

Appendix B

Instruction of the assignment

RADIOLINK SYSTEMS Nokia MetroHopper 58 GHz



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2. ABBREVIATIONS

AGC	Automatic Gain Control
FB1	Flexbus 1
FB2	Flexbus 2
FLPY	Floppy
GND	Ground
LMP	Local Management Port
MP	Measuring Point
RX	Receive
TSE	Test Sequence Errors (bit errors)
TX	Transmit

3. ASSIGNMENT

3.1 Prerequisites

The requirements of the preliminary knowledge and the material of the course Fixed Radio Networks (S-72.173) or its equivalent is assumed to be acquired before this exercise.

3.2 Group

Assignment is done in the group of two persons.

3.3 General information

The laboratory work is done in the in the student laboratory E305. The purpose of the course is to provide student with knowledge about radio links systems and understanding where and how radio links can be used. Additionally, special properties of 58 GHz frequency are familiarized. However, it should be understood that Nokia MetroHopper is only one type of several radio links and it is used here only for demonstrating the general properties of the radio links.

The laboratory work is planned to take about 15-20 hours, depending on the background of a student. 8-12 hours are reserved for handling preliminary material, 3 hours are need from the laboratory measurements and the rest of the time is spent for analyzing the measurement results.

3.4 Passing the assignment

A student is expected to become familiar with radio link systems, for that he is provided with laboratory material and course material. Additionally there exists a plenty of literature for deeper examining the matter. After becoming familiar with background information the student should make the preliminary exercises. After submitting the preliminary exercises the group is allowed to reserve laboratory time.

Preliminary exercises and returning instructions can be found in the chapter 4 of this document.

3.5 Grading of the assignment

The laboratory work is graded accepted / rejected. The rejected work should be corrected and resubmitted to the assistant.

3.6 Background of the assignment

The equipments used in this laboratory work are provided by the producer as a donation and the laboratory work has been developed from them. The equipment is suitable for investigating the effect of weather in 58 GHz frequency band. The assignment contains the equipments shown on figure 1.

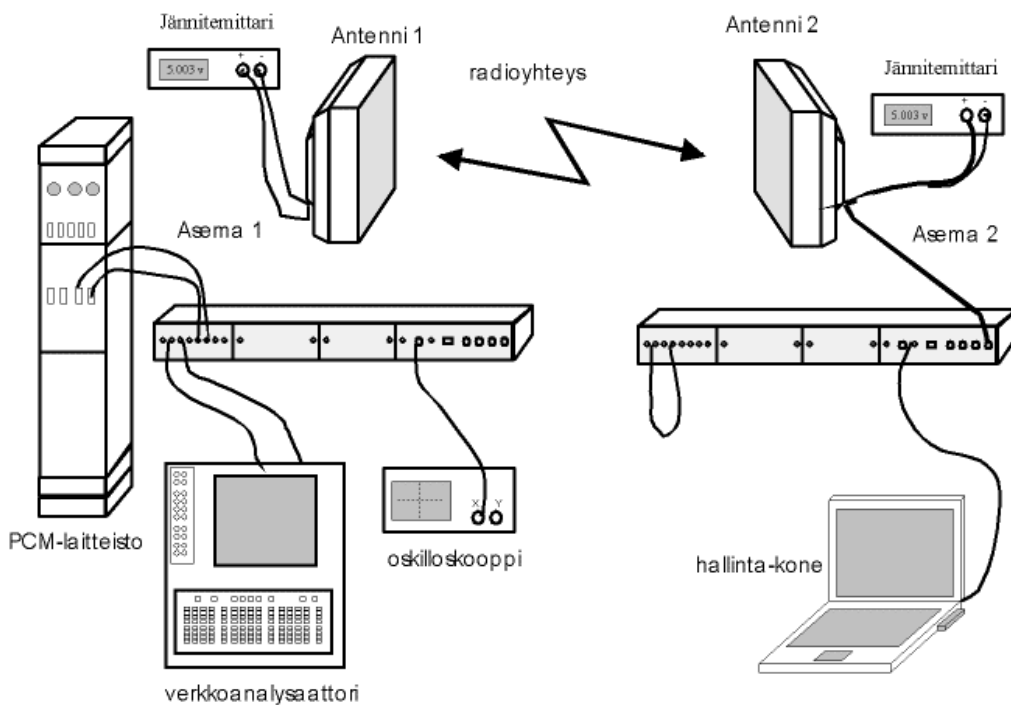


Figure 1. Equipment in the laboratory work.

4. PRELIMINARY ESERCISES

The purpose of the preliminary exercises and of laboratory work is to give a practical picture of the basic choice and possibilities of radio link systems next to the mere theory. The theory and preliminary exercises facilitate in doing the laboratory measurement themselves. When making exercises, try to think how the matters would have been carried out in a separate frequency band in some other radio link system. The solved preliminary exercises should be returned to the return box of the course. The assistant provides feedback about the laboratory exercises and if everything is in order, you can reserve the laboratory shift for the measurements.

1. Where are the radio links used? Why?
2. What is the Fresnel zone? What does it mean to a radio link? Calculate the maximum diameter of the 1st Fresnel zone for 58 GHz radio link. The tendon length is a) 1 km b) 50 m.
3. What are the special properties of 58 GHz radio frequency? How these properties can be utilized in radio links?
4. List usage cases (applications) where MetroHopper radio links can be used (where, when, what is transmitted, used interfaces ...)
5. List the benefits of digital modulation methods.
6. Explain the concepts TDD, BER, MSK, Q-funktio ja AGC.
7. Explain shortly what the following units mean: dBm, dBW, dBi, A/m, V/m and W/m^2 . Prove the claim about dangers to health stated in the chapter 2.4.
8. Calculate the free space loss of a radio link system if the tendon length is 50 m and the frequency 58 GHz.
9. Calculate the free space loss in the connection when a passive mirror is used (figure 2). The tendon length is 50 m and the frequency is 58 GHz. The attenuation due to the reflection in mirror is 25 dBm.

