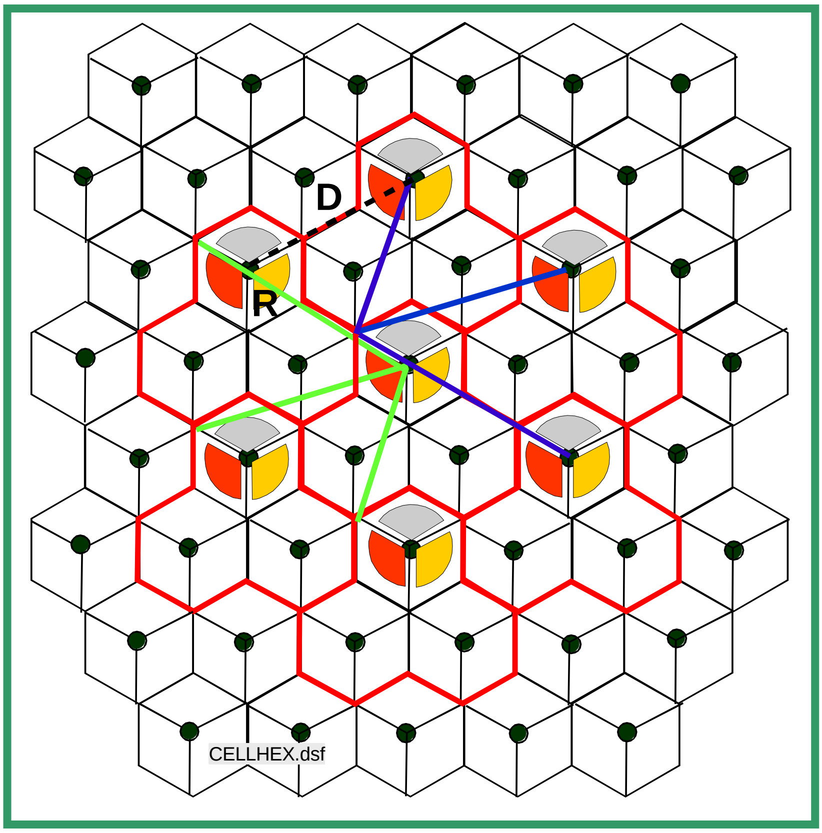
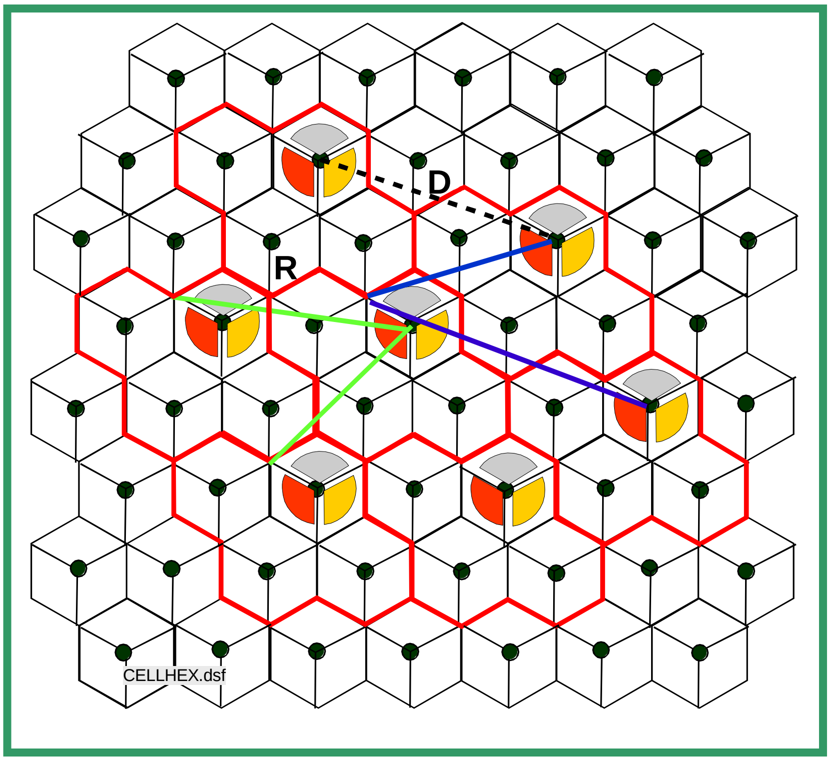
HOME WORK 1

