected at each test point is discussed below.

#### 3.5.2.1 Test Point 1: Region 1, Uniform Digital Coverage

Performance in this region is characterized by uninterrupted, virtual CD-quality digital audio. Region 1 extends beyond signal strengths of 50 dBu, and is indicated in Figures 4 and 6 by black radials. The field test data shows that Digital System C covers a huge area with no lapses in digital coverage; the audio is completely free of degradation due to the noise, multipath, and interference that typically plague existing analogue service.

Analysis of recordings made at Test Point 1 show while the analogue receiver suffers from the effects of noise and multipath, the IBOC receiver delivers unimpaired, virtual CD-quality audio. Not only is the digital audio free of impairments when analogue audio is not; the digital audio quality is superior to analogue, even when the analogue audio is unimpaired.

#### 3.5.2.2 Test Point 2: Region 1/Region 2 Boundary, Blend Area

This test point is located just beyond the point of the initial blend to analogue. Performance around Test Point 2 is characterized by recurrent blending between analogue and digital audio. This point is located near the 45 dBu signal level, at the first black-to-yellow transition on the Washington-Baltimore test radial of Figures 4 and 6.

Audio recordings made at Test Point 2 demonstrate the seamless performance of the blend function, and indicate that the IBOC receiver, even while recurrently blending, delivers audio quality which is superior to the analogue receiver. In fact, analogue audio from the IBOC receiver often sounds better than audio from the analogue receiver, due largely to proprietary FM demodulation techniques developed to mitigate the effects of multipath.

The recordings also indicate that, at the point where the digital signal begins to degrade - that is, the blend point - the corresponding analogue audio itself exhibits audible degradation. Hence, the analogue audio is degraded at signal levels where digital audio degradation is not yet perceptible. The same conclusion was made as a result of the laboratory performance tests; this field data simply confirms the laboratory results.

#### 3.5.2.3 Test Point 3: Region 2/Region 3 Boundary, Edge of Digital Coverage

This test point is located at the edge of digital coverage, around the point of the final blend to analogue. Performance around Test Point 3 is dominated by analogue audio, with a couple of brief blends to digital. This point falls between signal levels of 30 dBu and 40 dBu, at the yellow-to-red transition on the Washington-Baltimore test radial of Figures 4 and 6.

Audio recordings around TP3 indicate that, for much of the segment, both the digital and analogue receivers' audio is beyond the point of failure. This field data validates the results of the laboratory evaluations, which indicate that the point of failure for existing analogue radios lies between received signal strengths of 30 dBu and 40 dBu. As a result, the coverage of the IBOC signal is comparable to that of existing analogue service.

Careful examination of the strip-chart recording in Figure 5 reveals the presence of an upper first adjacent channel in the region of TP3. This interferer is WHFC, an 1100-watt, Class A station located in Bel Air, Maryland. Figure 5 shows that the D/U becomes negative over the range of TP3. This growing first adjacent impairs digital performance; this is consistent with the measured results of the laboratory block error rate tests.

Most importantly, these results show the graceful degradation of the IBOC signal. When the digital signal degrades sufficiently, the receiver blends to analogue, without subjecting the listener to annoying digital artifacts, drop-outs, and muting. In this manner, the performance of the IBOC signal can never be worse than, and is usually much better than, the performance afforded by existing analogue service.

### 3.6 Las Vegas Performance Tests

These tests were conducted using KWNR, a Class C FM commercial radio station which broadcasts 92.0 kW Effective Radiated Power ("ERP"), with a transmitter power output of 29 kW at 95.5 MHz in the Las Vegas, Nevada metropolitan area. The station's transmitter is located on a mountain outside Las Vegas with coordinates 36°00'31" N latitude and 115°00'22" W longitude. The test procedures and approach were similar to those used for the Washington/Baltimore tests.

It is well known that the Las Vegas, Nevada area is located in a "bowl" shaped desert valley. Mountainous areas encircling the city often block completely the KWNR analogue signal. This shadowing also impacts digital reception. The tests indicated system blending occurs as a result of a significant drop in received signal strength. When cross-referenced to the corresponding terrain profile, it becomes apparent that blending begins at a point that experiences extreme terrain shadowing. In fact, the signal profile closely approximates the terrain profile, indicating that signal strength is proportional to elevation.

Figure 7 illustrates the coverage of the digital system in all test radials. The results are plotted against terrain to provide some context for the system's performance.

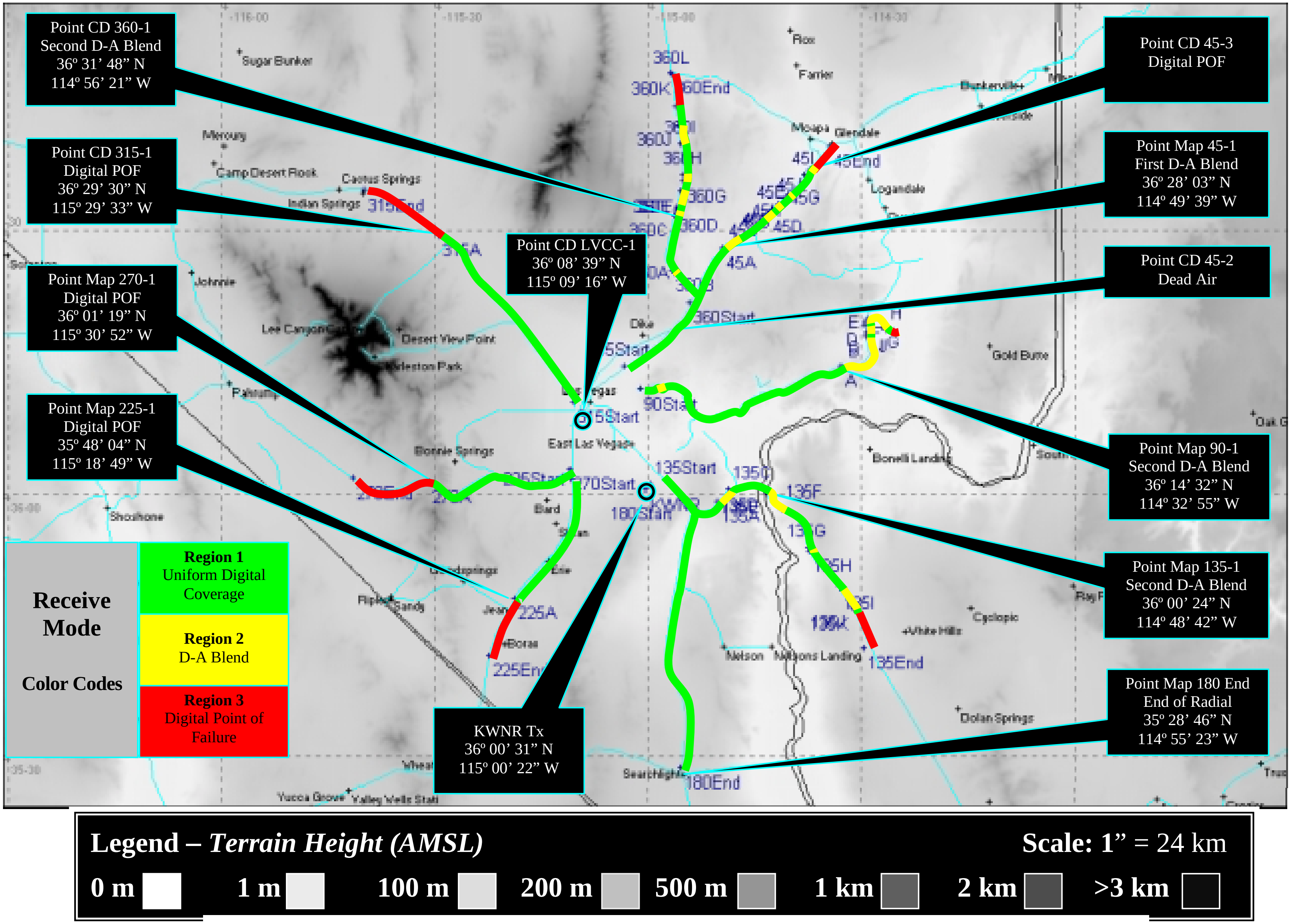



**Figure 7 - KWNR FM IBOC Coverage Map**

### 3.6.1 Comparison of IBOC Coverage to Existing Analogue Signal Levels

To facilitate a meaningful comparison of analogue and digital coverage, the test radials are superimposed in Figure 8 on a map which predicts the analogue signal levels of KWNR.

