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Plicanic, Vanja; Lau, Buon Kiong

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Impact of spacing and gain imbalance between two dipoles on HSPA throughput performance

V. Plicanic and B. K. Lau

This Letter reports the throughput performance of two parallel half-wavelength dipoles with different antenna spacings and antenna gain imbalances for two frequency bands in a live High-Speed Packet Access (HSPA) network. It was found that an antenna spacing of 0.25 wavelengths and gain imbalances of up to 6 dB are sufficient to provide significant throughput gain for the same transmit power, or equivalently, an increase in network coverage for a given throughput, as compared to a single dipole.

Introduction: Receiver and system performance evaluations for WCDMA systems have shown antenna receive diversity to be an effective method for fading mitigation and thus increasing the capacity and coverage in the network [1-3]. However, these evaluations are usually based on the assumptions that the receive signals are sufficiently decorrelated and of equal gain. In general, these conditions require equal antenna gains and minimum antenna separation of 0.5 wavelengths at the antenna operating frequency. Implementation of multiple antennas in user equipment (UE) employing High-Speed Packet Access (HSPA), such as laptops, PC cards and mobile phones, is restricted by the small size of the UE and the allocated antenna space and location and might not, in reality, follow the common assumptions about antenna gains and separation. Thus, there is motivation to closely explore these assumptions to look for implementable designs that do not compromise the overall performance of the system.

This Letter reports on how throughput, as a system and user experience parameter, is affected by implementing different cases of receive antenna diversity spacing and gain imbalance. An extensive measurement campaign with a set of dual dipole configurations were evaluated with a commercial HSPA product platform in a live HSPA network for two frequency bands. The results were compared with the throughput performance of a single dipole in the same environment to determine the gain in throughput and cell coverage when using two antennas instead of one. Future work extends antenna configurations to common-ground and practically implementable antennas for mobile terminals.

Throughput measurement: Throughput performance was studied in a live HSPA network for the frequencies of 0.89 GHz (WCDMA850) and 1.93 GHz (WCDMA1900). To allow for system repeatability when evaluating different antenna configurations, network settings were fixed and the measurements were performed on the User Datagram Protocol (UDP) layer. Moreover, a repeatable multi-path environment was created in a shielded chamber using a turn table for the UE or device under test (DUT), fixed scatterers around the turn table and a rotating scatterer between the turn table and the Node B. The chamber is otherwise furnished as a laboratory space which further increases the number of scatterers in the environment. A cross polarized horn antenna was used at the Node B and placed 3 m from the DUT.

The HSPA platform used in the measurement campaign is a stand-alone test-bed of a commercial Ericsson M365 platform for PC-cards. It utilizes a GRAKE receiver and supports receiver antenna diversity [4]. It also supports category 8 High-Speed Downlink Packet Access (HSDPA), i.e. 7.2 Mbps throughput on the downlink.

For each of the antenna configurations, measurements were performed by attenuating the Node B output power in steps of 5 dB to simulate different distances between the DUT and Node B in the cell.

Antenna configurations: A set of dipole antenna configurations with spacings of 0.05, 0.25 and 0.5 wavelengths were evaluated. Further, for each of the spacings, equal gain and gain imbalances of 3 dB and 6 dB between the two antenna branches were evaluated. The imbalance was obtained by adding attenuators to the antenna connected to the diversity path in the test-bed. Identical dipoles were placed in parallel and oriented for vertical polarization during the measurements. The dipoles were chosen for the simplicity in altering the spacing between them.

For the purpose of extracting actual throughput gain from the measurements, the throughput for a single dipole was measured with the second dipole removed and the receive diversity turned off.

