A Method for Estimating the Average Packet Error Rates of Multi-carrier Systems With Interference

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Motivation & Challenges

- More accurately predict average PER of multi-carrier systems with interference
- Improved spectrum and interference management
- Most work on interference focuses on BER
- Error rates of multi-carrier differ from single carrier systems
- Different SNR for each sub-carrier
- Error control coding

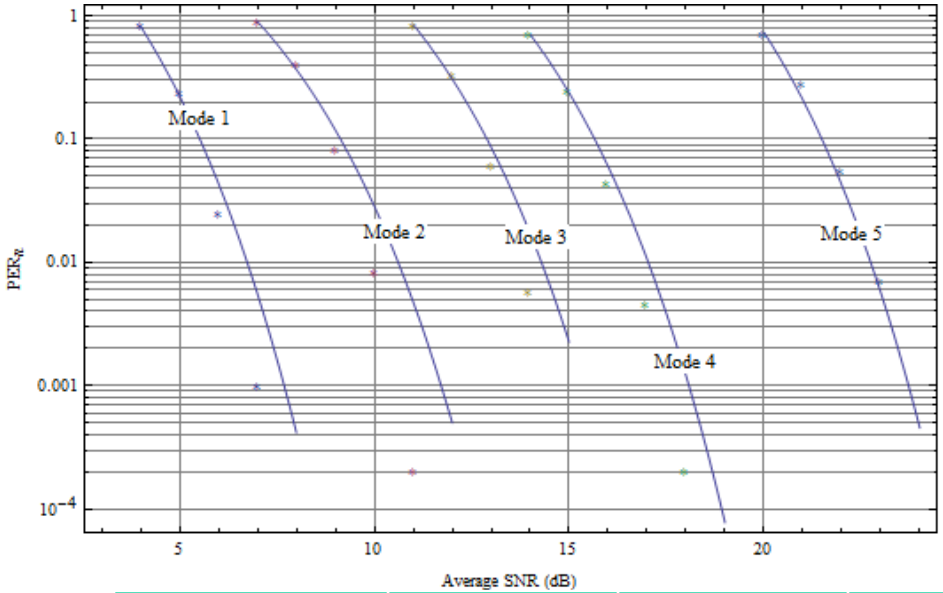
Proposed Method

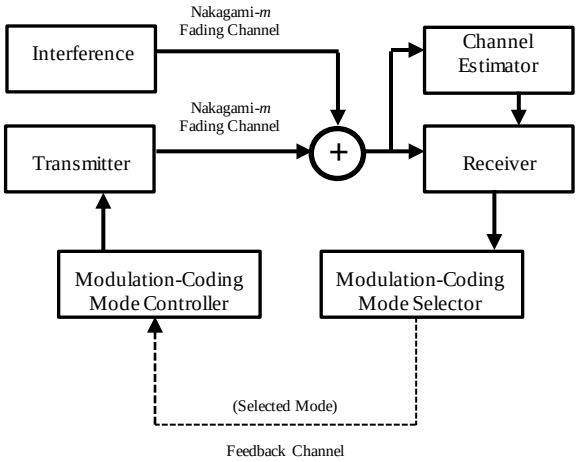
- Integrate between zero crossings of each affected sub-carrier
- $\rho_i = \frac{1}{B_c} \int_{f_i - \frac{B}{2}}^{f_i + \frac{B}{2}} sinc^2 \left(\pi \frac{f - k f_s}{B_c} \right) df$
- Calculate average
- $\bar{\gamma}_c = P_c \frac{\sum_{i=1}^{I} \rho_i}{I}$
- Equate to AWGN

