Title:	Modeling Intercell Interference
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1. INTRODUCTION

It has been suggested that intercell interference be explicitly modeled for system simulations, because by ignoring the spatial structure of the interference, the performance of detectors such as the MMSE receiver may be compromised. In this document, we present a preliminary investigation on the modeling of intercell interference for system level MIMO simulations based on the signal to interference plus noise (SINR) metric at the output of a MMSE receiver.

2. METHODOLOGY

The MMSE receiver has been proposed as a baseline receiver for comparing system performance results [1]. The tap weights of the MMSE receiver are a function of the spatial characteristics of the interference from adjacent cells. One can account for the interference explicitly by the modeling it as spatially colored noise, or one can model it as spatially white noise. By modeling the interference as spatially white noise, the resulting MMSE receiver would not account for the spatial nature of the interference, and the SINR output may not accurately reflect the SINR output of an MMSE receiver that accounted for it. For example, if there is strong spatial interference from a given direction, the MMSE receiver that accounts for it may be able to suppress it and give a much higher SINR. On the other hand, by modeling the interference from all bases explicitly, while the MMSE receiver may more closely reflect an adaptive MMSE receiver that may be implemented in practice, the complexity in modeling the interference completely may be restrictively high. Using the MMSE the completely models the interference as a baseline, we use the system simulation methodology proposed in [2] and evaluate the error in the SINR at the output of the MMSE receiver as the amount of explicitly modeled interference is reduced.

We consider the received signal by a mobile receiver with R antennas in the center cell of a system with 2 rings of hexagonal cells, each with 3 sectors for a total of 57 sectors. Each of the bases has T transmit antennas. As in [2], the received powers from all 57 sectors are determined based on path loss and shadow fading, and the sector with the strongest power is chosen to be the serving sector. Let the received signal for a given chip interval be given by

$$\mathbf{r} = \sum_{i=0}^{57} A_i \mathbf{H}_i \mathbf{b}_i + \mathbf{n}$$

where A_i (i = 0, 1, …, 56) is the amplitude (per transmit antenna) of the signal from the ith sector, $\mathbf{H}_i$ is the R-by-T channel matrix corresponding to this sector, $\mathbf{b}_i$ is the T-dimensional vector corresponding to the chip elements of the T transmitted signals from this sector. For simplicity, we ignore the presence of additive white Gaussian noise. The elements of the matrices $\mathbf{H}_i$ are i.i.d., complex Gaussian random variables with unit power. In general, the elements of these matrices are derived from the spatial channel model. The elements of $\mathbf{b}_i$ have unit power, and the index i = 0 corresponds to the serving sector so that A_0 is greater than all other A_i (i = 1, 2, …, 56). The other sectors can be ordered in an arbitrary order. Given the received signal, the MMSE receiver is the R-by-T matrix [2]:

$$\mathbf{W} = \mathbf{H}_0 \left(\mathbf{H}_0^H \mathbf{H}_0 + \sum_{i=1}^{56} \frac{A_i^2}{A_0^2} \mathbf{H}_i^H \mathbf{H}_i \right)^{-1} \quad (1)$$

Suppose we wish to spatially model the interference from only a subset of the bases. More specifically, let $F(w)$ denote this subset of sector indices such that $A_i / A_0 > w$. Therefore $F(0)$ is the entire index set ($i = 1, 2, \ldots, 56$), and $F(1)$ is the null set. The interference power from sector i outside of this set $F(w)$ is given by $A_i^2 T$. Therefore the MMSE receiver which models the spatial interference from the set $F(w)$ explicitly is

$$\mathbf{W}(w) = \mathbf{H}_0 \left(\mathbf{H}_0^H \mathbf{H}_0 + \sum_{i \in F(w)} \frac{A_i^2}{A_0^2} \mathbf{H}_i^H \mathbf{H}_i + \sum_{i \notin F(w)} \frac{A_i^2}{A_0^2} \mathbf{I}_T \right)^{-1}. \quad (2)$$

Note that for $w = 0$, $\mathbf{W}(w)$ in (2) is equivalent to $\mathbf{W}$ in (1). Writing the matrices $\mathbf{H}_0$ and $\mathbf{W}(w)$ in terms of their column vectors $\mathbf{H}_0 = [\mathbf{h}_1 \cdots \mathbf{h}_T]$ (we drop the 0 subscript for the vectors) and $\mathbf{W}(w) = [\mathbf{w}_1(w) \cdots \mathbf{w}_T(w)]$, the SINR for the tth antenna ($t = 1 \ldots T$) is

$$SINR_t(w) = \frac{A_0^2 \left| \mathbf{w}_t^H(w) \mathbf{h}_t \right|^2}{A_0^2 \sum_{\substack{j=1 \\ j \neq t}}^{T} \left| \mathbf{w}_t^H(w) \mathbf{h}_j \right|^2 + \sum_{i=1}^{56} A_i^2 \left\| \mathbf{W}^H(w) \mathbf{H}_i \right\|^2}. \quad (3)$$

Note that while the MMSE receiver may not account for the spatial nature of all the interferers, the SINR must.

