Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Receive Beamforming with Null Steering in the 802.16m**
Date Submitted	**2008-07-07**
Source(s)	Michael Erlihson, michaele@runcom.co.il Doron Ezri, dorone@runcom.co.il Itzik Kitroser itzikk@runcom.co.il Runcom Technologies Moshe Levi St. 11, Rishon LeZion 75658, Israel
Re:	IEEE C802.16m-08/024 - Call for Comments and Contributions on Project 802.16m System Description Document (SDD)- Interference cancellation.
Abstract	This contribution describes the rational for Rx BF and proposes to include 4 antenna receiver BF at the BS as mandatory feature in 802.16m SDD document.
Purpose	To incorporate the requirement of placing of at least 4 Rx antennas at the BS.
Notice	
Release	
Patent Policy	

Receive Beamforming with Null Steering in the 802.16m

Michael Erlihson, Doron Ezri, Itzik Kitroser

Runcom Technologies LTD

1. Introduction

Receive beamforming (Rx BF) has become one of the prominent methods for interference mitigation in communications systems. The concepts underlying Rx BF originate from the field of phased array systems in RADAR theory. In phased array techniques it is long 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. This may be viewed as spatial filtering (see Fig 1).

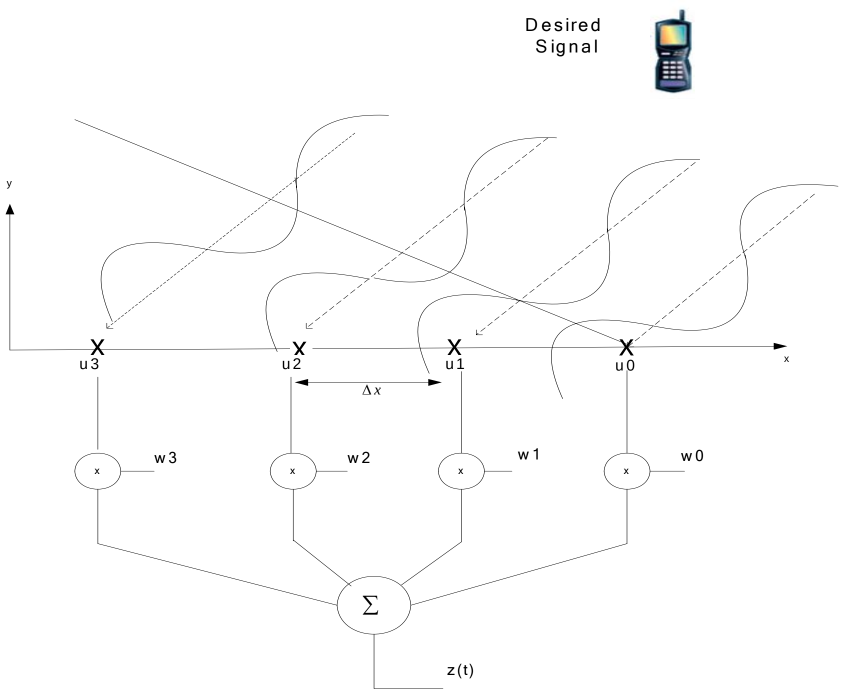


Fig. 1: Main principle of Rx beamforming

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 small frequency bands (smaller than the coherence bandwidth of the channel) as done with PUSC without subchannel rotation in the UL. Thus, standard Rx BF methods do not apply to ranging signals that spread about the entire bandwidth. This means that a different BF procedure is should be invoked for Ranging.

In this document we compare the performance of Rx BF on PUSC without subchannel rotation UL signals with that of standard MRC. Moreover, we give the performance of Rx BF applied to Ranging signals. The simulations reveal the significant robustness of Rx beamforming algorithms when the BS is equipped with (at least) 4 Rx antennas.

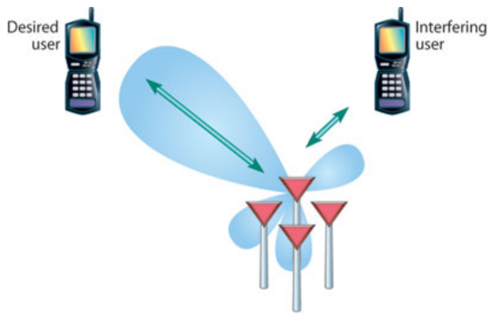


Fig. 2: Typical scenario of Rx beamforming. The BS constructs a beam aiming at the desired user while trying to eliminate the contribution from the interfering user (spatial nulls).

