Introduction to wireless systems

Internet of Things (ex. Advanced Topics in Networking)

a.a. 2015/2016

Un. of Rome "La Sapienza"

Lesson 2

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Google group

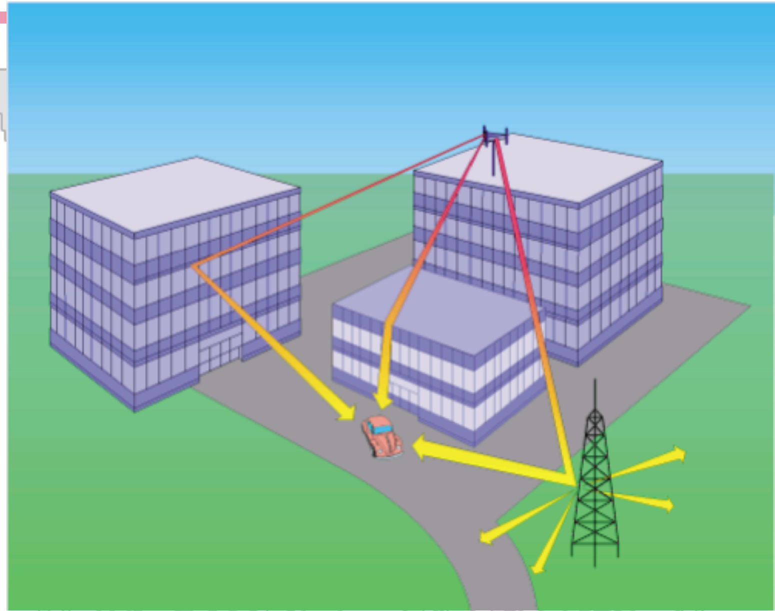
- Please subscribe to

  IoT_class_Sapienza_CS_2015_2016@googlegroups.com

- Please fill the following google form to allow me to get info on the background of the class (needed to plan activities)

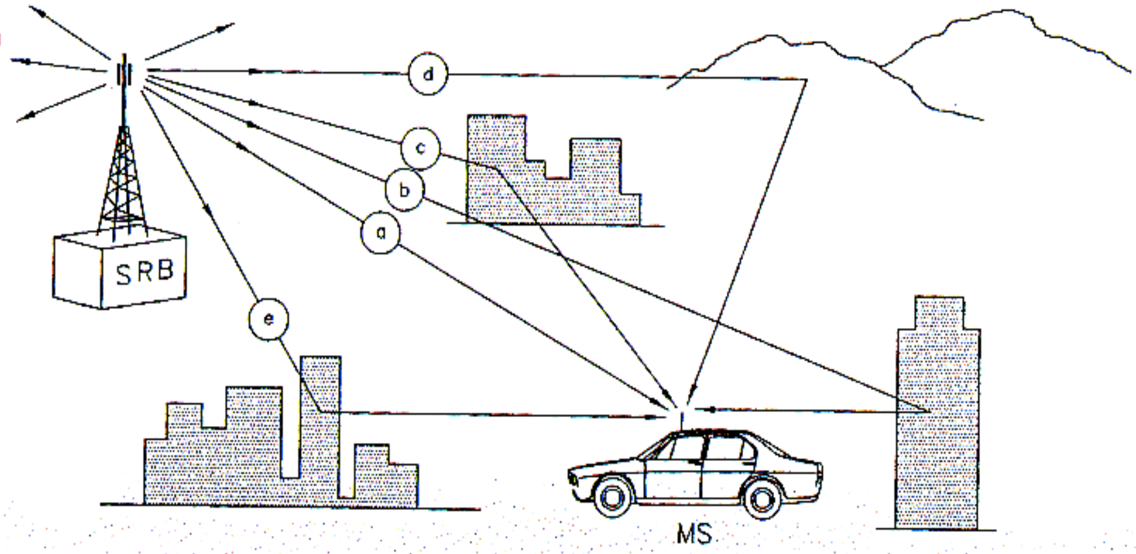
  https://docs.google.com/forms/d/1sse2ppAS5kEpQq4ix_osg-cgmKSsUVSCyb0oSwn4GnI/viewform?c=0&w=1

Wireless channel: multipath fading



- While propagating from source to destination the signal can follow multiple paths. At the receiver different components (received over different paths, with different phases and amplitudes) are combined.
- Signal can be reflected, diffracted, scattered based on the obstacles it founds over its path towards destination.
- Low frequencies can traverse without or with low attenuation many objects; when frequency increases waves tend to be absorbed or reflected by obstacles (at very high frequency– over 5 GHz – communication is LOS).

