MOBILE ATSC M/H VHF COVERAGE PROPAGATION MODEL

Prepared for OMVC

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Introduction

The Open Mobile Video Coalition (OMVC) commissioned a project to develop a signal propagation prediction model of the ATSC Mobile/Handheld (M/H) standard specifically for broadcast stations operating in the high-VHF band. This project was completed by Victor Tawil of the *National Association of Broadcasters (NAB*) and Charles Cooper of *du Treil, Lundin & Rackley*.

The results of this study provide the initial propagation model planning factors for the VHF M/H system validated using empirical data collected in a limited number of cities across the United States. The current version of the VHF model is only applicable to the automobile (mobile) use case with an external ¼ wave vertical whip antenna mounted on the roof of a vehicle. Field data was also collected for the handheld cases but was not sufficient to develop and validate the proposed model for the pedestrian use cases. This VHF model development is similar to that undertaken for the OMVC UHF model.[1]

The result of this project is considered the initial VHF M/H prediction model (Version 1.0). Future work will seek to improve both the confidence of the automobile use case coverage predictions and expand the model to include handheld use case coverage predictions.

[1] See A New Prediction Model for M/H Mobile DTV Service Prepared for OMVC, June 28, 2011.

Model Development

Development of a mobile prediction model at VHF requires a different coverage prediction methodology than traditionally used by broadcasters for providing service to fixed receive locations. This is because the received antenna height in a mobile service is usually located close to the ground, where the received signal is generally not line-of-sight and is ever-changing due to the non-stationary nature of the receiver. Moreover, given the larger physical receive antenna size required to efficiently receive the VHF signal for hand-held devices, the predicted model should ultimately take into account additional attenuation losses in the event the handheld device uses a shorter, less efficient receive antenna (i.e. UHF monoplole) to receive the VHF signal.

The OMVC-VHF model was derived using some of the previous investigations and experiences gained from the development of the OMVC-UHF model and a review of similar mobile services currently or soon to be deployed, at VHF outside the United States. The research review on these available systems yielded only two systems: T-DMB and DVB-H. While both employ OFDM signal encoding, they are configured for different RF channel bandwidths. The review focused on the same use-case developed herein, a VHF M/H receiver in an automobile connected to an external antenna.

The T-DMB system, used primarily in South Korea, has an RF bandwidth of 1.536 MHz with an effective rate of 1.1 Mbps using QPSK modulation.[2] This bandwidth permits two video services. The theoretical minimum field strength for this service is 44 dBu for mostly reliable service and 50 dBu for reliable service.[3] [4] As a comparison, the planning factors for outdoor and indoor pedestrian handheld service are 56 dBu and 66 dBu, respectively, for reliable reception.

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[2] It is suggested that three separate T-DMB channels could be configured in one 6 MHz broadcast channel to increase the effective data rate. See Overview of T-DMB/ATSC PowerPoint, Youngsu Kim, ETRI, May 22, 2011.

[3] See Planning Parameters for Hand Held Reception Concerning the use of DVB-H and T-DMB in Bands III, IV, V and the 1.5 GHz Band, EBU, Geneva, July, 2007.

[4] A paper on field tests for the T-DMB system suggests the minimum received power for a reliable service ranged from -94 dBm to -82 dBm. Using nominal assumptions, these values correspond to field strength from 30 dBu to 42 dBu. See Field Trials for Advanced T-DMB System, ETRI, presented at the 2011 IEEE Broadcast Symposium.

The DVB-H system, used primarily in Europe, has an RF bandwidth of 7 MHz in the VHF Band with an effective rate of 3.27 Mbps using QPSK modulation. The theoretical minimum field strength for this service is 45 dBu for mostly reliable service and 51 dBu for reliable service.[5] As a comparison, the planning factors for outdoor and indoor pedestrian service are 57 dBu and 67 dBu, respectively, for reliable reception.

While the research review yielded planning factors for both the T-DMB and DVB-H services, no paper on the development of types of propagation models to support the prediction employing these planning factors were found.

