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Title	**Receive Beamforming with Interference Nulling in the 802.16m**
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Re:	IEEE C802.16m-08/052 - Call for Comments and Contributions on Project 802.16m System Description Document (SDD).
Abstract	This contribution describes the rationale for Receive Beamforming with Interference Nulling (RXBFIN) and proposes to include it as an interference mitigation technique into the SDD.
Purpose	To include the RXBFIN into the SDD as one of the interference mitigation techniques.
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Receive Beamforming with Interference Nulling in 802.16m

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1. Introduction

Receive beamforming with interference nulling (hereafter will be known as RxBFIN), has become one of the most prominent methods for interference mitigation in wireless communications systems. The concepts underlying Receive Beamforming originate from the field of phased array systems in RADAR theory. It is well known that adequate complex weighting of an antenna array results in an equivalent directional antenna. Similarly, complex weighting of an antenna array may lead to the formation of spatial nulls, suppressing the radiation from certain directions (see Fig 1).

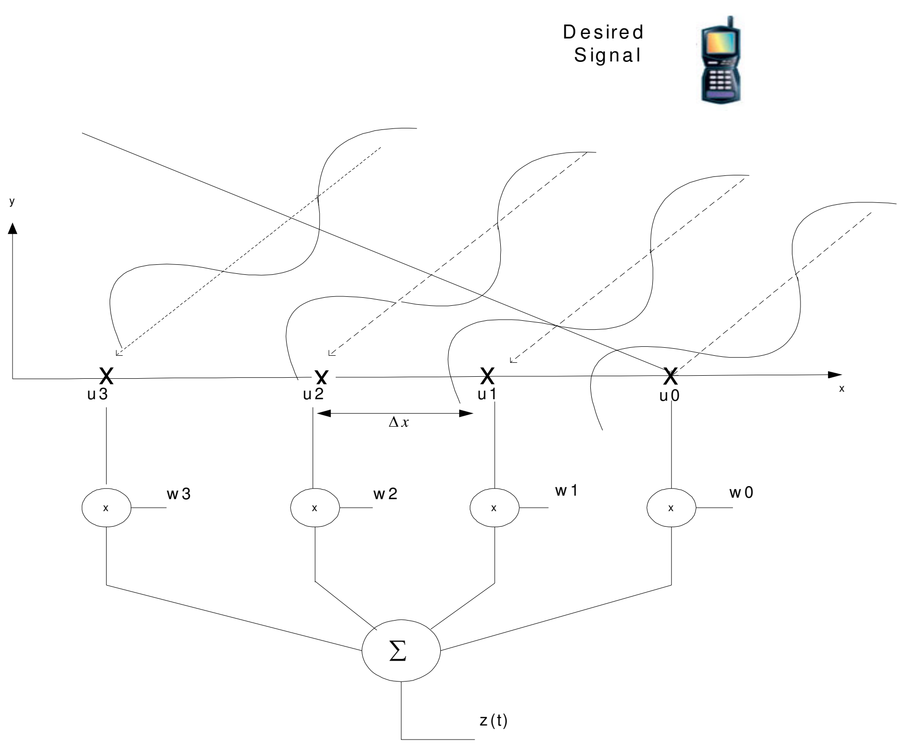

Figure 1: Main principle of Rx_BF with Nulling

In communications systems, the receiver is usually aiming at the amplification of desired information sources and the suppression of interfering sources. When the desired sources and interferers are spatially separated, it is possible to apply beamforming techniques to enhance the communication link.

In OFDMA, weight vectors are usually applied independently to narrow frequency bands in which the channel can be assumed constant.

In this document we compare the performance of Rx BF with that of MRC, when the UL data is transmitted with PUSC without subchannel rotation (as defined in the 802.16e). Note that the UL resource unit structure as defined within the 16m SDD is very similar to the structure considered in this contribution, thus the simulation results presented in this contribution conform also for the former case.

The simulations reveal the significant robustness of Rx beamforming algorithms when the BS is equipped with (at least) 4 Rx antennas.

