**National Public Radio**
**Washington, D.C.**

# Tomorrow Radio[SM] Field Testing in the Washington, D.C., New York City San Francisco, and Los Angeles (Long Beach) Radio Markets

**Project Sponsors:** **National Public Radio**
**Kenwood Corporation**
**Harris Corporation**

January 6, 2004

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HAMMETT & EDISON, INC.
CONSULTING ENGINEERS
SAN FRANCISCO

**National Public Radio • Washington, D.C.**
**2003 Field Testing of Tomorrow Radio℠ FM HD Radio Enhancement**

## Executive Summary

The National Public Radio (NPR) Tomorrow Radio℠ field testing project was conceived to evaluate mobile reception performance of a modification to the In-Band On-Channel (IBOC) digital FM system presently authorized by the FCC. The Tomorrow Radio℠ concept extends IBOC digital radio by splitting the single digital program channel into two digital program channels. The purpose of the field testing project has been to evaluate "real world" mobile reception coverage of the Tomorrow Radio℠ channel portion of the system to determine if it exhibits robustness sufficient to support a stand-alone second program service, capable of being delivered to a wide audience within the normal analog service area of the host FM station.

Field test data gathering of the Tomorrow Radio℠ enhancement has taken place over the summer and autumn of 2003 in four separate radio markets, Washington, D.C., New York City, San Francisco, and Los Angeles/Long Beach. Testing has been sponsored by project partners NPR, Harris Corporation, and Kenwood Corporation, with added project support by iBiquity Digital Corporation.

Testing took place in two phases. The original testing phase took place in all four markets over August and September 2003, while a regression testing phase took place in the Washington, D.C. and New York City radio markets October through December 2003. Regression testing was needed to evaluate subsequent changes made by iBiquity Digital to the system audio coder technology implementation and to solve technical issues discovered in the original data gathering system. Correction of those issues more closely replicated a typical installation of an IBOC receiver in a consumer vehicle.

Field data analysis utilized a "best-fit" of terrain-sensitive propagation modeling comparison to the mapped field test performance. This comparison was used to derive a contour level, within which mobile receivers would decode Tomorrow Radio℠ data to a certainty of 95%.

Based on analysis of the collected Tomorrow Radio℠ performance data collected during regression and original field testing, it was concluded that the Tomorrow Radio℠ usable service area would fall within the 60 to 70 dBu service area of a typical FM station.

Hammett & Edison, Inc.
Consulting Engineers
January 6, 2004

## Report of Hammett & Edison, Inc., Consulting Engineers

The firm of Hammett & Edison, Inc., Consulting Engineers, has been retained by National Public Radio ("NPR"), Washington, D.C., to provide consulting services related to field testing of an In-Band On-Channel ("IBOC") digital FM broadcasting channel multiplexing enhancement known as "Tomorrow Radio℠."

## Background and Objectives

The NPR Tomorrow Radio℠ field testing project was conceived to evaluate mobile reception performance of a modification to the IBOC digital FM system presently authorized by the FCC (MM Docket 99-325, adopted October 11, 2002). The IBOC FM system contains a feature for analog blend, in that when digital radio reception is impaired, receivers automatically revert to demodulated FM analog audio carrying the same audio program.

The Tomorrow Radio℠ concept extends IBOC digital radio by splitting the single digital program channel into two digital program channels. The first digital program channel (main audio program, or MAP) behaves identically to the presently defined system operation, exhibiting the blend-to-analog feature. However, the supplemental audio channel (SAC, the Tomorrow Radio℠ enhancement) does not have an analog program backup. MAP can be reduced from a 96 kbps data stream to lower rates, with the remaining data bandwidth used for SAC. For this field test, the data rates used were 64 kbps for MAP and 32 kbps for SAC, with results expected to be similar at other data rates.

The purpose of the field testing project has been to evaluate "real world" mobile reception coverage of the SAC portion of the system to determine if it exhibits robustness sufficient to support a stand-alone second program service, capable of being delivered to a wide audience within the normal analog service area of the host FM station. The progress of these evaluations has been reported periodically to the Digital Audio Broadcasting Subcommittee of the National Radio Systems Committee (NRSC) for informational purposes. While the members of the project team are also members of the NRSC, the NRSC did not sponsor or participate in the field testing described in this report.

## Test Description and Methodology

Field test data gathering of the Tomorrow Radio℠ enhancement has taken place over the summer and autumn of 2003 in four separate radio markets, utilizing a selected host FM station in each market. Testing has been sponsored by project partners NPR, Harris Corporation, and Kenwood Corporation, with added project oversight by iBiquity Digital Corporation.[1] Harris Corporation outfitted each

[1] A list of project participants appears in Appendix A1, while a summary of project chronology appears in Appendix A2.

station with appropriate production broadcast transmission hardware, while Kenwood Corporation utilized a modification of its pre-existing field testing package to gather Tomorrow Radio℠ performance data over defined mobile test routes, under the direct supervision of NPR. For the purposes of the scope of Tomorrow Radio℠ testing, it was assumed that transmission system hardware could be considered "tested and fully operational" when installed under the direct supervision of Harris Corporation, thus requiring no special additional evaluation.[2] Prototype production receivers, which were modified to decode the Tomorrow Radio℠ test version of HD Radio as provided by iBiquity, were provided by Kenwood Corporation as a part of the field test data gathering package.

Participating field test stations consisted of FM Stations WETA, 90.9 MHz, Washington, D.C., WNYC-FM, 93.9 MHz, New York, New York, KALW, 91.7 MHz, San Francisco, California, and KKJZ, 88.1 MHz, Long Beach, California. For each of these stations, an IBOC transmitting facility was established, under FCC Special Temporary authority, that included a software modification to the digital exciter allowing Tomorrow Radio℠-format transmissions. Defined test routes consisted of eight radial routes plus much of the D.C. Beltway in the Washington, D.C. area, four radial routes and a Manhattan downtown loop in the New York City area, previously utilized NRSC test loops in the San Francisco Bay Area and in downtown San Francisco, and three newly defined intersecting test loops in the Long Beach/Los Angeles area. The Washington, D.C. and New York routes were designed to be similar to the routes used during NRSC IBOC testing in 2001/2002. Detailed descriptions and route maps for each test market appear in Appendix B to this report. Each wide area map includes the plotted locations of the test station and adjacent-channel stations that could have a potential interference impact on IBOC receiver performance.

Testing took place in two phases. The original testing phase took place in all four markets over August and September 2003, while a regression testing phase took place in the Washington, D.C. and New York City radio markets October through December 2003. The reasons for conducting the tests in two phases was twofold. First, the recently implemented HDC audio coder technology was not used during the original summer Tomorrow Radio℠ field testing (the predecessor PAC coder was used), so some degree of retesting using the new coder was necessary. Second, deficiencies were identified in the RF distribution network of the initial data gathering package; a different, simplified, configuration was used during regression testing.

As shown in the block diagram of Appendix C1A and photographs of Appendix C2B, the original test van equipment configuration consisted of two Kenwood IBOC receivers (one reference receiver and one Tomorrow Radio℠-capable receiver),[3] along with a spectrum analyzer, two Global Positioning

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[2] Representative photographs of the equipment installation at Station WNYC-FM, 93.9 MHz, Empire State Building, New York City, are shown in Appendix A3.

[3] Custom interfaces were added to the Kenwood IBOC receivers to provide performance data to the computers.

System (GPS) receivers, a split-screen video recording system (fed by a forward-looking camera, a computer screen image capture, and spectrum analyzer image capture), and two PC laptop computers to collect data from the IBOC receivers, position data from the GPS receivers, and trace data from the spectrum analyzer. Field testing in the San Francisco market (conducted first, chronologically) utilized separate quarter-wave magnetic-mount receiving antennas feeding each receiver and the spectrum analyzer. However, despite attempts to optimize their positions on the test vehicle, the initial review of test data showed some antenna interaction effects. Thus, testing in the remaining markets and for subsequent regression testing was changed to a single roof-mounted quarter-wave receiving antenna.[4] During the original test phase, this antenna was connected to a preamplifier and power splitter feeding the receivers and spectrum analyzer. The purpose of the preamplifier was to compensate for the power split loss. The regression test phase equipment configuration, shown in the block diagram of Appendix C1B, eliminated the antenna network and fed the test receiver directly. Additionally, just a single GPS receiver and data gathering computer were used during regression testing. The simplification of the test setup reduced concerns about RF noise generated by the test package itself, and eliminated issues related to the suitability of the RF preamplifier/power splitter network.[5]

A period of 2 to 3 days in sequence was required to drive the test routes in each market. At the start of each test day, the test vehicle was driven to a specified location at the staging area hotel to confirm consistent IBOC spectrum characteristics of the test station RF carrier signal. During field test data gathering, several parameters were continuously obtained from the test receiver(s), with the decoding status of SAC and MAP of particular interest,[6] along with corresponding GPS position data. As a part of regression testing in the Washington, D.C. area, a set of reference field test runs were made for standard IBOC transmission without the Tomorrow Radio℠ enhancement being transmitted.[7]

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4 Representative photographs of the multiple and single receiving antenna configurations on utilized minivan-class vehicles are shown in Appendix C2A.

5 Removal of the preamplifier/splitter network during regression testing was necessitated by two factors. First, while every effort was made to maintain a unity gain system, the inherent gain of the preamplifier, being connected directly to the receiving antenna, increased the risk of overload (as was actually observed in New York City/Manhattan testing, in particular, since that route closely encircled the WNYC-FM Empire State Building transmitter location). Second the preamplifier and alternator introduced undesired gain and noise figure degradations, which did materially affect the test results when compared to previous NRSC IBOC test results. The project team's decision was to use an approach that would most closely match a receiver installation in a typical consumer vehicle.

6 As illustrated in the Appendix C1 block diagrams, a facility was made to determine if MAP or SAC decoding was occurring using both a digital Digital Audio Acquired (DAA) signal, generated in the receiver interface hardware, and by monitoring Analog Audio Presence (AAP) through a USB audio interface. A 1 kHz audio tone was continuously transmitted on the IBOC subchannel for use with the AAP detection system. In practice, no significant differences were noted between the two methods, so DAA data was used as the basis for all maps contained in this report.

7 Similar reference field test runs were made during the original testing in the New York City area.

## Issues Related to Tomorrow Radio℠ Field Testing

This report provides findings of Tomorrow Radio℠ field test performance. However, it is appropriate to briefly discuss two issues that may have a bearing on the results:

1. MAP/SAC Multiplexing - Multiplexing of the Tomorrow Radio℠ enhancement was made in the audio coder for the purposes of field testing. Future alternate implementations of the technology may also utilize multiplexing in the packet framer. Performance differences using such a transport multiplex method would likely be small, related to the positioning of system overhead for supplementary data transmission.

2. Receiver Characterization - Due to various factors, the Kenwood test receivers have not been characterized for performance in comparison to the iBiquity reference receiver, within the Tomorrow Radio℠ project. Kenwood and iBiquity have independently characterized these units; the Kenwood receiver has been certified by iBiquity as compliant with their receiver performance specifications.

## Field Test Data Analysis and Findings

Field data analysis utilized a "best-fit" of terrain-sensitive propagation modeling comparison to the mapped field test performance. This comparison was used to derive a contour level, within which mobile receivers would decode MAP or SAC data to a certainty of 95%. That is, for all measurement locations contained within a derived terrain-sensitive contour level, no more than 5% of those locations experienced loss of MAP or SAC decoding, as appropriate for the test data being gathered. The terrain-sensitive analysis method selected for use was Terrain-Integrated Rough Earth Model (TIREM), which is based on a proprietary implementation of the JSC propagation algorithm, utilizing 3-second terrain data. The results of the testing are provided in the maps of Appendices D and E. Appendix D contains the most recent field data for each test market, while Appendix E contains original (superceded) data from the Washington, D.C. and New York City markets. In addition to providing trails of digital decoder status (green=service, red=no service), the maps show the derived TIREM service area and FCC 60 and 70 dBu service contours (54 dBu also shown for Class B WNYC-FM, operating in the commercial FM band). An overview of TIREM is provided in Appendix F. A discussion of market-by-market results follows:

Washington, D.C. Area - Regression testing using the HDC coder and simplified direct-connect receiving antenna configuration began in the Washington, D.C. market in October, 2003. At that time, a Tomorrow Radio℠ implementation of the HDC coding system was not yet available, so reference runs were made with the Kenwood test receiver to evaluate MAP coverage only. As shown in the map of Appendix D1B, analysis of MAP decoding performance yielded a 66.0 dBu

TIREM service area, containing 4,496,212 persons, as based on the 2000 U.S. Census. This population figure represents 111% of the population contained in the projected 70 dBu FCC F(50,50) contour and 85.6% of the population contained in the projected 60 dBu FCC F(50,50) contour. With the availability of Tomorrow Radio℠ capable transmission encoders and receiver decoders, regression testing resumed in Washington, D.C. during December, 2003. As shown in the map of Appendix D1A, analysis of SAC decoding performance yielded a 64.9 dBu TIREM service area, containing 4,656,986 persons. This population figure represents 115% of the population contained in the projected 70 dBu FCC contour and 88.7% of the population contained in the projected 60 dBu FCC contour. Since MAP and SAC are derived from the same data stream, they should provide the same service area. The tests yielded a 1.1 dB discrepancy, which is considered reasonable considering the nature of field testing and the separation in time between the MAP and SAC performance data gathering. For comparison, the 67.2 dBu contour was derived for the original Tomorrow Radio℠ SAC field test data, gathered during the summer of 2003, as shown in the map of Appendix E1. The revised contour derivation represents a 2.3 dB improvement versus the older, original measured SAC performance.

New York City Metropolitan Area - Regression testing of Tomorrow Radio℠ SAC decoding performance took place during December, 2003. As shown in the maps of Appendix D2, analysis of SAC decoding performance yielded a 61.0 dBu TIREM service area, containing 15,747,274 persons. This population figure represents 129% of the population contained in the projected 70 dBu FCC contour, 103% of the population contained in the projected 60 dBu FCC contour, and 93.6% of the population contained in the projected 54 dBu FCC contour. Since data gathering on the spur routes was nearly continuous, two large area maps are provided; Appendix D2A shows outbound route performance and Appendix D2B shows inbound route performance. The map of Appendix D2C provides SAC decoding performance for the New York City/Manhattan run, which shows nearly perfect decoding except at the New Jersey side of the Lincoln Tunnel, due to signal blockage. Note that decoding performance is not shown for areas where GPS position data did not exist, such as within the Lincoln Tunnel. The maps of Appendix E2 show the overall system performance for the original test runs, made during September, 2003. Because of antenna preamplifier overloading and other effects that occurred close to the WNYC-FM transmitter location at the Empire State Building, a reasonable "best fit" TIREM projection could not be calculated for the original performance data.[8] The calculated 60 dBu TIREM service area is shown

[8] Test runs without the preamplifier/attenuator/spitter (i.e., a direct antenna connection to the receiver) were made during the original testing, which demonstrated elimination of the overloading effect and that it was not related to receiver performance. However, it was decided that test runs taken under differing equipment configurations would not be intermixed in the data analysis.

in Appendix E2A for reference. As discussed above, subsequent regression testing eliminated the overload problem.