This map, generated using propagation prediction software, displays the predicted analogue signal strength at a given location using colour-coded pixels. For example, green areas correspond to signal levels in the 50 to 59 dBu range; a location on the innermost portion of the green area would have a signal strength of 59 dBu, while a location on the outer edge of the green area would have a signal strength of 50 dBu.

The strip-chart recordings for each radial can be used to confirm the validity of the propagation predictions in Figure 8. The strip charts confirm the IBOC receiver begins to blend at desired signal levels of about 45 dBu. Figure 8 shows that blends for most radials commence in the center of the light-blue region, which corresponds to a 45 dBu signal level. Therefore, actual field measurements verify that the signal-strength prediction map in Figure 8 is indeed accurate.

### 3.6.2 Comparison of Measured Digital Performance with Existing Analogue Service

Besides showing that the IBOC receiver begins to blend at a signal level of about 45 dBu, Figure 8 illustrates that the edge of digital coverage lies beyond the 40 dBu signal level, and that solid, unperturbed digital coverage extends to the 50 dBu signal level. As was the case with the Washington/Baltimore tests, these results demonstrate digital coverage is comparable to existing analogue coverage. To further interpret these results, the data collected at each test point is discussed below.

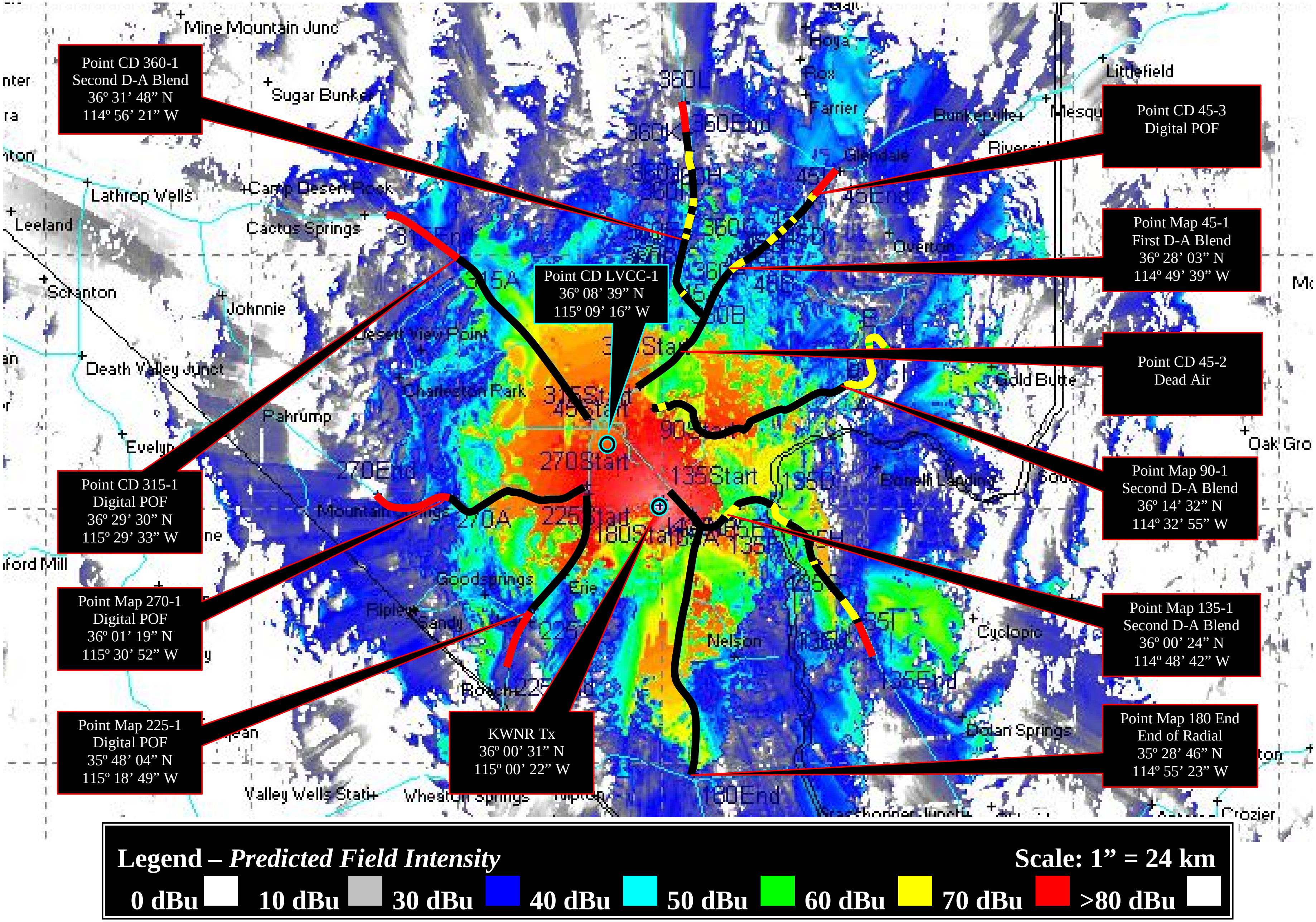



**Figure 8 - Overlay of IBOC Coverage Radials on Analogue Signal Strength Prediction Map of Las Vegas**

The Las Vegas tests confirm the results observed in Washington/Baltimore. Performance in Region 1 is characterized by uninterrupted, virtual CD-quality digital audio beyond signal strengths of 50 dBu. Performance in Region 2 is characterized by recurrent blending between analogue and digital near the 45 dBu signal level. Region 3, past the edge of digital coverage, falls between signal levels of 30 dBu and 40 dBu.

### 3.6.2.1 Test Radials

Each of the eight test radials extend outward from the KWNR transmitter site in as straight a line as local highways allow. In any case, distance from the transmitter always increases (or decreases) with time. Due to the wide variance in terrain, analogue and digital signal characteristics on each radial are worthy of further description:

- 45º Radial

The 45º radial run began on Route 15 at the intersection of Range Road just northwest of Nellis Air Force Base. The starting point is located approximately 27 kilometres from the transmitter and does not experience any terrain blockage. Altitude increased from 700 to 900 metres AMSL heading northeast on Route 15 for another 27 kilometres. During this time the digital audio quality showed no impairment, while the analogue was distorted by a small amount of the "specular multipath" characteristic of this area. The first blend to analogue occurred at 54 kilometres from the transmitter, where the test radial was in the shadow of a mountain that exceeded the path clearance by 500 metres. The route emerged out of the shadow at 57 kilometres, where the system reacquired digital audio. The signal remained digital until 64 kilometres, when again, the route was shadowed. The route continued heading northeast. At this point, the system blended to analogue three more times. At 75 kilometres from the transmitter, the digital signal level dipped below the threshold of detection. As can be seen on the strip chart for the 45º radial, the point of blend to analogue uniformly occurs at a level of 40 to 45 dBu. The analogue audio quality at this point is sufficiently degraded as to become unlistenable. Figure 9 contains a strip chart detailing performance for this radial.

- 90º Radial

The 90º radial run began shortly before crossing the peak of Sunrise Mountain, to the west of Las Vegas. After cresting the peak, the KWNR signal was severely degraded by the shadowing of the immediately adjacent rock outcroppings. Most of the recovered analogue transmission at this point was reflected signal, with severe multipath. After emerging from behind Sunrise Mountain, the receiver blended back to digital and remained unimpaired until 48 kilometres from the transmitter on route SSR 167 (eastbound). At this point, the local terrain elevation was approximately 150 metres below a clear transmission path and the received field approached 45 dBu. The receiver blended to analogue and remained that way for the remainder of the radial, except for a few transitions to digital from 55 to 65 kilometres. At a distance of approximately 45 kilometres, KWNR inadvertently broadcast 30 seconds of "dead air". This fortuitously provided a demonstration of the level of digital system signal to noise improvement over analogue. Figure 10 contains a strip chart detailing performance for this radial.