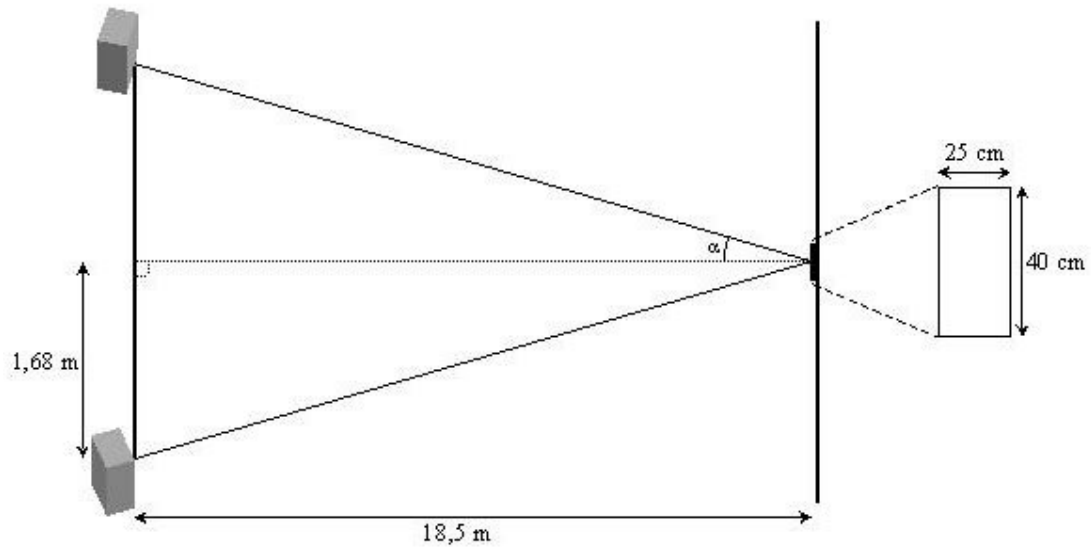


Figure 2. Usage of a passive mirror in the laboratory measurement

10. Calculate the received signal power level received in system in figure 2. The system parameters are selected for Nokia MetroHopper radio link.

5. INSTRUCTIONS

The actual measurements are divided into four parts. First the use of the equipment and the control of MetroHopper will be practiced with a Nokia Hopper Manager programme. The setup is a direct connection and the distance between the antennas is few meters. In this setup the correct settings and the effect of polarization on the connection are tested. In the second part a the connection is made by using a passive mirror. In the opposite wall, seen from the window, is a visible part of aluminium that serves as a passive mirror. When the connection is established, the signal is transmitted and cross-connection, attenuations, alarms are tested by using the test interface.

The measurements and the questions to be answered for the final report are usually found under their own heading. In the text under each heading there are also few questions that have to be answered in the final report.

5.1 Setting up the equipment

5.1.1 Indoor unit FIU 19

The internal unit FIU 19 uses 48 V power supply that can be provided from connector on the windowsill in the laboratory. The outdoor unit will be connected to the connector with Flexbus cable to connector FB1 or FB2. The maintenance computer COM port should be connected to LMP connector. MP- connector provides a test signal for an oscilloscope (figure 3).

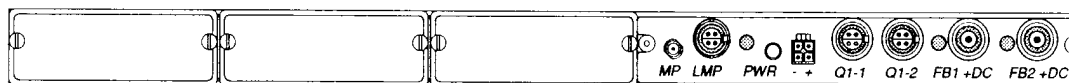


Figure 2. FIU 19 indoor unit

The plug-in unit in figure 4 is connected to internal unit. To each of the pairs of plug in unit can be connected 2Mbit/s signal.

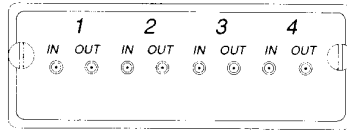


Figure 3. Plug-in unit

5.1.2 Outdoor unit

The outdoor units FB+ connection is connected to the Flexbus cable. To AGC-connector is connected a voltage meter, that allows to measure AGC voltage. In this laboratory work GND and Sync connectors are not used.

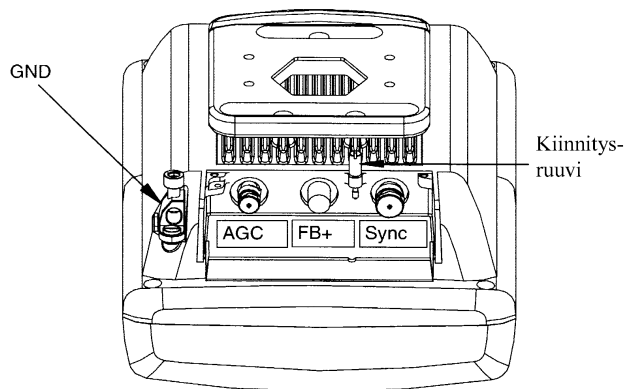


Figure 4. Connectors in the outdoor unit

The outdoor unit can be connected as it is or it can be fixed to a special rack. The connection into the rack and fastening of grip can be made only by usage of special screws seen on figure 6. **Do not relax other screws, then the rack will not bend.** If the stand bends the antenna should be redirected with use of a passive mirror manually.

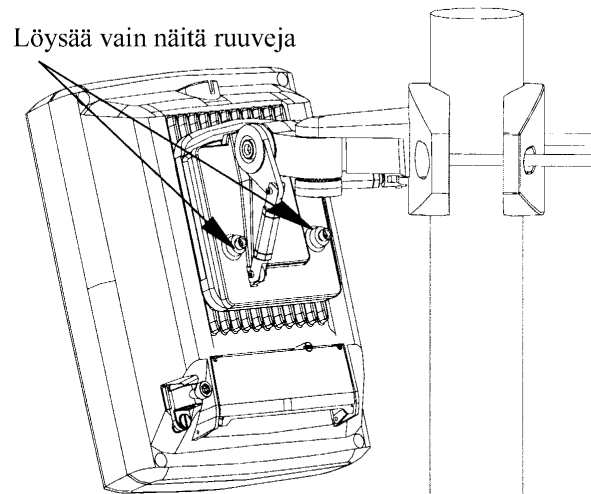


Figure 5. Connection of the outdoor in a rack

5.2 Measurement 1: Direct connection, antennae in the same room.

Position antennas in front of each other such, that it would be easy to establish a connection between them. Establish a connection by using Nokia Hopper Manager program.

