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ENGINEERING REPORT
EVALUATION OF THE USE OF SEPARATE TRANSMITTING ANTENNAS FOR IN-BAND-ON-CHANNEL DIGITAL AND ANALOG FM BROADCASTING
PREPARED FOR THE NATIONAL ASSOCIATION OF BROADCASTERS

Table of Contents

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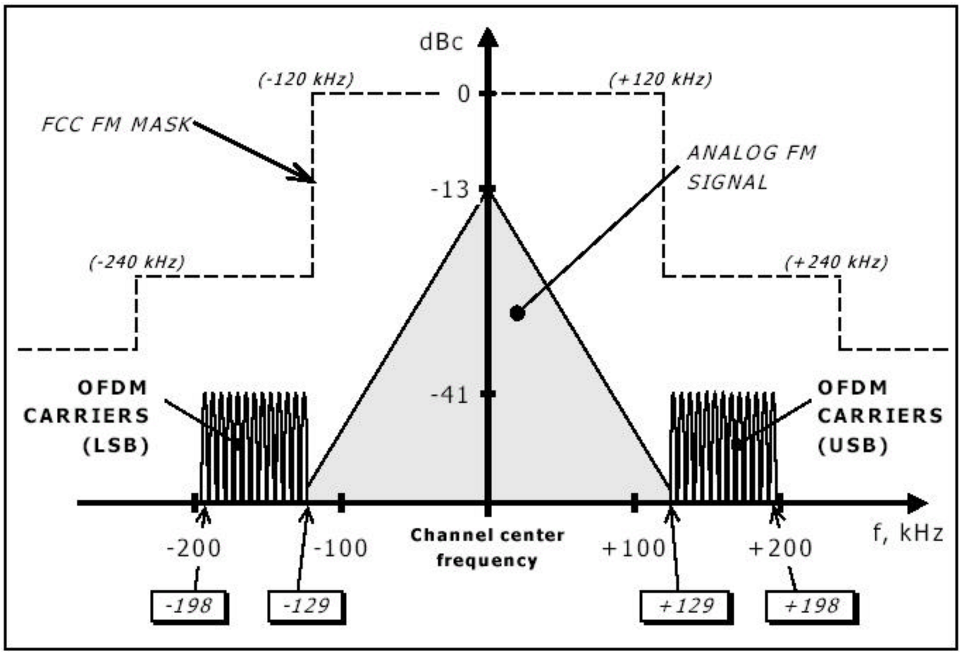
ENGINEERING STATEMENT

INTRODUCTION

This engineering report has been prepared on behalf of the National Association of Broadcasters (NAB) to detail the results of a study evaluating the use of separate transmitting antennas for FM In-Band-On-Channel (IBOC) digital transmissions and host analog transmissions. In October 2002, the Federal Communications Commission, in Mass Media Docket Number 99-325, adopted iBiquity Digital Corporation's (iBiquity) IBOC transmission system for AM and FM broadcasting. iBiquity's IBOC system makes use of underutilized spectrum in the broadcast transmission channel for IBOC digital signals. The FM IBOC hybrid analog and digital transmission channel is characterized in the following figure.



Due to the linearity required for the transmitter amplification of IBOC digital transmissions, most FM broadcast stations will require an additional transmitter to implement IBOC. The upper and lower sideband digital carriers from the IBOC transmitter must be combined with the signal from the analog transmitter to form the hybrid signal. Typically, the joining of the IBOC and analog signals would be done using a signal combining system. Signal combining systems with low electrical losses typically require more physical space and have significantly higher costs. The simpler 10-dB hybrid combining system used for many IBOC test operations requires the use of an IBOC transmitter with an additional 10 dB of output power. Additionally, an analog transmitter overhead of about 0.5 dB is required to compensate for combiner losses. This additional power from the analog and digital transmitters is dissipated into a reject load as part of the combining process.

As an alternative to high-level combining, it is possible to use the isolation afforded by separate transmitting antennas to combine the analog and IBOC signals. For financial and operational reasons, some stations are considering using the separate transmitting antenna combining approach for their initial IBOC operations. In some cases this would facilitate the early transition to IBOC at a lower cost. For example, this would allow some stations with established auxiliary facilities, collocated with their main transmission facility, to utilize their auxiliary system for IBOC transmissions. However, concern has been raised that the use of separate antenna systems may create conditions where the IBOC signal interferes with the host analog station or that IBOC coverage will be substantially reduced by the use of separate antennas.

To address concerns pertaining to the use of separate antennas for IBOC, NAB established an *ad hoc* technical group comprised of broadcasters, manufacturers and FCC staff. It is under the direction of this *ad hoc* technical group that the separate antenna test program was developed. The tests summarized herein compare the IBOC-to-analog received power levels for separate and combined antennas operations.

TEST STATIONS

The NAB *ad hoc* technical group established criteria for separate antenna IBOC operations that could be routinely approved by the FCC. These criteria include:

1) The IBOC transmissions will utilize a licensed auxiliary antenna and must be located within three seconds of latitude or longitude of the main analog facility.

2) The height of the IBOC antenna will be between 70 percent and 100 percent of the height above average terrain (HAAT) of the main analog antenna.

Three FM stations that have main and auxiliary facilities meeting the tentative criteria were available for conducting tests of IBOC operations using separate antennas. These include WDHA-FM, Dover, New Jersey; WMGC-

FM, Detroit, Michigan; and KDFC-FM, San Francisco, California. Details of the main and auxiliary facilities for these stations are included in the following table.

Station, Channel, And Facility	FCC File Number	Antenna Make, Model Number, and (Number of Sections)	Analog ERP (kW)	IBOC Digital ERP (Watts)	Antenna HAAT (Meters)	Antenna HAMSL (Meters)
WDHA-FM 288A						
Main	BLH-19990726KC	ERI, SHPX-1AE (1)	0.98	9.8	175	354
Auxiliary	BXLH-20020920ABT	ERI, LPX-1E (1)	1.00	9.8	171	350
WMGC-FM 286B						
Main	BLH-19990708KD	ERI, COG-1083-2CA (2)	13.5	135	291	490
Auxiliary	BLH-19990708KE	SHPX-2AE (2)	16.5	135	228	427
KDFC-FM 271B						
Main	BLH-19940914KA	ERI, G5CPS-4AE (4)	33.0	330	319	386
Auxiliary	BLH-19900604KB	ERI, SHPX 2AC (2)	16.0	330	294	355

Experimental authority from the FCC was obtained to operate these stations using two modes of operation. The first mode was for a combined IBOC/analog operation using the main antenna. The second mode permitted IBOC operations using the auxiliary antenna while analog operations utilized the main antenna. The FCC File Numbers associated with the experimental authorities for these stations are as follows.

Station	FCC File Number
WDHA-FM	BSTA-20030129AMU
WMGC-FM	BSTA-20030129AMV
KDFC-FM	BSTA-20030129AMW

Each of the three test stations has characteristics that present different conditions for the separate antenna testing of IBOC signals. WDHA-FM is a relatively low powered Class A station located in an area of varying terrain. The WDHA-FM IBOC digital ERP employed for the tests was only 9.8 Watts. Additionally, WDHA-FM is terrain limited to the west as shown by the Longley-Rice propagation study included as Page 1 of Appendix A2. In contrast, WMGC-FM is a Class B station located on a tall tower in an area of relatively flat terrain providing close to ideal propagation conditions. Lastly, KDFC-FM is a Class B station located in San Francisco, which is characterized by area of both mountainous and flat terrain. Additionally, the KDFC-FM auxiliary antenna is not located on the same supporting structure as the main antenna, but rather on a nearby shorter supporting structure at the same communications site.

MEASUREMENT PROCEDURE

As described in the Test Procedures of Appendix A1 of this report, mobile received power measurements were made on each test station using the combined and separate modes of IBOC operation. For each station, measurements were made along four radial routes extending away from the station. Three of these routes extended 10 miles from the station and one radial extended up to 40 miles from the station depending on the received power levels of the IBOC sidebands.

The two mobile test vehicles used in the study were similarly equipped and were provided by iBiquity. These vehicles have seen extensive use for this type of data collection. Pictures of the Warren, New Jersey, test vehicle used for measurements on WDHA-FM are included as Figures 14 and 15 of Exhibit 4 of this report.

The data collection system consisted of a roof-mounted, 31-inch, vertically polarized antenna connected to the input of a Hewlett Packard, model 8591E, spectrum analyzer. The spectrum analyzer was controlled by a personal computer using custom data collection software developed by iBiquity. The data collection software controlled all of the settings of the spectrum analyzer and was configured to extract and to save the data points corresponding to the spectrum analyzer trace at 1.5-second intervals. Along with these data, the software recorded the latitude and longitude position of the vehicle from a Global Positioning System (GPS) receiver. Other than the reference level, the spectrum analyzer settings remained constant during the measurements. These settings include of a span of 500 kilohertz (kHz), a resolution bandwidth (RBW) of 10 kHz, and a video bandwidth (VBW) of 3 kHz. The spectrum analyzer center frequency was set to correspond to the station frequency. As necessary, the spectrum analyzer reference level was adjusted through the data collection software to provide adequate signal resolution.

Prior to field measurement for the combined antenna case, the ratio of the IBOC-to-analog power at the output of the combiner was adjusted nominally to -20 dB using a procedure developed by iBiquity. Under this procedure, the input of the spectrum analyzer is connected to the transmission line power sample point located between the combiner and the antenna. Using the spectrum analyzer, two measurements are made of the total analog power level averaged over 100 traces. Measurement of the IBOC sidebands is made using the noise marker feature of the spectrum analyzer with the marker centered on the upper and lower sidebands and averaged over 50 traces. The noise marker measurements, which have units of dBm/Hertz, are converted to linear units and multiplied by the width of the IBOC sideband of 69 kHz to determine the total sideband energy. The energy in the upper and lower sidebands is added together to get the total IBOC power. The ratio of this power to the analog total power is the IBOC-to-analog power ratio. Copies of the spectrum analyzer plots for these power measurements are included in Appendix B of this report.

For the separate antenna measurements, the IBOC ERP was set 20 dB below the main antenna ERP by using different techniques depending on the station being measured. For WDHA-FM, 40 dB of attenuation was applied to the output of the IBOC transmitter to permit measurement of the transmitter output power on a Boonton, model 4532, RF power meter. Accounting for the attenuation, the transmitter output power was set to 24 watts. Transmission system losses and antenna gain resulted in an IBOC ERP of 9.8 watts. For WMGC-FM, a power meter was used to calibrate of the front panel display on the Harris, model Z10 CD, IBOC FM transmitter. Accounting for transmission system losses and antenna gain, an IBOC ERP of 135 watts was achieved with a transmitter output power of 180 watts. Due to the higher IBOC transmitter output power needed for KDFC-FM, adequate attenuator components were not available to directly measure the IBOC power level. Instead, an initial setting of the IBOC transmitter power was made and a field location was selected to confirm the ratio using the test vehicle antenna and the same measurement technique used for the combined antenna setup. The test point is located on a hilltop 3.5 miles northwest of the transmitter site with clear line-of-sight to the KDFC-FM antennas.

Depending on technical capabilities and available time, additional spectrum analyzer plots were taken to characterize the occupied bandwith of the analog and IBOC transmissions. Copies of these spectrum analyzer plots are included in Appendix B of this report.

DATA ANALYSIS

The measured data collected for each station was post-processed and graphically analyzed using spreadsheet software. For each data point, an analysis of the IBOC signal levels was made to determine if any locations existed where the margin of the IBOC sideband energy to the noise floor was less than 6 dB. An inadequate signal-to-noise margin will result in the calculated IBOC-to-analog ratio being artificially increased as the noise floor contributes to the IBOC signal levels. To minimize the potential for error, these data points were removed from analysis. Additionally, data points were removed where geographic coordinate data were not properly recorded from the GPS receiver. Overall, one percent of the 23,204 collected data points were removed due to an inadequate signal-to-noise margin. Approximately, four percent of the data points were removed due to bad GPS data. Most of the GPS data problems occurred due to a communication problem with the GPS receiver experienced while measuring the KDFC-FM southwest radial in the combined mode. Despite the GPS communication problems experienced on this route, over 1,900 valid data points remained for use in the analysis.

For the remaining data points, the upper and lower IBOC sideband power was added to determine the total IBOC received power level. The analog power level at each point was then subtracted from the IBOC received power level at each point, producing an instantaneous IBOC-to-analog power ratio. A moving median of 10 sample points was also calculated for each radial. The distance from the transmitter was averaged for the 10 sample points contributing to each median calculation. In all cases where calculations were made on logarithmic values expressed in dB, conversion to linear values was first performed. The resulting values were then converted back to logarithmic values.

Plots of the measured IBOC-to-analog power ratios have been prepared for each radial and are included herein as Exhibit 1 of this report. For each radial, three plots have been prepared. The first two plots show the IBOC-to-analog power ratio versus distance for the combined and separate antenna operations respectively. Each of these plots includes the instantaneous and median IBOC-to-analog power ratios. Additionally, these first two plots include the received analog and IBOC power levels. For comparison purposes, the last plot shows both the median IBOC-to-analog power ratios for the combined and separate antenna operations. A discussion of the analysis for each station follows.

<u>WDHA-FM</u>

As shown in the photograph of Figure 1, Exhibit 4, of this report, WDHA-FM employs two similar rototiller antennas for it's main and auxiliary operations. With only the WDHA-FM analog facility operating into the main antenna, the isolation between the antennas was measured using a power meter connected to the input of the transmission line for the auxiliary antenna. Compensating for transmission line losses the antenna isolation was determined to be 56.7 dB.

With an IBOC ERP of only 9.8 Watts, WDHA-FM has the lowest ERP of all of the test stations. This low ERP resulted in difficulty overcoming interference from adjacent channel stations. Increases in the IBOC-to-analog power ratio seen particularly on the southwest radial are due to interference from first adjacent channel station WDAS-FM, channel 287B, Philadelphia, Pennsylvania. The presence of energy from a first adjacent channel station combined with weak IBOC signal levels results in artificially higher IBOC-to-analog power ratios. However, this effect is evident in the graphs for both the combined and separate antenna operations indicating that it is not the result of differences in the transmitting antenna systems.

Additionally, some difficulty was experienced when setting the IBOC-to-analog power ratio at the transmitter site. This likely explains the slightly lower shift in the IBOC-to-analog power ratio data for the separate antenna case. However, the trend of the data along the radials does not indicate significant departures in the analog-to-IBOC ratio.

WMGC-FM

WMGC-FM employs a 2-bay cogwheel style panel antenna for its main antenna (Exhibit 4, Figure 4) and a 2-bay side mounted rototiller antenna for its auxiliary antenna (Exhibit 4, Figure 5). With only the WMGC-FM analog facility operating into the main antenna, the isolation between the antennas was measured using a spectrum analyzer connected to the transmission line sample port for the for the auxiliary antenna system. Compensating for transmission line losses the antenna isolation was determined to be 69.8 dB.

The measurement data for WMGC-FM highlights the potential differences resulting from antenna mounting configurations. While both the main and auxiliary transmitting antennas are theoretically nondirectional, the side mounted configuration of the auxiliary antenna results in suppression in the horizontal plane northwest of the transmitter site. Thus, as is evident in the graph of Page 24, Exhibit 1 of this report, the IBOC-to-analog ratio in this direction is approximately 10 dB below the ratio for the combined antenna. While this does not pose an interference threat to the analog operation, it may limit IBOC coverage in this direction.

The data for WMGC-FM also includes examples of deviations in the IBOC-to-analog power ratio due to differences in the vertical plane radiation of the main and auxiliary antennas. This is particularly evident on the graphs of pages 15 and 21, of Exhibit 1 of this report. However, these departures in the IBOC-to-analog power ratio are not likely to have any significant impact since they are isolated to areas very close to the WMGC-FM transmitter site. No impact to the host analog signal was noted.

KDFC-FM

The KDFC-FM transmitter is located at the Beacon Hill communications site on Wolfback Ridge. The KDFC-FM auxiliary antenna (Exhibit 4, Figure 11) is located on a shorter structure adjacent to the main KDFC-FM antenna supporting structure (Exhibit 4, Figure 10). With only the KDFC-FM analog facility operating into the main antenna, the isolation between the antennas was measured using a spectrum analyzer connected to the auxiliary antenna system transmission line via a 30 dB attenuator. Compensating for transmission line losses the antenna isolation was determined to be 54.8 dB.

A comparison of the IBOC-to-analog power ratio for the combined and separate antenna tests shows good correlation of the ratios for the southeast and southern routes as shown in pages 30 and 33 respectively of Exhibit 1 of this report. On the northern and northwestern routes, the effect of terrain and the difference in the antenna radiation center heights of the main and auxiliary antennas results in grazing or obstructed paths from the KDFC-FM transmitter site. This was verified by a terrain shadow study which indicates increased terrain obstructions along these routes, particularly at the lower radiation center of the auxiliary antenna. This affect may be compounded by reflections of the IBOC signal radiated from the KDFC-FM auxiliary antenna off the taller supporting structures located at the site.

Like WMGC-FM, the KDFC-FM data illustrates some departures in the IBOC-to-analog power ratio close to the KDFC-FM transmitter. This was particularly evident near the starting location for the measurement routes. At this location the IBOC-to-analog power ratio was close to 0 dB. Like WMGC-FM, these significant departures in the IBOC-to-analog power ratio are at locations very close to the KDFC-FM transmitter site and are not likely to significantly impact analog service. No impact to the host analog signal was noted.

For KDFC-FM data on IBOC system performance was collected from an IBOC test receiver. This data provides information on the digital performance of the IBOC system for both the combined and separate antenna modes of operation. The maps of Exhibit 2 of this report illustrate graphically the locations where the IBOC digital signal was received in green and locations where the IBOC receiver blended to analog in yellow. The route data for the separate antenna case has been intentionally displaced geographically from the combined antenna case on the same map for ease of analysis. An indication on the maps that the IBOC receiver has blended to analog does not necessarily indicate that a useable analog signal was available but does indicate that a useable IBOC digital signal was not available. The maps illustrate that IBOC digital coverage is essentially the same for the combined and separate antenna cases for most of the KDFC-FM routes. However, data for the northwest route, where limited line-of-sight propagation conditions exists, illustrates the potential impact of using an auxiliary antenna at a lower antenna height on IBOC performance. Along this route the percentage of time an IBOC digital signal could be received was reduced from 75.0 percent for the combined antenna operation to 65.7 percent for the separate antenna operation.

SUMMARY

In order to evaluate the potential use of auxiliary antennas for IBOC transmissions, this study collected measured data for IBOC and analog operations using combined and separate antenna operations for three stations with auxiliary antenna systems that meet the *ad hoc* technical group's tentative criteria. Specifically, this study examined the impact of IBOC separate antenna transmissions on the ratio of the IBOC-to-analog signals. While there are many examples herein showing close correlation of the resulting IBOC-to-analog ratio between combined antenna and separate antenna operations, the collected data also illustrates certain conditions where this ratio may be impacted.

One of these conditions results from the differences in vertical plane directivity of the main and auxiliary transmitting antennas. Due to these differences, the IBOC-to-analog ratio can deviate substantially at locations close to the transmitter site. Generally, this results in locations where the power ratio was substantially reduced. . This is evident from the data collected on WMGC-FM and KDFC-FM, where for certain routes, the IBOC-to-analog ratio approached 0 dB within one mile of the transmitter site.

Differences in the "real world" horizontal directivity of the main and auxiliary transmitting antennas can also impact the IBOC-to-analog ratio. While a side-mounted nondirectional transmitting antenna is considered nondirectional for regulatory purposes, the mounting arrangement of the antenna can affect the horizontal directivity of the antenna. Test data for the WMGC-FM northwest radial illustrates the potential impact of using a side-mounted auxiliary antenna for IBOC transmissions. For the northwest route, the WMGC-FM auxiliary antenna mounting arrangement results in IBOC signals that are approximately 10 dB weaker than for the combined antenna case.

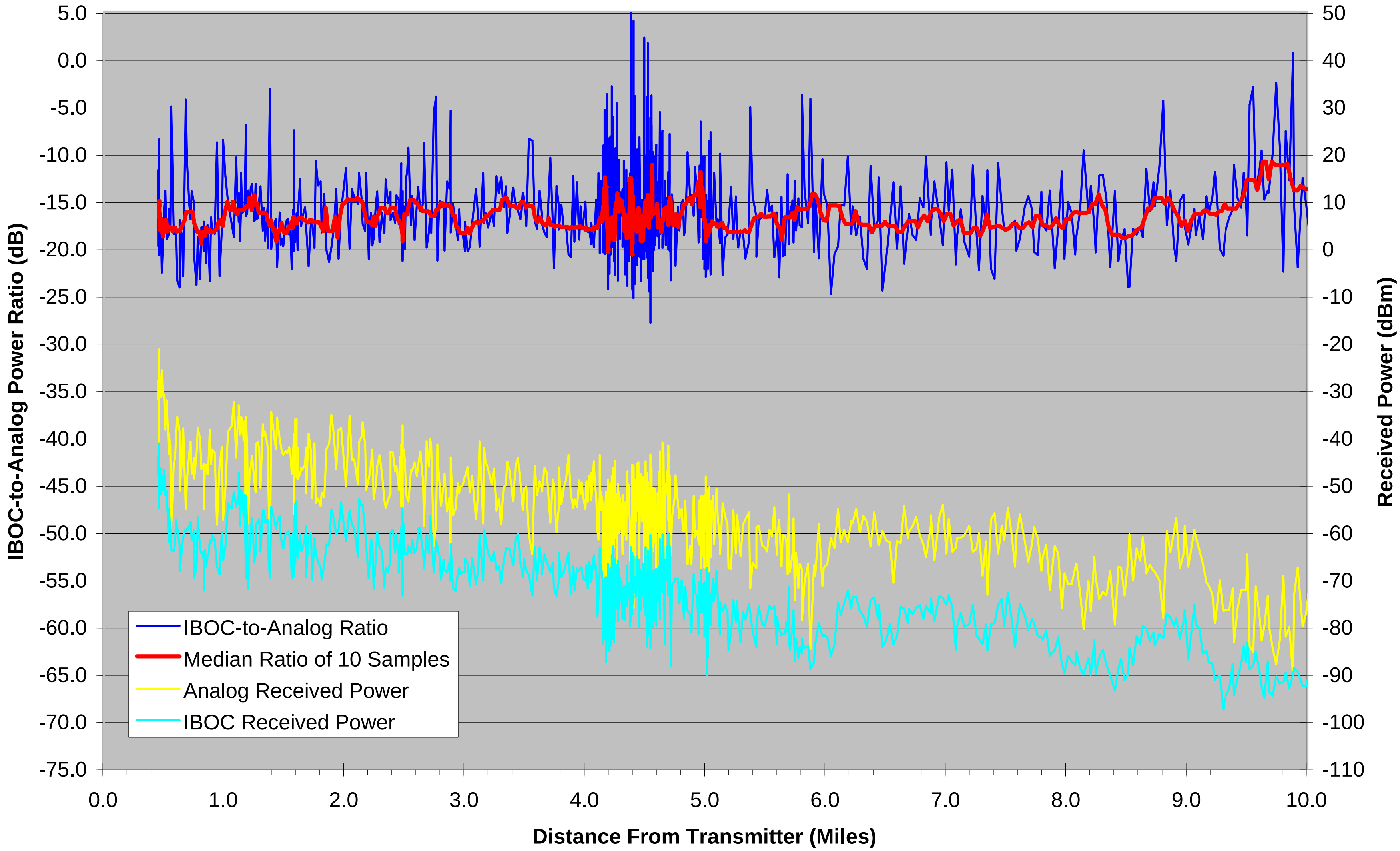
A combination of factors can also impact the ratio of the IBOC-to-analog signals. This is particularly evident under conditions where terrain or other obstacles may limit line-of-sight propagation conditions. IBOC performance data collected for the northwest route of KDFC-FM illustrates the potential combined impact from the reduced auxiliary antenna height and signal interactions with other nearby taller structures at the site. Along this route, the use of the KDFC-FM auxiliary antenna reduced the percentage of times an IBOC digital signal could be received by 9.3 percent.