- 135º Radial

The 135º radial began 58 kilometres from the transmitter on the Arizona side of the Colorado River. This radial was run in a reverse direction (towards the transmitter). Data collection began near the intersection of Route 93 and the road leading to Doran Springs, Arizona. At this point the signal had blended to severely impaired analogue. The terrain profile at this point was that of a desert plain, with mountain ranges that shadow the KWNR signal on each side of the river. Nevertheless, heading west on Route 93, the signal blended to digital at about 45 kilometres from the transmitter.

It remained digital for the next 10 kilometres (except for a short blend to analogue at 40 kilometres). At 35 kilometres, shadowing from the mountains to the west of the river caused a blend to analogue, which remained in effect as the route descended into the Colorado River Valley and crossed Hoover Dam. The system did not reacquire digital transmission until approximately 15 kilometres from the transmitter (Measurement Point 135-1, which is severely obstructed by mountains to the west) as the route crossed the shielding mountains. The signal remained robust and unimpaired digital until the radial ended in sight of the transmitting tower. Figure 11 contains a strip chart detailing performance for this radial.

- 180º Radial

The 180º radial began at 60 kilometres from the transmitter in Searchlight, Nevada, and proceeded north on Route 95 to an intersection with Routes 93 and 515. This is another one of the three "reverse" radials that was measured as the test van approached the transmitter site. The digital signal was robust and unimpaired for the duration of the radial. Figure 12 contains a strip chart detailing performance for this radial.

- 225º Radial

The 225º radial began on Interstate Route 15 South at the intersection of Route 160. The digital signal remained robust and unimpaired until the test van was about 50 kilometres from the transmitter at a point near the Roach Dry Lake Cutoff. The signal then blended to analogue and stayed below the threshold of digital acquisition. Measurement Point 225-1 in Figure 13 (Digital POF) is severely shadowed by two mountain ranges to the north. Figure 13 contains a strip chart detailing performance for this radial.

- 270º Radial

The 270º radial began on Route 160 at the intersection of Interstate 15, west of Las Vegas, which sits in a desert valley surrounded by mountains. Heading west on 160 toward the mountains, the digital signal was unimpaired until the route passed through the extreme terrain of Red Rock Canyon. At that point (270-1), 46 kilometres from the transmitter) the signal blended to analogue and remained that way until the radial ended in Pahrump, Nevada. Figure 14 contains a strip chart detailing performance for this radial.

- 315º Radial

The 315º radial began on N. Rancho Blvd in Northwest Las Vegas and continued nothwest on Interstate Route 95. The digital signal stayed robust and unimpaired until the highway curved around a mountain just past the intersection of Route 156. Figure 15 contains a strip chart detailing performance for this radial.

- 360º Radial

The 360º radial was another radial that was measured in a reverse direction, approaching the transmitter site. Measurements began on Route 93 South at its intersection with Route 168. The signal at this point was below digital threshold of detection, and the analogue signal quality was severely impaired, due to low signal level. At approximately 80 kilometres, the system acquired the digital transmission and observed mode blending every 5 kilometres until 58 kilometres from the transmitter. At this point (Measurement Point 360-1), the overall elevation increased sufficiently to allow for unimpaired reception of the digital signal. The field intensity dropped enough to cause a short blend to analogue at 45 kilometres. At this point, the test van was in the direct shadow of an adjacent mountain. From this location, and until the radial ended at the intersection with Interstate Route 15, the signal remained digital and unimpaired. Figure 16 contains a strip chart detailing performance for this radial.

