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NRSC-R102
Measurement of AM Band RF Noise Levels and Station Signal Attenuation
January, 2025

NAB
NATIONAL ASSOCIATION OF BROADCASTERS

1 M Street SE
Washington, DC 20003
Tel: 202-429-5346
www.nab.org

CTA
Consumer Technology Association, producer of CES®

1919 South Eads Street
Arlington, VA 22202
Tel: 703-907-4366
www.cta.tech

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FOREWORD

This report covers measurements of RF noise levels on various roadway types from open interstate highways to city streets, to determine how the noise would affect AM broadcast reception. These environments reflect the current habits of AM radio listening, which is primarily in vehicles. In addition to RF noise level, RF signal levels were measured for three AM stations operating on frequencies in the low, middle and high ends of the AM broadcast band. These measurements provide a better understanding of how AM radio reception is affected by RF signal strength and noise in a range of roadway environments from rural to dense urban environments.

The AFAB chairperson at the time of adoption and first revision of NRSC-R102 was Martin Stabbert, Townsquare Media. The NRSC AIWG was chaired by Brian Henry, Henry Communications. AIWG members J. Kean and T. King performed the measurements described herein. Dave Hershberger provided data processing and input on the test design and J. Kean is the principal author of this report.

The NRSC is jointly sponsored by the Consumer Technology Association and the National Association of Broadcasters. It serves as an industry-wide standards-setting body for technical aspects of terrestrial over-the-air radio broadcasting systems in the United States.

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MEASUREMENT OF AM BAND RF NOISE LEVELS AND STATION SIGNAL ATTENUATION

1 INTRODUCTION AND BACKGROUND

AM radio broadcasters are increasingly concerned about environmental radio frequency (RF) noise, which is deteriorating reception quality and contributing to decreased listenership. To better characterize this issue, the AM Improvement Working Group (AIWG) of the NRSC's AM and FM Analog Broadcasting Subcommittee (AFAB) supported this study to help understand current signal quality degradation and identify potential areas for improvement for AM service.

This study focuses on RF noise levels on roadways, since in-vehicle listening is how most listeners receive AM radio. RF noise levels were measured on various roadway types ranging from open interstate highways to city streets.

Reception quality is a combination of desired signal strength and in-channel noise. In addition to RF noise, the study included calibrated measurements of signal strength from three AM stations operating at different points within the AM broadcast band. This comprehensive data provides insight into how AM radio reception is affected by signal strength and noise in diverse roadway environments, from rural to urban areas.

2 REFERENCES

2.1 Normative References

This is an informative report. There are no normative references.

2.2 Informative References

The following references contain information that may be useful to those interested in AM radio measurements.

[1] Propagation Measurements and Analysis of MF and HF Bands in Urban Areas in the Netherlands, K. Fockens, et.al., IEEE Transactions On Electromagnetic Compatibility, June 2022.

[2] AM Technical Assignment Criteria: An Examination of Issues Raised in MM Docket No. 87-267, H. Klein, National Radio Systems Committee NRSC-R13, June 1988.

2.3 Informative Reference Acquisition

Documents are distributed free of charge via the NRSC website at: https://www.nrscstandards.org/.

2.4 Symbols and Abbreviations

In this Report the following abbreviations are used.

AFAB	AM and FM Analog Broadcasting Subcommittee
AM	Amplitude Modulation
AIWG	AM Improvement Working Group (of the NRSC AFAB Subcommittee)
D/U	Desired-to-Undesired Signal Ratio
dBr	Decibels relative
FCC	Federal Communications Commission (U.S.)

IBOC	In-Band/On-Channel
NRSC	National Radio Systems Committee
RF	Radio Frequency
SDR	Software-defined receiver

2.5 Definitions

In this Report the following definitions are used:

Audio bandwidth: The maximum bandwidth of the audio signal input to an AM transmission system, indicated as a positive number such as 10 kHz. The term is employed in a general sense, unless a specific low-pass filter curve is specified.

Signal bandwidth: The maximum bandwidth of the AM radio frequency signal, which is twice the audio bandwidth and may be represented as a positive number, such as 20 kHz, representing the amount of spectrum occupied by the upper and lower sidebands of the AM signal, or as a dual-signed number, such as ±10 kHz, representing the maximum offset of the sidebands from the RF carrier frequency.

3 TEST PROCEDURE

3.1 Measurement System

The measurement hardware was specifically designed for use in a moving vehicle. Unlike traditional AM field strength meters used in stationary environments, this system must receive signals from all directions while in motion. To support vehicular operation, a vertical monopole antenna was mounted on the vehicle's roof instead of a directional loop antenna. This monopole, like antennas used on vehicles, effectively captures the electric field (E-field) of AM signals. The measurement vehicle with antenna is shown in Figure 1.

The base of the monopole antenna contains an impedance converter to provide a 50-ohm output for the instrumentation that follows. Field strength voltages from the antenna were compared to readings from a Potomac Instruments FIM-41 field strength meter. Comparisons were made at a cemetery in Arlington, Virginia at low, medium and high AM station frequencies. The cemetery provides an open area that is free of buildings, light poles, and power lines, which may introduce errors into the station fields. These measurements produced calibration factors across the AM band so that the mobile measurements would correspond to fixed field strength readings taken with the FIM-41.

A simplified diagram of the measurement system is shown in Figure 2. Signals from the monopole antenna are fed into the system. An active impedance converter at the antenna base ensures compatibility with the 50-ohm measurement equipment. To eliminate electrical noise from the vehicle’s power 12-volt power line, instruments are powered through a noise filter.

A software defined receiver (SDR, model RSPdx, used in combination with SDRuno software, see Appendix 1) was used to collect noise measurements on locally unused AM channels as well as field strengths from three regional AM stations. This SDR is suited to these measurements because of high sensitivity and automatic filter preselection ahead of the analog-to-digital converter. Tests of the measurement system found its equivalent noise level to be low (without station interference, approximately 0.03 mV/m at 555 kHz and 0.02 mV/m at 1625 kHz).

Figure 1. Measurement vehicle and antenna being calibrated with Potomac Instruments FIM-41 field strength meter.

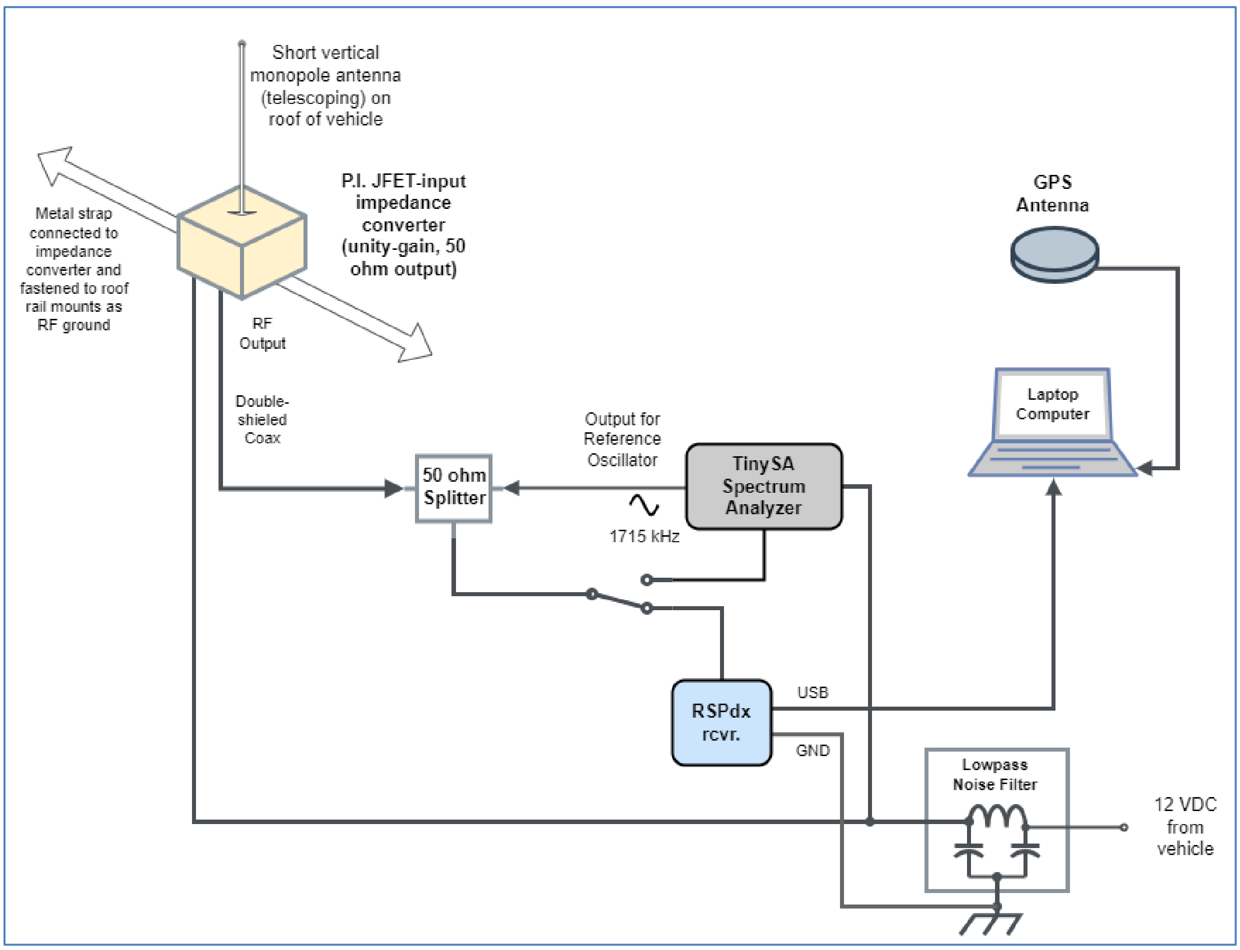

Figure 2. Measurement system diagram.

A combination spectrum analyzer/signal generator (model TinySA, see Appendix 1) was used to produce a fixed reference carrier at 1715 kHz to correct automatic gain control shifts in the RSPdx. A switch allowed the TinySA to be converted from a signal generator to spectrum analysis when needed to study signals from the roof antenna. A laptop computer running Windows 10 was connected to the RSPdx and a GPS antenna to store AM band measurements and location data.

The RSPdx and SDRuno files allowed later playback as audio for quality assessment. Nearly three- and one-half hours of audio and data were collected for each of the three AM stations and three low-noise channels over the entire route.

3.2 Test Route Selection

Measurements were collected on March 23, 2023, between noon and 5 PM EST. The weather was cool and dry, and no lightning was detected in the region. The route covered 50 miles of roadway as shown in Figure 3, beginning with Germantown, Maryland to the west and ending south of downtown Baltimore, Maryland. Short stops were made between route segments to store data files and restart the instrumentation. The route passed through areas that are categorized, according to building clutter density in Table 1.

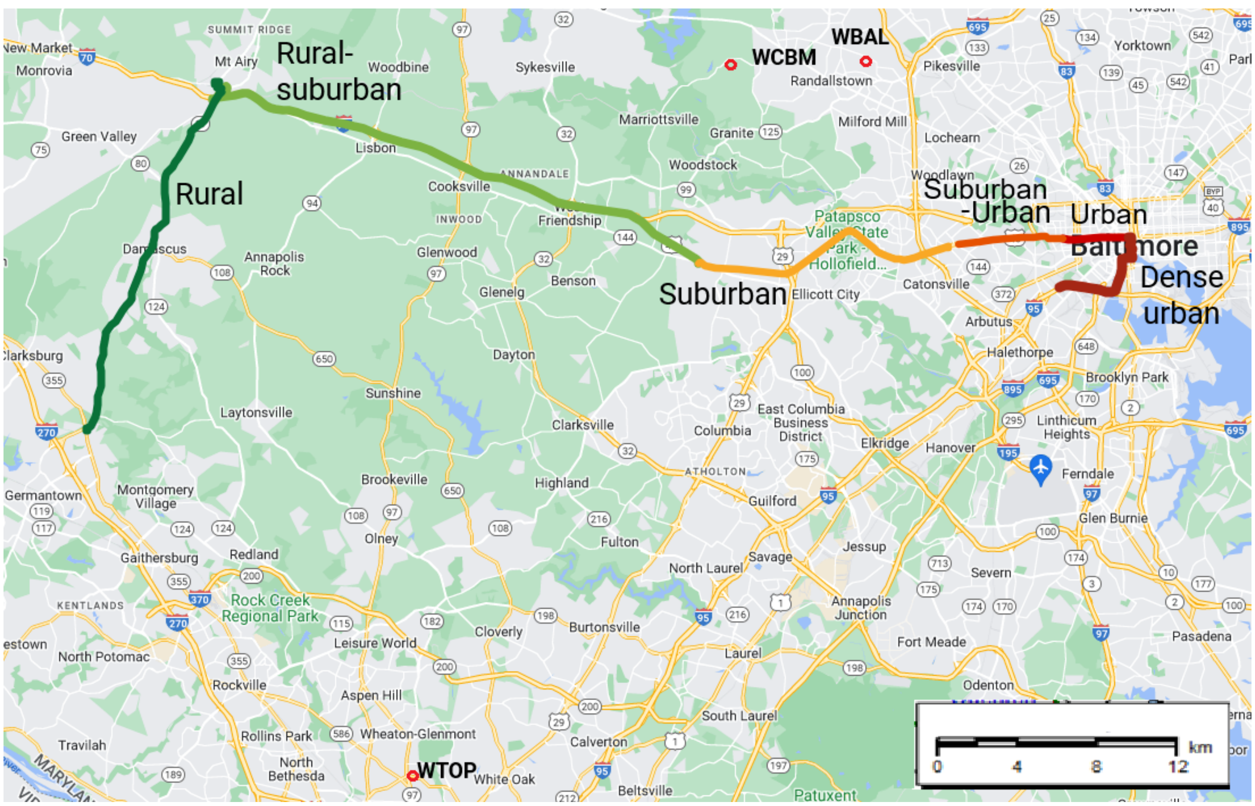

Figure 3. Map showing measurement route with build-up areas shown in gray.

This study examines whether noise levels change with building clutter density, which assumes that RF environmental noise in denser areas is degrading AM reception quality. However, RF noise is only one factor in reception quality: the other being the strength of the desired signal. To address this critical signal factor this study collected simultaneous field strength measurements with three regional AM stations, listed in Table 2.

Table 1 – Environment categories in this study.

Environment	Description
Rural	Geographic area located outside of towns and cities, predominantly natural landscape
Rural-suburban	Transitional area blending residential, agricultural and commercial land uses
Suburban	Residential areas on the outskirts of cities, apartment complexes, commercial spaces
Suburban-Urban	Transitional area blending suburban and urban areas
Urban	Highly developed areas with mix of low or medium rise apartments and commercial buildings and industrial use
Dense urban	High population density, tall buildings, extensive streets and transportation systems

Table 2. AM stations used for signal strength measurements.

Call Sign	City	Frequency (kHz)	Class	Power kW Day	Antenna Mode Day
WCBM	Baltimore MD	680	B	50	DA
WBAL	Baltimore MD	1090	A	50	Non-D
WFED	Washington DC	1500	A	50	DA

3.3 Station selection and signal performance

The AM stations listed in Table 2 were chosen to meet several criteria:

- To span the AM band by frequency,
- Operating channels free of co- and first-adjacent channel station interference,
- Have transmitter sites distanced from the measurement route to avoid signal overload, and
- Provide wide coverage across the measurement area.

The map of Figure 4 shows the daytime groundwave contours of the stations, color-keyed to their respective transmitter sites. Given the dynamic range capability of the RSPdx receiver, these stations provide measurable coverage over most of the drive-test route.

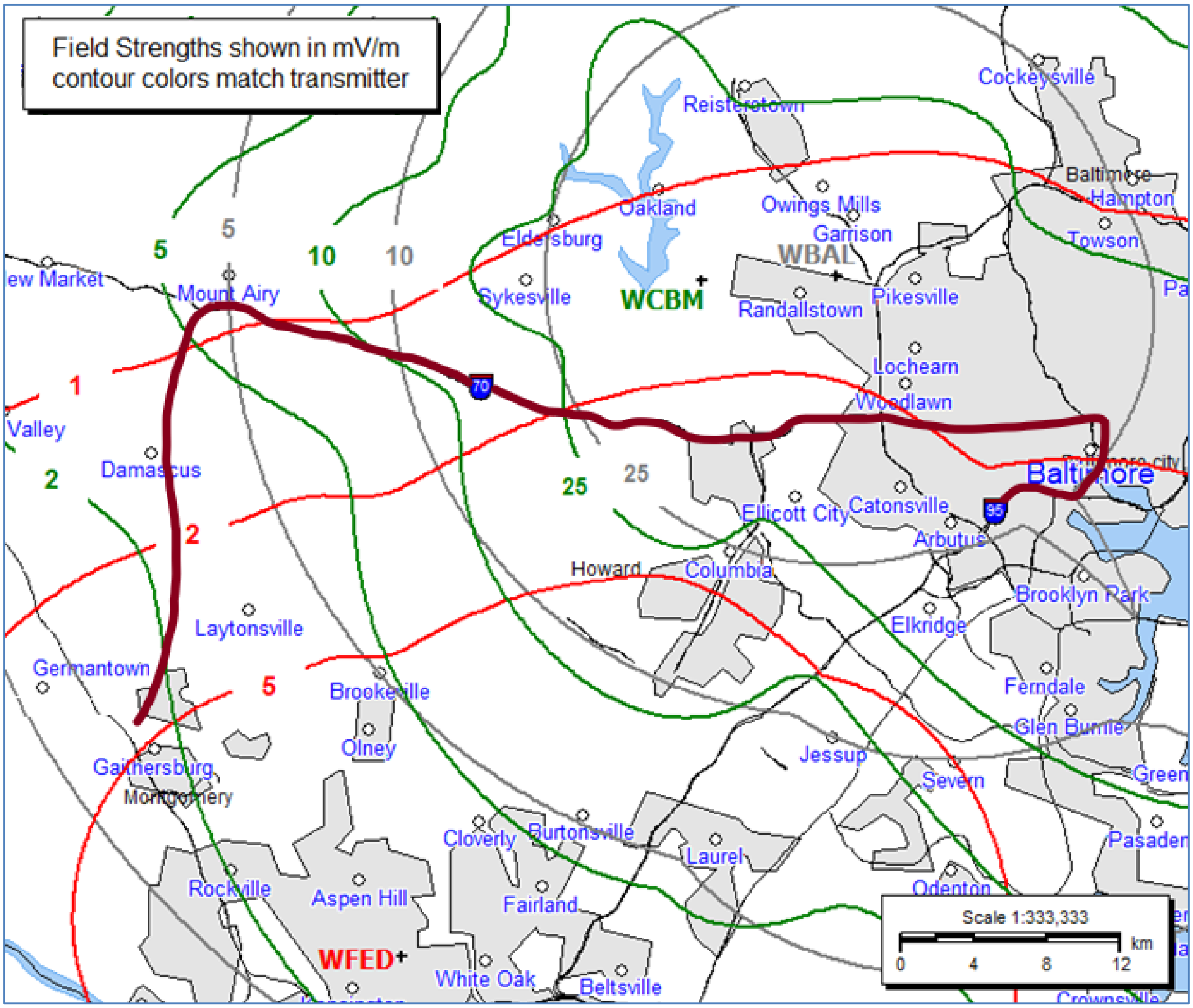

Figure 4. Transmitters and signal contours of WCBM (green), WBAL (gray) and WFED (red).

4 RF NOISE MEASUREMENTS

4.1 Measurement criteria

To avoid interference from nearby AM stations, noise measurements were taken at three frequencies, selected for separation to the same and adjacent channels used for local RF noise measurements:

- 555 kHz (noise channel 1)
- 1075 kHz (noise channel 2)
- 1625 kHz (noise channel 3)

The RSPdx receiver captured the entire AM radio spectrum (approximately 2 MHz) at a 14-bit depth. The in-phase (I) and quadrature (Q) components of the signal were stored as left and right channels in a WAV file format. A custom OCTAVE program extracted signal strength and RF channel noise data from these raw WAV files and converted them into numerical CSV files.

Noise measurements were taken within 1 kHz bandwidths centered 5 kHz away from each of the three noise channel center frequencies. This frequency offset helped to minimize interference from distant radio stations. To process the data, noise measurements were extracted in 2-second blocks. For each block, the peak and root mean square (RMS) noise values were calculated and saved in the CSV file.

The noise measurements used the same antenna system and RSPdx receiver as the station signal measurements, making it possible to convert the noise data into standard values such as microvolts per meter. However, collecting noise data in a moving vehicle complicates the calibrated reference techniques traditionally used in human-caused radio noise measurements. Mobile measurements are also less comparable to fixed, time-averaged measurements, which are beyond the scope of this study. Therefore, the noise measurements are presented as relative values, using the same horizontal-axis scales for comparison.

This study aimed to compare noise levels across five different environments as discussed in Section 3.2:

- Rural
- Rural-suburban (transition area)
- Suburban
- Urban
- Dense urban

The goal was to understand how these types of environments impact AM radio reception, both in terms of signal strength and RF noise conditions. Excluding signal interference from other radio stations, reception quality is a function of both radio signal strength and prevailing RF noise. Station interference is defined by the FCC's allocation rules and is primarily an issue in fringe areas of a desired station (usually less than the station's 2 mV/m daytime groundwave contour).[1] Figure 4 illustrates that the study area is primarily within this contour for all three test stations, the notable exception being parts of the rural and rural-suburban environments for WFED which fall outside of the 2 mV/m contour.

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[1] 47 CFR § 73.182, Engineering standards of allocation, subpart (d) states that "The groundwave signal strength required to render primary service is 2 mV/m for communities with populations of 2,500 or more and 0.5 mV/m for communities with populations of less than 2,500."

4.2 Processing of RF Environmental Noise

Figure 5 is an example of how the RF noise is presented on the three measurement channels. The red trace shows the RMS RF noise level in mV/m in a 6 kHz bandwidth around 555 kHz, the lowest "quiet" test frequency. This sample is for the rural-designated route segment between Germantown and Mount Airy, Maryland. The horizontal scale indicates the sample time in seconds.

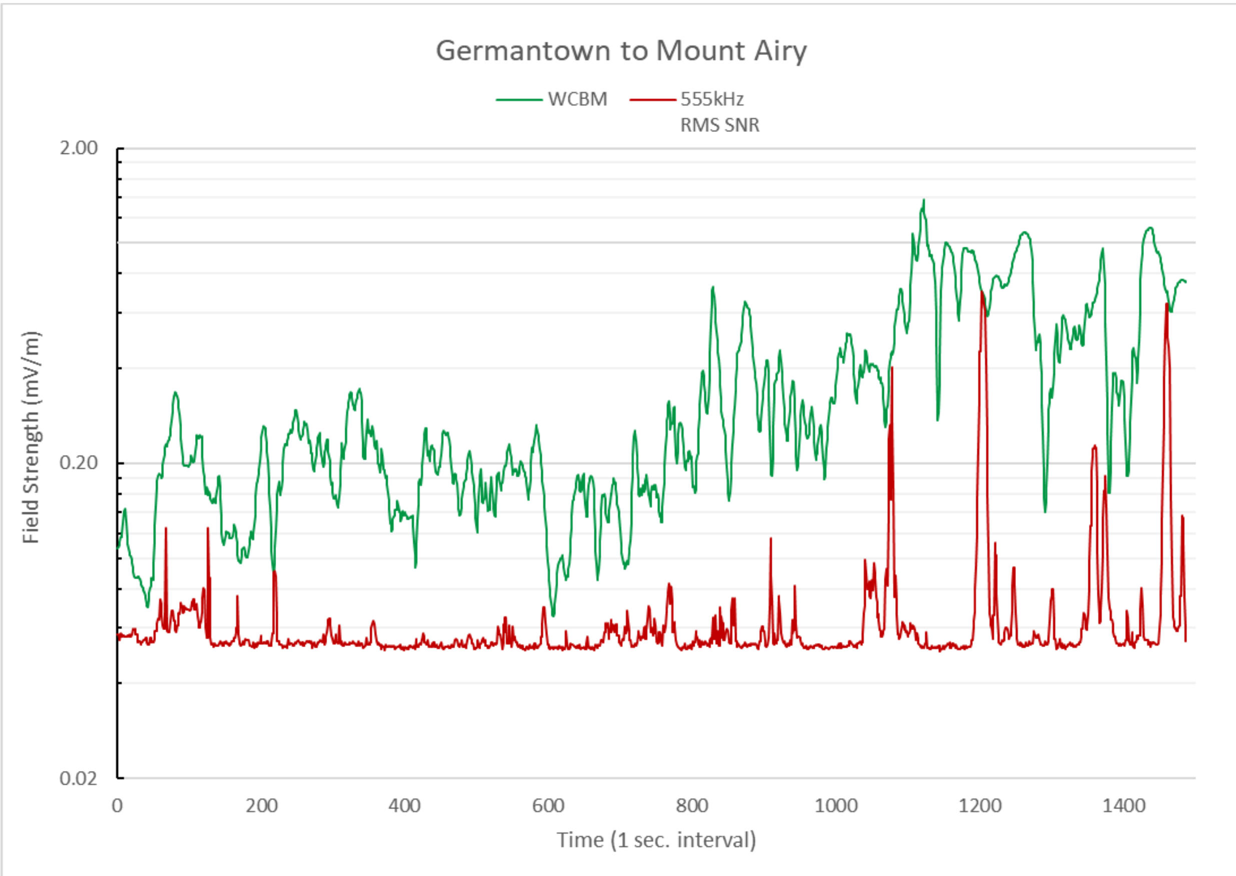


Figure 5. Chart showing RMS noise level at 555 kHz on the rural route segment with the signal from WCBM on 680 kHz.

