Field Evaluation of the Phase II LMR Multiband Antenna System

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Contents

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1 Summary

This report documents field evaluation of a prototype land mobile radio (LMR) multiband antenna system, intended for vehicular installations. This antenna system is being developed as part of our project "Antenna Systems for Multiband Mobile & Portable Radio" [1]. The overall goal of this project is to develop and demonstrate LMR antenna systems which can operate in the VHF-Low (25–50 MHz), VHF-High (138–174 MHz), 220–222 MHz, UHF (406–512 MHz), and 764–862 MHz bands without physically changing antennas. The present ("Phase II") design of the system consists of a reconfigurable monopole-type antenna consisting of a base element plus a switched extension element, and an automatic electronic antenna tuner, and is documented in [2].

Preliminary field measurements using the antenna with a rudimentary version of the antenna tuner have already been reported in [3]. This document describes similar field tests using a completed implementation of the tuner in the VHF-High, UHF, and 800 MHz bands. The measurement methodology is described in Section 2. In each band the performance of the Phase II antenna system is compared that of a commercial antenna using an analysis of signals received from actual LMR transmitters. The results are summarized in Section 3; in particular, in Figures 2–4.

2 Measurement Methodology

The setup used to perform the field measurements is shown in Figure 1. The Phase II reconfigurable antenna and the commercial (reference) antennas are mounted on their own individual aluminum ground planes, each about 1.2 m × 0.6 m in size. The ground planes are mounted to the top of a cart, which carries all other instrumentation (including, in the case of the Phase II system, the antenna tuner) on a lower shelf. For both systems there is a total of about 6 ft of semi-rigid 50 Ω coaxial cable between antenna terminals and receivers. Also, variable step attenuators are inserted at the inputs to both receivers in order to lower audio signal-to-noise ratio (SNR) to values in the 5–35 dB range, where small differences in antenna system performance result in relatively large differences in audio SNR. These attenuators were set to 25 dB for VHF-High, 26 dB for UHF, and 23 dB for 800 MHz measurements based on initial trials indicating that these were reasonable values. Audio from each receiver was captured simultaneously to identical but separate netbook-class computers.

After the experiment, the digitized sound files were examined using the technique documented in [4] and [5]. Summarizing: For each separate and identifiable transmission recorded, the SNR of the private line (PL) tone within a 270 Hz (3 dB bandwidth) span of the sub-audio portion of the signal was estimated separately for the signals from the Phase II antenna system and from the commercial antenna. The integration time used for PL tone SNR estimation was 100 ms. The relative performance of these antennas was then determined by comparison of the audio SNRs accumulated over many transmissions, as shown in Figures 2–4.

All measurements reported in this document were performed on the third floor balcony of Whittemore Hall, on the main (Blacksburg, VA) campus of Virginia Tech. To mitigate against systematic bias from multipath fading, the cart shown in Figure 1 was periodically reoriented. The measurements in each orientation as well as results for the the combined set of orientations is reported in each case.

The tuning solutions used in the Phase II system were as indicated in [2], except the VHF-band measurements used Stub 3 (i.e., Stub 3 "ON"), which was found to yield a slightly better antenna match in a measurement immediately proceeding the data collection. In each case the tuning solution was fixed once data collection began; i.e., the tuner was not allowed to adapt using closed-loop tuning.

Table 1 shows the specific LMR systems that were monitored to collect data for this study. Also indicated is the commercial antenna which was used in each case. The Laird Tech. Model C150/450C is a dual-band antenna marketed for use in the 150–174 MHz and 450–474 MHz bands, whereas the

Figure 1: Location and test fixture. The Phase II antenna and commercial antenna (in this case, Laird Tech. Model C150/450C) appear to the left and right, respectively, in the top two figures. The Phase II tuner is the aluminum box located directly under the Phase II antenna. Views are: *top/left*, approximately Southwest; *top/right*, approximately Northwest; *bottom/left*, approximately South; *bottom/right*, approximately North.

Band Band	Freq MHz	PL Hz	System/ User	Commercial Antenna
VHF-High	155.535	162.2	VT Police	Laird Tech. C150/450C
UHF	453.625	203.5	Blacksburg Transit	Laird Tech. C150/450C
800 MHz	851.150	186.2	Blacksburg Police	Laird Tech. B8065C

Table 1: LMR systems and commercial antennas used for testing in each band.

Laird Tech. Model B8065C is a single-band antenna marketed for use in the 806–896 MHz bands. Additional information on the performance of these commercial antennas can be found in [3] (see esp. Figures 1 and 3) as well as [6].