2. **Preliminaries**

2.1 PUSC UL Tile Structure

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

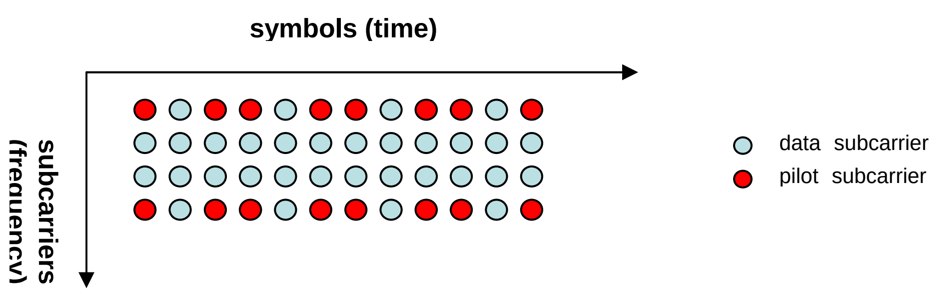


Fig. 3: UL PUSC frame structure

2.2 Mathematical Model and Definitions

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

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

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:

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

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.

2.3 Ranging

Ranging codes are transmitted from the user to the BS in order to obtain information on the network set-up and synchronize the link. In particular, ranging is used to perform power and time synchronization with the user.

The fundamental mechanism of ranging involves the user transmitting a randomly selected ranging code (a CDMA code) in a specified ranging channel, on a randomly selected ranging slot. The BS receives this code and determines the required information. One ranging channel usually contains 144 subcarriers.

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, 06 (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 antennas.

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

3.2 Simulations results

a) **Ranging**

We start with the analysis of the ranging process (short or long for that matter) in the presence of a strong interference. We examine this scenario with variable number of Rx antennas at the BS. We show that increasing the number of Rx antennas at the BS significantly improves the quality of the ranging reception. It turns out that a BS equipped with 4 Rx antennas exhibits high performance ranging code reception up to SIR =–25dB for various channel models. We assume that there are 5 active users with different ranging codes, transmitting concurrently on same ranging slot. The graphs below show the empirical probability of misdetection. Ranging code detection is defined here as the event of successful detection of the code and timing offset estimation with accuracy of 5 samples. In the following figures, the SNR, SIR, and SINR values refer to the ranging signals (not the data).

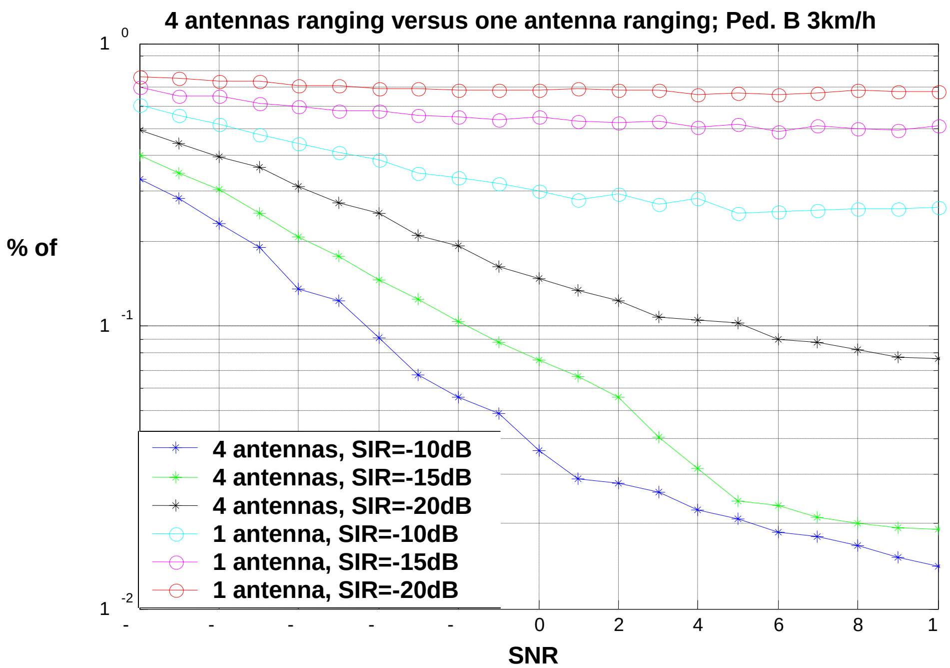


Fig. 4: Number of Rx antennas effect, Ped. B 3km/h;
No correlation.

