MTR 03W0000021V1

MITRE TECHNICAL REPORT

Experimental Measurements of the Third-Adjacent Channel Impacts of Low-Power FM Stations

Volume One: Final Report

May 2003

Sponsor:	Federal Communications Commission	**Project No.:**	1201FCC3-AA
Contract No.:	CON01000020		

MITRE

MITRE Project Approval:

D. James Chadwick

Director, Spectrum Management

Table of Contents

List of Figures

List of Tables

Executive Summary

On October 25, 2000, Congress passed HR 4942, Section 632(b) of which required that the Federal Communications Commission (FCC) "conduct an experimental program to test whether low-power FM radio stations will result in harmful interference to existing FM radio stations if such stations are not subject to the minimum distance separations for third-adjacent channels required by Subsection (a)." The Commission was also directed to "select an independent testing entity to conduct field tests in the markets of the stations in the experimental program." The legislation stated that "up to nine" different markets could be considered. In July 2001, The MITRE Corporation was selected to perform this work, based on its technical knowledge, engineering experience, independence and freedom from any actual or perceived conflict of interest.

MITRE competitively selected an experienced, independent subcontractor to perform the field measurements, which were made during the fall of 2002. Before starting the measurements, MITRE approved a set of detailed subcontractor-developed test plans and test procedures. Measurements were made at up to eight sample receiver locations for each of seven different low-power FM (LPFM) transmitter sites. The selected sites covered a diverse range of geographic, population density, market size and program material combinations. The measurements included the operation of the test LPFM station at the maximum power and antenna height values that are specified in the FCC Rules. Measurements were also made with the LPFM transmitter turned off to identify possible cases where there was receiver degradation even in the absence of LPFM transmissions.

Six different commercially available FM receivers were tested, covering a range of cost and portability options. An analog subcarrier receiver that provides reading services to the visually impaired (RSVI) was included in the set. So were typical auto, home, clock, boombox and small personal receivers. An FM translator was also tested to determine the effect that a third-adjacent LPFM station could have if it interfered with the translator's input receiver.

The subcontractor submitted its final measurement data report to MITRE in March 2003, along with studio-quality digital recordings of the output of the five or six receivers under test for each measurement location. MITRE studied the field measurements and recordings, and analyzed the results in terms of the feasibility of relaxing or eliminating the third-adjacent protection requirement for LPFM Stations. That analysis is described in Section 2 of this report. A theoretical analysis was also done to ensure that the measurements were consistent with well established engineering principles. That analysis is contained in Section 4.

MITRE's tasking from the FCC also required an evaluation of the potential impact that third-adjacent LPFM stations might have on the transition of FM broadcasting to a digital format. MITRE procured the necessary digital broadcasting and receiving equipment and made laboratory measurements to determine the effects that LPFM stations could have on these operations. The digital analysis is described in Section 3 of this report.

Summary of Findings

In summary, based both on the measured data and the theoretical analysis, MITRE has concluded that LPFM stations can be operated on third-adjacent channels with respect to existing “Full Power” FM (FPFM) stations provided that relatively modest distance separations are maintained between any LPFM station and receivers tuned to the potentially affected FPFM station. These required separations are on the order of a few tens of meters in the best case, to slightly more than a kilometer in the worst case. MITRE has determined, based both on the field measurements and its own theoretical analysis, that no case of harmful third-adjacent LPFM interference will exist outside of an area with a radius of 1100 m surrounding the LPFM antenna, for an LPFM transmitter Effective Radiated Power (ERP) of 100 W or less and an LPFM antenna height of 30 m or less.

The 1100 m separation value applies to LPFM locations that are near the protected contour of the third-adjacent channel FPFM station. In other cases where the LPFM station is closer to the FPFM station, this radius will become much smaller – on the order of tens of meters, to one or two hundred meters, depending on the proximity. A formula was developed, based on the field measurements and the theoretical analysis, to compute the distance separation that is required between LPFM stations and receivers tuned to FPFM stations on third-adjacent channels. The formula accounts for the relative locations of receivers, LPFM stations and FPFM stations. This equation is shown in Section 5.2.1 and could be used to develop licensing rules for LPFM stations in lieu of the third-adjacent channel separation rules now in effect.

In the measured data, LPFM interference was not strongly correlated with variations in terrain or program material type. The measurements also did not show a strong dependence on LPFM antenna height. MITRE’s model (Section 4) does show a dependence on antenna height because higher LPFM antennas could extend the distance to which a second-power propagation law applies. This factor argues in favor of retaining the current Rules regarding reduction of the LPFM ERP for antenna heights above 30 m.

In terms of the impact of an LPFM station due to interference on the audience of an FPFM station, in the worst case measured, the fraction of the protected coverage area of an existing station that could be subjected to harmful interference is 0.13%. In most other cases, this fraction is orders of magnitude smaller.

The measurements show that, for the one case examined where the affected FPFM station carries RSVI, there was no significant LPFM interference to the RSVI receiver when it was located more than 80 meters away from the LPFM antenna. However, at some distances greater than 80 meters, the RSVI signal was degraded even in the absence of LPFM transmissions. No significant interference was noted in the auto or home receivers at distances greater than 130 meters, or in any of the other non-translator receivers at a distance exceeding 550 meters. However, interference still might be possible at greater distances under certain unfavorable circumstances. In general, however, the required LPFM-to-receiver separations will vary according to the formula given in paragraph 5.2.1 of this report.

Paragraph 5.1.2 of this report identifies a relationship that was developed, on the basis of the field measurements, to compute the distance separation that is required between FM translator receiving antennas and LPFM stations. During the field tests, the LPFM antenna was placed in the main beam of the translator receiver's antenna at a distance of about 450 m. The LPFM power was varied from zero to 100 W. No harmful interference was seen for an LPFM power of 2 W or less at that distance, in the main beam of the translator receiver. Taking into account a typical translator receiver's antenna pattern, a 100W LPFM station can be as close as 0.9 km to a translator that is itself operating at the protected contour distance from its primary station, if the LPFM antenna is 90^{o} or more off the translator antenna's main beam axis (i.e., gain is 0 dBd or less). As the LPFM station approaches the translator's main beam axis, this value increases to about 3.2 km.

The digital analysis has shown that the iBiquity IBOC system is very robust and performed about as well in the presence of LPFM signals as the analog car radio used in the tests. As a result, no interference from LPFM stations to digital receivers is likely to occur at a distance of more than 130 m, even at the FPFM protected contour distance.

Section 1

Introduction

1.1 Background

On January 27, 2000, the Federal Communications Commission (FCC) released a Report and Order (FCC-00-19) for Docket MM-99-25 that created a Low Power FM (LPFM) Radio Service. Therein, the Commission established the service rules for LPFM that specified technical and eligibility requirements for LPFM licenses. The purpose of these rules was to provide a viable LPFM service without causing harmful interference to licensed full-power FM (FPFM) stations within their protected service contour.

In Paragraph 70 of the Report and Order, the FCC decided not to require third-adjacent channel separation requirements between LPFM and FPFM stations. This decision was challenged by several parties, resulting in the issue of a Memorandum Opinion and Order on Reconsideration (FCC-00-349) on September 28, 2000 which reaffirmed the decision that third-adjacent channel separations were not needed.

On October 25, 2000, the Congress passed, HR 4942 ("the Act"), in which Section 632(b) directed the FCC to impose third-adjacent channel separation requirements on LPFM applications and licenses. President Clinton signed the Bill into law on December 21, 2000. However, the language in the Act left the issue open by requiring that the Commission "conduct an experimental program to test whether low-power FM radio stations will result in harmful interference to existing FM radio stations if such stations are not subject to the minimum distance separations for third-adjacent channels required by subsection (a)."

On April 2, 2001, the FCC issued a Second Report and Order (FCC-01-100) that carried out the requirements of the Act and imposed a third-adjacent separation distance. The effectiveness of an LPFM radio service is significantly affected by the decision on third adjacent channel restrictions. If the rules that are in FCC-01-100 are permanently retained, then there could be a significant number of communities that will not have LPFM service.

Section 632(b)(2) of the Act directs the Commission to "select an independent testing entity to conduct field tests in the markets of the stations in the experimental program." "Independent" was considered to mean that the entity had no past, current or future interest in the LPFM issue on either side. The MITRE Corporation was selected based on its independence, freedom from any conflict of interest, and technical capabilities and facilities.

1.2 Tasking

The Commission tasked MITRE to perform the tests that were required by the legislation and to issue a Final Report on the findings. Specifically, MITRE was tasked to:

- Conduct market research to use in planning and managing a field test program carried out by a subcontractor;
- Develop and implement an acquisition program to competitively select a field measurements subcontractor who met the independence requirements; and,
- Perform a detailed analysis of the results of the field measurements and prepare a Final Report that includes conclusions and recommendations as to whether or not the third-adjacent channel distance separations for LPFM stations can be eliminated or reduced.

The measurement program was to include the following elements:

- Tests in no more than nine FM radio markets
- Tests in urban, suburban and rural geographical areas
- Tests to evaluate the impact on FM translator stations
- Tests in the markets of minority and small-market broadcasters
- Tests involving FM stations that provide reading services for the visually impaired to the public
- Tests to evaluate the effects that may result from the transition of terrestrial FM broadcasting to a digital format

During the tests, the Act directs that the testing entity provide the opportunity for public comment on any interference that may be produced as a result of the tests. An independent audience listening test was also specified, "to determine what is objectionable and harmful interference to the average radio listener."

1.3 Technical Approach

1.3.1 Market Research

MITRE conducted a search for qualified field testing companies using sources that included:

- "Sources Sought" advertising in leading Industry and Trade Journals, including:
  - *Commerce Business Daily*
  - *Broadcasting and Cable Weekly*
- In addition to these publications, an announcement was placed on:
  - The FCC Web site

– The MITRE Corporation Web site

MITRE staff members who are familiar with the field testing industry made telephone inquiries to specific organizations known to be in the business. From these sources, a MITRE Request for Proposal was sent to 34 companies. Of these, six vendors were identified who appeared likely to meet both the technical and independence requirements, based on an initial screening. Three formal proposals were received in response to the RFP.

1.3.2 MITRE Subcontracting Methodology and Source Selection

The FCC retained the services of MITRE to assist the FCC in establishing and implementing an LPFM measurement program and preparing the final test report. Specifically, MITRE assisted the FCC by:

- Establishing and implementing an acquisition program
- Developing high-level test requirements and procedures
- Competitively selecting a subcontractor to perform the measurements
- Managing the subcontractor and monitoring selected activities
- Reviewing the subcontractor test plans, data and results
- Performing a detailed analysis of the measurement results to draw conclusions
- Developing a final report for delivery to the FCC

MITRE established and implemented a formal acquisition program to select a subcontractor to perform the required LPFM measurements. The acquisition approach for the LPFM program was designed to promote full and open competition among all interested offerors.

MITRE established a Source Selection Organization and rigorous source selection procedures to ensure a fair evaluation process and one that would result in a selection providing the best opportunity for success. It was also designed to ensure that the subcontractor selected did not have, or appear to have, a conflict of interest. The Source Selection Organization is shown in Figure 1-1. It consisted of the Source Selection Authority (SSA), the Technical Evaluation Team (TET), and the Business Evaluation Team (BET). Advisors were also available to assist the Evaluation Teams in specific technical and business areas during the selection process.

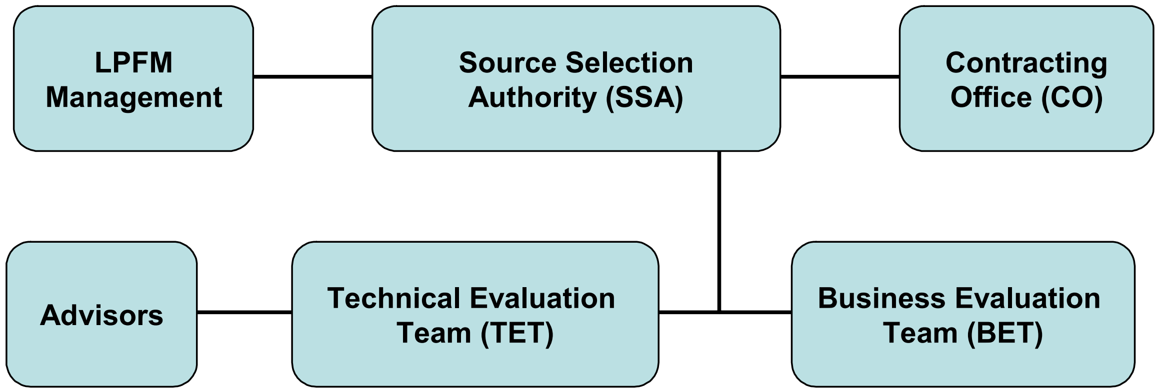


Figure 1-1. Source Selection Organization

Evaluation criteria and proposal preparation instructions were provided to all prospective offerors and each offeror was required to submit a Technical Proposal and a Business Proposal. In addition, each offeror was required to submit past performance references to enable MITRE to verify and assess the offeror's ability to perform on this contract given its performance on other similar past efforts.

The initial phase of the evaluation consisted of three parts: (1) evaluation of past performance information, (2) evaluation of each offeror's technical approach against the evaluation criteria, (3) evaluation of each offeror's business proposal to assess the bidder's financial strength and corporate stability. At the conclusion of this phase of the evaluation, the MITRE Contracting Officer determined, based on a recommendation from the Technical Evaluation Team, a competitive range containing offerors who were selected to enter the final evaluation phase. Each offeror that remained in the competitive range was asked to provide an oral presentation on its technical approach to the evaluation team.

Following the oral presentation and an offeror site visit, MITRE provided each offeror in the competitive range with their technical weaknesses and identified risks. MITRE requested each offeror to submit revised Technical Proposals and Business Proposals with best and final offers. The revised technical proposal, past performance findings, and oral presentation information for each offeror in the competitive range were individually reviewed again. The revised Business proposals were also reviewed to assess if the prices proposed were realistic for the work to be performed, demonstrated an understanding of the RFP requirements, and were consistent with the elements in each offeror's Technical Proposal.

Based on the technical and business evaluations of each offeror's proposal, the Technical Evaluation Team performed a Best Value Analysis to develop its Source Selection Recommendation for submission to the Source Selection Authority. After reviewing the Technical Evaluation Team's source selection recommendation and supporting rationale, the Source Selection Authority made the final source selection decision. The Contracting Office then negotiated the contract provisions and awarded a firm fixed price contract to the selected offeror, Comsearch, Inc. (hereinafter, "the subcontractor").

1.3.3 Field Measurement Program

1.3.3.1 Test Plans

The subcontractor was required to prepare two test plans prior to commencing the field tests. The first of these, the Field Test Plan (FTP), was designed to define the test site selection process, the measurements to be performed, program content variations, test scenarios, data collection procedures and test equipment architecture and descriptions. The FTP is included as Annex I in Volume Two of this report. The second plan, the Test Procedures Plan (TPP), described the precise test procedures to be followed at each test site. This very detailed plan was written to the level of individual instrument switch settings and exact descriptions of data collection procedures. The TPP is contained in Annex II in Volume Two of this report. Pertinent segments of these plans are summarized below.

1.3.3.2 Test Site Selection

The FCC furnished MITRE with a list of 39 LPFM license applications that were in markets where there were not duplicate filings, in order to preclude the chance that the field tests might favor one applicant over others. This is the only input to the LPFM project that the FCC made. These sites are listed in Appendix A. From these 39 sites, subcontract offerors chose a set that would meet the following selection criteria, established by MITRE:

- Population Density Diversity (urban, suburban, rural)
- Geographic Diversity (flat, hilly, mountainous)
- FPFM Station Class Diversity (A, B, C, etc.)
- Program Material Type (news/talk, unprocessed music, and processed music)
- Widely varying values of "distance ratio" (distance from the LPFM site to the incumbent FPFM station, divided by the FPFM station's primary coverage radius) among LPFM site, FPFM service contour radius and test receiver locations
- Inclusion of an FM translator
- Inclusion of at least one station using an analog subcarrier to broadcast Reading Services for the Visually Impaired (RSVI)
- Inclusion of at least one minority-owned/small market station

The subcontractor chose the LPFM sites listed in Table 1-1. All of the selection criteria listed above were met in this set.

THIS PAGE INTENTIONALLY LEFT BLANK

Table 1-1. Field Measurement Sites and Associated Incumbent FPFM Stations

LPFM Site	Avon, CT	Brunswick, ME	East Bethel, MN	Owatonna, MN (Site A)	Owatonna, MN (Site B)	Winters, CA	Benicia, CA
Frequency	107.5 MHz	97.3 MHz	91.7 MHz	106.3 MHz	91.1 MHz	103.1 MHz	100.3 MHz
Latitude (N)	41° 46′ 39.0″	43° 54′ 23.0″	45° 19′ 08.3″	44° 06′ 44.8″	44° 05′ 18.4″	38° 31′ 39.2″	38° 10′ 55.9″
Longitude (W)	72° 51′ 41.2″	69° 59′ 48.7″	93° 13′ 48.0″	93° 12′ 42.0″	93° 08′ 45.9″	121° 57′ 33.2″	122° 15′ 21.8″
Site Elevation (m) above Avg. Terrain	-31.8	-0.9	-0.7	-1.0	12.6	-54.0	-43.1
Terrain	Hilly	Hilly	Flat	Flat	Flat	Flat	Mountainous
Area Type	Suburban	Urban	Rural	Suburban	Rural	Suburban	Suburban
Incumbent FPFM Station	WCCC (106.9 MHz)	WCME (96.7 MHz)	KNOW (91.1 MHz)	K289AE (105.7 MHz)	KGAC (90.5 MHz)	KSFM (102.5 MHz)	KFRC (99.7 MHz)
Station Class	B	B1	C	FX	C1	B	B
ERP (kW)	23.0	15.5	100.0	0.170	75.0	50.0	40.0
HAAT (m)	221	127	400	103	216	152	396
Program Content	Processed music	News/Talk	Unprocessed music	Unprocessed music and news/talk	Unprocessed music and news/talk	Processed music	Processed music
Latitude (N)	41° 47′ 48.4″	44° 01′ 31.3″	45° 03′ 43.9″	44° 05′ 18.9″	44° 13′ 19.9″	38° 35′ 19.7″	37° 41′ 14.8″
Longitude (W)	72° 47′ 50.4″	69° 34′ 15.2″	93° 08′ 21.8″	93° 08′ 25.7″	94° 07′ 03.9″	121° 43′ 33.9″	122° 26′ 07.9″
Primary Contour Radius (km)	64.91	44.73	79.76	11.89	Not applicable	65.33	84.13
Distance (km) from LPFM Site	5.77	36.56	29.42	6.27	Not applicable	21.38	57.21
LPFM/Contour Distance Ratio	0.09	0.82	0.37	0.54	Not applicable	0.33	0.68
Calc. FPFM Field Strength (dBu) at LPFM Site	99.9	61.3	83.7	71.2	52.5	78.1	65.4
Remarks			RSVI on subcarrier	Translates KGAC signal (small market)	K289AE translator input	Minority FPFM market	

Before beginning any measurements, the subcontractor sent a team to each selected site to validate its overall suitability, including issues such as accessibility, and the availability of a suitable location for the LPFM tower. This process resulted in the selection of an alternate site for the Benicia, CA tests. The original site was found to be swampy and the radial along which receiver test locations would be placed would have run through private land that was not accessible. The new site had a very similar path profile to the FPFM station in downtown San Francisco, and an almost identical distance ratio.

An FCC Form 309 was filed with the Media Bureau to obtain official authority to operate the LPFM transmitter on the third-adjacent channel of the FPFM station at the new selected sites. These were approved by the FCC prior to tests at each site.

1.3.3.3 Field Measurement Test Equipment Configuration

The test equipment used for the tests consisted of two parts: (a) a transmitter assembly and, (b) a receiver van. The transmitter assembly consisted of a commercial LPFM transmitter with a power output of 300 W to allow for line losses in order to be able to obtain the required maximum ERP of 100W, an antenna on a telescoping tower, and various test equipment needed for determining power and antenna VSWR. It also included equipment needed to generate the LPFM program material. The receiver van contained the six receivers used in the tests, and the digital recording system. The details of these two configurations can be found in Volume Two, Annex I, Figures 2 and 3. A high-quality GPS receiver was used to determine the locations of the two parts of the measurement system at each site and test location.

1.3.3.4 Program Material Combinations

Because it affects the average carrier deviation of the FM signal, one would expect that the amount of interference perceived as the result of an LPFM station would be a function of program material type on both the FPFM and LPFM stations. There are three basic categories of program material. The first is a "News/Talk" format, where little, if any, music is played. The second is the broadcast of music with its full dynamic range ("unprocessed"), most often employed by classical music stations. Last, there is the "processed" music format, where an audio leveling (volume compressor) technique is used to maintain the highest possible average carrier deviation and thus improve the quality of the broadcast signal in the outer regions of the coverage contour.

In order to study the effects of this parameter, the tests were run with all combinations of program material across the set of LPFM and FPFM stations. Since the format of each FPFM station was fixed, the subcontractor varied the LPFM content and chose FPFM stations with different program content in order to make measurements for all possible combinations of program type across the measurement set as a whole.

Since few stations broadcast a "pure" content all the time – news/talk format stations occasionally have music in commercials or as fill, and music format stations have talk in commercials, DJ chatter and newscasts – an effort was made to make the digital recordings at times when the required content was being broadcast by the FPFM station. In a few cases, the content changed within the original, field-recorded 2 minute audio sample. This was taken into account in the analysis.

1.3.3.5 LPFM Transmitter Power Settings

LPFM stations are proposed to be licensed in two ranges of effective radiated power (ERP): 1-10W and 50-100W. The service rules call for de-rating the ERP for 100W stations with an antenna height above average terrain (HAAT) of more than 30 meters to ensure that the 1 mV/m contour does not exceed a distance of 5.6 km from the station. For the field measurements, the maximum power (10W and 100W) in each of these ranges was used, along with a set of measurements at each test location when the LPFM transmitter was turned off ("0 W"). Great care was taken to calibrate the transmitter/transmission line /antenna setup to ensure that the correct ERP was actually transmitted. See Volume Two, Annex II, Paragraph 2.1.2.1 for details.

1.3.3.6 LPFM Antenna Height Settings

A transportable, telescoping tower high enough to obtain a HAAT of 30 m at three of the sites (Avon, CT, Winters, CA and Benicia, CA) was not available. A HAAT of 30 m *was* achievable at four of the sites that have relatively flat terrain. (Brunswick, ME, East Bethel, MN and the two sites in Owatonna, MN.) When the HAAT of 30 m could not be obtained, the actual HAAT at the site was computed. Measurements were then made with the antenna center of radiation at 10 m and 30 m above ground level at each site in order to provide data for an analysis of interference effects as a function of HAAT.

1.3.3.7 Radio Receiver Types Tested

The most important element in the field testing was the type of radio receiver subjected to potential interference. It was expected that the susceptibility to third-adjacent-channel interference would be strongly dependent on the selectivity of the receiver's RF and IF stages. This, in turn, was expected to be a function of the initial cost of the receiver. Six kinds of FM radio receivers were tested. All except the subcarrier receiver that provides reading services to the visually impaired (RSVI) were stereo receivers.

- Automobile Radio – "Premium" AM/FM stereo receiver, standard equipment in the 2001 Ford Expedition®
- Home Receiver – Kenwood Model VR-605
- Clock Radio – RCA Model RP3755

- "Boom Box" – Sony Model CFD-F5000
- Personal Radio – Sony Walkman® Model SRF-M35
- Subcarrier Receiver – Success Model ML922 RSVI receiver, furnished by Minnesota State Services for the Blind.

1.3.3.8 Test Scenario Development

The likelihood of harmful interference from a third-adjacent channel LPFM station is a function of the distance relationships among the LPFM station, the FPFM station and potential victim receivers, and the position of the receivers within the FPFM station's service contour. For example, there is less likelihood of harmful LPFM interference in a case where the receiver is relatively close to the FPFM station than if it is closer to the FPFM station's protected contour. Likewise, a receiver close to an LPFM site and far away from the FPFM station to which it is tuned is more likely to suffer harmful interference. In order to provide a full range of data for the analysis, a "distance ratio" was included among the parameters used to select sites for measurement. It is the ratio of the distance between the FPFM and the LPFM transmitter sites, and the distance along the common radial from the FPFM station to its protected coverage contour.

Eight measurement locations were chosen for each LPFM site. These locations were placed as close as possible to a line extending from the FPFM site through the LPFM site and beyond, which represents the worst case. The first location was chosen at a distance of .02 km beyond (with respect to the FPFM site) the LPFM antenna. The most distant location was selected to be the greater of 8.05 km and the point at which the predicted desired-to-undesired (D/U) signal ratio was zero dB. The six intervening locations were then spaced according to the formula:

$$K = 10^{[\log(L/F)/(N\text{-}1)]} \tag{1}$$

where:

K = multiplier, starting with the nearest location
L = Distance to farthest point
F = Distance to the nearest point
N = Number of locations (8)

The reason for the logarithmic spacing was to maximize the precision of the test results in the area closest to the LPFM transmitter where interference, if any, was deemed most likely to occur. The results of this computation for all sites and locations can be found in Volume Two, Annex I, Table 6. Even in those cases where locations right along the radial could not be used, the distance multiplier was used in the selection of the nearby location that was selected.

Table 1-2 shows the actual distance, measured with the aid of a GPS receiver, from each LPFM test site to each of its associated receiver test locations. Owatonna Site B had only two receiver locations, for reasons explained in Section 1.3.3.9. Every other site had eight locations. In general, the distances shown in Table 1-2 for those locations deviated slightly from the planned distances computed using equation (1), because it was usually not feasible in practice to park the receiver van exactly at the preplanned locations. However, the deviations from the planned distances were relatively small.

Table 1-2. Actual Distances (km) of Receiver Test Locations from LPFM Test Sites

	LPFM Site						
Receiver Location	**Avon, CT**	**Brunswick, ME**	**East Bethel, MN**	**Owatonna, MN (Site A)**	**Owatonna, MN (Site B: Translator Input Test)**	**Winters, CA**	**Benicia, CA**
1	0.018	0.013	0.011	0.023	6.392	0.014	0.021
2	0.034	0.064	0.034	0.050	12.469	0.035	0.055
3	0.100	0.126	0.080	0.116	—	0.095	0.126
4	0.206	0.370	0.232	0.401	—	0.235	0.333
5	0.570	0.935	0.550	0.867	—	0.573	0.906
6	1.362	2.416	1.481	2.263	—	1.368	2.409
7	3.161	7.025	3.346	6.101	—	3.314	6.222
8	8.008	19.607	8.048	16.559	—	8.143	17.003

1.3.3.9 Special Handling of FM Translator Input Measurement

The FM translator at Owatonna, MN was used to make two sets of measurements. First, measurements were made using the translator's transmitter ("Translator Output") as a low-power-range, small-market, FPFM station as at other sites. Second, the translator's receiver ("Translator Input") was subjected to an LPFM signal on its third-adjacent channel to determine what effects might occur if LPFM stations were sited near FM translators. For this test, the LPFM transmitter was located a small distance (0.45 km) from the translator input antenna and along a line between the translator input antenna and the FPFM station that is being translated. The LPFM transmitter power was sequentially set to 1, 2, 5, 10, 20, 50 and 100 W and measurements were taken at each power level to determine the point at which harmful interference occurred. The receiver van was stationed at two locations. The first was 6.39 km from the translator, about halfway to the translator's F(50,50) contour. The second was 12.47 km away, close to the F(50,50) contour for the translator. This measurement was used to determine whether or not receivers tuned to the translator's output frequency would detect harmful interference caused by third-adjacent channel signals into the translator input. This measurement was particularly important because harmful interference to a translator's input will impact all receivers within its coverage area, regardless of their proximity to the LPFM station.

1.3.3.10 RSVI Receiver Measurements

Analog FM subcarriers are used by many FPFM stations to provide reading services to the visually impaired (RSVI). The subcarriers are commonly operated at baseband frequencies between 67 kHz and 92 kHz. Because they are more removed from the carrier frequency, they may be more susceptible to adjacent-channel interference than the main stereo program.

The RSVI measurements that were done for this project used an RSVI receiver that was furnished by the Minnesota Services for the Blind, and is the same receiver they distribute to visually impaired citizens in the State. The measurements were done at the subcarrier output of the receiver. A technical discussion of analog FM subcarriers can be found in Section 2.1.1.3.

1.3.3.11 Digital Transition Analysis

One of the scenarios for which The Act requires testing is the planned evolution of FM broadcasting from an analog to a digital format over the next 10-15 years. The transition from an analog service to digital will go through an intermediate "hybrid" phase, where broadcasters may transmit a composite signal that contains both formats in the same channel. The transition may last many years, and so the hybrid mode represents the most likely situation that has to be evaluated in terms of potential LPFM interference. This "In Band, On Channel" (IBOC) strategy has only been implemented to date by one company, iBiquity.

Because of the more complex nature of the digital system, MITRE elected to perform the measurements for this scenario in its laboratory. A commercially available digital exciter was purchased from Harris Corporation, however, production receivers for the hybrid system will not be available until late summer, 2003. The measurements in this report were done using an iBiquity pre-production prototype receiver that employs the same software version as the exciter used in the measurements and by the hybrid stations that are on the air at present. Section 3 of this report discusses the results of the digital tests.

1.3.3.12 Data Collection Process

1.3.3.12.1 Signal Strength Data

At each receiver test location, the signal strength of the LPFM and FPFM stations was entered on a data sheet. This data was transcribed into a computer spreadsheet and verified by both the subcontractor and MITRE. The test equipment used in these measurements is described in Volume Two, Annex I, Section 7.

1.3.3.12.2 Receiver Output Recordings

The subcontractor acquired a studio-grade digital audio workstation that was mounted in the receiver test van. This system was used to simultaneously record both stereo tracks from all of the test receivers (mono track from the RSVI receiver). Once the tests were completed for a site, the collected digital audio data was written to a compact disk (CD) for later use. At the time of the recording, the subcontractor technician who was operating the workstation annotated the data sheet with his perception of the level of interference for each receiver type. These perceptions were later verified from the CDs by a MITRE engineer who had received and passed a certified hearing examination.

1.3.3.12.3 Public Comments

The Act required that an opportunity be afforded the general public to comment on any cases of perceptible interference they detected during the tests. The subcontractor retained an independent survey company, Southeastern Institute of Research, to take the phone calls from the public via an "800" number. The results are presented in Volume Two, Annex III, Appendix A. In summary, there were no reports from the public of radio interference that coincided with the LPFM tests at any site.

1.3.3.13 Field Measurement Quality Assurance Measures

MITRE engineers attended an initial demonstration of the measurement procedures that was run at the Avon, CT site to work out any details in the TPP that needed refining. At least one MITRE engineer was present at each of the remaining sites during the measurements. They were responsible for ensuring that the TPP was followed exactly as written. Two copies of the raw data from the audio workstation were recorded to a CD at each site. One copy was sent to the subcontractor's facility in Virginia for final formatting into the audio CDs, and the other was retained with the measurement team as a backup.

1.3.3.14 Subcontractor Field Measurement Data Final Report

The subcontractor's Field Measurement Data (FMD) Final Report is contained in Volume Two, Annex III. It contains all of the raw data collected at the field measurement sites.

1.3.3.15 Listener Tests

As stated earlier, the perception of harmful interference is a very subjective area. The FCC tasking to MITRE included a provision for conducting independent listener tests on the data resulting from the measurement program. Although it might have been desirable to have a test audience present at each test location during the measurements, logistical and cost factors made this impossible. As stated above, studio-quality digital recordings were made during the measurement program for later use in listening tests.

In the subcontractor offers that were received by MITRE, the proposed cost of the listening tests was very high and substantially exceeded the available budget. These costs were driven by the size of the sample audience that is needed to produce statistically significant results, and were similar across the offers received. Since incurring the expense for listening tests for cases where there is no perceptible interference is wasteful, MITRE initially recommended that the listener tests be included as a Phase II of the project, and which would examine only those cases, if any, where perceptible interference was detected by hearing-certified engineers. This recommendation was accepted by the FCC.

However, as a result of the measurement results reported herein, MITRE does not feel that there are enough cases of perceptible interference from LPFM stations operating on third-adjacent channels to warrant the expense of a formal listener test program.

1.3.3.16 Economic Analysis

The Act called for an analysis of the economic impact on FPFM stations that could result from LPFM interference within their protected contours. Since the listener tests that would be used to support such an impact analysis have been included in a possible second phase, the economic analysis has likewise been deferred.

As with the listener tests, MITRE does not feel that there is enough perceptible interference from LPFM stations operating on third-adjacent channels to warrant the expense of a Phase II economic analysis.

1.3.4 Theoretical Analysis

A limited number of test sites was permitted in the legislation, and feasible within the allocated budget. MITRE sought to assess the theoretical impact of third-adjacent channel interference in order to bound the likely results if more measured data had been available. The results of this analysis are presented in Section 4. In summary, the measured and theoretical results were generally consistent, within the error bounds of the field tests and the analytical model.

Section 2

Analog Measurement Results Analysis

2.1 Measurement Strategy

This section discusses the interference mechanisms that may occur in the measurement scenario and the strategy that was developed to identify and quantify any interference that might occur.

2.1.1 Interference Mechanisms

2.1.1.1 FPFM Stations

There are three dominant mechanisms for interference that could result from any signal (LPFM or otherwise) being introduced into the FM radio spectrum, either individually or in aggregate. The first mechanism, referred to as desensitization (or sometimes compression) occurs when the front-end components of an FM receiver are overwhelmed by power. Since the radio frequency amplifier of the typical FM receiver has a bandwidth that is larger than a single FM channel (200 kHz), the receiver front-end can be susceptible to any large signal, even if it is separated in frequency by several channels.

The observable effect of this interference is a reduction in the gain of the front-end, and corresponding reduction in the level of the desired FPFM signal. This effect can manifest itself as a reduction in audio output volume of the receiver in the least severe case. As the level of the interfering signal increases, distortions of the audio signal in amplitude or frequency can occur. In the worst case, the front end can become saturated by the interfering signal to the point where the desired signal is totally suppressed. These extreme cases of interference, often called “blanketing,” are only likely in the very close proximity to an LPFM transmitter, because the maximum ERP of LPFM stations is 100 W.

The second mechanism for interference to an FPFM station occurs when a component of the undesired signal is in-channel with the FPFM station. In the case where the LPFM station on a third adjacent channel is the potential interferer, in-channel energy can be derived from effects such as LPFM transmitter spurious outputs, local oscillator phase noise, spectral re-growth out of amplifiers, or poor internal filter roll-off characteristics.

The observable effect of this mechanism of interference is to introduce audio artifacts into the received signal. These artifacts can manifest as noise or buzzing. Sometimes a distorted version of the program content of the interfering station can be discerned. The degree to which this constitutes harmful interference is subjective, and is a function of the program content and the personal tolerance of the listener.

In this study, this effect is most likely to be observed when the FPFM signal is at its lowest power. This occurs when the receiver is located close to the protected service boundary for the FPFM station, and the LPFM transmitter is located close to the receiver as well.

The final interference mechanism takes place within the FM receiver itself and is sometimes referred to as reciprocal mixing. In the downconversion process that occurs in superheterodyne receivers, (typically prior to FM channel selection filtering), the phase noise of the local oscillator can serve to "widen" the spectral footprint of unintended signals. This can effectively move artifacts of adjacent channel signals into the desired channel. The effect of this mechanism is the same as those mentioned above.

This type of interference is more frequently observed in less expensive receiver equipment with lower local oscillator stability. Less expensive receivers may also have other components that render them more susceptible to interference such as a wider bandwidth of (or complete lack of) filters and lower selectivity in RF and IF amplifiers.

Both the second and third interference mechanisms are somewhat mitigated by the FM "Capture Effect." This property of FM demodulators is derived from the fact that the limiter-discriminator combination will only process the zero crossings of the input waveform that has the largest amplitude. Other competing signals are treated as noise and rejected. When the signal-to-interference ratio reaches the range of 1-2 dB (depending on receiver design), the demodulator may toggle between the two signals. This can also occur when the desired and interfering signals are fading independently.

2.1.1.2 FM Translator Stations

There are two interference mechanisms involved with FM translator stations. The first type is identical to the discussion of FPFM stations, above, because the transmitter that is producing the translator's output signal is functioning as the "FPFM" station. The other mechanism involves interference to the receiver that serves as the input source to the translator. In this case, the translator input receiver is simply an additional receiver type being tested. The differences in this case are that (a) the receiver site is fixed, and (b) harmful interference to the translator's input results in interference to *all* listeners in the translator output service area.

2.1.1.3 RSVI Subcarriers

FM radio stations in the United States are assigned to carrier frequencies between 88.1 and 107.9 MHz. The authorized bandwidth around the carrier frequency is 200 kHz (100 kHz above and below). The United States standard for the FM deviation ratio (the ratio of the peak carrier deviation to the maximum modulating frequency; sometimes referred to as the modulation index) for broadcast transmitters is 5. A fundamental property of FM is that the number of significant sidebands decreases with modulation frequency if the peak deviation is fixed. As a result, the "main" entertainment material uses only part of the 200 kHz channel. The original 1933 FM patent issued to Edwin Armstrong described what he called "multiplexing," stating that the process could be used to broadcast an independent program over an FM station.

In 1955, the FCC granted a "Subsidiary Communications Authority" (SCA) to FM broadcasters that allowed them to use the remaining bandwidth for other purposes without a separate license or authorization. The SCA concept grew out of a practice by early FM stations called "simplexing", where they broadcast an ultrasonic tone during periods when the studio microphone was keyed in order to provide a "background music" service devoid of voice announcements to stores and restaurants. Simplexing and then SCA were a way of using the full 200 kHz bandwidth to enhance radio station revenue, which was a critical issue in the days before stereo rescued the FM broadcast industry from obscurity.

One of the earliest applications of the SCA was the distribution of a separate program of background music to hotels, stores and restaurants, which saved the cost of a telephone line to each customer location. Prior to 1961, FM stations used subcarriers at 42 kHz and 67 kHz. With the introduction of the stereo subcarrier at 38 kHz in 1961, the "standard" subcarrier frequencies became 67 and 92 kHz, although the rules permit any subcarrier frequency to be used as long as the sidebands remain in the range between 53 and 99 kHz.

These subcarriers are first frequency modulated with an analog (voice, music) source, and then the composite signal that results is itself used to frequency modulate the main carrier. The deviation ratio used for the initial subcarrier modulation is small (~0.2-0.5), and so virtually all of the information content of the signal is contained in the first pair of sidebands. Further, the maximum audio frequency of the SCA source material is limited to a value between 4 kHz and 7.5 kHz, which allows even a 92 kHz subcarrier frequency to operate within the 200 kHz channel.

The fraction of the 75 kHz deviation of the main carrier that the sum of all subcarriers can occupy is limited to 20%. Subcarrier frequencies above 75 kHz are limited to a 10% "injection" level. However, stations that employ subcarriers can increase the deviation of the main carrier to 110% of the normal 75 kHz, or 82.5 kHz. This partially compensates for the loss of main program channel deviation and hence improves the stereo program's signal-to-noise ratio at a receiver. Figure 2-1 depicts the baseband structure of an FM station, showing the relationships among the main channel, stereo subcarrier and SCA subcarriers.

The SCA signals fall well outside both the passband of common FM receivers, and of human hearing. As long as care is taken to properly maintain the linearity of the subcarrier generator and FM transmitter, subcarriers do not degrade the station's primary programming in most cases. Interference in the form of cross-coupling between subcarriers and the primary stereo channel can occur in some cases of multipath or other propagation channel non-linear properties. These effects are not a persistent phenomenon in most cases, and frequently impair reception of the stereo program itself without any subcarrier effects.

A wide array of services has become available from this source, and over the years digital subcarrier modulation methods have increased the capacity of the channels. Common uses of analog subcarriers include providing language translation services and reading services for the visually impaired (RSVI). The latter service is an important component of the societal support to visually impaired Americans.

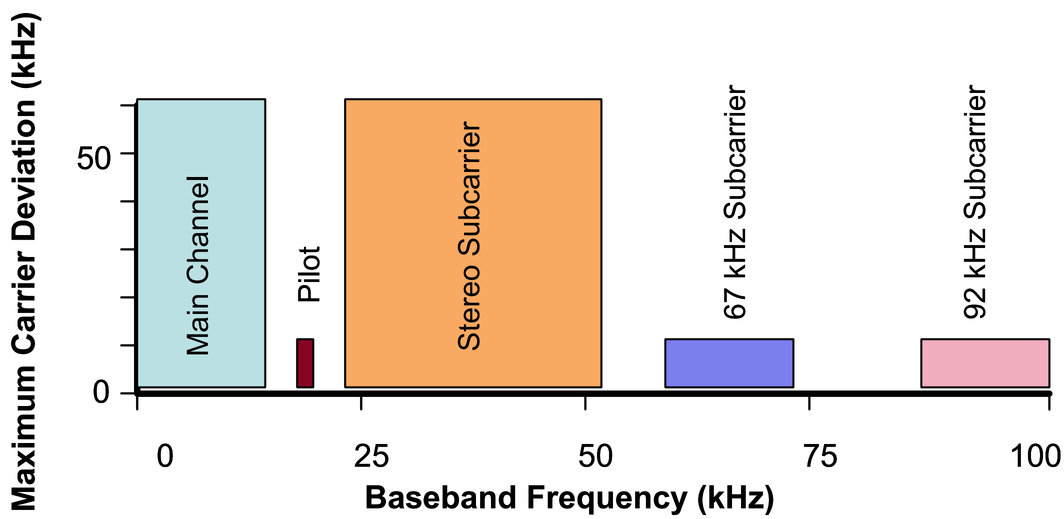


Figure 2-1. Baseband Structure of an FM Broadcasting Station

Because their sideband components are farther removed from the carrier than the stereo baseband channels, and because they have a low deviation ratio, analog subcarriers are more susceptible to noise and to distortion caused by nonlinearities in the propagation path. This also means that they may be more affected by adjacent-channel interference. One of the tests required in this study was to measure the effect that a third-adjacent channel LPFM station might have on an FPFM station's analog subcarrier.

The tests were run at the proposed LPFM site in East Bethel, MN near where radio station KNOW-FM uses a 67 kHz analog subcarrier to broadcast RSVI programming in cooperation with the Minnesota State Services for the Blind, which provided their standard receiver for the tests. In the figures and tables throughout the Final Report, the data for the RSVI receiver was extracted from the SCA channel audio output only.

2.1.2 Strategy

The FCC requirement was that subjective, independent listening tests be performed to adjudicate the presence of harmful interference to FPFM signals. It was not possible to perform listening tests simultaneously with the field testing because of the large number of people involved in a test audience and the resulting cost for travel and accommodations. Therefore, high quality digital recordings were made to preserve the FPFM audio for appropriate use at a later time.

2.1.3 Testing Locations

Candidate testing locations were chosen from a list of LPFM applicants that is contained in Appendix A. The legislation required that no more than nine sites were to be used to make the measurements, in varying population density and terrain environments. In addition, measurements were to be made for at least one minority-owned station, one FM translator station, and one station using a subcarrier to provide RSVI. Selection of the sites based upon the LPFM applications established the LPFM center frequency as well as the FPFM station of interest.

Sites were also chosen in order that a range of proximities between the LPFM station and the FPFM service contour could be used. A further discussion of the methodology used to select sites is presented in Volume Two, Annex I.

2.1.4 Field Measurements

As discussed in Section 1, field measurements were conducted at seven geographic locations in order to meet the requirements outlined in previous subsections.

2.1.5 RF Equipment

Representative consumer-grade FM radio receivers and a commercially available LPFM transmitter were chosen for the execution of the measurement program. The receiver equipment spanned a wide range of cost and performance, including home stereo, car radio, boom box, clock radio, personal receiver (Walkman®),[1] and analog FM subcarrier equipment (Table 1.1). Technical details for this equipment can be found in Volume Two, Annex II.

The LPFM transmitter that was used met the appropriate FCC technical specifications. [Paragraph I(E), FCC 00-19 and Paragraph II(A) of FCC 00-349, along with referenced sections of CFR47, Part 73]. The specific transmitter selected, manufactured by Energy-Onix, was chosen based on cost and availability, and is typical of commercially available transmitters being sold for LPFM applications.

Figure 2-2 shows the results of phase-noise measurements performed on the LPFM transmitter, operating at an output carrier power of 100 W, before field testing began.

---

1 Throughout the remainder of this report, the "personal receiver" is referenced by the trade name of the receiver that was used in the tests—the Sony Walkman®—which is a trademark of the Sony Corporation.

A carrier frequency of 107.5 MHz was used in these bench tests. The resultant total phase noise, integrated over the entire 200-kHz bandwidth of the "upper" third-adjacent channel centered at 108.1 MHz, was approximately –56 dBc. The total phase noise in the "lower" third-adjacent channel centered at 106.9 MHz was about –59 dBc, about 3 dB better.

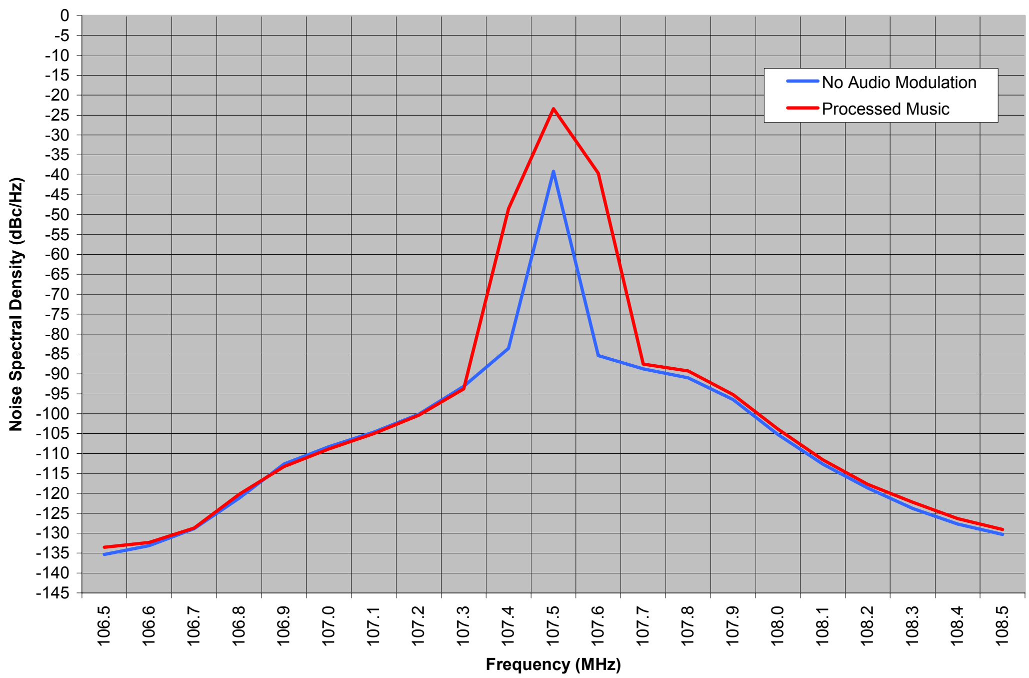


Figure 2-2. Measured Phase-Noise Spectral Density of LPFM Transmitter

2.1.6 Other Equipment

Other equipment used in the measurement program is described in detail in Volume Two, Annex II.

2.2 Definitions Used in the Data Analysis for the Analog Measurement Results

For each LPFM site and measurement location the field engineers recorded the measured data onto the appropriate data sheets. All receiver outputs were also recorded according to the TPP. For each LPFM site, measurement location, scenario and receiver, the appropriate data sheet provides information regarding the perceived signal degradation. If the subcontractor field engineer did not detect degradation in the audio quality before the LPFM was transmitting, then N is bolded in the data sheet for the "Degrad. w/o LPFM", otherwise Y is bolded. Similarly, if the field engineer did not detect degradation in the audio quality when the LPFM was transmitting, then N is bolded in the data sheet for the "Degrad. On

Rec.," otherwise Y is bolded. Therefore for each scenario and each receiver there is a transition associated with the perceived effect of the LPFM transmitter after being turned on. Based on the data sheet this transition can be an N to N (N→N), N to Y (N→Y), Y to Y (Y→Y) or Y to N (Y→N) type of transition.

"Delta Degradation" is defined as the difference between the perceived degradation after the LPFM was turned on and the perceived degradation when the LPFM was turned off. If a Y was bolded in the data sheet for a given degradation, then a numeric value of 1 is associated with it. If an N was bolded in the data sheet for a given degradation, then a numeric value of 0 is associated with it. For an N→Y transition a Delta Degradation value of 1 is obtained using this convention.

After receiving the recorded audio samples from the subcontractor, a hearing-tested MITRE engineer listened to the recordings associated with the N→Y transitions. The actual recording was performed when the LPFM was transmitting; therefore for the N→Y transition the recording captured the "Degrad. On Rec.," which represents the Y part of the transition. For the "Degrad. w/o LPFM" part of the transition, the recording listened to was associated with the same receiver, same LPFM antenna height, and same program content. The only difference was that the LPFM ERP was 0 W (i.e., the LPFM was not transmitting). Although this recording had an N→N transition, it was used to identify cases where receiver degradation could be present even without LPFM effects.

The subsequent analog measurement analysis uses all these transitions extensively, and all the definitions and conventions are summarized as follows:

- An N→N transition (green in plots and bar charts) is a transition in which the field engineer did not detect degradation in the audio quality either with the LPFM transmitting or when the LPFM was off. An N→N transition has a Delta Degradation value of 0 in the Delta Degradation plots. These plots show the Delta Degradation as a function of desired-to-undesired signal ratio (D/U).
- A Y→Y transition (blue in plots and bar charts) is a transition in which the field engineer has detected degradation in the audio quality before the LPFM was turned on (LPFM was not transmitting) and during the LPFM transmission. A Y→Y transition also has a Delta Degradation value of 0 in the Delta Degradation plots.
- An N→Y transition is a transition in which the field engineer did not detect degradation when the LPFM was off, but detected degradation during the LPFM transmission. An N→Y transition has a Delta Degradation value of 1 in the Delta Degradation plots. After listening to the N→Y transitions, two subcategories have been identified and defined as transitions with "Significant Degradation" and transitions with "Non-Significant Degradation."

- Significant degradation in this context means a situation in which one of the following scenarios has been observed during listening:
  - The FPFM program was heard, but the recording had a lot of static.
  - The FPFM program was not heard at all.
  - The FPFM program was heard but a different program could also be heard in the background. This program might be transmitted by the LPFM or by a different radio station. If the LPFM ERP was 0W (LPFM was not transmitting) and a different program was heard in the background, then the program was received from a different radio station that was not involved in the tests.
- Significant degradation cases are shown using red in plots and bar charts, and the "N→Y (S)" notation is used in the legends.
- Non-significant degradation in this context means a situation in which one of the following scenarios have been observed during listening:
  - Some static was detected for the recording, but it was not bothersome and the FPFM program was still clearly understandable.
  - No degradation was detected during listening by the MITRE engineer, but the recording was marked as an N→Y transition by the subcontractor field engineer.
- Non-significant degradation cases are shown using orange in plots and bar charts, and the "N→Y (NS)" notation is used in the legends.

- A Y→N transition (magenta in the plots and bar charts) is a transition in which the field engineer detected degradation when the LPFM was off, but did not detect degradation when the LPFM was transmitting. There is only one such case in the whole data set, and it occurred at Brunswick. A Y→N transition has a Delta Degradation value of (-1) in the Delta Degradation plots.

The following assumptions have been used for the data analysis:

- If a FPFM signal level is inadvertently missing for a measurement location, the measurement points for that location are not used in the analysis because the D/U ratio cannot be evaluated from the measured data (East Bethel location 8 and Owatonna location 3).
- If a LPFM signal level is missing for a measurement scenario, the measurement points for that scenario are not used in the analysis because the D/U ratio cannot be evaluated from the measured data (Brunswick location 6, last scenario; Owatonna location 6, last scenario).

- The BR118T1 data point is not used in the analysis because neither Y nor N was bolded in the data sheet.

We focused our attention on the N→Y transitions which have been identified by the field engineers as situations in which signal degradation was detected after the LPFM was turned on, but was not detected when the LPFM was turned off. There might be Y→Y transitions in which the signal degradation increases after the LPFM was turned on, but degradation already existed prior to the LPFM transmitting. These cases might exist in the data set, but no listening of the Y→Y recordings was performed for this analysis. The separation of the N→Y transitions in cases with significant degradation and cases with non-significant degradation was done to refine our analysis and it was not meant to replace an actual formal listening test. However, our findings could help in the selection of recordings that would be most useful in a subsequent listening test if that is deemed necessary.

Table 2-1 presents the recording ID codes, arranged by LPFM site and measurement locations, of all measurements deemed to have significant N→Y transitions. The table also repeats the site-location distances previously shown in Table 1-2. Except for the special case of the Owatonna translator input test, only one such transition was noted beyond receiver location 4 (333 meters away from the LPFM site) and none beyond receiver location 5 (550 meters away). As noted later in Section 2.6, the single case at location 5 appears anomalous.

Table 2-1. ID Codes of Recordings with N□Y Transitions and Perceived Significant Degradation

	LPFM Site						
Receiver Location	**Avon, CT**	**Brunswick, ME**	**East Bethel, MN**	**Owatonna, MN (Site A)**	**Owatonna, MN (Site B: Translator Input Test)**	**Winters, CA**	**Benicia, CA**
1	(0.018 km) AV118P4	(0.013 km) BR118U5 BR128T5 BR128U1 BR128U5	(0.011 km) EB115P2 EB115P3 EB115P4 EB115U2 EB115U3 EB115U4 EB118P2 EB118P3 EB118P4 EB118U2 EB118U3 EB118U4 EB125P2 EB125P3 EB125P4 EB125U2 EB125U3	(0.023 km) No significant cases noted	(6.392 km) OT114P1 OT114P2 OT114P5 OT115P1 OT115P2 OT115P5 OT116P1 OT116P2 OT116P5 OT117P1 OT117P2 OT117P5 OT117T2 OT117U2 OT118P1 OT118P2 OT118P5	(0.014 km) WI115T3 WI115T4 WI115U3 WI115U4 WI118T2 WI118T3 WI118T4 WI118T5 WI118U2 WI118U3 WI118U4 WI118U5 WI128T2 WI128T3 WI128T4 WI128U2 WI128U3	(0.021 km) No significant cases noted

	LPFM Site						
Receiver Location	**Avon, CT**	**Brunswick, ME**	**East Bethel, MN**	**Owatonna, MN (Site A)**	**Owatonna, MN (Site B: Translator Input Test)**	**Winters, CA**	**Benicia, CA**
			EB125U4 EB128P1 EB128P2 EB128P3 EB128P4 EB128U2 EB128U3 EB128U4		OT118T2 OT118U2 OT118U5 OT125P1 OT125P2 OT125P5 OT126P1 OT126P2 OT126P5 OT127P1 OT127P2 OT127P5 OT128P1 OT128P2 OT128P5	WI128U4	
2	(0.034 km) No significant cases noted	(0.064 km) BR228T5 BR228U5	(0.034 km) EB215P3 EB215P4 EB215U3 EB215U4 EB218P2 EB218P3 EB218P4 EB218P6 EB225P2 EB225P3 EB225P4 EB225P5 EB225P6 EB225U2 EB225U3 EB225U4 EB225U6 EB228P2 EB228P3 EB228P4 EB228P5 EB228P6 EB228U2 EB228U3 EB228U4 EB228U5 EB228U6	(0.050 km) OW215P2 OW218P2 OW218T2 OW225P2 OW225T2 OW228P2 OW228P5 OW228T2 OW228T5	(12.469 km) OT214P1 OT214P5 OT215P1 OT215P5 OT215T5 OT215U5 OT216P1 OT216P5 OT216T5 OT216U5 OT217P1 OT217P5 OT217T5 OT217U5 OT218P1 OT218P5 OT218T5 OT218U5	(0.035 km) WI215T3 WI215U3 WI218T2 WI218T3 WI218T4 WI218U2 WI218U3 WI218U4 WI225T2 WI225T3 WI225T4 WI225U2 WI225U3 WI225U4 WI228T1 WI228T2 WI228T3 WI228T4 WI228U1 WI228U2 WI228U3 WI228U4	(0.055 km) BE225U2 BE228P2 BE228P3 BE228U2
3	(0.100 km) No significant cases noted	(0.126 km) BR325U5 BR328U5	(0.080 km) EB315P3 EB315P4 EB315P6 EB315U3 EB315U4	(0.116 km) No significant cases noted	—	(0.095 km) WI315T3 WI315T4 WI318T2 WI318U2 WI318U3	(0.126 km) No significant cases noted

	LPFM Site						
Receiver Location	**Avon, CT**	**Brunswick, ME**	**East Bethel, MN**	**Owatonna, MN (Site A)**	**Owatonna, MN (Site B: Translator Input Test)**	**Winters, CA**	**Benicia, CA**
			EB315U6 EB318P2 EB318P3 EB318P4 EB318U3 EB318U4 EB318U6 EB325P2 EB325P3 EB325P4 EB325P6 EB325U2 EB325U3 EB325U4 EB325U6 EB328P2 EB328P3 EB328P4 EB328P6 EB328U2 EB328U3 EB328U4 EB328U6			WI325T3 WI325T4 WI325U3 WI325U4 WI328T2 WI328T3 WI328T4 WI328T5 WI328U2 WI328U5	
4	(0.206 km) No significant cases noted	(0.370 km) No significant cases noted	(0.232 km) EB418P3	(0.401 km) No significant cases noted	—	(0.235 km) WI418T2 WI418T3 WI418T4 WI418U2 WI418U3 WI418U4 WI428T3 WI428U3 WI428U4	(0.333 km) BE418P3 BE418U3
5	(0.570 km) No significant cases noted	(0.935 km) No significant cases noted	(0.550 km) EB525U2	(0.867 km) No significant cases noted	—	(0.573 km) No significant cases noted	(0.906 km) No significant cases noted

Note: Recording ID convention:

First and Second symbol: Site abbreviation
Third symbol: Test location number
Fourth symbol: 1 = LPFM antenna height at 30m AGL, 2 = LPFM antenna height at 10 m AGL
Fifth symbol: 1 = 0 W ERP, 2 = 1 W ERP, 3 = 2 W ERP, 4 = 5 W ERP, 5 = 10 W ERP, 6 = 20 W ERP, 7 = 50 W ERP, 8 = 100 W ERP
Sixth symbol: Format of LPFM Programming (P = Processed, U = Unprocessed, T = News/Talk)
Seventh symbol: Receiver number (1 = auto, 2 = clock, 3 = boom box, 4 = Walkman, 5 = home, 6 = RSVI)

2.3 Avon Data Analysis

The Avon FPFM station is WCCC-FM. The LPFM transmitter test site location is defined by the following coordinates 41° 46’ 39.0” N and 72° 51’ 41.2” W (NAD 83). The name of the corresponding 7.5 Minute Series topographic map for both the FPFM station and the LPFM transmitter site is Avon, Connecticut. The separation distance between the LPFM transmitter and the FPFM station was 5.77 km for this test in the FMD. The distance ratio for this site is 0.09. The LPFM transmitter program contents were processed music and news/talk. Pertinent data for the Avon site are summarized in Table 1-1.

The path profiles from the FPFM station and the LPFM station respectively, to the receivers’ measurement locations are presented in Appendix B Figures B-1 to B-12. The path profiles presented correspond to measurement locations 3 to 8. This is due to the fact that measurement locations 1, 2 and 3 are quite close to each other and the path profiles from FPFM and LPFM to location measurement 3 show with a good approximation the path profiles to the other two locations. The area is quite hilly as observed from the path profiles, and was described as heavily wooded in the FMD. From the path profile plots we observe that the paths from the LPFM transmitter to measurement locations 6, 7 and 8 have obstructions. The path from the FPFM station to measurement location 7 is also obstructed.

The Delta Degradation plots as a function of D/U are presented in Appendix C, Figures C-1 to C-3, with each subplot corresponding to a receiver type.

No N→Y transitions have been recorded for the auto and home receivers. Moreover there were only N→N transitions for the home receiver.

The clock radio receiver had two N→Y transitions which were perceived as having non-significant degradation of the audio quality. They occurred at D/U ratios of -18 dB and -41 dB, respectively.

For the boom box receiver all six N→Y transitions were perceived as having non-significant degradation. One of them occurred at a D/U ratio of -18 dB and the others occurred for D/U ratios below -37 dB.

The Walkman receiver had the only N→Y transition that was perceived as having significant degradation of the audio quality. It occurred for a D/U ratio of -37.3 dB and at the first measurement location (which is at .02 km from the LPFM transmitter). There were also two N→Y transitions which had non-significant degradation of the audio quality. One of them occurred for a D/U ratio of -18 dB. The other transition occurred for a D/U ratio of 37.5 dB and for a LPFM ERP of 0 W; therefore it cannot be attributed to the effect of the LPFM (since the LPFM was not transmitting).

As a general comment for the Avon test site, there were only a few N→Y and Y→Y transitions, with the majority of transitions being N→N transitions.

2.4 Brunswick Data Analysis

The Brunswick FPFM station is WCME-FM and it serves a small-market area in the FMD. The LPFM transmitter test site location is defined by the following coordinates 43° 54' 23.0" N and 69° 59' 48.7" W (NAD 83). The names of the 7.5 Minute Series topographic maps for the FPFM station and the LPFM transmitter are Damariscotta, ME and Brunswick, ME, respectively. The separation distance between the LPFM transmitter and the FPFM station was 36.56 km for this test in the FMD. The distance ratio for this site is 0.82 in the FMD. The LPFM transmitter program contents were unprocessed music and news/talk. Pertinent data for the Brunswick site are summarized in Table 1-1.

The path profiles from the FPFM station and the LPFM station respectively, to the receivers' measurement locations are presented in Appendix B, Figures B-13 to B-24. The path profiles presented correspond to measurement locations 3 to 8. The area is quite hilly as it can be observed from the path profiles, and was described as moderately to heavily wooded in the FMD. From the path profile plots we observe that the paths from the LPFM transmitter to measurement locations 5, 7 and 8 have obstructions. The paths from the FPFM station to measurement locations 6, 7 and 8 are also obstructed.

The Delta Degradation plots as a function of D/U are presented in Appendix C, Figures C-4 to C-6, with each subplot corresponding to a receiver type.

For the auto receiver there were only two N→Y transitions. Both occurred at D/U ratios of about -80 dB. One of them was perceived as having significant degradation while the other was perceived as having non-significant degradation.

For the home receiver there were seven N→Y transitions with significant degradation which occurred at D/U ratios below -50 dB. There were also two cases of N→Y transitions that have been perceived as non-significant which occurred at D/U ratios of about 6 and 9 dB. However, these two cases occurred for LPFM ERP of 0 W; therefore they cannot be attributed to the effect of the LPFM (since the LPFM was not transmitting).

For the clock radio and Walkman receivers all transitions were Y→Y. For the boom box receiver there was only one N→N transition and the rest were Y→Y transitions.

For the Brunswick test site the auto receiver had the best performance experiencing the least amount of degradation. The clock radio, boom box and Walkman receivers had the worst performance by already experiencing degraded audio quality at all measurement locations even when the LPFM was not transmitting.

2.5 East Bethel Data Analysis

The East Bethel FPFM station is KNOW-FM which has a reading service for the visually impaired. The LPFM transmitter test site location is defined by the following coordinates 45° 19' 8.3" N and 93° 13' 48.0" W (NAD 83). The names of the 7.5 Minute Series topographic maps for the FPFM station and the LPFM transmitter are New Brighton, MN and Coon Lake Beach, MN, respectively. The separation distance between the LPFM transmitter and the FPFM station was 29.42 km for this test in the FMD. The distance ratio for this site is 0.37. The LPFM transmitter program contents were unprocessed and processed music. Pertinent data for the East Bethel site is summarized in Table 1-1.

The path profiles from the FPFM station and the LPFM station, respectively, to the receivers' measurement locations are presented in Appendix B Figures B-25 to B-36. The path profiles presented correspond to measurement locations 3 to 8. The area is characterized by flat terrain as it can be observed from the path profiles, and was described as having both wooded and open areas in the FMD. From the path profile plots we observe that the paths from the LPFM transmitter to all the measurement locations do not have terrain obstructions. Similarly, the paths from the FPFM station to all measurement locations do not have terrain obstructions.

The Delta Degradation plots as a function of D/U are presented in Appendix C, Figures C-7 to C-9, with each subplot corresponding to a receiver type.

For the auto receiver there was only one N→Y transition, which occurred at a D/U ratio of -48.9 dB. This transition was perceived as having significant degradation.

For the home receiver there were five N→Y transitions with perceived significant and non-significant degradations. All these cases occurred at D/U ratios below -37.7 dB.

For the clock radio there were eighteen N→Y transitions with perceived significant degradation at D/U ratios below -28 dB. There were also two N→Y transitions with perceived non-significant degradation which occurred at D/U ratios of -37.6 dB and -8.7 dB, respectively. There was also one N→Y transition (at location 5) with perceived significant degradation which occurred at a D/U ratio of 1.3 dB. However, the recording for this particular measurement exhibits degraded audio quality for about 54 seconds and then no degradation can be detected for the rest of the recording. Also the degradation on this recording is quite different from all other recordings, consisting of a humming noise. Therefore, it is quite likely that the degradation on this recording is not due to LPFM transmission. The subcontractor reached a similar conclusion in the FMD.

For the boom box receiver there were twenty-four N→Y transitions with perceived significant degradation at D/U ratios below -27.8 dB. There was also one N→Y transitions with perceived non-significant degradation at a D/U ratio of -31.7 dB.

For the Walkman receiver there were twenty-three N→Y transitions with perceived significant degradation at D/U ratios below -27.8 dB. There were also five N→Y transitions with perceived non-significant degradations with D/U ranging from -22 dB to 1.3 dB.

As a general observation for all the receivers mentioned previously, there were very few Y→Y transitions, with the majority of transitions being N→N transitions.

For the Reading Service for the Visually Impaired (RSVI) receiver, all twelve N→Y transitions were perceived as having significant degradation of the audio quality. These transitions occurred for D/U ratios below -27.8 dB and they occurred at measurement locations 2 and 3. No case of significant interference to the tested RSVI receiver at East Bethel was ever identified at a distance more than 80 meters from the LPFM transmitter. For the RSVI receiver, unlike all the other receivers at this test site, the Y→Y transitions were the largest number of transitions.

For the East Bethel test site the auto receiver had the best performance, experiencing only one case of degradation. The RSVI receiver had the worst performance with a majority of the transitions being Y→Y transitions. All of the N→Y transitions for this receiver were perceived as having significant degradation of audio quality.

2.6 Owatonna Translator Output Test Data Analysis

The Owatonna FPFM station is the translator station K289AE. The LPFM transmitter test site location is defined by the following coordinates 44° 06' 44.8" N and 93° 12' 42.0" W (NAD 83). The name of the 7.5 Minute Series topographic maps for both FPFM translator station and the LPFM transmitter is Owatonna, MN. The separation distance between the LPFM transmitter and the FPFM translator station was 6.27 km for this test in the FMD. The distance ratio for this site is 0.54. The LPFM transmitter program contents were processed music and news/talk. Pertinent data for the Owatonna Translator site are summarized in Table 1-1.

The path profiles from the FPFM translator station and the LPFM station, respectively, to the receivers' measurement locations are presented in Appendix B, Figures B-37 to B-48. The path profiles presented correspond to measurement locations 3 to 8. The area is relatively flat as it can be observed from the path profiles, and was described as flat farmland to the north of the LPFM transmitter with housing towards the south in the FMD. From the path profile plots we observe that the paths from the LPFM transmitter to all measurement locations are not obstructed. The paths from the FPFM translator station to measurement locations 4 and 6 have some terrain obstructions.

The Delta Degradation plots as a function of D/U are presented in Appendix C, Figures C-10 to C-12, with each subplot corresponding to a receiver type.

For the auto receiver all three N→Y transitions were perceived as having non-significant degradation.

For the home receiver there were two cases of N→Y transitions perceived as having significant degradation which occurred at D/U ratios below -61.9 dB. There was also one N→Y transition perceived as having non-significant degradation at a D/U of 23.8 dB. However, this transition occurred for a LPFM ERP of 0 W; therefore, it cannot be attributed to the effect of the LPFM (since the LPFM was not transmitting).

For the clock radio there were seven N→Y transitions perceived as having significant degradation at D/U ratios below -37.5 dB. There was also one N→Y transition perceived as having non-significant degradation which occurred at a D/U ratio of 27.4 dB. However this transition occurred for a LPFM ERP of 0 W; therefore, it cannot be attributed to the effect of the LPFM (since the LPFM was not transmitting).

For the boom box and Walkman receivers, all transitions were Y→Y.

For the Owatonna translator output test site the auto receiver had the best performance experiencing only non-significant degradation. The boom box and Walkman receivers had the worst performance by already experiencing degraded audio quality at all measurement locations with no LPFM transmission.

2.7 Owatonna Translator Input Test Data Analysis

The Owatonna translator input test analyzed the effect of a LPFM transmitter upon the receiver input of the translator station. The effect was measured indirectly. If the receiver input of the translator station had experienced degradation due to the effect of the LPFM transmission on the third adjacent channel from the translator receiver frequency, then its output was also degraded. The test receivers were tuned to the frequency of the translator output and recorded the translator output program.

Two measurement locations were used for this test. The first measurement location was at a distance of 6.39 km from the translator station, which represents approximately half of the F(50,50) contour distance for the translator station in the FMD. The second measurement location was at 12.48 km from the translator, very close to its F(50,50) contour in the FMD.

The LPFM transmitter was located very close to the translator receiving antenna and as close as possible to the propagation path from the FPFM master station KGAC-FM to the translator in the FMD. The path profile from the master station KGAC-FM to the translator receiver is presented in Figure B-51. The LPFM transmitter test site location is defined by the following coordinates 44° 05’ 18.4” N and 93° 08’ 45.9” W (NAD 83). The name of the 7.5 Minute Series topographic maps for both FPFM translator station and the LPFM transmitter is Owatonna, MN. The separation distance between the LPFM transmitter and the translator station was .46 km for this test. All three types of LPFM program content (processed music, unprocessed music and news/talk) were used in the test.

No terrain obstructions were observed between the LPFM transmitter and the receiving antenna of the translator station. This can also be viewed in the path profile plot from Figure B-52. The path profiles from the translator station to the two measurement locations are presented in Figures B-49 and B-50. They show no terrain obstructions. The area between the translator transmitter and the receiver measurement locations is also described as farmland and mostly flat in the FMD.

For the Owatonna translator input test the LPFM ERP was set to the following values: 100, 50, 20, 10, 5, 2, 1 and 0 W. Figures C-13 to C-15 are bar charts showing transition counts associated with each LPFM ERP value. The bar charts also show the calculated D/U ratio values at the input of the translator receiver for each LPFM ERP value. The D/U ratio was calculated using the FCC Propagation Curves Calculations program.[2]

Each bar chart corresponds to a receiver type. For each LPFM ERP value in the bar chart, the order of the bars is the same, and it starts from left to right with N→Y (S) followed by N→Y (NS), N→N and Y→Y. If certain types of transitions have not occurred for an ERP value, then the appropriate bars are not present in the chart, but the order of the existing bars is maintained as described.

For the auto receiver it can be observed that N→Y transitions perceived as having significant degradation of the audio quality start to appear at LPFM ERP of 5 W (no such transitions occurred at LPFM ERP of 2 W or less). For the auto receiver there was one N→Y transition at LPFM ERP of 2 W, but it was perceived as having non-significant degradation.

The same trend can be observed for the home and clock radio receivers with N→Y transitions perceived as having significant degradation of the audio quality starting to appear at LPFM ERP of 5 W. For the home and clock radio receivers no N→Y transitions were observed at or below an LPFM ERP of 2 W.

For the boom box receiver there was only one N→N transition. All other transitions were Y→Y transitions.

For the Walkman receiver all transitions were Y→Y transitions.

Based the results shown in Appendix C, Figures C-13 through C-15, significant interference does not occur for D/U values of -34 dB or higher at the translator input. Based on this result and the fact that the LPFM antenna was well within the main beam of the translator receiver's antenna, the minimum LPFM-to-translator separation that will ensure a D/U of -34 dB is given by:

$$d_u = 133.5 \text{ antilog } [(P_{eu} + G_{ru} - G_{rd} - E_d) / 20]$$

where

d_u = the minimum separation in km
P_{eu} = LPFM ERP in dBW
G_{ru} = gain (in dBd) of the translator receiver's antenna, in the direction from which the LPFM signal arrives

2 http://www.fcc.gov

G_{rd} = gain (in dBd) of the translator receiver's antenna, in the direction from which the primary FPFM signal arrives

E_d = predicted field strength (in dBu) of the primary FPFM signal entering the translator receiver's antenna.

2.8 Winters Data Analysis

The Winters FPFM station is KSFM-FM and it serves a minority market in the FMD. The LPFM transmitter test site location is defined by the following coordinates 38° 31' 39.2" N and 121° 57' 33.2" W (NAD 83). The names of the 7.5 Minute Series topographic maps for the FPFM station and LPFM transmitter are Davis, CA and Winters, CA, respectively. The separation distance between the LPFM transmitter and the FPFM station was 21.38 km for this test. The distance ratio for this site is 0.33. The LPFM transmitter program contents were news/talk and unprocessed music. Pertinent data for the Winters site are summarized in Table 1-1.

The path profiles from the FPFM station and the LPFM station respectively, to the receivers' measurement locations are presented in Appendix B, Figures B-53 to B-64. The path profiles presented correspond to measurement locations 3 to 8. The area is mostly flat as it can be observed from the path profiles, and was described as having a few trees and being densely populated in the FMD. From the path profile plots we observe that the path from the LPFM transmitter to measurement location 8 is obstructed. The path from the FPFM station to measurement location 8 is also obstructed. All other paths from both LPFM and FPFM transmitters to measurement locations 3 to 7 present no terrain obstructions.

The Delta Degradation plots as a function of D/U are presented in Appendix C, Figures C-16 to C-18, with each subplot corresponding to a receiver type.

For the auto receiver there were three N→Y transitions. Two of these transitions that occurred at D/U ratios below -51 dB were perceived as having significant degradation of the audio quality. The third N→Y transition occurred at a D/U of -43 dB and it was perceived as having non-significant degradation of the audio quality.

For the home receiver there were four N→Y transitions with perceived significant degradation. There were also four cases of N→Y transitions with perceived non-significant degradation. All these transitions occurred at D/U ratios below -47 dB.

For the clock radio there were sixteen N→Y transitions with perceived significant degradation. They occurred at D/U ratios below -37 dB. There were also two N→Y transitions that have been perceived as having non-significant degradation which occurred at D/U ratios of below -38 dB.

For the boom box receiver there were twenty-three cases of N→Y transitions with perceived significant degradation which occurred at D/U ratios below -30 dB. There were also four N→Y transitions with perceived non-significant degradation which occurred at D/U ratios below -21 dB.

For the Walkman receiver there were nineteen cases of N→Y transitions with perceived significant degradation which occurred at D/U ratios below -30 dB. There were also two N→Y transitions with perceived non-significant degradation which occurred at D/U ratios of above 25 dB. However, these two transitions occurred for a LPFM ERP of 0 W; therefore, they cannot be attributed to the effect of the LPFM (since the LPFM was not transmitting).

2.9 Benicia Data Analysis

The Benicia FPFM station is KFRC-FM in the FMD. The LPFM transmitter test site location is defined by the following coordinates 38° 10' 55.9" N and 122° 15' 21.8" W (NAD 83). The names of the 7.5 Minute Series topographic maps for the FPFM station and LPFM transmitter are San Francisco South, CA and Cuttings Wharf, CA, respectively. The separation distance between the LPFM transmitter and the FPFM station was 57.21 km for this test. The distance ratio for this site is 0.68. The LPFM transmitter program contents were unprocessed and processed music.

The path profiles from the FPFM station and the LPFM station, respectively, to the receivers' measurement locations are presented in Appendix B, Figures B-65 to B-76. The path profiles presented correspond to measurement locations 3 to 8. The area is mountainous as it can be observed from the path profiles, and was described as having a few trees and being densely populated in the FMD. From the path profile plots we observe that the path from the LPFM transmitter to measurement location 8 is obstructed. The path from the FPFM station to measurement location 8 is also obstructed. All other paths from both LPFM and FPFM transmitters to measurement locations 3 to 7 present no terrain obstructions.

The Delta Degradation plots as a function of D/U are presented in Appendix C, Figures C-19 to C-21, with each subplot corresponding to a receiver type.

For the auto receiver there are no N→Y transitions and a few Y→Y transitions. The majority of the transitions are N→N transitions.

For the home receiver all five N→Y transitions were perceived as having non-significant degradation of the audio quality, and occurred at D/U ratios below -36 dB. There were no Y→Y transitions for the home receiver.

For the clock radio there were three N→Y transitions perceived as having significant degradation of the audio quality and they occurred at D/U ratios below -47 dB. There were also two N→Y transitions perceived as having non-significant degradation and they occurred at D/U ratios of -29 dB and -12.7 dB respectively.

For the boom box receiver there were three N→Y transitions perceived as having significant degradation of the audio quality and they occurred at D/U ratios below -41 dB.

There were also three N→Y transitions perceived as having non-significant degradation of the audio quality and they occurred at D/U ratios of -29 dB, -12.7 dB and -2.9 dB respectively.

For the Walkman receiver there was only one N→Y transition which was perceived as having non-significant degradation of the audio quality and it occurred at a D/U ratio of -12.7 dB.

For the auto, home and clock radio receivers the majority of transitions were N→N transitions. For the boom box and Walkman receivers the majority of transitions were Y→Y transitions.

2.10 Combined Data Analysis

2.10.1 Analysis Regarding the Impact of LPFM ERP for All Non-Translator-Input Tests

The analog measurement results for each LPFM test site have been presented and analyzed in Sections 2.2 to 2.9. In this section the measurement results are evaluated as a data set in order to identify data trends.

This subsection analyzes the data set only based on LPFM ERP values, using all receiver measurement locations from all non-translator-input tests. This means that the data set doesn't include the Owatonna translator input test data, due to the fact that this test had a different setup. The Owatonna translator input test setup consisted of two receiver measurement locations with LPFM ERP values of 100, 50, 20, 10, 5, 2, 1 and 0 W being transmitted at each location. The impact of the LPFM ERP for the Owatonna translator input test was analyzed in Section 2.7.

Appendix C, Figure C-22 shows the transition counts for all non-translator input test sites, receiver measurement locations and LPFM ERP values added together. At each LPFM test site data was collected from eight receiver measurement locations and at each location three LPFM ERP values (100, 10 and 0 W) were transmitted. From this data we observe the small number of N→Y transitions (with both significant and non-significant degradations) for the auto and home receivers. For the clock radio, boom box and Walkman receivers we note an increase in the N→Y transitions with perceived significant degradation. For the RSVI receiver we observe the much smaller sample size (due to the fact that this receiver was measured at the East Bethel LPFM test site which had a reading service for the visually impaired) and we also note the fact that all N→Y transitions were perceived as having significant degradation.

Appendix C, Figures C-23, C-24, and C-25 separate the data set by LPFM ERP values, and show the transition counts for all measurements with LPFM ERP values of 100 W, 10 W, and 0W, respectively.

The transition counts presented in Appendix C, Figures C-22 to C-25 represent the raw data set. This means that data from all receiver measurement locations have been added together, without considering the probability of an actual receiver being located in a given area. These figures provide a general view of the data set.

However, a more detailed analysis of the data set was performed to better quantify the potential third adjacent interference problem. Area-weighted probabilities of N→Y transitions have been defined for this analysis.

These area-weighted probabilities have been evaluated to better quantify the potential third adjacent channel interference problem from a LPFM transmitter to an analog receiver, randomly located inside the F(50,50) contour of a FPFM station. The area-weighted probabilities of N→Y transitions have been calculated using the measured data set for all non-translator-input tests. The data set was separated by ERP values, and area-weighted probabilities have been calculated for each ERP value and each receiver type.

The following assumptions were used for the analysis:

- The receiver was placed at a randomly selected point inside the F(50,50) contour of one of the six non-translator-input test sites selected at random
- The appropriate area-weighting factor was applied to each transition based upon the measurement location at which that transition had occurred. The weighting factor, which depends on the measurement location (*k*) and test site (*j*) is defined by one of the following equations:

$$w_1^{(j)} = \frac{R_2^{\,2}}{C_j^{\,2}} \tag{2}$$

$$w_k^{(j)} = \frac{R_{k+1}^{\,2} - R_k^{\,2}}{C_j^{\,2}}, \text{ where k} = 2\ldots6 \tag{3}$$

$$w_7^{(j)} = \frac{\left[\min\left(C_j, R_8\right)\right]^2 - R_7^{\,2}}{C_j^{\,2}} \tag{4}$$

$$w_8^{(j)} = 1 - \frac{\left[\min\left(C_j, R_8\right)\right]^2}{C_j^{\,2}} \tag{5}$$

where:

k is the receiver measurement location number ($k = 1\ldots8$)
j is the non-translator-input test site number ($j = 1\ldots6$)
R_k is the radius of a circle from LPFM transmitter to measurement location *k*

C_j is the radius of the F(50,50) contour of the FPFM station associated with the j^{th} non-translator-input test site

From equation (3) we observe that the area-weighting factor for a given location is defined using the area between the current measurement location and the next measurement location. This conservative definition for the weighting factors allows for the calculation of conservative area-weighted probabilities for the N→Y transitions.

The data set was separated by LPFM ERP values. Area-weighted probabilities of N→Y transitions for all non-translator-input test sites have been separately calculated for all measurements with LPFM ERP values of 100 W, 10 W, and 0 W, respectively. These probabilities are shown in Figures 2-3, 2-4, and 2-5.

Figure 2-3 shows that, for all measurements with LPFM ERP of 100 W, the probability of an N→Y transition with perceived significant degradation is below 3×10^{-5} for the home, clock radio, boom box and Walkman and RSVI receivers. For the auto receiver the probability of an N→Y transition with perceived significant degradation is of the order of 3×10^{-7}. For the RSVI receiver all N→Y transitions were perceived as having significant degradation of the audio quality. The probabilities of N→Y transitions with perceived non-significant degradation are below 10^{-4} for the home, clock radio, boom box and Walkman receivers. For the auto receiver the probability of an N→Y transition with perceived non-significant degradation is on the order of 10^{-2}. This is mostly due to a non-significant degradation N→Y transition that occurred at the Owatonna translator output test at location 6. As expected, due to the area weighting, transitions that occurred at locations farther away from the LPFM transmitter have a larger weighting factor than transitions that occurred closer to the LPFM transmitter, and therefore a larger contribution to the final area-weighted probability result.

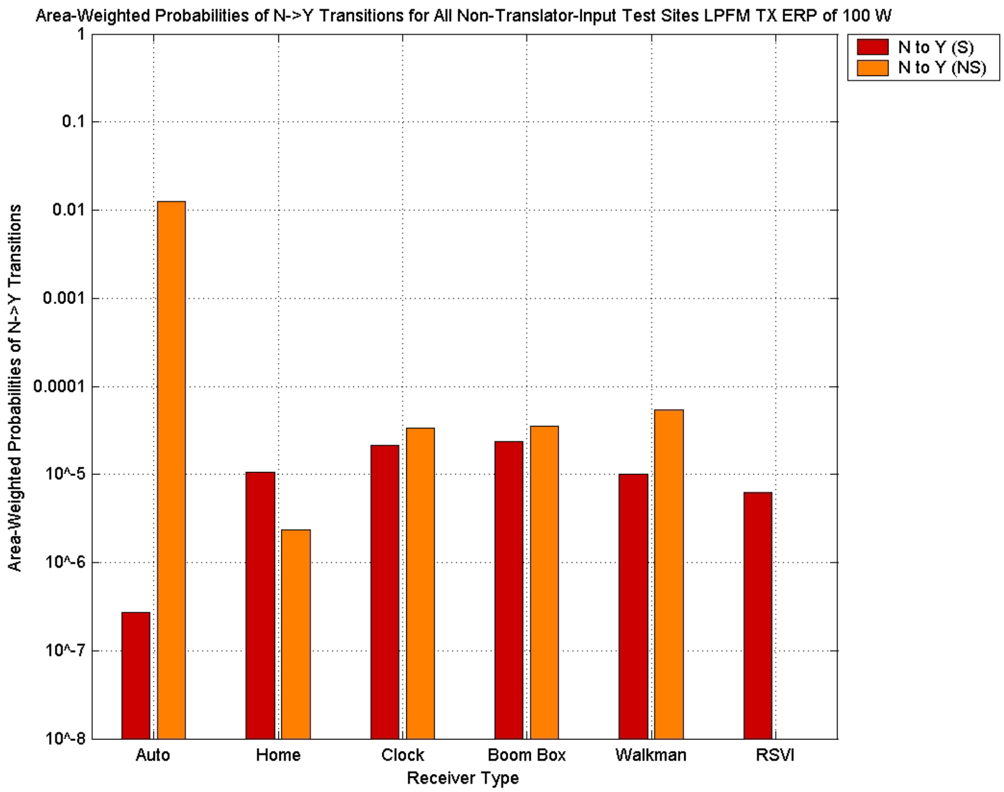


Figure 2-3. Area-Weighted Probabilities of N□Y Transitions for All Non-Translator-Input Test Sites, LPFM ERP Value of 100 W

Figure 2-4 shows the area-weighted probabilities of N→Y transitions for all non-translator-input test sites for all measurements using LPFM ERP of 10 W.

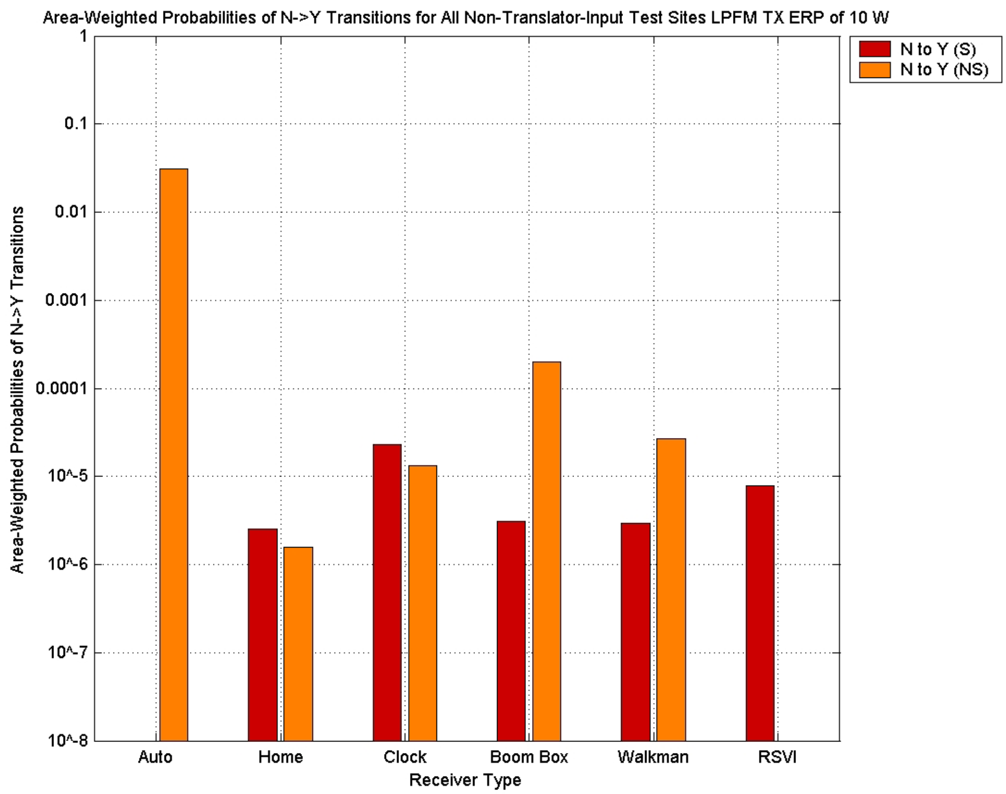


Figure 2-4. Area-Weighted Probabilities of N□Y Transitions for All Non-Translator-Input Test Sites, LPFM ERP Value of 10 W

Figures 2-3 and 2-4 show that for the home, boom box and Walkman receivers the area-weighted probabilities of N→Y transitions with perceived significant degradation are lower for the cases with LPFM ERP of 10 W than for the cases with LPFM ERP of 100 W. Figure 2-4 shows that for the auto receivers there were no N→Y transitions with significant degradation for the cases with LPFM ERP of 10 W. For the clock radio there was a slight increase in the probability of an N→Y transition with perceived significant degradation for the cases with LPFM ERP of 10 W, but this is due to the contribution of an anomalous case which occurred at location 5 and for LPFM ERP of 10 W. This case was already separately discussed in the data analysis for East Bethel. For the RSVI receiver it is noted that all N→Y transitions have been perceived as having significant degradation regardless of LPFM ERP of 100 W or 10 W.