As relatively few high-VHF broadcast stations have implemented an M/H service, there is of course a limited amount of data available to analyze the performance of the M/H system and to develop a VHF M/H prediction model.[6] [7] The dataset used in this development was collected by the Open Mobile Video Coalition (OMVC) and Mobile Content Venture (MCV).[8]

These mobile data were gathered by a calibrated ¼-wave vertical whip antenna mounted atop the test vehicle connected to a spectrum analyzer and a LG M/H receiver. Using a GPS receiver, during every measurement second, the field strength, receiver status and geographic location were logged. These data were post-processed to analyze the data over line segments. From the line-segments, the median field strength and receiver availability statistics over regularly spaced measurements were calculated.[9]

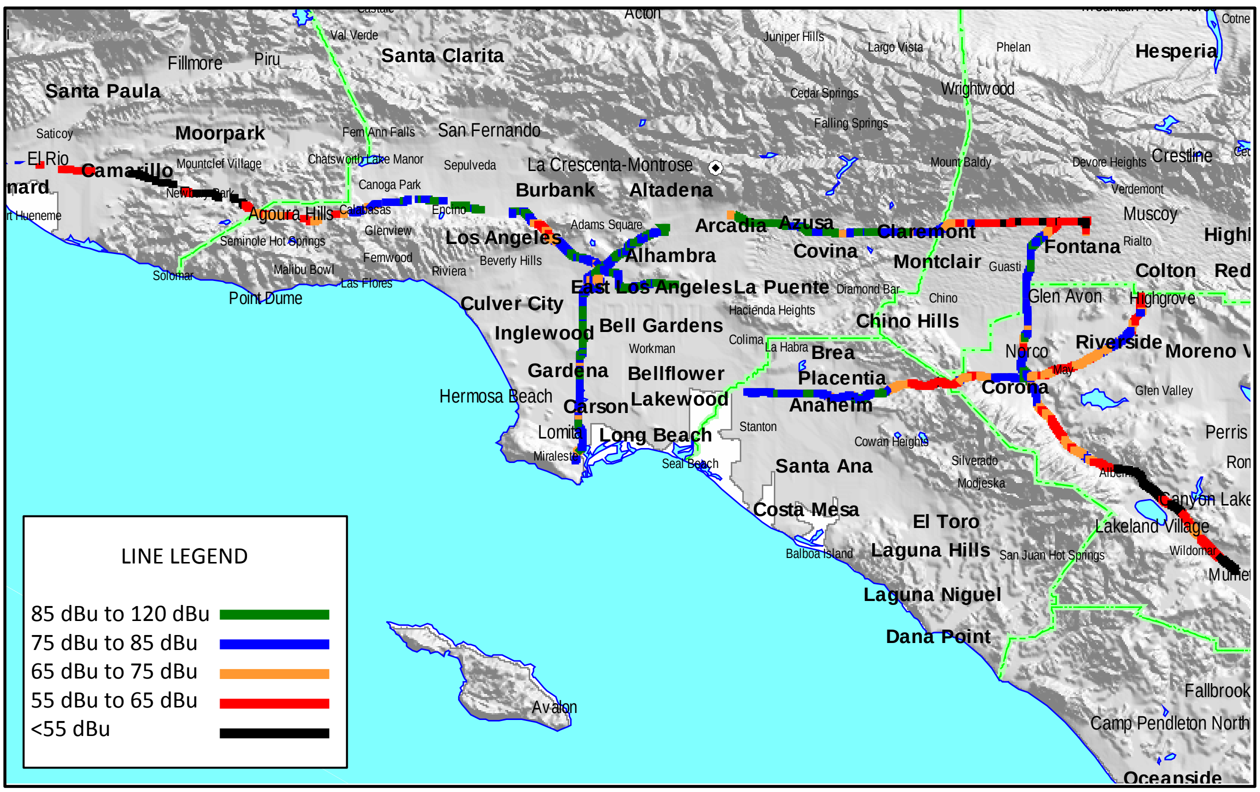
[5] Ibid at 4.
[6] There are 7 available television channels in the high-VHF band compared to 37 available channels in the UHF band.
[7] VHF field data was collected in Washington DC, Dallas and Los Angeles. Only the Dallas and Los Angeles data were used to validate the model. The Washington data was excluded as it contained few samples and employed a different data collection methodology.
[8] The consulting engineering firm of Meintel, Sgrignoli, & Wallace (MSW) was retained by OMVC and MVC to acquire these data in 2010 and 2011. MVC consented to share their Los Angeles data (KCOP on Channel 13) with the OMVC as part of this project.
[9] The primary purpose of these line segments is to remove the short-term fading (multipath) effects by making the points regular spaced and to avoid the clustering effect when the measurement vehicle has a non-uniform velocity, or is stopped.