The 4 antennas BS shows good performance also in the case where the users' channels are correlated. In the next figure the performance of the scheme with 4 and 6 Rx antennas, and 0, 0.5 channel correlation is given. It follows that Rx BF is quite resilient to the channel correlation (the degradation here is about 1dB).

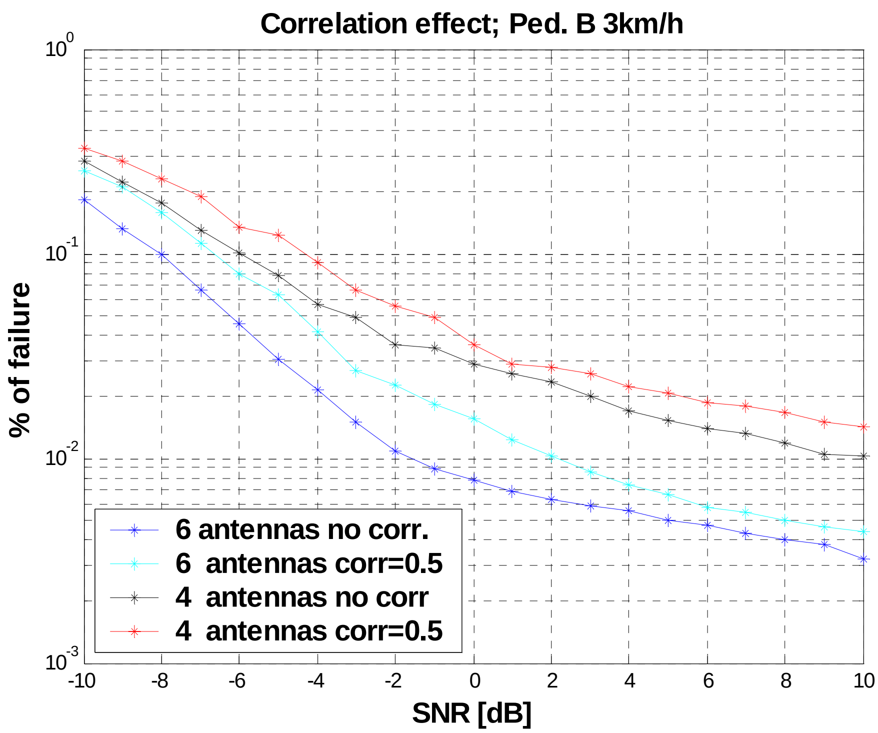


Fig. 5: Correlation effect; SIR=-10dB, Ped. B 3km/h;

Finally, the impact of the channel model is examined considering 4 Rx antennas. It is obvious that the user's mobility has almost no effect on ranging.