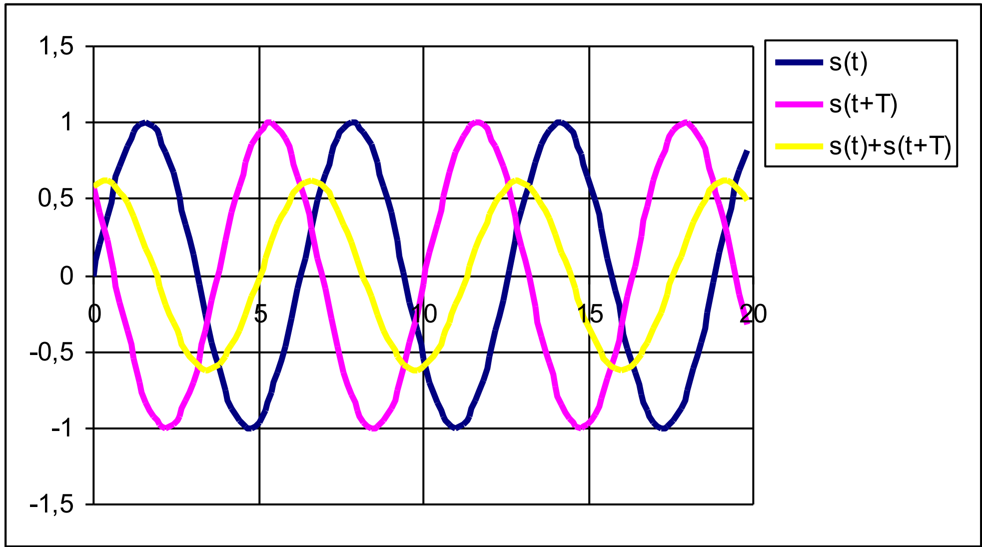
Multipath fading



- Signal replicas received via different propagation paths are combined at the receiver
- The results depends on
  - The number of replicas
  - Their phases
  - Their amplitudes
  - Frequency

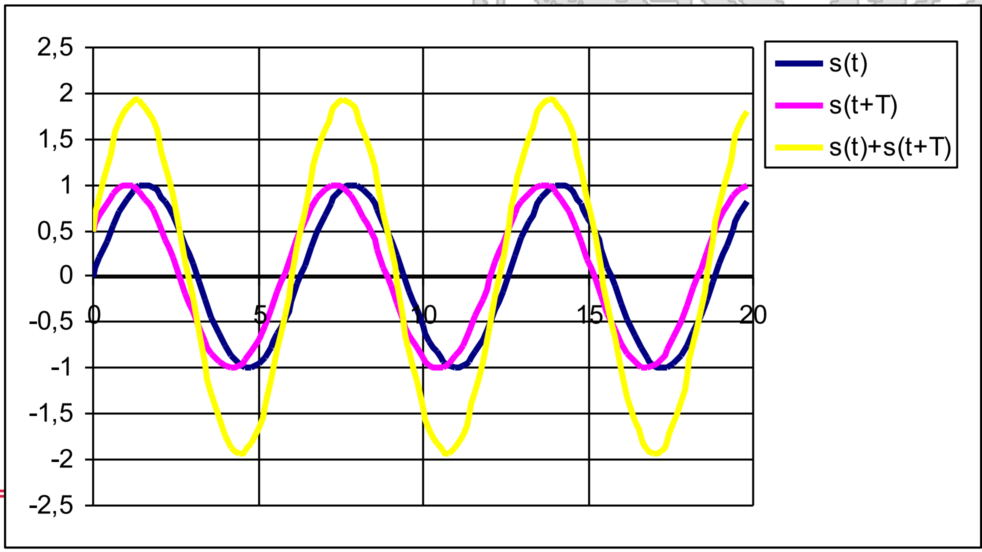
- **Received power differs, as a result**
  - **from place to place, from time to time!**