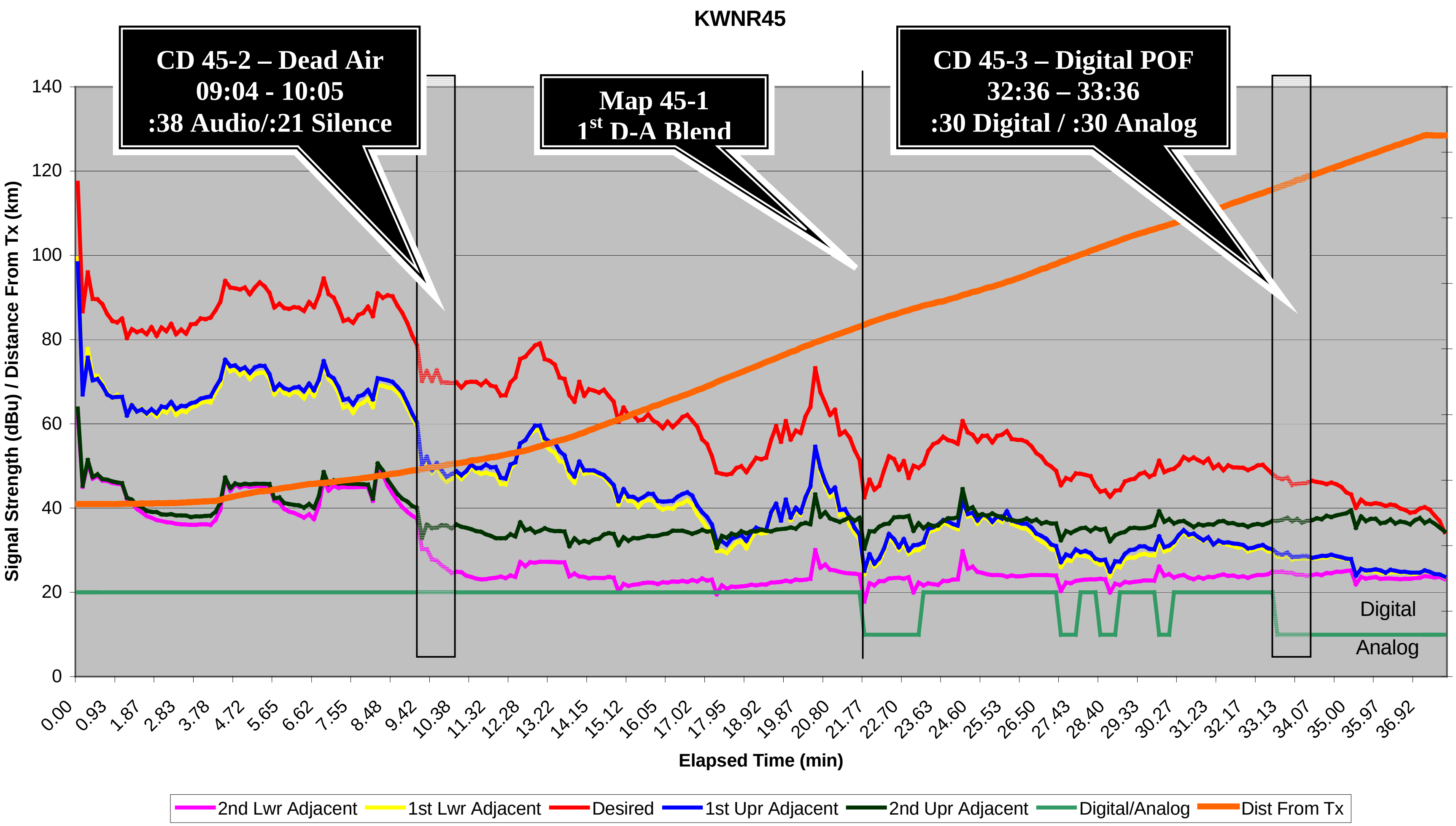



**Figure 9 - KWNR Strip-Chart Recording of Las Vegas 45° Radial**

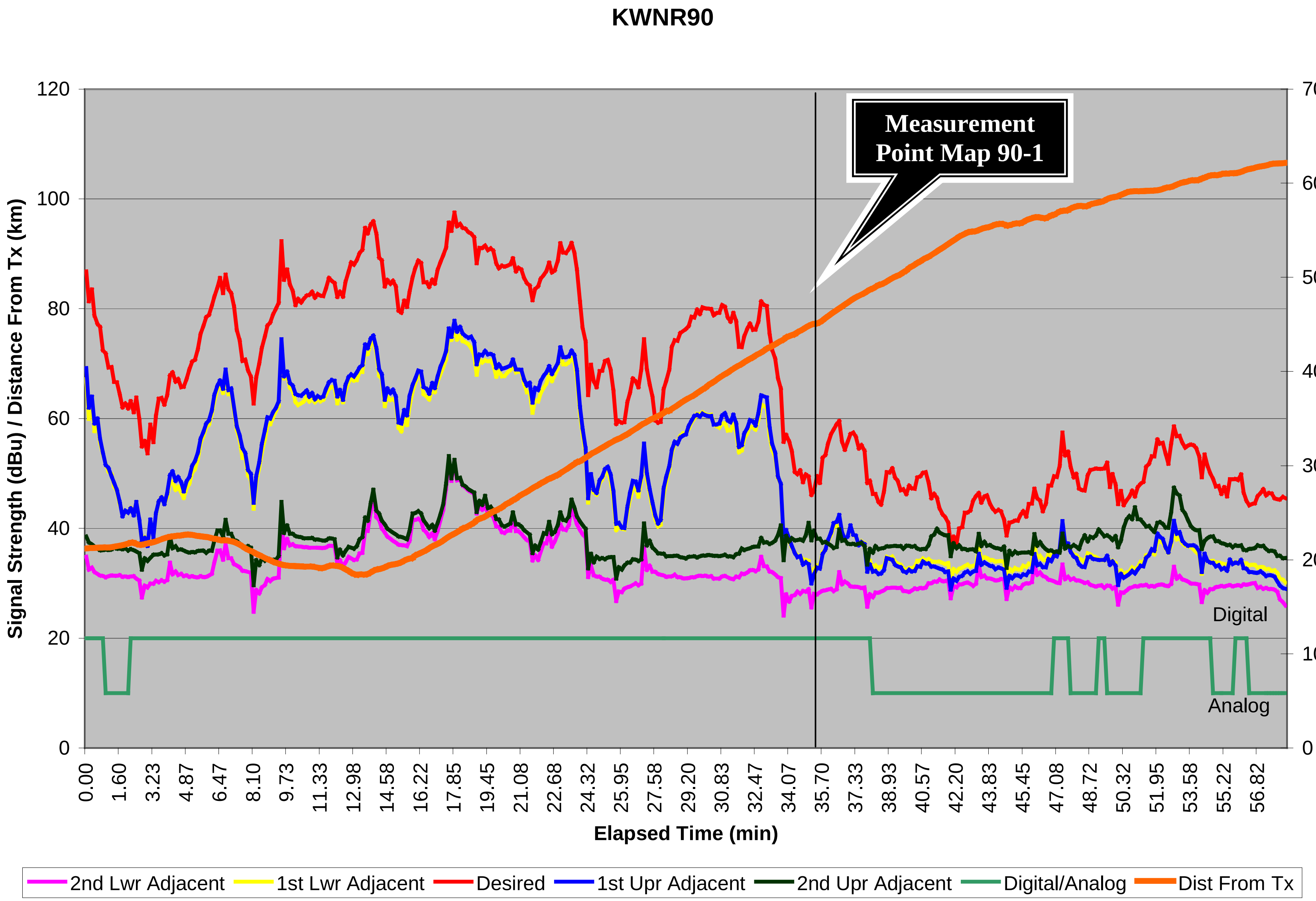



**Figure 10 - KWNR Strip-Chart Recording of Las Vegas 90° Radial**

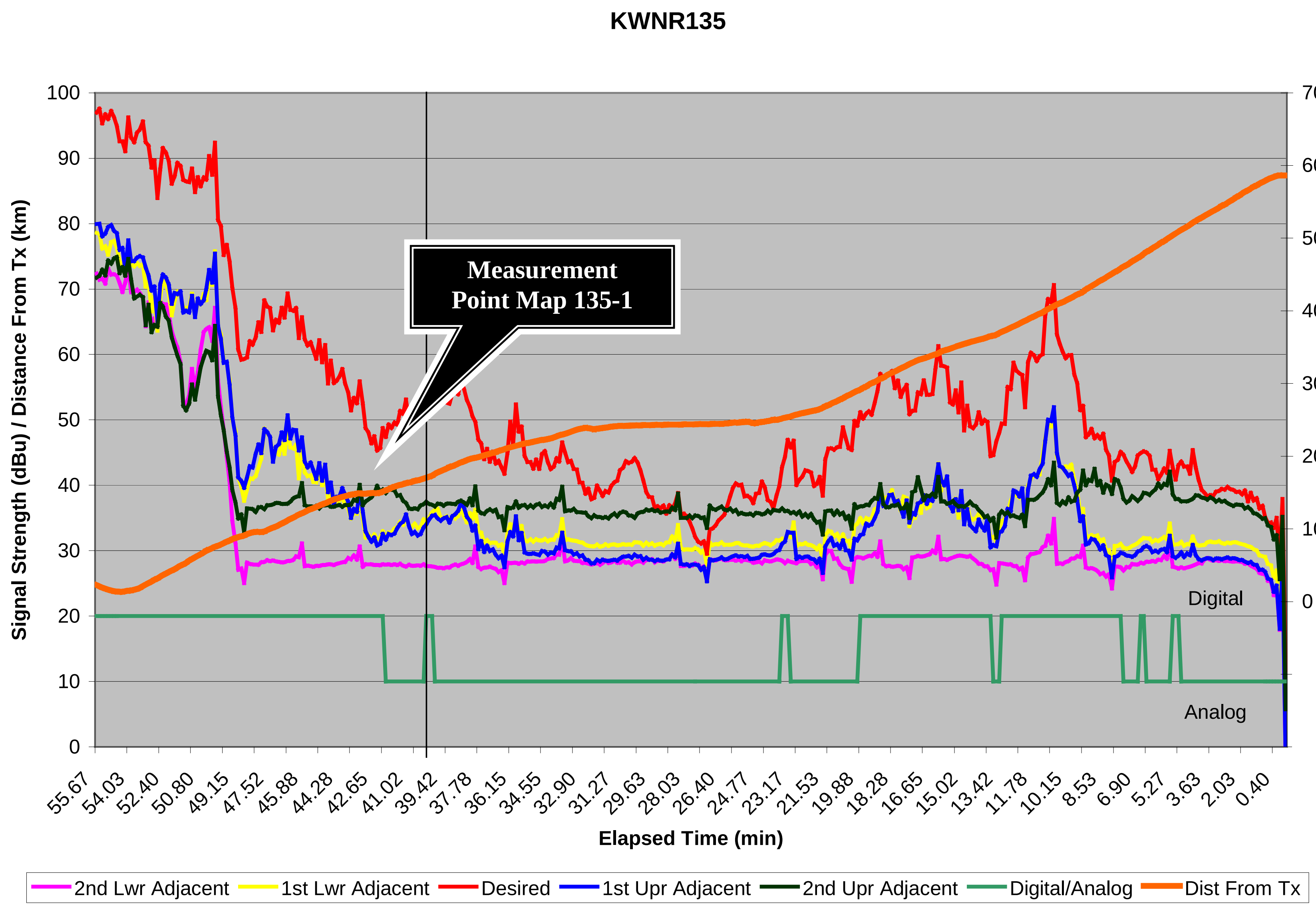



**Figure 11 - KWNR Strip-Chart Recording of Las Vegas 135° Radial**

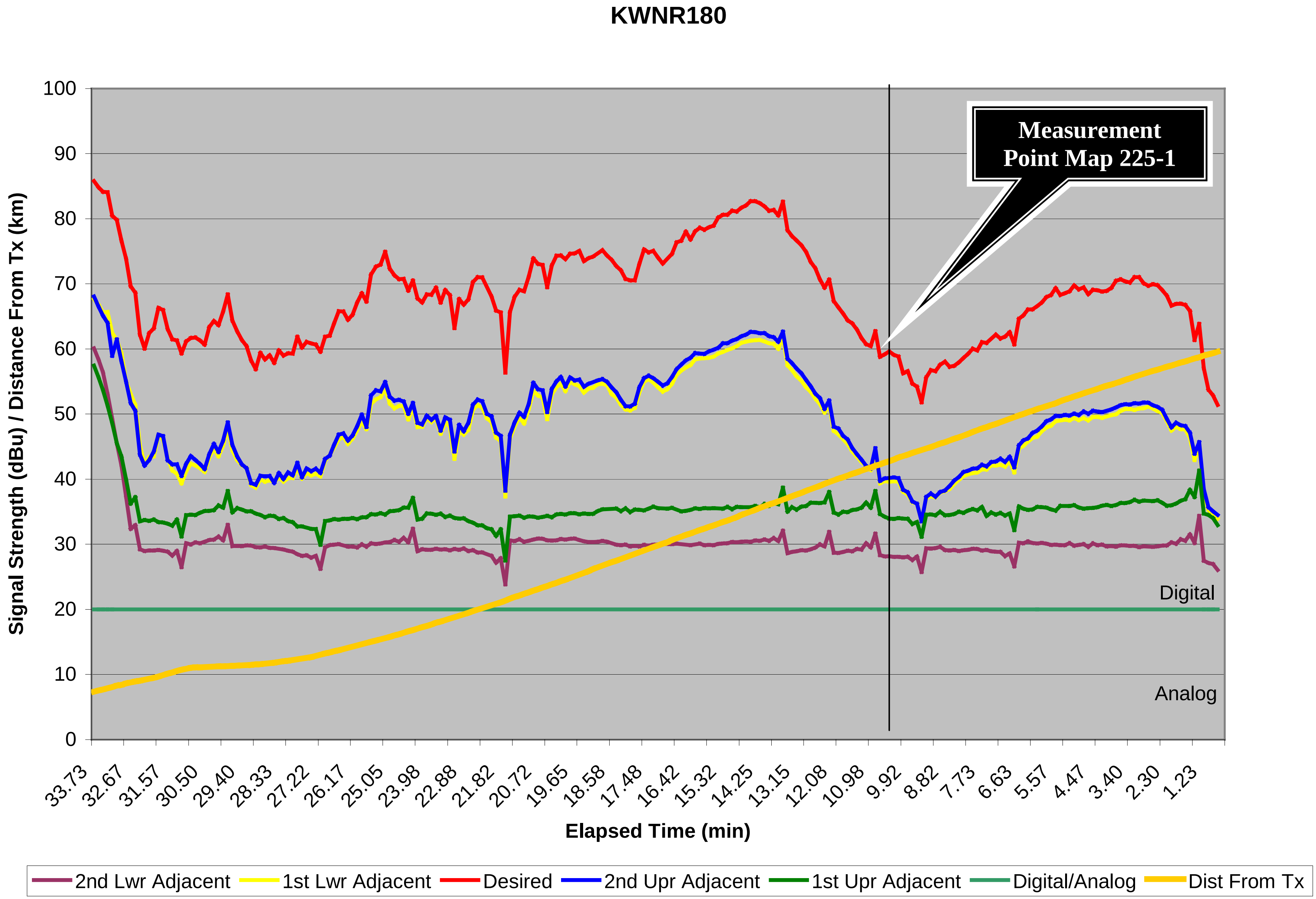
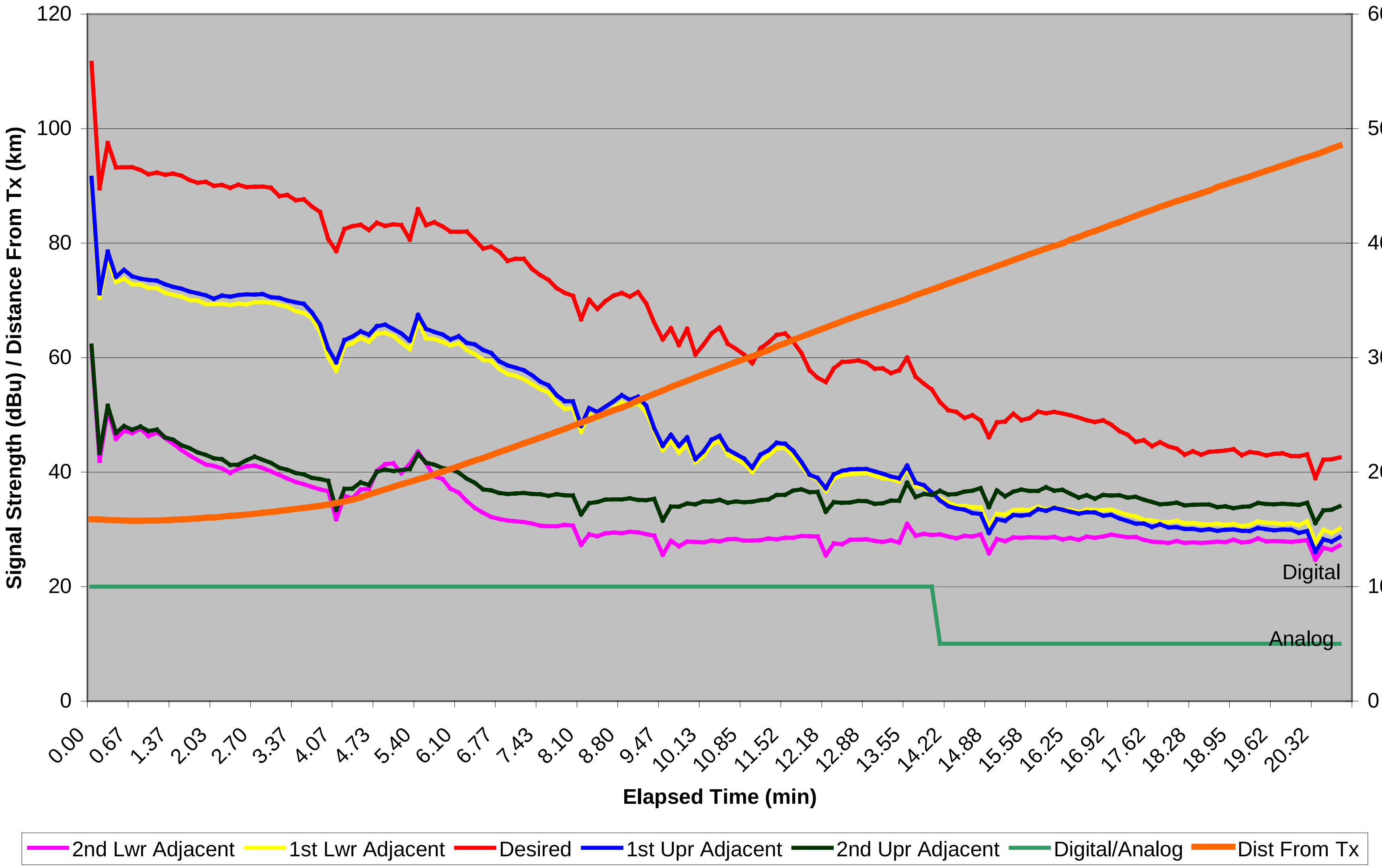



**Figure 13 - KWNR Strip-Chart Recording of Las Vegas 225° Radial**

**KWNR225**


120
100
80
60
40
20
0
60
50
40
30
20
10
0
Signal Strength (dBu) / Distance From Tx (km)
0.00
0.67
1.37
2.03
2.70
3.37
4.07
4.73
5.40
6.10
6.77
7.43
8.10
8.80
9.47
10.13
10.85
11.52
12.18
12.88
13.55
14.22
14.88
15.58
16.25
16.92
17.62
18.28
18.95
19.62
20.32
Elapsed Time (min)
Digital
Analog
2nd Lwr Adjacent
1st Lwr Adjacent
Desired
1st Upr Adjacent
2nd Upr Adjacent
Digital/Analog
Dist From Tx

