Lab Report

on

Signals spectrum, bandwidthm, path loss

Measurements

Aalto University

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1 Preface

In this lab you will use spectrum analyzer and USRP SDR to measure the bandwidth and power of the following technologies: FM, WLAN, GSM, 3G and LTE. The correct frequency bands for the technologies should be found in the preliminary exercise.

The antennas, cables and connectors used in the exercise are not specified in the instructions. One goal of this exercise is to learn working methods in laboratory; therefore, making the connections you will learn to work independently in a laboratory.

In the end of lab sections, there are the questions that should be answered in the report. Make sure that your notes and pictures are sufficient for answering them.

2 Commercial radio signals bandwidth and power measurements: WLAN and Bluetooth

2.1 WLAN

- Set the spectrum analyzer to scan the whole frequency band that WLAN and Bluetooth are using at 2.4 GHz band.
- Select a suitable antenna for these frequencies.
- Set on spectrum analyzer
  - one trace to max hold
  - other trace to clear/write
- Use the lab computer and scan for wlan networks.
  - Use WLAN connection either in a lab computer or a mobile phone.
  - In Ubuntu Linux computer in laboratory you can do scanning from command line either

```
sudo iwlist scan
nmcli device wifi
sudo iw wlan0 scan
```

where wlan0 should be the wlan card interface name in particular computer

(1) Make notes about the spectrum when the device is scanning the network. Repeat the scan as needed.

- In the laboratory is wlan network an channel 6 at 2.4 GHz.
- Establish WLAN connection to the access point.
  - Use exercise computer or special computer in the lab.
  - Ask details for connection from the assistant.
- Reset the spectrum analyzer trace that has max hold.
- To the Wlan computer is connected a computer with iperf server.
- Create Wlan network traffic by running iperf speed test.

```
iperf3 -c 192.168.1.10
```

(1) Make notes about the spectrum behavior

(2) Measure the used channel bandwidth ? — 22 MHz

(3) Measures the signal power in the used channel. −42,34 dBm

(4) Save the screenshot in spectrum analyzer.

(5) Record the test result in computer.

2.2 Bluetooth

- We do Bluetooth transmission of a big file between these two devices while Wlan connection between other computers is active.
- In the laboratory are two laptops with Bluetooth.
  - If the computers are not attached to each other by Bluetooth you have to pair them first.
- Reset the spectrum analyzer trace that has max hold.
- Start WLAN connection and data transmission as in previous measurement.
- Start Bluetooth file transmission
  - In the workspace of one computer is file `largedata.dat`. Copy it over Bluetooth to the other computer.

(6) Save a spectrum analyzer screenshot of Bluetooth spectrum behavior.

- While bluetooth is transmitting the large file. Repeat the speed test on WLAN connection as before.

(7) Save the spectrum analyzer screenshot.

(8) Record the speed test result.

2.3 Post measurements questions

(9) Explain the screenshots taken and observations you made (bandwidth, spectrum shape, power etc.). Do this match with the preliminary exercise results? If not, why?

(10) How is it possible that WLAN and Bluetooth operate on the same frequency band simultaneously?

(11) What happened to the speedtest when they were operating simultaneously, how the spectrum looked like?

(12) Did you find anything surprising?

3 Commercial radio signals bandwidth and power measurements: Mobile networks and FM radio

3.1 GSM

bandwidth
257 KHZ

- Select frequency band suitable for GSM 900 downlink and select a suitable antenna.
- Set in spectrum analyzer to scan this band.
- Select the GSM channel with strongest signal. 935MHZ - 936MHZ
- Tune the spectrum analyzer to this channel.

power signal
-40.53dBm

(13) Measure the bandwidth of the signal in the channel

(14) Measure the power of the signal in that channel.

(15) Save the screenshot.

- Try to find uplink transmissionsin the uplink band. It is highly possible that nothing is visible. If you can set a mobile phone to use only GSM (i.e. 2G) and make a phone call. In this way you can create uplink transmission.

  (16) Measure the bandwidth and power in uplink channel.

  (17) Save the screenshot.

3.2 3G

- Set frequency range suitable for UMTS 2 GHz network and select a suitable antenna.
- Set in spectrum analyzer to scan the downlink and then uplink band.

(16) Find the uplink and downlink signals and save both spectrum scan screenshots.