Figure 5 illustrates WCBM's signal reception in green along the route, contrasting it with measured background noise levels in red. While an audio signal-to-noise ratio (SNR) along the route would offer a deeper understanding of reception quality, this metric is influenced by a variety of factors such as audio bandwidth, noise duration, noise frequency distribution, and station program level. These factors vary across stations and receiver models, making a simple audio SNR a limited representation of perceived AM reception quality. Therefore, this report presents a combination of measured field strength and RMS noise level. Although not a direct measure of quality, the vertical difference between the two can provide some indication of reception quality.

While field strength and RMS noise levels can offer insights into reception quality, a benchmark for minimum AM reception quality has traditionally been a 25 dB audio signal-to-noise ratio (SNR). However, modern car radios often have narrow audio passbands, which can make a lower SNR acceptable for listening (at the expense of poor audio fidelity). Considering this trend, a more practical ratio between field strength and measured noise in quiet channels might be 20 dB, equivalent to a 10:1 voltage ratio on the chart. For instance, a field strength of 1 mV/m would require noise levels below 0.1 mV/m at the same moment. This generalization would apply to other station field strengths. WCBM's signal consistently meets this 20 dB signal to RF noise ratio criteria in only the last quarter of this route, and even then, there are several moments when noise peaks sharply drop that ratio.

Noise analysis in various environments, including urban and rural areas, reveals a common pattern: frequent, low-level background noise often near the measurement system's noise floor, are punctuated by intermittent noise bursts. In rural settings, these bursts are primarily caused by power lines crossing the road, resulting in spikes in the RMS noise graphs seen on the graphs.

Passing beneath highway overpasses has little significant impact on received noise levels. This is because these locations are not inherently more likely to have noise sources than the adjacent road segments. However, the sharp signal drops can trigger rapid responses from AM receivers' automatic gain control (AGC) systems, amplifying any ambient RF noise during these moments.

Another measurement on the "quiet" channels was noise peaks, which make "pops" in the received audio. For this, the value of the highest noise peak per second was measured, relative to the RMS noise (in field strength) in that second. The number of noise peaks at values in each second of time was then counted. Peak sensing is normalized to the_RMS noise in the block second, thus_the peak noise values are treated as dB relative (dBr) measurements. What is of most interest is the distribution of peak values in each histogram: peaks that frequently extend to higher values are an indication of noisy and unpleasant reception.

The count for each threshold is displayed in a histogram, with the horizontal axis representing the threshold levels and the vertical axis representing the frequency of occurrence for the route segment. Figure 6 illustrates the 555 kHz channel on the Rural route segment, demonstrating that the frequency of impulses decreases as the peak amplitudes increase. In this case, however, higher level (and louder) noise peaks extend to field strength levels up to 20 dB greater than the frequently occurring peaks. This distribution can vary widely with frequency and locale, as seen in subsequent charts.

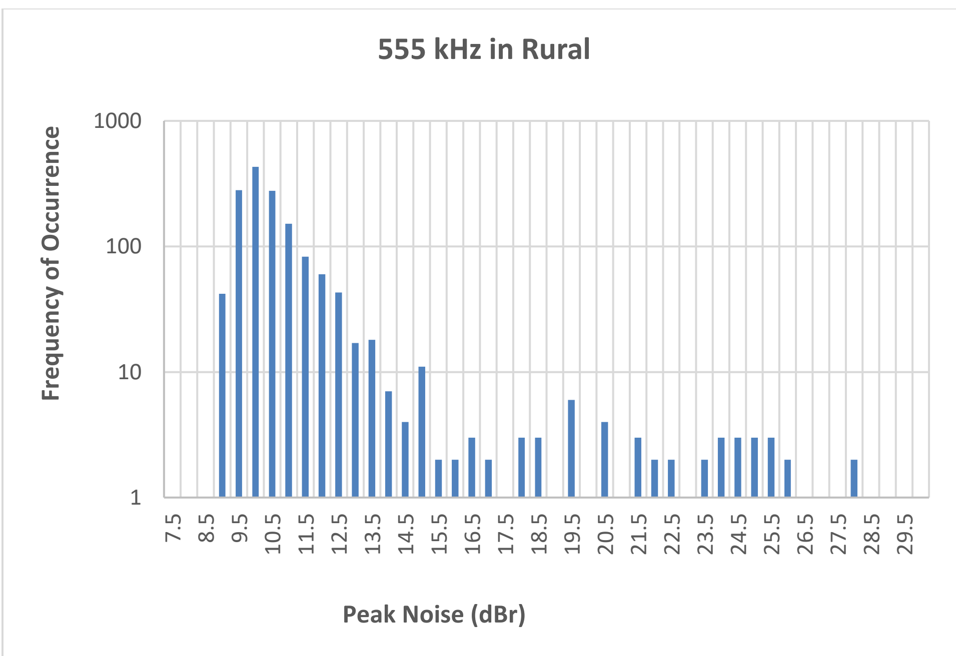


Figure 6. Sample chart showing the impulse noise histogram on a route segment.

5 FIELD MEASUREMENT OF STATION SIGNALS AND RF ENVIRONMENTAL NOISE

5.1 Germantown to Mount Airy (Rural) segment

The maps in Figure 7 show the first route segment (driven from south to north) with a color-coded line to represent field strength in mV/m.

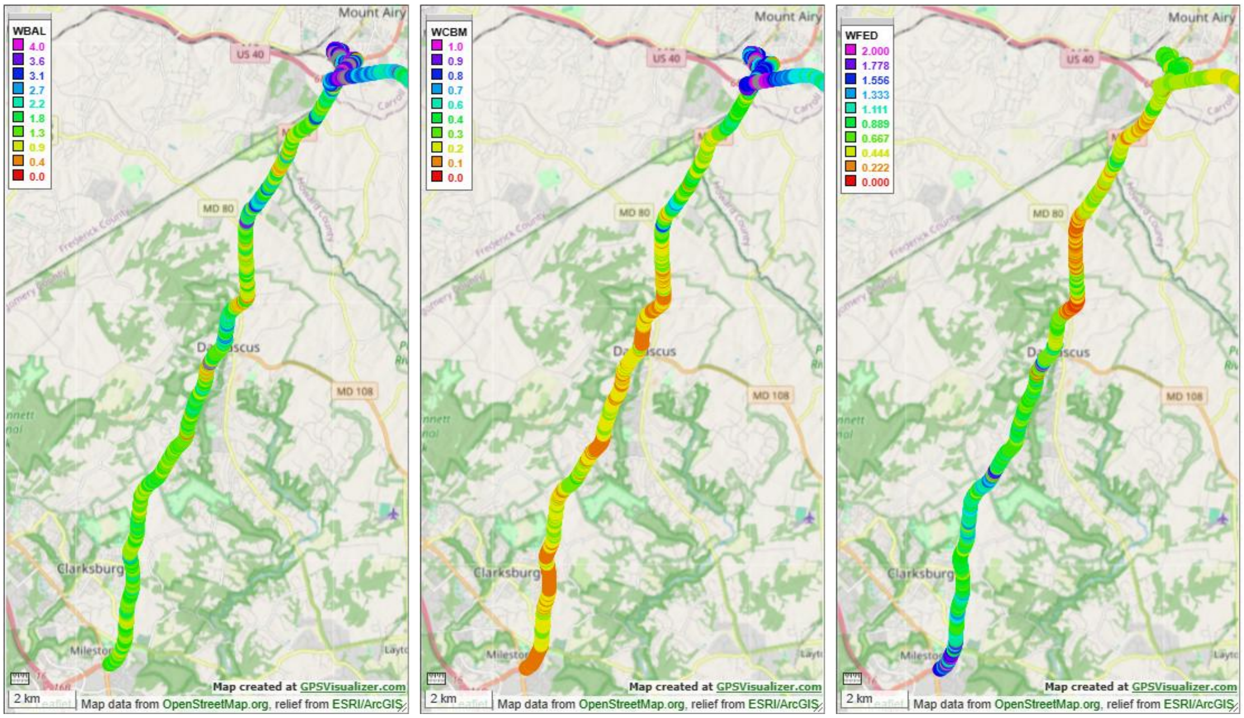


Figure 7. Measured field strength of WBAL, WCBM, and WFED along the rural segment. The legend in upper left shows field strengths in mV/m according to color.

This 13-mile route, primarily a two-lane road (Maryland route 27), passes through a mix of farmland and residential areas set back from the road. The route goes through Damascus, Maryland, a town with small stores and two schools (high school and elementary school) located roughly halfway along the route. A 12.6 kV power line runs parallel to most of the route, and there are numerous low-voltage AC service lines crossing the road.

Comparing the measured field strengths to the predicted groundwave contours for each station in Figure 4, we observe that the measured values are significantly lower than predicted. For example, WCBM's predicted field strengths on this segment range from 2 to 5 mV/m, but the measured values are only about 0.2 to 0.7 mV/m.

WFED's predicted groundwave ranges from 4 mV/m at the southern end to 1 mV/m at the northern end. However, the measured field strengths along this route are between 0.5 and 0.2 mV/m. The exact reasons for these discrepancies are uncertain, but they could be attributed to factors such as variations in ground conductivity within the region, changes in road elevation relative to the surrounding terrain, local building obstructions, and other environmental factors.

For comparison of signals along the roadway on Germantown to Mount Airy (rural) route, Figure 8 shows the field strengths of WCBM, WBAL and WFED. This is graphed over 1500 seconds (25 minutes) along this route segment. WCBM and WBAL have somewhat parallel traces at first, but later with a difference in the field strength generally in a ratio of 10:1. However, the groundwave field strength contours of the two stations in Figure 4 (WCBM in green, WBAL in gray) predicts both signals in the range of 2 to 5 mV/m and generally closer in ratio.

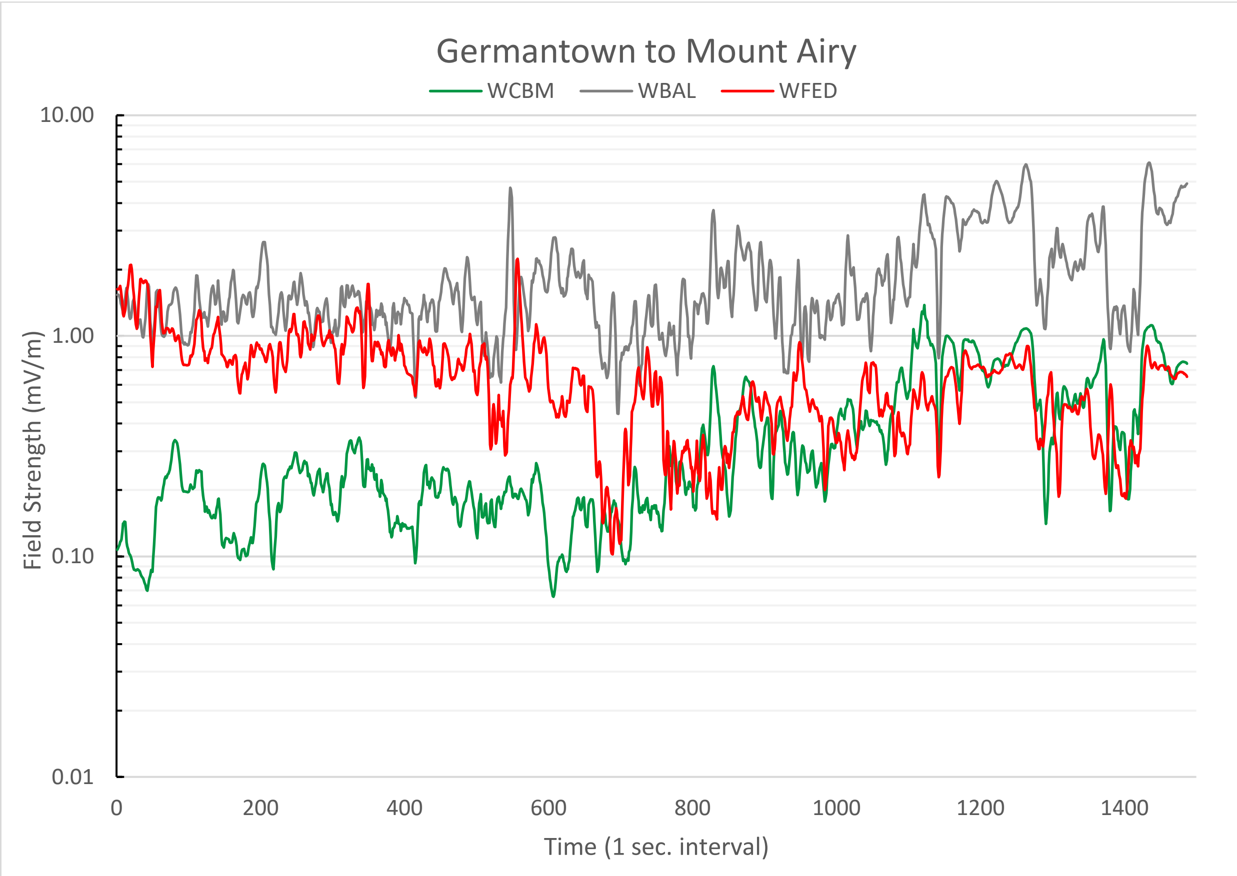


Figure 8. Field strengths of the three AM stations for the rural segment shown in Figure 7.

The direction to the transmitter sites of WCBM and WBAL are both northeast of this route, while WFED's transmitter is south-southeast. The WFED field strength decreases with distance and its predicted field is expected to decrease from approximately 5 mV/m to 1 mV/m. Like WCBM and WBAL, WFED's measured field strength starts near 2 mV/m and drops to around 0.5 mV/m. These differences between measured and predicted measured fields are notable, although their cause is beyond the scope of this study. It has been suggested by expert reviewers of this report that differences are not unusual at large receiving distances and may be due to errors in the FCC ground conductivity data. Others point out that the E field measurements could be adversely affected by clutter and terrain height near the roadways.

The other part of this investigation determined the RF environmental noise levels along with field strengths. As discussed above, three "quiet" channels were selected, each being near in frequency to one of the test stations. For comparison, the RF noise power in the test channel was converted to a field strength value in comparison with the associated AM station. The data was graphed separately for the three station and noise pairs on all route segments for both RMS (averaged) and peak values.

While this approach could be viewed as a "signal to noise" ratio (SNR), there are several factors that govern the perceptual measure of SNR, such as audio content type and modulation level, channel bandwidth, and duration of noise. Given this caution, one can view the momentary ratio between the field strength and noise level for a general sense of the quality of reception: a ratio of 10:1 (20 dB voltage) could be a marginally unacceptable condition. (Audio recordings of the received station signals were collected for the three stations on the full route, which provides an opportunity for a reader to make their own judgement of the audio reception quality. These recordings will be posted on the nrscstandards.org website for downloading.)

Figure 9 illustrates the measured field strength for WCBM, plotted alongside the average noise level (RMS) on the rural route segment. Significant decreases in field strength are evident, primarily due to overhead obstructions like highway overpasses. While these obstructions do not directly increase RMS noise, they can potentially amplify background noise on the desired channel because of receiver Automatic Gain Control (AGC) adjustments.

The noise peaks observed on the bottom line are attributed to the presence of overhead power lines or noisy electrical equipment near the road. These factors, however, have minimal impact on signal strength. Their influence on noise levels is contingent on the strength of the station's signal at the specific moment the noise source is encountered.

The graphs for WBAL and WFED in the rural route segment are show in Figure 10 and Figure 11. Color coding is the same as WCBM. Baseline RMS noise at 1075 kHz and 1625 kHz are like 555 kHz but the number of peaks in the noise has reduced significantly. With the exception of a couple of short moments, WBAL’s signal would produce acceptable reception quality across the entire route. WFED’s reception quality is good until its field strength drops below about 1 mV/m after 500 seconds from the start.

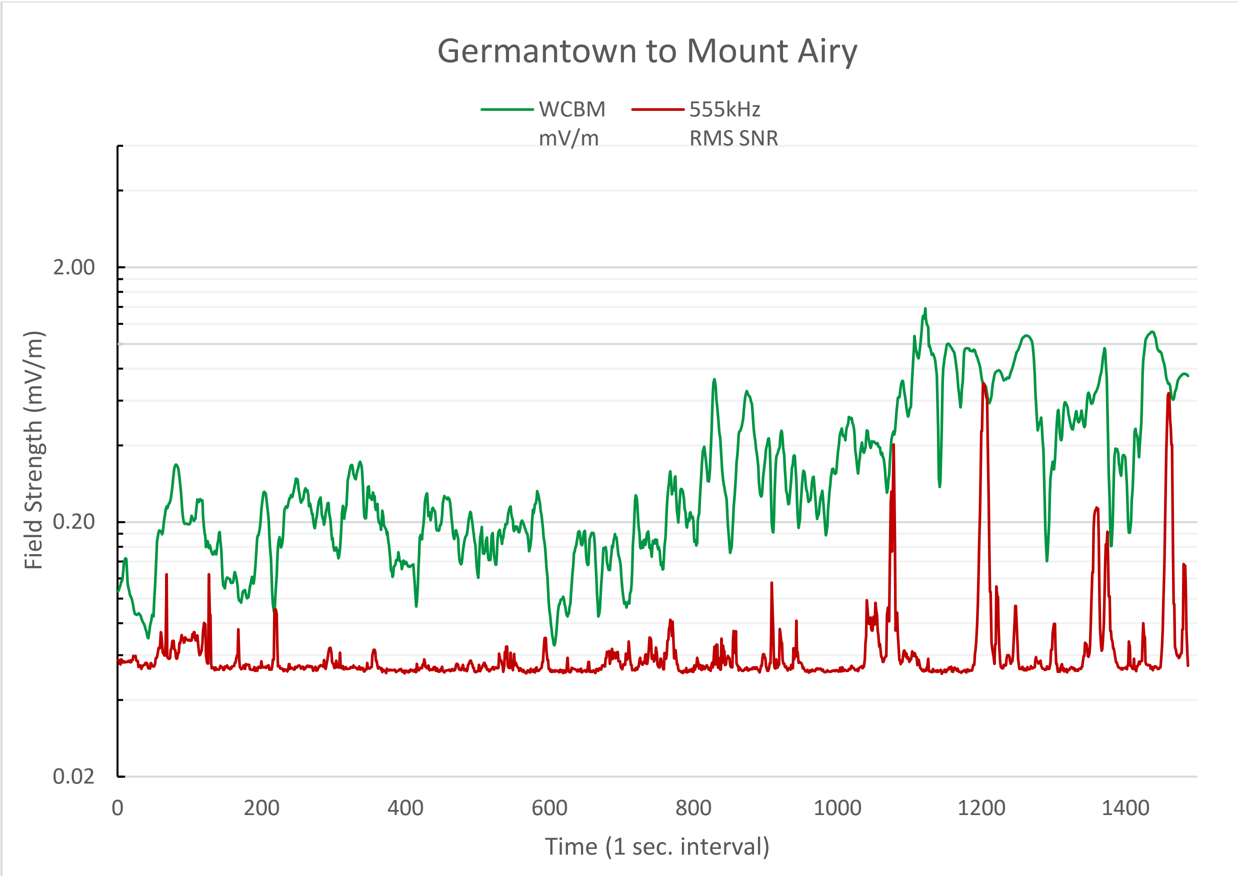


Figure 9. WCBM field strength (green) and 555 kHz RMS noise measurement (red).

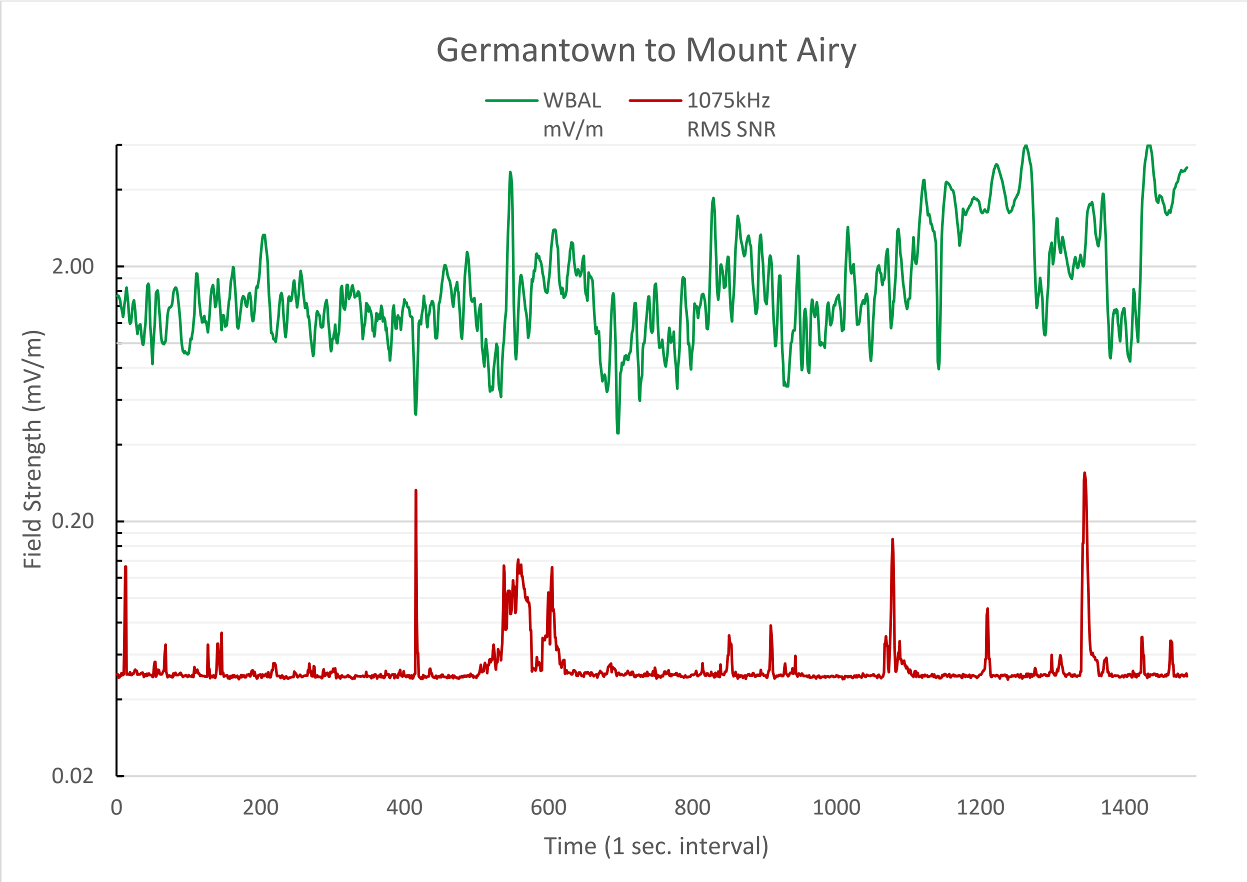


Figure 10. WBAL field strength (green) and 1075 kHz RMS noise measurement (red).

It is notable that the RMS noise around 550 seconds appears at 1075 kHz and 1625 kHz but is not detected at 555 kHz. This means that RF environmental noise can be frequency-dependent, according to how the noise was generated. For example, broadband noise, such as arcing contacts in a large motor, could be frequency-shaped by cable inductance and distributed capacitance in its wiring.

"Peak Noise" in this study is calculated as the ratio of the maximum instantaneous noise voltage in a "quiet" noise channel compared to the channel's average noise level (RMS). Listeners would perceive this noise as a sudden pop or crack that is significantly louder than the background hiss.

"Buzzing" noises are primarily measured as contributors to the RMS noise level rather than as a series of distinct peaks. The frequency (or number of occurrences) of these events per measurement second is calculated and displayed below as histograms. The charts in Figure 12 illustrate the distribution of noise peaks for each noise channel along the rural segment.