San Francisco Bay Area - Due to time and expense constraints, no regression testing was performed in the San Francisco Bay Area. The maps of Appendix D3 show SAC decoding performance for the original testing, conducted during August, 2003. As discussed earlier, San Francisco testing utilized separate receiving antennas for each device requiring an antenna connection. However, interaction between the antennas could not be completely eliminated, although the differences likely averaged out somewhat over all of the test routes. Further, FM Station KALW operates at relatively low power (1.9 kW ERP) and reception from its transmitter site, located in central San Francisco, is significantly terrain-limited in outlying areas. Thus, it is expected that the results of any regression testing would show similar geographic reach and population coverage, but that some minor outages close to the transmitter site would be corrected. As shown in the map of Appendix D3A, analysis of SAC decoding performance yielded a 66.0 dBu TIREM service area, containing 1,603,323 persons. This population figure represents 107% of the population contained in the projected 70 dBu FCC contour and 58.9% of the population contained in the projected 60 dBu FCC contour. The downtown San Francisco results map of Appendix D3B shows a few outage areas. The two areas showing decoder dropout in the northwest are at tunnels, while the areas in the northeast are severely shadowed by San Francisco Financial District buildings. The outage area in the southwest is likely caused by receiver intermodulation or overload. That particular area is nearby and between the two major San Francisco FM broadcast sites at Sutro Tower and San Bruno Mountain.

Los Angeles/Long Beach Area - As with San Francisco field testing, no regression testing was performed in the Los Angeles/Long Beach area. The map of Appendix D4 provides SAC decoding performance for the original testing phase, conducted during August, 2003.[9] As shown, analysis yielded a 70.8 dBu TIREM service area, containing 4,181,551 persons. This population figure represents 161% of the population contained in the projected 70 dBu FCC contour and 63.3% of the population contained in the projected 60 dBu FCC contour. Based on collected regression data in the other markets, it is anticipated that regression testing in Los Angeles/Long Beach would yield a TIREM service area about 2-3 decibels lower than that of the original testing, due mostly to elimination of the Phase I receiving antenna preamplifier/splitter network.

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9 The Los Angeles map has been magnified over the original route map to add clarity. No SAC service was present in areas outside the boundaries shown in the map of Appendix D4.

## Additional Comments and Observations

To maintain consistency with service contours based on FCC methods, a 9.1-meter (30-foot) receiving antenna height above ground was assumed for the TIREM calculations. Service contour levels for a 2-meter receiving antenna height are on the order of 6 dB lower than those shown on the maps.

During initial testing, a non-Tomorrow Radio℠ Kenwood reference receiver was operated in parallel with the Tomorrow Radio℠ test unit receiver. Use of the reference receiver was discontinued during regression testing due to the simplification of the receiving antenna network, which then only fed the test receiver. Analysis of original test data showed fairly close correlation between the two receivers in MAP decoding.

Some significant interference effects were noted from co-channel and adjacent-channel stations. An anomalous in-band interfering signal was observed using spectrum analysis techniques on Washington, D.C. Test Route 4 (Highway 4) during original testing, but the signal was no longer present in recent regression testing. Our data analysis showed that effects from adjacent-channel stations were observed at edge-of-coverage areas on Test Route 2 near Baltimore, Maryland, and on Test Route 5 near Fredericksburg, Virginia. Testing in other markets did not yield any significant instances of interference. In general, when the test station's 60 dBu service contour was impinged by a strong in-band transmission, there was an observable effect that somewhat reduced the coverage area, which explains the reduced performance in the Washington, D.C., area as compared to the New York City Metropolitan area. However, these effects did not dominate the test results.

## Summary

The table provided below summarizes the results of the Tomorrow Radio℠ field testing project:

| Test Market | Tomorrow Radio℠ Population Served (2000 U.S. Census) | TIREM Best-fit Contour |
|---|---|---|
| **Regression Test Markets (HDC)** | | |
| Washington, D.C. | 4,656,986 persons | 64.9 dBu |
| New York City | 15,747,274 persons | 61.0 dBu |
| **Original Test Markets (PAC)** | | |
| Washington, D.C. | 4,341,266 persons | 67.2 dBu |
| New York City | (not calculated: see report text) | |
| San Francisco | 1,603,323 persons | 66.0 dBu |
| Los Angeles (Long Beach) | 4,181,551 persons | 70.8 dBu |

## Conclusion

Based on our analysis of the MAP and SAC performance data collected in four markets during regression and original field testing, we conclude that, with 95% certainty, the Tomorrow Radio℠

usable service area would fall within a given FM station's 60 to 70 dBu service area. This conclusion is predicated on the assumption that IBOC decoding performance of the Kenwood test receiver would be representative of that found in similar receivers available from Kenwood and from other manufacturers. It also assumes nominal allocation conditions for the FM station. The presence of short-spaced or grandfathered co-channel or adjacent-channel facilities and terrain features within a subject station's service area could degrade the Tomorrow Radio℠ service area; similarly, more optimum allocation and terrain conditions could enhance the Tomorrow Radio℠ service area to below the 60 dBu contour level.[10]

## List of Appendices

In carrying out these engineering studies, the following included appendices were prepared under my direct supervision:

A. Project participants, chronology, and representative transmission system installation
B. Test route descriptions and maps
C. Test van system block diagrams and representative photographs
D. Maps showing most recent test results for each market
E. Maps showing results of original testing in Washington, D.C. and new York City markets
F. About TIREM coverage projection maps.

Respectfully submitted,

Stanley Salek, P.E.

January 6, 2004

[10] This phenomenon was particularly observed for Washington, D.C. Test Route 6. That route, over gently rising terrain and with no observed manmade or FM station interference factors, exhibited performance to well under 60 dBu.

## National Public Radio • Washington, D.C.

## NPR Tomorrow Radio℠ Field Test Project
## Active Project Participants

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FM Station WETA, Washington, D.C.; Dan Devany, General Manager, Mike Byrnes, Engineer

Station WNYC-FM, New York, NY; Laura Walker, President and CEO, Philip L. Redo, Vice President, Steve Shultis, Engineer

FM Station KALW, San Francisco, CA; Nicole Sawaya, General Manager, Phil Hartman, Engineer

FM Station KKJZ, Long Beach, CA; Judy Jankowski, General Manager, Ron Thompson, Engineer

The project team gratefully acknowledges the assistance of Ibiquity Digital Corporation, including staff members Thomas Walker, Patrick Malley, Al Shuldiner, and Ashruf El-Dinary, and Doug Vernier, technical consultant to the Corporation for Public Broadcasting.

## National Public Radio • Washington, D.C.

## NPR Tomorrow Radio℠ Field Test Project
## Project Chronology

| Time Period | Event |
|---|---|
| December 2002 | Project inception |
| March – April 2003 | Assembly of project team |
| April 2003 | Project status report to NRSC |
| April – July 2003 | Field test planning |
| August – September 2003 | Original field testing in San Francisco, Los Angeles (Long Beach), Washington, D.C., and New York City Metropolitan areas (PAC audio coder). |
| October 2003 | Project status report to NRSC |
| October 2003 | Initial regression testing in Washington, D.C. HDC Coder implementation, HD Radio main channel only (Tomorrow Radio℠ HDC implementation not yet ready). |
| November – December 2003 | Full regression testing in Washington, D.C. and New York City metropolitan areas. HDC/Tomorrow Radio℠ implemented. |
| January 2004 | Project report submission to NRSC (January 9 meeting at Consumer Electronics Show, Las Vegas, Nevada). |

**National Public Radio • Washington, D.C.**

**NPR Tomorrow Radio℠ Field Test Project**
**Representative Photographs of Transmission System Installation**


WNYC-FM Transmitter Room. Equipment racks, exciter rack, analog FM transmitter, analog FM/HD radio transmitter. (courtesy WNYC Radio)


WNYC-FM Transmitter Room. Exciter rack and transmitters. (courtesy WNYC Radio)

## National Public Radio • Washington, D.C.

## NPR Tomorrow Radio℠ Test Routes – Washington, D.C. Area

### General Information

Described below are the NPR Tomorrow Radio℠/WETA test routes for the Washington, D.C. area. For reference, all routes begin and end in Alexandria, Virginia. The routes were selected to simulate eight radial directions from Washington, D.C. and to take measurements near stations operating on adjacent channels in Baltimore (WBJC, 91.5 MHz), Worton, Maryland (WKHS, 90.5 MHz), and Alexandria, Virginia (WJYJ, 90.5 MHz and FM Translator Station W217BC. 91.3 MHz). Traffic patterns and road conditions occasionally necessitated minor revisions to the actual routes driven. The path of each route is described below. All routes are shown in composite form on an accompanying map figure.

### Route 1 (N/NW Loop)

Take the I-495 D.C. Beltway north (clockwise) and exit at Route 97 north. Continue on Route 97, crossing I-70, until the signal is no longer usable. Turn around and travel south on Route 97, transitioning to I-70 west. Continue on I-70 west, past Frederick, until the signal is no longer usable. Turn around and travel east on I-70, transitioning to I-270 in Frederick. Take I-270 southeast to I-495 (counterclockwise), and continue to Alexandria.

### Route 2 (NE Loop)

Take I-95 north (counterclockwise on the D.C. Beltway) and continue on I-95 toward Baltimore. Nearing Baltimore, follow signs for the Harbor Tunnel (I-395) and continue through the tunnel. At the north end of the tunnel, rejoin I-95 and exit at the Baltimore Beltway, I-695 (counterclockwise). Continue around the full beltway and join with Route 295 south of Baltimore. Take Route 295 south toward and through Washington, D.C. Take I-95 south a short distance back to Alexandria.

### Route 3 (E Spur)

Take I-95 north (easterly, counterclockwise on D.C. Beltway). Transition to Highway 50/301 toward Annapolis. Continue past Annapolis across Chesapeake Bridge east bound, to the Highway 301/50 split at Queenstown, Maryland. Take Highway 301 northeasterly toward the Delaware border, until the signal is no longer usable. Turn around and travel back to Queenstown on Highway 301, joining with Highway 50 south-southeasterly, toward Salisbury. Continue on Highway 50 until signal is no longer usable.

## NPR Tomorrow Radio℠ Test Routes – Washington, D.C. Area

### Route 4 (SE Spur)

Take I-95 north (easterly, counterclockwise on D.C. Beltway). Transition to Route 4 toward Prince Frederick. Continue on this road until the signal is no longer usable or until the road ends in Leonardtown, Maryland.

### Route 5 (S/SW Loop)

Take I-95 north (easterly) and join with Route 5 south at Morningside. Travel south on Route 5, which becomes Highway 301, through Waldorf and La Plata, crossing the bridge into Virginia. Near Port Royal, transition to Highway 17 northwesterly. Cross I-95 and take Route 1 north to the I-95 on-ramp at Exit 126. If the signal is still usable, take I-95 south until it is not and then turn around and head north on I-95 back to Alexandria. If the signal is not usable at the Exit 126 interchange, take I-95 directly north, back to Alexandria.

### Route 6 (W Spur)

Take I-95 south (westward), continuing on I-495 (D.C. Beltway) in a northerly direction. At Falls Church, Virginia, take I-66 west toward Front Royal. Continue on I-66 west until signal is no longer usable. Continue on I-81 south, if appropriate, until signal is not usable.

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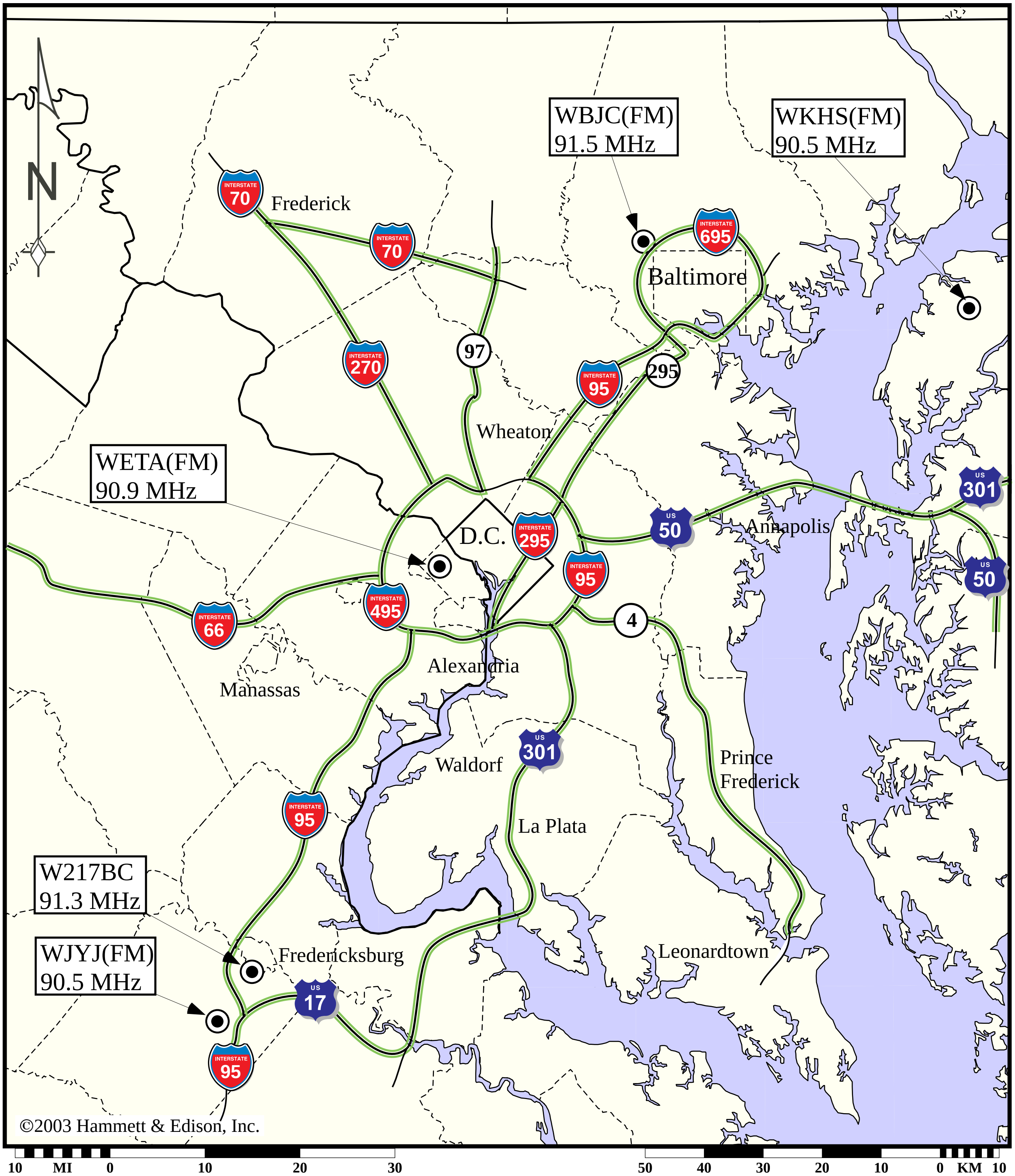
## NPR Tomorrow Radio℠ Test Routes – Washington, D.C. Area




Lambert conformal conic map projection. Map data taken from Sectional Aeronautical Charts, published by the National Ocean Survey. County lines shown taken from U.S. Census Bureau TIGER/Line 2000 data.