Multipath fading



- Resulting signal can be attenuated

T=4/5π



- Or amplified

T= π /6

Rayleight fading

$$e_r(t) = \sum_{k=1}^{N} a_k \cos(2\pi f_0 t + \phi_k) =$$

recall that : $\cos(2\pi f_0 t + \phi_k) =$
$= \cos(2\pi f_0 t)\cos(\phi_k) - \sin(2\pi f_0 t)\sin(\phi_k)$

$$= \cos(2\pi f_0 t)\sum_{k=1}^{N} a_k \cos\phi_k - \sin(2\pi f_0 t)\sum_{k=1}^{N} a_k \sin\phi_k =$$
$$= X\cos(2\pi f_0 t) - Y\sin(2\pi f_0 t)$$

In the assumptions:

- N large (many paths)
- ϕ_k uniformly distributed in $(0,2\pi)$
- a_k comparable (no privileged path such as LOS)

X,Y are gaussian, identically distributed random variables

Rayleigh fading power distribution

$$f_p(x) = \frac{1}{2\sigma^2} e^{-x/2\sigma^2}$$

Sigma² is the Variance of The X,Y variables

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Rayleight fading

$$e_r(t)=\sum_{k=1}^{N} a_k \cos(2\pi f_0 t+\phi_k)=$$

recall that : $\cos(2\pi f_0 t+\phi_k)=$
$=\cos(2\pi f_0 t)\cos(\phi_k)-\sin(2\pi f_0 t)\sin(\phi_k)$

= c

= X

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X,Y are

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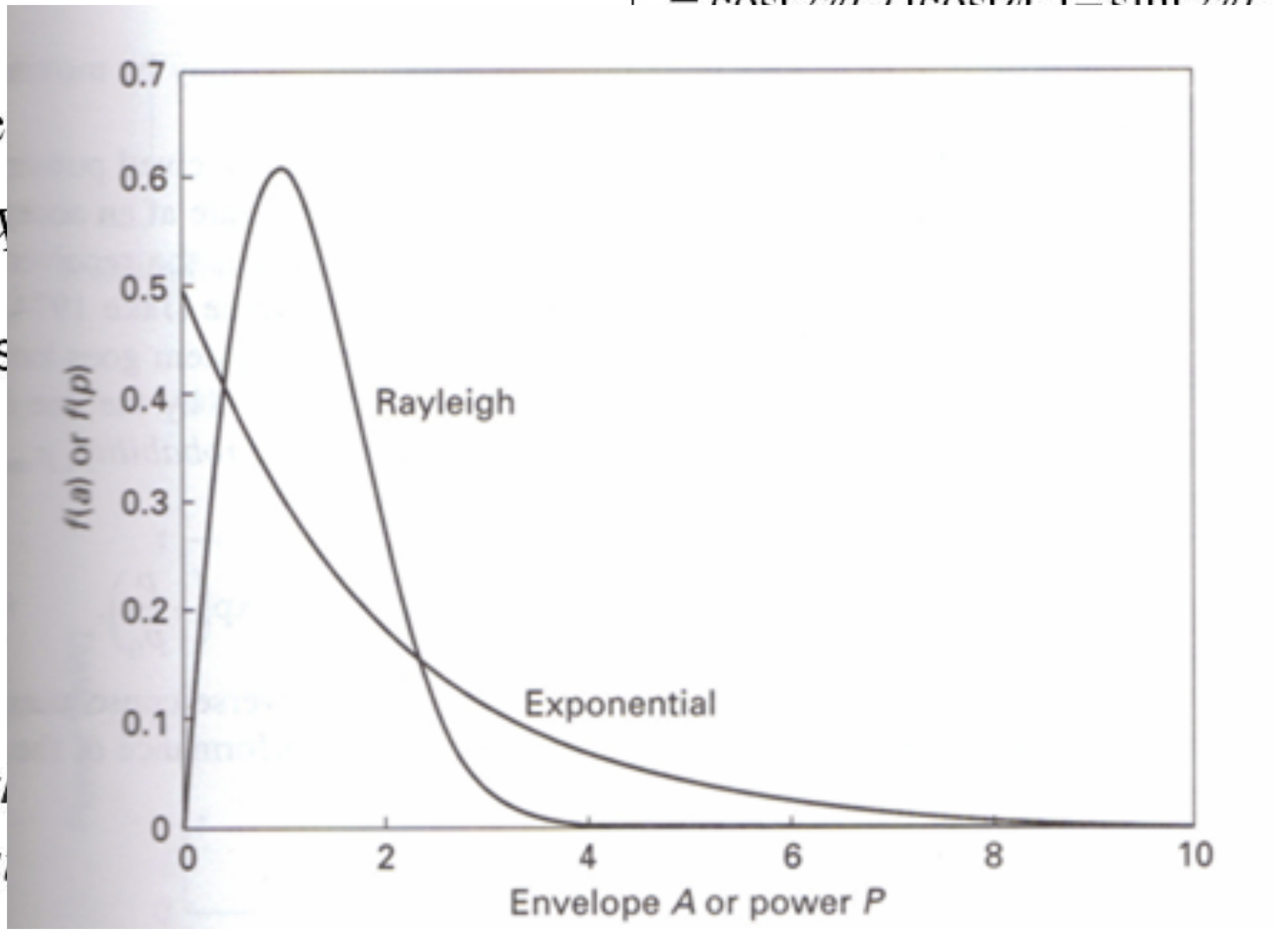