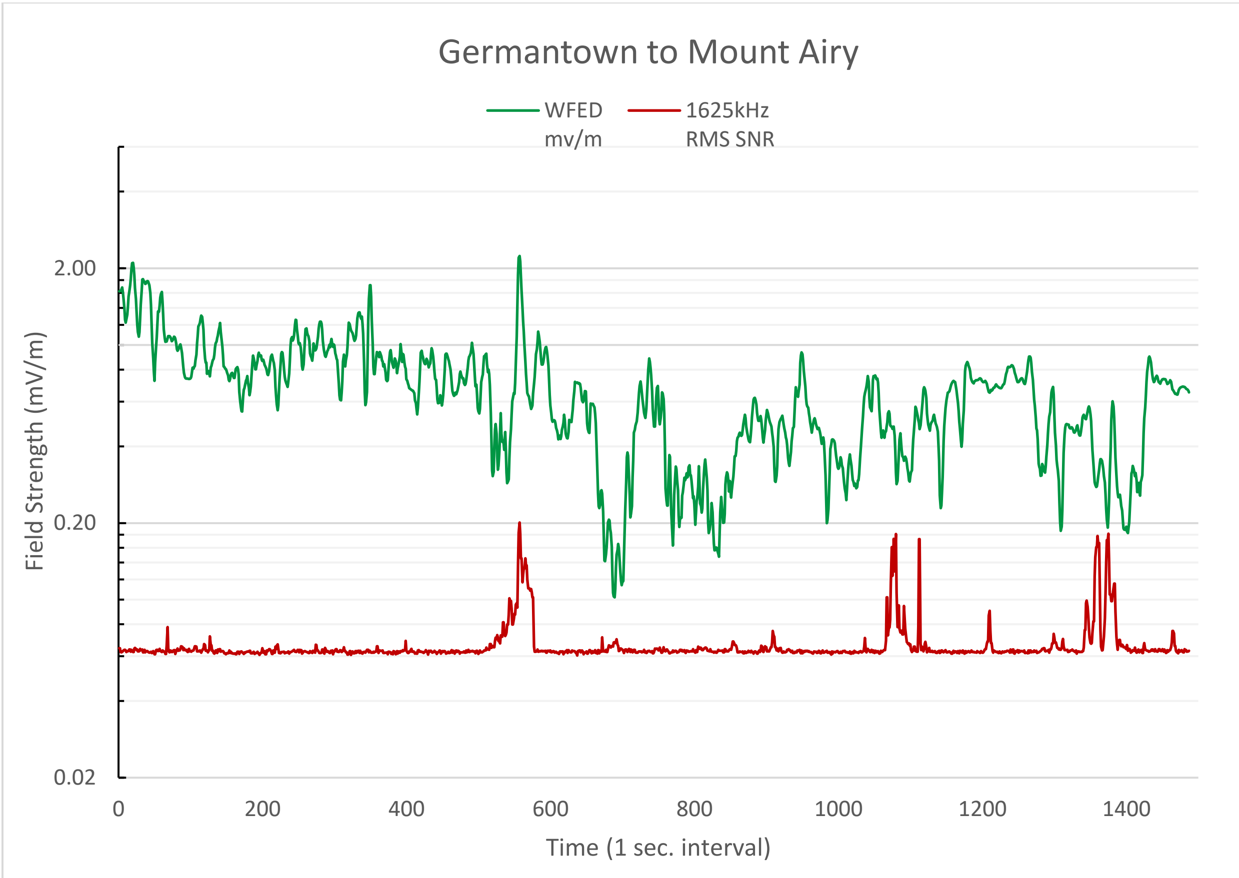


Figure 11. WFED field strength (green) and 1625 kHz RMS noise measurement (red).

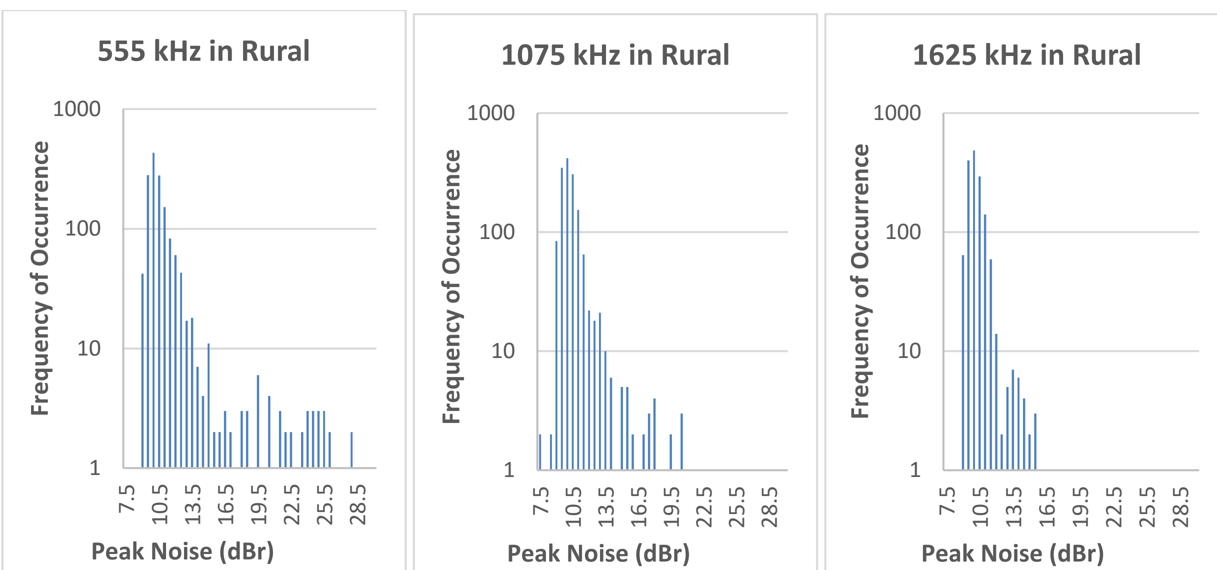


Figure 12. Distribution of noise peaks for each noise channel along the rural route segment.

Noise peaks were almost always greatest on the lower frequency channel (555 kHz) compared to the middle channel (1075 kHz), and the highest frequency channel (1625 kHz). This can be seen by the height and density of vertical lines on the histograms. Again, by a noticeable margin, the lower frequency channel had a scattering of peaks at far higher amplitudes than the other two channels. The 1625 kHz channel above shows noise peaks ending at 15 dBr, while the 555 kHz channel peaks extend to 28 dB. Listeners in lower signal areas can be expected to hear occasional pops and crackles that are noticeably louder than on the middle and higher frequency channels at similar station field strengths.

This observation aligns with research showing that human-caused noise sources like power lines and distant lightning events decrease as the frequency increases. Therefore, listeners on the higher end of the AM band would experience less impulsive noise, although the groundwave signal propagation is generally weaker at those frequencies.

5.2 Mount Airy to Ellicott City (Rural-Suburban)

The maps in Figure 13 show the rural-suburban segment (driven from west to east) with a color-coded line to represent field strength in mV/m. This route begins in a mixed rural and suburban setting on Interstate 70, a wide, open roadway environment that cuts over to US Route 40, a four-lane divided highway much like I-70.

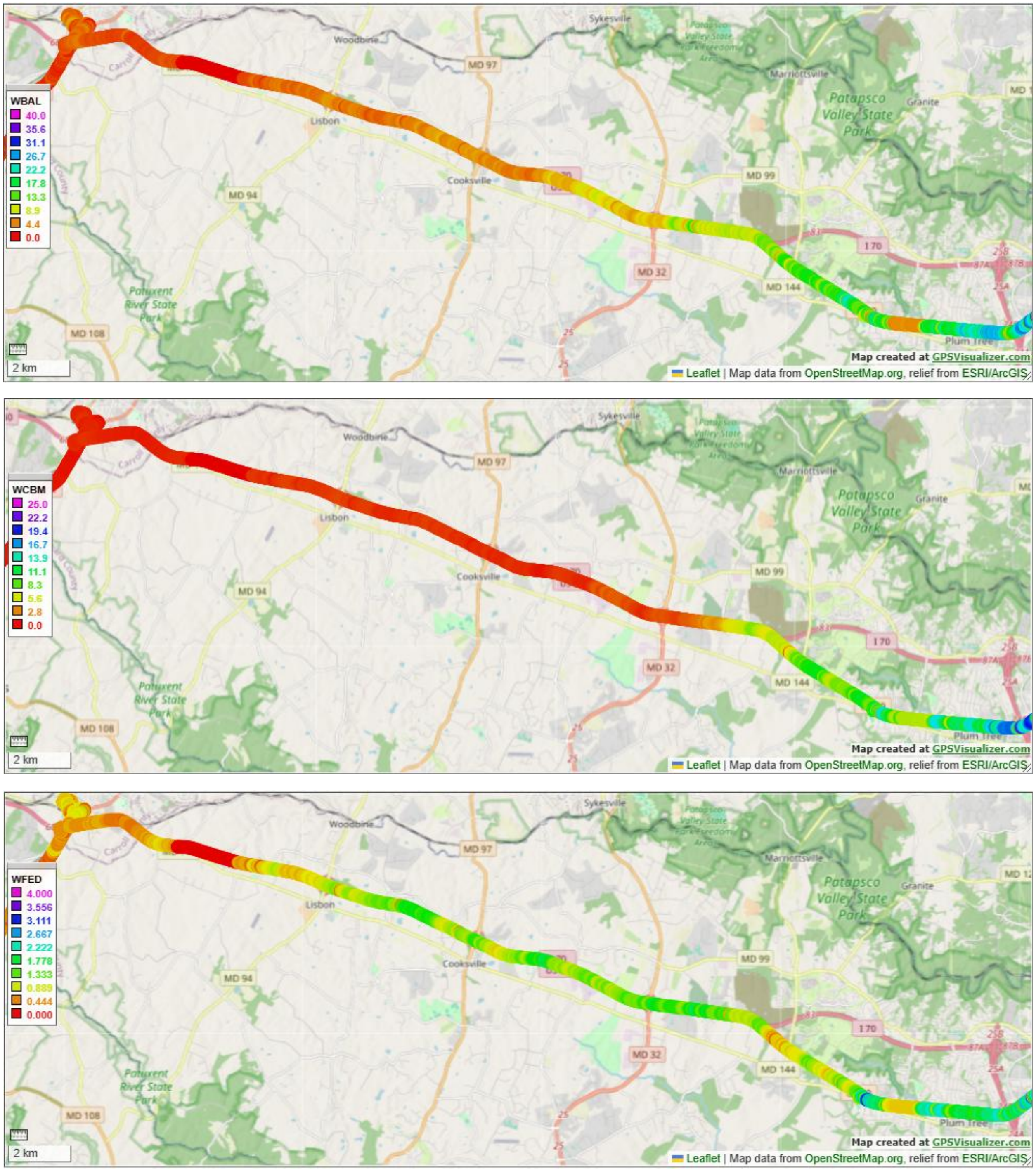


Figure 13. Measured field strength of WBAL, WCBM, and WFED along rural-suburban segment. Legend depicts field strength colors in mV/m.

This segment generally has stronger signal strengths compared to nearby arterial roads, which may present building obstructions, electrical power lines, and other factors that can scatter and weaken radio signals.

WBAL's signal in Figure 14 is significantly stronger than those of WCBM and WFED. The three stations share a low-signal area between Mount Airy and Lisbon. After the split from I-70 to US-40 the WCBM's signal nearly catches up to WBAL. Interestingly, WFED's signal drops in nearly the same area that WCBM rises. The cause is not clear. A notable feature of this area is that the interstate passes through embankments of approximately twenty feet on one or both sides. The terrain elevation continues to decrease in this route section. These factors may be creating apertures that attenuate the AM signals.

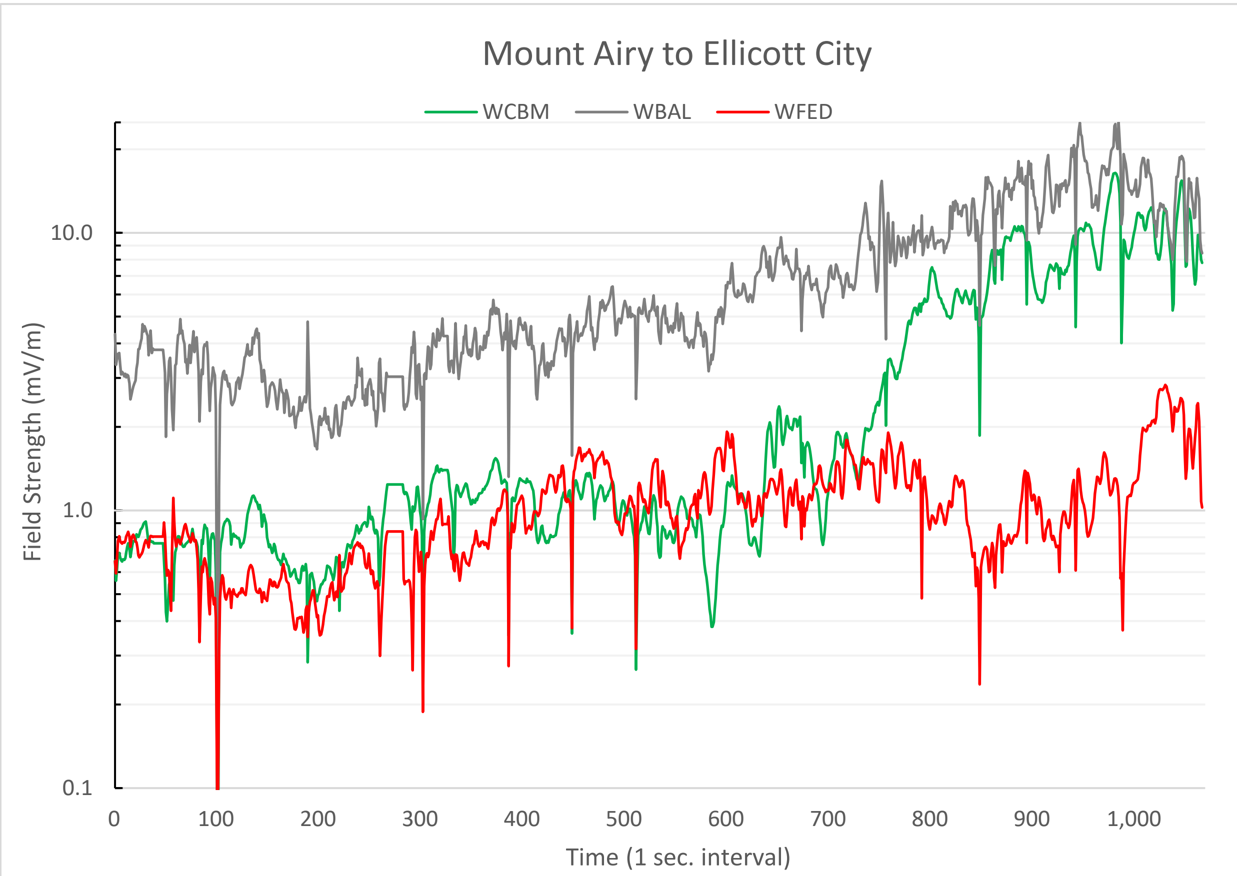


Figure 14. Field strengths on the rural-suburban segment (25 to 0.1 mV/m scale).

The signals shown in Figure 14 show a striking similarity in their downward spikes along the route. The largest spike, located on the far left, occurred at a large overpass. The other downward spikes occurred at smaller, two-lane overpasses typical of state roads, which the measurement vehicle passed under more quickly. The signal fades were prolonged enough to significantly reduce the field strengths and, in the case of WCBM and WFED, to substantially lower their signal-to-noise ratio.

This highway route segment shows how low RF noise can be in the AM band – essentially at the RMS noise floor of the instrumentation (approximately 40 to 60 mV/m, depending on frequency). Open surroundings on this open highway place it far away from electrical noise emitters such as power lines, traffic signals and electrical equipment. Even at field strengths of 1 mV/m the station signals provide listenable and comfortably quiet reception.

Figure 15 adds the RMS measurement on 555 kHz for comparison to WCBM's field strength. It is apparent that noise is unaffected by the downward signal drops discussed above. There is also no connection between the three noise spikes in red and the field strength measurements. The first two, at approximately 143 seconds and 943 seconds, are very brief. This is because they were physically small sources of noise, in contrast to power line noise, which was found to stretch for longer periods of time, and were passed quickly at highway speeds.

The last noise blip at about 1060 seconds was a little long because the measurement car had pulled off the highway and slowed down. Given WCBM's high field strength at this point the noise was unnoticeable.

The charts in Figure 16 and Figure 17 illustrate the levels of RMS noise for the mid-band and high-band channels along the route segment. Common to other route segments, they decrease with frequency.

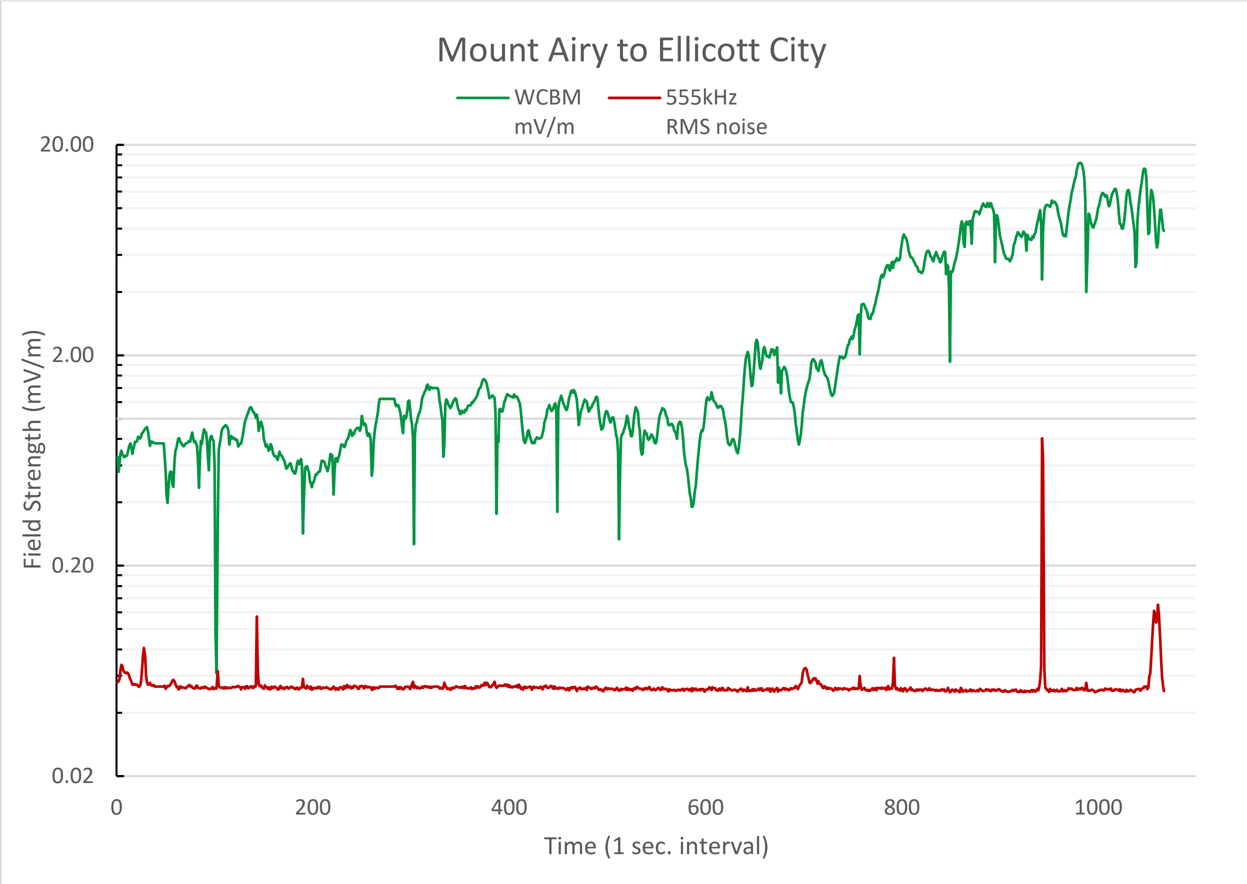


Figure 15. WCBM field strength (green) and 555 kHz RMS noise measurement (red).

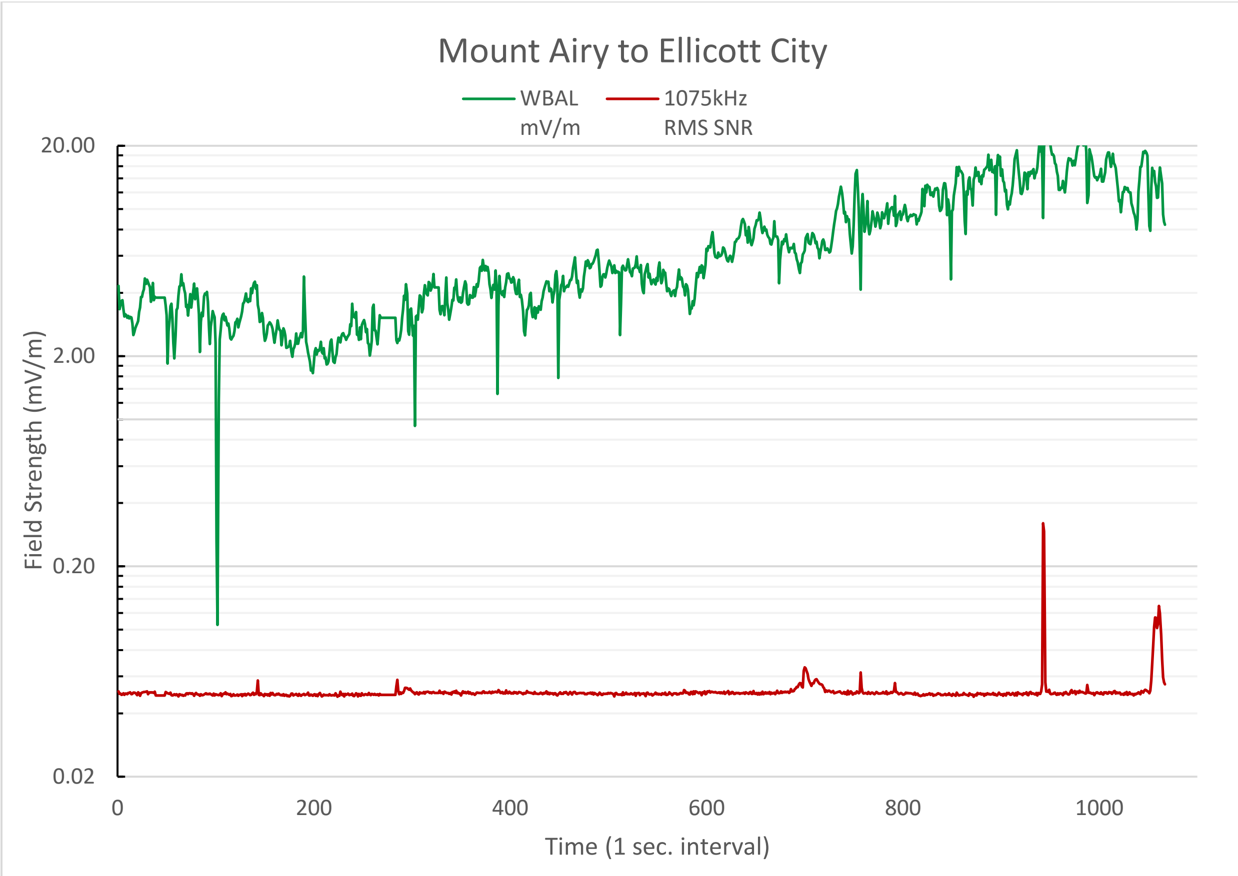


Figure 16. WBAL field strength (green) and 555 kHz RMS noise measurement (red).