Results and discussion: The average throughput performance is shown in Figs. 1 and 2 for 0.89 and 1.93 GHz, respectively, at different attenuations of the Node B output power. At 1.93 GHz, Node B had 2 dB lower power than at 0.89 GHz. Thus, attenuation of 55 dB for 0.89 GHz in Fig. 1, i.e., the cell edge in this study, corresponds to the attenuation of 53 dB at 1.93 GHz in Fig. 2. The throughput performance for the two dipoles at both frequencies shows substantial diversity gain at higher attenuations, i.e. DUT locations closer to and at the cell edge. No significant gain is obtained when the DUT is close to Node B.

The results show that the spacings of 0.25 and 0.5 wavelengths facilitate significant gain in throughput at the cell edge for both 0.89 and 1.93 GHz, regardless of gain imbalance. At the low frequency band, an increase in throughput is on average 30%, compared to a single antenna performance. At the high frequency band, the increase is on average 50%. An increase of throughput is also seen at higher Node B output powers at 1.93 GHz than at 0.89 GHz. The lower throughput gain at the low band may be due to differences between the propagation environments at the two frequencies [5].

Figs. 3 and 4 show the effect of spacing and gain imbalance on the power gain for a given throughput obtained for the dual dipole configurations compared to that for a single stand-alone dipole antenna, i.e. the actual power gain. For 0.89 GHz and 1.93 GHz, the actual power gain is obtained for the average throughput results at the Node B attenuations of 55 dB and 53 dB, respectively. For both frequencies the gain is found to be very similar for the two dipoles with spacings of 0.25 and 0.5 wavelengths, with and without gain imbalance. At 1.93 GHz it is at best 8 dB and at 0.89 GHz 4 dB. For each gain imbalance step of 3 dB, the achieved power gain decreases by approximately 1 dB. The results suggest that on average there is no gain when the spacing is 0.05 wavelengths. Thus, like the MIMO capacity performance shown in [6], the throughput performance of very closely spaced dipoles is similar to that of a single dipole.

As a sanity check, actual diversity gain (ADG) [7] was calculated from the measured field patterns for the dual dipole configurations and single dipole antenna, assuming uniform 3-D angular power spectrum (see Figs. 3 and 4). Calculations were performed using the maximum ratio combining (MRC) technique at the cumulative probabilities of 25% and 50% for 0.89 GHz and 5% and 15% for 1.93 GHz. The specific probabilities were chosen in an attempt to fit the calculated ADG values to those from actual power gain performance. Absolute comparison is not relevant here, since the actual power gain in throughput performance also depends on the receiver, system and propagation channel. However, it is of interest to see if the trend in the diversity gain for different antenna configurations is reflected in the system throughput behaviour. This is the case observed in Figs. 3 and 4.

Conclusions: For dual dipoles, it is possible to go beyond the common assumptions of equal antenna gains and antenna separation of 0.5 wavelengths for good diversity, without compromising significantly on the throughput performance in a live HSPA network and a repeatable multipath environment. For a dual dipole configuration with spacing 0.25 wavelengths and antenna gain imbalances of up to 6 dB, power gains of 4 dB and 8 dB can be expected at 0.89 and 1.93 GHz, respectively, compared to a single dipole antenna. The performance gain is obtained mainly at the cell edge.

References

1 Kunze, J.W., Schmits, C., Bilgic, A., and Hausner, J.:'Receive antenna diversity architectures for HSDPA'. Proc. 67th IEEE Veh. Technol. Conf., May 2008, Marina Bay, Singapore, pp. 2071 - 2075

2 Ventola, M., et al.:'Performance of dual antenna diversity reception in WCDMA terminals'. Proc. 57th IEEE Veh. Technol. Conf., Apr. 2003, Orlando, Florida, US, Vol. 2, pp. 1035-1040

3 Ishii, H., et al.:'Experiments on HSDPA throughput performance in W-CDMA Systems', IEICE Trans. on Fundamentals of Electronics, Commun. and Computer Sciences, 2006, E89-A (7), pp. 1903-1912

4 Fulghum, T., et al.:'Low complexity parameter estimation for the multi-antenna generalized rake receiver'. Proc. 63rd IEEE Veh. Technol. Conf., May 2006, Melbourne, Australia, Vol. 4, pp. 1874-1878