One antenna is hanged to the fastening handle in the work table left upper corner (figure 7). Other antenna is fixed to the handler on the table on the other side of the room (figure 8).

Check visually that the antennas are directed towards each other and are about the same height.

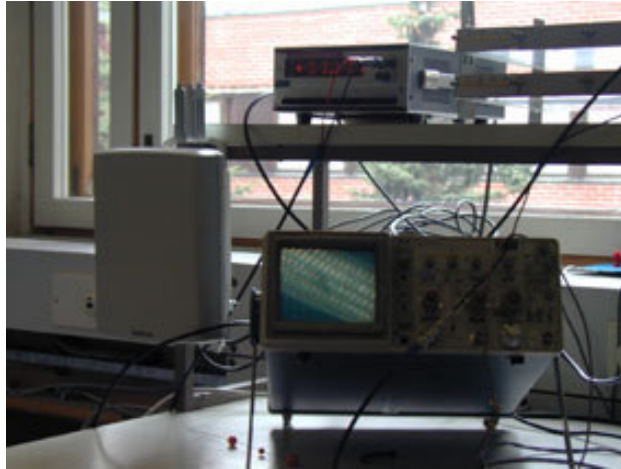


Figure 6. The first antenna is connected to the fastening handle in the corner in the measurement table



Figure 7. The second antenna is hung to a rack on the opposite table.

5.2.1 Connections

Make a connection accordingly to the scheme on figure 9.

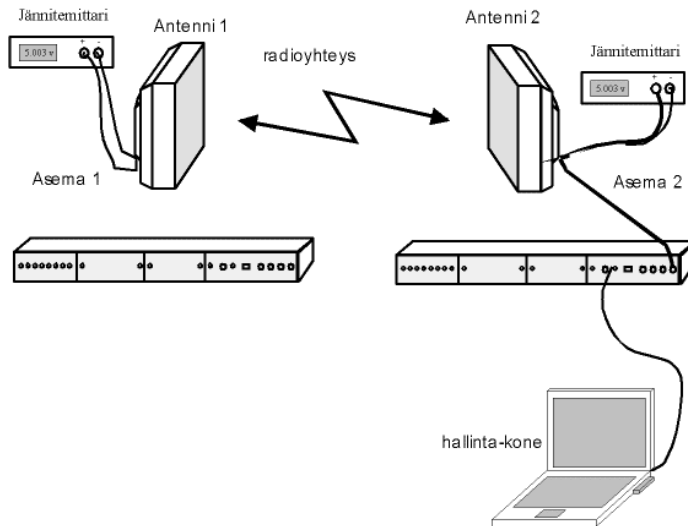


Figure 8. Schematics of the first simple connection

Connect antennas to the internal unit by Flexbus cable. You can use any of the FB connectors. Connect voltmeter to AGC connector of the antenna. Add the power supply unit and connect a laptop computer to the LMP connector of one of the indoor units. Turn the units on and start the Nokia Hopper program. On the screen should appear a window similar to the one in figure 10.

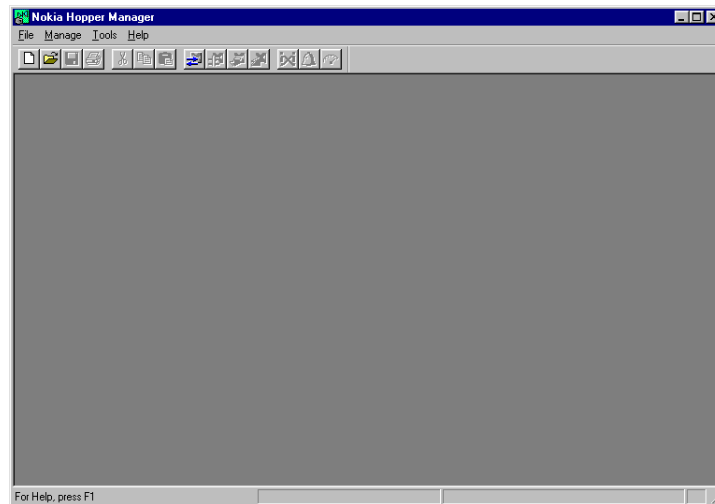


Figure 9. Opening window of the Nokia Hopper Manager

Establish the local connection between the programme and MetroHopper. For that you can select **Manage**→**Connect Locally** or push a button **Connect locally** from

the window bar. The program initiates the connection to the Metro Hopper and after which the window looks like in figure 11.

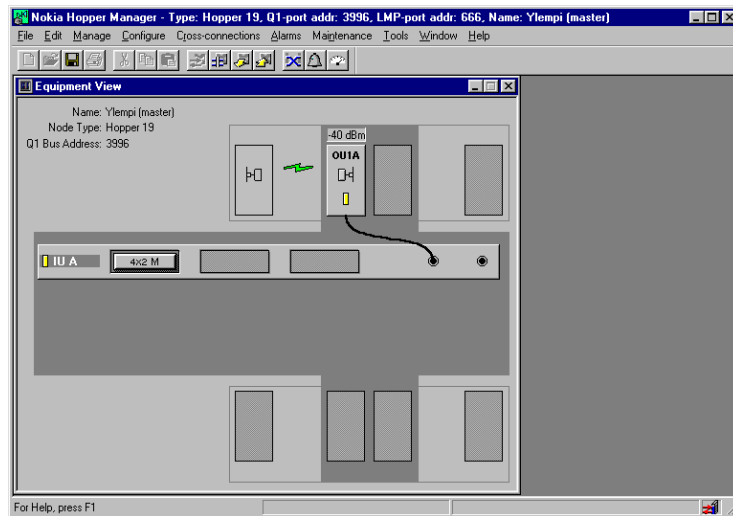


Figure 10. Metro Hopper Manager window for a working connection

In the windows are visible indoor and outdoor units, received power, signaling leds of the units, and the names of the units together with some of the choices. The MetroHopper continues from the state where it was during the shut down. If during switch off a connection was established the Metro Hopper attempts to reestablish it that is the reason if the connection is established automatically. Initiate a new connection even if the connection was established.

