SNS COLLEGE OF TECHNOLOGY

Coimbatore – 35

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

19ECT311 / Wireless Communication

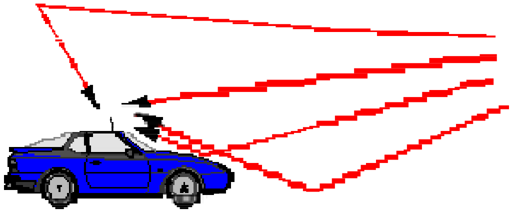
III ECE/ VI SEMESTER

Unit II **- MOBILE RADIO PROPAGATION**

Topic 9: Rayleigh and Rician distribution

Multipath fading

Multiple reflected waves arrive at the receiver



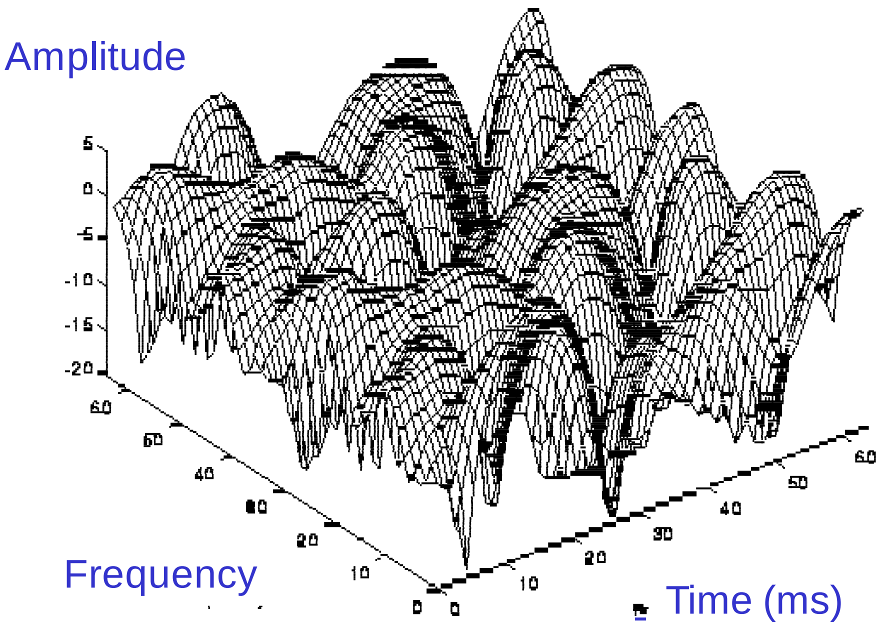
Narrowband model

•Different waves have different phases.

•These waves may cancel or amplify each other.

•This results in a fluctuating (“fading”) amplitude of the total r eceived signal.

Rayleigh Multipath Reception



The received signal amplitude depends on location and frequency

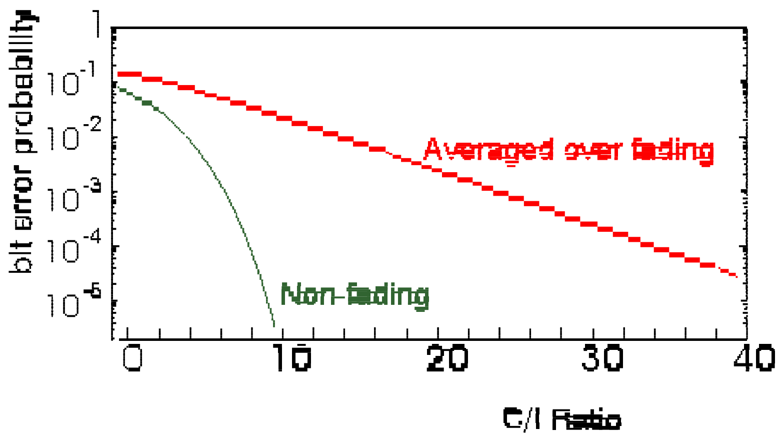
If the antenna is moving, the location *x* changes linearly

with time *t* ($x = v\,t$)

Parameters:

- probability of fades
- duration of fades
- bandwidth of fades

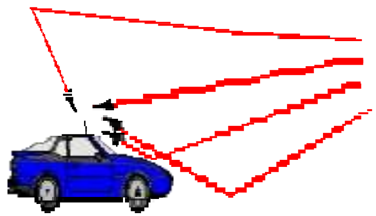
Effect of Flat Fading



- In a fading channel, the BER only improves very slowly with increasing C/I
- Fading causes burst errors
- Average BER does not tell the full story
- Countermeasures to improve the slope of the curve