Proposed Method

- Find expected value (average) PER
- $\overline{PER_n}(\bar{\gamma}) = \int_0^\infty PER_n(\gamma) f_\gamma(\gamma) d\gamma$
- Pdf of received SNR, Nakagami-*m*
- $$f_\gamma(\gamma) = \frac{1}{2\sqrt{\pi}\gamma\,\Gamma(m)} m^{2m} \left(\frac{1}{\bar{\gamma}_c}\right)^m \left(\frac{\gamma}{\bar{\gamma}}\right)^m e^{\frac{m(\bar{\gamma}-\bar{\gamma}_c\gamma)}{2\bar{\gamma}\bar{\gamma}_c}} \left(m\left(\frac{\gamma}{\bar{\gamma}}+\frac{1}{\bar{\gamma}_c}\right)\right)^{\frac{1}{2}-m} \left(K_{\frac{1}{2}-m}\left(\frac{m(\bar{\gamma}+\bar{\gamma}_c\gamma)}{2\bar{\gamma}\bar{\gamma}_c}\right) + K_{-m-\frac{1}{2}}\left(\frac{m(\bar{\gamma}+\bar{\gamma}_c\gamma)}{2\bar{\gamma}\bar{\gamma}_c}\right)\right),$$
- Compare to simulation
- Investigate ability of method to predict PER of target system for SNR, interference SNR, and fading

PER as a function of SNR



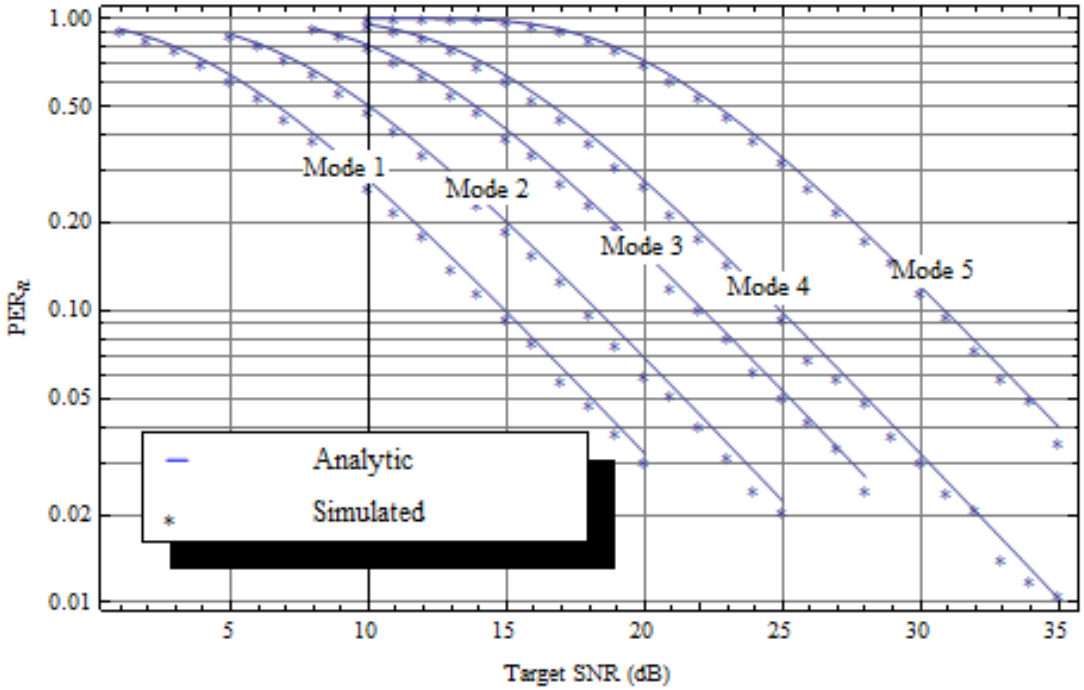


	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
Modulation (M_n)	QPSK	QPSK	16-QAM	16-QAM	64-QAM
Coding Rate R_c	1/2	3/4	9/16	3/4	3/4
Rate (bits/sym)	1.00	1.50	2.25	3.00	4.50
a_n	124.9390	28.8989	42.9191	47.9713	97.5387
g_n	1.9992800	0.6920240	0.3116290	0.1679410	0.0488942
γ_{pn} (dB)	3.82877	6.86698	10.81470	13.62620	19.71630

- Least squares curve fitting
- 10,000 packets per point, 12 sub-carriers
- 1080 bits per packet, convolutional codes [1]

