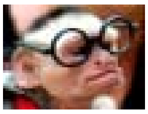


E 5.1

A mobile telephone is moving in a city environment.

i) The received signal is exposed to a Rayleigh multipath fading. What is the minimum required fading margin (in dB) to make the channel available with a 95% probability?

ii) The signal is now, in addition to the multipath fading, also exposed to shadow fading with a (log-) standard deviation of 4 dB. Assume that the total fade margin can be derived by summing the fade margins for the Rayleigh fading and the shadow fading processes. What is the new minimum required fading margin (in dB) to make the channel available with 95% probability.

Answer:

i) The received signal is exposed to Rayleigh multipath fading, so Signal power pdf is exponentially distributed.

$$F_\Gamma(\gamma) = \begin{cases} 1 - e^{-\frac{\gamma}{\gamma_0}} & for \quad \gamma \geq 0 \\ 0 & for \quad \gamma < 0 \end{cases}$$

$$Here, \ \gamma = changing \ signal \ power \ with \ time; \ \gamma_0 = average \ signal \ power = E[\gamma]$$

$$Now \ We \ denote \ k_f = fade \ margin$$

$$Channel \ availability, \ T_f = 0.95 = P\left\{\Gamma > \frac{\gamma_0}{k_f}\right\} = 1 - P\left\{\Gamma \leq \frac{\gamma_0}{k_f}\right\}$$

$$Thus, P\left\{\Gamma \leq \frac{\gamma_0}{k_f}\right\} = 0.05;$$

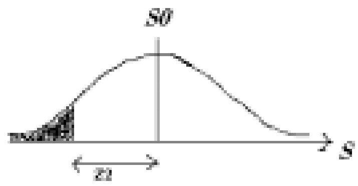
$$\Rightarrow F_\Gamma\left(\frac{\gamma_0}{k_f}\right) = 0.05; \quad \Rightarrow 1 - e^{-\frac{\gamma_0 / k_f}{\gamma_0}} = 0.05; \quad \Rightarrow 1 - e^{-\frac{1}{k_f}} = 0.05; \quad \Rightarrow e^{-\frac{1}{k_f}} = 0.95; \Rightarrow \frac{1}{k_f} = -\ln(0.95)$$

$$Thus, \ k_f = 19.495 \Leftrightarrow 12.9dB$$

ii) Rayleigh plus shadowing have occurred.

We know that shadowing is log-normal fading, with S_0 as mean value and σ as standard deviation, thus we can express it as N(S_0,σ).

$$T_f = P\{S \geq S_0 - Z_2\}$$
$$= P\left\{\frac{S-S_0}{\sigma} \geq -\frac{Z_2}{\sigma}\right\}$$
$$\Rightarrow Q\left(-\frac{Z_2}{\sigma}\right) = 0.95$$
$$\Rightarrow \frac{Z_2}{\sigma} \approx 1.65$$
$$\Rightarrow Z_2 = 4\times 1.65 = 6.6dB$$
$$Total \quad fade \quad margin = (12.9+6.6)dB = 19.8dB$$



E 5.2

A Rayleigh fading radio channel has a delay spread of T_m=1 ms and a Doppler spread B_d= 10 Hz. The signalling bandwidth is 25 kHz.

i) Estimate the coherence bandwidth and the coherence time of the channel; ii) Is this channel frequency selective; ii) Are we dealing with slowly fading channels?

Answer:

$$Delay \quad spread, \ T_m = 1mS; \ Doppler \quad spread, \ B_d = 10Hz$$

$$a) \quad Coherencebandwidth, \ B_m \approx \frac{1}{T_m} = \frac{1}{1mS} = 1KHz$$

$$Coherence \quad time, \ T_d \approx \frac{1}{B_d} = \frac{1}{10} = 0.1S$$

$$b) \ Signalling \quad bandwidth, \ B = 25kHz \quad and \quad coherenc \quad bandwidth, \ B_m = 1kHz$$

$$Thus, \ B > B_m \quad \Rightarrow The \quad channel \quad is \quad frequency \quad selective$$

$$c) \ Signal \quad duration, \ T \approx \frac{1}{B} = \frac{1}{25\times 10^{-3}} = 4\times 10^{-5} S$$

$$Thus, \ T << T_d \quad \Rightarrow The \quad channel \quad is \quad slowly \quad fading$$

E 5.3

A local spatial average of a power delay profile is shown in Figure 5.1

i) Determine the rms delay spread and mean excess delay for the channel.

ii) Determine the maximum excess delay (-20 dB).