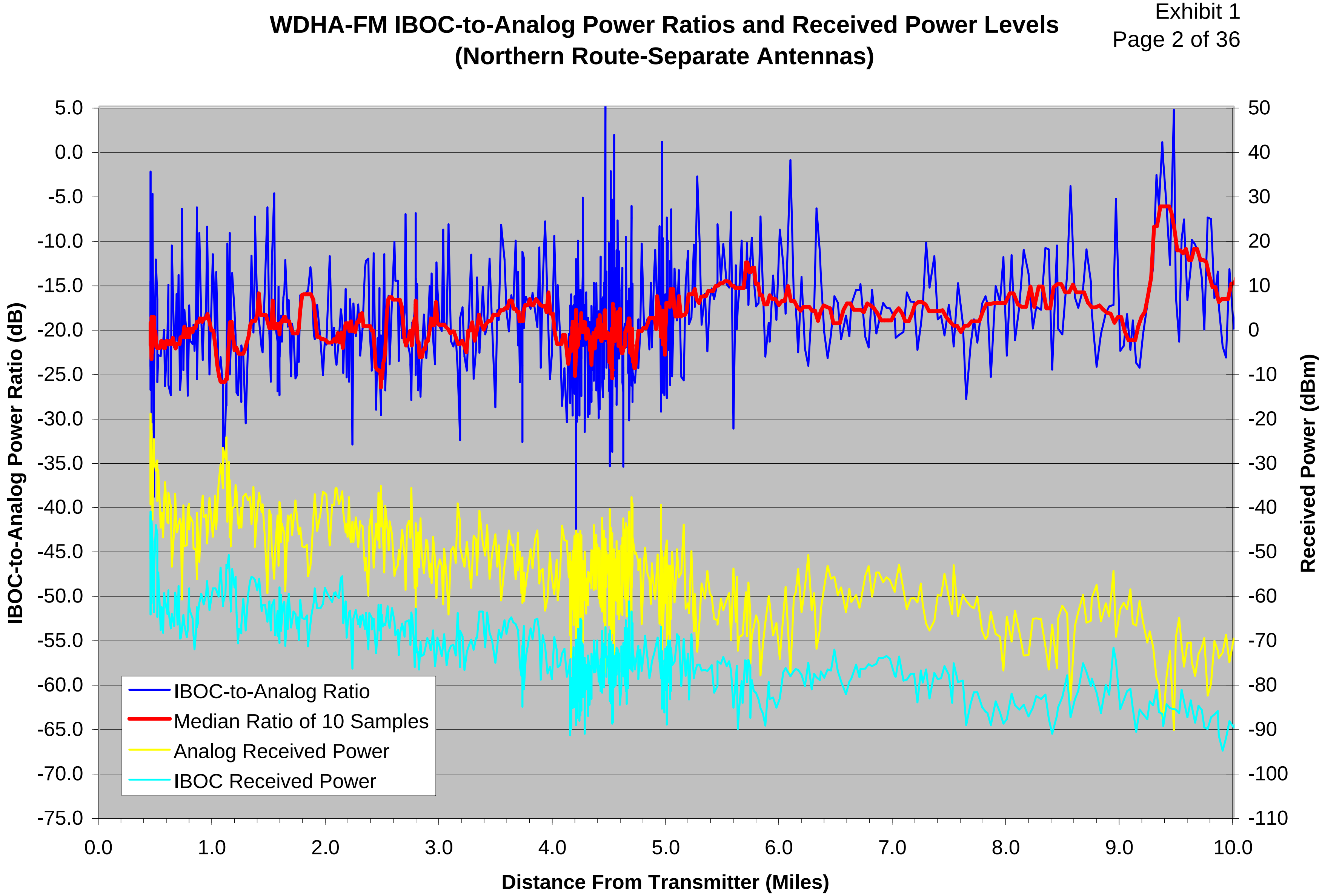
KDFC-FM IBOC performance data for the three remaining KDFC-FM routes appears to be unaffected by these factors. For each of these routes, the IBOC digital signal is receivable at least 98 percent of the time when the KDFC-FM auxiliary antenna is used for IBOC transmissions. This essentially equals the availability of the IBOC digital signal that results when the KDFC-FM antenna is used in the combined antenna mode.

Alan R. Rosner, P.E.

May 28, 2003

WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northern Route-Combined Antennas)




WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northern Route-Separate Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0.0
1.0
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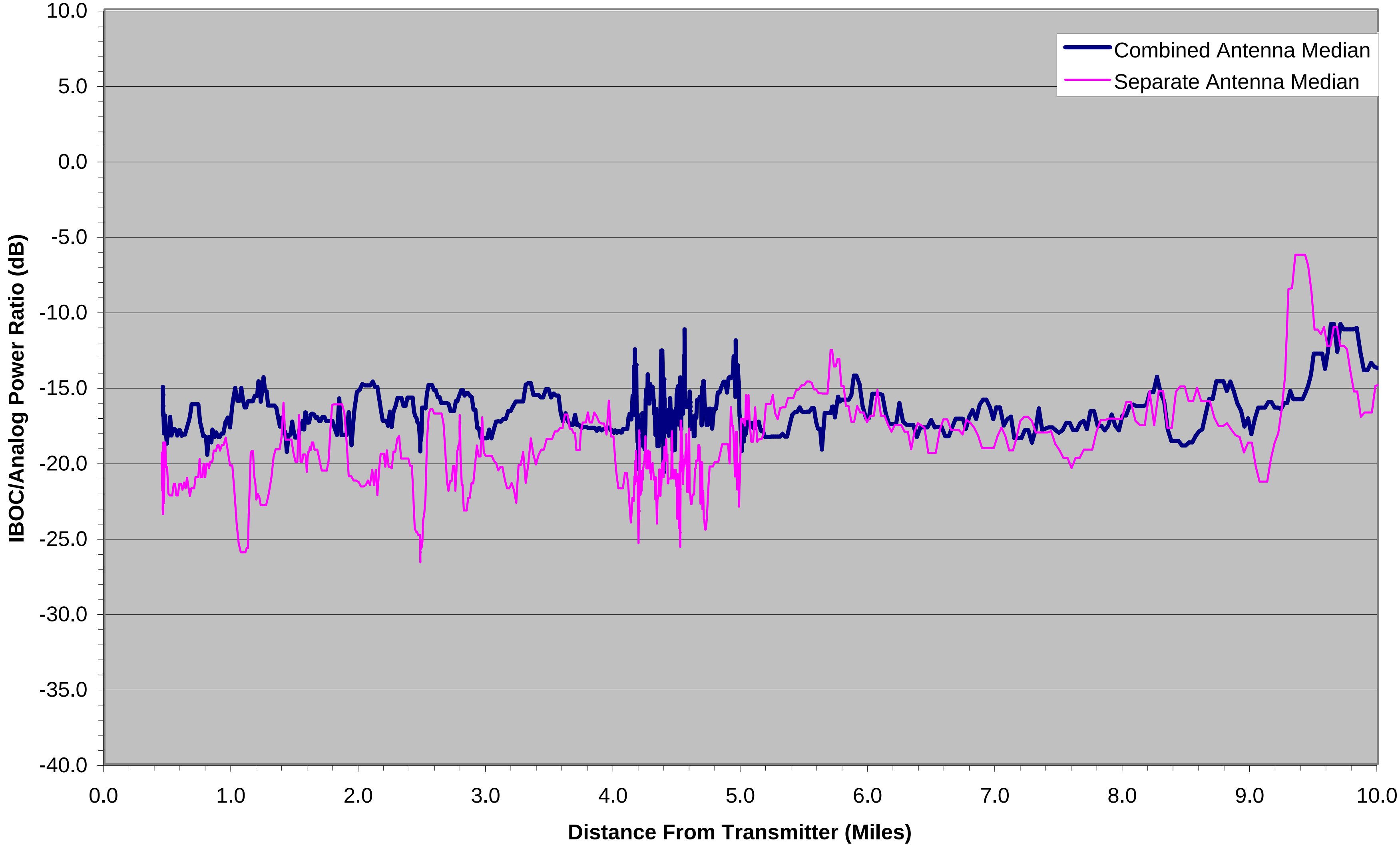
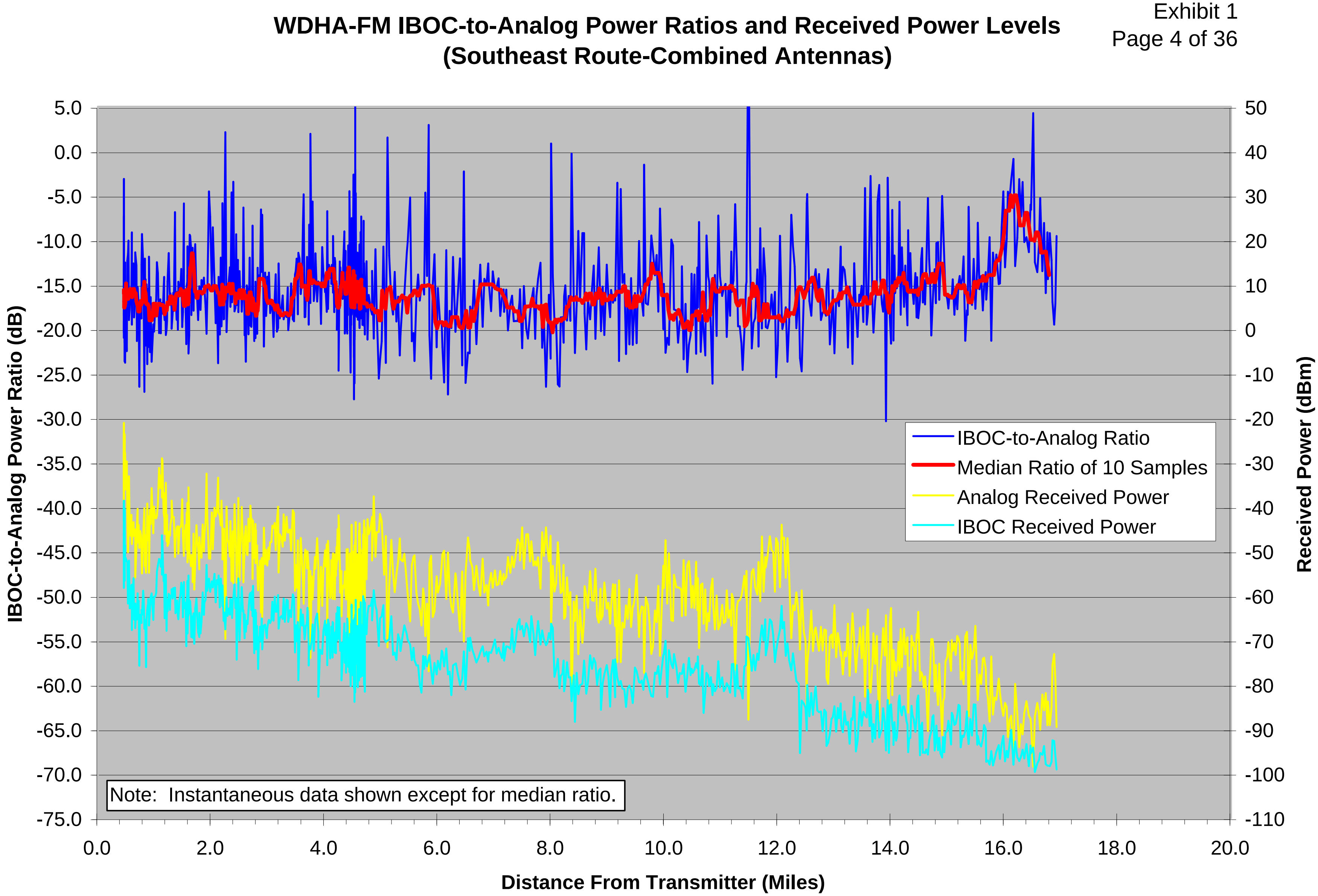
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

WDHA-FM Median IBOC-to-Analog Power Ratios (Northern Route)




WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southeast Route-Combined Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
50
40
30
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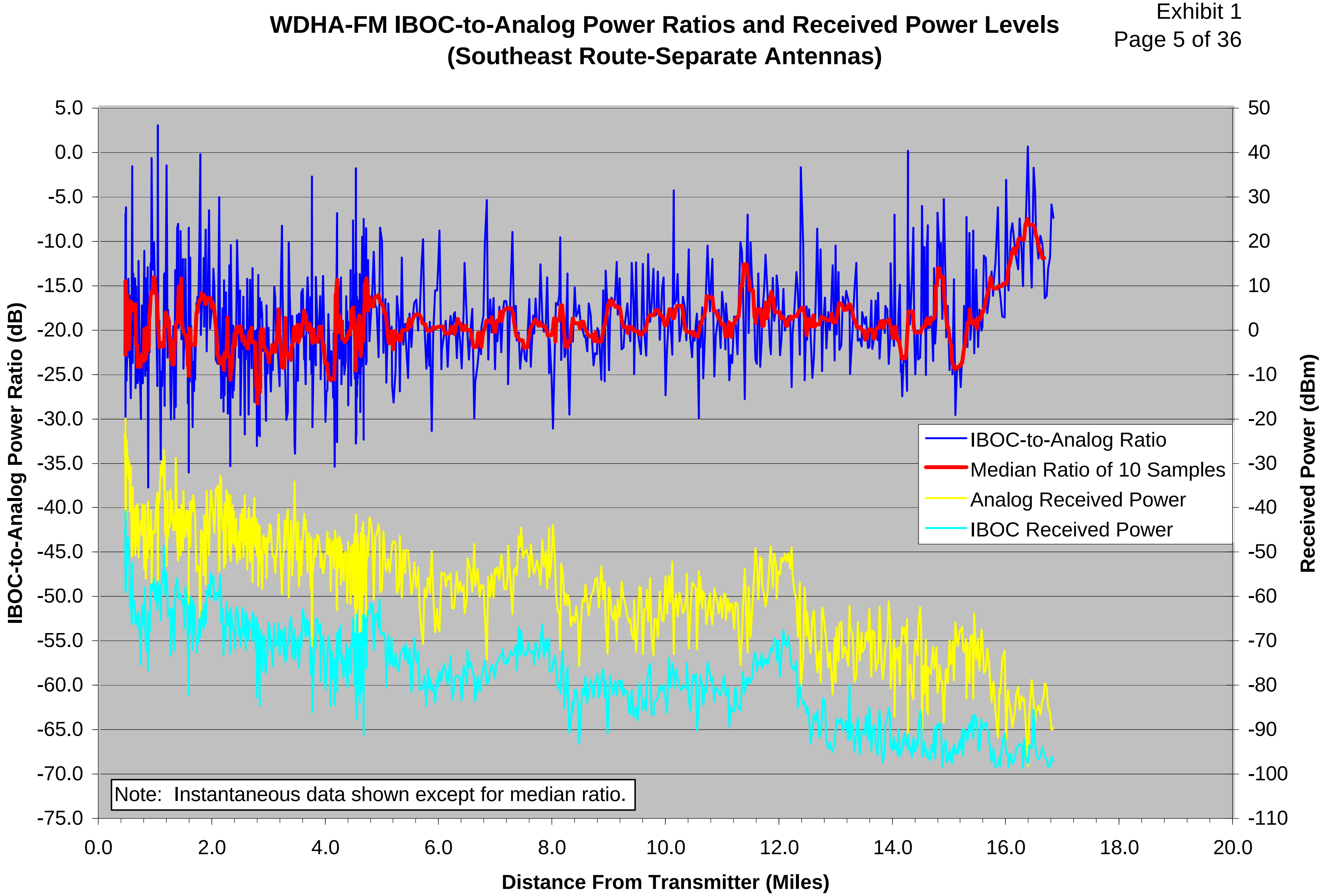
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.


WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southeast Route-Separate Antennas)
IBOC-to-Analog Power Ratio (dB)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
Received Power (dBm)
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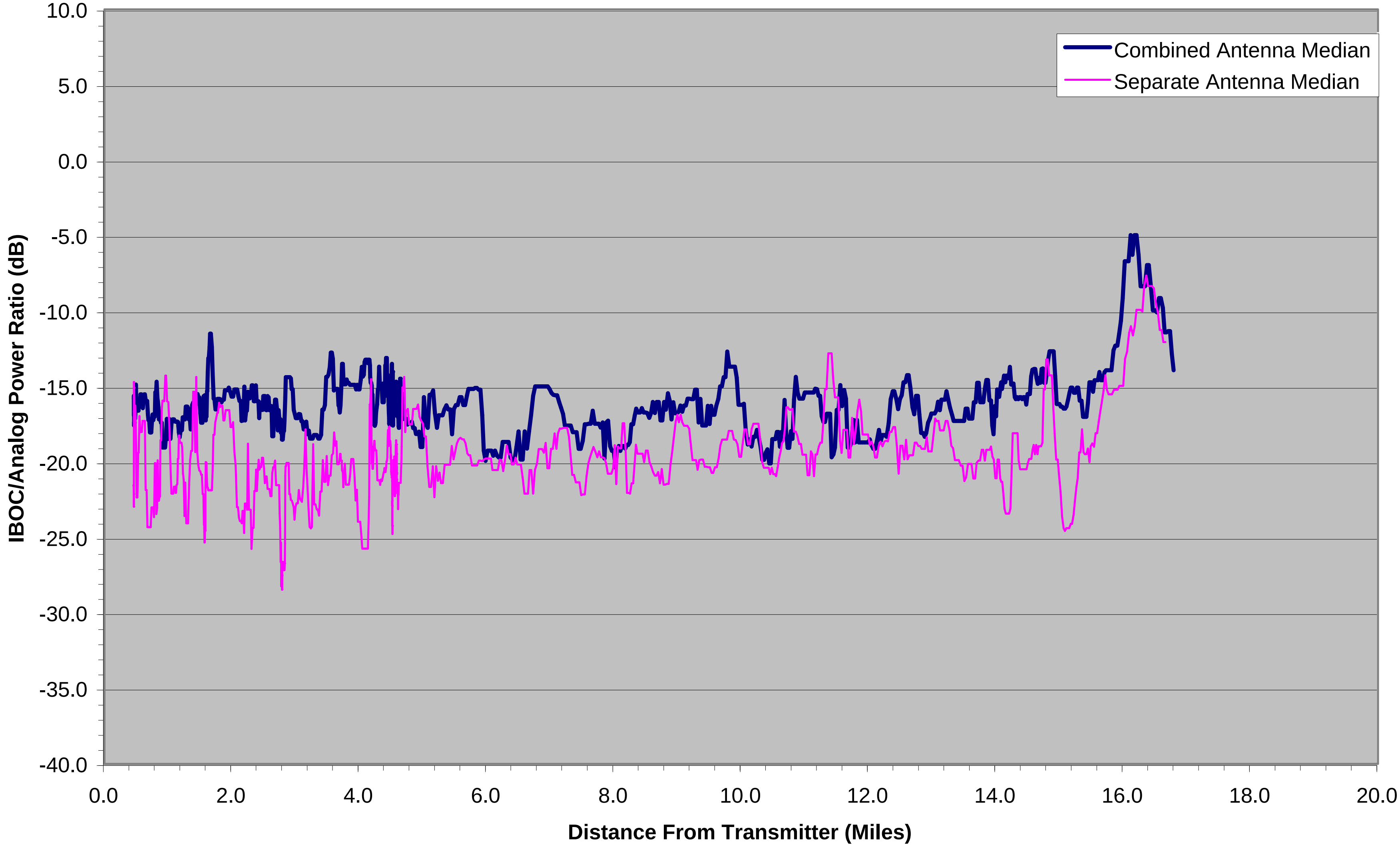
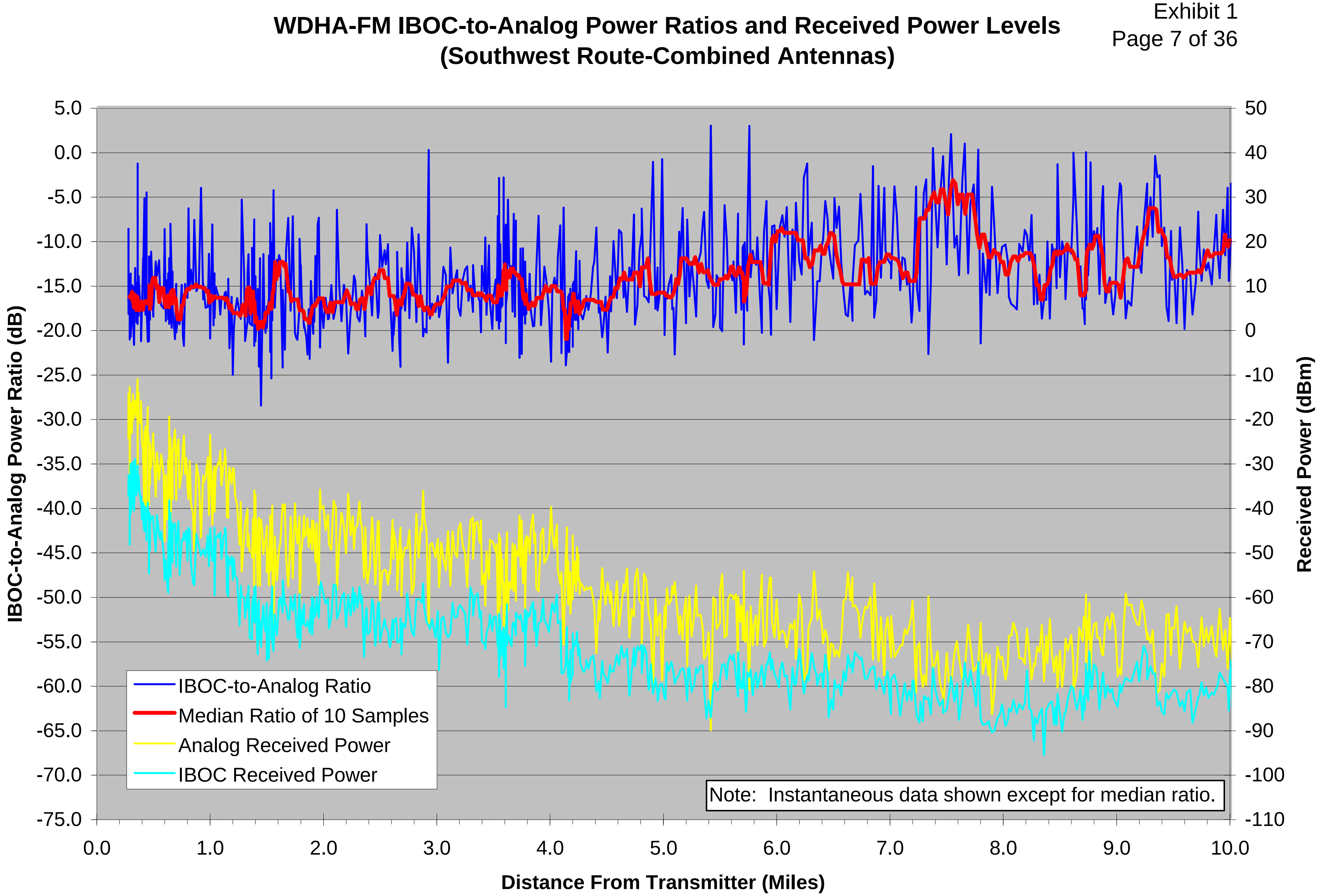
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Distance From Transmitter (Miles)

WDHA-FM Median IBOC-to-Analog Power Ratios (Southeast Route)




WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southwest Route-Combined Antennas)
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-60.0
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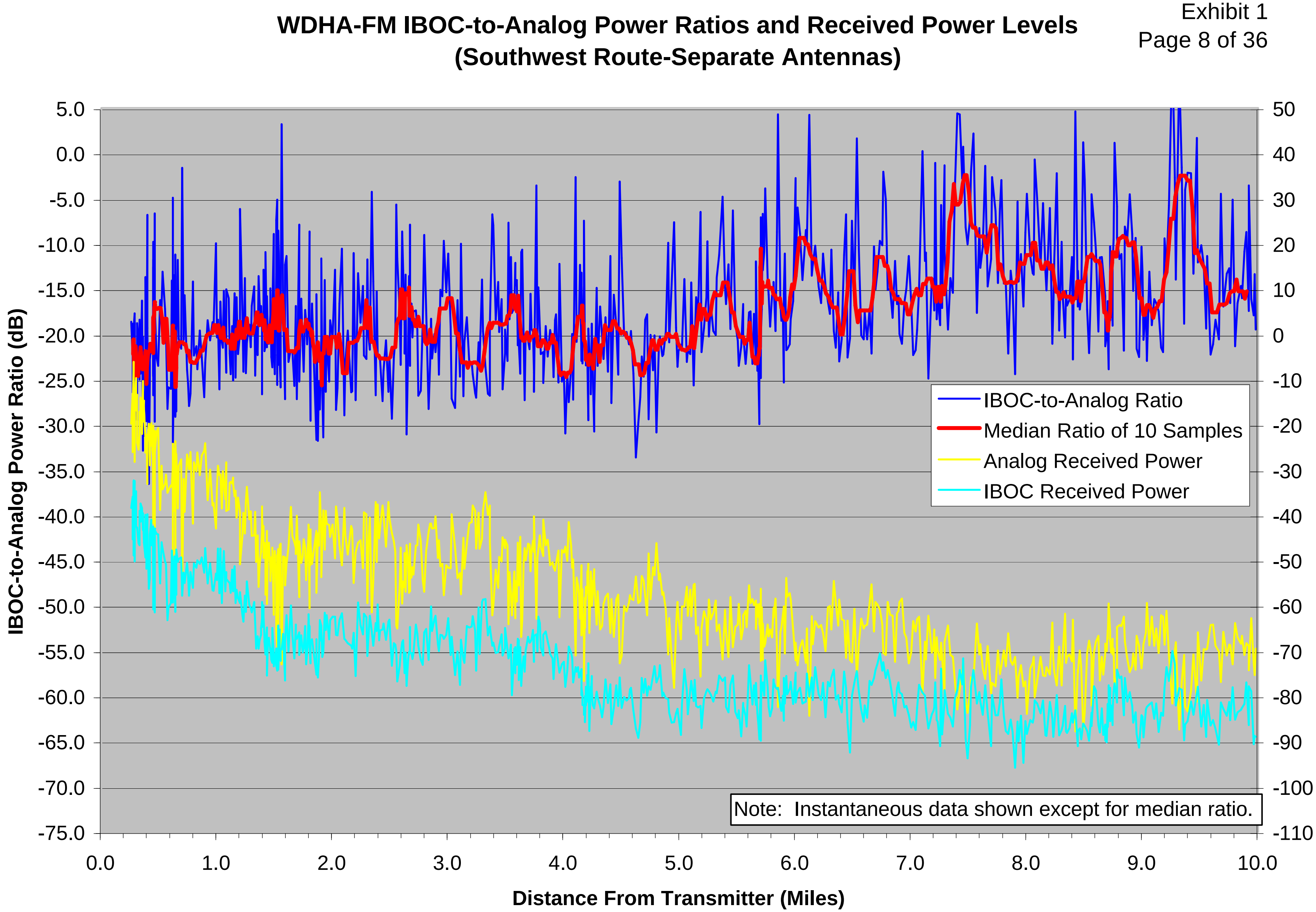
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.


WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southwest Route-Separate Antennas)
IBOC-to-Analog Power Ratio (dB)
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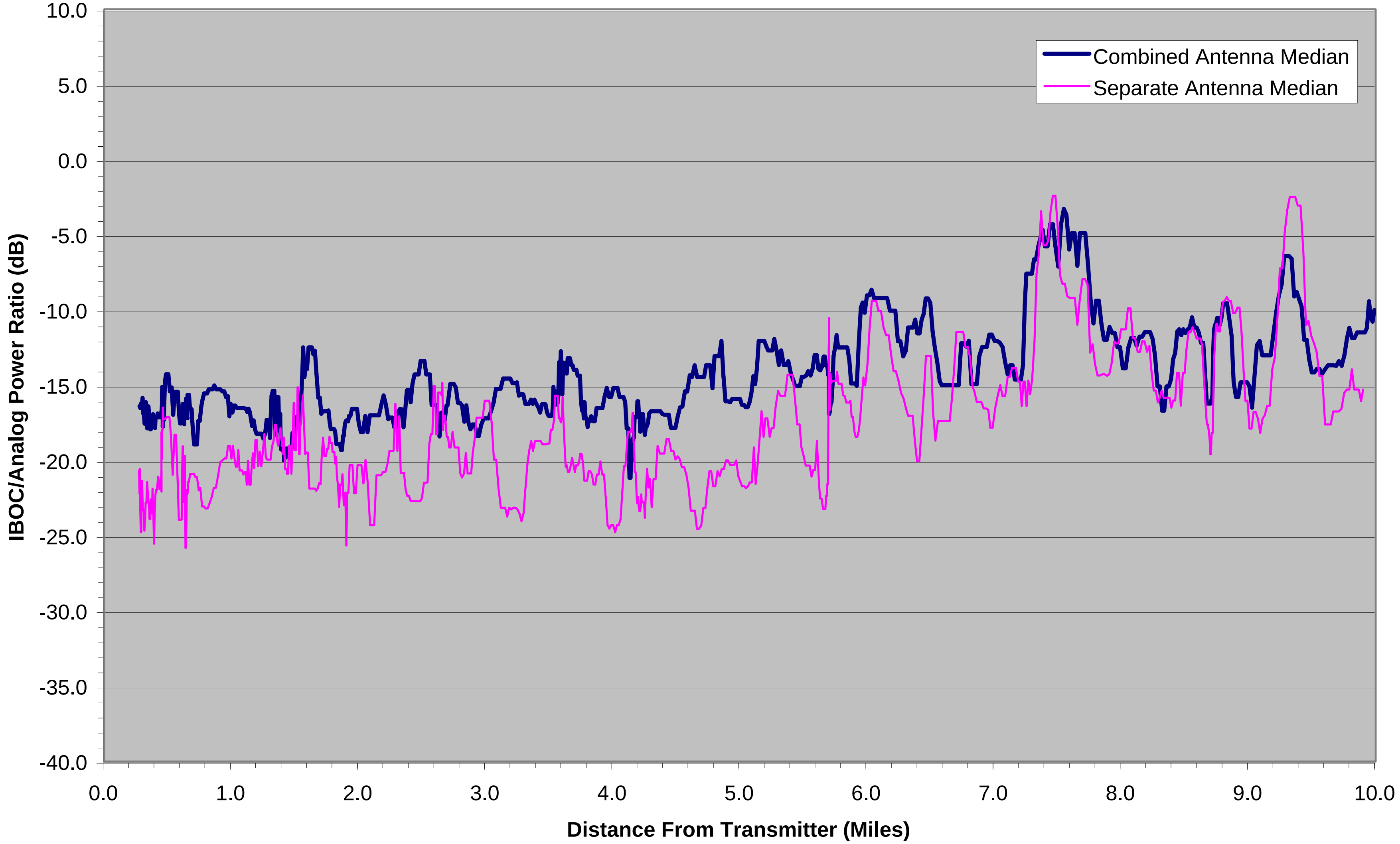
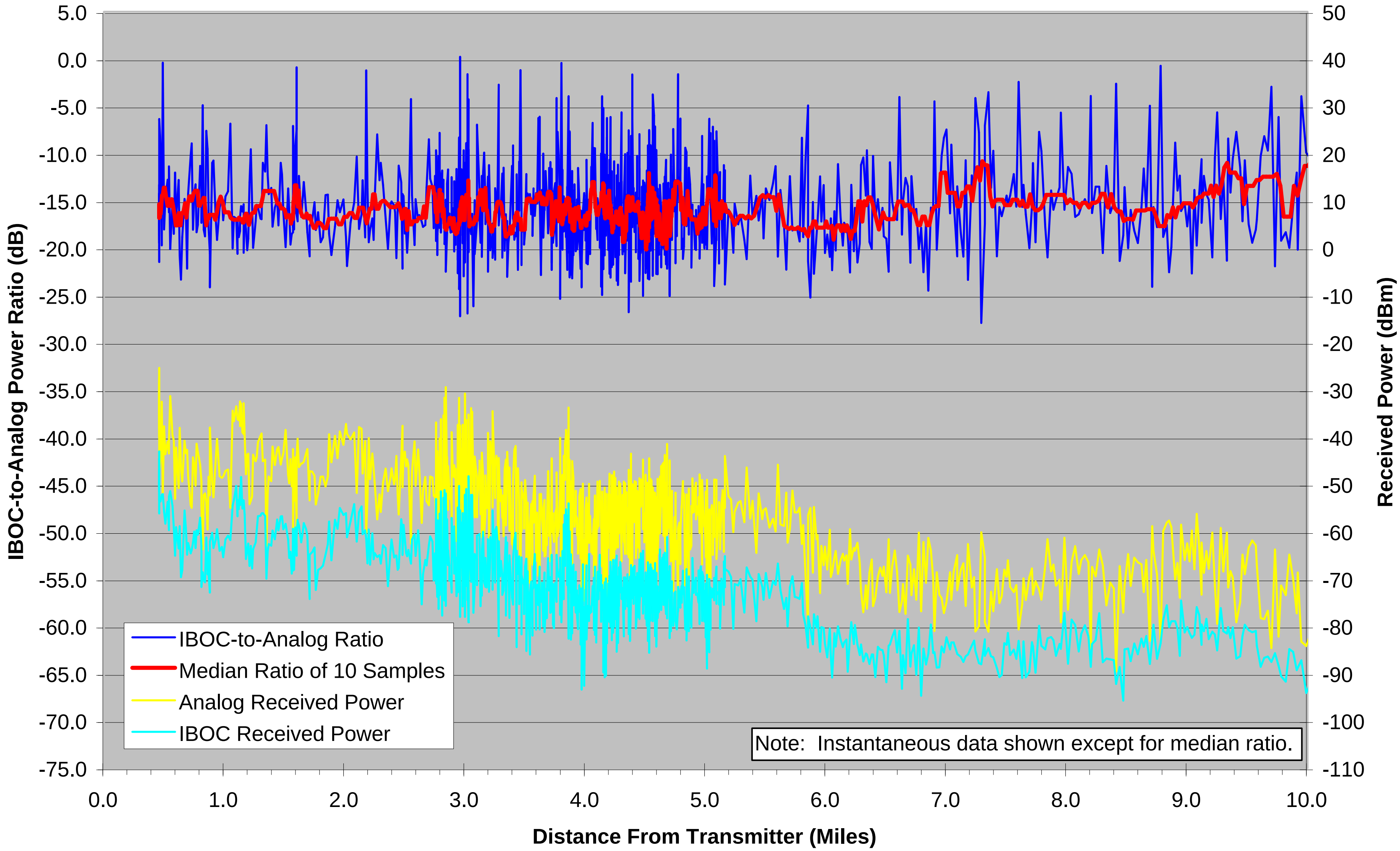
**WDHA-FM Median IBOC-to-Analog Power Ratios
(Southwest Route)**




WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Western Route-Combined Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
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Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.
5.0
0.0
-5.0
-10.0
-15.0
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-100
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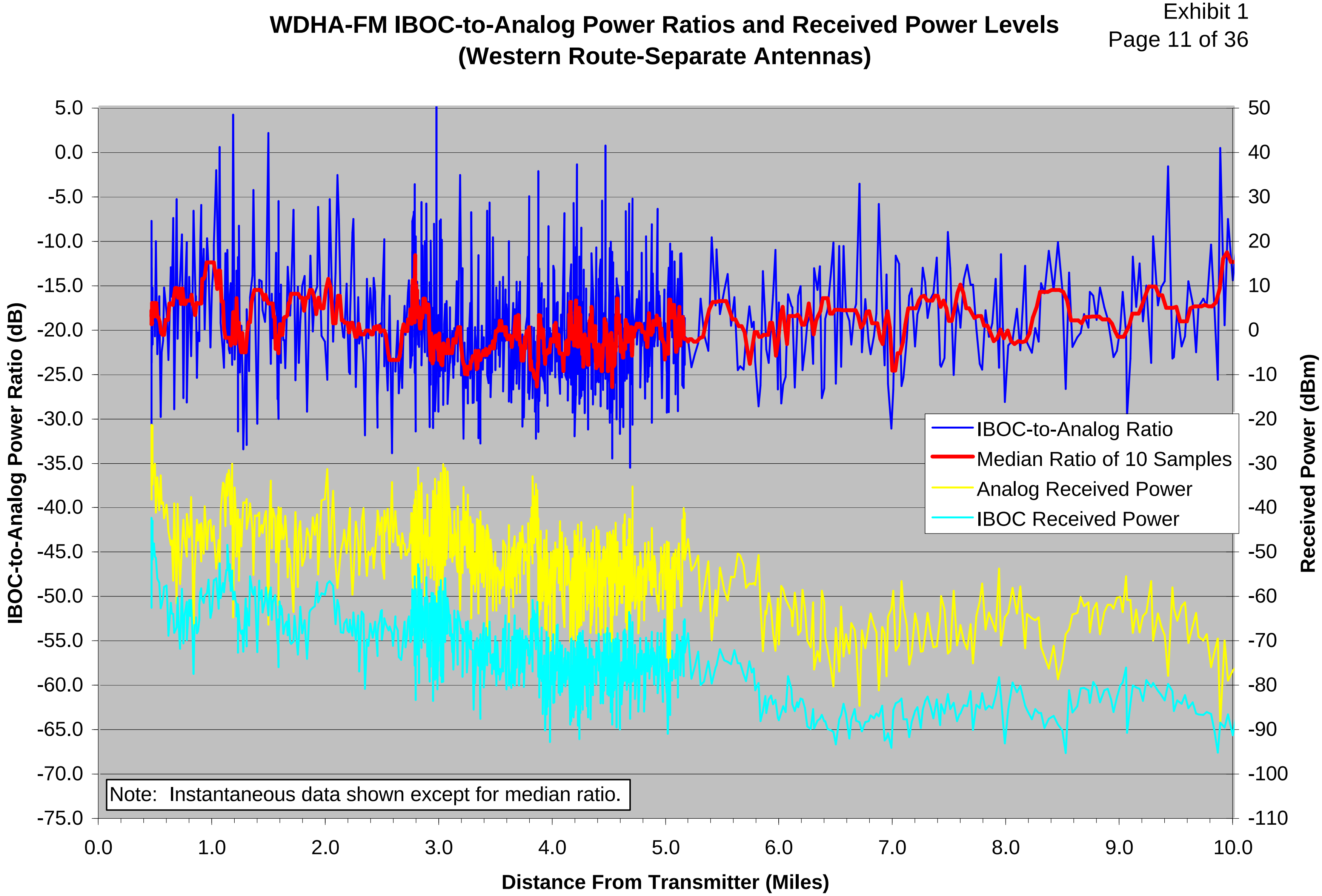
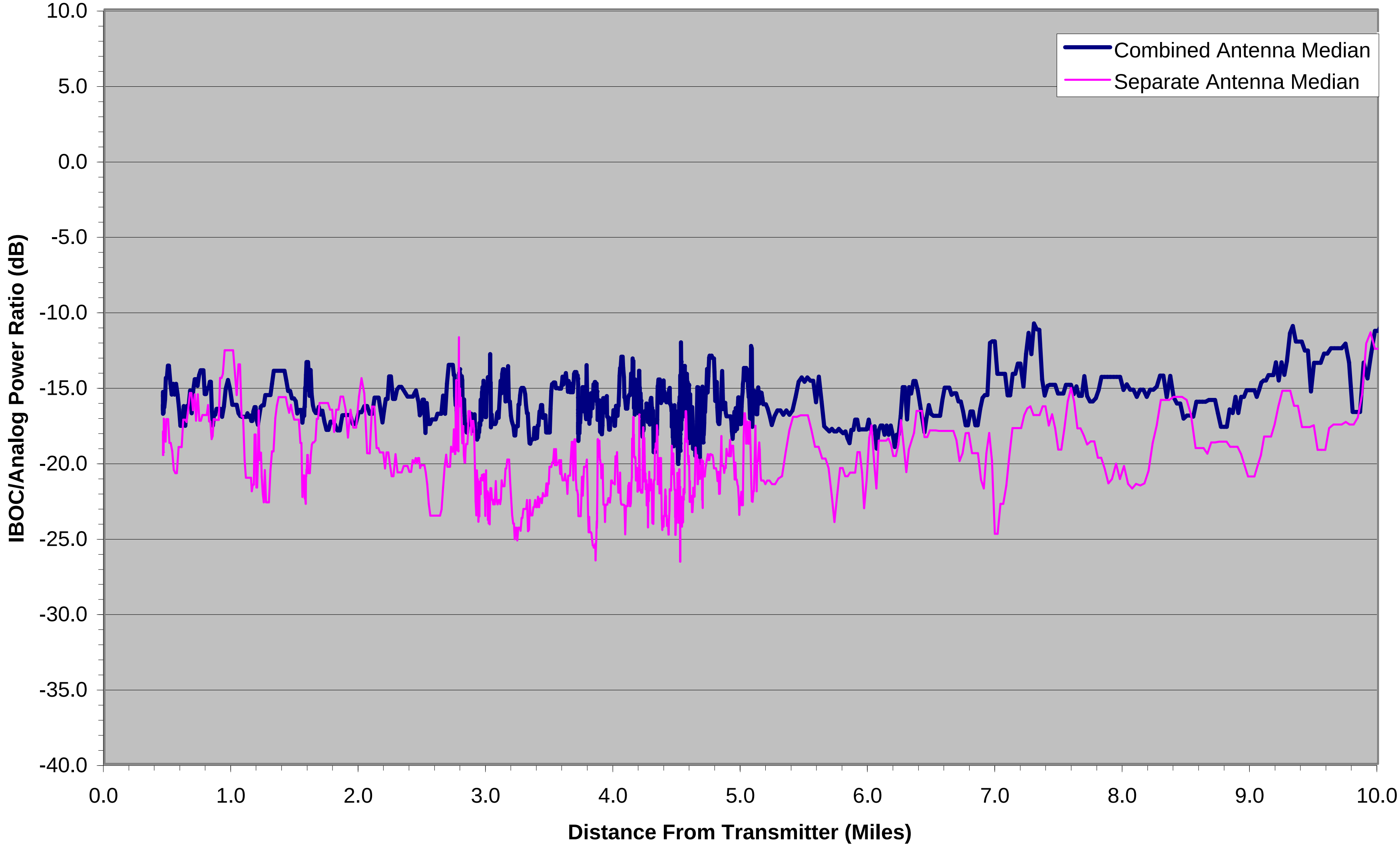
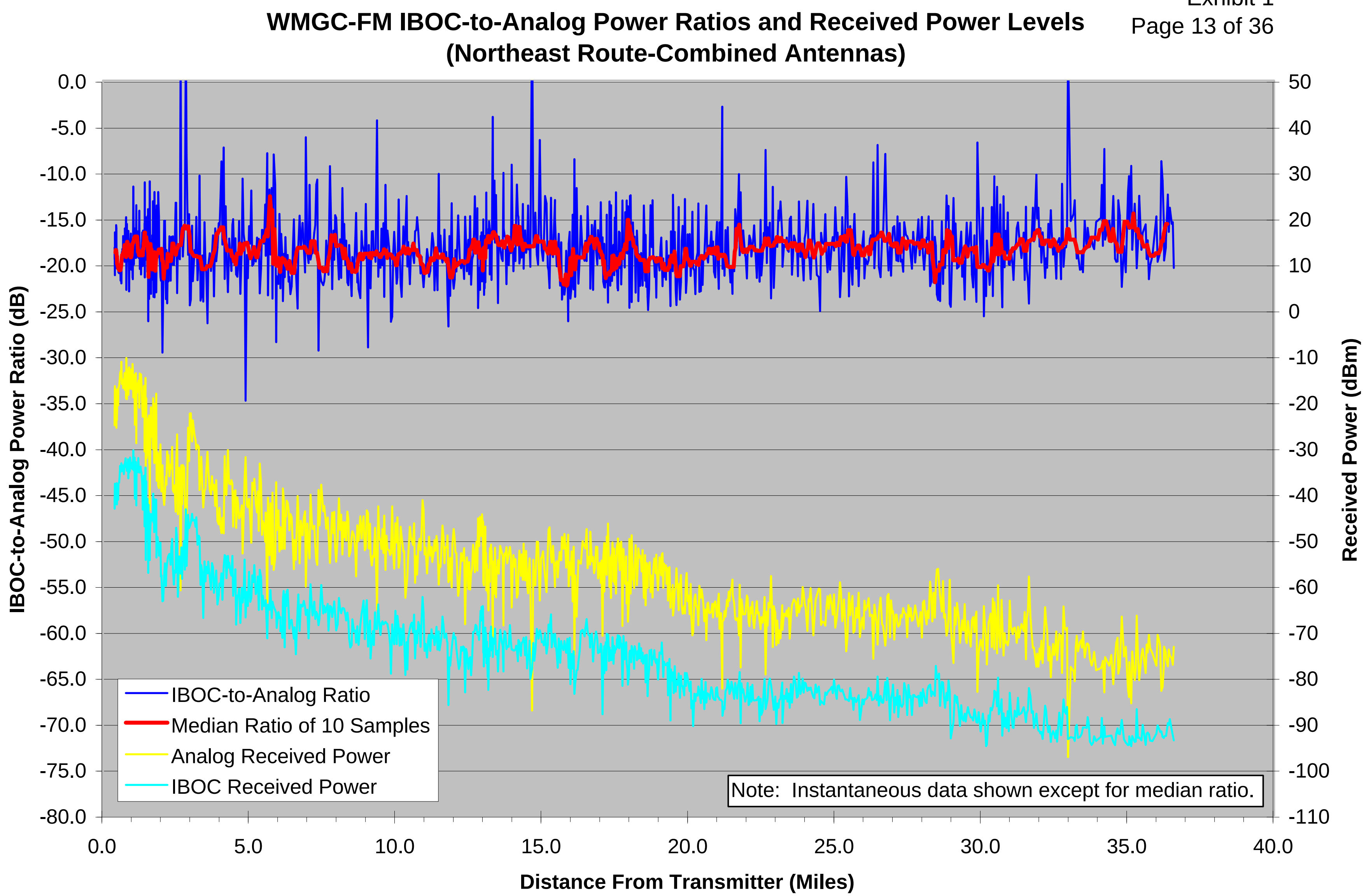
9.0
10.0

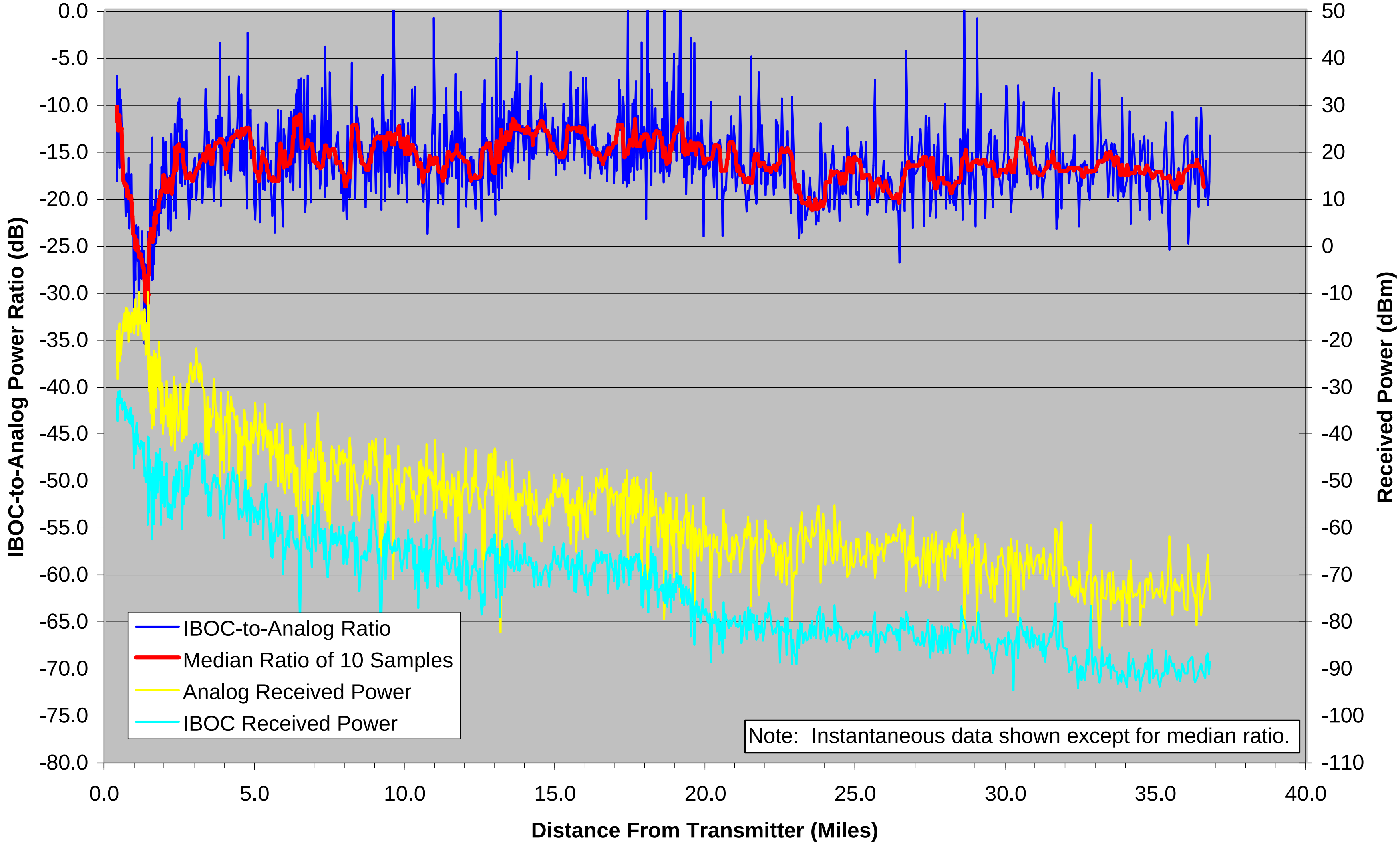

WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Western Route-Separate Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.