Figure 2-4 shows that probabilities of N→Y transitions with perceived non-significant degradation are below 10^{-4} for the home, clock radio, and Walkman receivers. For the auto receiver the probability of an N→Y transition with perceived non-significant degradation is on the order of 10^{-2}. This is mostly due to a non-significant degradation N→Y transition that occurred at the Owatonna translator output test at location 7. For the boom box receiver the probability of an N→Y transition with perceived non-significant degradation is on the order of 10^{-4}. This is mostly due to a non-significant degradation N→Y transition that occurred at Benicia at location 6. As it was already mentioned, due to the area weighting, transitions that occurred at locations farther away from the LPFM transmitter have a larger weighting factor than transitions that occurred closer to the LPFM transmitter, and therefore a larger contribution in the final area-weighted probability result.

Figure 2-5 shows the area-weighted probabilities of N→Y transitions for all non-translator-input test sites for all measurements using LPFM ERP of 0 W.

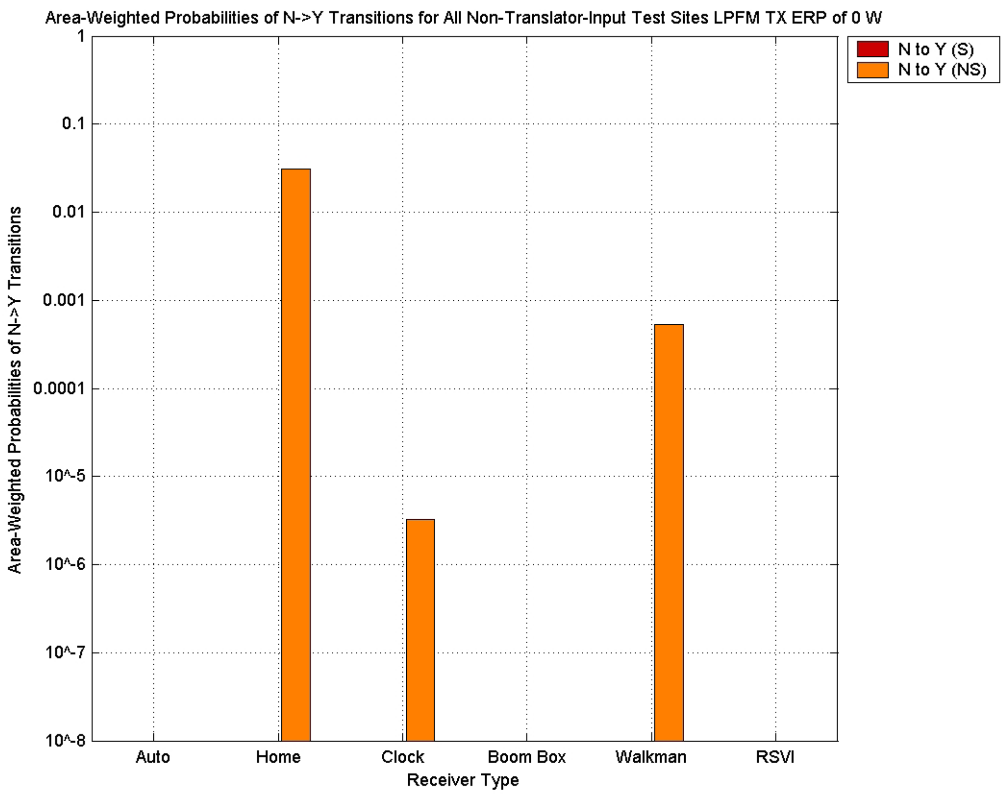


Figure 2-5. Area-Weighted Probabilities of N□Y Transitions for All Non-Translator-Input Test Sites, LPFM ERP Value of 0 W

For all scenarios with LPFM ERP of 0 W there were no N→Y transitions with perceived significant degradation. Also there were no N→Y transitions with perceived non-significant degradation for the auto, boom box and RSVI receivers. There were N→Y transitions with perceived non-significant degradation for the home, clock radio and Walkman receivers, and the area-weighted probabilities for these transitions are presented in Figure 2-5. For the clock radio receiver the area-weighted probability is below 10^{-5}. For the home receiver the area-weighted probability is on the order of 10^{-2}. This was mostly due to a non-significant N→Y transition that occurred at location 7 at the Owatonna translator output test site. For the Walkman receiver the area-weighted probability is below 10^{-3}. This was mostly due to a non-significant N→Y transition that occurred at location 7 at Avon.

These non-significant N→Y transitions cannot be attributed to the effect of the LPFM since the LPFM was not transmitting (LPFM ERP was 0 W). However their presence in the data set generated the probabilities presented in Figure 2-5. This is one reason for which the N→Y transitions with perceived significant degradation have been discussed in more detail in the presentation of the analysis results.

2.10.2 Analysis Regarding the Impact of LPFM-To-Receiver Distance for All Non-Translator-Input Tests

This subsection analyzes the data set containing the measurements from all non-translator-input test sites in order to analyze the impact of LPFM-to-receiver distance.

Appendix C, Figure C-26 shows the data set separated into two subsets, the first subset showing receiver measurement locations 1 to 4, and the second one showing receiver measurement locations 5 to 8. Table 2-1 shows that N→Y transitions with perceived significant degradation occurred at locations close to the LPFM transmitter. This observation was used in the decision to separate the data by location into the two subsets previously defined. From this figure we observe that starting with location 5 there were no N→Y transitions with perceived significant degradation except one anomalous case which occurred for the clock radio receiver at location 5. The recording associated with this case was discussed in Section 2.5. As it was previously mentioned, the recording for this transition exhibits degraded audio quality for only about half of its duration, and the degradation is quite different, consisting of a humming noise. Therefore it is quite likely that the degradation on this recording is not due to LPFM transmission.

Therefore we conclude that, for our data set, no N→Y transitions with perceived significant degradation were measured at distances beyond 0.55 km from the LPFM transmitter. If the effect of the anomalous transition for the clock radio is not considered, then no N→Y transitions with perceived significant degradation were measured at distances beyond 0.33 km from the LPFM transmitter. Also based on Table 2-1, no N→Y transitions with significant degradation involving an LPFM ERP of less than 100 W were identified at any distance more than 126 meters except the anomolus case already mentioned. Numerous significant degradation cases were identified at distances less than 240 meters, and especially at distances less than 100 meters.

Appendix C, Figures C-27 and C-28 which show the data set separated by location (locations 1 to 4, and locations 5 to 8) and also separated by the LPFM ERP value. From Appendix C, Figure C-27 we observe that for the cases with LPFM ERP of 100 W no N→Y transitions with perceived significant degradation occurred starting with location 5. Appendix C, Figure C-28 shows one significant degradation case for the clock radio receiver for locations 5 to 8. This case occurred at location 5, and was the anomalous case already discussed.

The transition counts presented in Appendix C, Figures C-26 to C-28 represent the raw data set. This means that data from the appropriate receiver measurement locations have been added together, without considering the probability of an actual receiver being located in a given area. These figures provide a general view of the data set.

For a more detailed analysis of the data set, the area-weighted probabilities of N→Y transitions defined and calculated in the previous subsection are further analyzed. In this subsection we evaluate the contributions of the transitions from locations 1 to 4, and from locations 5 to 8 to the area-weighted probabilities.

The two subplots in Figure 2-6 show the contributions of the two subsets of locations to the area-weighted probabilities of N→Y transitions for all measurements with LPFM ERP of 100 W. This figure shows that only locations 1 to 4 contribute to the area-weighted probabilities of N→Y transitions for the cases with perceived significant degradation. This is an expected result, since it is known that no N→Y transitions with significant degradation occurred beyond location 4 for the cases with LPFM ERP of 100 W. It can also be observed that locations 5 to 8 have no contributions to the probabilities of N→Y transitions for both the home and RSVI receivers. For the N→Y transitions with perceived non-significant degradation the contributions from locations 5 to 8 are larger than the contributions from locations 1 to 4 for the auto, clock radio, boom box and Walkman receivers. This can be explained by the fact that due to the area weighting, transitions that occurred at locations farther away from the LPFM transmitter have a larger weighting factor than transitions that occurred closer to the LPFM transmitter, and therefore a larger contribution to the final area-weighted probability result.

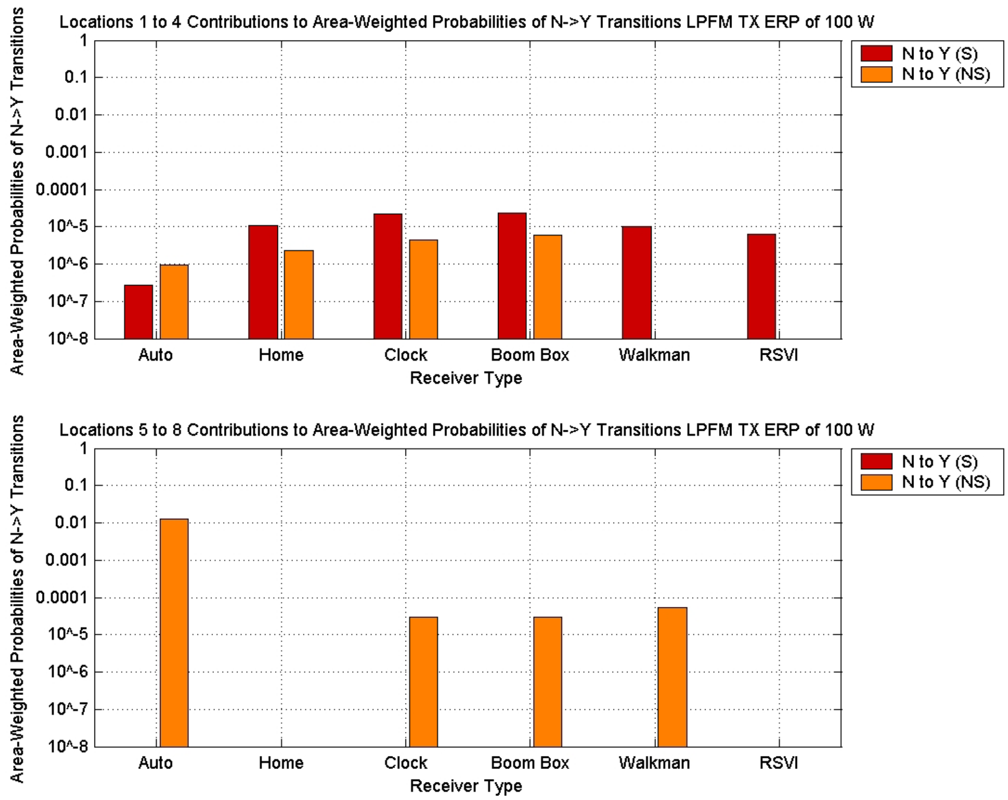


Figure 2-6. Location Contributions to Area-Weighted Probabilities of N□Y Transitions for All Non-Translator-Input Test Sites, LPFM ERP Value of 100 W

The two subplots in Figure 2-7 show the contributions of the two subsets of locations to the area-weighted probabilities of N→Y transitions for all measurements with LPFM ERP of 10 W. The same comments made for the previous plot are also valid for this plot. In addition, it can be observed that locations 1 to 4 have no contributions to the probabilities of N→Y transitions for the auto receiver. This figure also shows the contribution from locations 5 to 8 to the area-weighted probability of N→Y transitions with significant degradation for the clock radio receiver. This is due to the anomalous case already discussed.

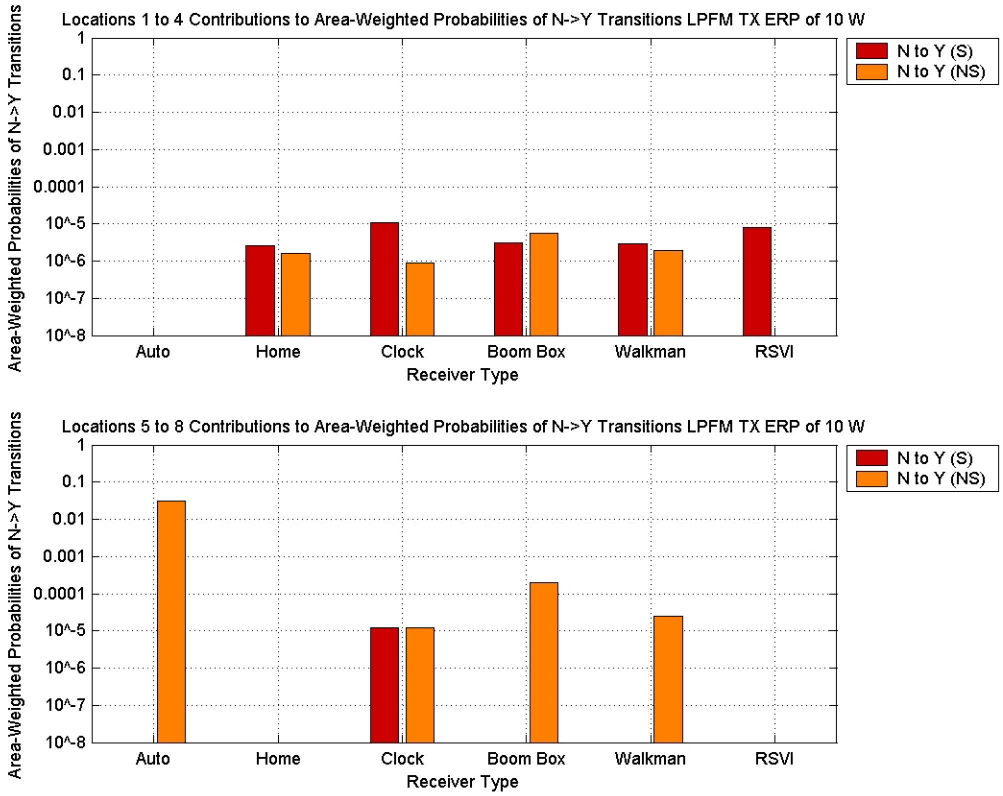


Figure 2-7. Location Contributions to Area-Weighted Probabilities of N□Y Transitions for All Non-Translator-Input Test Sites, LPFM ERP Value of 10 W

The two subplots in Figure 2-8 show the contributions of the two subsets of locations to the area-weighted probabilities of N→Y transitions for all measurements with LPFM ERP of 0 W.

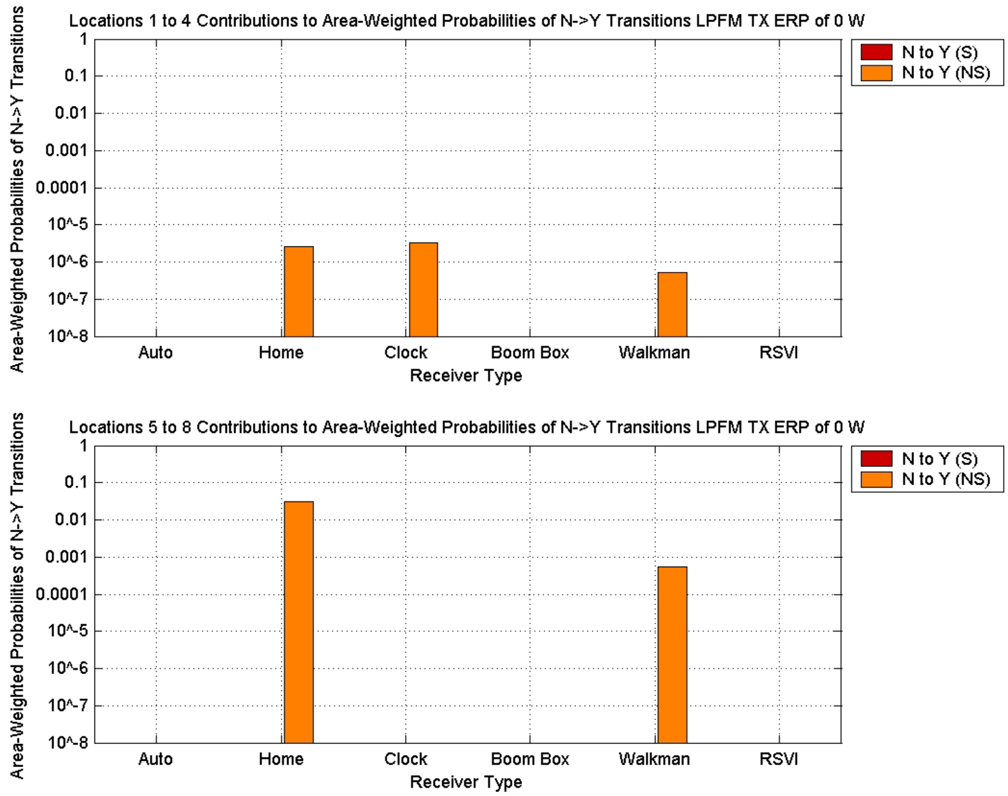


Figure 2-8. Location Contributions to Area-Weighted Probabilities of N□Y Transitions for All Non-Translator-Input Test Sites, LPFM ERP Value of 0 W

As already mentioned, for all scenarios with LPFM ERP of 0 W there were no N→Y transitions with perceived significant degradation. Also there were no N→Y transitions with perceived non-significant degradation for the auto, boom box and RSVI receivers. There were N→Y transitions with perceived non-significant degradation for the home, clock radio and Walkman receivers, and the probabilities for these transitions are observed in the two subplots of Figure 2-8. For the home and Walkman receivers, the contributions to the area-weighted probabilities from locations 5 to 8 are larger than the ones from locations 1 to 4. This can be explained by the fact that due to the area weighting, transitions that occurred at locations farther away from the LPFM transmitter have a larger weighting factor than transitions that occurred closer to the LPFM transmitter, and therefore a larger contribution to the final area-weighted probability result.

2.10.3 Analysis Regarding the LPFM-FPFM Program Content Combination in All LPFM Tests

In order to evaluate the impact of the LPFM-FPFM program content combination, the analog measurement results from all LPFM test sites are analyzed as a data set. This means that the data set contains the results from all the non-translator-input test sites as well as the results from the Owatonna translator input test site. All receiver measurement locations and all LPFM ERP levels are used in this analysis.

Appendix D contains the plots used in the LPFM-FPFM program content combination analysis. These plots present the raw data set, with the percentages calculated for each LPFM-FPFM program content combination and each receiver type. No area-weighting was applied to the transition count percentages shown in these plots; therefore they do *not* represent probabilities of transitions. Appendix E contains the Delta Degradation plots as a function of D/U for all-non-input-translator test sites, for each receiver type and also for the various LPFM-FPFM content combinations. These plots provide additional information for interpreting the data trends for the various program content combinations.

Table 2-2 shows the LPFM-FPFM program content combinations and the LPFM test sites where these combinations have been measured.

Table 2-2. LPFM-FPFM Program Content Combinations and the Appropriate LPFM Test Sites

FPFM Program Content	LPFM Program Content		
	Processed	Unprocessed	News/Talk
Processed	Avon and Benicia	Benicia and Winters	Avon and Winters
Unprocessed	Owatonna Translator Output Test and Owatonna Translator Input Test	Owatonna Translator Input Test	Owatonna Translator Output Test and Owatonna Translator Input Test
News/Talk	East Bethel and Avon*	East Bethel and Brunswick	Brunswick and Avon*

* Avon had a number of recordings for which the FPFM program content was news/talk, even though the main program content of the FPFM station was processed music, therefore these recordings were analyzed as having the FPFM program content as news/talk.

Appendix D, Figure D-1 shows the entire data set taking into account the various LPFM-FPFM program content combinations. We observe that for the cases with FPFM program content as processed music there are a small number of N→Y transitions in general. N→N transitions represent the majority of transitions. We also observe that the Processed→Processed program content combination has a smaller number of N→Y transitions than the News/Talk→Processed and Unprocessed→Processed program content combinations. This can be due to the fact that the Avon and Benicia LPFM test sites are both characterized by a small number of N→Y transitions, and these are the only sites at which Processed→Processed program content combination was used. At Winters, it was observed that news/talk and unprocessed music had similar effects on the processed music program content transmitted by the FPFM station, when all other scenario parameters (i.e., LPFM ERP, LPFM antenna height AGL, and receiver measurement location) were the same. This trend can be also observed in Appendix D, Figure D-1.

For the cases with FPFM program content as unprocessed music, we observe that Y→Y transitions represent the majority of transitions. These cases represent test results for Owatonna translator output tests and Owatonna translator input tests. For the Owatonna translator output tests only a small number of N→Y transitions were measured. It was observed that processed music and news/talk music had similar effects on the unprocessed music program content transmitted by the FPFM station, when all other scenario parameters (i.e., LPFM ERP, LPFM antenna height AGL, and receiver measurement location) were the same. Again this conclusion is from a small number of N→Y transitions. For the Owatonna translator input tests, the processed music program content for LPFM seems to have a bigger impact than either news/talk or unprocessed music when the program content of the FPFM station is unprocessed music. This will be discussed in more detail later in the section when the data from Owatonna translator input test is presented separately.

For the cases with FPFM program content as news/talk, we observe that the percentages of the various types of transitions vary substantially with the type of program content transmitted by LPFM. This can be due to the fact that data was collected from LPFM test sites which had quite different measurement results. Comparing the various results is more difficult for these cases. However, we can compare the program content pairs under the same set of conditions (i.e., from the same LPFM test site). At East Bethel, it was observed that processed and unprocessed music had similar effects on the news/talk program of the FPFM station, when the N→Y transitions that occurred under the same set of conditions were analyzed. Appendix D, Figure D-1 shows a larger percentage of N→Y transitions for the processed music program content of the LPFM station than for the unprocessed music, but this is mainly due to the fact that unprocessed music was also transmitted at Brunswick. At Brunswick, we recall that there were few N→Y transitions, and the majority of transitions were Y→Y transitions, and this explains the percentage difference. This also explains why for the Unprocessed→News/Talk program content combination there are much more Y→Y transitions than for the Processed→News/Talk program content combination (again the effect of the Brunswick data). The News/Talk→News/Talk combination was measured mainly at Brunswick (with some data points from Avon), but for both Brunswick and Avon the number of N→Y transitions is small, which was also discussed in Sections 2.3 and 2.4. Due to the small sample size it is difficult to compare this combination pair with the other two combinations that had news/talk as the FPFM program content.

For all non-translator input tests no strong correlation was noted between the tested combination of LPFM and FPFM program contents (where each content could be processed music, uprocessed music, or news/talk) and the observed number of significant degradation transitions.

The program content plots for each receiver type are presented in Appendix D, Figures D-2 to D-7. The general data trends that have been discussed for Appendix D, Figure D-1 are also observed in these plots.

From Appendix D, Figure D-2 we observe that for the auto receiver using the processed-processed program content combination there are no N→Y transitions. Also for the News/Talk→News/Talk combination there are no N→Y transitions with perceived significant degradation. As a general comment, for the cases in which the FPFM program content was either processed or news/talk (i.e., the data was for non-translator-input tests only) there were very few N→Y transitions in general. For the cases in which the FPFM program content was unprocessed music, the effect of the Owatonna translator input test results is quite clear in the sense that there are a large number of N→Y transitions. It can be observed that for the auto receiver the LPFM processed music program content seems to have a bigger impact on the FPFM unprocessed music program content than either news/talk or unprocessed music.

From Appendix D, Figure D-3 we also observe that for the home receiver using the processed-processed program content combination there are no N→Y transitions with perceived significant degradation. If we compare Appendix D, Figure D-2 with Figure D-3 we observe a lot of similarities for the two receivers.

From Appendix D, Figure D-4 we observe that the data trends for the clock radio receiver matched quite well the data trends identified in Appendix D, Figure D-1, which had data from all receivers.

Appendix D, Figures D-5 and D-6 show that the data trends for the boom box and Walkman receivers are similar. For the cases in which the FPFM program content was unprocessed music almost all transitions are Y→Y transitions for the boom box and all transitions are Y→Y transitions for the Walkman. There are no N→Y transitions for either receiver. Therefore we cannot identify an effect of the LPFM program content on the FPFM program content for these cases and these receivers. Also for the News/Talk→News/Talk program content combination there are no N→Y transitions for either receiver. Therefore we cannot identify an effect of this program content combination on these receivers or compare it to other program content combinations.

Appendix D, Figure D-7 shows the data for the RSVI receiver. This data was measured at the East Bethel LPFM test site. From the N→Y transitions we observe that processed and unprocessed music have similar effects on the news/talk program content of the FPFM station when the other test conditions were the same. This conclusion was more generally identified in the analysis related to Appendix D, Figure D-1, and it was also based on the data analysis from the East Bethel site.

The results for the Owatonna translator input tests are also analyzed separately and presented in Appendix D, Figures D-8 to D-11. This is done due to the different setup of this test which was described in detail in Section 2.7.

For the Owatonna translator input test it was observed that the unprocessed music program content of the FPFM station was more susceptible to degradation for the cases in which processed music was transmitted by the LPFM, than for the cases in which either unprocessed or news/talk was transmitted by the LPFM. Also unprocessed music and news/talk program contents of the LPFM station seem to have similar effects on the unprocessed music of the FPFM station. This could be observed in Figure D-8 that shows the data from all receivers, as well as Appendix D, Figures D-9, D-10 and D-11 which show the data for auto, home and clock radio receivers respectively. For the boom box and Walkman receivers there were no N→Y transitions, therefore the effects of the program content could not be analyzed for these receivers at this test site (and no plots were used in the analysis). However, the sample size for the Owatonna translator input test was quite small.

2.10.4 Analysis Regarding the Impact of LPFM Transmitter Antenna Height for All LPFM Tests

In order to analyze the impact of LPFM transmitter antenna height above ground level (AGL) we have separated the measured results in two sets. The first set looks at all measurement results from all non-translator-input test sites and the second set contains the measurements from the Owatonna translator input test. This separation was done due to the different setup of the Owatonna translator input test as described in Section 2.7.

Two antenna heights were used for each LPFM test site and each receiver location. These two heights were 30 m and 10 m AGL. To evaluate the impact of antenna height AGL we have analyzed each data set, and calculated the percentages of each transition type at the two AGL values. For all non-translator-input test sites the data was further separated by location into two subsets. The first subset includes the data from receiver measurement locations 1 to 4. The second subset includes the data from receiver measurement locations 5 to 8. For a given LPFM transmitter antenna height AGL and for a given location subset, all LPFM ERP values, all program contents and all receiver types have been included in the calculation. These transition count percentages were calculated using the raw data set. No area-weighting was applied in these calculations; therefore they do not represent probabilities of transitions.

Table 2-3. Percentage Transition Counts as a Function of LPFM Antenna Height

Transition Type	All Non-Translator-Input LPFM Test Sites				Owatonna Translator Input Test Site	
	Locations 1 to 4		Locations 5 to 8		Locations 1 and 2	
	LPFM Antenna Height AGL		LPFM Antenna Height AGL		LPFM Antenna Height AGL	
	30 m	10 m	30 m	10 m	30 m	10 m
N→Y (S)	10.0%	13.7%	0.0%	0.1%	17.3%	5.5%
N→Y (NS)	2.1%	3.4%	1.0%	0.9%	9.5%	4.5%
N→N	59.3%	54.1%	61.3%	63.3%	14.1%	21.4%
Y→Y	28.6%	28.7%	37.7%	35.7%	59.1%	68.6%
Y→N	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%

From Table 2-3 it can be observed that for all non-translator-input LPFM test sites and receiver measurement locations 1 to 4 the percentage of N→Y transitions (both with perceived significant and non-significant degradation of the audio quality) is slightly higher for the cases in which the LPFM antenna height AGL is 10 m than for the cases in which it is 30 m. This could be explained by the fact that, at receiver measurement locations close to the LPFM transmitter, a lower antenna height might increase the undesired signal level because of the effect of the vertical directivity of the antenna. This would increase the likelihood of an N→Y transition. However, the percentages for all transition types vary only very slightly with LPFM antenna height AGL. Almost no variation with LPFM antenna height AGL was observed for the percentage of N→Y transitions at receiver measurement locations 5 to 8.

For the Owatonna translator input test it can be observed that a larger percentage of N→Y transitions occur for the cases in which the LPFM antenna height AGL is 30 m than for the cases in which it is 10 m. This is a different result than the one observed for the non-translator-input test data, and it could be due to the different setup of the translator input test and multipath propagation effects.

2.10.5 Threshold D/U Analysis

2.10.5.1 Estimation of Reception Degradation Thresholds

A threshold in terms of D/U is used to serve as a measure for estimating the listeners' tolerance of reception degradation. The thresholds are estimated based on a "group-weight-average" approach. In this method, the reception qualities of the test data items shown in Appendix C are first categorized according to the scheme described in Section 2.2. For convenience of discussion, the data items are denoted as YY for those of persistent degradation (i.e., Y→Y), G for those of no degradation (i.e., N→N), NS for those of non-significant degradation (i.e., N→Y with minor degradation), and S for those of significant degradation (i.e., N→Y with significant degradation). A weight, or relative degradation index, is assigned to each type of data item: unity to the S data item, zero to the G data item, and a specific trial weight is assigned to the NS data item depending on the case of investigation. Three cases are investigated. Each case corresponds to one level of degradation significance (expressed as a fraction relative to the degradation in the S data items) that could probably be associated with the NS data items. The weight for the NS data items is 0.5 in Case 1, 0.2 in Case 2, and 0 in Case 3. Table 2-4 summarized the weight assignment in different cases.

Table 2-4. Cases of Threshold Estimation

	Weight Assignment		
	NS Data Item	**S Data Item**	**G Data Item**
Case 1	0.5	1	0
Case 2	0.2	1	0
Case 3	0	1	0

All the YY data items are excluded in the analysis since no new information can be obtained due to their persistent degradation before and after the introduction of LPFM signals. Also excluded is the data item associated with Y→N measured at Brunswick.

The data items used for analysis are first grouped based on their associated D/U values: items in every 10 dB interval are grouped. For example, the group of 50 dB D/U contains those data items in the interval of D/U between 45 dB and 55 dB, the group of 40 dB D/U contains those data items in the interval of D/U between 35 dB and 45 dB, etc. Then the (group-weight-average) relative degradation index, which is defined as the average of the relative degradation indices of the data items in each D/U group interval, is evaluated. For the investigation in this section, data items of different program contents are lumped together. In a given case for each radio type, the resultant relative degradation index associated with each D/U group is estimated by averaging that group's group-weight-average relative degradation indices from all the test sites.

For illustration purposes, the graphs depicting the Case 2 results are presented in Figures 2-9 through 2-19. The legend for the graph series representing respective test sites is as follows:

- Series 1 for Avon
- Series 2 for Brunswick
- Series 3 for East Bethel
- Series 4 for Owatonna

- Series 5 for Winters
- Series 6 for Benicia

Note that the graph for the RSVI program test, Figure 2-19, contains only one set of measurements because the service for readers with impaired vision was tested only in the East Bethel site.

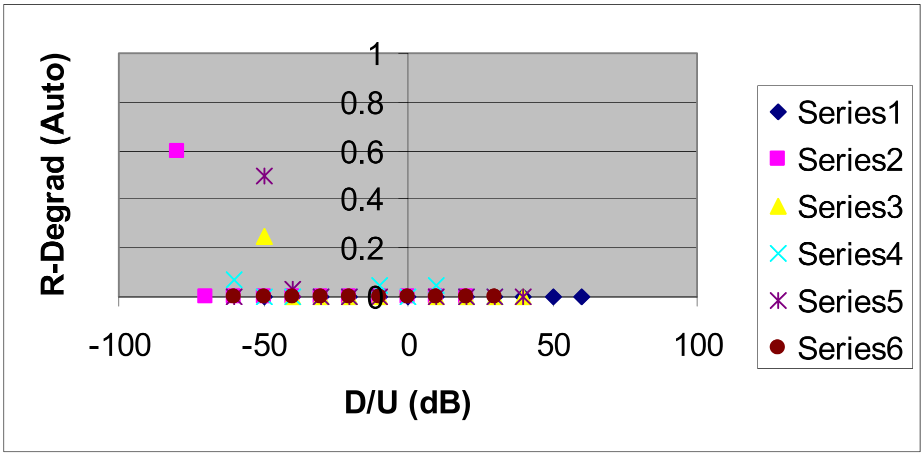


Figure 2-9. Relative Degradation for Auto Radio (Case 2)

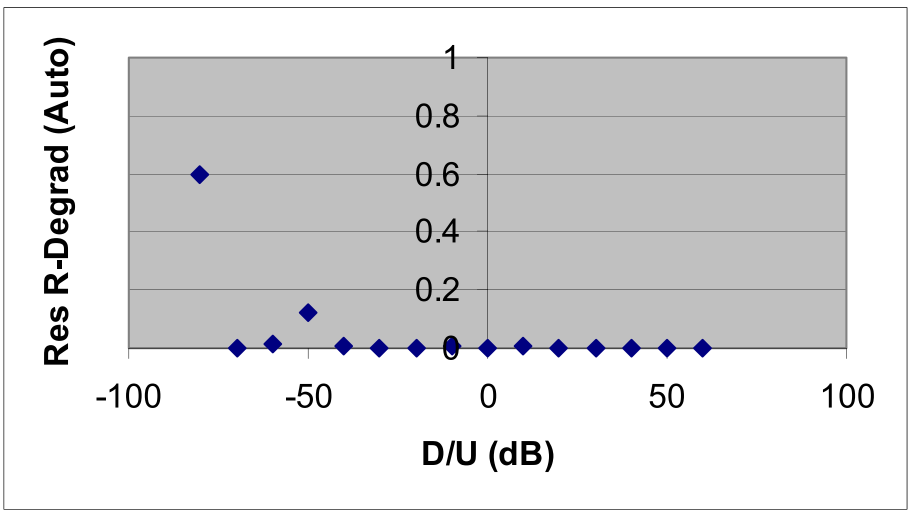


Figure 2-10. Resultant Relative Degradation for Auto Radio (Case 2)

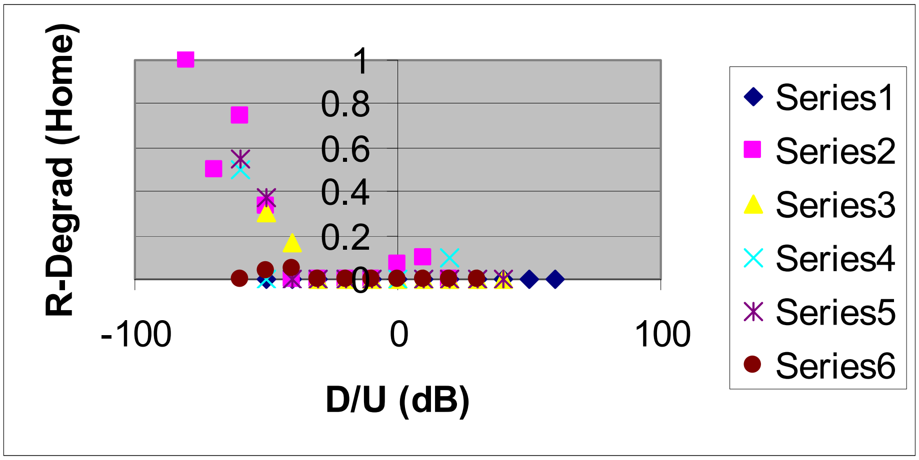


Figure 2-11. Relative Degradation for Home Radio (Case 2)

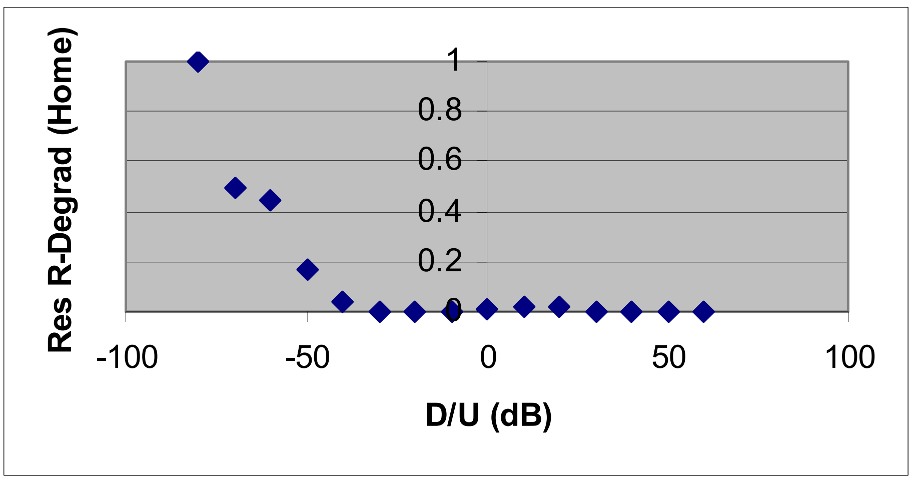


Figure 2-12. Resultant Relative Degradation for Home Radio (Case 2)

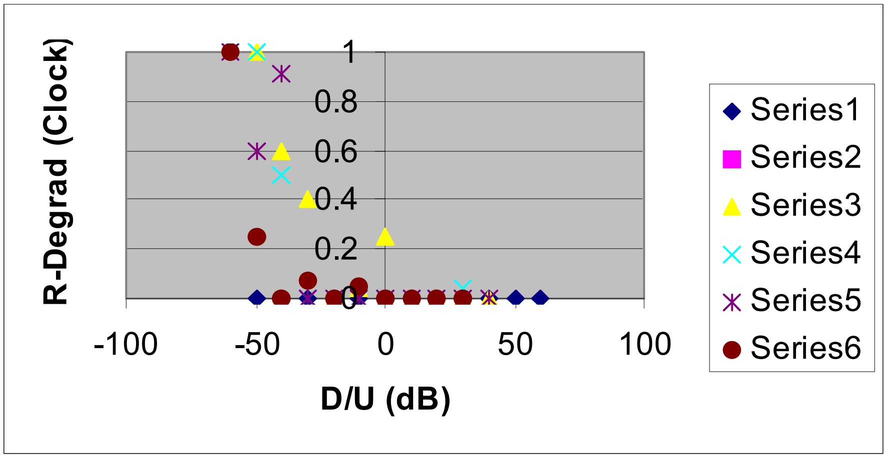


Figure 2-13. Relative Degradation for Clock Radio (Case 2)

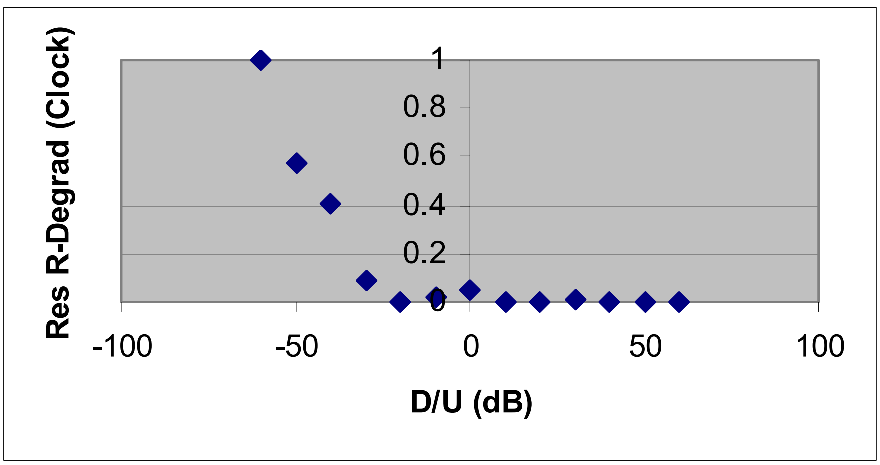


Figure 2-14. Resultant Relative Degradation for Clock Radio (Case 2)

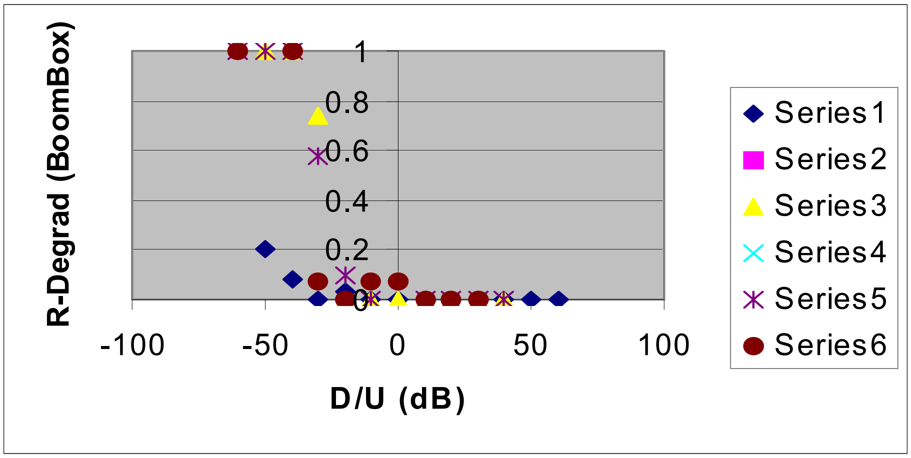


Figure 2-15. Relative Degradation for Boom Box Radio (Case 2)

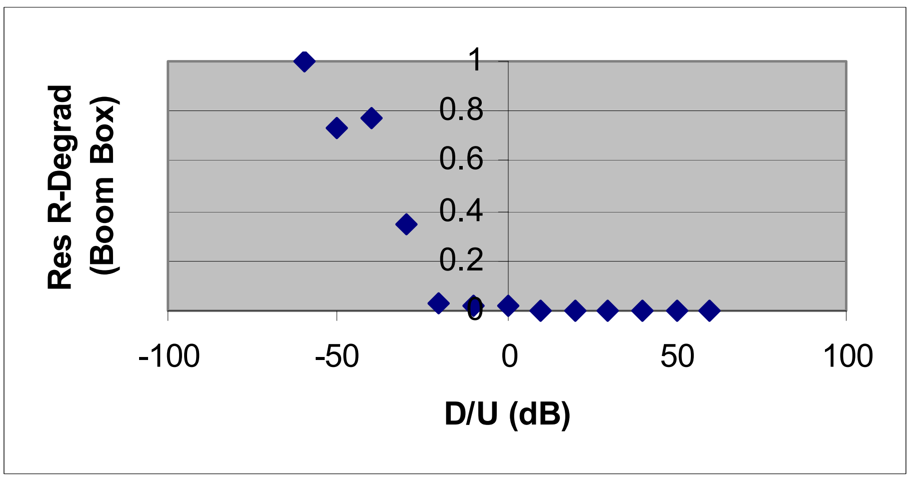


Figure 2-16. Resultant Relative Degradation for Boom Box Radio (Case 2)

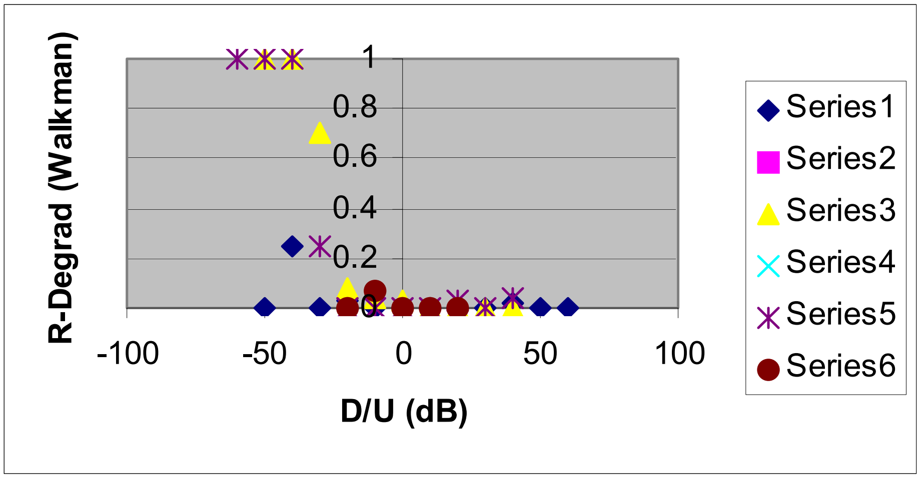


Figure 2-17. Relative Degradation for Walkman Radio (Case 2)

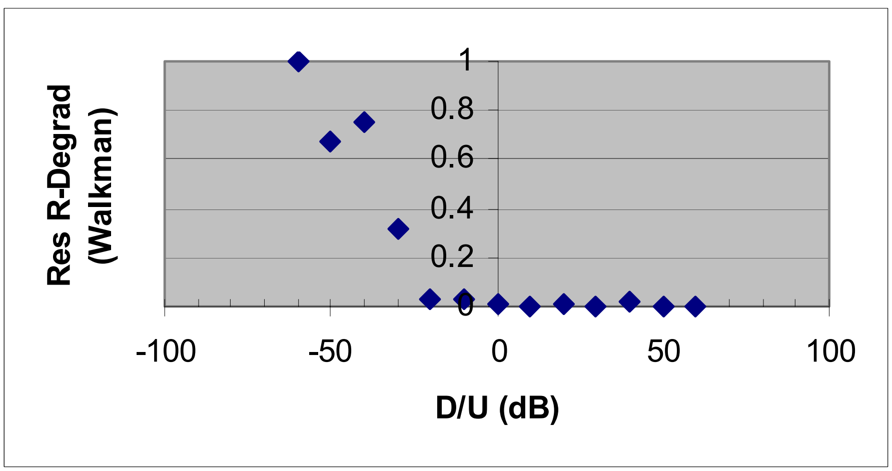


Figure 2-18. Resultant Relative Degradation for Walkman Radio (Case 2)

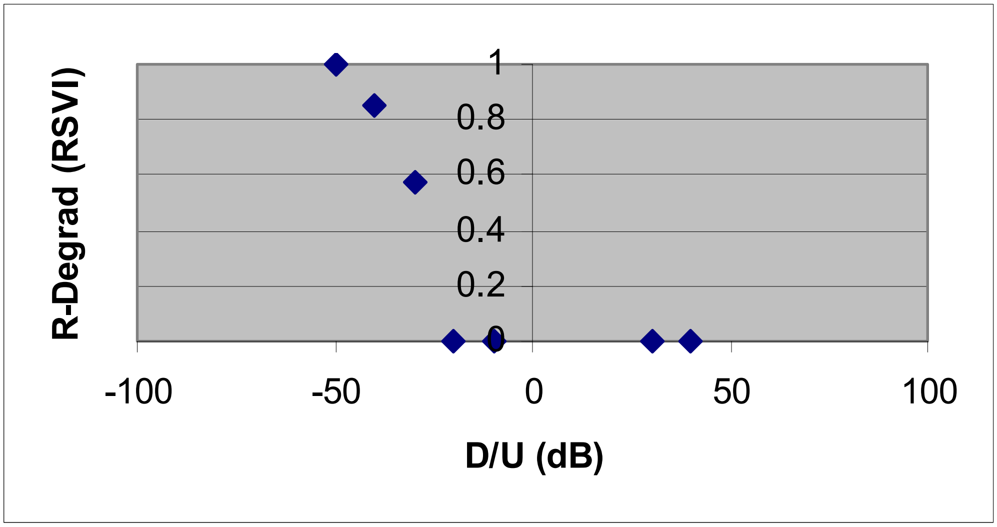


Figure 2-19. Resultant Relative Degradation for RSVI Radio (Case 2)

Note that the (resultant) relative degradation index used here should be treated in a more qualitative than quantitative sense as a description of the interference susceptibility of the radio receivers. Without a formal subjective testing, it would not be possible to reliably translate the relative degradation index to the more standard measure such as the Mean Opinion Score (MOS). Under this restriction, however, one would still be able to investigate the relative susceptibility of the radios based on a convenient reference value, say 0.3, of the relative degradation index. At this degree of degradation, it would be safe to expect that certain level of interference should be perceptible to the listeners (but the corresponding MOS value would require a formal subjective testing to establish). The estimated threshold D/U values (in dB) based on 0.3 (resultant) relative degradation index for the three cases are presented in Table 2-5.

Table 2-5. Estimated Threshold D/U Values (in dB)

	Auto	Home	Clock	Boom Box	Walkman	RSVI
Case 1	-60	-55	-37	-27	-27	-26
Case 2	-60	-55	-37	-27	-27	-26
Case 3	-61	-56	-37	-30	-30	-26
Average	-60	-55	-37	-28	-28	-26

Within the accuracy of the estimation (± 5 dB in D/U), the thresholds are not sensitive to the possible weights assigned to the NS data items. Therefore, the threshold values thus estimated are believed to be showing the intrinsic nature of the data and can be associated with the radio operational thresholds. As shown in Table 2-5, the auto receiver was the most robust in the presence of third-adjacent-channel LPFM transmissions, showing little or no significant degradation except when the D/U value fell below a threshold of -60 dB. The home receiver was nearly as robust, with a D/U threshold of -55 dB. The clock radio's much lower threshold of -37 dB was still significantly better than those of the boom box, Walkman, and RSVI receiver (-27, -27, and -25 dB, respectively).

2.10.5.1.1 Owatonna FM Translator

An analysis, with the same weight assignment scheme to the relevant data items, is also applied to investigate the degradation thresholds when the signal of interest is transmitted through an FM translator station. The translator test was performed at Owatonna, MN and the field measurements were performed using the same collection of radios. Due to the small variation range in D/U, no D/U interval grouping is used. Because a large proportion of the degradation data items are non-significant in the critical D/U regions, the relative degradation indices for the three cases are quite different. Therefore the relative degradation indices of all three cases are presented instead of their averaged values. The results are shown in Figures 2-20 through 2-22. The legend for the graph series representing respective Cases is as follows:

- Series 1 for Case 1
- Series 2 for Case 2
- Series 3 for Case 3

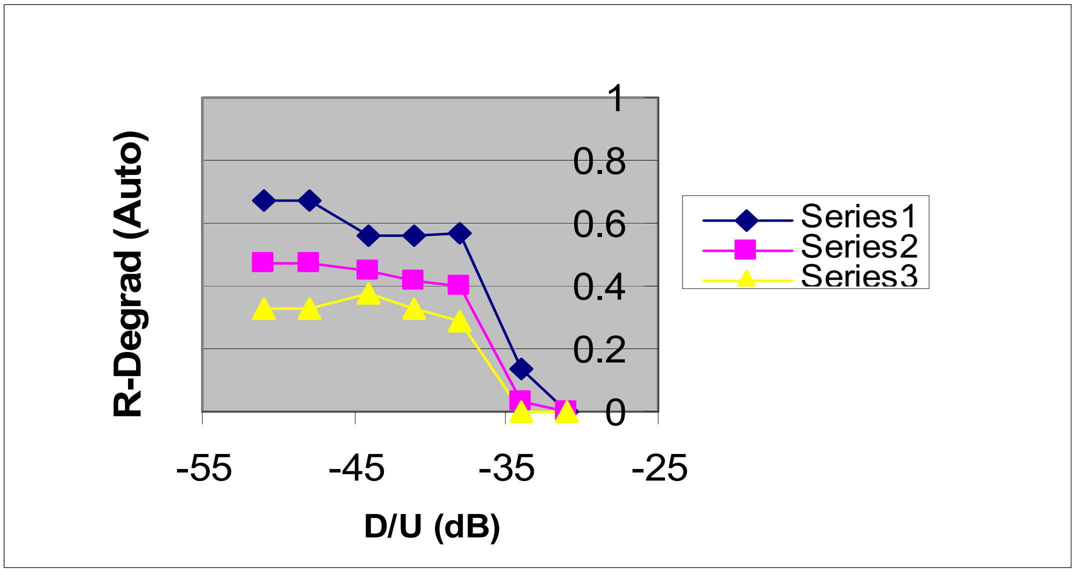


Figure 2-20. Relative Degradation for Auto Radio in FM Translator Test

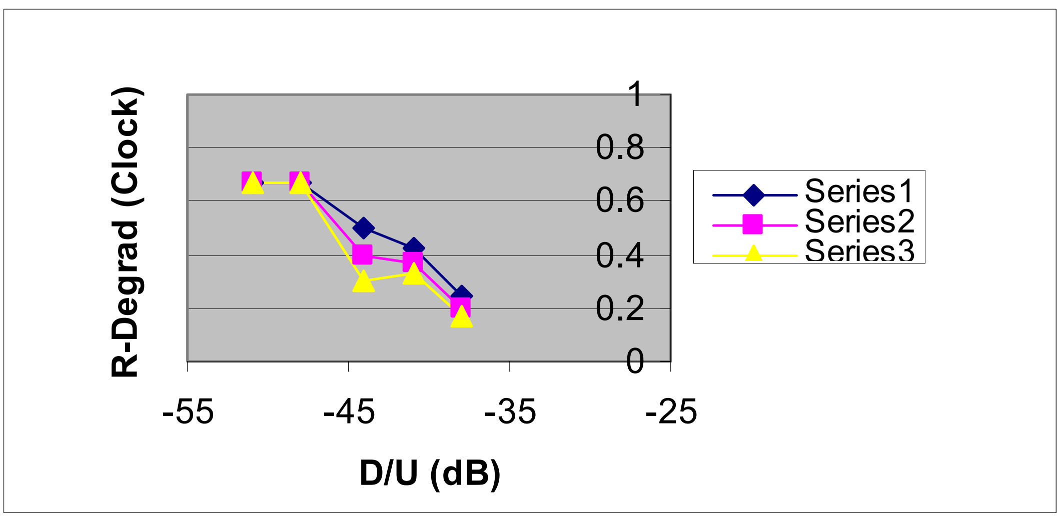


Figure 2-21. Relative Degradation for Clock Radio in FM Translator Test

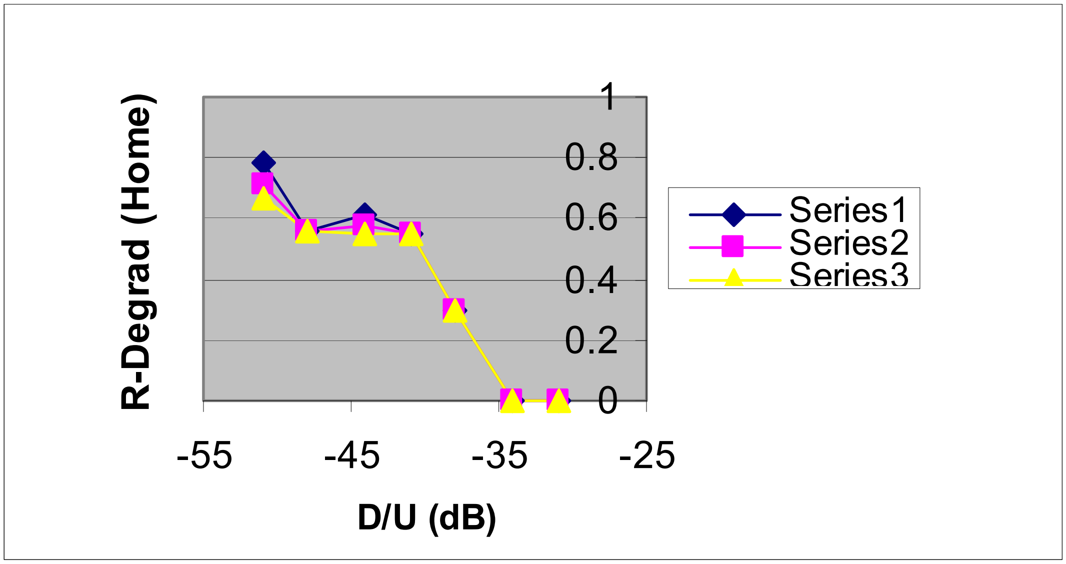


Figure 2-22. Relative Degradation for Home Radio in FM Translator Test

Note that these figures do not show the Boom Box and Walkman radios because the data of these two radios all belong to the YY category (i.e., Y→Y) and hence are ignored.

For the auto radio, it is seen from Figure 2-20 that, as long as D/U is kept above -36 dB, the relative degradation indices of all three cases will remain below 0.3. Hence a conservative value of the degradation threshold for the auto radio would be -36 dB. Similarly, for the clock radio, it is seen from Figure 2-21 that, as long as D/U is kept above -39 dB, the relative degradation indices of all three cases will remain below 0.3. Hence a conservative value of the degradation threshold for the clock radio would be -39 dB. From Figure 2-22, the degradation threshold of the Home radio can be established more precisely and is estimated to be -38 dB. The Owatonna FM translator's input threshold is averaged to be -38 dB which is about the same as the threshold of the clock radio receiver shown in Table 2-6. The results are summarized in Table 2-6.

Table 2-6. Estimated Threshold D/U Value for Translator Input Test

Auto	Home	Clock	Average
-36 dB	-38 dB	-39 dB	-38 dB

2.10.5.2 Dependence of Interference Susceptibility of Radios on Program Contents

In this subsection, the program-content-specific thresholds of different types of radio are investigated. We notice that the results of Section 2.10.5.1 indicate that the estimated threshold values for Cases 1, 2, and 3 are practically the same. Hence we will perform the analysis in this subsection based on the Case 2 parameters. In particular, a weight of 0.2 is used for the non-significant data items.

As the test data items shown in Appendix E are categorized according to their program contents involved, the number of available items in each category is usually quite limited. For the instances where there are not too few data items involving degradation transition, the reception degradation thresholds can be estimated using the same method as described in Section 2.10.5.1. In many instances, however, the number of data items involving degradation is either too few or none, and only upper bounds (but the bounds may not be tight) can be assigned for the thresholds.

The program-content-specific thresholds thus estimated are shown in Table 2-7.

Table 2-7. Program-Content-Specific Thresholds (dB)

	LPFM PC→ FPFM PC	Auto	Home	Clock	Boom Box	Walkman	RSVI
Brunswick	T→T	< -70	-60	x	x	x	NA
	U→T	-70	-45	x	x	x	NA
Benicia	P→P	< -60	< -60	-53	-33	x	NA
	U→P	< -60	< -60	-44	-32	x	NA
Avon	P→P	< -50	< -50	< -50	< -40	< -40	NA
	T→P	< -50	< -50	< -50	< -40	< -50	NA
East Bethel	P→T	-50	-44	-31	-24	-24	-26
	U→T	< -50	-47	-34	-26	-25	-26
Owatonna (Site A)	P→U	< -50	-54	-34	x	x	NA
	T→U	< -50	-58	-43	x	x	NA
Winters	T→P	< -50	-50	-35	-25	-33	NA
	U→P	< -50	-50	-35	-26	-31	NA

Legend:

T = News/Talk program content
P = Processed music program content
U = Unprocessed music program content
PC = Program Content

< N = Value less than N
x = Data ignored due to persistent degradation
NA = Not applicable

The results shown in Table 2-7 are consistent with those in Table 2-5. However, a careful comparison of the results in these two tables does indicate that the radio receiver thresholds are somewhat dependent on the LPFM/FPFM program content combination.

From the Brunswick data, it seems that (T→T) is less susceptible to interference than (U→T). From the data of East Bethel and Winters, it seems that the degrees of susceptibility of (P→T), (U→T), (T→P), and (U→P) are about the same. With slightly less certainty, the data of Benicia and Owatonna seem to imply that (P→P) is less susceptible than the program combinations (U→P), (P→U), and (T→U) while among these three roughly the same susceptibility applies. As a consequence, both (T→T) and (P→P) are expected to be more robust than all the other LPFM/FPFM program content combinations mentioned earlier. However, it is hard to compare the susceptibility between (P→P) and (T→T) based on the present test data. More discriminative data is required to resolve the difference.

Section 3

Digital Measurement Results Analysis

3.1 Background

The United States has been a proponent of introducing digital signals in the FM commercial audio broadcasting frequency band using a technique whereby a station would transmit both its analog signal and two digital signals of lesser amplitude—one on each side of the existing analog FM signal—within the allowed spectrum mask. Systems operating with this technology are commonly called In Band, On Channel (IBOC) systems. The iBiquity FM IBOC system is the only terrestrial digital audio broadcasting (DAB) system in the United States at this time.

The iBiquity IBOC design provides a flexible means of transitioning to a fully digital broadcast system by providing three new waveform types: Hybrid, Extended Hybrid, and All Digital. While both the Hybrid and Extended Hybrid types retain the analog FM signal, the bandwidths of the digital sidebands in the Extended Hybrid waveform are extended toward the analog FM signal to increase digital capacity. In the All Digital waveform case, the analog signal is removed and the bandwidth of the digital sidebands is fully extended to occupy this vacated frequency band as well.

The National Radio Systems Committee (NRSC) and the iBiquity Digital Corporation had submitted test reports to the FCC on the performance of iBiquity's FM IBOC prototype system subject to interference from sources of co-channel up to the second adjacent channels. On October 10, 2002, the Commission, by First Report and Order (FCC 02-286), approved the Hybrid mode operation of iBiquity IBOC systems in the commercial FM band.

MITRE is supporting the FCC to investigate the impact of the third adjacent channel interference (ACI) from LPFM to FPFM broadcasting. In concert with the FCC's approval in 2001, our task emphasized the IBOC hybrid mode with the interference signal from the analog LPFM station operating at the third adjacent channel. Strategically, this hybrid waveform is used during an initial transitional phase preceding conversion to the all digital waveform. However, this transition phase is expected to last for a considerable period of time before the other waveform modes are introduced.

3.1.1 Brief Overview of iBiquity FM IBOC System in Hybrid Mode

The digital signal is transmitted in Primary Main (PM) sidebands on either side of the analog FM signal. The power level of each sideband is approximately 20 dB below the total power in the analog FM signal. The analog signal may be monophonic or stereo, and may include Subsidiary Communications Authority (SCA) channels. The waveform envelope falls below allocated spectral emissions mask as currently defined by the FCC. Figure 3-1 illustrates the hybrid mode IBOC signal with digital sidebands occupying a portion of spectrum used by the analog signal of two first adjacent channel stations.

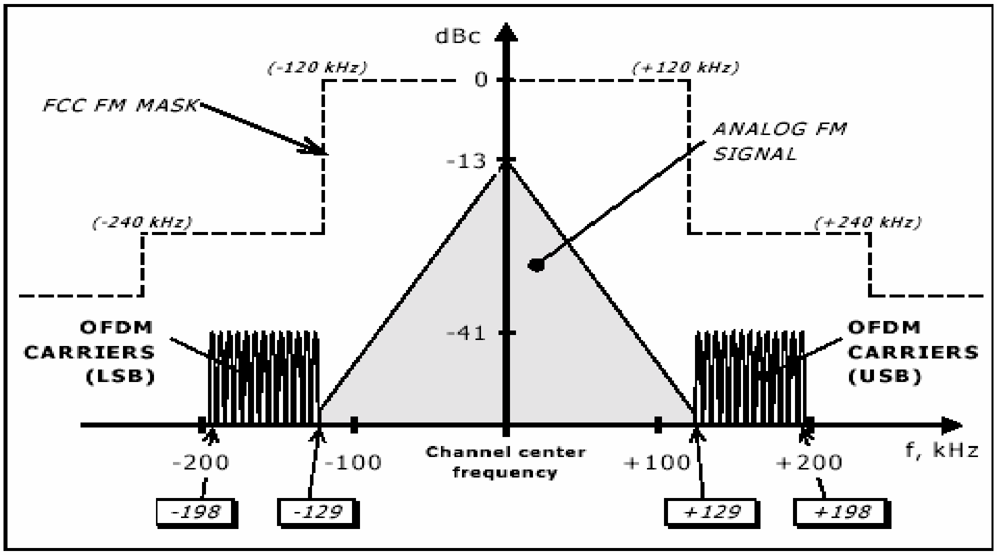


Figure 3-1. Illustration of FM IBOC Hybrid Mode Spectrum[3]

A brief summary of the features of the hybrid mode operation follows:

- IBOC enables simultaneous transmission of analog and digital audio signals in existing allocated FM channel.
- IBOC analog signals are the same as those in existing analog FM.
- IBOC digital audio signals are Quadrature Phase-Shift Keying (QPSK) modulated and transmitted on Orthogonal Frequency Division Multiplexing (OFDM) carriers.
  - OFDM is a scheme that enables many QPSK-modulated subcarriers to be frequency-division-multiplexed in an orthogonal fashion.
  - Instead of a single wideband carrier at a high signaling rate, OFDM employs a large number of narrowband subcarriers that are simultaneously transmitted at a much lower composite symbol rate. The long symbol times of OFDM provide robustness in the presence of multipath fading and interference.

3 *Evaluation of the iBiquity Digital Corporation IBOC System, Part 1 – FM IBOC*, November 29, 2001, National Radio Systems Committee, Washington, DC.

- Digital signals are perceptually audio coded allowing for high-quality digital audio using low bit rate (e.g., 96 kbps) transmission.
- Two groups of these digitally modulated carrier signals are placed as sidebands adjacent to the analog FM host signal.
- The IBOC system has a blend-to-analog feature that will revert to analog FM when received digital signal quality is impaired, and smoothly blend back to digital when the digital signal can be recovered again.

3.2 Equipment Description and Test Setup

The test data was collected through measurements conducted in the MITRE laboratory in Bedford, MA. Since the digital signals are perceptually coded, our effort focused on the subjective testing and analysis. The engineer who performed the laboratory tests received and passed a certified hearing examination. Some field tests should be conducted to verify the results obtained in the laboratory. However, this latter endeavor is beyond the scope of the present task.

3.2.1 Equipment

The equipment used in the tests is categorized below:

Exciters

- IBOC FM exciter manufactured by Harris Corporation
  - FM IBOC Exciter: DEXSTAR
  - FM Analog Exciter: DigiCD
  - FM Audio Processor: Orband OPTIMOD ORB8400
  - Audio Interface Unit: ePAL
  - Low Power Combiner: Mini Circuits 15442 ZFAC-2-2
- SCA exciter

Receivers

- For FM IBOC signal: iBiquity IBOC FM Development Receiver (Serial Number 48)
- For SCA signal: RSVI receiver provided by Minnesota State Services for the Blind. ComPol Brand, 67 kHz SCA.

Test Equipment

- HP8568B Spectrum Analyzer

- HP 8644A Synthesized Signal Generator
- HP 8622A Synthesized Signal Generator
- NC7106 Programmable Noise Generator
- HP438A Power Meter

Signal Attenuators

- (3) Kay Variable Attenuators
- (1) Texscan Variable Attenuator
- (1) Alan Industries Variable Attenuator

Combiners and Couplers

- (2) Mini Circuits 15542
- (1) Anzac THV-50
- (1) Mini Circuits ZF-DC-10-2

Other Equipment

- BE FS-30 FM Stereo Generator
- (2) Panasonic CD Players with Headphone Jack

3.2.2 Test Setup

The test setup consisted of the Harris IBOC Exciter, a link, and a test receiver.

The Harris Exciter performs several functions as shown in Figure 3-2. First, the incoming Audio Engineering Society (AES) digital format signal is received, duplicated and synchronized by the audio interface unit (ePAL). Next, the audio is run through a processor, called the Optimod, where the sound is given a distinct equalization. After this step, the processed audio is fed into the Dexstar IBOC exciter. The digital feed is modulated and broadcast; the analog feed is delayed and sent into the DigitCD FM exciter. The FM exciter also allows for a modulated SCA input. The FM and IBOC signals are combined and sent to the link. This is the Desired signal. There is also an option on the ePAL to bypass this delay.

The link provides attenuation to the Desired signal and then combines it with the Low Power FM interferer (the Undesired signal), and then with white noise as shown in Figure 3-3. The Undesired signal is output from a separate CD player, run through a Stereo Generator, and finally FM modulated using a synthesized signal generator.

The receiver is the final piece of the test setup. The Hybrid signal is received by the iBiquity test receiver which is set to automatically switch between digital and analog when the incoming signal is too low. The SCA signal is received using a mono SCA receiver.

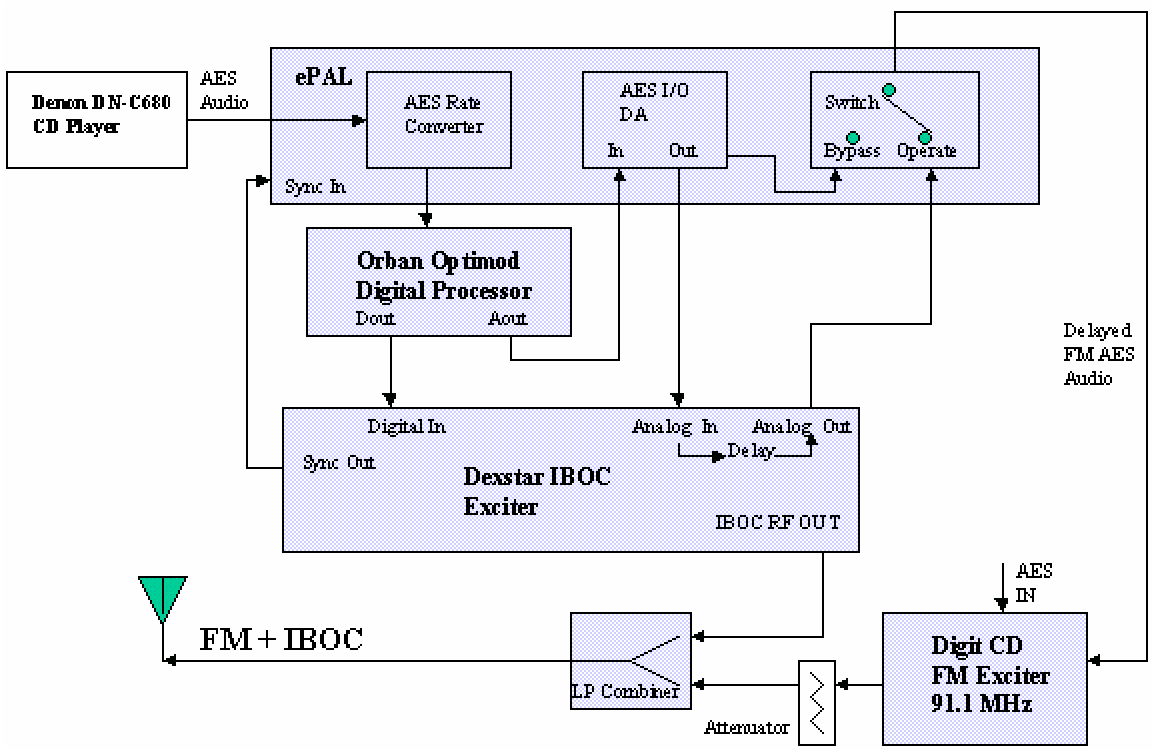


Figure 3-2. Circuit Setup of IBOC Exciter

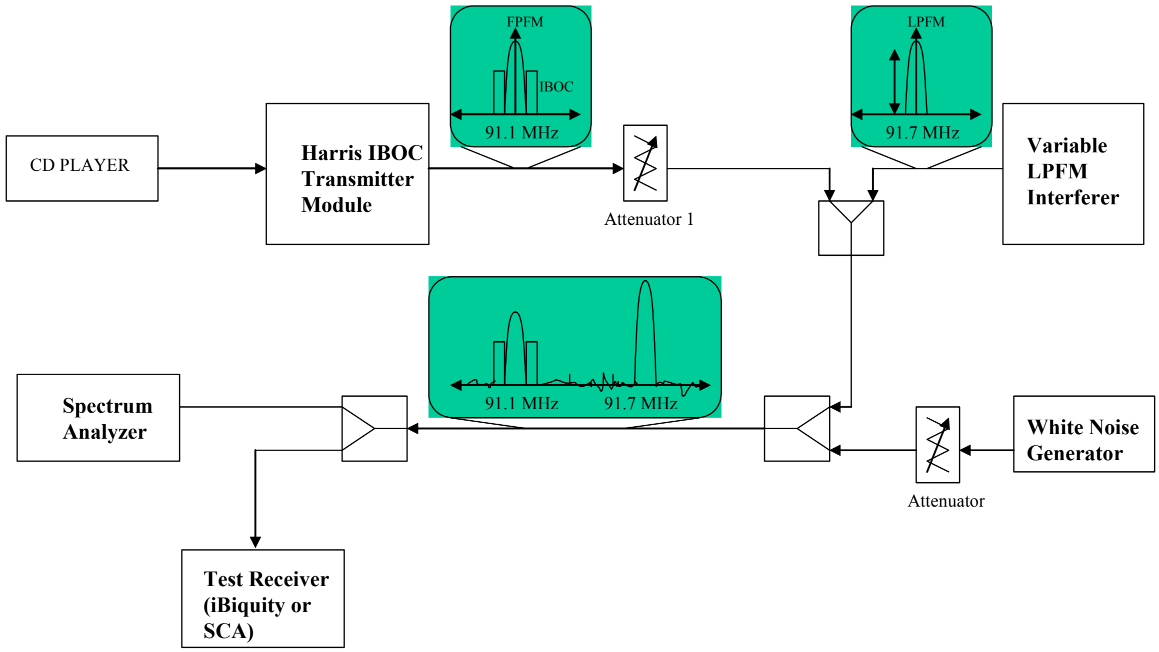


Figure 3-3. Link Setup

3.3 Simplifying Assumptions

As mentioned, the present digital test only considers the analog-to-hybrid interference case. The center frequency for the LPFM transmission is 91.7 MHz. The center frequency used for the FPFM IBOC hybrid mode transmission is 91.1 MHz. The RSVI program is carried by a 67 kHz SCA subcarrier with voice (News/Talk) as the program content. This choice is coincident with the operating frequency of the FPFM station KNOW used in the LPFM field tests in East Bethel, MN. This FPFM station also provides a 67 kHz RSVI service.

As a first approximation, impulse noise and multipath effects was ignored. However, additive white Gaussian noise (AWGN) of 30000 ºK was included. The number of interference sources was limited to one.

3.4 Outline of Test Procedure

A list of permutations in terms of the system test parameters that characterize the test scenarios is shown in the following table:

Table 3-1. Parameters of Test Scenario

Parameter	Values
Test receivers	IBOC FM receiver, SCA receiver
FPFM signal level	58.6 dBu, 52.6 dBu (slightly off from protected contours 60 dBu and 54 dBu, respectively, due to test equipment constraints)
FPFM program content	News/Talk, Unprocessed music, Processed music
LPFM program content	News/Talk, Unprocessed music
SCA program content	News/Talk
FPFM signal	IBOC hybrid, IBOC hybrid plus SCA

Each test is characterized by a set of parameters:

- D – the Desired signal referring to the FPFM hybrid signal or the SCA signal, depending on the signal of interest in a given test scenario
- U – the Undesired signal referring to the LPFM signal
- MOS – Mean Opinion Score

In subjective tests, the end results are presented in terms of the five-level Mean Opinion Score:

- 5(Excellent – interference imperceptible)
- 4(Good – interference perceptible but not annoying)
- 3(Fair – interference slightly annoying)
- 2(Poor – interference annoying)
- 1(Bad – interference very annoying)

The values of D/U, in units of dB, used in the test should cover the range that will span MOS from 1 to 5 for third adjacent channel interference measurements. For convenience of presentation, the D/U value associated with an MOS of n will be denoted as $(D/U)_n$.

The measurement process was carried out in accordance with the following guidelines:

Case when FPFM signal is the victim

1. First, the test engineer estimated the minimum value of $(D/U)_5$ and the maximum value of $(D/U)_1$
2. Then, the test engineer determined the values of $(D/U)_2$ and $(D/U)_4$

3. The test engineer subsequently proceeded to perform three more measurements with D/U values uniformly spaced between these two limits plus one more measurement with the same step size in D/U outside each limit
4. To examine the IBOC system's blend-to-analog feature, the test engineer measured the D/U value, denoted as $(D/U)_b$, and estimated the MOS value when the blend-to-analog starts

This measuring procedure consisted of sets of ten measurements for each test scenario. The following table illustrates the concept of the measurement procedure.

Table 3-2. Illustration of Concept of Measurement Procedure

MOS	5	1	2	4	Three measurements associated with instances of MOS between 2 and 4			Measurement with the MOS < 2	Measurement associated with the MOS > 4	MOS at IBOC blend-to-analog instance
D (dBu)										
U (dBu)										
D/U (dB)										

Case when SCA signal is the victim

1. First, the test engineer determined the maximum value of MOS that could be achieved and the corresponding minimum value of D/U [denoted as $(D/U)_M$].
2. Then the test engineer determined the maximum value of D/U associated with MOS 1 [denoted as $(D/U)_1$].
3. The test engineer subsequently proceeded to perform five more measurements with D/U values uniformly spaced between $(D/U)_M$ and $(D/U)_1$.

3.5 Measured Data and Comments

Since the synthesized signal generator could only provide +8.5 dBm of Undesired signal into the receiver, the Desired signal levels were chosen to ensure that blend to analog would occur for all test cases. In the cases where 8.5 dBm was not enough to achieve an MOS value of 1, the Desired signal was attenuated with the Undesired signal set at its maximum level to decrease the D/U levels until MOS 1 was observed. The Desired signal levels were set using an adjustable attenuator and a spectrum analyzer and were measured with the music turned off so that only the carrier was present. This represents the total spectral power of the FM voice or music signal. The Undesired signal was adjusted directly on the signal generator and was also measured using a spectrum analyzer with the music off.

In the testing, the FM+IBOC attenuator was set to provide the Desired signal levels. The Undesired signal was then increased until sound degradation was observed.

Levels into Receiver

FM Carrier: -32.4 dBm w/Attenuator 1 = 0

- IBOC Sidebands: -73.2 dBm w/Attenuator 1 = 0
- Total IBOC Power : -21 dB from total FM Power
- LPFM Interferer Max into Rx = 8.4 dBm
- SCA: -24.5 dBc, 9% Injection
- Test Points*: Attenuator 1 = 25 dB (FM = -57.4 dBm, that is 58.6 dBu)
  Attenuator 1 = 31 dB (FM = -63.4 dBm, that is 52.6 dBu)
  *These test points were carefully selected to maximize the potential MOS scale readings. The conversion from dBm to dBu is based upon a postulated receiving-antenna gain of 1.7 dBd (3.8 dBi).
- iBiquity IBOC Receiver Switch Point without interferer (Digital to Analog): Attenuator 1 = 35 dB, FM = -67.4 dBm

MOS Comments

The following MOS accounts were based on the tester's perception experience in reference to the test results presented in this subsection.

- MOS 5-The voice/music was of CD quality. The tester was unable to hear any crackles, pops or volume changes in the music or voice. There was minimal high-pitched hissing background noise present in the signal.
- MOS 4-There were slight crackles and pops observed in what would be an otherwise flawless signal. Minimal background noise.
- MOS 3-This was characterized by the onset of hissing background noise. The crackles and pops were slightly more prominent and frequent than MOS 4. Volume changes were encountered occasionally.
- MOS 2-At this level, the interference was not only noticeable but annoying as well. In these tests, the tester noticed that the hissing noise became almost as loud as the voice/music. Pops and crackles in the sound were very prominent and frequent.
- MOS 1-The hissing noise was as loud as, or louder than, the music or voice signal. Crackles and pops practically drown out the already diminished audibility of the signal. Very annoying to listen to.

The set of detailed measured data as recorded by the test engineer during the lab tests can be found in Appendix F. The following figures and tables elaborate the essence of the measured data.

(1) FPFM signal being the victim with SCA off

The MOS-D/U measured data for the case when the FPFM signal is the victim are shown in Appendix F, Tables F-1 through F-12. To facilitate presentation and analysis, these measurements are illustrated, respectively, in Figures 3-4 through 3-15. The legend for A→B refers to the case that the interfering LPFM signal uses program content A while the victim FPFM signal uses program content B.