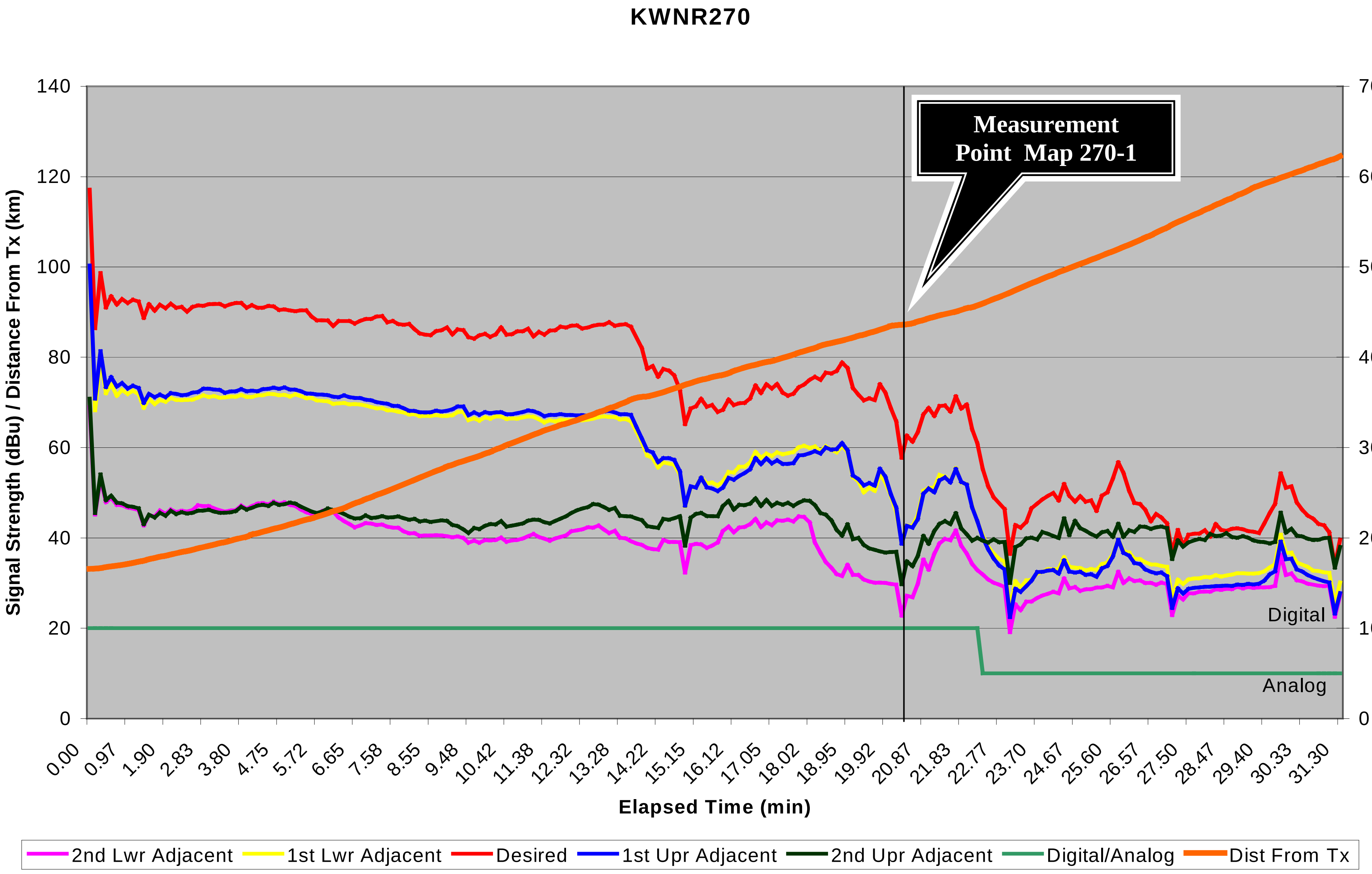



**Figure 14 - KWNR Strip-Chart Recording of Las Vegas 270° Radial**

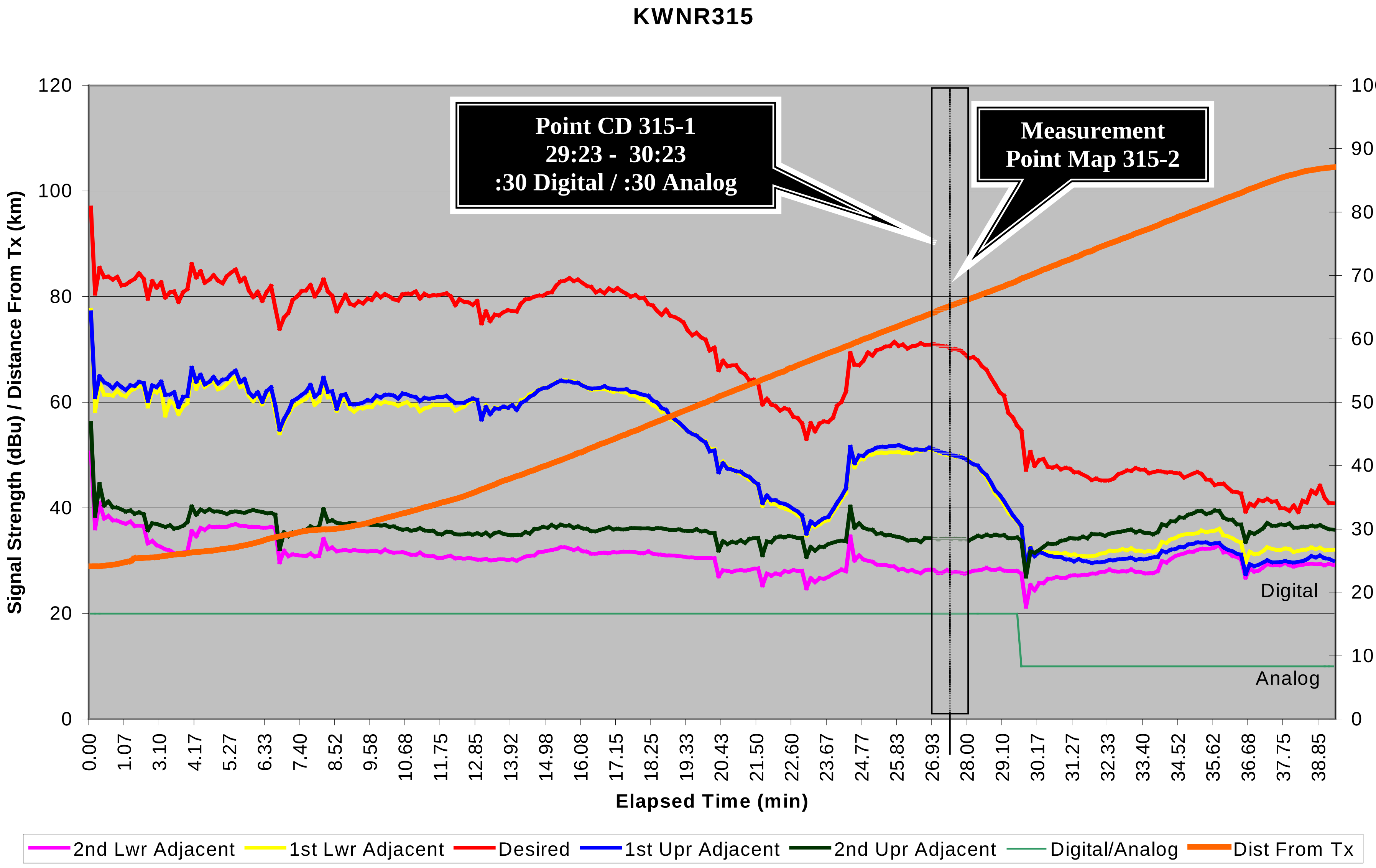



**Figure 15 - KWNR Strip-Chart Recording of Las Vegas 315° Radial**

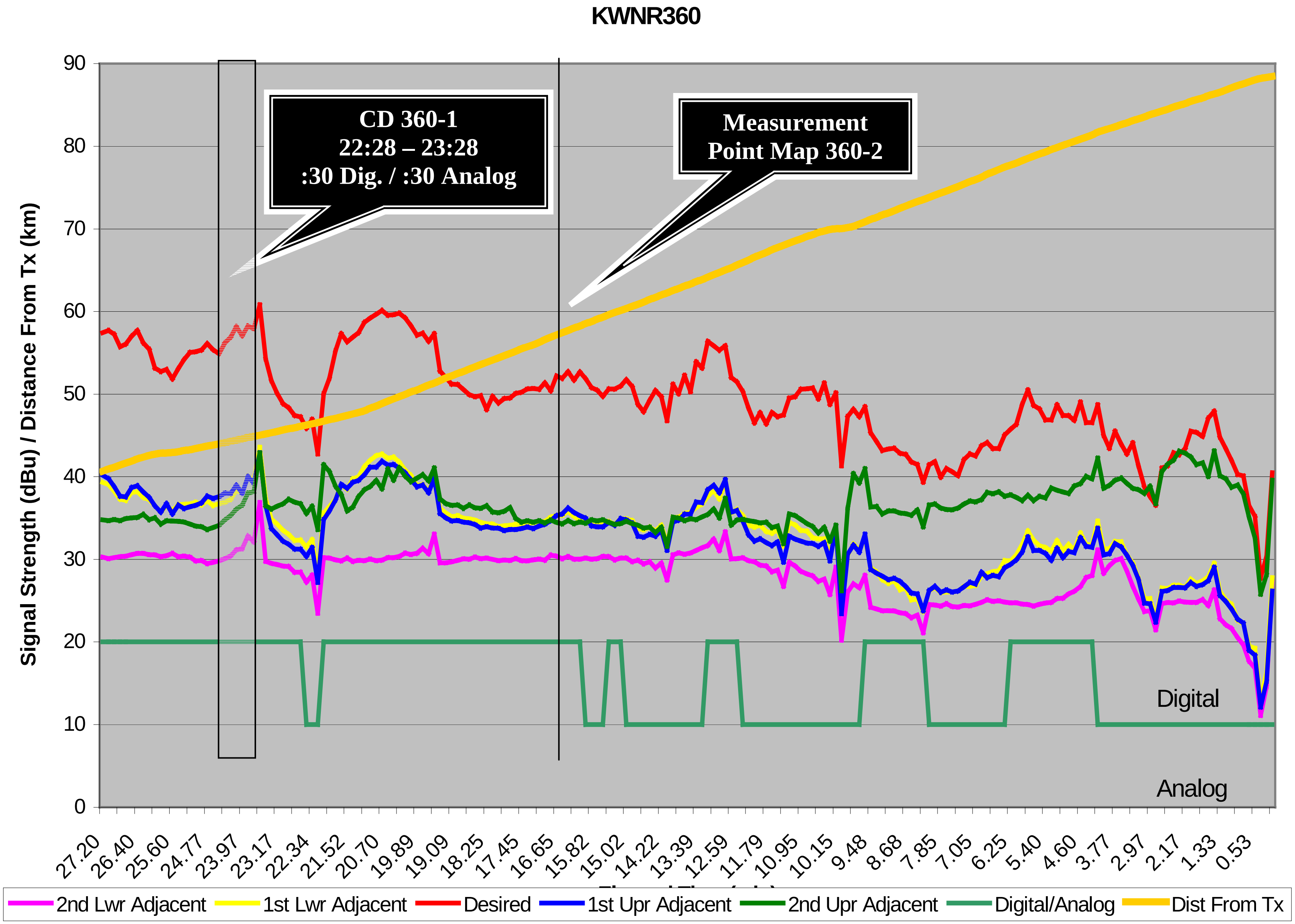



**Figure 16 - KWNR Strip-Chart Recording of Las Vegas 360° Radial**

### 3.7 Summary of Digital Coverage Tests

Within Region 1, the IBOC signal covers a huge area with no lapses in digital coverage; the audio is completely free of degradation that typically plagues existing analogue service. Even in unimpaired conditions, the digital audio quality is superior to analogue audio quality.

Within Region 2, the blend function exploits the availability of both the analogue and digital portions of the hybrid signal. The receiver outputs unimpaired digital audio, and seamlessly blends to analogue when the digital audio is sufficiently impaired. This maximizes the quality of the audio beyond that of existing analogue service.

Within Region 3, the IBOC signal exhibits graceful degradation. When the digital signal deteriorates and the receiver blends to analogue, the performance of the IBOC signal mirrors that of existing analogue service, without subjecting the listener to muting and annoying digital artifacts.

The results of the Digital Coverage field test have confirmed the findings of extensive simulations and laboratory performance tests: the audio quality of the Digital System C signal is superior to analogue audio quality, and the digital coverage is comparable to that provided by existing analogue service.