WDHA-FM Median IBOC-to-Analog Power Ratios (Western Route)

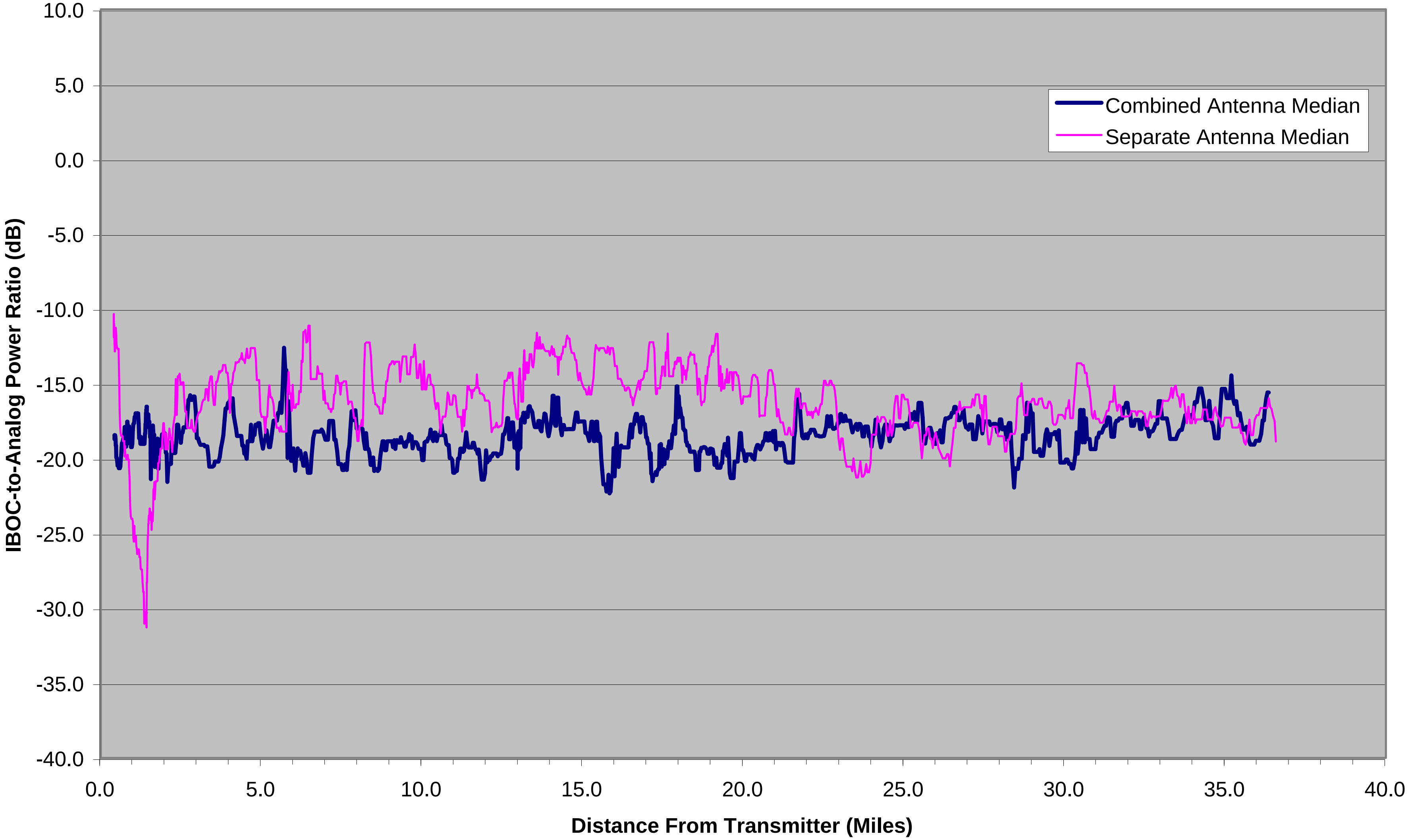


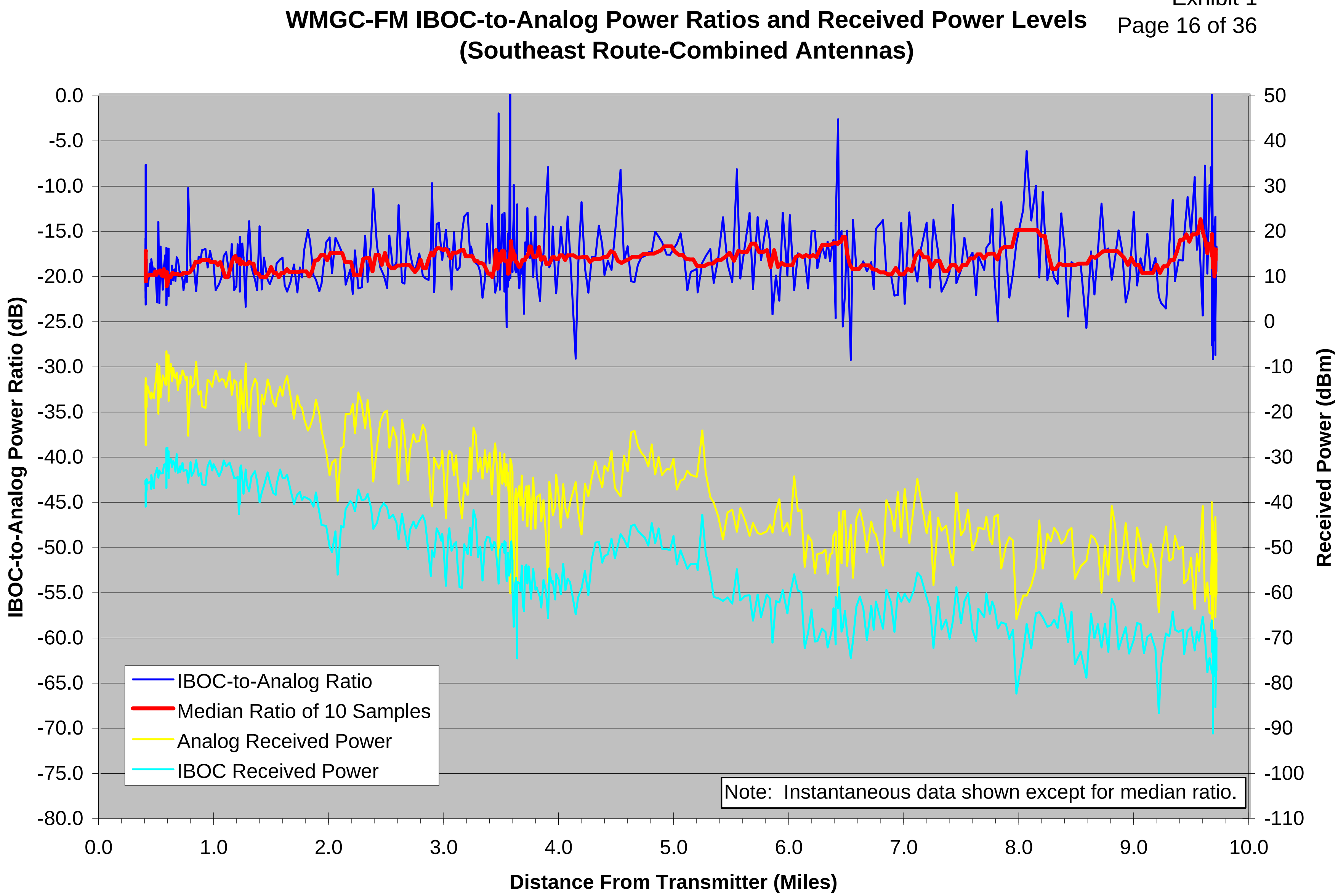

WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northeast Route-Combined Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.

WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northeast Route-Separate Antennas)

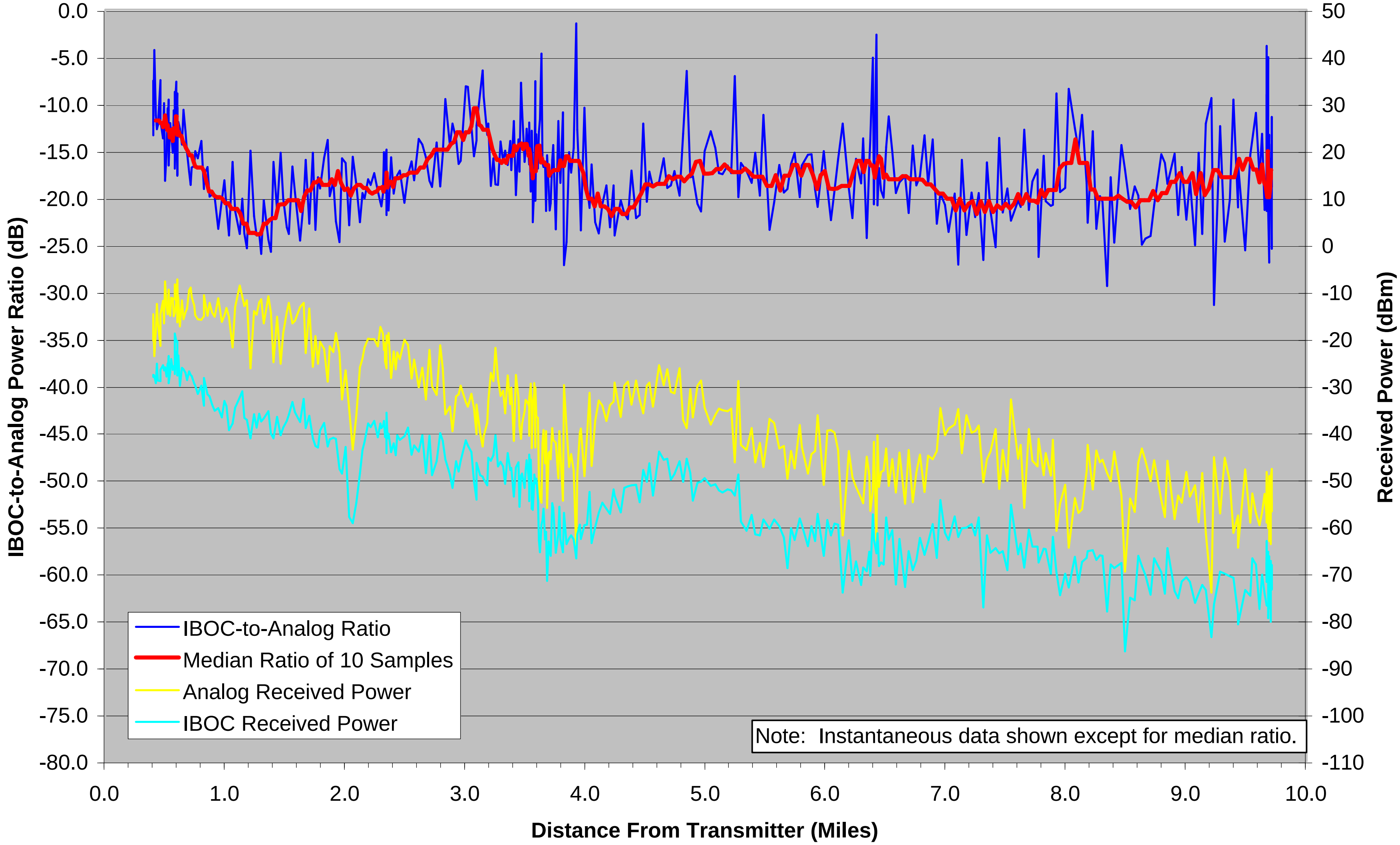


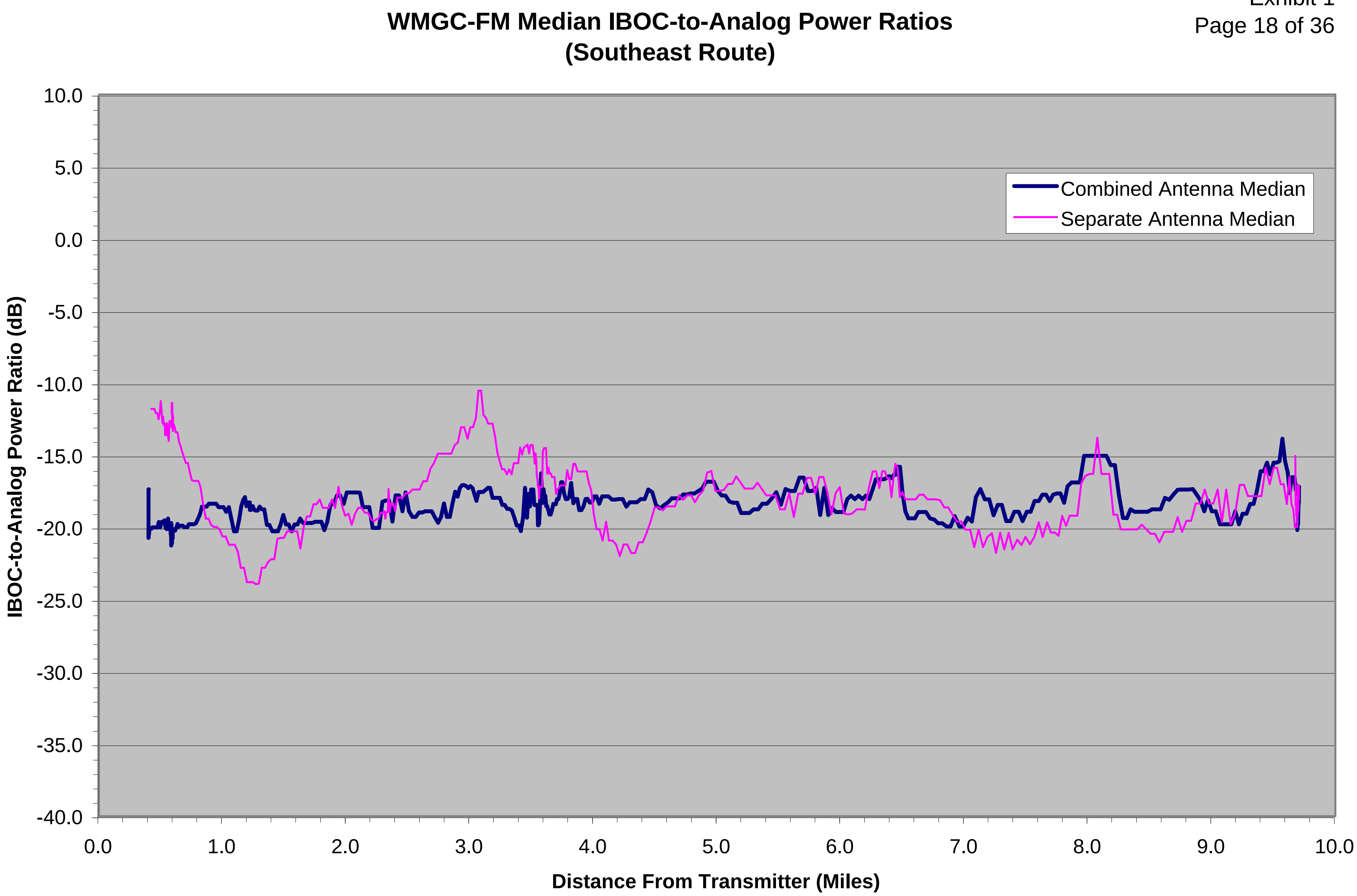
**WMGC-FM Median IBOC-to-Analog Power Ratios
(Northeast Route)**

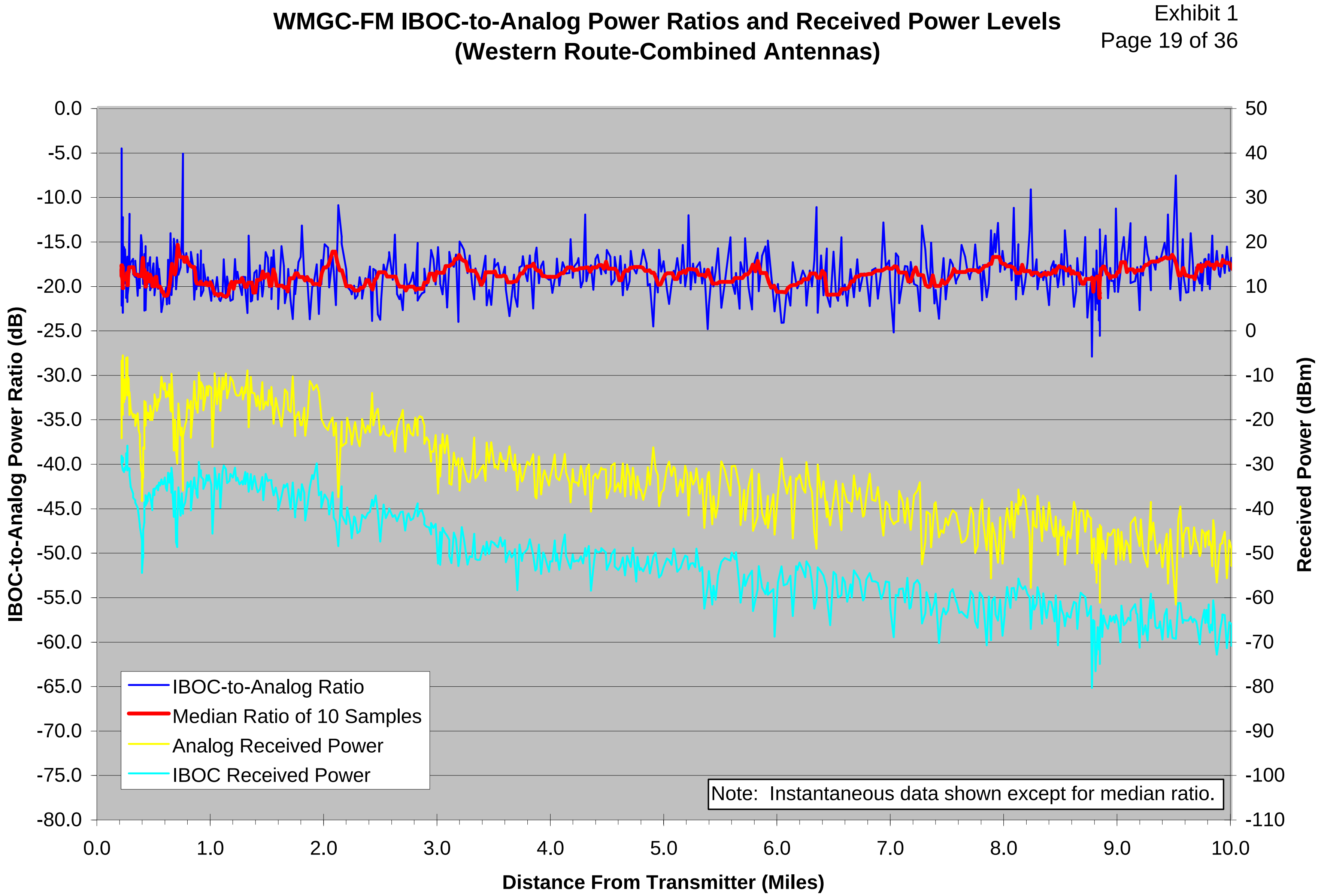


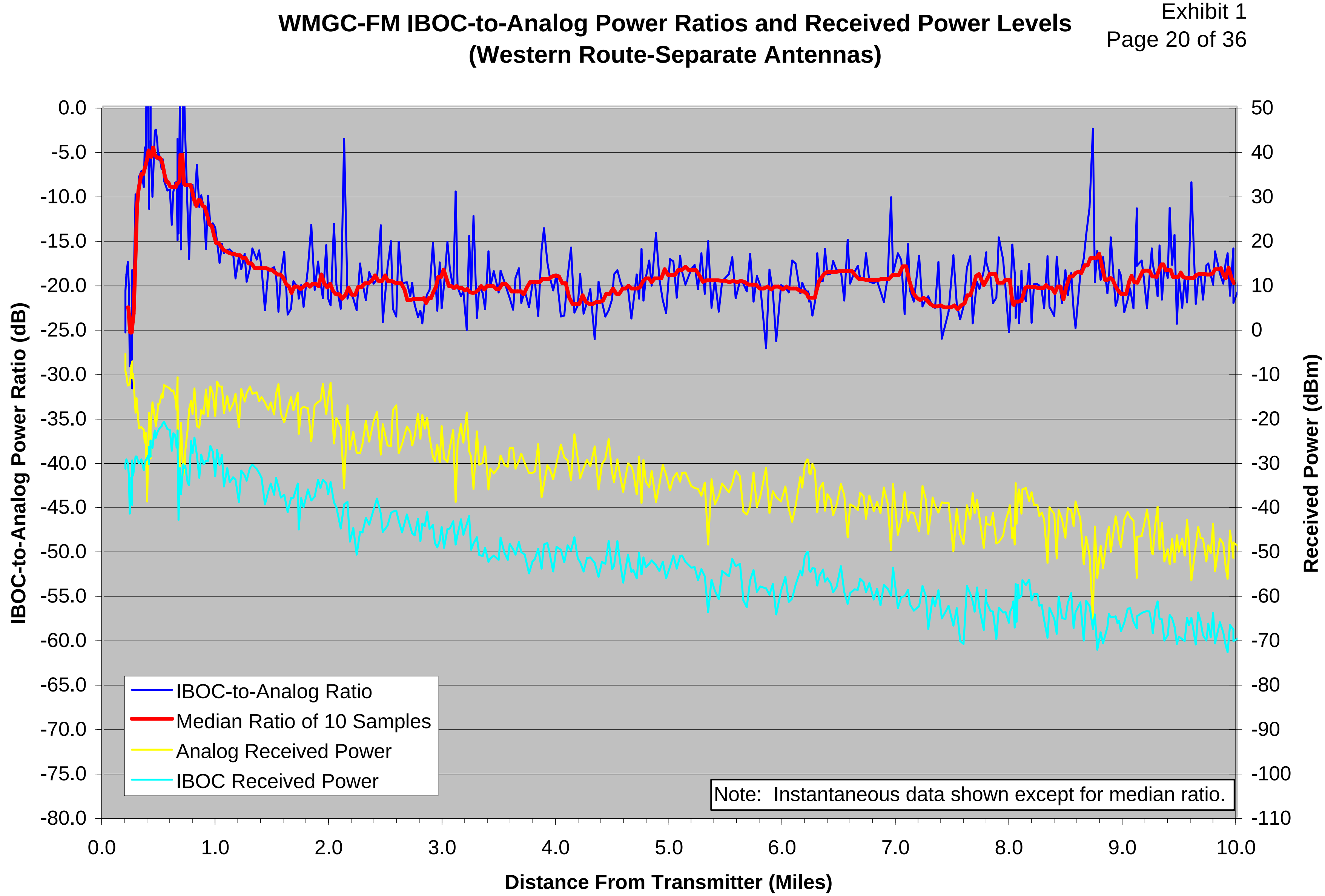

WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southeast Route-Combined Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.