Below are the FCC licensed transmission parameters for KCOP:

Facility:	KCOP
Transmitter Site Geographic Coordinates:	34-13-29 North Latitude 118-03-48 West Longitude *Mount Wilson*
Polarization:	Elliptical 25% Vertical Polarization
Radiation Center:	905 m HAAT
Effective Radiated Power:	120 kW (Horizontal Polarization)
Transmitting Antenna Type:	Non-Directional Pattern (1.5° Electrical, 1.5° Mechanical at 210°)

Table 1. KCOP Transmission Parameters.

Below is a map showing the measured field strengths for KCOP that were considered in this analysis.



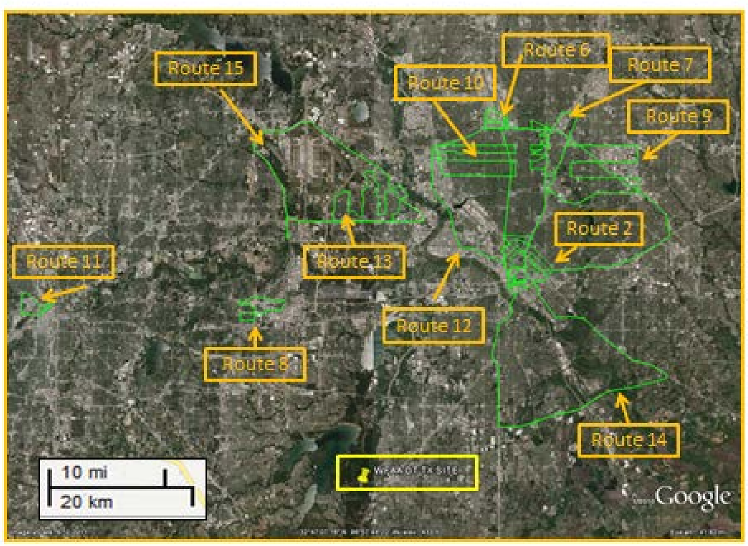
Map 1. KCOP Field Strength Measurement Locations and Measured Field Strengths.

The OMVC measurement program in the Dallas area focused exclusively on the impact of different transmit antenna configurations at VHF for the mobile hand-held use cases.[10] This measurement program compared two High-VHF transmit antenna configurations, a traditional horizontal-only and a circular polarized. Tabulated below were the test transmission parameters for WFAA.

Facility:	WFAA
Transmitter Site Geographic Coordinates:	32-35-06 North Latitude 96-58-41 West Longitude *Cedar Hill*
Polarization:	(1) Horizontal (2) Circular
Radiation Center:	(1) 525 m HAAT (2) 495 m HAAT
Effective Radiated Power:	(1) 49 kW (2) 55 kW (each polarization)

