

Grading method

There is a total of **100** points to be distributed as follows:

Part 1 – Technical exercises

- Exercise 1	6 points
- Exercise 2	5 points
- Exercise 3.1	4 points
- Exercise 3.2	7 points
- Exercise 3.3	4 points
- Exercise 4	6 points
- Exercise 5.1	2 points
- Exercise 5.2	7 points
- Exercise 6.1	14 points
- Exercise 6.2 (part 1)	9 points
- Exercise 6.2 (part 2)	4 points

Part 2 – Soft skills

- Teamwork and presentation	32 points
-----------------------------	-----------

100 points

Presentations

Please enter the points obtained into the fields provided for this purpose directly under the exercise and then copy them to the summary.

Each team has 15 minutes of time for the presentation. If the time limit is exceeded, the presentation will not be interrupted. For each minute over the time limit, 0.5 points will be deducted, however.

The presentation can be made using PowerPoint or a flip chart/pin board. Adequate materials are provided to the teams for this purpose, including paper and a presentation toolkit.

Model Solution, Preliminary Round, Case Study Competition 2009

Part 1 – Technical exercises

Exercise 1

Max. path loss L_p :

$L_p = \text{transmit power} - \text{sensitivity} - \text{margin} - 2 \times \text{cable loss} + 2 \times \text{antenna gain}$ (2 points)

- | Ground: Transmit power of 30 W corresponds to +45 dBm | Air: Transmit power of 10 W corresponds to +40 dBm
- | Sensitivity -103 dBm (on the ground and in the air)
- | Margin = 7 dB
- | Cable loss = 2×1 dB (1 dB each on the ground and in the air)
- | Antenna gain = 0 dB on the ground | -3 dB in the air, i.e. for both antennas a total of -3 dB

Calculation, ground \rightarrow air: $L_p = 45 \text{ dBm} - (-103 \text{ dBm}) - 7 \text{ dB} - 2 \text{ dB} - 3 \text{ dB} = 136 \text{ dB}$ (1 point)

Calculation, air \rightarrow ground: $L_p = 40 \text{ dBm} - (-103 \text{ dBm}) - 7 \text{ dB} - 2 \text{ dB} - 3 \text{ dB} = 131 \text{ dB}$ (1 point)

Range:

Free-space loss: $L_p \text{ [dB]} = 28.15 + 20 \log f \text{ [MHz]} + 20 \log d$

Frequency $f = 130 \text{ MHz}$:

For $L_p = 136 \text{ dB}$ we have: $d = 1905 \text{ km}$ (1 point)

For $L_p = 131 \text{ dB}$ we have: $d = 1070 \text{ km}$ (1 point)

Exercise 1					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
6					

Model Solution, Preliminary Round, Case Study Competition 2009

Exercise 2

Free-space loss L_p between two $\lambda/2$ dipoles at 130 MHz and 400 km distance:

Free-space loss: $L_p = 28.15 + 20\log f[\text{MHz}] + 20\log d[\text{dB}] \rightarrow L_p = 122.5 \text{ dB}$ (1 point)

Maximum signal strength S to be expected at receiver on the ground:

$S = \text{transmit power} - L_p - \text{margin} - \text{cable loss (aircraft)} + \text{antenna gain (aircraft)}$ (1 point)

- I Transmit power of 10 W corresponds to +40 dBm (air)
- I Margin = 7 dB
- I Cable loss = 1 dB
- I Antenna gain = -3 dB in aircraft

Signal strength on the ground: -93.5 dBm (1 point)

Minimum required transmit power P on the ground:

$P = \text{sensitivity} + L_p + \text{margin} + \text{cable loss (aircraft)} - \text{antenna gain (aircraft)}$ (1 point)

- I Sensitivity = -103 dBm for (S+N)/N of 10 dB
- I Margin = 7 dB
- I Cable loss = 1 dB
- I Antenna gain = -3 dB in aircraft

Required transmit power on the ground: 30.5 dBm (approx. 1 W) (1 point)

Exercise 2					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
5					

Exercise 3

Exercise 3.1

Reflection coefficient for VSWR 2:1: $R = (V-1) / (V+1) = (2-1)/(2+1) = 1/3$ (1 point) in dB: 9.5 dB (1 point)

