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Arbitrary Constellations with Coded Maximum Ratio Transmission over Downlink Nakagami-m Fading Channels

Mehmet Cagri Ilter, Pawel A. Dmochowski and Halim Yanikomeroglu

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VTC2016-Fall MONTRÉAL A Connected World at your Fingertips

HUAWEI

VICTORIA UNIVERSITY OF WELLINGTON TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI

- Why do we need such an analysis which includes **the use of irregular 2D constellation**?

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- What does **an error performance analysis considering irregular constellation** bring as a promise to wireless systems?

- The gap between conventional uniform QAM constellations and the Shannon limit increases with SNR value for the certain coded systems (BICM)*

- The use of non-equally spaced constellation has suggested for current wireless standards**

Zöllner, Jan, and N. Loghin. "Optimization of high-order non-uniform QAM constellations." *IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, 2013.

Morgade, Javier, et al. "Improving the DVB-T2 BICM performance by newly optimized Two-Dimensional Non-Uniform Constellations." *IEEE Fourth International Conference on Consumer Electronics Berlin (ICCE-Berlin)*, 2014.

Earlier & ongoing work

- **Mehmet Cagri Ilter and Halim Yanikomeroglu,** "An upper bound on BER in a coded two-transmission scheme with same-size arbitrary 2D constellations", *IEEE 25th International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, 2–5 September 2014, Washington, DC, USA.

- **Mehmet Cagri Ilter, Halim Yanikomeroglu, and Pawel Dmochowski,** "BER upper bound expressions in coded two-transmission schemes with arbitrarily spaced signal constellations", *IEEE Communications Letters*, vol. 20, no. 2, pp. 248-251, February 2016.

- **Mehmet Cagri Ilter, Pawel A. Dmochowski, and Halim Yanikomeroglu,** "Arbitrary constellations with coded maximum rate transmission over downlink Nakagami-m fading channels", *IEEE Vehicular Technology Conference (VTC2016-Fall)*, 18–21 September 2016, Montreal, QC, Canada.

- **Mehmet Cagri Ilter, Pawel Dmochowski, and Halim Yanikomeroglu,** "BER bounds for irregular constellations with transmit maximum ratio combining over Nakagami-fading channels", under review *in IEEE Transactions on Communications*.