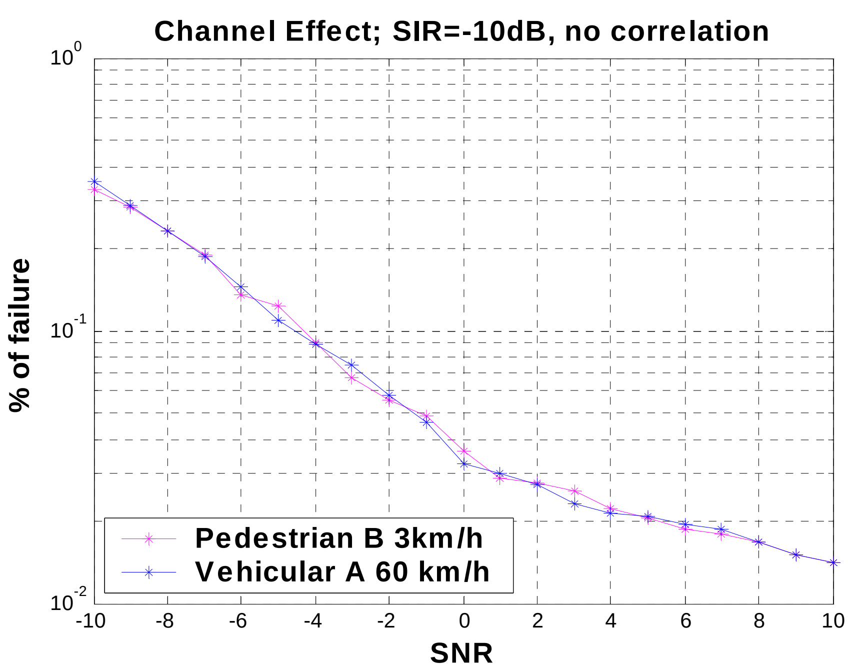


Fig. 6: Channel effect; SIR=-10dB, no correlation

b) **Rx BF on UL Data**

In the next two graphs, the performance of Rx BF 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 