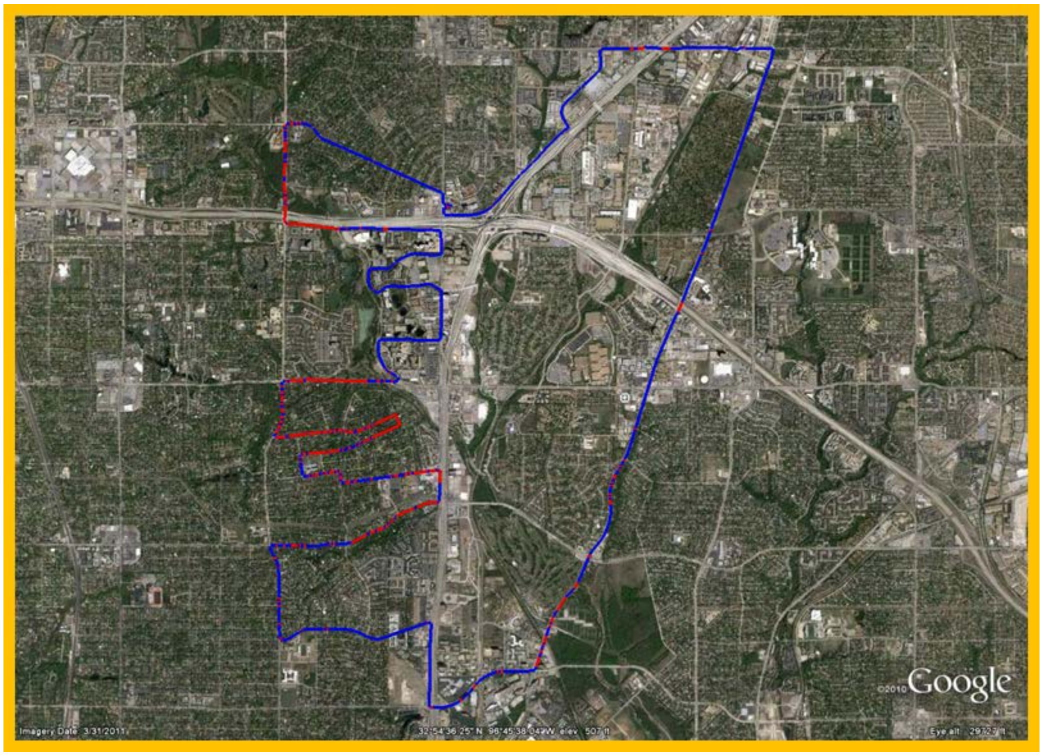
Table 2. WFAA Transmission Parameters.

A total of 26 mobile runs (split between each antenna configuration) were completed. Map 2 shows the locations of the mobile measurement routes, and Maps 3 and 4 show an example of the reception statistics for a sample run (Route 7) for both the horizontally and a circularly polarized transmitted signals. The signals were received using a ¼ wave vertical whip antenna mounted on roof of the vehicle.

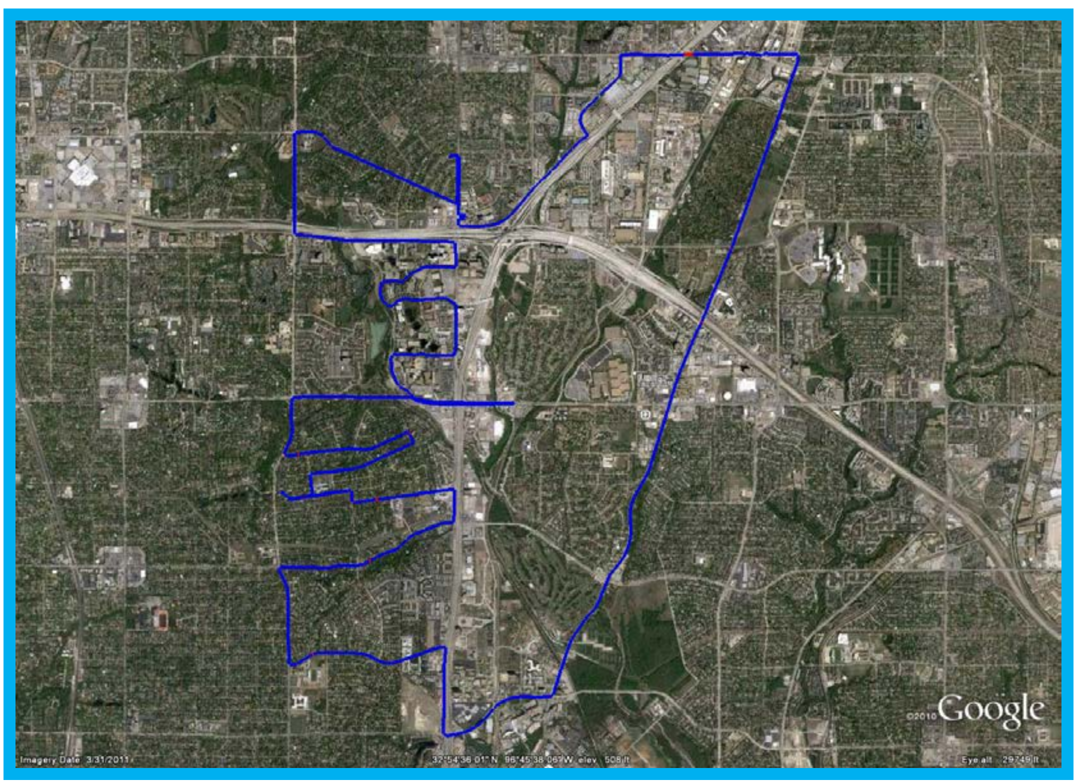


Map 2. Location of WFAA Channel 8 mobile measurement runs.