## 4 First adjacent Compatibility Test

WPOC, a Class B FM station which broadcasts 16.0 kW ERP at 93.1 MHz in the Baltimore, Maryland metropolitan area, was used for the First Adjacent Compatibility and Host Compatibility tests. The transmitter is located at 39°17'14" N latitude and 76°45'17" W longitude. The power in each of the DSB sidebands was 25 dB below the total power in the analogue host; thus, the total digital power was 101 watts ERP.

Its closest first adjacent interferers are: WMMR, a class B FM station which broadcasts 18 kW ERP at 93.3 MHz in Philadelphia, Pennsylvania at 39°57'09" N latitude and 75°10'05" W longitude, and WFLS, a Class B FM station which broadcasts 50 kW ERP at 93.3 MHz in Fredericksburg, Virginia at 38°18'46" N latitude and 77°26'20" W longitude.

### 4.1 Overview

This test demonstrates that a hybrid IBOC signal does not interfere with its nearest analogue first adjacent channels. WPOC transmitted the hybrid IBOC signal, and WMMR and WFLS served as the analogue first adjacent channels. In these tests, audio was recorded from WFLS or WMMR while the DSB portion of the hybrid signal was toggled on and off over a five-minute interval. This interval was chosen to allow evaluation of audio quality with and without DSB over a variety of programming content.

### 4.2 Test Point Locations

Using ComStudy 2.2 coverage prediction software, a map was created that shows the 74 dBu, 54 dBu, and 40 dBu contours of WPOC, and the 54 dBu and 40 dBu contours of WMMR and WFLS. Test points were chosen at the points on the 54 dBu and 40 dBu contours of the analogue first adjacent channels where the hybrid IBOC signal was believed to be strongest. Figure 17 identifies these test points.