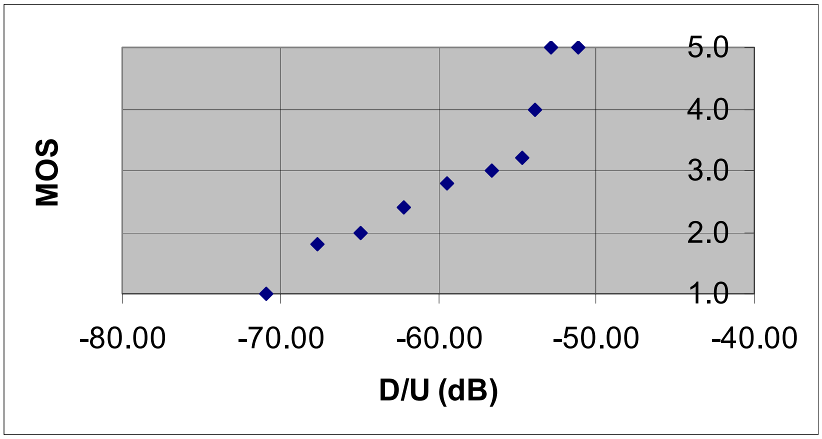


Figure 3-4. MOS-D/U Measurement for U□P at 58.6 dBu FPFM (FPFM is Victim)

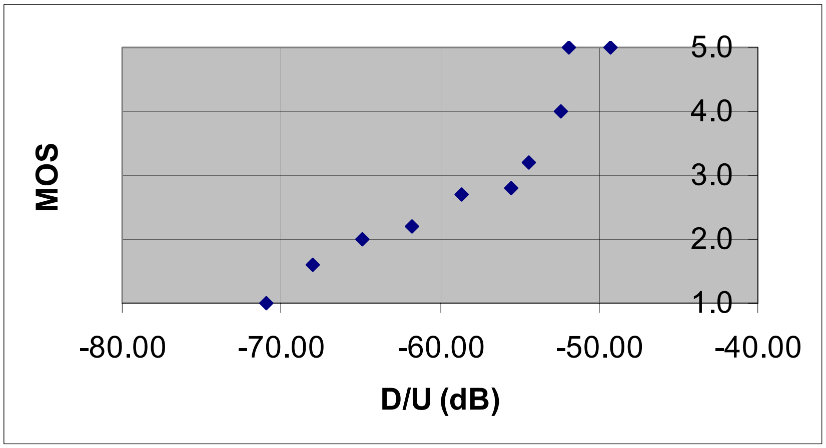


Figure 3-5. MOS-D/U Measurement for U□P at 52.6 dBu FPFM (FPFM is Victim)

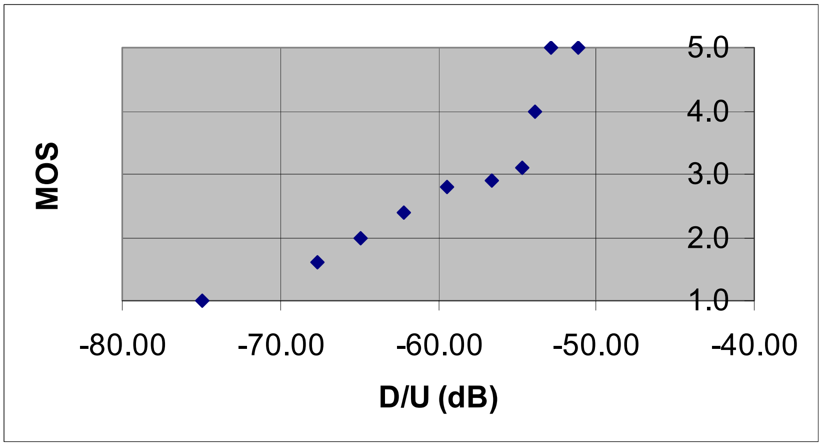


Figure 3-6. MOS-D/U Measurement for U□U at 58.6 dBu FPFM (FPFM is Victim)

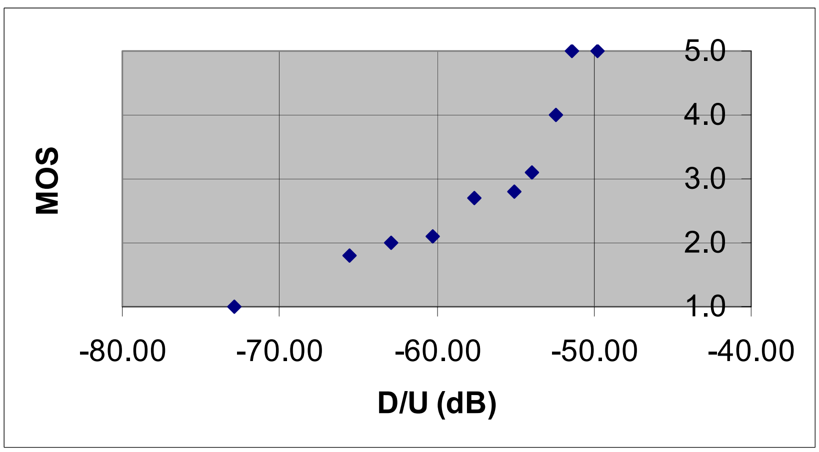


Figure 3-7. MOS-D/U Measurement for U□U at 52.6 dBu FPFM (FPFM is Victim)

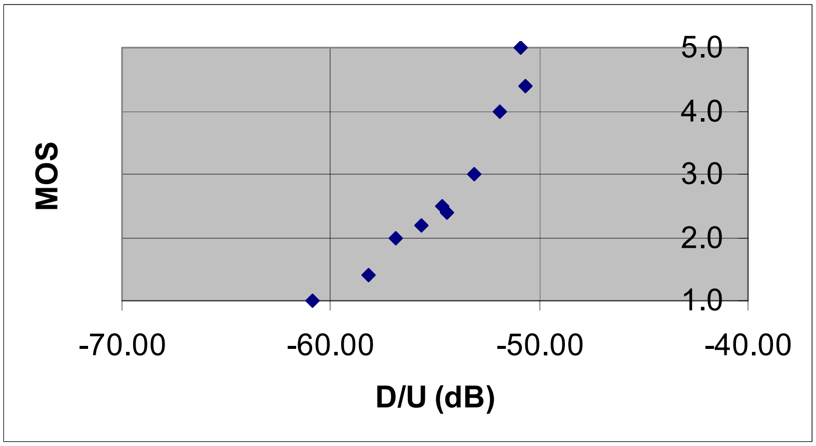


Figure 3-8. MOS-D/U Measurement for U/T at 58.6 dBu FPFM (FPFM is Victim)

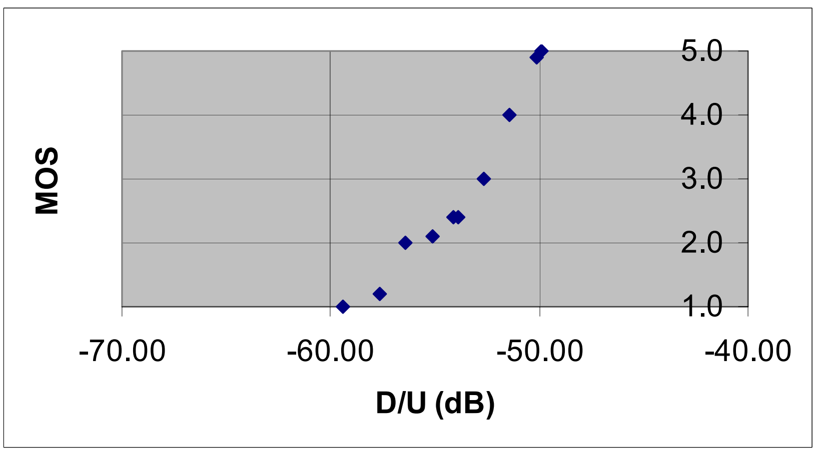


Figure 3-9. MOS-D/U Measurement for U/T at 52.6 dBu FPFM (FPFM is Victim)

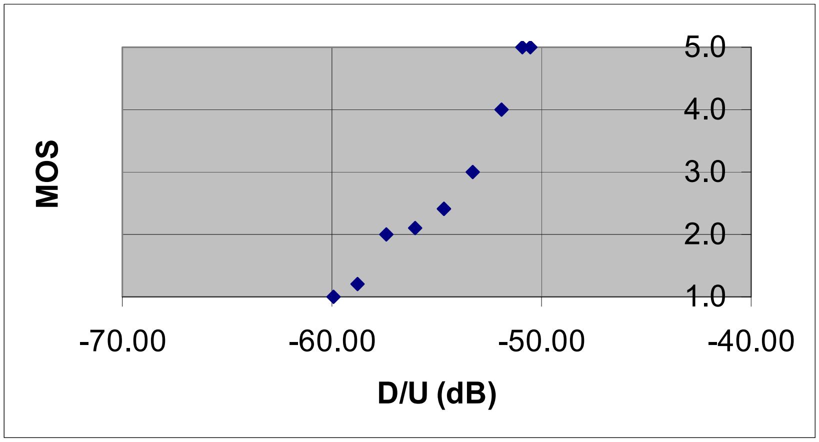


Figure 3-10. MOS-D/U Measurement for T□T at 58.6 dBu FPFM (FPFM is Victim)

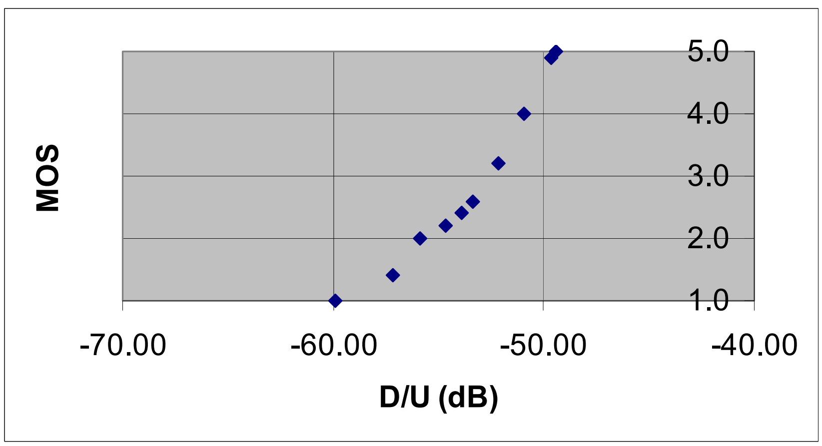


Figure 3-11. MOS-D/U Measurement for T□T at 52.6 dBu FPFM (FPFM is Victim)

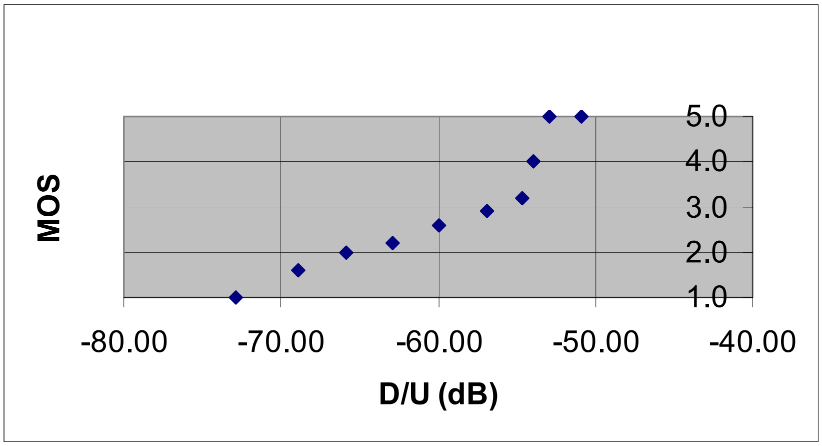


Figure 3-12. MOS-D/U Measurement for T□U at 58.6 dBu FPFM (FPFM is Victim)

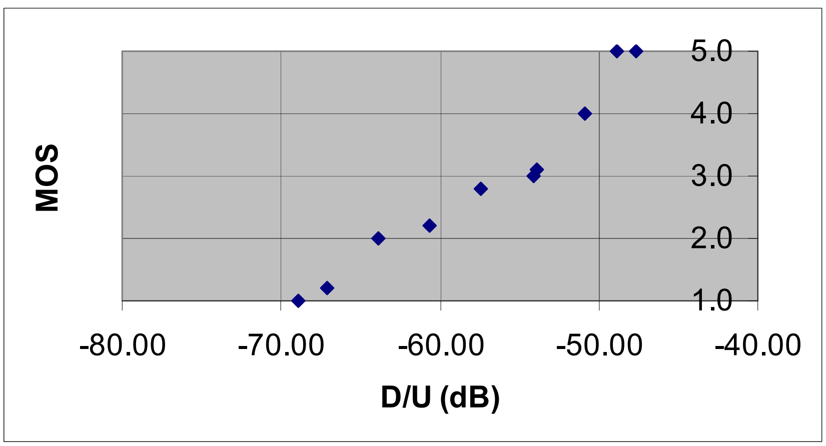


Figure 3-13. MOS-D/U Measurement for T□U at 52.6 dBu FPFM (FPFM is Victim)

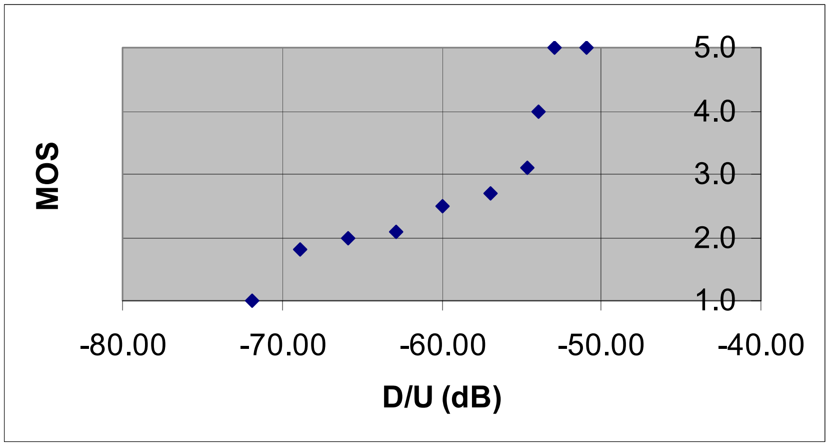


Figure 3-14. MOS-D/U Measurement for T□P at 58.6 dBu FPFM (FPFM is Victim)

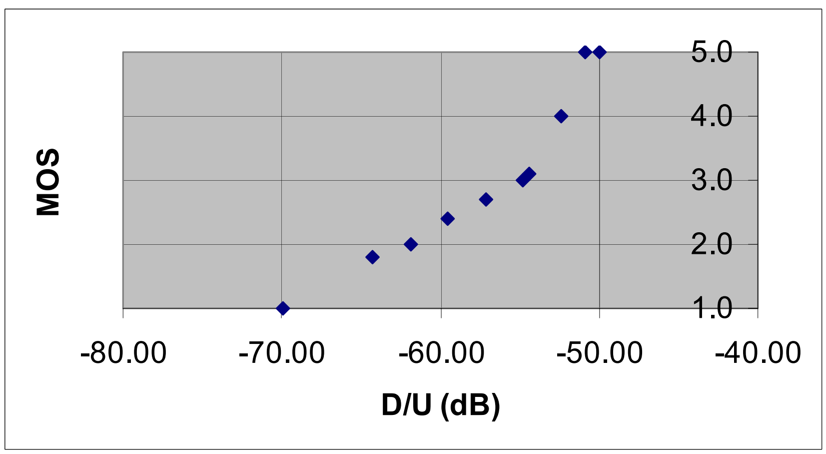


Figure 3-15. MOS-D/U Measurement for T□P at 52.6 dBu FPFM (FPFM is Victim)

The blend-to-analog operating points of the IBOC receiver measured with various LPFM/FPFM program content combinations are shown in Table 3-3.

Table 3-3. IBOC Receiver Blend-to-Analog Operating Point

LPFM/FPFM Program Content Combination	FPFM Signal Level (dBu)	IBOC Blend-Point	
		D/U (dB)	Estimated MOS
U→P	58.6	-54.7	3.2
	52.6	-54.4	3.2
U→U	58.6	-54.7	3.1
	52.6	-53.9	3.1
U→T	58.6	-54.7	2.5
	52.6	-54.2	2.4
T→T	58.6	-54.7	2.4
	52.6	-53.9	2.4
T→U	58.6	-54.7	3.2
	52.6	-53.9	3.1
T→P	58.6	-54.7	3.1
	52.6	-54.4	3.1

(2) SCA signal being the victim with IBOC on (i.e., digital portion of FPFM signal turned on)

The MOS-D/U measured data for the case when the SCA signal is the victim signal are shown in Appendix F, Tables F-13 through F-24. To facilitate presentation and analysis, these measurements are illustrated, respectively, in Figures 3-16 through 3-27. The legend for A→B refers to the case where the interfering LPFM signal uses program content A while the victim SCA signal uses program content B.

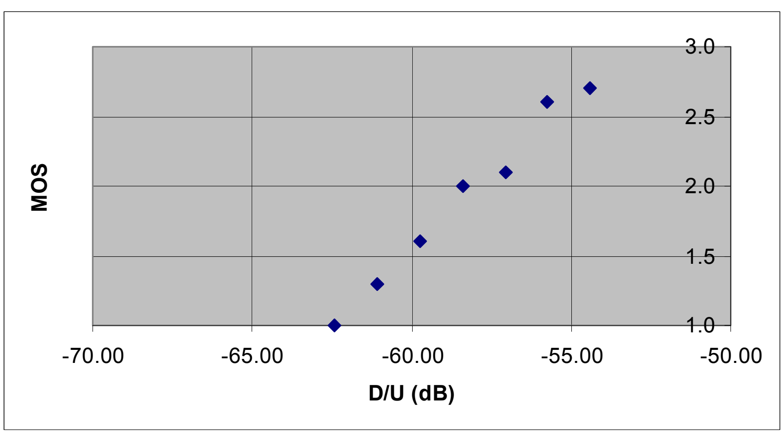


Figure 3-16. MOS-D/U Measurement for U□T at 58.6 dBu FPFM (FPFM in P, Digital On, SCA is Victim)

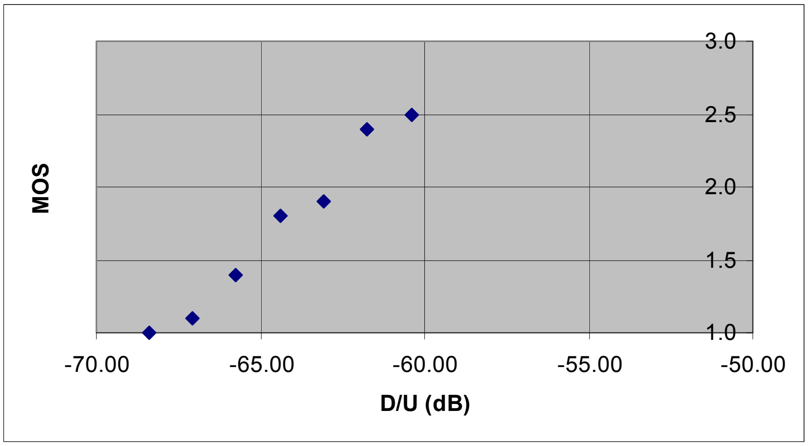


Figure 3-17. MOS-D/U Measurement for U□T at 52.6 dBu FPFM (FPFM in P, Digital On, SCA is Victim)

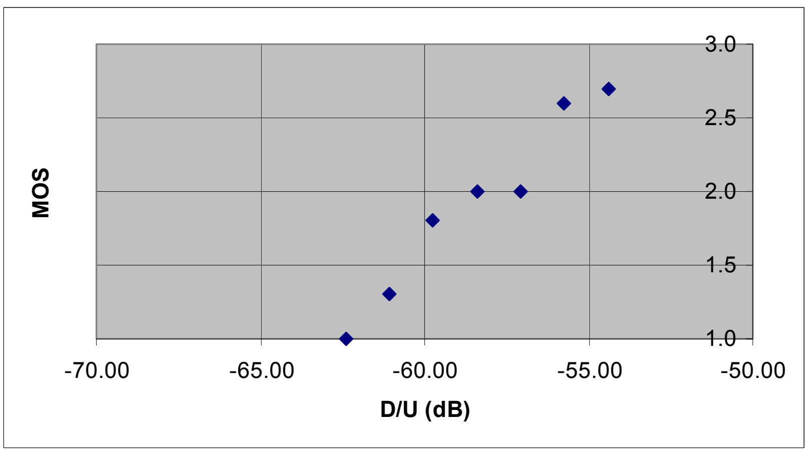


Figure 3-18. MOS-D/U Measurement for U□T at 58.6 dBu FPFM (FPFM in U, Digital On, SCA is Victim)

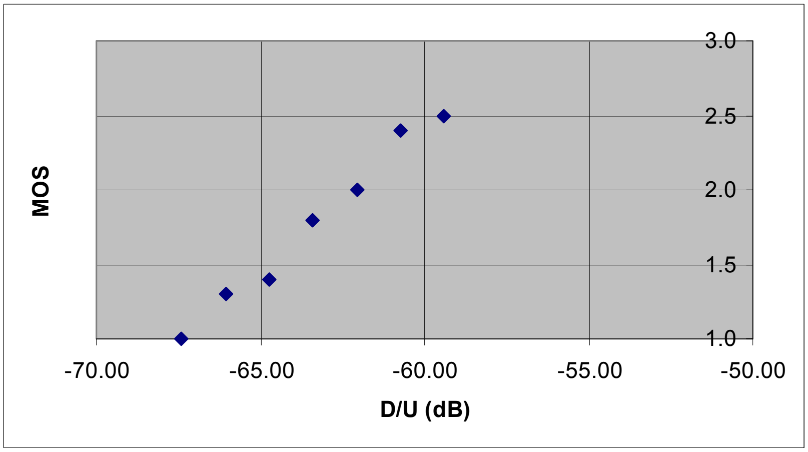


Figure 3-19. MOS-D/U Measurement for U□T at 52.6 dBu FPFM (FPFM in U, Digital On, SCA is Victim)

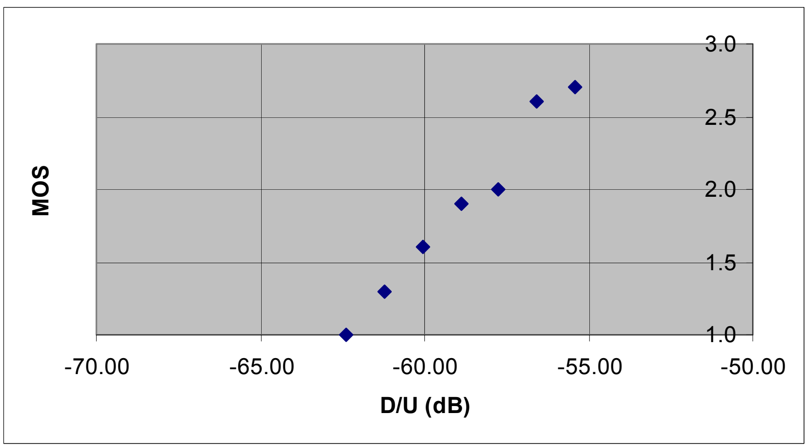


Figure 3-20. MOS-D/U Measurement for T□T at 58.6 dBu FPFM (FPFM in U, Digital On, SCA is Victim)

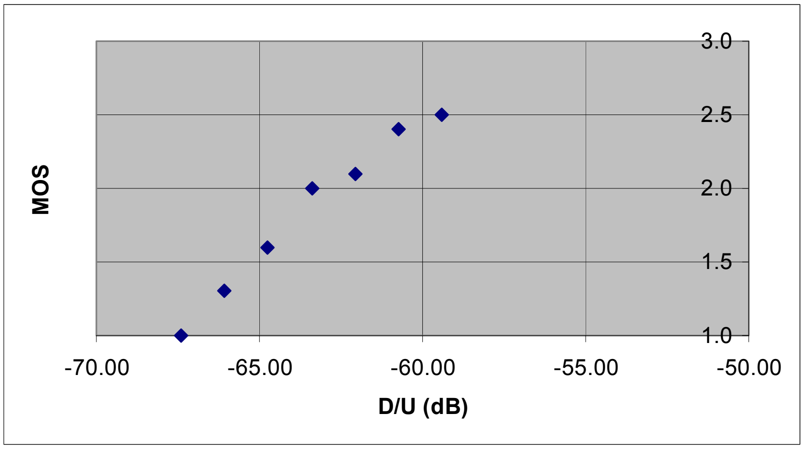


Figure 3-21. MOS-D/U Measurement for T□T at 52.6 dBu FPFM (FPFM in U, Digital On, SCA is Victim)

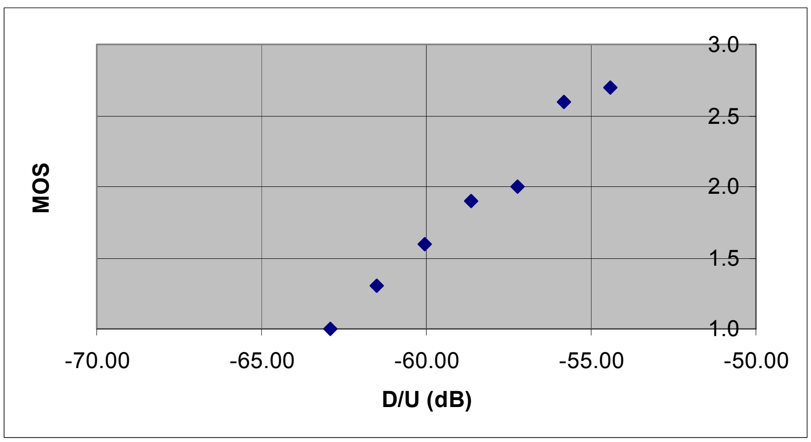


Figure 3-22. MOS-D/U Measurement for T□T at 58.6 dBu FPFM (FPFM in T, Digital On, SCA is Victim)

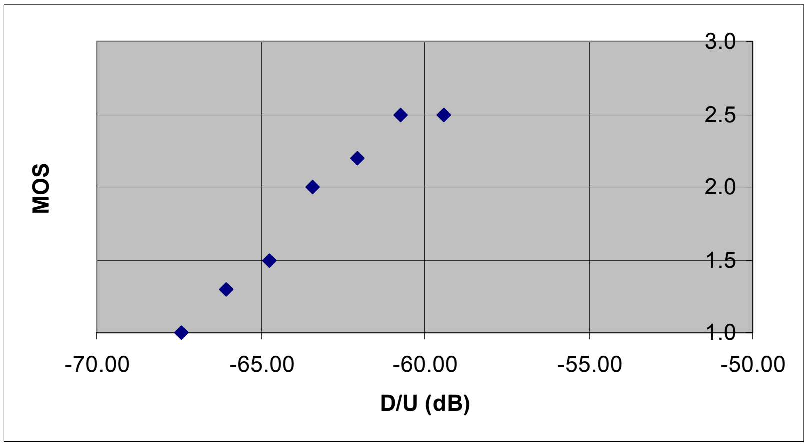


Figure 3-23. MOS-D/U Measurement for T□T at 52.6 dBu FPFM (FPFM in T, Digital On, SCA is Victim)

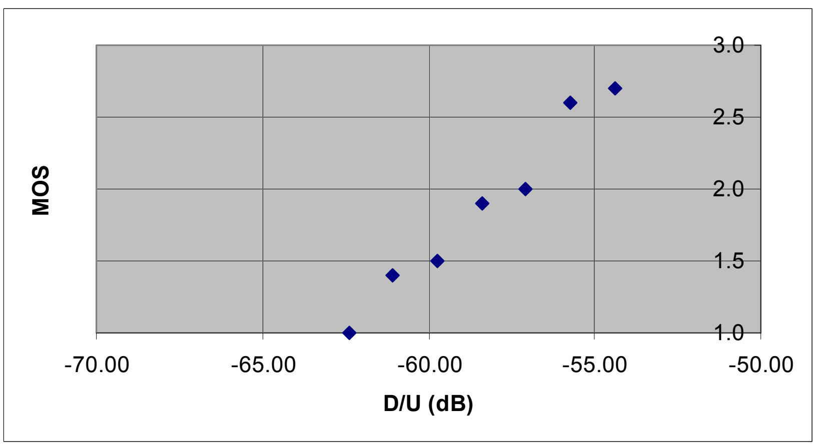


Figure 3-24. MOS-D/U Measurement for U□T at 58.6 dBu FPFM (FPFM in T, Digital On, SCA is Victim)

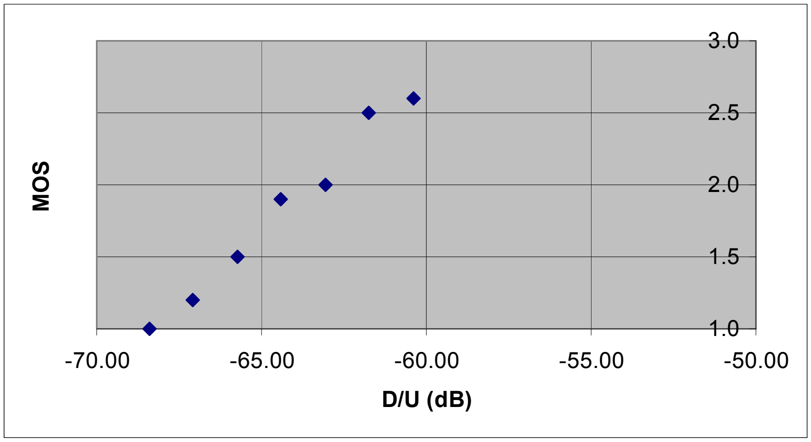


Figure 3-25. MOS-D/U Measurement for U□T at 52.6 dBu FPFM (FPFM in T, Digital On, SCA is Victim)

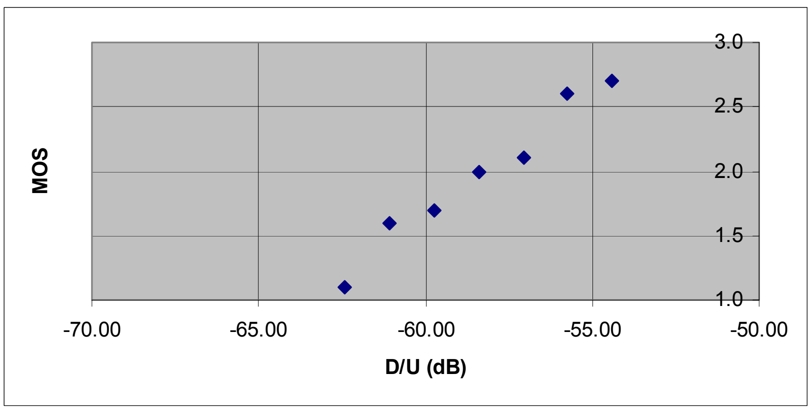


Figure 3-26. MOS-D/U Measurement for T□T at 58.6 dBu FPFM (FPFM in P, Digital On, SCA is Victim)

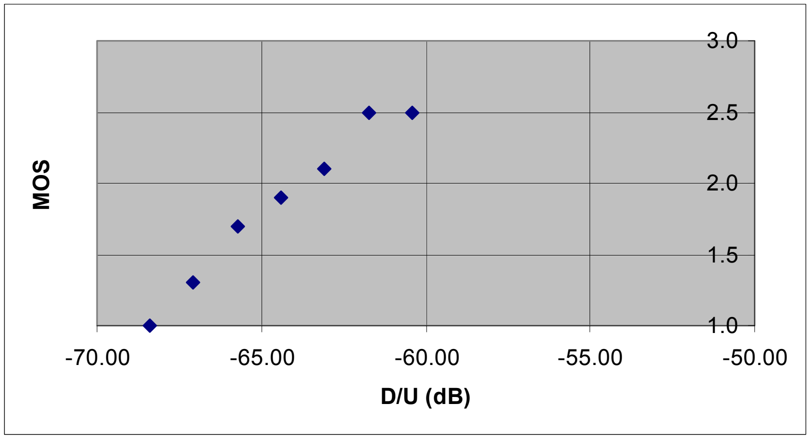


Figure 3-27. MOS-D/U Measurement for T□T at 52.6 dBu FPFM (FPFM in P, Digital On, SCA is Victim)

(3) SCA signal being the victim with IBOC off (i.e., digital portion of FPFM signal turned off)

Since the quality of the SCA signal reception scored low, additional SCA test data were collected with the digital portion of the hybrid signal turned off. In other words, the FPFM in this case would transmit in its conventional analog mode. The purpose of this additional test was to examine whether the third adjacent channel interference from LPFM on SCA would change due to the presence of IBOC signals. The measured data in Appendix F showed no noticeable difference between the cases with (Tables F-13 to F-24) and without (Tables F-25 to F-36) the IBOC signal. Thus, no graphs are needed to elaborate these latter measurements. Interested readers are referred to the tables in Appendix F for detail.

3.6 Analysis and Results

This subsection presents the threshold estimation for the IBOC receiver with reference to the MOS value 3. With reception quality having an MOS of 3, interference is perceptible but not annoying. However, one should not attempt to make direct detailed comparisons between the receiver thresholds referencing to MOS 3 and those with reference to the relative degradation index 0.3 (as presented in Section 2.10.5) because the relationship between these two scales has not been quantified.

Based on Figures 3-4 to 3-15, the receiver thresholds with respect to MOS 3 were examined. The estimated values are shown in Table 3-4. Also included in the table are the receiver blend-to-analog operating points in the presence of IBOC hybrid mode signals and the associated MOS values. Due to test equipment constraints, the two FPFM signal strength levels used in the test, 52.6 dBu and 58.6 dBu, are slightly different from those for the F(50,50) protected contours of the FM broadcast stations, 54 dBu for Class B stations, 57 dBu for Class B1 stations, and 60 dBu for the rest. The impact of program content on the threshold was investigated by grouping the estimated thresholds at these two test levels according to their respective LPFM/FPFM program content combinations.

Table 3-4. IBOC Program-Content Specific Threshold

LPFM/FPFM Program Content Combination	FPFM Signal Level (dBu)	Threshold D/U (dB)	IBOC Blend-Point	
			D/U (dB)	MOS
U→P	58.6	-56.7	-54.7	3.2
	52.6	-55.0	-54.4	3.2
U→U	58.6	-55.7	-54.7	3.1
	52.6	-54.3	-53.9	3.1
U→T	58.6	-53.2	-54.7	2.5
	52.6	-52.7	-54.2	2.4
T→T	58.6	-53.3	-54.7	2.4
	52.6	-52.6	-53.9	2.4
T→U	58.6	-56.2	-54.7	3.2
	52.6	-54.2	-53.9	3.1
T→P	58.6	-55.2	-54.7	3.1
	52.6	-54.8	-54.4	3.1

From Table 3-4, the following results can be drawn:

1. The average threshold of the IBOC receiver over all possible program content combinations is seen to be -54.5 dB.
2. The receiver susceptibility seems to vary slightly (within 2 dB for threshold) with the strength of the FPFM IBOC signal over the range of tested levels.
3. The maximum difference among the threshold values of various program combinations is about four dB. The susceptibility difference is seen in that the group consisting of (U→T) and (T→T) seems to be less robust than the group consisting of the other program combinations. However, the average threshold difference between these two groups is seen to be only 2.2 dB. Therefore, the dependence of susceptibility on program content combination is regarded as minor.
4. The IBOC receiver blend-point D/U value seems to be independent of the LPFM/FPFM program content combination. The MOS level at switching is basically independent of the strength of the FPFM IBOC signal. However, the MOS level at blending varies noticeably, ranging from 2.4 to 3.2, among different program content

combinations. The estimated MOS at blending is about 2.4 for (U→T) and (T→T), and about 3.2 for the other program content combinations.

5. Therefore, the performance of the IBOC receiver in the presence of third-adjacent-channel LPFM signals was comparable to that of the analog home and auto receivers, reaching the MOS value of 3 when D/U was approximately -55 dB.

3.6.1 Analysis of SCA Test Results

Since subcarrier signals are inherently lower in quality than the main channel signals, the MOS scores in the SCA tests are expected to not score high when the same anchor point of reference for quality is used as in the FPFM main channel IBOC tests. The data for SCA tests, as seen in Figures 3-16 through 3-27, show that the 67 kHz SCA signal quality is consistently no better than MOS 2.7.

As the measured data show, the reception of the RSVI receiver degrades in a similar fashion in both the high (with FPFM at 58.6 dBu) and low (with FPFM at 52.6 dBu) desired signal levels. It is further noticed that, at the same MOS value, the D/U value seems to decrease (i.e., attains better performance) for smaller desired signal inputs. The most likely explanation for this observation is that, at such low input signal levels, the receiver employs an Automatic Gain Control (AGC) function at its input to boost the desired signal: a six dB drop in the desired input signal would result in an increase of about six dB in the receiver gain. Although a six dB decrease in the desired signal level would cause the D/U measurement to be lowered by six dB, the effective D/U value at the receiver should remain the same. The noise level would increase as a consequence of higher AGC so there would be some input signal-to-noise degradation which is readily illustrated by the initial MOS reading being lower for the lower (52.6 dBu) input case when compared to the 58.6 dBu case in the measurements.

The listener "keep-on/turn-off" threshold had been estimated to be 2.3 for voice.[4] This threshold refers to the operating point associated with a reception quality below which more than 50% of the listeners would turn off the radio. The "keep-on/turn-off" thresholds of D/U for the RSVI receiver based on the reference value of MOS 2.3 were estimated from the test data. The results are presented in Table 3-5.

From Table 3-5, the following results are drawn:

1. The 67 kHz RSVI receiver susceptibility is independent of the program content combination.

---

4 *FM IBOC DAB Laboratory and Field Testing Report- Appendix J*, August 7, 2001, iBiquity Digital Corporation, Columbia, Maryland.

2. In the presence of LPFM third ACI, the average “keep-on/turn-off” threshold of the receiver over the two tested FPFM signal levels is -59 dB.
3. The impact of LPFM third ACI on the 67 kHz SCA reception is not affected by the presence of the IBOC signal.

Table 3-5. RSVI Receiver “Keep-on/Turn-off” Threshold D/U

LPFM/SCA Program Content Combination	FPFM		Threshold (dB)	
	Program Content	Signal Level (dBu)	IBOC On	IBOC Off
U→T	P	58.6	-56.5	-56.1
		52.6	-62.0	-62.1
	U	58.6	-56.4	-56.3
		52.6	-61.1	-61.1
	T	58.6	-56.4	-56.5
		52.6	-62.3	-62.4
T→T	P	58.6	-56.5	-56.4
		52.6	-62.4	-62.1
	U	58.6	-57.2	-57.2
		52.6	-61.2	-61.2
	T	58.6	-56.5	-56.7
		52.6	-61.6	-61.4

Section 4

Approximate Theoretical Analysis

4.1 Introduction

In the assessment of any potential interference problems, it is often advantageous to evaluate the impact of new signals using both field tests and mathematical analyses. Field tests are essential to provide actual performance data in realistic environments, however, testing every possible scenario is prohibitively expensive. Conversely, analyses can cover a broader range of cases, but must be validated by test data to ensure accuracy. Mathematical analyses also provide a sanity check for field test results and can provide valuable insight into the reasons for observed test results. Hence, these two approaches are synergistic.

In the current assessment of potential third-adjacent interference caused by LPFM transmissions, we desire an ability to quantitatively predict and understand the field test results. This was the motivation for developing an approximate mathematical analysis for the effects of LPFM transmissions. This analysis is the topic of this section.

Section 4.2 discusses the path loss model used in the analysis. In Section 4.3 the interference model is discussed. In that section, we attempt to find the minimum separation distance between a LPFM transmitter and a victim receiver that has the FPFM station as its desired signal. This is done as a function of the distance between the LPFM and FPFM stations. Other metrics are also computed. Section 4.4 shows computed results for the scenarios used in the field tests. Section 4.5 considers how performance would have changed, had the field tests been done at the F(50,50) contour for each of the stations.

4.2 Path Loss Models

The model for path attenuation in free space is well known. Free space loss is proportional to the square of the distance. Expressed as a path gain, the expression for this type of loss is:

$$\frac{1}{a_2} = \left(\frac{\lambda}{4\pi r}\right)^2 \tag{6}$$

Where:

a_2 = the free-space attenuation that is proportional to the 2nd power of the distance
This is a power ratio (*i.e.*, not in decibels)
λ = the wavelength of the signal (meters)
r = the distance between the transmitter and the receiver (meters)

We compare the results of equation (6) to the curves in CFR 47, part 73, paragraph 73.699, Figure 9. In that figure, the upper right parts of the curves are well approximated by free space loss. To improve the match with the part 73 curves, we introduce a correction factor as follows:

$$\frac{1}{a_2} = m_2 \left(\frac{\lambda}{4\pi r} \right)^2 \tag{7}$$

Where:

m_2 = correction factor to improve the match to the curves in Part 73.

It is well known that a free space path loss model is not accurate in terrestrial communications for large distances between transmitter and receiver. Often, a model is used that has attenuation proportional to the fourth power of the distance. A well-known model is shown here:[5]

$$\frac{1}{a_4} = m_4 \left(\frac{h_T h_R}{r^2} \right)^2 \tag{8}$$

Where:

a_4 = the path attenuation that is proportional to the fourth power of the distance
This is a power ratio (*i.e.*, not in decibels)
h_T = the height of the transmitting antenna
h_R = the height of the receiving antenna
m_4 = correction factor to improve the match to the curves in Part 73

This fourth-law expression can also be compared to the curves in Part 73. The upper left parts of the curves correspond to fourth-law path loss. Again, we use a correction factor to improve the match between the model and the curves. Expressed in decibels, we use a matching factor of +1.8 dB for the free space path loss and –0.7 dB for the fourth law path loss.

We expect the free space loss to be a good model for short distances, and the fourth law model to be accurate for greater distances. However, we desire a smooth transition between the two regions. We model the path loss for all distances of interest as follows:

$$a_c = \left(a_2^n + a_4^n \right)^{1/n} \tag{9}$$

---

5 *Mobile Comminications Design Fundamentals: Second Edition*, by William C. Lee, published by John Wiley & Sons, 1993, p. 60.

Where:

a_c = the combined path attenuation (not in decibels)
n = an exponent that controls the sharpness of the transition

Combining equations (7) through (9), we get:

$$a_c = \left(\left[\left(\frac{4\pi}{\lambda} \right)^2 \frac{r^2}{m_2} \right]^n + \left[\frac{r^4}{m_4 h_T^2 h_R^2} \right]^n \right)^{1/n} \qquad (10)$$

The results of this path loss model are shown in Figure 4-1 for a case that closely matches the curves in Part 73. In this model we use $n = 2$ in equation (10). Results appear to be within a few dB of the Part 73 curves for all scenarios of interest. Cases of interest are at distances shorter than the radio line of sight (RLOS).

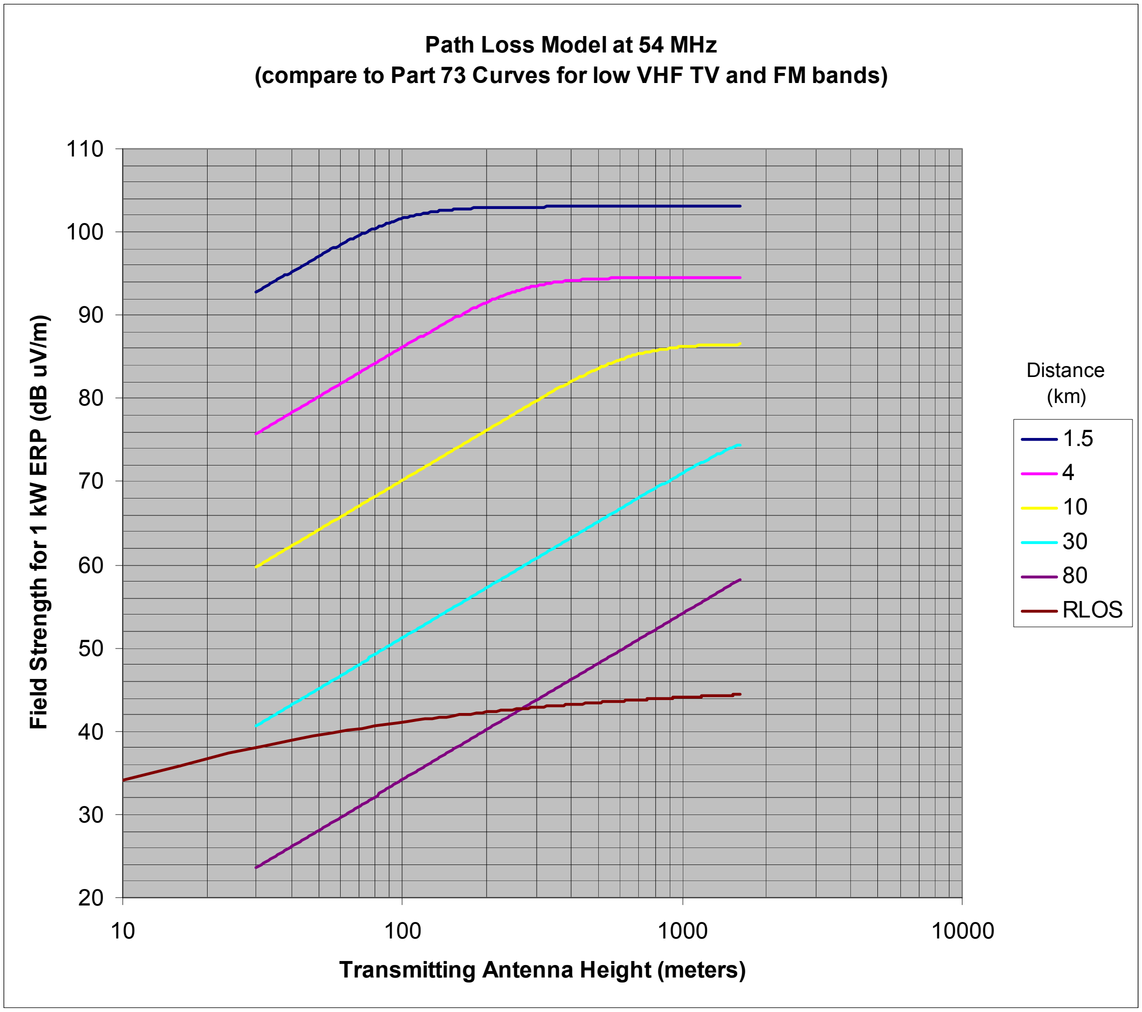


Figure 4-1. Path Loss Model at 54 MHz (for Comparison to Part 73 Curves)

The curves in Figure 4-1 are intended for comparison to the curves in Part 73 that show loss for the low VHF TV and FM bands. Hence for comparison purposes, the curves in Figure 4-1 are shown for a frequency of 54 MHz. Actual calculations for the models described below were done at the average of the LPFM and FPFM frequencies. See Figure 4-2 for example results at 98 MHz using the same model.

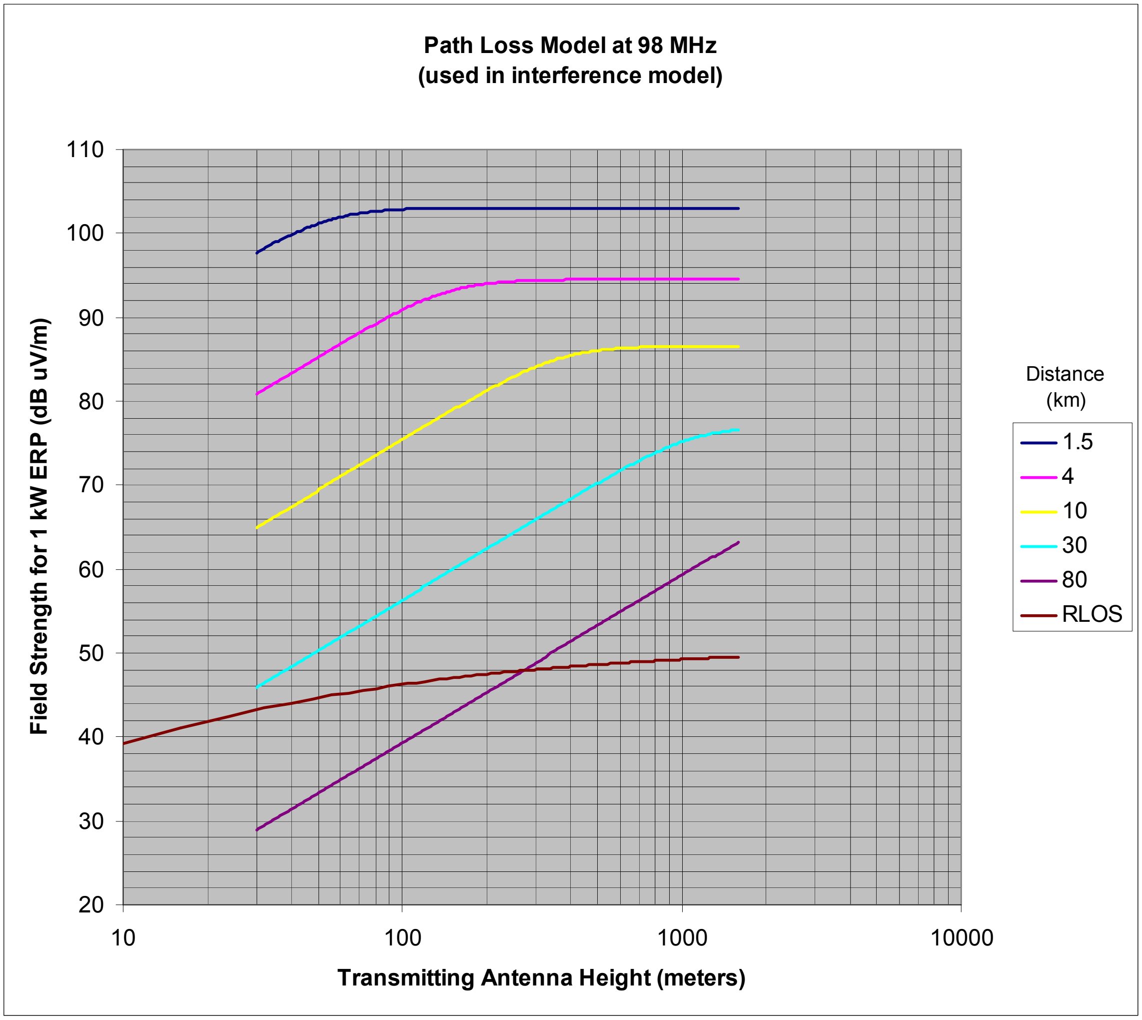


Figure 4-2. Path Loss Model at 98 MHz

In summary, we have developed a path loss model to use in the subsequent interference analysis. The model we will use has both square-law and fourth law attenuation characteristics, with a smooth transition between the two. This model matches well with Part 73 curves often used to predict path attenuation and signal levels in the FM band.

4.3 Interference Model

We desire a model that predicts the circumstances when significant third adjacent interference will, and will not, occur. We assume that audio performance will be acceptable when the actual ratio of IF signal to noise and interference in a receiver is greater than a given value. We write this as:

$$\rho \le \frac{S}{N+I} \tag{11}$$

Where:

ρ = the desired IF ratio of signal to noise and interference (not in decibels)
S = the IF signal level
N = the IF noise level in the receiver
I = the interference level measured in the IF, prior to detection

Ignoring gain in the receiver, we can compute the above values as follows:

$$S = \frac{E_F G_R}{a_F} \tag{12}$$

Where:

E_F = The effective radiated power of the FPFM station in the direction of the receiver
G_R = The antenna gain of the receiver in the direction of the FPFM station
a_F = The path attenuation between the FPFM station and the receiver

In a similar way, the interference is computed as follows:

$$I = \frac{E_L G_R}{a_L s} \tag{13}$$

Where:

E_L = The effective radiated power of the LPFM station in the direction of the receiver
G_R = The antenna gain of the receiver in the direction of the LPFM station
a_L = The path attenuation between the LPFM station and the receiver
s = the third adjacent channel selectivity (rejection ratio) of the receiver

Combining equations (11) through (13) we get:

$$\rho \le \frac{\left(E_F G_R / a_F \right)}{N + \left(E_L G_R / a_L s \right)} \tag{14}$$

Now, we want to use equation (14) to determine, approximately, the locations where receivers attempting to monitor a signal from the FPFM station will suffer significant interference from the LPFM transmission. We want to know the size of this region and how the interference region compares to the overall coverage area of the FPFM station. We expect the interference region to be nearly circular, and we want to know the radius and area of this circle. These concepts are illustrated in Figure 4-3.

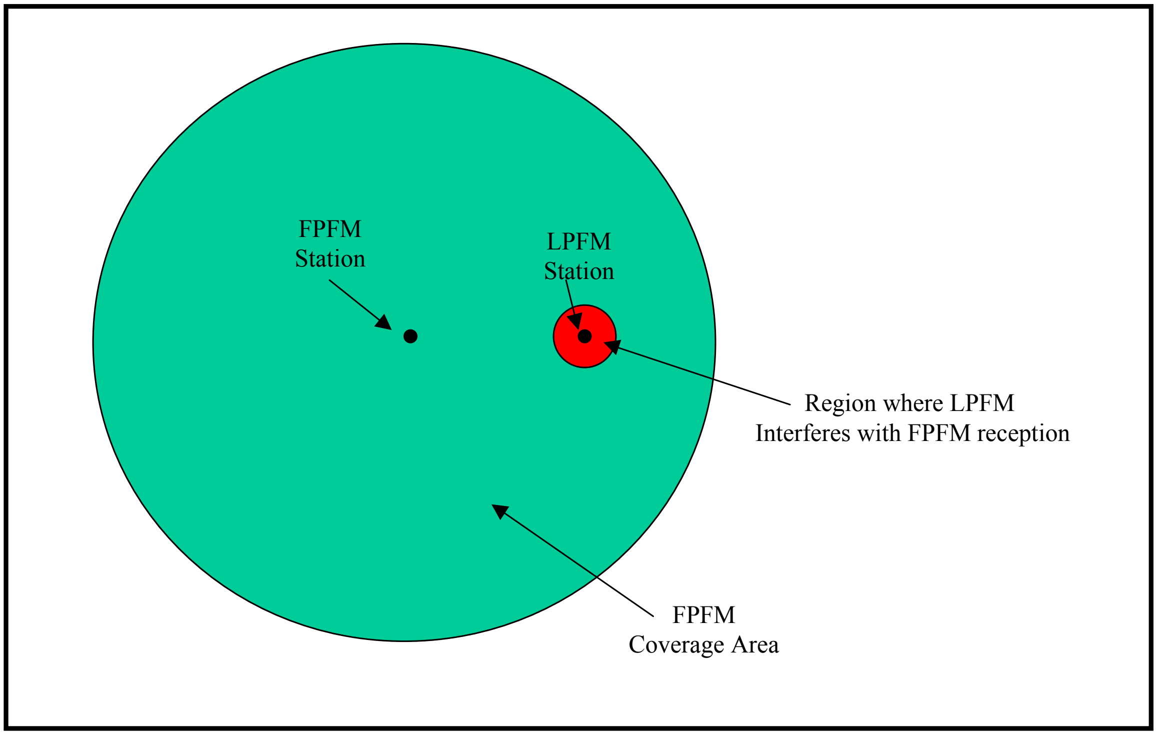


Figure 4-3. Notional Interference Area

In order to determine the area of interference, we define new variables as shown in Figure 4-4, which is an expansion of Figure 4-3. The variable d, is the distance between the FPFM and LPFM stations. The variable x is the distance between the LPFM transmitter and the victim receiver. We want to find the set of values for x that do not satisfy equation (14).

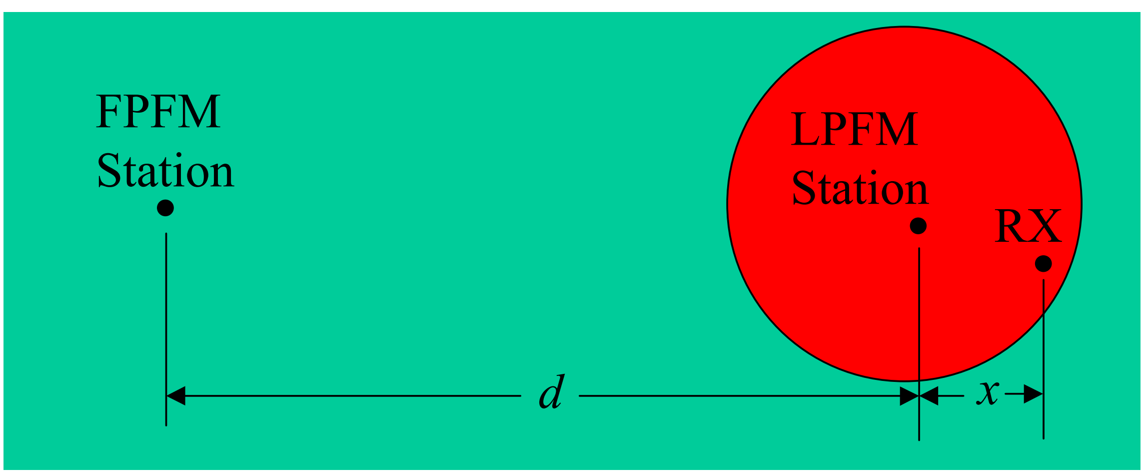


Figure 4-4. Distance Variables

Operating on equation (14), we assume that x is sufficiently small compared to d, that the attenuation, a_F, does not depend on x. Further, we assume that a_F is entirely fourth-law attenuation. We allow a_L to be either square-law or fourth-law. Using these assumptions, equation (14) can be rearranged to form:

$$a_L \geq \frac{E_L G_R \delta}{\left(\frac{E_F G_R}{a_F}\right) - N\rho} \tag{15}$$

Where:

δ = is the third-adjacent rejection ratio of the receiver (D/U ratio), defined as follows:

$$\delta \equiv \frac{\rho}{s} \tag{16}$$

We assume that the receiver antenna gain is the same in the direction of the LPFM station as it is in the direction of the FPFM transmitter. Now, when equation (15) is satisfied, receiver performance will be acceptable. We desire to find the locations where (15) is not satisfied. We note that the left side of (15) is a function of x, while the right side of (15) is a function of d, since a_F depends on d.

Using the assumptions above and the path loss models previously described we get the following. First, substituting d for r in (8) we get the a_F attenuation:

$$\frac{1}{a_F} = m_4 \left(\frac{h_F h_R}{d^2}\right)^2 \tag{17}$$

Where:

h_F = the height of the FPFM antenna
h_R = the height of the receiver antenna

Also, substituting x for r in (10) we obtain the a_L attenuation:

$$a_L(x) = \left(\left[\left(\frac{4\pi}{\lambda}\right)^2 \frac{x^2}{m_2}\right]^n + \left[\frac{x^4}{m_4 h_L^2 h_R^2}\right]^n\right)^{1/n} \tag{18}$$

Equations (17) can be substituted into (15) to get:

$$a_L(x) \geq \frac{E_L G_R \delta}{\left(\frac{E_F G_R m_4 h_F^2 h_R^2}{d^4}\right) - N\rho} \tag{19}$$

We assume the interference region is circular. We use equality in (19) and we desire to solve for x, which is the radius of the interference region. We can solve for x using (18) and (19). We define the right side of (19) as a function $g(d)$, as follows:

$$g(d) \equiv \frac{E_L G_R \delta}{\left(\frac{E_F G_R m_4 h_F^2 h_R^2}{d^4}\right) - N\rho} \tag{20}$$

Using equation (18) we get:

$$g(d) = \left(\left[\left(\frac{4\pi}{\lambda} \right)^2 \frac{x^2}{m_2} \right]^n + \left[\frac{x^4}{m_4 h_L^2 h_R^2} \right]^n \right)^{1/n} \tag{21}$$

This needs to be solved for x. Toward this end, we define a new variable:

$$y \equiv x^{2n} \tag{22}$$

Substituting into (21) and rearranging we get:

$$0 = \left(\frac{1}{m_4 h_L^2 h_R^2} \right)^n y^2 + \left(\frac{16\pi^2}{m_2 \lambda^2} \right)^n y - \left(g(d) \right)^n \tag{23}$$

Equation (23) is quadratic in y, and can be easily solved for y. We use the largest (most positive) root. This root can be used to compute x using (22). We note that x can be either positive or negative, but it has a single magnitude.

The derivation above can be used to determine the radius of the circle that defines the interference region. From this radius, it is a simple matter to compute the area of the interference region. Also, given the radius of the FPFM coverage area, the relative area can be computed as the ratio of the two areas.

In addition to computing the quantities above as a function of the distance, d, we also desire to determine their values at the edge of the FPFM station's F(50,50) contour. This can be computed by recognizing that the first term in the denominator of equations (19) and (20) is a received power level. We can substitute the following for that term:

$$\frac{F^2 \lambda^2 G_R}{4\pi\eta_0} \tag{24}$$

Where:

η_0 = is the impedance of free space, 377 ohms
F = the field strength that defines the F(50,50) contour

Hence, at the edge of coverage, we get a new definition for g as follows:

$$g_e \equiv \frac{E_L G_R \delta}{\left(\dfrac{F^2 \lambda^2 G_R}{4\pi\eta_0}\right) - N\rho} \tag{25}$$

We note that g_e applies to the edge of coverage, and so, is not a function of the distance between LPFM and FPFM stations, d. The quantity g_e can be substituted into (23) instead of $g(d)$ so that the values for y and x can be determined as described above.

4.4 Predicted Results at Test Locations

In this section we provide predicted results for all of the cases tested in the field, except the translator input. Results are organized by test location with a summary at the end of the section. For each location we show the following predicted results:

- The minimum separation between the LPFM transmitter and the victim receiver. This defines the radius of the interference region
- The area of the interference region. By interference region, we mean the region where a receiver tuned to the FPFM station is likely to experience significant interference due to the LPFM station on the third adjacent channel.
- The relative area of the interference region as compared to the coverage area of the FPFM station. This is just the ratio of the area of the interference region described above divided by the area of coverage for the FPFM station.

All results are shown as a function of the distance between the LPFM station and the FPFM station. The distance used in the field tests is marked on the graphs. Results are shown for two radio cases. In one case we use a third-adjacent rejection ratio (D/U) of -35 dB. This corresponds to the performance expected of the clock radio. In the other case we use a rejection ratio of –60 dB. This value is more typical of a good home or automobile receiver.

In the results that follow, we have made the following assumptions:

- The ERP of the LPFM transmitter is 100 Watts
- The height of the LPFM antenna is 30 meters
- The sensitivity of each receiver is -90 dBm
- The height of the receive antenna is 1.5 meters
- The receive antenna gain is 0 dBi

4.4.1 Avon

Figure 4-5 shows the separation required to avoid interference as a function of the distance between the two transmitting stations. The two curves are for the two different types of radios. In the figure we can clearly see the two types of propagation loss. Square-law loss is in the lower left, while fourth law loss is seen in the upper right. In the Avon test the LPFM station is relatively close to the FPFM transmitter. As a result, the minimum separation between the LPFM stations and receivers is predicted to be small.

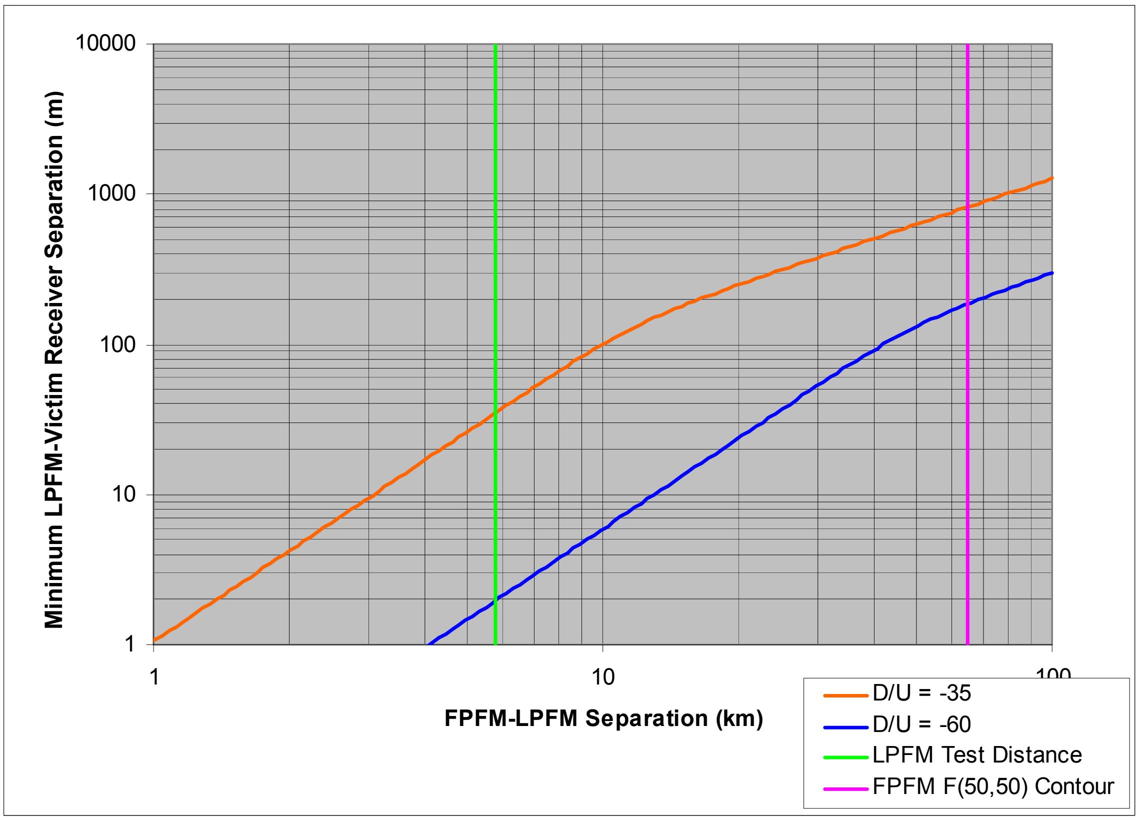


Figure 4-5. Avon Minimum Separation

Figure 4-6 shows the area of the interference region as a function of FPFM-LPFM distance separation. At the test location, this area is relatively small, less than 0.01 square kilometers. At the edge of coverage, the area would have been a little larger than 1 square kilometer for the clock radio and about 0.1 square kilometer for a car radio or home receiver.

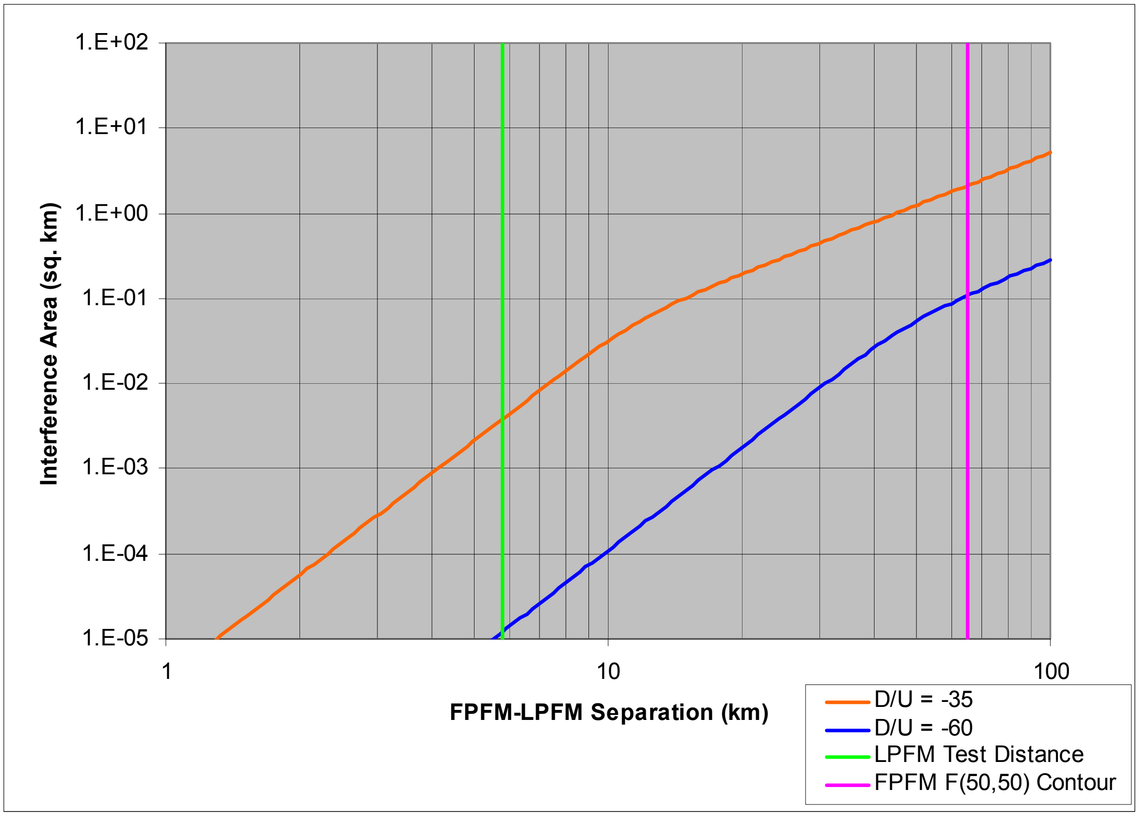


Figure 4-6. Avon Interference Area

Figure 4-7 shows the relative interference area. As a fraction of the coverage area, this is as small as 10^{-9} for the home receiver at the test location. It would be about 10^{-4} at the edge of coverage [F(50,50) contour] for the clock radio.

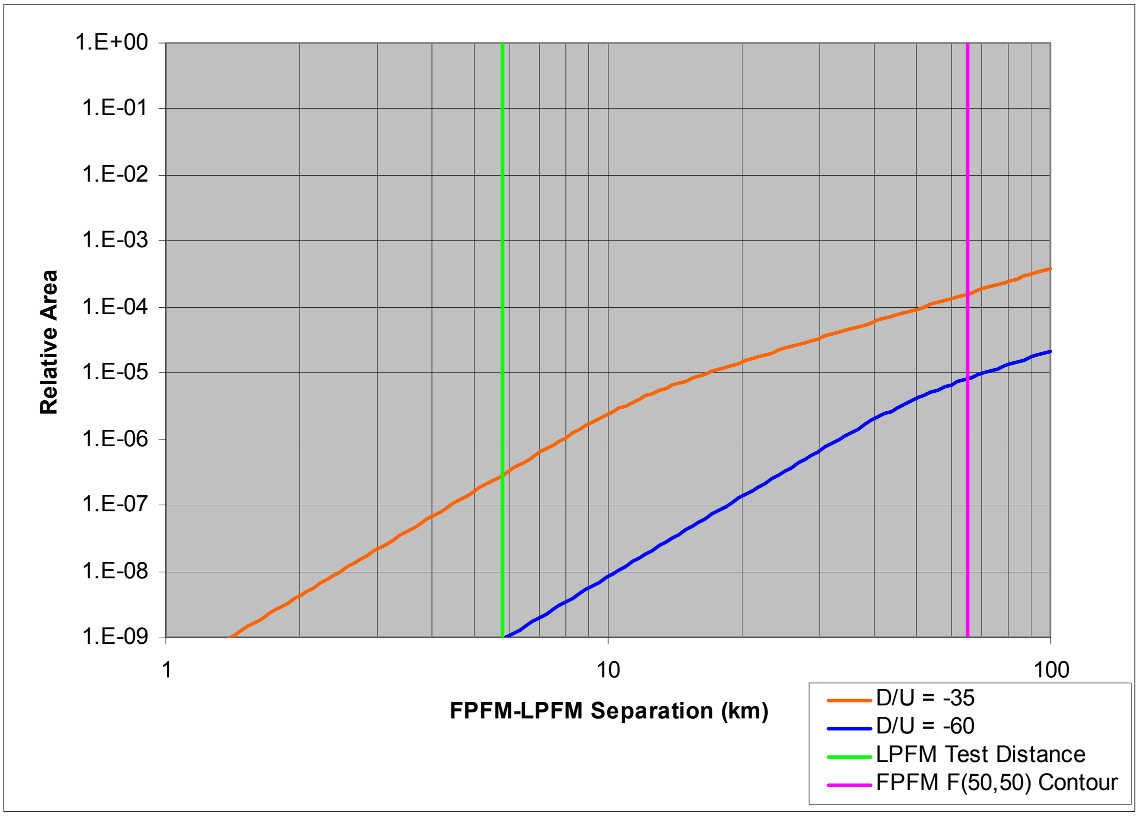


Figure 4-7. Avon Relative Area

4.4.2 Brunswick

The results at Brunswick show many similarities to the results for Avon. However, in Brunswick the test location was much closer to the edge of coverage of the FPFM station. Hence, at that location the predicted minimum separation, interference area, and relative area are larger than for the tests at Avon. Again we see both square-law and fourth-law attenuation characteristics. The required separation between an LPFM station and clock radio receivers for this case is a little more than 800 m at the F(50,50) contour, and is only 200 m for home stereo or car radios.

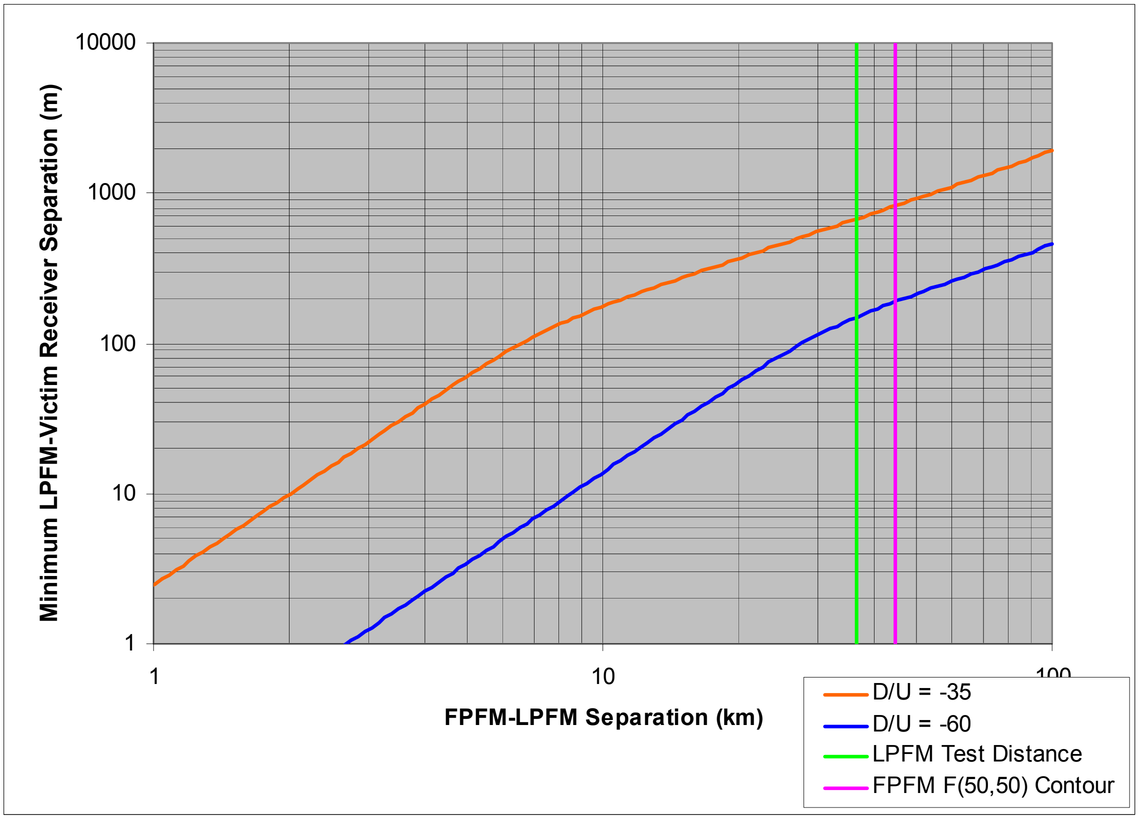


Figure 4-8. Brunswick Minimum Separation

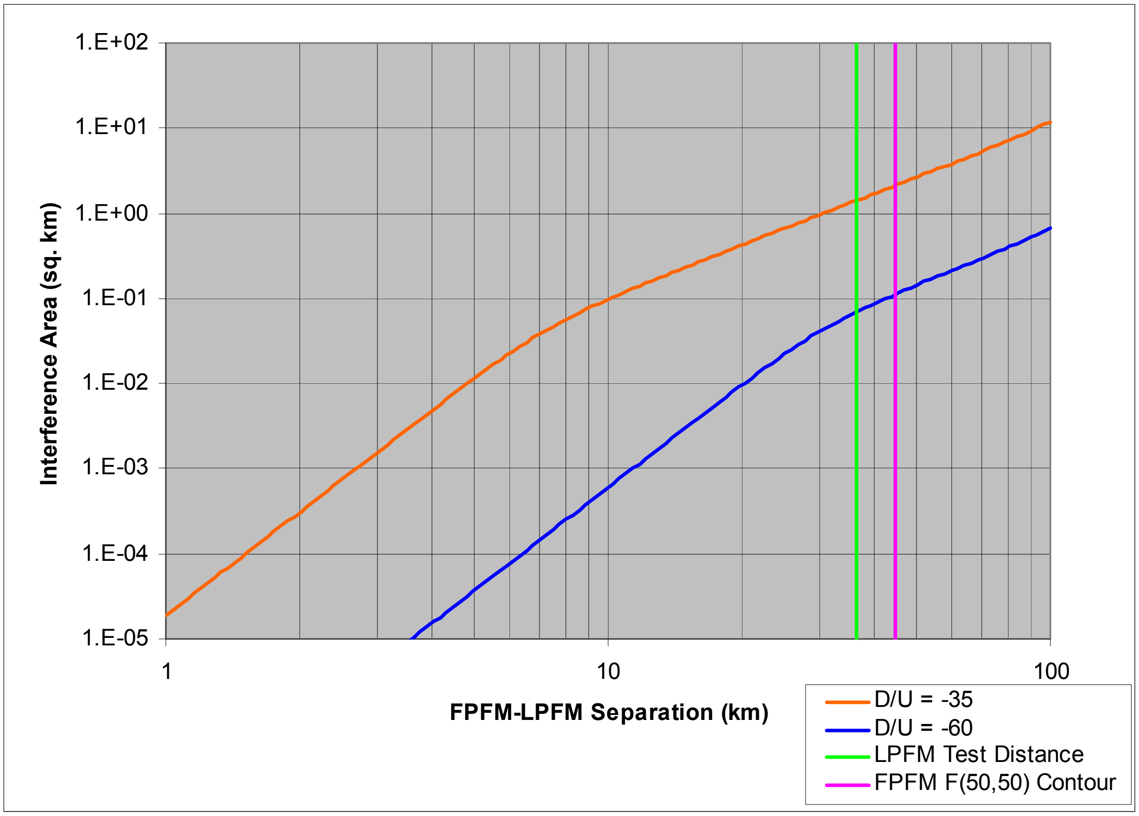


Figure 4-9. Brunswick Interference Area

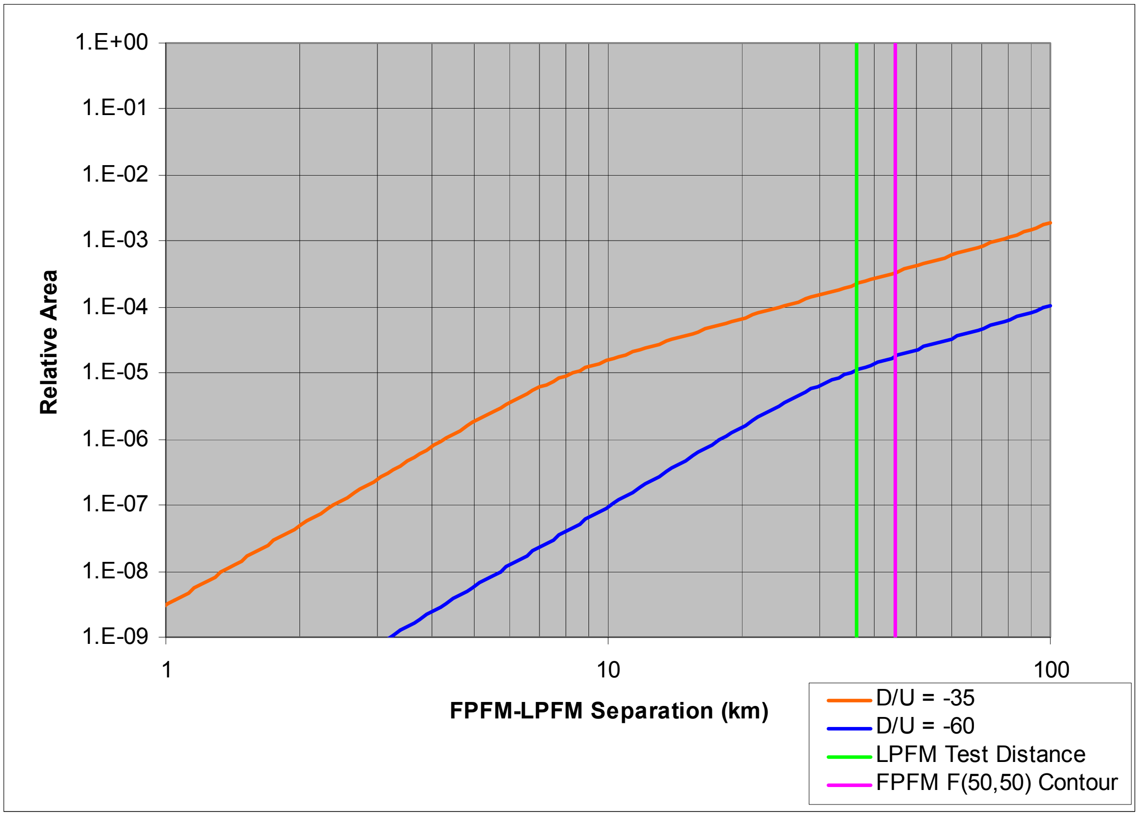


Figure 4-10. Brunswick Relative Area

4.4.3 East Bethel

The results at East Bethel, MN are as expected for a test location relatively close to the F(50,50) contour. The worst-case separation requirement [clock radio at the F(50,50) contour] is about 500 m. It is about 100 m for a car radio.

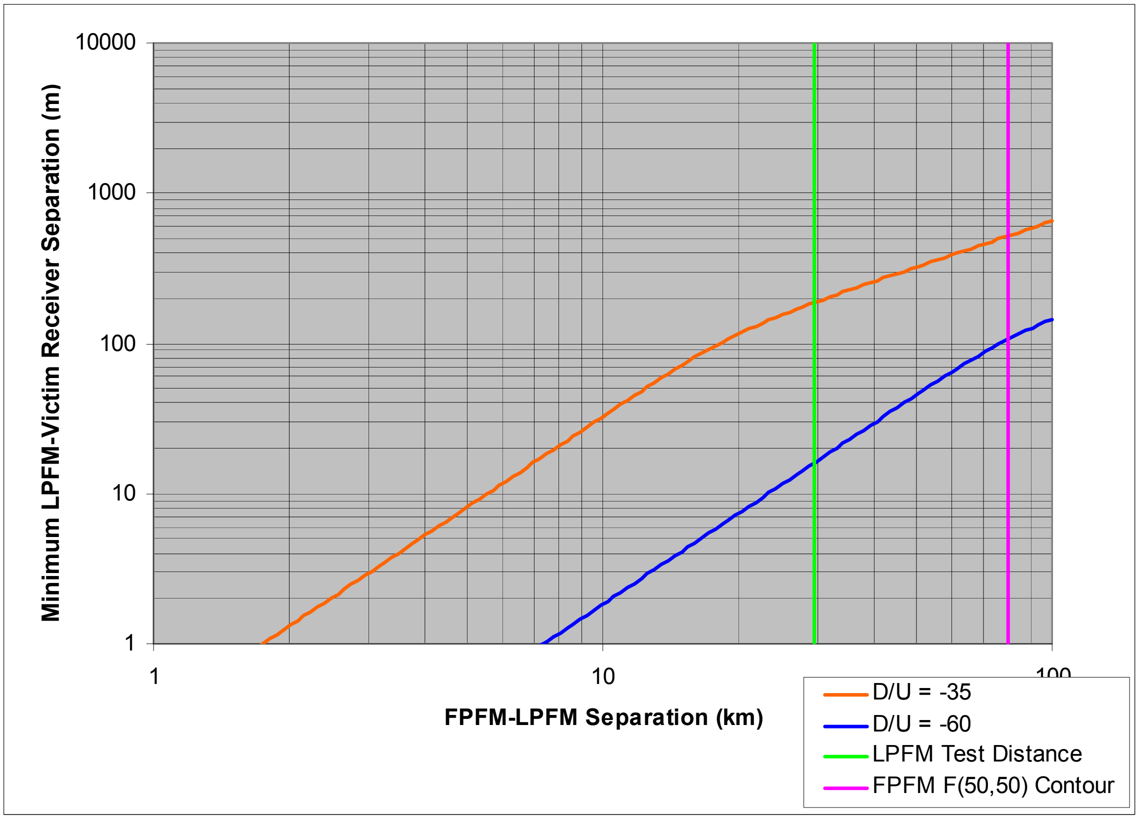


Figure 4-11. East Bethel Minimum Separation

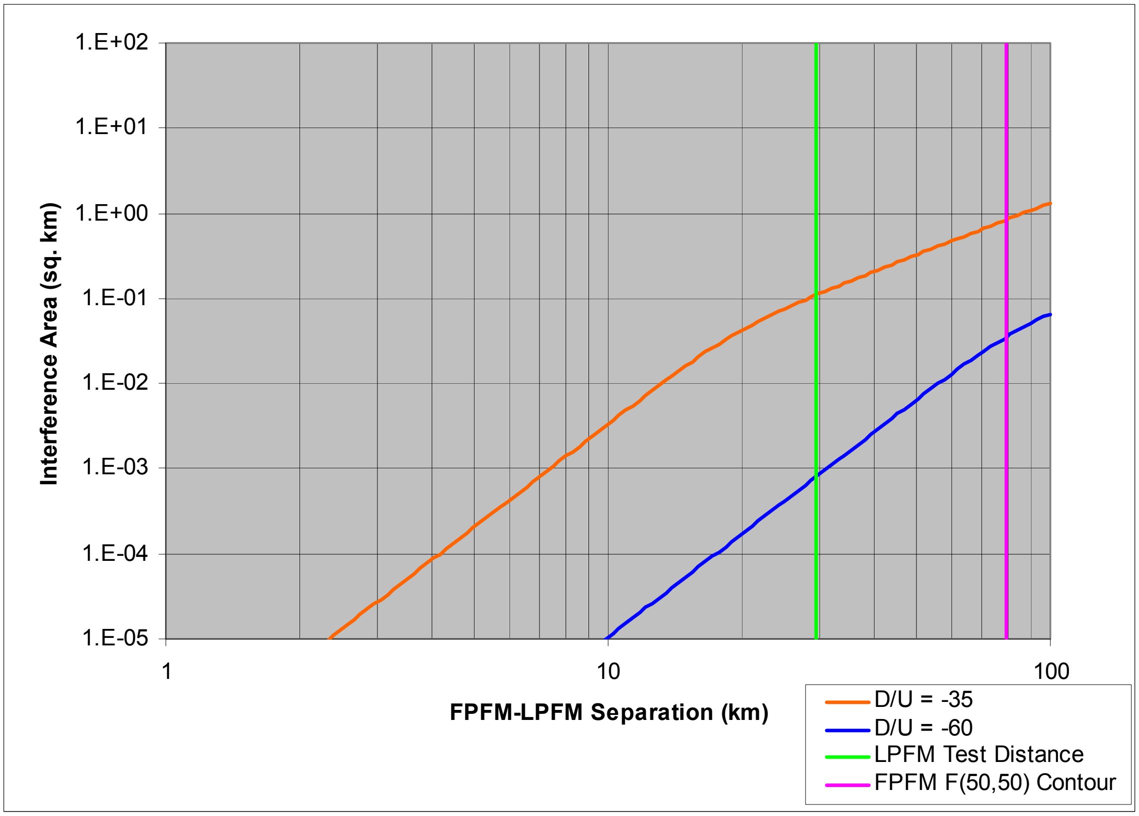


Figure 4-12. East Bethel Interference Area

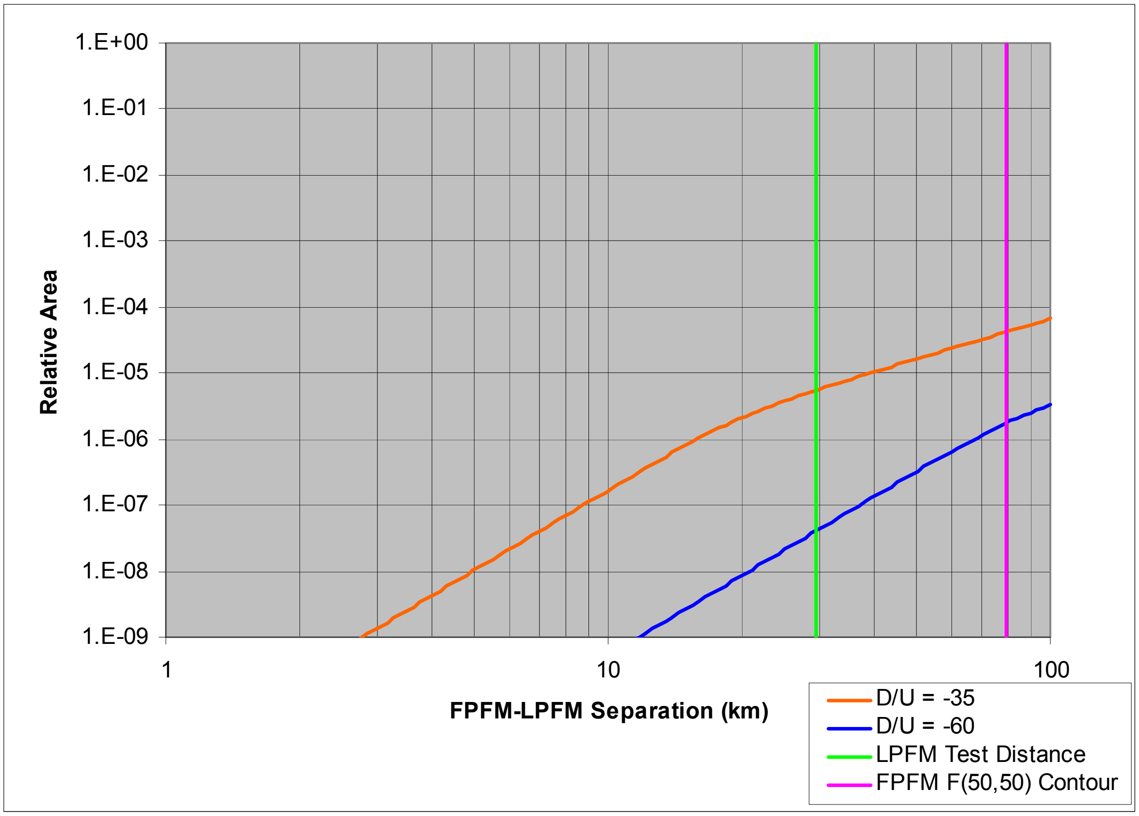


Figure 4-13. East Bethel Relative Area

4.4.4 Owatonna

The results at the Owatonna translator output show a new characteristic. We expect somewhat different results because the transmitter power of the translator is much smaller than for other "FPFM" stations. As a result the curves are shifted to the left as compared to other curves shown above. Also, in these curves, the results become unbounded because the signal to noise reaches the threshold even without interference. The required separation is about 750 m for a clock radio at the translator's F(50,50) contour.