# NPR Tomorrow Radio℠ Test Routes – New York City Metropolitan Area

## General Information

Described below are the NPR Tomorrow Radio℠/WNYC-FM test routes for the New York City Metropolitan Area. For reference, all routes begin and end in northern New Jersey, just west of the George Washington Bridge. The routes were selected to simulate four radial directions from New York City, along with a Manhattan loop route, similar to the routes used in previous NRSC digital radio testing, and to take measurements near stations operating on adjacent channels in New Rochelle, New York (WRTN, 93.5 MHz), Pomona, New York (W232AL, 94.3 MHz), Asbury Park, New Jersey (WJLK-FM, 94.3 MHz), Smithtown, New York (WMJC, 94.3 MHz), Middletown, New York (W229AA, 93.7 MHz), and Newburgh, New York (W231AG, 94.1 MHz). Traffic patterns and road conditions occasionally necessitated minor revisions to the actual routes driven. The path of each route is described below. All routes are shown on an accompanying map figure, along with a detail map of the Manhattan Loop.

## Route 1 (N Radial)

Take I-80 east to the Palisades Parkway, just west of the George Washington Bridge. Take the Palisades Parkway northerly, and then northwesterly, into New York State. Take Highway 6 at Exit 18 and travel westerly, connecting with I-87 North near Harriman. Continue on I-87 north until signal is no longer usable.

## Route 2 (E Radial)

Take I-80 east, across the George Washington Bridge, joining with I-295 south across the Throgs Neck Bridge, continuing south to I-495, the Long Island Expressway. Take the Long Island Expressway easterly until signal is no longer usable.

## Route 3 (S Radial)

Take I-80 to I-95 (New Jersey Turnpike) south at Exit 68. Continue south on I-95 to the Garden State Parkway (Exit 10 from I-95). Take the Garden State Parkway south until the signal is no longer usable.

## Route 4 (W Radial)

Take I-80 west until signal is no longer usable.

## Route 5 (Manhattan Loop)

Take I-80 to I-95 south at Exit 68. Take Exit 16E toward the Lincoln Tunnel. Cross into Manhattan and connect to West 40th Street, eastbound. At Broadway, turn right (southerly) and continue past the Empire State Building, Union Square, and City Hall, to State Street, near Battery Park. Take State Street southerly and then southeasterly to South Street. Turn left and travel northerly on South Street, past South Street Seaport, to Pike Street. Turn left on Pike Street and travel northerly until joining with First Avenue at Houston Street/East First Street. Travel northeasterly on First Avenue to East 110th Street. Turn left on East 110th Street and travel northwesterly, across Central Park North, continuing on West 110th Street. At Broadway, turn left, traveling in a southerly direction. At 41st Street, turn right and travel back into New Jersey, westbound through the Lincoln Tunnel.

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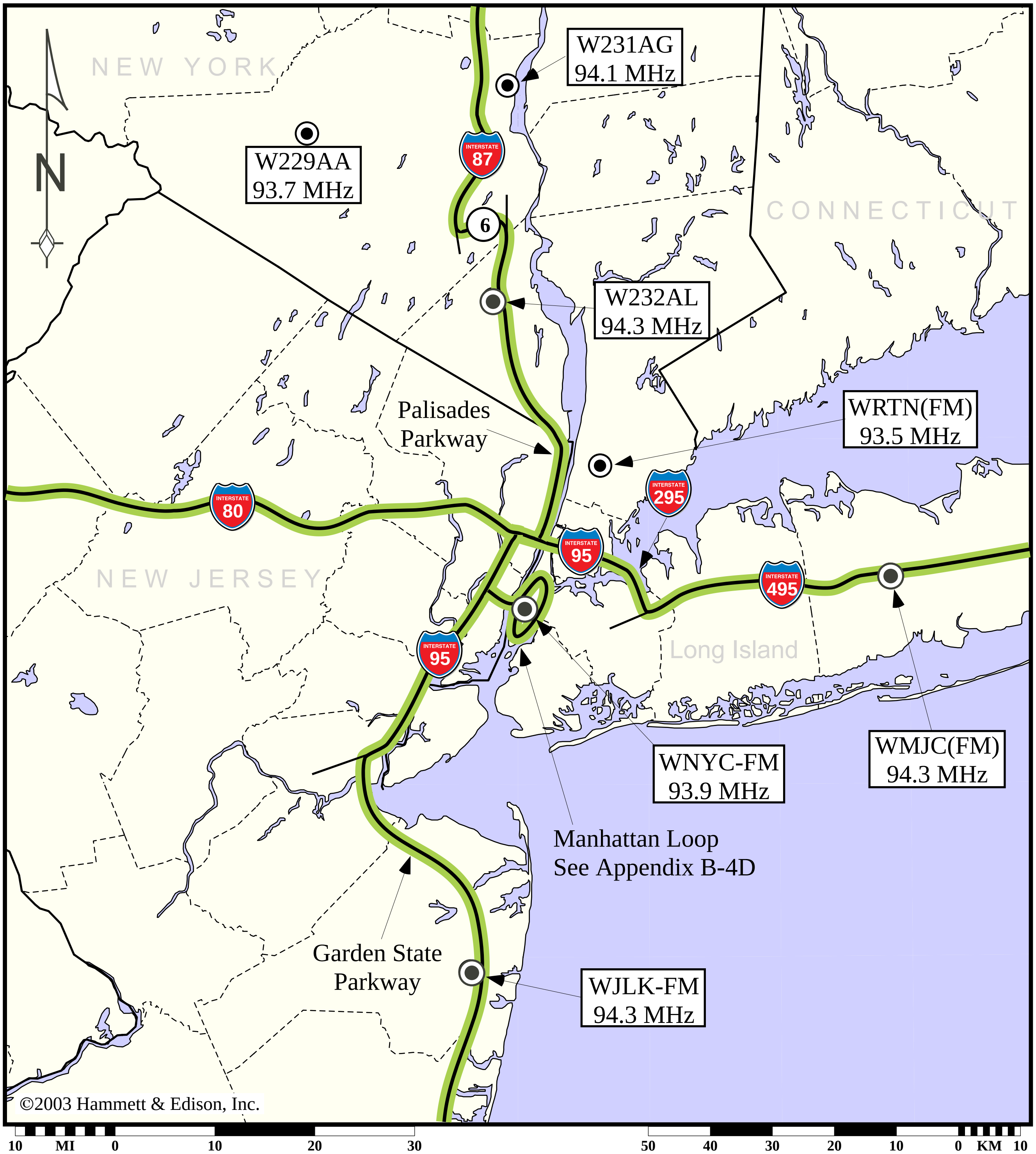
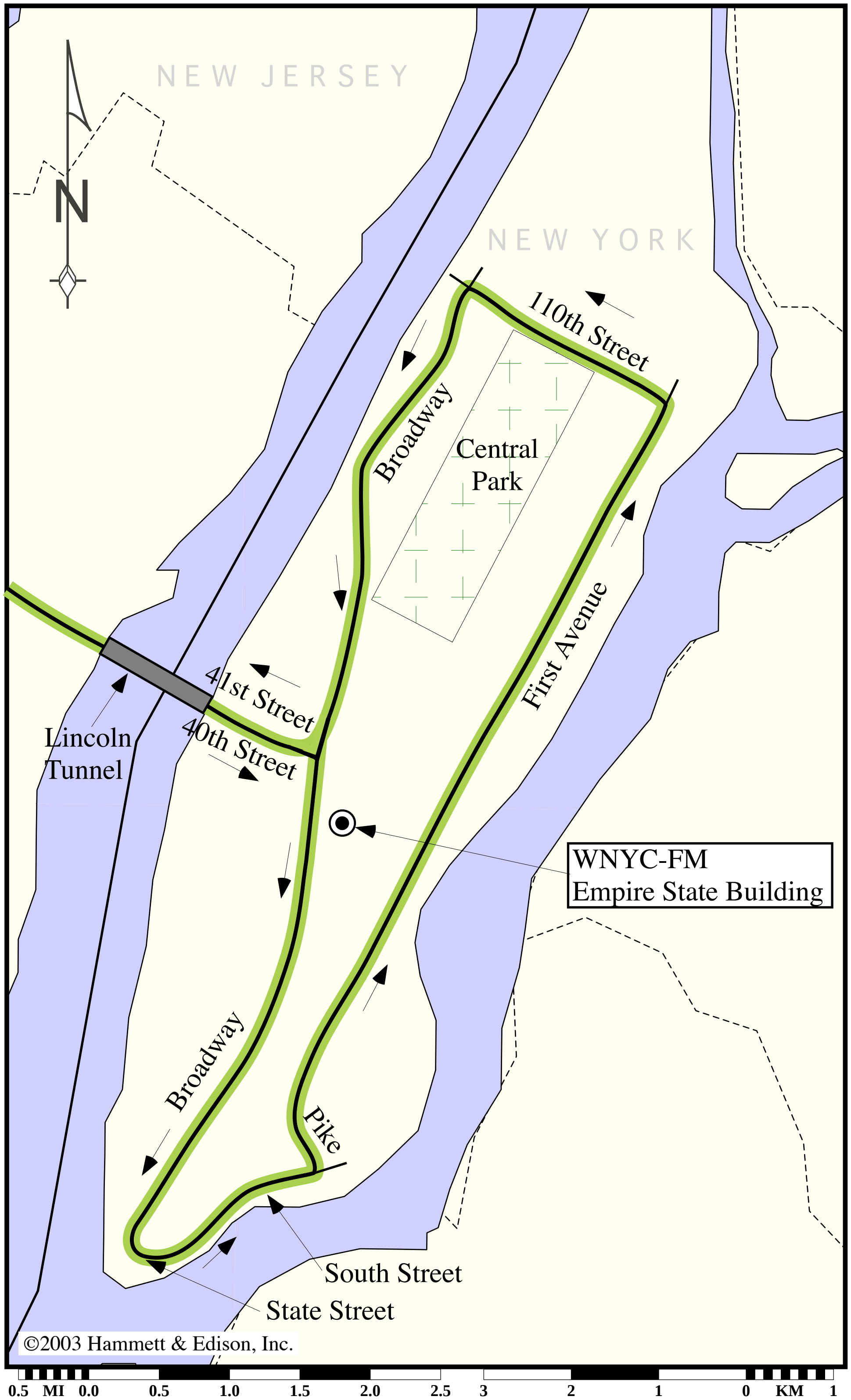
## NPR Tomorrow Radio[SM] Test Routes – New York City Metropolitan Area




Lambert conformal conic map projection. Map data taken from Sectional Aeronautical Charts, published by the National Ocean Survey. County and state lines shown taken from U.S. Census Bureau TIGER/Line 2000 data.

## NPR Tomorrow Radio℠ Test Routes – New York City Metropolitan Area
## Manhattan Loop Route




Transverse Mercator map projection. Map data taken from Sectional Aeronautical Charts, published by the National Ocean Survey. County and state lines shown taken from U.S. Census Bureau TIGER/Line 2000 data.

# NPR Tomorrow Radio℠ (NRSC) Test Routes – San Francisco Bay Area

## General Information

Described below are the NPR Tomorrow Radio℠/KALW test routes for the San Francisco Bay Area. These routes duplicate those used previously for NRSC FM digital radio field testing. The locations of stations operating on adjacent channels in San Mateo (KCSM, 91.1 MHz) and Walnut Creek (KFJO, 92.1 MHz) are shown. The chosen starting points are arbitrary, as are the directions of travel around the loops, although they were chosen in some cases for best anticipated traffic flow. Traffic patterns or road conditions occasionally necessitated minor revisions to the actual routes driven. The path of each route is described below and shown graphically on accompanying figures.

## Route P (San Francisco Perimeter)

Begin just south of Golden Gate Bridge on Highway 101; take Highway 1 (19th Avenue) exit south through Golden Gate Park, continuing south to Brotherhood Way; take Brotherhood Way east to I-280 north; transition to Highway 101 north; transition to I-80 east; take I-80 east to 4th Street (last San Francisco exit); at end of exit ramp, turn left on Bryant Street to The Embarcadero; turn left on The Embarcadero and travel into Wharf area; turn left on Bay Street at Pier 31; turn right onto Laguna Street; travel two blocks to Marina Boulevard (Marina District); turn left onto Marina Boulevard, which becomes Highway 101 north.

## Route D (San Francisco Downtown)

Begin at easternmost end of Market Street; take Market Street southwest; transition to Portola Avenue, then to Woodside Avenue; at the end of Woodside Avenue, turn right on Laguna Honda at Dewey; take next right onto Clarendon; travel up Clarendon, which becomes Twin Peaks Boulevard, Clayton Street, then Ashbury Street; turn right on Frederick Street; travel two blocks to Masonic Avenue; turn left on Masonic Avenue and travel to Bush Street; turn left after one block onto Presidio Avenue; turn right after two blocks onto California Street; take California Street east to Sansome Street; take Sansome Street north to Jackson Street; take Jackson Street east to Battery Street; take Battery Street south to Pine Street; take Pine Street west to Sansome Street; take Sansome Street north to Jackson Street; take Jackson Street east to Battery Street; take Battery Street south to Market Street.

