**S-72.3210 Channel modeling for radio communication systems**
**Exam 10.1.2008**

This is an open-book exam. Of the following six tasks the five best answered are considered.

1. According to ITU-R Rec. P835 the temperature (K), pressure (hPa) and water vapor pressure (hPa) at different heights $h$ [km] above sea level are given by:

$$T(h)=T_o+\frac{\partial T}{\partial h}\cdot h,\ P(h)=P_o\left[\frac{T_o}{T(h)}\right]^{\frac{34.163}{\partial T/\partial h}},\ e(h)=\frac{\rho_o\,\mathrm{e}^{-0.5h}\,T(h)}{216.7}.$$

$T_o$ and $P_o$ are the temperature and pressure at sea level, and $\rho_o\left[\mathrm{g/m^3}\right]$ is the amount of water in air at sea level. $\partial T/\partial h$ is the vertical temperature gradient [N-units/km].

a) Calculate the refractivity during standard propagation conditions at the heights 0 and 65 m, when

$$T_o=288\ \mathrm{K},\ P_o=1013\ \mathrm{hPa},\ \rho_0=7.5\ \mathrm{g/m^3},\ \partial T/\partial h=-6.5\ \mathrm{K/km}.$$

b) Calculate based on these two values the value of the vertical refractivity gradient.

2. The ITU-R Rec. P530 gives the following expression for the excess diffraction loss in dB on a path over "average terrain":

$$L_e=10+20\frac{e}{R_{F1}}.$$

$R_{F1}$ is the radius of the 1st Fresnel zone and $e$ is the height above the virtual line-of sight of the dominant obstacle. The expression is valid for $L_e\geq 6$ dB.

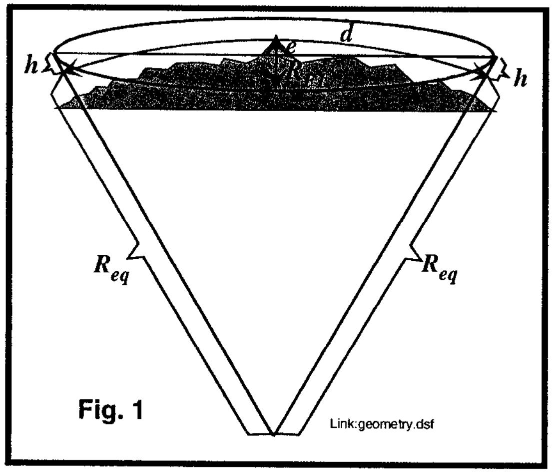
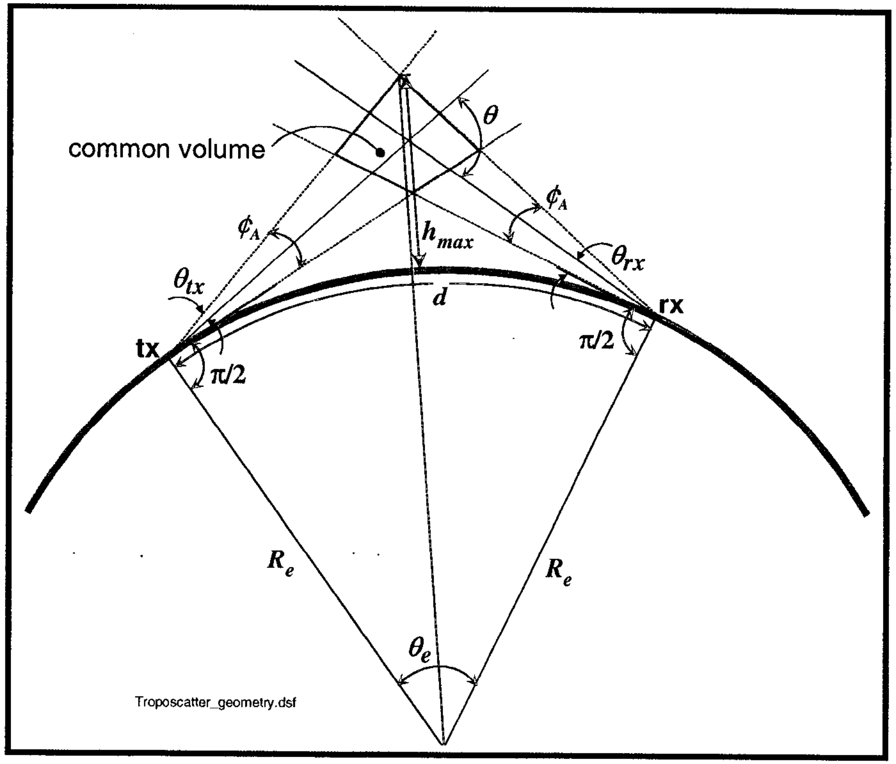


Fig. 1

a) Derive an expression for the excess loss as function of the path length $d$, $h$, $R_{F1}$, and wavelength $\lambda$ for the case depicted in Fig. 1, where $h$ is the transmitter and receiver antenna height above a reference Earth touching the dominant obstacle located at the midpoint of the path, and $R_{eq}$ is the equivalent radius of this reference Earth.

b) Calculate the numerical value of the excess loss when $R_{eq}=8500$ km, $h=0$ km, $f=6$ GHz, and $d=$ i) 50 km, ii) 100 km.

3.




Based on the difference between the longest and shortest ray path in the tropo-scatter link geometry shown in the above figure, calculate the delay spread in the great circle plane assuming ideal conical antenna lobes just touching the ground as depicted in the figure. The path length along Earth's surface is 500 km, $\phi_A = 1$ degree, and the equivalent Earth radius $R_e$ is 8500 km. The propagation speed is assumed to be $3 \cdot 10^8$ m/s.

4. What is the maximum bandwidth of an ideal band-pass signal that it could be considered to be a narrow-band signal in the rural environment channel model in GSM. This model has 6 taps with delays and average power levels given in the table. The required signal to error signal ratio is 12 dB.

| i | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $\tau_i$/µs | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
| $P_{im}$/dB | 0 | –4.0 | –8.0 | –12.0 | –16.0 | –20.0 |
| | Rice | class | class | class | class | class |

5. It is assumed that the COST231 Hata-model in normal city environment is valid at 2150 MHz frequency. How large may the wall penetration loss be, that the average path loss is unchanged, when the loss at outdoor street level with 1.5 m antenna height and in the indoor 2nd floor level with 10 m antenna height are compared?

6. The multipath fading in a narrow-band radio channel is Rayleigh-distributed. How large is the probability that the received signal level is: a) faded more than 10 dB, and b) enhanced more than 10 dB with respect to the median level. The signal level is above and below median level with probability 0.5.

$$\int \frac{x}{\sigma^2} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx = -\exp\left(-\frac{x^2}{2\sigma^2}\right) + C$$