Rediscovering Product-State Matrix Method*

- **Generalized version of conventional transfer function analysis**

- **Less restrictive performance bounds for convolutional coded system.**

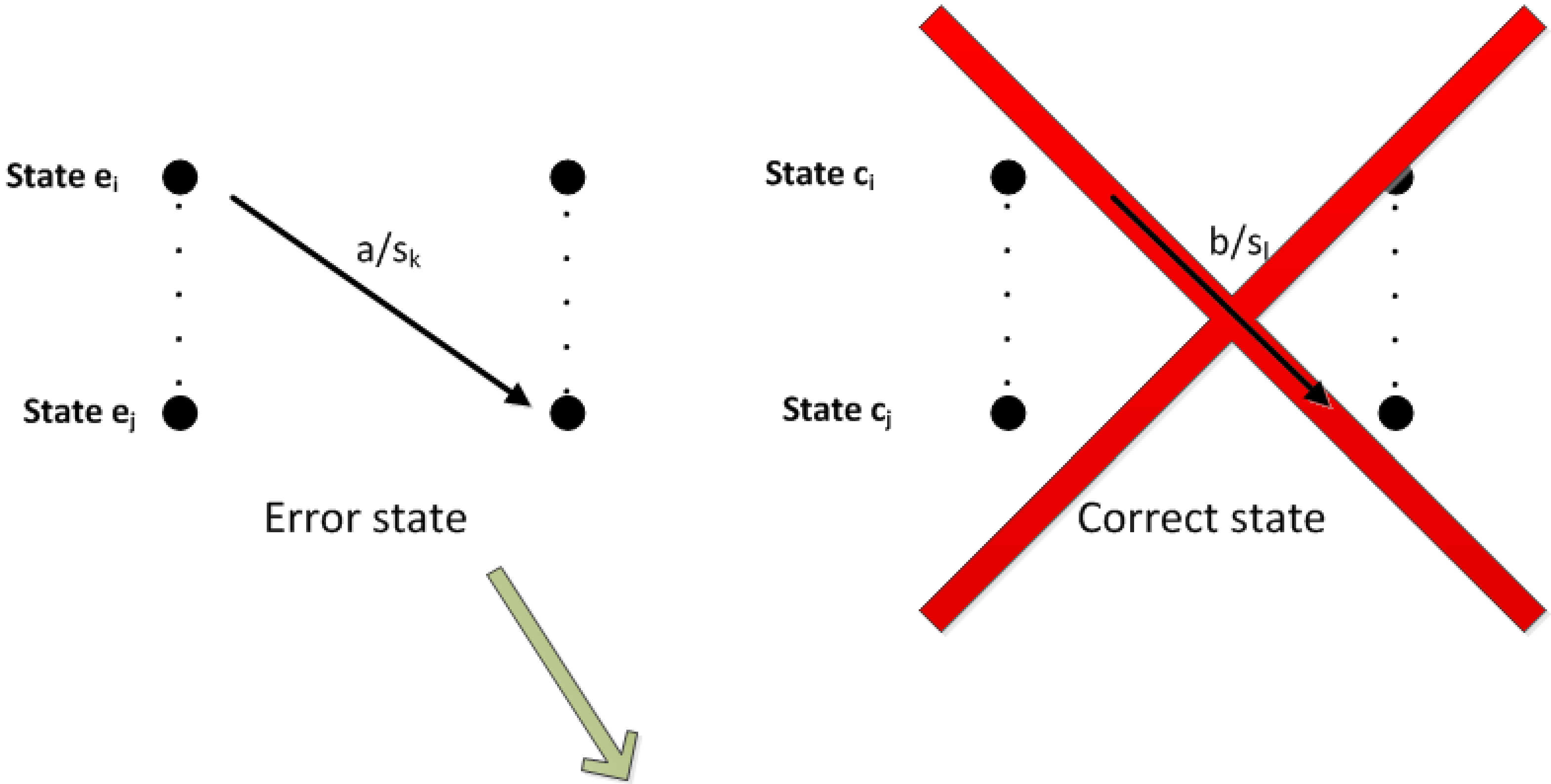
Encoder + Constellation → Non-quasi regular, nonlinear,…

Quasi-regularity (QR): All zero sequences are assumed to be transmitted throughout the error bound analysis.

*__Biglieri, Ezio,__ "High-Level Modulation and Coding for Nonlinear Satellite Channels," *IEEE Transactions on Communications,* vol. 32, no.5, pp.616-626, May 1984.

Rediscovering Product-State Matrix Method

Independence of what is actually transmitted!



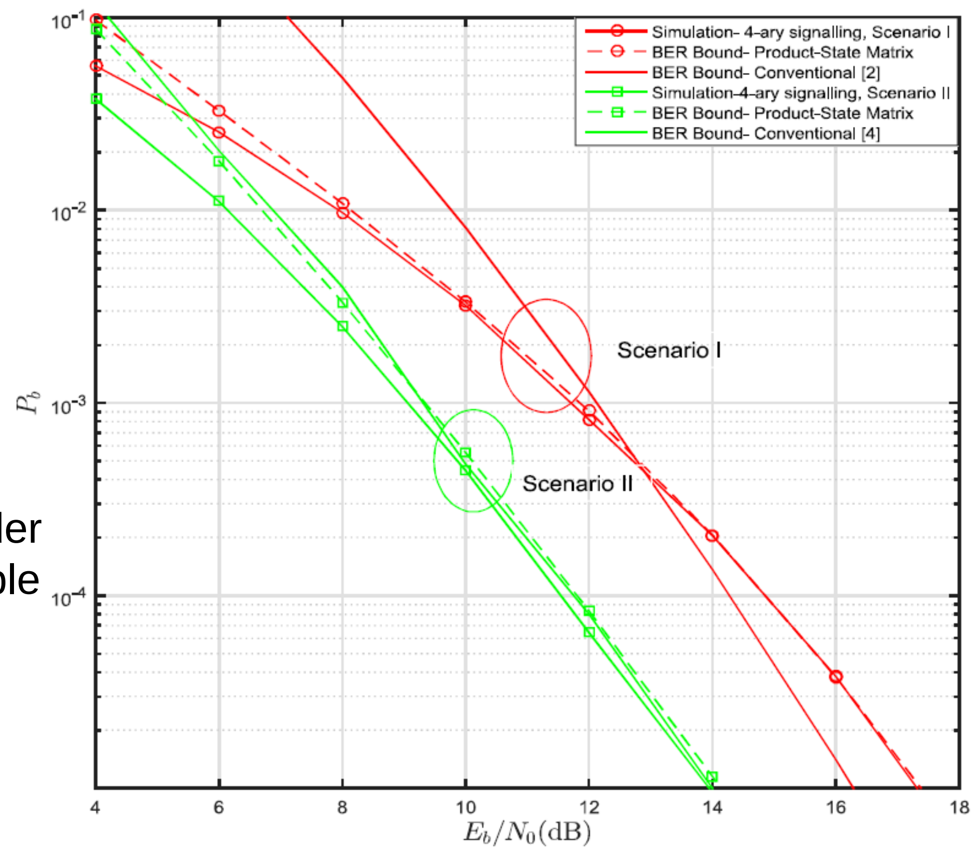
$$\mathbf{S}((e_i)\rightarrow(e_j))=I^{d_H(a,0)}\quad f(d_E(|s_k-s_0|^2))$$