## Route W (San Francisco Peninsula)

Take I-280 to Highway 1 south, near Pacifica; continue south on Highway 1 along coast to Half Moon Bay; turn left on Highway 92, heading east, crossing under I-280 to Highway 101; take Highway 101 north to I-380, then I-380 west to I-280 north, back to the starting point.

## NPR Tomorrow Radio[SM] (NRSC) Test Routes – San Francisco Bay Area

### Route E (East Bay)

Begin on I-80 at San Francisco side of Bay Bridge; cross bridge (lower deck) to I-580; take I-580 east to Highway 24; take Highway 24 east to I-680; take I-680 south to I-580, near Dublin; take I-580 west to Bay Bridge (Oakland side); cross bridge (upper deck) and end on San Francisco side.

### Route N (North Bay)

Begin at junction of Highway 101 and I-580 in San Rafael; take Highway 101 north to Highway 37; take Highway 37 east to Highway 29 south; connect to I-80 in Vallejo, then south to Central Avenue west, one block to I-580 west; take I-580 west across the Richmond Bridge; transition to Highway 101.

### Route S (South Bay)

Begin at junction of Highway 101 and Highway 84 (Dumbarton Bridge exit) east; cross Dumbarton Bridge to Fremont, then travel south on I-880; transition to Highway 237; take Highway 237 west to Lawrence Expressway (also known as County Road G2); take Lawrence Expressway south to I-280; take I-280 north to Highway 85 north; take Highway 85 north to Highway 101 north, back to Dumbarton Bridge exit.

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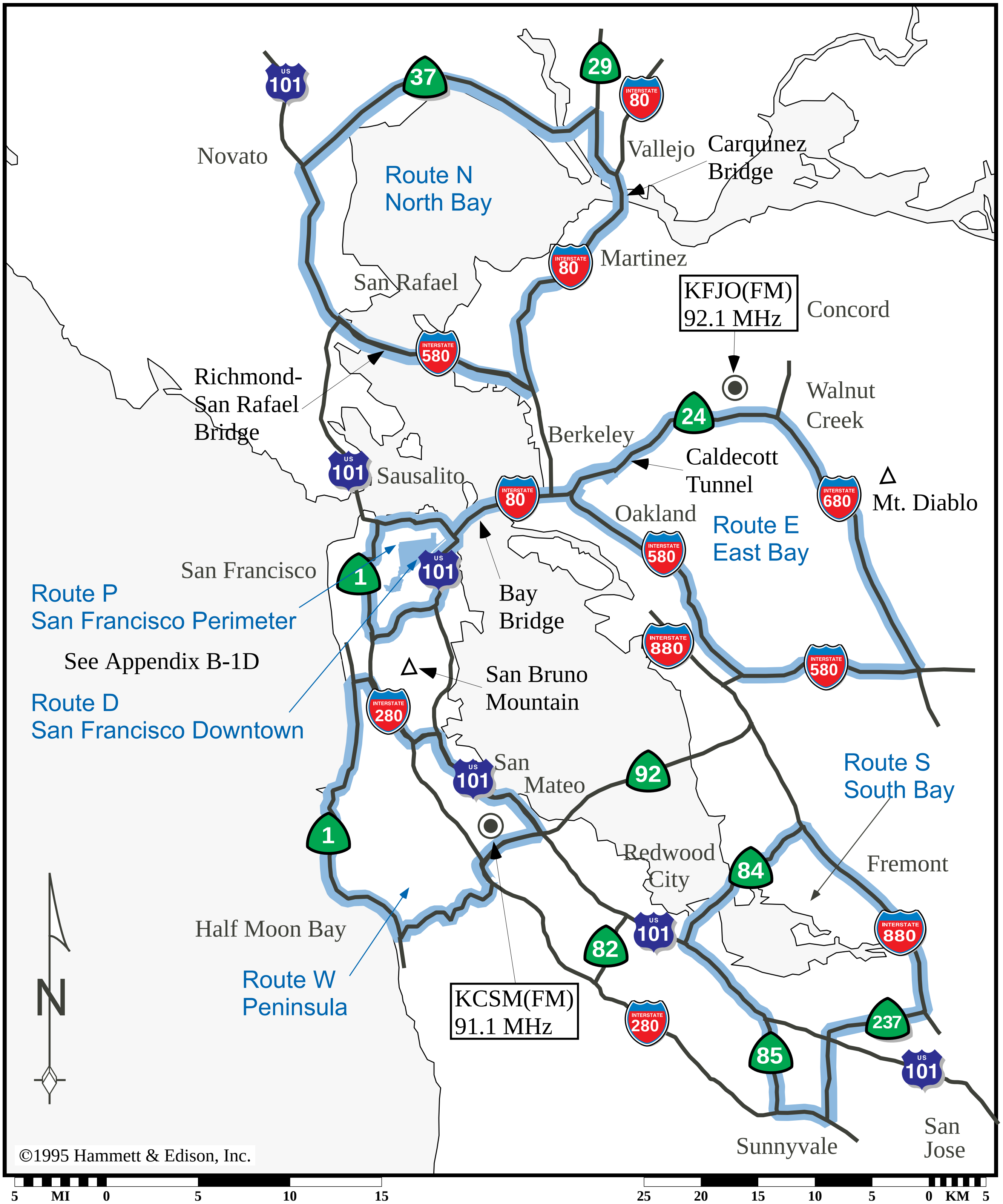
## NPR Tomorrow Radio℠ (NRSC) Test Routes – San Francisco Bay Area

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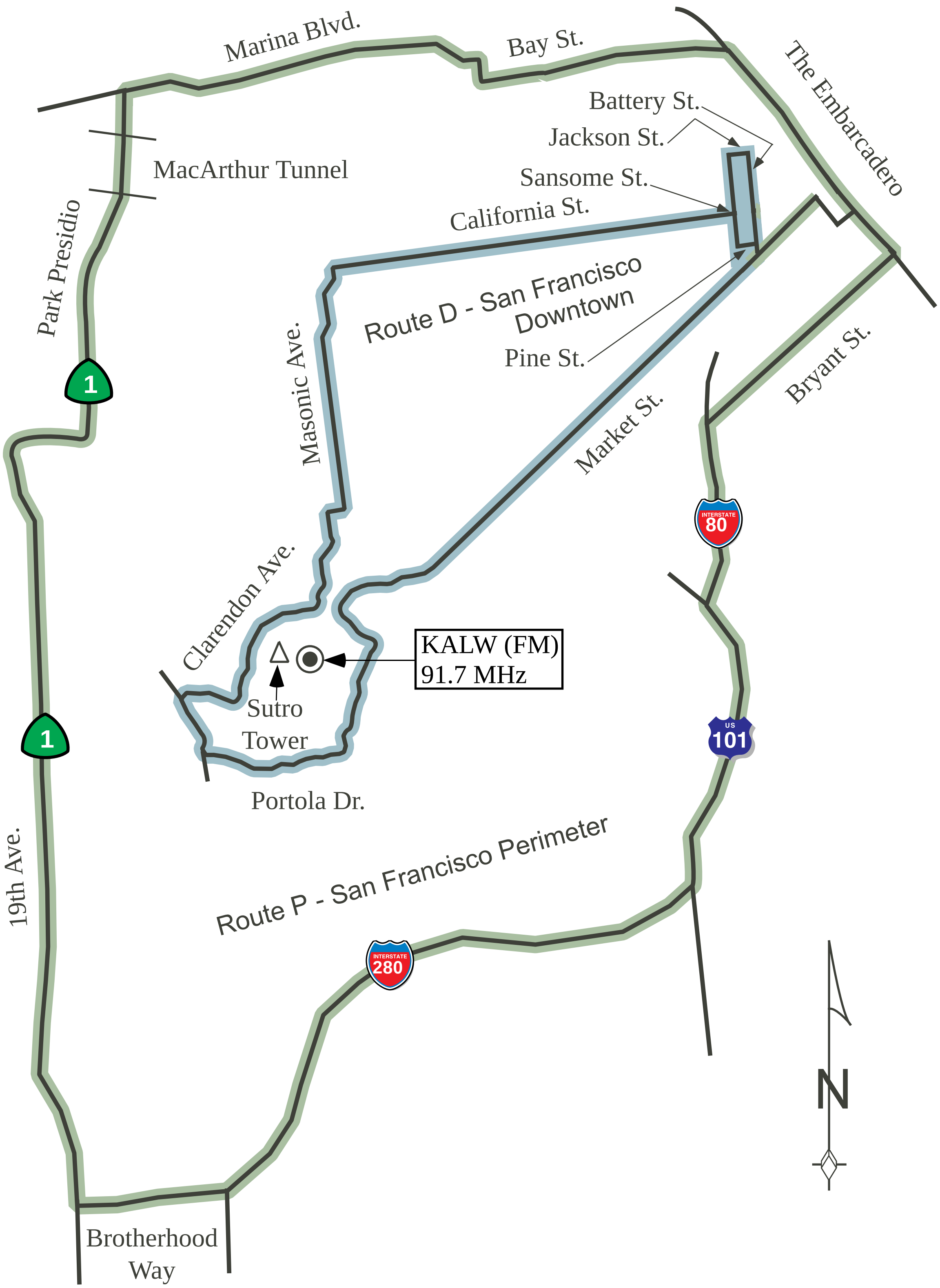
## NPR Tomorrow Radio[SM] (NRSC) Test Routes – San Francisco Bay Area

## Downtown San Francisco Routes



# NPR Tomorrow Radio℠ Test Routes – Los Angeles Area

## General Information

Described below are the three NPR Tomorrow Radio℠/KKJZ test routes for the Los Angeles/Southern California area. All routes begin and end in Long Beach. The routes were selected for easy transitions and to take measurements past stations operating on adjacent channels in Mission Viejo (KSBR, 88.5 MHz), Riverside (KUCR, 88.3 MHz), Claremont (KSPC, 88.7 MHz), Northridge (KCSN, 88.5 MHz), and Thousand Oaks (KCLU, 88.7 MHz). Traffic patterns and road conditions occasionally necessitated minor revisions to the actual routes driven. The path of each route is described below and is also shown on an accompanying figure.

## Route 1 (Western Wide Area)

Take Highway 1 south to Highway 22. Take Highway 22 east and transition to I-405 South (the San Diego Freeway) near Westminster. Travel south on I-405 through Santa Ana and Irvine. Transition onto I-5 and continue south past Mission Viejo and San Juan Capistrano. Continue south on I-5 toward San Diego until the signal level is no longer usable. Turn around and travel north on I-5 back past Mission Viejo. Continue on I-5 north past Santa Ana, Anaheim, Norwalk, Montebello, Los Angeles, Glendale, and Burbank. Continue north on I-5 past San Fernando until the signal level is no longer usable. Turn around and transition to I-405 south at San Fernando. From I-405 south, transition to Highway 118 west (Ronald Reagan Freeway). Travel west to Simi Valley; transition to Highway 23 south to Thousand Oaks. Transition to Highway 101 south (actually heading east). Travel on Highway 101 to Encino, then take I-405 south through Brentwood, Culver City, Inglewood, and Torrance, transitioning to I-605 south after passing Long Beach. After a short distance, take Highway 22 west, back to the starting point in Long Beach.

## Route 2 (East Valley)

From Long Beach, take I-710 north (Long Beach Freeway) through Lakewood. Transition to Highway 91 east (Gardenia/Artesia/Riverside Freeways) and take it past Cerritos, Anaheim, Fullerton, Yorba Linda, Corona, and Riverside. After Riverside, transition to I-215 north. Near Loma Linda, transition to I-10 west (San Bernardino Freeway). Travel west on I-10 past Ontario, Pomona, West Covina, and El Monte. Near Monterey Park, transition to I-710 south, past East Los Angeles, Bell Gardens, Downey, and back to the starting point in Long Beach.

## NPR Tomorrow Radio[SM] Test Routes – Los Angeles Area

### Route 3 (Inner Loop/Downtown LA/Santa Monica)

Take Highway 1 south to Highway 22. Take Highway 22 east (Garden Grove Freeway) to Orange; transition to Highway 57 north (Orange Freeway) and travel past Placentia and Diamond Bar. Transition to I-210 northward after crossing I-10. Continue west on I-210 (Foothill Freeway) at San Dimas, passing Monrovia, Pasadena, and Glendale. Near Magnolia Park, transition to Highway 101 southward (Hollywood Freeway) toward Los Angeles. Just after crossing I-110 (Harbor Freeway), take the next exit onto Temple Street. Turn left on Temple Street and travel one block to Grand Avenue south (right turn). Take Grand Avenue south through downtown Los Angeles. Approximately 18 blocks south on Grand Avenue, enter I-10 west (Santa Monica Freeway). Continue on I-10 west past Culver City to Santa Monica. In Santa Monica, find a convenient location to turn around. Travel east on I-10 and transition to I-110 south (Harbor Freeway). Travel on I-110 south past Compton and Carson, transitioning onto Highway 1 (Pacific Coast Highway) south (actually eastward) back to the starting point in Long Beach.