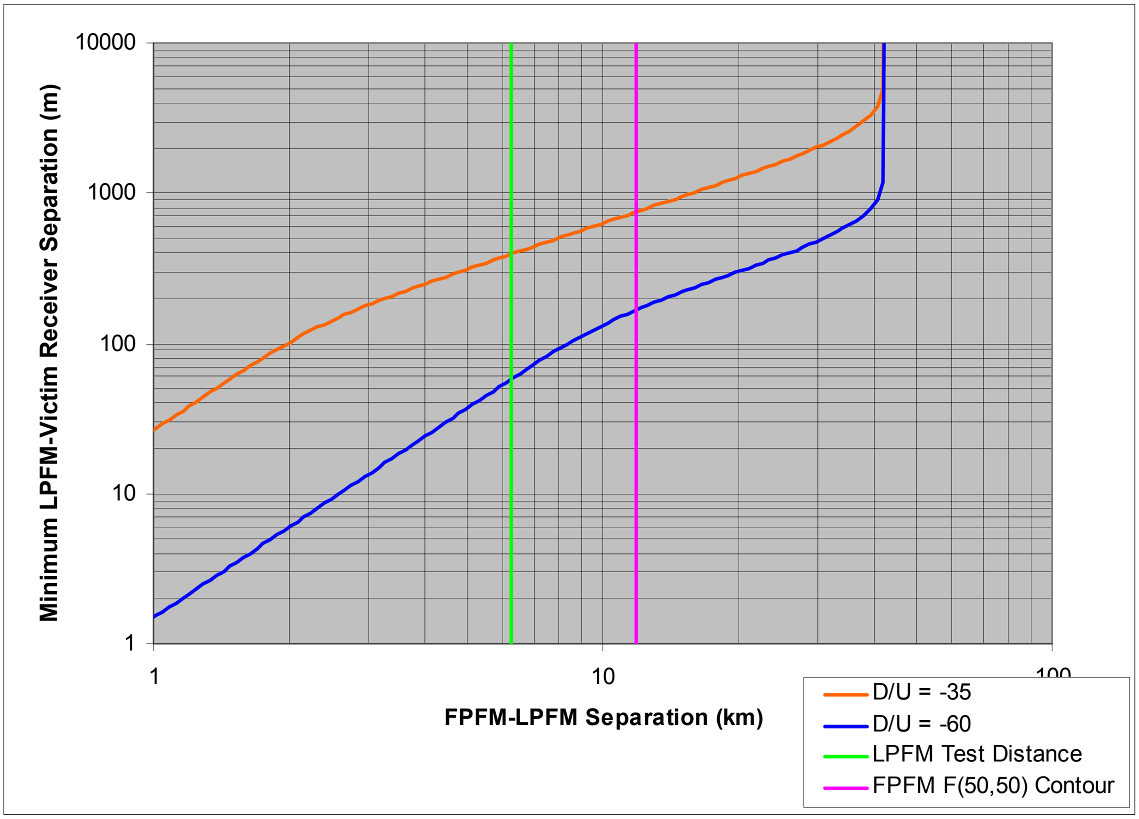


Figure 4-14. Owatonna Minimum Separation

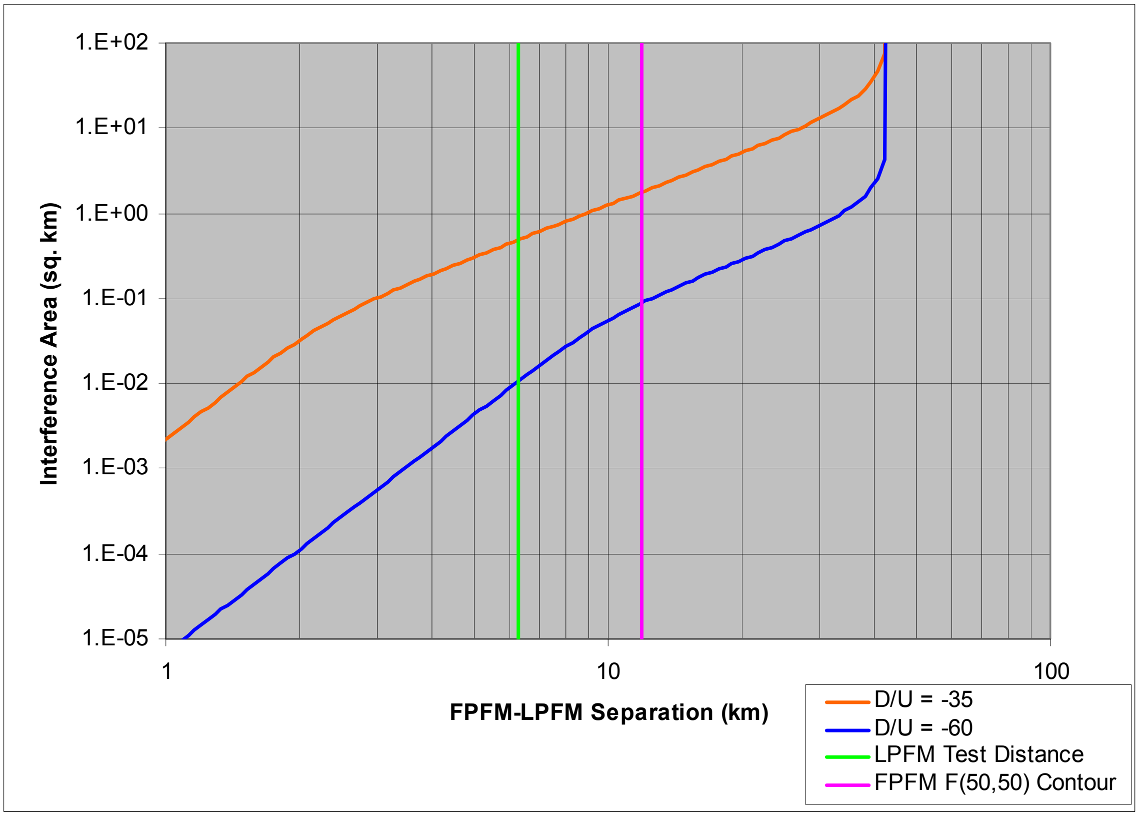


Figure 4-15. Owatonna Interference Area

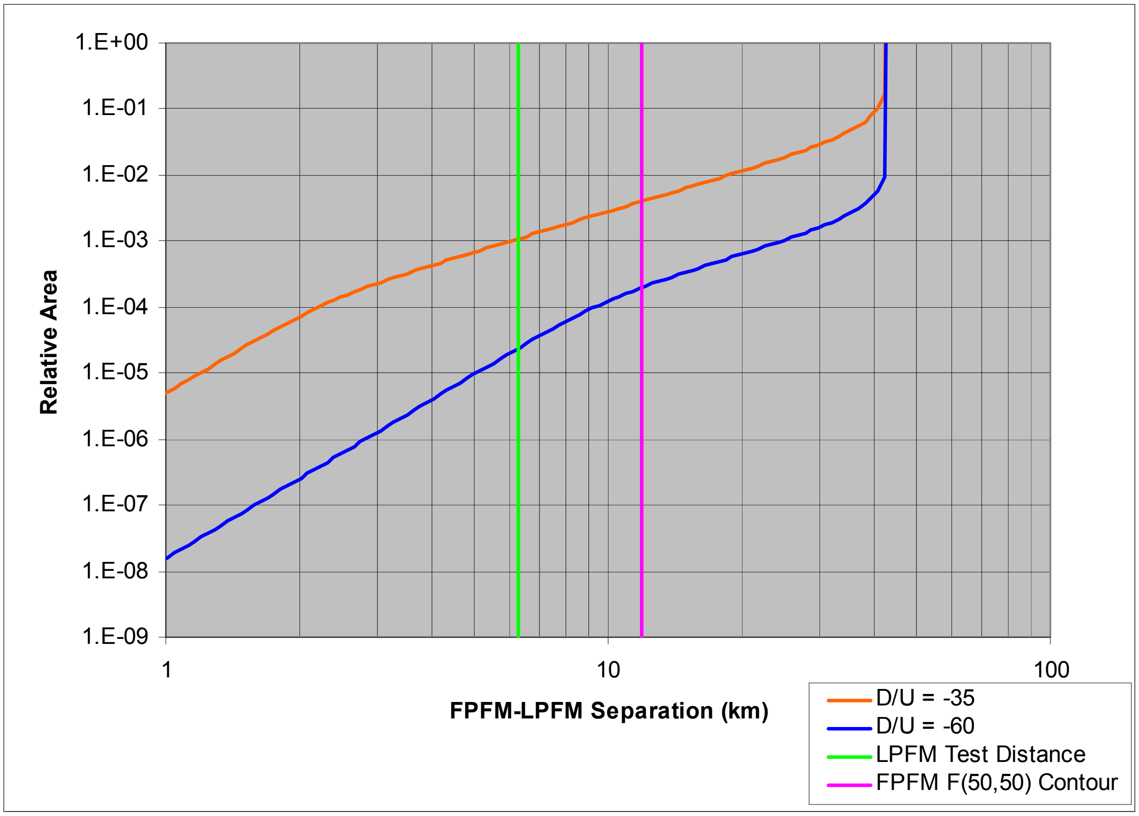


Figure 4-16. Owatonna Relative Area

4.4.5 Winters

The test site for Winters was about half way to the FPFM station's F(50,50) contour. The required LPFM to receiver distance at the test location is 265 m for the clock radio and 850 m at the F(50,50) contour.

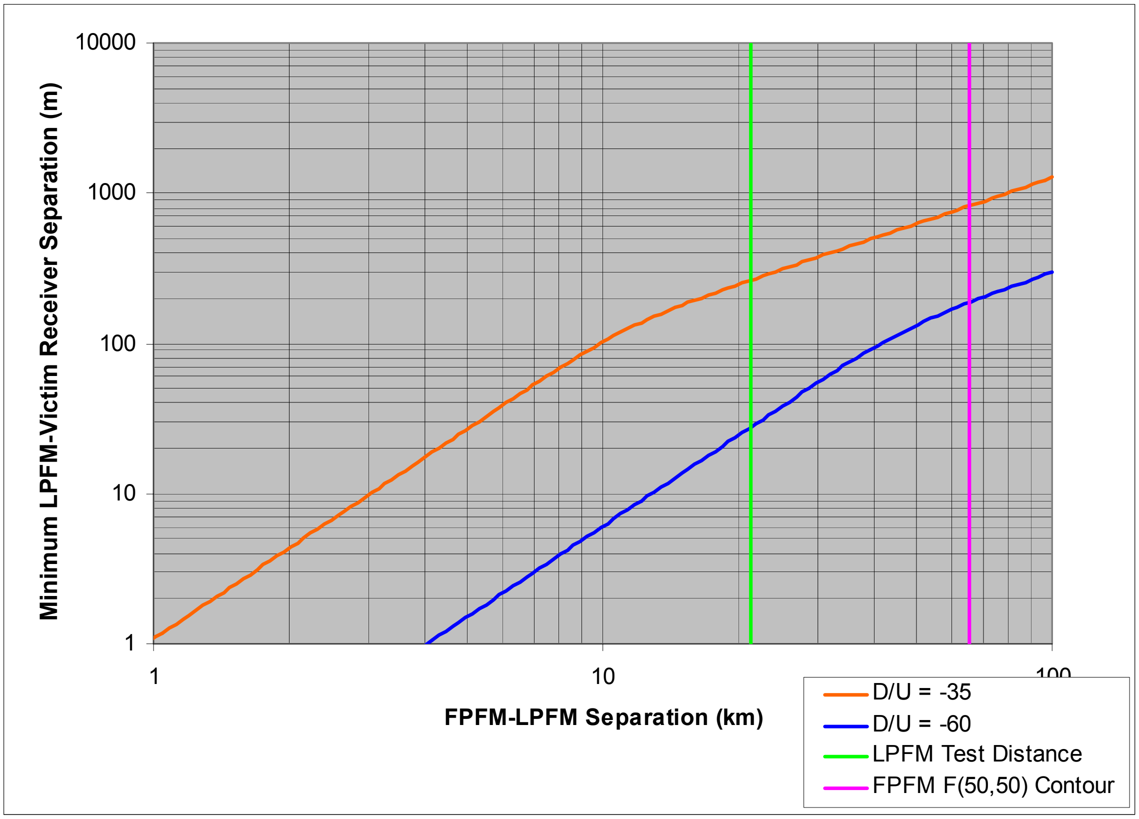


Figure 4-17. Winters Minimum Separation

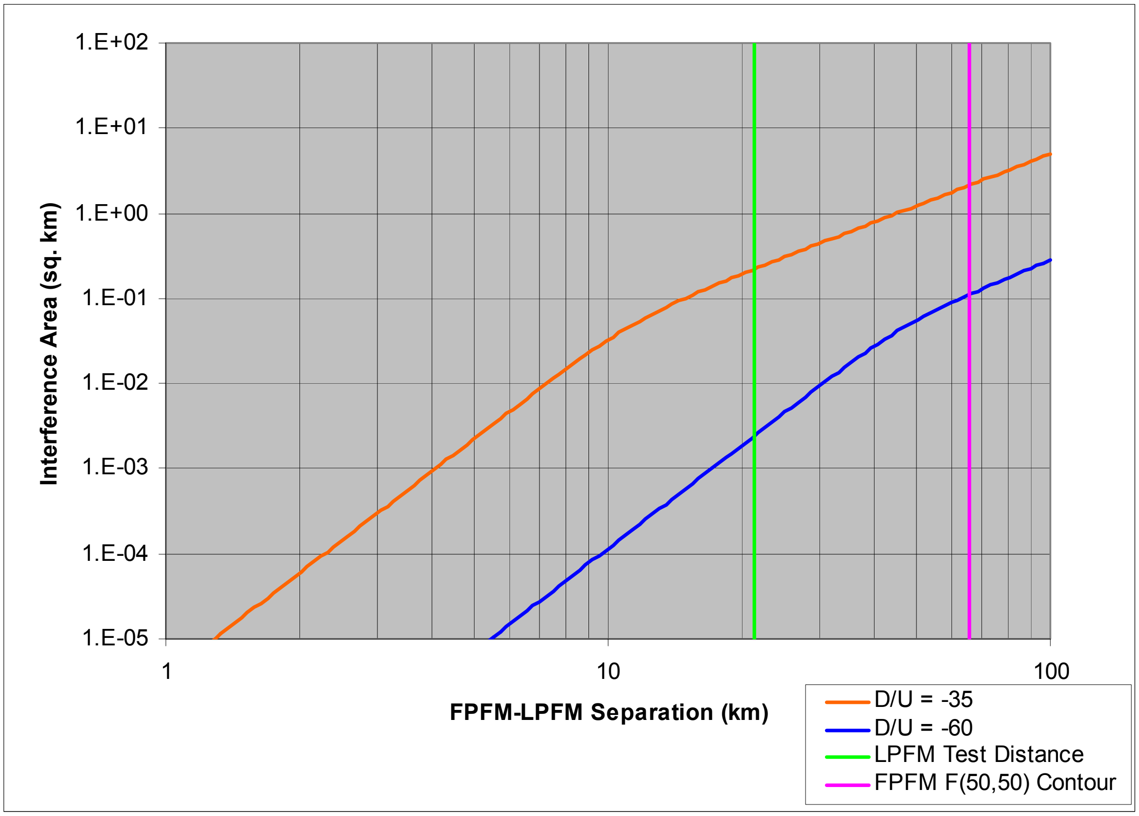


Figure 4-18. Winters Interference Area

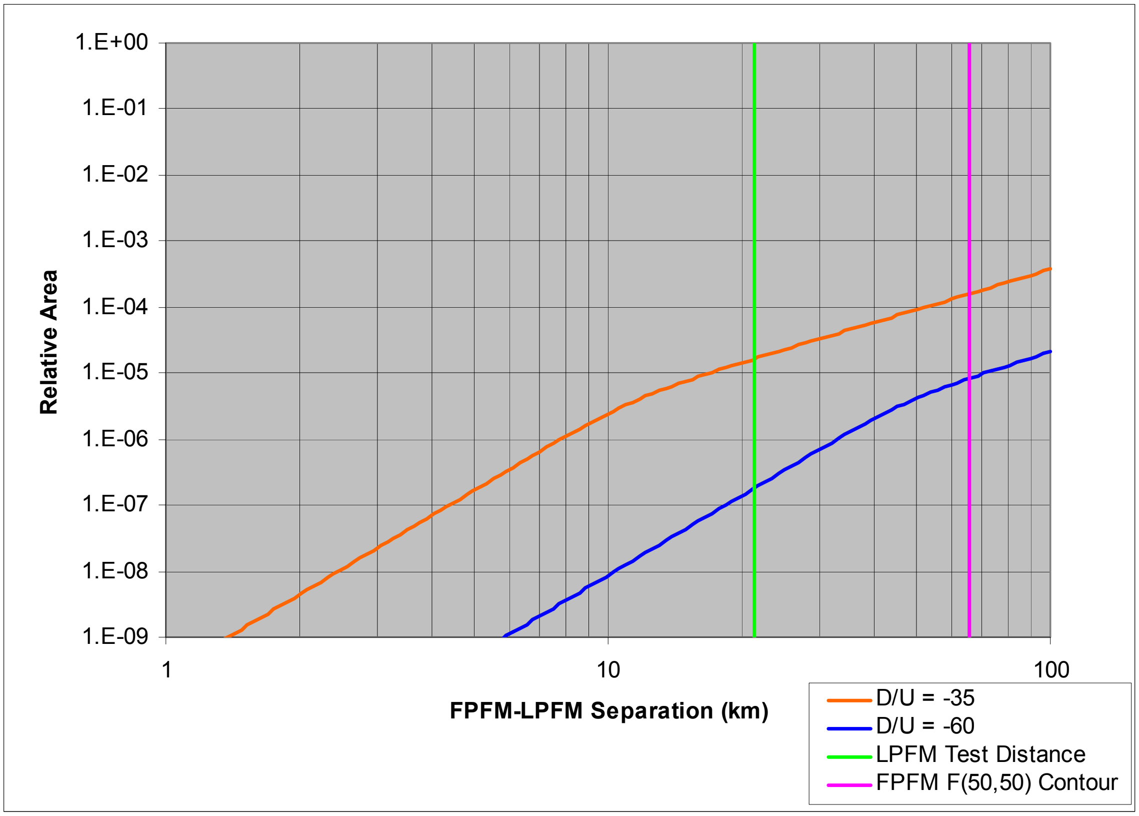


Figure 4-19. Winters Relative Area

4.4.6 Benicia

The Benicia site was located almost 60 km from the FPFM station, whose F(50,50) contour was the largest among the stations used at about 85 km. The required LPFM-receiver separation at the test location is about 470 m for the clock radio. The separation requirement for a car radio at the F(50,50) contour is about 160 m.

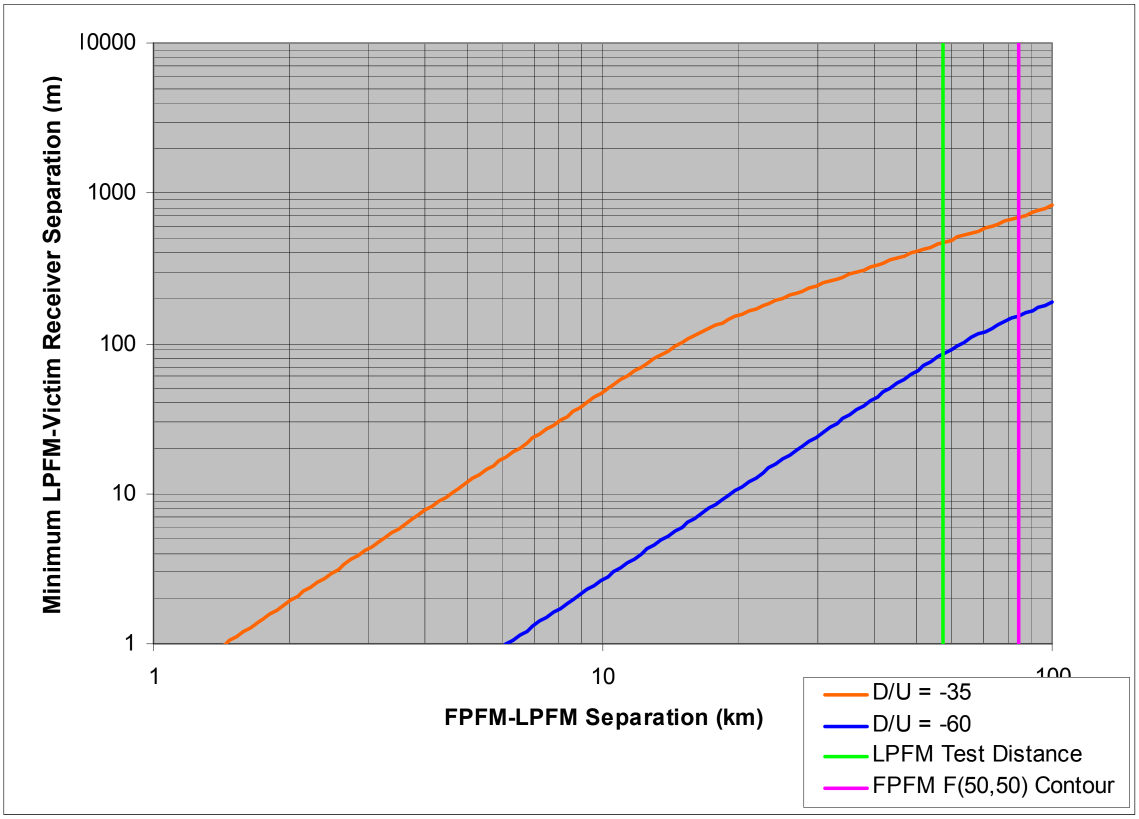


Figure 4-20. Benicia Minimum Separation

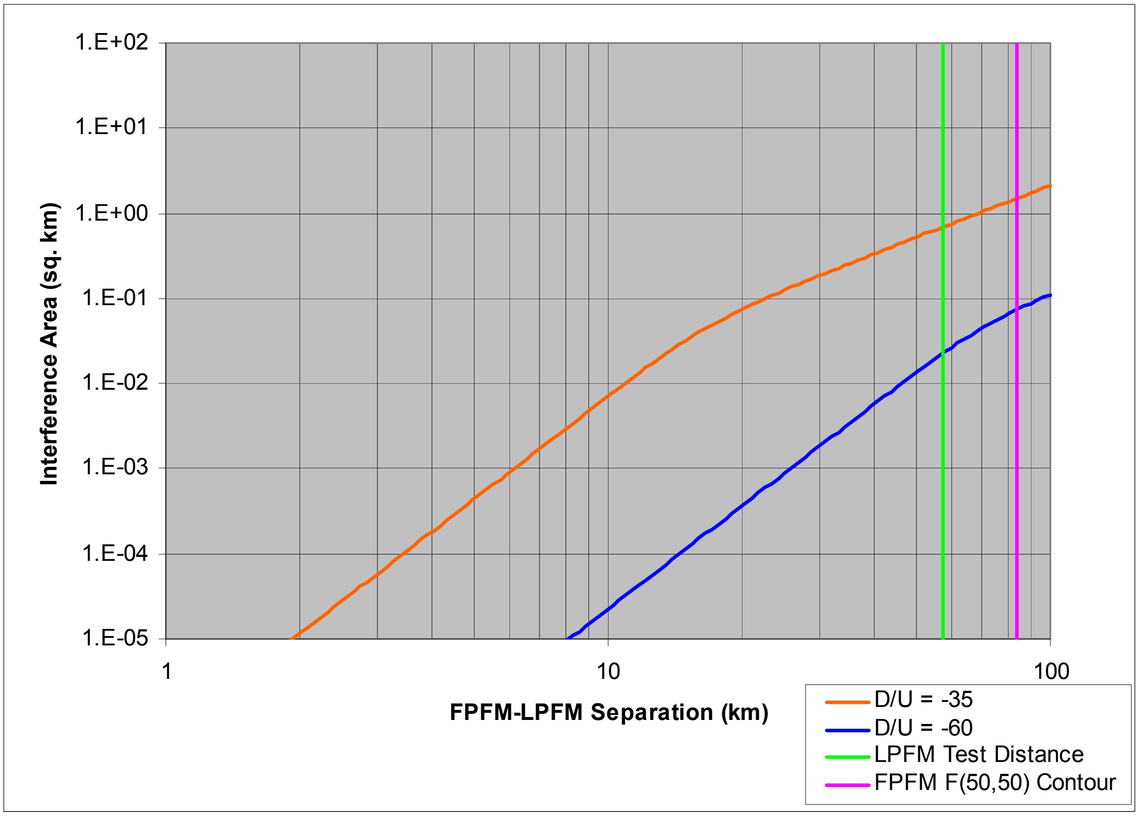


Figure 4-21. Benicia Interference Area

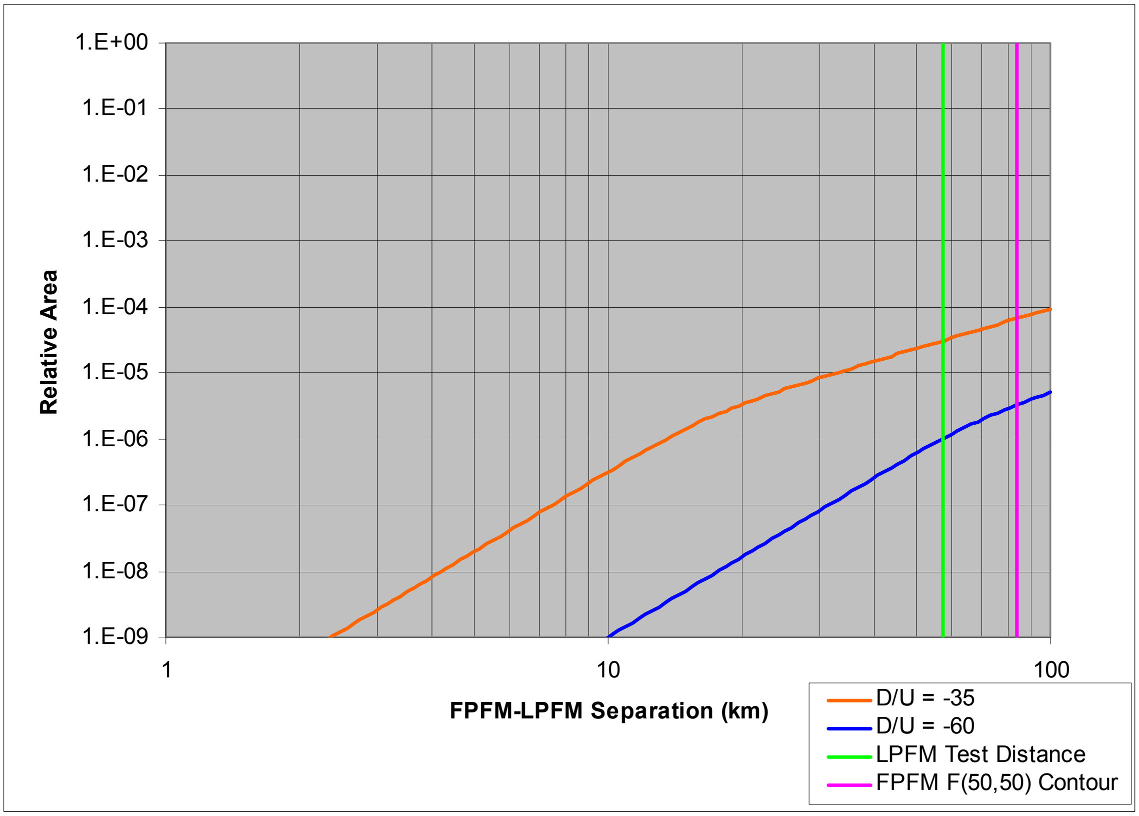


Figure 4-22. Benicia Relative Area

4.4.7 Summary

In the following tables, the results shown in Sections 4.4.1 through 4.4.6 are summarized. Table 4-1 shows the minimum separation at the test distance for the two types of receivers and the six test locations described above. Table 4-2 shows the area of the interference region at each test location. Finally, Table 4-3 shows the relative area at the test locations. Note that results for locations at the edge of coverage are given below in Section 4.5.

Table 4-1. Minimum Separation Distance at Test Location (m)

Radio D/U	Avon	Brunswick	East Bethel	Owatonna	Winters	Benicia
-35	35	672	186	394	265	469
-60	2	149	16	58	28	85

Table 4-2. Interference Area at Test Location (sq. km)

Radio D/U	Avon	Brunswick	East Bethel	Owatonna	Winters	Benicia
-35	0.00	1.42	0.11	0.49	0.22	0.69
-60	0.00	0.07	0.00	0.01	0.00	0.02

Table 4-3. Relative Area at Test Location (area ratio)

Radio D/U	Avon	Brunswick	East Bethel	Owatonna	Winters	Benicia
-35	2.9E-07	2.3E-04	5.4E-06	1.1E-03	1.6E-05	3.1E-05
-60	9.2E-10	1.1E-05	4.0E-08	2.4E-05	1.8E-07	1.0E-06

4.5 Predicted Results at F(50,50) Contour

In Section 4.4 we showed the results of interference as a function of distance between the LPFM and FPFM stations. Here in Section 4.5, we show results at the edge of FPFM coverage, that is at the F(50,50) contour. Results here are based on the specific field strength given in CFR47 Part 73.215 (a) (1) for the FPFM class of station. On the other hand, results in Section 4.4 (both tables and graphs) are based on the path loss models described in Section 4.2. Minor differences in these two calculations at the edge of coverage for the FPFM station are due to different assumptions about antenna height and antenna gain. In other words, assumptions used by the station to compute the F(50,50) contour do not necessarily match the conditions during the LPFM tests described in this report. For Class B stations, we assume an edge-of-coverage field strength of 54 dBu. A value of 57 dBu is used for Class B1 stations. All others use 60 dBu.

The results shown in the following tables are clearly larger than those shown in Section 4.4. However the following figures show a greater consistency than the ones in the previous section. In particular, we see that the minimum separation distance is relatively constant for all test sites. Because of this consistency, minimum separation is one important way to express conditions for interference avoidance.

Table 4-4. Minimum Separation Distance at Edge of FPFM Coverage (m)

Radio D/U	Avon	Brunswick	East Bethel	Owatonna	Winters	Benicia
-35	602	482	393	423	590	582
-60	123	91	66	67	122	121

Table 4-5. Interference Area at Edge of FPFM Coverage (sq. km)

Radio D/U	Avon	Brunswick	East Bethel	Owatonna	Winters	Benicia
-35.00	1.14	0.73	0.49	0.56	1.09	1.06
-60.00	0.05	0.03	0.01	0.01	0.05	0.05

Table 4-6. Relative Area at Edge of FPFM Coverage (area ratio)

Radio D/U	Avon	Brunswick	East Bethel	Owatonna	Winters	Benicia
-35	8.6E-05	1.2E-04	2.4E-05	1.3E-03	8.1E-05	4.8E-05
-60	3.6E-06	4.1E-06	6.9E-07	3.1E-05	3.5E-06	2.1E-06

4.6 Assessment and Conclusions

The results shown in Section 4.4 are generally consistent with the field test results. Differences between the field test results and analytical predictions are within the accuracy of the analysis assumptions and the field measurements. Comparing the results in Section 4.4 with test results shown elsewhere in the report, we are recommending in Section 5, guidelines that always bound the performance.

We see that the size of the interference area is a strong function of the distance between the two stations. Large separations between the FPFM and LPFM stations are worse because the FPFM signal is weaker. Hence placing a LPFM station at the edge of coverage results in a larger interference area. Table 4-4 shows that the largest radius (at edge of coverage) for the scenarios tested is about 600 meters. In the worst case examined, the relative interference area ratio is 0.13% of the FPFM station’s coverage area.

We also see that for poorly performing radios with third-adjacent rejection ratios (D/U) of -35 dB, and for locations near the edge of FPFM coverage, the path loss model is always fourth-law.

We can develop an expression for the limits of interference based on a simplification of the analysis previously shown. If we use the minimum of equations (7) and (8) instead of equation (10), this provides a simplification for a_L in equation (19). Furthermore we ignore the small correction factors used in equations (7) and (8). Also, we have seen that we can ignore the second term in the denominator of equation (19). Substituting into (19) and rearranging we obtain the following expression:

$$x_{\min} = \min\left\{ \frac{d^2\lambda}{4\pi h_F h_R}\sqrt{\frac{\delta E_L}{E_F}}, d\left(\frac{\delta E_L h_L^2}{E_F h_F^2}\right)^{1/4} \right\} \tag{26}$$

This expression describes the separation distance required to avoid interference. Note that the δ factor is based on radio performance in terms of third adjacent rejection. A D/U value for this parameter of 0.002 (-27 dB) would provide protection for the clock radio, RSVI, and automobile receivers tested.

Table 4-7 shows x_{min} values based on a δ value of 0.002 and corresponding to the cases represented by the field tests described in this report. A summary of the results of the field tests is also provided in the table for reference.

Table 4-7. Example Xmin Values, Field Test Results, and Predicted Separations (meters)

	Avon	Brunswick	East Bethel	Owatonna (Site A)	Winters	Benicia
x_{min}	66	1065	303	627	425	745
Largest test distance with significant interference (excluding anomalous case)	18	126	232	50	235	333
Smallest test distance without significant interference (excluding anomalous case)	34	370	550	116	573	906
Predicted minimum required separation distance for radio having -35 dB D/U threshold	35	672	186	394	265	469

Section 5

Conclusions and Recommendations

5.1 Conclusions

5.1.1 Effects of Receiver Proximity to LPFM Station

- During the analog field tests, no significant LPFM-related degradation of a non-translator receiver was ever identified more than 333 meters from the test LPFM transmitter, and no such case involving an LPFM ERP less than 100 W was identified at any distance more than 126 meters, except for a single anomalous case involving a 10 W LPFM transmitter 550 meters from a receiver. Numerous significant degradation cases were identified at distances less than 240 meters, and especially at distances less than 100 meters. Significant degradation could occur at somewhat larger distances in certain unfavorable circumstances, as indicated in Table 4-7.
- No case of significant interference to the tested RSVI receiver at East Bethel was ever identified at a distance more than 80 meters from the LPFM transmitter. Numerous cases of significant degradation were identified at locations within 80 meters of the LPFM site.
- Since LPFM-induced third ACI appears to occur only in close proximity to LPFM transmitters, it follows that if reasonable transmitter emission standards are established, and reasonable restrictions are observed when siting LPFM transmitters, then third-adjacent channel interference will have relatively little impact on the listening audiences of neighboring incumbent FPFM stations. Applying "area weighting" to the test data has indicated that the overall probability of significant interference from an LPFM transmitter with a 100 W ERP to an analog receiver, randomly selected from the set of six test receivers and placed at a randomly selected point in one of the six non-translator-input-test FPFM coverage areas selected at random, is below 3×10^{-5}. For the auto receiver, that probability is much lower, on the order of 3×10^{-7}.

5.1.2 Effects of Desired-to-Undesired Power Ratio (D/U)

- The most important predictor of whether a given location is susceptible to LPFM third ACI is the D/U of the incumbent FPFM signal with respect to the LPFM signal at that location. Locations close to a strong FPFM transmitter and well within its coverage contour generally have high D/Us and very low rates of significant degradation associated with LPFM, as exemplified by the test results at Avon. Locations farther from the center of an FPFM coverage area, like those tested at other sites, have lower D/U ratios and higher rates of significant degradation (although if they are at the fringes of an FPFM coverage area, like those at Brunswick, the LPFM-related degradation is masked to some extent by the inherent degradation associated with a weak desired signal).

- In the translator input test, where undesired LPFM signals were broadcast from a point within the main beam of the Owatonna translator receiver and 447 meters away, numerous cases of significant degradation were noted when the LPFM ERP was 7 dBW or more (producing a calculated D/U of –38 dB or less at the input to the translator receiver), but none were noted when the ERP was 3 dBW or less (yielding a calculated D/U of –34 dB or more).

  The minimum LPFM-to-translator distance separation d_u, in kilometers, that will ensure a calculated D/U of –34 dB or less (assuming free-space path loss) is given by:

$$d_u = 110 \text{ antilog } [(P_{eu} + G_{ru} - G_{rd} - E_d) / 20] \qquad (27)$$

  where

  P_{eu} = LPFM ERP in dBW
  G_{ru} = gain (in dBd) of the translator receiver's antenna, in the direction from which the LPFM signal arrives
  G_{rd} = gain (in dBd) of the translator receiver's antenna, in the direction from which the primary FPFM signal arrives
  E_d = predicted field strength (in dBu) of the primary FPFM signal entering the translator receiver's antenna.

- Of the analog receivers tested, the auto receiver was the most robust in the presence of third-adjacent-channel LPFM transmissions, showing little or no significant degradation except when the D/U value fell below a threshold of –60 dB. The home receiver was nearly as robust, with a D/U threshold of –55 dB. The clock radio's much lower threshold of –37 dB was still significantly better than those of the boombox, Walkman, and RSVI receiver (–27, –27, and –25 dB, respectively).

5.1.3 Effects of LPFM Antenna Height

- No significant correlation between LPFM antenna height and receiver degradation was observed during the non-translator-input field tests. The obvious reason is that free-space loss weakens the LPFM signal below the tested receivers' third-ACI thresholds well before it propagates to a distance at which a 30-meter antenna height AGL would provide the LPFM any significant advantage over a 10-meter height. Similar reasons explain the absence of any meaningful correlation between test area type (urban, suburban, or rural) or terrain (flat, hilly, or mountainous) and receiver degradation. On the other hand, our approximate theoretical analysis indicates that for radios with third-adjacent-channel D/U thresholds on the order of -35 dB, at the edge of coverage of the FPFM station, we always have fourth-power-law attenuation characteristics. This implies that antenna height could have a significant effect for poor radios when the LPFM station is near the edge of the FPFM coverage.

- During the translator input test, substantially fewer degradation transitions were associated with the 10-meter LPFM antenna height than with the 30-meter height. Since the LPFM antenna was within the translator receiving antenna's main beam in both cases, the difference is believed to have resulted primarily from local multipath effects.

5.1.4 Effects of LPFM and FPFM Program Contents

- The analog field testing did not establish a strong correlation between the tested combination of LPFM and FPFM program contents (where each content could be processed music, unprocessed music, or news/talk) and the observed number of significant degradation transitions. However, FPFM processed music did appear to be relatively robust in the presence of LPFM processed music, as did FPFM news/talk in the presence of LPFM talk.

5.1.5 Feasibility of Modernized Third-Adjacent-Channel Emission Mask

- A limit of –55 dBc on third-adjacent-channel emissions from all causes, including phase noise and discrete spurious tones, is a reasonable requirement to impose on LPFM transmitters. That limit was observed by the LPFM transmitter used in the analog field tests, and many manufacturers of comparable equipment advertise spurious emission limits that are even lower (e.g., -70 to -85 dBc).

5.1.6 Digital IBOC Test Results

- The performance of the IBOC receiver in the presence of third-adjacent-channel LPFM signals was comparable to that of the analog home and auto receivers, reaching an MOS value of 3 when D/U was approximately -55 dB.

- The IBOC bench testing did not establish a strong correlation between LPFM program content and the D/U degradation threshold of the IBOC receiver.

5.2 Recommendations

5.2.1 Operating Rules for LPFM

Based on the measurements and analysis reported herein, existing third-adjacent channel distance restrictions should be waived to allow LPFM operation at locations that meet all other FCC requirements, subject to the stipulations below.

- No LPFM station should be licensed within x_{min} meters of any location that is likely to have a high density of receivers that lie within the FPFM protected area. The quantity x_{min} is defined as:

$$x_{\min} = \min\left\{ \frac{d^2 \lambda}{4\pi h_F h_R} \sqrt{\frac{\delta E_L}{E_F}}, d\left(\frac{\delta E_L h_L^2}{E_F h_F^2} \right)^{1/4} \right\} \quad (28)$$

  Here:

  d = the distance between the LPFM station and the FPFM station (meters)
  λ = the wavelength of either of the signals (meters)
  h_F = the HAAT of the FPFM transmitter antenna (meters)
  h_L = the height (AGL) of the LPFM transmitter (meters)
  h_R = the smallest likely height (AGL) of the receivers in the high density area (meters)
  E_L = the ERP of the low power transmitter (Watts)
  E_F = the ERP of the full power transmitter (Watts)
  δ = the third adjacent channel rejection (ratio of D/U) of the victim radio that is to be protected. For this calculation a value of 0.002 (-27 dB) shall be used, based on the measured vulnerability of RSVI receivers

  If the actual D/U ratio can be shown to be –15 dB or better (*i.e.*, more positive) at most locations in the area of high receiver density for a candidate LPFM transmitter site, then the proposed site may be used, even if it is closer then x_{min} meters from the area of high receiver density. This recommendation is believed to provide adequate protection to RSVI as well all non-RSVI receivers.

- No LPFM station with an ERP of P_{eu} dBW should operate within d_u kilometers of an FM translator receiver on the third adjacent channel, where d_u is defined in 5.1.2.

- Any LPFM applicant who is allowed to operate at a smaller distance than d_u kilometers from a third-adjacent-channel FM translator receiver should be required to perform preliminary interference testing and then to pay for any necessary mitigatory measures, such as a more selective bandpass filter for the translator receiver.

- The FCC should impose, for LPFM transmitters, a more stringent limit on third-adjacent-channel emissions than the –35 dBc that CFR Sec. 73.317 (c) currently allows at frequency offsets up to and including 600 kHz. The total energy emitted by the transmitter in the third adjacent channel, in the form of phase noise spread across the channel and/or discrete tones within the channel, should not exceed the level of -55 dBc that was emitted by the LPFM transmitter used in the analog field tests. However, the existing Sec. 73.317 (d) limitation of –43 dBW on discrete tones offset more than 600 kHz from the carrier should not be relaxed.

5.2.2 Listening Tests and Economic Analysis

The FCC should *not* undertake the additional expense of a formal listener test program or a Phase II economic analysis of the potential radio interference impact of LPFM on incumbent FPFM stations. Other economic impacts are outside the scope of this effort. Perceptible interference caused during the tests by temporary LPFM stations operating on third-adjacent channels occurred too seldom, especially outside the immediate vicinity of the sites where the stations were operating, to warrant the additional expense that those follow-on activities would entail.

Appendix A

FCC-Selected Candidate LPFM Test Locations

Table A-1. FCC-Selected Candidate LPFM Test Locations

FCC Record ID	City	State	Channel	Lat (N)	Long (W)	Map Name
BNPL20000830AAV	EAST BETHEL	MN	219	45-19-07	093-13-51	COON LAKE BEACH
BNPL20000605AHL	BRICELAND	CA	259	40-09-20	123-53-30	ETTERSBURG
BNPL20000605AMN	CALEXICO	CA	238	32-40-42	115-29-23	CALEXICO
BNPL20000605AGZ	CARMEL	CA	235	36-33-21	121-54-33	(CAL OVERSIZE)
BNPL20000602AID	CORONA	CA	288	33-51-02	117-29-56	LAKE MATTHEWS
BNPL20000605AFP	ELK GROVE	CA	289	38-26-54	121-20-09	ELK GROVE
BNPL20000605AKJ	HEMET	CA	245	33-45-23	116-56-41	SAN JACINTO
BNPL20000608AFY	NEEDLES	CA	269	34-49-14	114-36-43	NEEDLES
BNPL20000608ACO	OAKHURST	CA	263	37-18-29	119-37-15	BASS LAKE
BNPL20000602AFN	POINT ARENA	CA	287	38-54-41	123-41-37	POINT ARENA
BNPL20000605ACP	REEDLEY	CA	284	36-38-31	119-28-31	WAHTOKE
BNPL20000605ALC	UKIAH	CA	280	39-09-15	123-12-24	UKIAH
BNPL20000608AFU	SPRINGVILLE	CA	252	36-17-14	118-50-17	DENNISON PEAK
BNPL20000605AGD	SHASTA LAKE	CA	231	40-40-49	122-22-08	PROJECT CITY
BNPL20000602AHO	SALINAS	CA	242	36-41-18	121-33-18	NATIVIDAD
BNPL20000605AKT	WINTERS	CA	276	38-31-18	121-58-10	WINTERS
BNPL20000608ABD	SAN MIGUEL	CA	254	35-45-11	120-41-58	SAN MIGUEL
BNPL20000605AED	CLEARLAKE	CA	230	38-57-13	122-38-32	CLEAR LAKE HIGHLANDS
BNPL20000531AAP	CAMBRIA	CA	300	35-32-57	121-04-30	CAMBRIA
BNPL20000608ACJ	VICTORVILLE	CA	300	34-52-00	117-04-54	BARSTOW SE
BNPL20000605AEL	SUMMERLAND	CA	281	34-25-29	119-32-55	CARPINTERIA
BNPL20000602AEN	LAGRANGE	CA	263	37-39-45	120-27-15	LA GRANGE
BNPL20000606AAZ	EL DORADO	CA	248	38-39-27	120-56-18	SHINGLE SPRINGS
BNPL20000831ADT	GUILFORD	CT	251	41-16-58	072-40-49	GUILFORD
BNPL20000608AFE	MORENO VALLEY	CA	297	33-54-38	117-05-39	EL CASCO
BNPL20000531ACY	BENICIA	CA	262	38-06-18	122-05-11	VINE HILL
BNPL20000605AJN	BAKERSFIELD	CA	265	35-21-08	119-01-19	GOSFORD
BNPL20000901AEL	AVON	CT	298	41-46-49	072-52-35	AVON
BNPL20000901AGF	TORRINGTON	CT	253	41-49-18	073-04-36	TORRINGTON
BNPL20000901AHA	UNCASVILLE	CT	246	41-28-05	072-06-00	UNCASVILLE
BNPL20000606ABG	BRUNSWICK	ME	247	43-53-42	069-59-52	BRUNSWICK
BNPL20000901AHI	OWATONNA	MN	292	44-06-28	093-12-42	OWATONNA
BNPL20000828ACU	ROUND LAKE	MN	296	43-32-25	095-28-05	ROUND LAKE

FCC Record ID	City	State	Channel	Lat (N)	Long (W)	Map Name
BNPL20000830ACE	STILLWATER	MN	284	45-03-36	092-48-50	STILLWATER
BNPL20000830AAB	CANDIA	NH	269	43-03-41	071-16-50	CANDIA
BNPL20000901AEJ	DOVER	NH	278	43-11-42	070-52-30	DOVER WEST
BNPL20000901AEK	PORTSMOUTH	NH	268	43-04-33	070-45-37	PORTSMOUTH
BNPL20000830AAS	FALLON	NV	241	39-28-04	118-46-24	FALLON
BNPL20000608ACM	WESTERLY	RI	296	41-21-16	071-46-12	WATCH HILL

Appendix B

Terrain Profiles

The following figures show terrain profiles from LPFM sites and associated FPFM stations to measurement locations 3 through 8. For Owatonna, MN translator input test terrain profiles are shown from the translator station to measurement locations 1 and 2 and from LPFM site to the translator station.

Profiles were generated using digitized 3-second terrain database. For the short paths between the LPFM antenna and the test locations, quantization of the database is evident in the profiles.