- Decoupling is calculated as follows:
- | | |
|---|-----------|
| 1. Forward power passing through coupler: | S5n = 0.5 |
| 2. Reflection at antenna: | 1/3 |
| 3. Reflected power passing through coupler: | S5n = 0.5 |

Total for these three relationships (1 point)

Decoupling is the product of all of the components 0.083 or 21.6 dB (1 point)

Exercise 3.1					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
4					

Model Solution, Preliminary Round, Case Study Competition 2009

Exercise 3.2

Forward power per channel: Input power (30 W) reduced by insertion loss (1 point)
Loss is 0.5 or -6 dB, 30 W = 45 dBm, i.e. 39 dBm per radio line arrive at the output. (1 point)

Peak power per channel: m = 100 %, i.e. double voltage or fourfold carrier power as PEP, (1 point)
i.e. the peak power is 39 dBm + 6 dB = 45 dBm. (1 point)

Power loss in coupler: Since the insertion loss is 6 dB, 75 % of the supplied power remains in the coupler. (1 point)
RMS power of an input signal: For AM 100 %, the RMS power is 1.5 times the carrier power, i.e. 45 W. (1 point)
33.75 W (75 %) per radio signal remain in the coupler. This means that with four signals, 135 W remain in the coupler. (1 point)

Exercise 3.2					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
7					

Exercise 3.3

Peak voltage: 45 dBm PEP per radio signal arrive at the output (30 W). This corresponds to a peak voltage of 38.7 V into 50 Ω. (1 point)

Since we have four signals with different frequencies, the four voltages are superimposed to produce a total of 155 V. (1 point)

45 dBm PEP per radio signal arrive at the output (30 W). This corresponds to a peak current of 0.77 A into 50 Ω. (1 point)

Since we have four signals with different frequencies, the four voltages are superimposed to produce a total peak current of 3.1 A. (1 point)

Exercise 3.3					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
4					

Model Solution, Preliminary Round, Case Study Competition 2009

Exercise 4

Transmit power $30\text{ W} = 45\text{ dBm}$, relative signal-to-noise ratio 155 dBc/Hz , i.e. absolute noise power at the transmitter's antenna output: $45 - 155 = -110\text{ dBm/Hz}$ (1 point)

A noise figure of 12 dB means that the equivalent inherent noise floor at the RX input is equal to $-174 + 12 = -162\text{ dBm/Hz}$. (1 point)

A degradation by 3 dB means that the noise coming from the transmitter may be as high as the RX inherent noise, i.e. -162 dBm/Hz . (1 point)

The necessary decoupling is equal to the difference between the noise density directly at the transmitter output and the permissible noise density at the RX input, i.e. $-162 - (-110) = 52\text{ dB}$ (1 point)

What measures must be taken?

The main issue is an improvement in the transmit noise:

- This requires filters in the transmit path, either in the equipment or after the transmitter. (1 point)
- Note: Filters inserted after the transmitter must of course be capable of handling the corresponding load. (1 point)

Exercise 4					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
6					

Exercise 5

Exercise 5.1

Basic assumptions: $F_{ADC} = 12\text{ dB}$, $SNR_{ADC} = 68\text{ dB}$, $f_{nyq} = 200\text{ MHz}$

$$S_{\text{max,ADC}} = F_{ADC} + SNR_{ADC} - 174\text{ dBm} + 10 \log(f_{nyq})$$

$$S_{\text{max,ADC}} = 12\text{ dB} + 68\text{ dB} - 174\text{ dBm} + 83\text{ dB} = -11\text{ dBm}$$
 (1 point)

The receiver cannot be operated without a pre-filter since it can only tolerate a maximum interference level of 0 dBm at its input. (1 point)

Exercise 5.1					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
2					

Model Solution, Preliminary Round, Case Study Competition 2009

Exercise 5.2

Since the RX itself only handles -11 dBm and an interference level of +10 dBm is required, the pre-filter must provide an additional 21 dB of attenuation. [\(1 point\)](#)

