Technische Universität Braunschweig

Institut für Nachrichtentechnik

Fundamentals of Mobile Radio Communications

Exercise 8: Radio Channel Effects

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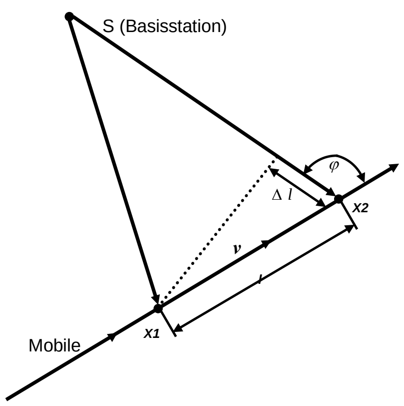
1 Doppler Effect

1.1 What is the Doppler effect? How does it affect the received signal?

The Doppler effect is the change in the frequency of waves as the source and observer approach or move away from each other, i.e. move relative to each other.
Assuming multipath propagation, the Doppler effect leads to a spread of energy in the frequency domain (Doppler spectrum), often modeled as an U-shaped Jakes spectrum.

1.2 A mobile phone user is logged on to a radio cell with a carrier frequency of $f_c = 1800\,\text{MHz}$. He is driving his car on a motorway at a speed of 200 $\frac{\text{km}}{\text{h}}$. What is the maximum Doppler shift?



2 Multipath Propagation

For all calculations in this section, consider the multipath components in table 1.

path no. i	delay τ_i	power level $P_{i,\text{dBm}}$
1	2100 ns	–60 dBm
2	2600 ns	–60 dBm
3	3100 ns	–80 dBm
4	3600 ns	–80 dBm
5	4100 ns	–100 dBm

Table 1: Power level and delays of multipath components (MPCs)

2.1 How many meters do the signals travel? What kind of environment could this be (indoors, outdoors, ...)? Plot the measurements using the given coordinate system in fig. 1a.

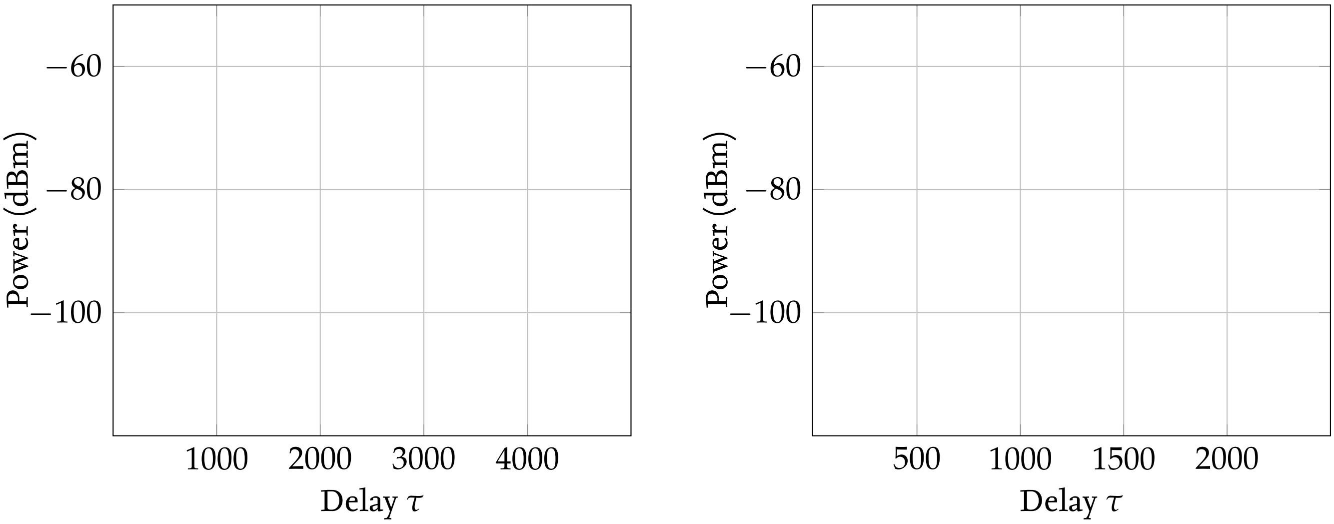
path no. i	delay τ_i	distance
1		
2		
3		
4		
5		

Table 2: Delays and corresponding distances

2.2 How long are the delays in relation to the direct path? Plot the measurements using the given coordinate system in fig. 1b.

path no. i	relative delay $\tau_i - \tau_1$
1	
2	
3	
4	
5	

Table 3: Relative delays



(a) PDP with absolute delays

(b) PDP with relative delays

Figure 1: Power Delay Profile with absolute and relative delays

2.3 What is the maximum excess delay?

2.4 What is the RMS delay spread?

RMS Delay Spread is a measure of the time spread of the channel due to multipath propagation. The RMS delay spread should be significantly less than the symbol duration ($\tau_{\mathrm{RMS}} \ll T_{\mathrm{S}}$).

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

3 Fading

3.1 What is fast fading? What causes it and what probability density functions are typically used to describe it statistically?

The fluctuations in the received signal level caused by multipath propagation and the Doppler effect are called fast fading. Fast fading is characterised over short distances corresponding to a few tens of wavelengths. Fast fading effects are often categorized for two cases:

When there is line-of-sight (LoS) between the TX and RX: The LoS component of the received signal dominates the other components received from Rx by multipath propagation. In this case, the fast fading effect is typically described by a Rice distribution.

When there is no direct line of sight between TX and RX (Non-Line-of-Sight/NLoS): In the NLoS case, the received level at the MS is assumed to be an infinite sum of multipath components whose real and imaginary parts are normally distributed with mean 0 and whose phases are uniformly distributed $[0, 2\pi]$. This process results in a Rayleigh distributed random variable for the amplitude.

3.2 What is the effect of shadowing on the received signal level of the mobile station? How is this described statistically? What is this effect called?

In the case of shadowing, it is observed that the local average receive level is log-normally distributed. This effect is known as slow fading.

3.3 How could the effects of fast fading be minimized?

Through diversity methods and combining methods