Apply the spectrum efficiency calculation in demo task 1 in a three sector cell structure with antennas having deal 120 degree beams. Depending on the reuse pattern size there will be either 3 ($M = 3$) or 2 ($M > 3$) dominating interferers. Because it is expected that the reuse pattern size will be less than 7, the real shortest distance R_I should be used instead of $D - R$. Note that the sectors may have different number of carriers.





Answer: $\eta = 5.08 \dfrac{\text{Erlang}}{\text{MHz} \cdot \text{km}^2}$

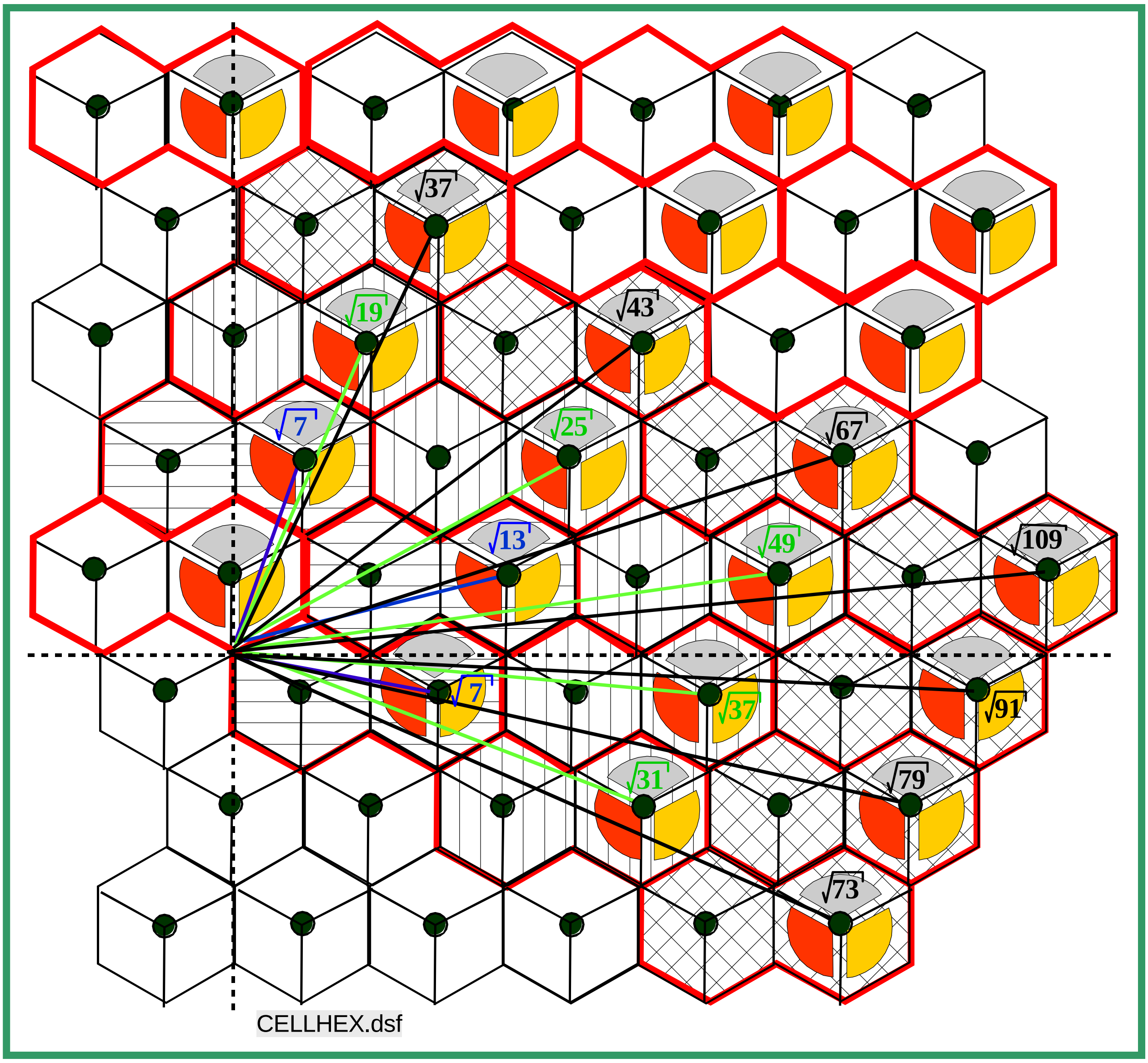
Using the approach of the corrected method in Problem 1 the result is