the MRC has an error floor at BER=0.3, while the Rx BF possesses much better performance.

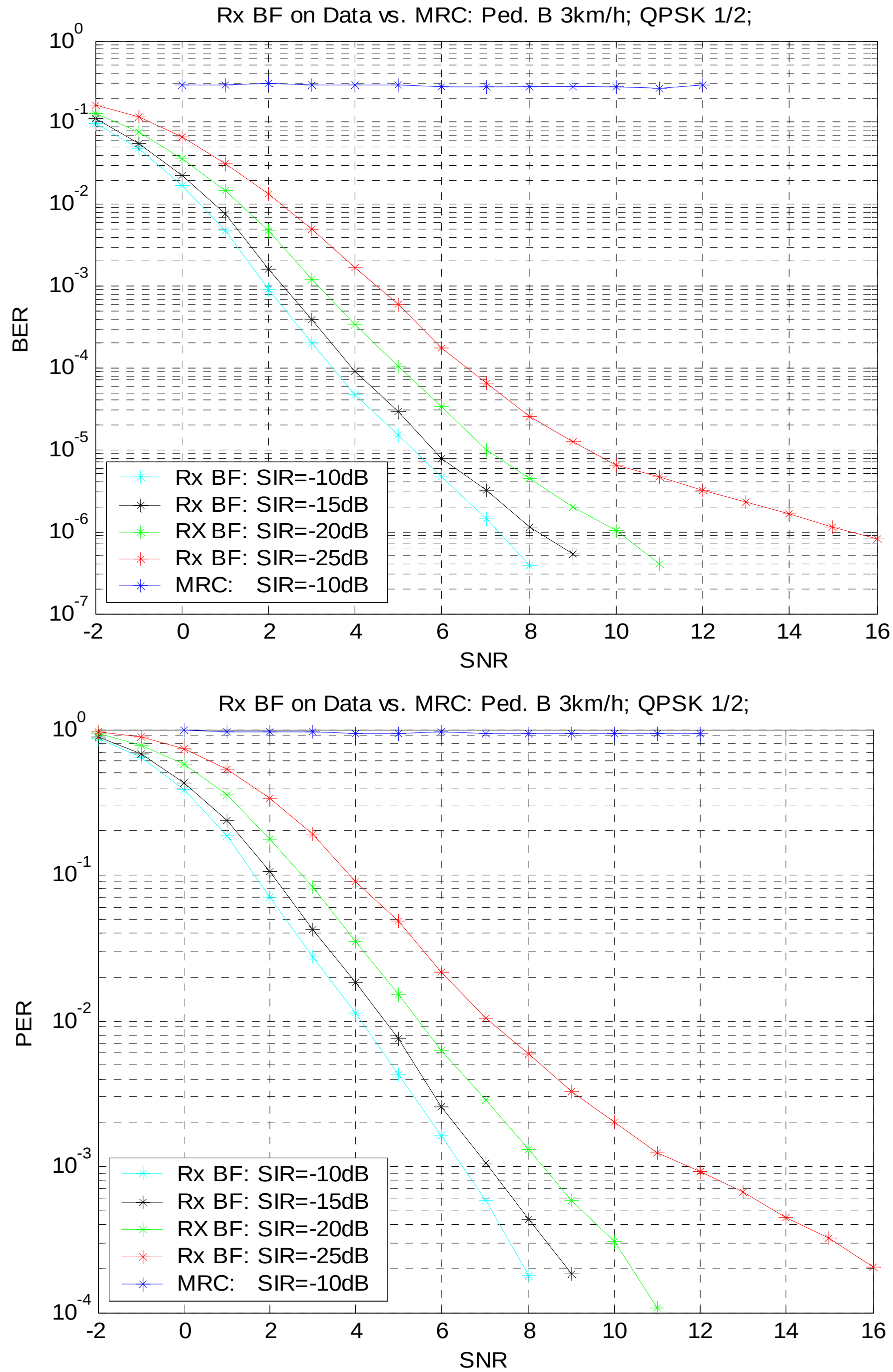
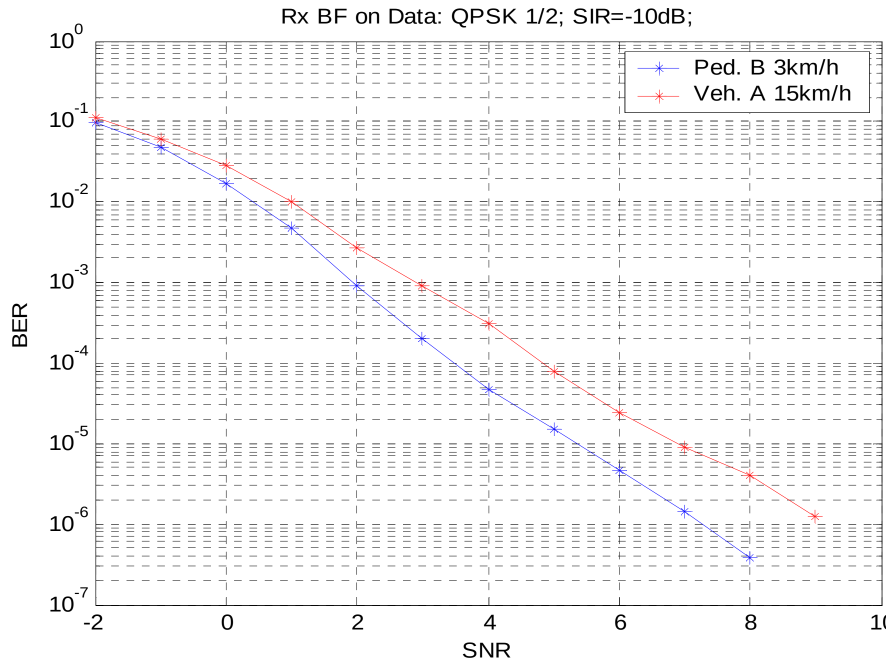