5.2.2 Commissioning

You can start a connection by using a commissioning wizard. It starts by selecting **Manage**→**Commission...** During the startup the program asks the required parameters and based on those attempts to establish a connection.

1. Connection establishment begins by first selecting which FB-connection is used. Selection is made by marking the correct FB and selecting **Start**. Program attempts to find the outdoor unit trough the FB-connector and informs when the unit is found by text *Radio Found!*

2. Name the unit and give the parameters that allow to identify this unit from other MethoHoppers. In this laboratory works it is enough to name the units, other parameters are not necessary.
3. Select the operational mode. The options are terminal, chaining, branching. Select *Terminal*. The only option for the protection device is *Single*.
4. Select the type of the Flexbus connector and which outside units are switched on. The capacity of MetroHopper is constant 4 x 2 Mbit/s.
5. Select parameters for Q1 port. In the laboratory work we are not using Q1 connectors, therefore do not change any of these parameters.
6. Establish connection over Q1 - bus for control traffic. In this laboratory work Q1 bus is not used. For not using Q1 make a connection accordingly to figure 12.

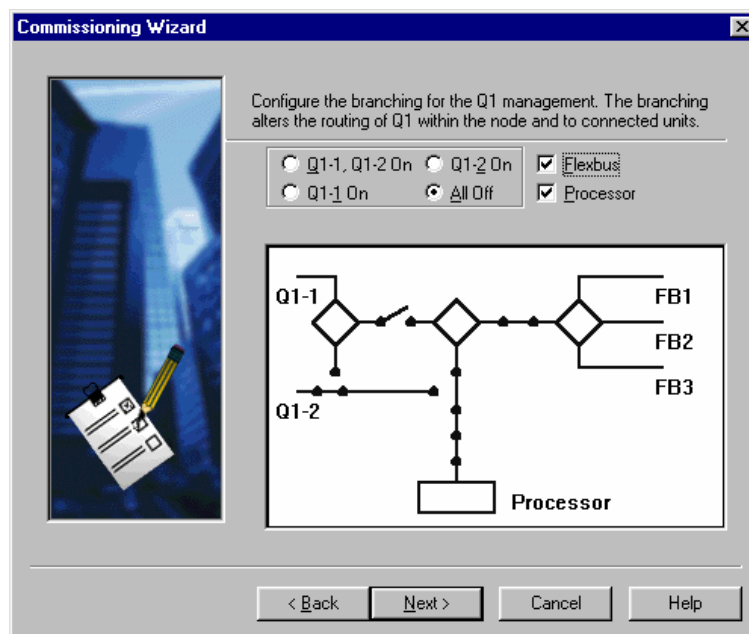


Figure 12. The correct connection of control signals when Q1-channel is not used.

7. Select parameters for the outdoor unit. First you have to select the operational mode, the unit should be either master or slave. You can use **Synchronising master** if many MetroHoppers are near by. Temporary **Hop ID** a identification code that the system uses for establishing the connection. After the connection is

established the system changes the ID value. **Check that the both sides have the same temporary ID.**

8. Set the channel selection method. MetroHopper has an automatic channel selection method that is recommended to be used here. In the manual mode the user selects which channels to use. In manual settings it is possible to measure the channels interference levels. That method is used if channel is directed with of AGC voltage (this method is explained below). Select now *AutoSearch* and from the following page select all possible channels that the automatic channel search can use.
9. Finally the system system presents all the selections you have made. You still can check the set up and it is possible to cancel the modifications. Choose *Finish* if you are satisfied with the choices.
10. After submitting the selections it is still possible to check the system state.
11. Add your name and reset the counters

Repeat the set up also in the other side of the link. For that change the computer to the connector of the other indoor units LMP connector and select **Refresh**.

5.2.2.1 Establishing connection manually

If the connection is not established automatically you have to make connection manually. The establishing connection starts from master unit. Click **Configure** → **Settings**, select *OUIA: MetroHopper*. Program opens a window (figure 13).

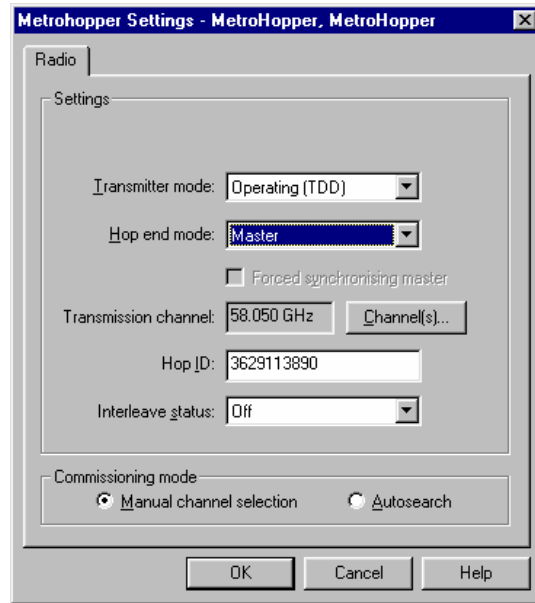


Figure 13. Control window of outdoor unit.

Select *Manual channel selection* and click **Channel(s)**, this operation measures the channel interference levels. Select the required channel, change the *Transmitter mode* value to *Commissioning* and check that *Hop ID* and *Interleaving status* are in the both sides the same. Select **OK** and repeat this set up in the *slave* side.

The method described above can also be used for changing settings of an outdoor unit. **(When you change settings, remember always to measure channel interference levels, since in some reasons the program does not let you to change the settings).**

- Follow AGC voltage during connection setup, what happens? Why?

Set the system clock, that is necessary for acquiring right timings into log files. You can change the time from **Configure** → **Set Node Clock**. Remember to set the time in both sides of the connection.