Rayleight fading

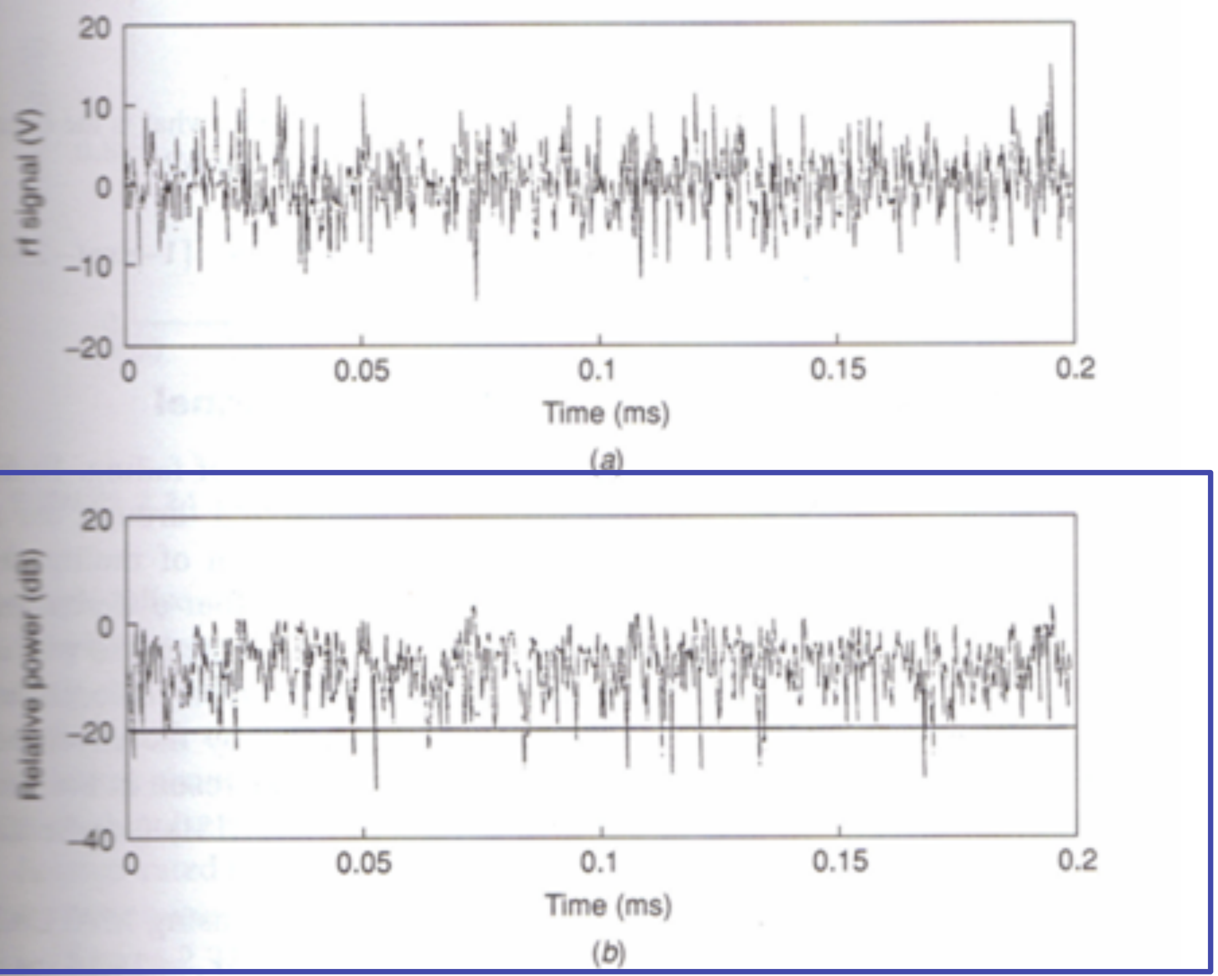


FIGURE 2.19 Rayleigh-faded rf signal (*a*) and its power (*b*). The plots were generated from 11 multiple paths. The envelope was obtained