5 Bultitude, R.J.C., et al.:'A comparison of indoor radio propagation characteristics at 910 MHz and 1.75 GHz', IEEE Journal on Selec. Areas in Commun., 1989, Vol. 7, Nr. 1, pp. 20-30

6 Wallace, J.W., and Jensen, M.A.:'Mutual coupling in MIMO wireless systems: A rigorous network theory analysis', IEEE Trans. on Wireless Commun., 2004, 3 (4), pp. 1317-1325

7 Plicanic, V., Lau, B.K., Derneryd, A. and Ying, Z.:'Actual diversity performance of a multiband diversity antenna with hand and head effects', IEEE Trans. on Antennas and Propagat., (in press)

Authors' affiliations:

V. Plicanic (Sony Ericsson Mobile Communications AB, SE-221 80 Lund, Sweden and Department of Electrical and Information Technology, Lund University, SE-221 00 Lund, Sweden)

E-mail: vanja.plicanic@sonyericsson.com

B. K. Lau (Department of Electrical and Information Technology, Lund University, SE-221 00 Lund, Sweden)

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Figures:

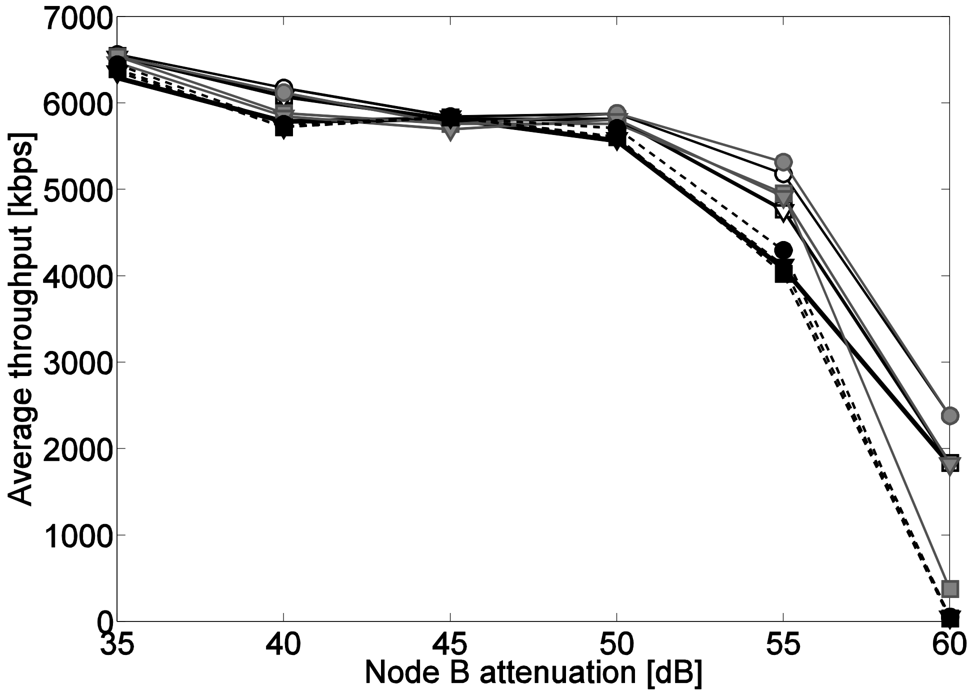

Fig. 1 Measured average throughput at different Node B output powers for single dipole and nine configurations of spacing and gain imbalance between two dipoles at 0.89 GHz

—— Single dipole
—○— 0.5 lambda
—□— 0.5 lambda, 3 dB
—▽— 0.5 lambda, 6 db
—●— 0.25 lambda
—■— 0.25 lambda, 3 dB
—▼— 0.25 lambda, 6 dB
--●-- 0.05 lambda
--■-- 0.05 lambda, 3 dB
--▼-- 0.05 lambda, 6 dB