Fig. 7: Rx BF on Data: MRC vs. Rx BF for various SIRs, no correlation, Pedestrian B. 3km/h.

It turns out that the Rx BF technique shows a good performance for higher mobility users (up to 15km/h examined here).



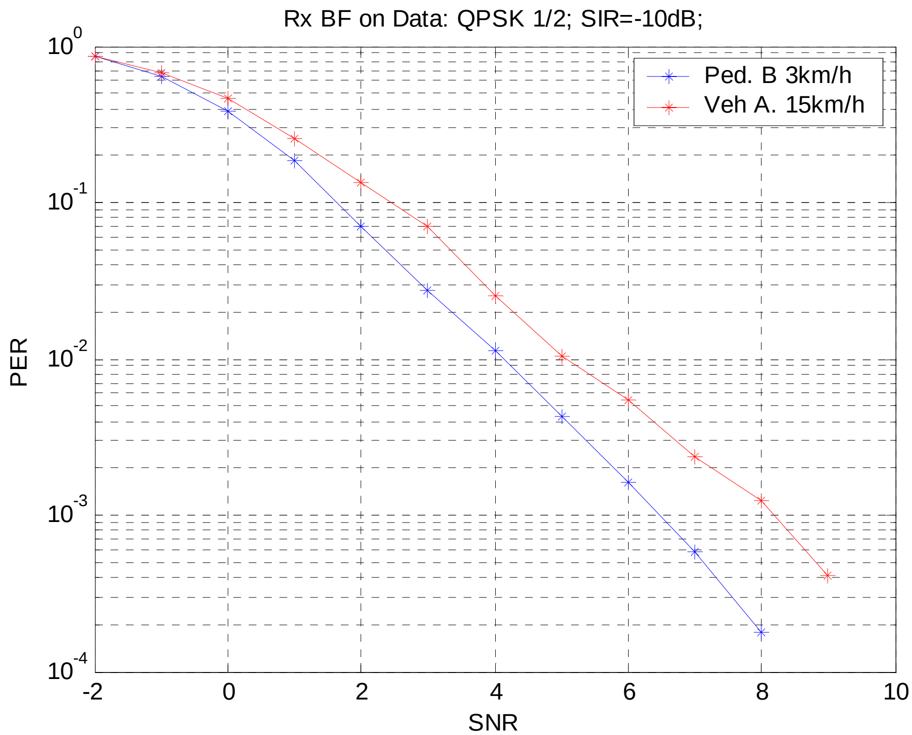
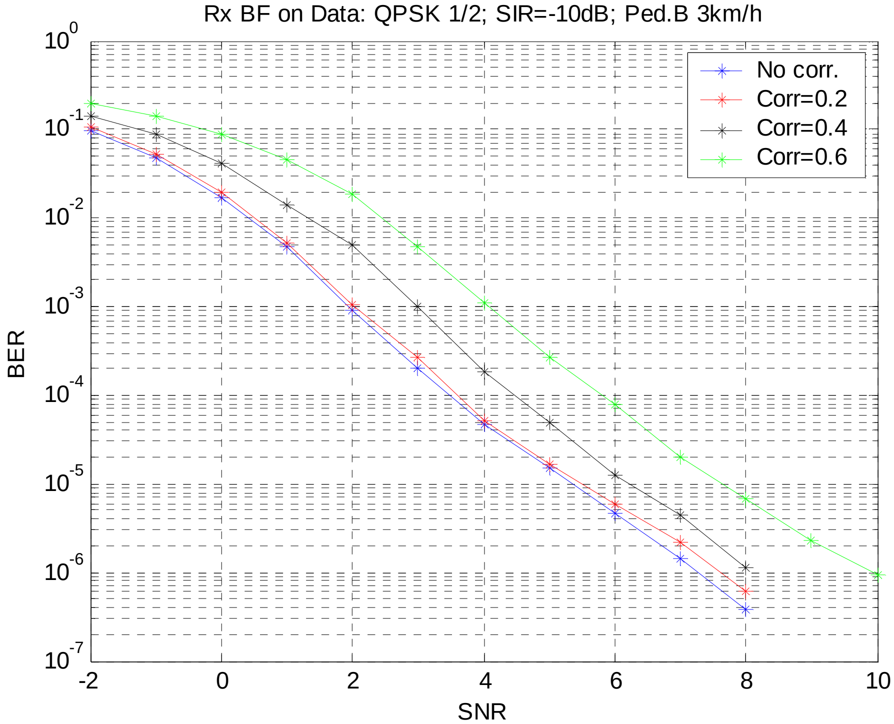


Fig. 9: Rx BF on Data: Mobility effect, Pedestrian B 3km/h.

In the next two graphs we present the performance of Rx BF 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).