(17) Downlink: Measure the bandwidth of the signal.

(18) Downlink: Measure the received power of the signal.

- If it is possible, set a mobile phone to use only 3G network and generate Internet traffic.

  (19) Observe the uplink transmission from the mobile phone and measure the bandwidth and power.

  (20) Save the screenshot.

3.3 LTE

- LTE exists in multiple frequency bands. Visit cellmapper.net website and discover commercial LTE networks (e.g. Elisa, DNA, Telia) near the building.

801MHZ - 811MHZ

- Use suitable antennas with spectrum analyzer and try to find the strongest LTE downlink signal.

(19) Measure the average power of the downlink signal -55.25 dBm

(20) Measure the bandwidth of the downlink signal. 10.1 MHZ

(21) Make notes about the spectrum behavior and take a few screenshots of the spectrum.

(22) Find the corresponding uplink band and try to catch some uplink transmissions and take screenshots. If nothing is visible, adjust spectrum analyzer settings for attenuation and preamplifier use and be patient!

469 KHZ , -49.91 dBm

3.4 FM

- In the lab computer check that the USRP B210 unit is connected to it.
- Connect long antenna suitable for FM radio band to USRP.
- Set the spectrum analyzer to scan the FM radio spectrum.
- Start `gqrx` program for listening the radio and load the config for `lab2FmWhole.conf`

(23) Take spectrum screenshot from spectrum analyzer.

(24) Take spectrum screenshot from `gqrx`

(25) how many radio channels you observe

- Pick a channel with strong signal and preferably with no close channels. (For instance RadioSuomi at 94.0 MHz.)
- Zoom the spectrum analyzer to this channel to see whole FM radio spectrum (For example with 0.5-1 MHz bandwidth).

(26) Take the screenshot of the spectrum.

(27) What is the max frequency?

(28) Try to take screenshot for both when the channel is silent and when there is voice or music.

- If the just measured channel had music with `gqrx` find channel where is speech. (or alternatively if you just measured channel speech select channel with music).
- Tune spectrum analyzer to this other channel to see whole FM spectrum.

(29) Take the screenshot of the spectrum.

(30) what is the max frequency?

3.5 Post measurements questions

(31) Explain the screenshots taken and observations you made (bandwidth, spectrum shape, power etc.). Do this match with the preliminary exercise results? If not, why?

(32) What are the peaks in the FM spectrum when the broadcast is silent?

(33) In GSM measurement, why the spectrum of uplink transmission is barely visible while the downlink is clearly visible?

(34) In 3G measurement, when using your phone; why the uplink is clearly visible but the downlink is barely visible? What did you see on the UMTS-2000 network?

(35) Compare LTE spectrum behavior to 3G.

(36) In LTE uplink signal why it often does not cover the entire bandwidth?

(37) How are multiple users sharing the same bandwidth in 3G and LTE?

(38) Why do you think that the uplink transmissions often use lower frequencies than the downlink transmission?

(39) Did you find anything surprising?

4 Path loss measurement

In this measurement you use two USRP units for measuring path loss in a radio channel. One USRP unit is used as generator and other as receiver. The channel is measured from hallway to the laboratory by moving the generator USRP in the hallway and recording the signal.

Signal levels are measured with two individual antennas. The measured path loss curve is compared to ITU indoor path loss model with link budget calculations derived in preliminary exercise.

