Technology Opportunity Bulletin

# Diversity Coding Method for MIMO-OFDM
# Tech ID: 2005-052

A novel coding method for multiple input, multiple output (MIMO) antenna systems with orthogonal frequency division multiplexing (OFDM), or **diversity-coded MIMO-OFDM,** has been developed by researchers at Queen's University. This method increases reliability without lowering the transmission rate, at a cost of modest processing complexity and delay.

**Description:**
A key longstanding challenge facing future high-data-rate wireless communications services is to provide high-data rates with maximum reliability. Recently, multiple input, multiple output (MIMO) antenna systems have attracted considerable attention as a means to dramatically boost rate and reliability of broadband wireless communications services. Multi-carrier modulation, in particular, orthogonal frequency division multiplexing (OFDM), mitigates frequency selectivity (multi-path delay spread) in channel fading by transforming a wideband multi-path channel into multiple parallel narrowband flat fading channels, enabling simple equalization.

The powerful attractive combination of MIMO and OFDM techniques, or MIMO-OFDM, will impact the evolution of wireless LANs, and is a leading candidate for future fourth generation (4G) wireless communications systems. The MIMO-OFDM advantage is very high capacity and spectral efficiency achieved by simultaneously employing the time, space and frequency domains. A key component of a practical MIMO-OFDM system is improved communications reliability, i.e., reduced bit error rate (BER), achieved at reasonable computational complexity.

MIMO-OFDM systems are able to create parallel channels in spatial and frequency domains. However, high-data-rate spatial and frequency multiplexing are prone to independent parallel channel fades, leading to poor performance unless available diversity is properly exploited.

We have invented a novel coding method for MIMO-OFDM systems, which we refer to as *diversity-coded MIMO-OFDM*. **This method increases reliability without lowering the transmission rate**, **at a cost of modest processing complexity and delay.** Table 1, below, highlights the significant advantages and features of the new invention.


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| **Issue** | **Diversity-coded MIMO-OFDM** | **Uncoded MIMO-OFDM** |
|---|---|---|
| Diversity | High | None |
| Data symbol rate | Max $N_T N_C$ data sym. per OFDM block time period | $N_T N_C$ data symbols per OFDM block time period |
| Coding rate | Arbitrary (up to one) | One (no coding) |
| Added Complexity | Modest increase: same processor core Per symbol complexity proportional to channel order | N/A |
| No. of transmit antennas | arbitrary | arbitrary |
| No. of subcarriers per OFDM block | arbitrary | arbitrary |
| Compatibility | Modular upgrade. Backward compatible | N/A |
| Tolerates spatial correlation | Yes | Yes |
| BER performance | Very good | Poor |
| Channel knowledge at Tx | Not required | Not required |
| Channel knowledge at Rx | Required | Required |

Table 1: Comparison of proposed method to generic MIMO-OFDM physical layer.

Below, the MIMO-OFDM systems have $N_T$ transmit antennas, $N_R$ receive antennas and $N_C$ sub-carriers per OFDM block.

**Status of Development:**

We have a proof-of-concept demonstrating:

1. A two-transmit, two-receive antenna MIMO-OFDM system;
2. A frequency-selective 3-path channel order with exponential power delay profile. Channel coefficients remain constant within an OFDM block or group of blocks, but vary arbitrarily (statistically-independently) over subsequent OFDM block groups. We parameterize the temporal channel change rate (CCR) as the number of OFDM blocks over which the channel stays constant;
3. 32 sub-carriers per OFDM block;
4. QPSK data symbols.
5. The normalized average signal-to-noise-ratio (SNR) at each receive antenna is independent of the number of transmit antennas.

Figure 1 (below) shows increased reliability: the proposed diversity-coded MIMO-OFDM system outperforms an uncoded MIMO-OFDM system by 9.8dB at BER $10^{-3}$. Note that the coding rate of this new design is one, identical to that of uncoded MIMO-OFDM. No bandwidth is lost due to coding. (We neglect the overhead pilot and guard symbols common to both systems).

