Comparison of Space and Polarization Diversity 800MHz Cellular Antenna Systems through Empirical Measurements

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Abstract— Wireless cellular telephone systems receive diversity antenna systems to enhance the efficiency of the reverse path (portable to the cellular base station receiver). A conventional receive diversity arrangement, in the simplest form, consists of two base station receivers, each of which is connected to a dedicated antenna. Diversity becomes possible when the two receive antennas, having identical pattern signatures, are positioned so that the E and H plane patterns of both antennas overlay the cellular coverage area equally. The efficiency of the diversity array is related to the horizontal spacing between the antennas as given by Lee[1]. It is the need for two antennas and the spacing requirement which adds to the expense of the installation and in some cases may render the facility unusable from the viewpoint of the local zoning board.

I. Introduction

Until recently, there has been no deviation or solution to the spatial diversity requirements. The proliferation of wireless systems has burdened the system operator in obtaining suitable locations within design budgets. One of the most significant challenges in securing a proposed location is the approval from local or state zoning commissions. In suburban locations, facilities are needed to cover neighborhoods, but there is often difficulty in achieving the approval of local zoning boards for the typical antenna laden supporting structure. The same is often true in urban areas. Additionally, in some locations, the cellular operator is charged for each antenna used. A typical-three sector cellular facility may consist of up to nine antennas per facility.

An alternative approach that would reduce the number of antennas per site could definitely provide a saving in facility installation cost. Moreover, it may offer some significant benefits in addressing the environmental impact issue. An alternative approach that addresses these issues without compromising system performance was the focus of this work.

II. Description of Data Measurement

The data contained in this report was taken at an actual 800MHz cellular facility.

The data contained in this report was taken at an actual 800MHz cellular facility. We compared a standard two-antenna spatial diversity configuration with that of a single antenna containing two elements of different polarization. The antenna selected for the comparison contains two such elements, one section is polarized slant left and the other is polarized slant right. The signal strengths recovered by each antenna were compared in several tests involving varying reverse path characteristics typical in the cellular environment. The gain and the H-Plane beamwidth of the dual polarized antenna were selected to match, as closely as possible, those characteristics of the existing spatial diversity antennas. Both antenna types achieve gain by a collinear arrangement of the radiating elements and reflector assembly to focus the radiation in a preferred direction, thereby concentrating the radiation pattern to a limited range of angles lying orthogonal to the axis of the radiating element.

Five tests were conducted, all using a Motorola Digital Personal Communicator Cellular® telephone in maintenance mode set to transmit on an unused voice channel to capture both changes in clutter and handset usage.

In each of these tests, the channel was monitored at the cellular facility using a Cellscope Pro®, manufactured by the Grayson Company. The Grayson Cellscope was configured in the Linear Averaging mode, where the sampling rate is fixed at 400 samples per second. The actual number of data points written to the file is set by the RSSI update interval. With a 100ms RSSI update sampling interval, the Cellscope Pro takes 40 sample measurements each second, which are averaged and then written to the log as one entry. In linear averaging, each of the 40 samples is converted to an absolute power, averaged, and finally converted to a logarithmic relationship relative to 0.0 dBm.

The Cellscope Pro contains four receivers, one per port, each of which is capable of the signal measurement and processing described above.

In this measurement configuration, the individual performance of each antenna is captured. As such, the data reflects the computed signal strengths for each antenna and does not consider the effects of receiver diversity combining o selection. The port assignments are listed below to aid in interpreting the data. The test area, within the sector area, was selected so that all measurement locations fell within the E and H plane beamwidth of the antennas under evaluation.

Because the system used for the analysis was in operation during the tests, power dividers were required between the multicouplers of the system and the spatial diversity antennas. The losses associated with the power dividers and those associated with the interconnecting transmission line were found by measurement and were then applied to the results to normalize the data.