$$\eta = 1.58 \frac{\text{Erlang}}{\text{MHz} \cdot \text{km}^2}$$

Furthermore, by using the exact distances of the interfering base stations, it turns out that also the reuse factor M = 2 is feasible. The solution for that case is shown below.

$M = 2$

Here we make a more accurate analysis considering the individual distances from each interfering base station. From the figure we obtain



$$CIR_{tot} \approx \frac{P/cR^4}{\sum\limits_{k=1}^{N} P/cR_k^4} = \frac{1}{\sum\limits_{k=1}^{N} \left(R/R_k \right)^4}$$

$$= \frac{1}{\underbrace{2 \cdot \frac{1}{7^2} + \frac{1}{13^2}}_{1^{\text{st}} \text{ interferer tier}} + \underbrace{\frac{1}{19^2} + \frac{1}{25^2} + \frac{1}{37^2} + \frac{1}{49^2}}_{2^{\text{nd}} \text{ interferer tier}} + \underbrace{\frac{1}{37^2} + \frac{1}{49^2} + \frac{1}{67^2} + \frac{1}{73^2} + \frac{1}{79^2} + \frac{1}{91^2} + \frac{1}{109^2}}_{3^{\text{rd}} \text{ interferer tier}}}$$

$$= \frac{1}{0.046733 + 0.005517 + 0.001923} = 18.46 \leftrightarrow 12.66 \text{ dB}$$

As the CIR-value is clearly less than 9 dB and will stay so regardless of how many interferer tiers are considered, the reuse factor 2 can be used.

Thus the number of carriers in a BS is

$$N_{carrier\_BS} = \frac{N_{tot}}{M_{\min}} = \frac{B/\Delta f}{M_{\min}} = \frac{7/0.2}{2} = 17.5$$

$\rightarrow$ sector carrier numbers 6, 6, and 5

Each carrier is divided into 8 time-slots in GSM, which theoretically offers 48, 48, and 40 traffic channels. However, perhaps 2 time-slots are reserved for signalling in each sector, which leaves us with 46, 46, and 38 voice channels.

For the actual parameter values B = 0.02 and N = 46, 46, and 38 the corresponding offered traffic values are 36.53, 36.53, and 29.17 Erlang and the whole cell served traffic which is using the air interface is

$$T_{served} = (1 - B) \cdot \sum_{k=1}^{3} T_{offered,k} = 0.98 \cdot (36.53 + 36.53 + 29.17)$$

$$= 100.19 \text{ Erlang}$$

Now it is possible to calculate the spectrum efficiency.

$$\eta = \frac{T_{served,NW}}{B_{NW} A_{NW}} = \frac{N_{cell} T_{served,cell}}{B_{NW} N_{cell} A_{cell}} = \frac{T_{served,cell}}{B_{NW} A_{cell}}$$

$$= \frac{T_{served,cell}}{B_{NW}\left(6 \cdot \frac{1}{2} R \cdot \frac{R\sqrt{3}}{2}\right)} = \frac{T_{served,cell}}{B_{NW}\left(1.5\sqrt{3}R^2\right)}$$

$$= \frac{100.19}{2 \cdot 7 \cdot \sqrt{6.75} \cdot 1^2} \frac{\text{Erlang}}{\text{MHz} \cdot \text{km}^2} = \frac{100.19}{36.373} \frac{\text{Erlang}}{\text{MHz} \cdot \text{km}^2}$$

$$= 2.755 \frac{\text{Erlang}}{\text{MHz} \cdot \text{km}^2}$$

HOME WORK 2

The noise figure of a radio receiver is 1.5 dB (T_S = 290 K).

a) What is the SNR degradation (dB) in the receiver when the source noise temperature is i) 290 K, ii) 75 K, iii) 4 K and the source is directly connected to the receiver?

b) Repeat the SNR degradation calculation comparing the signal to noise ratios in the receiver input and output, when the source is connected to the receiver with a lossy cable, the loss being L = 2 dB.

c) Repeat the SNR degradation calculation comparing the signal to noise ratios in the source output and the receiver output, when the source is connected to the receiver with the lossy cable in sub-task b.