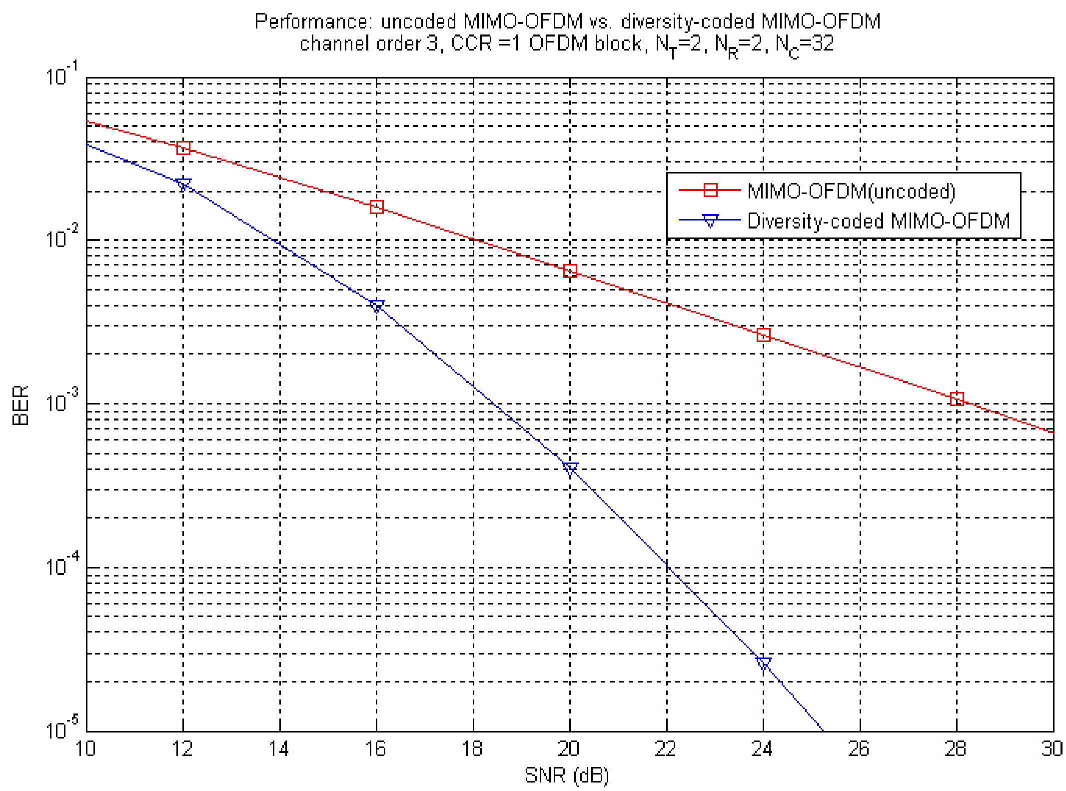


Figure 1. Reliability comparison. Both systems have same coding rate (one).

Figure 2 (below) depicts the performance the diversity-coded MIMO-OFDM under different channel dynamics. Note that at lower CCR the system is able to better exploit the increased available diversity of faster temporally fading channels across multiple OFDM blocks. The same parameters for diversity-coded MIMO-OFDM were used for all curves.