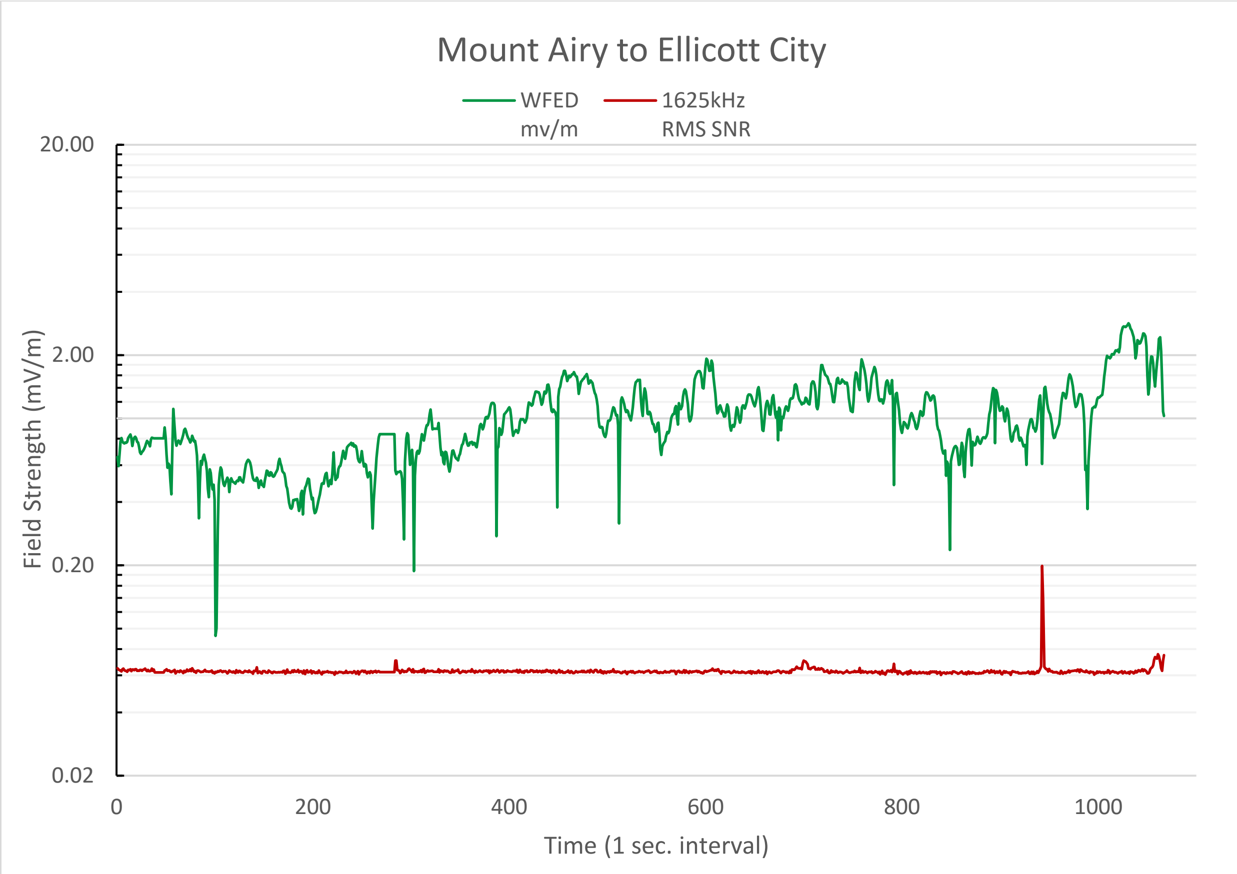


Figure 17. WFED field strength (green) and 555 kHz RMS noise measurement (red).

The distribution of peak noise occurrences are displayed in Figure 18 for all three channels on this interstate highway segment. Like the RMS noise measurements, this interstate highway exhibited the lowest peak noise occurrences among all the route segments.

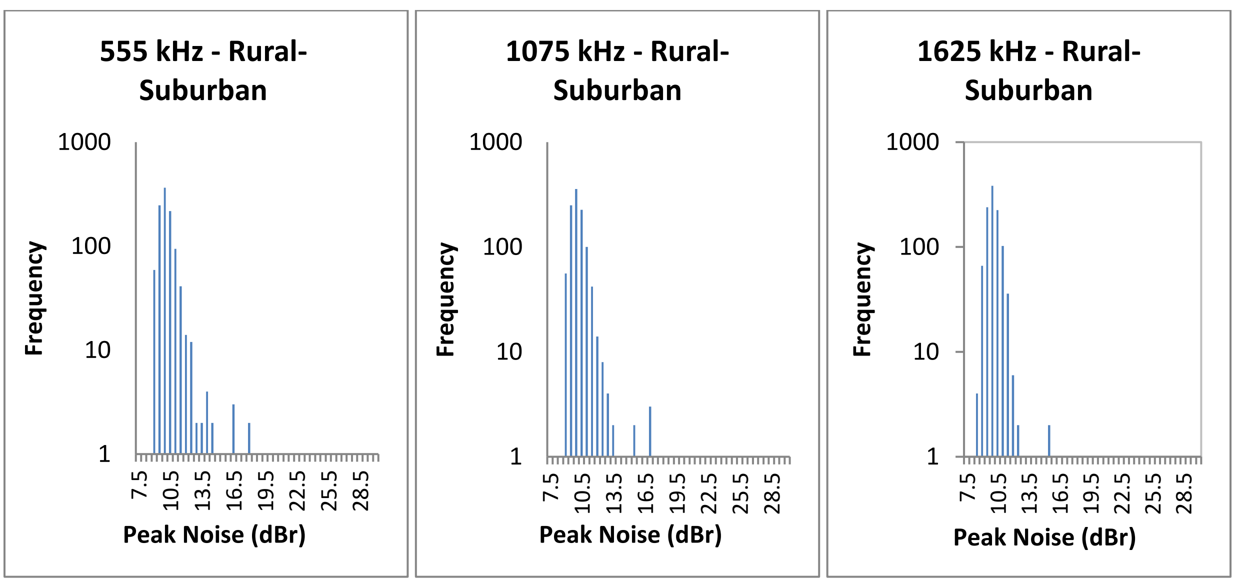


Figure 18. Distribution of noise peaks for each noise channel along the rural-suburban route segment.

5.3 Ellicott City to Catonsville (Suburban)

The maps in Figure 19 show the mostly suburban segment (driven from west to east) with a color-coded line to represent field strength in mV/m. This route segment is US Route 40, a four-lane divided highway which transitions east of the state part (green area) to a low-speed suburban highway, flanked by open shopping centers and interspersed with stop lights.

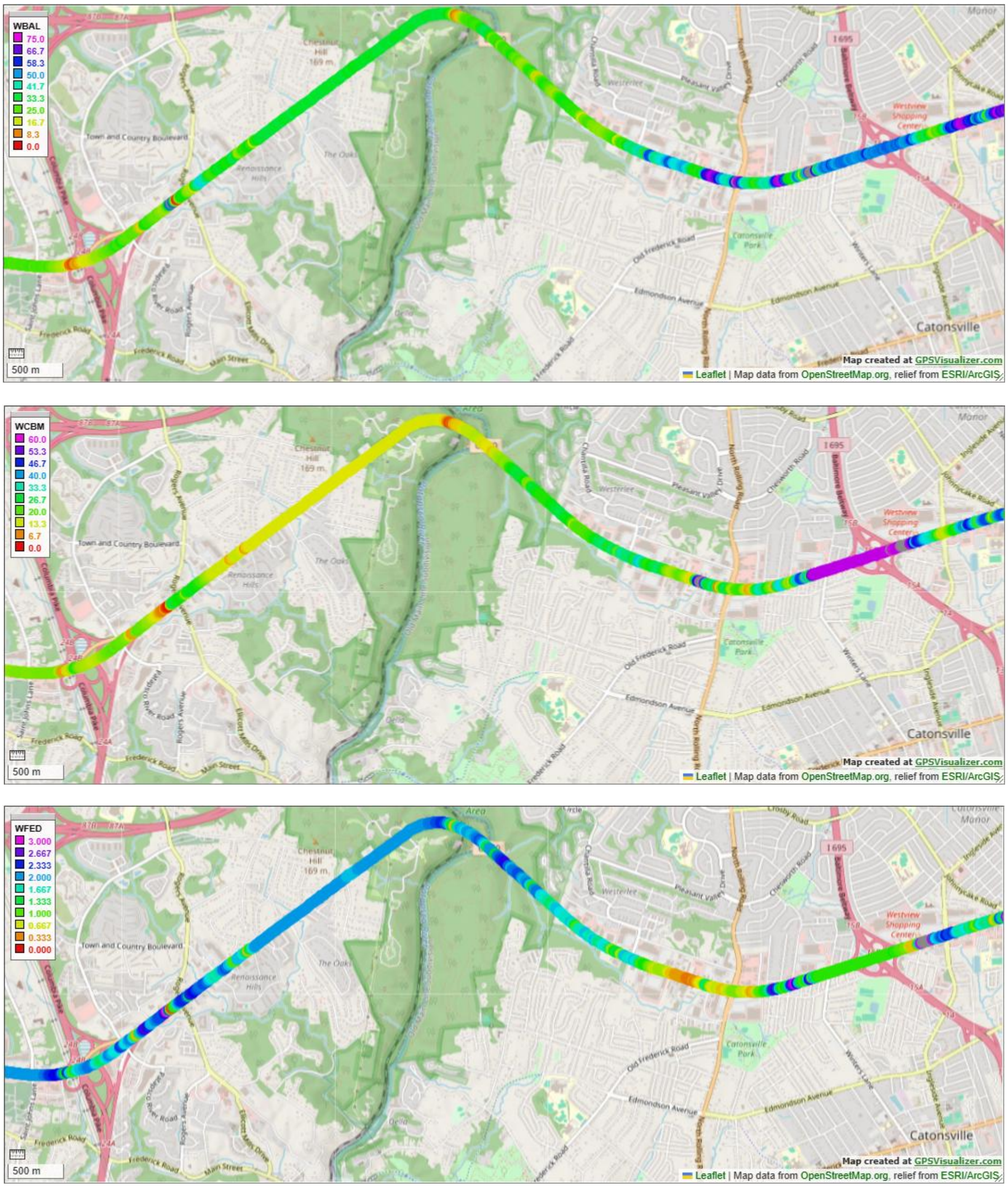


Figure 19. Measured field strength of WBAL, WCBM, and WFED along suburban segment. Legend depicts field strength colors in mV/m.

Field strengths climb from single digits to nearly 60 mV/m for WCBM and 75 mV/m for WBAL. WFED remains around 2 mV/m in the eastern half and shows some clutter loss effect to the signal in the business areas to the eastern half.

The maps in Figure 19 show the mostly suburban segment (driven from west to east) with a color-coded line to represent field strength in mV/m. This route segment is US Route 40, a four-lane divided highway which transitions east of the state part (green area) to a low-speed suburban highway, flanked by open shopping centers and interspersed with stop lights. Field strengths climb from single digits to nearly 60 mV/m for WCBM and 75 mV/m for WBAL. WFED remains around 2 mV/m in the eastern half and shows some clutter loss effect to the signal in the business areas to the eastern half.

The field strengths in Figure 20 show a gradual climb, reaching or exceeding 100 mV/m for WCBM and WBAL. WFED's signal stays mostly between 1 and 2 mV/m and is less affected by RMS noise and signal dropouts under overpasses.

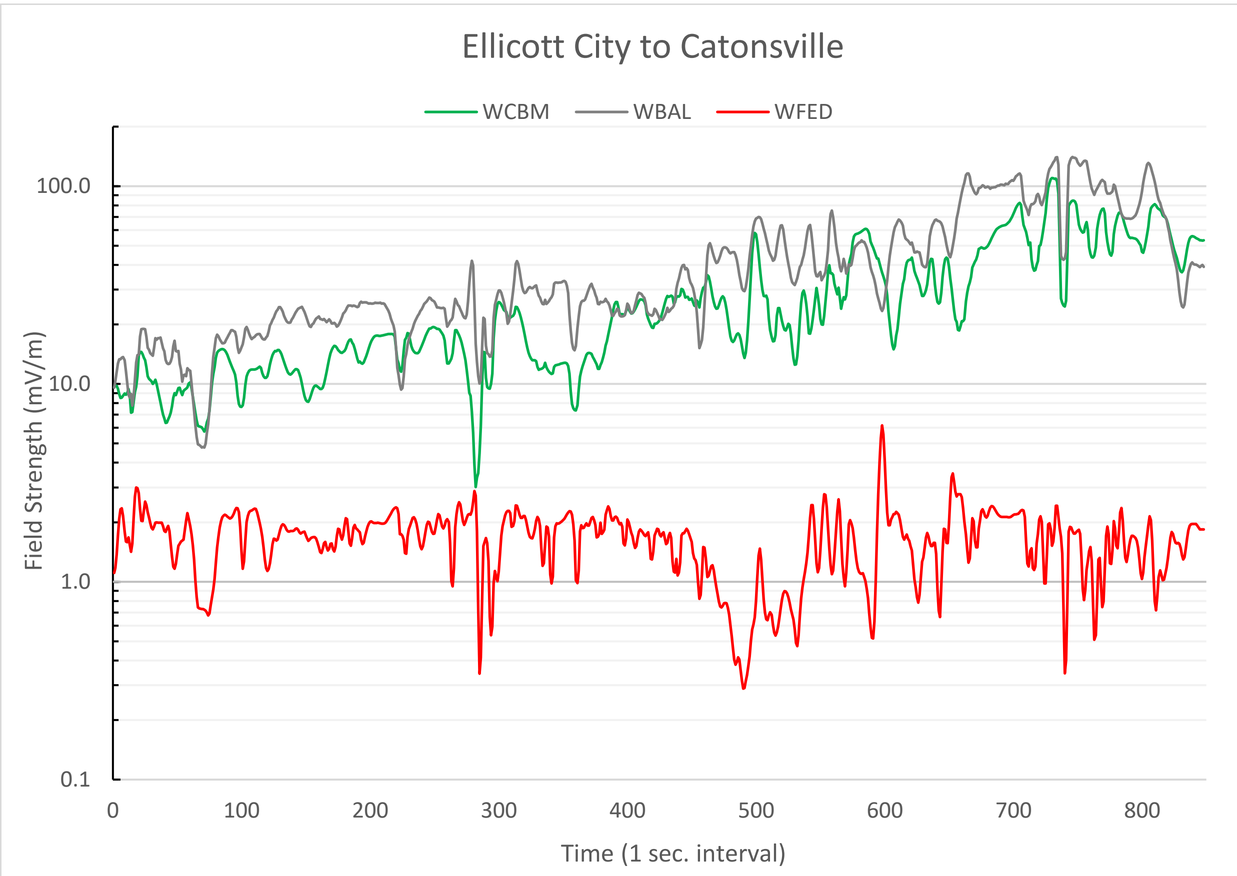


Figure 20. Field strengths along the suburban segment.

On Figure 21 this Suburban-classified route the RMS noise levels begin to rise as the measurements proceed east. This is evident in the red line in the right half of the route.

Figure 22 and Figure 23 show the common reduction in RMS noise as the channel frequencies increase. WFED's measured field strength, nearly 2 mV/m, is close to the predicted groundwave field strength. This results in a usable, but somewhat noisy signal from the receiver audio, indicating that a consistent 25 dB (approximately 18:1) ratio of signal to noise is needed for quiet reception.

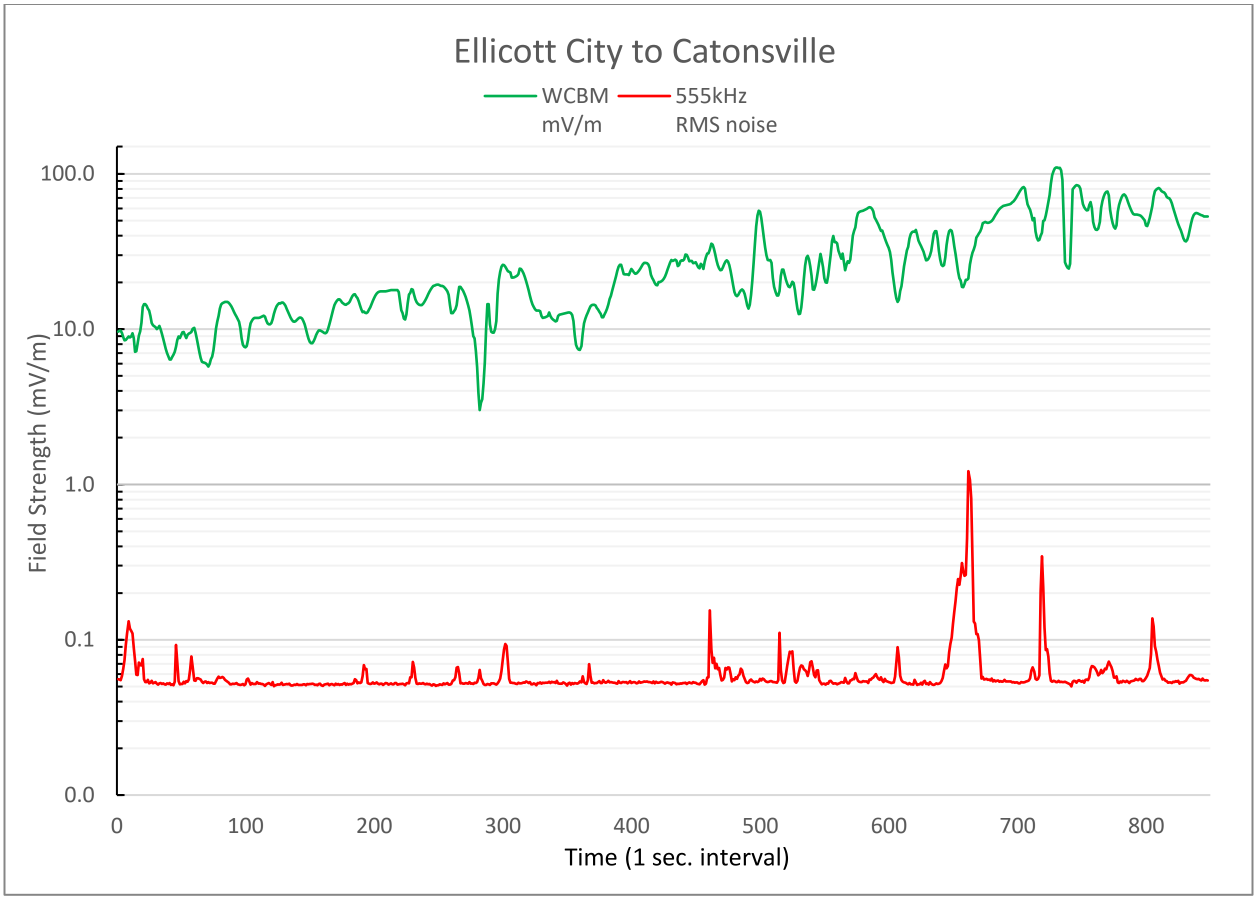


Figure 21. WCBM field strength (green) and 555 kHz RMS noise measurement (red).

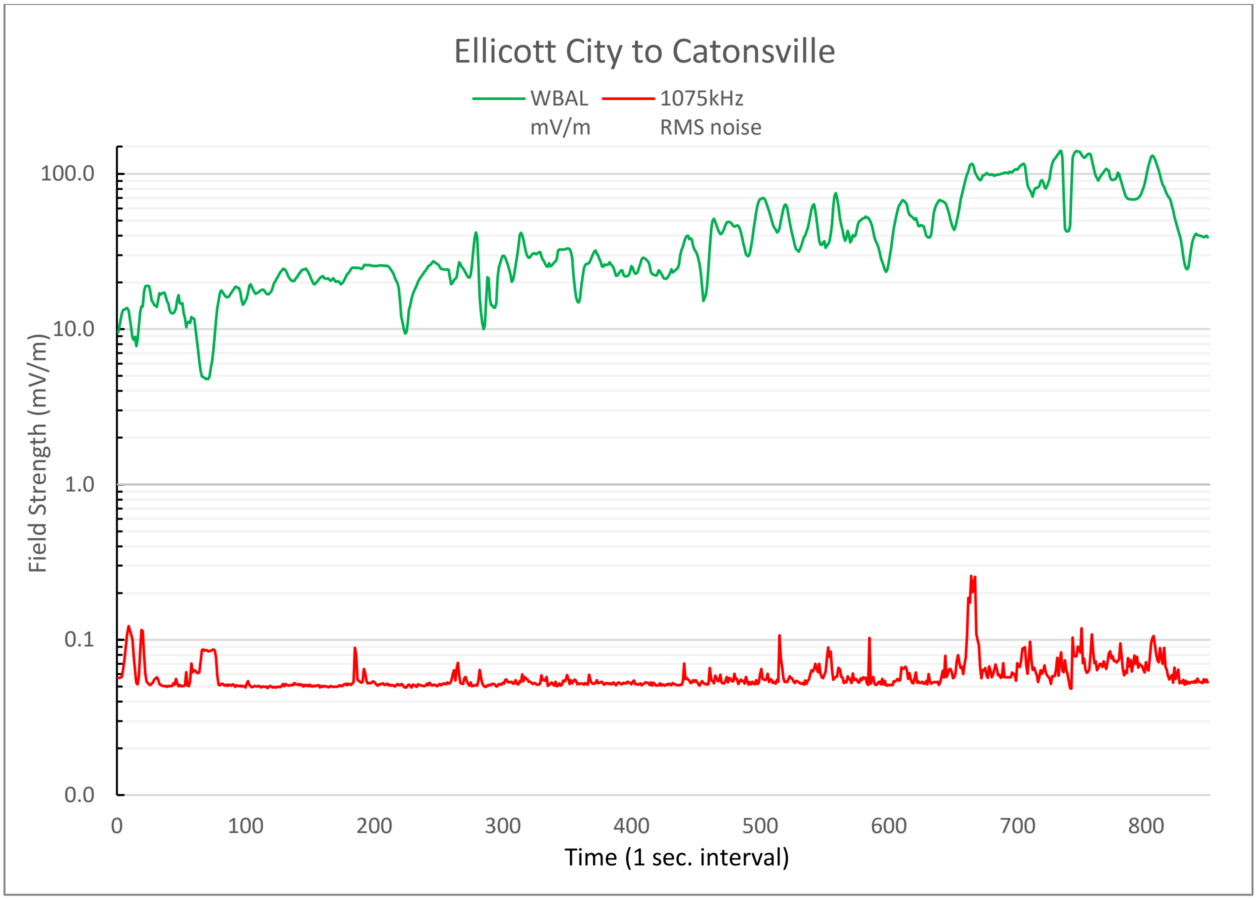


Figure 22. WBAL field strength (green) and 555 kHz RMS noise measurement (red).

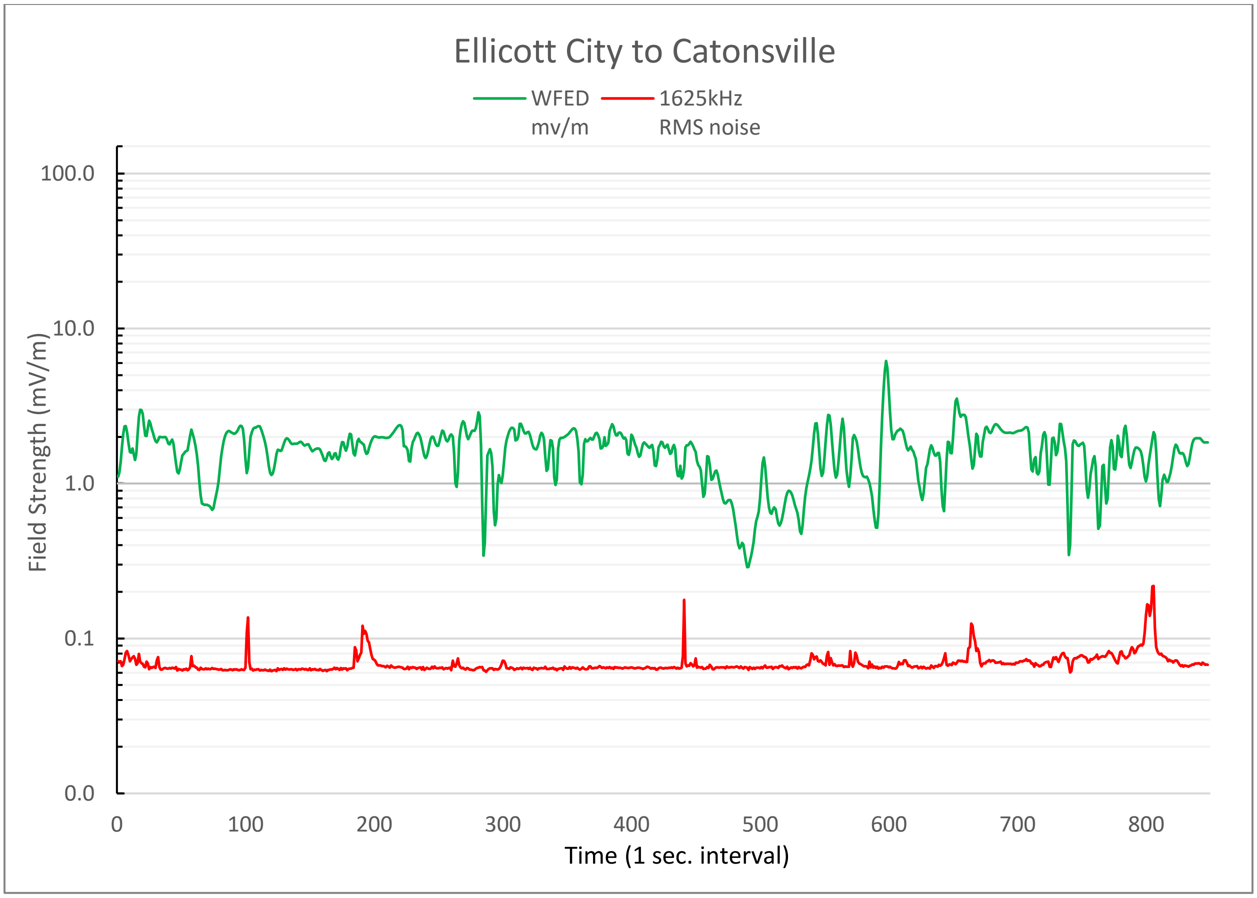


Figure 23. WFED field strength (green) and 555 kHz RMS noise measurement (red).