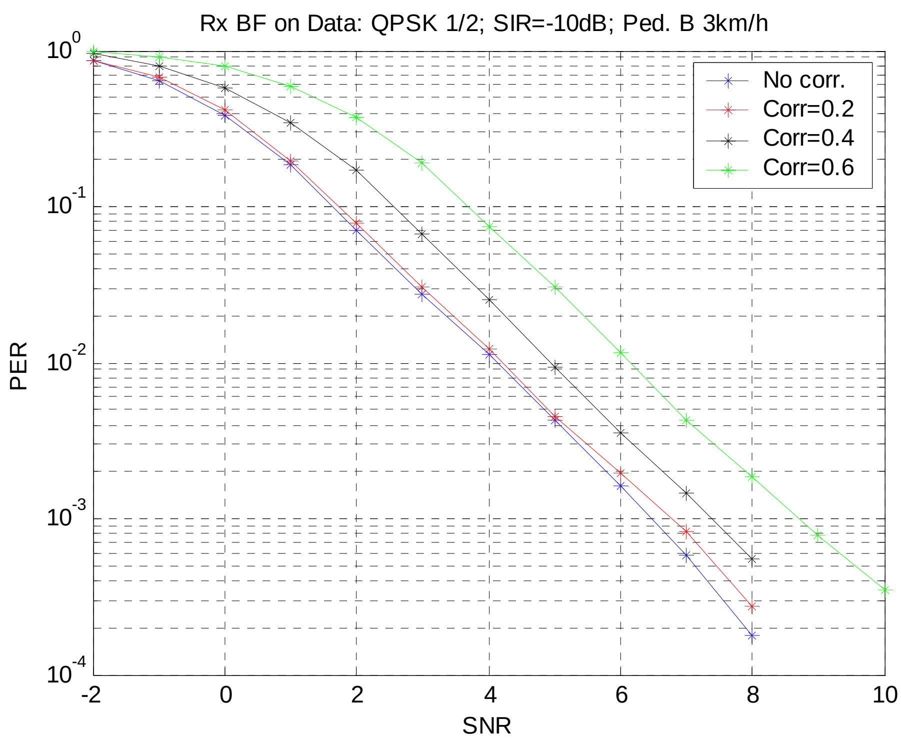


Fig. 10: Channel Correlation effect; SIR=-10dB, Pedestrian B 3km/h.

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

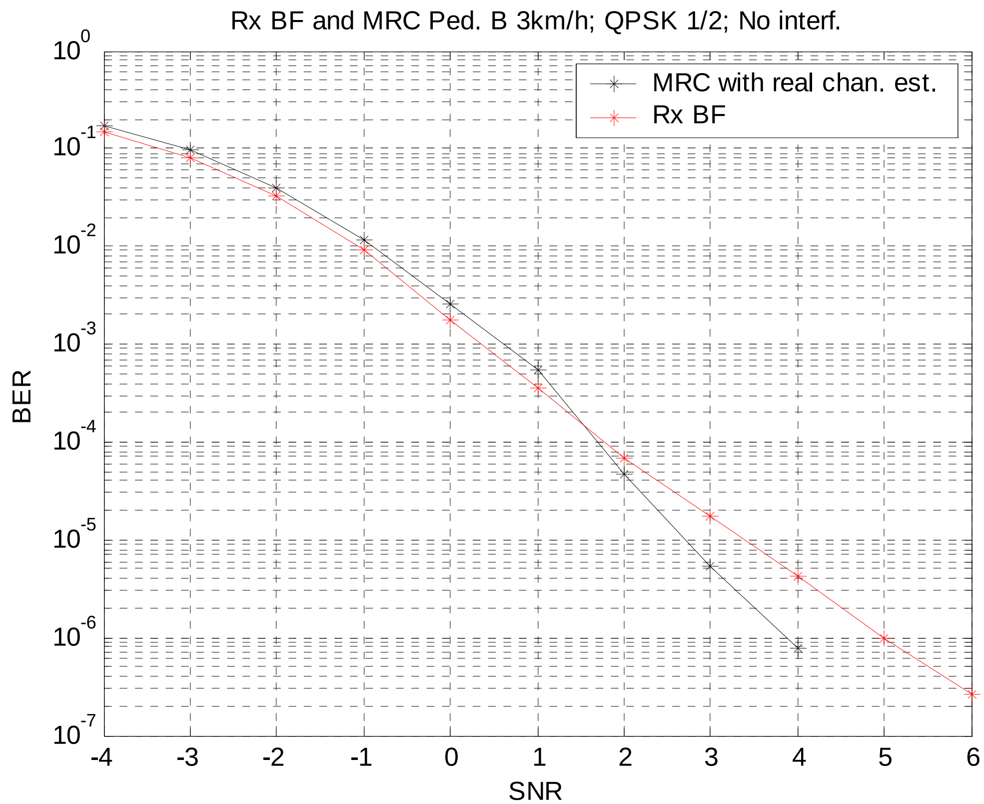


Fig. 11: Rx BF on Data: Rx BF vs. MRC for non-interference case

Finally, we compare the performance of Rx BF for the various number of Rx 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).