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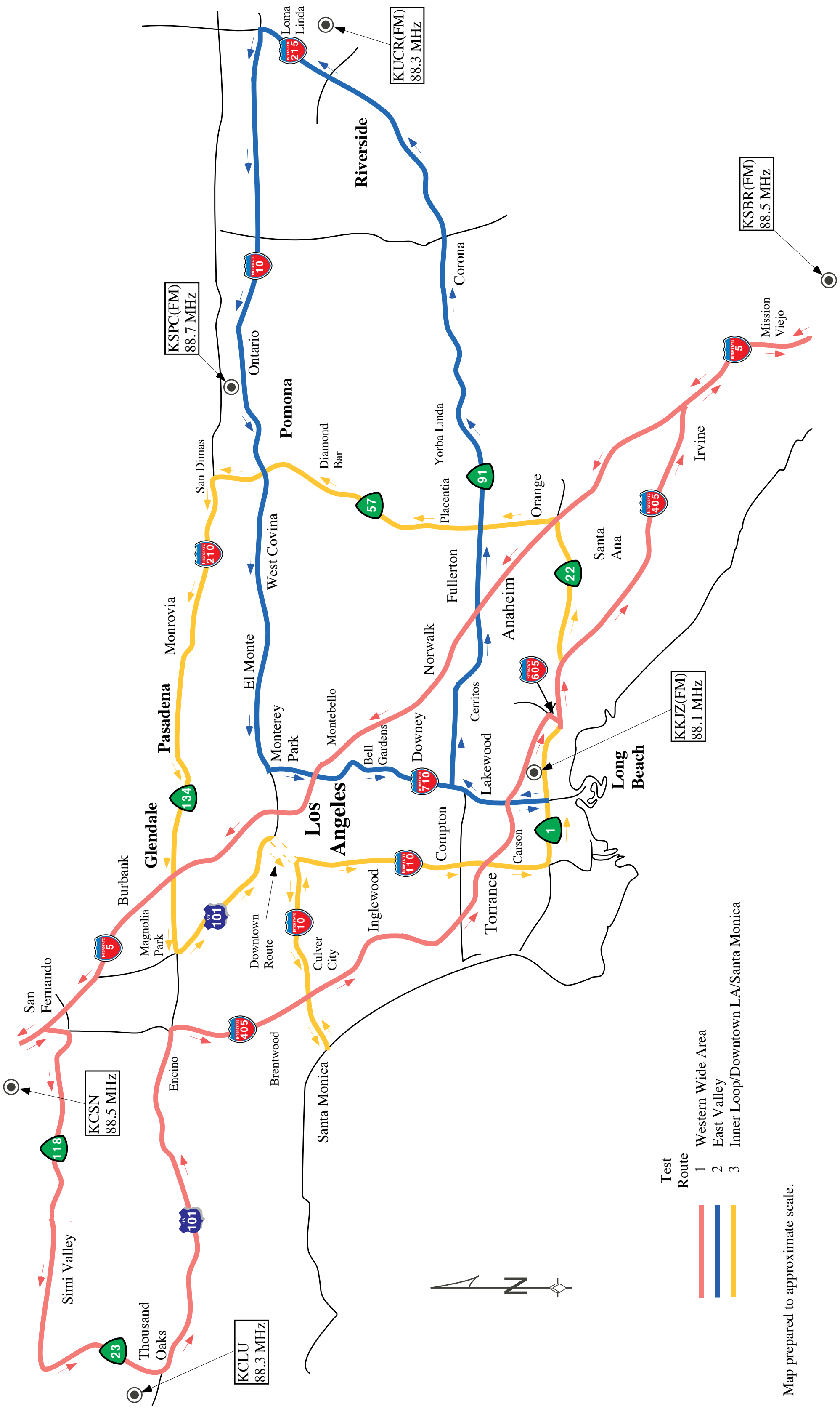
## NPR Tomorrow Radio[SM] Test Routes – Los Angeles Area



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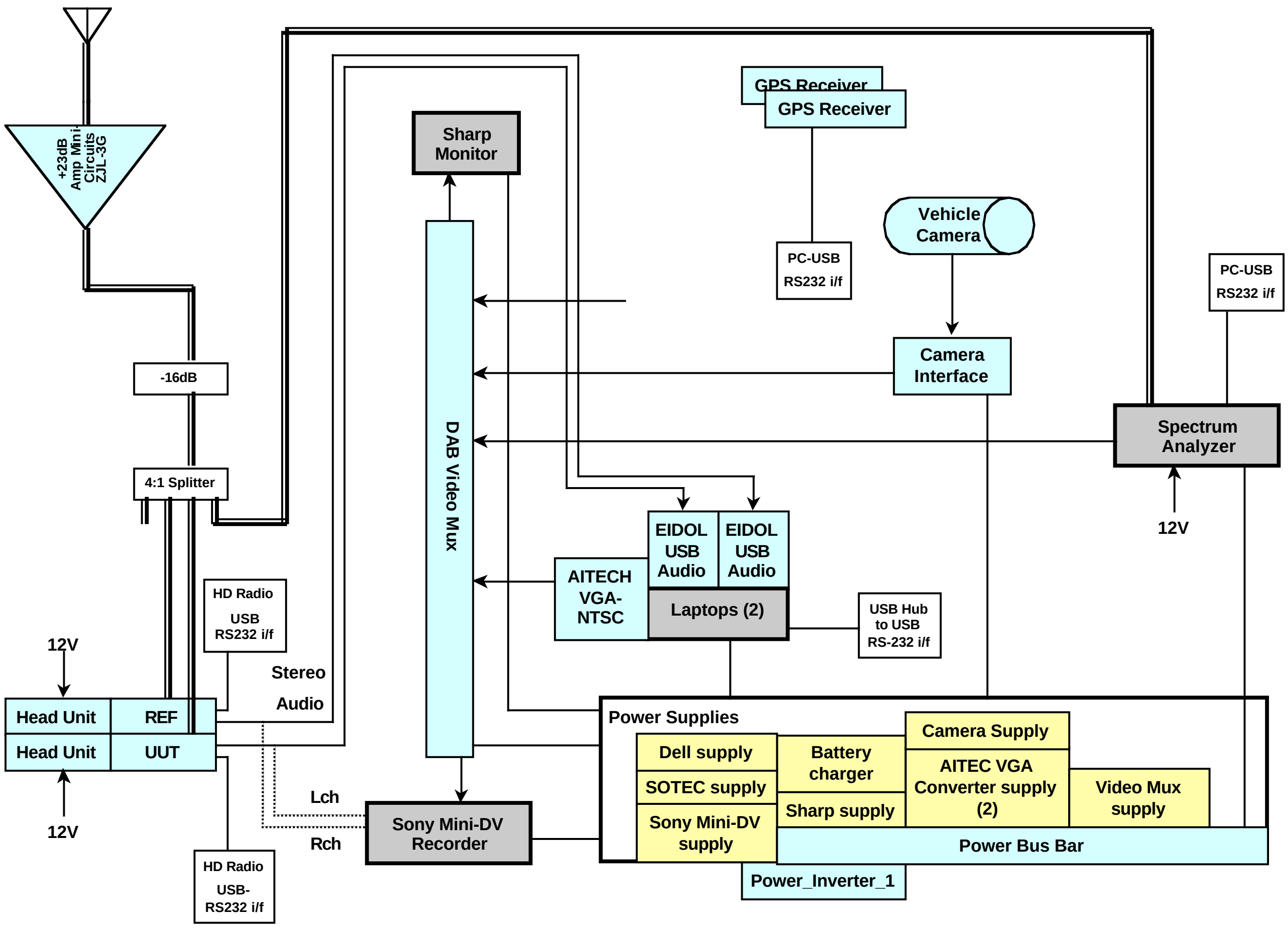
## NPR Tomorrow Radio[SM] Field Test Project
## Test Van Equipment Block Diagram
## Original Configuration




Note: 1. Diagram supplied by Kenwood Corporation

2. Antenna distribution network shown as used in all test markets except San Francisco. San Francisco configuration employed 3 separate receiving antennas feeding the test receiver, reference receiver, and spectrum analyzer. No RF amplifier, attenuator, or power splitter were employed in San Francisco or in subsequent regression testing.

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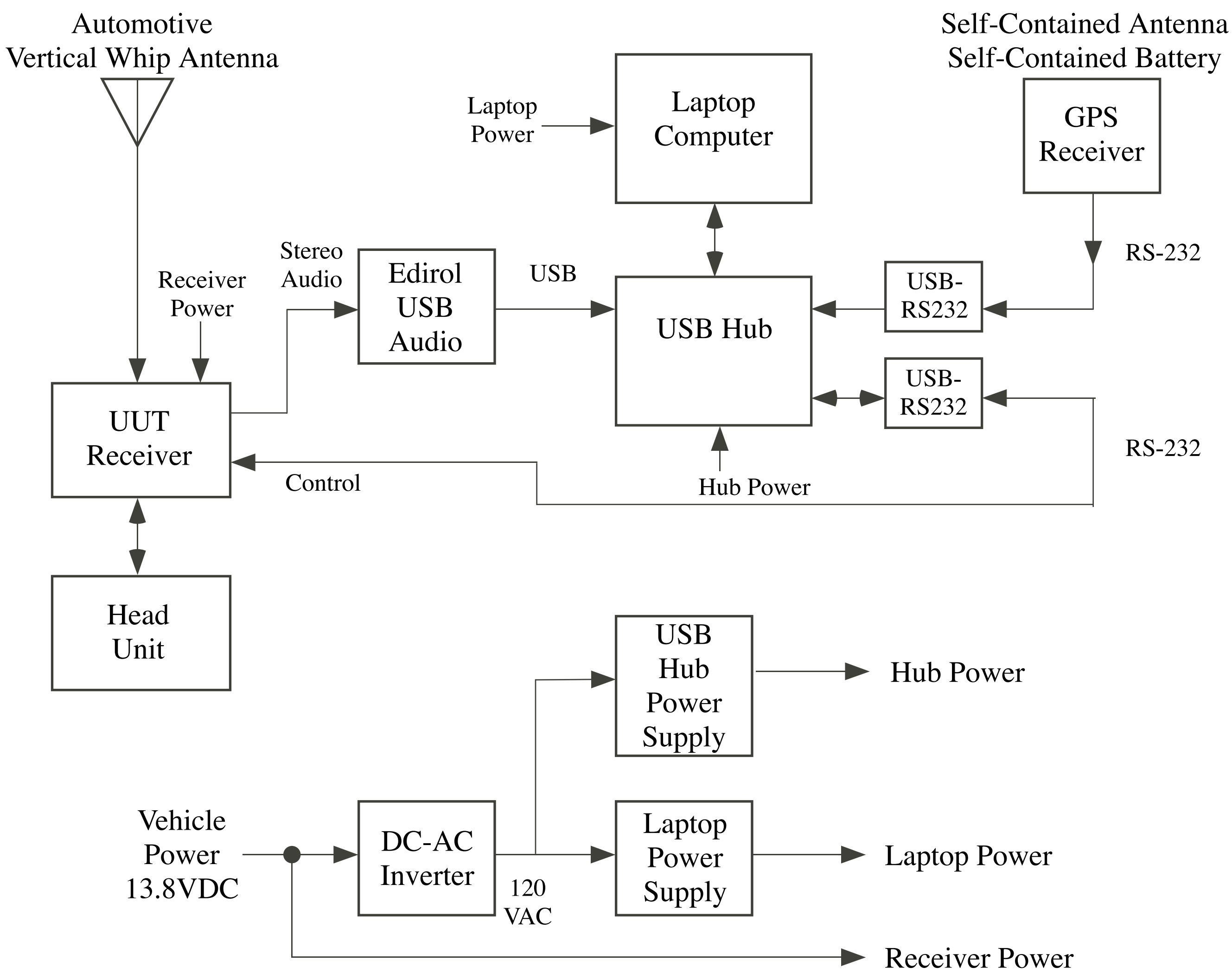
NPR Tomorrow Radio$^{SM}$ Field Test Project
Test Van Equipment Block Diagram
Simplified Configuration Used During Regression Testing




Notes: 1. Spectrum analyzer used for daily system calibration testing but not continuously operated
2. Receiving antenna connects directly to UUT receiver

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**NPR Tomorrow Radio℠ Field Test Project**
**Representative Photographs of Mobile Test Van**


San Francisco / KALW Configuration.  Multiple receiving antennas


Other Markets for original and regression testing (WNYC-FM / New York shown).  Single receiving antenna

## National Public Radio • Washington, D.C.

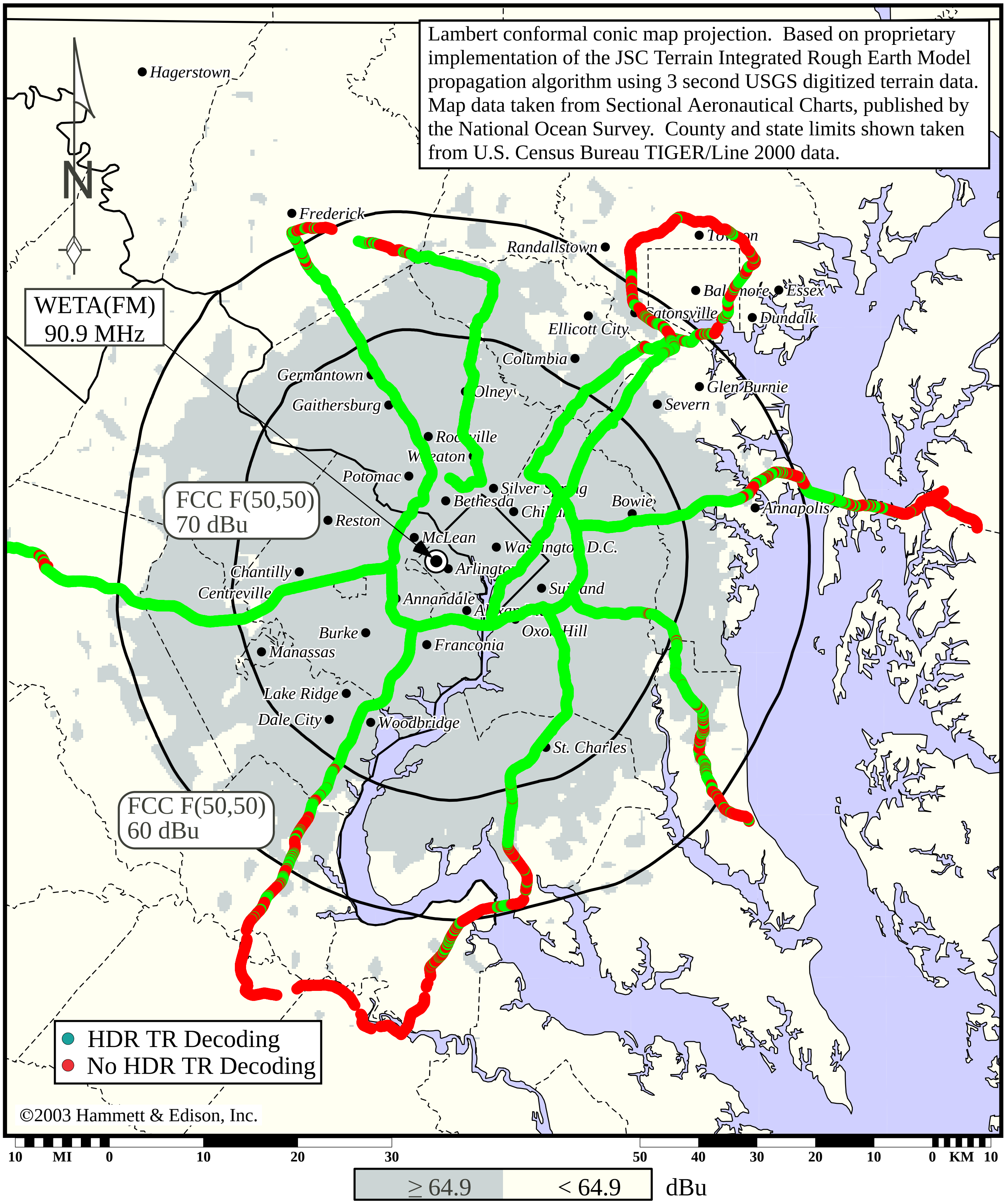
## NPR Tomorrow Radio℠ Field Test Project
## Representative Photographs of Mobile Test Van


Portion of mobile test package showing test receivers and data gathering computer. (Courtesy Kenwood Corporation)


Video monitor in observer position used during original testing. Displayed spectrum, computer screen, forward camera image.

