Technische Universität Braunschweig

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Fundamentals of Mobile Radio Communications

Exercise 1: Basic Terms and Calculations in Decibel

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1 Mobile Radio Systems - Basics

1.1 Draw a simplified network architecture of an infrastructure-based mobile radio system (e.g. GSM) and explain the function of each component of this system.

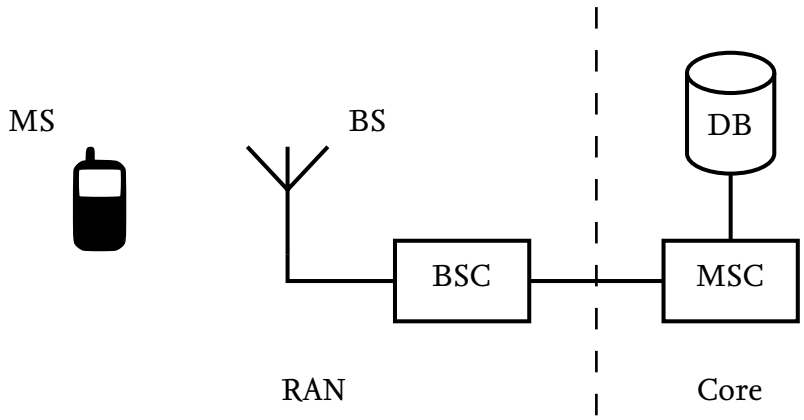

Figure 1: Simplified topology of a GSM-based mobile network

- **Mobile Station (MS)** – contains the SIM card and hardware features that allow radio transmission according to mobile radio standards and thus communication with the BS.
- **Base Station (BS)** – controls the MSs of a radio cell and allows subscribers to access the operator's network through the radio channel.
- **Base Station Controller (BSC)** – controls the BSs and is responsible for managing handover and other procedures.
- **Mobile Switching Center (MSC)** – contains information of the network operator's subscribers and is responsible for data exchange with other networks and the outside world.

1.2 In the sketch of Task 1.1, identify the radio access network (RAN) and the core network (Core) and explain their roles.

- **RAN** – enables subscribers to access the operator's network via air interface.
- **Core** – contains information about a network operator's subscribers and enables them to communicate with other subscribers and the outside world (Internet, private networks, IP multimedia subsystems, etc.) using standardized protocols.

1.3 In the context of mobile radio communications, please explain the following terms and give examples.

1.3.1 communication channel

A physical medium (for example, a wire, air) that can be used to transfer information. In mobile radio communications, the air interface is used to transfer information using electromagnetic waves.

1.3.2 carrier frequency, frequency band

The electromagnetic wave is used to transmit information. This information is "modulated" onto a carrier wave which carries the information to be transmitted over the air. In the electromagnetic spectrum, various radio services are allocated into a specific range of frequencies or frequency bands.

1.3.3 Multiplexing, Channel Access Methods, Duplex

Multiplexing – a method to enable the transmission of multiple signals over a shared medium.
Channel Access Methods – allow more than two terminals connected to the same transmission medium to transmit over it and share its capacity. These techniques are based on multiplexing.
Duplex – a method that allows bidirectional communication simultaneously (e.g., FDD) or in an alternating fashion (e.g., TDD).

1.3.4 Shadowing

A phenomenon occurring when an MS is positioned behind an object (in its shadow) and the direct connection is obscured. In such cases, only a fraction of the transmitted power will be received by the MS.

1.3.5 Roaming

Roaming is a term which refers to the use of a MS outside of its home network.

1.4 Why do new generations of mobile radio systems use higher frequency bands than previous generations?

New use cases and services often require higher data rates. Due to the dependency of the bandwidth to the data rate ($C \propto B$, Shannon-Hartley theorem), higher bandwidths are needed for higher data rates. Since the bandwidth is usually more limited in lower frequency bands, new standards often use higher frequency bands to meet the requirement of higher data rates (and therefore higher bandwidths).

1.5 How long does it take for a signal to reach the MS when the base station is 0.1 km, 1 km and 300 km away from the MS?