SOLUTION

a) i) $T_S = 290 \text{ K} \rightarrow \Delta SNR = 1.50 \text{ dB}$

ii) $T_S = 75 \text{ K} \rightarrow \Delta SNR = 4.14 \text{ dB}$

iii) $T_S = 4 \text{ K} \rightarrow \Delta SNR = 14.90 \text{ dB}$

b) i) $T_S = 290 \text{ K} \rightarrow \Delta SNR = 1.50 \text{ dB}$

ii) $T_S = 75 \text{ K} \rightarrow \Delta SNR = 2.49 \text{ dB}$

iii) $T_S = 4 \text{ K} \rightarrow \Delta SNR = 3.20 \text{ dB}$

c) i) $T_S = 290 \text{ K} \rightarrow \Delta SNR = 3.50 \text{ dB}$

ii) $T_S = 75 \text{ K} \rightarrow \Delta SNR = 7.63 \text{ dB}$

iii) $T_S = 4 \text{ K} \rightarrow \Delta SNR = 19.58 \text{ dB}$

HOME WORK 3

Determine the maximum radius of a GSM900 cell in a rural environment by using the up-link power budget and the COST231 Hata average path loss model:

$$L = 69.55 + 26.16\log_{10}(f) - 13.82\log_{10}(h_{bs}) - A_{h_{ms},i} + \left(44.9 - 6.55\log_{10}(h_{bs})\right)\left[\log_{10}(d)\right]^{\beta}$$

where

$$A_{h_{ms},4} = \left(1.1\log_{10}(f) - 0.7\right)h_{ms} - \left(1.56\log_{10}(f) - 0.8\right) + 4.78\left[\log_{10}(f)\right]^2 - 18.3\log_{10}(f) + 40.9$$

The parameter β is given by

$$\beta = \begin{cases} 1, & d \le 20km \\ 1 + \left(0.14 + 1.87\cdot 10^{-4} f + 0.00107 h_{bs}\right)\left[\log_{10}\left(\frac{d}{20}\right)\right]^{0.8} & d \in [20, 100km] \end{cases}$$

The highest up-link carrier frequency in GSM900 is 915 MHz, the mobile antenna height h_{ms} is 1.7 m, the base station antenna height h_{bs} is 100 m. The mobile station output power is 0.9 W and its antenna gain including antenna feeder losses is –0.5 dBi. The base station receiver sensitivity is –104 dBm, its antenna gain is 18 dBi. The feeder includes a 15 m horizontal part, and the feeder cable characteristic loss is 0.04 dB/m. Feeder connector losses are 2 dB.

Hint. Determine first the maximum path loss from the radio link power budget and then solve by using a suitable numerical method the maximum path loss from the given path loss expressions

Answer: $31.8\cdot[\lg(d)]^{1+0.418\left[\lg\left(\frac{d}{20}\right)\right]^{0.8}} = 54.18$

A trial and error method gives the maximum distance d = 38.64 km

Somebody claimed that the given Hata-model has parenthesis in the wrong place. However, the parentheses are put in the same way as in the ITU-R Rec. P529-3

HOME WORK 4

A fixed radio path length is 48 km and the carrier frequency 7500 MHz. The antenna heights above sea level are 200 m and 400m. The value of the refractivity gradient dN_1 is –250 N-units/km, and the standard deviation of the terrain in the path area is 60 m.

a) Which fading depth is exceeded during 0.01 % of time?
b) Which enhancement value is exceeded during 0.01 % of time?