[10] See Power Point Presentation: OMVC Dallas Measurements - Preliminary Analysis, October 13, 2011, Draft 1.1. The average field strength improvement statistics were derived from data collected in the same manner as the Los Angeles field trials. A total of approximately 65,000 field strength measurements from 15 different mobile routes in the Dallas-Fort Worth areas were used to derive the average field strength improvement statistics.



Map 3. Locations where a horizontal-only polarized transmitted signal was successfully (blue) and unsuccessfully received (red).



Map 4. Locations where a circular polarized transmitted signal was successfully (blue) and unsuccessfully received (red).

For the M/H model development, the fundamental propagation model had to be first selected for the prediction model. The two considered models, Longley-Rice and Terrain Integrated Rough-Earth Model (TIREM), were investigated.[11] [12] These are both point-to-point deterministic type of models, which considers the terrain along the entire propagation path.[13]

The selected model is the TIREM based upon comparisons of the measured and predicted field strengths. The analysis revealed that the Longely-Rice model predicted field strengths for the KCOP dataset that had a larger standard deviation than the measured field strengths for TIREM. Also, the Longely-Rice model does not significantly adjust the received field strengths for receive heights from 9 meters (30 feet) to 1 meter (3 feet) when operating in the free-space propagation mode. Therefore, the TIREM appears to offer slightly better predictions of field strength compared to Longley-Rice in this situation. Furthermore, TIREM is also the same model selected by the OMVC in the earlier project developing similar predictions for the M/H service for UHF stations.[14]

The effect of localized clutter located around the receiver was also determined from the KCOP dataset. These empirically derived clutter values were determined by analyzing the areas where the TIREM predicted values were either equal to the free-space predictions or differed by a specific range. The KCOP dataset provided five areas of clutter classification, Open Land, Agricultural, Residential, Mixed Urban/Buildings and Commercial/Industrial.[15] The results of this analysis are provided in Appendix A.

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[11] Rice, P.L., Longley, A.G., North, K.A., and Barsis, A.P., Transmission Loss Predictions for Tropospheric Communication Circuits, Volumes 1 and 2, NBS Technical Note 101, CRPL, NBS, Boulder, CO, May 1965, Revised January 1967.

[12] Sciandra, R.M., Tirem/SEM Programmer's Reference Manual, ECAC-CR-90-039, Dod ECAC, Annapolis, MD, July 1990.

[13] The TIREM and Longley-Rice propagation models compute the median basic transmission loss in two steps. First the terrain profile is examined, and an initial mode of propagation is selected based upon path geometry. The model then branches to the appropriate subroutine that computes the signal propagation loss.

[14] Ibid at 2.

[15] The clutter factors for the remainder of the land use classifications were obtained from Thomas N. Rubinstein, "Clutter Losses and Environmental Noise Characteristics Associated with Various LULC Categories," IEEE Transactions on Broadcasting, Vol. 44, No. 3, September 1998.

The effect of the predicted received field strengths resulting from the elliptical transmit polarization of KCOP was also analyzed. KCOP operates with 25 percent elliptical polarization (30 kilowatts). It has been reported from the OMVC VHF tests completed in the Dallas area, that a circular-polarized VHF transmit antenna system would have an average received field strength improvement of 9.2 dB compared to a similar powered horizontally-polarized transmit antenna system for the automobile use case employing a vertically polarized whip antenna.[16] However, any improvement effects with the use of elliptical transmit polarization could not be derived from this KCOP dataset. As shown in Appendix B, the average clutter values at free-space environment locations closer to the subject transmitter site are similar to the values further removed from the transmitter site (where the received field is likely to be more de-polarized). Therefore, the effects of elliptical polarization are inconclusive.

The threshold field strength values for this use case were also obtained from the MCV KCOP field tests, using an LG receiver. These threshold values were validated when applying the Dallas data for the horizontal transmission case.

Based on the aforementioned analysis, below are the initial VHF M/H prediction modeling parameters for the automobile (mobile) use case with an external antenna.