Models for Multipath Fading

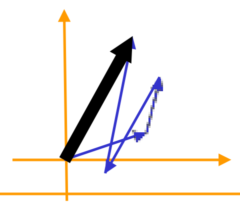
Rayleigh fading



- (infinitely) large collection of reflected waves
- Appropriate for macrocells in urban environment
- Simple model leads to powerful mathematical framework

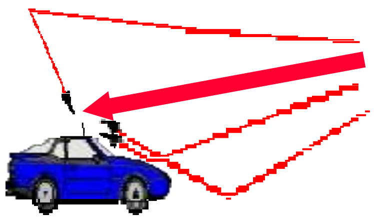
Transmit $s(t) = \cos(\omega_c t),$

Receive $v(t) = \sum_{n=1}^{N} \rho_n s(t - T_n),$



N=4 waves with amplitude ρ_n and phase shift due to delay T_n

Ricean fading



- (infinitely) large collection of reflected waves plus line-of sight
- Appropriate for micro-cells
- Mathematically more complicated

Rayleigh Model

Use Central Limit Theorem

inphase $s_I(t) = \zeta$ and

quadrature $s_Q(t) = \xi$ components are zero- mean independently identically distributed (i.i.d.) jointly Gaussian random variables

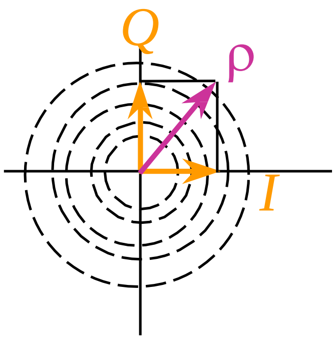
PDF:

$$f(\xi, \zeta) = \frac{1}{2\pi\sigma^2} \exp\left\{-\frac{\xi^2 + \zeta^2}{2\sigma^2}\right\}$$

Conversion to polar co-ordinates:

Received amplitude ρ: $\rho^2 = \zeta^2 + \xi^2$.

$\zeta = \rho \cos \phi$; $\xi = \rho \sin \phi$,



PDF of Rayleigh Amplitude

After conversion to polar co-ordinates:

!!

$$f_{P,\Phi}(\rho,\phi)=\frac{\rho}{2\pi\sigma^2}\exp\left\{-\frac{\rho^2}{2\sigma^2}\right\}$$

Integrate this PDF over ϕ from 0 to 2π:

Rayleigh PDF of ρ

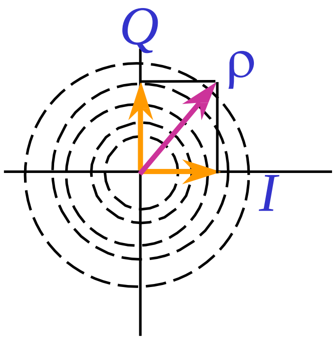
$$f_{\rho}(\rho)=\frac{\rho}{\bar{p}}\exp\left(-\frac{\rho^2}{2\bar{p}}\right)$$

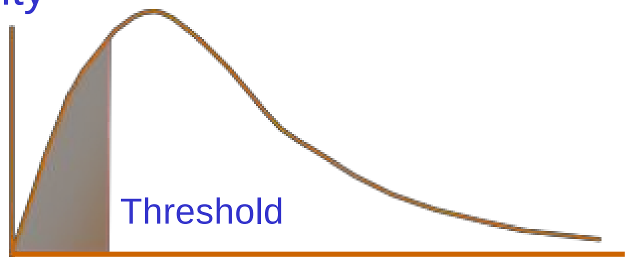
where

– p is the local mean power total scattered power ($p = \sigma^2$).

Received Amplitudes

Wireless





$$f_P(\rho) = \frac{\rho}{\bar{p}} \exp\left\{-\frac{\rho^2}{2\bar{p}}\right\}.$$

Received Power

Conversion from amplitude to power ($p = \rho^2/2$) gives the exponential distribution:

$$f_p(p) = f_\rho(\rho)\left|\frac{d\rho}{dp}\right| = \frac{1}{\bar{p}}\exp\left\{-\frac{p}{\bar{p}}\right\}.$$

Exponential distributions are very convenient to handle mathematically.

Who was Rayleigh?