# National Public Radio/Harris/Kenwood • Tomorrow Radio℠ Project

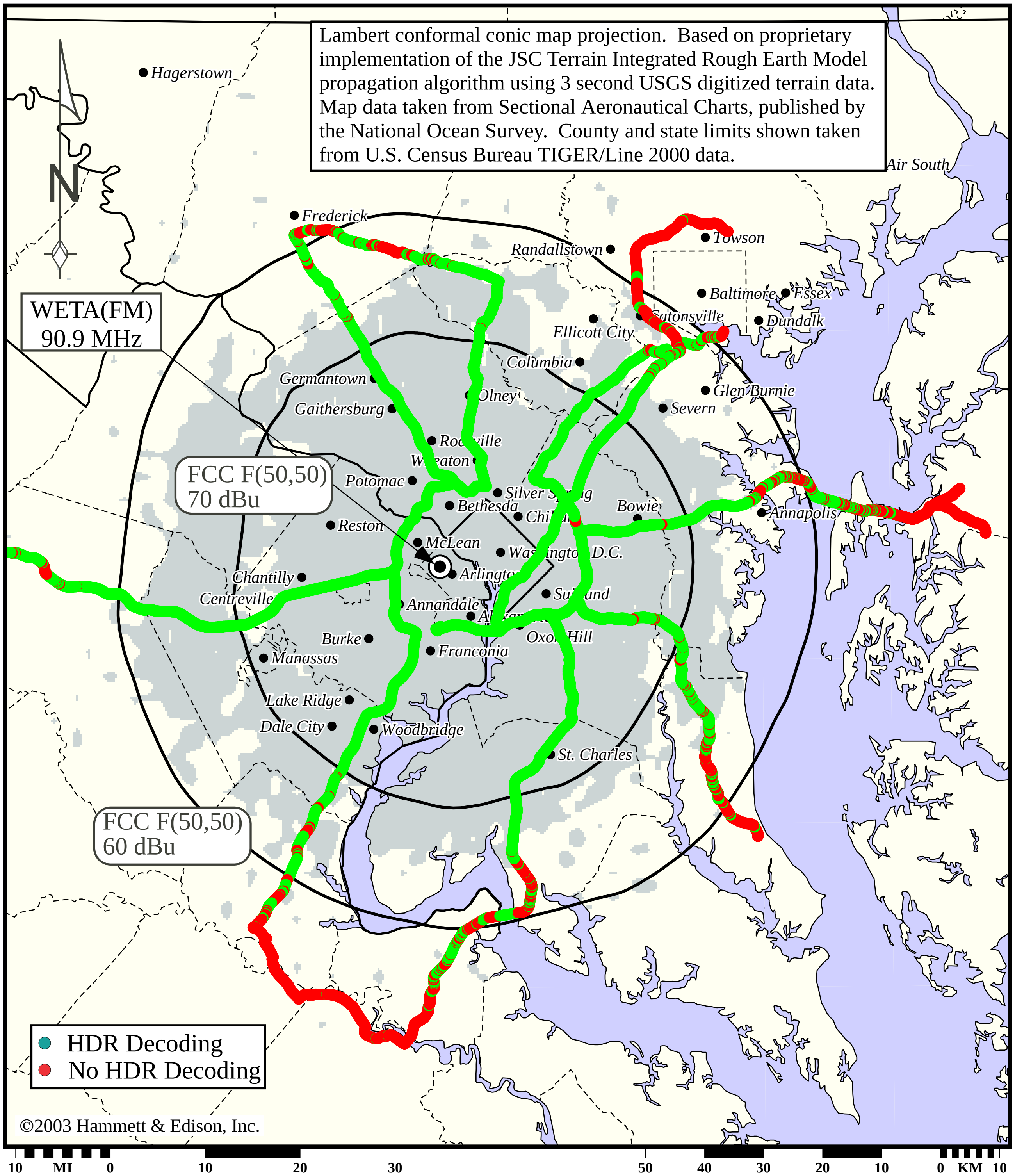
## Washington, D.C. Area Field Test Results
## Final HDC and Tomorrow Radio℠ Version




TIREM Coverage Prediction
4,656,986 persons (2000 U.S. Census)

## National Public Radio/Harris/Kenwood • Tomorrow Radio[SM] Project

## Washington, D.C. Area Field Test Results
## HD Radio-Only Reference Run, HDC




TIREM Coverage Prediction
4,496,212 persons (2000 U.S. Census)

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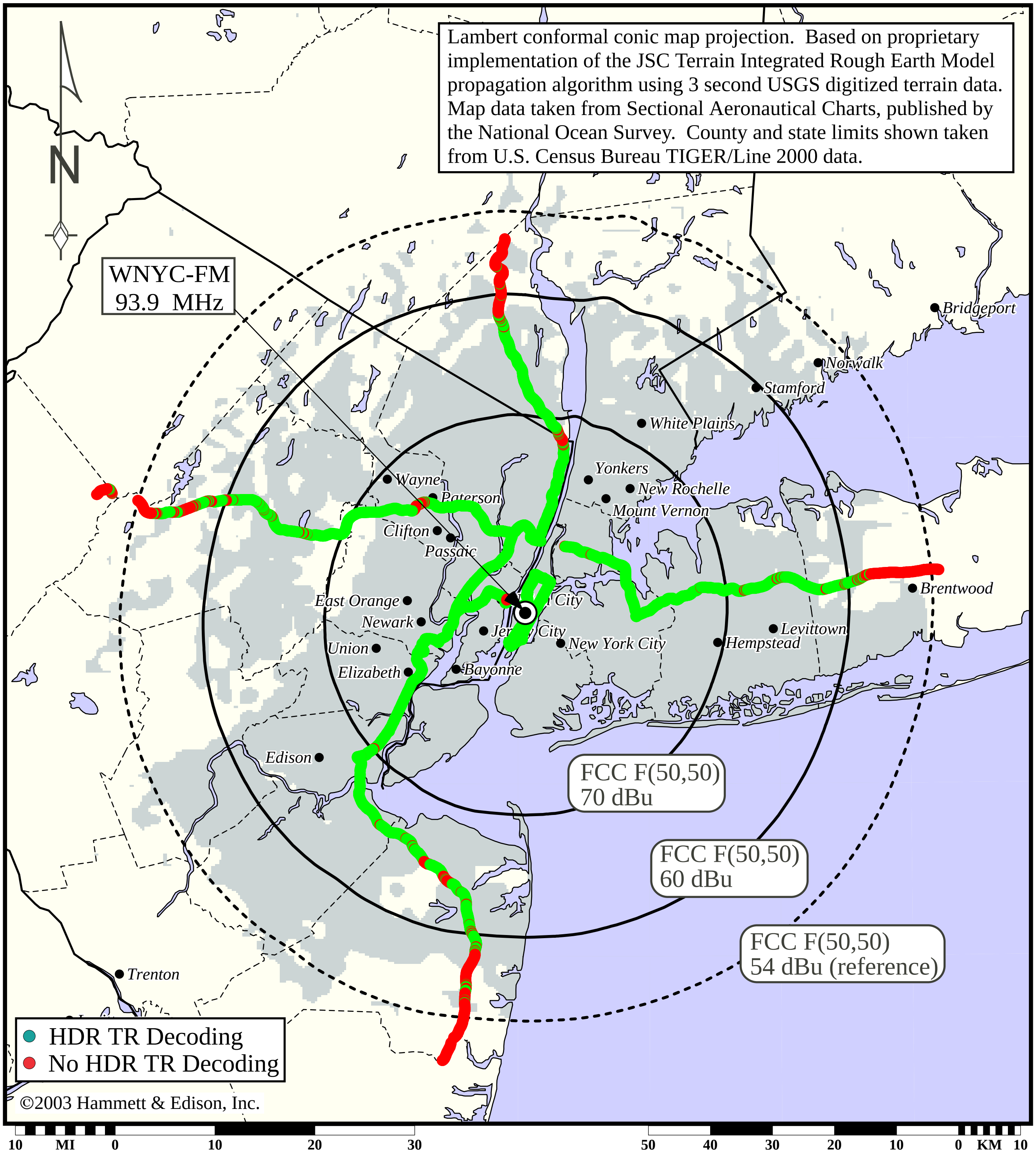
## National Public Radio/Harris/Kenwood • Tomorrow Radio[SM] Project

## New York City Metropolitan Area Field Test Results
## Final HDC and Tomorrow Radio[SM] Version




| ≥ 61.0 | < 61.0 | dBu |
|---|---|---|

TIREM Coverage Prediction
15,747,274 persons (2000 U.S. Census)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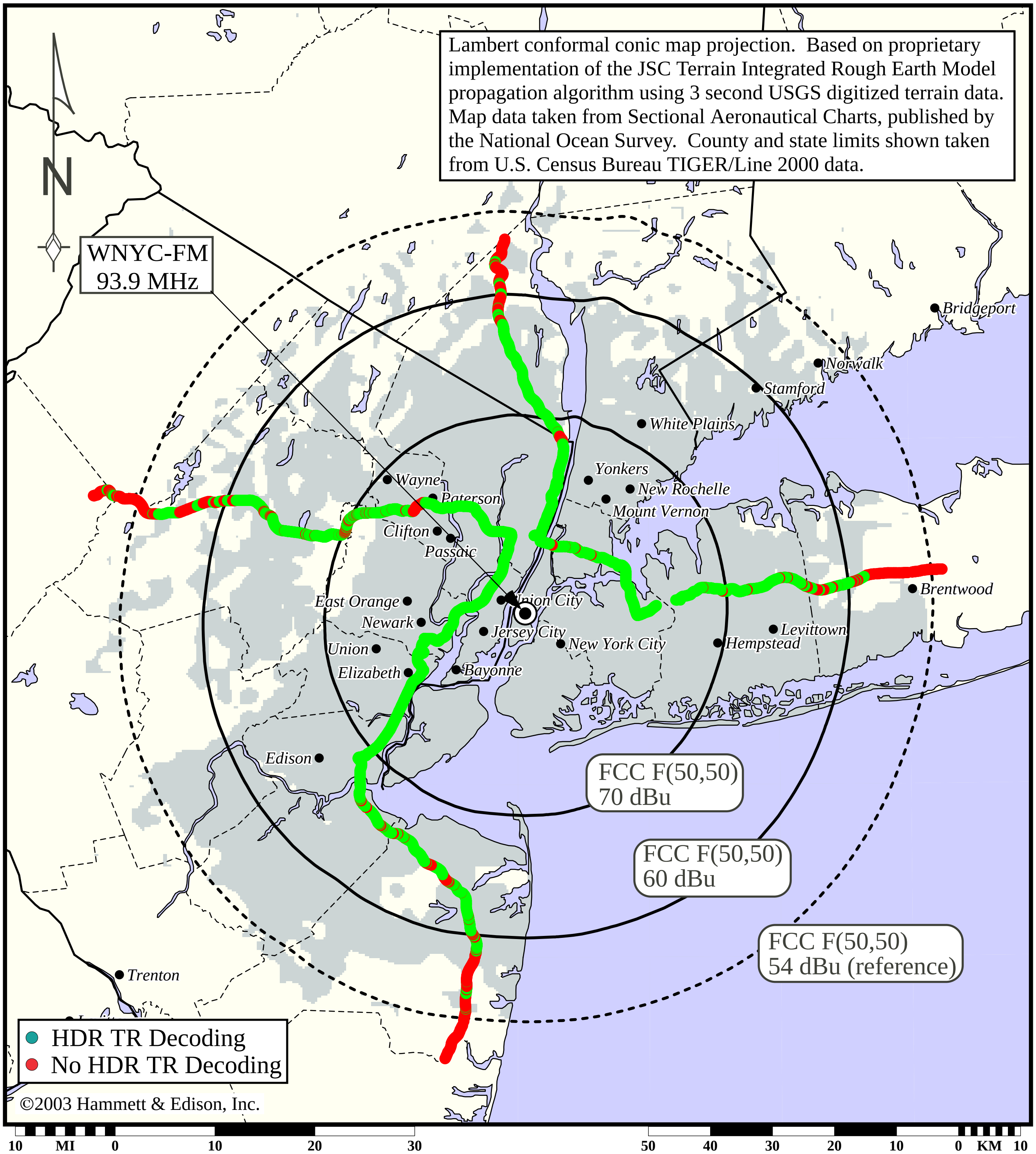
## National Public Radio/Harris/Kenwood • Tomorrow Radio[SM] Project

## New York City Metropolitan Area Field Test Results
## Final HDC and Tomorrow Radio[SM] Version




TIREM Coverage Prediction
15,747,274 persons (2000 U.S. Census)