III. Resultant Data and Exhibits

The resultant data for each test is summarized in a simple bar graph illustrating the average signal level for each test for each antenna. The calculated average signal level was converted to a power level, as explained above, in comparing the performance of the antennas. In tests four and five, the resultant data was divided conveniently into two exhibits each because of a 4000-line limitation in the post-processing software. The division points for both tests are shown in the exhibits.

IV. Test Scenarios and Measured Data

Test One

The terminal was held at normal speaking position with respect to the user within ~1000 feet of the cellular facility. The path was comprised completely of free-space losses, meeting first Fresnel zone clearance criteria.

Test Two

The terminal was held in the same position as in test one, except the path between the terminal and the cellular facility was completely blocked.

Test Three

The terminal was used in a normal speaking position during a walk around a two-block area. The route provides various propagation characteristics, including both clear paths and blocked paths.

Test four

The same route followed in test three was driven in a vehicle. The terminal was held at normal speaking position inside the vehicle. The speed of the vehicle was <35mph. when moving throughout a downtown environment with surrounding building height equal to or greater than the ACL of the facility.

Test five

This test was identical to test four, except that the terminal was laid on the seat of the vehicle with antenna retracted to mimic what is thought to be a typical habit of most Class III handset users when the handset is not in use.

Cellscope Port Assignments for Data Logging

Port One **Purple**

Spatial Diversity Antenna A (DB 834) 105 Deg. H-Plane beamwidth 10.0dBd.

Port Two **Burgandy**

Spatial Diversity Antenna B (DB 834) 105 Deg. H-Plane beamwidth 10.0dBd.

Port Three **Light Yellow**

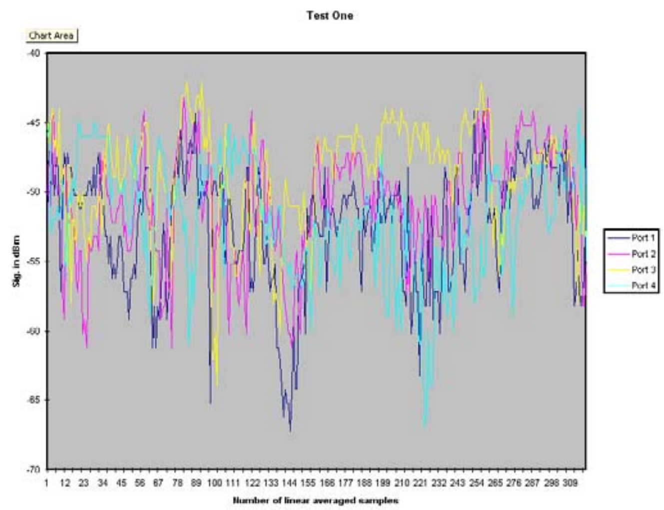
Polarization Diversity - Slant-Left (FS90-11-00N) 90 Deg. 11.0dBd.

Port Four **Light Green**

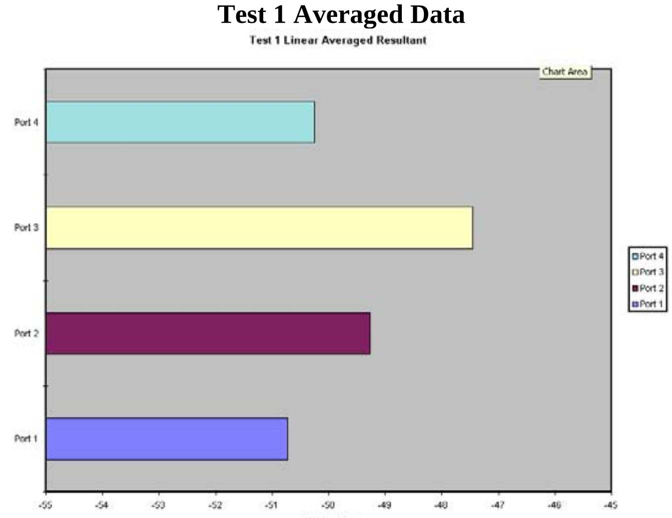
Polarization Diversity - Slant-Right (FS90-11-00N) 90 Deg. 11.0dBd.