Check the connection state by observing the alarms from **Current Alarms** button. Only alarm of *Loss of incoming signal* is allowed. This alarm appears since there is no signal connected to the system.

5.2.3 Measurements and questions

At this first state there are two measurements: effect of the directing antenna and polarization of the antenna on the received power level.

1. Turn the antenna in the rack on the table in different directions and measure power and AGC voltage in different points with about 10 degree steps. Draw a graph of the measurement results and compare the results to the theory, explain the results. (Notice that the AGC voltage has a slight error because of the mismatch).
2. Change the antenna polarization. Take antenna into your hands and change the polarization angle. Measure power and AGC voltage. Draw the results in a graph and explain the results.

5.3 Arrangement 2: Direct connection with PCM signal

The transferable signal is added to the previous connection by using PCM system in the laboratory (a room 306). The connection is made to two channels: radio programme to channel 2 and to channel 4 a sine wave. In these channels a 2 Mbit/s PCM signal is transmitted through MetroHopper to the PCM system in the receiving end (room 305 a rack on the work table). The signals can be connected to the loudspeakers through the channel selector. The PCM system is connected from one room to another and the MetroHopper is part of this connection. The PCM signal can be checked also by oscilloscope (Telequipment D83). This oscilloscope is located in the right corner of the work table. Before connecting PCM to MetroHopper check the PCM signal through the loudspeakers.

Connect the PCM system to MetroHopper so that the signal coming from the room E306 will be connected to the inlet pair no.1 of one Plug-in- unit and PCM from the room E305 to the output pair no. 1 of another Plug-in-unit of MetroHopper (figure 14).

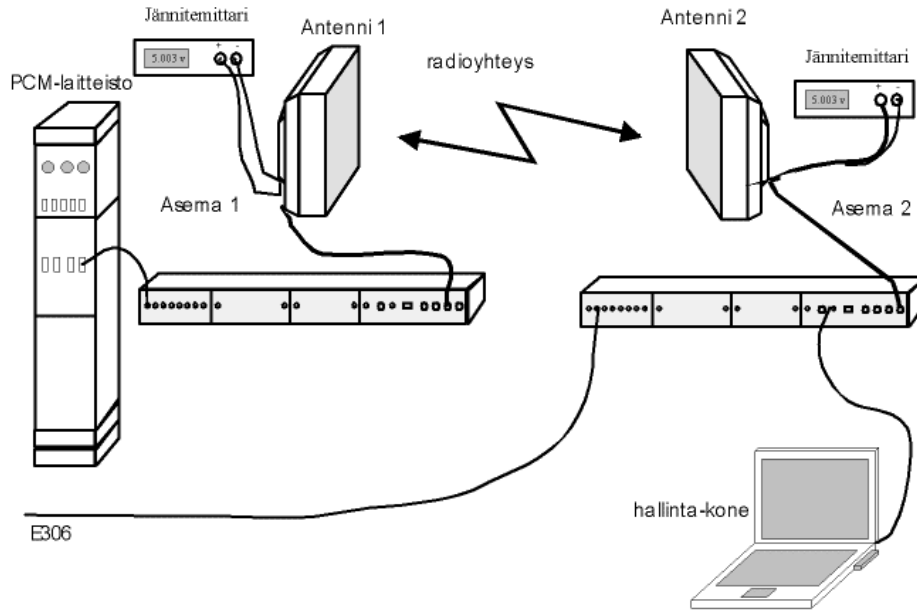


Figure 14. Connection of the PCM MetroHopper systems

Set the crossconnection, for that select **Cross-connections** → **View** and edit cross-connection tables of both indoor MetroHoppers units to be like in figure 15 (This is done if FB1 is used). The modifications are confirmed with **Send**-button, after which the program sends the modifications to the indoor units.

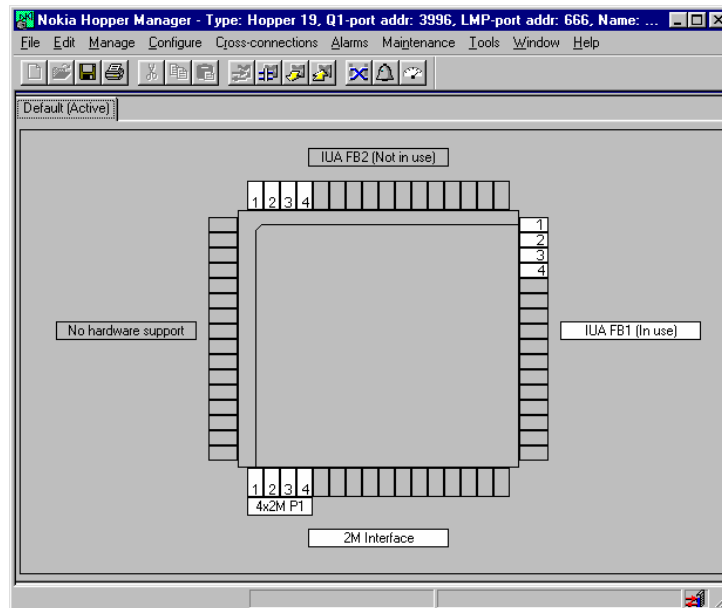


Figure 15. Cross-connection table.

5.3.1 Measurements and questions

After establishing connections test both channels through the loudspeakers. Also check for any alarms in both devices. In case of alarms attempt to correct them. If you are not able to remove alarms just identify the reasons for them.

1. In the cross connection table form a connection 2M Interface 1 - IUA FBx 2 in both indoor units. Why does the connection operate even connectors were not moved in either units?
2. Establish a cross-connection in which the PCM signal goes to MetroHopper from the pair no. 1 and will return from the pair no 4.
3. In MetroHopperilla one can transmit 4 x 2 Mbit/s in both directions. In our configuration we are using 1 x 2 Mbit/s in one direction. Form a connection described on figure 16 and configure the cross-connection table appropriately. Draw a scheme of the required cross connection.

