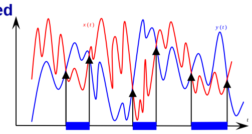
Fade Statistics in Interference-Limited Environment

Introduction

- Wireless channels are characterized by multipath propagation
  - Causes signal impairment - *fading*
- Level crossing rate (LCR) and average fade duration (AFD): two important radio channel statistics closely related to the quality of received signals
  - LCR is the expected number of crossings per second of a specified threshold by the signal
  - AFD gives expected duration of a signal fade
- Interference-limited environment
  - noise negligible, interference main concern
  - signal above a specified signal level does not guarantee satisfactory signal reception
  - signal strength relative to the interference has to be examined



LCR and AFD

- Channel model
  - Nakagami-m distribution:To model fading environment
  - received signal is

$$r(t) = \alpha(t)\cos\left(\omega_c t + \theta_s(t)\right) + \beta(t)\cos\left(\omega_c t + \theta_i(t)\right) + n(t)$$

- Single Interferer case
  - Envelopes of desired and interfering signals, $\alpha(t)$ and $\beta(t)$ are mutually independent random variables
  - Signal-to-interference envelope ratio is critical in determining signal reception quality
  - A protection ratio of k is assumed necessary for reliable reception, i.e. $\alpha(t)/\beta(t) \geq k$
  - *LCR* - expected number of crossings per second of the signal envelope, $\alpha(t)$ against a time-varying level $k\beta(t)$
  - This is equivalently expressed as the zero crossing rate of $g(t) = \alpha(t) - k\beta(t)$
  - The LCR is thus derived and is given by

$$N = \frac{\Gamma\left(m_s + m_i - \frac{1}{2}\right)}{\sqrt{2\pi}\,\Gamma(m_s)\Gamma(m_i)} \frac{\left(\frac{m_s}{\Omega_s}\right)^{m_s}\left(\frac{m_i}{k^2\Omega_i}\right)^{m_i}}{\left(\frac{m_s}{\Omega_s} + \frac{m_i}{k^2\Omega_i}\right)^{m_s + m_i - \frac{1}{2}}} \left(\frac{k^4\Omega_i\left|\gamma_i''(0)\right|}{m_i} + \frac{\Omega_s\left|\gamma_s''(0)\right|}{m_s}\right)^{\frac{1}{2}}$$

  - The AFD of the signal can be calculated by calculating the AFD of $g(t)$ below zero.

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LCR and AFD

- Multiple Interferer case
  - First, the case of N i.i.d. interfering signals are considered
  - The envelope of the total interference is

$$\beta = \sqrt{\beta_1^2 + \beta_2^2 + \cdots + \beta_N^2}$$

  - This is shown to also be Nakagami distributed with parameters

$$m_i = \sum_{n=1}^{N} m_n \qquad \Omega_i = \sum_{n=1}^{N} \Omega_n$$

  - The derived formula can be used to calculate LCR and AFD
  - Consider the N interfering signals to be Nakagami distributed with arbitrary fading parameters
  - The total interference is approximated to be Nakagami distributed with parameters

$$m_i = \left(\sum_{n=1}^{N}\Omega_n\right)^2 \Bigg/ \sum_{n=1}^{N}\left(\frac{\Omega_n}{m_n}\right)$$

$$\Omega_i = \sum_{n=1}^{N}\Omega_n$$

  - The LCR and AFD are obtained by applying the derived expression

LCR and AFD – Numerical Analysis