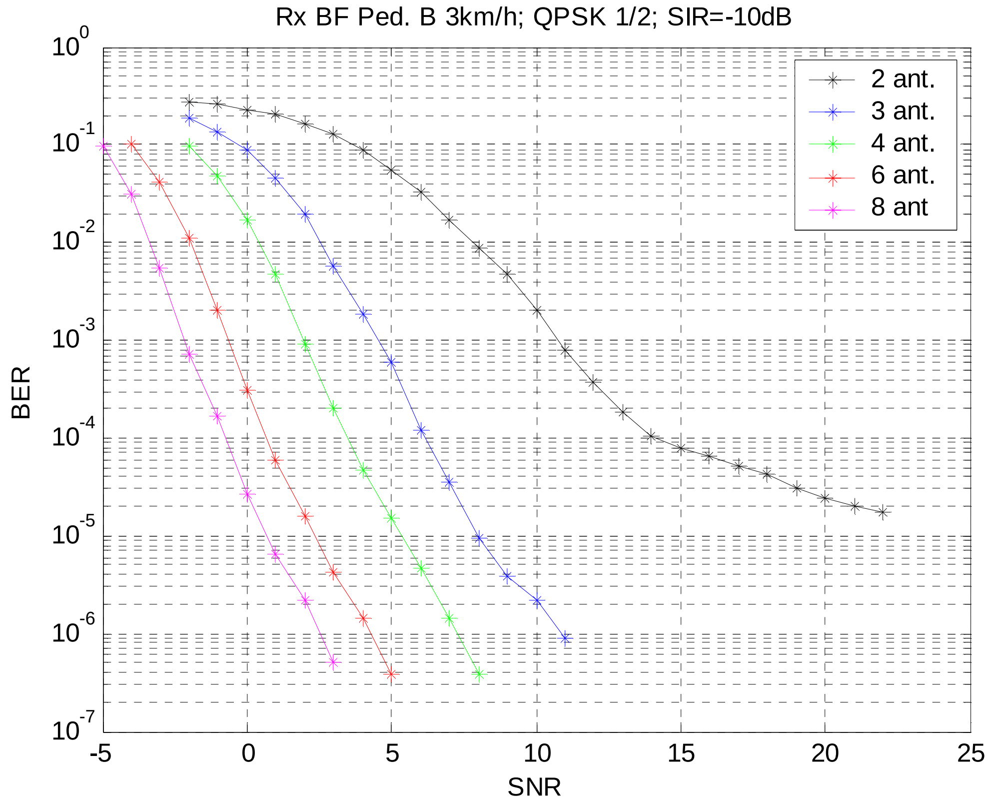


Fig. 12: Rx BF on UL data for various number of antennas at the BS

4. Conclusions

In this contribution we examined the performance of Rx BF employed at the BS. Two different Rx BF scenarios were considered, one for the ranging signals and the other for UL data. In both cases, Rx BF provides significant performance gain in the case of strong interference. Moreover, the latter technique shows very small degradation in the interference free scenario compared to the MRC with channel estimation. The additional advantage of Rx BF is its resilience to channel correlation.

The scenarios of extremely strong interference were chosen to demonstrate the resilience of the Rx BF methods to interference in various transmission methods (not necessarily narrow band signals as PUSC without subchannel rotation). 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. **Since Rx BF methods require larger number of antennas at the BS, we believe 4 antennas at the BS should be a starting point for the 16m**.

5. **Proposed Changes**

[*Change section 8.1, page 20, line 18 as indicated* by underline:]

Interference Management block performs functions to manage the inter-cell/sector interference. The operations may include:

- MAC layer operation
  - Interference measurement/assessment report sent via MAC signaling
  - Interference mitigation by scheduling and flexible frequency reuse
- PHY layer operation
  - Transmit power control
  - Interference randomization
  - Interference cancellation
  - Interference measurement
  - Tx beamforming/precoding
  - Rx beamforming

Mobility Management block supports functions related to Intra-RAT/ Inter-RAT handover. It handles the Intra-RAT/ Inter-RAT Network topology acquisition which includes the advertisement and measurement, and also decides whether MS performs Intra-RAT/ Inter-RAT handover operation.

For efficient support of Rx beamforming, the BS shall support at least four Rx antennas.