V. Resultant Data

Test One



Test 1 Averaged Data



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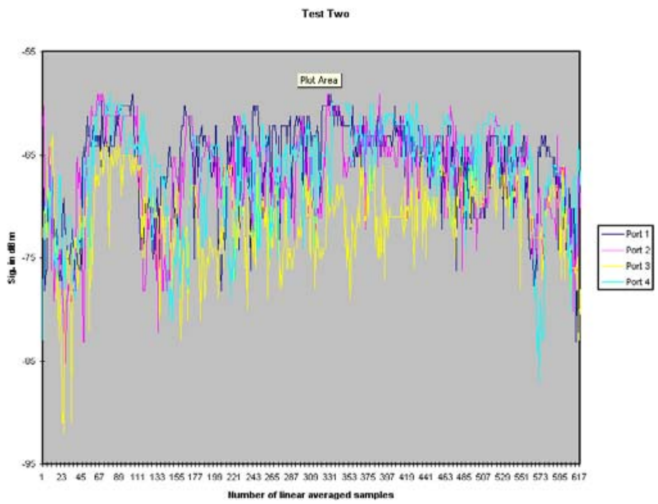

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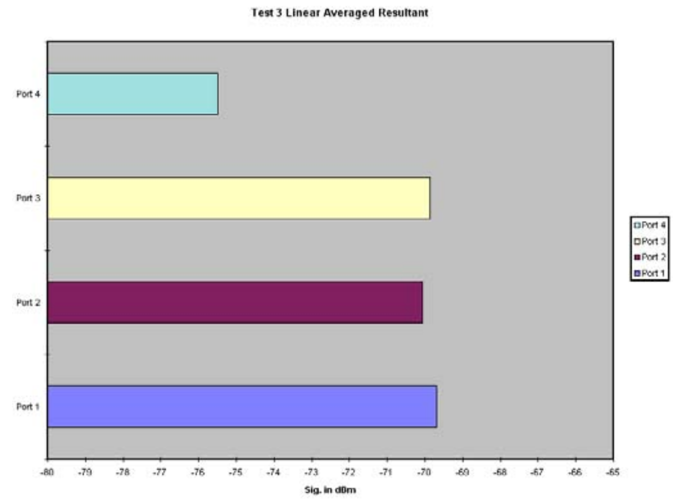

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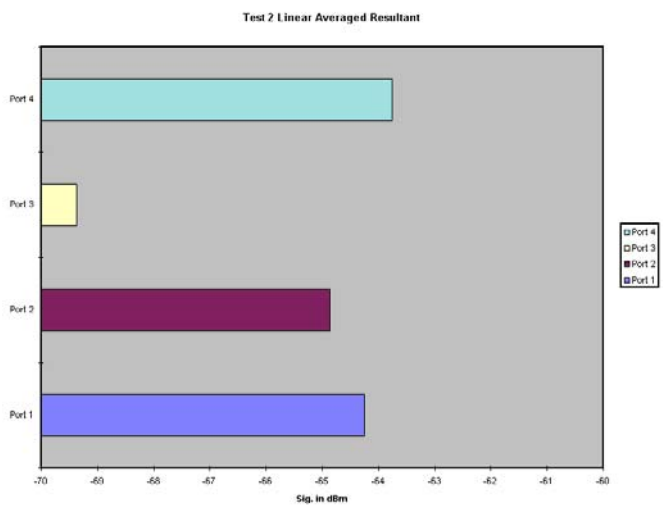