3 Results

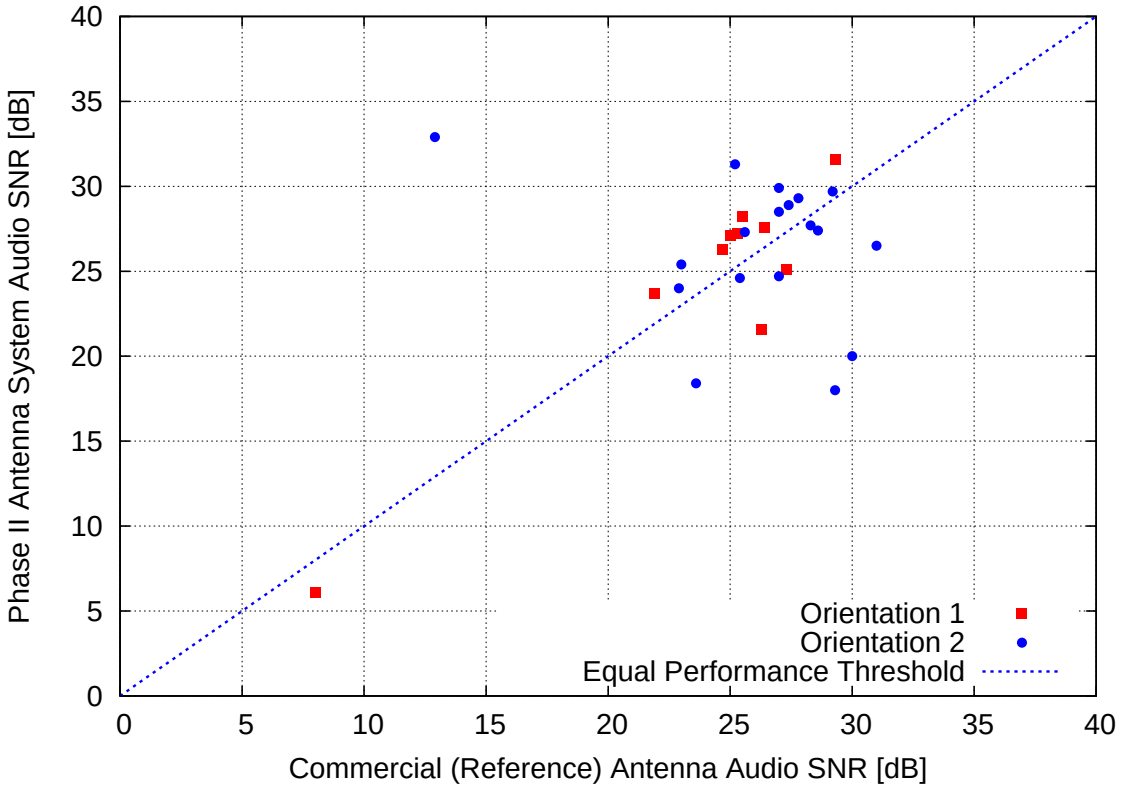
155.535 MHz. Figure 2 shows the estimated SNR for each transmission simultaneously received by both the antenna under test (the Phase II antenna system) and the reference (commercial) antenna indicated in Table 1. In this representation, each point of the scatter plot represents a transmission, and the vertical and horizontal coordinates are the observed audio SNRs obtained from the Phase II system and the commercial antenna, respectively. Thus, data points above or below the diagonal line indicate that the Phase II system is performing better or worse, respectively, than the commercial antenna. Note that there is considerable scatter in results; this is as expected due to the time-varying nature of multipath fading, which can be expected to have similar characteristics everywhere (i.e., this is not a phenomenon specific to the test location) and underscores the importance of using multiple orientations as explained in Section 2.

Figure 2 also shows a statistical analysis of this data. Note first that the result using all data from both orientations ("Combined") indicates that the Phase II system is, on average, +0.3 dB better, with a correlation coefficient $r = +0.42$. The rather large standard deviation is probably attributable to time-varying multipath conditions. The prevalence of multipath is further confirmed by the large difference in performance between the two orientations; clearly one of the two possible antenna positions is significantly better than the other. We conclude that the Phase II system is certainly performing better on a statistical basis, and perhaps is also consistently better, although the later is difficult to ascertain since it is obviously impossible to evaluate both antennas simultaneously at the same location.

453.625 MHz. Figure 3 shows the estimated SNR for each transmission simultaneously received by both the antenna under test (the Phase II antenna system) and the reference (commercial) antenna indicated in Table 1, in the same manner as for the 155.535 MHz testing described above. Figure 3 also shows a statistical analysis of this data. Note first that the result using all data from both orientations ("Combined") indicates that the Phase II system is, on average, +3.2 dB better, with a correlation coefficient $r = +0.92$, and a much smaller standard deviation than the VHF-High measurements. We also note once again that one of the orientations is statistically better than the other. We conclude that the Phase II system is performing significantly better than the commercial antenna at 453.625 MHz.