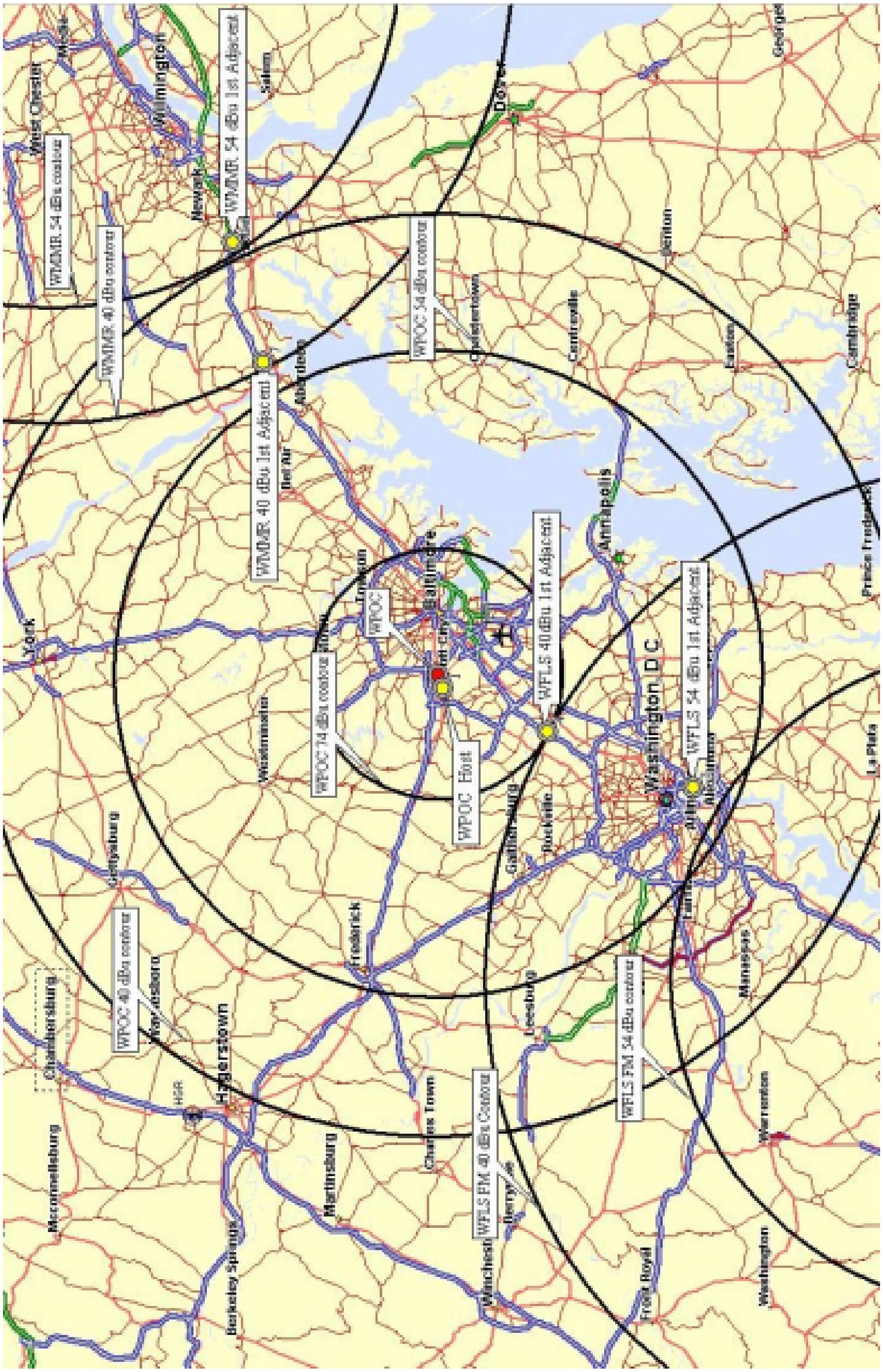



FIGURE 17

**Location of First Adjacent and Host Compatibility Test Points**

## 4.3 Test Procedure

a) Drive to the selected test location and tune the analogue receivers to the desired operating frequency. Load the recording media into the Digital Audio Recorder, set the analogue audio levels, and label the audio recording cut. Place a tape into the VCR and setup to record.

b) All notes, tapes, and data should have the same time reference, which is derived from the GPS. Be sure all clocks are synchronized.

c) Simultaneously begin recording on the VCR and Digital Audio Recorder (for all analogue receivers).

d) Coordinate with the transmitter site to begin the following five-minute test sequence:

   i) 00:00 DSB carriers ON for 15 seconds;

   ii) 00:15 DSB carriers OFF for 15 seconds;

   iii) 0:30 DSB carriers ON for 15 seconds;

   iv) 00:45 DSB carriers OFF for 15 seconds;

   v) 01:00 DSB carriers ON for 30 seconds;

   vi) 01:30 DSB carriers OFF for 30 seconds;

   vii) 02:00 DSB carriers ON for 30 seconds;

   viii) 02:30 DSB carriers OFF for 30 seconds;

   ix) 03:00 DSB carriers ON for 1 minute;

   x) 04:00 DSB carriers OFF for 1 minute.

e) Upon completion of the recording remove the recording media.

f) Repeat steps a) through e) for each test location.

## 4.4 Test Results

### 4.4.1 Analysis of Audio Performance at Test Points

#### 4.4.1.1 WMMR Results

On both receivers, at both the 40 dBu and 54 dBu contours of WMMR, there was no perceptible difference in the recorded audio upon addition or removal of DSB sidebands from WPOC. Therefore, the addition of DSB sidebands to the first adjacent analogue signal did not introduce audible degradation at this point.

#### 4.4.1.2 WFLS Results

On both receivers, at the 54 dBu contour of WFLS, there is no perceptible difference in the recorded audio upon addition or removal of DSB sidebands from WPOC. At the 40 dBu contour of WFLS, the Delco receiver does not exhibit audible degradation due to the addition of DSB sidebands to WPOC. The Yamaha receiver does exhibit audible degradation at this point. This is immaterial, however, since both receivers are already well beyond the analogue point of failure at this location before the introduction of DSB sidebands to WPOC.

### 4.4.2 Summary

This test indicates that the addition of DSB sidebands to a first adjacent interferer will not degrade the audio quality of the desired analogue signal within its listenable coverage area. This conclusion, based on measured field data, corroborates the laboratory compatibility test results, which found that the introduction of DSB sidebands to a large first adjacent interferer should be inaudible. Since the introduction of IBOC DSB to WPOC in August 1999, no listener complaints have been received.

## 5 Host Compatibility Test

### 5.1 Overview

This test demonstrates that the DSB portion of the hybrid IBOC signal does not interfere with its analogue host. In this test, analogue audio was recorded from WPOC while the DSB portion of its hybrid signal was toggled on and off over a five-minute interval. This interval was chosen to allow evaluation of audio quality with and without DSB over a variety of programming content.

### 5.2 Test Point Location

A point between one and two miles from the test transmit site was selected. This distance assures that the effects of the DSB sidebands can be accurately evaluated, without being masked by noise and interference. Figure 17 shows the location of the selected test point.

### 5.3 Test Procedure

a) Drive to the selected test location and tune the analogue receivers to the desired operating frequency. Load the recording media into the Digital Audio Recorder, set the analogue audio levels, and label the audio recording cut. Place a tape into the VCR and setup to record.

b) All notes, tapes, and data should have the same time reference, which is derived from the GPS. Be sure all clocks are synchronized.

c) Simultaneously begin recording on the VCR and Digital Audio Recorder (for all analogue receivers).

d) Coordinate with the transmitter site to begin the following five-minute test sequence:

   i) 00:00 DSB carriers ON for 15 seconds;

   ii) 00:15 DSB carriers OFF for 15 seconds;

   iii) 00:30 DSB carriers ON for 15 seconds;

   iv) 00:45 DSB carriers OFF for 15 seconds;

   v) 01:00 DSB carriers ON for 30 seconds;

   vi) 01:30 DSB carriers OFF for 30 seconds;

   vii) 02:00 DSB carriers ON for 30 seconds;

   viii) 02:30 DSB carriers OFF for 30 seconds;

   ix) 03:00 DSB carriers ON for 1 minute;

   x) 04:00 DSB carriers OFF for 1 minute.

e) Upon completion of the recording remove the recording media.

### 5.4 Test Results

On all three receivers, there was no perceptible difference in the recorded audio upon addition or removal of DSB sidebands from WPOC. Since the addition of DSB was not audible in such a clean, high-signal, interference-free environment, it will certainly not degrade the host signal in most listening environments. This conclusion, based on measured field data, corroborates the laboratory compatibility test results, which also found that the introduction of baseline DSB had no audible effect on the analogue host.

## 6 Field Test Summary

These field test results demonstrate the superior performance of the Digital System C in a real-world environment, and have validated the results of extensive simulations and laboratory performance tests. The Digital Coverage test illustrated that the DSB audio quality exceeded that of an existing analogue FM signal, and showed that IBOC DSB offers coverage comparable to existing analogue service. The First Adjacent Compatibility test verified that the DSB signal does not interfere with the reception of its first adjacent analogue FM neighbours. The Host Compatibility test showed that the digital portion of the hybrid IBOC DSB signal does not interfere with its analogue host.