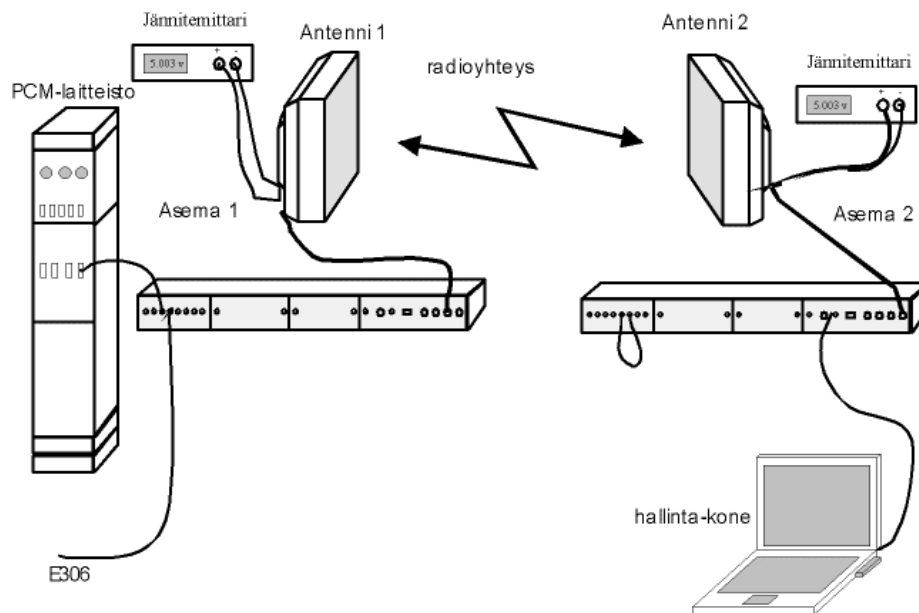


Figure 11. Connection where PCM signal in two directions at the same time.

5.4 Arrangement 3: A connection with passive mirror

Turn both MetroHopper units off, disconnect the PCM system from the Plug-in-units, and disconnect the cables to the outdoor unit. Put the antennae to the racks next to the windows in the room E305 and E306 and establish a connection accordingly to instructions in the part 5.2.2. Remember to set the clock values for the indoor units.

5.4.1 Alining the antenna by using AGC-voltage

First check the direction of the antenna towards the mirror visually. If the alignment seems to be very bad ask from assistant for permission for the turning of the antenna rack. When the antenna direction seems to be correct fine tuning of the antenna can be made with help of AGC voltage.

1. Start from the master unit. Click **Configure** → **Settings** select *OUIA: MetroHopper* and the program opens a window similar to one on figure 13. Stop the connection establishment if the unit is in state **Commissioning (Comm)**.
2. Set the units *Transmission mode* to **Receiving only (Rx)** state, in that state the unit operates only as receiver.
3. Ensure that the *Commissioning mode* is in state **Manual Channel Selection** and click **Channels** button. Now MetroHopper measures the interference levels of the channels. Write the values up.
4. Select the channel with the smallest disturbance level. N.B! if the second transmitter sends a signal it is seen as an interference. Click **OK**.
5. Click again **OK** and return to the basic state.
6. Stop the commissioning in the slave unit if it has not yet been stopped.
7. Set the units *Transmission mode* into state **Forced transmit (Tx)** in which it transmits incessantly. Change the variable *Hop end* into **master** (only the master can be set into **Tx** state).
8. Repeat the section 3 to that unit.

9. Add the interference levels from measurements in section 3 and 8 and select the channel with the lowest interference level.
10. Click **OK** and return into basic state. Slave unit should send not incessantly.
11. Return back to master unit. Change the frequency of the master unit to be same as of slave unit. Now the units should be on the same channels.
12. Adjust the outdoor units direction by focusing screws with the help of the small adjustable spanner. Be careful not to turn too much. **Do not loosen any screws!** Align the antenna to the position where the AGC voltage is the smallest. (You can get help from the Table 1 from the theoretical part of the assignment.)
13. Set the master unit to send continuously and the slave unit to receive continuously.
14. Direct also the other antenna with help of AGC like in the section 12.
15. Set the transmitter and receiver into state **Commissioning (Comm)**. If a connection is not successful, make sure that the **AGC** voltage is under 4 volt at the both ends. If this requirement is not satisfied repeat the alignment of the antennas.
16. If you do not succeed to make connection automatically you have to establish connection manually accordingly to the instructions given in section 5.2.2.1.

After establishing connection take up the received power level and compare it with the values calculated in the preliminary exercises.

5.5 Arrangement 4: Connection with a passive mirror with 2 Mbit/s signal

The 2 Mbit/s signal is generated with the network analyzer ANT-20E. The same analyzer is also used for the measurements.

5.5.1 Initializing network analyzer and generating the signal

Switch on the analyzer ANT-20E and the monitor. Start the network analysing program ANT-20. Start a new ANT-20 Application by clicking on the upper window bar of the ANT-20 program window. Select the following instruments: *Signal Structure* and *Anomaly/Defect Analyzer* and click **OK**. For this measurements we need 2 Mbit/s pseudorandom-signal, its *Signal Structure* is like in figure 17.

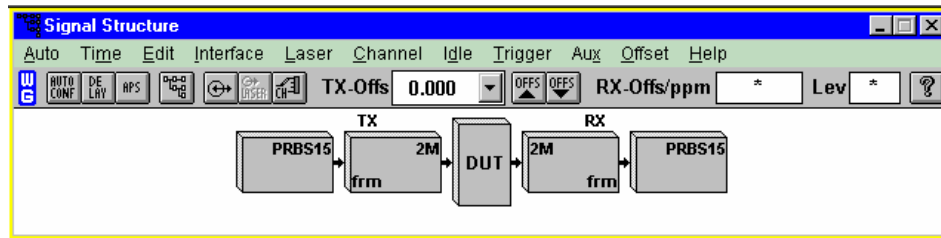


Figure 12. A 2 Mbit/s pseudorandom-signal in ANT-20 programme.