by demodulating the rf signal.

Fading-why is it important?

Answer1:

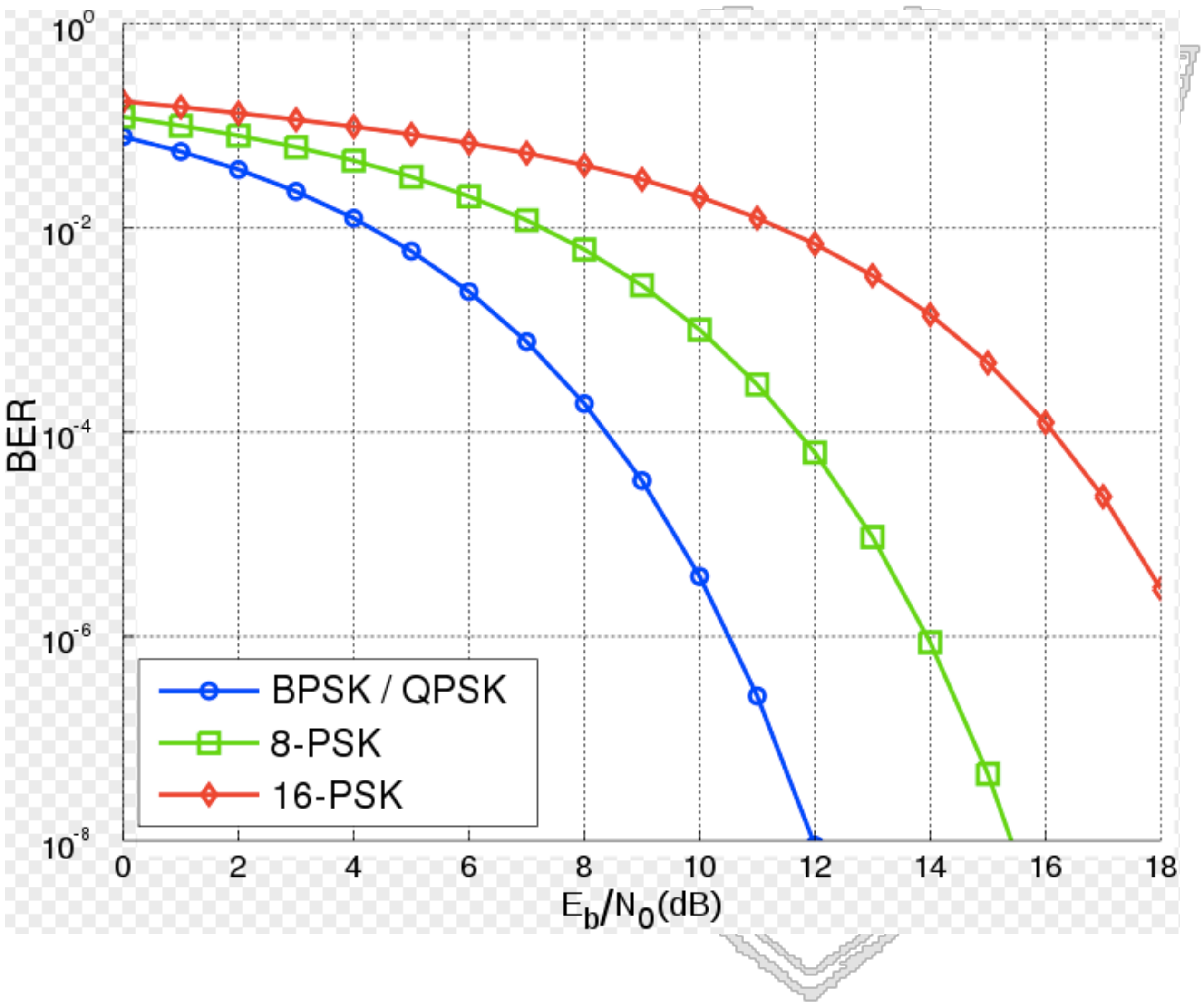
Outage Probability→Probability that received power is lower than a given threshold