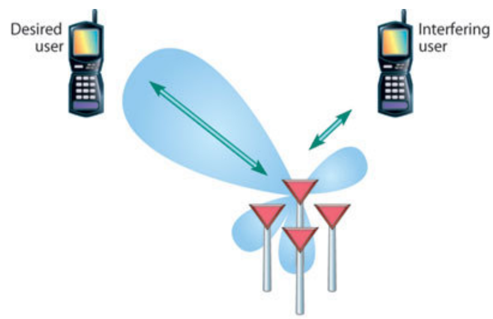

Figure 2: Typical scenario of Rx beamforming. The BS constructs a beam aiming at the desired user while trying to eliminate the contribution from the interfering user (spatial nulls).

2. <u>Preliminaries</u>

2.1 802.16e PUSC UL Tile Structure

We consider hereafter the 802.16e PUSC w/o subchannel rotation UL format. This transmission format is applied here since it allows a large density of pilots in a relatively narrow frequency band. This allows the generation of an independent weight vector designed for a band as small as 4 subcarriers.

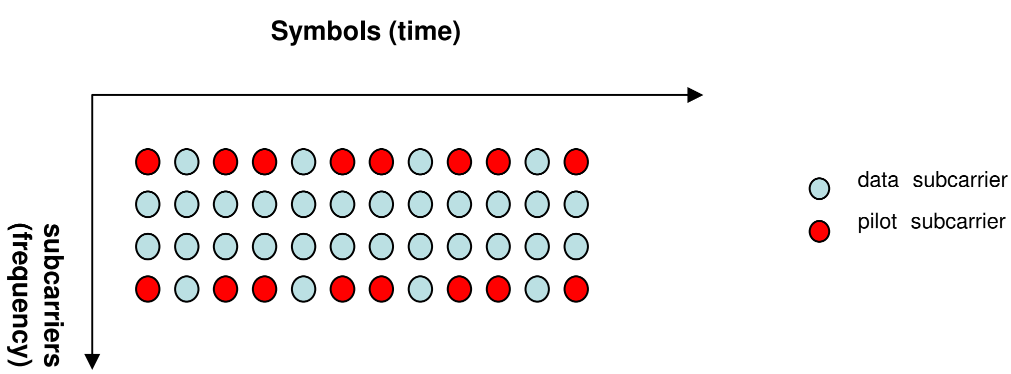

Figure 3: 802.16e UL PUSC Pilot Pattern

2.2 Mathematical Model and Definitions

The mathematical model for the received signal $\mathbf{y}$ (on a subcarrier level) is

$$\mathbf{y} = \mathbf{h}_0 s_0 + \sum_{i=1}^{N} \mathbf{h}_i s_i + \rho \mathbf{n}, \tag{1}$$

where $\mathbf{h}_0$ is the channel of the desirable user, $\mathbf{h}_i, i = 1,\ldots,N,$ is the channel of the i-th interference source, s_i is the transmitted QAM symbols, and $\mathbf{n}$ is an additive white Gaussian noise (AWGN) with unit power.

Assuming that the signals have unit power, we define the signal to interference ratio (SIR), the signal to noise ratio and the signal to interference and noise ratio (SINR) as follows:

$$\mathbf{SIR} = \frac{P_D}{\sum_{i=1}^{N} P_i}, \quad \mathbf{SNR} = \frac{P_D}{\rho^2}, \quad \mathbf{SINR} = \frac{P_D}{\sum_{i=1}^{N} P_i + \rho^2}, \tag{2}$$

where P_D is the channel power of the desirable user, P_i is the channel power of i-th interferer and ρ is the noise intensity.

3. Simulation Results

3.1 Simulations parameters

We used the ITU Pedestrian B 3 km/h and Vehicular A. 15km/h channels. The correlation between BS's channels is 0, 0.2, 0.4, 0.6 (the correlations are assumed to be real valued). The interference channels are assumed uncorrelated with the desirable user channels. We also assume that the BS utilizes all its receive antennas.

Other simulation parameters are: Convolutional Turbo Coding, FEC block size=480 bits, QPSK1/2 and carrier frequency=2.5GHz.

3.2 Simulations results

In the next two plots, the performance of RXBFIN versus the performance (BER and PER) of the standard MRC 1X4 scheme (with real-life channel estimation) is presented for SIRs in the range [-25dB, -10dB]. The users' channels are assumed here to be uncorrelated. The graphs show that MRC has an error floor at BER=0.3, while the RxBFIN scheme performs significantly better.