3. NUMERICAL RESULTS

We compute the SINR in equation (3) for N channel realizations, and we denote the nth realization ($n = 1 \ldots N$) as $SINR_t(w,n)$. Recall that for $w = 0$, $SINR_t(w,n)$ corresponds to the MMSE when all of the interference is accounted for. We compute $N = 10000$ realizations of $SINR_t(w,n)$ ($w = 0, 0.01, 0.03, 0.1, 0.3, 1$) by randomly placing a user uniformly in the center cell of a 19-cell, two-ring hexagonal cell configuration. We let

$$e_t(w,n) := \left| \frac{SINR_t(w,n) - SINR_t(0,n)}{SINR_t(0,n)} \right|$$

be the normalized error between $SINR_t(w,n)$ and $SINR_t(0,n)$ for the nth realization. We collect the errors for all $t = 1 \ldots T$ and $n = 1 \ldots N$ and plot its cumulative distribution function (CDF) in Figure 1. Figure 2 gives the CDF of the number of sectors whose interference levels are higher than w. In Figure 1, starting from the left, the CDF of the error for $w = 0.01$ is less than 1% at least 90% of the time. Figure 2 shows that for $w = 0.01$, the fraction of interference power from 20 out of 56 sectors is less than $w = 0.01$ for over 90% of the realizations. Therefore, by ignoring the spatial structure of a significant number of interferers, the inaccuracy in the SINR output is minimal a significant fraction of time. One can simplify the channel model even more by increasing w and decreasing the number of explicitly modeled interferers. For $w = 0.1$, the number of interferers modeled is less than 5 for over 90% of the realizations, and the SINR error is less than 10% for over 95% of the realizations.

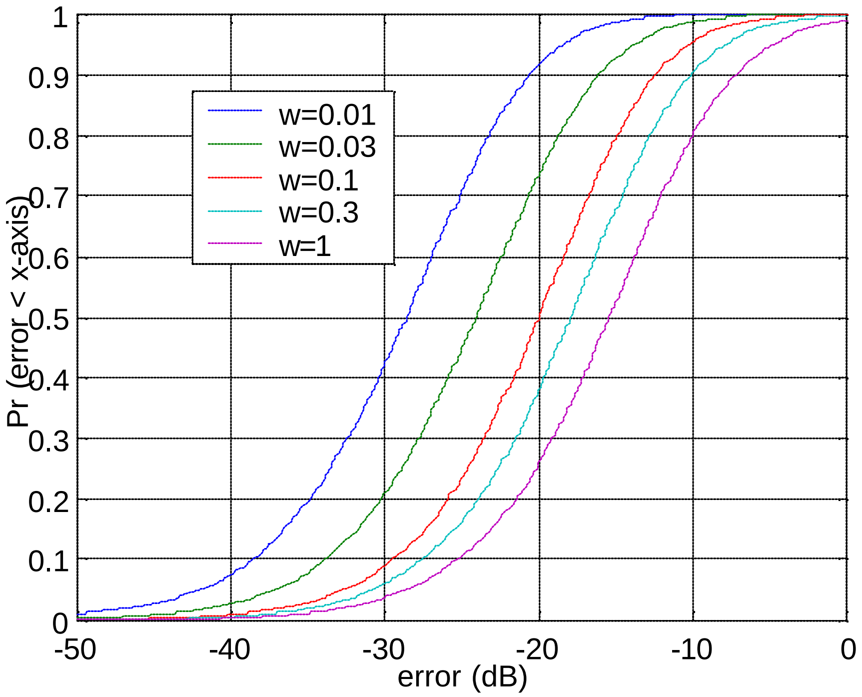

Figure 1. CDF of error

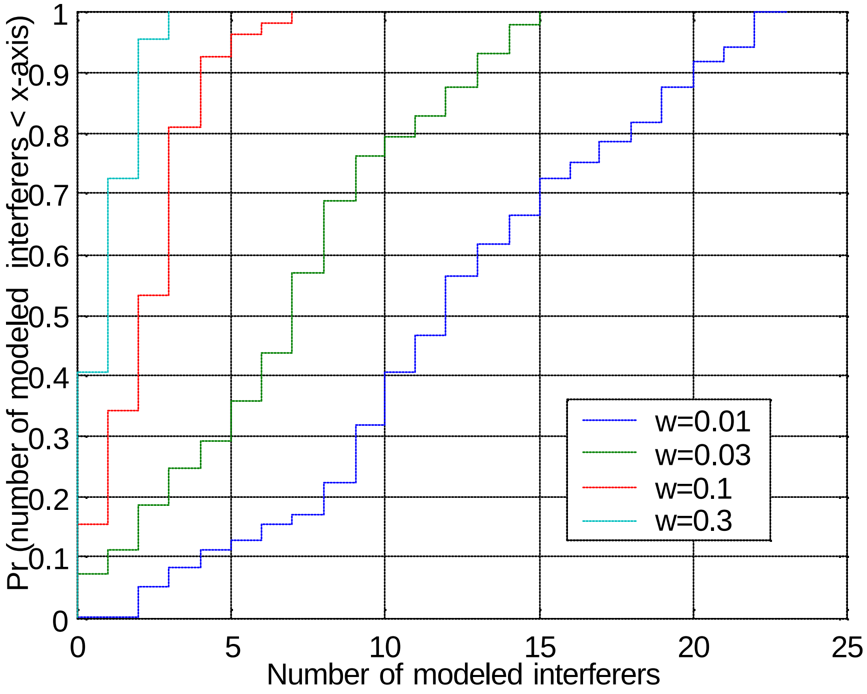

Figure 2. CDF of number of modeled interferers

4. CONCLUSIONS

We propose a threshold-based technique for determining how to account for intercell. We show that by modeling only a small fraction of the strongest interferers spatially, the system simulation complexity can be reduced significantly without significantly impacting the resulting SINR measurement at the output of an MMSE detector. Based on these observations, we propose that the system simulation methodology follow a similar technique to account for intercell interference.

5. REFERENCES

[1] SCM-056, Motorola, “A proposed receiver for system evaluations.”
[2] SCM-058, Lucent, “Preliminary system-level simulation results.”