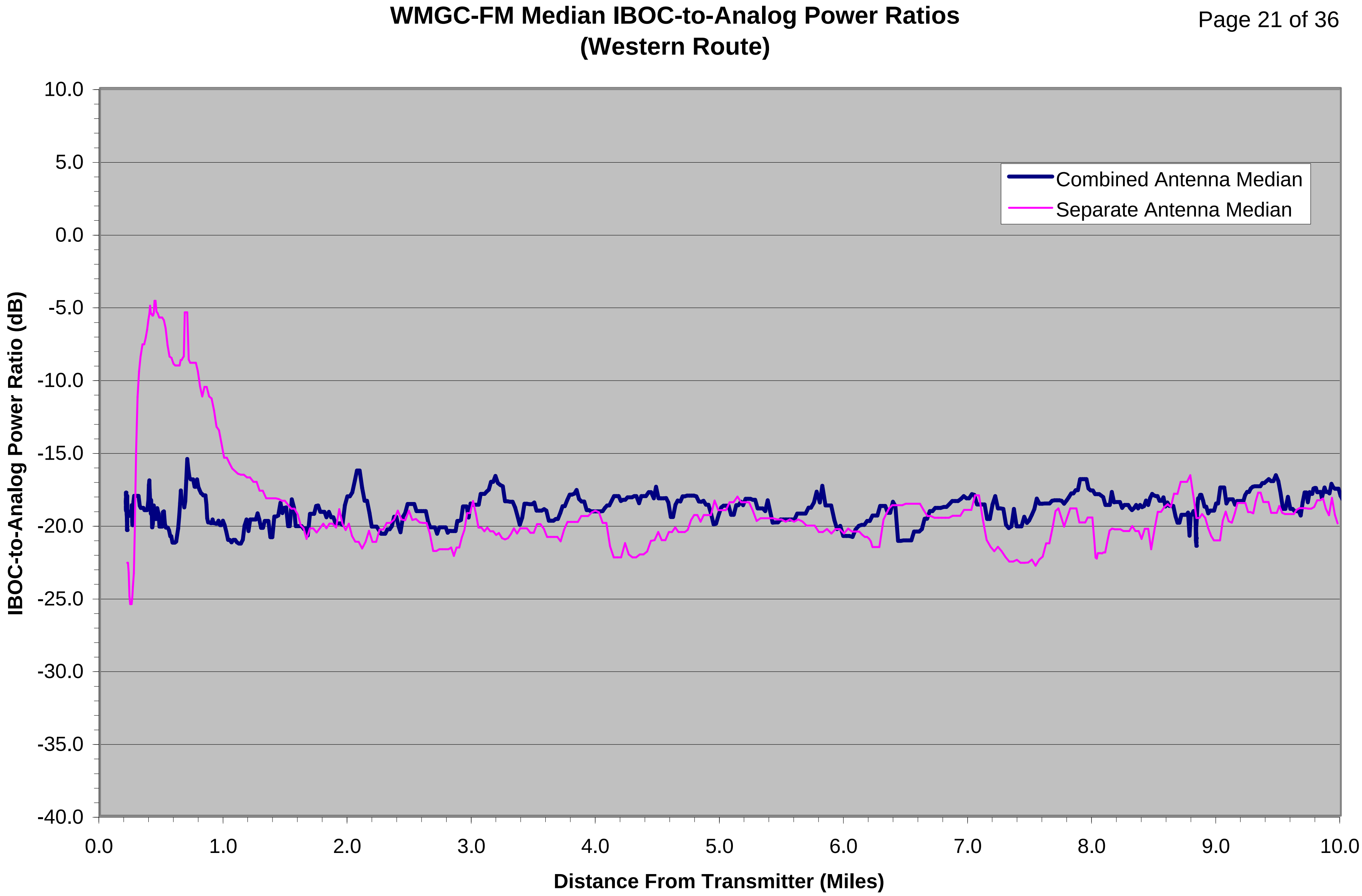
WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Southeast Route-Separate Antennas)



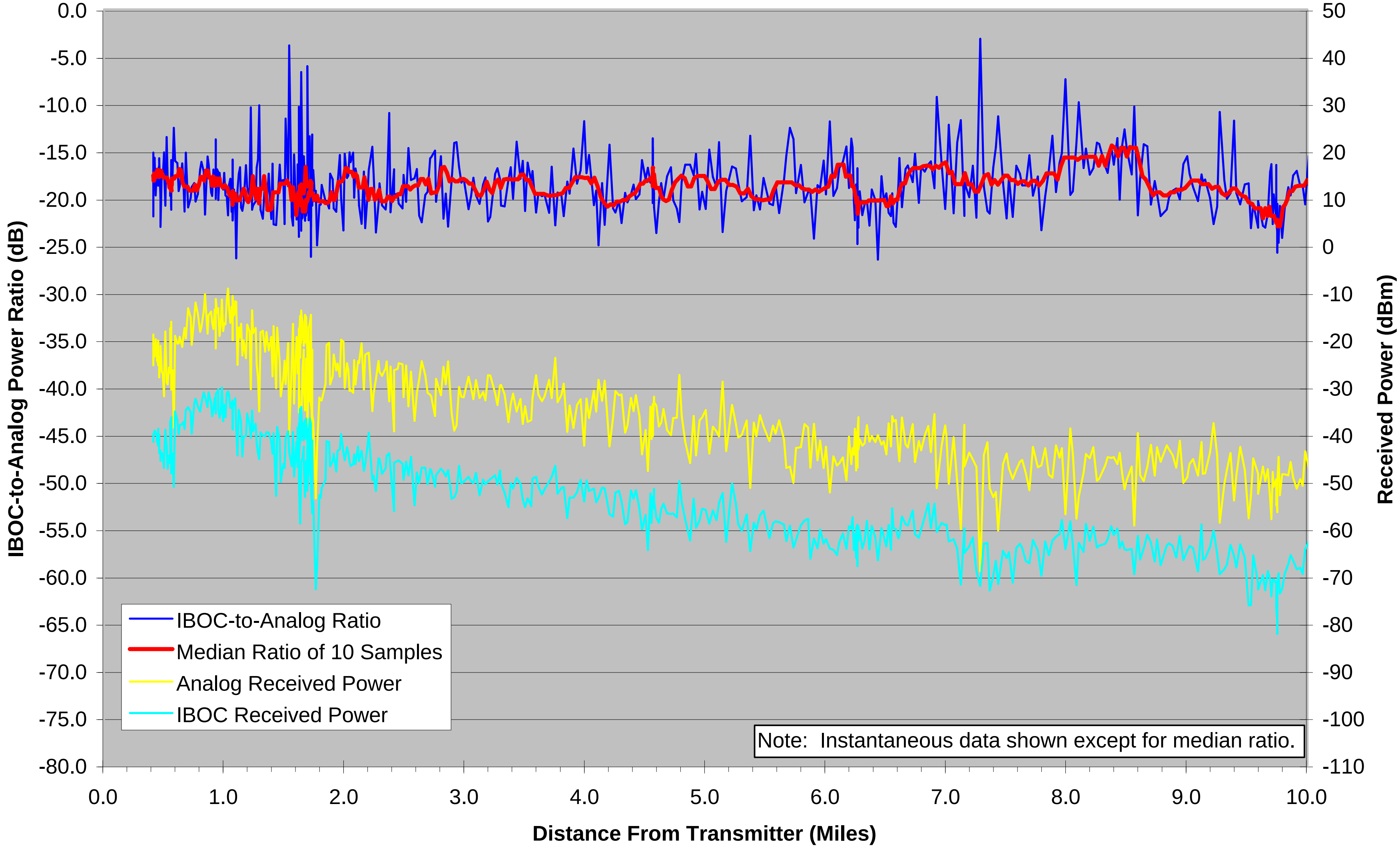

WMGC-FM Median IBOC-to-Analog Power Ratios
(Southeast Route)
IBOC-to-Analog Power Ratio (dB)
Distance From Transmitter (Miles)
Combined Antenna Median
Separate Antenna Median
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0


WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Western Route-Combined Antennas)
IBOC-to-Analog Power Ratio (dB)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
Received Power (dBm)
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Distance From Transmitter (Miles)
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.

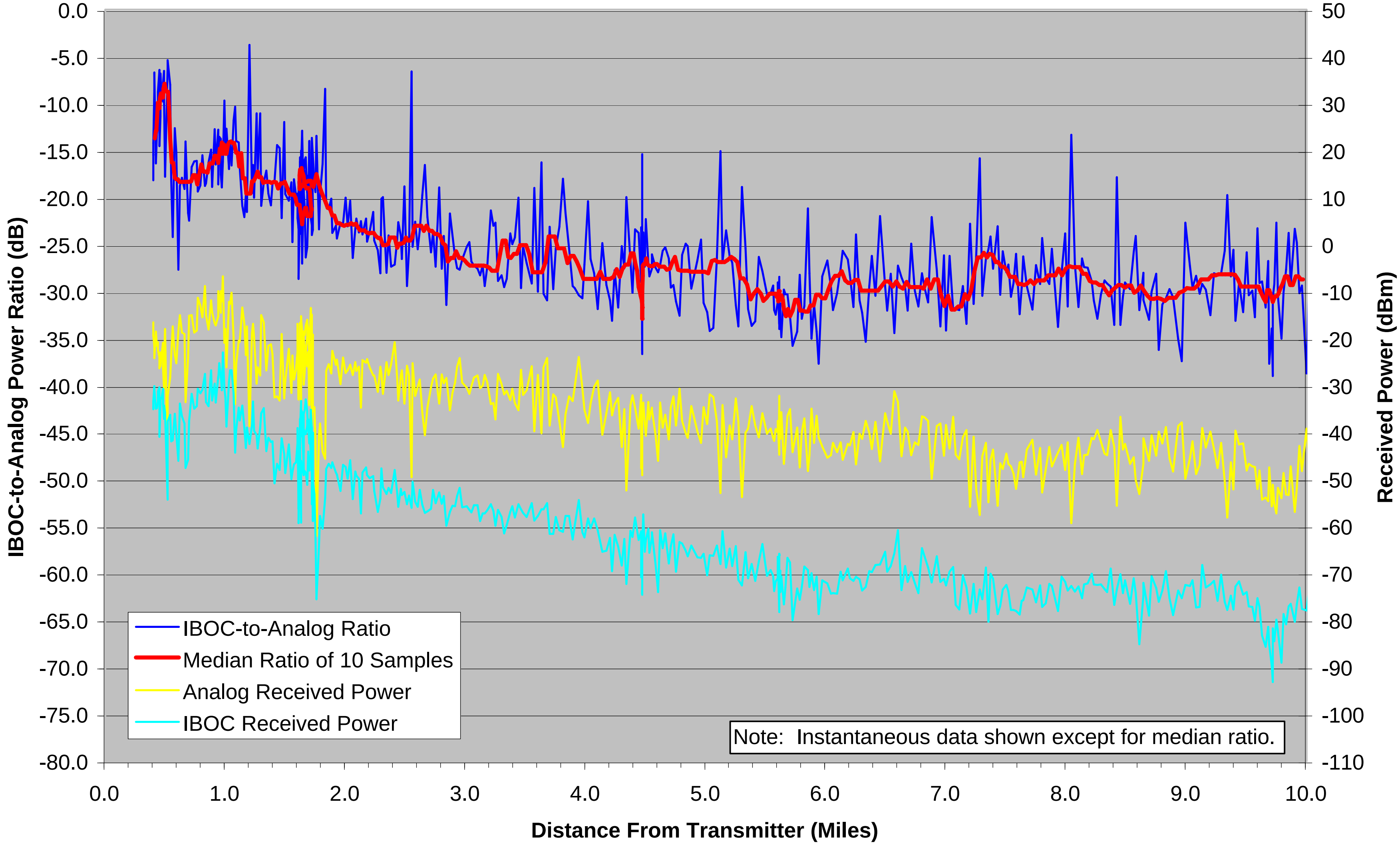

WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Western Route-Separate Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.

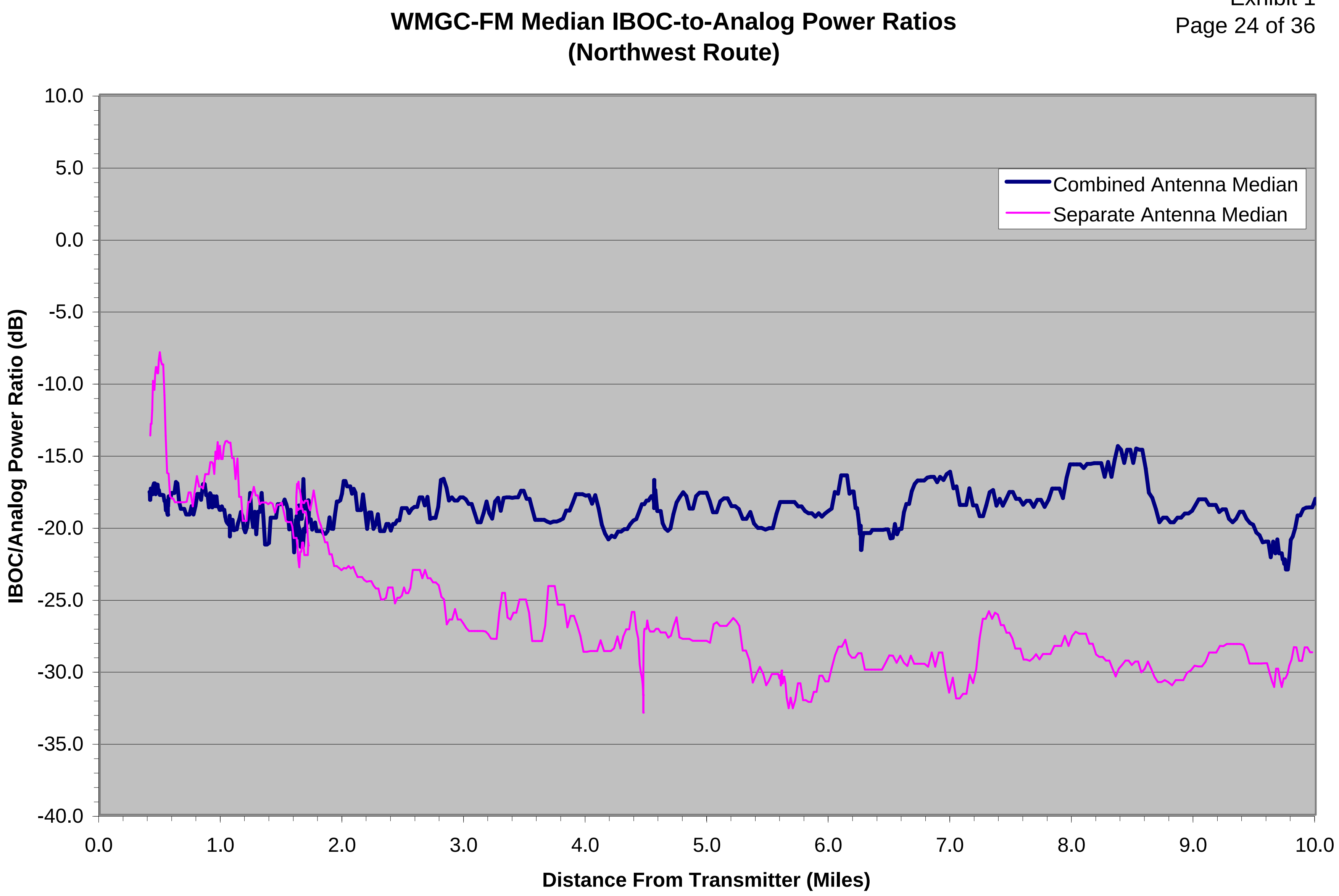

WMGC-FM Median IBOC-to-Analog Power Ratios
(Western Route)
IBOC-to-Analog Power Ratio (dB)
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Distance From Transmitter (Miles)
Combined Antenna Median
Separate Antenna Median

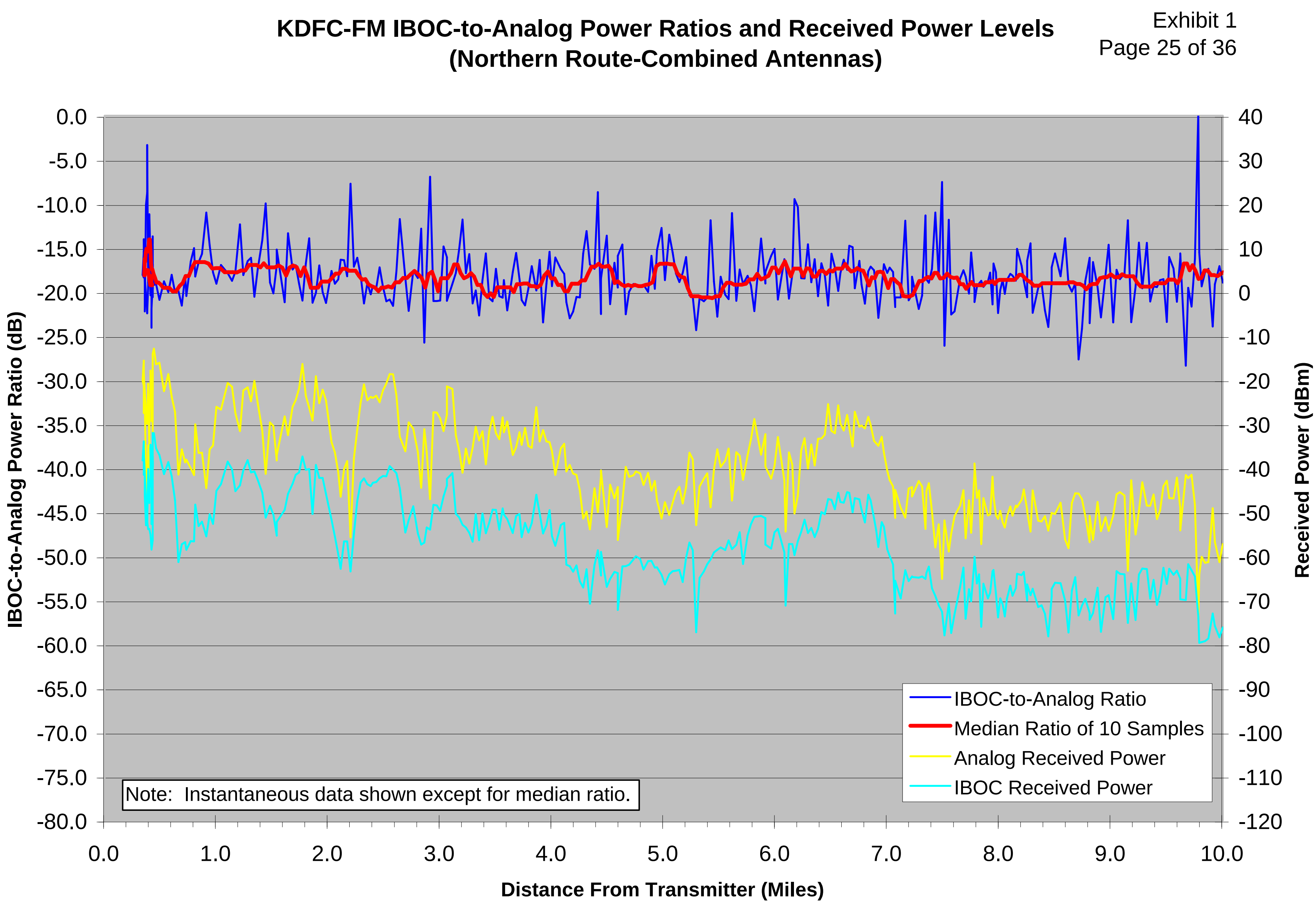
WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northwest Route-Combined Antennas)

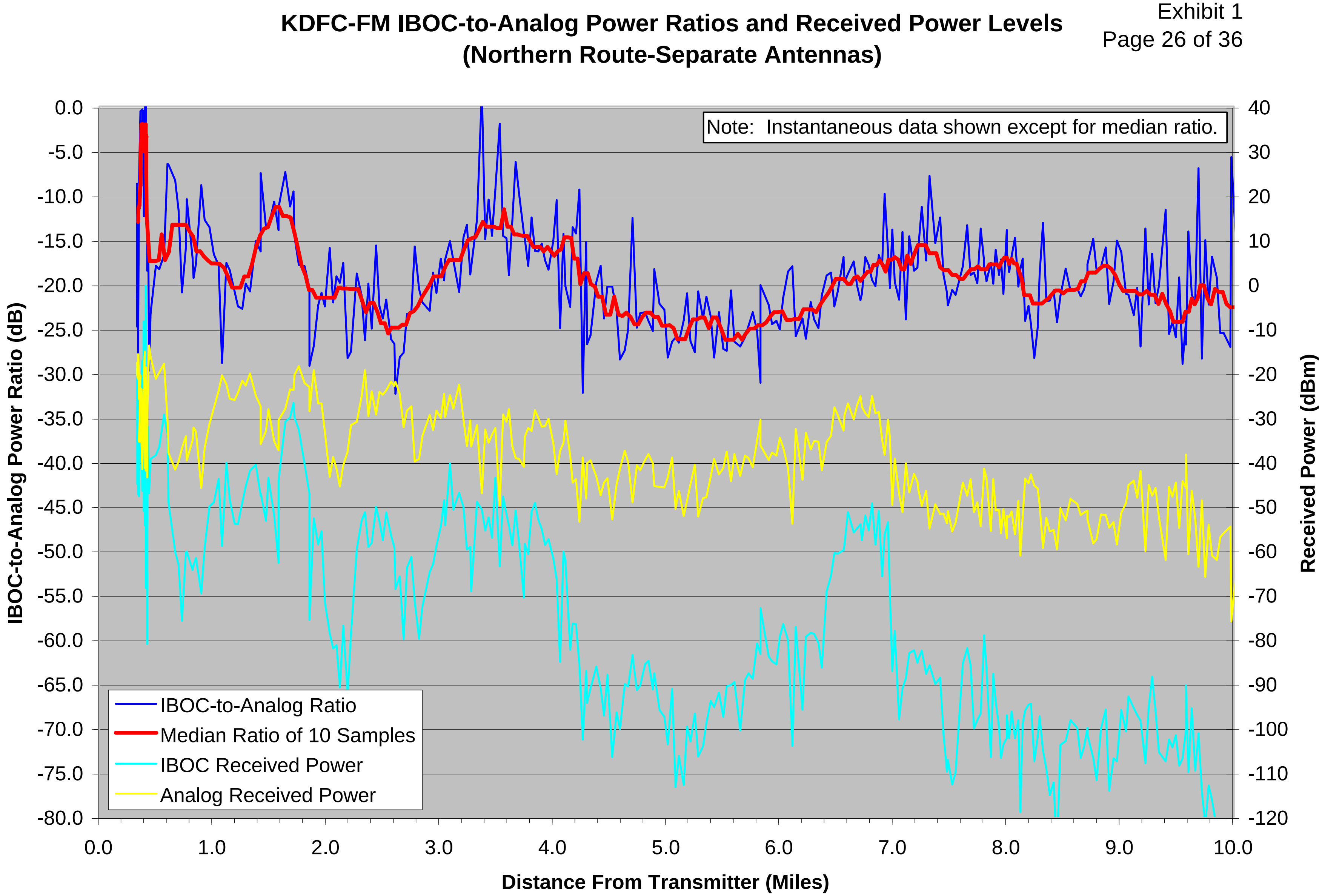


WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northwest Route-Separate Antennas)

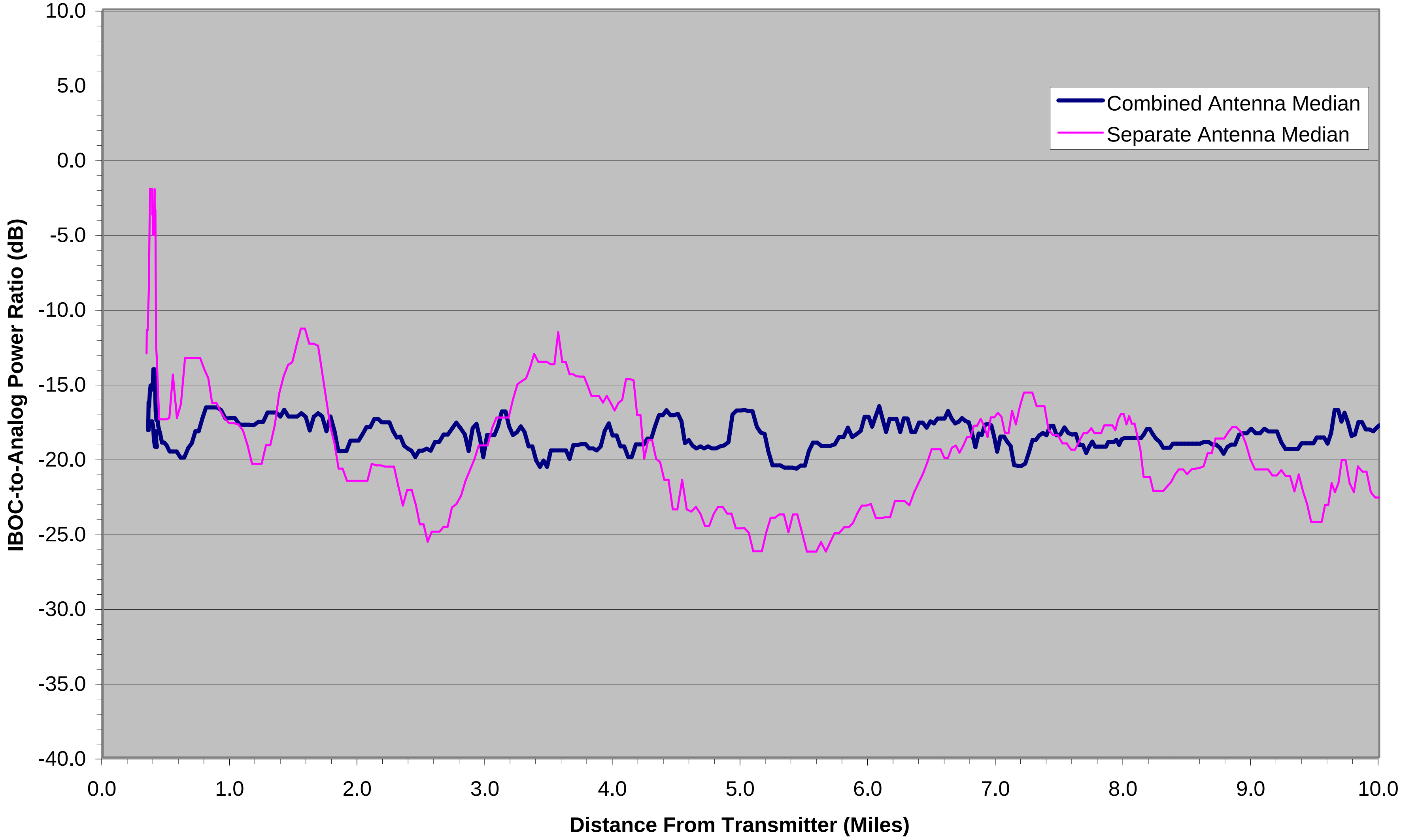



WMGC-FM Median IBOC-to-Analog Power Ratios
(Northwest Route)
Combined Antenna Median
Separate Antenna Median
IBOC/Analog Power Ratio (dB)
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Distance From Transmitter (Miles)

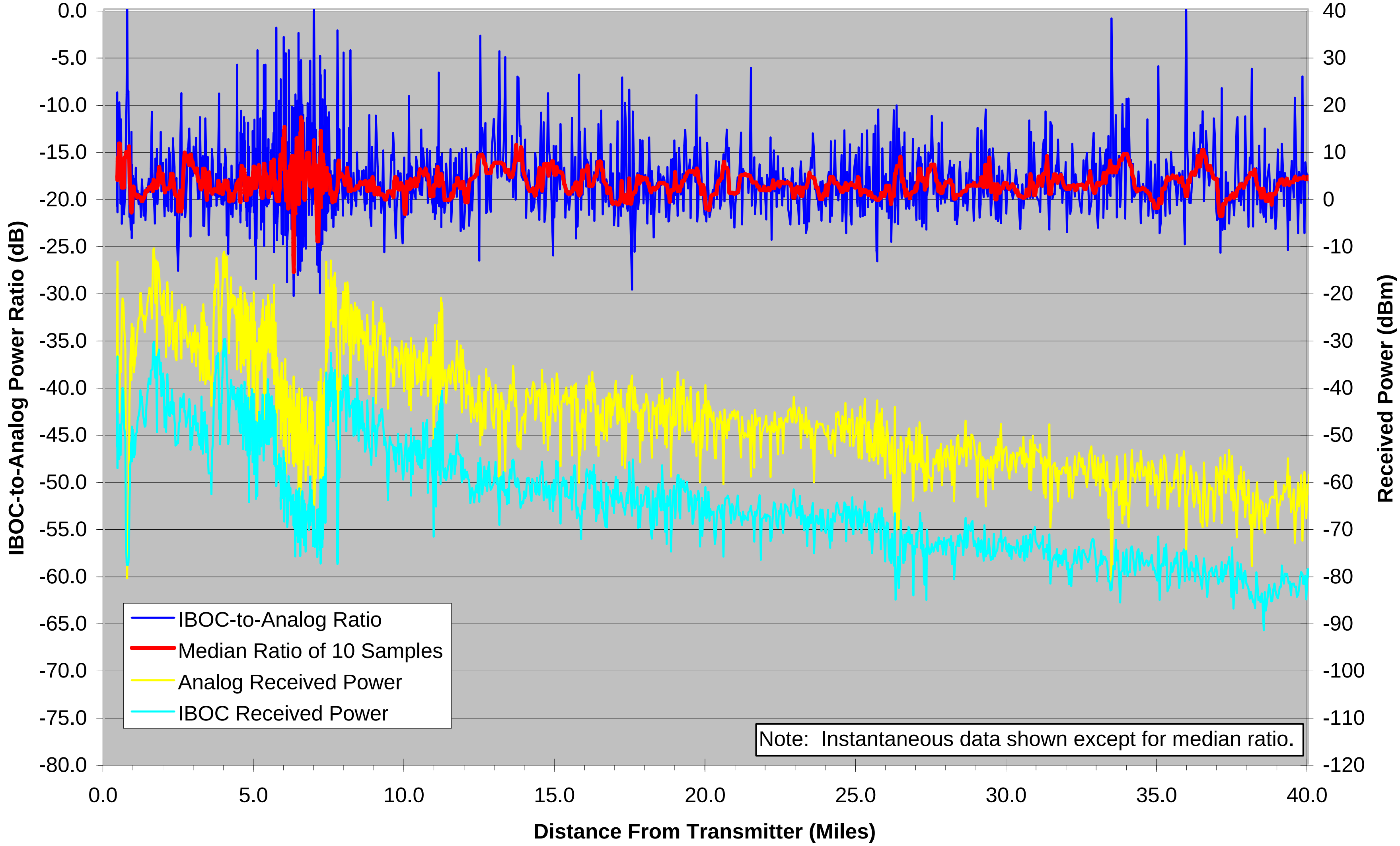

KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northern Route-Combined Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.


KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northern Route-Separate Antennas)
Note: Instantaneous data shown except for median ratio.
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
IBOC Received Power
Analog Received Power
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

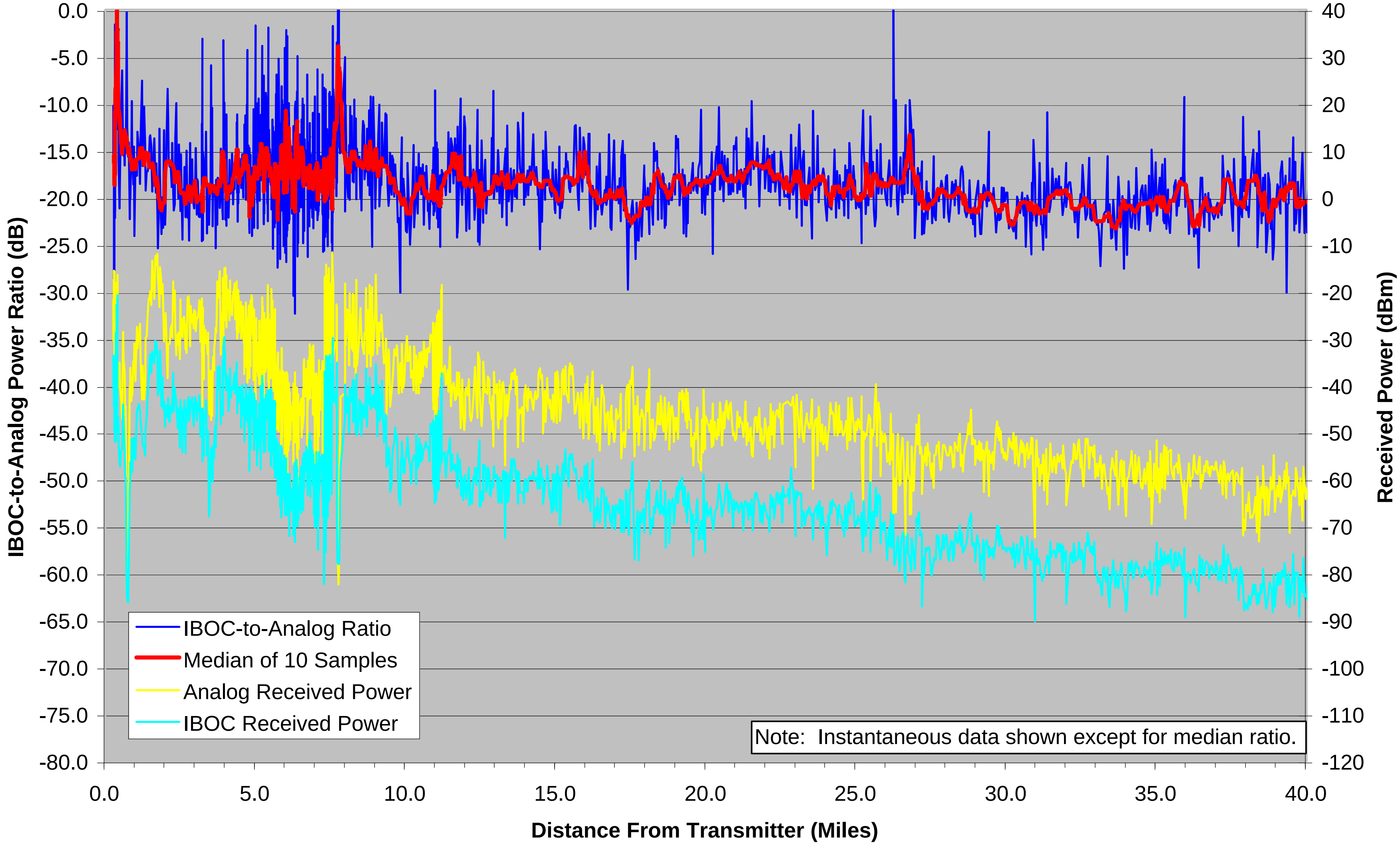
KDFC-FM Median IBOC-to-Analog Power Ratios (Northern Route)



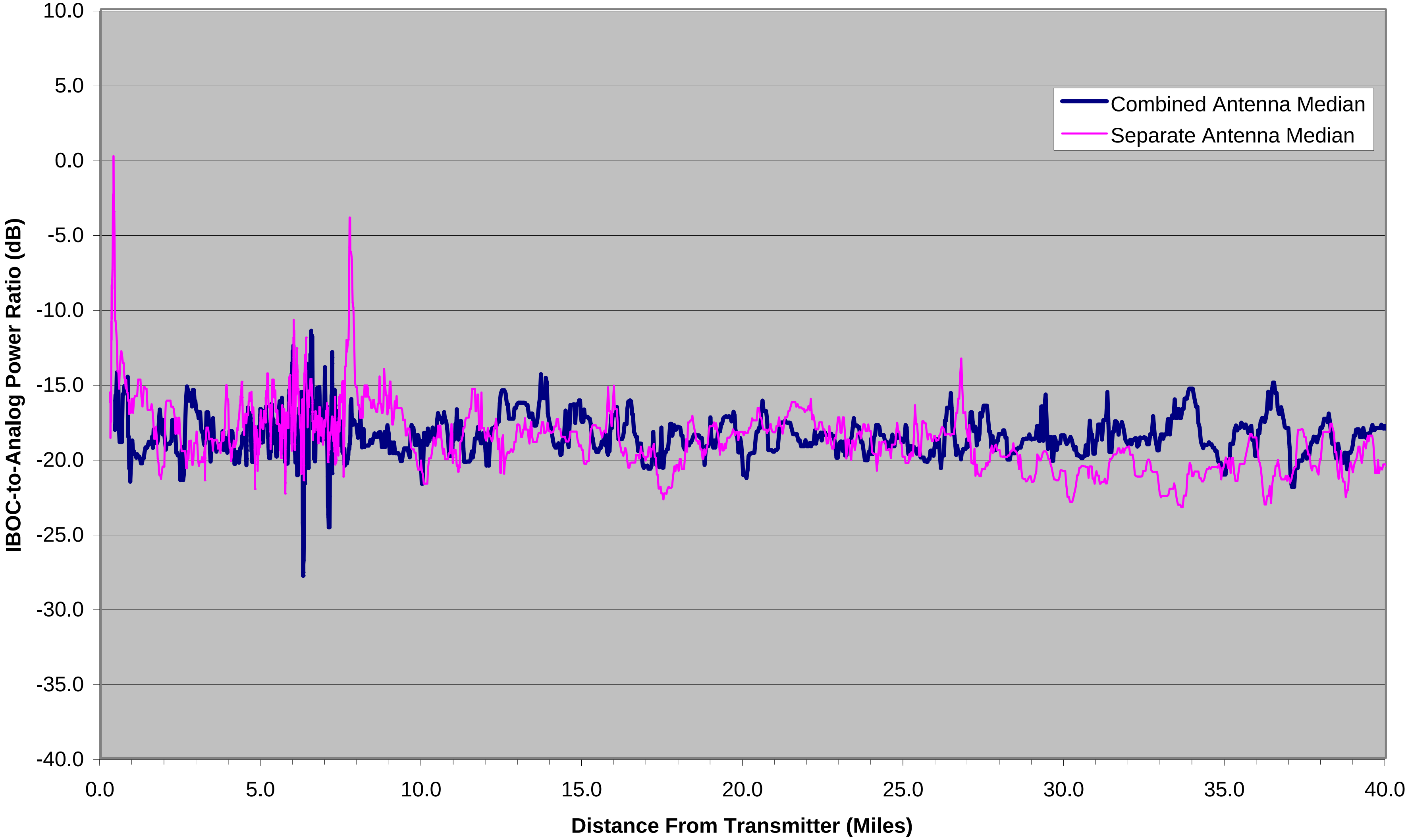
KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Southeast Route-Combined Antennas)

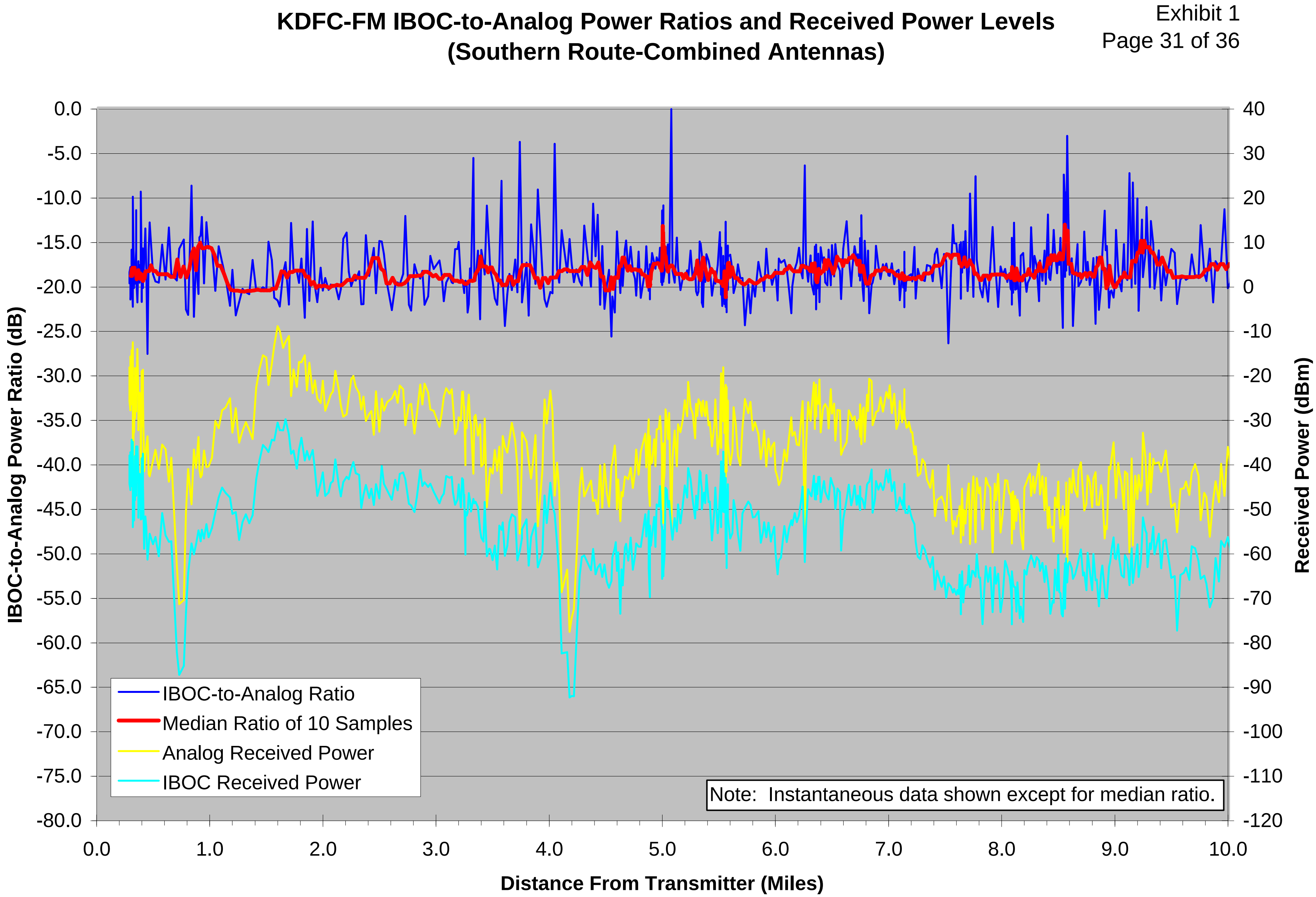


KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southeast Route-Separate Antennas)

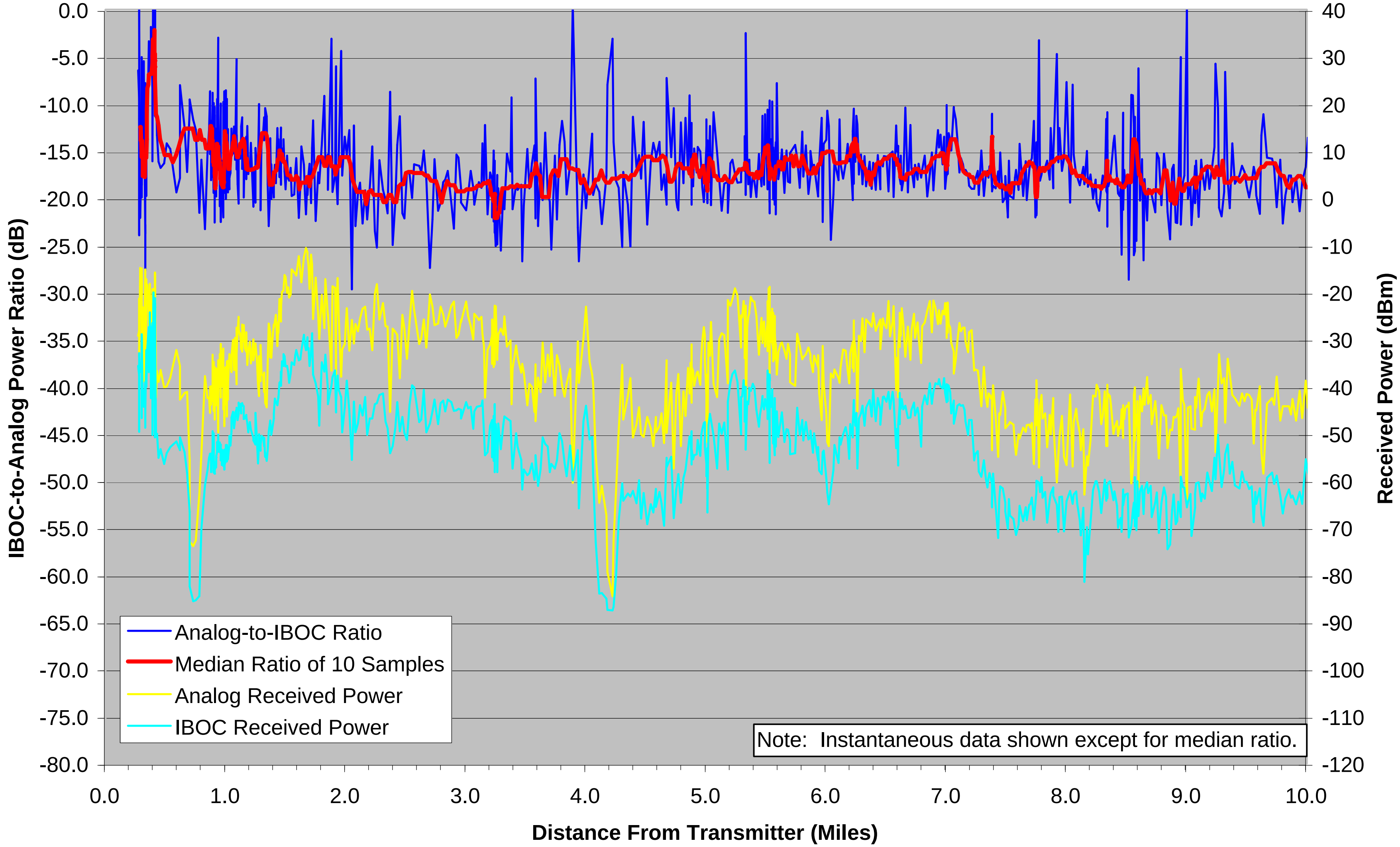


KDFC-FM Median IBOC-to-Analog Power Ratios (Southeast Route)

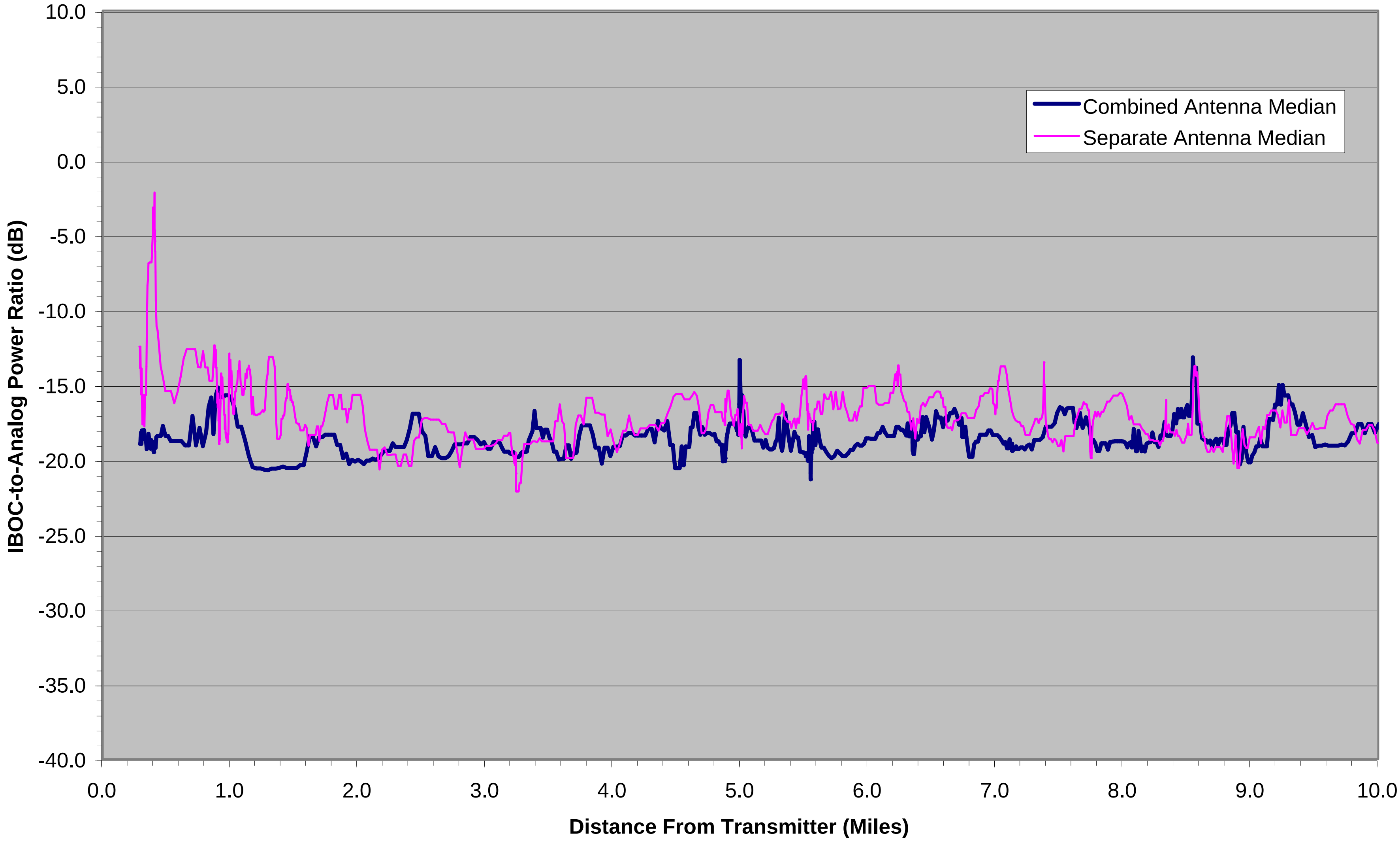


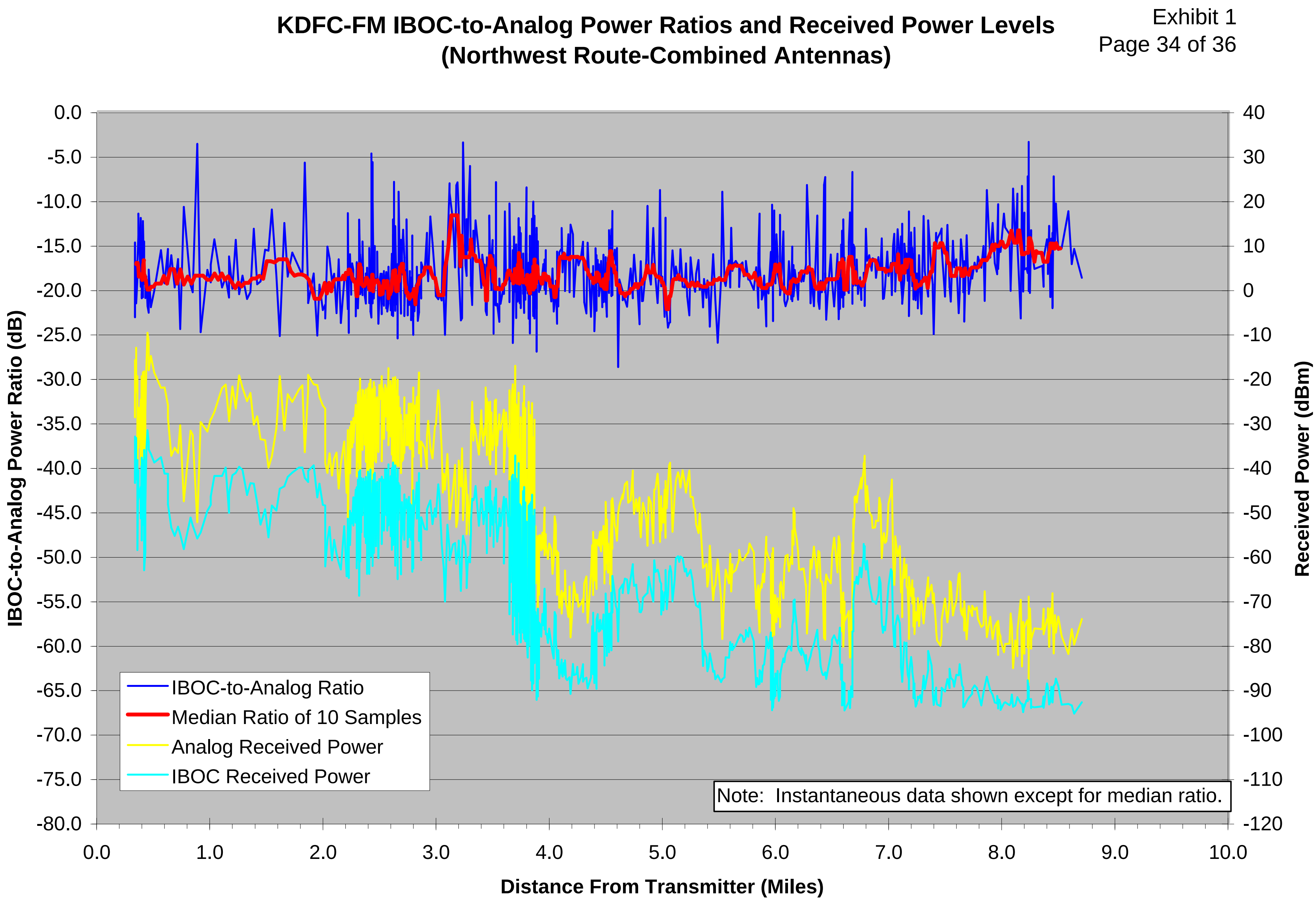

KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southern Route-Combined Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.

KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southern Route-Separate Antennas)

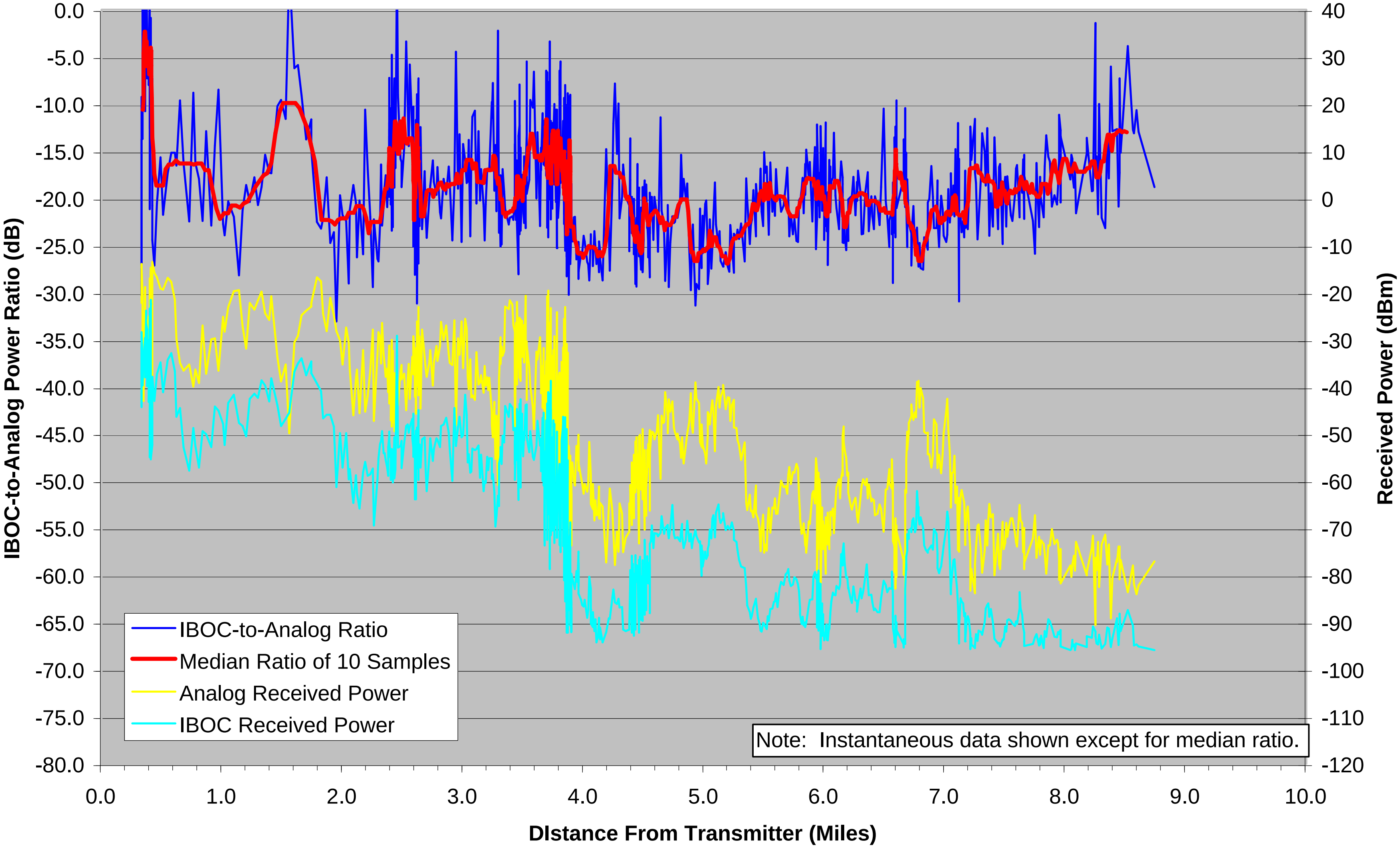


KDFC-FM Median IBOC-to-Analog Power Ratios
(Southern Route)

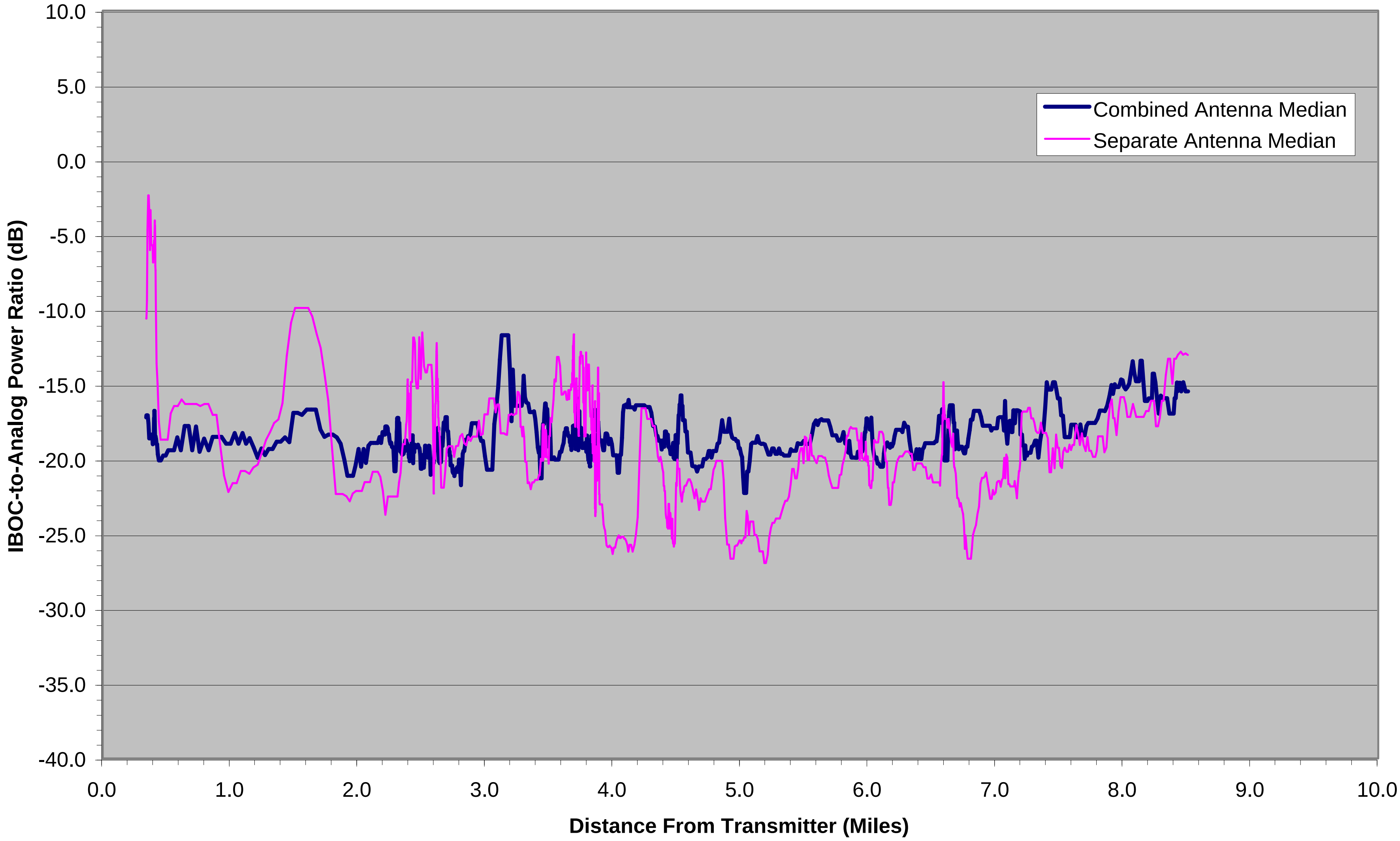



KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northwest Route-Combined Antennas)
IBOC-to-Analog Power Ratio (dB)
Received Power (dBm)
Distance From Transmitter (Miles)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
IBOC-to-Analog Ratio
Median Ratio of 10 Samples
Analog Received Power
IBOC Received Power
Note: Instantaneous data shown except for median ratio.

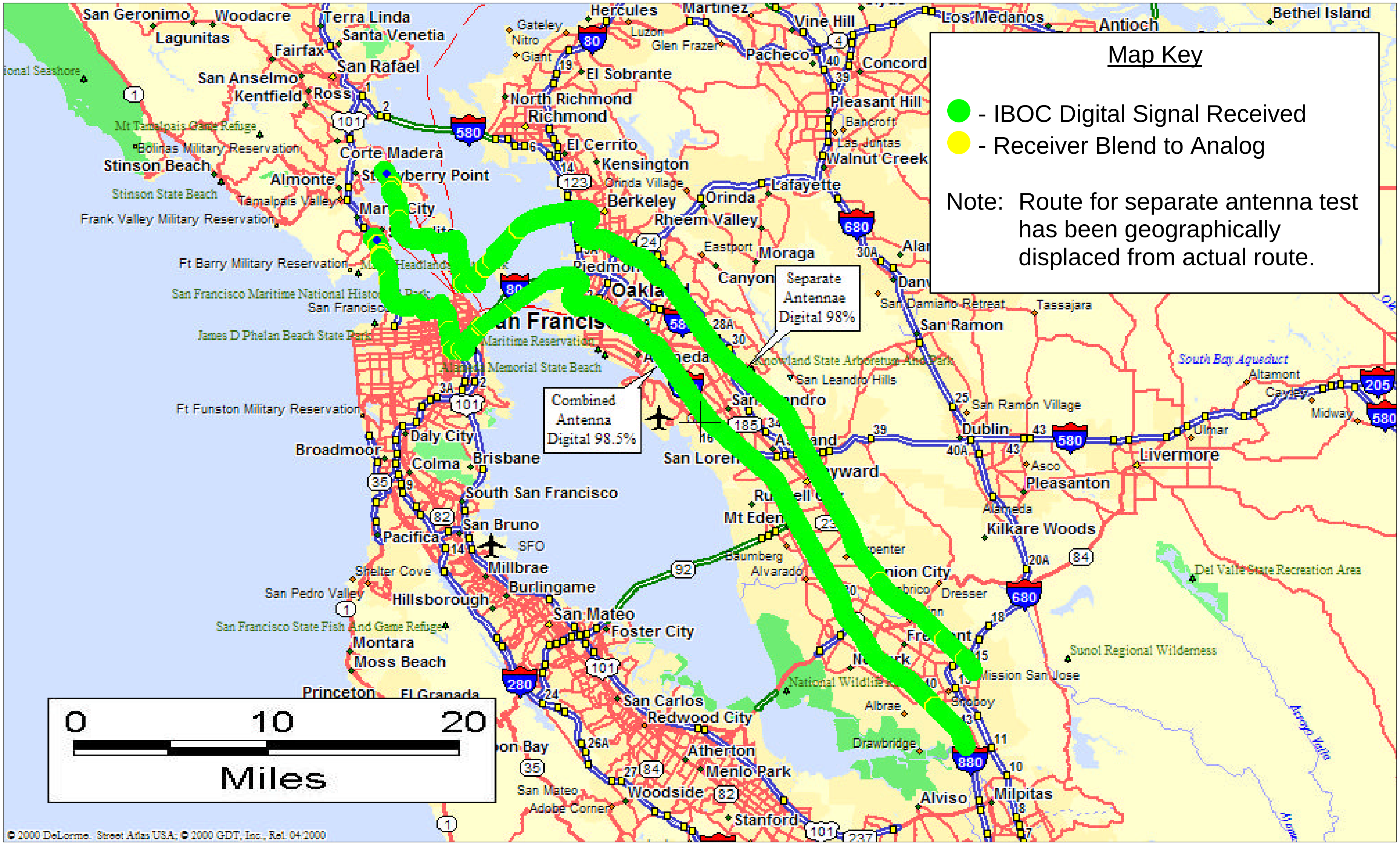
KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northwest Route-Separate Antennas)



KDFC-FM Median IBOC-to-Analog Power Ratios
(Northwest Route)

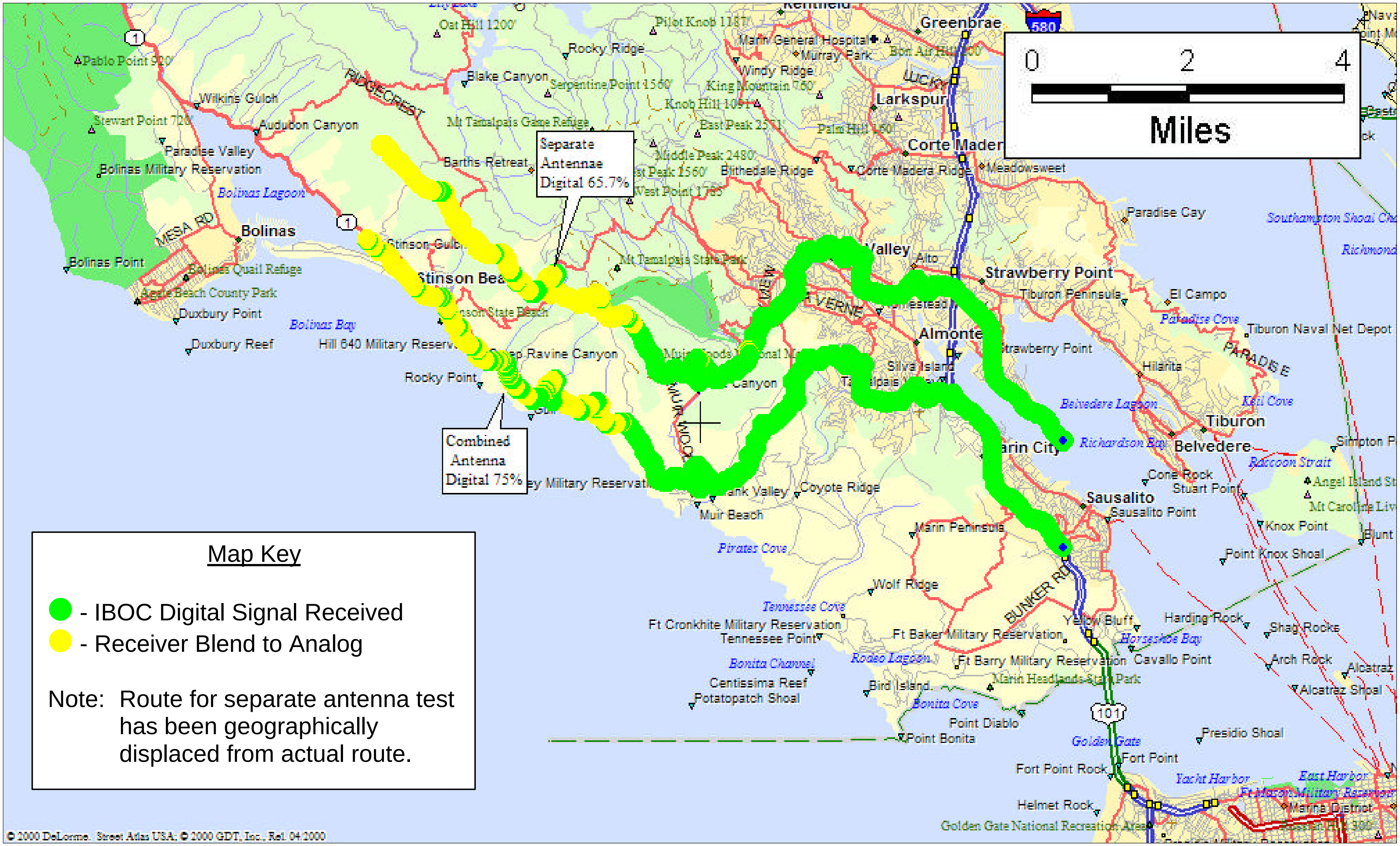


KDFC-FM, San Francisco – Separate vs. Combined Antenna - Northern Route

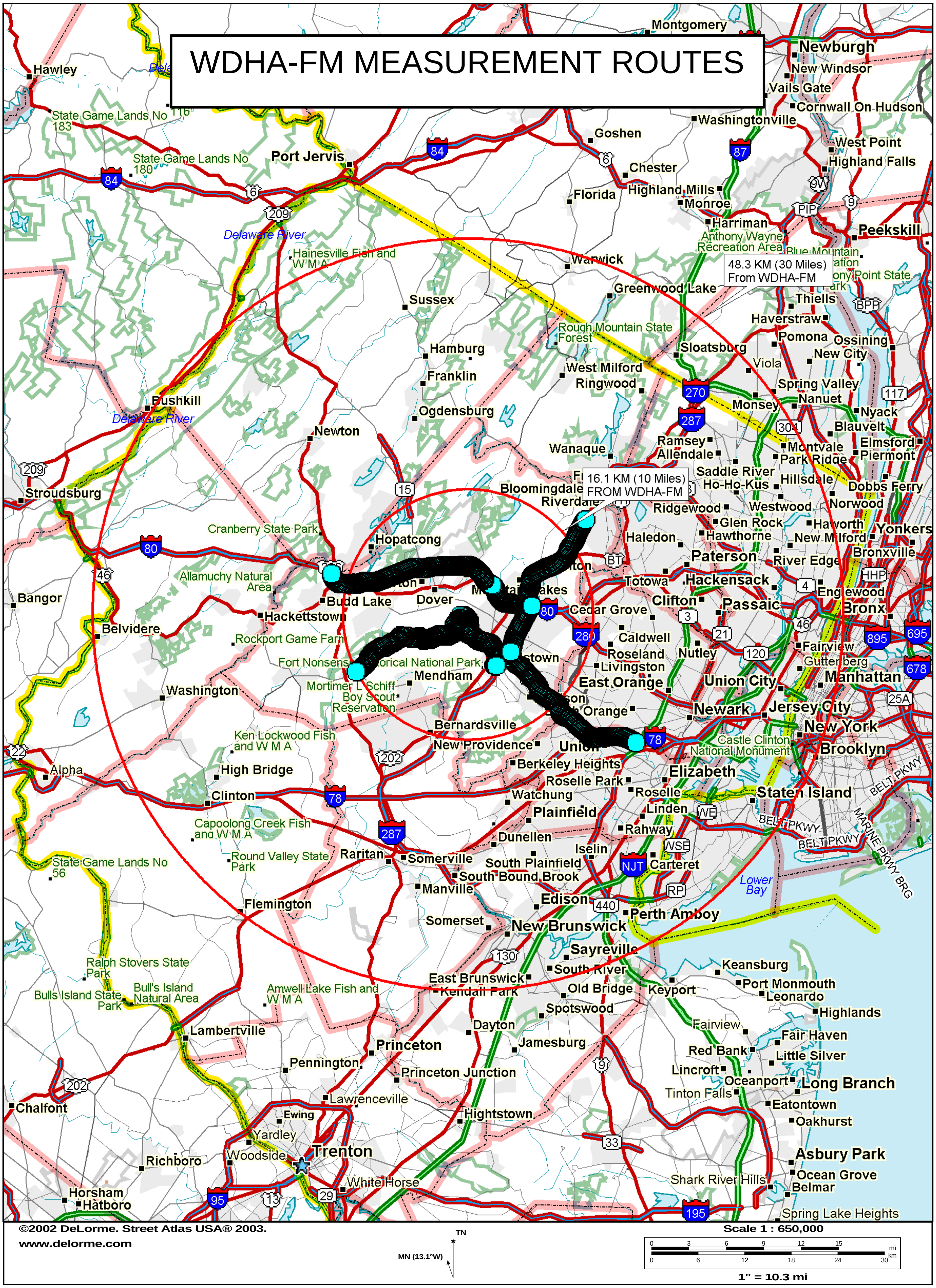


KDFC-FM, San Francisco – Separate vs. Combined Antenna – Southeast Route

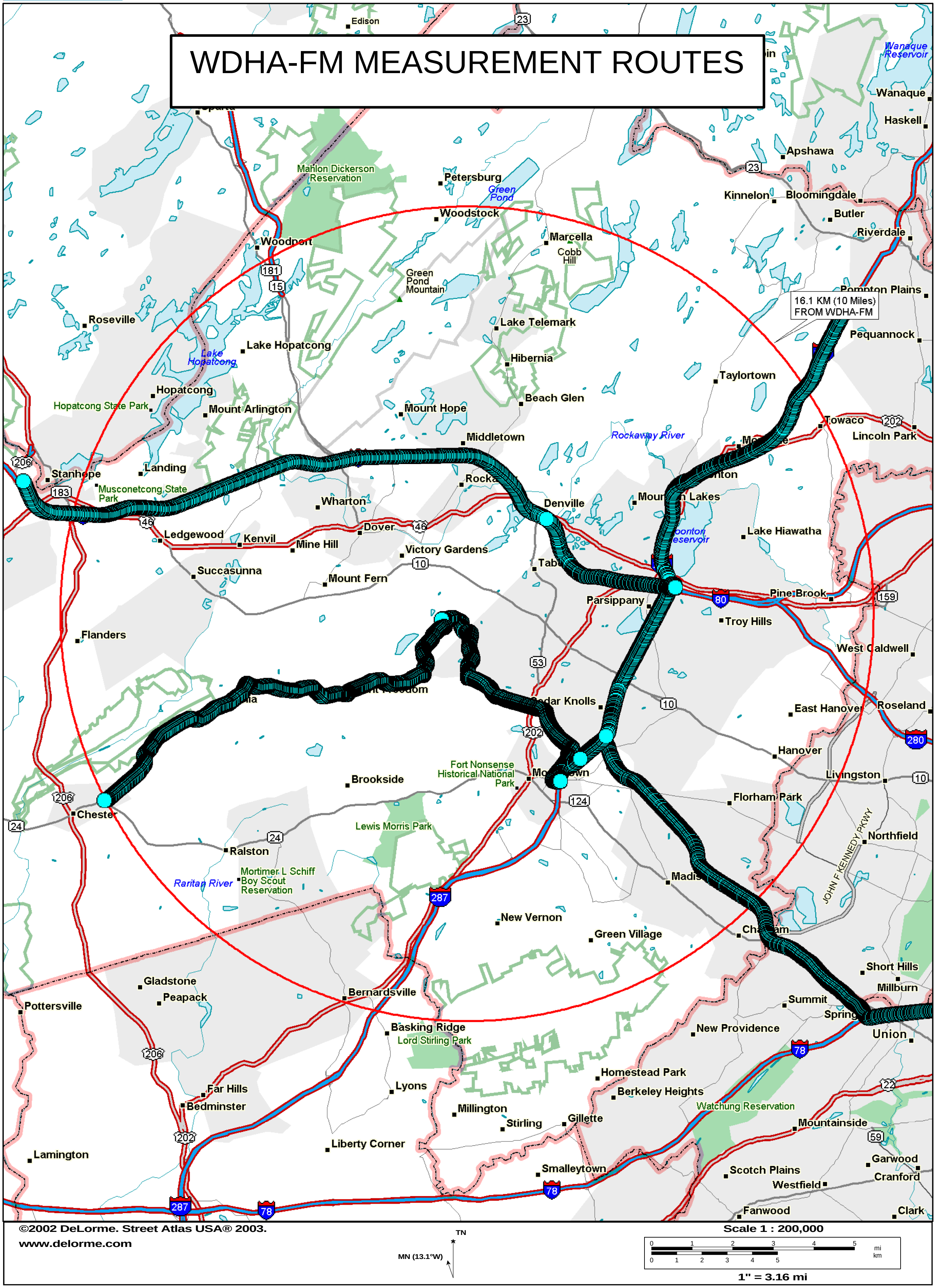
KDFC-FM, San Francisco – Separate vs. Combined Antenna – Southern Route



KDFC, San Francisco – Separate vs. Combined Antenna – Northwest Route


WDHA-FM MEASUREMENT ROUTES
48.3 KM (30 Miles)
From WDHA-FM
16.1 KM (10 Miles)
FROM WDHA-FM
Scale 1 : 650,000
1" = 10.3 mi
MN (13.1°W)
TN

DELORME


WDHA-FM MEASUREMENT ROUTES
16.1 KM (10 Miles)
FROM WDHA-FM
Edison
Wanaque Reservoir
Wanaque
Haskell
Apshawa
Mahlon Dickerson Reservation
Petersburg
Green Pond
Kinnelon
Bloomingdale
Butler
Woodstock
Riverdale
Marcella
Cobb Hill
Woodport
Green Pond Mountain
Pompton Plains
Roseville
Lake Telemark
Pequannock
Lake Hopatcong
Hibernia
Taylortown
Hopatcong
Beach Glen
Hopatcong State Park
Mount Arlington
Mount Hope
Towaco
Lincoln Park
Middletown
Rockaway River
Landing
Stanhope
Musconetcong State Park
Wharton
Denville
Lake Hiawatha
Ledgewood
Kenvil
Dover
Mine Hill
Victory Gardens
Succasunna
Mount Fern
Parsippany
Pine Brook
Troy Hills
Flanders
West Caldwell
Cedar Knolls
East Hanover
Roseland
Hanover
Livingston
Brookside
Fort Nonsense Historical National Park
Florham Park
Chester
Ralston
Lewis Morris Park
Northfield
JOHN F KENNEDY PKWY
Raritan River
Mortimer L Schiff Boy Scout Reservation
New Vernon
Green Village
Short Hills
Millburn
Gladstone
Peapack
Bernardsville
Summit
Pottersville
Union
Basking Ridge
Lord Stirling Park
New Providence
Homestead Park
Berkeley Heights
Watchung Reservation
Far Hills
Bedminster
Lyons
Millington
Stirling
Gillette
Mountainside
Garwood
Cranford
Liberty Corner
Lamington
Smalleytown
Scotch Plains
Westfield
Fanwood
Clark
TN
MN (13.1°W)
Scale 1 : 200,000
mi
km
1" = 3.16 mi