Answer:

a) $A = 28.61$ dB
b) $E = 11.02$ dB

HOMEWORK 5

During the worst month the measured channel model of a terrestrial radio relay hop gives the following prediction formulas for the outage probability caused by frequency selective fading and flat fading respectively: $P_{o,sf} = P_{sf} W \tau \, \mathrm{e}^{-B/4.2}$, $P_{o,ff} = r \cdot 10^{-FFM/10}$.

the parameter values of the channel models are:	the fade tolerance parameters of the receiver are:
• P_{sf} = 0.015 • r = 0.07 • τ = 6.3 ns	• FFM = 37 dB • B is the M-signature height (dB) • W is the signature width (GHz) The signature is the same in both minimum phase and non-minimum phase channel

The total outage target due to flat and selective fading is 0.002%. Calculate the necessary signature height when the signature width is a) 10 MHz, b) 20 MHz, c) 30 MHz outage improvement.

Answer:

$W = 0.01$ GHz $\rightarrow B = 24.28$ dB

$W = 0.02$ GHz $\rightarrow B = 27.19$ dB

$W = 0.03$ GHz $\rightarrow B = 28.89$ dB

HOME WORK 6

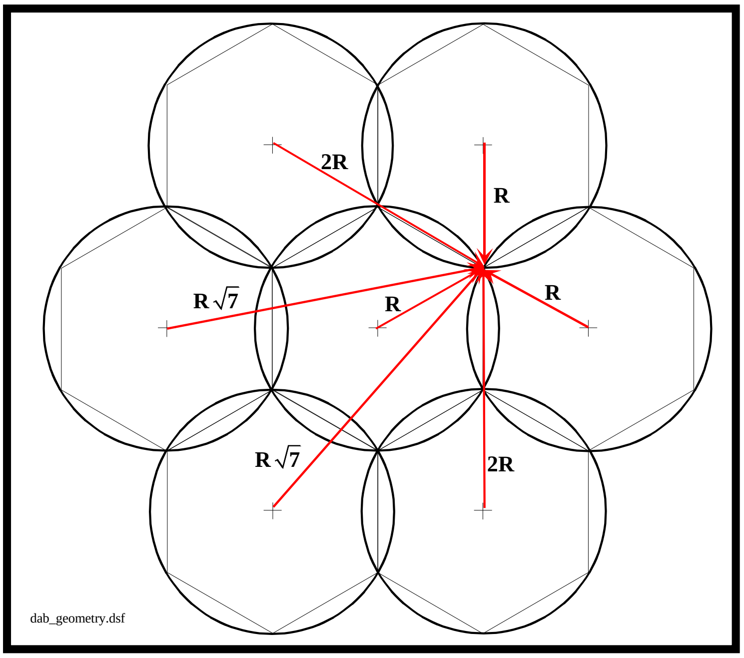
An audio broadcasting network is initially built for FM-transmission. The planning parameters are:

transmitter power: P_{tx} = 60 kWEIRP,

transmitter antenna height: h_{tx} = 300 m,

required field strength at coverage area border: E_{rx} = 54.0 dBμV/m.

a) Estimate the radius of the coverage area.



This broadcasting network should be utilised for DAB-transmission at 200 MHz requiring the field strength of 44.0 dBμV/m at the coverage area border.

b) Determine the required transmitter power (kWEIRP) in the case of a single DAB-transmitter.

c) Estimate the field strength at the receiver place, marked with arrows in the figure, from the other transmitters compared to the field from the transmitter in the centre (all transmitter parameters are identical).

d) In the DAB-network only one transmitter frequency is used, and it is assumed that the received powers (W) of the six nearest transmitters around the "own" transmitter sum up in the receiver. (This presumes that the propagation time difference is less than the OFDM guard interval.) Determine the required transmitter power (kWEIRP) in this case.

Answer:

a) $R \approx 81$ km

b) $P_{tx,DAB} = 10.96$ kW

c)

$$R = 81 \text{ km} \rightarrow E = 47.86\ \mu\text{V/m}$$

$$R = 2R = 162 \text{ km} \rightarrow E = 3.51\ \mu\text{V/m}$$

$$R = \sqrt{7}R = 214 \text{ km} \rightarrow E = 1.36\ \mu\text{V/m}$$

d) $P_{tx,DAB} = 3.64$ kW