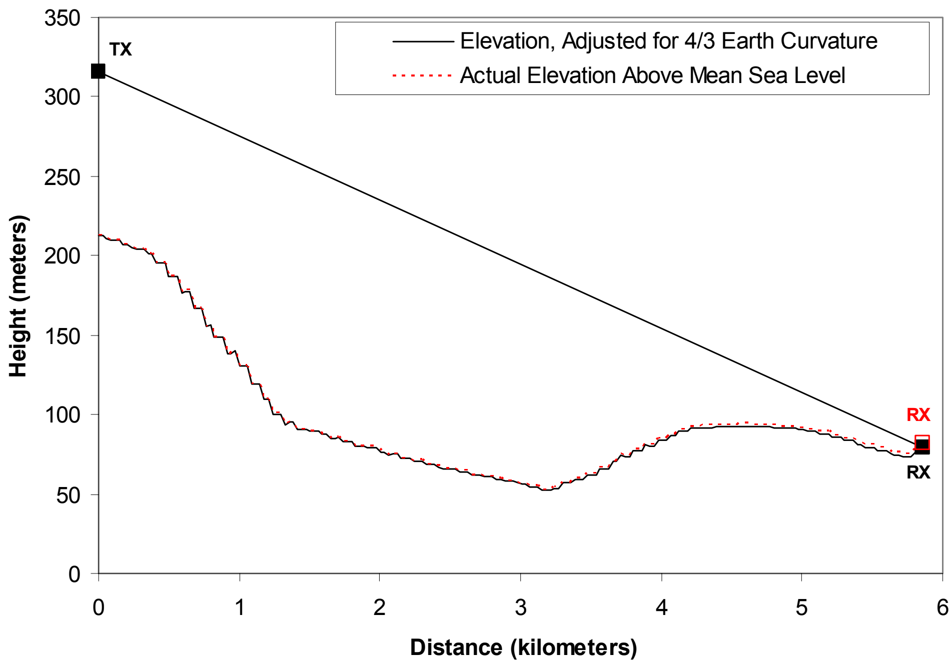


Figure B-1. Path Profile: WCCC (FPFM) to Avon Location 3

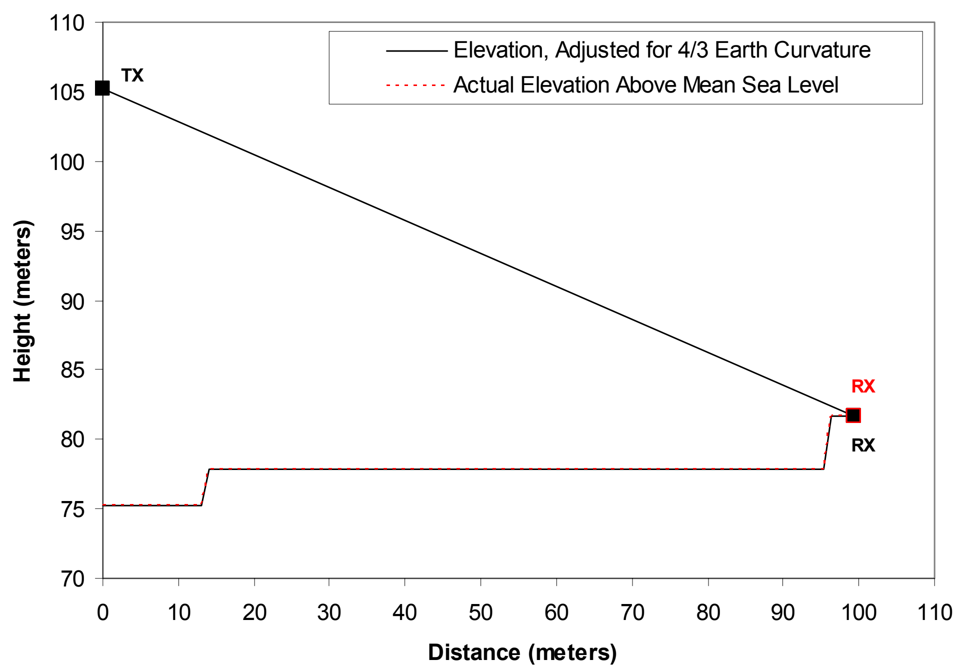


Figure B-2. Path Profile: LPFM to Avon Location 3

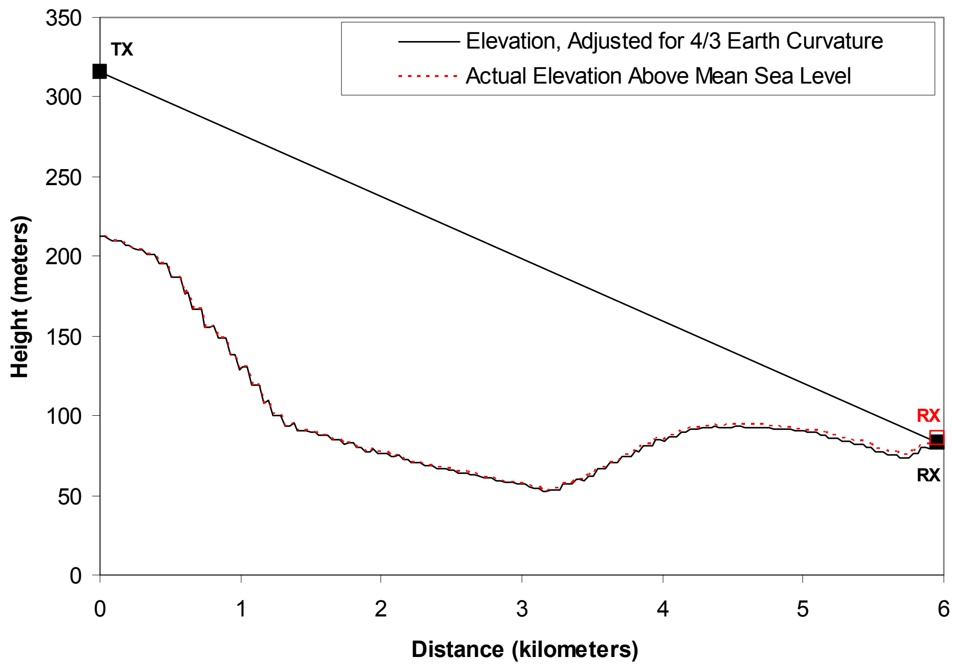


Figure B-3. Path Profile: WCCC (FPFM) to Avon Location 4

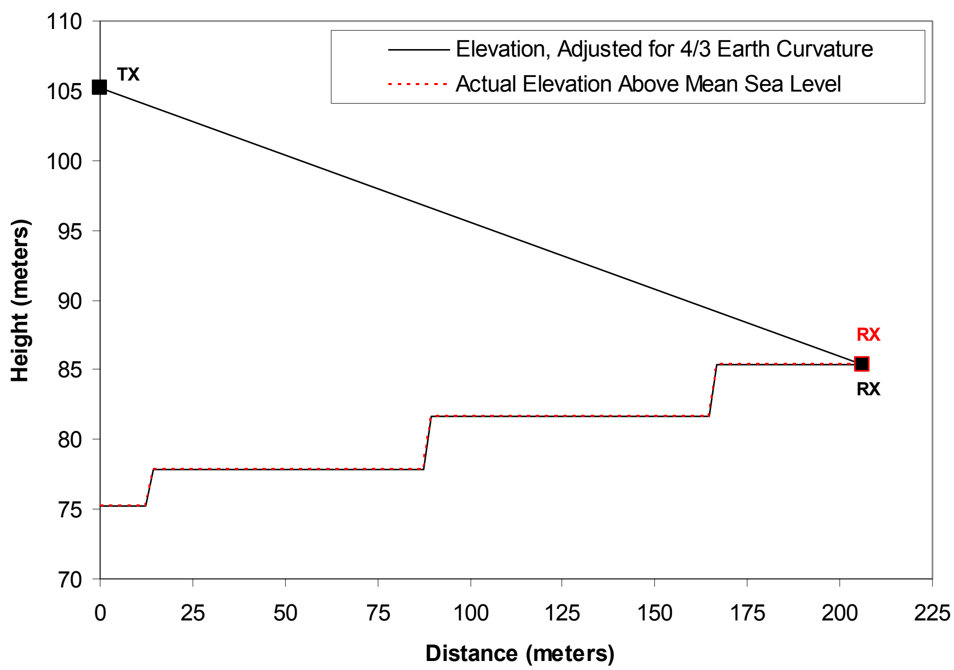


Figure B-4. Path Profile: LPFM to Avon Location 4

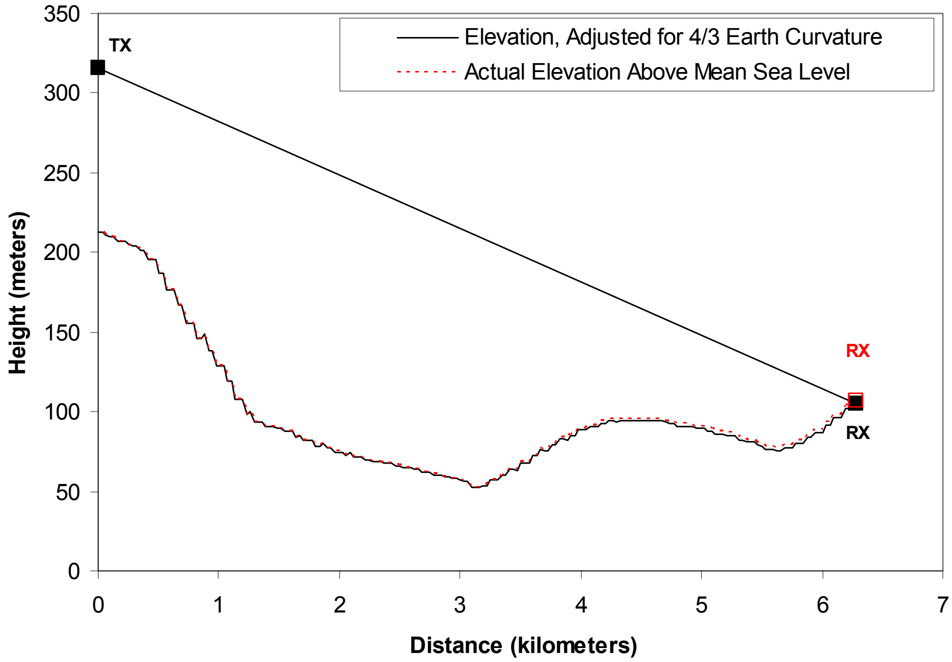


Figure B-5. Path Profile: WCCC (FPFM) to Avon Location 5

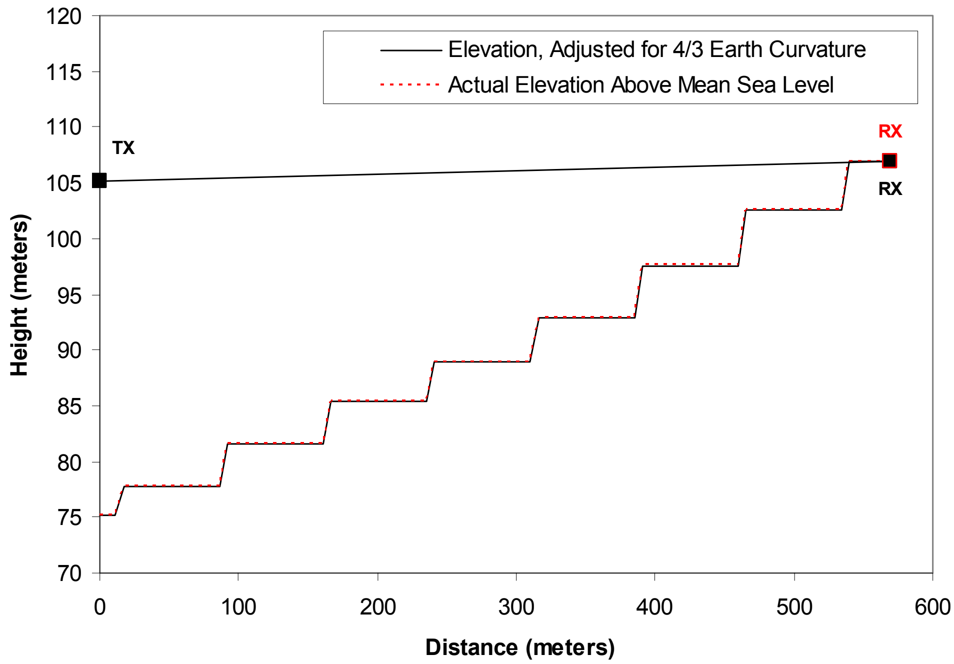


Figure B-6. Path Profile: LPFM to Avon Location 5

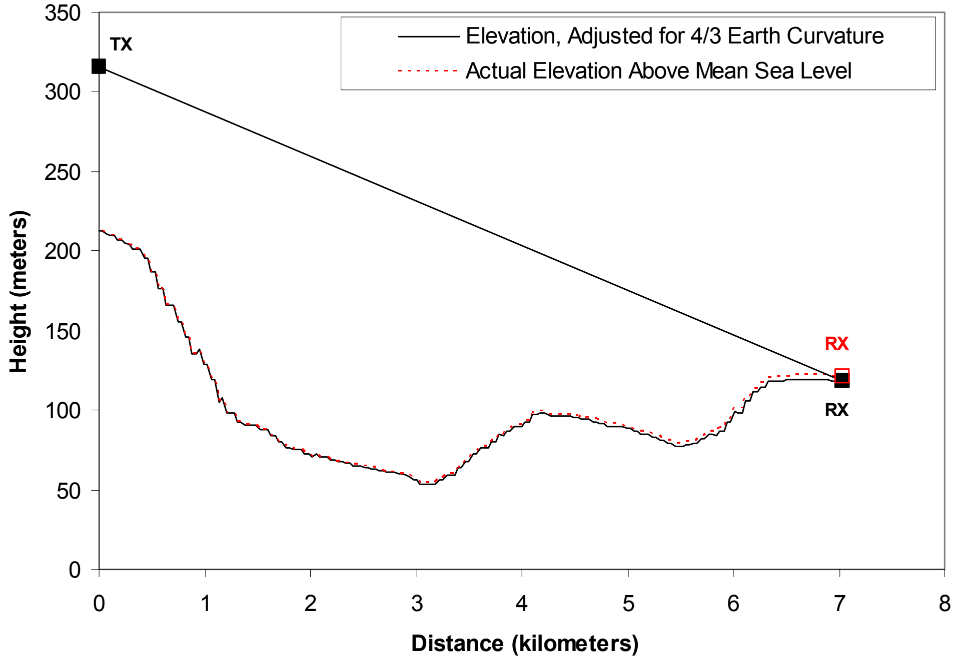


Figure B-7. Path Profile: WCCC (FPFM) to Avon Location 6

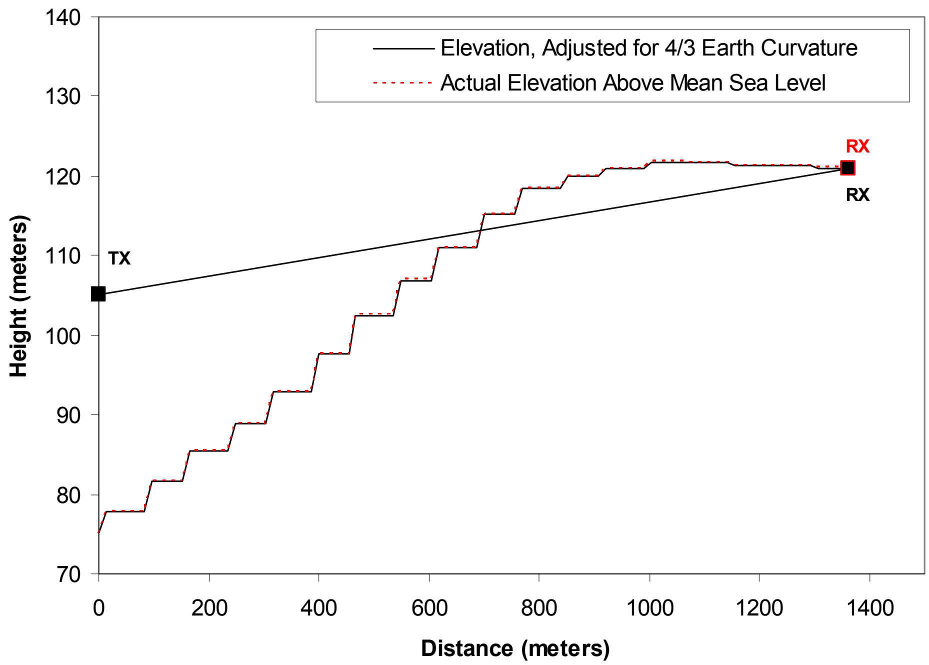


Figure B-8. Path Profile: LPFM to Avon Location 6

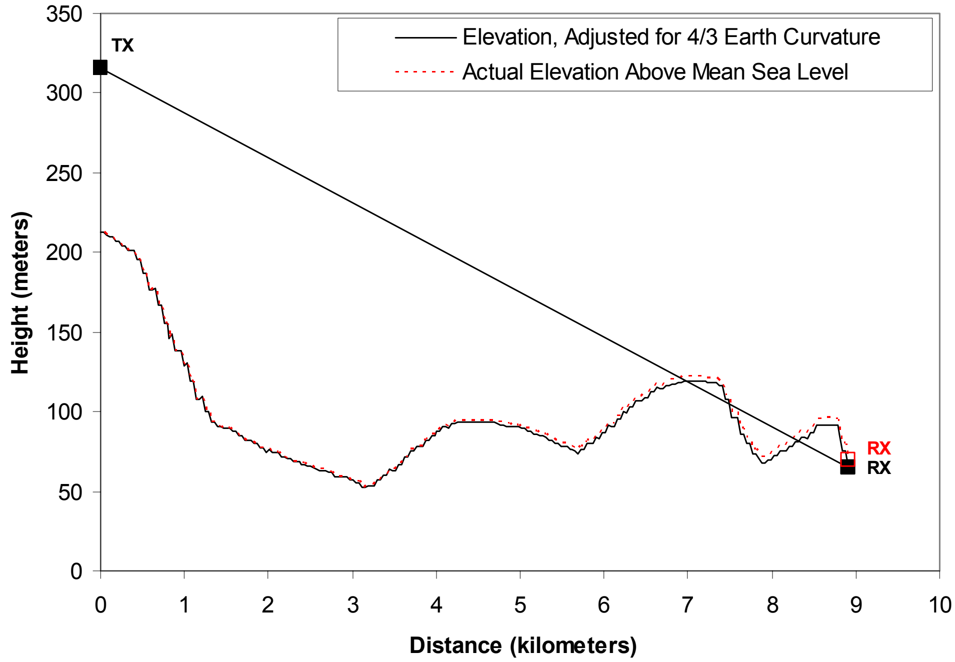


Figure B-9. Path Profile: WCCC (FPFM) to Avon Location 7

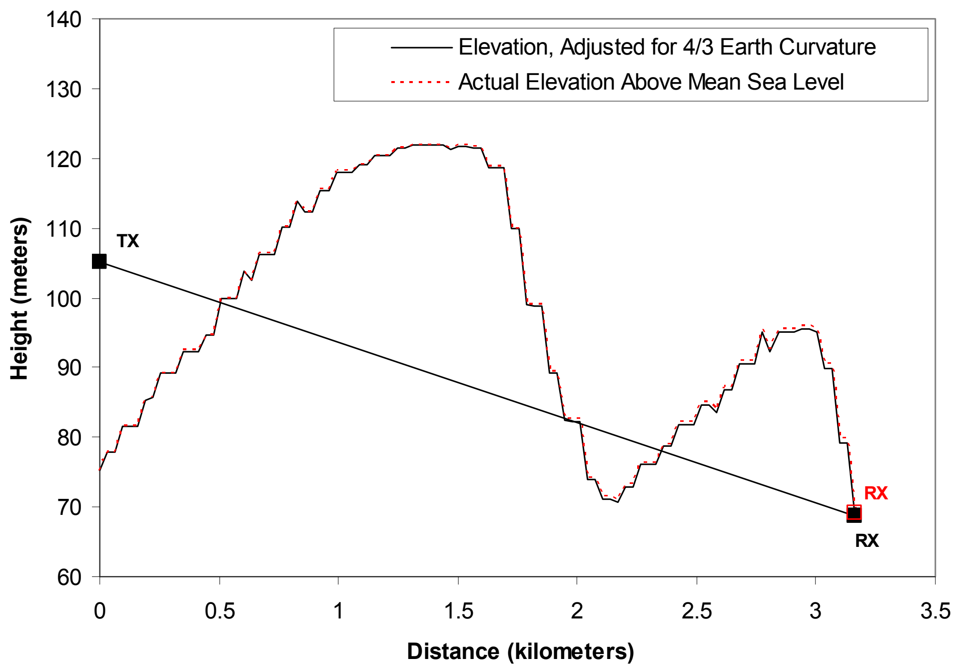


Figure B-10. Path Profile: LPFM to Avon Location 7

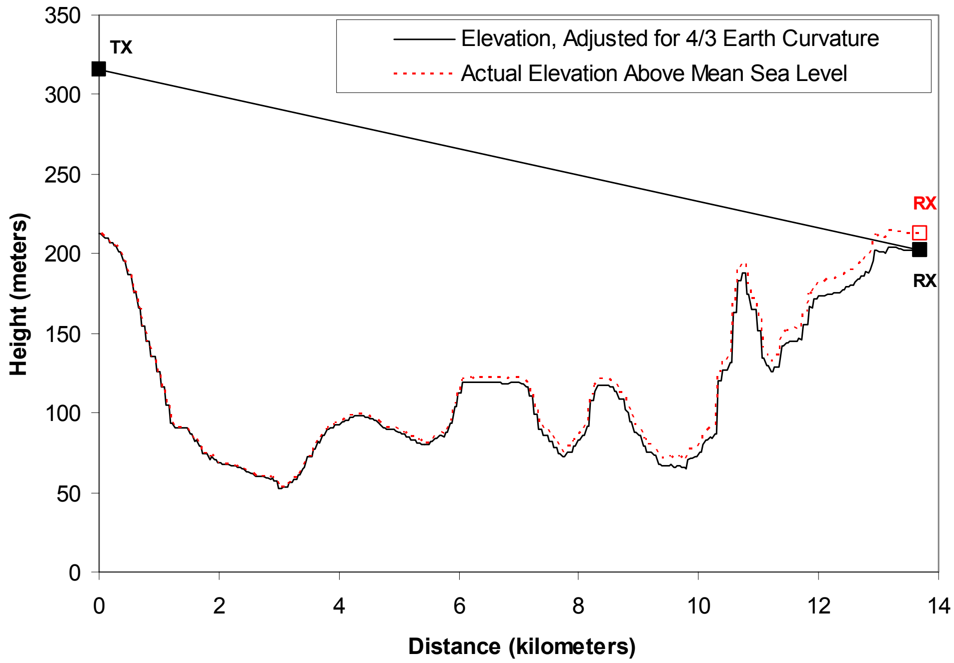


Figure B-11. Path Profile: WCCC (FPFM) to Avon Location 8

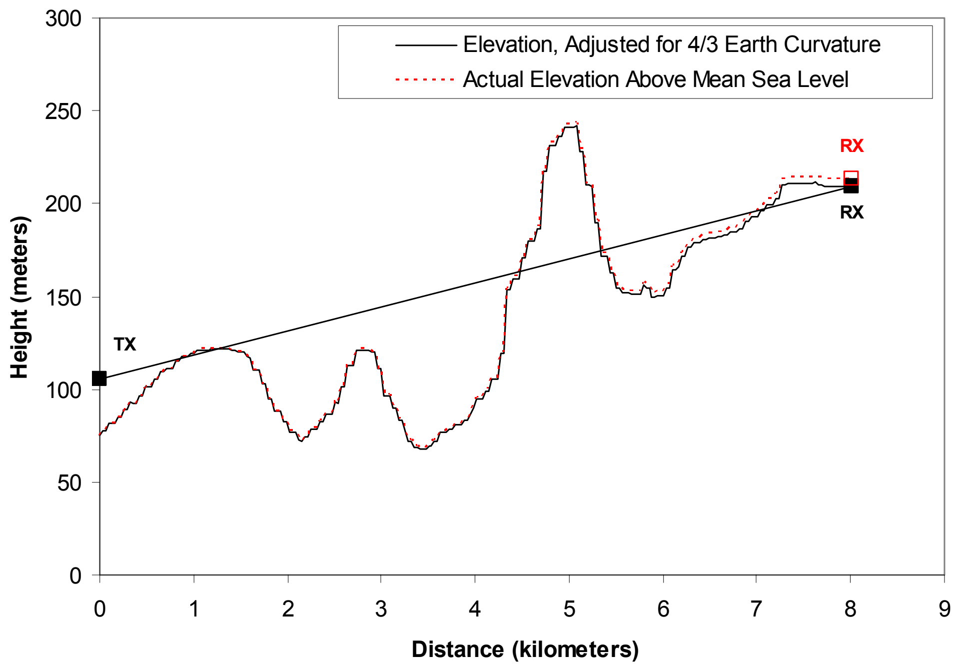


Figure B-12. Path Profile: LPFM to Avon Location 8

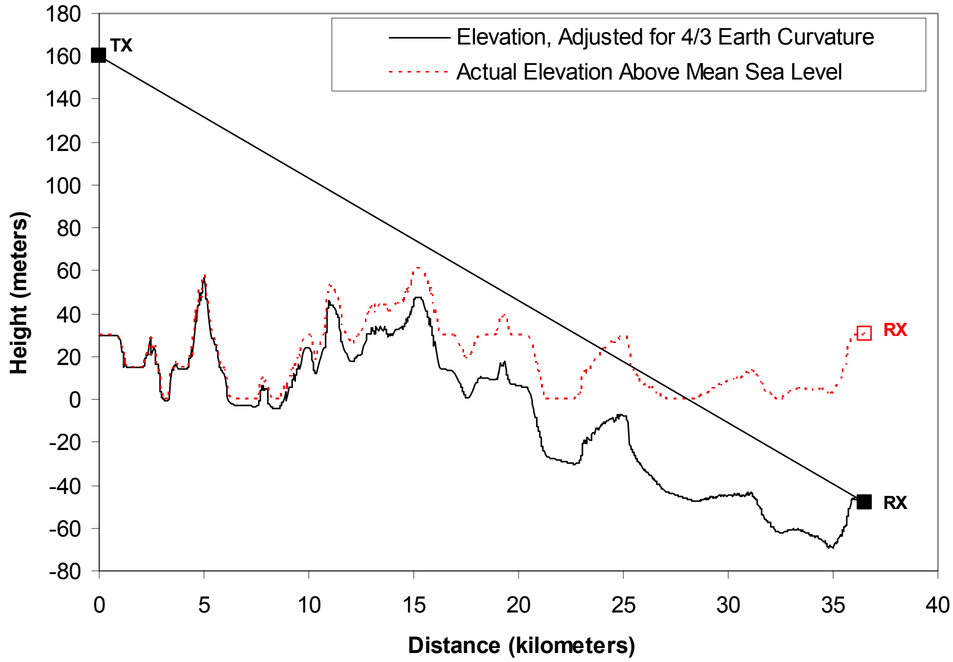


Figure B-13. Path Profile: WCME (FPFM) to Brunswick Location 3

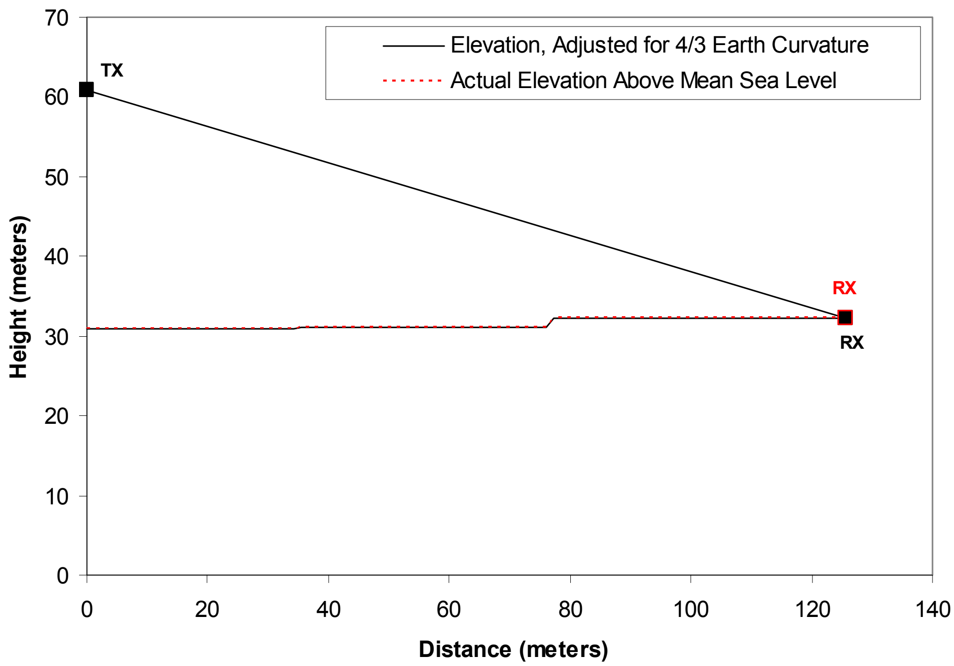


Figure B-14. Path Profile: LPFM to Brunswick Location 3

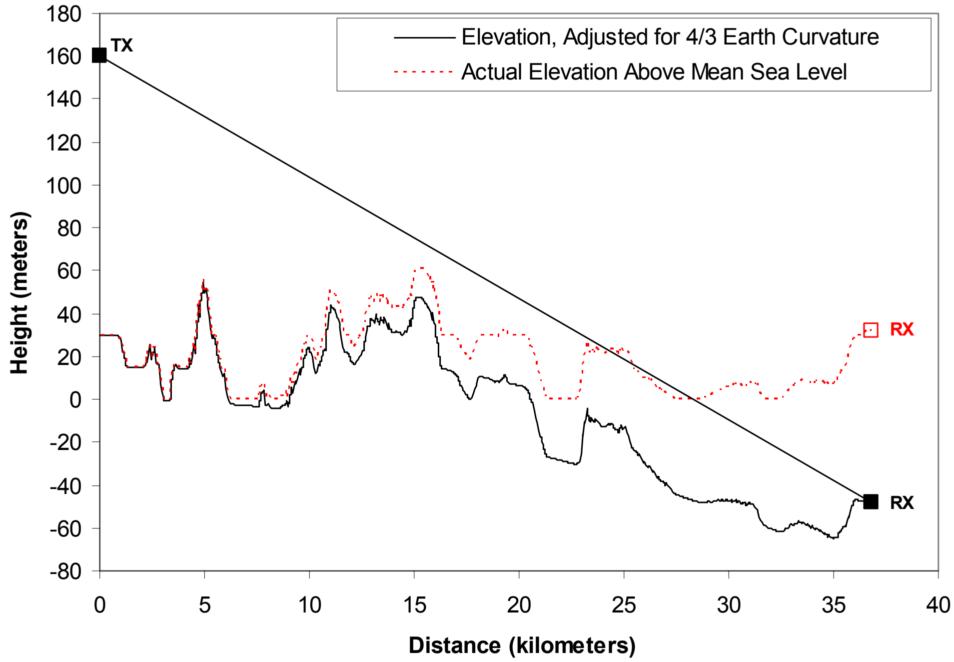


Figure B-15. Path Profile: WCME (FPFM) to Brunswick Location 4

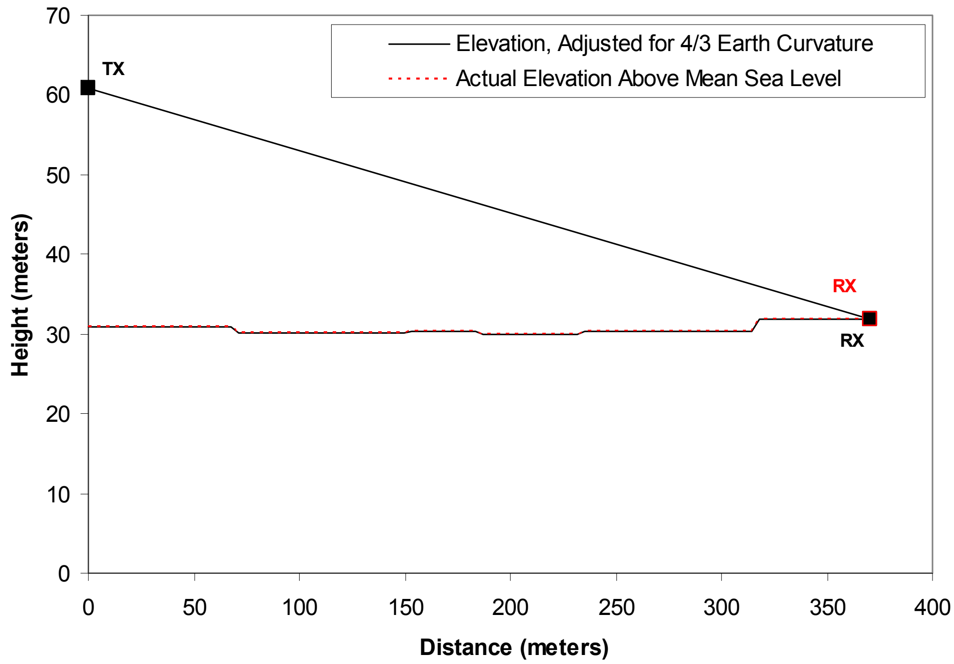


Figure B-16. Path Profile: LPFM to Brunswick Location 4

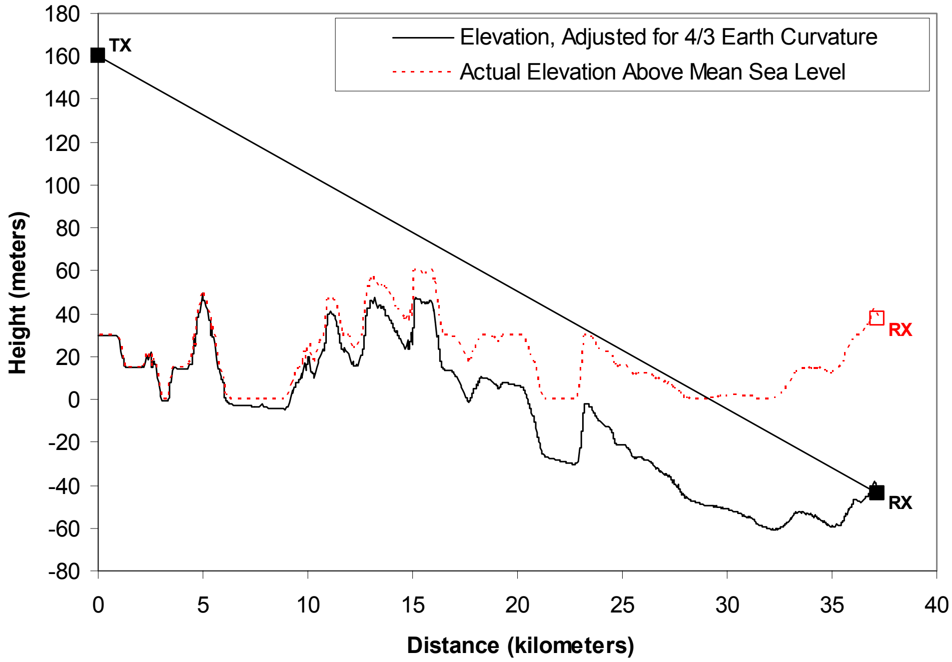


Figure B-17. Path Profile: WCME (FPFM) to Brunswick Location 5

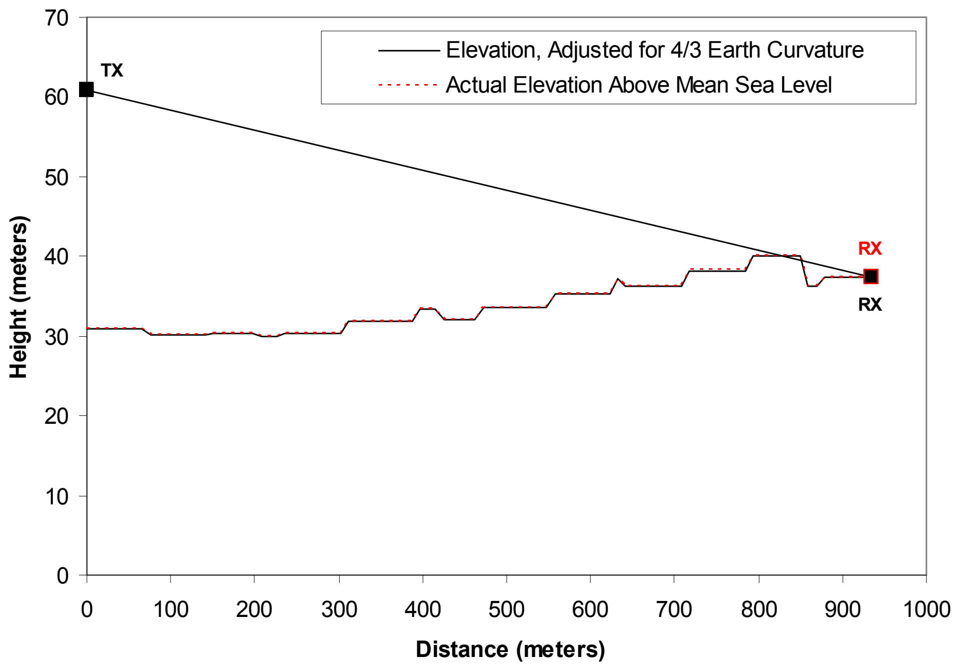


Figure B-18. Path Profile: LPFM to Brunswick Location 5

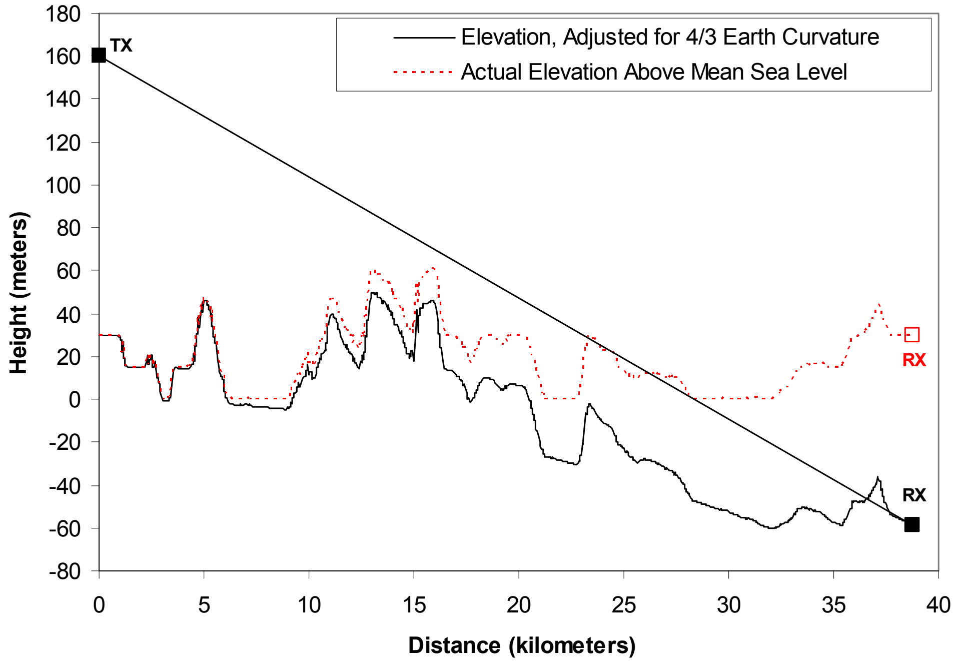


Figure B-19. Path Profile: WCME (FPFM) to Brunswick Location 6

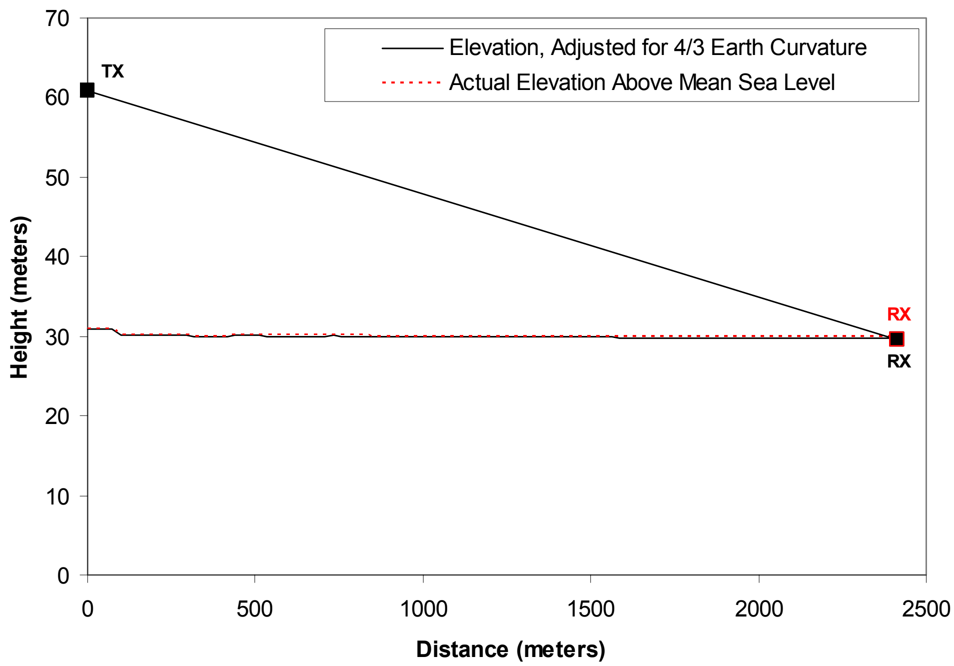


Figure B-20. Path Profile: LPFM to Brunswick Location 6

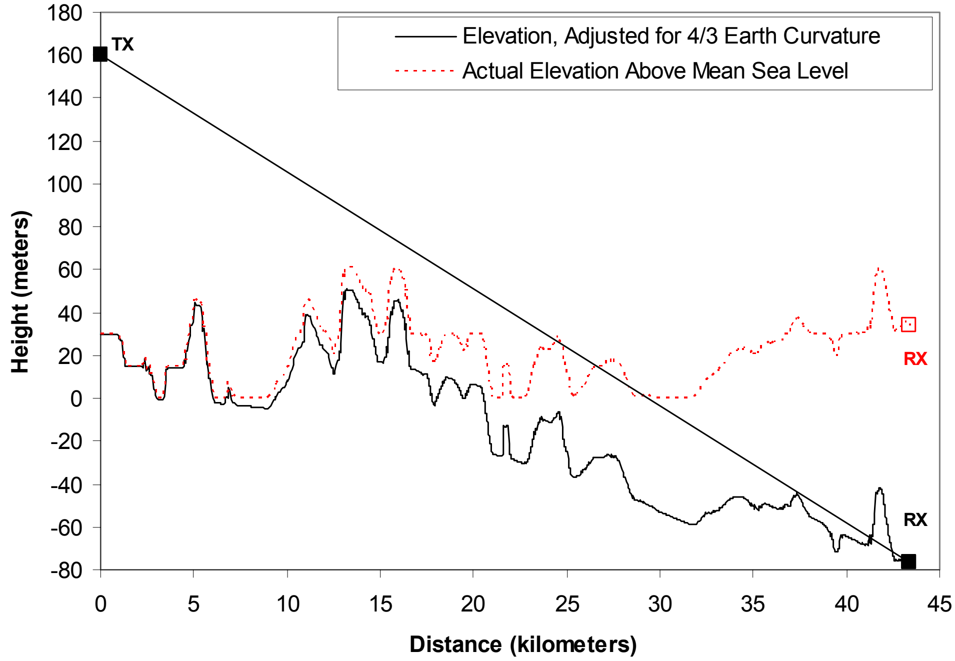


Figure B-21. Path Profile: WCME (FPFM) to Brunswick Location 7

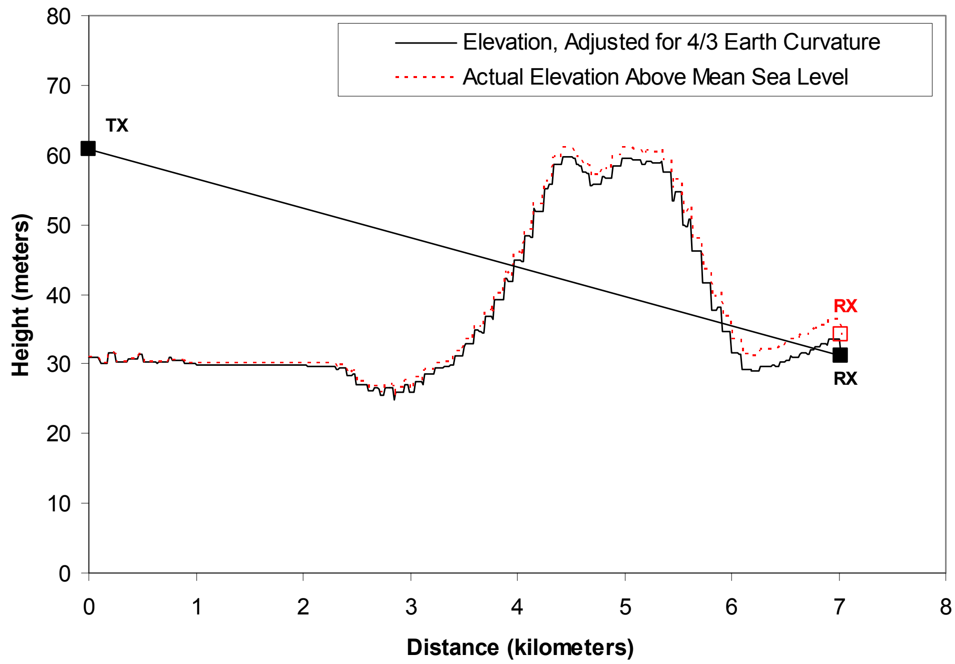


Figure B-22. Path Profile: LPFM to Brunswick Location 7

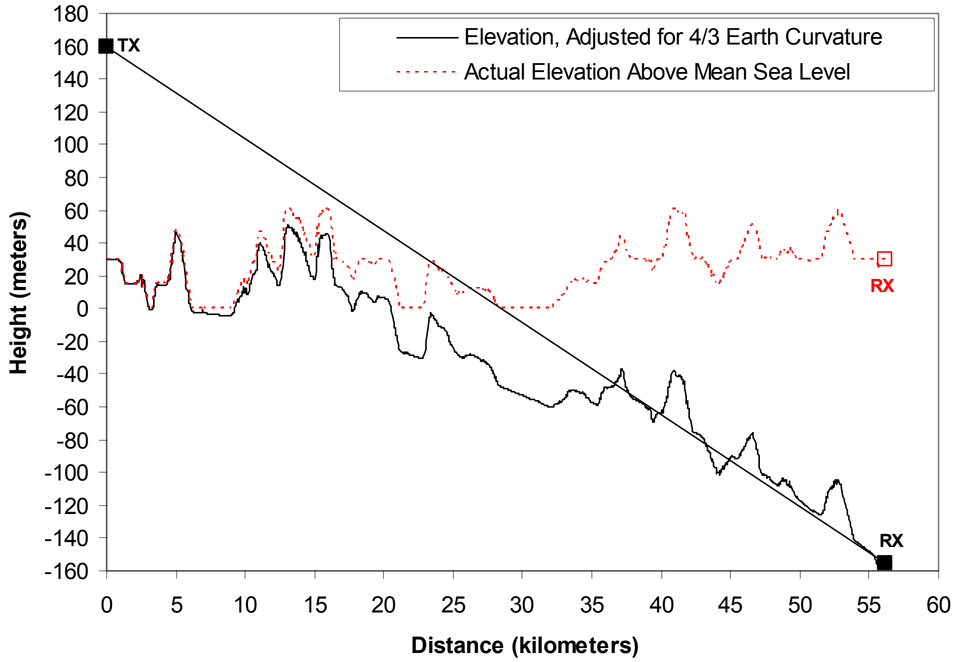


Figure B-23. Path Profile: WCME (FPFM) to Brunswick Location 8

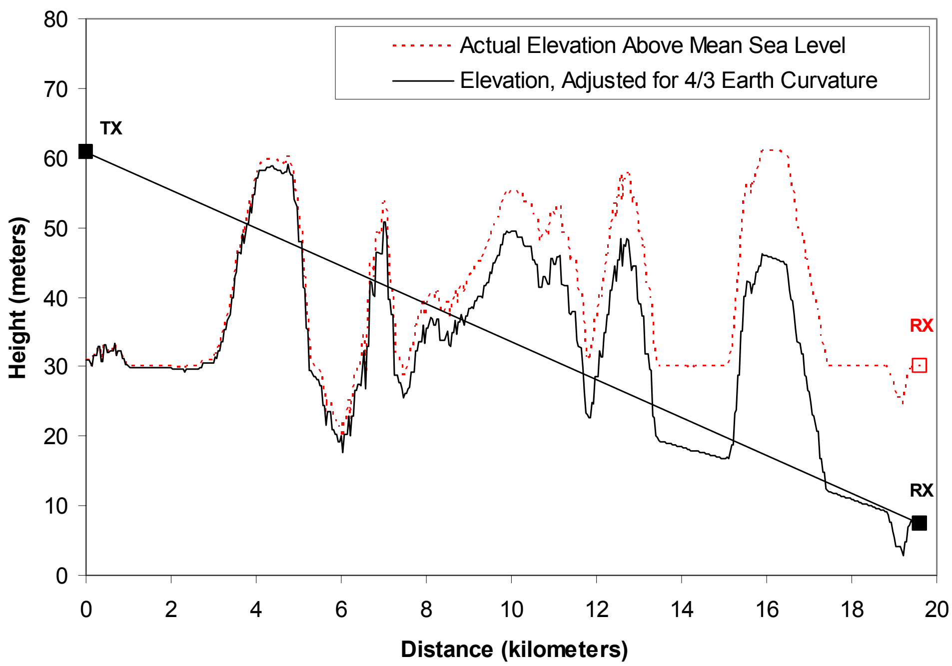


Figure B-24. Path Profile: LPFM to Brunswick Location 8

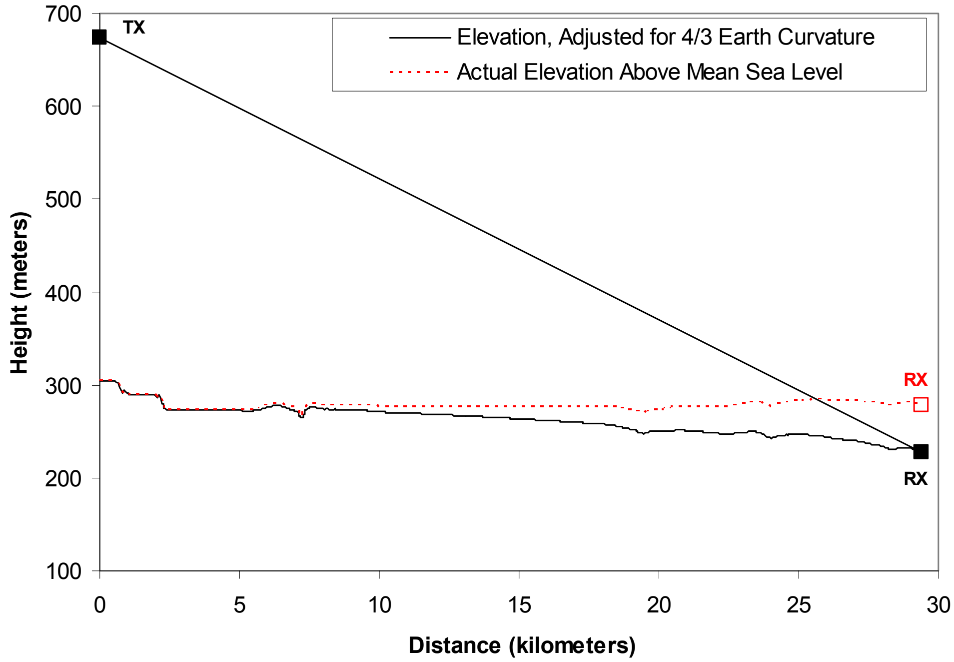


Figure B-25. Path Profile: KNOW-FM (FPFM) to East Bethel Location 3

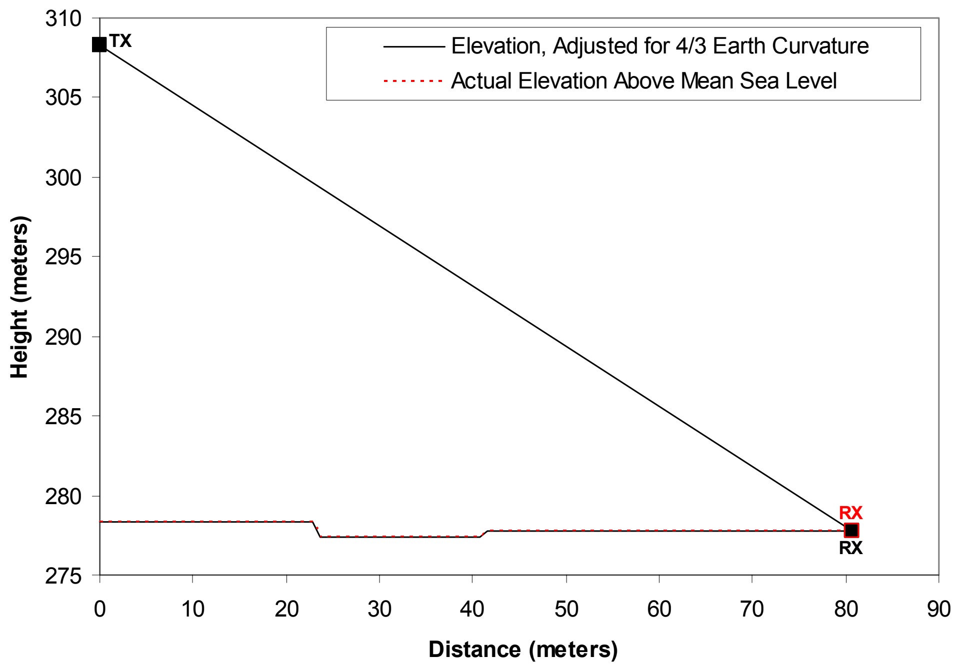


Figure B-26. Path Profile: LPFM to East Bethel Location 3

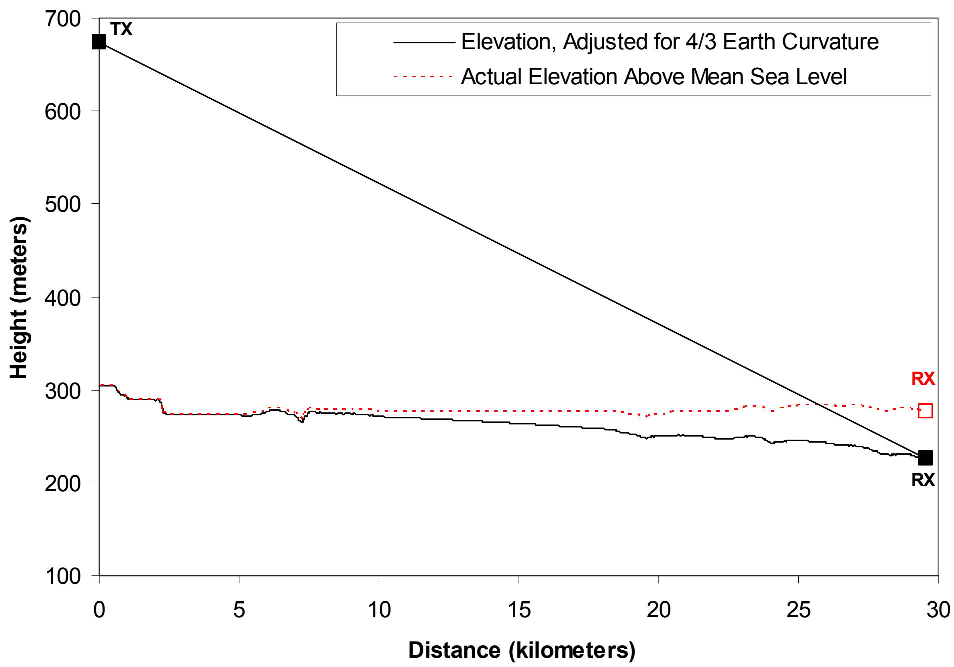


Figure B-27. Path Profile: KNOW-FM (FPFM) to East Bethel Location 4

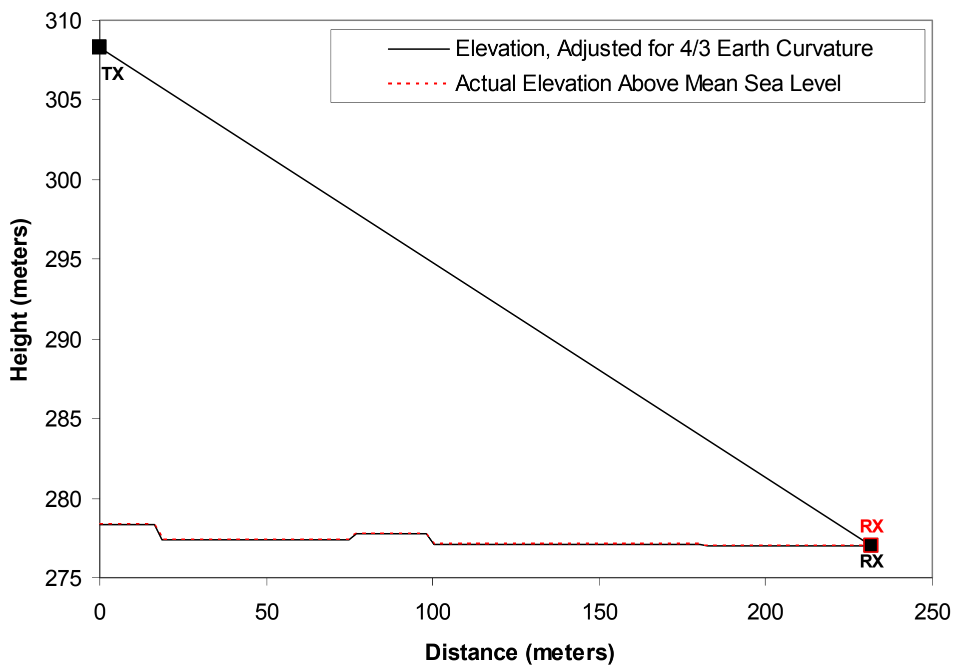


Figure B-28. Path Profile: LPFM to East Bethel Location 4

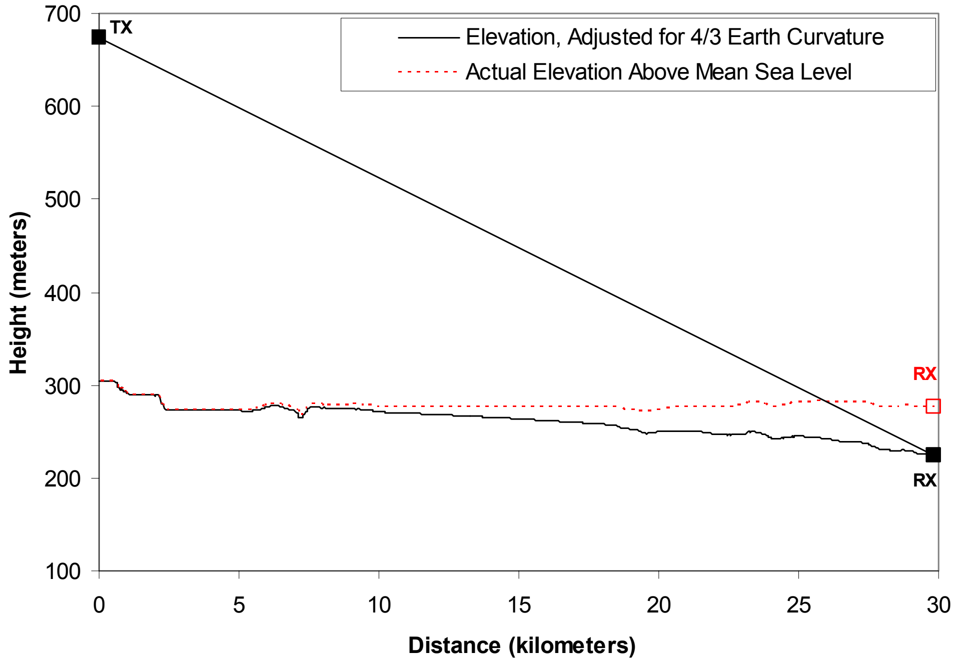


Figure B-29. Path Profile: KNOW-FM (FPFM) to East Bethel Location 5

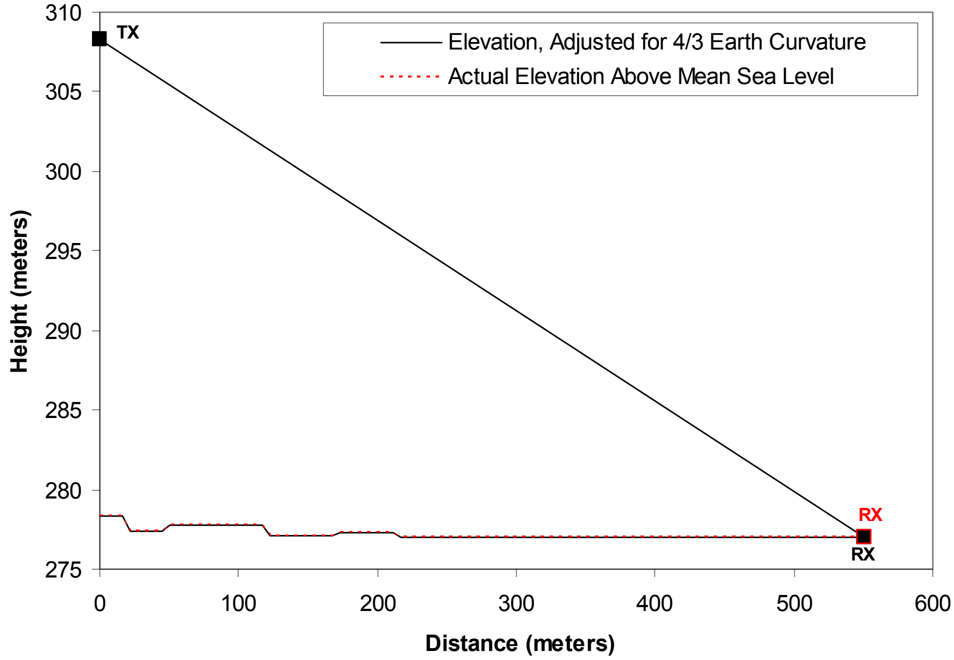


Figure B-30. Path Profile: LPFM to East Bethel Location 5

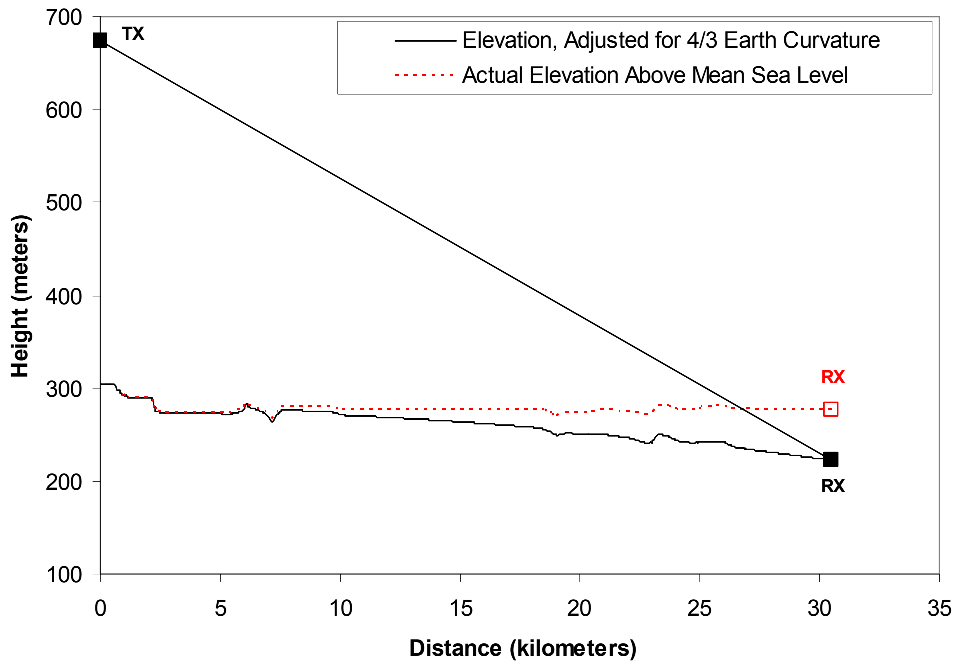


Figure B-31. Path Profile: KNOW-FM (FPFM) to East Bethel Location 6

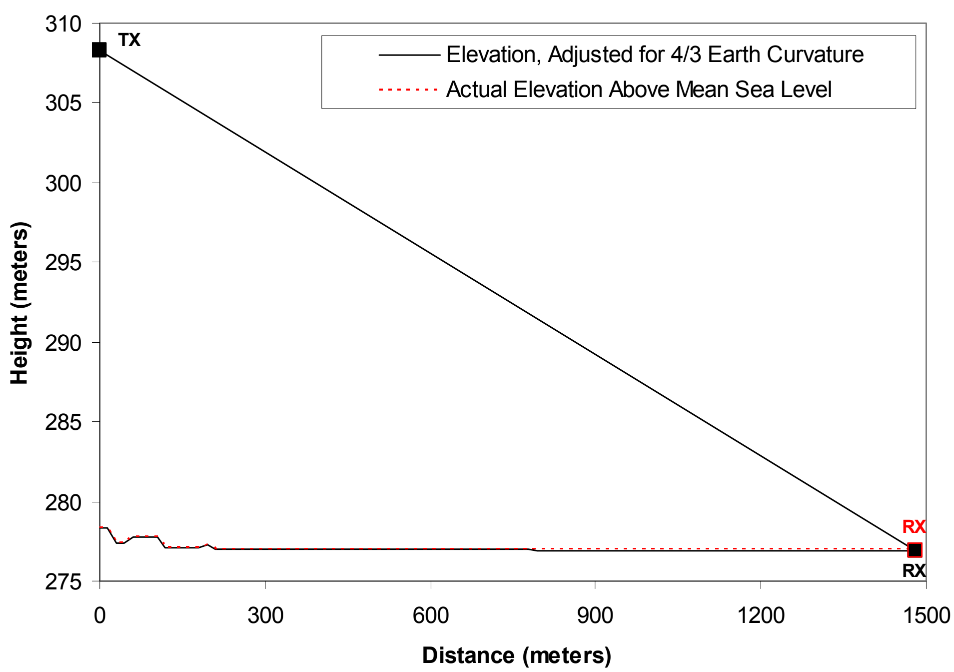


Figure B-32. Path Profile: LPFM to East Bethel Location 6

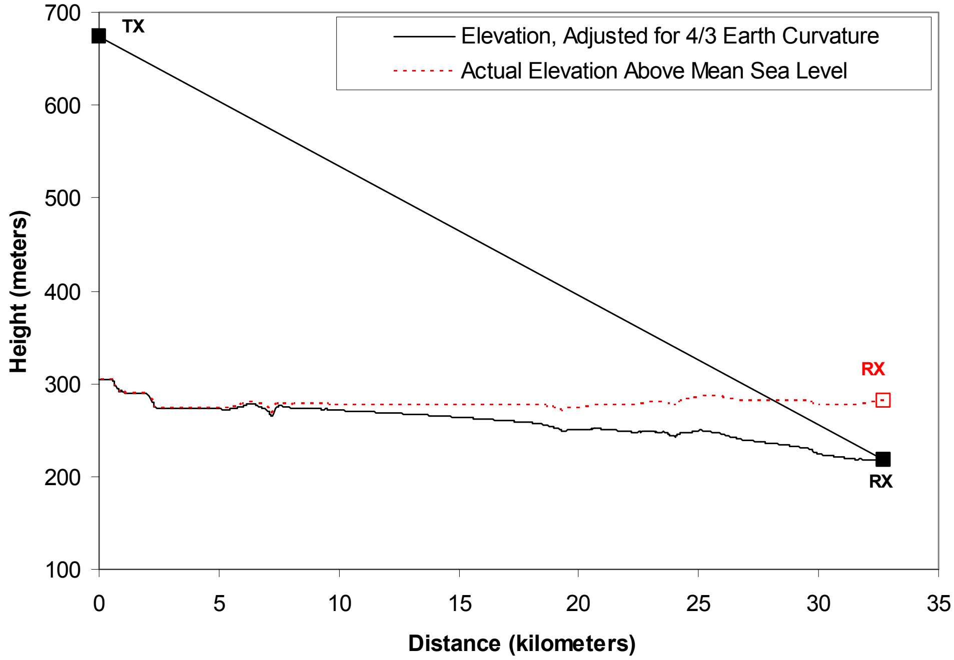


Figure B-33. Path Profile: KNOW-FM (FPFM) to East Bethel Location 7

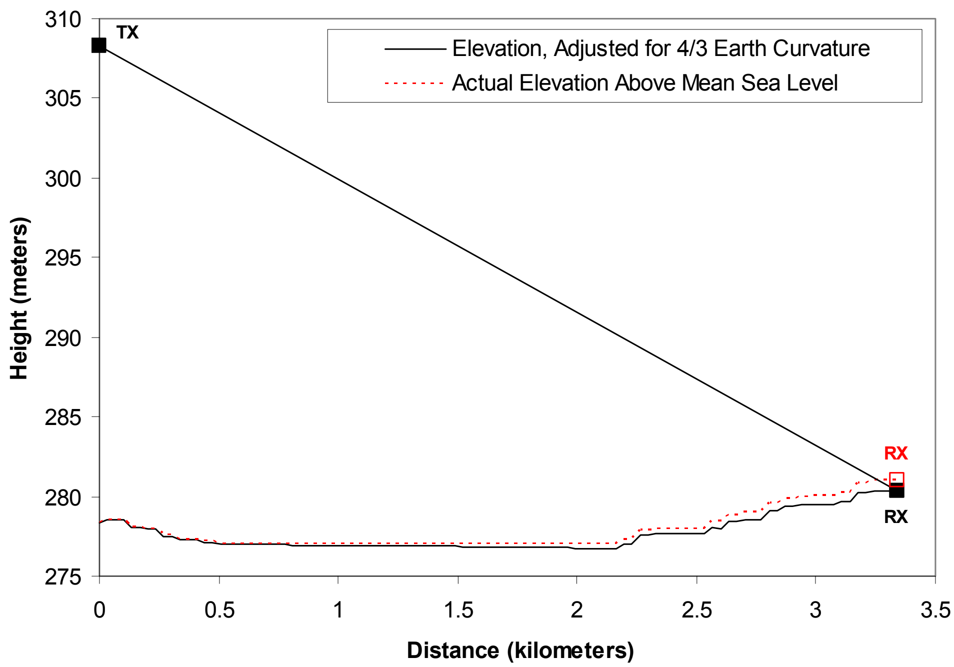


Figure B-34. Path Profile: LPFM to East Bethel Location 7

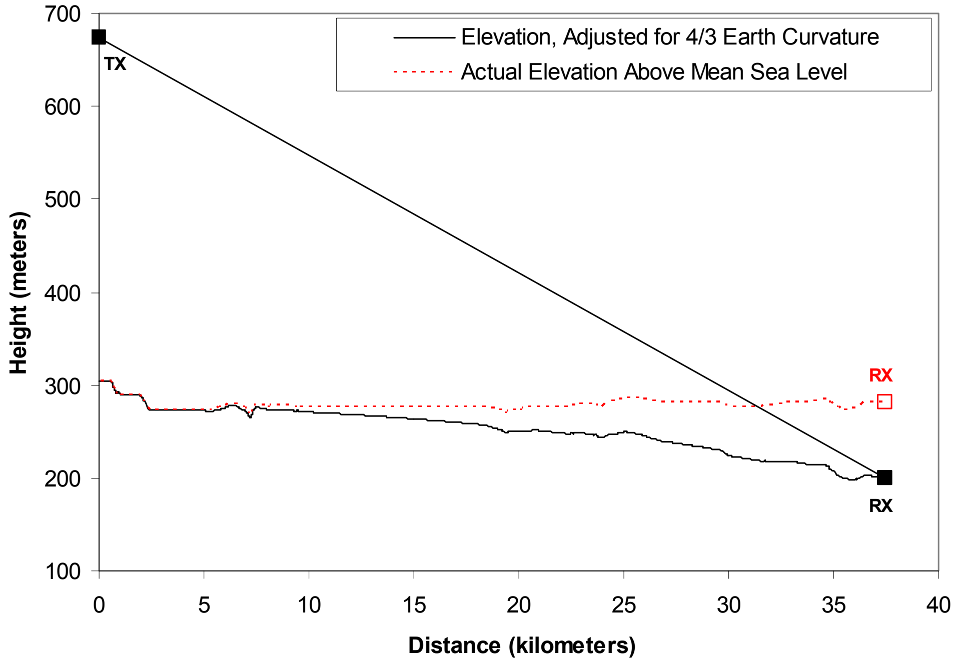


Figure B-35. Path Profile: KNOW-FM (FPFM) to East Bethel Location 8

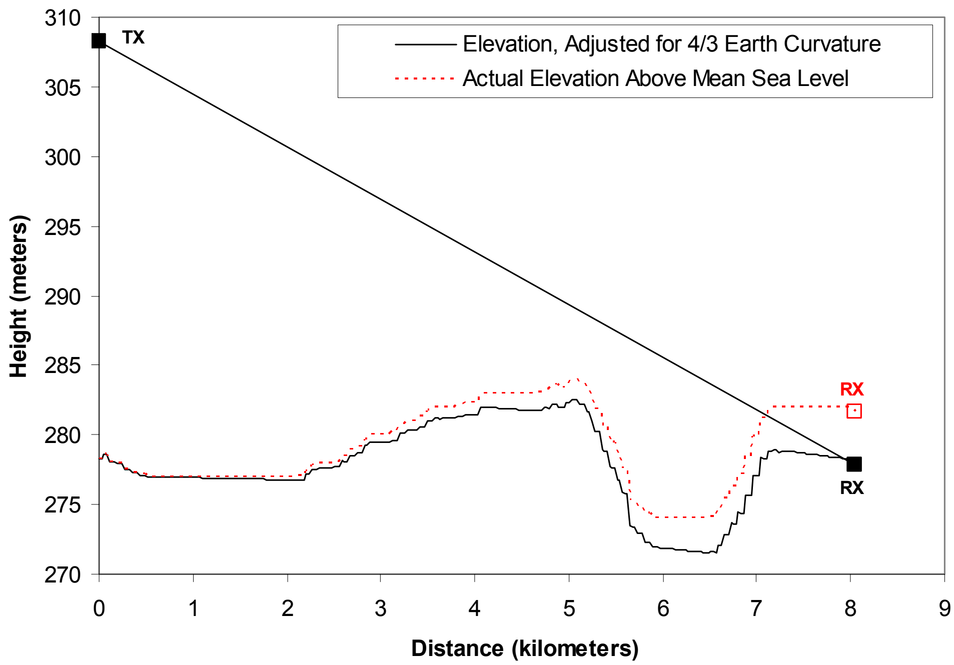


Figure B-36. Path Profile: LPFM to East Bethel Location 8

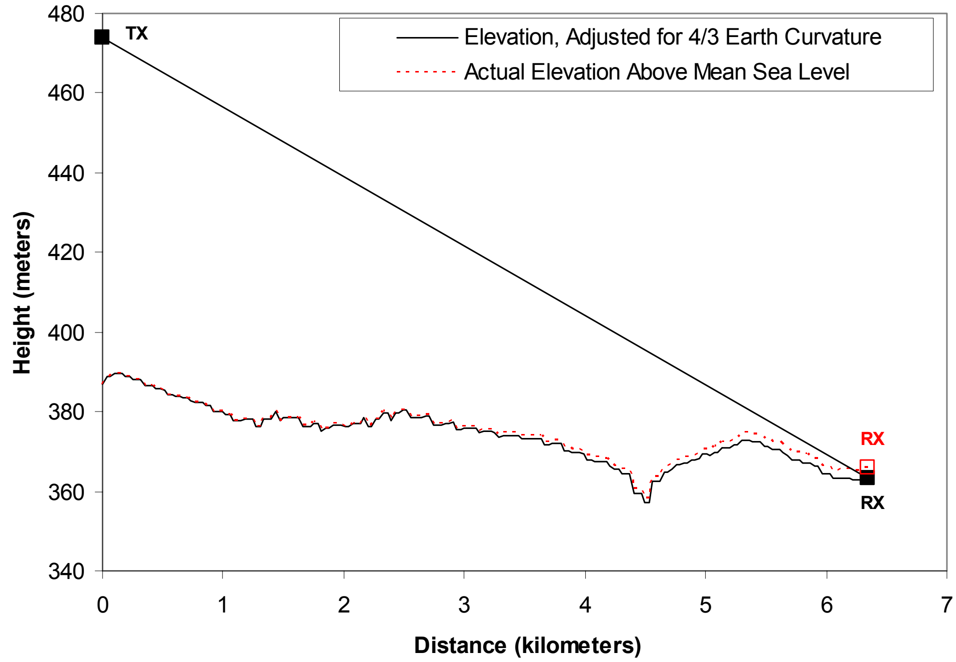


Figure B-37. Path Profile: K289AE (FPFM) to Owatonna Location 3

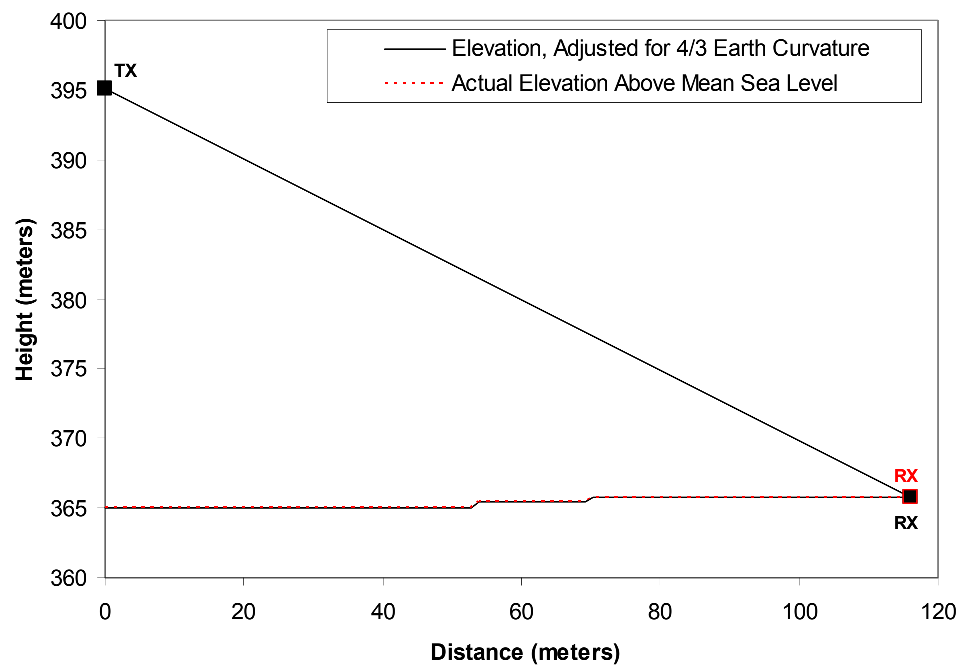


Figure B-38. Path Profile: LPFM to Owatonna Location 3

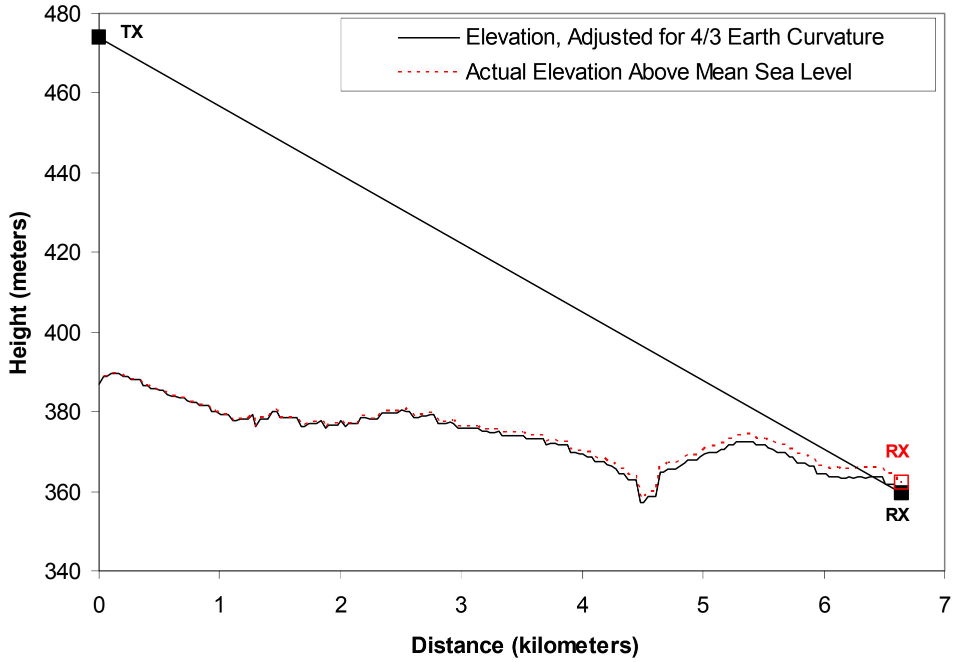


Figure B-39. Path Profile: K289AE (FPFM) to Owatonna Location 4

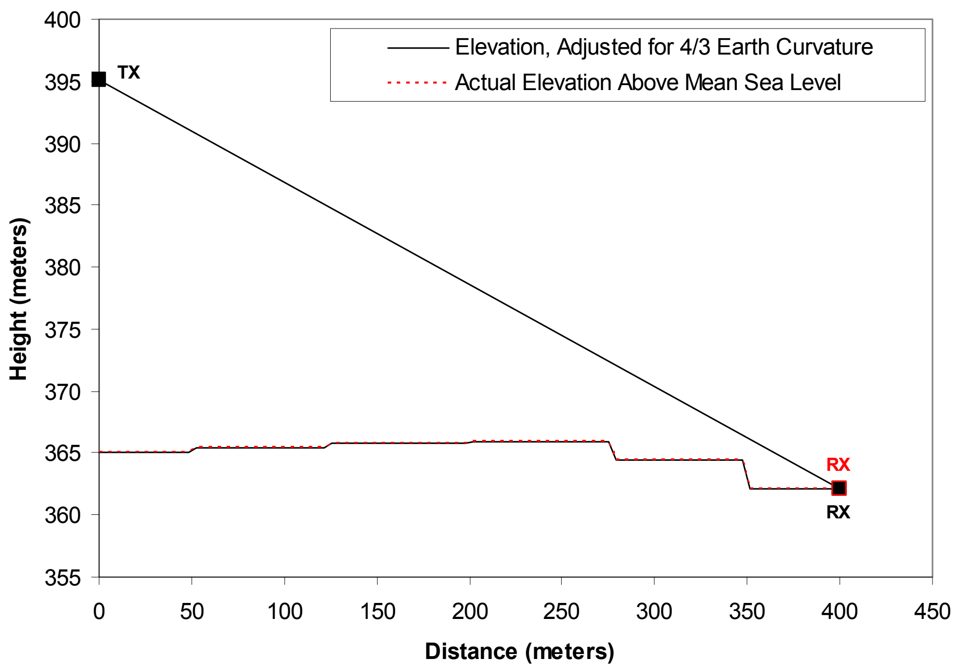


Figure B-40. Path Profile: LPFM to Owatonna Location 4

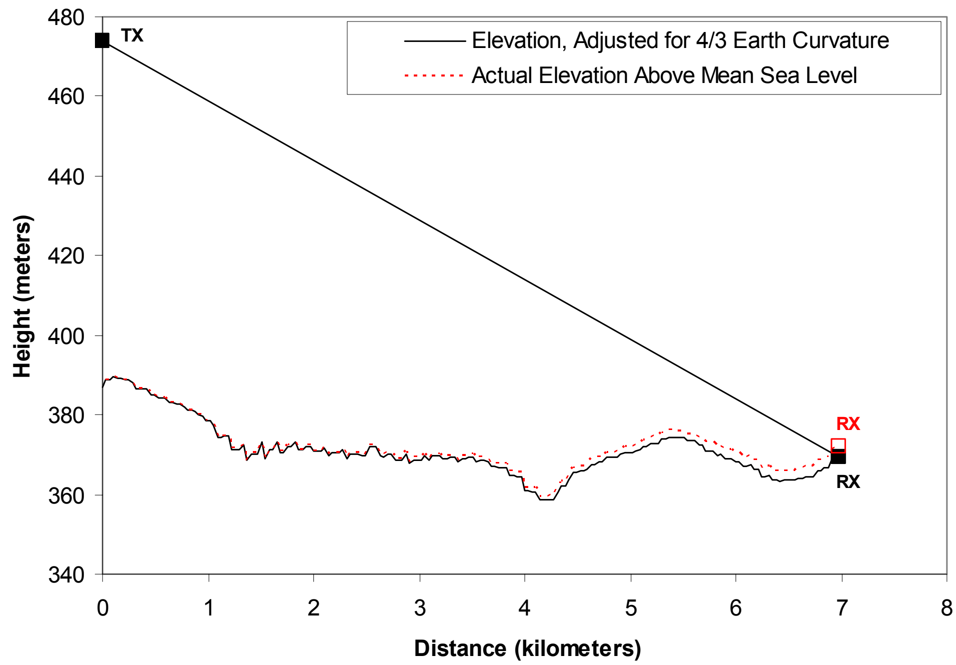


Figure B-41. Path Profile: K289AE (FPFM) to Owatonna Location 5

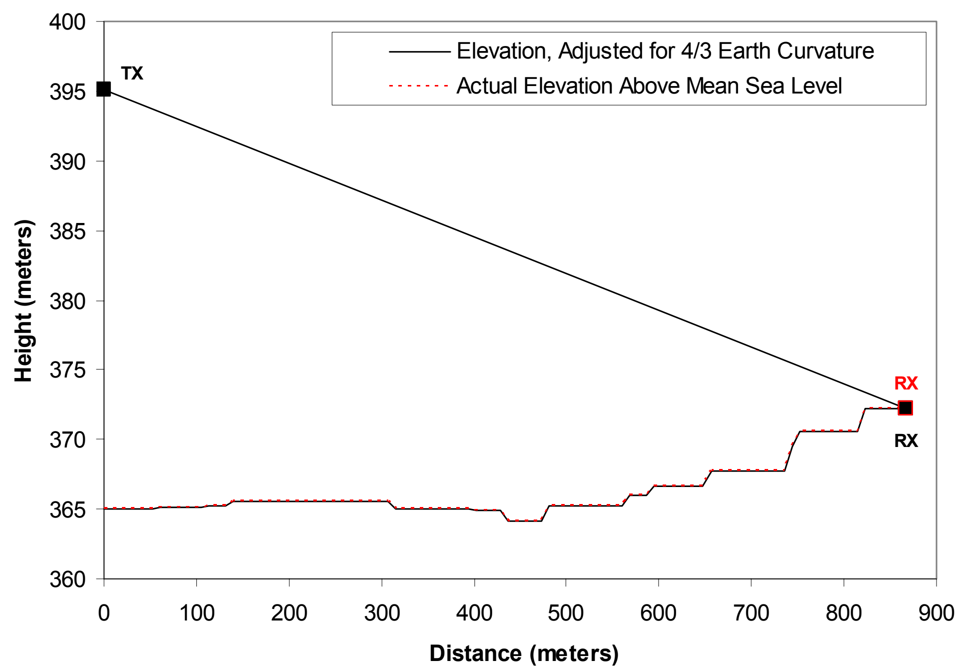


Figure B-42. Path Profile: LPFM to Owatonna Location 5

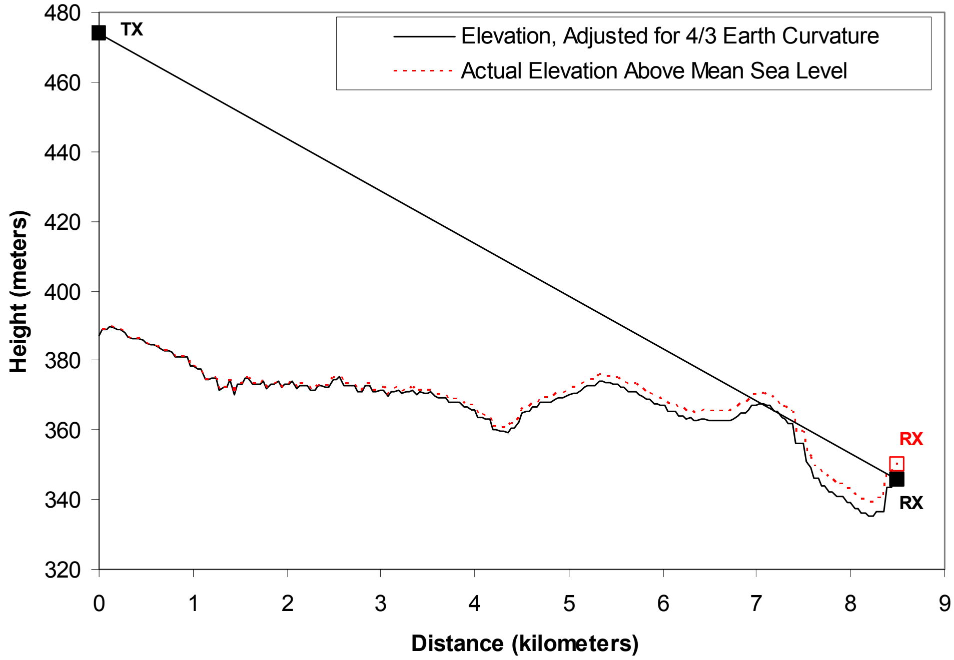


Figure B-43. Path Profile: K289AE (FPFM) to Owatonna Location 6

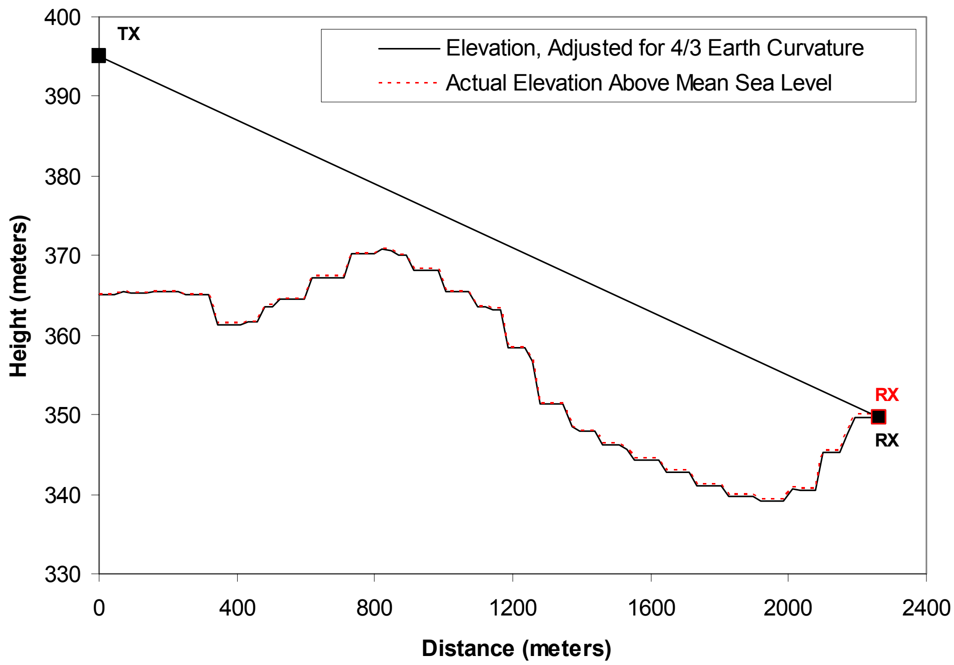


Figure B-44. Path Profile: LPFM to Owatonna Location 6

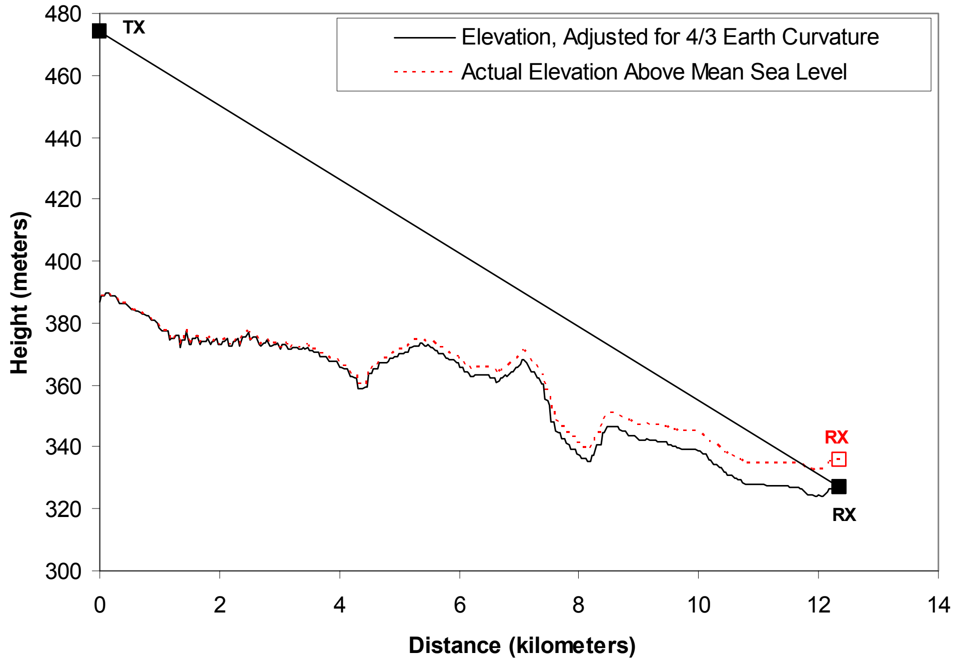


Figure B-45. Path Profile: K289AE (FPFM) to Owatonna Location 7

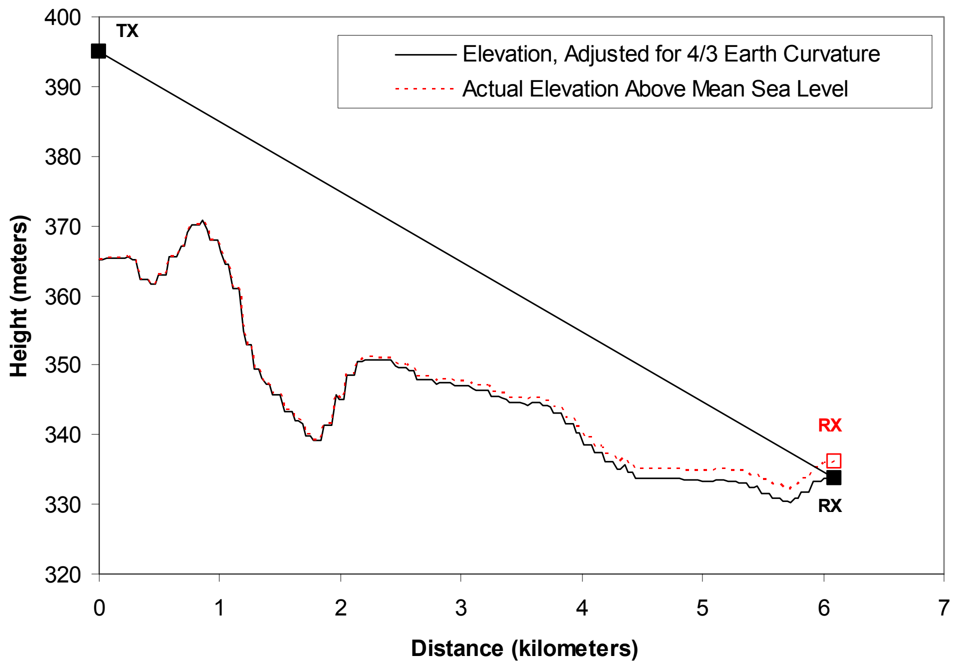


Figure B-46. Path Profile: LPFM to Owatonna Location 7

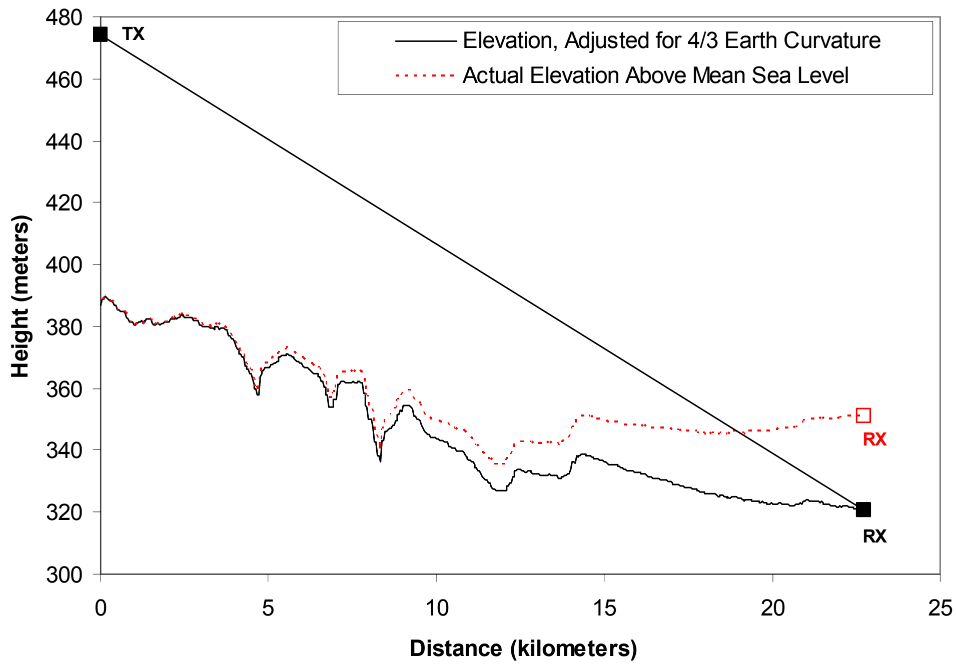


Figure B-47. Path Profile: K289AE (FPFM) to Owatonna Location 8

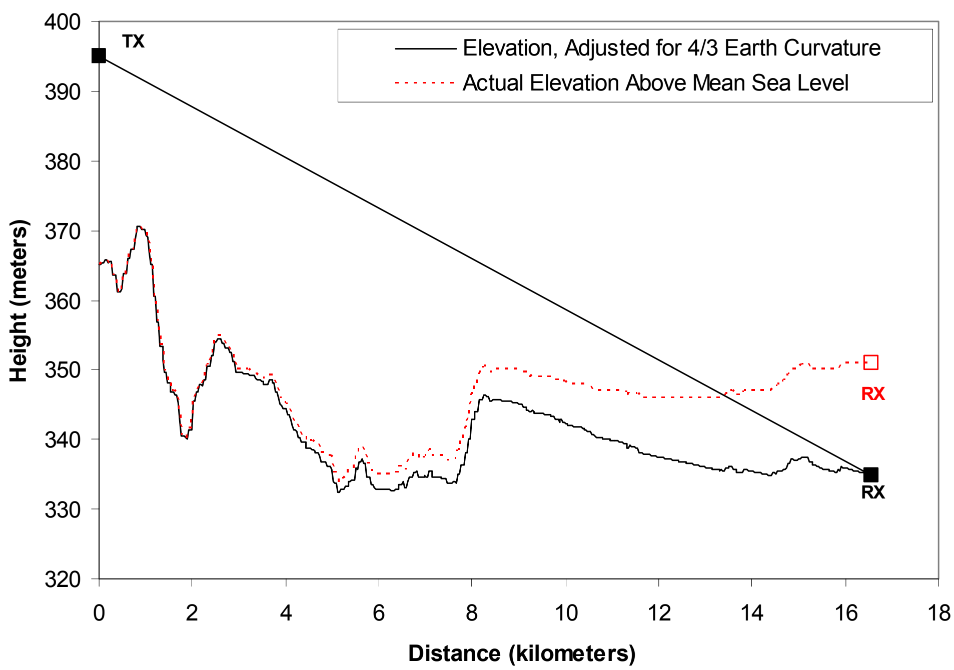


Figure B-48. Path Profile: LPFM to Owatonna Location 8

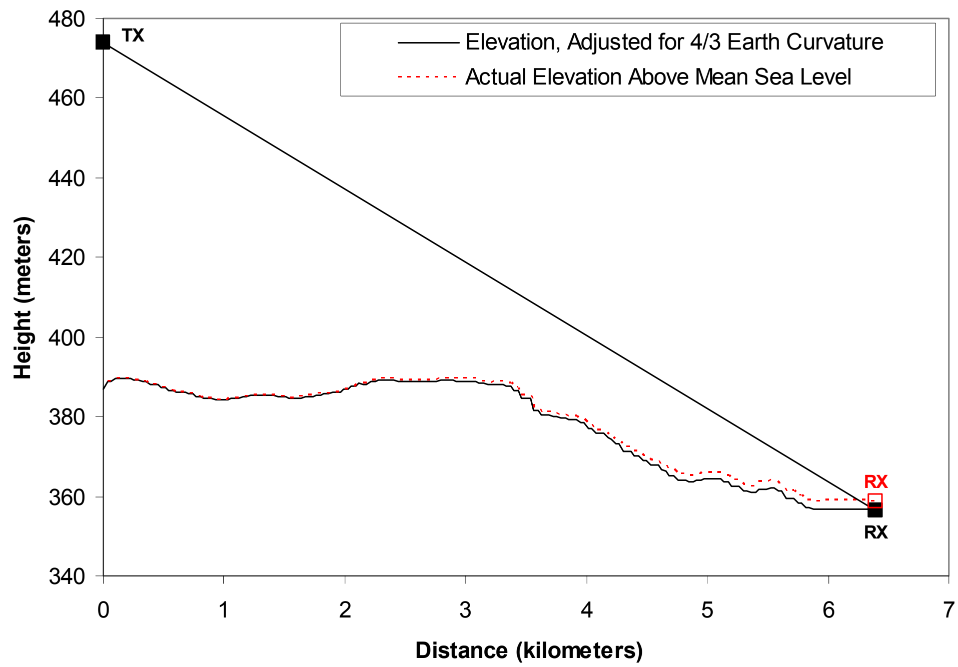


Figure B-49. Path Profile: K289AE (FPFM) to Owatonna Location 1 (Translator Input)

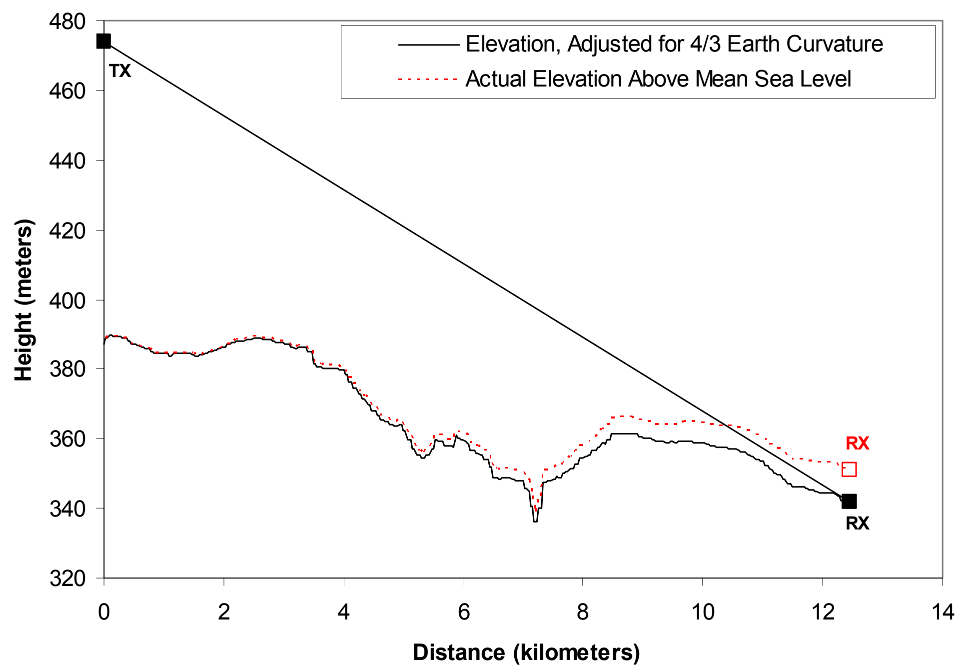


Figure B-50. Path Profile: K289AE (FPFM) to Owatonna Location 2 (Translator Input)

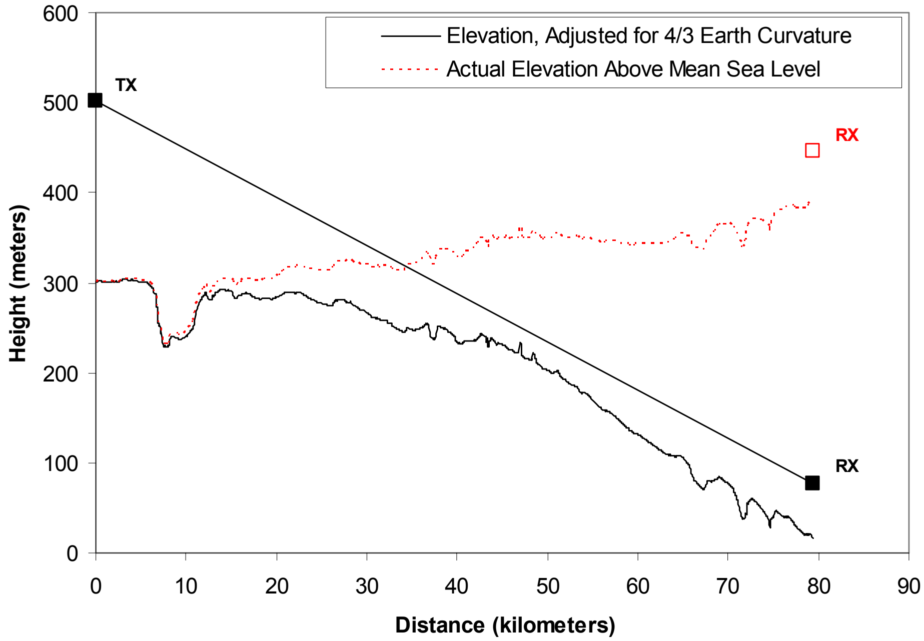


Figure B-51. Path Profile: KGAC (Primary FPFM) to K289AE (Owatonna Translator)

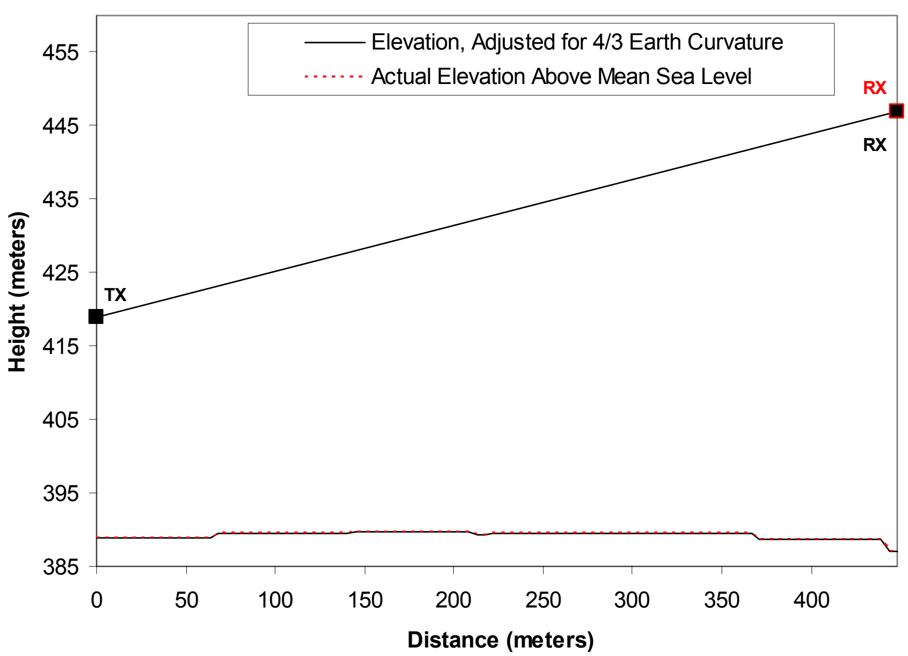


Figure B-52. Path Profile: Owatonna LPFM (Translator Input) to K289AE (Owatonna Translator)