The charts in Figure 24 illustrate the distribution of noise peaks for each noise channel along the suburban segment. The histograms for this segment of the route show little peak noise on 555 and 1625 kHz, while 1075 kHz alone has some added noise occurrences.

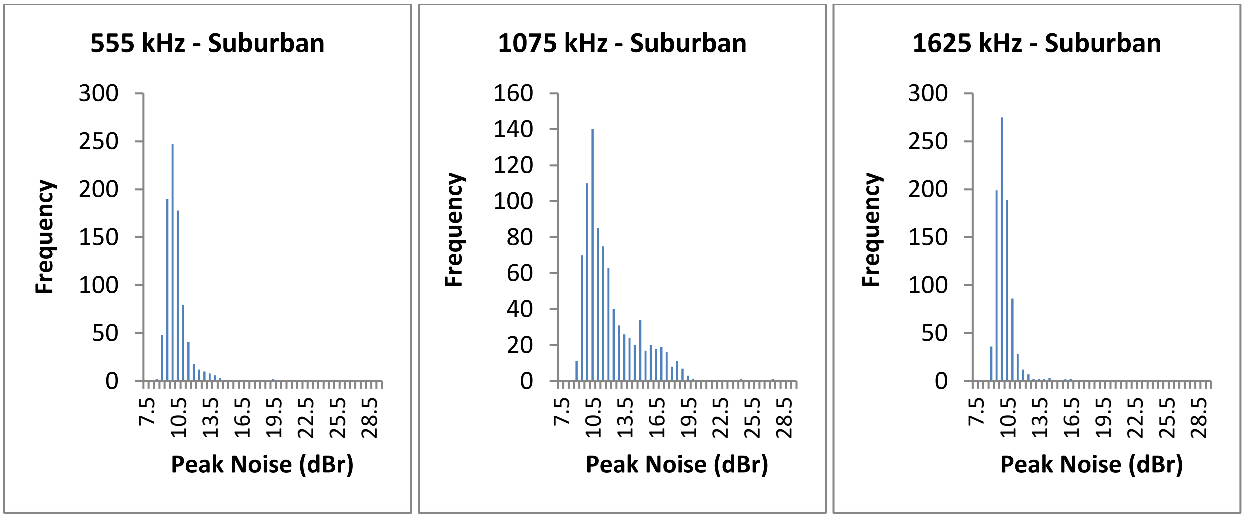


Figure 24. Distribution of noise peaks for each noise channel along the suburban route segment.

The audio tracks for the noise channels, in Figure 25, show that most of the increased noise at 1075 kHz was produced by a burst of noise with 60 Hz "buzz" characteristic.

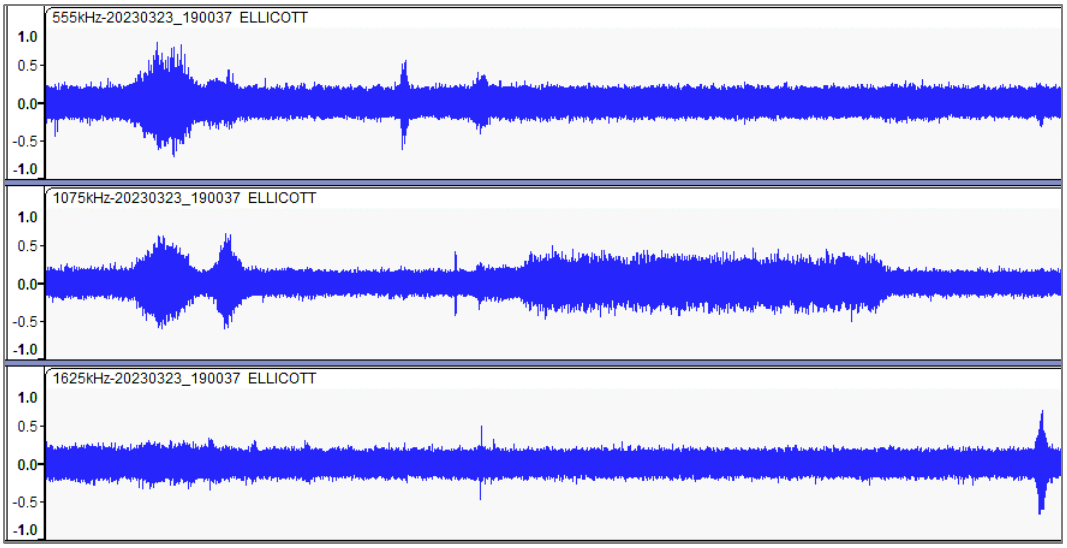


Figure 25. Noise measurement of 555 kHz (top), 1075 kHz (center) and 1625 kHz (bottom) along the suburban route.

The audio waveforms of the three noise channels in the first 2.6 minutes of the suburban route show the noise burst beginning midway through this sample and lasting for more than a minute. The noise channels at 555 kHz and 1625 kHz were not affected by the RF noise on 1075 kHz.

The differences in noise by frequency is clear from Figure 25: some noise can be limited in frequency mostly to one frequency, or two frequencies, but hardly at all on all three frequencies. The frequency restriction may be due to inductive and capacitive characteristics of the electrical device and its wiring, which forms a resonance, low pass or high pass filter.

5.4 Catonsville to West Baltimore (Suburban-Urban)

The maps in Figure 26 show the transition to a suburban-urban segment (driven from west to east) with a color-coded line to represent field strength in mV/m.

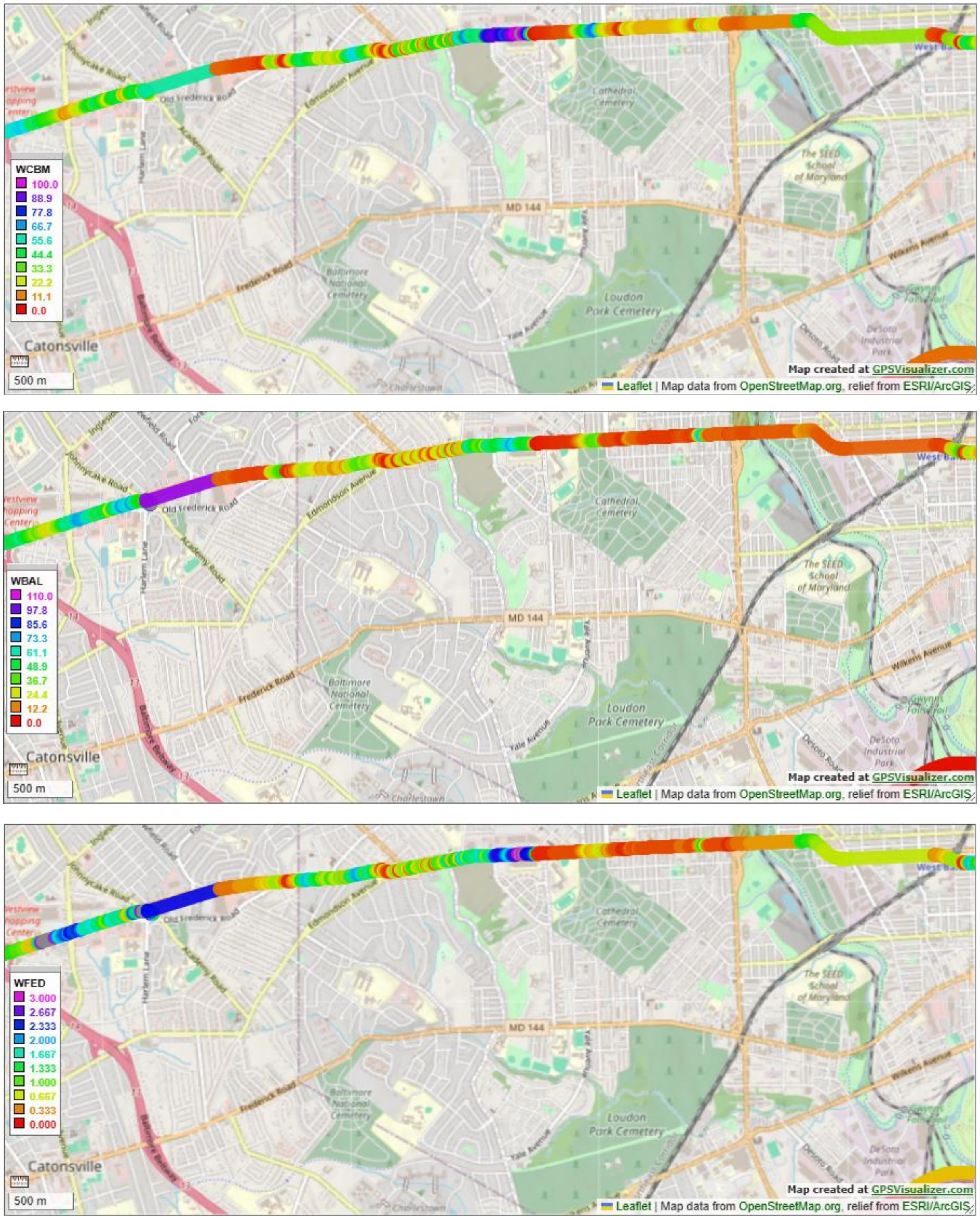


Figure 26. Measured field strength of WBAL, WCBM, and WFED along suburban-urban segment. Legend depicts field strength colors in mV/m.

One thing that is striking is the intensity of the WCBM and WBAL signals, which reach maximums of 100 mV/m and 110 mV/m (shown in violet). It is notable that WCBM is farther northwest, at 11 miles from the maximum, and WBAL is closer to north of the maximum at 6 miles, yet the signal peaks are reversed in location.

The path ray from WCBM to its peak on US Route 40 appears to be in line with a forested area and a creek Gwynns Falls/Leakin Park, which may improve the ground conductivity. There is nothing apparent about the location of WBAL's peak field strength: earlier parts of the previous route segment, north of Ellicott City, are closer to the transmitter site than the peak, northeast of Catonsville.

Field strengths gradually decline off their peaks from the suburban route segment as shown in Figure 27, settling to approximately 40 mV/m for WCBM and 20 mV/m for WBAL. WFED's signal remains within 1 and 2 mV/m.

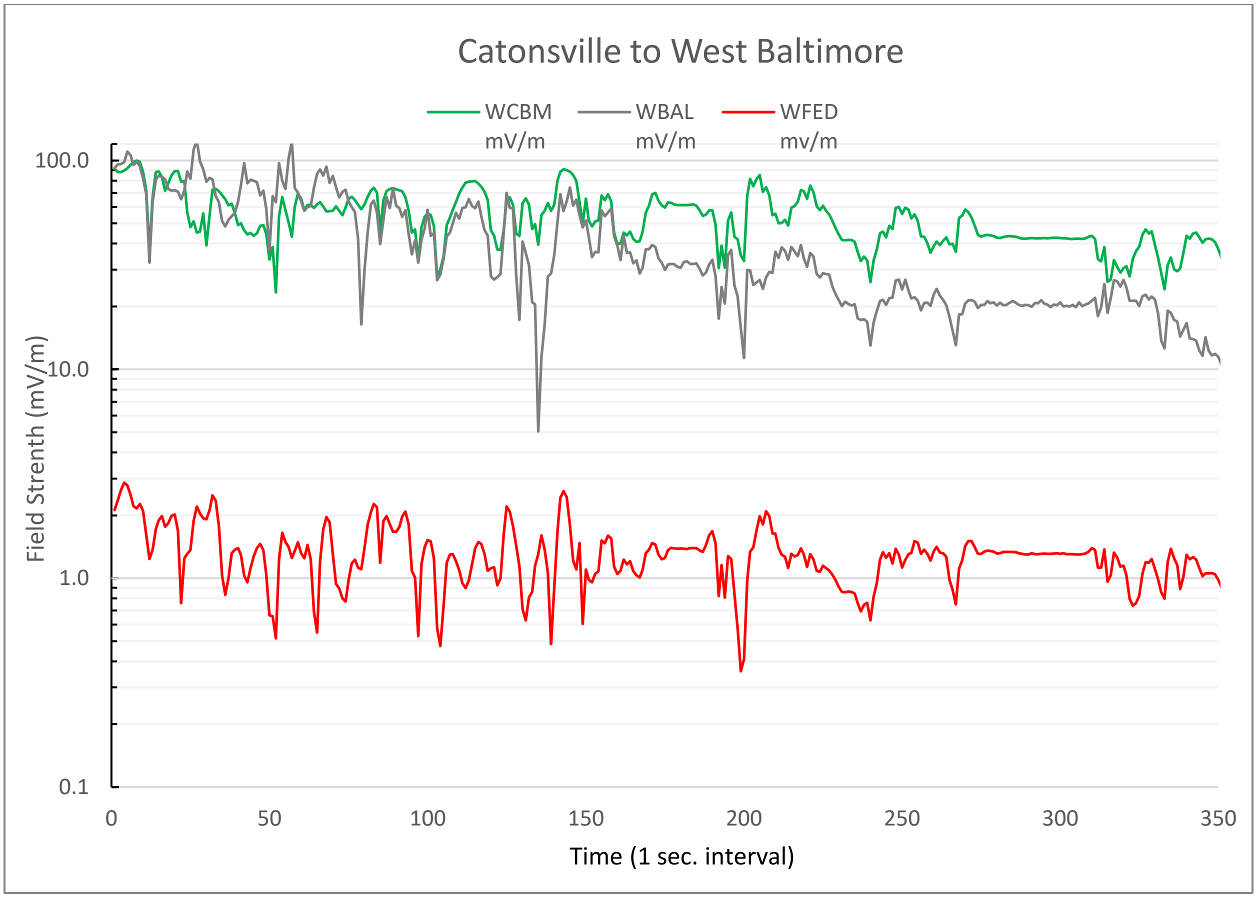


Figure 27. Field strengths along the suburban-urban segment.

The relative uniformity in station signals is due to two factors. First, this section of US Route 40 (becoming West Franklin Street to the east) is a wide 6-land divided roadway with few nearby obstructions. Second, much of the West Baltimore area has neighborhoods comprised of apartments and homes that are no more than two stories high. This building clutter environment has a minimal effect of groundwave signal propagation, particularly from the open roadway.

The charts in Figure 28 to Figure 30 illustrate the distribution of noise peaks for each noise channel along the route segment. Peak RF noise levels on the test frequencies are relatively low due to the significant separation from power lines, traffic signals, and buildings on US Route 40 and West Franklin Street, which minimize interference from these kinds of noise sources.

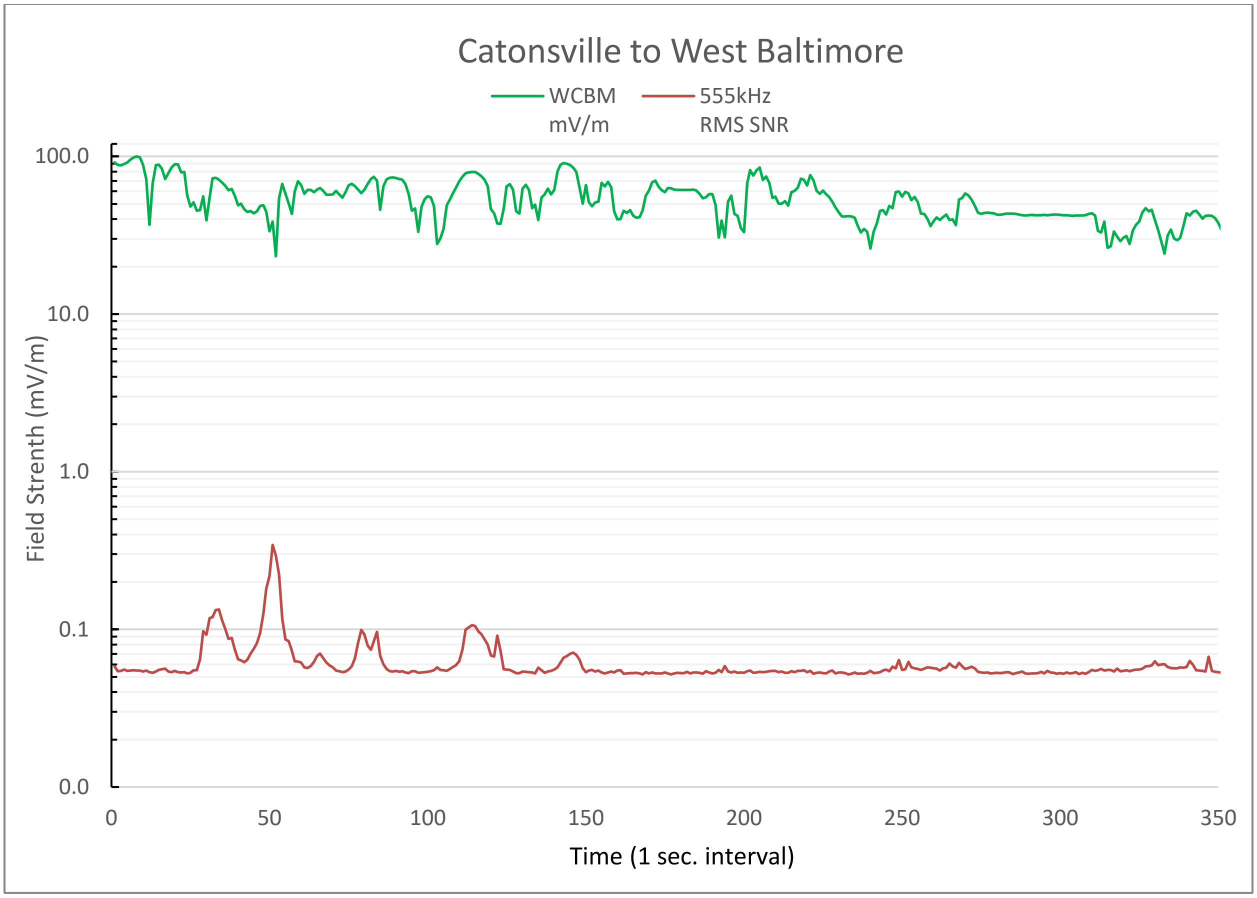


Figure 28. WCBM field strength (green) and 555 kHz RMS noise measurement (red).

The lowest test frequency, for 555 kHz shows some scattered occurrences at higher noise levels, while 1075 and 1625 kHz have tighter distributions at the lower noise levels.

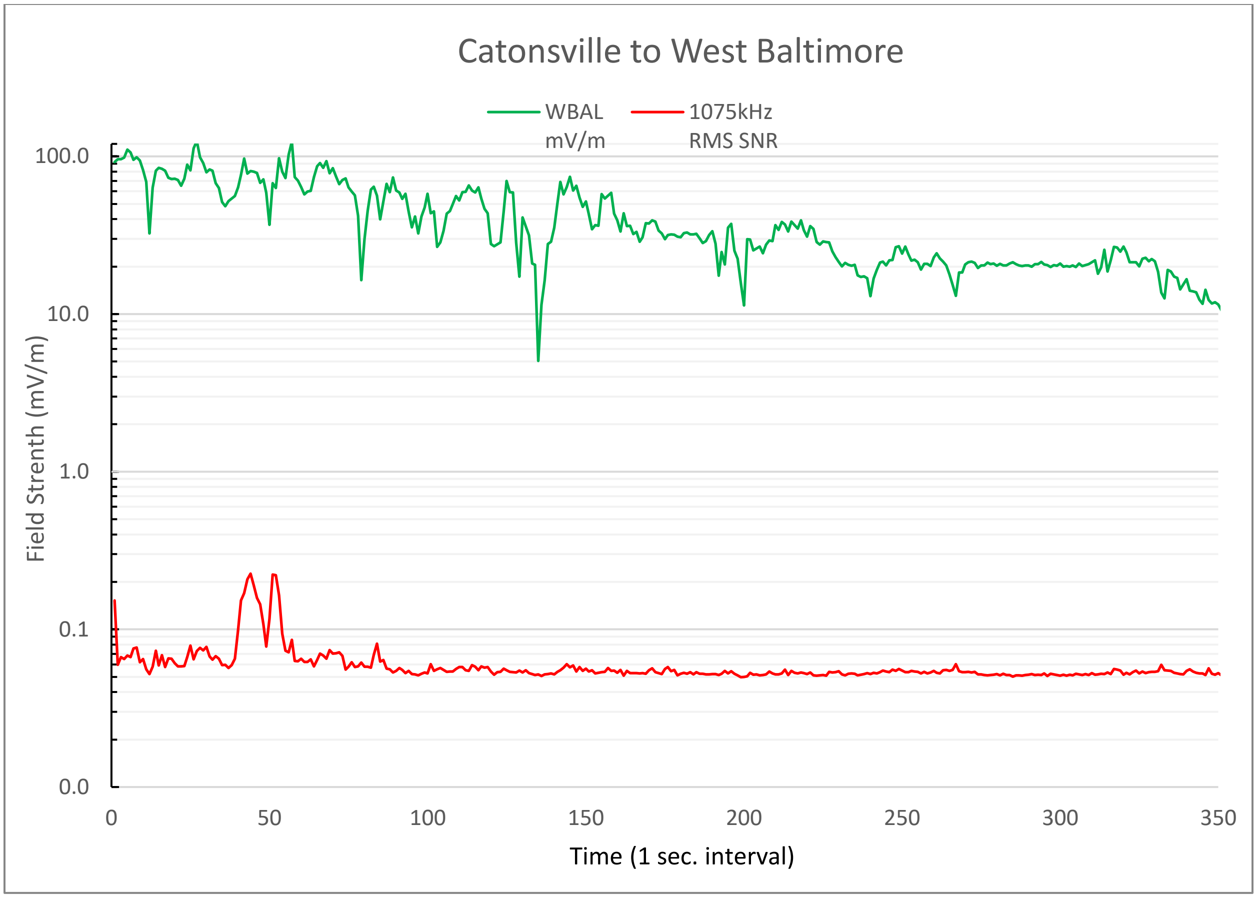


Figure 29. WBAL field strength (green) and 555 kHz RMS noise measurement (red).

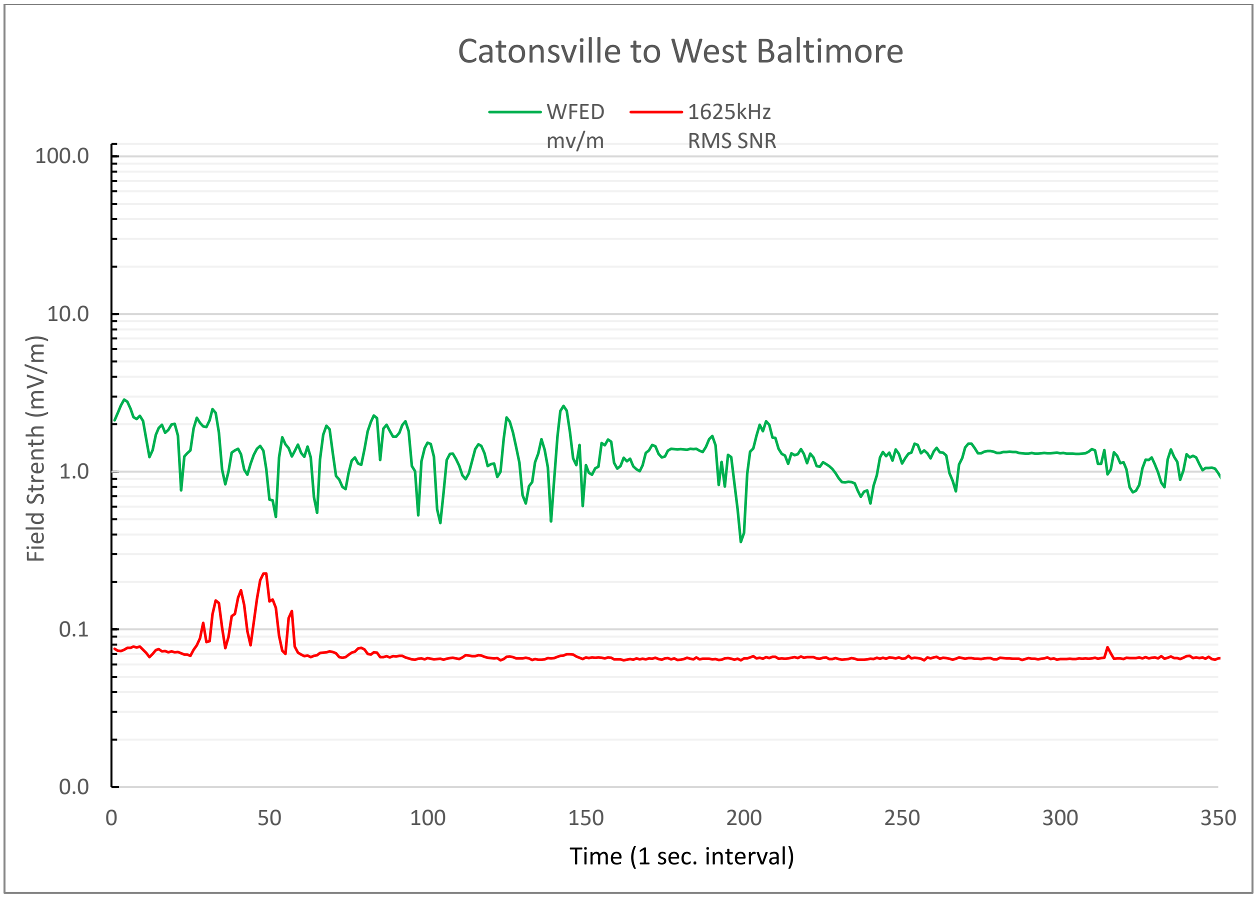


Figure 30. WFED field strength (green) and 555 kHz RMS noise measurement (red).