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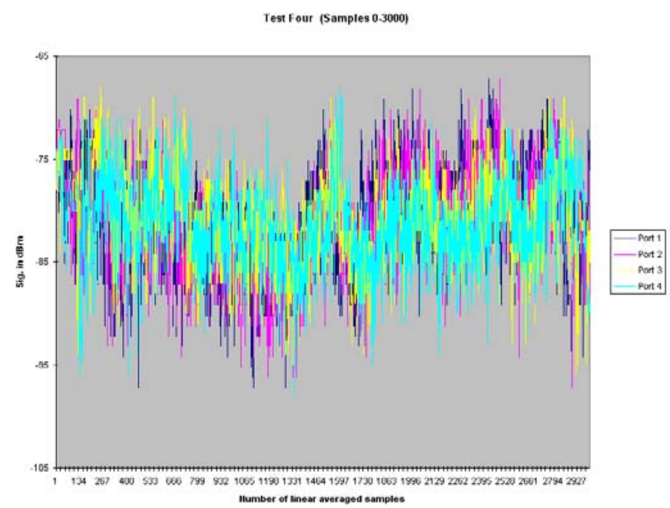
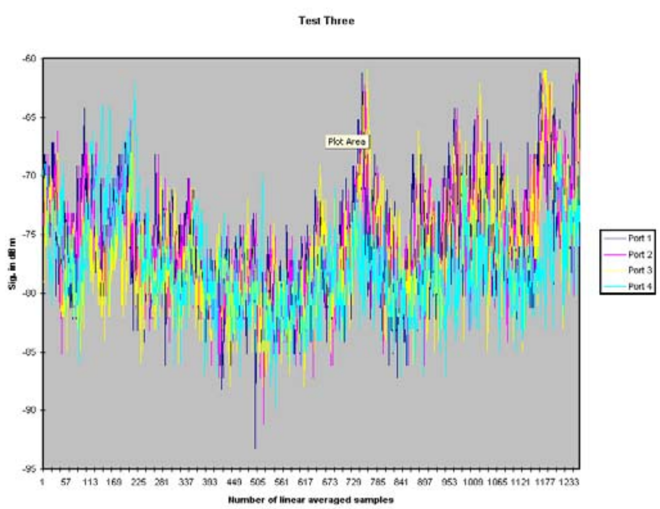
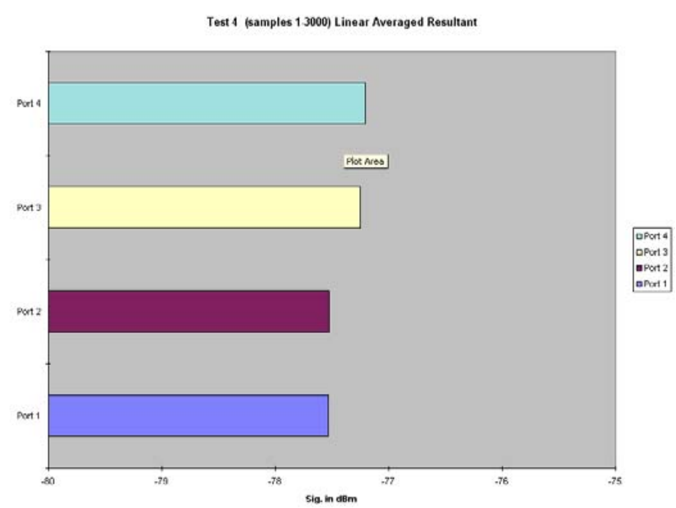