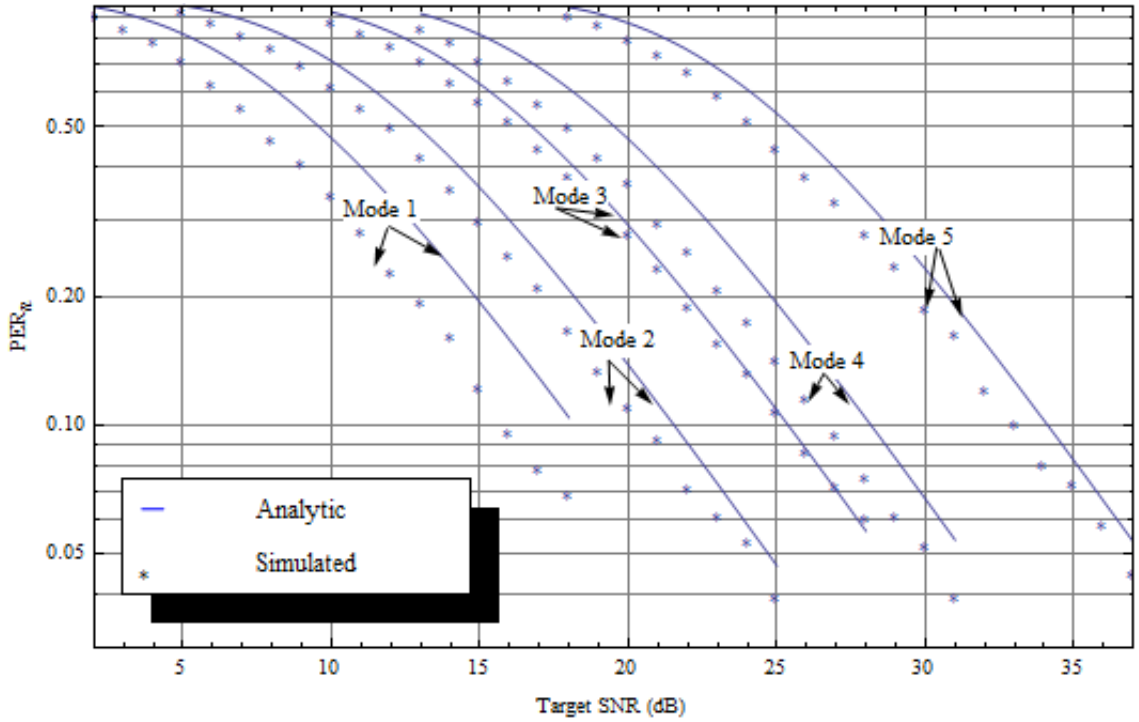
$$PER_n(\gamma) \approx \begin{cases} 1, & if\ 0 < \gamma < \gamma_{pn}, \\ a_n e^{-g_n \gamma}, & if\ \gamma \geq \gamma_{pn} \end{cases}$$