The charts in Figure 31 illustrate the distribution of noise peaks for each noise channel along the suburban-urban segment.

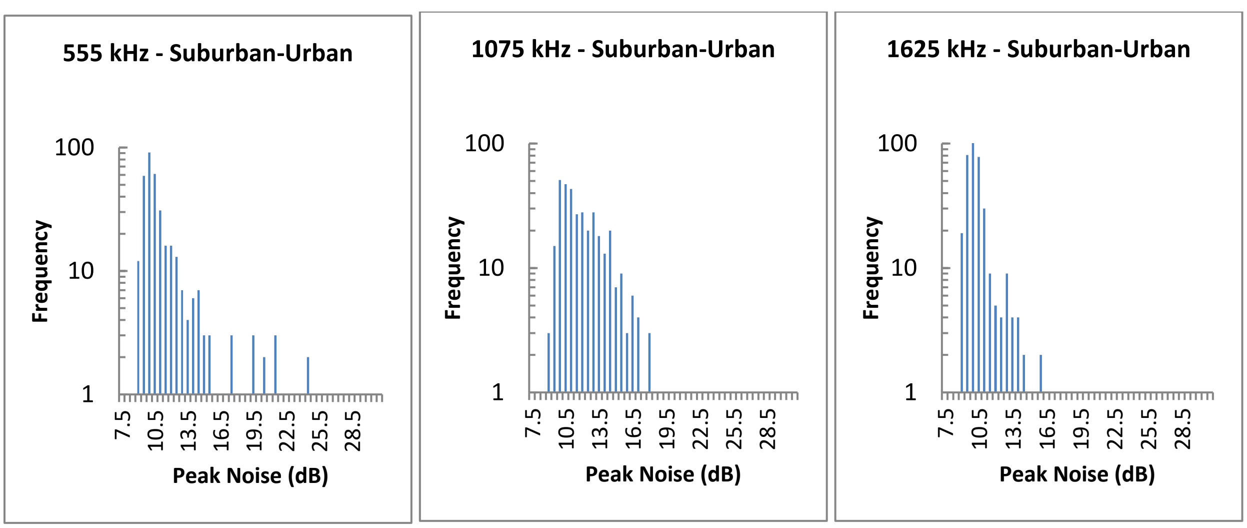


Figure 31. Distribution of noise peaks for each noise channel along the suburban-urban route segment.

5.5 West Franklin to West Mulberry Streets (Urban)

The maps in Figure 32 show the urban segment (driven from west to east) with a color-coded line to represent field strength in mV/m.

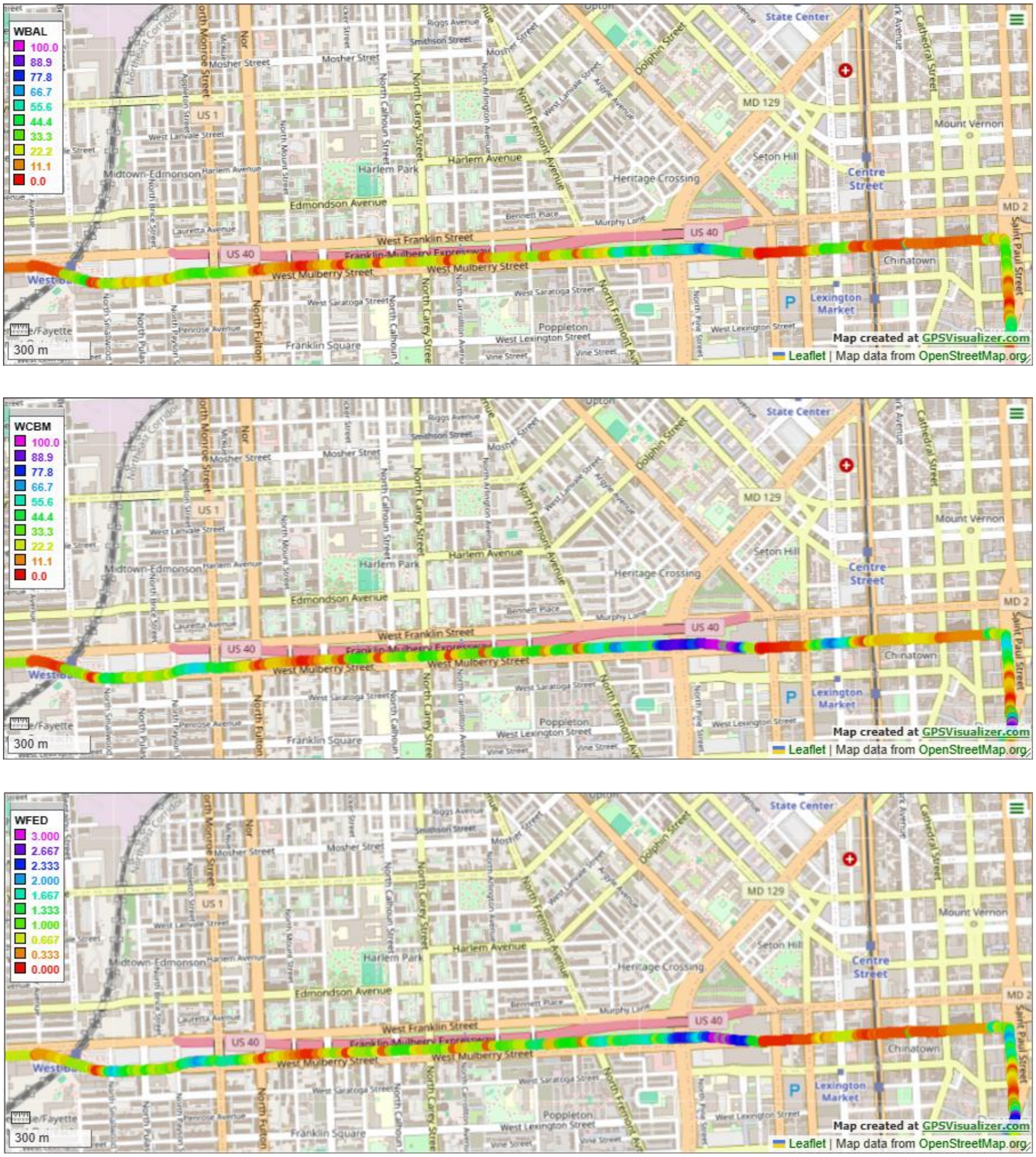


Figure 32. Measured field strength of WBAL, WCBM, and WFED along urban segment. Legend depicts field strength colors in mV/m.

Field strengths from WCBM and WBAL again reach high levels, sharing the 100 mV/m scale (see Figure 33). WFED shows a remarkably similar track of field strengths, but on a scale of 3 mV/m maximum. West Mulberry Street comprises much of this route segment and is part of US-40, a fast four-lane divided road.

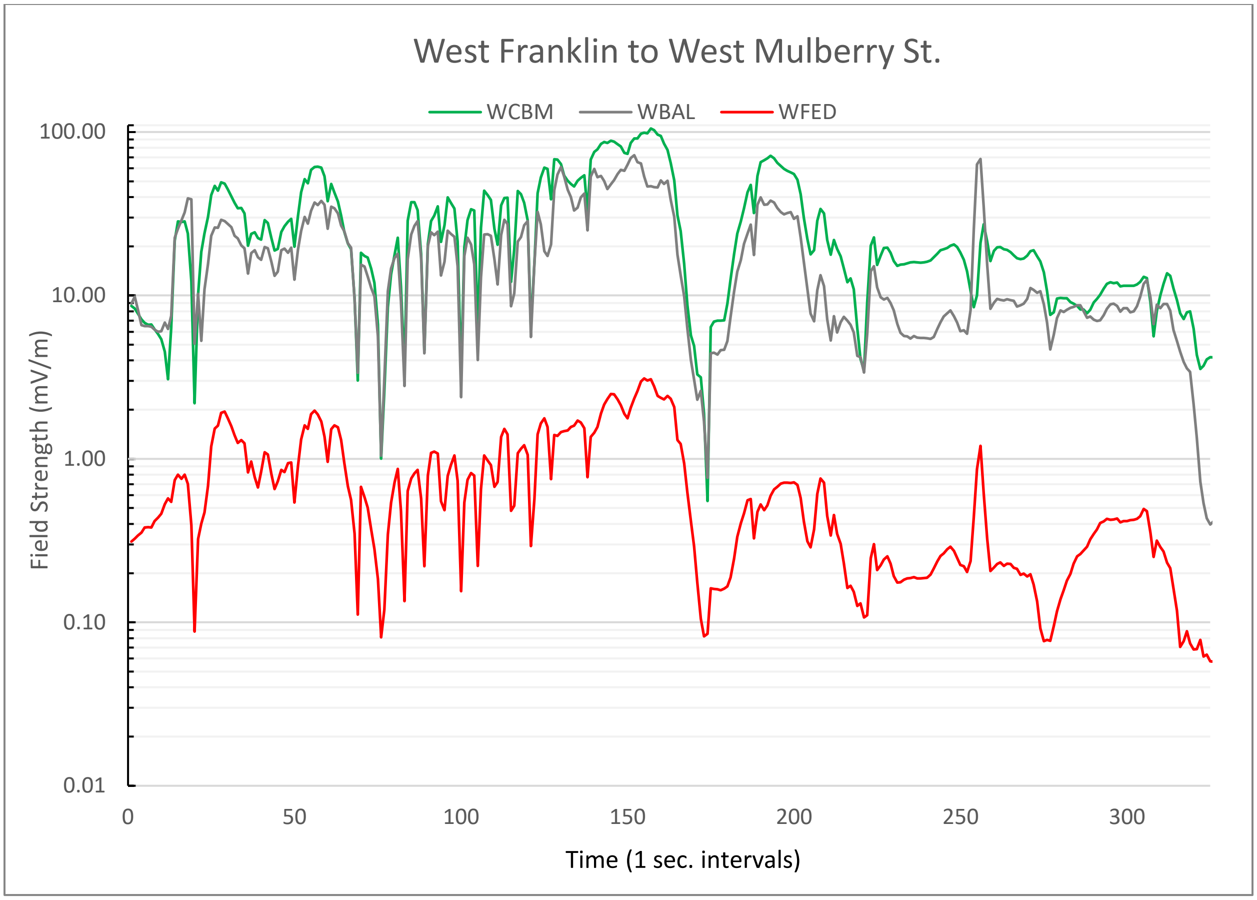


Figure 33. Field strengths along the urban segment

Field strengths in the open section of this route field strengths remain relatively high but display a regular pattern of signal rise and fall. In the middle of blocks the signals dip because of clutter attenuation. The signals reach maximums near the crossing of MD Route 129, which is an open area that is distant from buildings. The three signals drop in the last half mile to the east, where it turns into a city street, flanked by two- to three-story buildings.

The cyclical effect on signals in passing through city blocks is clear in these charts. Driving under the large Metro West Garage caused a major dip in signals in the middle. Continuing east, signals decline in the dense low-rise business district.

Figure 34 shows a major jump in noise around 255 seconds from the segment's start, crossing North Howard Street in Baltimore. The environment in this area continued as densely packed two story buildings, and nothing appears out of the ordinary until one notices the electric streetcar lines overhead. The effect was a loud “buzz” in the station audio reception.

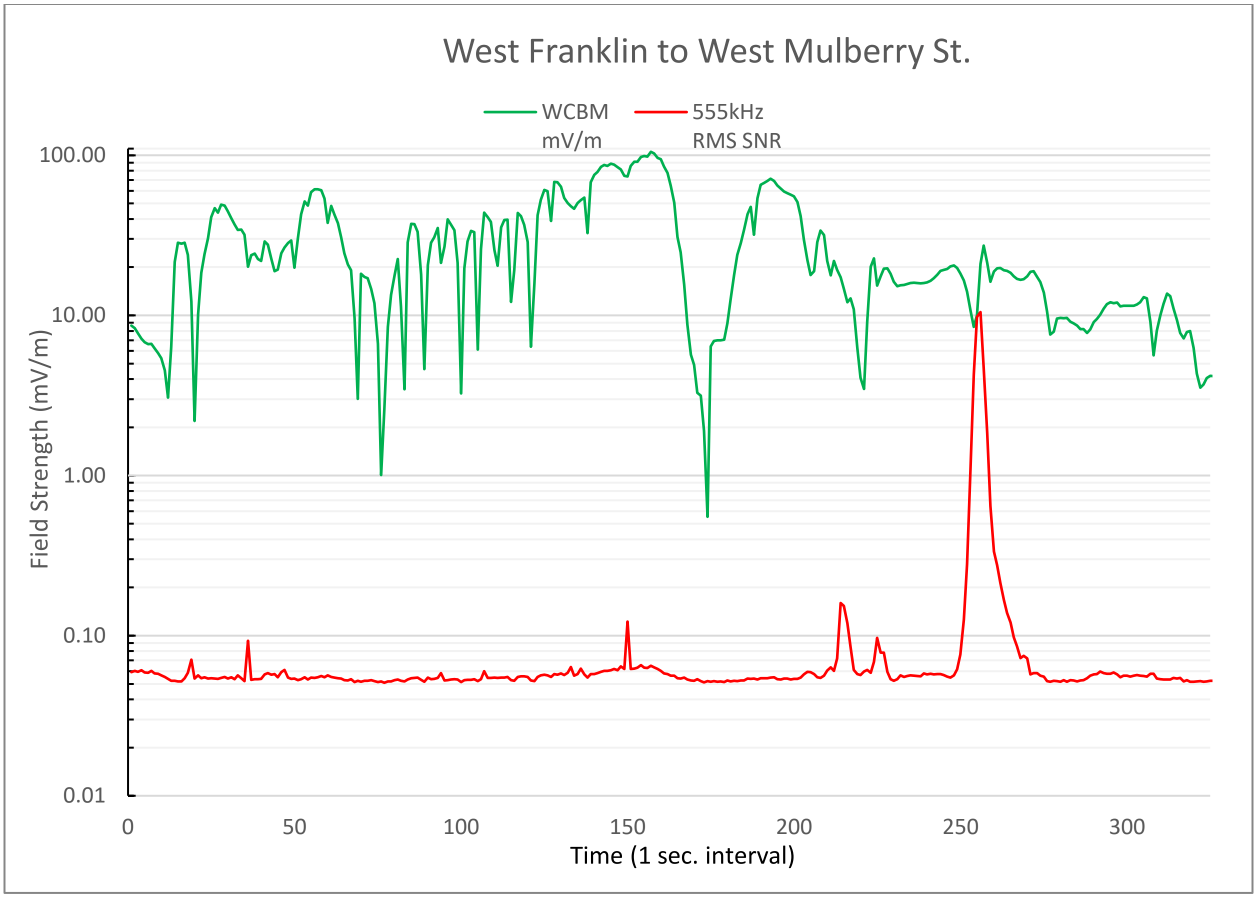


Figure 34. WCBM field strength (green) and 555 kHz RMS noise measurement (red).

North Howard is a north-south route for the Light RailLink line, shown in Figure 35. This line can be seen in the map of Figure 32. Although there was no trolley nearby at the time, the electric lines, less than 25 feet over the road, appear to continuously radiate high levels of RF noise. It is notable that the field strength of these emissions decrease with frequency, by comparing Figure 34, Figure 36 and Figure 37.

Figure 35. Baltimore Light RailLink.

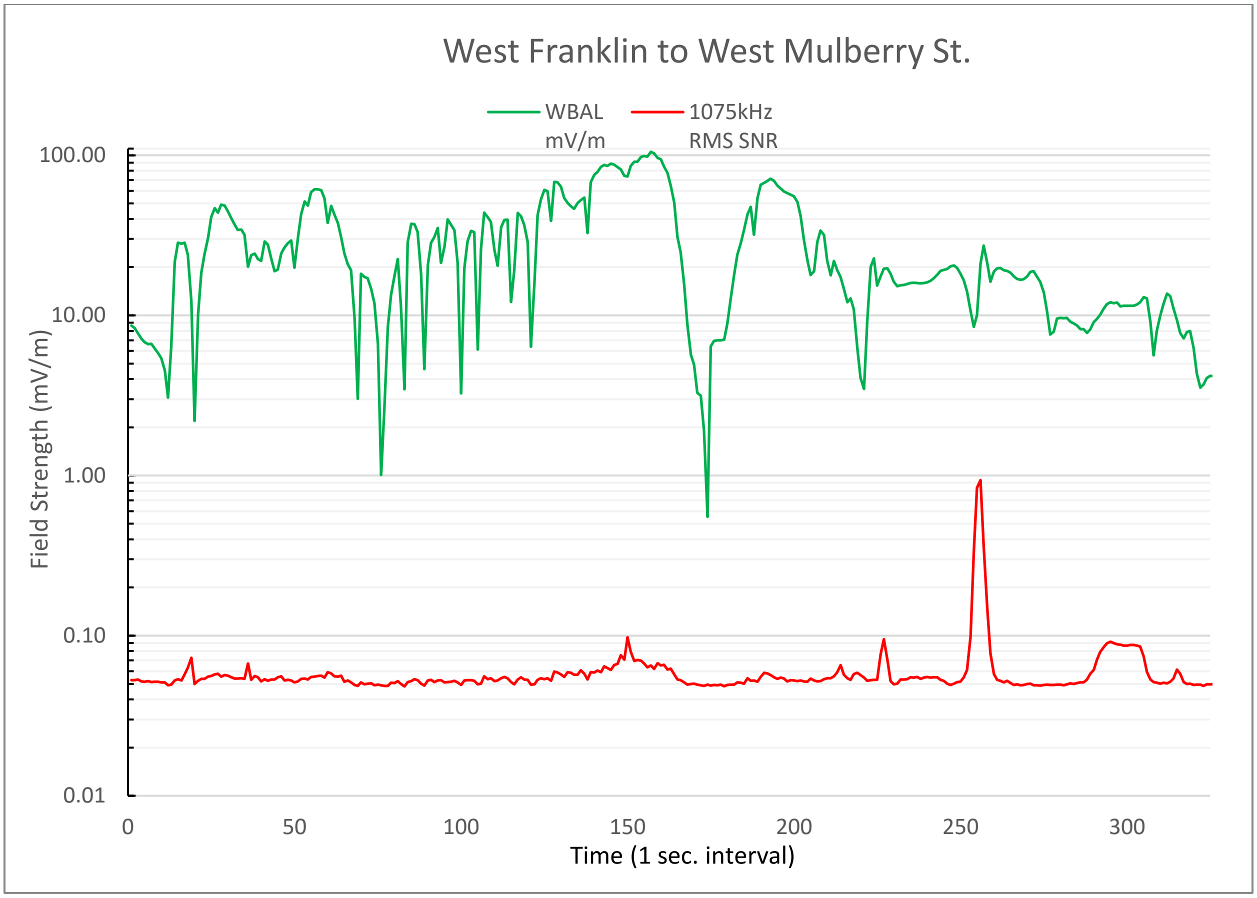


Figure 36. WBAL field strength (green) and 1075 kHz RMS noise measurement (red).

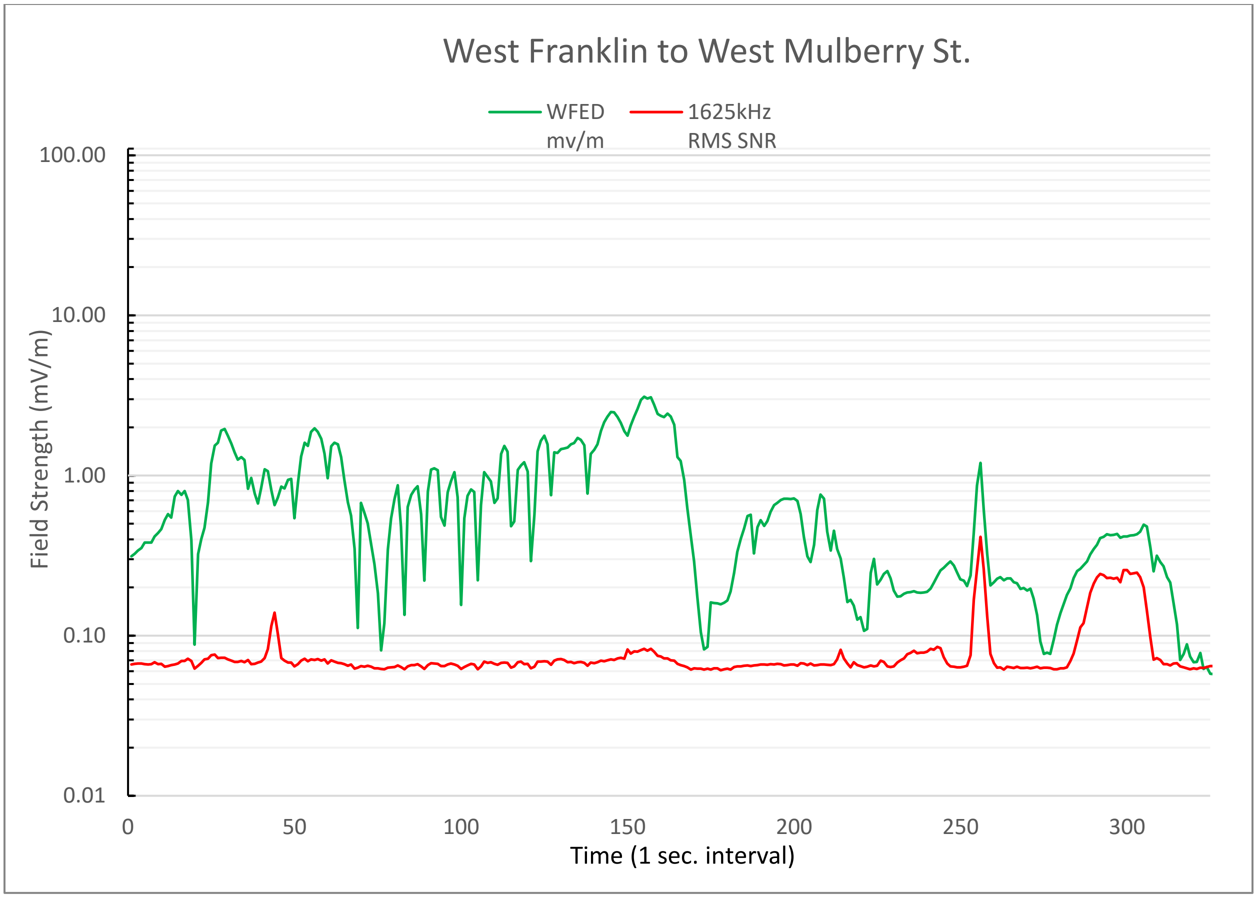


Figure 37. WFED field strength (green) and 1625 kHz RMS noise measurement (red).

The charts in Figure 38 illustrate the distribution of noise peaks for each noise channel along the urban segment. Due to the relatively open space around most of this route the occurrence of noise peaks is reduced. The 1625 kHz test frequency shows slightly higher peaks than usual.

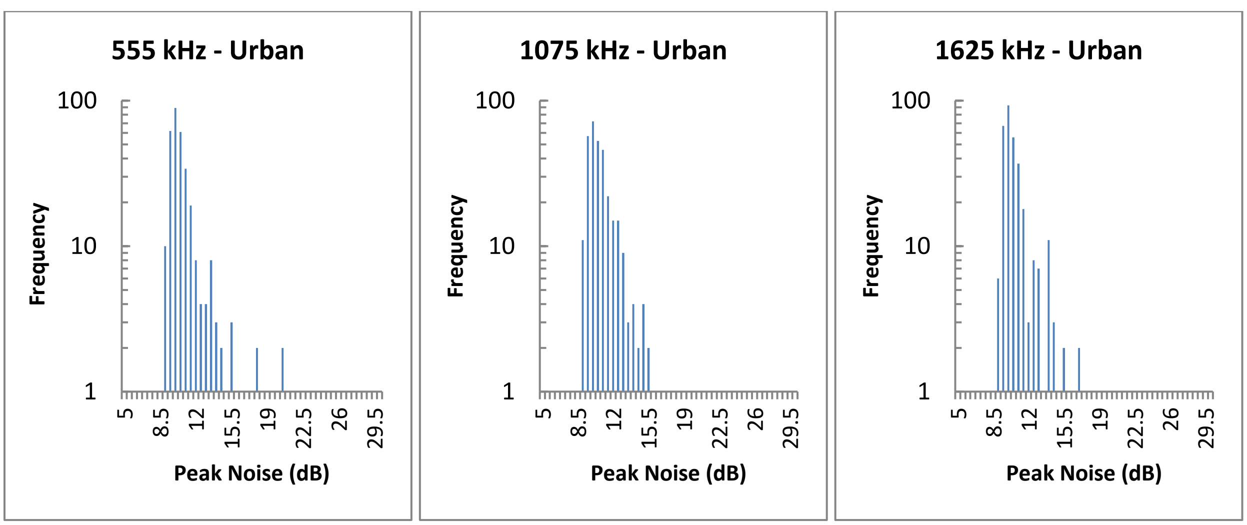


Figure 38. Distribution of noise peaks for each noise channel along the urban route segment.