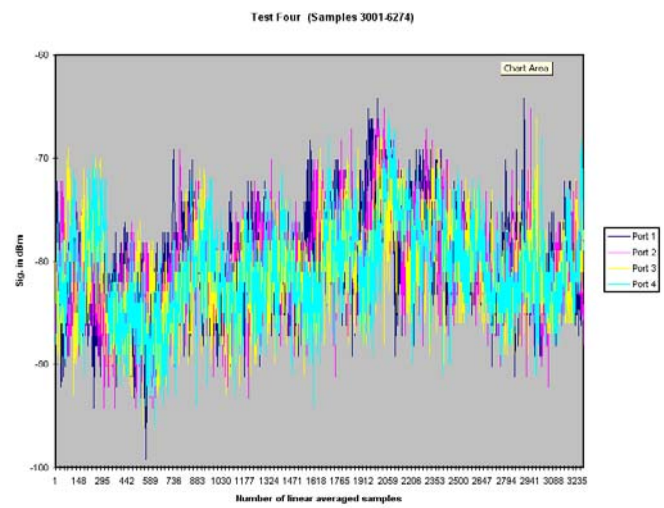
Test 3



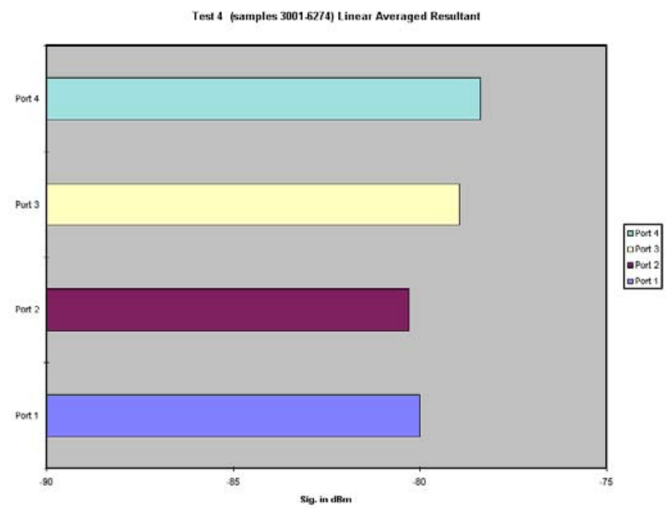
Test 4 Averaged Data



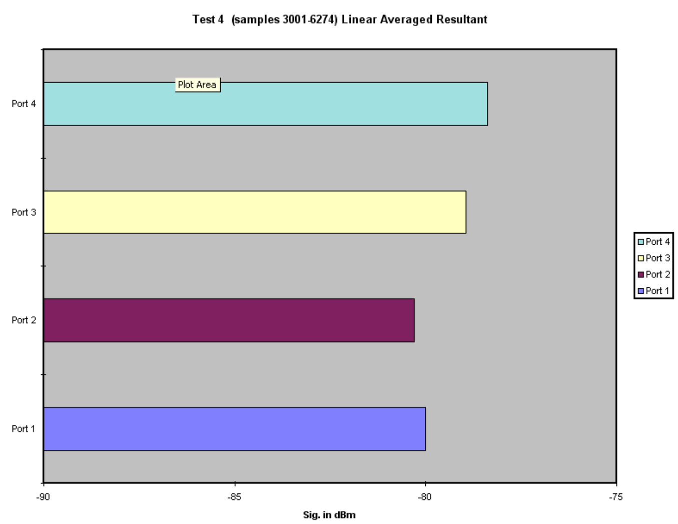
Test 4 Part 2



Test 5 Averaged Data



Test 4 Part 2 Averaged Data



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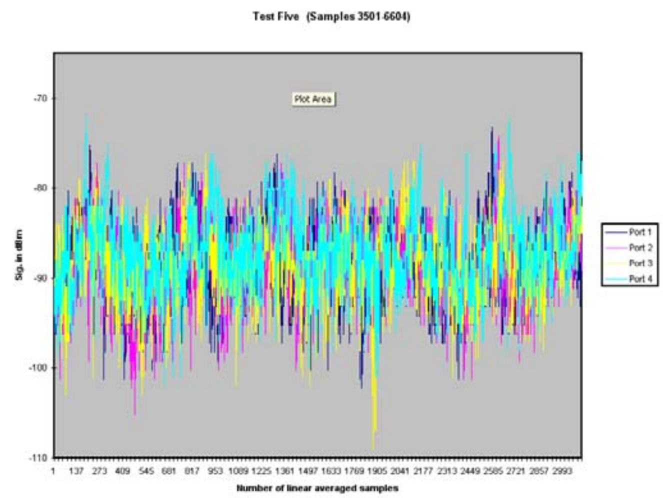
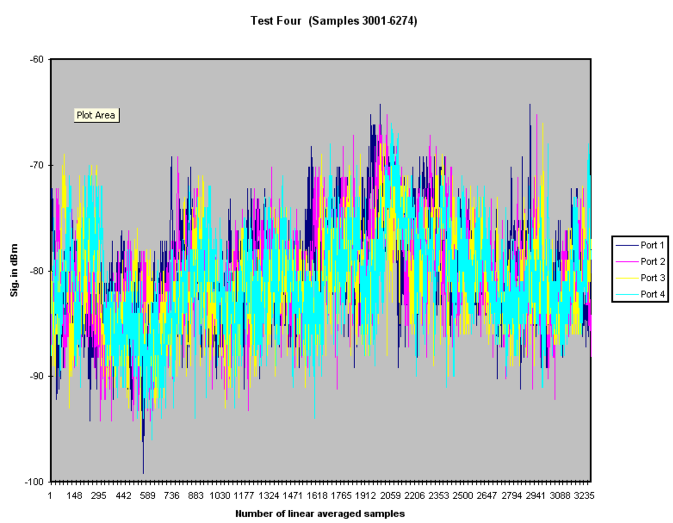
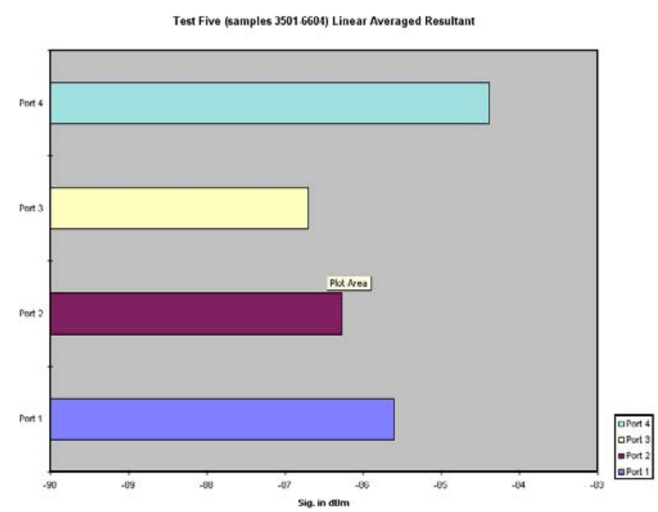


Test 5



Test 5 Part 2 Averaged Data



VI. Conclusions

From the data collected, the polarization diversity antenna offered improved signal strength in all but one test. Even though there were no significant differences in the magnitude of the recorded data between the two antenna types, the tests suggest that polarization diversity is comparable to spatial diversity. In some cases, it was shown to be superior. The benefit to the system operator is that one antenna position may be eliminated with polarization diversity without compromising diversity performance. Moreover, the results of these tests show that this benefit holds true whether the reverse path is LOS or blocked in a variety of real world scenarios.

Additionally, antennas are available which provide a vertically polarized transmit antenna and a receive diversity, slant-left/slant-right dual polarized antenna, in the same radome.

The resultant overall findings are 1) Single antennas with polarization diversity perform better or equal to the two spatial diversity configurations, 2) Significant savings can be realized in deployment costs eliminating at least three antennas per site. Additionally, this reduces wind loading on the tower and could lead to reduced effort and cost in obtaining zoning and siting approvals.

VII. Acknowledgements

The authors would like to thank Dr. Pete Bernardin and John Ferguson, both of Nortel for their review of the material.

Additionally, we would like to acknowledge EMS Wireless for their assistance in providing the Dual Polarized Antennas used in this study and the studies that preceded this work. In particular, I would like to thank Jim Grosch in his support of this effort and Tommy Thompson for his assistance in providing information used in the presentation of this work.

Finally, appreciation goes to Bell Mobility for assisting in the initial effort where the initial studies began in providing cellular facilities and to Mr. Jim Fredrickson, V.P Engineering and Chief Technical Officer, Palmer Wireless and Bryan Thacker, Outside Plant Manager, Palmer Wireless in making facilities available in completing these tests.

References

1. W.C.Y. Lee, “Mobile Communications Design Fundamentals”, Howard W. Sams & Company, 1986, page 202-206.