If a signal looks like something else, you can edit it by clicking in *Signal Structure* - window **Edit** → **Signal Structure**. In the Edit-menu are **TX** and **RX**, select **Clear** in both of them. This allows you to generate the signal again. Make the following choices to both sides, **TX** and **RX**: *Edit: ITU-T*, *Interface: Electric.*, *PDH: 2M* and *PDH mode: Frm.* and click **OK**. If the signal still is not in accordance with figure 17 consult with the assistant.

5.5.2 Connections

Establish a connection like in figure 18: trough the MetroHopperilla is send a 2 Mbit/s signal generated by the network analyzer. Validate the cross-connection remove the possible alarms.

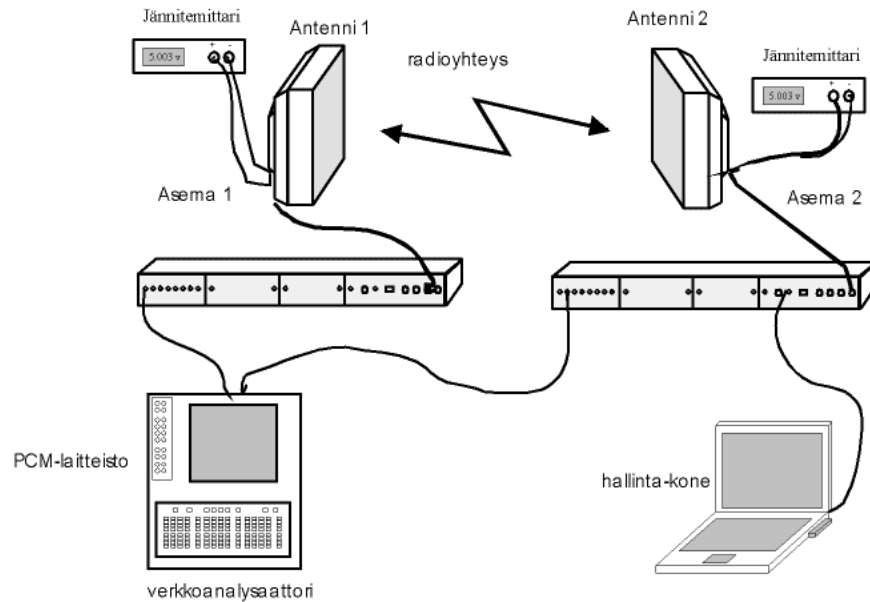


Figure 13. A connection where the signal from the network analyzer is transferred through MetroHopper.

5.5.3 Measurements and questions

1. Measure the delay caused by the transfer through the radio link. For that click in the *Signal Structure* -window **Time** → **Delay Measurement** ja **Start**.

The parts of the Venetian blind (curtain) of the window are aluminium and the desired number of obstacles will be added by turning them in front of the antenna. By changing the angle of the blinds the attenuation between the MetroHoppers is increased. The attenuation impacts the signal propagation and number of errors, alarms and the relation of errors to the attenuation can be studied. In this measurement we simulate the conditions occurring due to the weather in long radio link connections.

Before modifying the attenuation measure the capacity of MetroHoppers. Select the length of the measurement period by clicking **Tools** → **Options** → **Manager Options** and set the interval between the measurements to be 10s. That is the smallest possible measurement time. Start the performance measurements for MetroHopper from Nokia Hopper Manager by clicking **Maintenance** → **Performance** → **Measurements** and select the bit error rate BER measurement for the connected Flexbus from FIU 19 and *Rx level* measurements for

the indoor unit. Store the results into a log file. Start the monitoring of alarms by clicking **Alarms** → **View** and save also those into a log file. Start the monitoring of statistics for the Flexbus you are using: **Maintenance** → **Performance** → **Statistics...** .

2. Measure BER with different attenuations. When increasing attenuation be careful not to break connection. During the measurements also monitor the alarms. Draw the graph BER versus attenuation attach the it alarms and explain why they were created. Also monitor the leds of the network analyzer (ANT-20E) and write up the occurring alarms. The meanings of leds are explained in figure 19.

HISTORY		
<input type="checkbox"/>	LOS	Loss of signal
<input type="checkbox"/>	LOF/OOF	Loss of frame/Out of frame
<input type="checkbox"/>	MS-AIS/AIS-L	Multiplexer section alarm indication signal/Alarm indication signal line
<input type="checkbox"/>	B1/B2	B1 or B2 Bit interleaved parity errors
<input type="checkbox"/>	MS-RDI/RDI-L	Multiplexer section remote defect indication/Remote defect indication line
<input type="checkbox"/>	AU-LOP/LOP-P	AU Loss of pointer/Loss of pointer path
<input type="checkbox"/>	AU-AIS/AIS-P	AU Alarm indication signal/Alarm indication signal path
<input type="checkbox"/>	HP-UNEQ/UNEQ-P	High order path unequipped/Unequipped path
<input type="checkbox"/>	HP-PLM/PLM-P	High order path path label mismatch/Path label mismatch path
<input type="checkbox"/>	B3	B3 Bit interleaved parity errors
<input type="checkbox"/>	HP-RDI/RDI-P	High order Path remote defect indication/ Remote defect indication path
<input type="checkbox"/>	(TU)-LOM	Loss of multiframe
<input type="checkbox"/>	TU-LOP/LOP-V	TU Loss of pointer/Loss of pointer VT
<input type="checkbox"/>	TU-AIS/AIS-V	TU Alarm indication signal/Alarm indication signal VT
<input type="checkbox"/>	LP-UNEQ/UNEQ-V	Low order path unequipped/Unequipped VT
<input type="checkbox"/>	LP-PLM/PLM-V	Low order path path label mismatch/Path label mismatch VT
<input type="checkbox"/>	LP-BIP/BIP-V	Low order path bit interleaved parity errors/Bit interleaved parity errors VT
<input type="checkbox"/>	LP-RDI/RDI-V	Low order path remote defect indication/Remote defect indication VT
<input type="checkbox"/>	AIS	Alarm indication signal (payload)
<input type="checkbox"/>	LOF/LCD	Loss of frame (payload) / Loss of cell delineation
<input type="checkbox"/>	LSS	Loss of sequence synchronization
<input type="checkbox"/>	RDI(AIS-)Yellow	Remote defect indication (payload) / (Alarm indication signal) yellow
<input type="checkbox"/>	FAS/CRC	Frame alignment signal errors (payload) / Cyclic redundancy check error
<input type="checkbox"/>	TSE	Test sequence errors (bit errors)
CURRENT		

Figure 14. ANT-20E signalling leds.