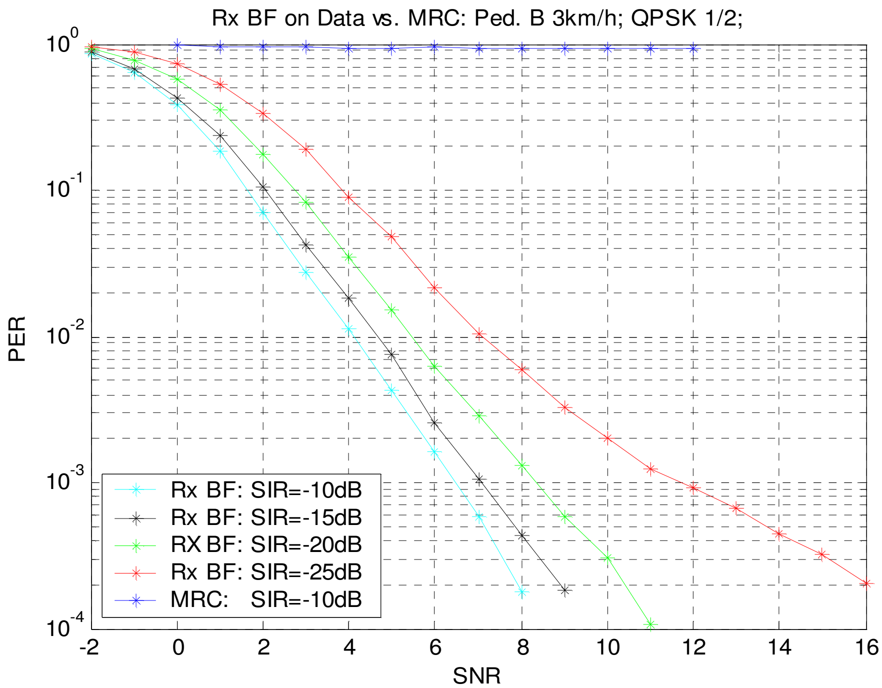

Fig. 4: MRC vs. RxBFIN for various SIRs, no correlation, Pedestrian B. 3km/h.

It turns out that the RXBFIN technique performs well for higher mobility users (up to 15km/h examined here), as can be seen in the following figure.

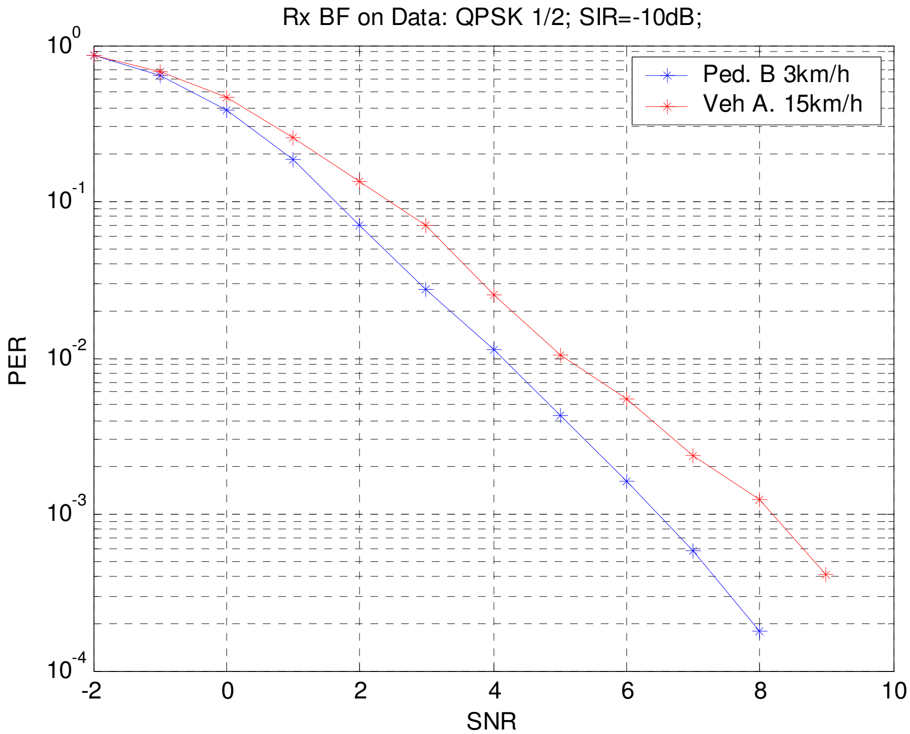

Figure 5: RxBFIN on Data: Mobility effect, Pedestrian B 3km/h.