Propagation Model:	Terrain Integrated Rough-Earth Model (TIREM) Version 3.19
Terrain Database:	1 second
Terrain Increment:	0.2 km
Long-Term Power Fading (time-variability):	50%
Assumed Receiver Height:	1 m above ground level
Desired Mobile Field Strength Thresholds:	Reliable Reception: > 65 dBu Mostly Reliable Reception: 55 dBu to 65 dBu
LULC Clutter Category[17]	Clutter Attenuation (dB)
Open Land:	6
Agricultural:	6
Rangeland:	9
Ocean:	0
Forest Land:	8

[16] Ibid at 10.
[17] The clutter loss is determined by reference to the Land Use and Land Cover (LULC) database of the USGS. This database is entered with the geographic coordinates of the reception point to find the point's LULC classification and, subsequently, to determine a clutter loss value. The clutter loss is then subtracted from the signal strength predicted by propagation model. The clutter classifications specified herein have a basis from the Commission's First Report and Order in ET Docket 00-11, *Establishment of an Improved Model for Predicting the Broadcast Television Field Strength Received at Individual Locations*, May 22, 2000.

Wetland:	0
Residential:	14
Mixed Urban/Buildings:	21
Commercial/Industrial:	21
Snow & Ice:	0
Fresh Water:	0

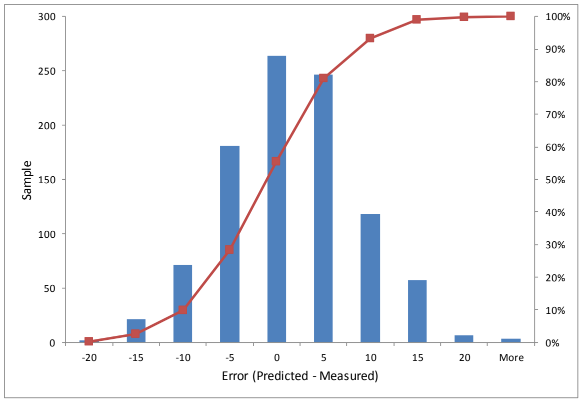
Table 3. Initial M/H Prediction Modeling Parameters, Automobile (Mobile) Use Case.

Model Results

Using the initial developed model, the predicted coverage for KCOP was calculated. The colored areas reflect ranges of field strengths; the green color indicates field strengths greater than 65 dBu and the tan color indicates field strengths between 65 dBu to 55 dBu. The line segments show the receiver availability obtained from the KCOP dataset, green is where the receiver had successful reception of 75 percent or more of the segment distance; yellow between 50 percent and 75 percent and red less than 50 percent of the segment distance.

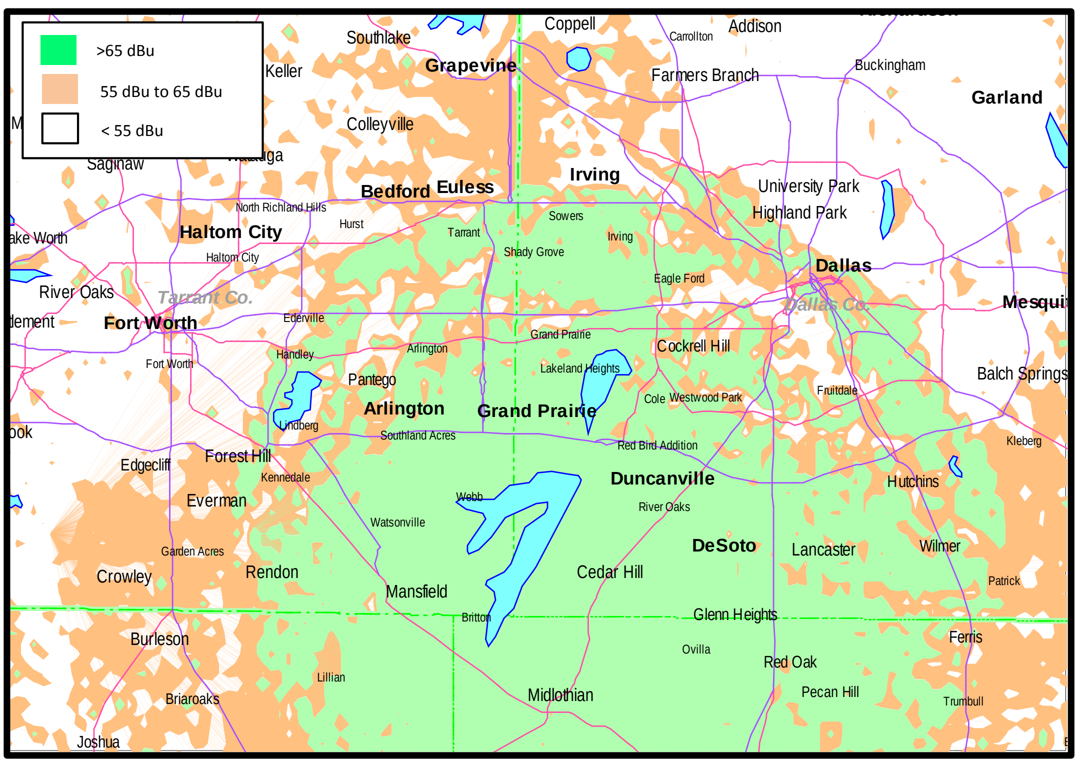
Map 5 KCOP Predicted & Receiver Availability Measured Field Strengths.