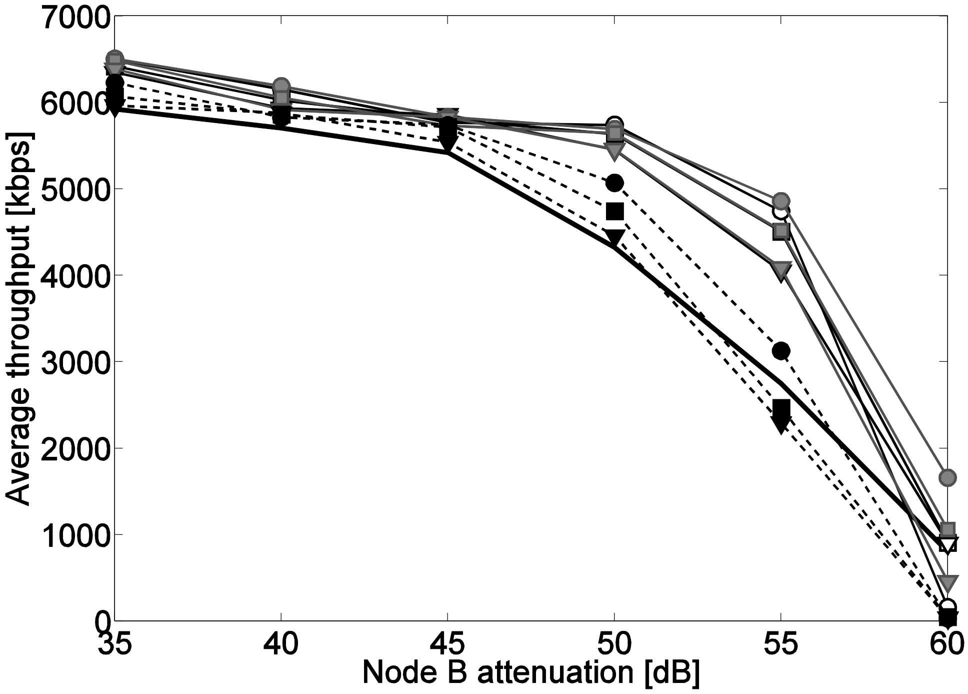

Fig. 2 Measured average throughput at different Node B output powers for single dipole and nine configurations of spacing and gain imbalance between two dipoles at 1.93 GHz

— Single dipole
○ 0.5 lambda
□ 0.5 lambda, 3 dB
▽ 0.5 lambda, 6 db
● 0.25 lambda
■ 0.25 lambda, 3 dB
▼ 0.25 lambda, 6 dB
● 0.05 lambda
■ 0.05 lambda, 3 dB
▼ 0.05 lambda, 6 dB