Listeners to WCBM and WBAL should receive low noise signals until the end of this route. The measurement includes a turn around the corner to Saint Paul Street, which shows a rapid fall in field strengths and a rise in noise-limited audio.

5.6 West Mulberry Street through downtown Baltimore (Dense Urban)

The maps in Figure 39 show the Dense Urban segment (driven from north to south) with a color-coded line to represent field strength in mV/m.

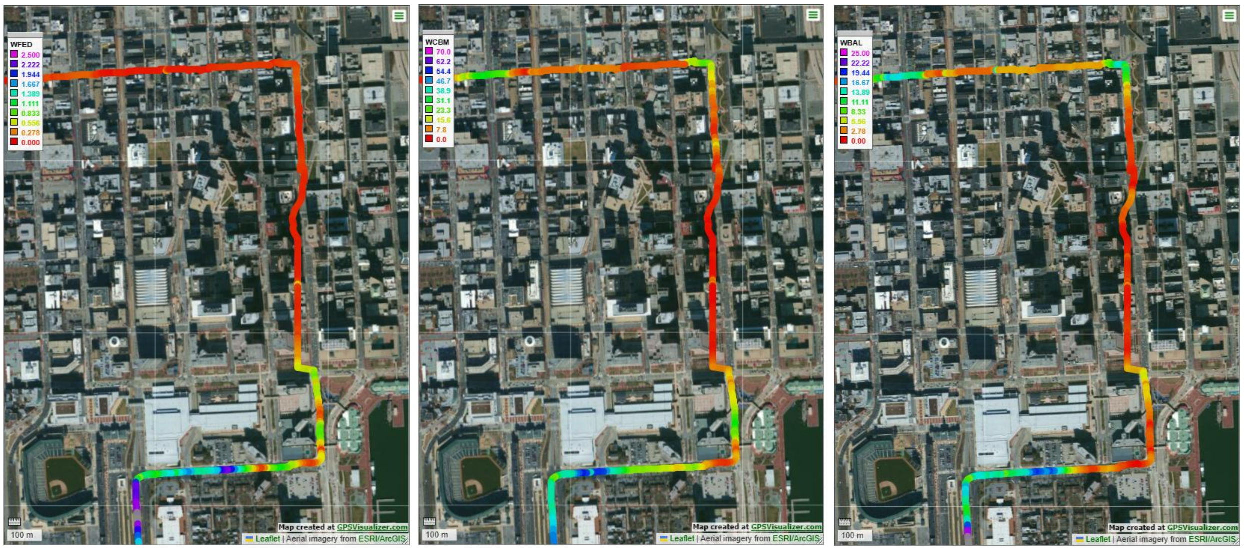


Figure 39. Measured field strength of WBAL, WCBM, and WFED along Dense Urban segment. Legend depicts field strength colors in mV/m.

The final segment of this route passes through Baltimore's central business district, starting at West Mulberry Street and turning onto Saint Paul Street (aka Light Street). Due to the city's numerous high-rise buildings, including at least five exceeding 35 stories, the radio signals from nearby transmitters exhibit varying levels of attenuation.

Field strengths for this route are shown in Figure 40. WBAL's signal, for example, reaches a peak of 20 mV/m on a small portion of Mulberry Street but quickly declines as you head south. Beyond the harbor, the signal drops below 0.5 mV/m, a significant reduction for a 50-kW transmitter just 10 miles away.

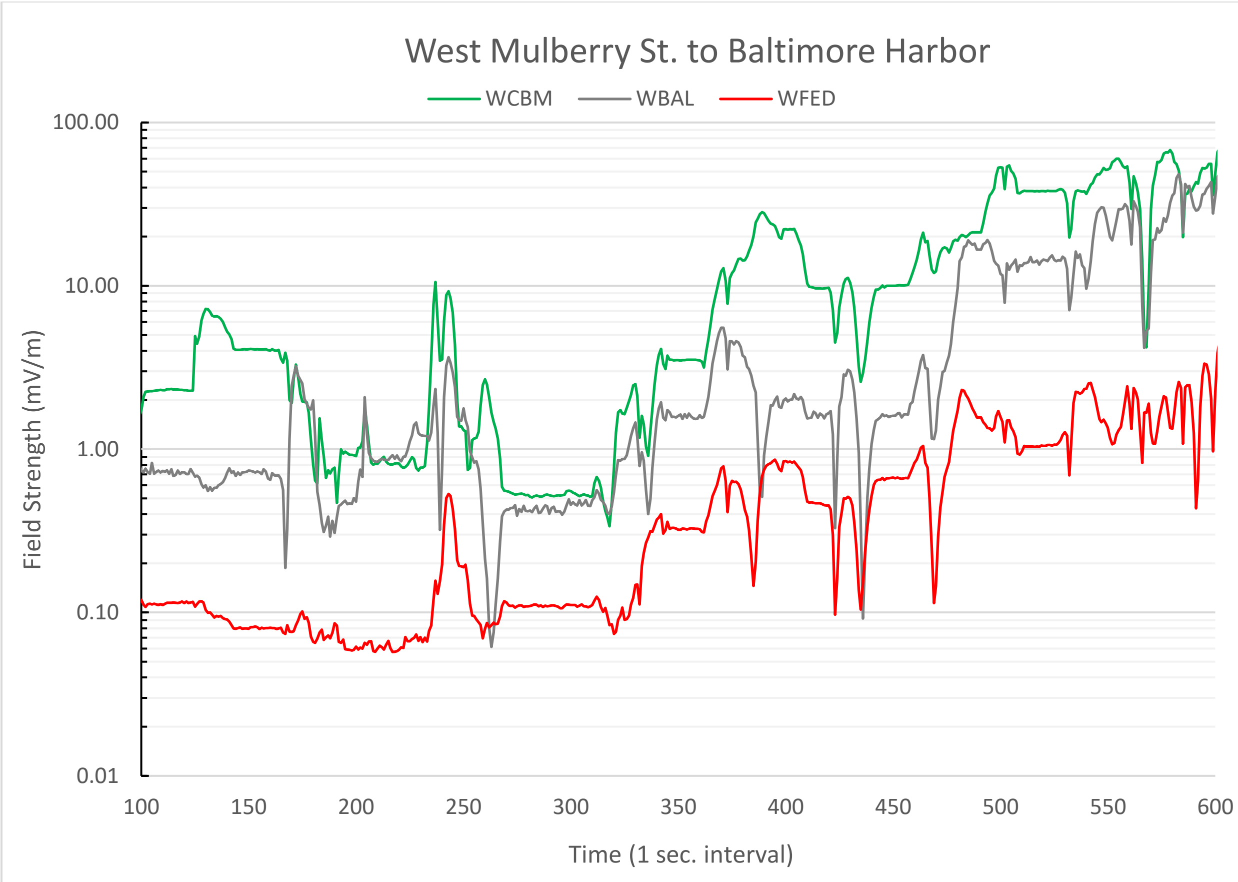


Figure 40. Field strengths along the dense urban segment.

In contrast, WCBM's signal performs similarly through the high-rise district, dropping to 0.6 mV/m. Both signals rise again out of the shadow of the high-rise area, rising to 20 mV/m for WBAL and 55 mV/m for WCBM on part of Conway Street, heading toward Camden Yards stadium. One can realize the devastating impact of urban clutter by observing that the field strengths of these two stations were nearly 100 mV/m on Mulberry Street, less than a mile away!

WFED's signal, arriving from the southwest, shows the reverse pattern. Signal weakens on the north side of downtown, rarely exceeding 0.1 mV/m along Saint Paul and Mulberry Streets.

The “urban canyon” on Saint Paul Street weakens the station signals to as low as 0.5 V/m, but conversely, Figure 41, Figure 42 and Figure 43 indicate that noise levels are for the most part exceptionally low. As shown in Figure 41, the field strength of RMS noise on 555 kHz is around 50 to 60 mV/m.

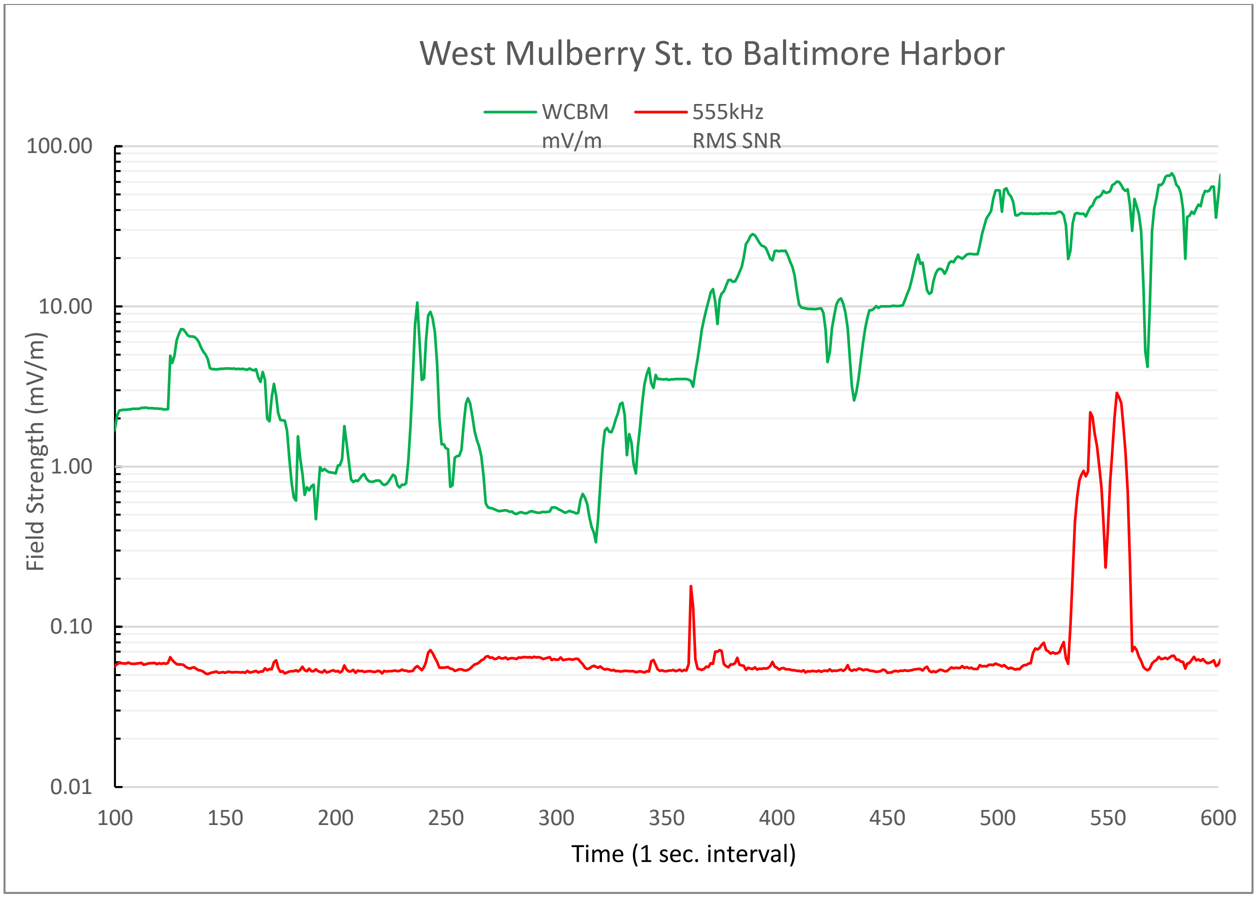


Figure 41. WCBM field strength (green) and 555 kHz RMS noise measurement (red).

While passing through the urban canyon in the first half of St. Paul Street the reception is weak and noisy, but once the measurements drove south of the skyscrapers, and turned west on Conway Street the field strengths returned. However, there are two closely spaced occasions where the RMS noise rises enormously, near the end of this route.

Close examination of the map found that this happened at the last (left) turn to Cal Ripken Way, across from the Camden Yards baseball stadium. Cal Ripken Way is South Howard Street, just two blocks north. These high-noise points occur at Camden Station, a depot for the Baltimore Light RailLink, and the same trolley line that causes the severe noise burst on Mulberry Street.

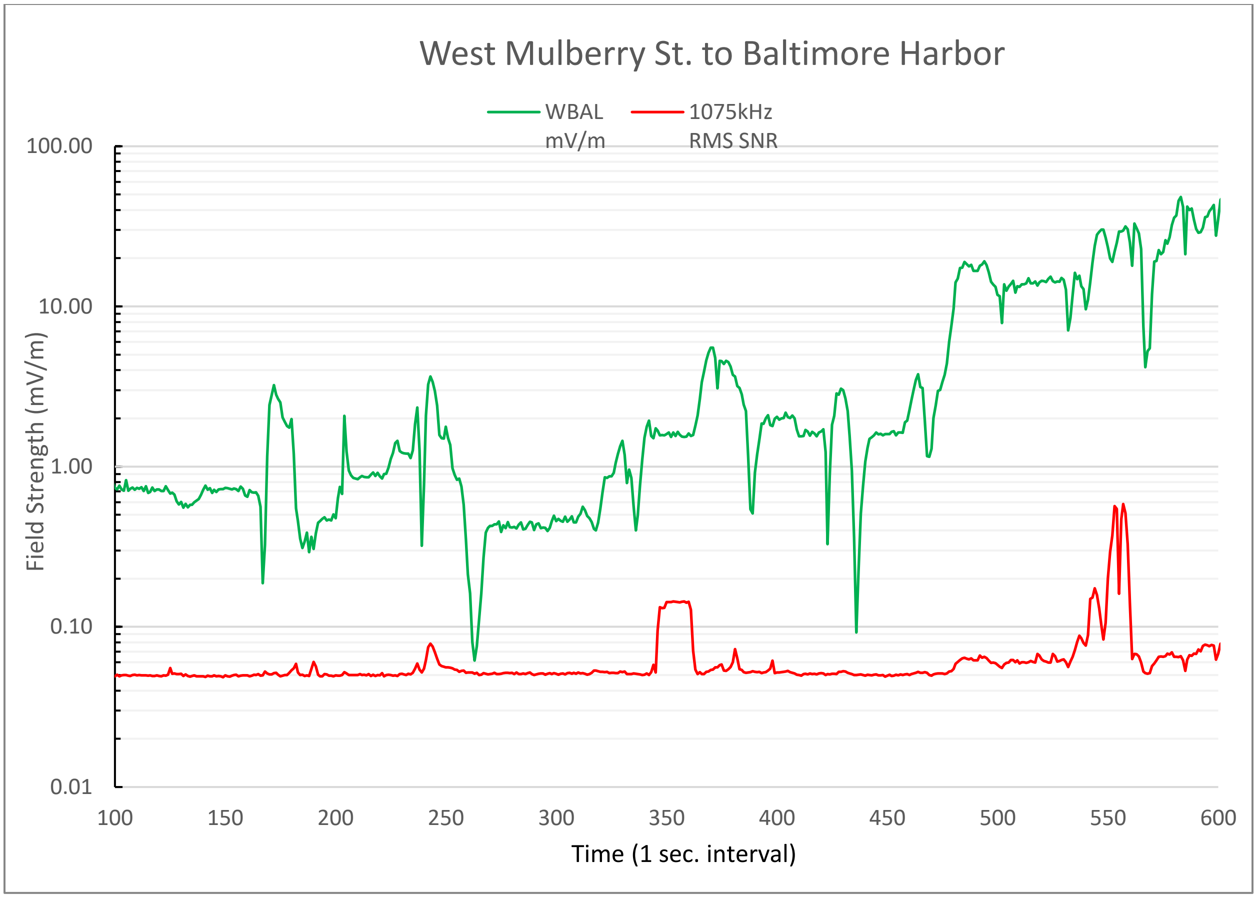


Figure 42. WBAL field strength (green) and 1075 kHz RMS noise measurement (red).

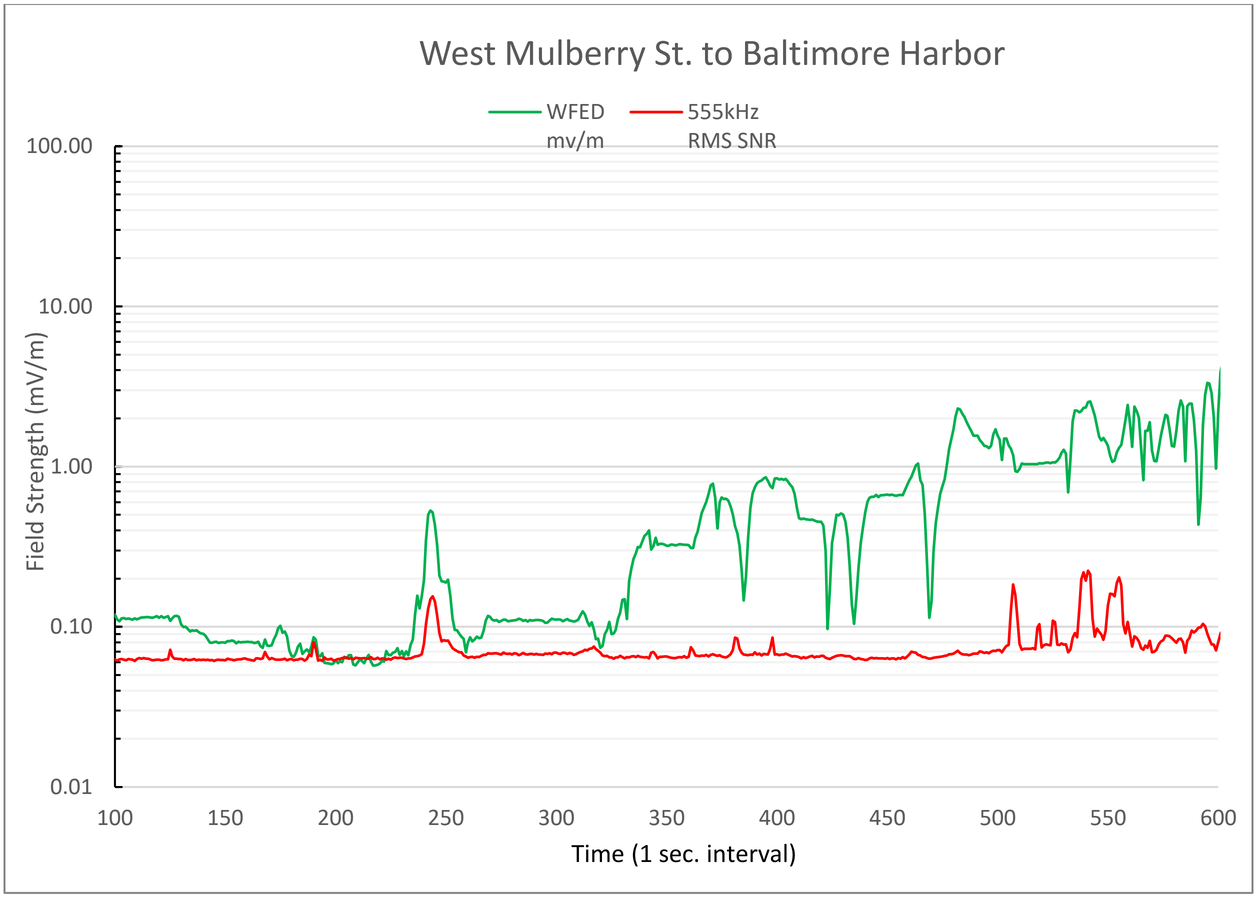


Figure 43. WFED field strength (green) and 1625 kHz RMS noise measurement (red).

The charts in Figure 44 illustrate the distribution of noise peaks for each noise channel along the route segment. This peak noise was surprisingly low, like the RMS noise measurements. Despite the drops in station signals discussed above, listening tests confirmed that that the noise increases were less of a "crackle" and more like swishing noises.

Perhaps contrary to what one would expect, the noise levels in Baltimore's downtown area are not high, aside from the intense RF noise near the light rail lines. If AM station signals were not severely weakened by building clutter loss and shadowing, the low urban RF noise levels would result in service quality that was found in suburban areas, far outside the city.

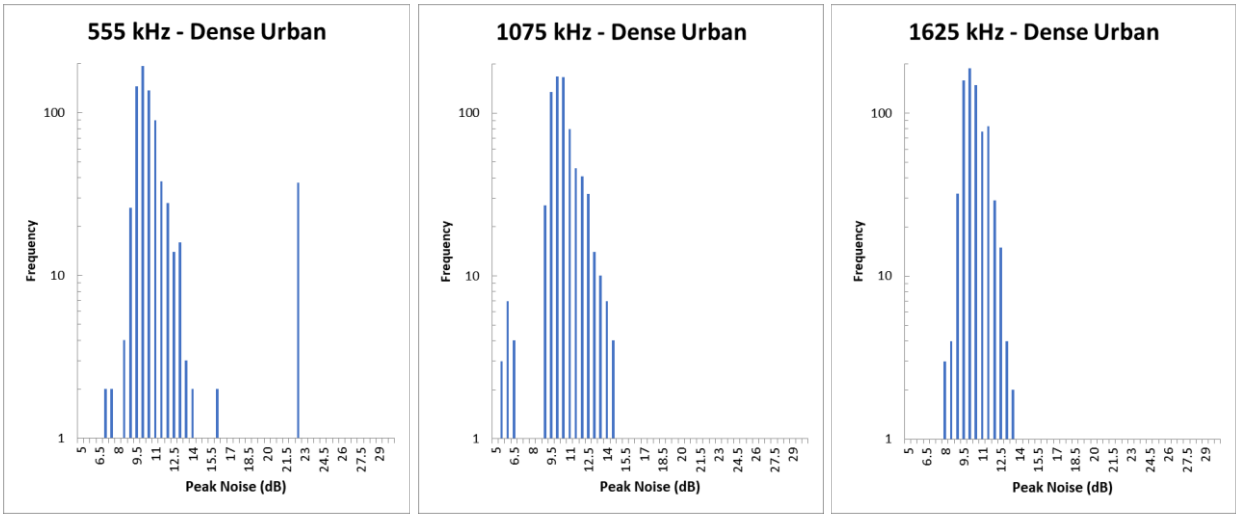


Figure 44. Distribution of noise peaks for each noise channel along the dense urban route segment.

6 CONCLUSIONS

This study examined the reception quality of large-class AM radio stations in various environments, including rural, suburban, and urban areas. While these stations boast wide-area coverage, audio quality can be affected by factors such as RF noise and field strength.

6.1 Rural Environments

In rural areas, field strengths and reception quality often fell short of predicted levels, as measured from a vehicle on the roadways. This discrepancy can be attributed to factors like terrain, vegetation, and power line interference. Despite average field strengths of 1.5 mV/m, which should theoretically provide satisfactory reception, noise fluctuations and occasional noise peaks can disrupt listening experiences.

6.2 Suburban Environments

Suburban areas, characterized by a mix of residential and commercial zones, offered a more stable reception environment compared to rural areas. However, noise from traffic, local businesses, and power lines could still impact signal quality. High field strengths from powerful stations like WCBM and WBAL helped to mitigate these effects.

6.3 Urban Environments

Downtown Baltimore presented the most challenging environment for AM radio reception. Densely populated areas with tall buildings significantly attenuated signal strength, leading to fading, noise and occasional loss of signal. This underscores the importance of strategic transmitter placement to ensure adequate coverage in urban centers.

6.4 Key Findings

- Field strength variations: Field strengths often deviated from predicted levels for two principal reasons: (1) electric fields from stations may be substantially less than the actual field strength based on traditional ground-wave propagation models, and, (2) building clutter can reduce field strengths by a factor of up to 100 to 1 (40 dB), which are not accounted for in signal coverage maps.
- Noise sources: Power lines, traffic, and nearby electrical equipment introduce noise into the AM band, but signal to RMS RF noise levels are generally good for mobile listening at field strengths as low as 3 to 5 mV/m.
- Urban challenges: Densely built-up areas can significantly attenuate AM signals that effectively result in coverage ‘holes’ where AM reception is unacceptable. These are of course areas of population concentration, which can result in large losses to a station’s service population.
- Frequency-specific noise: Noise can be frequency-dependent, affecting certain channels more than others.