In the next two graphs we present the performance of RXBFIN for different channel correlations. Note that the impact of channel correlation is negligible up to a value of .2. Even if the antennas are highly correlated (for instance 0.4 and 0.6 correlation) the degradation is rather small (~1-2dB).

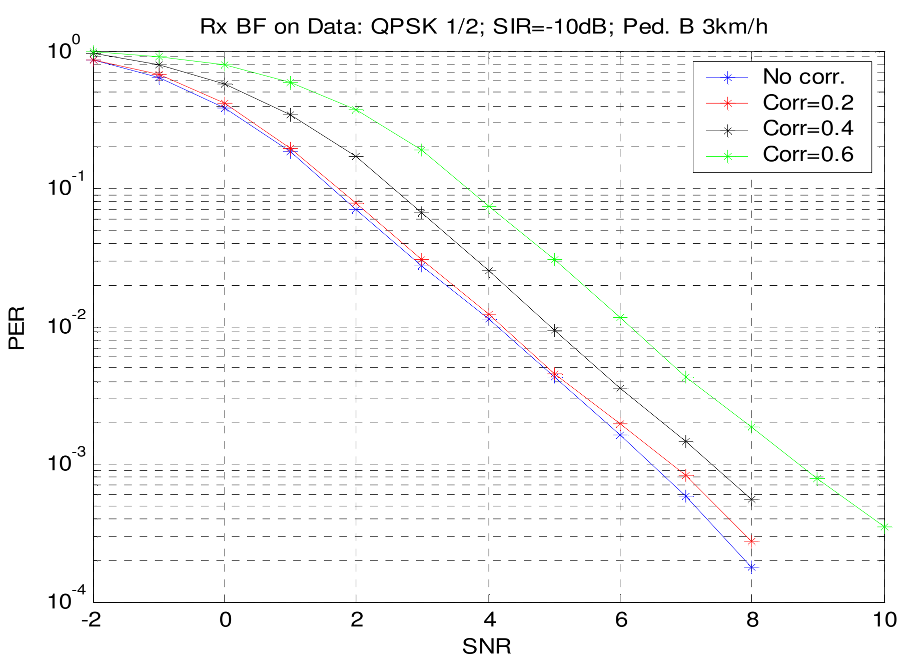

Figure 6: Channel Correlation effect; SIR=-10dB, Pedestrian B 3km/h.

Next, we show that in the interference free scenario (where the MRC is optimal), RXBFIN shows very near optimal performance.