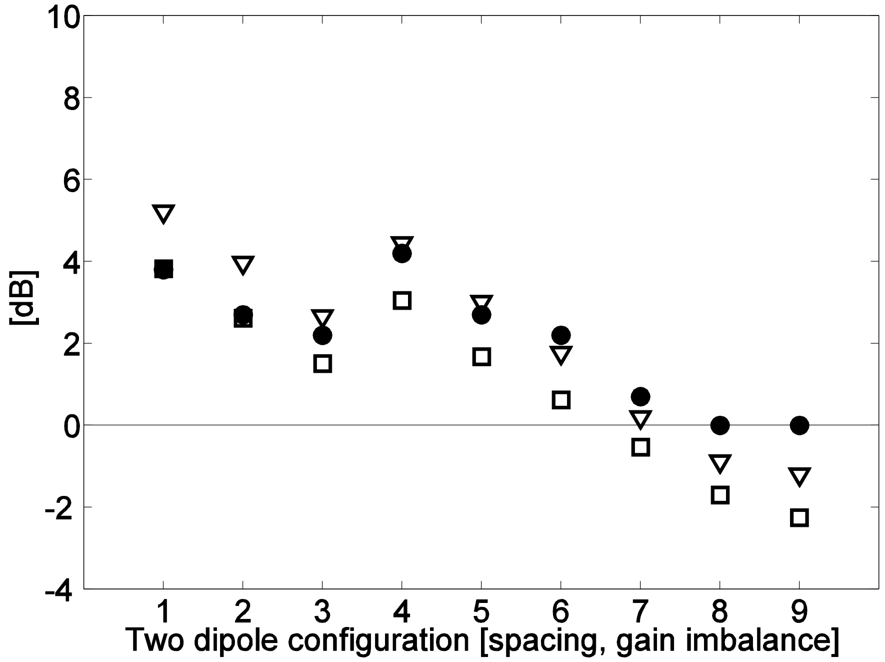

Fig. 3 Measured actual power gain and calculated actual diversity gain (ADG) at two probabilities for nine configurations of spacing and gain imbalance at 0.89 GHz

1 [0.5 lambda]
2 [0.5 lambda, 3 dB]
3 [0.5 lambda, 6 dB]
4 [0.25 lambda]
5 [0.25 lambda, 3 dB]
6 [0.25 lambda, 6 dB]
7 [0.05 lambda]
8 [0.05 lambda, 3 dB]
9 [0.05 lambda, 6 dB]

●Measured actual power gain
▽ADG @25%
□ADG @50%

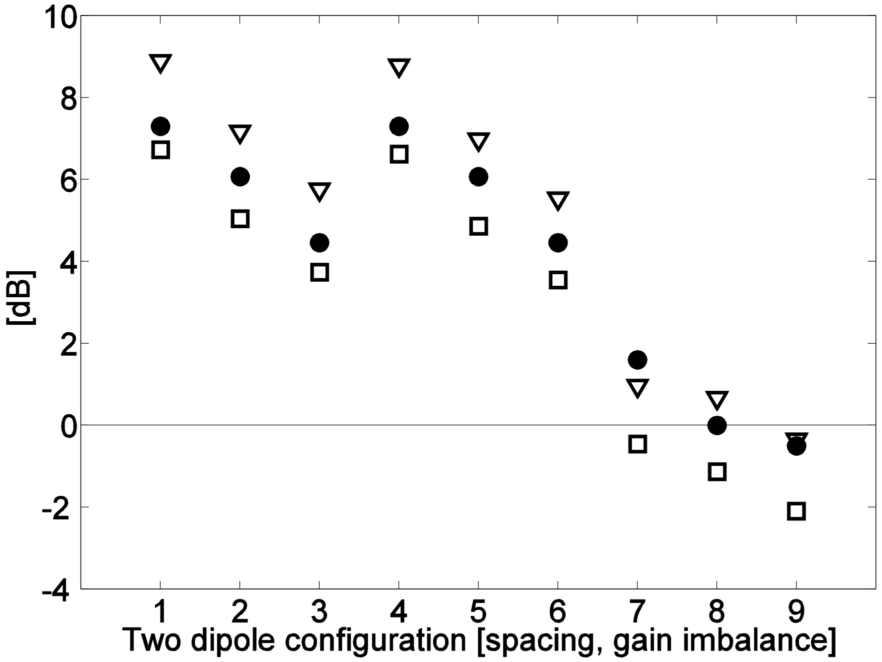

Fig. 4 Measured actual power gain and calculated actual diversity gain (ADG) at two probabilities for nine configurations of spacing and gain imbalance at 1.93 GHz

1 [0.5 lambda]
2 [0.5 lambda, 3 dB]
3 [0.5 lambda, 6 dB]
4 [0.25 lambda]
5 [0.25 lambda, 3 dB]
6 [0.25 lambda, 6 dB]
7 [0.05 lambda]
8 [0.05 lambda, 3 dB]
9 [0.05 lambda, 6 dB]

●Measured actual power gain
▽ADG @5%
□ADG @15%