5 dB Interference, m =1



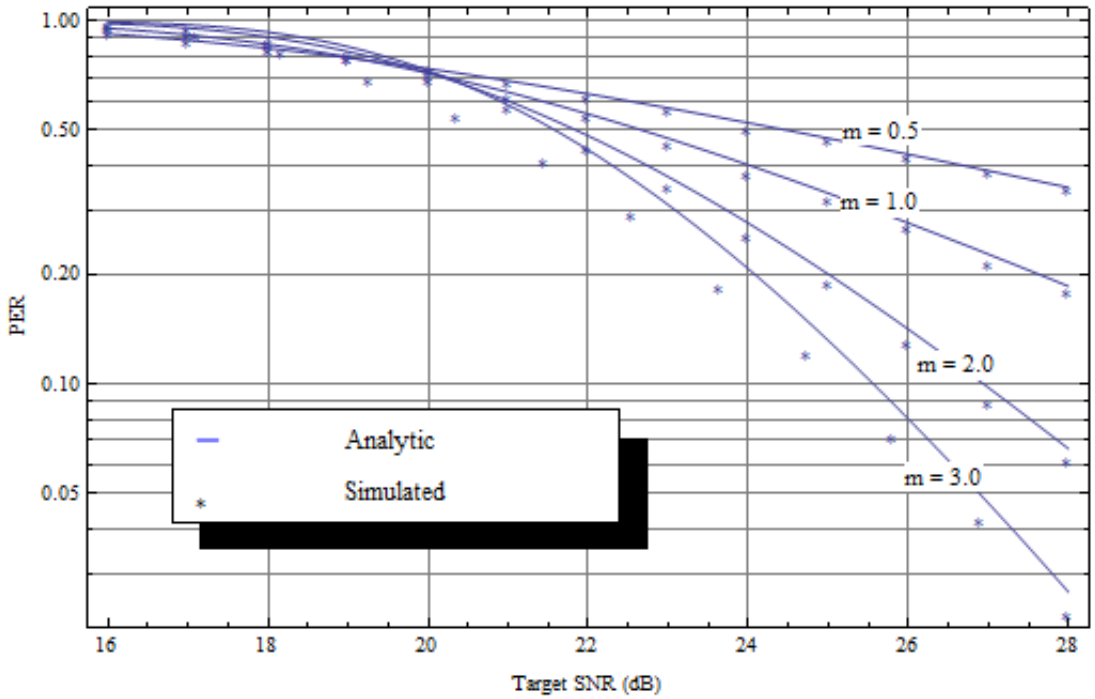
- Investigates modes
- Relatively low interference power
- Predicts PER within 1 dB

15 dB Interference, m =1



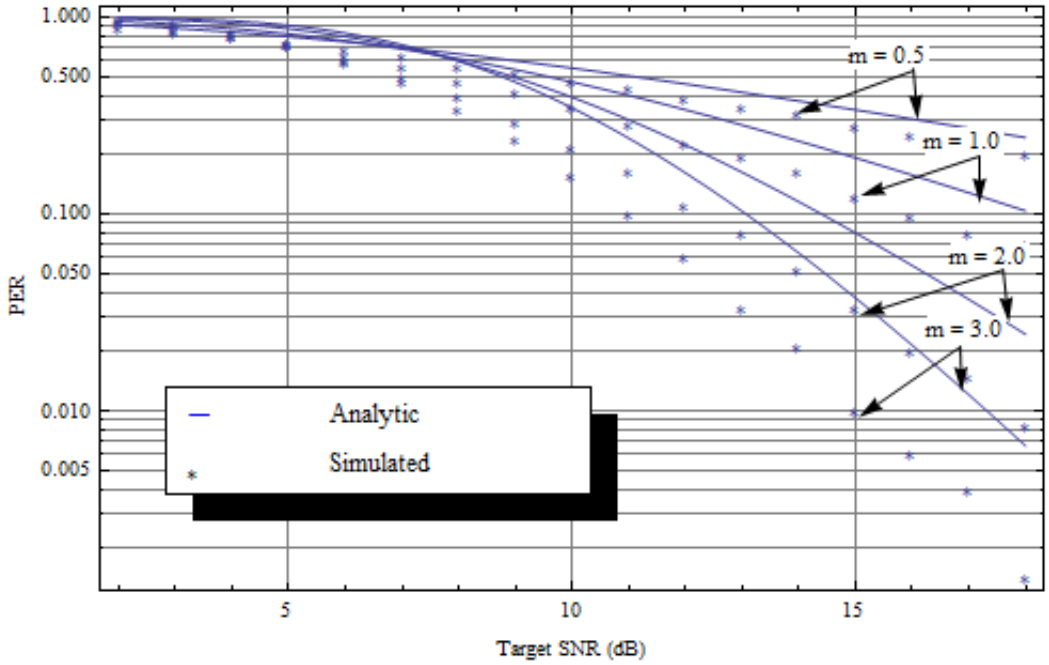
- Investigates modes
- Increase interference power to 15 dB
- Predicts PER within 3 dB