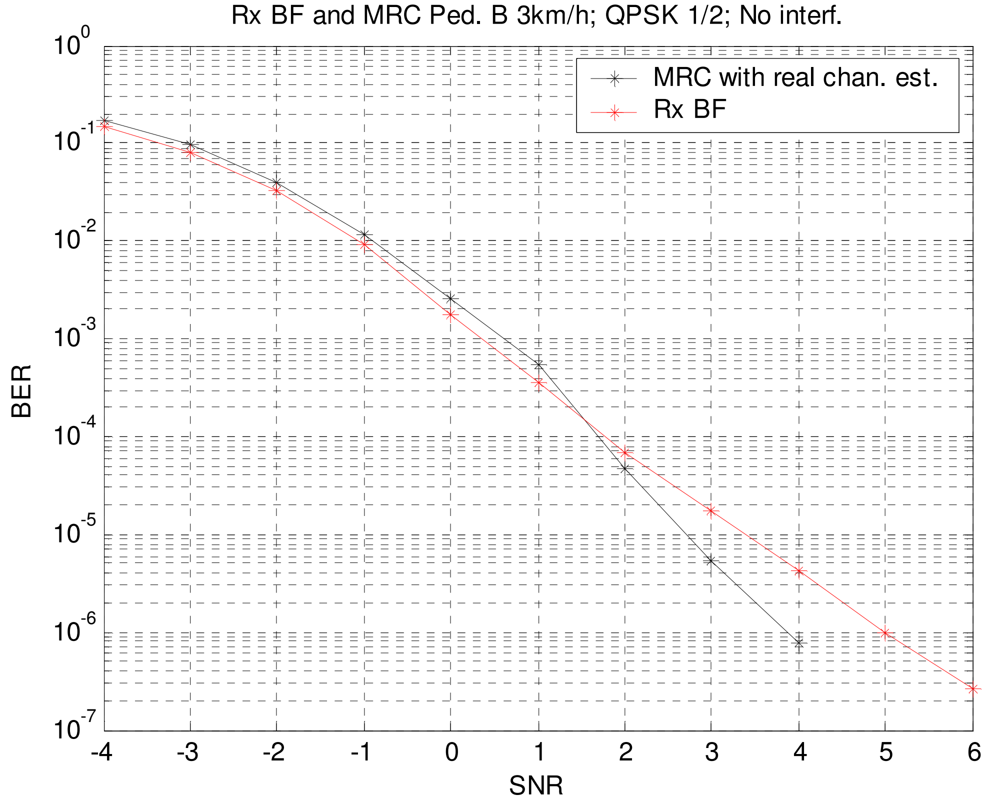

Figure 7: RxBFIN on Data: RxBFIN vs. MRC for non-interference case

Next we compare the performance of RxBFIN for the various number of receive antennas at the BS. It can be seen from the graphs below using a BS equipped with 6 antennas renders a 3dB gain over 4 antennas BS while for 3 antennas Bs possesses degradation of about 3dB for SIR=-10dB. Moreover, if the BS is equipped with 2 Rx antennas only, it fails to yield satisfactory results in this scenario (the BER has the error floor at 2*10^-5).

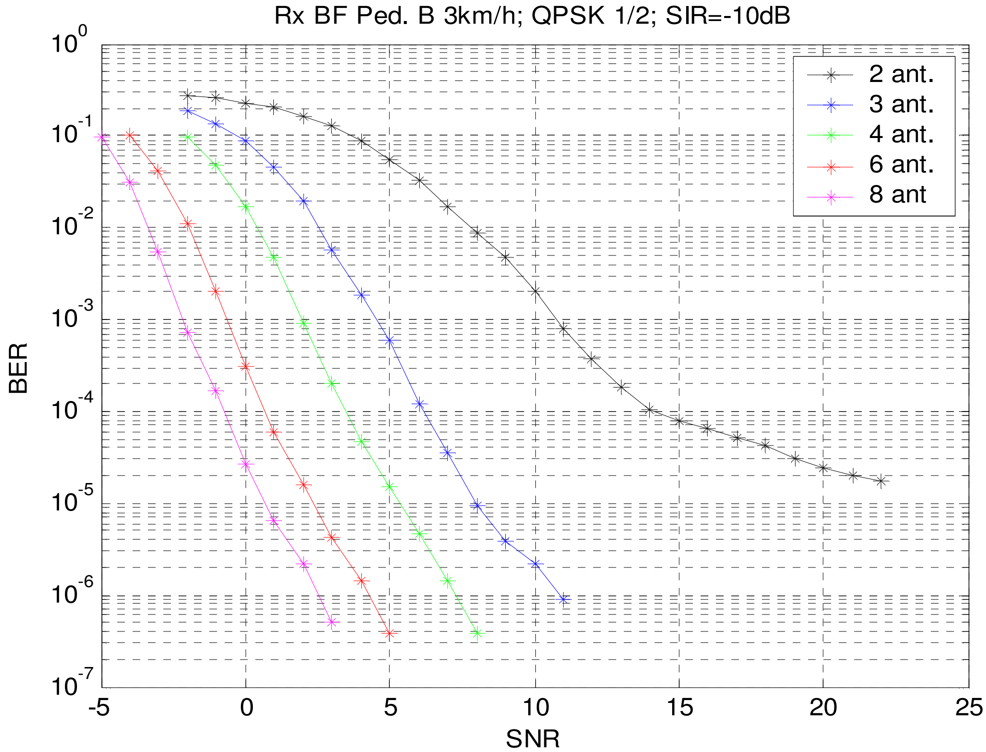

Figure 8: Rx BF on UL data for various number of Rx antennas at the BS

We conclude the section with the RxBIN performance curves for multiple interferers in the system. The relative power profile of the interferers are [0 -3] and [0 -3 -6] (in dB) for the 2 and 3 interferers scenarios respectively. The interferers are assumed to be statistically uncorrelated.