Rediscovering Product-State Matrix Method

For non-quasi regular (QR) cases, mostly used bound is not going to be valid upper bound

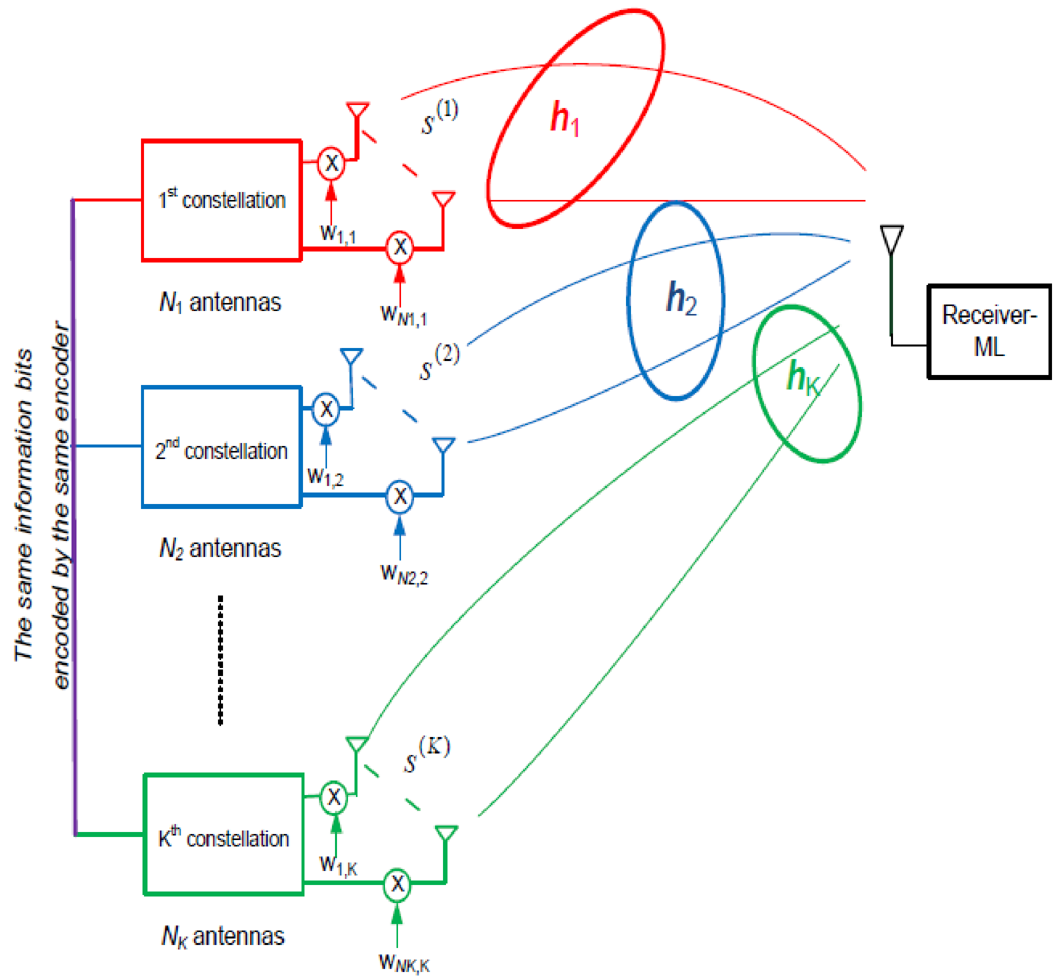
There are some code searching studies using product state method,