No, since it comes after the converter and thus cannot compensate for the overdrive of the converter. [\(1 point\)](#)

DDC: The usual catchphrases from the field of DDC should be encountered, e.g.:

- | Sample rate reduction, also in fractions
- | Preprocessing, e.g. filtering
- | Monitoring of the modulation of the ADC
- | Automatic gain control (AGC)
- | Format conversion, e.g. Cartesian coordinates to polar coordinates [\(5 points\)](#)

Comment on DDC grading: Each term and a rough explanation of what it stands for is worth one point [\(up to a maximum of 5 points\)](#). It is only necessary to check whether the subject area is basically known.

Exercise 5.2					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
7					

Exercise 6

Exercise 6.1

Filters in the system

- Filters in transmit path:
 - Improvement in spurious emissions, e.g. also noise (1 point)
 - Possible reduction in transmit power (1 point)
 - Possible reduction in range (1 point)
- Filters in receive path:
 - Improvement in immunity to interference by filtering (1 point)
 - Possible reduction in sensitivity (1 point)
 - Possible reduction in range (1 point)

Improved antenna decoupling

- Transmit direction: Spurious emissions are reduced, and no longer have such a strong impact on the RX. (1 point)
- Receive direction: Interfering signals coming from the transmitter no longer have such a strong impact. (1 point)

Attenuators in the system

- Transmit direction:
 - Reduction in transmit power (1 point)
 - Reduction in spurious emissions (1 point)
 - Reduction in range (1 point)
- Receive direction:
 - Reduction in sensitivity (1 point)
 - Increase in immunity to interference (1 point)
 - Reduction in range (1 point)

Exercise 6.1					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
14					

Exercise 6.2 – Part 1

1. First check what margins are available for use.

The desired system data offers significant margin with respect to the equipment specifications:

- The transmitter has 30 W, but only 5 W are needed (1 point)
 - i.e. up to 7.8 dB attenuation is permissible in the transmit direction. (1 point)
- The receiver has -110 dBm sensitivity, but -100 dBm are needed (1 point)
 - i.e. up to 10 dB attenuation would be permissible in the receive direction. (1 point)

Model Solution, Preliminary Round, Case Study Competition 2009

2. What minimum decoupling is required?

Transmit direction:

With the given signal-to-noise ratio of -160 dBc/Hz and transmit power of 30 W (45 dBm), -115 dBm/Hz are available at the transmitter output. [\(1 point\)](#)

At the RX input, up to -162 dBm/Hz may be present [\(1 point\)](#). This means that antenna decoupling of at least 47 dB is required. [\(1 point\)](#)

Receive direction:

The limit is determined by the permissible interference level (-10 dBm). [\(1 point\)](#)

For the given transmit power of 30 W (45 dBm), decoupling of at least 55 dB is required. [\(1 point\)](#)

Exercise 6.2 – Part 1					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
9					

Exercise 6.2 – Part 2

Summary of benchmark figures from Part 1:

Maximum permissible attenuation in transmit path:	7.8 dB
Maximum permissible attenuation in receive path:	10 dB
Minimum decoupling of a transmitter vis-à-vis the receiver:	47 dB
Minimum decoupling of a receiver vis-à-vis the transmitter:	55 dB

Summary: At least 55 dB decoupling must be obtained and max. 7.8 dB attenuation may be introduced in a path.

The starting point is the antenna specification "Standard 40 dB"; this means that 15 dB decoupling must be added. Attenuators alone will not do the job since due to the transceiver configuration, the same attenuation values must be used on both ends. We could insert a maximum of $(15/2)$ dB, but that is not available.

Solution: Install a standard filter on each end which provides 10 dB in each direction. [\(1 point\)](#)

The missing 5 dB can be provided using a 6 dB attenuator. [\(1 point\)](#)

Costs: Standard antenna decoupling (40 dB) (€ 20 K) + 2 x standard filter (€ 4 K) + 2 x 6 dB attenuator (€ 2 K) = € 26 K in total [\(2 points\)](#)

Exercise 6.2 – Part 2					
Max. points	Team 1	Team 2	Team 3	Team 4	Team 5
4					