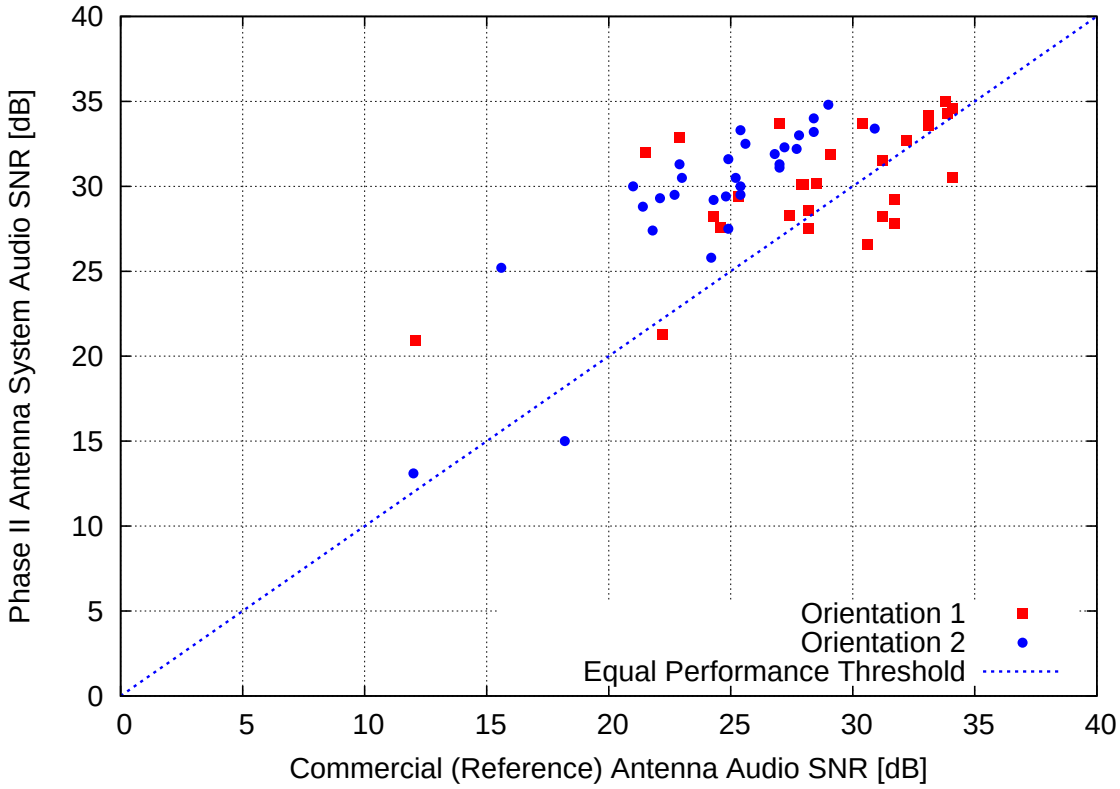
851.150 MHz. Figure 4 shows the estimated SNR for each transmission simultaneously received by both the antenna under test (the Phase II antenna system) and the reference (commercial) antenna indicated in Table 1, in the same manner as for the 155.535 MHz and 453.625 MHz testing described above. Figure 4 also shows a statistical analysis of this data. The result using all data from both orientations ("Combined") indicates that the Phase II system is, on average, about 2.5 dB worse than the commercial antenna. This corresponds to RF SNR difference of roughly 1 dB [5] between the two antenna systems.

We have identified two possible reasons for the relatively poor performance in this band. One reason may be that the tuning solution was not optimally set; recall that closed-loop tuning was disabled for this test. Another possible reason is insertion loss from the directional couplers used in the Phase II tuner's "tuner board", which is significantly worse in the 800 MHz band than at lower frequencies [2]. Either reason would be consistent with our previous finding that the reconfigurable antenna + stubline-only system evaluated in [3] exhibited audio SNR performance comparable to the same commercial antenna used in this study in this band. Thus, we believe that simple adjustments to the Phase II system would be sufficient to realize the same relative level of performance in the 800 MHz band as is exhibited in the VHF-High and UHF bands.