but constellation search, for a given encoder and system protocol (multi antenna, multiple transmission, etc.), is key element.



Mehmet Cagri Ilter, Halim Yanikomeroglu, and Pawel Dmochowski, "BER upper bound expressions in coded two transmission schemes with arbitrarily spaced signal constellations", *IEEE Communications Letters*, vol. 20, no. 2, pp. 248-251, February 2016.

TMRC Multi-Transmission System Model



- Convolutional coded
- Multiple orthogonal transmission stages
- Different numbers of Tx antenna each stage
- Irregular constellations can be different for each stage

Quick Look Into Math…

$$\mathbf{S} = \begin{bmatrix} \mathbf{S}_{\mathcal{G}\mathcal{G}} & \mathbf{S}_{\mathcal{G}\mathcal{B}} \\ \mathbf{S}_{\mathcal{B}\mathcal{G}} & \mathbf{S}_{\mathcal{B}\mathcal{B}} \end{bmatrix}$$

$$\mathbf{S}_{(u,v),(\bar{u},\bar{v})} = \Pr\left(u \to \bar{u} | u\right) \times \sum_{n} p_n I^{\mathrm{W}(u\to\bar{u})\oplus \mathrm{W}(v\to\bar{v})} D_{(u,v),(\bar{u},\bar{v})}$$

$$T\left(I\right) = \mathbf{1}^T \mathbf{S}_{\mathcal{G}\mathcal{G}} \mathbf{1} + \left(\mathbf{1}^T \mathbf{S}_{\mathcal{G}\mathcal{B}}\right)^T \left[\mathbf{I} - \mathbf{S}_{\mathcal{B}\mathcal{B}}\right]^{-1} \mathbf{S}_{\mathcal{B}\mathcal{G}} \mathbf{1}$$

$$P_b \leq \frac{1}{l} \frac{\partial T\left(I\right)}{\partial I}\bigg|_{I=1},$$

$$D_{(u,v),(\bar{u},\bar{v})} = \prod_{k=1}^{K} \prod_{i=1}^{N_k} \left(\frac{m_{k,i}}{\Omega_{k,i}}\right)^{m_{k,i}} \times -\bar{\mathrm{H}}^{0,N_k+1}_{N_k+1,N_k+1}\left[1 \left| \begin{matrix} \Xi^{(1)}_{N_{k,k}}, (1+d_k,1,1) \\ \Xi^{(2)}_{N_{k,k}}, (d_k,1,1) \end{matrix} \right.\right]$$