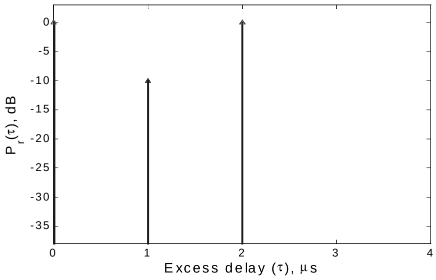


Figure 5.1 Power delay profile

iii) Determine the maximum RF symbol rate if the symbol duration *T* is less that 10σ, where σ is RMS delay spread, an ISI takes place.

iv) If the mobile travelling at 30 Km/hr receives a signal through the channel, determine the time over which the channel appears stationary.

Answer:

$$a)\ \ Average\ \ excess\ \ delay,\ \ \bar{\tau} = \frac{\sum_i \rho_i \tau_i}{\sum_i \rho_i}$$

$$RMS\ \ delay\ \ spread,\ \ \sigma = \sqrt{\overline{\tau^2} - \bar{\tau}^2};\ \ where\ \ \overline{\tau^2} = \frac{\sum_i \rho_i \tau_i^2}{\sum_i \rho_i}$$

$$From\ \ figure\ \ 5.1,\ \ \tau = [0\ \ 1\ \ 2]\ \ in\ \ \mu\sec\ \ and\ \ \rho = [0\ \ -10\ \ 0]\ \ in\ \ dB = [1\ \ 0.1\ \ 1]\ \ W$$

$$Thus,\ \ \bar{\tau} = 10^{-6}\sec\ \ \ \ and\ \ \overline{\tau^2} = 1.952\times10^{-12}\sec$$

$$\Rightarrow This\ \ gives,\ \ RMS\ \ delay\ \ spread,\ \ \sigma = 9.759\times10^{-7}\sec$$

b) Since all of the delay components have amplitudes in excess of -20dB, <u>the maximum excess delay at -20dB is 2μsec.</u>

c) The minimum symbol period, T_{min}=10*σ=9.759*10^{-6}sec.
Thus, the symbol rate, $R_s=1/T_{min=}$102.5Kbps

$$d)\ \ \ \ Assume,\ \ f_c = 900\ \ MHz;$$

$$Thus,\ \ carrier\ \ wavelength,\ \ \lambda = \frac{C}{f_c} = 0.333m,\ \ where\ \ C = speed\ \ of\ \ light$$

$$f_d = \frac{\upsilon}{\lambda} = \frac{30km/hr}{0.333m} = \frac{30{,}000}{0.333*3600}Hz = 25.025Hz$$

$$Coherence\ \ time, T_d \approx \frac{1}{f_d} = 0.04\sec$$

Homework-5 Deadline 04 March 2002 at 10.00

Homework return box is located at Otakaari 5, 2nd floor, near the E-wing. You can also return the answers to the assistant just before the class.

If a particular modulation provides suitable BER performance whenever $\sigma/T_s \leq 0.1$, determine the smallest symbol period T_s (and thus the greatest symbol rate) that may be sent through the indoor and outdoor RF channels shown in Figure 5.2 The received power is in dB.

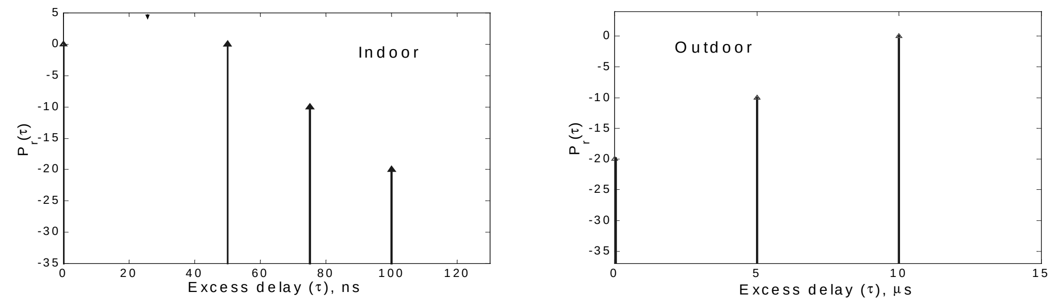


Figure 5.2