1.6 Why is channel modeling particularly important for mobile radio systems, and why can modeling be challenging?

To enable network operators to plan their radio networks as efficiently as possible, it is important to predict the received power of the MS. Such predictions are based on radio channel models. Since the electromagnetic wave is affected by propagation effects such as reflection, diffraction, scattering and attenuation in the atmosphere (channel), the received power cannot usually be determined deterministically, but rather as a random variable.

2 Calculations in Decibel

2.1 What does the term "level" mean?

In mobile communications, the power levels that occur, such as the received power, vary over several decades. For this reason, not only linear power values but also logarithmic values, known as levels, are used in the calculations.

$$1\,\mathrm{B} = \log_{10}\frac{P_1}{P_2}$$

The bel B is an auxiliary unit of the decadic logarithm and is named after Alexander Graham Bell.

2.2 What is a dB?

A decibel (dB) is a pseudo-unit for the logarithmic ratio of two quantities of power or energy with dimension 1. It is often used to describe attenuation, gain or other ratios.

Examples:

$$P_{\mathrm{dB}} = 10\log_{10}\frac{P_1}{P_2}\mathrm{dB} \quad\Longleftrightarrow\quad \frac{P_1}{P_2} = 10^{\frac{P_{\mathrm{dB}}}{10}}$$

$$U_{\mathrm{dB}} = 10\log_{10}\frac{U_1^2}{U_2^2}\mathrm{dB} = 20\log_{10}\left|\frac{U_1}{U_2}\right|\mathrm{dB} \quad\Longleftrightarrow\quad \left|\frac{U_1}{U_2}\right| = 10^{\frac{U_{\mathrm{dB}}}{20}}$$

2.3 What are the corresponding level differences for the following power factors: 2, 4, 5, 10, 0.5 and 0.2?

2.4 What do the units dBm, dBW, dBV, dBµV/m mean and how are they defined?

When levels are expressed in dB relative to a fixed reference, this is indicated by a suffix.

dBm (decibel milliwatt) Auxiliary unit of measurement of the power level P_{dBm} (ratio of a power P compared to the reference power 1 mW):

$$P_{\mathrm{dBm}} = 10 \log_{10} \left(\frac{P}{1\,\mathrm{mW}} \right) \mathrm{dBm}$$

Similarly: dBW refers to 1 W.

dBV (decibel volt) Auxiliary unit of measurement of the voltage level P_{dBV} (ratio of a voltage U compared to the reference voltage 1 V):

$$P_{\mathrm{dBV}} = 20 \log_{10} \left(\frac{|U|}{1\,\mathrm{V}} \right) \mathrm{dBV}$$

Similarly: dBµV refers to 1 µV, dBmV refers to 1 mV.

dBµV/m Auxiliary unit of measurement of the electric field strength level $P_{\mathrm{dB\mu V/m}}$ (ratio of a electric field strength E compared to the reference field strength 1 µV/m):

$$P_{\mathrm{dB\mu V/m}} = 20 \log_{10} \left(\frac{|E|}{1\,\mu\mathrm{V/m}} \right) \mathrm{dB\mu V/m}$$

2.5 What values correspond to 0 dB, 0 dBm and 0 dBV?

2.6 What is the difference between gain and loss (amplification / attenuation)?

A negative gain is a loss.

Example: A amplifier with a gain of 7 dB has a loss of –7 dB.

2.7 Why is there a factor of 20 in front of the logarithm when calculating the voltage ratio?

2.8 Without using a calculator, convert $P = 2\,\text{W}$, $P = 50\,\text{W}$ and $P = 0.1\,\text{mW}$ into power level values (dBm and dBW).

2.9 Convert $P_{\text{dBm}} = -40\,\text{dBm}$, $P_{\text{dBm}} = 44\,\text{dBm}$ and $P_{\text{dBm}} = 33\,\text{dBm}$ into linear power values without using a calculator.

2.10 A level of 30 dBm is received from 2 transmitters at a particular location. What is the total power received?