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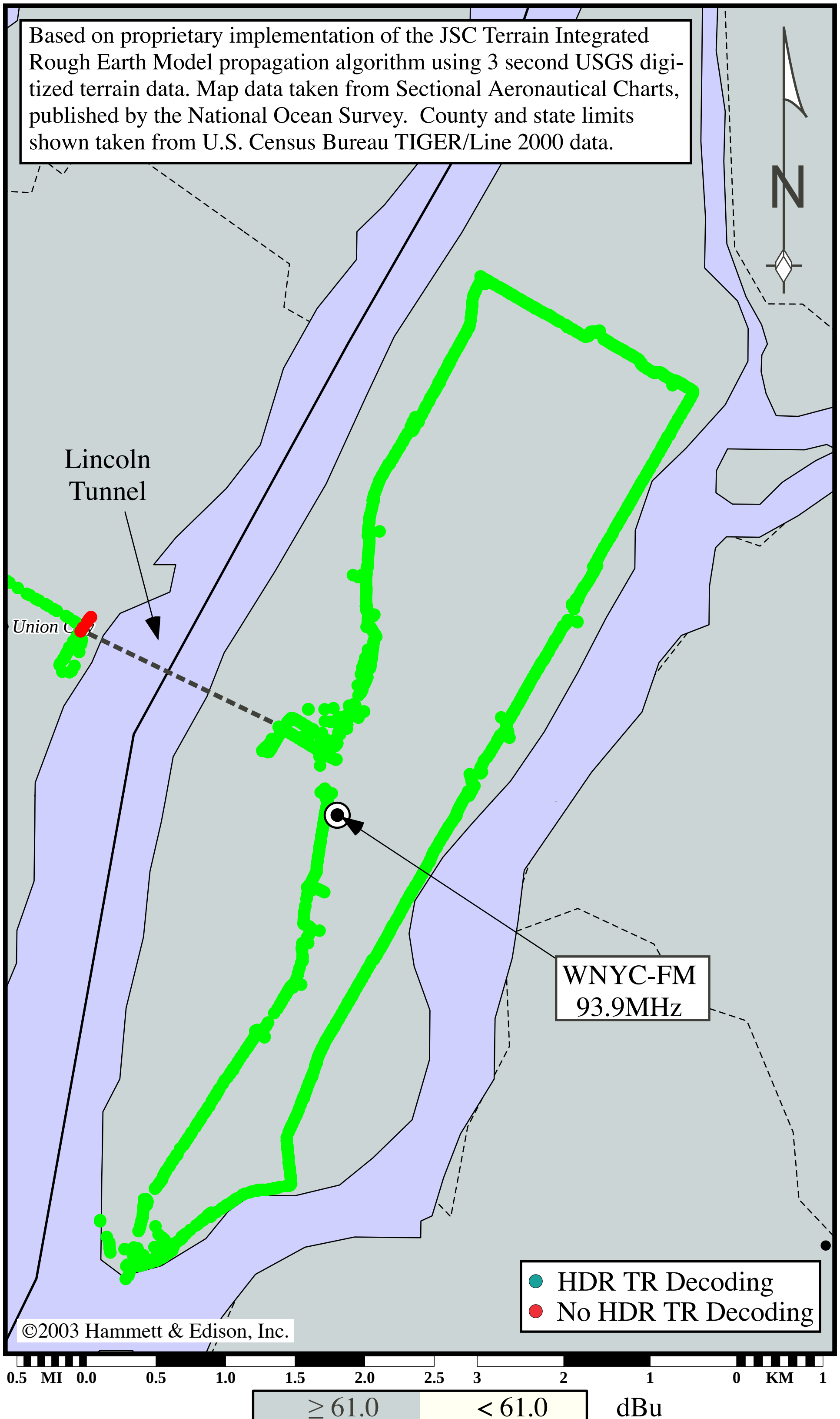
# National Public Radio/Harris/Kenwood • Tomorrow Radio℠ Project

## New York City/Manhattan Field Test Results
## Final HDC and Tomorrow Radio℠ Version




TIREM Coverage Projection

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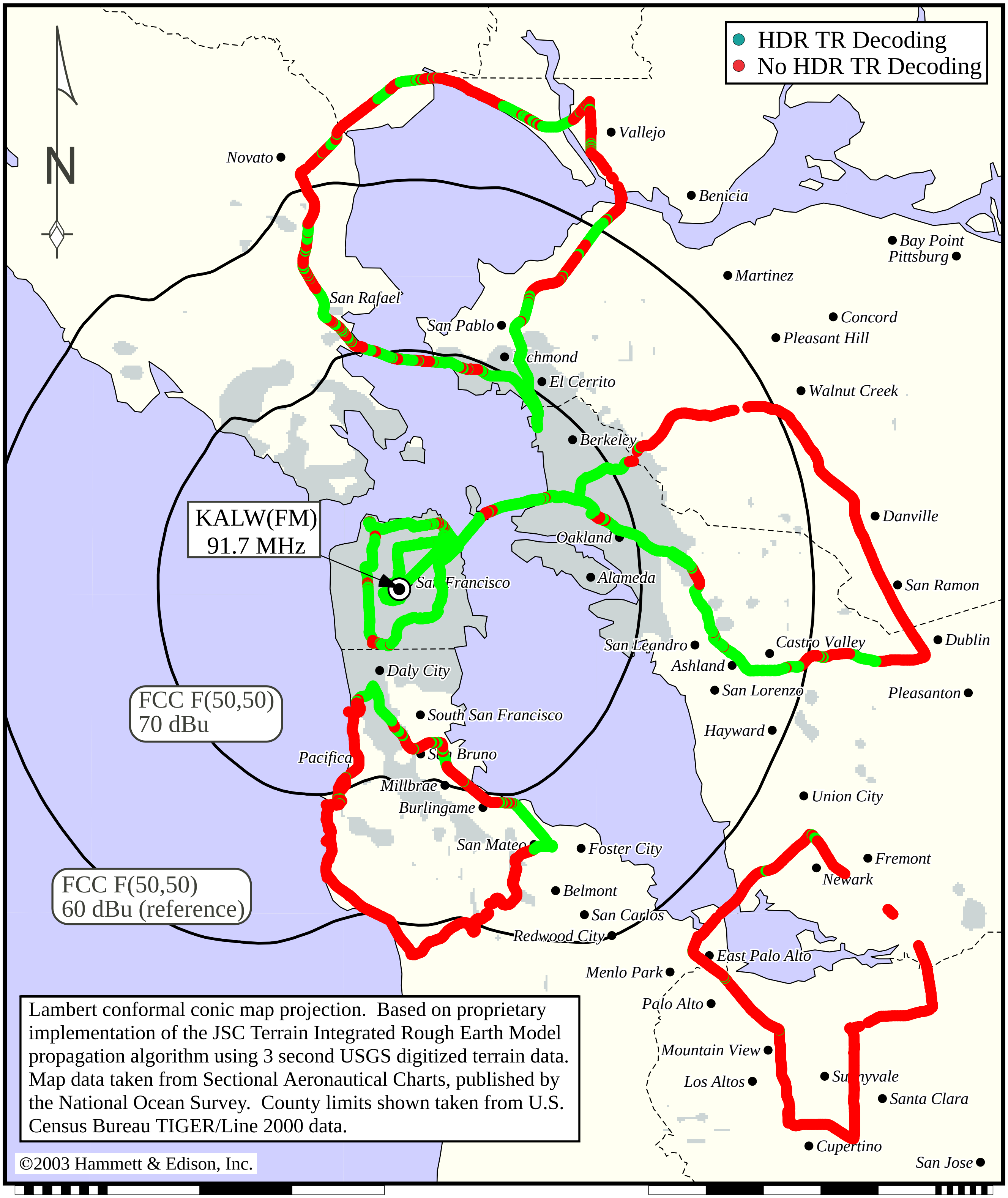
National Public Radio/Harris/Kenwood • Tomorrow Radio[SM] Project

## San Francisco Bay Area Field Test Results
## Original PAC and Tomorrow Radio[SM] Version




Lambert conformal conic map projection. Based on proprietary implementation of the JSC Terrain Integrated Rough Earth Model propagation algorithm using 3 second USGS digitized terrain data. Map data taken from Sectional Aeronautical Charts, published by the National Ocean Survey. County limits shown taken from U.S. Census Bureau TIGER/Line 2000 data.

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| ≥ 66.0 | < 66.0 | dBu |
|---|---|---|

TIREM Coverage Projection
1,603,323 persons (2000 U.S. Census)

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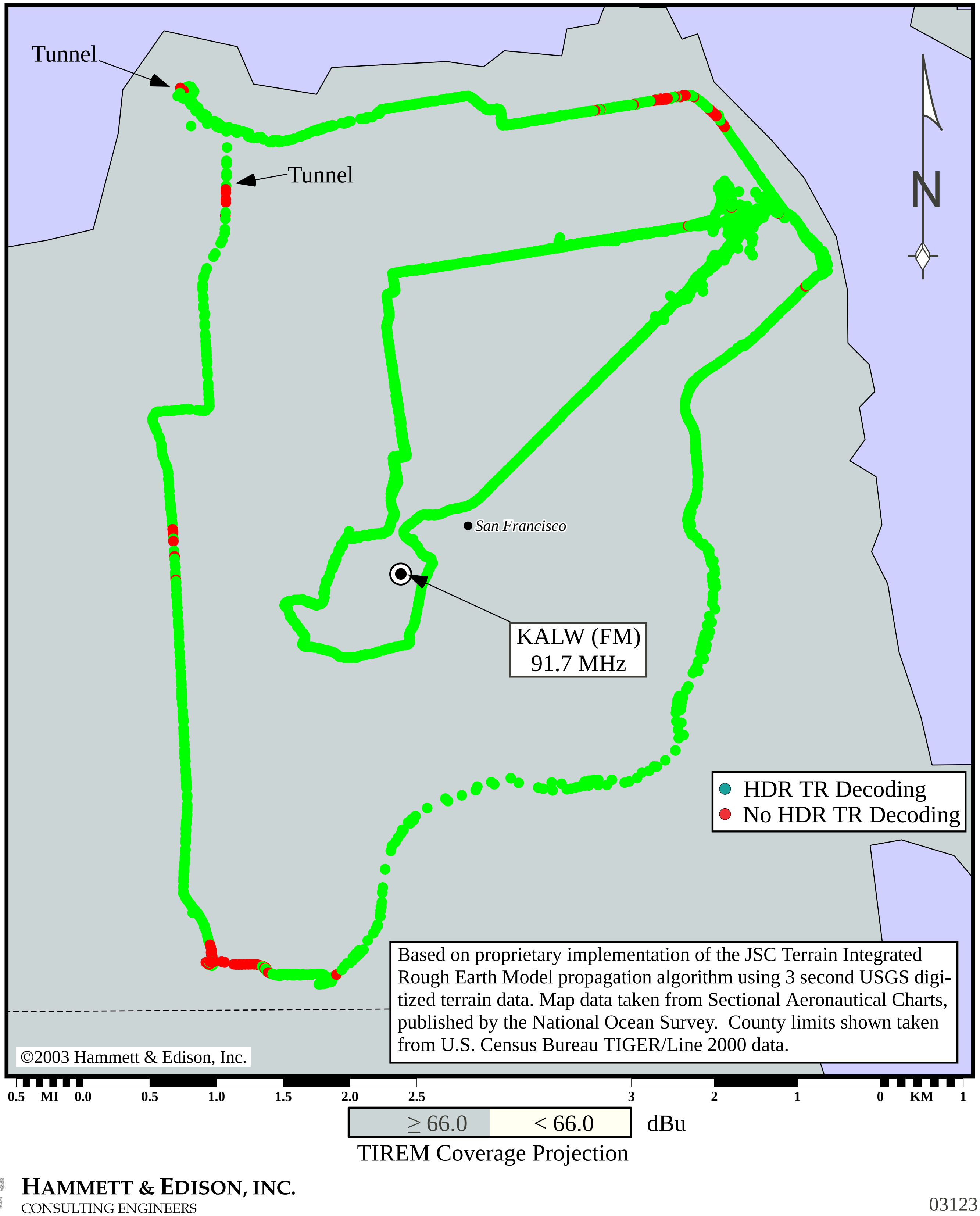
## National Public Radio/Harris/Kenwood • Tomorrow Radio^SM Project

## San Francisco Downtown Field Test Results
## Original PAC and Tomorrow Radio^SM Version





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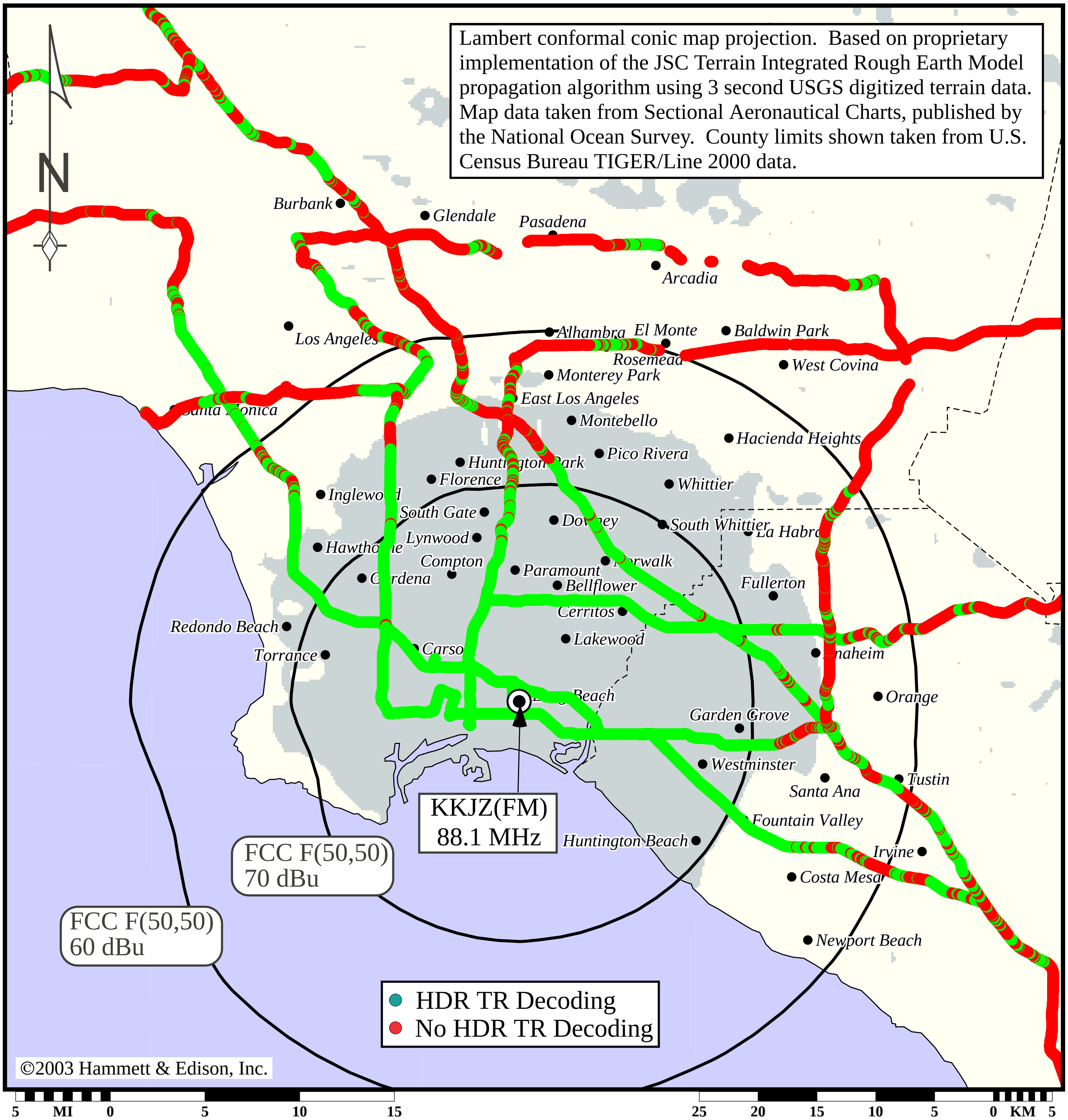
## National Public Radio/Harris/Kenwood • Tomorrow Radio℠ Project