When comparing the predicted and measured field strengths, the measured field strengths have a mean error of 1 dB (measured field strengths greater than the predicted) with a standard deviation of 7.1 dB. This is for all predicted field strengths above the use-case device field strength threshold of 55 dBu. Below as Graph 1 is a histogram of the comparison between the predicted and field strength data.

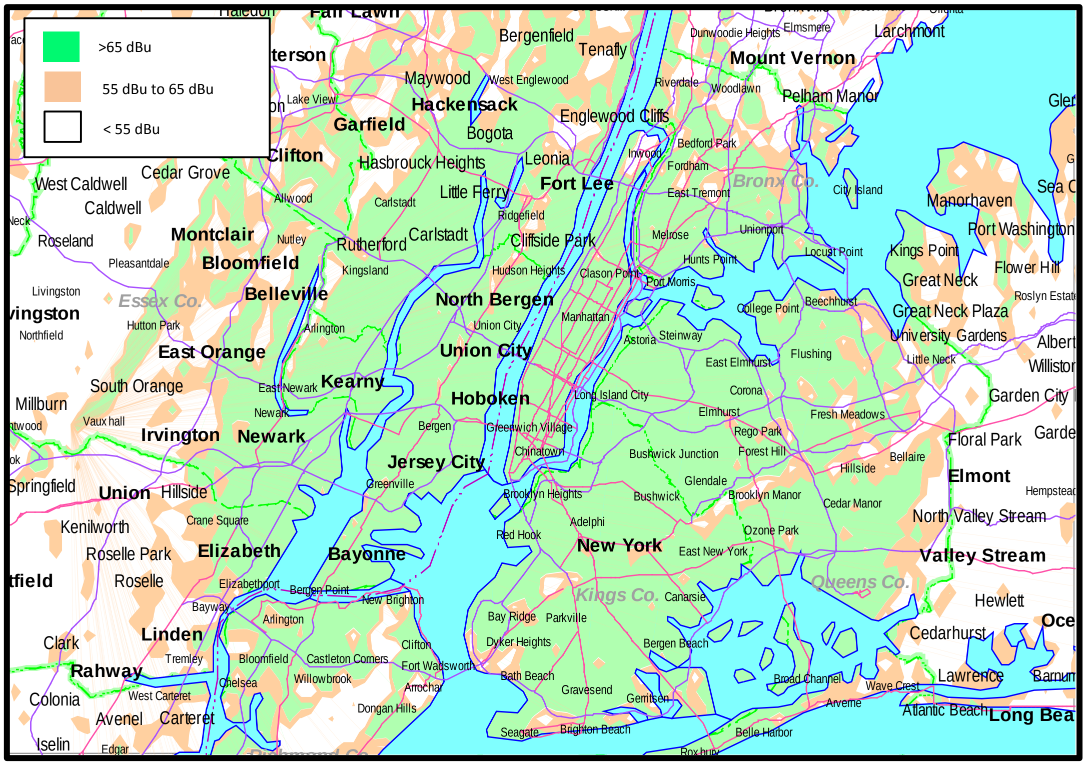


Graph 1 <u>Histogram of KCOP Predicted & Measured Field Strengths.</u>

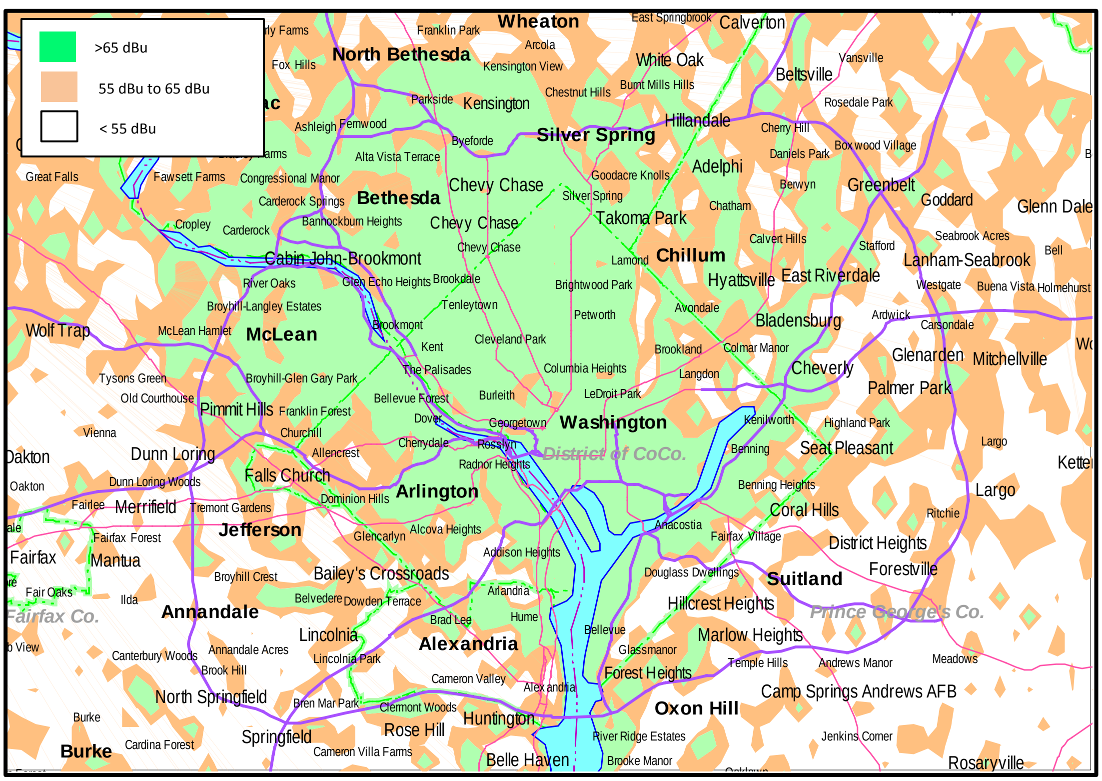
An example of other markets if VHF M/H service is implemented is provided below for selected stations.



Map 6 <u>WFAA Dallas Predicted Field Strengths.</u>



Map 7 WABC New York Predicted Field Strengths.



Map 8 WUSA Washington, D.C. Predicted Field Strengths.

Conclusion

This report detailed the initial propagation model planning factors for the ATSC M/H device in a mobile (automobile) High-VHF use case. The modeling parameters suggest the use of the TIREM propagation model at an assumed receiver height of 1 meter above ground level with appropriate application on the Land Use Land Clutter (LULC) attenuation values. The mobile use case has minimum reception thresholds of 55 dBu for mostly reliable reception and 65 dBu for reliable reception when an external ¼ wave vertical whip antenna mounted on the roof of a vehicle is employed. When comparing the model to measurements, the suggested model had a mean error of 1 dB with a standard deviation of 7.1 dB. While the effects of employing elliptical transmit polarization are inconclusive, the circular polarization improvement factor when using a vertical whip receive antenna is on the order of 9.2 dB compared to an equal power horizontally-only transmission.

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APPENDIX B

ELLIPTICAL POLARIZATION ANALYSIS FROM KCOP DATASET

APPENDIX A

CLUTTER ANALYSIS FROM KCOP DATASET