5 dB Interference, Mode 5



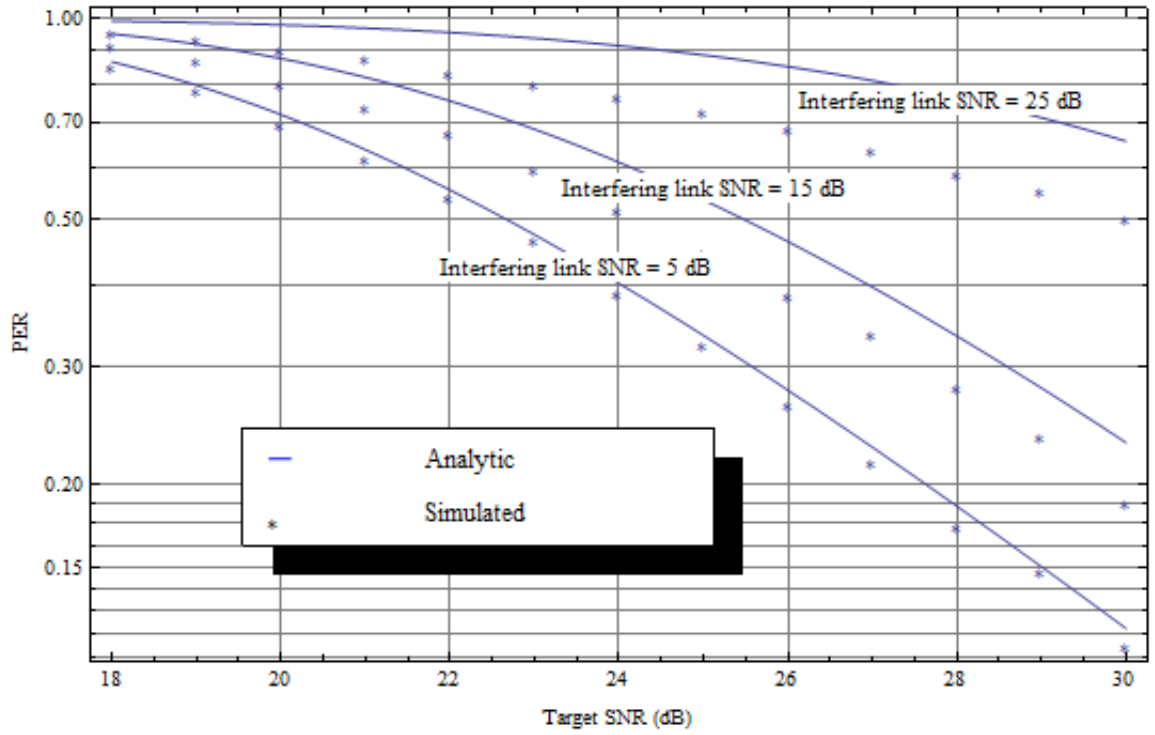
- Investigates fading
- Relatively low interference power
- Predicts PER within 2 dB

15 dB Interference, Mode 1



- Investigates fading
- Increase interference power to 15 dB
- Predicts PER within 3 dB

Mode 5, *m* =1



- Investigates interference power
- Predicts PER within 4 dB

Conclusions

- Presented method for estimating average PER with interference for multi-carrier systems
- Method is a good and conservative predictor
- Equating interference to AWGN overestimates the effect of a modulated interferer with a shaped spectrum
- Method can be utilized to predict higher layer performance

Thank You

- Questions?

References

[1] Q. Liu, S. Zhou, and G. B. Giannakis, "Cross-layer combining of queuing with adaptive modulation and coding over wireless links," in *Military Communications Conference, 2003. MILCOM '03. 2003 IEEE*, 2003, pp. 717-722 Vol.1.

[2] Z. Hijaz and V. S. Frost, "The impact of interference on an OFDM system with AMC, hybrid ARQ, and a finite queue on end-to-end performance," in *9th International Symposium on Communications Systems, Networks, and Digital Signal Processing-CSNDSP-14*, Manchester, England, 2014.

[3] Z. Hijaz and V. S. Frost, "The impact of interference from a covert link on a data link using OFDM, AMC, and Hybrid ARQ," in *IEEE International Performance Computing and Communication Conference*, San Diego, CA, 2013.