## Los Angeles/Long Beach Area Field Test Results
## Original PAC and Tomorrow Radio℠ Version

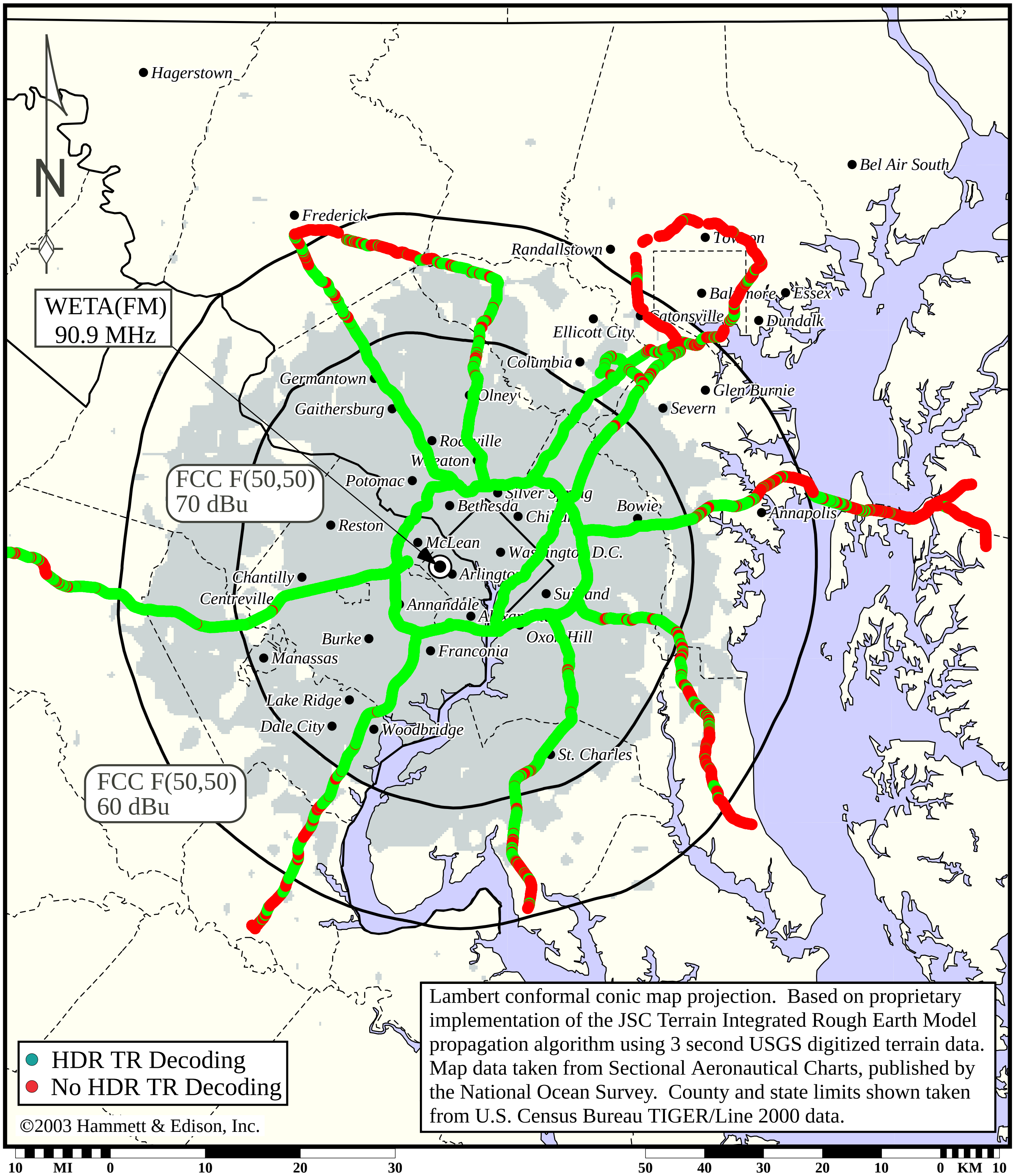



| ≥ 70.8 | < 70.8 | dBu |
|---|---|---|

TIREM Coverage Projection
4,181,551 persons (2000 U.S. Census)

## National Public Radio/Harris/Kenwood • Tomorrow Radio℠ Project

## Washington, D.C. Area Field Test Results
## Original PAC and Tomorrow Radio℠ Version

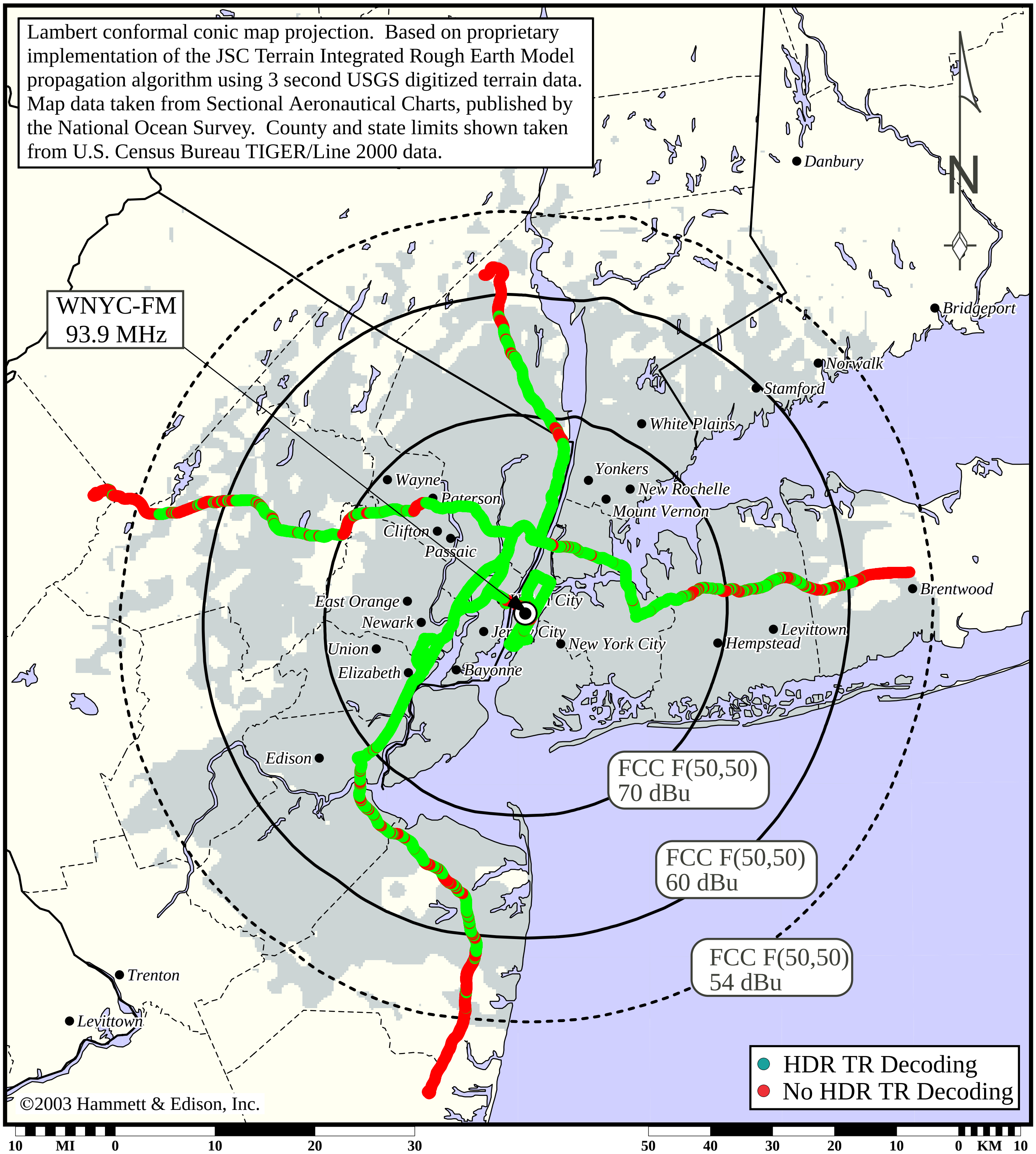



| ≥ 67.2 | < 67.2 | dBu |
|---|---|---|

TIREM Coverage Projection
4,341,266 persons (2000 U.S. Census)

## National Public Radio/Harris/Kenwood • Tomorrow Radio℠ Project

## New York City Metropolitan Area Field Test Results
## Original PAC and Tomorrow Radio℠ Version




TIREM Coverage Projection
15,931,352 persons (2000 U.S. Census)

*See discussion in report text

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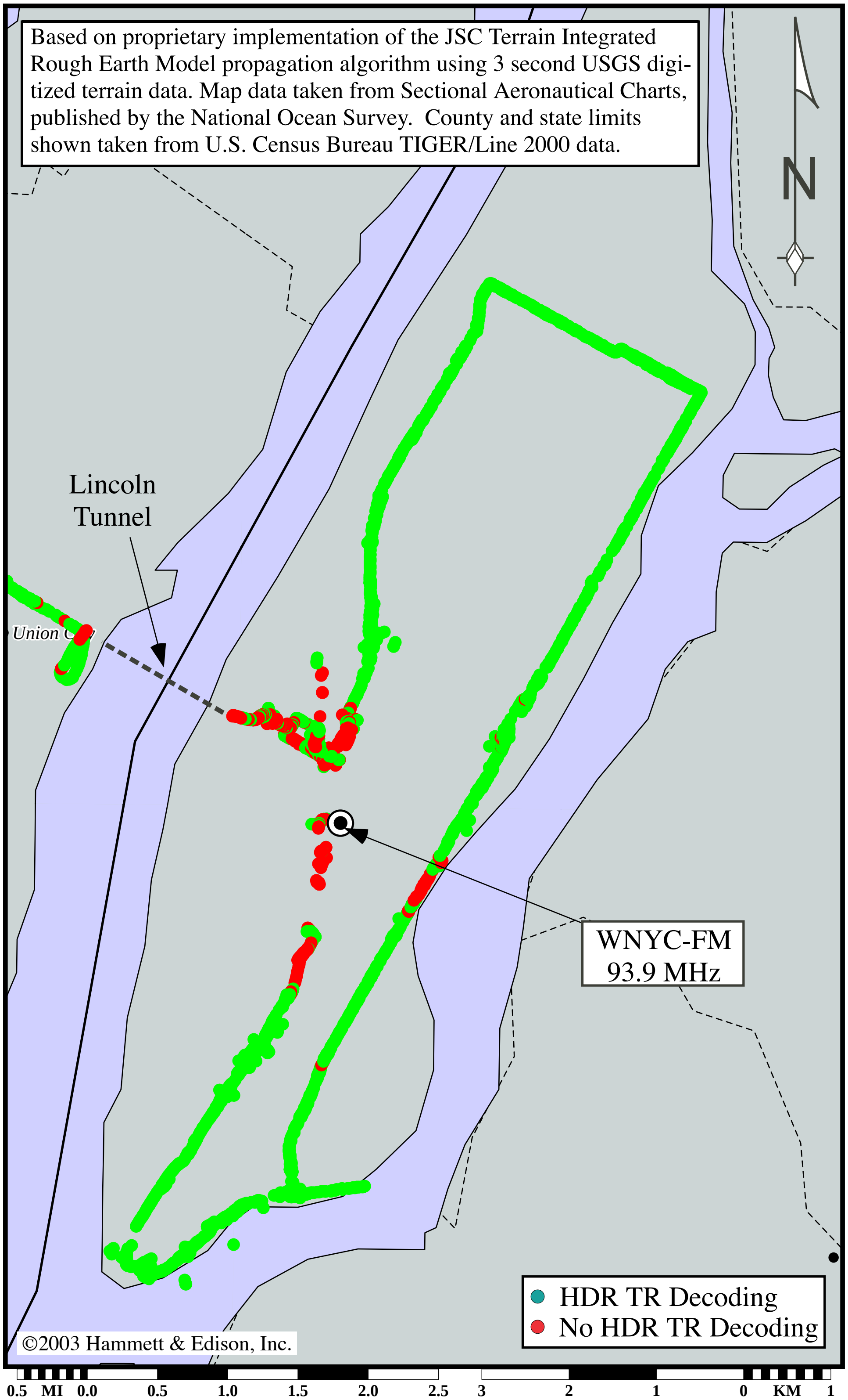
Appendix E2A

## National Public Radio/Harris/Kenwood • Tomorrow Radio$^{SM}$ Project

## New York City/Manhattan Field Test Results
## Original PAC and Tomorrow Radio$^{SM}$ Version




| ≥ 60 | < 60 | dBu |
|---|---|---|

TIREM Coverage Projection

## About TIREM Coverage Projection Maps

The coverage of FM and TV stations is greatly affected by the nature of the terrain in which the station is located. In flat or gently rolling country, coverage extends approximately the same distance in all directions and is controlled mainly by the power radiated and the height of the transmitting antenna. In such smooth terrain, the simple method of predicting coverage used by the FCC for over forty years provides useful and reasonably accurate maps of coverage. However, for stations located in rough terrain, the FCC-style maps fail to provide a meaningful measure of TV coverage.

To prepare coverage maps that realistically predict coverage under various terrain conditions, Hammett & Edison, Inc. developed a complete system to determine and show the actual effects of terrain on coverage. This system, first developed by the firm in 1989, uses the sophisticated propagation algorithm called the Terrain Integrated Rough Earth Model (TIREM), developed at the Joint Spectrum Center (JSC, formerly ECAC) in Annapolis, Maryland. TIREM uses detailed terrain profiles to compute values of basic transmission loss from point to point. The model evaluates the profile between two sites and, based on the geometry of the profile, selects automatically the most probable mode of propagation from various knife-edge models, a rough-earth diffraction model, and line-of-sight models. When combined with the United States Geological Survey (USGS) 3-second terrain database, as we have done, the TIREM model is the most accurate available means of predicting signal strength when details of terrain along the propagation path are known.

The TIREM contours shown on the attached maps should not be considered as FCC service or protected contours, because those are defined by the FCC Rules and apply only to maps prepared in accordance with the FCC's F(50,50) curves. TIREM contours instead represent the specified field intensity, which may be the same as the service or protected contours. Shading is applied to the map to make it easy to understand. Such maps are powerful engineering tools used in the initial design, evaluation, or the improvement of broadcast facilities.