⇨Below which signal cannot be correctly received

$$P_{out}=\int_{o}^{pthr} f(p)\, dp$$

Pay attention: making the assumption the network topology is a unit disc graph is a strong approximation to be aware of. Solutions relying heavily on this approximation sometimes fail completely in real life

BER performance



BER performance also depends on modulation

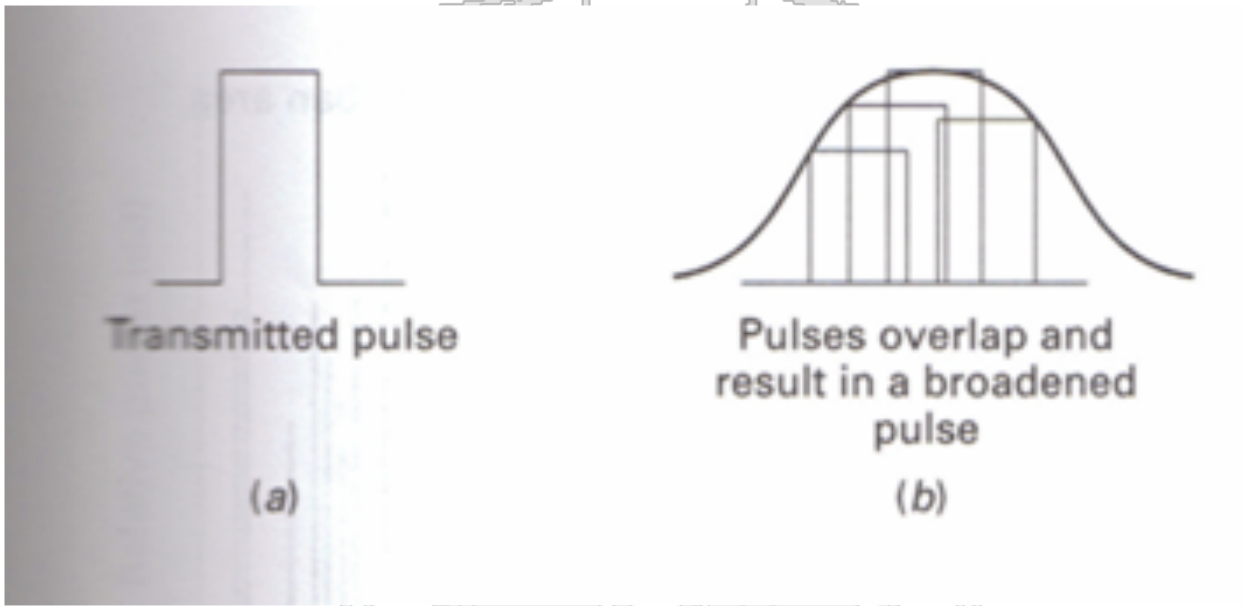
Given a S/N and a Modulation→BER

Using FEC BER Performance can be improved

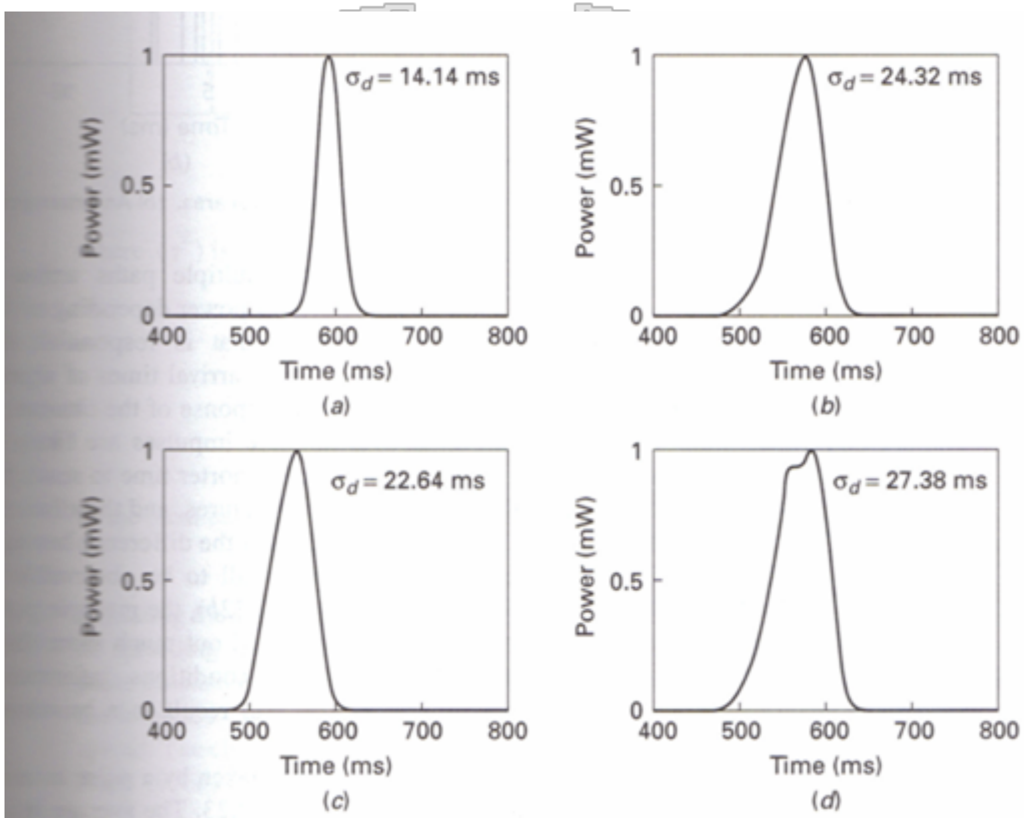
Multipath fading

- Different delays experienced by the different signal replicas (*delay spread*) can widen the channel impulse response leading to intersymbol interference (ISI – Inter-Symbol Interference)

