Experimental interference assessment between two independent and simultaneous 4x4 MIMO handset user links, operating at 5GHz

T. W. C Brown, Centre for Communication Systems Research, University of Surrey, UK
P. C. F. Eggers and G. F. Pedersen, Antennas, Propagation and Networking Section,
Aalborg University, Denmark

Abstract

Though interference is well known to be a significant burden on multiple input multiple output (MIMO) communication systems, mostly signal to noise ratio (SNR) limitations have been studied, whereas little experimental interference behavioural knowledge exist in open literature so far. In this letter we present measured simultaneous signal to interference ratio (SIR) data due to realistic terminal handling. Not only is the environment changing for two separate mobile terminals but the user interaction (handling) on each mobile is also changing independently. Thus, the user interaction on the wanted terminal will impact its ability to overcome interference of another user, while at the same time the other user's interaction on his/her terminal will influence the actual interference on the wanted terminal.

Introduction and Background

The measurements presented use the same data as in [1], i.e. two independent 4x4 MIMO handset users operating fully simultaneously at 5GHz while subject to three different base station (BS) links. A key metric to define, is the interference in the MIMO case. We base it on the singular value decomposition of the wanted normalised channel between a base station and mobile, which is denoted $\mathbf{H}_1$ and the interfering normalised channel between another base station and mobile, denoted as $\mathbf{H}_{2I}$. The same analysis can be made using $\mathbf{H}_2$ as the wanted channel and $\mathbf{H}_{1I}$ as the interfering channel instead). In general, for channel n , singular value decomposition can be applied as follows [2]:

$$\mathbf{H}_n = [\mathbf{u}_{n1} \quad \mathbf{u}_{n2} \quad \mathbf{u}_{n3} \quad \mathbf{u}_{n4}] \begin{pmatrix} s_{n1} & 0 & 0 & 0 \\ 0 & s_{n2} & 0 & 0 \\ 0 & 0 & s_{n3} & 0 \\ 0 & 0 & 0 & s_{n4} \end{pmatrix} \begin{bmatrix} \mathbf{v}_{n1}^H & \mathbf{v}_{n2}^H & \mathbf{v}_{n3}^H & \mathbf{v}_{n4}^H \end{bmatrix} \quad (1)$$

where the eigenvalues of $\mathbf{H}\mathbf{H}^H$ are s_{n1}^2 to s_{n4}^2 . Thus, we define the SIR the ratio of the dominant eigenvalue of the wanted channel, $\mathbf{H}_1$ (i.e. highest diversity order and highest link gain so other eigenvalues would contribute less significantly) to the total interfering power from all eigenmodes of the interfering channel, $\mathbf{H}_{2I}$:

$$\text{SIR} = \frac{s_{11}^2}{\left| \mathbf{u}_{11}^H \mathbf{H}_{21} \mathbf{v}_{21} \right|^2 + \left| \mathbf{u}_{12}^H \mathbf{H}_{21} \mathbf{v}_{22} \right|^2 + \left| \mathbf{u}_{13}^H \mathbf{H}_{21} \mathbf{v}_{23} \right|^2 + \left| \mathbf{u}_{14}^H \mathbf{H}_{21} \mathbf{v}_{24} \right|^2} \quad (2)$$

It is well known from previous research carried out that the branch power ratios (BPRs) on a mobile terminal will have far greater impact on the diversity performance and channel rank of a link to a mobile terminal [3]. Thus the interest in this paper for 4x4 MIMO links is with regards to the two terminals are defined as three cases taking the power at branches 2, 3, or 4 relative to branch 1 of the terminal for the n^{th} transmit branch:

$$\text{BPR}_{n1} = \frac{\overline{|h_{n1}|^2}}{|h_{n2}|^2} \quad \text{BPR}_{n2} = \frac{\overline{|h_{n1}|^2}}{|h_{n3}|^2} \quad \text{BPR}_{n3} = \frac{\overline{|h_{n1}|^2}}{|h_{n4}|^2} \quad (3)$$

Results

With 4 transmit antennas, each terminal results in having 12 BPRs represented as separate 'points' in the plots. Figure 1 compares the BPRs of the two mobiles MS1 and MS2. In the first case, with the clear circle plotting points, the BPRs of MS2 are significantly lower by as much as 10dB than that of MS1 resulting in significantly higher SIR as shown in the clear circles in Figure 2. In the filled squares in Figure 1, the same mobile is communicating with the same base station but for the same measurement, MS2 has switched from BS2 to BS3. Thus, only the BPR in MS2 changed as all measurements are simultaneous. In this instance, the higher BPR of MS2 has resulted in a higher SIR of MS1. The average SIR has reduced by over 10dB as a result of BPRs increasing to as high as 8dB. The average SIR of MS1 remains the same though the spread of SIR on both channels has reduced causing minor changes to the cumulative distribution of the SIR. In both cases it is observed that the majority of SIR instances are occurring around the (5.5dB, 5.5dB) coordinate. It is rarely the case that the SIR falls below this value for both terminals at the same time. Furthermore both terminals never fall below 0dB at the same time. As both users have diversity gain in their wanted channels but not with their interfering channels, it causes them both to have the average SIR in this region from constructive additions in the wanted channels.

A further comparison is made by the two sets of contour plots in Figure 2, which represent upper decentile regions (inside the contours) of SIR1 and SIR2 values. In the second case with dashed contours, where MS1 has comparable BPR to MS2, the contours are considerably more spread than when the BPRs are stronger on MS2 as in the first case that encapsulates the (5.5dB, 5.5dB) area. In this instance contour covers only a 5dBx3dB region.

Therefore comparable BPR (MS1 vs MS2) quantifies a significant shift in the SIRs being more than twice as likely to be as far as 10-15dB apart while the stronger BPR case of one terminal will keep both terminals' SIRs around 5.5dB and less than 3dBs away from each other.

Conclusion

These measurements evidence that MIMO interference on a mobile terminal is not only due to the user interaction (i.e. change in BPR) of the mobile terminal itself but also due to the user interaction of links to interfering mobiles. These results indicate that BPR seems a dominating factor in line with previous investigations on interference between two independent BS to MS links that were measured in this scenario. For handset based multiple user MIMO communications, the user interaction will therefore require inclusion in modelling interference characteristics.

Figure 1 - Scatter plot comparing the instantaneous BPRs of an interfering and wanted terminal

Figure 2 - Scatter plot comparing the instantaneous SIRs of an interfering and wanted terminal with contour boundaries showing the upper decentile of the 2D cumulative SIRs

References

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