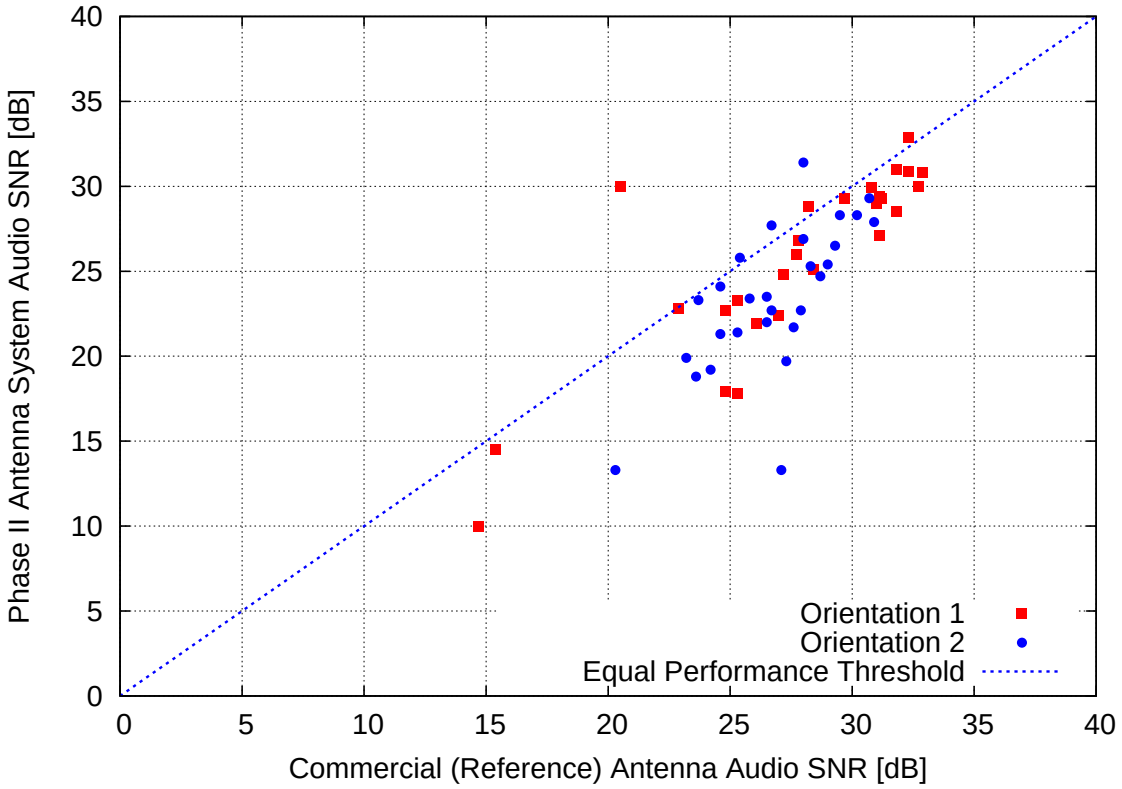
Orientation	No. Transmissions	mean$(y-x)$	std$(y-x)$	r
1	10	+0.5 dB	2.5 dB	+0.94
2	18	+0.2 dB	6.6 dB	−0.28
Combined	28	+0.3 dB	5.4 dB	+0.42

Figure 2: 155.535 MHz: *Top:* Estimated audio SNR for each transmission simultaneously received by both the Phase II antenna system and the commercial antenna. *Bottom:* Statistical analysis of the above data. x and y correspond to the measured SNRs, in dB, for the commercial antenna and Phase II system respectively, so "mean$(y-x)$" is positive when the Phase II system is better. "std$(y-x)$" is the standard deviation of $y-x$. r is the correlation coefficient between y and x.



Orientation	No. Transmissions	mean$(y-x)$	std$(y-x)$	r
1	28	+1.5 dB	3.7 dB	0.90
2	30	+4.7 dB	2.9 dB	0.97
Combined	58	+3.2 dB	3.6 dB	0.92

Figure 3: 453.625 MHz: *Top:* Estimated audio SNR for each transmission simultaneously received by both the Phase II antenna system and the commercial antenna. *Bottom:* Statistical analysis of the above data. x and y correspond to the measured SNRs, in dB, for the commercial antenna and Phase II system respectively, so "mean$(y-x)$" is positive when the Phase II system is better. "std$(y-x)$" is the standard deviation of $y-x$. r is the correlation coefficient between y and x.



Orientation	No. Transmissions	mean$(y-x)$	std$(y-x)$	r
1	27	−1.8 dB	3.0 dB	+0.92
2	28	−3.2 dB	3.2 dB	+0.86
Combined	55	−2.5 dB	3.1 dB	+0.89

Figure 4: 851.150 MHz: *Top:* Estimated audio SNR for each transmission simultaneously received by both the Phase II antenna system and the commercial antenna. *Bottom:* Statistical analysis of the above data. x and y correspond to the measured SNRs, in dB, for the commercial antenna and Phase II system respectively, so "mean$(y-x)$" is positive when the Phase II system is better. "std$(y-x)$" is the standard deviation of $y-x$. r is the correlation coefficient between y and x.

References

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