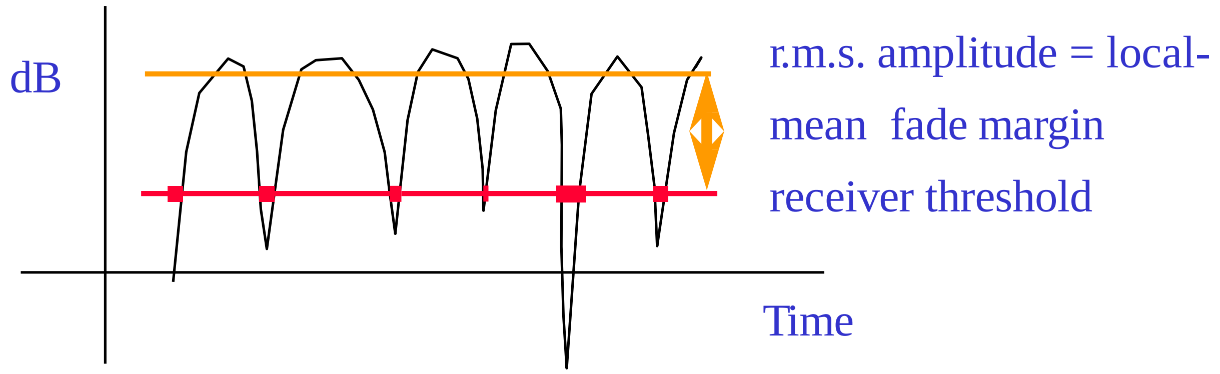
- The basic model of Rayleigh fading assumes a received multipath signal to consist of a (theoretically infinitely) large number of reflected waves with independent and identically distributed inphase and quadrature amplitudes.
- This model has played a major role in our understanding of mobile propagation.
- The model was first proposed in a comment paper written by Lord Rayleigh in 1889, describing the resulting signal if many violinists in an orchestra play in unison, long before its application to mobile radio reception was recognized.

[1] Lord Rayleigh, "On the resultant of a large number of vibrations of the same pitch and of arbitrary phase", Phil. Mag., Vol. 10, August 1880, pp. 73-78 and Vol. 27, June 1889, pp. 460-469.

Lord Ravleigh (John William Strutt) was an English physicist (1877 - 1919) and a Nobel Laureate (1904) who made a number of contributions to wave physics of sound and optics.

Fade Margin

Fade margin is the ratio of the average received power over some threshold power, needed for reliable communication.



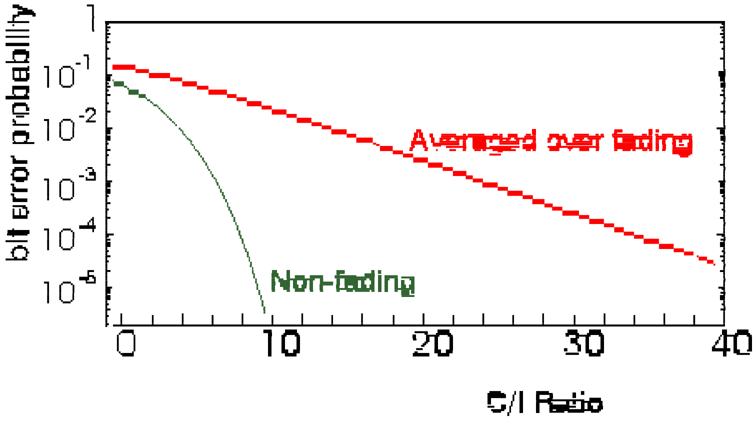
Average BER

The BER for BPSK with known instantaneous power *p*

$$P = \frac{1}{2} erfc \sqrt{\frac{E_b}{N_0}}$$

The BER averaged over an exponential distribution

$$\bar{P} = \int_0^\infty \frac{1}{\bar{p}} \exp\left\{-\frac{p}{\bar{p}}\right\} \frac{1}{2} erfc \sqrt{\frac{pT_b}{N_0}} dp = \frac{1}{2} - \frac{1}{2} \sqrt{\frac{\bar{p}T_b}{N_0 + \bar{p}T_b}}$$

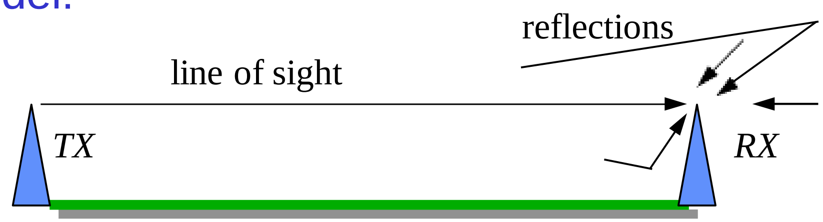


ACTIVITY

Activity: Draw a logo which may describe your character or things you like.