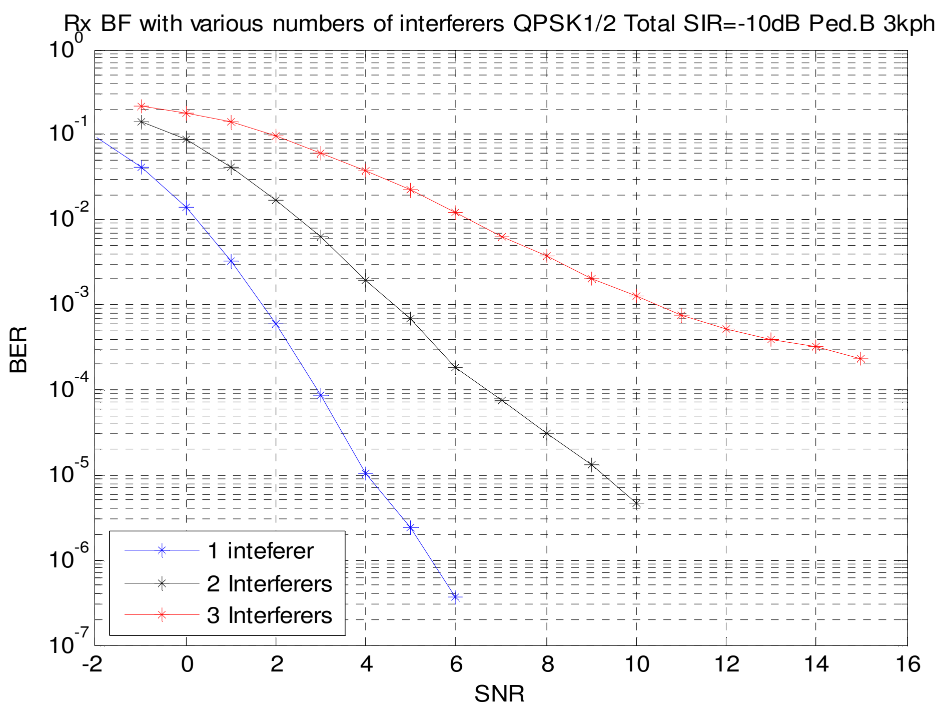

Figure 9: RxBFIN with multiple interferers

4. Conclusions

In this contribution we examined the performance of RxBFIN employed at the BS. The RxBFIN scheme provides significant performance gain in the case of strong interference. Moreover, it shows very small degradation in the interference free scenario compared to MRC with channel estimation. The additional advantage of RxBFIN is its resilience to channel correlation. Finally, RxBFIN processing doesn't require any knowledge about the interference at the receiver, thus cooperation between the Base Stations is not needed and no additional feedback information is required.

The scenarios of extremely strong interference were chosen to demonstrate the resilience of the RxBFIN methods to interference in various link conditions. Since in many of the deployment scenarios envisioned for 802.16m, the system performance is limited by interference (e.g. inter-cell interference), Rx BF techniques are likely to play a major role.

5. Proposed Changes

[*Insert the proposed text in section 20.2, page 151, after the line 7 as indicated* by underline]

Receive Beamforming with Interference Nulling is a known technique that can be used at the BS to mitigate interference. Specifically, in OFDM systems, Receive Beamforming with Interference Nulling mitigates the interference received at BS from MSs in neighbor cells. UL transmission design (pilots and subchannels structure, MIMO options etc.) will take into account implications of Receive Beamforming with Interference Nulling. The Receive Beamforming with Interference Nulling scheme can be combined with the Fractional Frequency Reuse (FFR) scheme defined in 20.1 or the schemes proposed in the following sub-sections in order to suppress the interference seen at the BS.