6.5 Recommendations

- Strategic transmitter placement: Consider locating AM transmitters to ensure adequate coverage in built-up areas, to overcome urban clutter loss.
- Deploy Single Frequency Networks: Relocation of primary transmitter sites near downtown areas may be prohibitively costly, but a synchronous booster transmitter (pending FCC approval) can fill

in urban signal loss, restoring thousands of potential listeners. The cost of a booster transmitter on a commercial building may be economically feasible, depending upon the population that may be served.

- Receiver design: Improve car AM antenna efficiency, which has been lost over time through miniaturization and for aesthetic reasons. Add mobile noise-reduction capabilities to enhance audio performance in challenging environments.

By addressing these factors, the AM radio industry can strive to provide a more consistent and reliable listening experience for audiences in diverse settings.

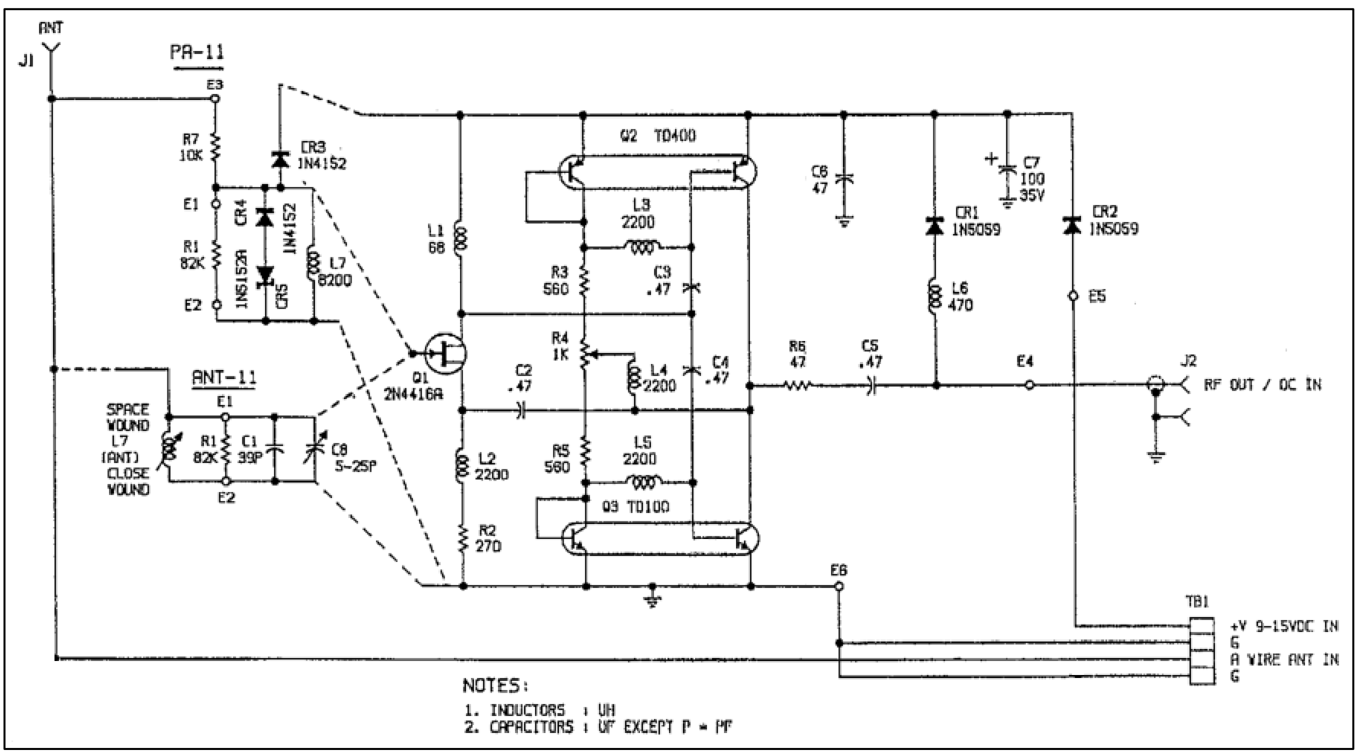
Appendix 1 – Information on Devices Used in Measurement

Measurement Antenna

The mobile measurement antenna (shown at right) is an active E-field type using a telescopic whip, strapped to the roof of the vehicle. The telescopic whip antenna was set for an extension of 28 inches, which balanced antenna gain and avoidance of overload from strong nearby AM stations.

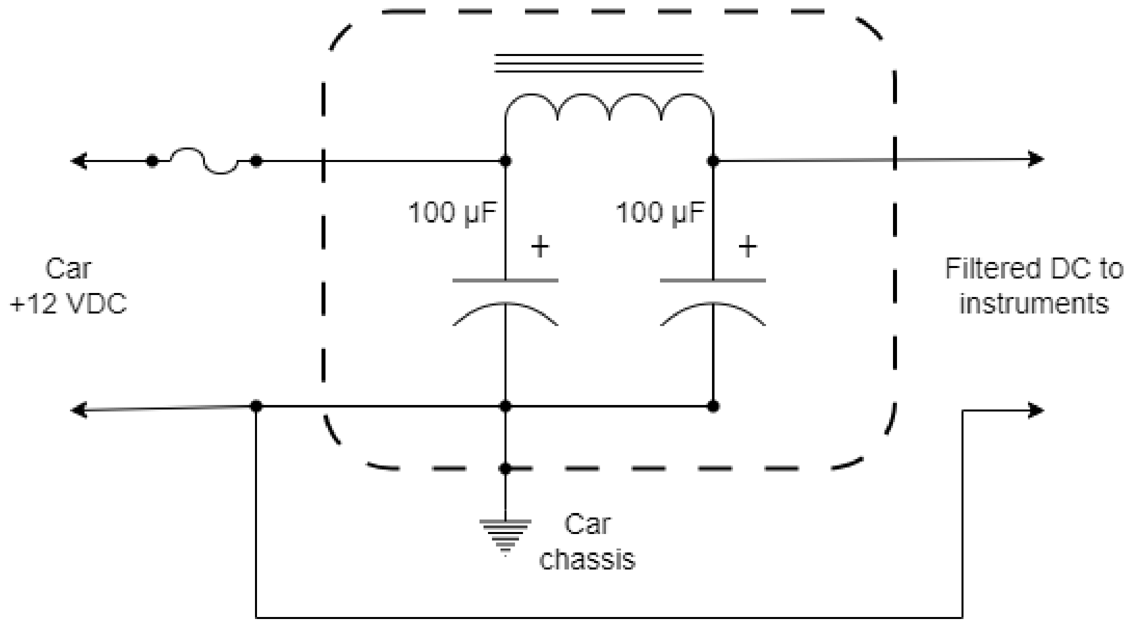
The antenna is connected to an integrated amplifier, providing unity gain across the AM band. The output impedance is approximately 50 ohms to drive LMR-200 cable. A schematic of the impedance converter is shown in the figure below, comprising a J-FET input and a balanced bipolar transistor output.

The amplifier case is surrounded in a styrofoam box on all sides, except the bottom, for support and stability at highway speeds. The 12 VDC power cable and RF coax were routed through the window to the instrumentation in the vehicle.



Potomac Instruments PI-11 Impedance Converter.

To ensure the 12-volt power to the instrumentation was free of car electrical noise, a low pass filter was used, as shown in the schematic and photo here. The filter's case was tied to a chassis bolt and the dash 12-volt socket and effectively removed alternator ripple as well a high frequency noise.



Receiver Hardware

The measurements were collected with an SDRplay model RSPdx® "software defined receiver" (SDR, shown at right) capable of monitoring radio frequencies from 1 kHz to 2 GHz at 14-bit resolution. With the supplied SDRuno® software it can analyze and store the entire AM broadcast band continuously. A Hewlett Packard Pavilion laptop running Windows 10 controlled the SDR and recorded data.

The RSPdx ensures a high dynamic range by activating a 2 MHz low pass filter for the AM band measurements. This ensured that out-of-band signals would not degrade performance.

The whole-band spectrum recordings are stored on the computer as WAV format files, except the I and Q data are stored in what would be left and right channels for audio. The data was processed later to convert the IQ data into audio files in FLAC format. The times on the audio files match the graphs, so readers can observe the measurements while they hear the reception on the three "quiet" channels and the three AM stations.

The SDRplay's measurements and controls are displayed continuously during operation, providing a real-time display, like spectrum analyzers. However, it offers some unique features during live operation. Shown on page A-6 is a screenshot of the unit in operation, displaying the full AM band and dozens of AM signals. The center portion displays a frequency range of 500 to 1750 kHz, including the carrier reference pilot at 1720 kHz. The lower portion of the display is a "waterfall" chart of the signal intensity and bandwidth over time.

A data sheet for the SDRplay is provided below.

RSPdx
Multi-antenna port 14-bit SDR

The SDRplay RSPdx is a wideband full-featured 14-bit SDR which covers the entire RF spectrum from 1kHz to 2GHz. Combined with the power of readily available SDR receiver software (including 'SDRuno' for Windows and Multi-Platform 'SDRconnect' supplied by SDRplay) you can monitor up to 10MHz spectrum at a time. The RSPdx provides three software selectable antenna inputs, and an external clock input. All it needs is a computer and an antenna to provide excellent communications receiver functionality. A documented API allows developers to create new demodulators or applications around the platform.

KEY BENEFITS & FEATURES

- Covers all frequencies from 1kHz through VLF, LF, MW, HF, VHF, UHF and L-band to 2GHz, with no gaps
- Receive, monitor and record up to 10MHz of spectrum at a time
- Performance below 2MHz substantially enhanced – improved dynamic range and selectivity
- Software selectable choice of 3 antenna ports
- Enhanced ability to cope with extremely strong signals
- External clock input for synchronisation purposes, or connection to GPS reference clock for extra frequency accuracy
- Excellent dynamic range for challenging reception conditions
- Free use of windows-based SDRuno software which provides an ever-increasing feature-set
- Strong and growing software support network
- Calibrated S meter/ RF power and SNR measurement with SDRuno (including datalogging to .CSV file capability)
- Documented API provided to allow demodulator or application development on multiple platforms

APPLICATIONS

Amateur
Shortwave radio listening
Broadcast DXing (AM/FM/TV)
Panadaptor
Aircraft (ADS-B and ATC)
Slow Scan TV
Multi-amateur band monitoring
WSPR & digital modes
Weather fax (HF and satellite)
Satellite monitoring
Geostationary environmental satellites
Trunked radio
Utility and emergency service monitoring
Fast and effective antenna comparison

Industrial
Spectrum Analyser
Surveillance
Wireless microphone monitoring
RF surveying
IoT receiver chain
Signal logging
RFI/EMC detection
Broadcast integrity monitoring
Spectrum monitoring
Power measurement

Educational/Scientific
Teaching
Receiver design
Radio astronomy
Passive radar
Ionosonde
Spectrum analyser
Receiver for IoT sensor projects
Antenna research

NEW SDRconnect™ SDR software for Windows, MacOS and Linux/Raspberry Pi

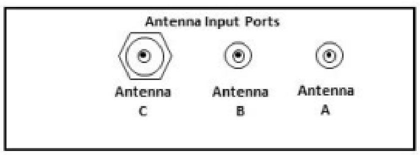
- All new intuitive graphical interface launched in 2023
- Highly integrated native support for the SDRplay family on Windows, MacOS, and Linux/Rasberry Pi 4/5
- Multiple 'virtual receivers' for simultaneous reception and demodulation of different types of signals within the same receiver bandwidth
- Multiple notch filters with BW adjustable to 1Hz
- Synchronous AM mode with selectable/adjustable sidebands.
- Calibrated RF Power Meter with > 100dB of usable range
- Calibrated S-Meter supporting IARU S-Meter Standard
- Integrated server allows remote cross-platform access via high speed LAN and regular internet WAN connectivity
- "Audio" (Compact) mode allows limited bandwidth WAN connections with spectrum visibility up to 10MHz plus multimode audio access (AM/Wideband FM/SSB/CW etc)
- Rolling release model allows for future feature enhancements
- Modular approach for future 3rd party development

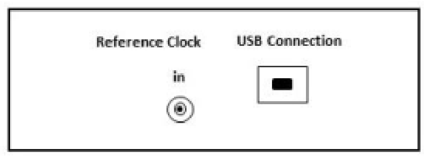
RSPdx
Multi-antenna port 14-bit SDR

SDRuno™ for Windows FEATURES

- High Dynamic Range mode ("HDR") for RSPdx use below 2MHz
- Highly integrated native Windows support for the SDRplay family
- Multiple 'virtual receivers' for simultaneous reception and demodulation of different types of signals within the same receiver bandwidth
- An integrated frequency scanner (for frequency ranges and stored memory panel lists)
- A selectivity filter with an ultimate rejection greater than 140dB.
- A unique distortion-free double stage AGC with fully adjustable parameters
- AFC for FM signals
- Multiple notch filters with BW adjustable to 1Hz + Notch Lock feature
- A unique synchronous AM mode with selectable/adjustable sidebands, dedicated PLL input filter, & selectable PLL time constants
- SNR (stereo noise reduction), featuring a proprietary noise reduction algorithm for stereo broadcast
- Powerful wideband noise filter for addressing common sources of RFI (e.g. power supplies, internet over DSL etc.)
- Calibration for receiver frequency errors
- RDS support optimised for low signal environment
- Active Noise cancelling
- CAT and Omnirig control
- Calibrated RF Power Meter with > 100dB of usable range
- Calibrated S-Meter supporting IARU S-Meter Standard
- The ability to save power (dBm) and SNR (dB)
- measurements over time, to a CSV file for future analysis
- IQ output accessible for 3rd party applications

CONNECTIONS





SPECIFICATIONS

General
- Weight 315g
- Size: 113mm x 94mm x 35mm
- Low current consumption:
  - 190mA @ >60MHz (excl Bias T)
  - 120mA @ <60MHz (excl Bias T)

Connectivity
- USB 2.0 (high speed) type B socket

Frequency Range
- Continuous coverage 1kHz – 2GHz

Antenna A Port Characteristics
- 1kHz – 2GHz operation
- 50Ω input impedance
- SMA female connector

Antenna B Port Characteristics
- 1kHz – 2GHz operation
- 50Ω input impedance
- SMA female connector
- Selectable 4.7V DC out (see Bias T)

Antenna C Port Characteristics
- 1kHz – 200MHz operation
- 50Ω input impedance
- BNC female connector

Reference Clock Input
- MCX female connector

Bias T (Antenna B Port only)
- Software selectable 4.7V @ 100mA

IF Modes
- Zero IF, All IF bandwidths
- Low IF, IF bandwidths ≤ 1.536MHz

IF Bandwidths (3dB)
- 200kHz
- 300kHz
- 600kHz
- 1.536MHz
- 5.0MHz
- 6.0MHz
- 7.0MHz
- 8.0MHz

ADC Characteristics
- Sample frequency 2 – 10.66MSPS
- 14-bit native ADC (2 – 6.048MSPS)
- 12-bit (6.048- 8.064 MSPS)
- 10-bit (8.064- 9.216MSPS)
- 8-bit (> 9.216 MSPS)

Maximum recommended input power
- 0dBm continuous
- 10dBm for short periods

Reference
- High temp stability 0.5PPM TCXO
- In-field trimmable to 0.01ppm.

External Reference Clock
- Plug in the external clock before power-up. Auto-detect will switch to the external reference.
- Frequency 24MHz sine/square wave
- 1V Pk-Pk Min
- 3.3V Pk-Pk Max

Typical Noise Figures
- 33dB @ 300kHz
- 20dB @ 2MHz
- 17dB @ 12MHz
- 15dB @ 25MHz
- 15dB @ 40MHz
- 2.6dB @ 100MHz
- 2.1dB @ 200MHz
- 6.0dB @ 340MHz
- 3.1dB @ 660MHz
- 4.4dB @ 1500MHz
- 5.0dB @ 1800MHz

Notch Filters
- FM Notch Filter:

>30dB 77 – 115MHz
>50dB 85 – 107MHz
>4dB 144 – 148MHz

- MW Notch Filter:

>15dB 400 – 1650kHz
>30dB 500 – 1530kHz
>40dB 540 – 1490kHz

- DAB Notch Filter:

>20dB 155 – 235MHz
>30dB 160 – 230MHz

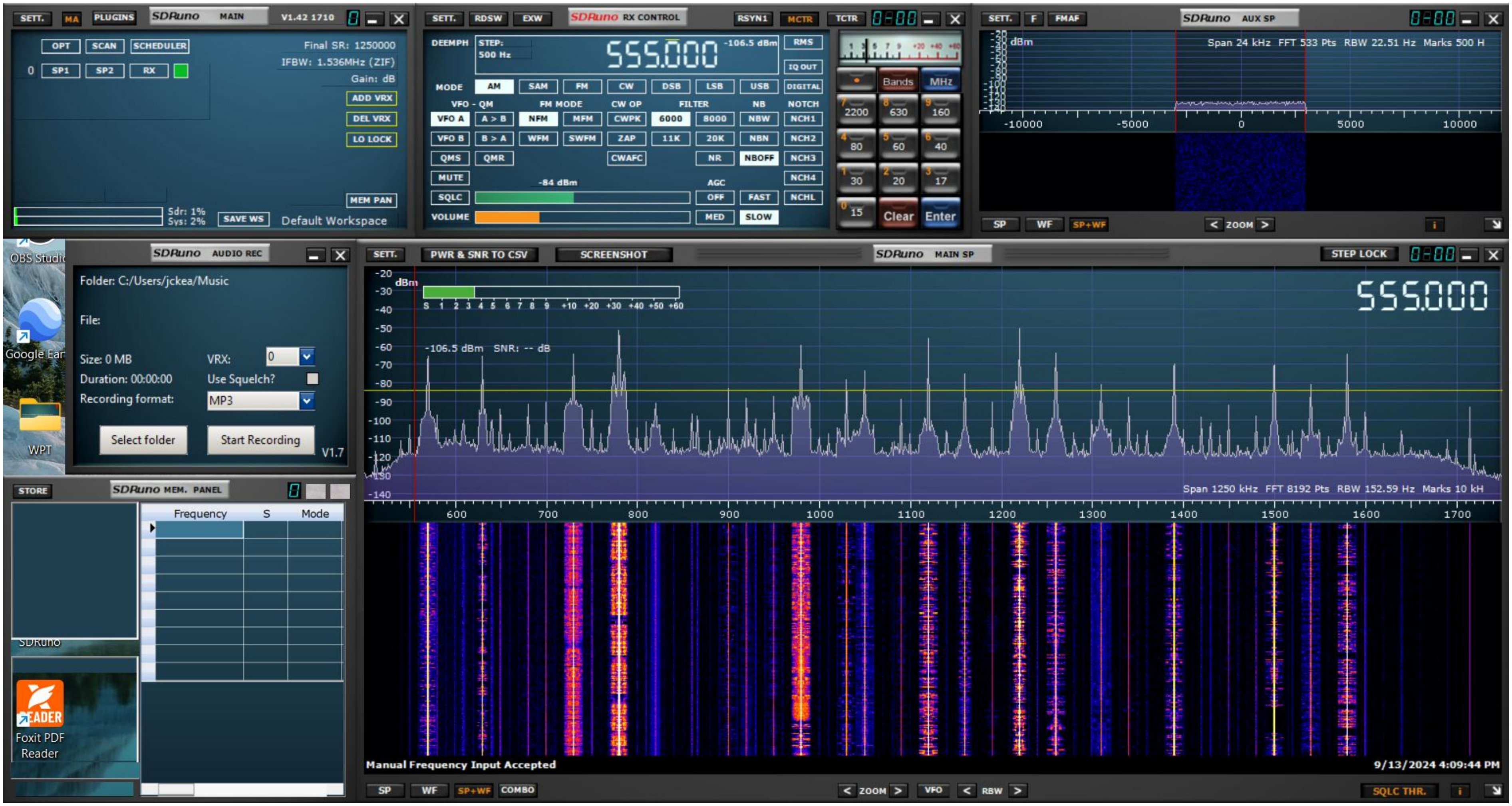
Note: The notch filters above are software selectable and remove specific broadcast bands.

Front End Filtering

Low Pass
- 500kHz
- 2MHz

Band Pass
- 2-12MHz
- 12-30MHz
- 30-60MHz
- 60-120MHz
- 120-250MHz
- 250-300MHz
- 300-380MHz
- 380-420MHz
- 420-1000MHz

High Pass
- 1000MHz



RSPdx screen display during operation.

Tiny SA Spectrum Analyzer and Signal Generator

The TinySA is a combination spectrum analyzer and signal generator with a screen size of 2.8 inches (shown in photo at right). In addition to signal testing and viewing, the unit includes a low noise and low distortion signal generator, which supplied the pilot reference carrier for the software-defined receiver.

Specifications:

User interface:

- Display resolution 320*240 pixels
- Screen diagonal 2.8"
- 16 bits per RGB pixels
- Resistive touch control
- Jog switch control
- USB serial port control
- Linear power supply to avoid switching noise.

The input/output specification of the TinySA is split over the 4 modes

Low input mode spec:

- Input frequency range from 100kHz to 350MHz (with some limitations down to 10kHz)
- Input impedance 50 ohm when input attenuation is set to 10dB or more.
- Selectable manual and automatic input attenuation between 0dB and 31dB in 1 dB steps
- Absolute maximum input level of +10dBm with 0dB internal attenuation
- Absolute maximum short term peak input power of +20dBm with 30dB internal attenuation
- Suggested maximum input power of +0dBm with internal attenuation in automatic mode
- Input Intercept Point of third order modulation products (IIP3) of +15dBm with 0dB internal attenuation
- 1dB compression point at -1dBm with 0dB internal attenuation
- Power detector resolution of 0.5dB and linearity versus frequency of +/-2dB
- Absolute power level accuracy after power level calibration of +/- 2dB
- Lowest discernible signal at 30MHz using a resolution bandwidth of 30kHz of -102dBm
- Frequency accuracy equal to the selected resolution bandwidth
- Phase noise at 30MHz of -90dB/Hz at 100kHz offset and -120dB/Hz at 1MHz offset
- Spur free dynamic range when using a 30kHz resolution bandwidth of 70dB
- Manually selectable resolution filters with a width of 3, 10, 30, 100, 300, 600kHz. Automatic selection of one of the 57 resolution filters.
- On screen resolution of 51, 101, 145 or 290 measurement points.
- Scanning speed of over 1000 points/second using largest resolution filters.
- Automatic optimization of actual scanning points to ensure coverage of the whole scan range regardless of the chosen resolution bandwidth
- Spur suppression option for assessing if certain signals are internally generated or present in the input signal

High input mode spec:

- Input frequency range from 240MHz to 960MHz
- Input impedance is frequency dependent and deviates from 50 ohm
- Absolute maximum input level without attenuation of +10dBm
- Input Intercept Point of third order modulation products (IIP3) of -5dBm with no internal attenuation
- 1dB compression point at -6dBm with no internal attenuation

- Power detector resolution of 0.5dB and linearity versus frequency of +/-2dB
- Absolute power level accuracy after power level calibration of +/- 2dB
- Lowest discernible signal using a resolution bandwidth of 30kHz of -115dBm
- Frequency accuracy equal to the selected resolution bandwidth
- Spur free dynamic range when using a 30kHz resolution bandwidth of 50dB
- Manually selectable resolution filters of 3, 10, 30, 100, 300, 600kHz. Automatic selection of one of the 57 resolution filters
- Optional 25dB to 40dB frequency dependent input attenuator. The power level error with this attenuator activated increases to +/- 10dB
- On screen resolution of 51, 101, 145 or 290 measurement points.
- Scanning speed of over 1000 points/second using largest resolution filters.
- Automatic optimization of actual scanning points to ensure coverage of the whole scan range regardless of the chosen resolution bandwidth

Low output mode spec:

- Sine wave output with harmonics below -40dB of fundamental
- Output frequency range from 100kHz to 350MHz
- Level accuracy +/- 2dB over the whole output frequency range
- Output frequency resolution either 156Hz below 47MHz output or 312Hz above 47MHz output
- Output level selectable in 1dB steps between -76dBm and -6dBm
- Optional AM, narrow FM and wide FM modulation with frequencies between 50Hz and 5kHz or slow sweep over selectable frequency span
- Optional output level sweep over maximum the entire output level range

High output mode spec:

- Square wave output
- Output frequency range from 240MHz to 960MHz
- Output frequency resolution either 156Hz below 480MHz output or 312Hz above 480MHz output
- Output level selectable in variable increments between -38dBm and +9dBm
- Optional narrow FM and wide FM modulation with frequencies between 50Hz and 6kHz or slow sweep

Reference generator spec:

- Optional square wave output with fundamental at -26dBm connected to high input/output
- Frequency can be set to 1MHz, 2MHz, 4MHz, 10MHz, 15MHz or 30MHz

NRSC Document Improvement Proposal

If in the review or use of this document a potential change appears needed for safety, health or technical reasons, please fill in the appropriate information below and email, mail or fax to:

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