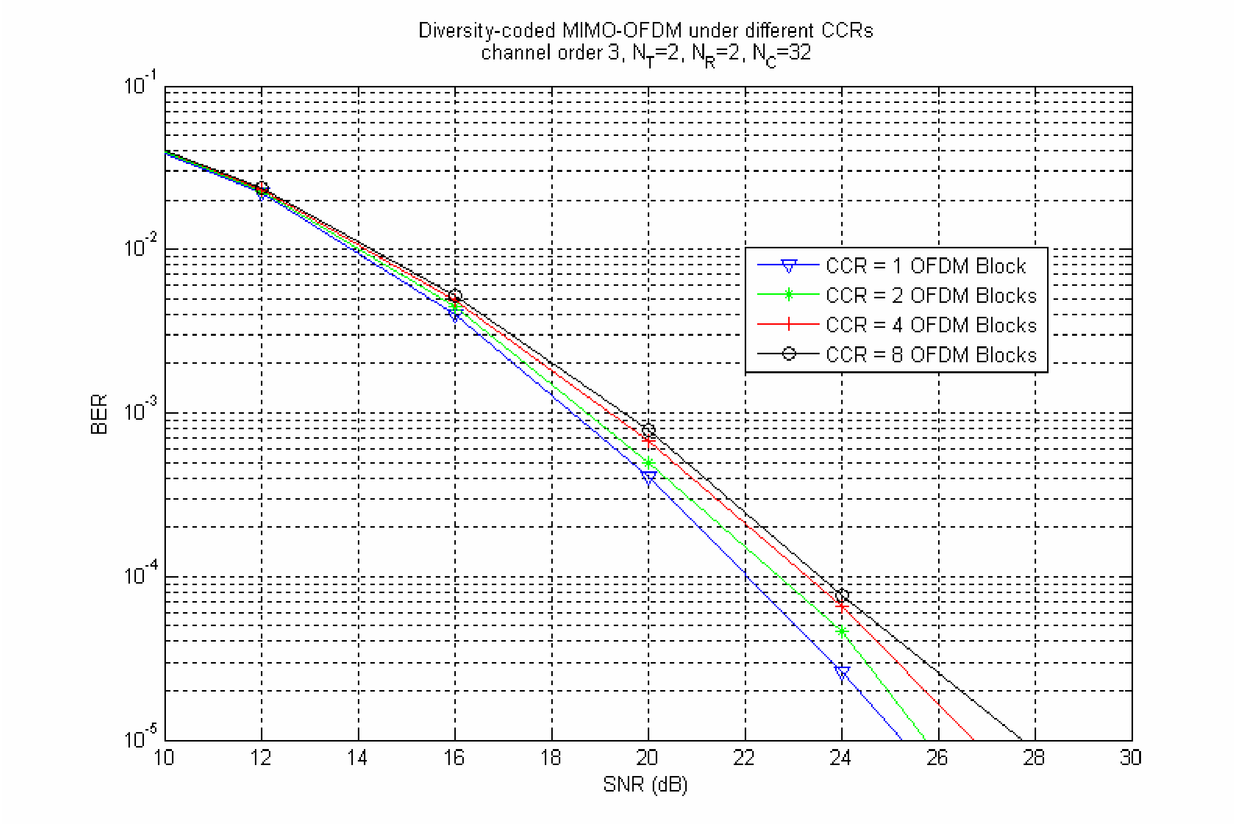


Figure 2. Performance as a function of channel dynamics.

Figure 3 (below) depicts the performance the diversity-coded MIMO-OFDM under different degrees of transmit spatial correlation, which indicates that the proposed system may be influenced by high spatial correlation. Note that even under modest transmit spatial correlation of 0.5 between the antennae, the designed system performs quite well. Again, the same system parameters for the new method were used for all comparison curves.

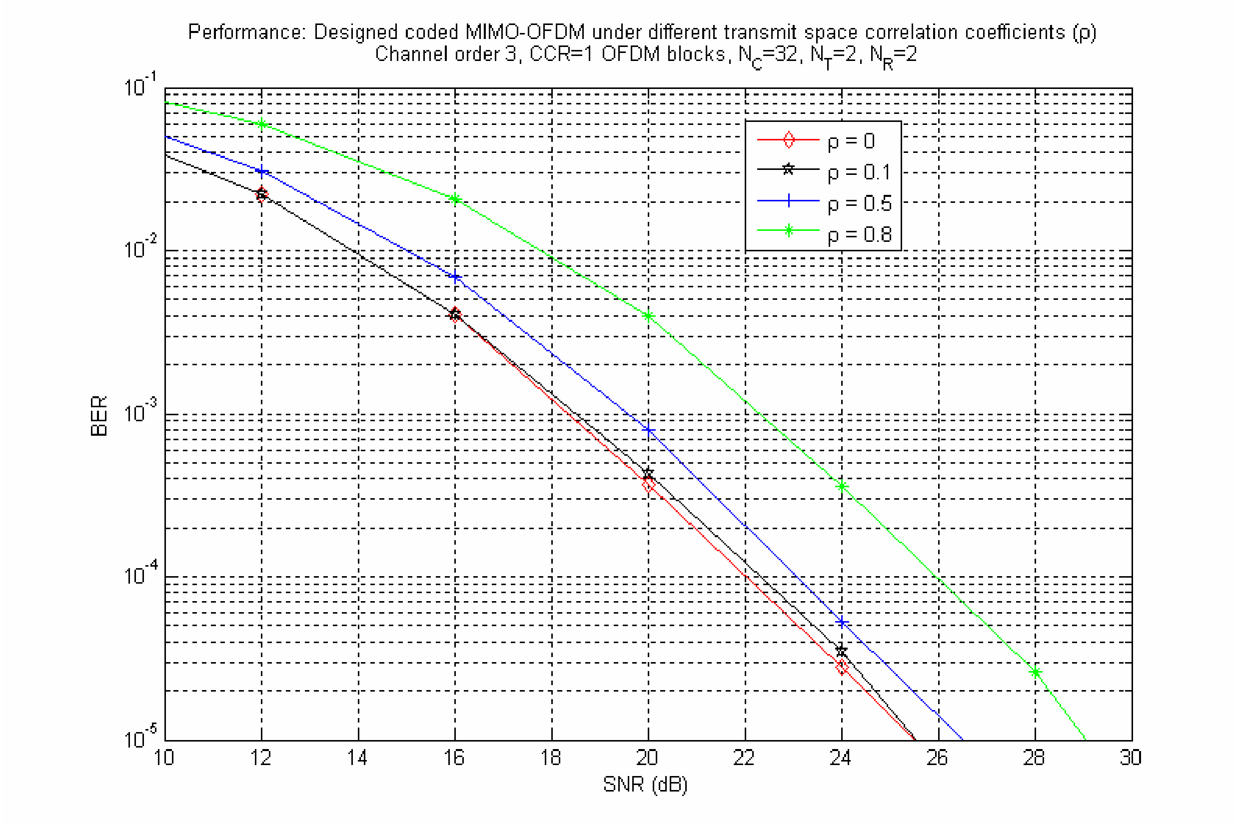


Figure 3. Performance as a function of transmit antenna cross-correlation.

**Status of Commercialization:**
PARTEQ Innovations, the technology transfer arm of Queen's University, is seeking industrial partners willing to support on-going development of the product and/or are interested in licensing the intellectual property

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