DELORME
WMGC-FM MEASUREMENT ROUTES
64.4 KM (40 Miles) FROM WMGC-FM
16.1 KM (10 miles) FROM WMGC-FM
Flint
Detroit
Ann Arbor
Port Huron
Redford
Troy
Lake Huron
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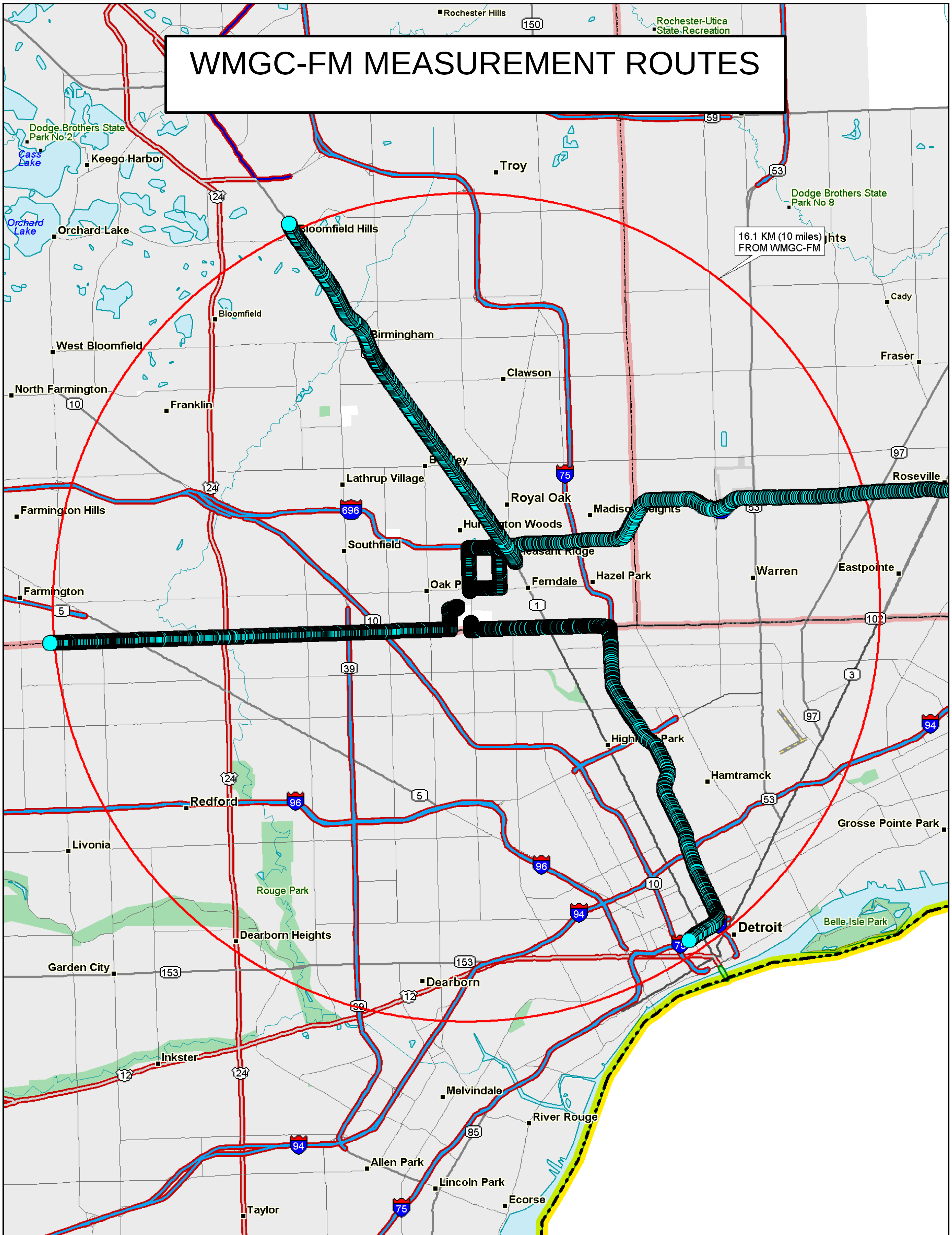
Scale 1 : 750,000
1" = 11.8 mi

Street Atlas USA® 2003

WMGC-FM MEASUREMENT ROUTES

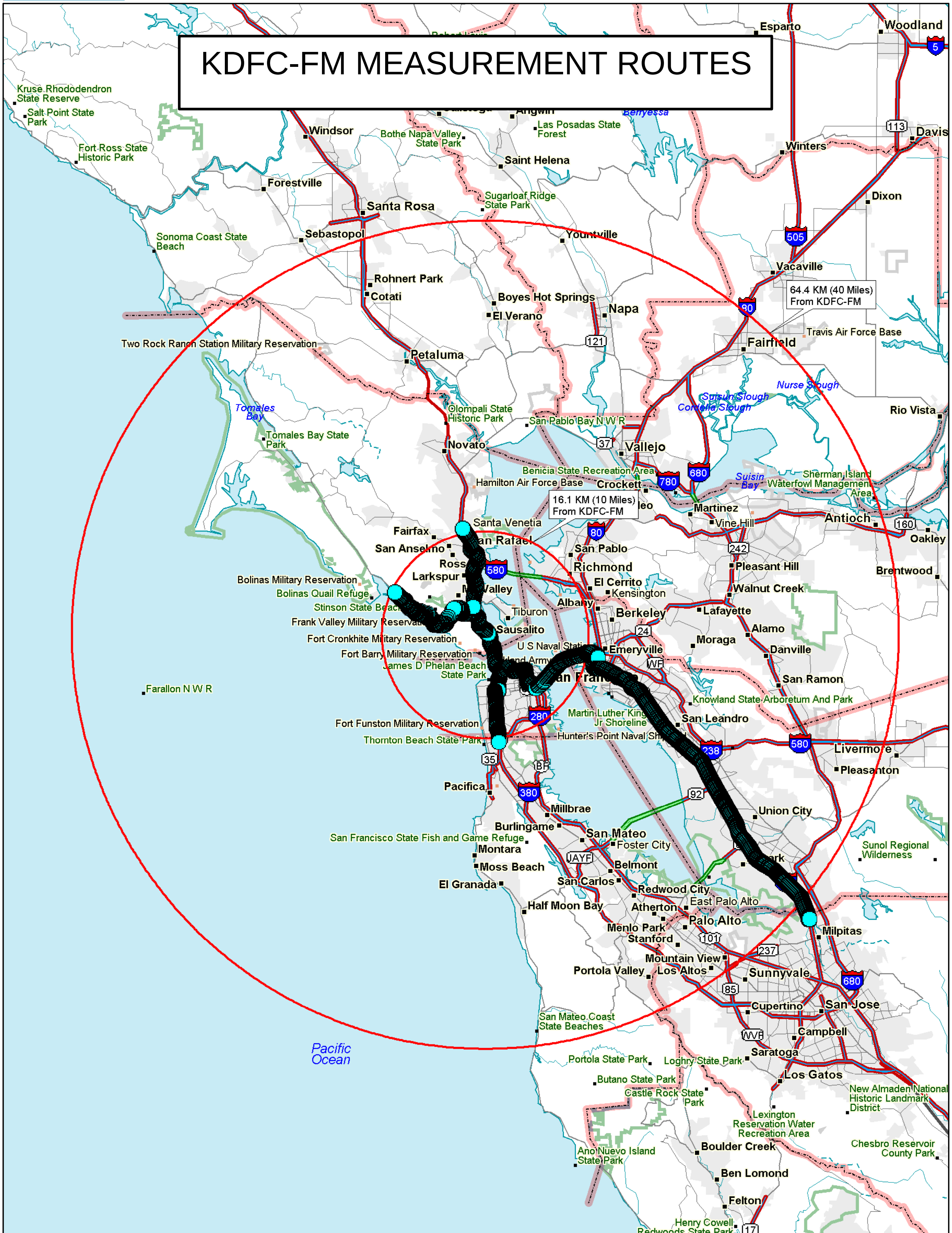


TN
MN (6.9°W)

Scale 1 : 200,000
1" = 3.16 mi

DELORME

Street Atlas USA® 2003



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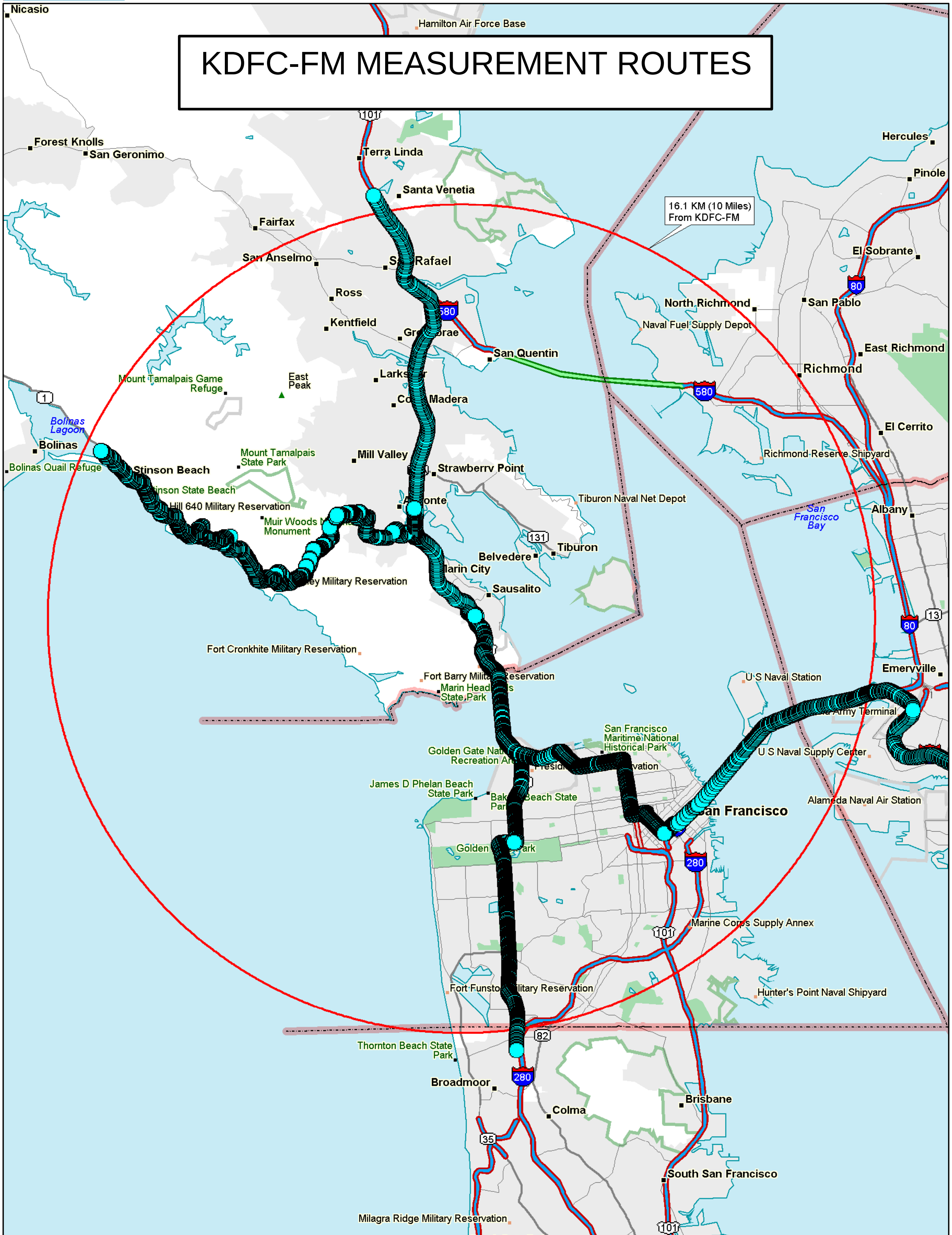
TN
MN (15.4°E)

Scale 1 : 800,000
1" = 12.6 mi

Street Atlas USA® 2003

KDFC-FM MEASUREMENT ROUTES



TN
MN (15.3°E)

Scale 1 : 200,000

1" = 3.16 mi

**ENGINEERING REPORT
EVALUATION OF THE USE OF
SEPARATE TRANSMITTING ANTENNAS FOR
IN-BAND-ON-CHANNEL DIGITAL
AND ANALOG FM BROADCASTING
PREPARED FOR
THE NATIONAL ASSOCIATION OF BROADCASTERS**

Site Photographs

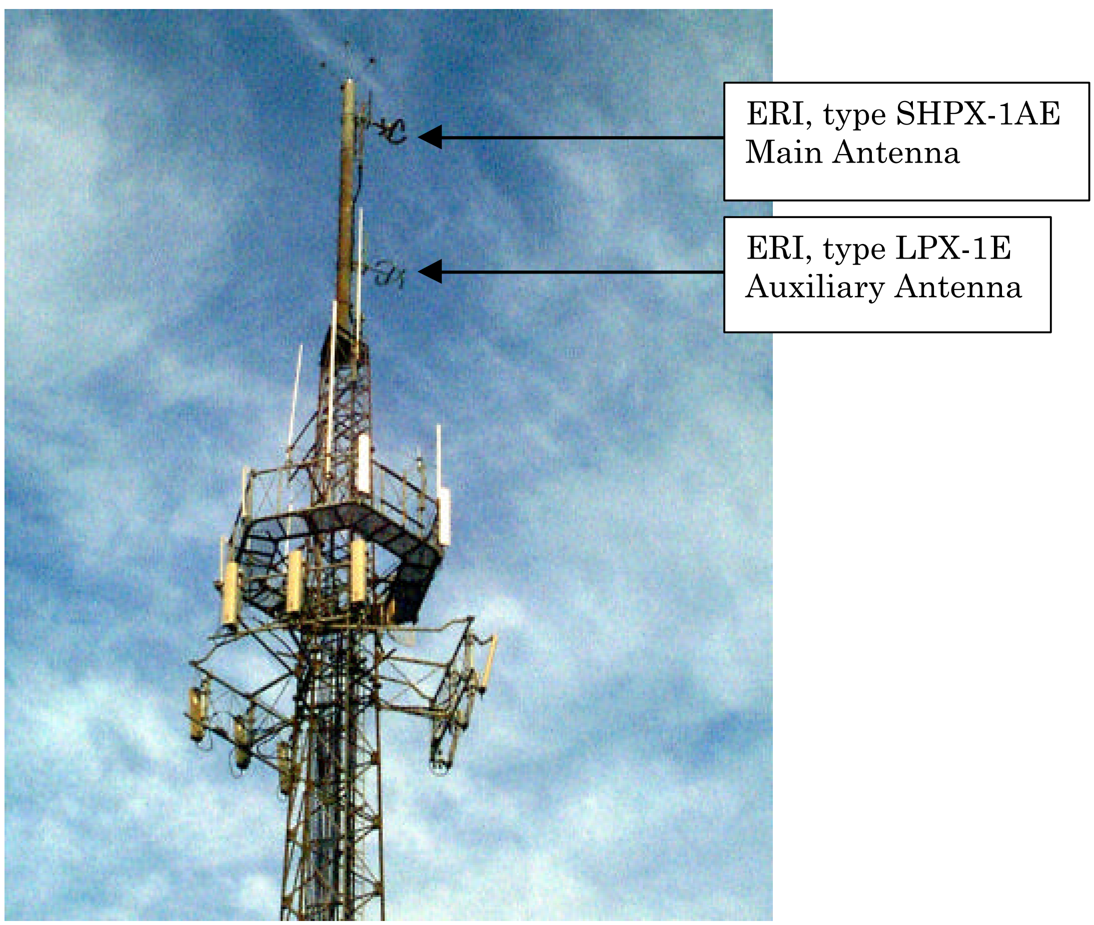


Figure 1 WDHA-FM Main and Auxiliary Antennas

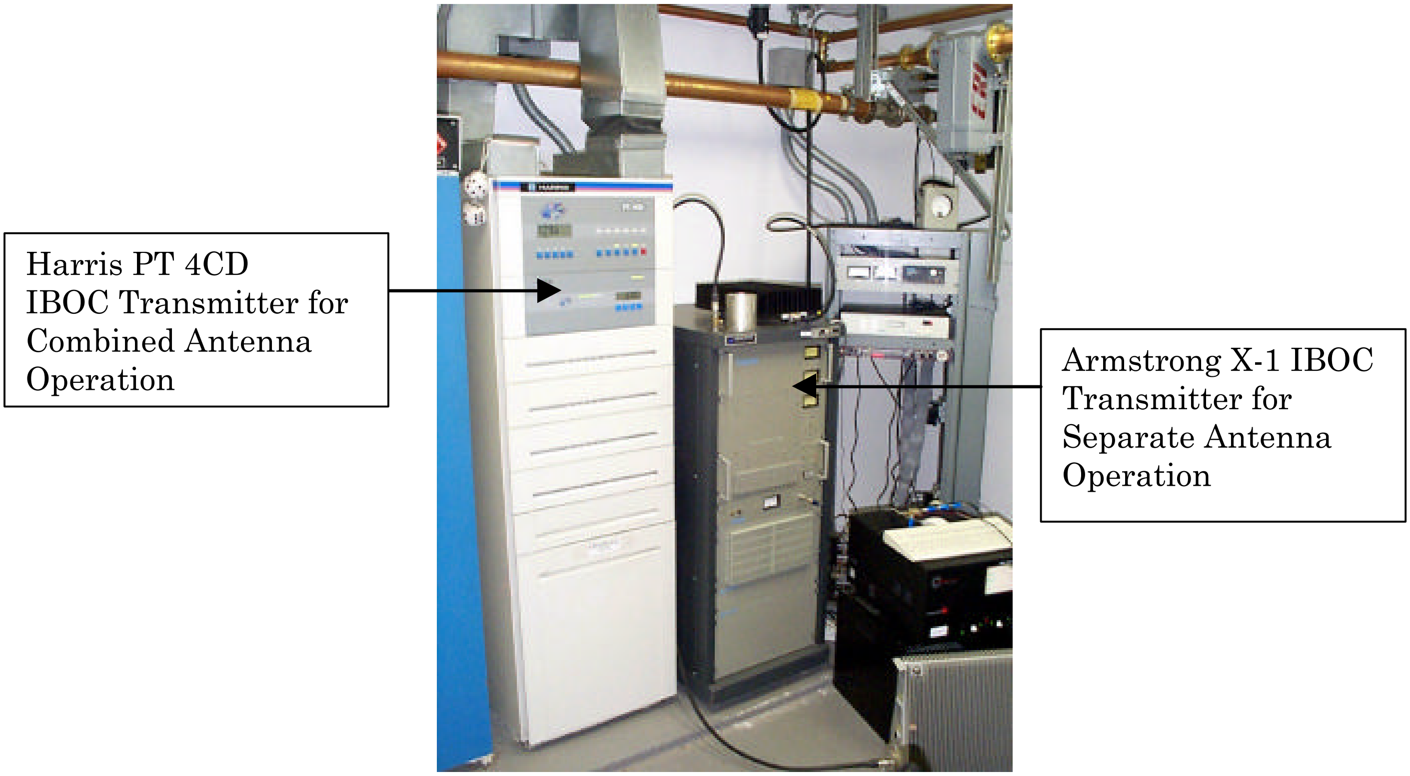


Figure 2 WDHA-FM IBOC Transmitters

Figure 3 WDHA-FM IBOC Combiner

Figure 4 WMGC-FM **ERI, type COG-1083-2CA** Main Antenna

Figure 5 WMGC-FM ERI, type **SHPX-2AE** Auxiliary Antenna

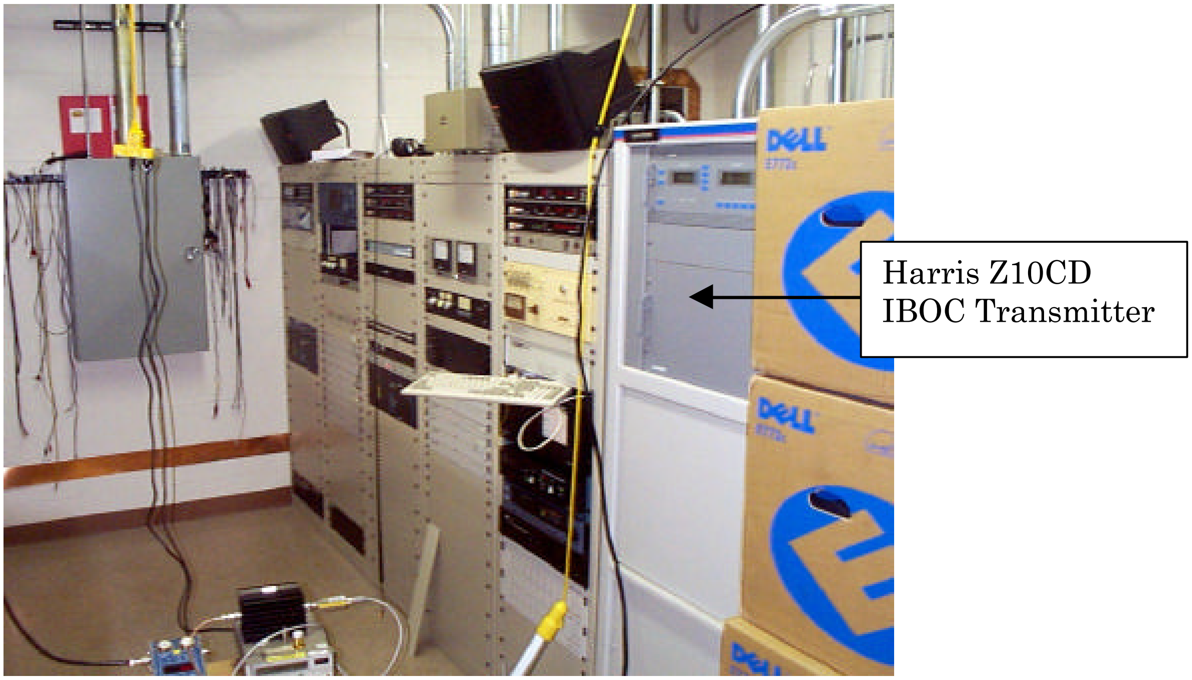


Figure 6 WMGC-FM IBOC Transmitter

Figure 7 WMGC-FM IBOC Combiner

Figure 8 WMGC-FM Main Antenna Combiner

Figure 9 WMGC-FM Auxiliary Antenna Combiner

Figure 10 KDFC-FM ERI, type G5CPS-4AE Main Antenna

Figure 11 KDFC-FM ERI, type SPHX 2AC Auxiliary Antenna

Figure 12 KDFC-FM Broadcast Electronics FMi 703 IBOC Transmitter

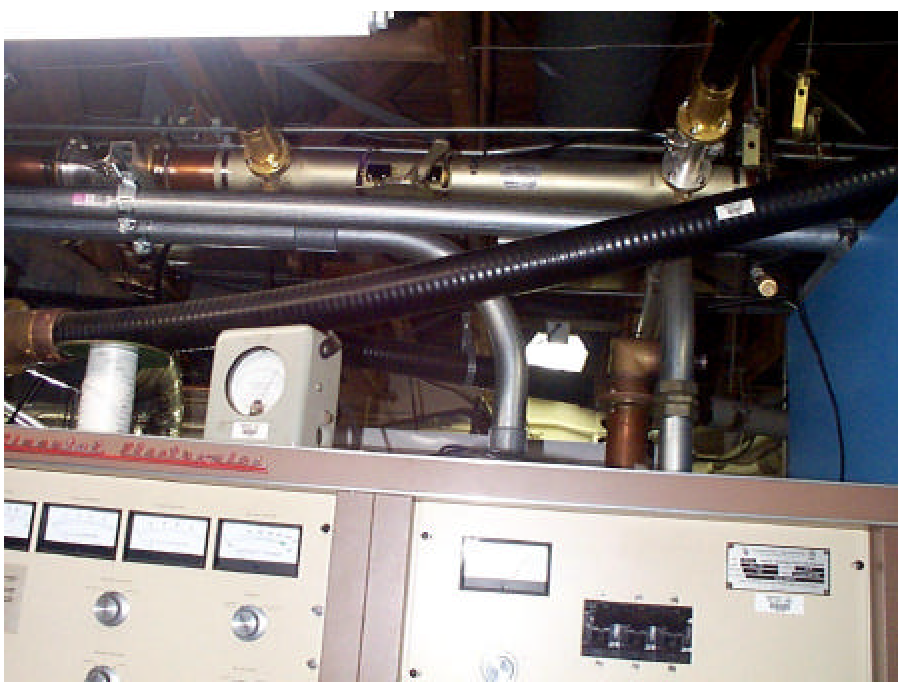


Figure 13 KDFC-FM IBOC Combiner

Figure 14 iBiquity Warren Test Vehicle

Figure 15 Test Vehicle Equipment