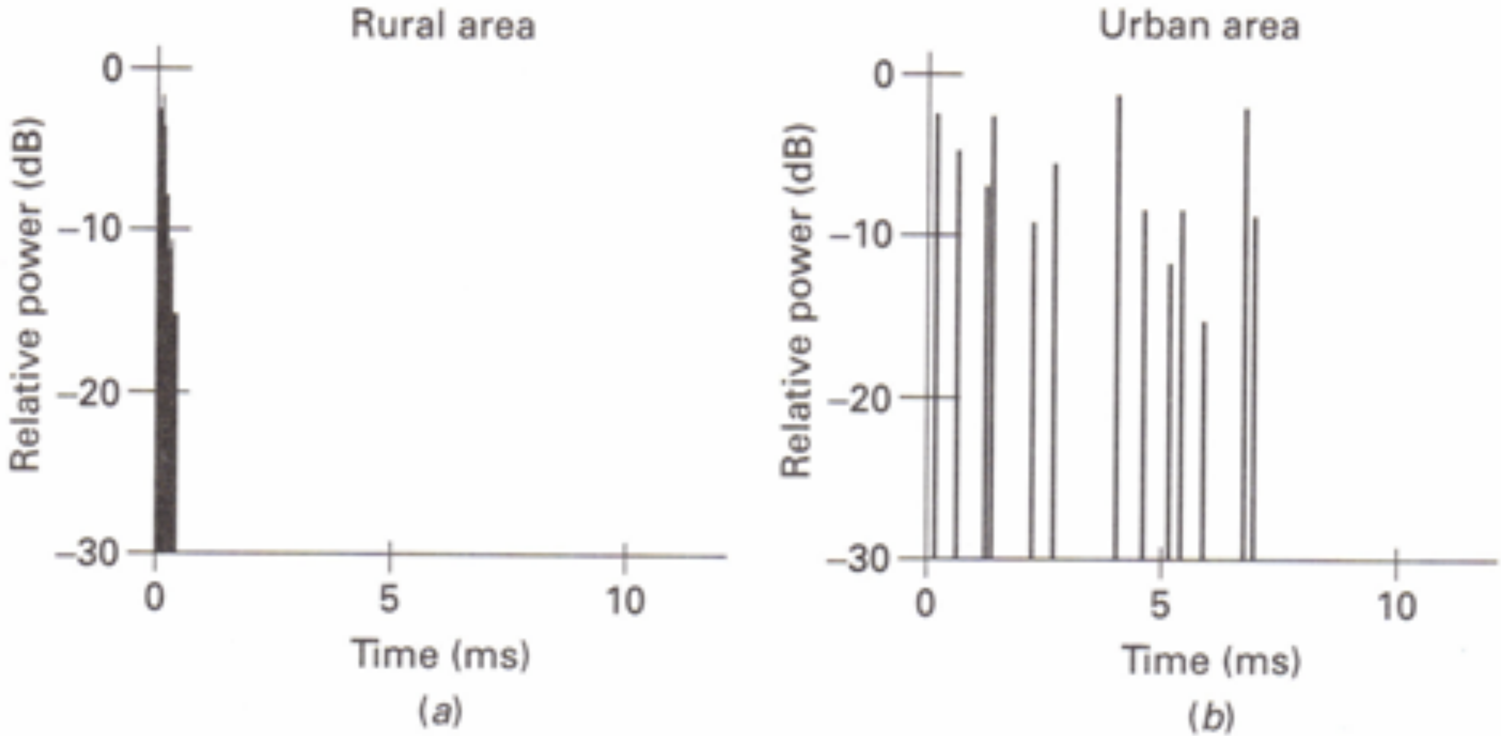
Examples


Transmitted pulse
Pulses overlap and
result in a broadened
pulse
(a)
(b)

Examples


σd = 14.14 ms
Power (mW)
Time (ms)
(a)
σd = 24.32 ms
Power (mW)
Time (ms)
(b)
σd = 22.64 ms
Power (mW)
Time (ms)
(c)
σd = 27.38 ms
Power (mW)
Time (ms)
(d)

Impulse response



Multipath fading

- Impact of delay spread can be quantified by computing the root mean square (RMS Delay Spread):

$$\tau_{RMS} = \sqrt{\frac{1}{\sum_{i=1}^{n} P_i} \sum_{i=1}^{n} \left(\tau_i^2 P_i\right) - \tau_d^2}$$

- **with**

$$\tau_d = \frac{\sum_{i=1}^{n} \left(\tau_i P_i\right)}{\sum_{i=1}^{n} P_i}$$

- **τ_{RMS}** **RMS delay spread**
- **τ_i** **delay on path i**
- **P_i** **power received on path i**
- **n** **number of paths**

Multipath fading

- The coherence bandwidth, which is a statistical measurement of the bandwidth interval over which the channel is 'flat' is approximated by the inverse of the delay spread
- If coherence bandwidth is >> signal bandwidth the channel is flat
- If coherence bandwidth is comparable to the signal bandwidth then delay spread results into intersymbol interference and reception errors

In case of intersymbol interference equalization is used, introducing complexity.