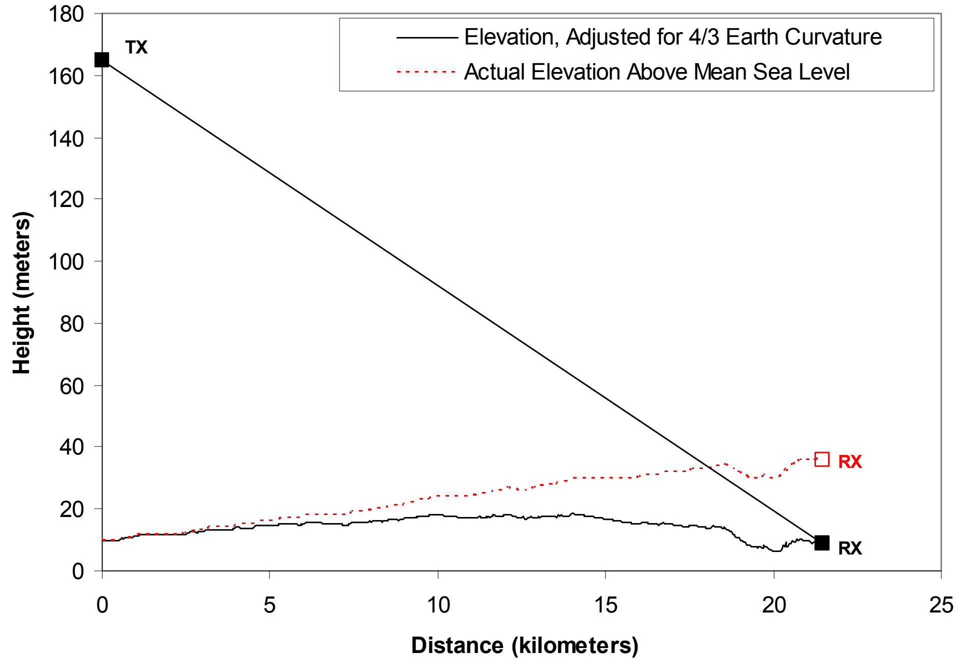


Figure B-53. Path Profile: KSFM (FPFM) to Winters Location 3

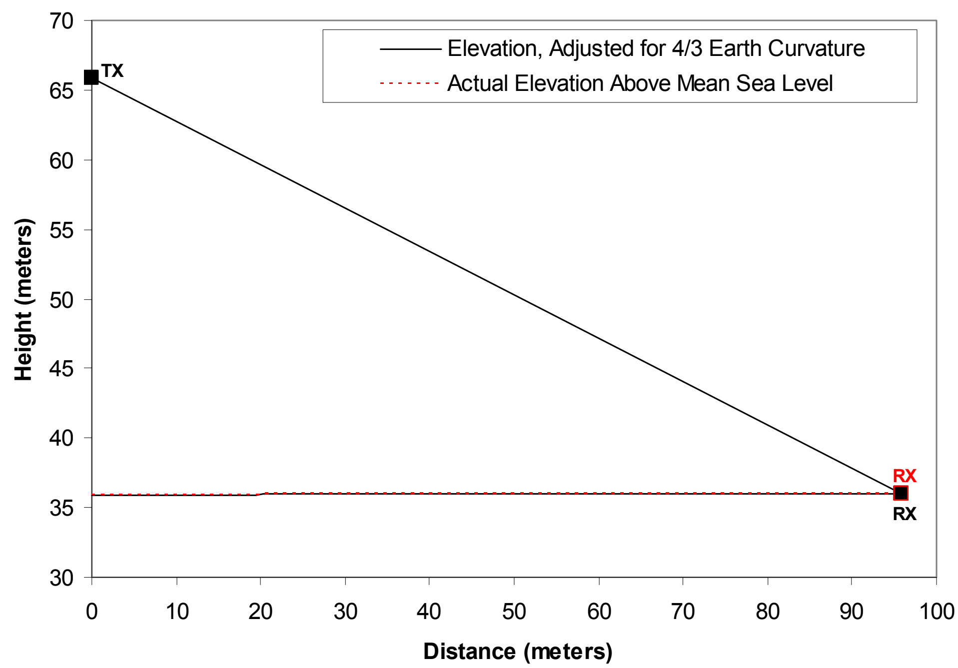


Figure B-54. Path Profile: LPFM to Winters Location 3

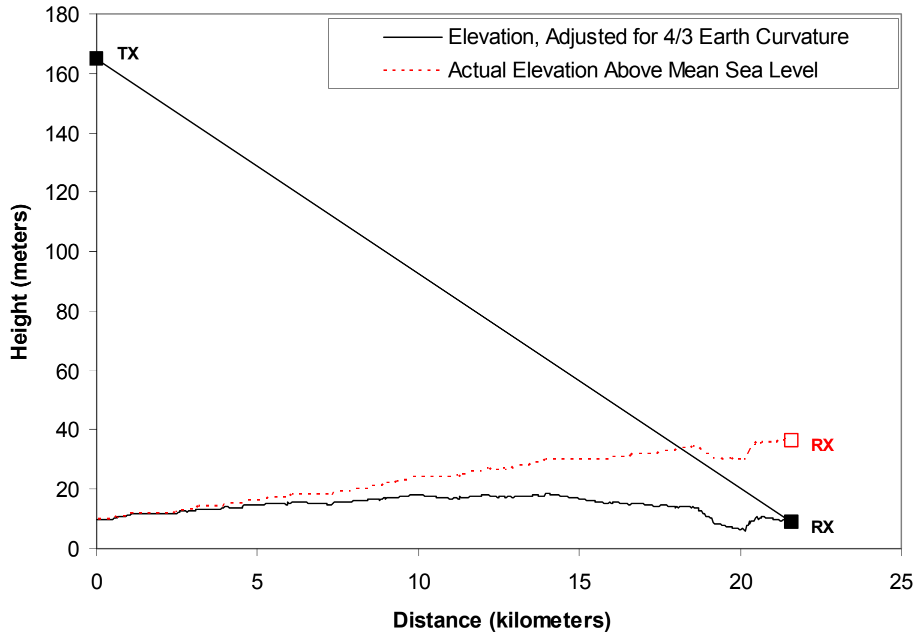


Figure B-55. Path Profile: KSFM (FPFM) to Winters Location 4

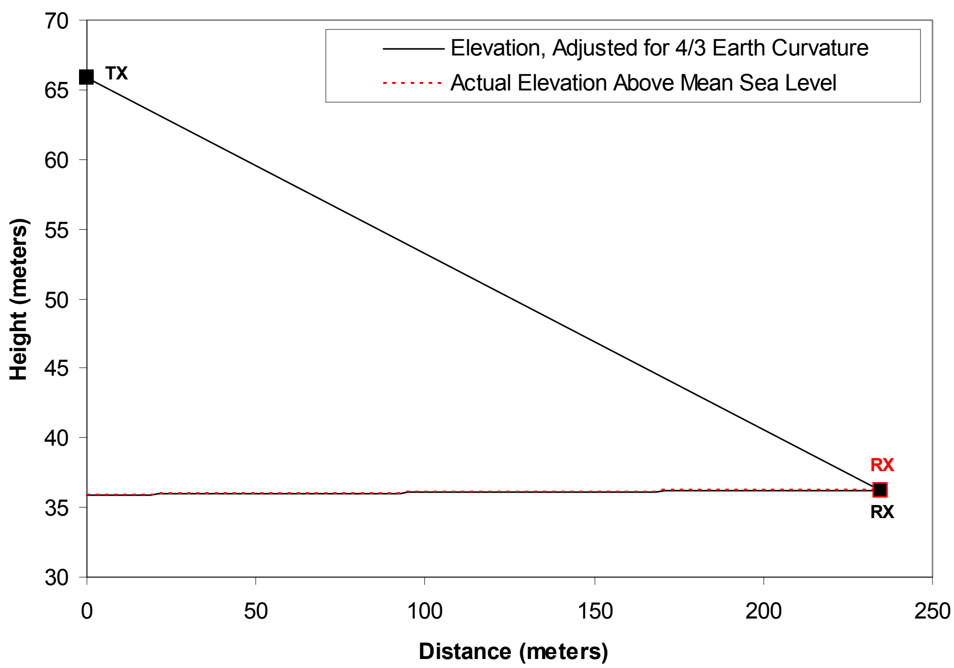


Figure B-56. Path Profile: LPFM to Winters Location 4

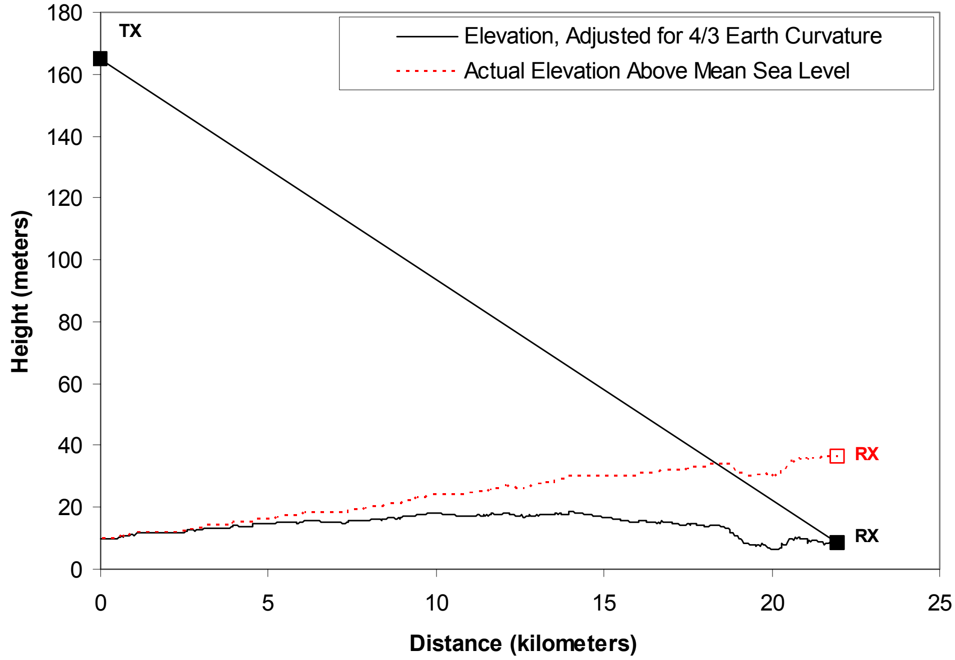


Figure B-57. Path Profile: KSFM (FPFM) to Winters Location 5

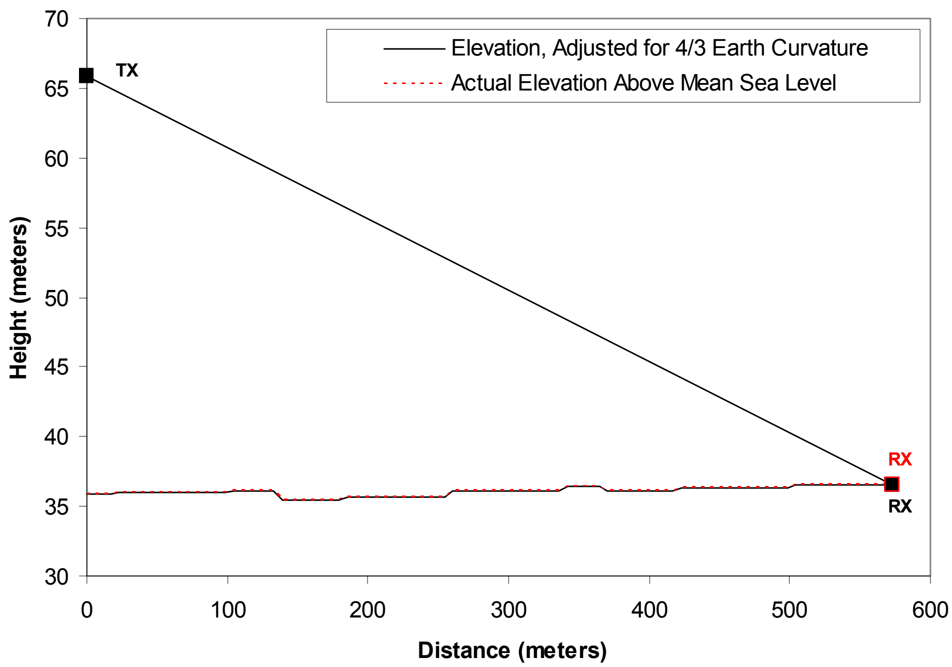


Figure B-58. Path Profile: LPFM to Winters Location 5

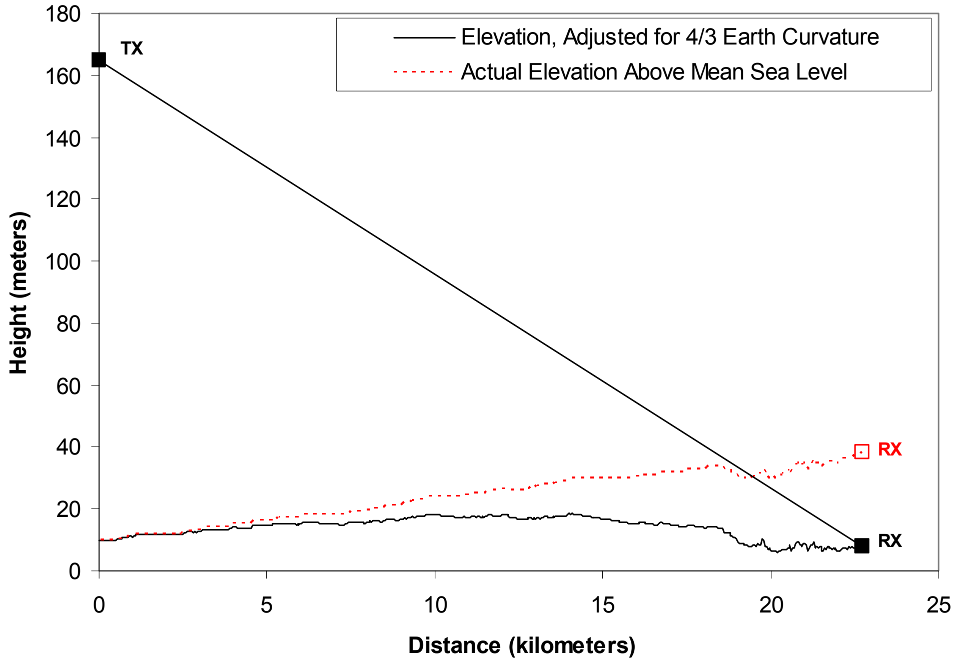


Figure B-59. Path Profile: KSFM (FPFM) to Winters Location 6

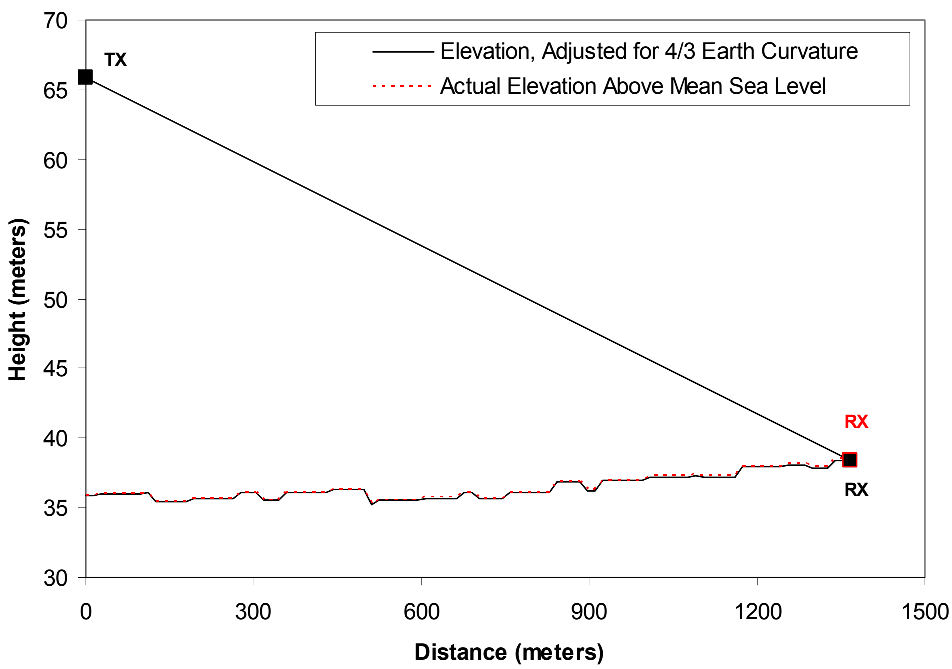


Figure B-60. Path Profile: LPFM to Winters Location 6

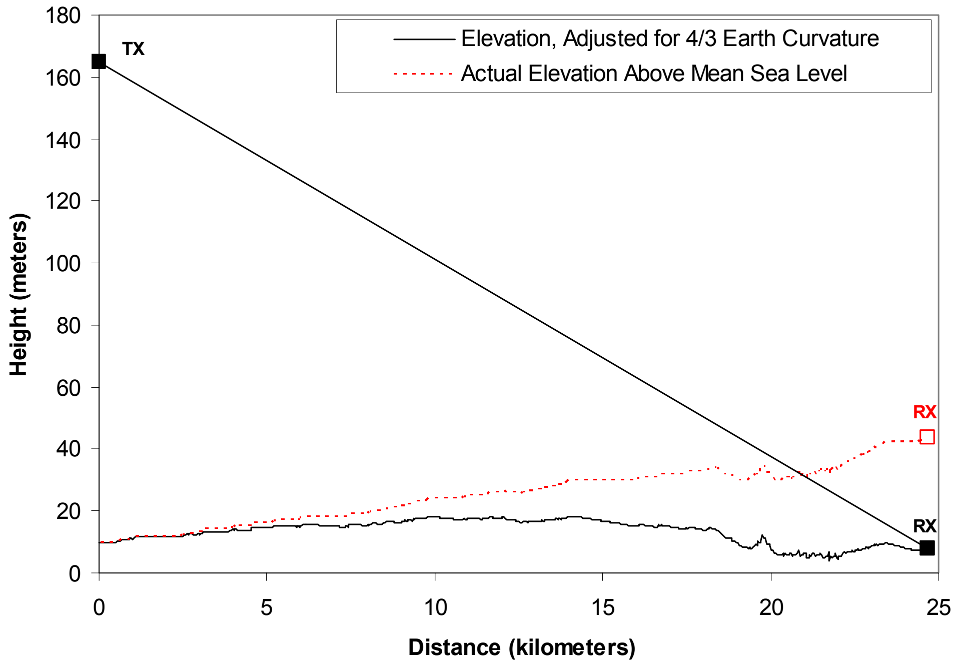


Figure B-61. Path Profile: KSFM (FPFM) to Winters Location 7

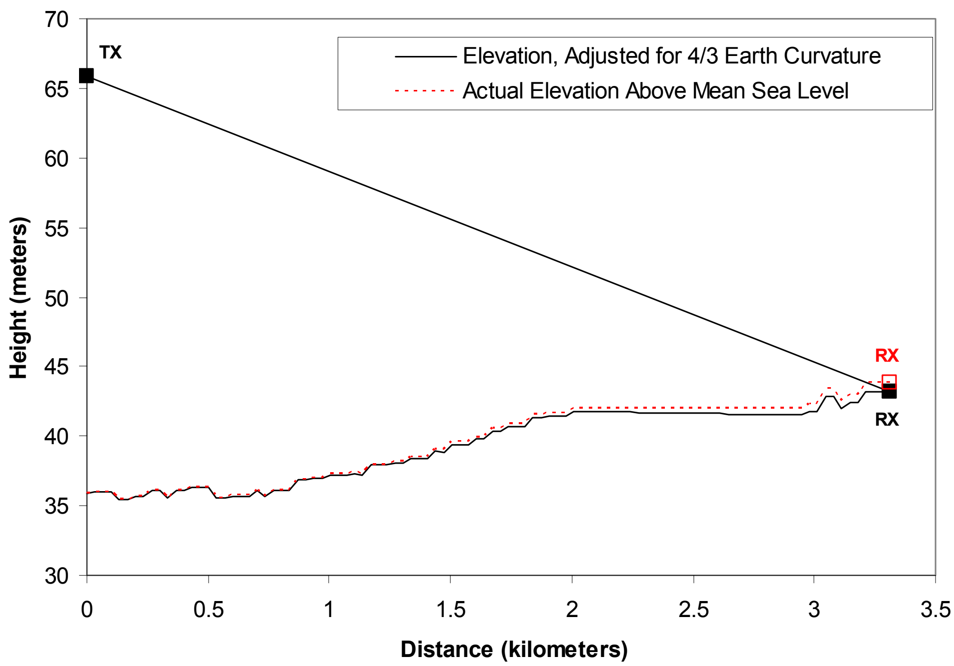


Figure B-62. Path Profile: LPFM to Winters Location 7

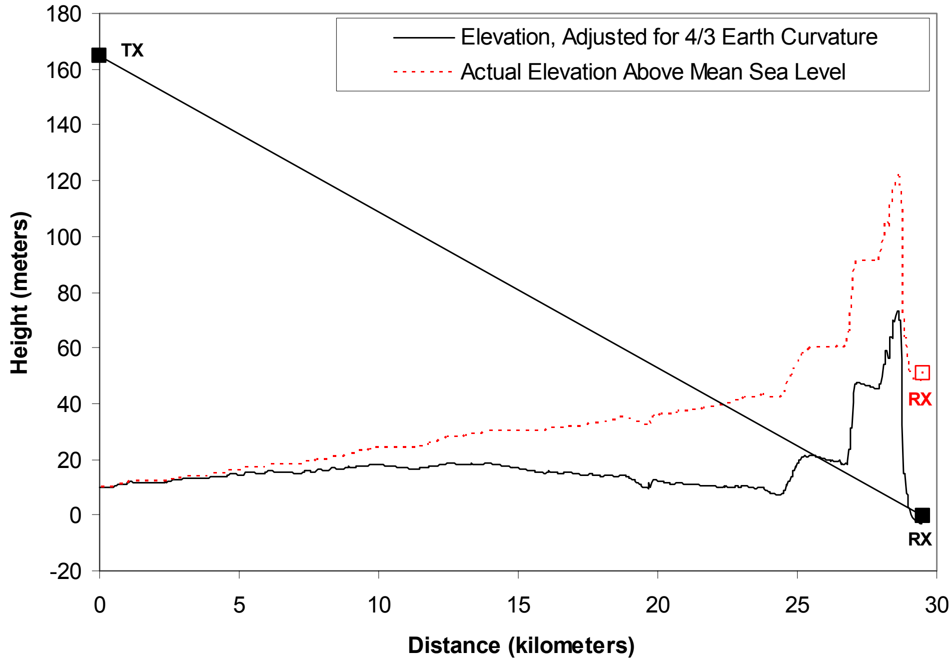


Figure B-63. Path Profile: KSFM (FPFM) to Winters Location 8

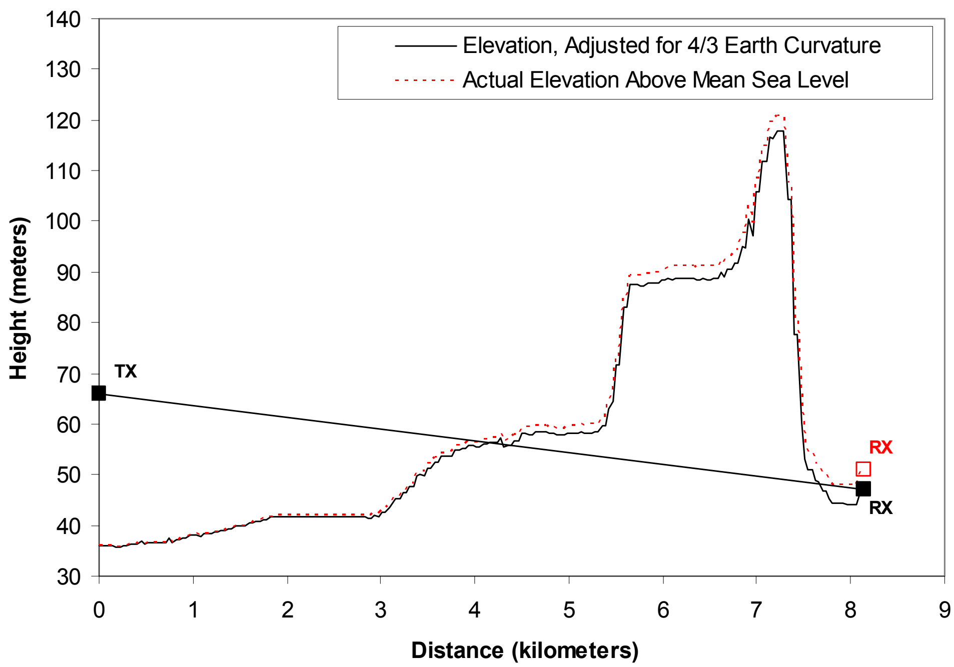


Figure B-64. Path Profile: LPFM to Winters Location 8

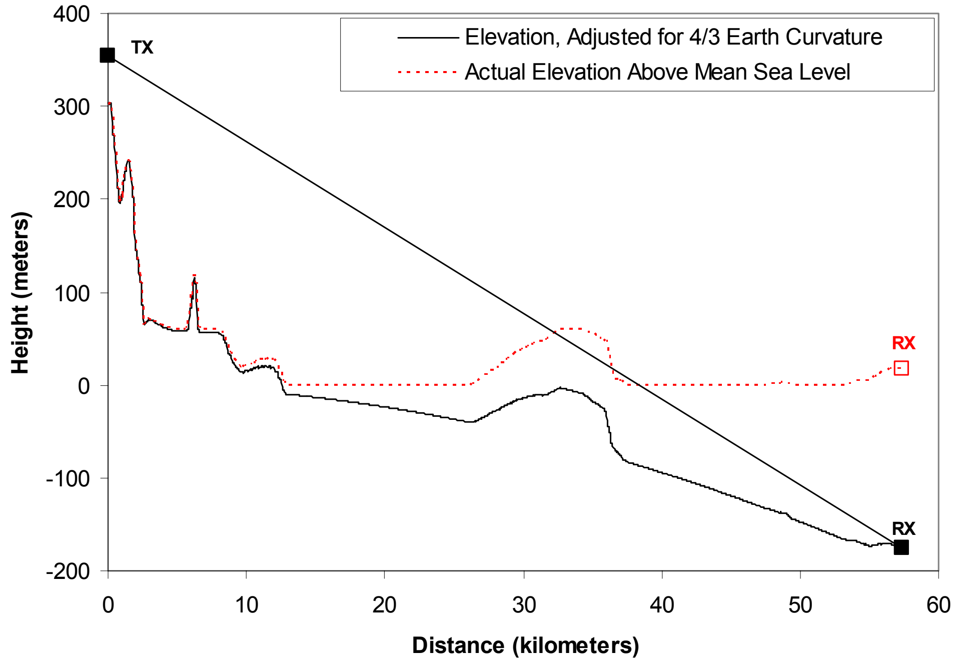


Figure B-65. Path Profile: KFRC (FPFM) to Benicia Location 3

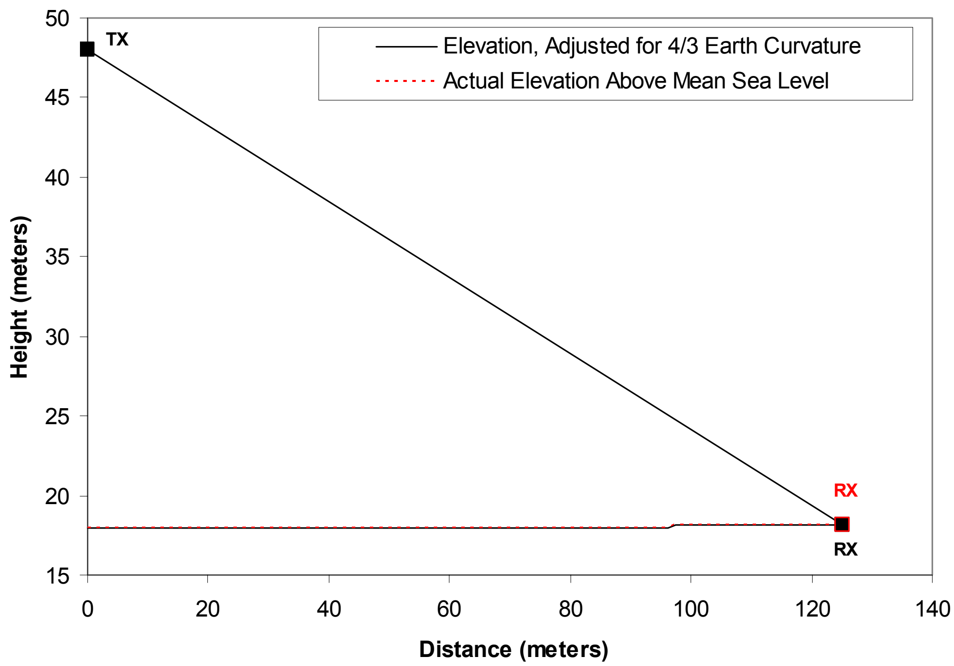


Figure B-66. Path Profile: LPFM to Benicia Location 3

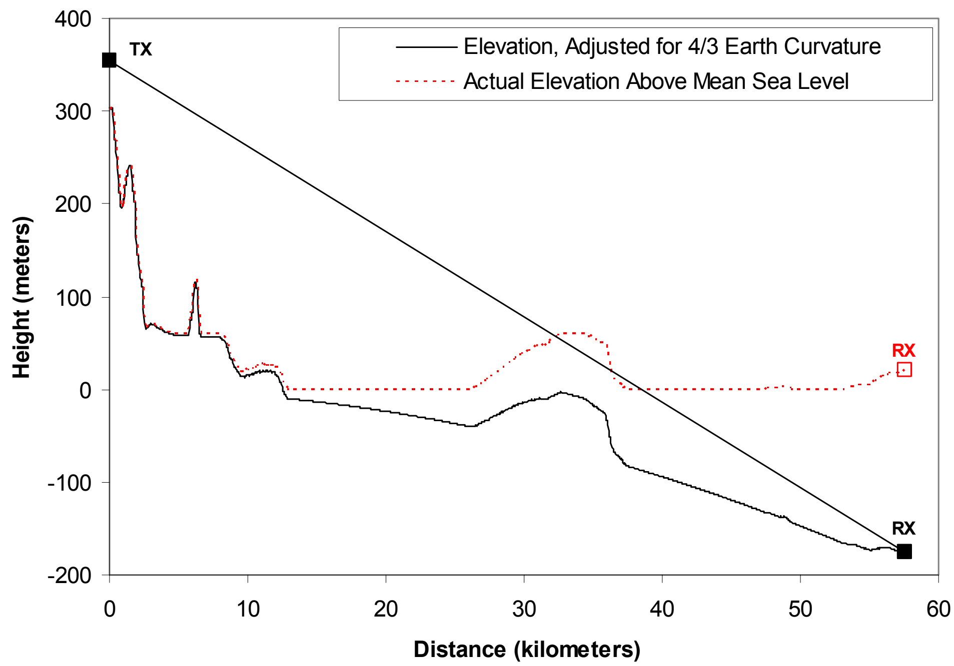


Figure B-67. Path Profile: KFRC (FPFM) to Benicia Location 4

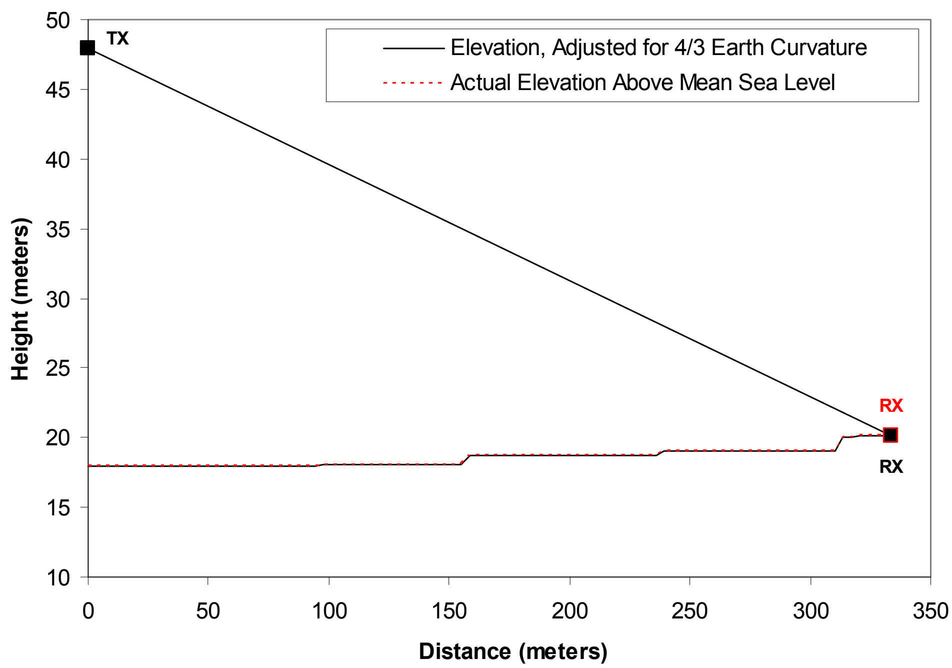


Figure B-68. Path Profile: LPFM to Benicia Location 4

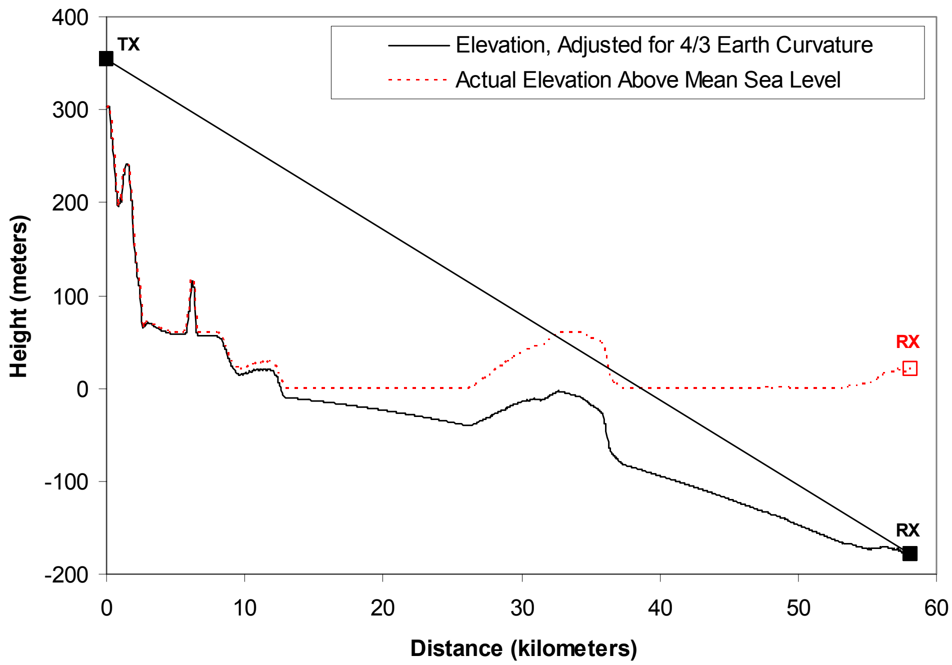


Figure B-69. Path Profile: KFRC (FPFM) to Benicia Location 5

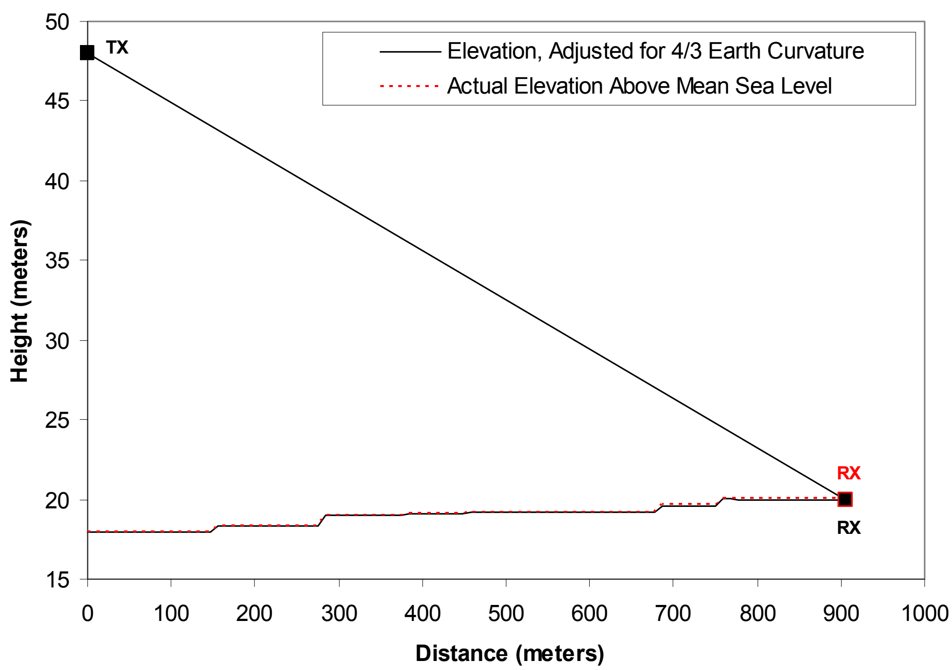


Figure B-70. Path Profile: LPFM to Benicia Location 5

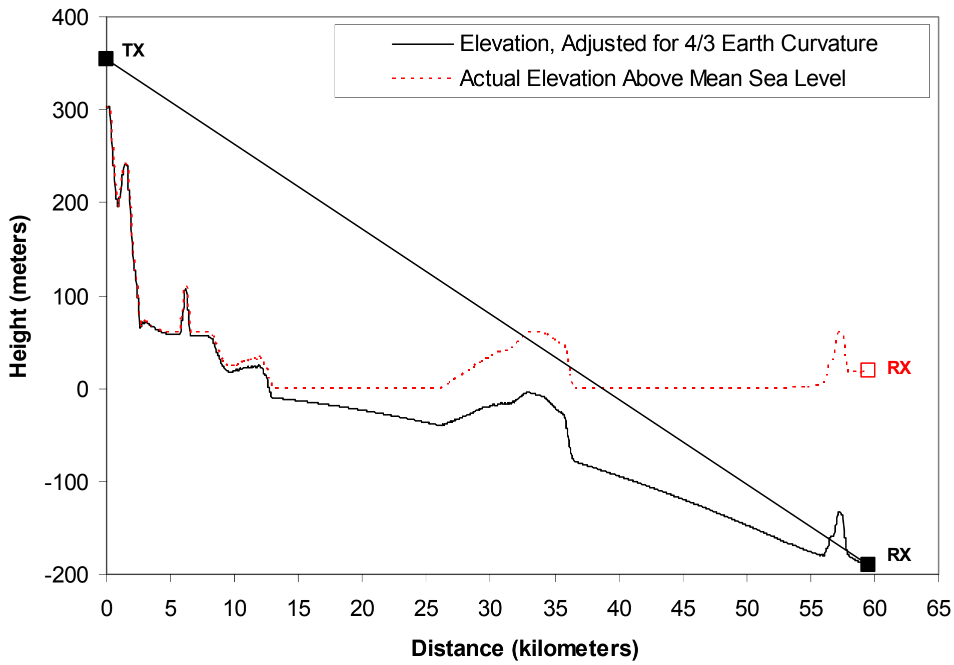


Figure B-71. Path Profile: KFRC (FPFM) to Benicia Location 6

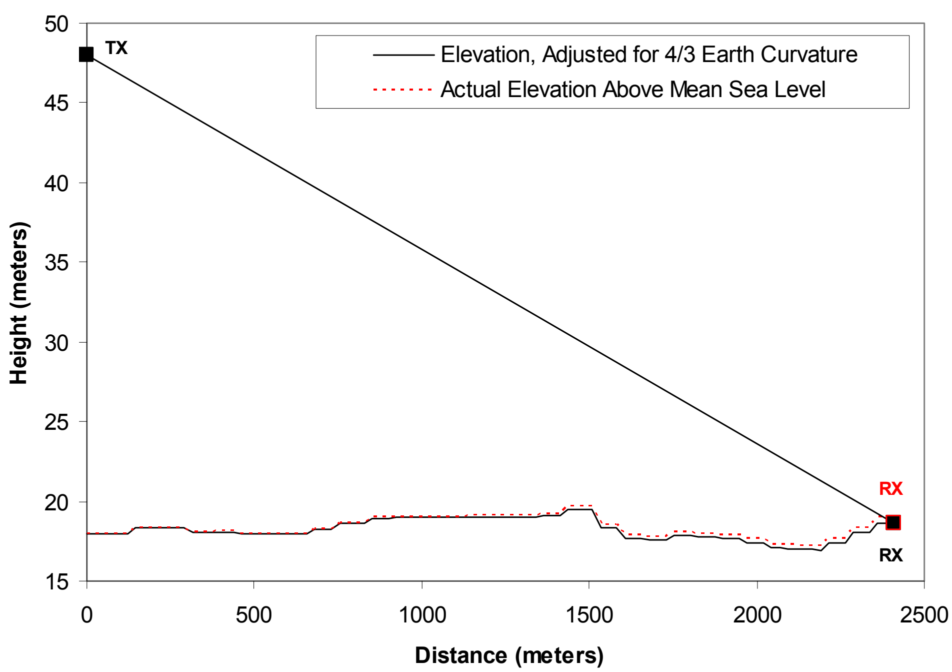


Figure B-72. Path Profile: LPFM to Benicia Location 6

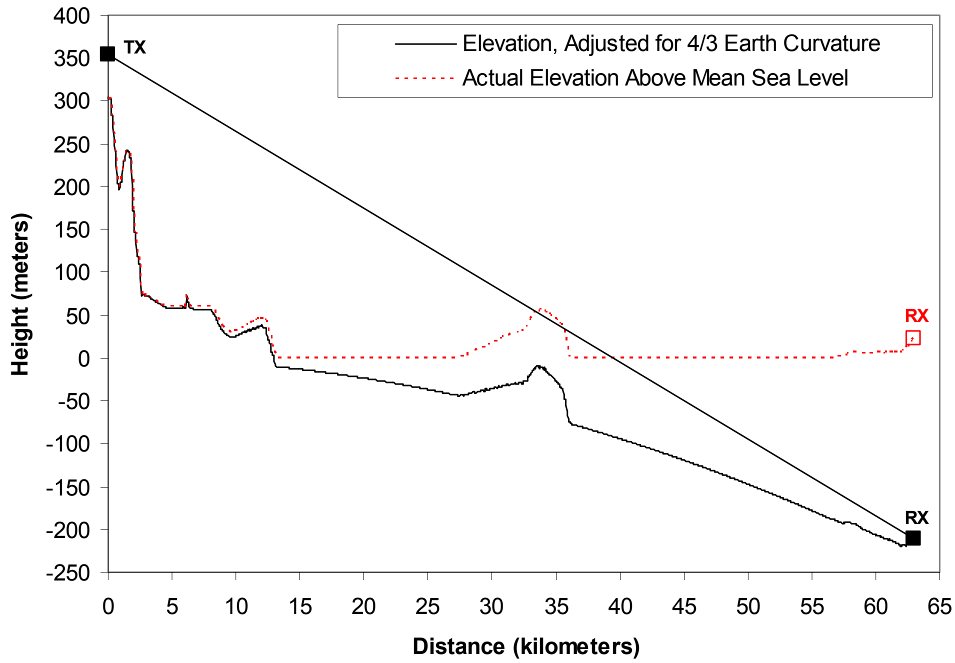


Figure B-73. Path Profile: KFRC (FPFM) to Benicia Location 7

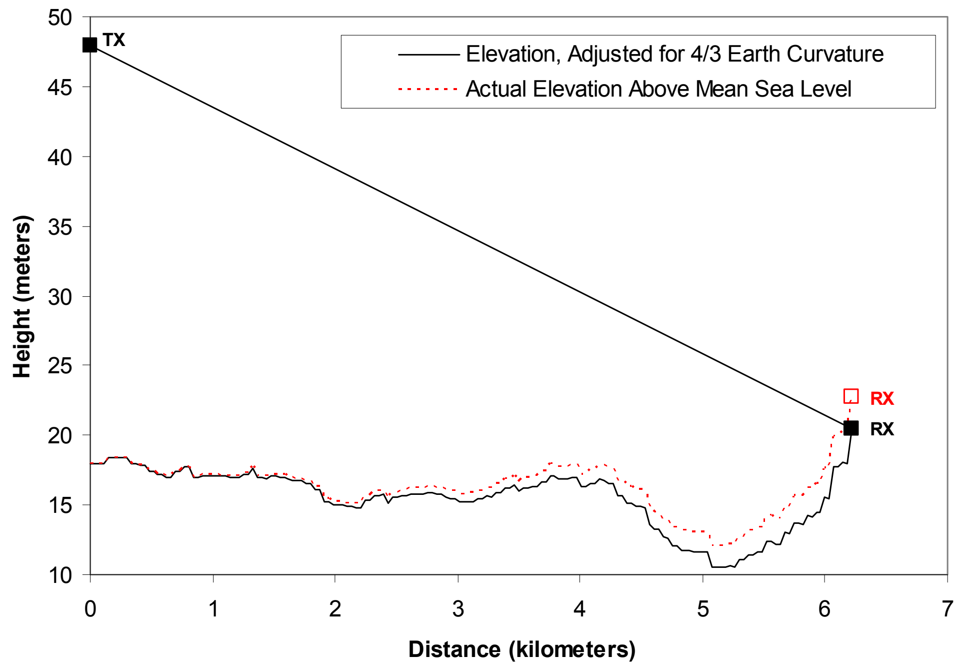


Figure B-74. Path Profile: LPFM to Benicia Location 7

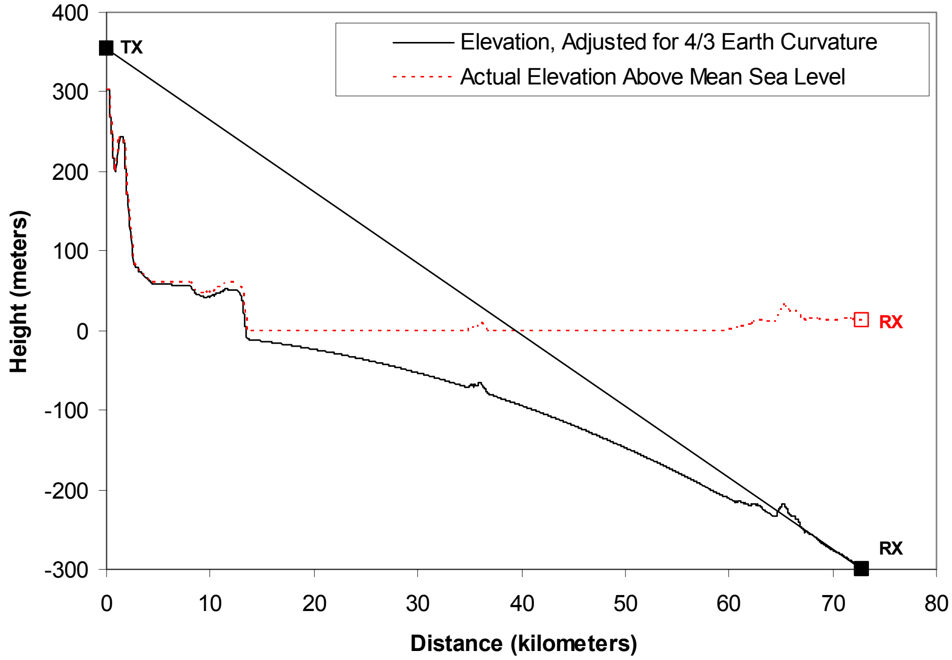


Figure B-75. Path Profile: KFRC (FPFM) to Benicia Location 8

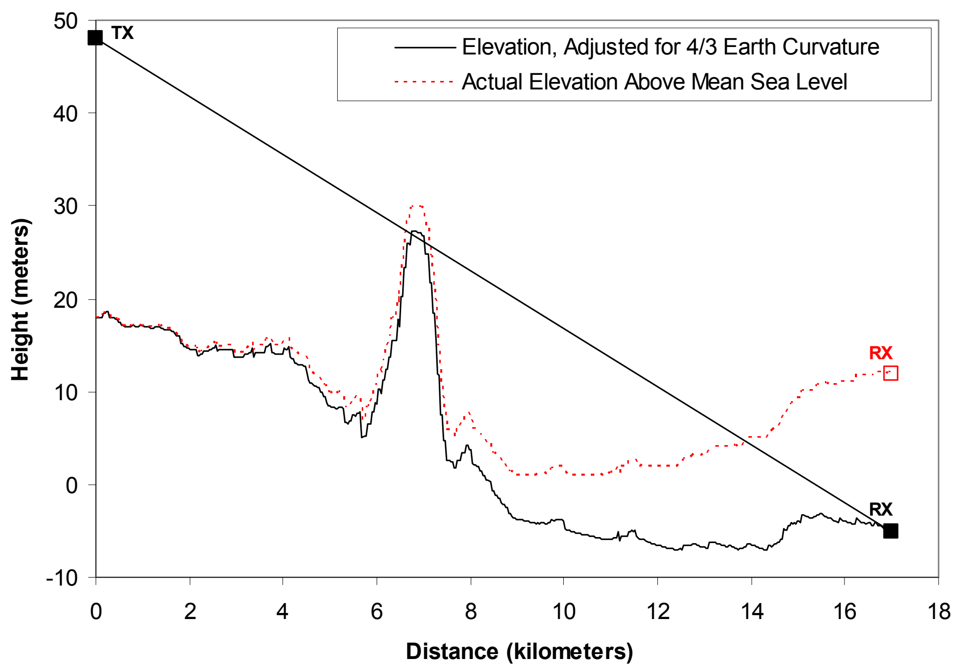


Figure B-76. Path Profile: LPFM to Benicia Location 8

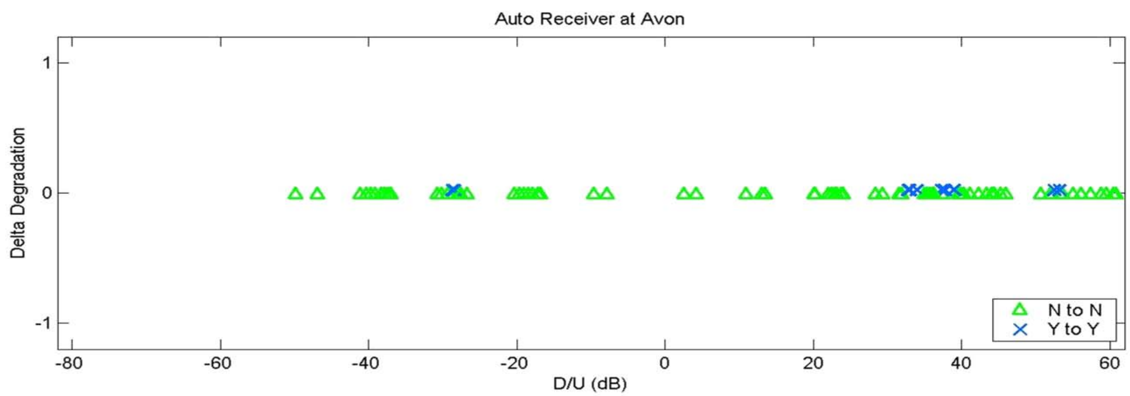
Appendix C

Degradation-Transition Cases for Each Site and Receiver

Figures C-1 to C-12 and C-16 to C-21 show the Delta Degradation as a function of D/U for all non-translator-input test sites and for each receiver type.

Figures C-13 to C-15 show Transition Count bar charts as a function of LPFM ERP for the Owatonna input translator test site and for each receiver type.

Figures C-22 to C-28 show Transition Count bar charts for all non-translator-input test sites and for each receiver type. These bar charts present the raw data set. No area-weighting was applied to the transition count numbers shown in these plots.



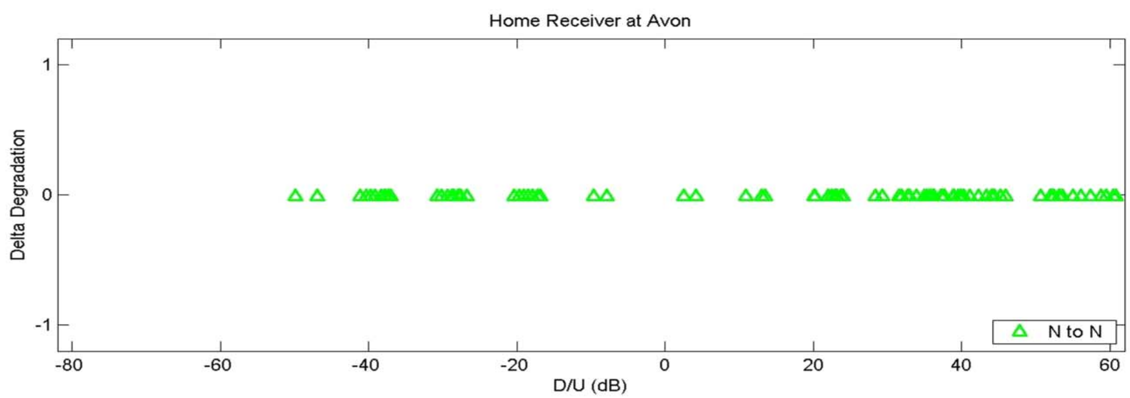


Figure C-1. Delta Degradation for the Auto and Home Receivers at Avon

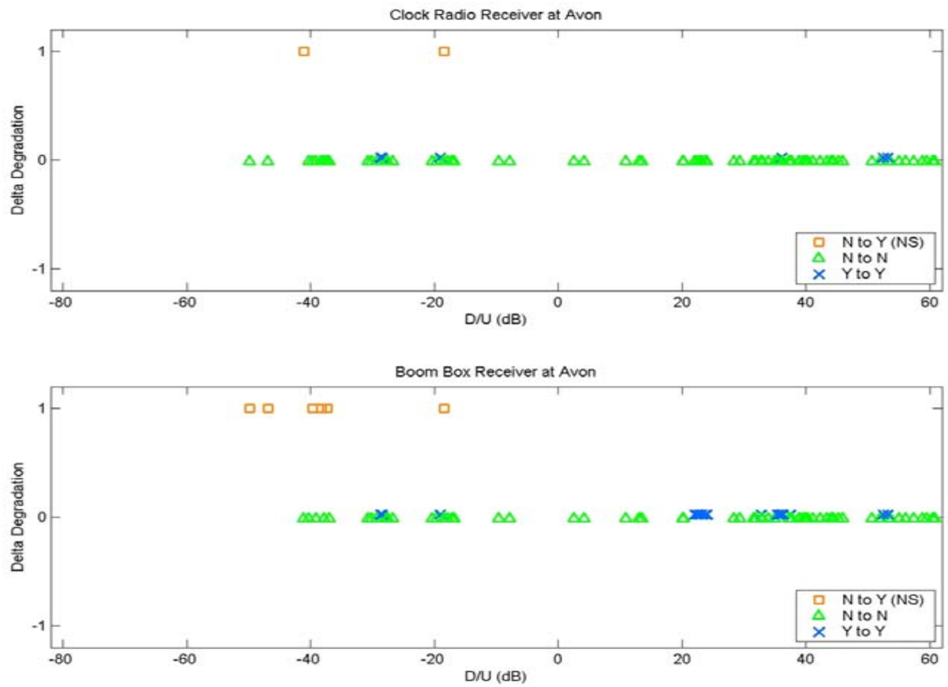


Figure C-2. Delta Degradation for the Clock Radio and Boom Box Receivers at Avon

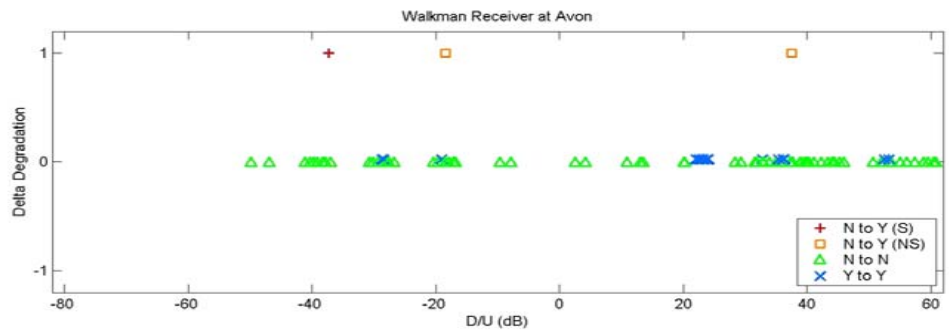


Figure C-3. Delta Degradation for the Walkman Receiver at Avon

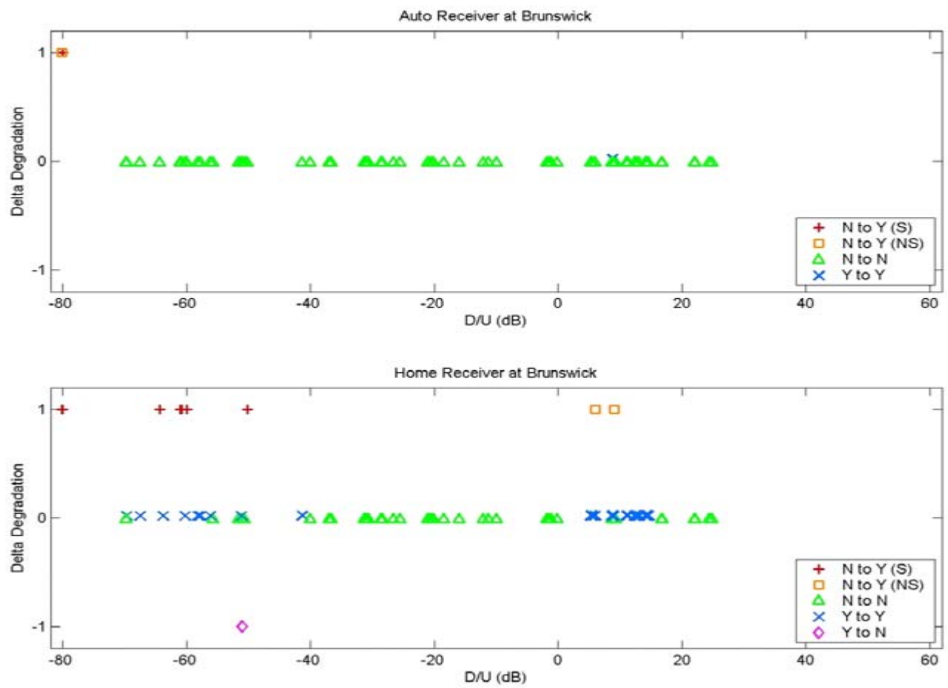


Figure C-4. Delta Degradation for the Auto and Home Receivers at Brunswick

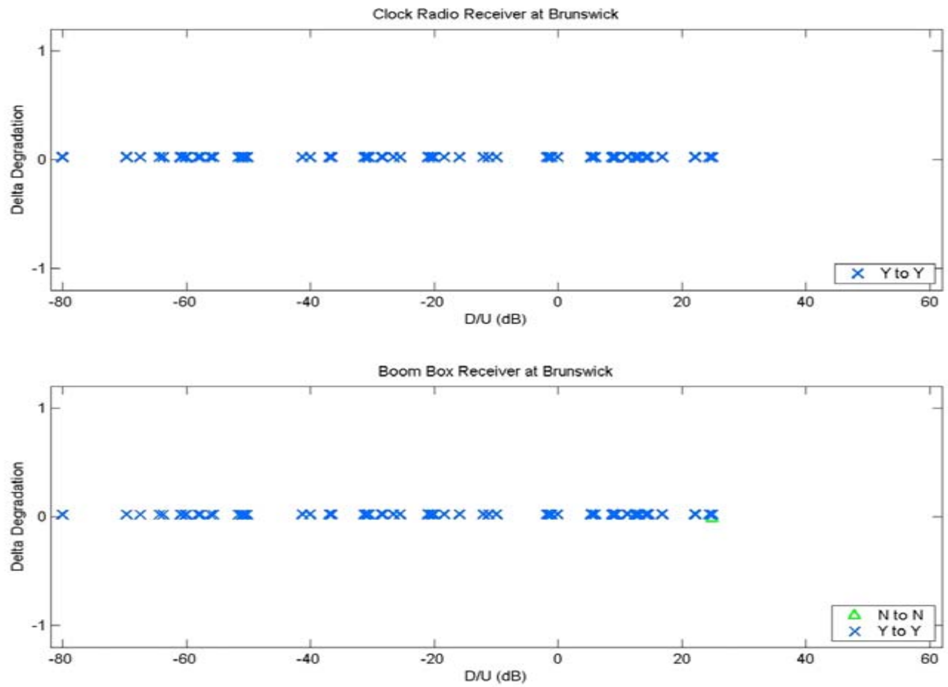


Figure C-5. Delta Degradation for the Clock Radio and Boom Box Receivers at Brunswick

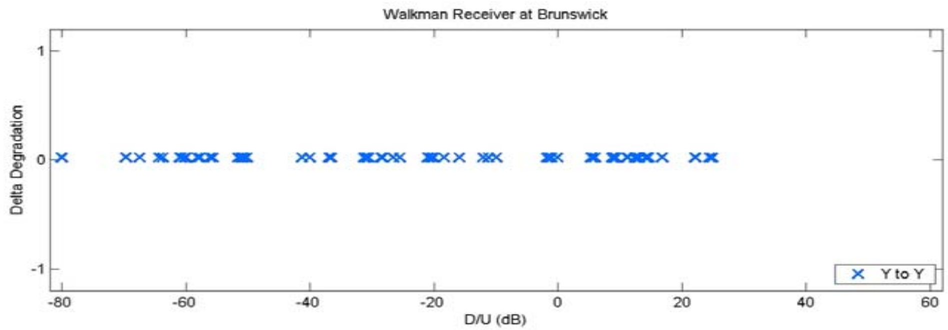


Figure C-6. Delta Degradation for the Walkman Receiver at Brunswick

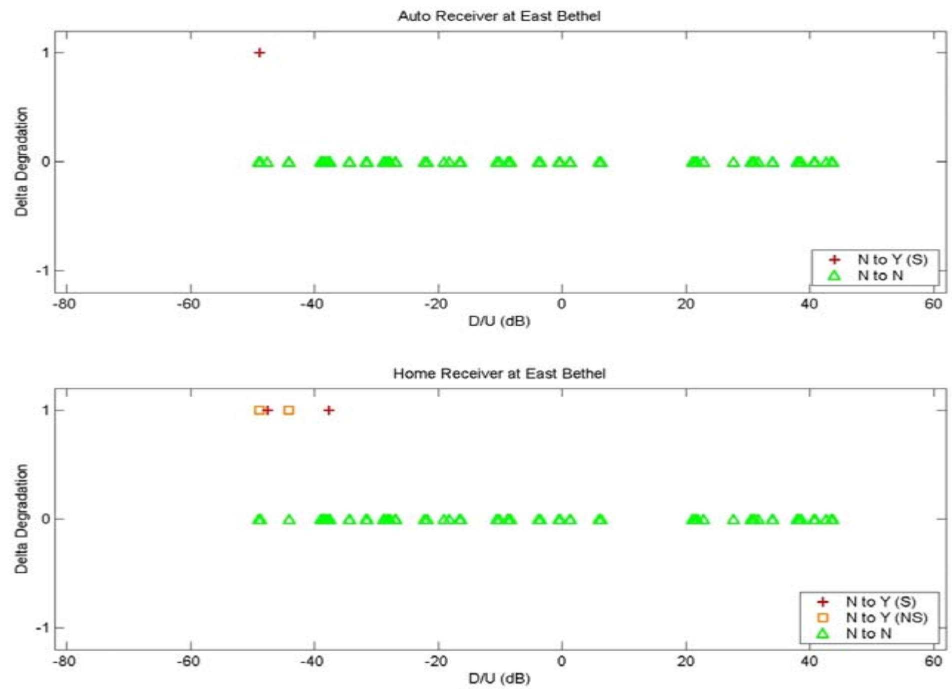


Figure C-7. Delta Degradation for the Auto and Home Receivers at East Bethel

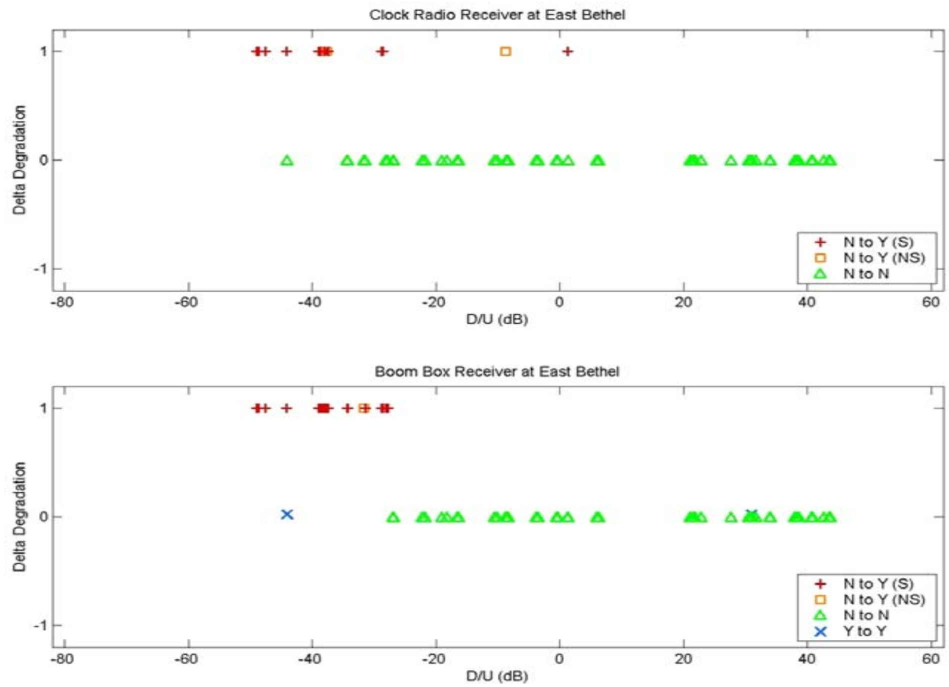


Figure C-8. Delta Degradation for the Clock Radio and Boom Box Receivers at East Bethel

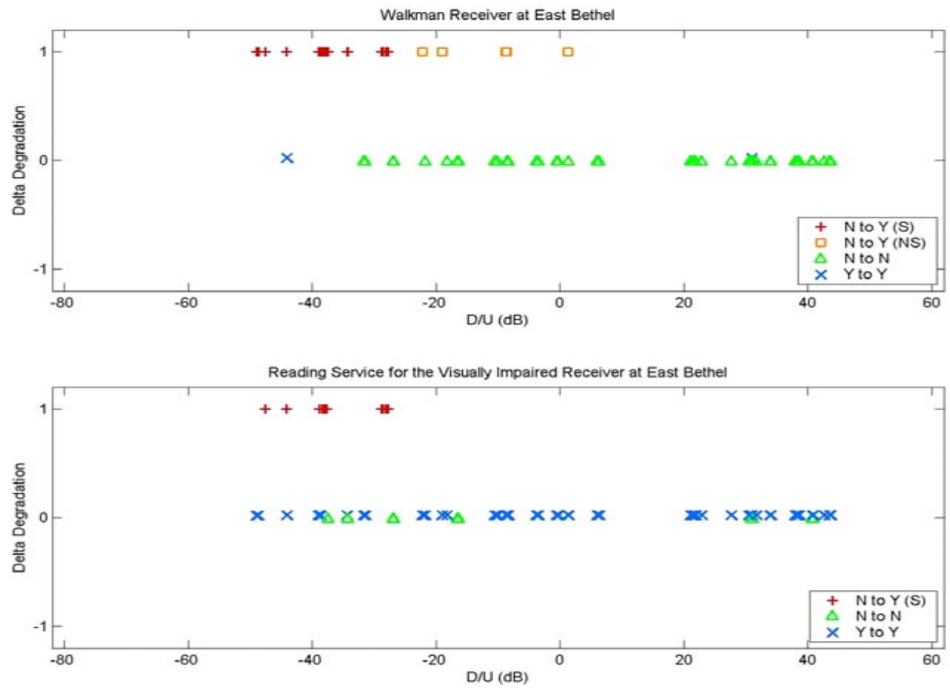


Figure C-9. Delta Degradation for the Walkman and the RSVI Receivers at East Bethel

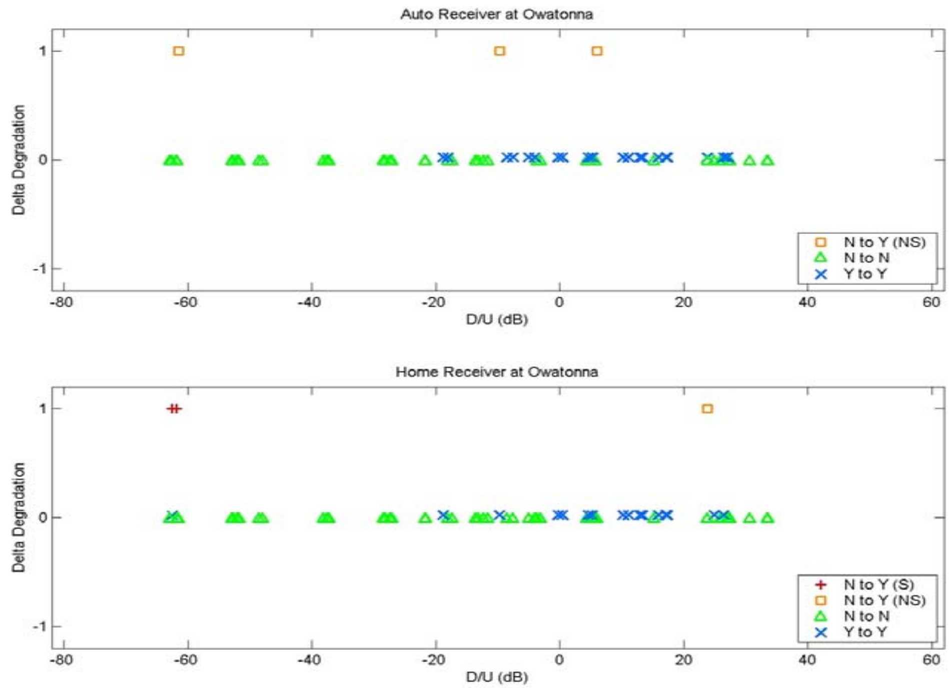


Figure C-10. Delta Degradation for the Auto and Home Receivers at Owatonna Translator Output Test

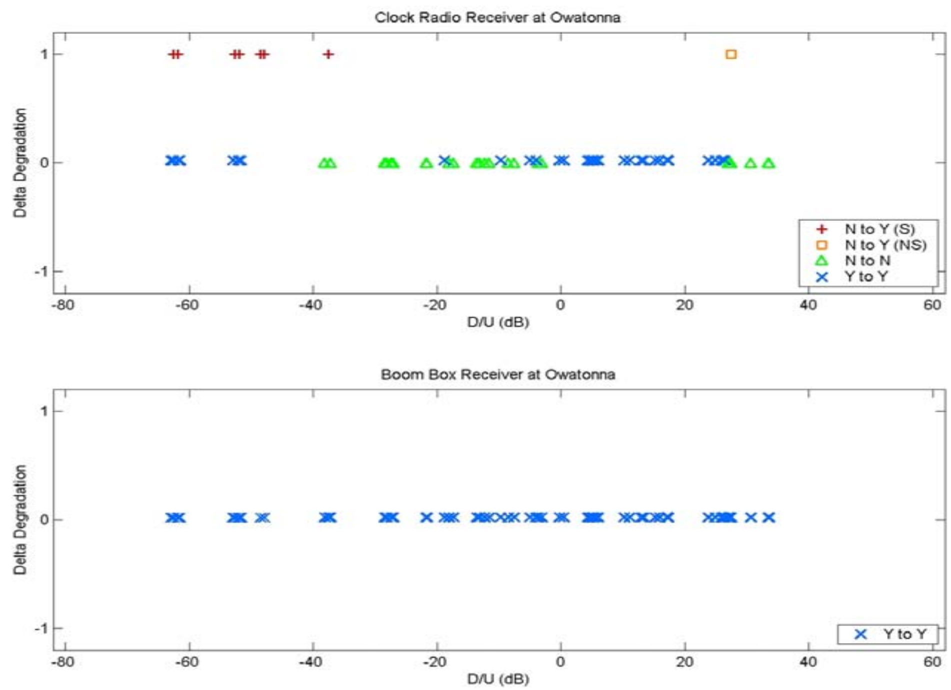


Figure C-11. Delta Degradation for the Clock Radio and Boom Box Receivers at Owatonna Translator Output Test

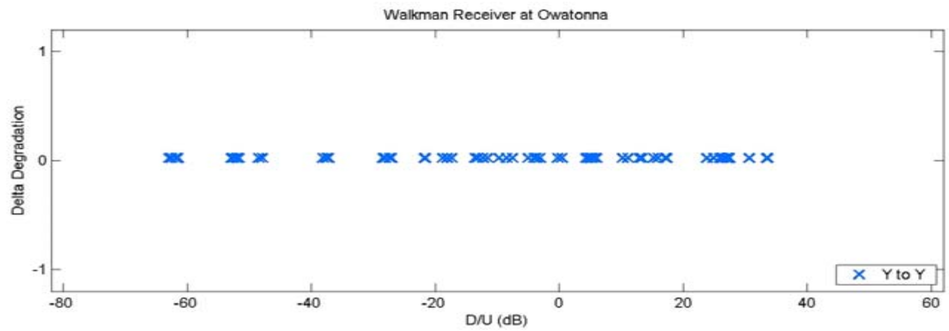


Figure C-12. Delta Degradation for the Walkman Receiver at Owatonna Translator Output Test

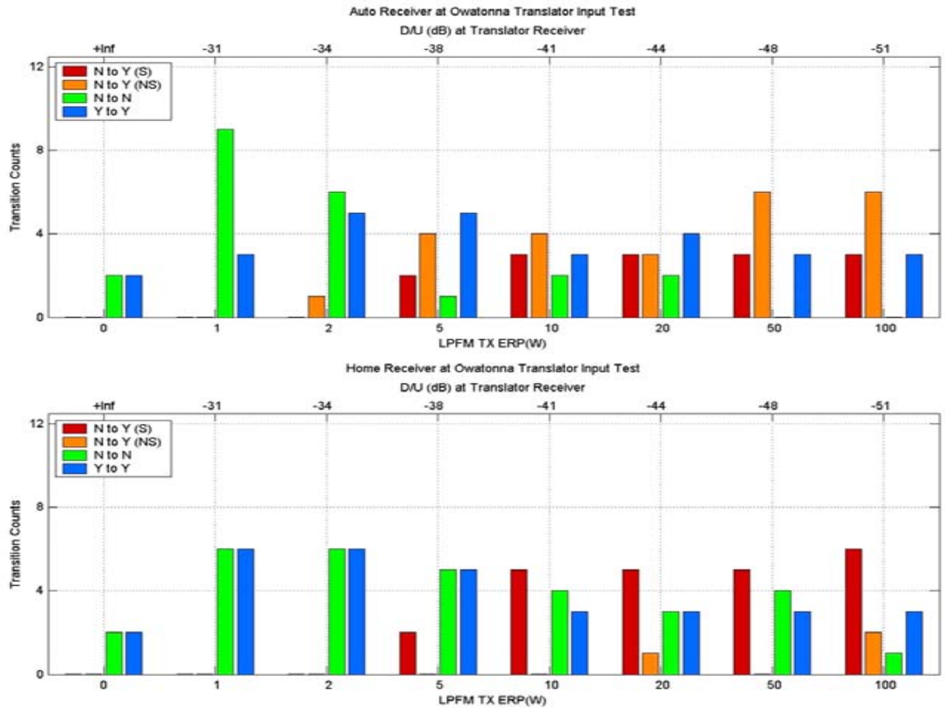


Figure C-13. Transition Counts for the Auto and Home Receivers at Owatonna Translator Input Test

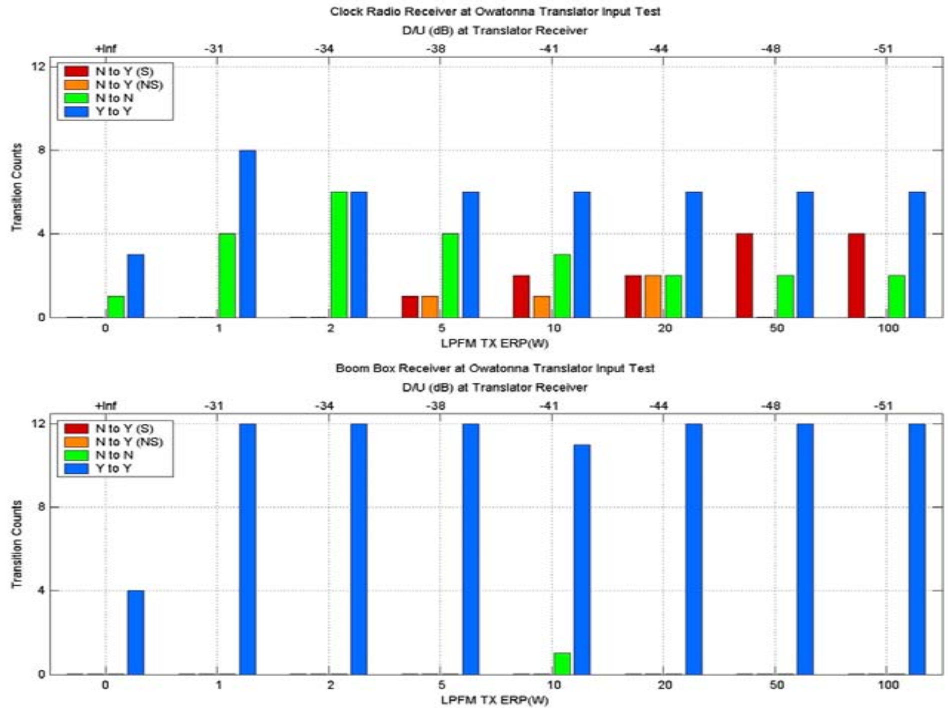


Figure C-14. Transition Counts for the Clock Radio and Boom Box Receivers at Owatonna Translator Input Test

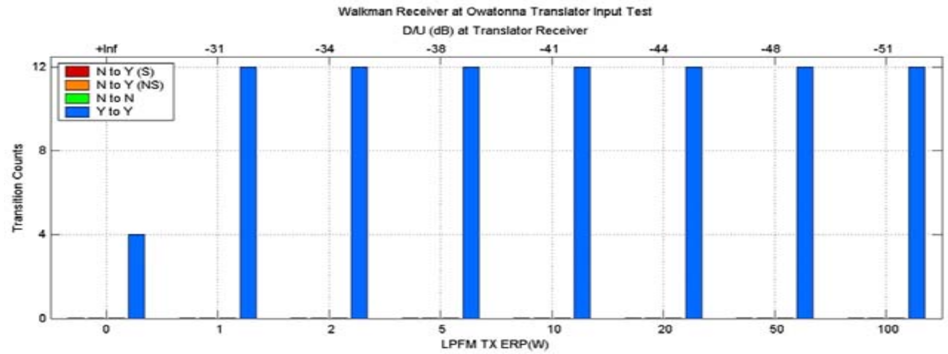


Figure C-15. Transition Counts for the Walkman Receiver at Owatonna Translator Input Test

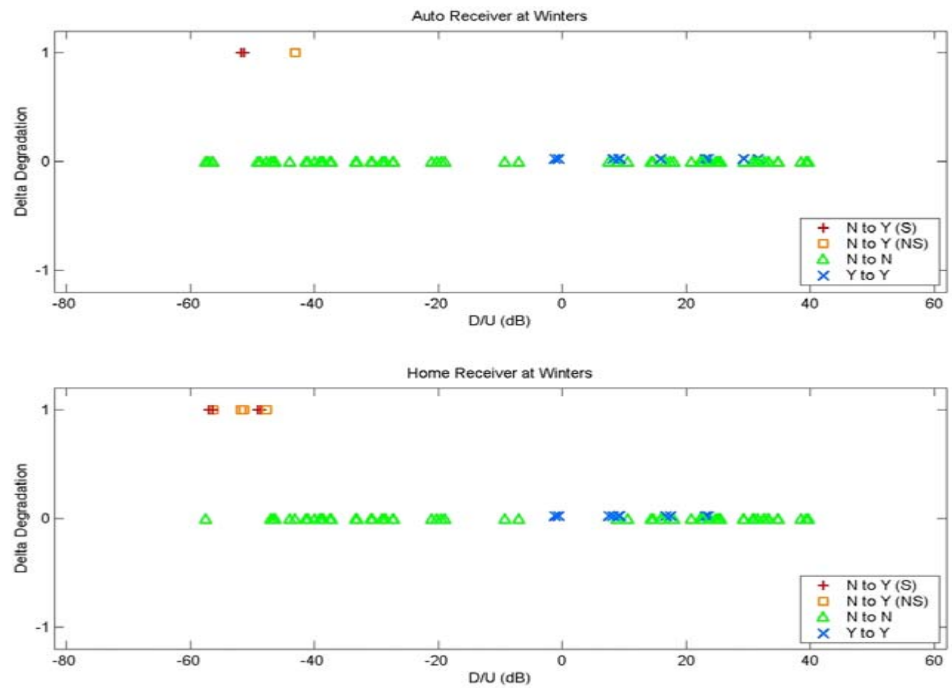


Figure C-16. Delta Degradation for the Auto and Home Receivers at Winters

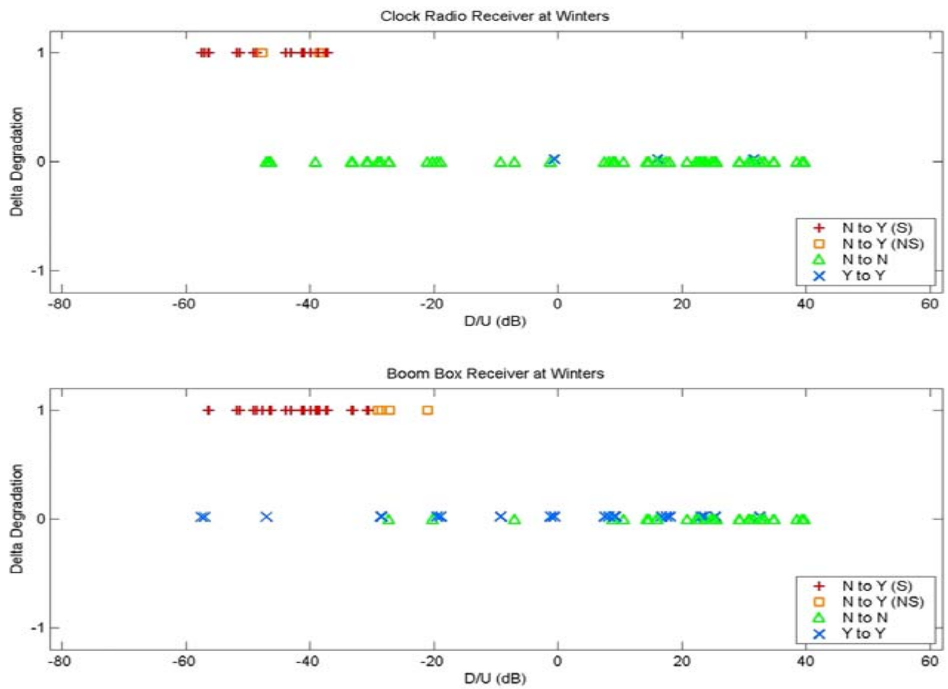


Figure C-17. Delta Degradation for the Clock Radio and Boom Box Receivers at Winters

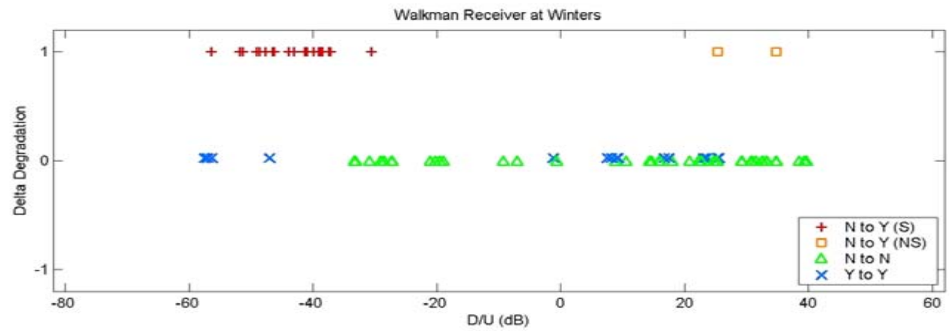


Figure C-18. Delta Degradation for the Walkman Receiver at Winters

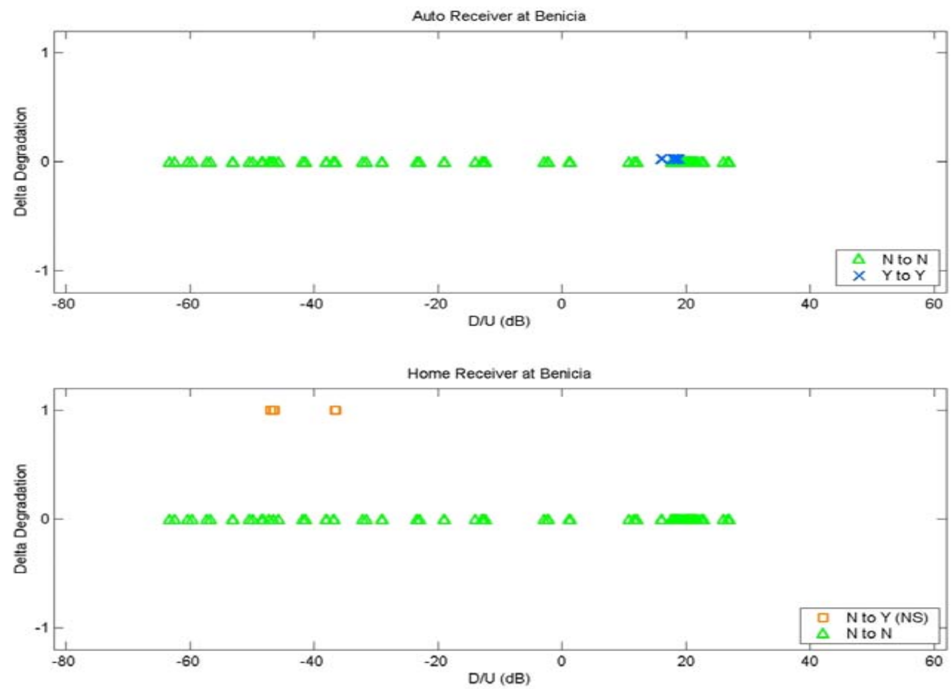


Figure C-19. Delta Degradation for the Auto and Home Receivers at Benicia

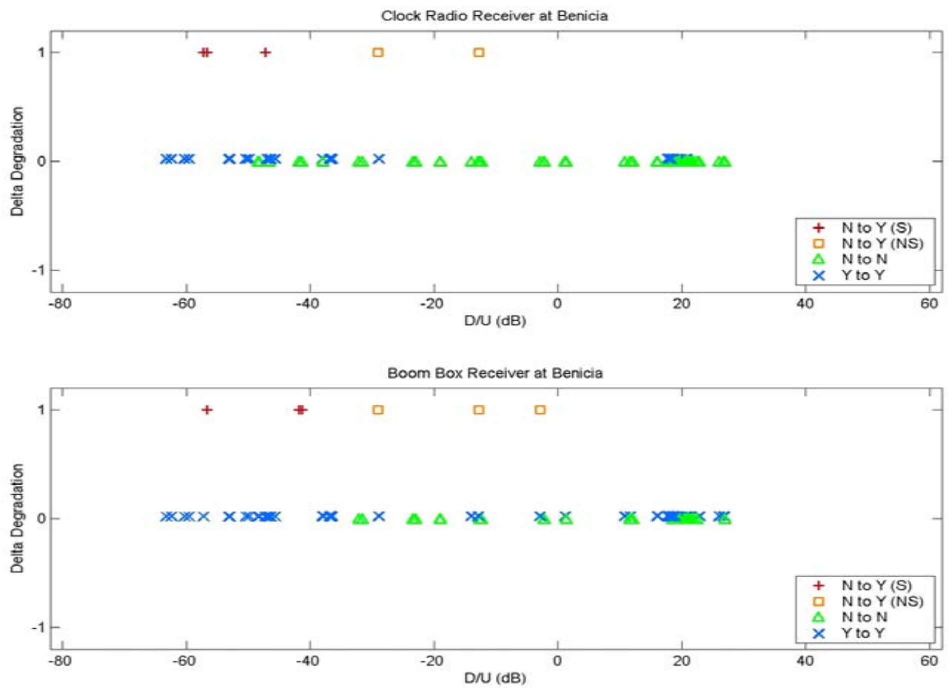


Figure C-20. Delta Degradation for the Clock Radio and Boom Box Receivers at Benicia

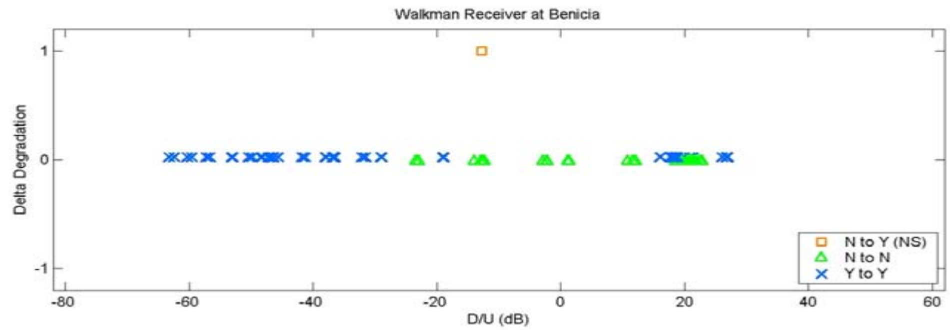


Figure C-21. Delta Degradation for the Walkman Receiver at Benicia

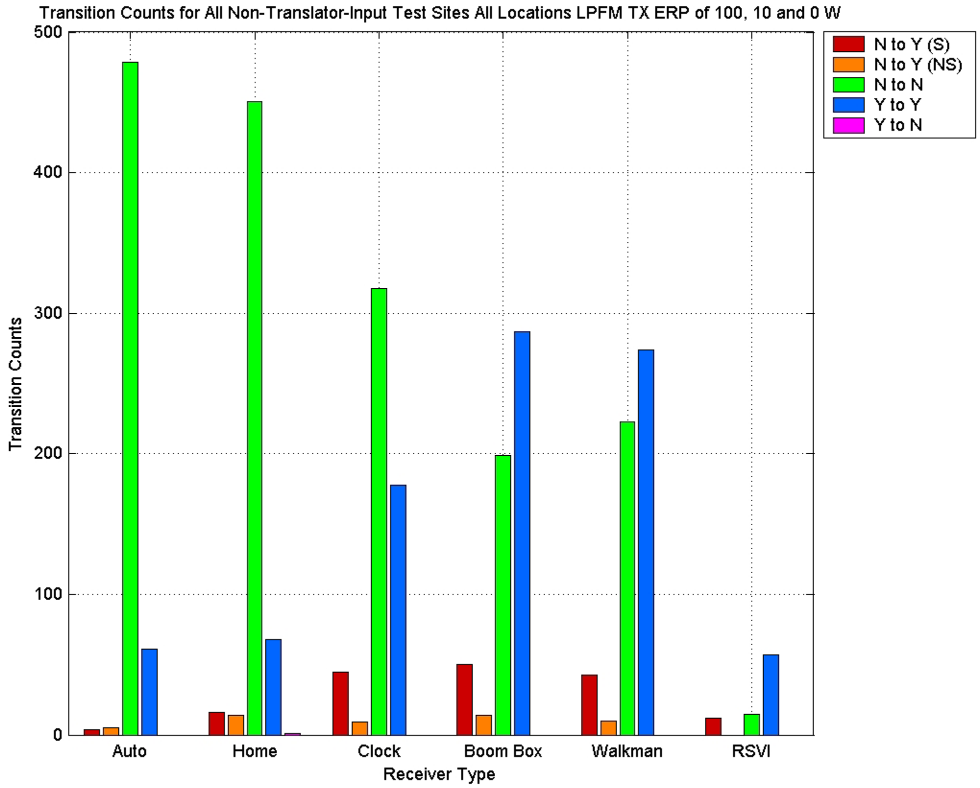


Figure C-22. Transition Counts for All Non-Translator-Input Test Sites, All Receiver Measurement Locations, All LPFM Values (100, 10, and 0 W)

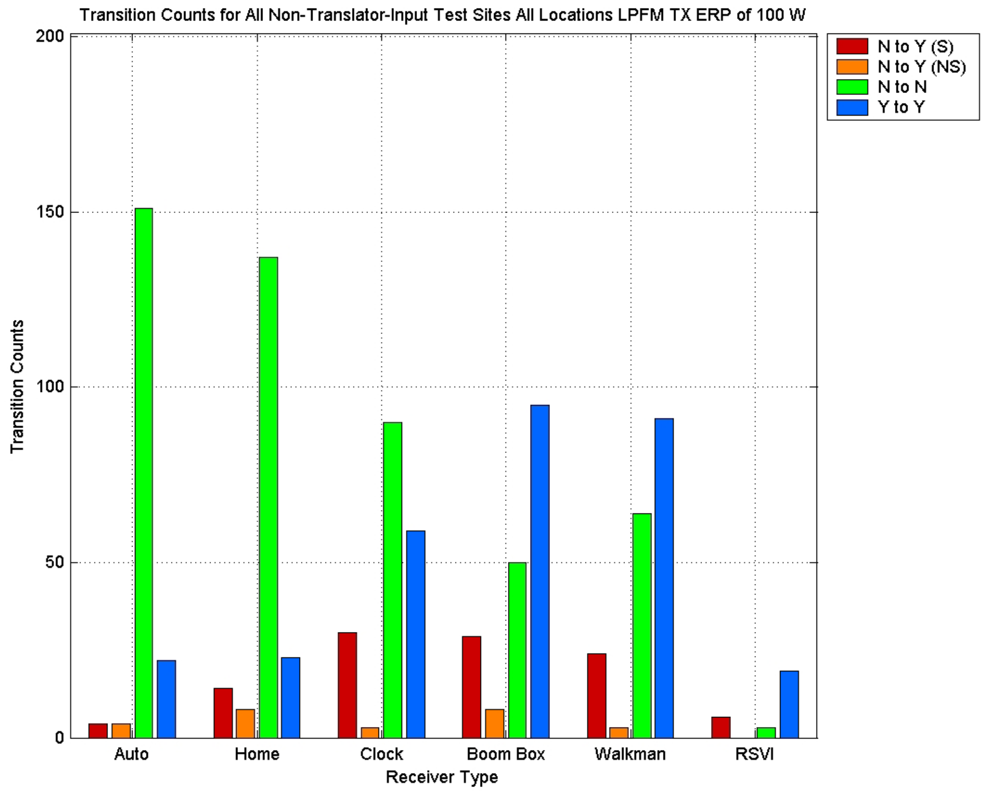


Figure C-23. Transition Counts for All Non-Translator-Input Test Sites, All Receiver Measurement Locations, LPFM ERP Value of 100 W

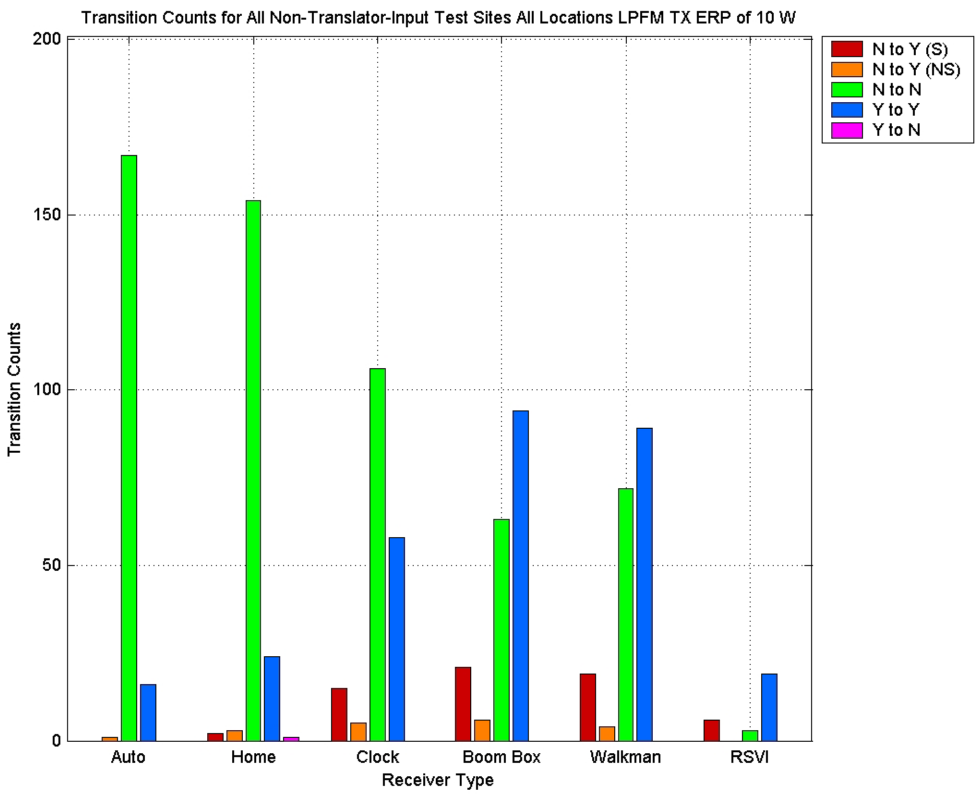


Figure C-24. Transition Counts for All Non-Translator-Input Test Sites, All Receiver Measurement Locations, LPFM ERP Value of 10 W

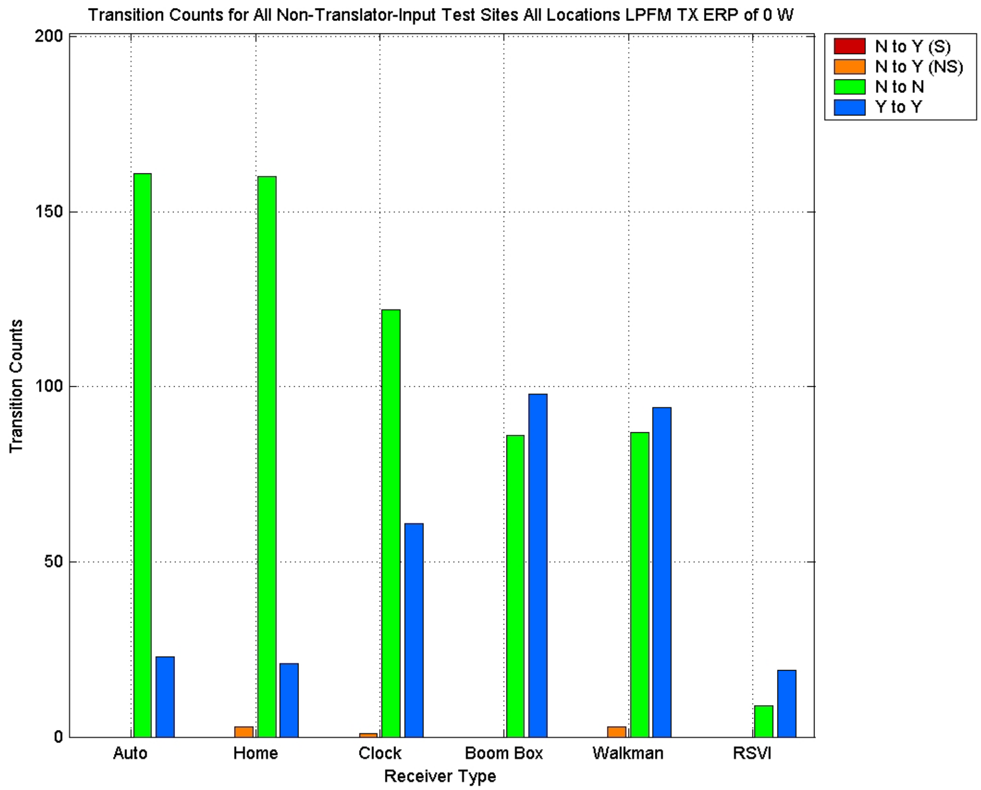


Figure C-25. Transition Counts for All Non-Translator-Input Test Sites, All Receiver Measurement Locations, LPFM ERP Value of 0 W

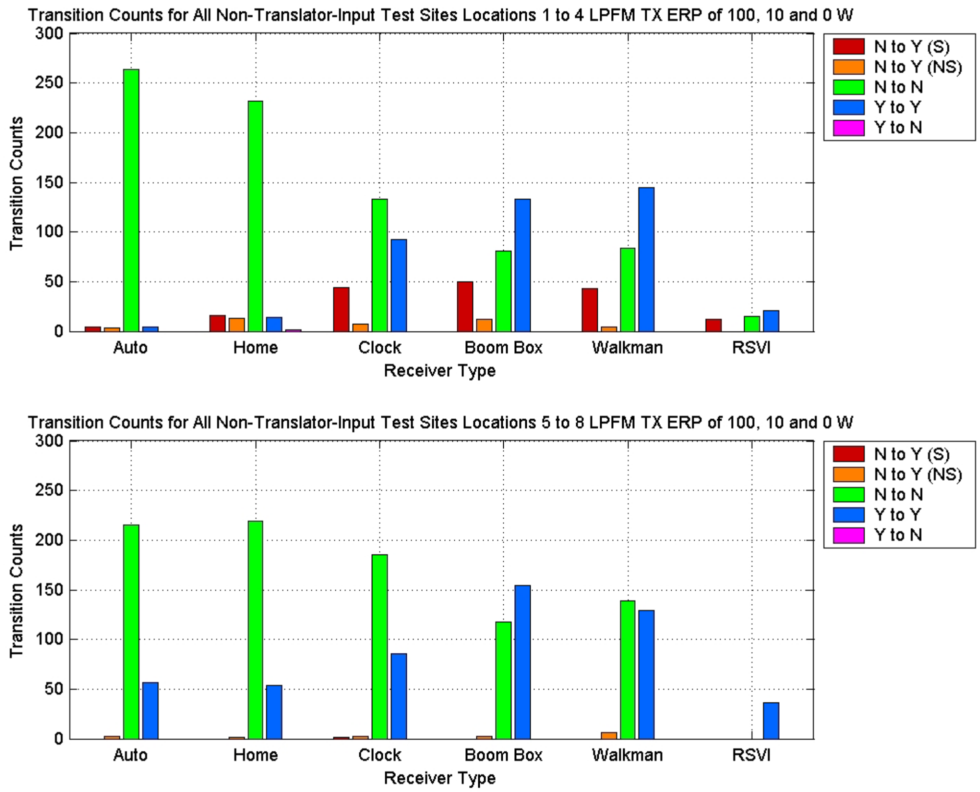


Figure C-26. Transition Counts for All Non-Translator-Input Test Sites, All LPFM ERP Values (100, 10, and 0 W) and Separating Locations 1 to 4, and Locations 5 to 8 in Two Subplots

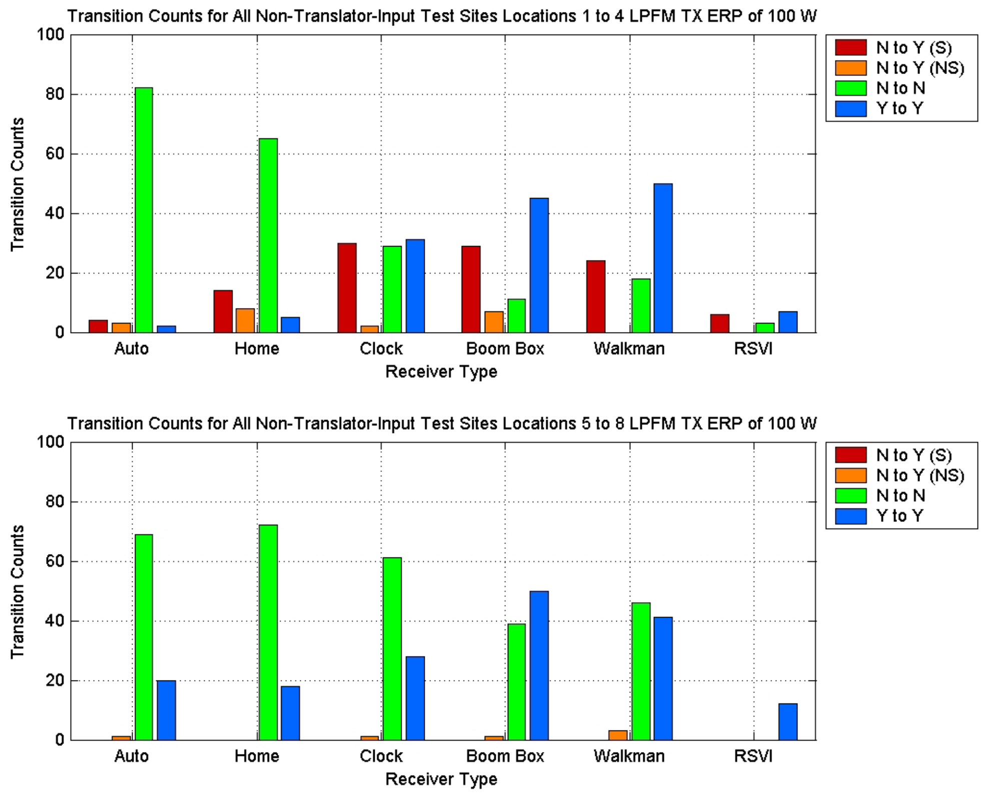


Figure C-27. Transition Counts for All Non-Translator-Input Test Sites, LPFM ERP Value of 100 W and Separating Locations 1 to 4, and Locations 5 to 8 in Two Subplots

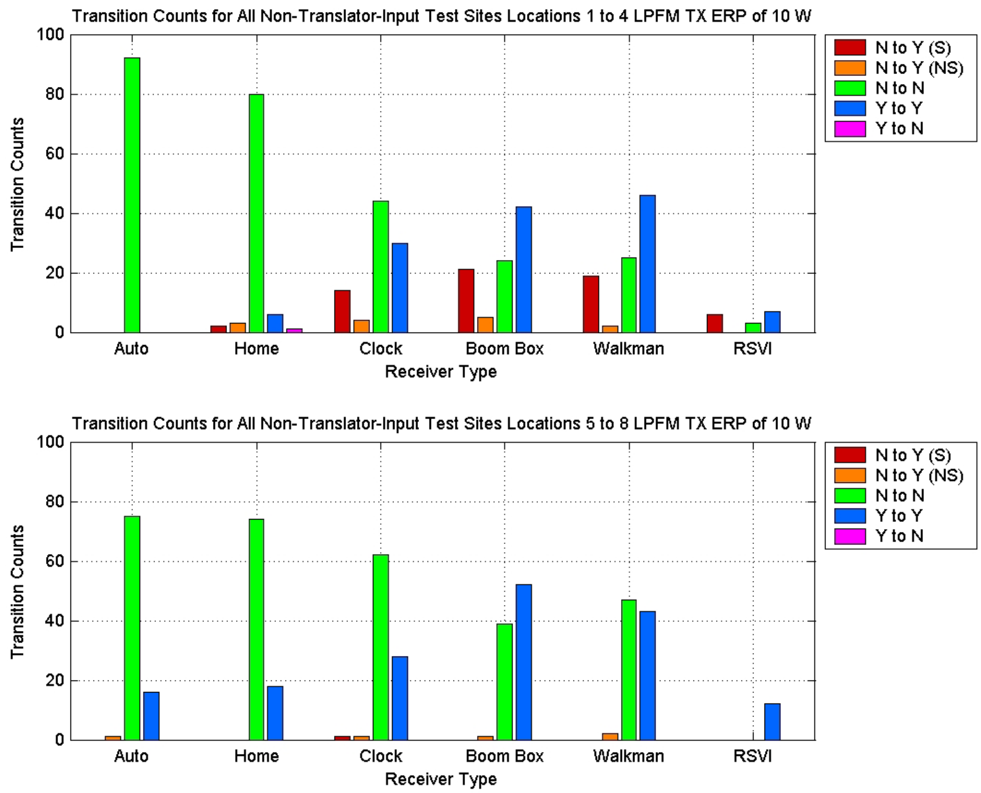


Figure C-28. Transition Counts for All Non-Translator-Input Test Sites, LPFM ERP Value of 10 W and Separating Locations 1 to 4, and Locations 5 to 8 in Two Subplots

Appendix D

Degradation-Transition Counts for Each Receiver and Program Content Combination

This appendix shows the LPFM-FPFM program content plots for all LPFM test sites in Figures D-1 to D-7. Figures D-8 to D-11 show the LPFM-FPFM program content plots for Owatonna Translator Input test.

These plots present the raw data set, with the percentages calculated for each LPFM-FPFM program content combination and each receiver type. No area-weighting was applied to the transition count percentages shown in these plots; therefore they do *not* represent probabilities of transitions.

The number of data points used to generate the LPFM Unprocessed → FPFM Unprocessed subplot in Figure D-1 was 140, and it represented the smallest sample size. For all other program content combinations the number of data points used to generate the appropriate subplots in Figure D-1 was at least 269.