3. Measure with ANT-20E BER for different attenuations. For that set the measurement time by clicking in the **ANT-20** window **Measurement** → **Settings** and select **Gate Time** to be 10s confirm the selection by clicking **OK**. The measurements starts by clicking on green traffic light in **ANT-20** -window. The

measurements results are interpreted in *Anomaly/Defect Analyzer* -window. We are interested in the measured quantity *TSE*, that corresponds to the BER of the test signal. The numerical values of *TSE* are read by clicking on **View** → **Num**. Compare the results measured by the network analyzer and Nokia Hopper Manager.

Connect the signal to be in a loopback for that set a loop into one of the MetroHoppers indoor plug-in-units and signal input output of the other MetroHoppers plug-in-units to the ANT-20E (figure 16).

4. Measure the delay again. Is there any difference compared to the previous measurements if yes explain why?
5. Repeat the BER measurements with network analyzer. Why there will be a difference compared to previous measurements?
6. Connect two-way PCM system. Adjust the attenuation to create a lot of errors. Check the signal from the loudspeaker. Has the voice changed? How? Why?

5.6 Arrangement 5: Measurements from the test interface

Disconnect the network analyzer and PCM system from MetroHopper and connect the oscilloscope to the measurement point MP of the indoor unit of MetroHopper. A signal is directed to MP by selecting **Maintenance** → **Tests** → **Measurement Interface**. Select the desired signal and click **Send**. One can save the oscilloscope picture in the *.tif format by inserting a floppy disk to the drive and selecting *Store* and choosing *Flopy* as target saving place. After pressing **Screen Dump** button the oscilloscope saves the displayed picture.

5.6.1 Measurements and questions

1. *2M TX Data* is a signal that is transferred between the indoor units in the Flexbus-cable. Direct *2M TX Data* signal to the testing point MP and draw picture of it. Identify the line coding that is used and interpret the sent data.

2. Connect the two-way PCM-system to MetroHopper and repeat the measurements in case 1. What happened and why? (The signal does not need to be interpreted).

6. OPTIONAL VOLUNTARY PART

6.1 Loopbacks

Establish loopbacks between different parts of the system by selecting **Maintenance** → **Tests** → **Loopbacks**. Investigate the transmitted signal by network analyzer (for example look at delays).

6.2 Forced controls

Try different forced control options from the menu **Maintenance** → **Tests** → **Forced Controls**.

8. ADDITIONAL MATERIAL AND REFERENCES

8.1 Literature

- Simon Haykin: Communication systems 3ed
- Arto Lehto, Antti Räisänen: Millimetriaaltotekniikka
- Antti Räisänen, Arto Lehto: Radiotekniikka
- Pentti Teppo: Siirtojärjestelmät tietoliikennetekniikassa
- Fawwaz T. Ulaby: Fundamentals of Applied Electromagnetics.
- Kirsi Voipio, Seppo Uusitupa: Tietoliikenneapinen

8.2 Standards

- ITU-T Recommendation G.703 (10/98): Physical/electrical characteristics of hierarchial digital interfaces
- ITU-T Recommendation G.826 (2/99):Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate
- ETSI Standardi ETS 300 408 v1.2.1 (2000-09): Fixed Radio Systems; Point-to-point equipment; Parameters for Radio-relay systems for the transmission of digital signals and analogue video signals operating at around 58 GHz, which do not require co-ordinated frequency planning. ETSI Syyskyy 2000

8.3 Internet

- Telehallintokeskus: Radiolinkkien käyttö taajuusalueella 57,2 – 58,2 GHz : <http://www.thk.fi/suomi/radio/radiolinkit58.htm>

- Telehallintokeskus: Radioliikenne, <http://www.thk.fi/suomi/radio/index.htm>
- Telehallintokeskus: Taajuusjakotaulukot, <http://www.thk.fi/suomi/radio/taulu.htm>
- Telehallintokeskus: Taajuusjakotaulukot osa V: 31,000 - 400 GHz, <http://www.thk.fi/suomi/radio/Taulukko5.htm>
- Telehallintokeskus: Luvanvaraisten radiolähettimien määrä vuodesta 1994 alkaen, <http://www.thk.fi/suomi/radio/lupatilasto.htm>
- Telehallintokeskus: Paikallisverkkokilpailuun lisää mahdollisuuksia - maailman radiokonferenssi antoi lisää taajuuksia laajakaistaisille Internet- ja multimediasyhteyksille, <http://www.thk.fi/suomi/ajankoht/wrcfwatiedote.htm>
- Telehallintokeskus: Luvanvaraisten radiolähettimien määrä vuodesta 1994 alkaen, <http://www.thk.fi/suomi/radio/lupatilasto.htm>
- Telehallintokeskus: Radiolaitteiden käyttö ja luvat, <http://www.thk.fi/suomi/radio/n2436.htm>
- Sosiaali- ja terveysministeriö: Päätös ionisoimattoman säteilyn altistuksen enimmäisarvoista. Sosiaali- ja terveysministeriön päätös nro 1474/1991 [http://finlex4.edita.fi/dynaweb/stp/stp/1991sd/@ebt-link?showtoc=false;target=IDMATCH\(id,19911474.sd\)](http://finlex4.edita.fi/dynaweb/stp/stp/1991sd/@ebt-link?showtoc=false;target=IDMATCH(id,19911474.sd))

8.4 Other publications

- Nokia Networks Oy: Nokia MetroHopper Radio User Manual. Nokia Networks 2000
- Tomas Sehm: A High-Gain 58-GHz Box-Horn Array Antenna with Suppressed Grating Lobes. IEEE Transactions on Antennas and Propagation, Vol. 47, No. 7, July 1999