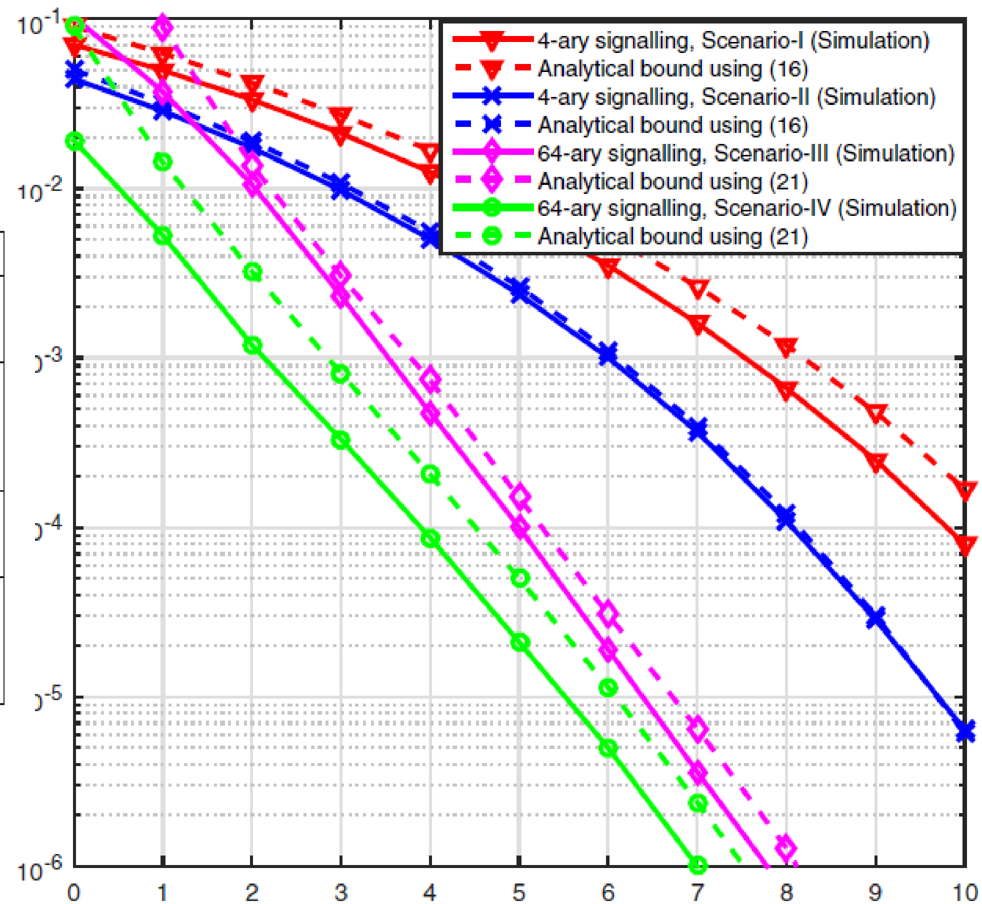
$$\Xi^{(1)}_{N_k} = \overbrace{\left(1 - \frac{m_{k,1}}{\Omega_{k,1}}, 1, m_{k,1}\right), \cdots, \left(1 - \frac{m_{k,N_k}}{\Omega_{k,N_k}}, 1, m_{k,N_k}\right)}^{N_k-\text{bracketed terms}}$$

$$\Xi^{(2)}_{N_k} = \overbrace{\left(-\frac{m_{k,1}}{\Omega_{k,1}}, 1, m_{k,1}\right), \cdots, \left(-\frac{m_{k,N_k}}{\Omega_{k,N_k}}, 1, m_{k,N_k}\right)}^{N_k-\text{bracketed terms}}.$$

$$D_{(u,v),(\bar{u},\bar{v})} = \prod_{k=1}^{K} \prod_{i=1}^{N_k} \left(1 + d_k \frac{\Omega_{k,i}}{m_{k,i}}\right)^{-m_{k,i}}$$

Performance Bounds

Scenarios	K	N_k	m_k	Ω_k
4-ary signalling Scenario-I	2	$N_1 = 2$ $N_2 = 3$	$m_1 = 2.5$ $m_2 = 3.5$	$\Omega_k = 1, \forall k$
4-ary signalling Scenario-II	3	$N_1 = 2$ $N_2 = 1$ $N_2 = 3$	$m_1 = 2.4$ $m_2 = 1.8$ $m_3 = 3.2$	$\Omega_1 = 0.9$ $\Omega_2 = 1.0$ $\Omega_3 = 0.8$
64-ary signalling Scenario-III	2	$N_1 = 2$ $N_2 = 1$	$m_1 = 2.0$ $m_2 = 3.0$	$\Omega_k = 1, \forall k$
64-ary signalling Scenario-IV	3	$N_1 = 2$ $N_2 = 1$ $N_3 = 1$	$m_1 = 2.0$ $m_2 = 1.0$ $m_3 = 1.0$	$\Omega_1 = 0.9$ $\Omega_2 = 1.0$ $\Omega_3 = 0.7$



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Future Research Direction

Constellation Design-Preliminary Results

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Constellation Design-Preliminary Results

- 64-ary signalling constellations…

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THANKS…