The number of data points used to generate the LPFM Unprocessed → FPFM Unprocessed subplot in Figure D-2 was 28, and it represented the smallest sample size. For all other program content combinations the number of data points used to generate the appropriate subplots in Figure D-2 was at least 47. The same comment applies to Figures D-3 to D-6.

The number of data points used to generate each subplot in Figure D-7 was 42.

The number of data points used to generate the LPFM Processed → FPFM Unprocessed subplot in Figure D-8 was 160 and it was 140 for the other two subplots.

The number of data points used to generate the LPFM Processed → FPFM Processed subplot in Figure D-9 was 32 and it was 28 for the other two subplots. The same comment applies to Figures D-10 and D-11.

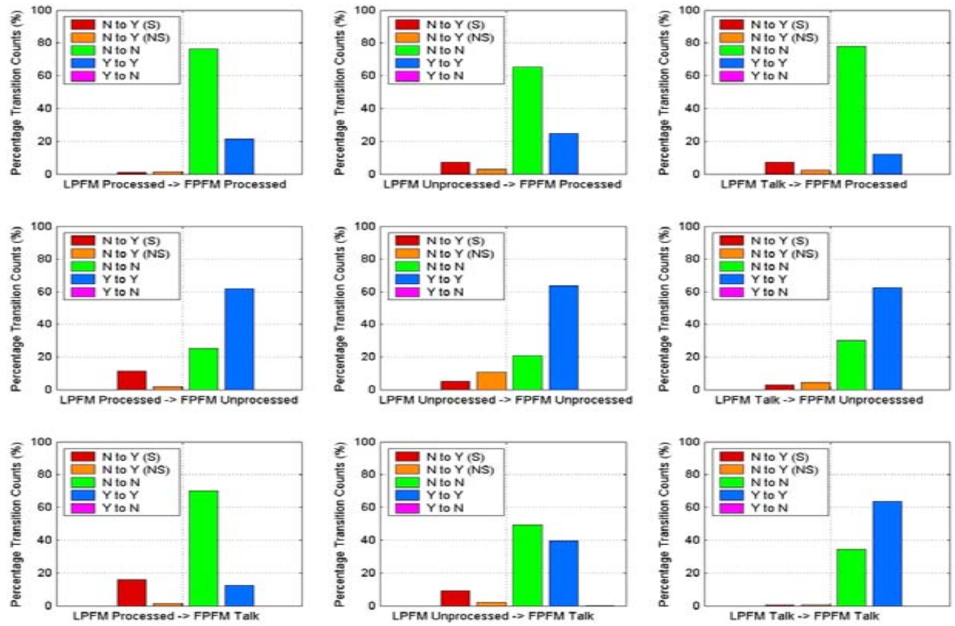


Figure D-1. Percentage Transition Counts for All Receiver Types, All LPFM Test Sites

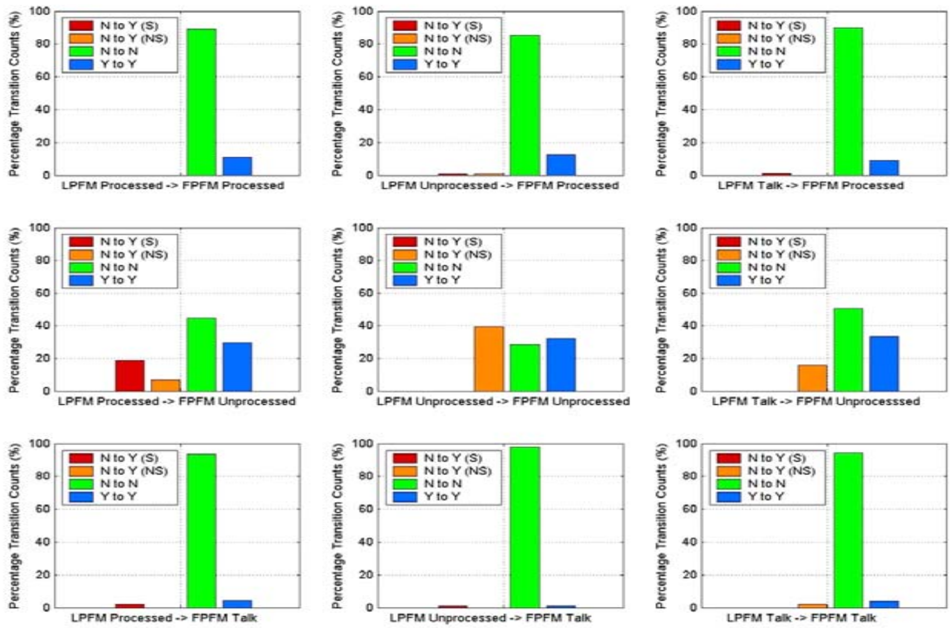


Figure D-2. Percentage Transition Counts for the Auto Receiver, All LPFM Test Sites

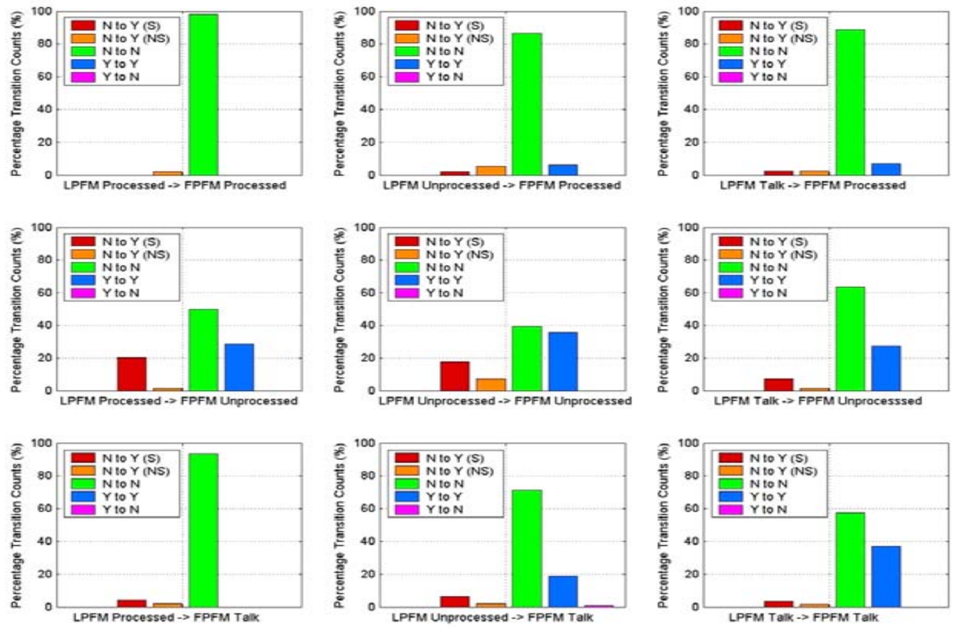


Figure D-3. Percentage Transition Counts for the Home Receiver, All LPFM Test Sites

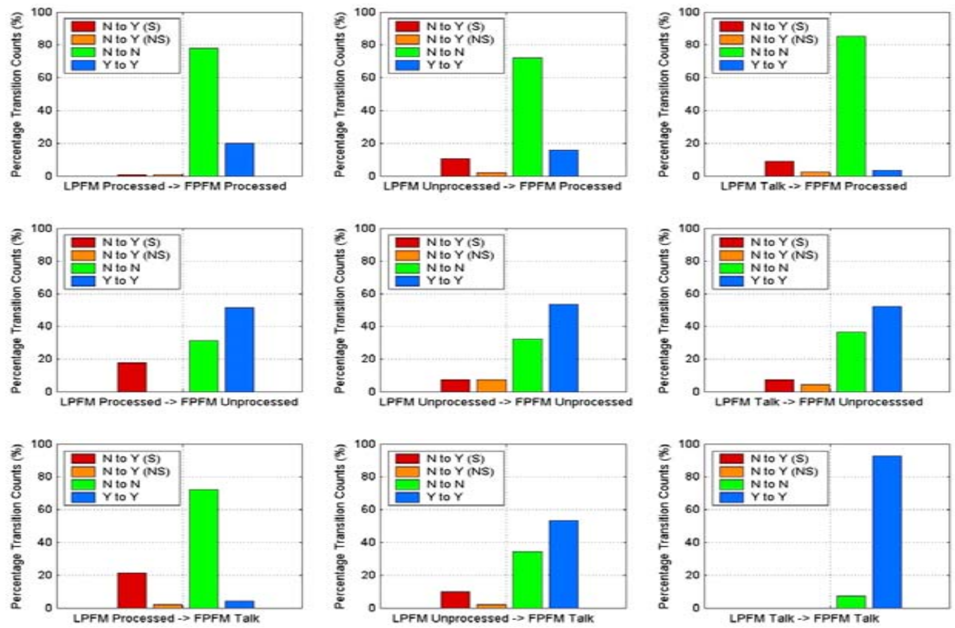


Figure D-4. Percentage Transition Counts for the Clock Radio Receiver, All LPFM Test Sites

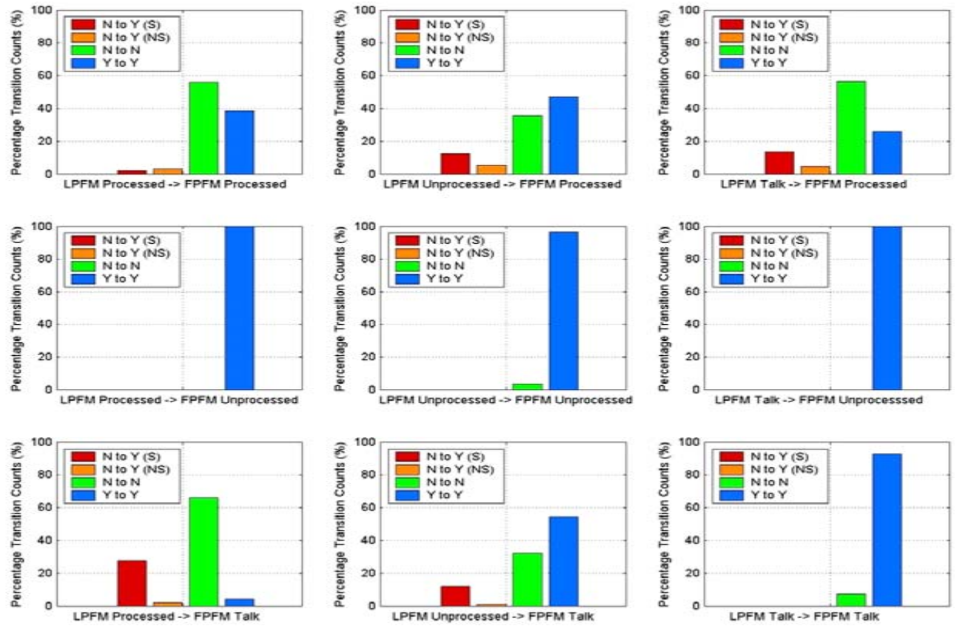


Figure D-5. Percentage Transition Counts for the Boom Box Receiver, All LPFM Test Sites

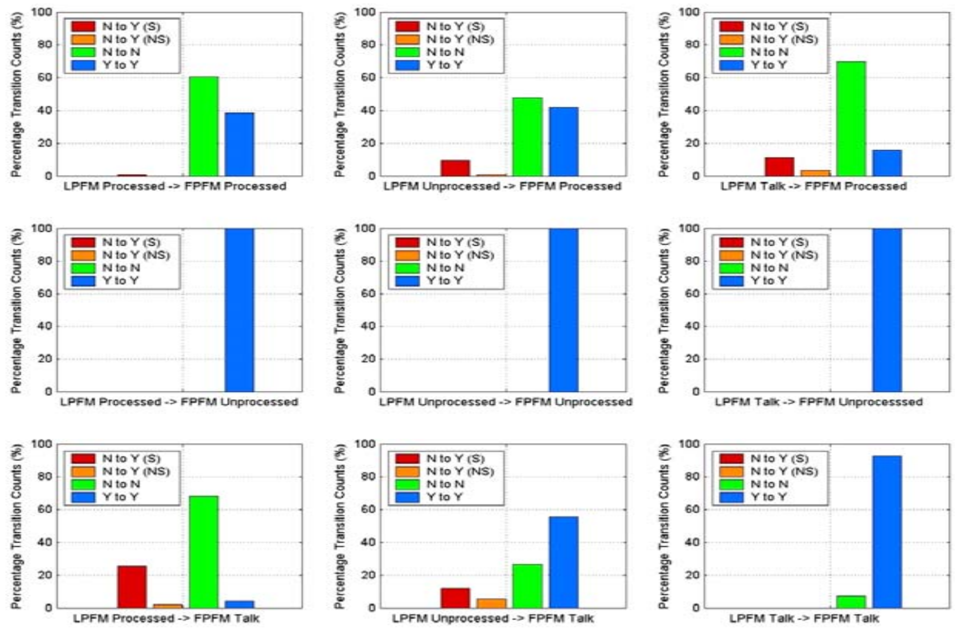


Figure D-6. Percentage Transition Counts for the Walkman Receiver, All LPFM Test Sites

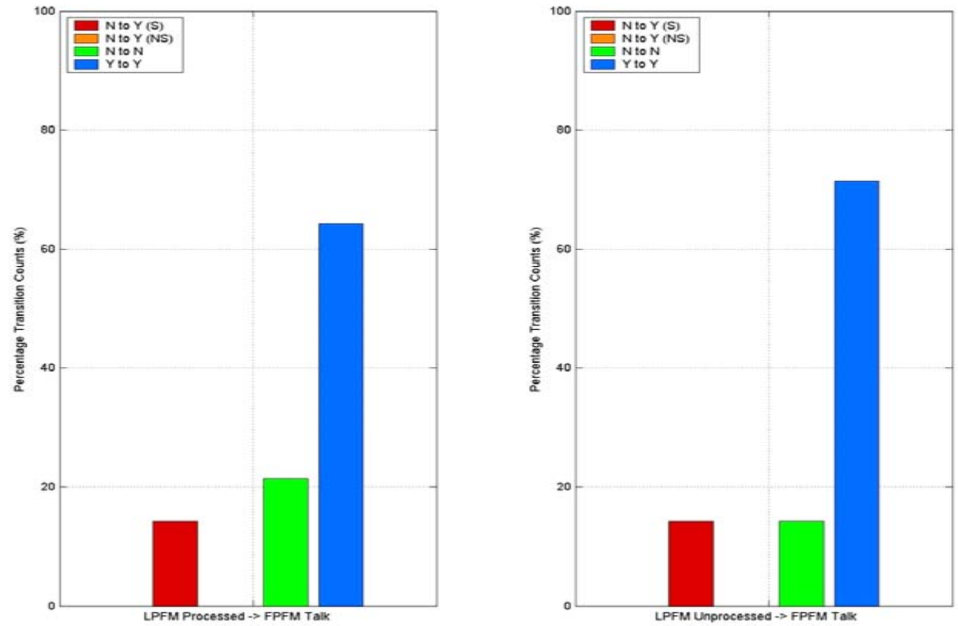


Figure D-7. Percentage Transition Counts for the RSVI Receiver, East Bethel LPFM Test Site

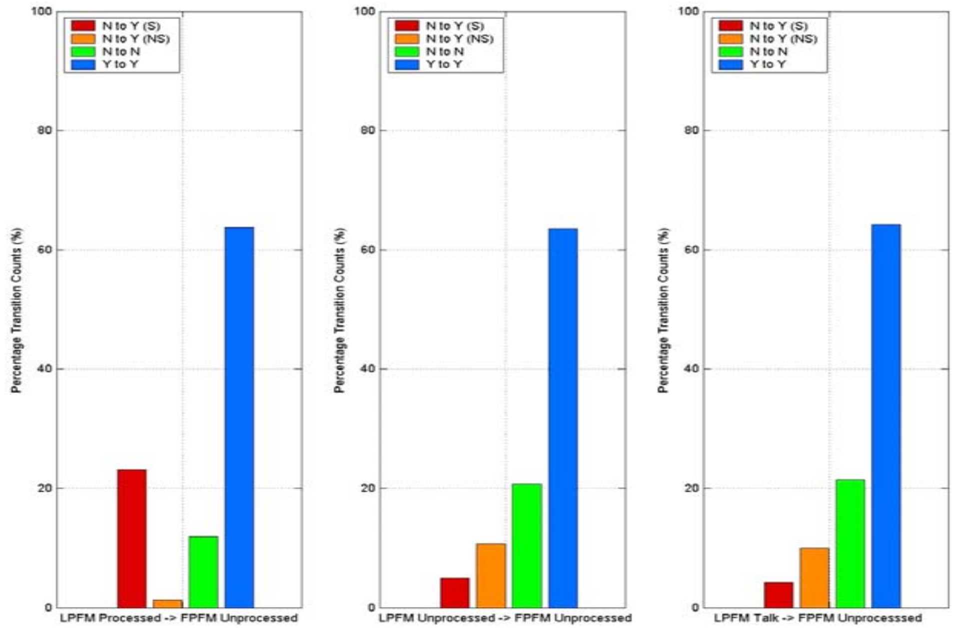


Figure D-8. Percentage Transition Count for All Receiver Types, Owatonna Translator Input Test Site

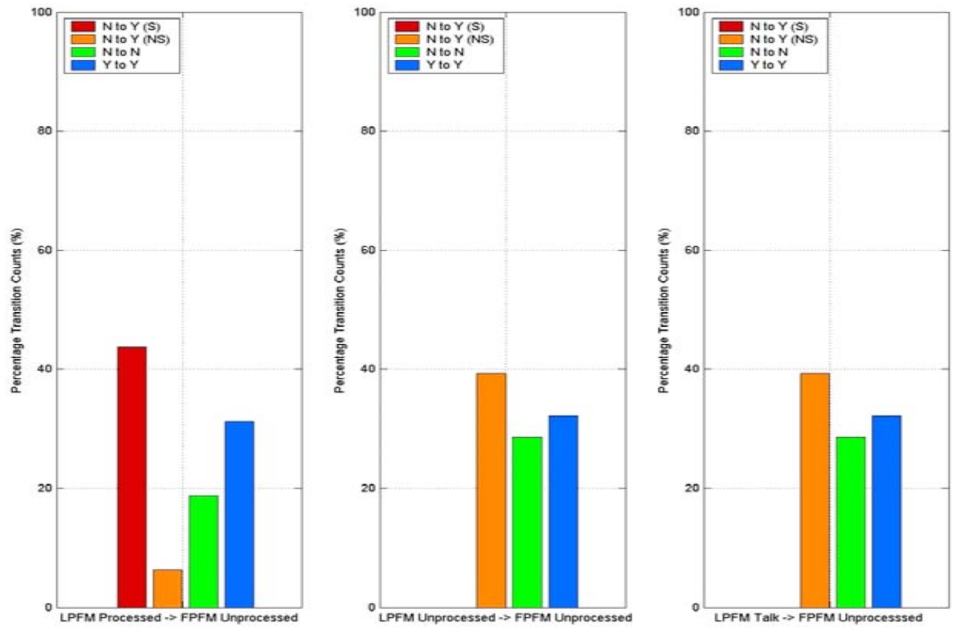


Figure D-9. Percentage Transition Counts for the Auto Receiver, Owatonna Translator Input Test Site

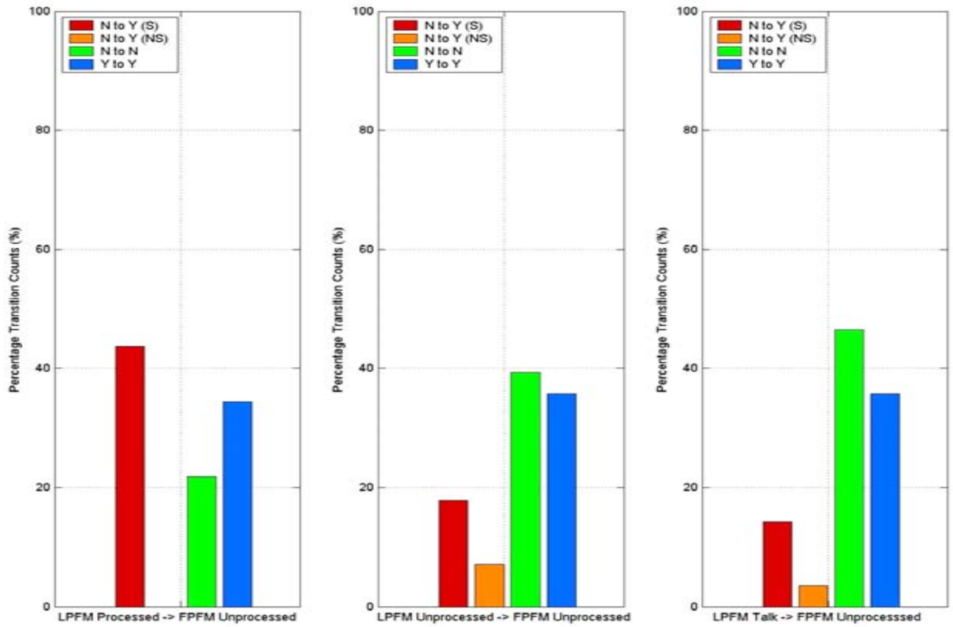


Figure D-10. Percentage Transition Counts for the Home Receiver, Owatonna Translator Input Test Site

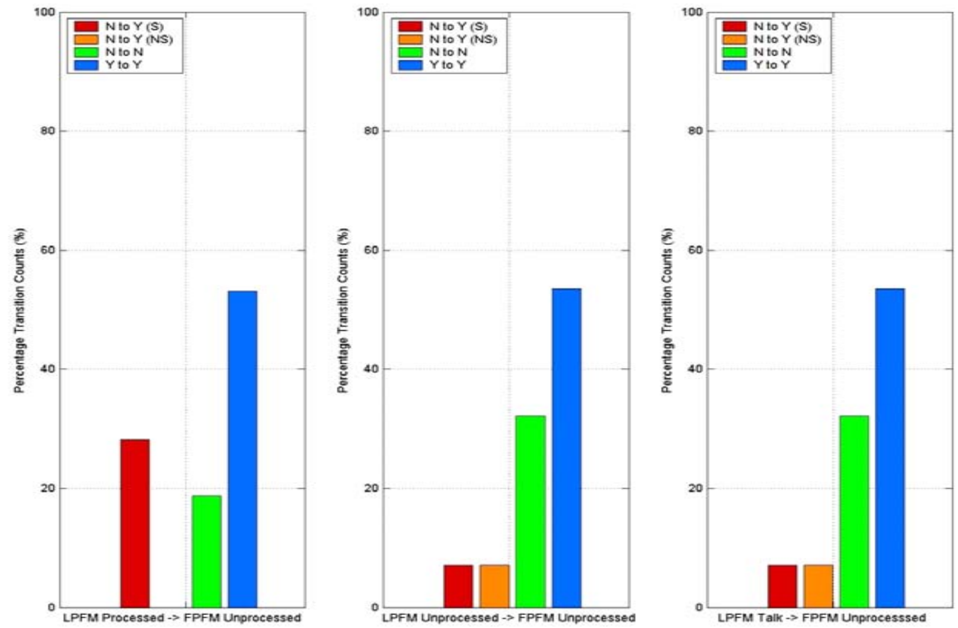


Figure D-11. Percentage Transition Counts for the Clock Radio Receiver, Owatonna Translator Input Test Site

Appendix E

Degradation-Transition Cases for Each Site, Receiver and Program Content Combination

This appendix presents the Delta Degradation plots as a function of D/U for all non-input translator test sites, for each receiver type and also for the various LPFM-FPFM program content combinations.

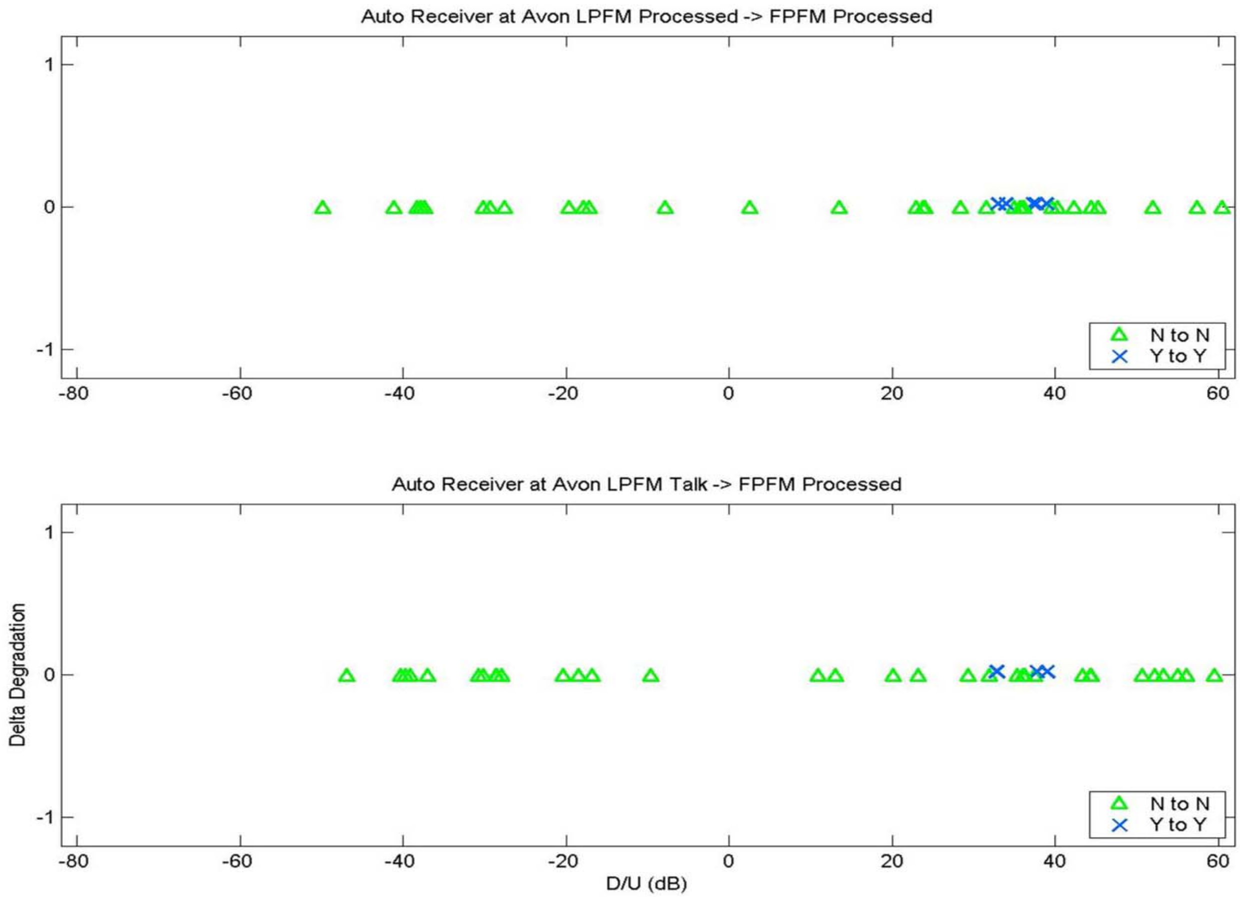


Figure E-1. Delta Degradation for the Auto Receiver at Avon and for the Specified LPFM-FPFM Program Content Combinations

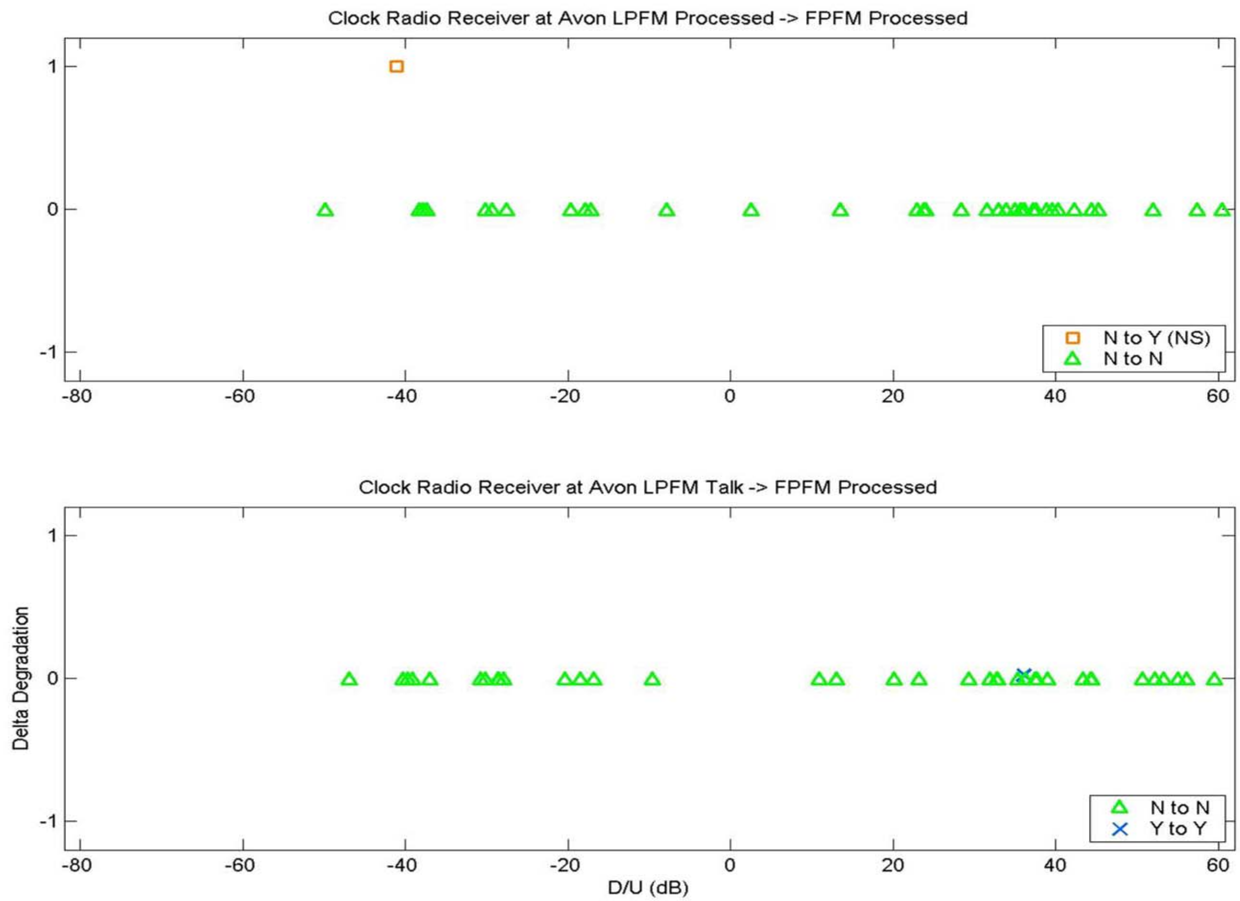


Figure E-2. Delta Degradation for the Clock Receiver at Avon and for the Specified LPFM-FPFM Program Content Combinations

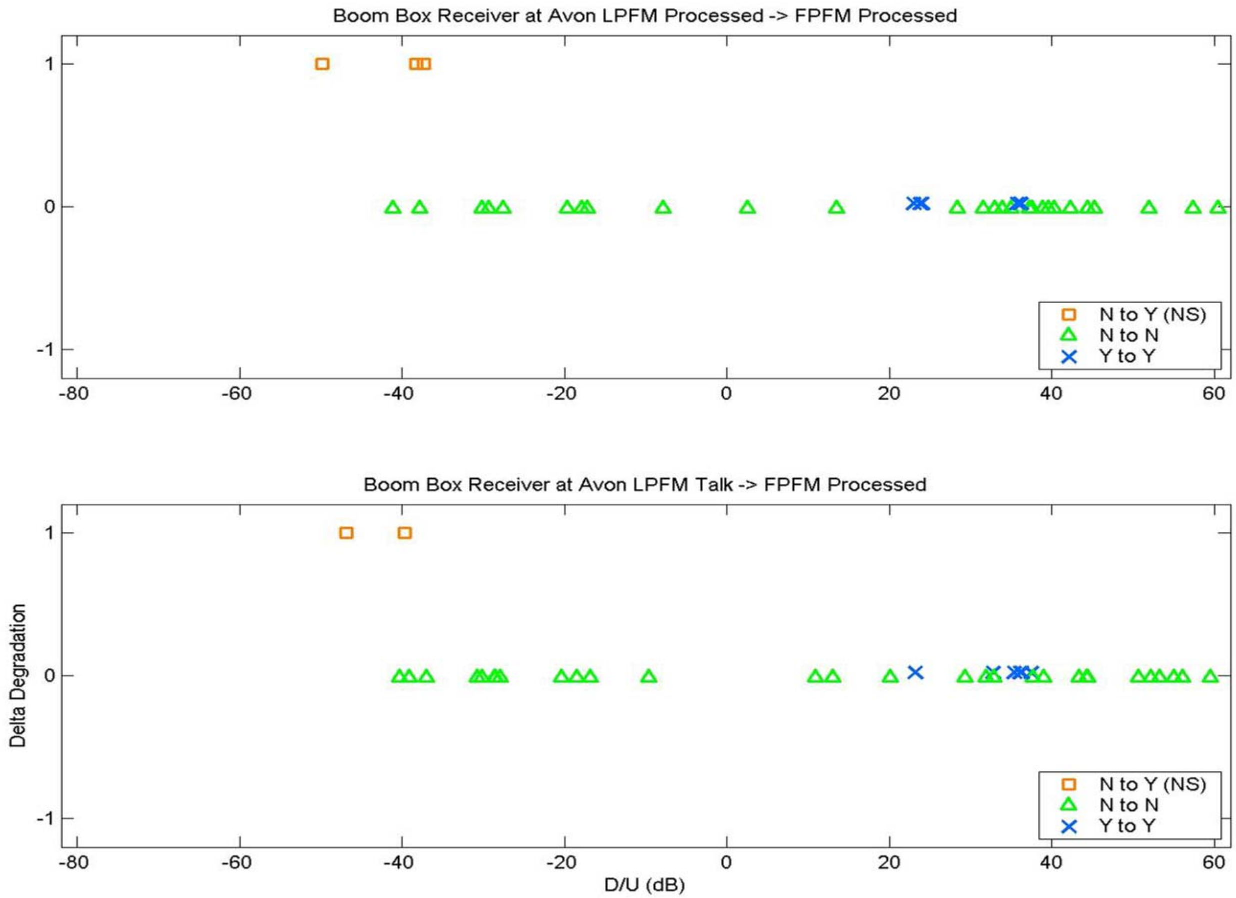


Figure E-3. Delta Degradation for the Boom Box Receiver at Avon and for the Specified LPFM-FPFM Program Content Combinations

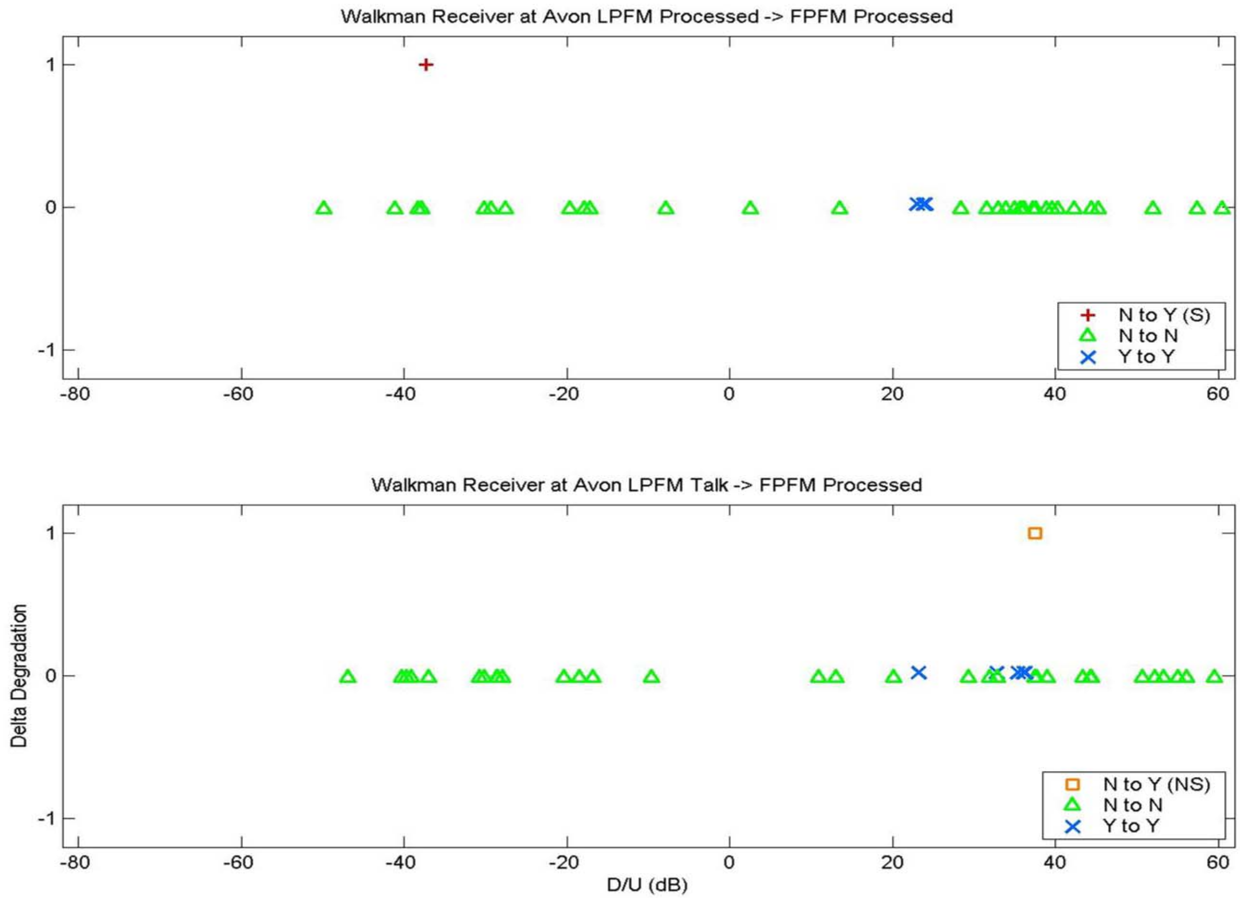


Figure E-4. Delta Degradation for the Walkman Receiver at Avon and for the Specified LPFM-FPFM Program Content Combinations

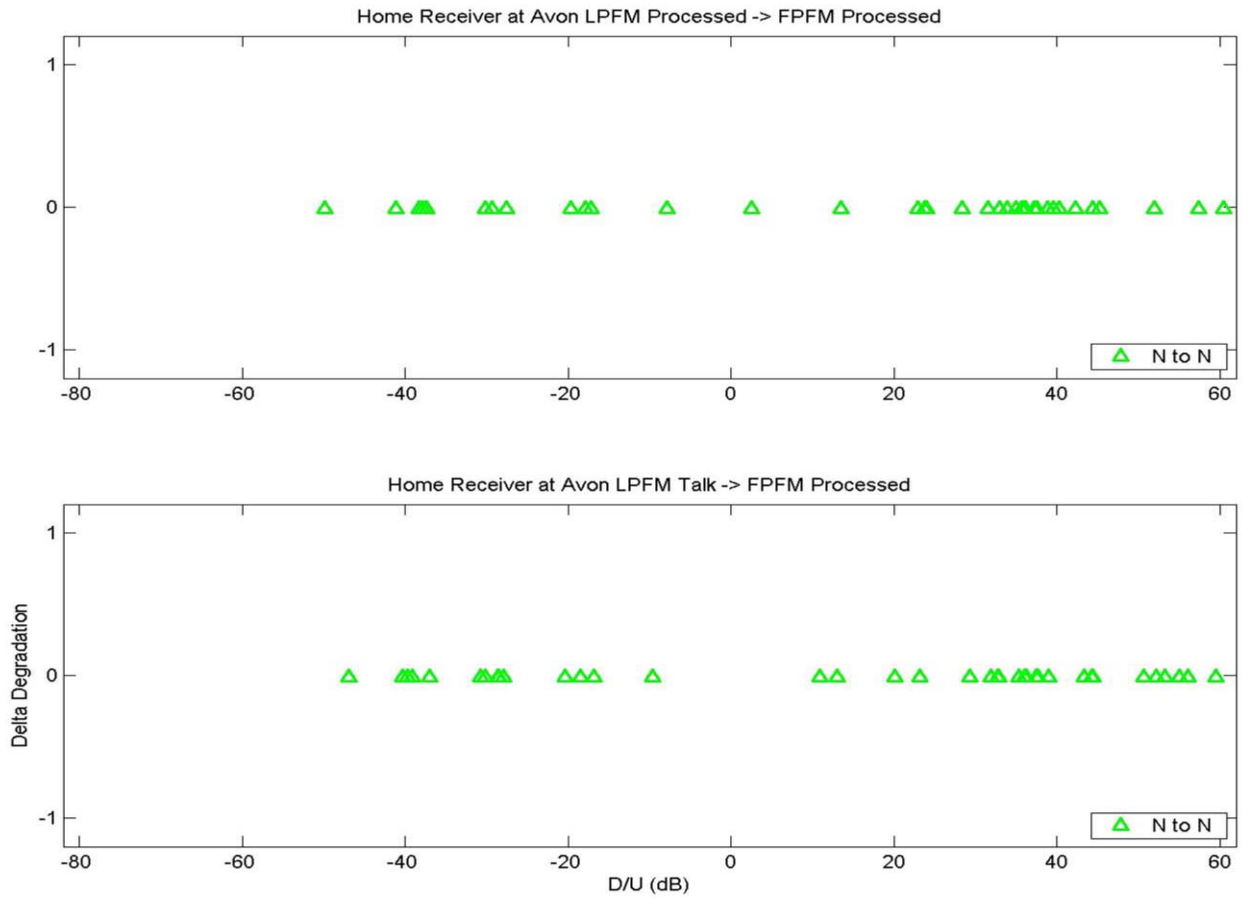


Figure E-5. Delta Degradation for the Home Receiver at Avon and for the Specified LPFM-FPFM Program Content Combinations

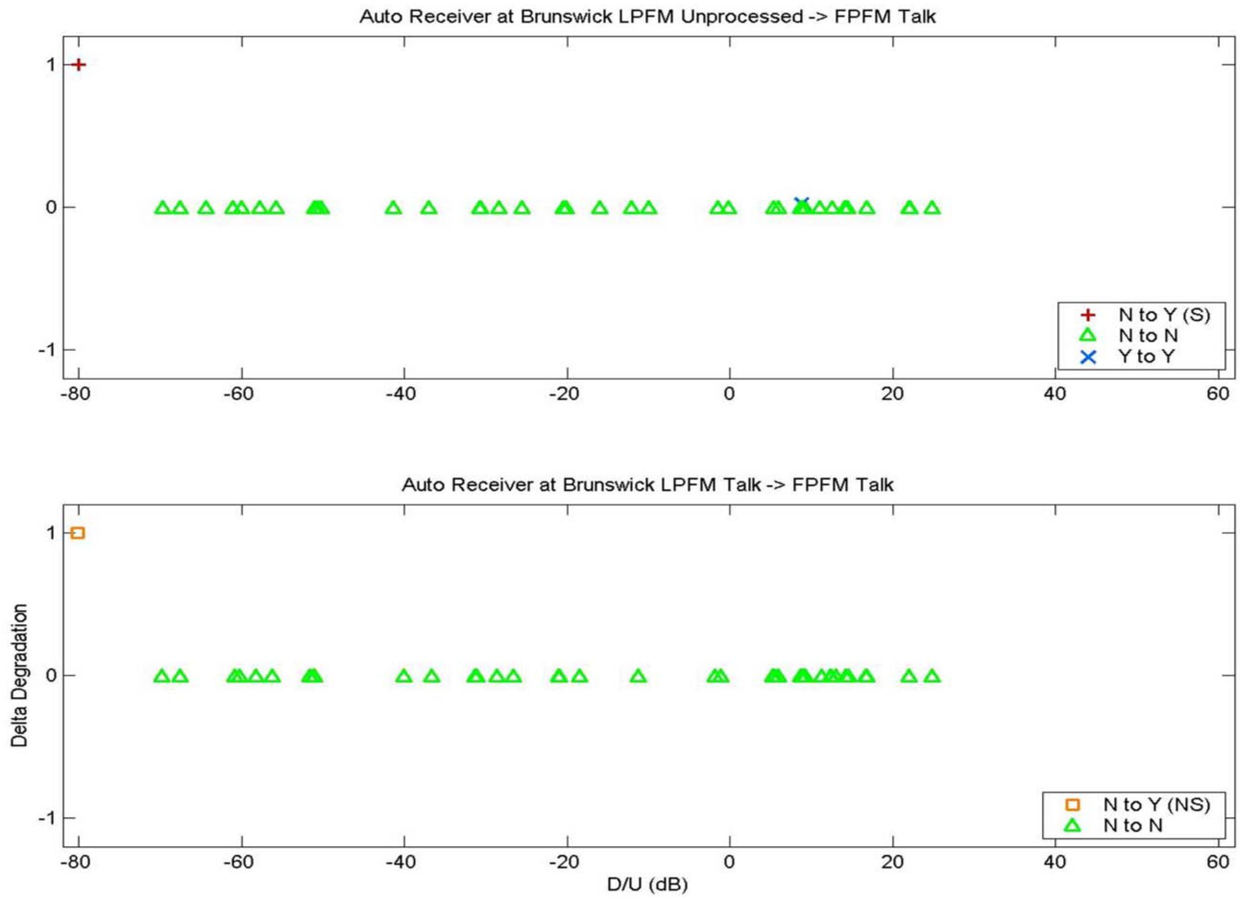


Figure E-6. Delta Degradation for the Auto Receiver at Brunswick and for the Specified LPFM-FPFM Program Content Combinations

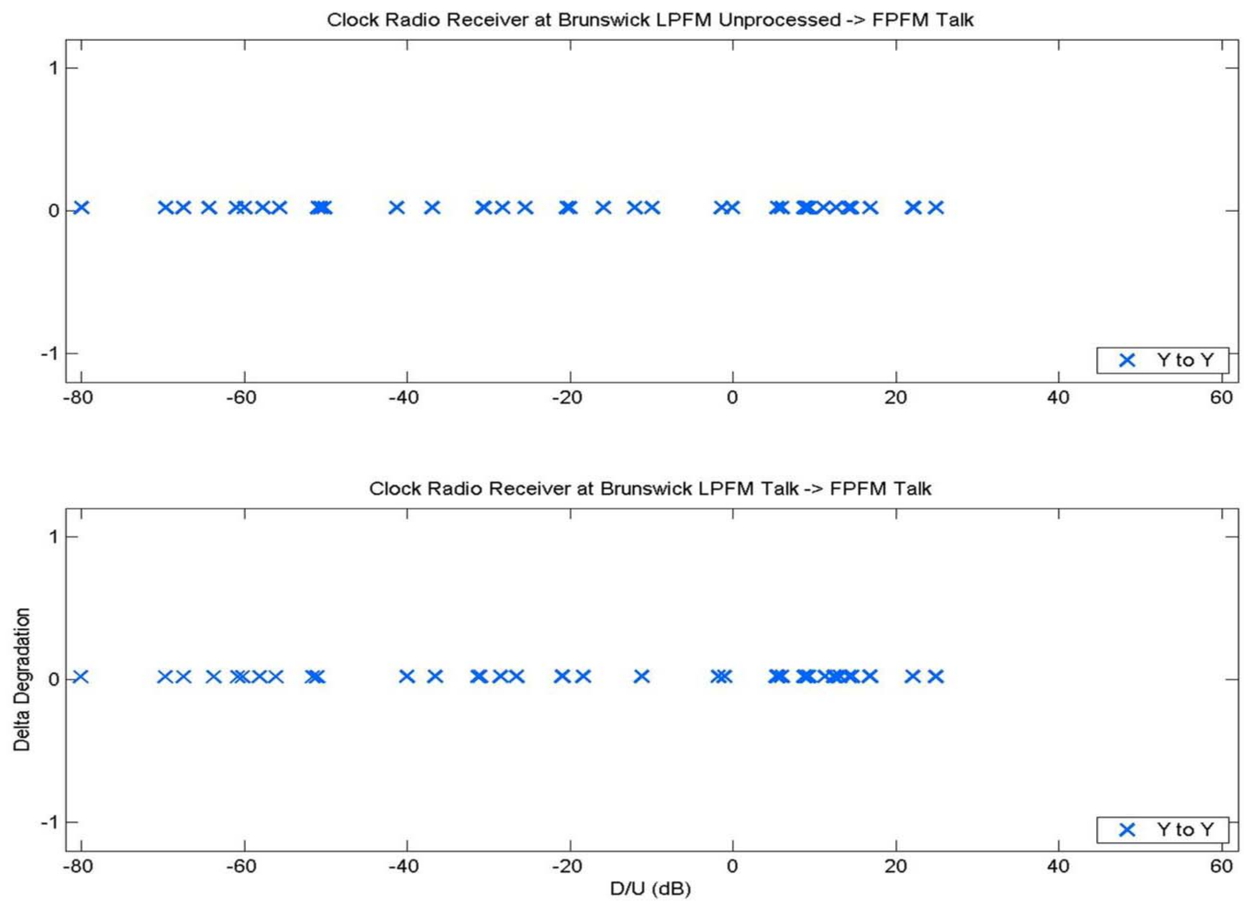


Figure E-7. Delta Degradation for the Clock Radio Receiver at Brunswick and for the Specified LPFM-FPFM Program Content Combinations

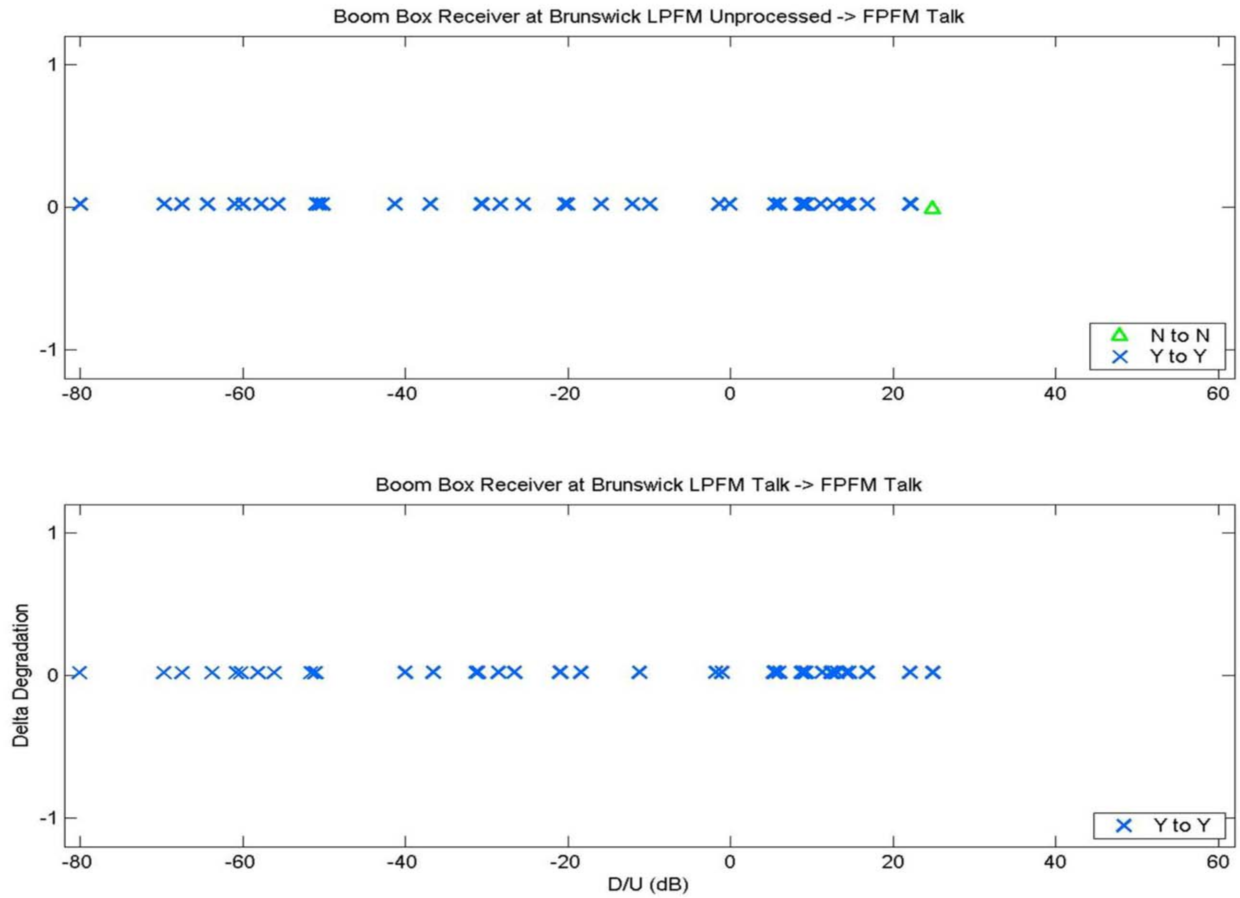


Figure E-8. Delta Degradation for the Boom Box Receiver at Brunswick and for the Specified LPFM-FPFM Program Content Combinations

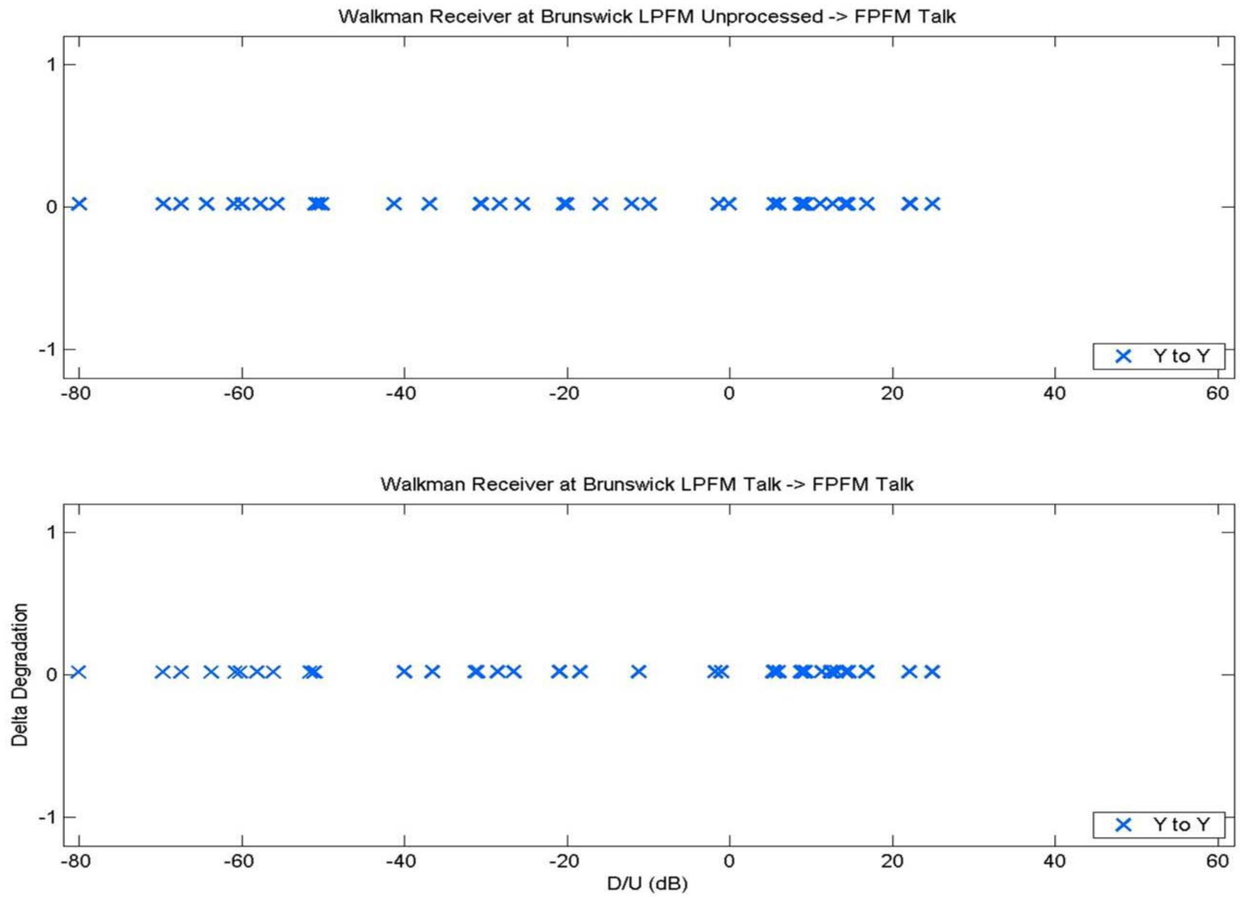


Figure E-9. Delta Degradation for the Walkman Receiver at Brunswick and for the Specified LPFM-FPFM Program Content Combinations

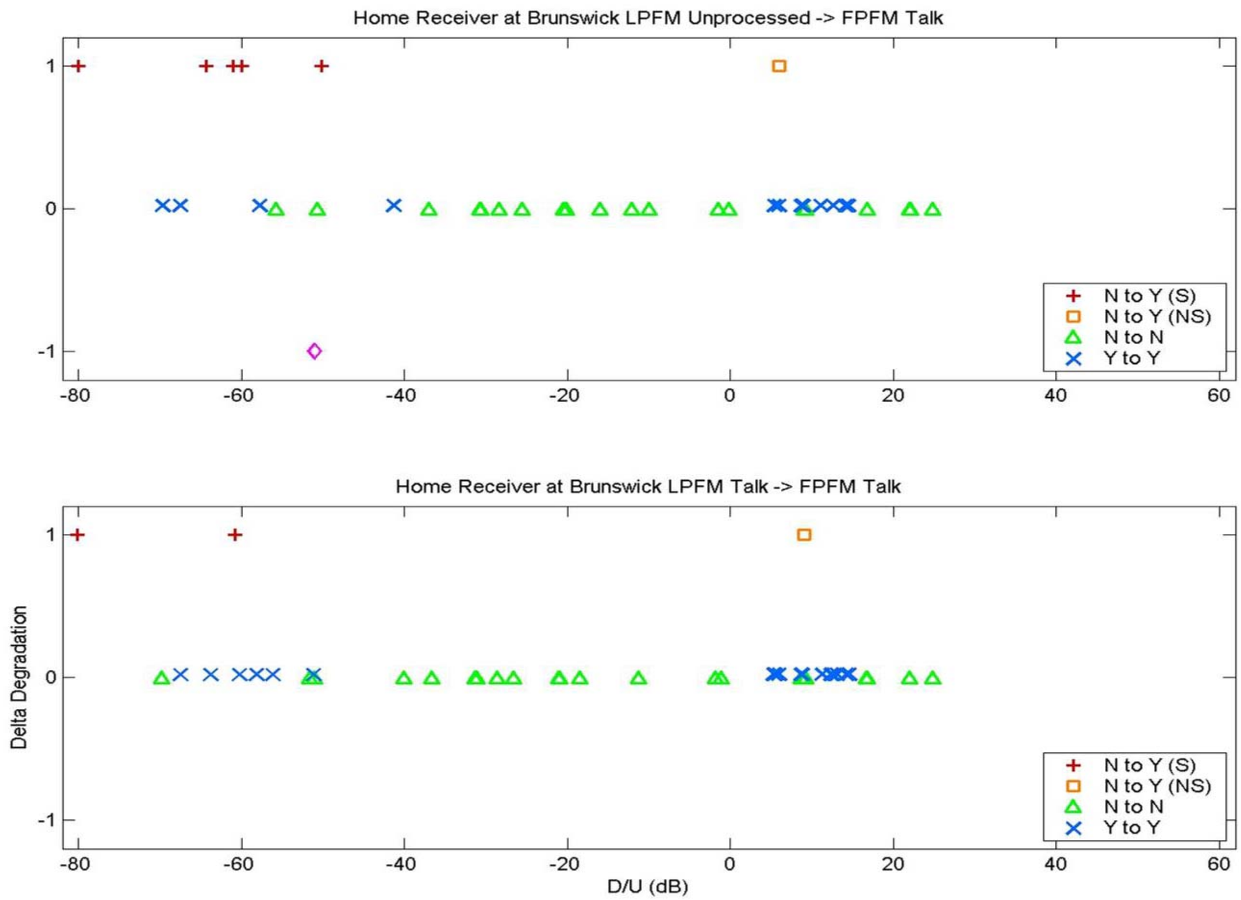


Figure E-10. Delta Degradation for the Home Receiver at Brunswick and for the Specified LPFM-FPFM Program Content Combinations

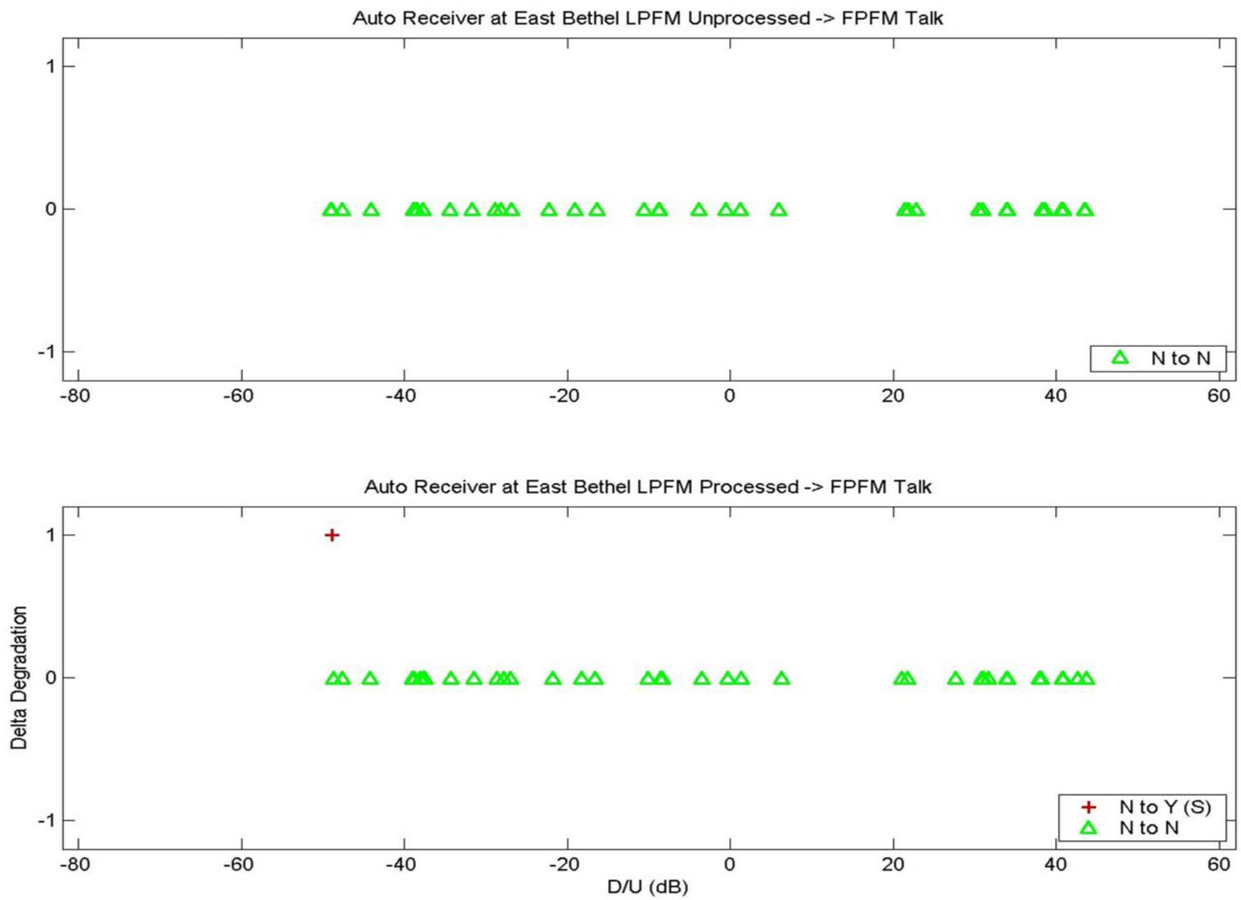


Figure E-11. Delta Degradation for the Auto Receiver at East Bethel and for the Specified LPFM-FPFM Program Content Combinations

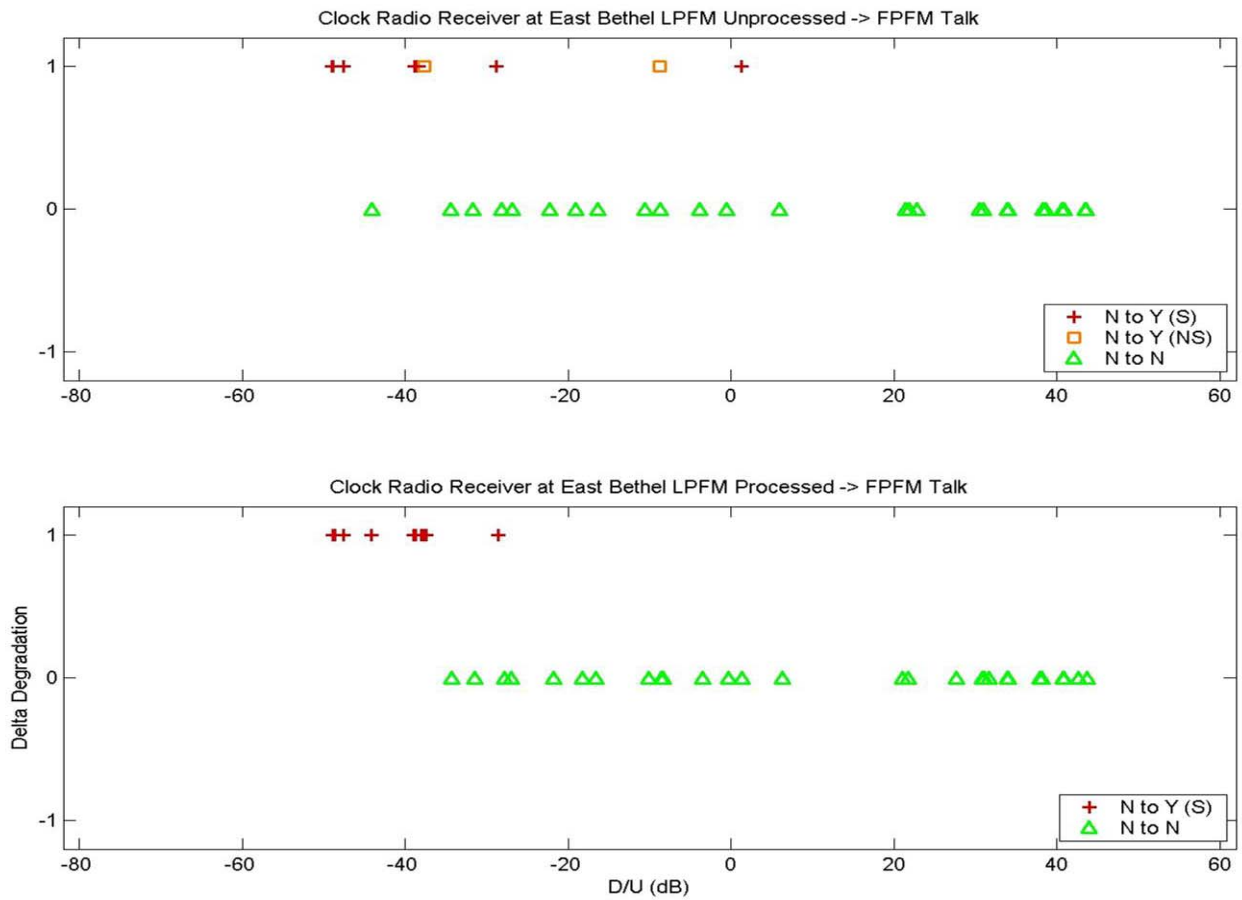


Figure E-12. Delta Degradation for the Clock Radio Receiver at East Bethel and for the Specified LPFM-FPFM Program Content Combinations

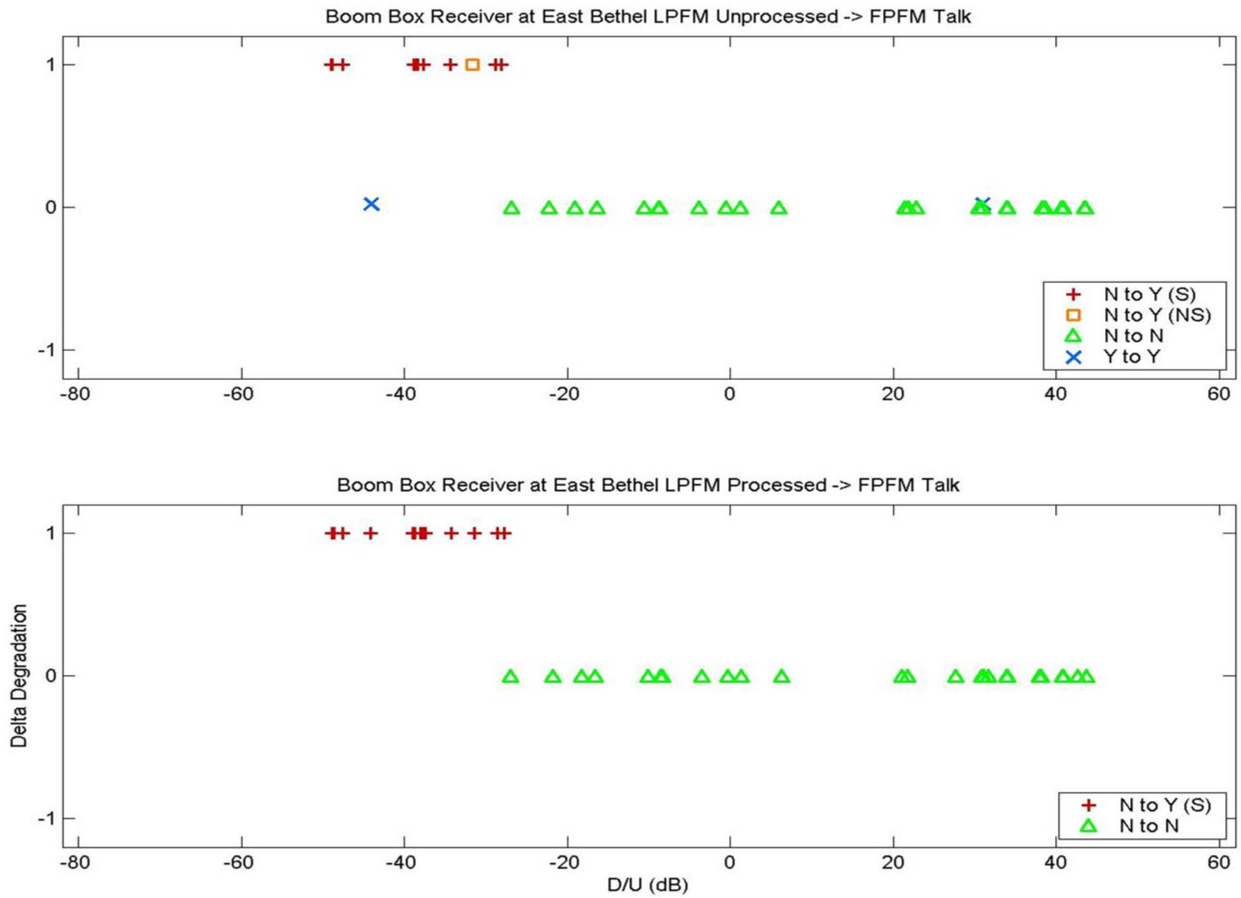


Figure E-13. Delta Degradation for the Boom Box Receiver at East Bethel and for the Specified LPFM-FPFM Program Content Combinations

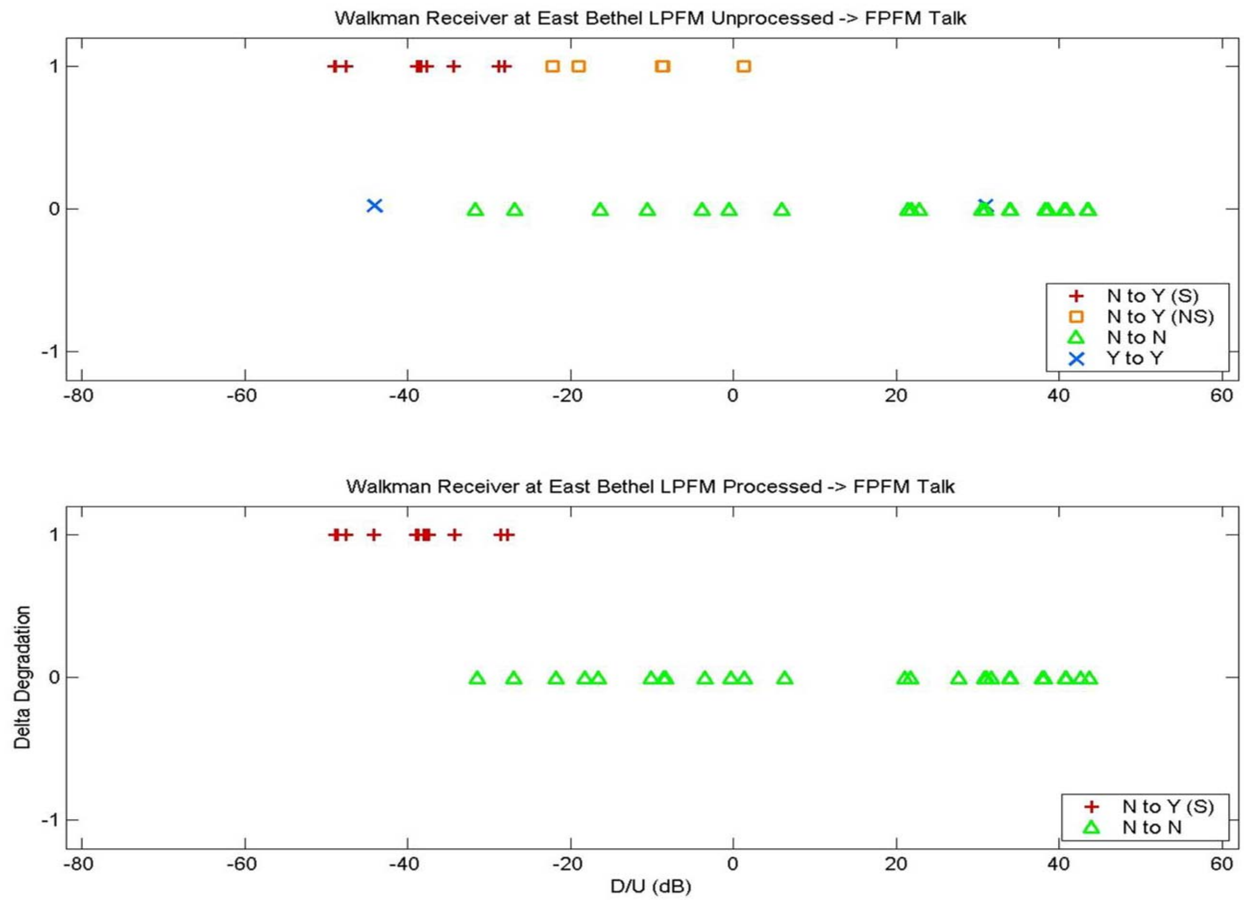


Figure E-14. Delta Degradation for the Walkman Receiver at East Bethel and for the Specified LPFM-FPFM Program Content Combinations

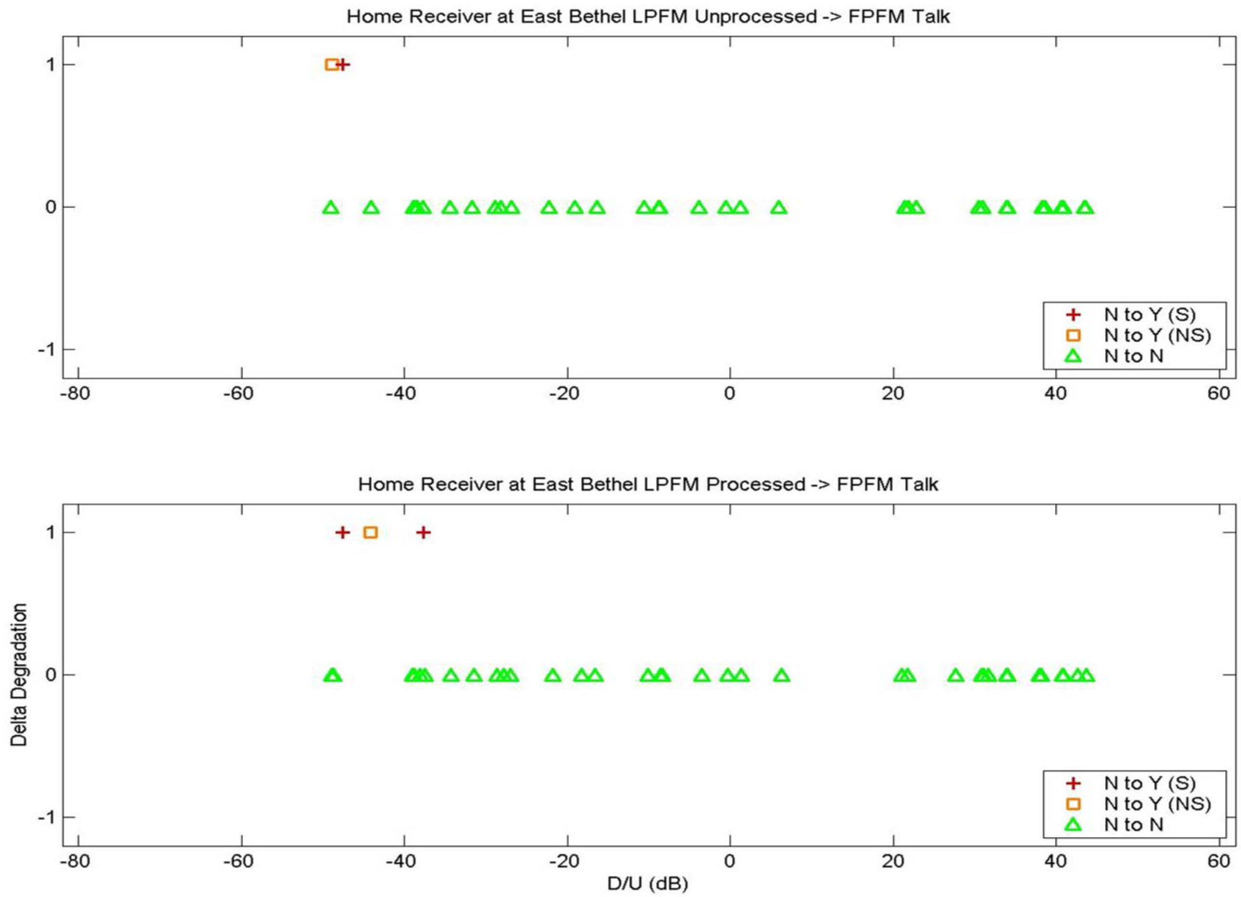


Figure E-15. Delta Degradation for the Home Receiver at East Bethel and for the Specified LPFM-FPFM Program Content Combinations

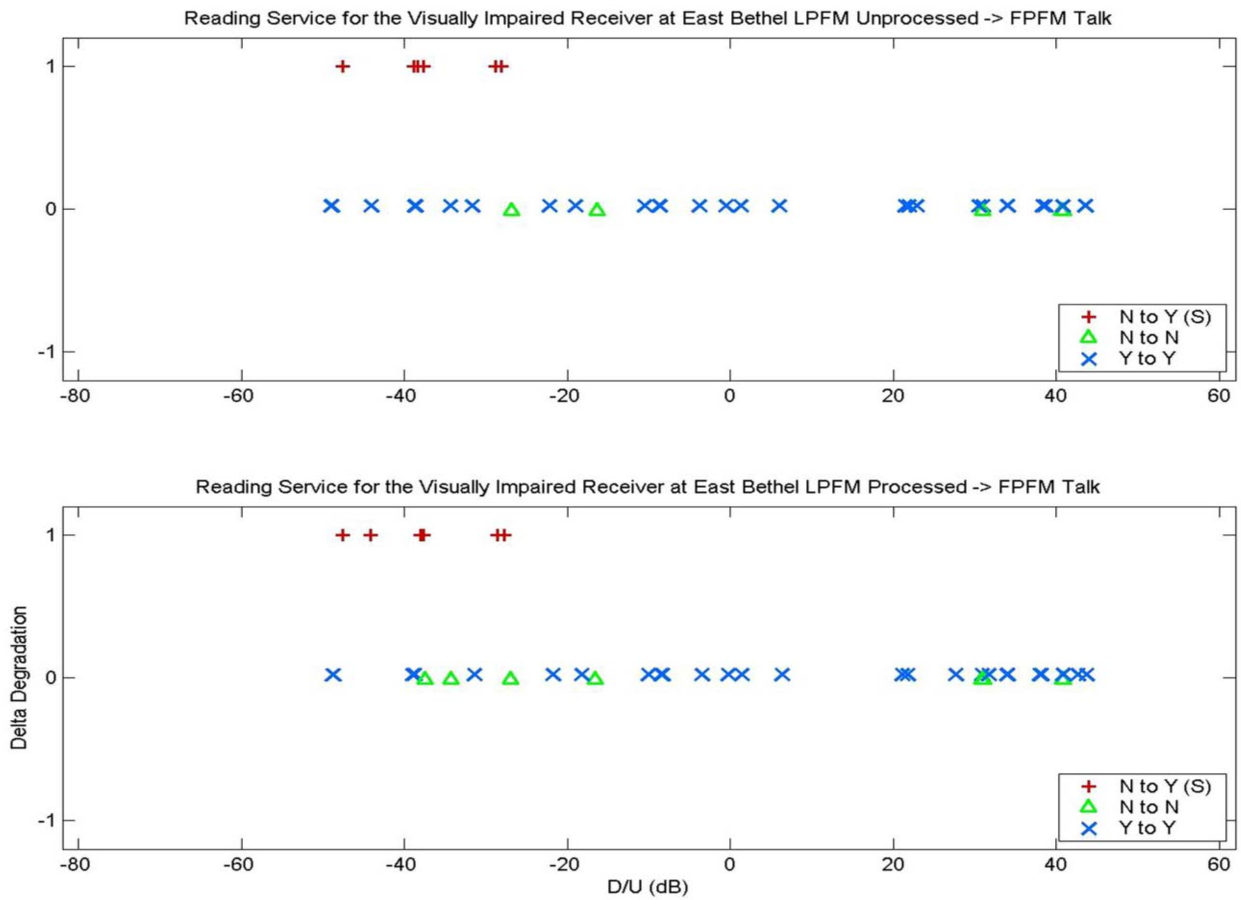


Figure E-16. Delta Degradation for the RSVI Receiver at East Bethel and for the Specified LPFM-FPFM Program Content Combinations

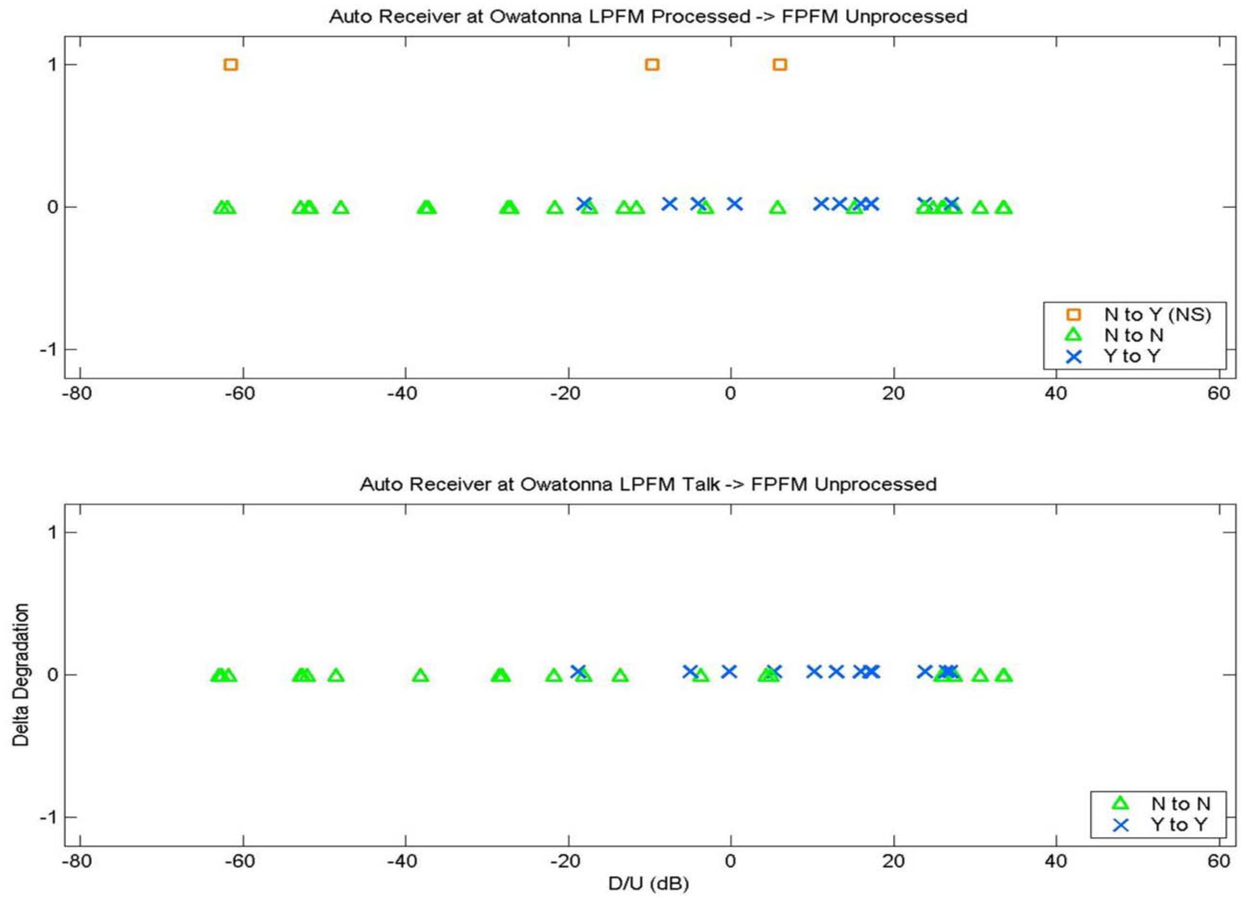


Figure E-17. Delta Degradation for the Auto Receiver at Owatonna Translator Output Test and for the Specified LPFM-FPFM Program Content Combinations