Ricean Multipath Reception

Narrowband propagation model:



Transmitted carrier $s(t) = \cos(\omega_t\, t)$

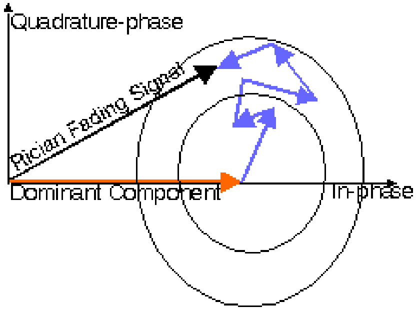
Receive d carrier

$$v(t) = C\cos\omega_c t + \sum_{n=1}^{N} \rho_n \cos(\omega_c t + \phi_n)\,,$$

where

- C is the amplitude of the line-of-sight component
- ρ_n is the amplitude of the n-th reflected wave
- ϕ_n is the phase of the n-th reflected wave

Ricean Multipath Reception



Received carrier:

$$v(t) = C \cos\omega_c t + \sum_{n=1}^{N} \rho_n \cos(\omega_c t + \phi_n),$$

where

ζ is the in-phase component of the reflections

ξ is the quadrature component of the reflections.

I is the total in-phase component ($I = C + \zeta$)

Q is the total quadrature component ($I = C + \zeta$)

Ricean Amplitude

After conversion to polar co-ordinates:

$$f_{P,\Phi}(\rho,\phi) = \frac{\rho}{2\pi\sigma^2} \exp\left\{-\frac{\rho^2 + C^2 - 2\rho C\cos\phi}{2\sigma^2}\right\}$$

Integrate this PDF over ϕ from 0 to 2π: Ricean PDF of ρ

$$f_\rho(\rho) = \frac{\rho}{\bar{q}} \exp\left(-\frac{\rho^2 + C^2}{2q}\right) I_0\left(\frac{\rho C}{\bar{q}}\right),$$

where

- $I_0(.)$ is the modified Bessel function of the first kind and zero order
- q is the total scattered power ($q = \sigma^2$).

Ricean Phase

After conversion to polar co-ordinates:

$$f_{P,\Phi}(\rho,\phi) = \frac{\rho}{2\pi\sigma^2} \exp\left\{-\frac{\rho^2 + C^2 - 2\rho C\cos\phi}{2\sigma^2}\right\}$$

Integrate this PDF over ρ

Special case: $C = 0$ …………. $f_{\Phi}(\phi) = \frac{1}{2\pi}$

Special case: large C ……….. $f_{\phi}(\phi) = \frac{C}{\sqrt{2\pi}\,\sigma} \exp\left\{-\frac{C^2\phi^2}{2\sigma^2}\right\}$

$\phi \approx \arctan(\zeta/C) \approx \zeta/C$

Ricean *K*-factor

calculate

Definition: K = direct power $C^2/2$ over scattered power q

Measured values

K = 4 ... 1000 (6 to 30 dB) for micro-cellular systems

Light fading (K -> infinity)

- Very strong dominant component
- Ricean PDF approaches Gaussian PDF with small σ

Severe Fading ($K = 0$):

- Rayleigh Fading

How do systems handle outages?

- Analog
  - Fast moving User experiences a click
  - Slow moving user experiences a burst of noise
- GSM
  - Speech extrapolation
- DECT
  - Handover to other base station if possible
  - Handover to different frequency
- WLAN / cellular CDMA
  - Large transmit bandwidth to prevent that the full signal vanishes in a fade

Assessment

- Link budget consists of calculation of
  a) Useful signal power
  b) Interfering noise power
  c) Useful signal & Interfering noise power
  d) Signal and Noise
- Link budget can help in predicting
  a) Equipment weight and size
  b) Technical risk
  c) Prime power requirements
  d) **Equipment weight and size, Technical risk and Prime power requirements**.
- Space loss occurs due to decrease in
  a) **Electric field strength**
  b) Efficiency
  c) Phase
  d) Signal power

Thank you