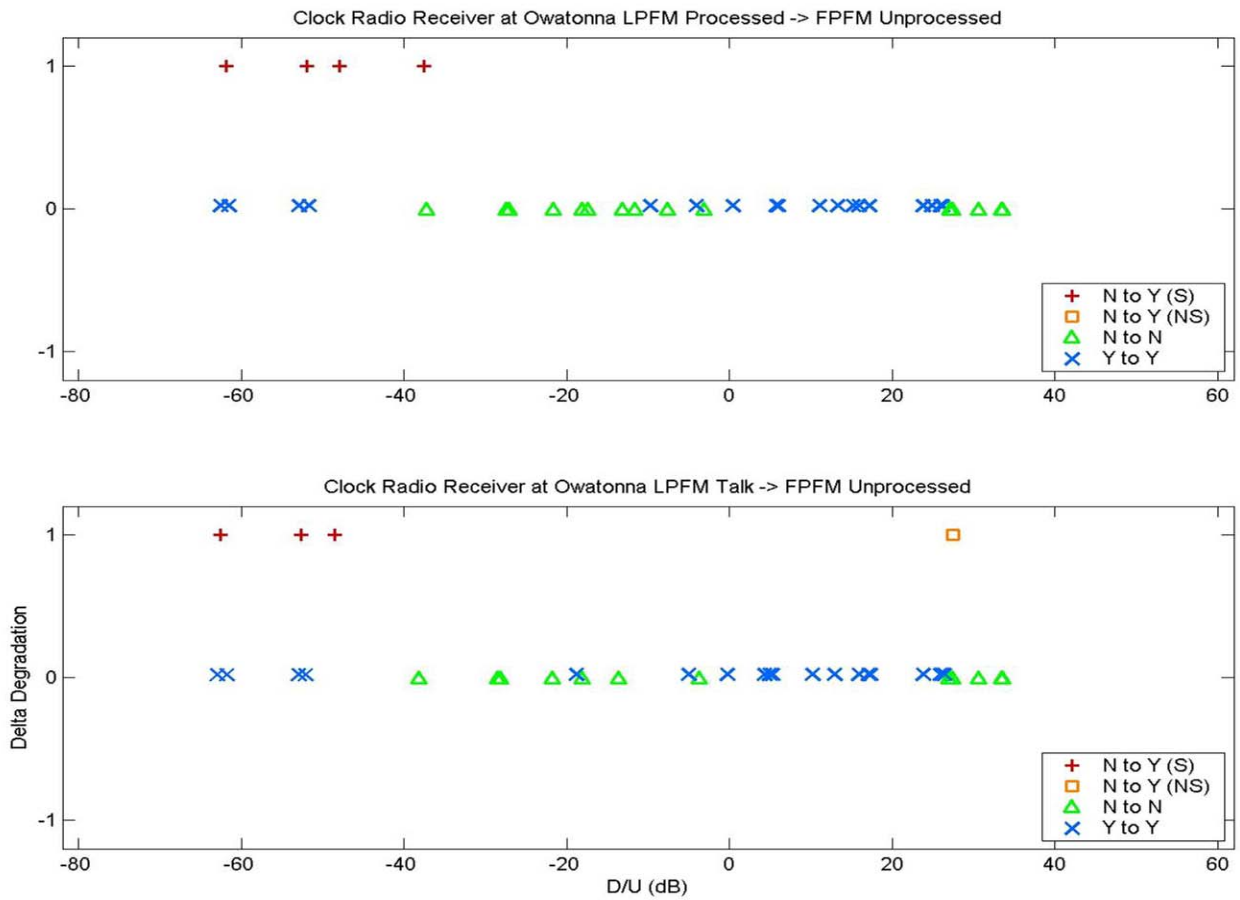


Figure E-18. Delta Degradation for the Clock Radio Receiver at Owatonna Translator Output Test and for the Specified LPFM-FPFM Program Content Combinations

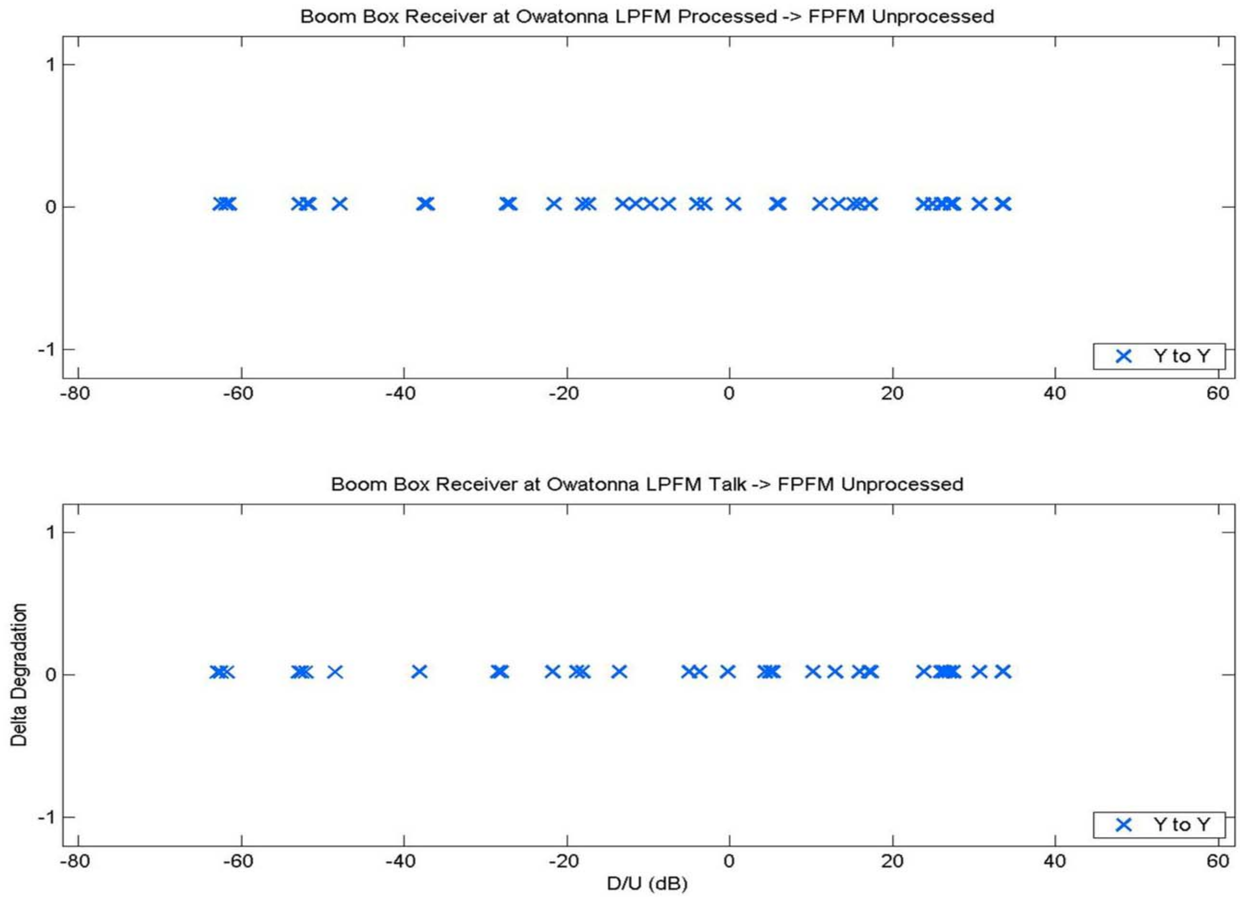


Figure E-19. Delta Degradation for the Boom Box Receiver at Owatonna Translator Output Test and for the Specified LPFM-FPFM Program Content Combinations

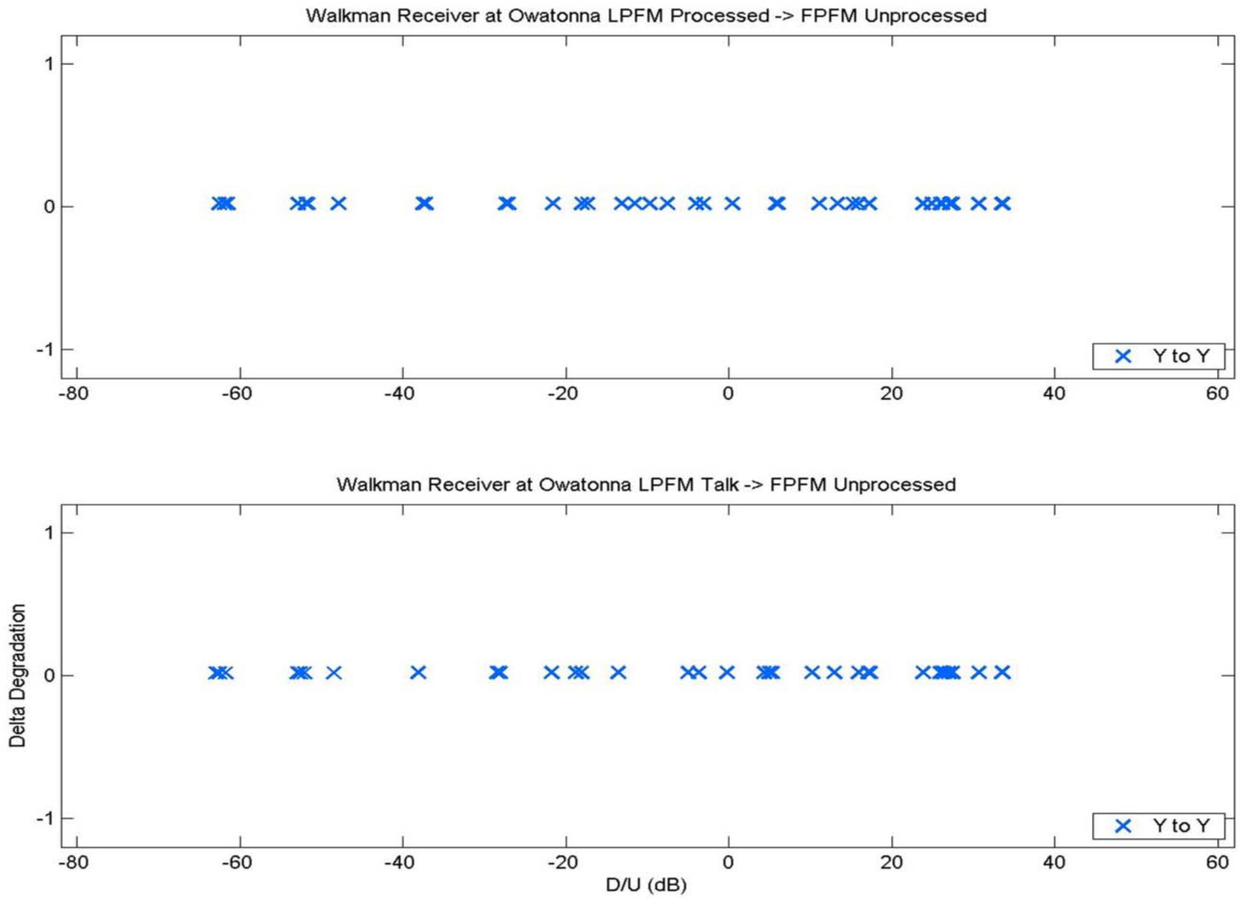


Figure E-20. Delta Degradation for the Walkman Receiver at Owatonna Translator Output Test and for the Specified LPFM-FPFM Program Content Combinations

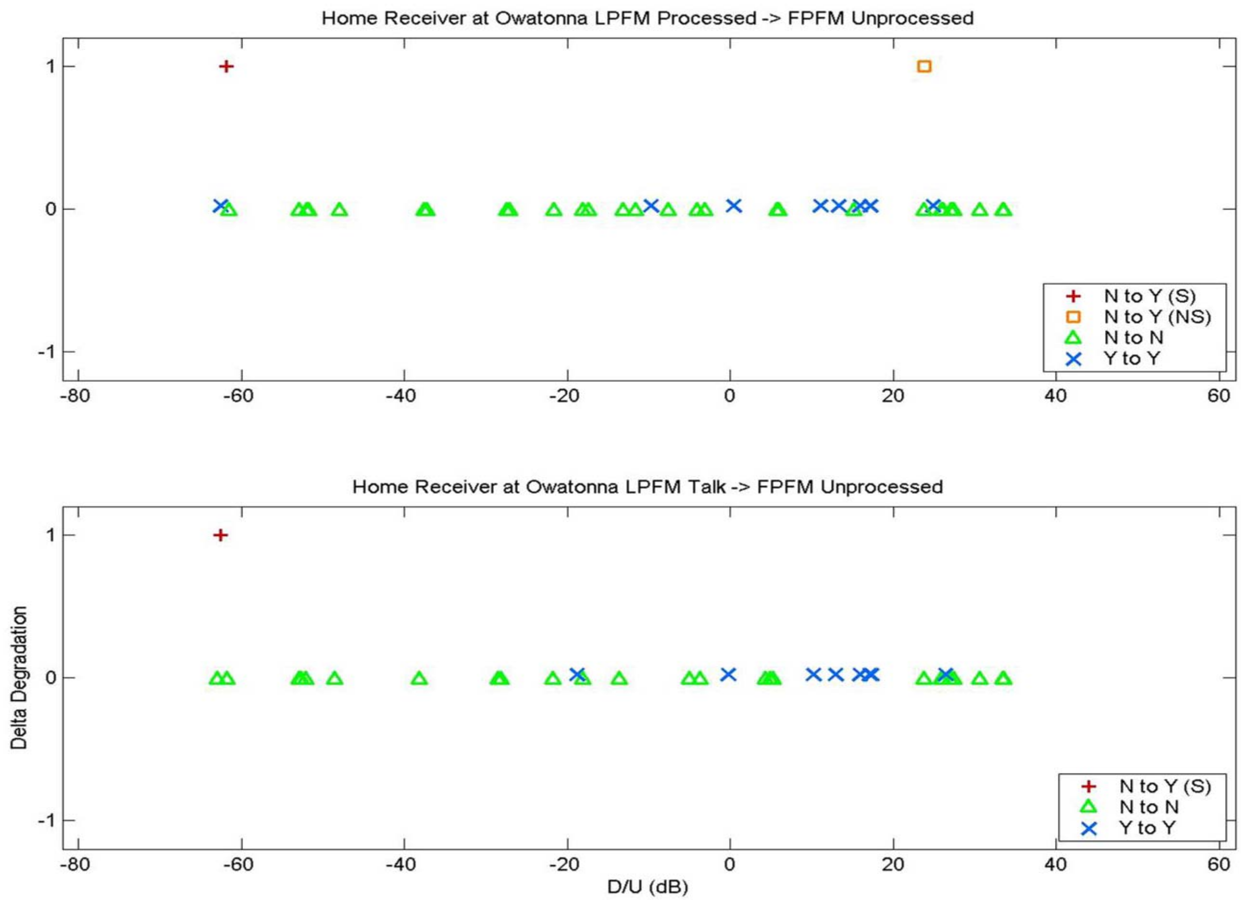


Figure E-21. Delta Degradation for the Home Receiver at Owatonna Translator Output Test and for the Specified LPFM-FPFM Program Content Combinations

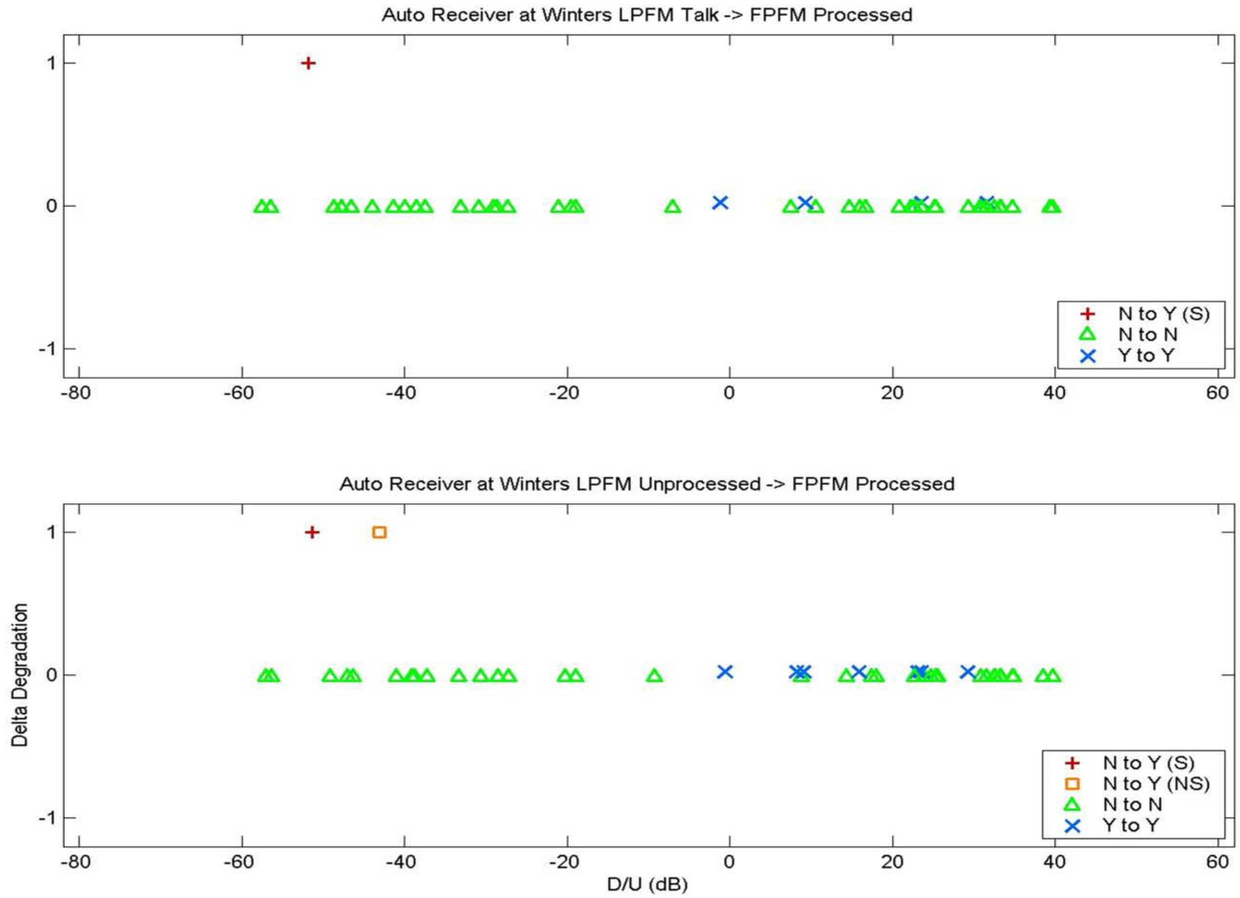


Figure E-22. Delta Degradation for the Auto Receiver at Winters and for the Specified LPFM-FPFM Program Content Combinations

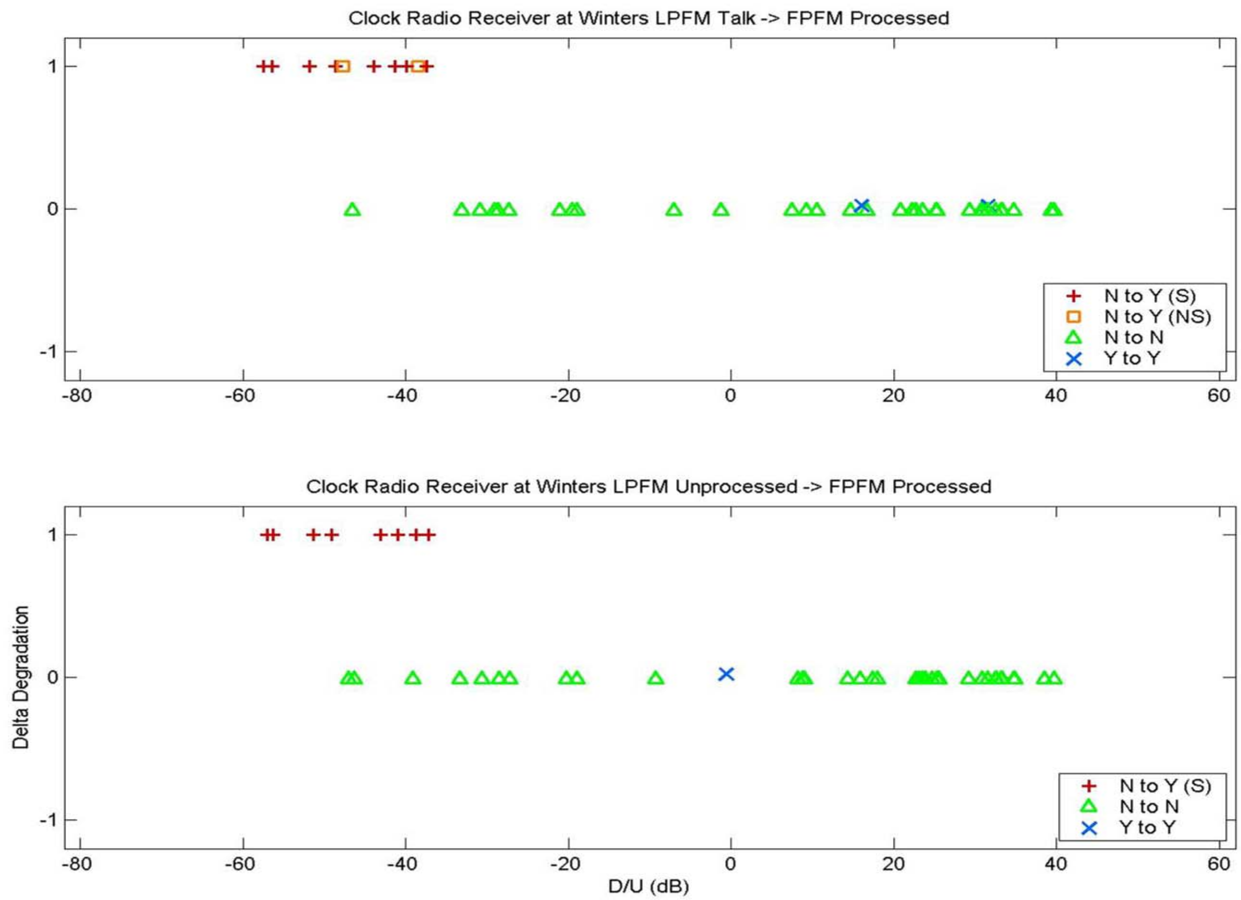


Figure E-23. Delta Degradation for the Clock Radio Receiver at Winters and for the Specified LPFM-FPFM Program Content Combinations

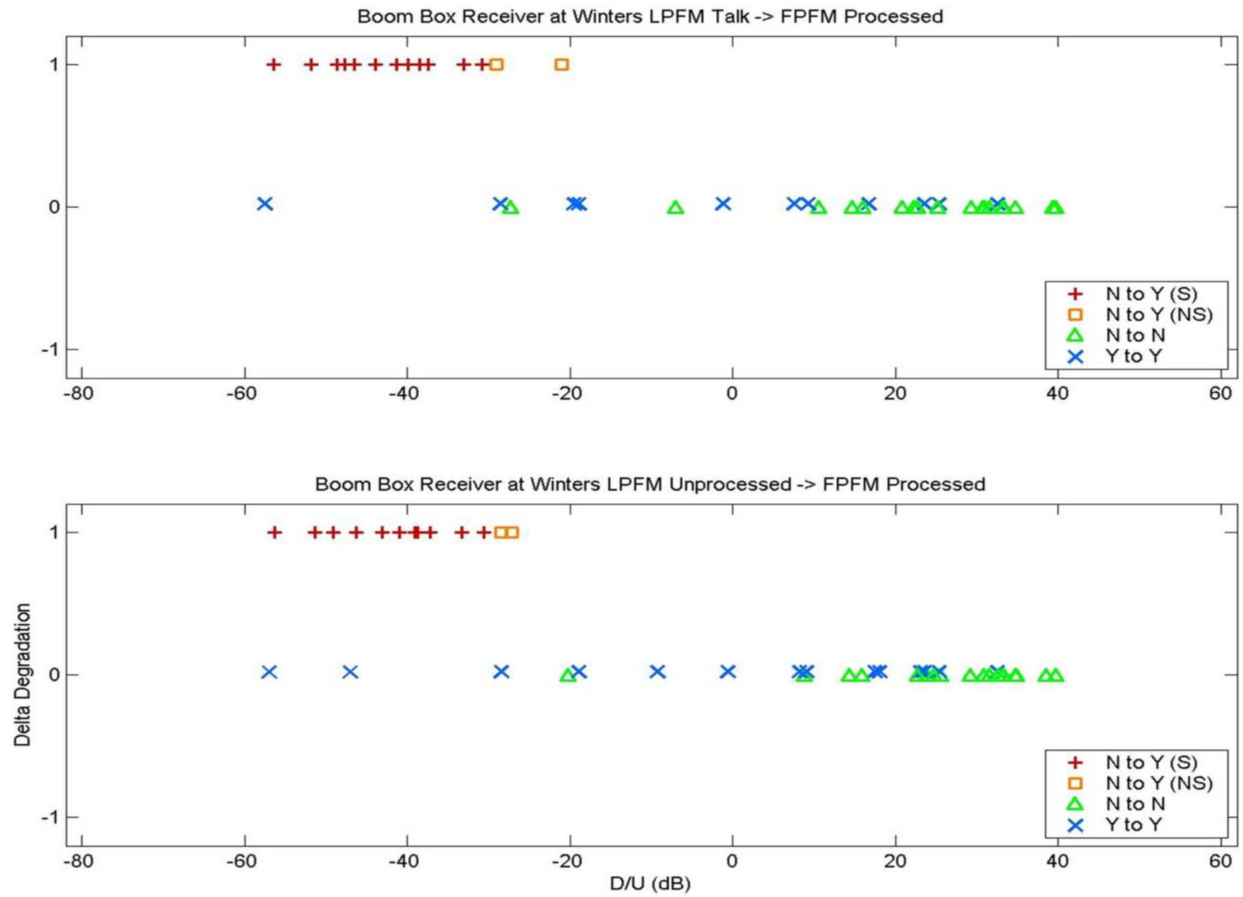


Figure E-24. Delta Degradation for the Boom Box Receiver at Winters and for the Specified LPFM-FPFM Program Content Combinations

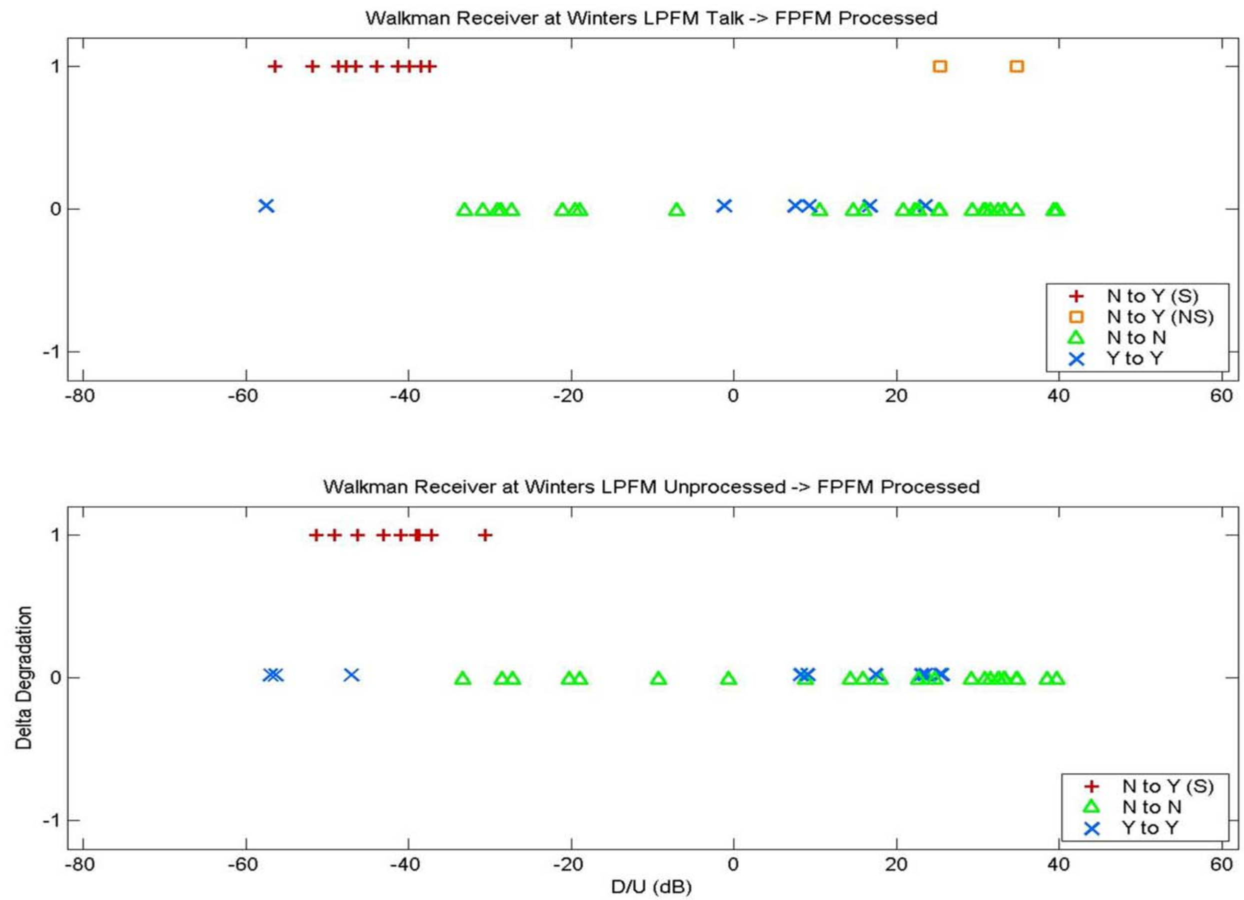


Figure E-25. Delta Degradation for the Walkman Receiver at Winters and for the Specified LPFM-FPFM Program Content Combinations

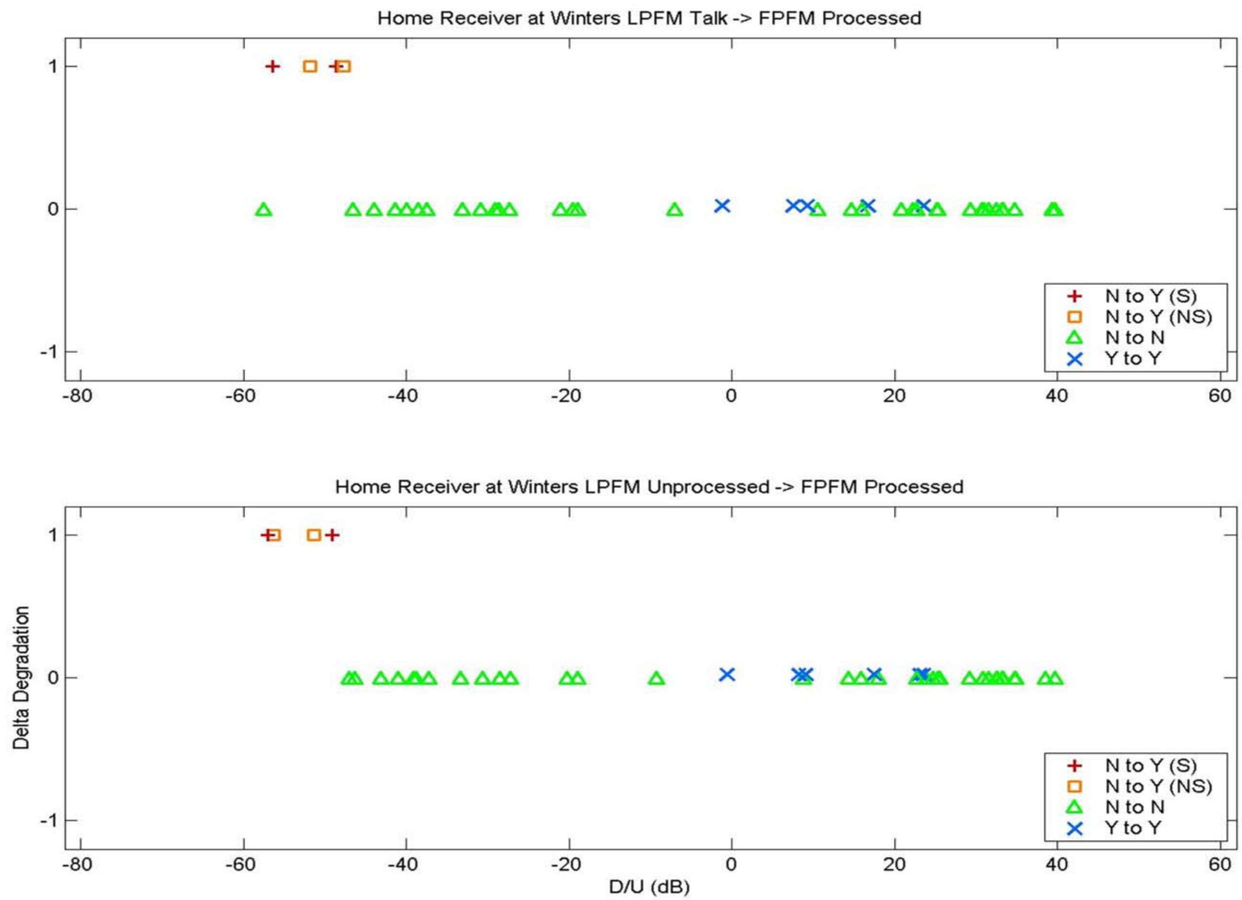


Figure E-26. Delta Degradation for the Home Receiver at Winters and for the Specified LPFM-FPFM Program Content Combinations

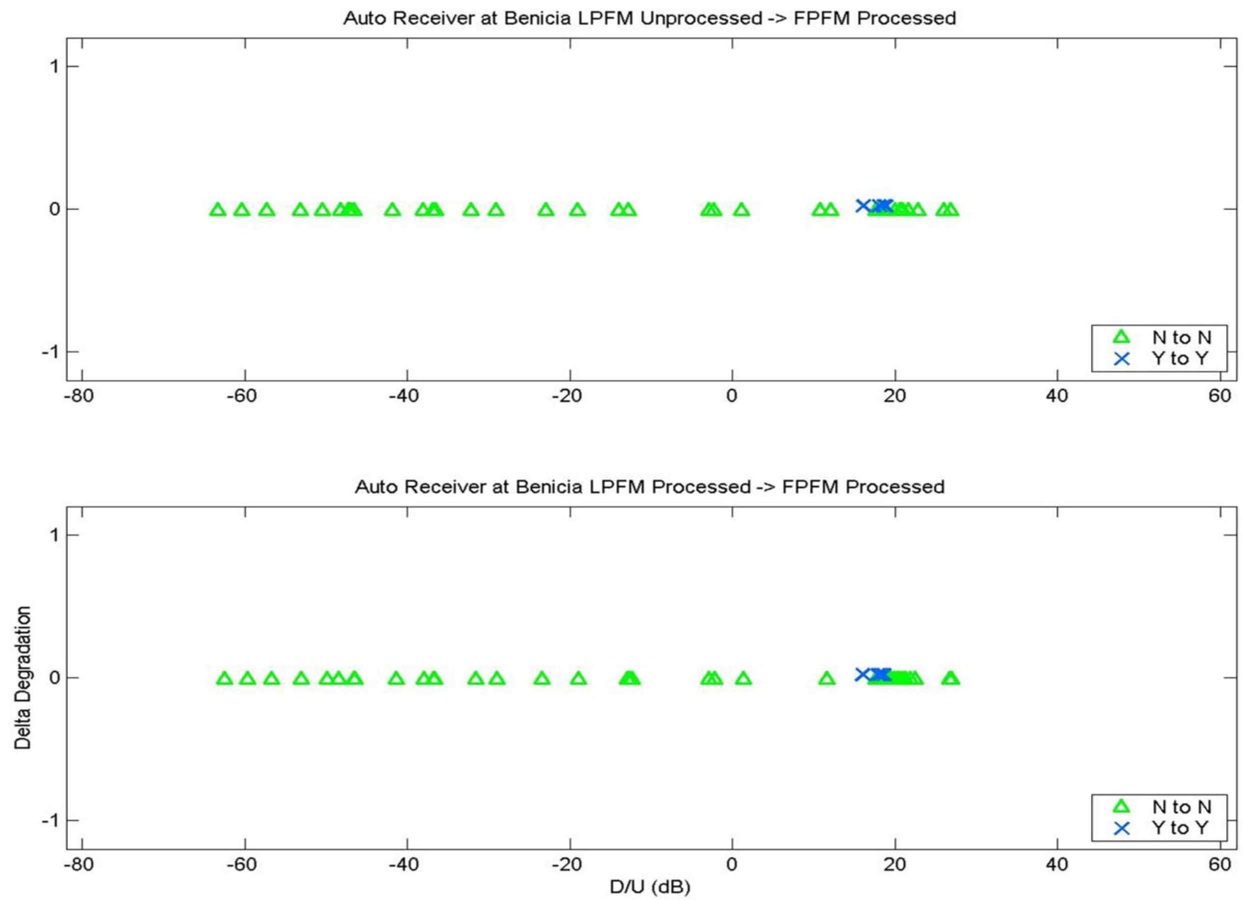


Figure E-27. Delta Degradation for the Auto Receiver at Benicia and for the Specified LPFM-FPFM Program Content Combinations

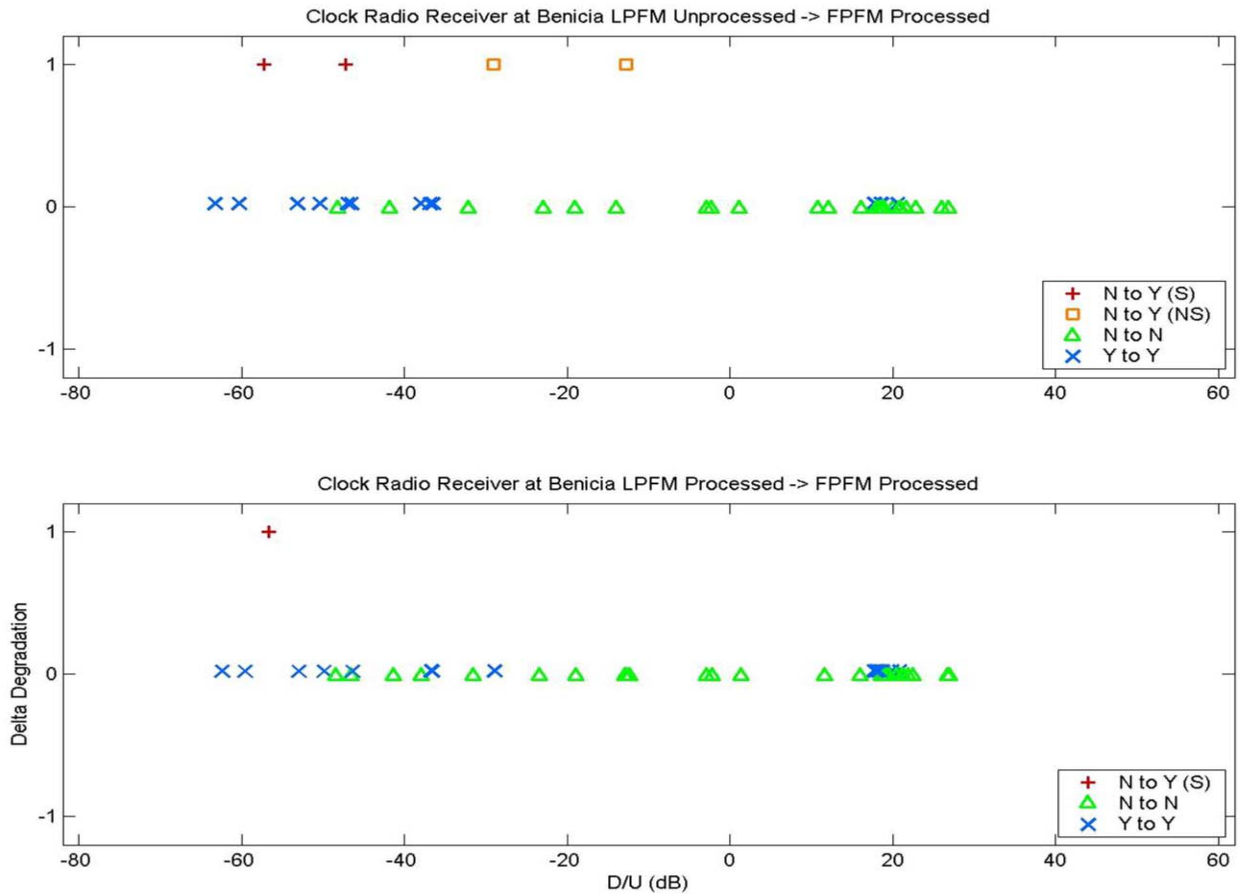


Figure E-28. Delta Degradation for the Clock Radio Receiver at Benicia and for the Specified LPFM-FPFM Program Content Combinations

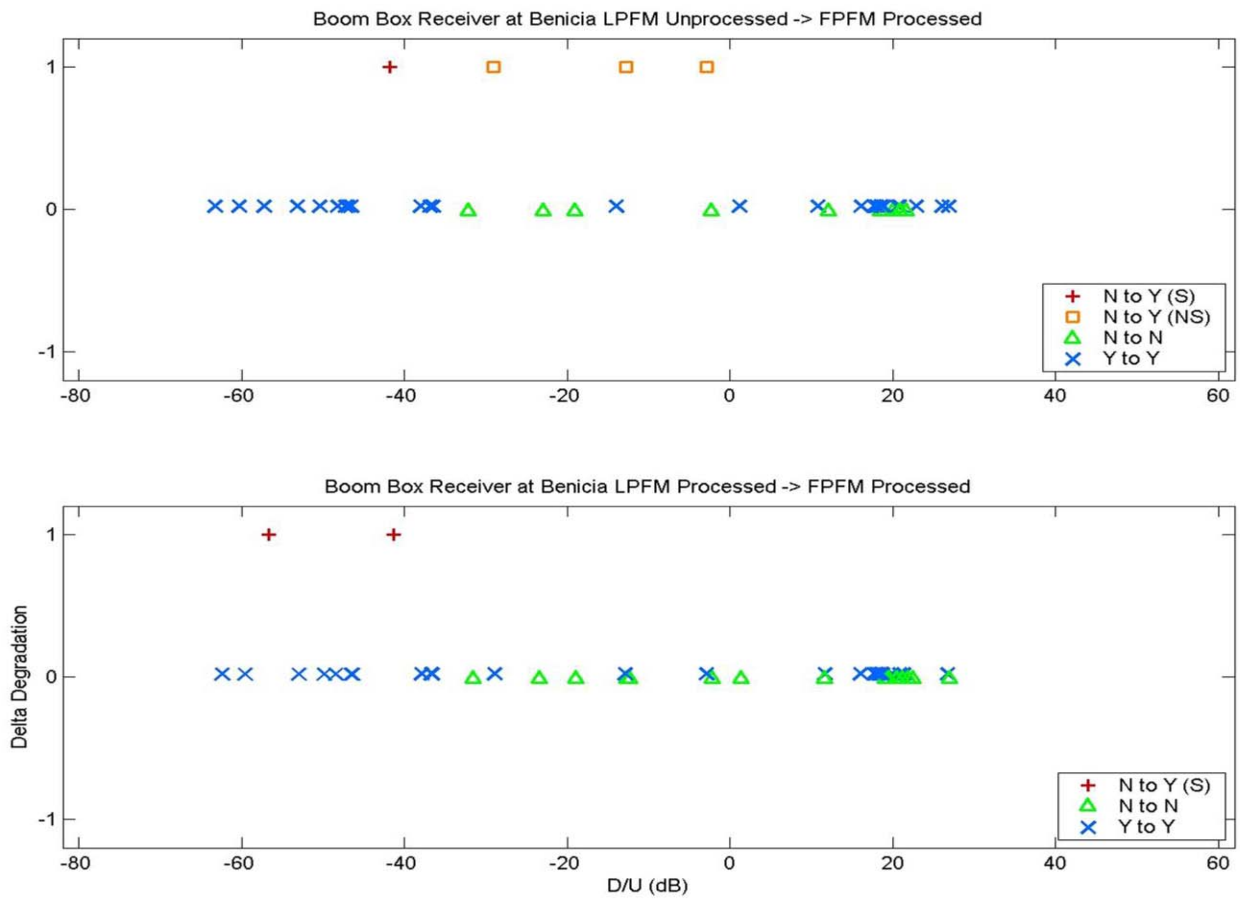


Figure E-29. Delta Degradation for the Boom Box Receiver at Benicia and for the Specified LPFM-FPFM Program Content Combinations

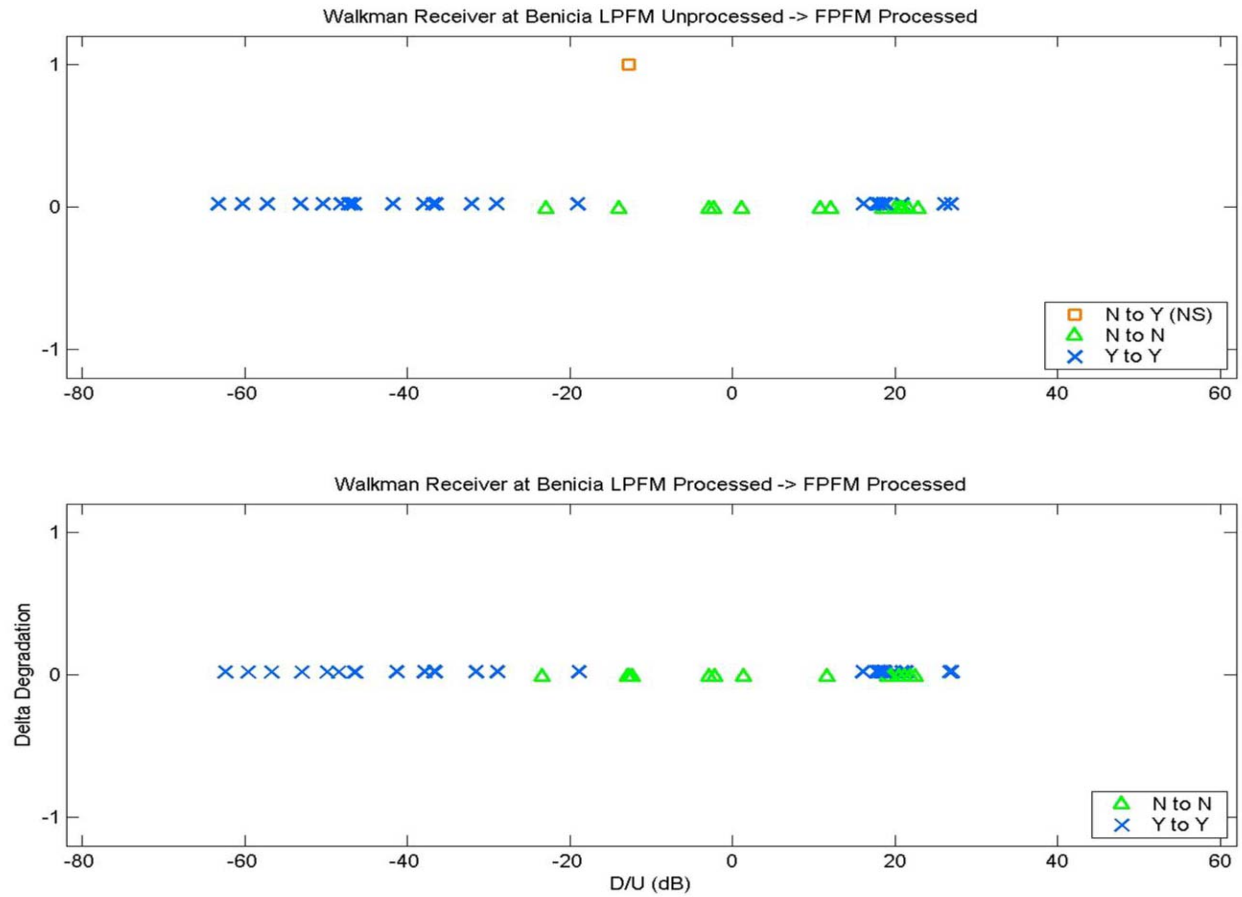


Figure E-30. Delta Degradation for the Walkman Receiver at Benicia and for the Specified LPFM-FPFM Program Content Combinations

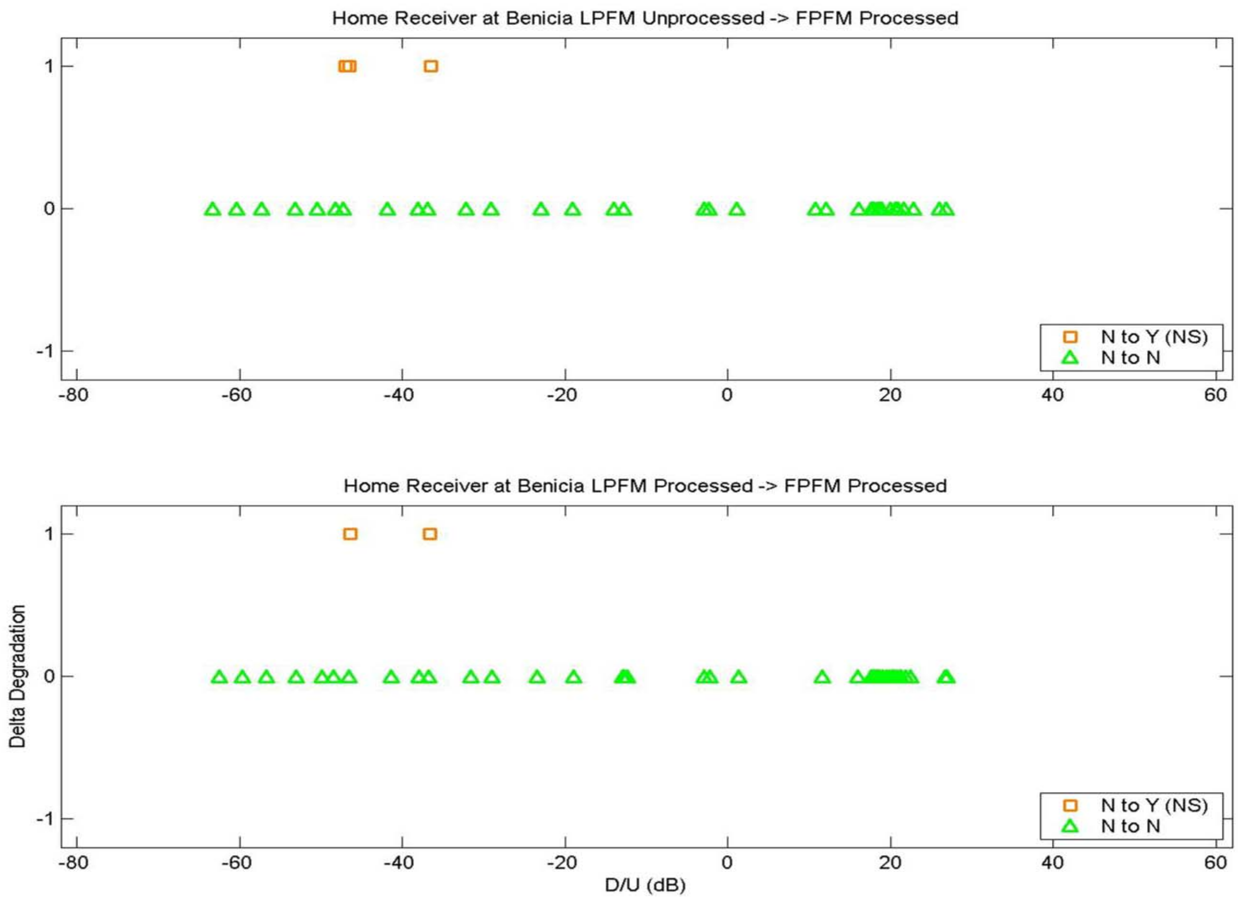


Figure E-31. Delta Degradation for the Home Receiver at Benicia and for the Specified LPFM-FPFM Program Content Combinations

Appendix F

Digital Measurement Data

This appendix presents the D/U measurement results of the FPFM IBOC performance and the 67 kHz SCA performance in the presence of interference from a third adjacent channel LPFM source. Also presented are the D/U test results for SCA while the digital portion of the FPFM signal is turned off. In this latter case, the resulting FPFM signal becomes the conventional analog version.

Table F-1. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□P, FPFM is Victim, No SCA)

CASE	Processed Music		Unprocessed Music		NO	FPFM
	FPFM		**LPFM**		**SCA**	**Received Signal**
	FPFM Signal Power (dBm)	**FPFM Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
MOS5	-57.40	58.60	-4.50	111.50	**-52.90**	5.0
MOS1	-57.40	58.60	13.50	129.50	**-70.90**	1.0
D/U Blend	-57.40	58.60	-2.75	113.25	**-54.65**	3.2
MOS4+X	-57.40	58.60	-6.25	109.75	-51.15	**5.0**
MOS4	-57.40	58.60	-3.50	112.50	-53.90	**4.0**
MOS2+3X	-57.40	58.60	-0.75	115.25	-56.65	**3.0**
MOS2+2X	-57.40	58.60	2.00	118.00	-59.40	**2.8**
MOS2+X	-57.40	58.60	4.75	120.75	-62.15	**2.4**
MOS2	-57.40	58.60	7.50	123.50	-64.90	**2.0**
MOS2-X	-57.40	58.60	10.25	126.25	-67.65	**1.8**
Increment	2.75					

Notes:
The maximum interferer Signal Level available was 8.5 dBm, and so MOS 1 was found by attenuating the Desired signal
Optimod Processor output -2.8 dBFS with setting ROCK-MEDIUM

Table F-2. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□P, FPFM is Victim, No SCA)

CASE	Processed Music FPFM		Unprocessed Music LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	**FPFM Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
MOS5	-63.40	52.60	-11.50	104.50	**-51.90**	5.0
MOS1	-63.40	52.60	7.50	123.50	**-70.90**	1.0
D/U Blend	-63.40	52.60	-9.00	107.00	**-54.40**	3.2
MOS4+X	-63.40	52.60	-14.13	101.88	-49.28	**5.0**
MOS4	-63.40	52.60	-11.00	105.00	-52.40	**4.0**
MOS2+3X	-63.40	52.60	-7.88	108.13	-55.53	**2.8**
MOS2+2X	-63.40	52.60	-4.75	111.25	-58.65	**2.7**
MOS2+X	-63.40	52.60	-1.63	114.38	-61.78	**2.2**
MOS2	-63.40	52.60	1.50	117.50	-64.90	**2.0**
MOS2-X	-63.40	52.60	4.63	120.63	-68.03	**1.6**
Increment	3.13					

Notes:
Optimod Processor output -2.8 dBFS with setting ROCK-MEDIUM

Table F-3. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□U, FPFM is Victim, No SCA)

CASE	Unprocessed Music FPFM		Unprocessed Music LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	**FPFM Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
MOS5	-57.40	58.60	-4.50	111.50	**-52.90**	5.0
MOS1	-57.40	58.60	17.50	133.50	**-74.90**	1.0
D/U Blend	-57.40	58.60	-2.75	113.25	**-54.65**	3.1
MOS4+X	-57.40	58.60	-6.25	109.75	-51.15	**5.0**
MOS4	-57.40	58.60	-3.50	112.50	-53.90	**4.0**
MOS2+3X	-57.40	58.60	-0.75	115.25	-56.65	**2.9**
MOS2+2X	-57.40	58.60	2.00	118.00	-59.40	**2.8**
MOS2+X	-57.40	58.60	4.75	120.75	-62.15	**2.4**
MOS2	-57.40	58.60	7.50	123.50	-64.90	**2.0**
MOS2-X	-57.40	58.60	10.25	126.25	-67.65	**1.6**
Increment	2.75					

Notes:
The maximum interferer Signal Level available was 8.5 dBm, and so MOS 1 was found by attenuating the Desired signal
Optimod in bypass mode

Table F-4. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□U, FPFM is Victim, No SCA)

CASE	Unprocessed Music FPFM		Unprocessed Music LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	FPFM Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
MOS5	-63.40	52.60	-12.00	104.00	**-51.40**	5.0
MOS1	-63.40	52.60	9.50	125.50	**-72.90**	1.0
D/U Blend	-63.40	52.60	-9.50	106.50	**-53.90**	3.1
MOS4+X	-63.40	52.60	-13.63	102.38	-49.78	**5.0**
MOS4	-63.40	52.60	-11.00	105.00	-52.40	**4.0**
MOS2+3X	-63.40	52.60	-8.38	107.63	-55.03	**2.8**
MOS2+2X	-63.40	52.60	-5.75	110.25	-57.65	**2.7**
MOS2+X	-63.40	52.60	-3.13	112.88	-60.28	**2.1**
MOS2	-63.40	52.60	-0.50	115.50	-62.90	**2.0**
MOS2-X	-63.40	52.60	2.13	118.13	-65.53	**1.8**
Increment	2.63					

Notes:
The maximum interferer Signal Level available was 8.5 dBm, and so MOS 1 was found by attenuating the Desired signal
Optimod in bypass mode

Table F-5. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□T, FPFM is Victim, No SCA)

CASE	Voice FPFM		Unprocessed Music LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	**FPFM Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
MOS5	-57.40	58.60	-6.50	109.50	**-50.90**	5.0
MOS1	-57.40	58.60	3.50	119.50	**-60.90**	1.0
D/U Blend	-57.40	58.60	-2.75	113.25	**-54.65**	2.5
MOS4+X	-57.40	58.60	-6.75	109.25	-50.65	**4.4**
MOS4	-57.40	58.60	-5.50	110.50	-51.90	**4.0**
MOS2+3X	-57.40	58.60	-4.25	111.75	-53.15	**3.0**
MOS2+2X	-57.40	58.60	-3.00	113.00	-54.40	**2.4**
MOS2+X	-57.40	58.60	-1.75	114.25	-55.65	**2.2**
MOS2	-57.40	58.60	-0.50	115.50	-56.90	**2.0**
MOS2-X	-57.40	58.60	0.75	116.75	-58.15	**1.4**
Increment	1.25					

Notes:
Optimod in bypass mode

Table F-6. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□T, FPFM is Victim, No SCA)

CASE	Voice FPFM		Unprocessed Music LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	FPFM Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
MOS5	-63.40	52.60	-13.50	102.50	**-49.90**	5.0
MOS1	-63.40	52.60	-4.00	112.00	**-59.40**	1.0
D/U Blend	-63.40	52.60	-9.25	106.75	**-54.15**	2.4
MOS4+X	-63.40	52.60	-13.25	102.75	-50.15	**4.9**
MOS4	-63.40	52.60	-12.00	104.00	-51.40	**4.0**
MOS2+3X	-63.40	52.60	-10.75	105.25	-52.65	**3.0**
MOS2+2X	-63.40	52.60	-9.50	106.50	-53.90	**2.4**
MOS2+X	-63.40	52.60	-8.25	107.75	-55.15	**2.1**
MOS2	-63.40	52.60	-7.00	109.00	-56.40	**2.0**
MOS2-X	-63.40	52.60	-5.75	110.25	-57.65	**1.2**
Increment	1.25					

Notes:
Optimod in bypass mode

Table F-7. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□T, FPFM is Victim, No SCA)

CASE	Voice FPFM		Voice LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	**FPFM Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
MOS5	-57.40	58.60	-6.50	109.50	**-50.90**	5.0
MOS1	-57.40	58.60	2.50	118.50	**-59.90**	1.0
D/U Blend	-57.40	58.60	-2.75	113.25	**-54.65**	2.4
MOS4+X	-57.40	58.60	-6.88	109.13	-50.53	**5.0**
MOS4	-57.40	58.60	-5.50	110.50	-51.90	**4.0**
MOS2+3X	-57.40	58.60	-4.13	111.88	-53.28	**3.0**
MOS2+2X	-57.40	58.60	-2.75	113.25	-54.65	**2.4**
MOS2+X	-57.40	58.60	-1.38	114.63	-56.03	**2.1**
MOS2	-57.40	58.60	0.00	116.00	-57.40	**2.0**
MOS2-X	-57.40	58.60	1.38	117.38	-58.78	**1.2**
Increment	1.38					

Notes:
Optimod in bypass mode

Table F-8. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□T, FPFM is Victim, No SCA)

CASE	Voice FPFM		Voice LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	**FPFM Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
MOS5	-63.40	52.60	-14.00	102.00	**-49.40**	5.0
MOS1	-63.40	52.60	-3.50	112.50	**-59.90**	1.0
D/U Blend	-63.40	52.60	-9.50	106.50	**-53.90**	2.4
MOS4+X	-63.40	52.60	-13.75	102.25	-49.65	**4.9**
MOS4	-63.40	52.60	-12.50	103.50	-50.90	**4.0**
MOS2+3X	-63.40	52.60	-11.25	104.75	-52.15	**3.2**
MOS2+2X	-63.40	52.60	-10.00	106.00	-53.40	**2.6**
MOS2+X	-63.40	52.60	-8.75	107.25	-54.65	**2.2**
MOS2	-63.40	52.60	-7.50	108.50	-55.90	**2.0**
MOS2-X	-63.40	52.60	-6.25	109.75	-57.15	**1.4**
Increment	1.25					

Notes:
Optimod in bypass mode

Table F-9. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□U, FPFM is Victim, No SCA)

CASE	Unprocessed Music FPFM		Voice LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	**FPFM Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
MOS5	-57.40	58.60	-4.50	111.50	**-52.90**	5.0
MOS1	-57.40	58.60	15.50	131.50	**-72.90**	1.0
D/U Blend	-57.40	58.60	-2.75	113.25	**-54.65**	3.2
MOS4+X	-57.40	58.60	-6.50	109.50	-50.90	**5.0**
MOS4	-57.40	58.60	-3.50	112.50	-53.90	**4.0**
MOS2+3X	-57.40	58.60	-0.50	115.50	-56.90	**2.9**
MOS2+2X	-57.40	58.60	2.50	118.50	-59.90	**2.6**
MOS2+X	-57.40	58.60	5.50	121.50	-62.90	**2.2**
MOS2	-57.40	58.60	8.50	124.50	-65.90	**2.0**
MOS2-X	-57.40	58.60	11.50	127.50	-68.90	**1.6**
Increment	3.00					

Notes:
The maximum interferer Signal Level available was 8.5 dBm, and so MOS 1 was found by attenuating the Desired signal
Optimod in bypass mode

Table F-10. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□U, FPFM is Victim, No SCA)

CASE	Unprocessed Music FPFM		Voice LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	**FPFM Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
MOS5	-63.40	52.60	-14.50	101.50	**-48.90**	5.0
MOS1	-63.40	52.60	5.50	121.50	**-68.90**	1.0
D/U Blend	-63.40	52.60	-9.50	106.50	**-53.90**	3.1
MOS4+X	-63.40	52.60	-15.75	100.25	-47.65	**5.0**
MOS4	-63.40	52.60	-12.50	103.50	-50.90	**4.0**
MOS2+3X	-63.40	52.60	-9.25	106.75	-54.15	**3.0**
MOS2+2X	-63.40	52.60	-6.00	110.00	-57.40	**2.8**
MOS2+X	-63.40	52.60	-2.75	113.25	-60.65	**2.2**
MOS2	-63.40	52.60	0.50	116.50	-63.90	**2.0**
MOS2-X	-63.40	52.60	3.75	119.75	-67.15	**1.2**
Increment	3.25					

Notes:
The maximum interferer Signal Level available was 8.5 dBm, and so MOS 1 was found by attenuating the Desired signal
Optimod in bypass mode

Table F-11. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□P, FPFM is Victim, No SCA)

CASE	Processed Music FPFM		Voice LPFM		NO SCA	FPFM Received Signal
	FPFM Signal Power (dBm)	FPFM Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
MOS5	-57.40	58.60	-4.50	111.50	**-52.90**	5.0
MOS1	-57.40	58.60	14.50	130.50	**-71.90**	1.0
D/U Blend	-57.40	58.60	-2.75	113.25	**-54.65**	3.1
MOS4+X	-57.40	58.60	-6.50	109.50	-50.90	**5.0**
MOS4	-57.40	58.60	-3.50	112.50	-53.90	**4.0**
MOS2+3X	-57.40	58.60	-0.50	115.50	-56.90	**2.7**
MOS2+2X	-57.40	58.60	2.50	118.50	-59.90	**2.5**
MOS2+X	-57.40	58.60	5.50	121.50	-62.90	**2.1**
MOS2	-57.40	58.60	8.50	124.50	-65.90	**2.0**
MOS2-X	-57.40	58.60	11.50	127.50	-68.90	**1.8**
Increment	3.00					

Notes:
The maximum interferer Signal Level available was 8.5 dBm, and so MOS 1 was found by attenuating the Desired signal
Optimod Processor output -2.8 dBFS with setting ROCK-MEDIUM

Table F-12. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□P, FPFM is Victim, No SCA)

CASE	Processed Music FPFM FPFM Signal Power (dBm)	FPFM Signal Strength (dBu)	Voice LPFM Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	NO SCA D/U (dB)	FPFM Received Signal MOS READING (1 to 5 Scale)
MOS5	-63.40	52.60	-12.50	103.50	**-50.90**	5.0
MOS1	-63.40	52.60	6.50	122.50	**-69.90**	1.0
D/U Blend	-63.40	52.60	-9.00	107.00	**-54.40**	3.1
MOS4+X	-63.40	52.60	-13.38	102.63	-50.03	**5.0**
MOS4	-63.40	52.60	-11.00	105.00	-52.40	**4.0**
MOS2+3X	-63.40	52.60	-8.63	107.38	-54.78	**3.0**
MOS2+2X	-63.40	52.60	-6.25	109.75	-57.15	**2.7**
MOS2+X	-63.40	52.60	-3.88	112.13	-59.53	**2.4**
MOS2	-63.40	52.60	-1.50	114.50	-61.90	**2.0**
MOS2-X	-63.40	52.60	0.88	116.88	-64.28	**1.8**
Increment	2.38					

Notes:
Optimod Processor output -2.8 dBFS with setting ROCK-MEDIUM

Table F-13. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□T, SCA is Victim, FPFM in P, Digital On)

CASE	Processed Music **FPFM**		Unprocessed Music **LPFM**		Yes/Voice **SCA**	SCA **Received Signal**
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.70
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.00
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.7**
MOS1+5X	-81.90	34.10	-26.17	89.83	-55.73	**2.6**
MOS1+4X	-81.90	34.10	-24.83	91.17	-57.07	**2.1**
MOS1+3X	-81.90	34.10	-23.50	92.50	-58.40	**2.0**
MOS1+2X	-81.90	34.10	-22.17	93.83	-59.73	**1.6**
MOS1+X	-81.90	34.10	-20.83	95.17	-61.07	**1.3**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-14. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□T, SCA is Victim, FPFM in P, Digital On)

CASE	Processed Music FPFM		Unprocessed Music LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-87.90	28.10	-27.50	88.50	-60.40	2.50
LOW MOS	-87.90	28.10	-19.50	96.50	-68.40	1.00
Highest MOS	-87.90	28.10	-27.50	88.50	-60.40	**2.5**
MOS1+5X	-87.90	28.10	-26.17	89.83	-61.73	**2.4**
MOS1+4X	-87.90	28.10	-24.83	91.17	-63.07	**1.9**
MOS1+3X	-87.90	28.10	-23.50	92.50	-64.40	**1.8**
MOS1+2X	-87.90	28.10	-22.17	93.83	-65.73	**1.4**
MOS1+X	-87.90	28.10	-20.83	95.17	-67.07	**1.1**
MOS1	-87.90	28.10	-19.50	96.50	-68.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-15. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□T, SCA is Victim, FPFM in U, Digital On)

CASE	Unprocessed Music FPFM		Unprocessed Music LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.70
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.00
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.7**
MOS1+5X	-81.90	34.10	-26.17	89.83	-55.73	**2.6**
MOS1+4X	-81.90	34.10	-24.83	91.17	-57.07	**2.0**
MOS1+3X	-81.90	34.10	-23.50	92.50	-58.40	**2.0**
MOS1+2X	-81.90	34.10	-22.17	93.83	-59.73	**1.8**
MOS1+X	-81.90	34.10	-20.83	95.17	-61.07	**1.3**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-16. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□T, SCA is Victim, FPFM in U, Digital On)

CASE	Unprocessed Music FPFM		Unprocessed Music LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-87.90	28.10	-28.50	87.50	-59.40	2.50
LOW MOS	-87.90	28.10	-20.50	95.50	-67.40	1.00
Highest MOS	-87.90	28.10	-28.50	87.50	-59.40	**2.5**
MOS1+5X	-87.90	28.10	-27.17	88.83	-60.73	**2.4**
MOS1+4X	-87.90	28.10	-25.83	90.17	-62.07	**2.0**
MOS1+3X	-87.90	28.10	-24.50	91.50	-63.40	**1.8**
MOS1+2X	-87.90	28.10	-23.17	92.83	-64.73	**1.4**
MOS1+X	-87.90	28.10	-21.83	94.17	-66.07	**1.3**
MOS1	-87.90	28.10	-20.50	95.50	-67.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-17. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□T, SCA is Victim, FPFM in U, Digital On)

CASE	Unprocessed Music FPFM		Voice LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-81.90	34.10	-26.50	89.50	-55.40	2.70
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.00
Highest MOS	-81.90	34.10	-26.50	89.50	-55.40	**2.7**
MOS1+5X	-81.90	34.10	-25.33	90.67	-56.57	**2.6**
MOS1+4X	-81.90	34.10	-24.17	91.83	-57.73	**2.0**
MOS1+3X	-81.90	34.10	-23.00	93.00	-58.90	**1.9**
MOS1+2X	-81.90	34.10	-21.83	94.17	-60.07	**1.6**
MOS1+X	-81.90	34.10	-20.67	95.33	-61.23	**1.3**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.0**
Increment	-1.17					

Notes:
ComPOL Rx used for testing

Table F-18. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□T, SCA is Victim, FPFM in U, Digital On)

CASE	Unprocessed Music FPFM		Voice LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-87.90	28.10	-28.50	87.50	-59.40	2.50
LOW MOS	-87.90	28.10	-20.50	95.50	-67.40	1.00
Highest MOS	-87.90	28.10	-28.50	87.50	-59.40	**2.5**
MOS1+5X	-87.90	28.10	-27.17	88.83	-60.73	**2.4**
MOS1+4X	-87.90	28.10	-25.83	90.17	-62.07	**2.1**
MOS1+3X	-87.90	28.10	-24.50	91.50	-63.40	**2.0**
MOS1+2X	-87.90	28.10	-23.17	92.83	-64.73	**1.6**
MOS1+X	-87.90	28.10	-21.83	94.17	-66.07	**1.3**
MOS1	-87.90	28.10	-20.50	95.50	-67.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-19. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□T, SCA is Victim, FPFM in T, Digital On)

CASE	Voice FPFM		Voice LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.70
LOW MOS	-81.90	34.10	-19.00	97.00	-62.90	1.00
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.7**
MOS1+5X	-81.90	34.10	-26.08	89.92	-55.82	**2.6**
MOS1+4X	-81.90	34.10	-24.67	91.33	-57.23	**2.0**
MOS1+3X	-81.90	34.10	-23.25	92.75	-58.65	**1.9**
MOS1+2X	-81.90	34.10	-21.83	94.17	-60.07	**1.6**
MOS1+X	-81.90	34.10	-20.42	95.58	-61.48	**1.3**
MOS1	-81.90	34.10	-19.00	97.00	-62.90	**1.0**
Increment	-1.42					

Notes:
ComPOL Rx used for testing

Table F-20. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□T, SCA is Victim, FPFM in T, Digital On)

CASE	Voice **FPFM** **SCA Signal Power (dBm)**	**SCA Signal Strength (dBu)**	Voice **LPFM** **Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	Yes/Voice **SCA** **D/U (dB)**	SCA **Received Signal** **MOS READING (1 to 5 Scale)**
HIGH MOS	-87.90	28.10	-28.50	87.50	-59.40	2.50
LOW MOS	-87.90	28.10	-20.50	95.50	-67.40	1.00
Highest MOS	-87.90	28.10	-28.50	87.50	-59.40	**2.5**
MOS1+5X	-87.90	28.10	-27.17	88.83	-60.73	**2.5**
MOS1+4X	-87.90	28.10	-25.83	90.17	-62.07	**2.2**
MOS1+3X	-87.90	28.10	-24.50	91.50	-63.40	**2.0**
MOS1+2X	-87.90	28.10	-23.17	92.83	-64.73	**1.5**
MOS1+X	-87.90	28.10	-21.83	94.17	-66.07	**1.3**
MOS1	-87.90	28.10	-20.50	95.50	-67.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-21. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□T, SCA is Victim, FPFM in T, Digital On)

CASE	Voice FPFM SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Unprocessed Music LPFM Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	Yes/Voice SCA D/U (dB)	SCA Received Signal MOS READING (1 to 5 Scale)
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.70
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.00
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.7**
MOS1+5X	-81.90	34.10	-26.17	89.83	-55.73	**2.6**
MOS1+4X	-81.90	34.10	-24.83	91.17	-57.07	**2.0**
MOS1+3X	-81.90	34.10	-23.50	92.50	-58.40	**1.9**
MOS1+2X	-81.90	34.10	-22.17	93.83	-59.73	**1.5**
MOS1+X	-81.90	34.10	-20.83	95.17	-61.07	**1.4**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-22. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□T, SCA is Victim, FPFM in T, Digital On)

CASE	Voice FPFM		Unprocessed Music LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-87.90	28.10	-27.50	88.50	-60.40	2.60
LOW MOS	-87.90	28.10	-19.50	96.50	-68.40	1.00
Highest MOS	-87.90	28.10	-27.50	88.50	-60.40	**2.6**
MOS1+5X	-87.90	28.10	-26.17	89.83	-61.73	**2.5**
MOS1+4X	-87.90	28.10	-24.83	91.17	-63.07	**2.0**
MOS1+3X	-87.90	28.10	-23.50	92.50	-64.40	**1.9**
MOS1+2X	-87.90	28.10	-22.17	93.83	-65.73	**1.5**
MOS1+X	-87.90	28.10	-20.83	95.17	-67.07	**1.2**
MOS1	-87.90	28.10	-19.50	96.50	-68.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-23. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□T, SCA is Victim, FPFM in P, Digital On)

CASE	Processed Music **FPFM**		Voice **LPFM**		Yes/Voice **SCA**	SCA **Received Signal**
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.70
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.10
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.7**
MOS1+5X	-81.90	34.10	-26.17	89.83	-55.73	**2.6**
MOS1+4X	-81.90	34.10	-24.83	91.17	-57.07	**2.1**
MOS1+3X	-81.90	34.10	-23.50	92.50	-58.40	**2.0**
MOS1+2X	-81.90	34.10	-22.17	93.83	-59.73	**1.7**
MOS1+X	-81.90	34.10	-20.83	95.17	-61.07	**1.6**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.1**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-24. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□T, SCA is Victim, FPFM in P, Digital On)

CASE	Processed Music FPFM		Voice LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-87.90	28.10	-27.50	88.50	-60.40	2.50
LOW MOS	-87.90	28.10	-19.50	96.50	-68.40	1.00
Highest MOS	-87.90	28.10	-27.50	88.50	-60.40	**2.5**
MOS1+5X	-87.90	28.10	-26.17	89.83	-61.73	**2.5**
MOS1+4X	-87.90	28.10	-24.83	91.17	-63.07	**2.1**
MOS1+3X	-87.90	28.10	-23.50	92.50	-64.40	**1.9**
MOS1+2X	-87.90	28.10	-22.17	93.83	-65.73	**1.7**
MOS1+X	-87.90	28.10	-20.83	95.17	-67.07	**1.3**
MOS1	-87.90	28.10	-19.50	96.50	-68.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing

Table F-25. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□T, SCA is Victim, FPFM in P, Digital Off)

CASE	Processed Music/NO DIGITAL FPFM SCA Signal Power (dBm)	 SCA Signal Strength (dBu)	Unprocessed Music LPFM Interferer Signal Power (dBm)	 Interferer Signal Strength (dBu)	Yes/Voice SCA D/U (dB)	SCA Received Signal MOS READING (1 to 5 Scale)
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.60
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.00
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.6**
MOS1+5X	-81.90	34.10	-26.17	89.83	-55.73	**2.4**
MOS1+4X	-81.90	34.10	-24.83	91.17	-57.07	**2.0**
MOS1+3X	-81.90	34.10	-23.50	92.50	-58.40	**2.0**
MOS1+2X	-81.90	34.10	-22.17	93.83	-59.73	**1.5**
MOS1+X	-81.90	34.10	-20.83	95.17	-61.07	**1.4**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-26. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□T, SCA is Victim, FPFM in P, Digital Off)

CASE	Processed Music/NO DIGITAL FPFM		Unprocessed Music LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-87.90	28.10	-27.50	88.50	-60.40	2.50
LOW MOS	-87.90	28.10	-19.50	96.50	-68.40	1.00
Highest MOS	-87.90	28.10	-27.50	88.50	-60.40	**2.5**
MOS1+5X	-87.90	28.10	-26.17	89.83	-61.73	**2.4**
MOS1+4X	-87.90	28.10	-24.83	91.17	-63.07	**2.0**
MOS1+3X	-87.90	28.10	-23.50	92.50	-64.40	**1.8**
MOS1+2X	-87.90	28.10	-22.17	93.83	-65.73	**1.4**
MOS1+X	-87.90	28.10	-20.83	95.17	-67.07	**1.1**
MOS1	-87.90	28.10	-19.50	96.50	-68.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-27. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□T, SCA is Victim, FPFM in U, Digital Off)

CASE	Unprocessed Music/NO DIGITAL **FPFM**		Unprocessed Music **LPFM**		Yes/Voice **SCA**	SCA **Received Signal**
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.60
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.00
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.6**
MOS1+5X	-81.90	34.10	-26.17	89.83	-55.73	**2.5**
MOS1+4X	-81.90	34.10	-24.83	91.17	-57.07	**2.0**
MOS1+3X	-81.90	34.10	-23.50	92.50	-58.40	**2.0**
MOS1+2X	-81.90	34.10	-22.17	93.83	-59.73	**1.7**
MOS1+X	-81.90	34.10	-20.83	95.17	-61.07	**1.3**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-28. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□T, SCA is Victim, FPFM in U, Digital Off)

CASE	Unprocessed Music/NO DIGITAL **FPFM**		Unprocessed Music **LPFM**		Yes/Voice **SCA**	SCA **Received Signal**
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-87.90	28.10	-28.50	87.50	-59.40	2.50
LOW MOS	-87.90	28.10	-20.50	95.50	-67.40	1.00
Highest MOS	-87.90	28.10	-28.50	87.50	-59.40	**2.5**
MOS1+5X	-87.90	28.10	-27.17	88.83	-60.73	**2.4**
MOS1+4X	-87.90	28.10	-25.83	90.17	-62.07	**2.0**
MOS1+3X	-87.90	28.10	-24.50	91.50	-63.40	**1.8**
MOS1+2X	-87.90	28.10	-23.17	92.83	-64.73	**1.4**
MOS1+X	-87.90	28.10	-21.83	94.17	-66.07	**1.3**
MOS1	-87.90	28.10	-20.50	95.50	-67.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-29. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□T, SCA is Victim, FPFM in U, Digital Off)

CASE	Unprocessed Music/NO DIGITAL FPFM		Voice LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-81.90	34.10	-26.50	89.50	-55.40	2.60
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.10
Highest MOS	-81.90	34.10	-26.50	89.50	-55.40	**2.6**
MOS1+5X	-81.90	34.10	-25.33	90.67	-56.57	**2.6**
MOS1+4X	-81.90	34.10	-24.17	91.83	-57.73	**2.0**
MOS1+3X	-81.90	34.10	-23.00	93.00	-58.90	**2.0**
MOS1+2X	-81.90	34.10	-21.83	94.17	-60.07	**1.6**
MOS1+X	-81.90	34.10	-20.67	95.33	-61.23	**1.4**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.1**
Increment	-1.17					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-30. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□T, SCA is Victim, FPFM in U, Digital Off)

CASE	Unprocessed Music/NO DIGITAL FPFM		Voice LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-87.90	28.10	-28.50	87.50	-59.40	2.50
LOW MOS	-87.90	28.10	-20.50	95.50	-67.40	1.00
Highest MOS	-87.90	28.10	-28.50	87.50	-59.40	**2.5**
MOS1+5X	-87.90	28.10	-27.17	88.83	-60.73	**2.4**
MOS1+4X	-87.90	28.10	-25.83	90.17	-62.07	**2.1**
MOS1+3X	-87.90	28.10	-24.50	91.50	-63.40	**2.0**
MOS1+2X	-87.90	28.10	-23.17	92.83	-64.73	**1.7**
MOS1+X	-87.90	28.10	-21.83	94.17	-66.07	**1.3**
MOS1	-87.90	28.10	-20.50	95.50	-67.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-31. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□T, SCA is Victim, FPFM in T, Digital Off)

CASE	Voice/NO DIGITAL FPFM		Voice LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.70
LOW MOS	-81.90	34.10	-19.00	97.00	-62.90	1.10
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.7**
MOS1+5X	-81.90	34.10	-26.08	89.92	-55.82	**2.6**
MOS1+4X	-81.90	34.10	-24.67	91.33	-57.23	**2.1**
MOS1+3X	-81.90	34.10	-23.25	92.75	-58.65	**1.9**
MOS1+2X	-81.90	34.10	-21.83	94.17	-60.07	**1.6**
MOS1+X	-81.90	34.10	-20.42	95.58	-61.48	**1.5**
MOS1	-81.90	34.10	-19.00	97.00	-62.90	**1.1**
Increment	-1.42					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-32. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□T, SCA is Victim, FPFM in T, Digital Off)

CASE	Voice/NO DIGITAL **FPFM**		Voice **LPFM**		Yes/Voice **SCA**	SCA **Received Signal**
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-87.90	28.10	-28.50	87.50	-59.40	2.40
LOW MOS	-87.90	28.10	-20.50	95.50	-67.40	1.00
Highest MOS	-87.90	28.10	-28.50	87.50	-59.40	**2.4**
MOS1+5X	-87.90	28.10	-27.17	88.83	-60.73	**2.4**
MOS1+4X	-87.90	28.10	-25.83	90.17	-62.07	**2.2**
MOS1+3X	-87.90	28.10	-24.50	91.50	-63.40	**1.9**
MOS1+2X	-87.90	28.10	-23.17	92.83	-64.73	**1.5**
MOS1+X	-87.90	28.10	-21.83	94.17	-66.07	**1.3**
MOS1	-87.90	28.10	-20.50	95.50	-67.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-33. MOS-D/U Measurement Results (at 58.6 dBu FPFM, U□T, SCA is Victim, FPFM in T, Digital Off)

CASE	VoiceNO DIGITAL FPFM		Unprocessed Music LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.60
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.00
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.6**
MOS1+5X	-81.90	34.10	-26.17	89.83	-55.73	**2.6**
MOS1+4X	-81.90	34.10	-24.83	91.17	-57.07	**2.1**
MOS1+3X	-81.90	34.10	-23.50	92.50	-58.40	**1.8**
MOS1+2X	-81.90	34.10	-22.17	93.83	-59.73	**1.5**
MOS1+X	-81.90	34.10	-20.83	95.17	-61.07	**1.3**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-34. MOS-D/U Measurement Results (at 52.6 dBu FPFM, U□T, SCA is Victim, FPFM in T, Digital Off)

CASE	Voice/NO DIGITAL FPFM		Unprocessed Music LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-87.90	28.10	-27.50	88.50	-60.40	2.60
LOW MOS	-87.90	28.10	-19.50	96.50	-68.40	1.00
Highest MOS	-87.90	28.10	-27.50	88.50	-60.40	**2.6**
MOS1+5X	-87.90	28.10	-26.17	89.83	-61.73	**2.5**
MOS1+4X	-87.90	28.10	-24.83	91.17	-63.07	**2.1**
MOS1+3X	-87.90	28.10	-23.50	92.50	-64.40	**1.9**
MOS1+2X	-87.90	28.10	-22.17	93.83	-65.73	**1.5**
MOS1+X	-87.90	28.10	-20.83	95.17	-67.07	**1.3**
MOS1	-87.90	28.10	-19.50	96.50	-68.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-35. MOS-D/U Measurement Results (at 58.6 dBu FPFM, T□T, SCA is Victim, FPFM in P, Digital Off)

CASE	Processed Music/NO DIGITAL FPFM		Voice LPFM		Yes/Voice SCA	SCA Received Signal
	SCA Signal Power (dBm)	SCA Signal Strength (dBu)	Interferer Signal Power (dBm)	Interferer Signal Strength (dBu)	D/U (dB)	MOS READING (1 to 5 Scale)
HIGH MOS	-81.90	34.10	-27.50	88.50	-54.40	2.70
LOW MOS	-81.90	34.10	-19.50	96.50	-62.40	1.10
Highest MOS	-81.90	34.10	-27.50	88.50	-54.40	**2.7**
MOS1+5X	-81.90	34.10	-26.17	89.83	-55.73	**2.6**
MOS1+4X	-81.90	34.10	-24.83	91.17	-57.07	**2.0**
MOS1+3X	-81.90	34.10	-23.50	92.50	-58.40	**2.0**
MOS1+2X	-81.90	34.10	-22.17	93.83	-59.73	**1.6**
MOS1+X	-81.90	34.10	-20.83	95.17	-61.07	**1.4**
MOS1	-81.90	34.10	-19.50	96.50	-62.40	**1.1**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Table F-36. MOS-D/U Measurement Results (at 52.6 dBu FPFM, T□T, SCA is Victim, FPFM in P, Digital Off)

CASE	Processed Music/NO DIGITAL **FPFM**		Voice **LPFM**		Yes/Voice **SCA**	SCA **Received Signal**
	SCA Signal Power (dBm)	**SCA Signal Strength (dBu)**	**Interferer Signal Power (dBm)**	**Interferer Signal Strength (dBu)**	**D/U (dB)**	**MOS READING (1 to 5 Scale)**
HIGH MOS	-87.90	28.10	-27.50	88.50	-60.40	2.50
LOW MOS	-87.90	28.10	-19.50	96.50	-68.40	1.00
Highest MOS	-87.90	28.10	-27.50	88.50	-60.40	**2.5**
MOS1+5X	-87.90	28.10	-26.17	89.83	-61.73	**2.4**
MOS1+4X	-87.90	28.10	-24.83	91.17	-63.07	**2.0**
MOS1+3X	-87.90	28.10	-23.50	92.50	-64.40	**1.8**
MOS1+2X	-87.90	28.10	-22.17	93.83	-65.73	**1.7**
MOS1+X	-87.90	28.10	-20.83	95.17	-67.07	**1.2**
MOS1	-87.90	28.10	-19.50	96.50	-68.40	**1.0**
Increment	-1.33					

Notes:
ComPOL Rx used for testing
No digital sidebands

Glossary

ACI	Adjacent-Channel Interference
AES	Audio Engineering Society
AGL	above ground level
AM	amplitude modulation
AWGN	additive White Gaussian noise
BET	Business Evaluation Team
CD	compact disk
CFR	Combined Federal Regulations
CO	Contracting Office
DAB	digital audio broadcasting
dB	decibel
dBc	decibel referred to carrier
dBd	decibel (gain) referred to a dipole antenna
dBFS	decibel relative to full scale
dBm	decibel referred to 1 milliwatt
dBu	decibel referred to 1 microvolt
dBW	decibel referred to 1 watt
DJ	disc jockey
D/U	desired-to-undesired
ERP	Effective Radiated Power
FCC	Federal Communications Commission
FM	frequency modulation
FMD	Field Measurement Data
FPFM	Full Power FM
FTP	Field Test Plan
GPS	Global Positioning System
HAAT	height above average terrain
IBOC	In Band, On Channel
IF	intermediate frequency
kbps	kilobits per second

kHz	kilohertz
km	kilometer
LPFM	Low Power FM
m	meter
MHz	megahertz
MOS	Mean Opinion Score
mV/m	millivolts/meter
NRSC	National Radio Systems Committee
NS	Non-Significant
OFDM	Orthogonal Frequency Division Multiplexing
P	Processed Music (Program Content)
PM	Primary Main (sidebands)
QPSK	quadrature phase shift keying
RF	radio frequency
RFP	Request for Proposal
RSVI	Reading Services for the Visually Impaired
Rx	receiver
SCA	Subsidiary Communications Authority
SSA	Source Selection Authority
T	News/Talk (Program Content)
TET	Technical Evaluation Team
TPP	Test Procedures Plan
U	Unprocessed Music (Program Content)
VSWR	Voltage Standing Wave Ratio
W	watt