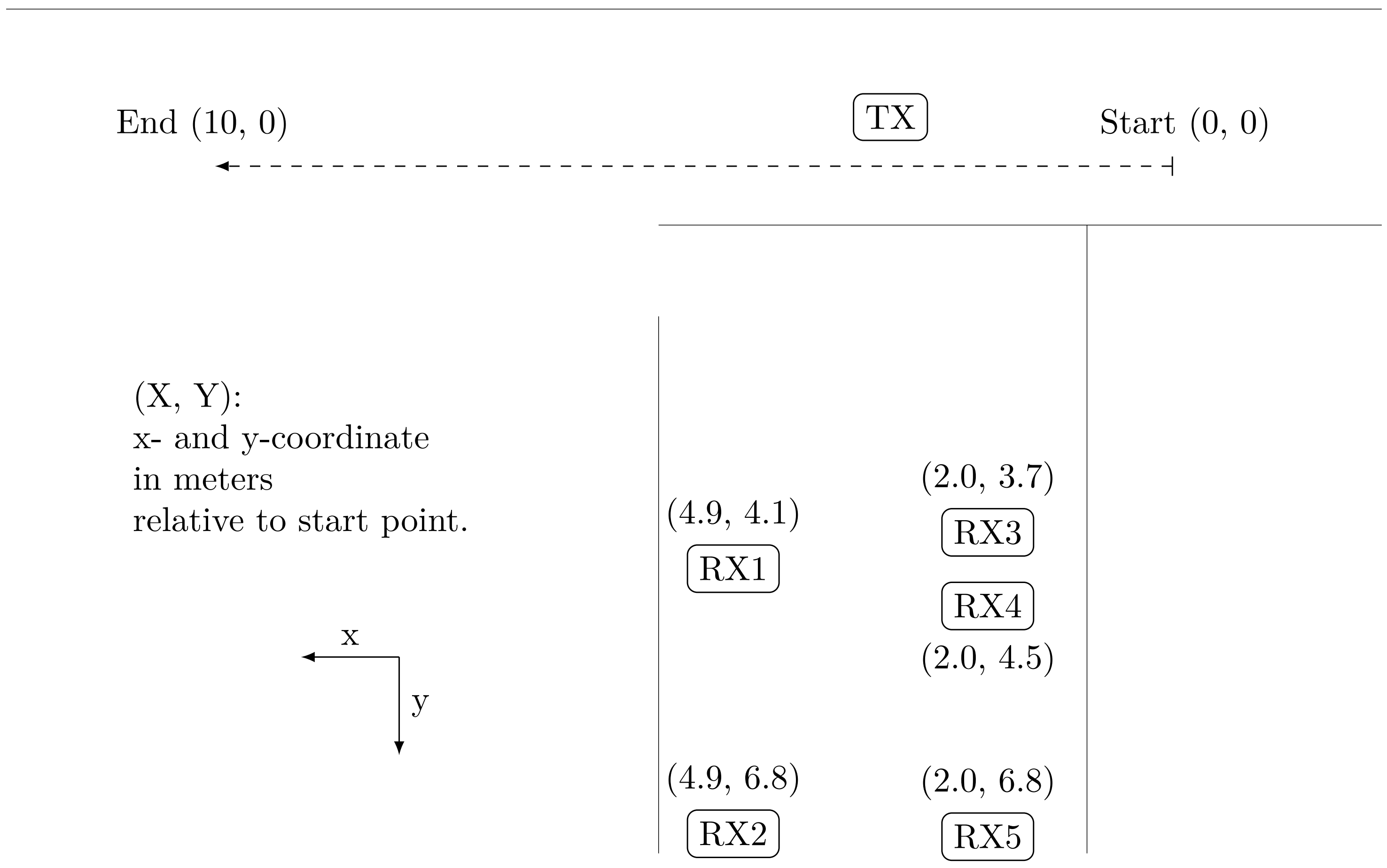

Figure 1: Measurement site floorplan.

Make the measurement for 2.46 GHz and 5.8 GHz bands. For each measurement point use different center frequency than other groups are using. Coordinate frequency selection with other groups.

(40) Include into report which frequencies you selected: at 2.46 GHz and 5.8 GHz band.

Repeat the measurements below for both frequencies you selected.

4.1 Calibration

4.1.1 Generator USRP power calibration

Since the USRP units gains can be tuned arbitrarily we have to measure the generator USRP output.

- The generator USRP has to be connected to a laptop.
- Connect the USRP output directly to spectrum analyzer.
- Start at the laptop with generator USRP Gnuradio sinus generator program `transmitSinus.grc`
- Set into the program the frequency you selected.
- Set the gain in the generator such that the received signal at the spectrum analyser is -10 dBm.
- Repeat the measurement for the other frequency.

(41) Record the gain you had to set in Gnuradio program to achieve this signal level: for both frequencies.

4.1.2 Receiver USRP power calibration

Since the USRP units receiver gains can be arbitrarily tuned we have to calibrate what is actual received signal level with particular RX gain.

- The receiver USRP has to be connected to the table computer.
- Connect signal generator output to USRP RX1 input.
- Adjust the transmitter frequency to the frequency you selected.
- Set signal generator output power to -40 dBm and activate the transmission.
- Start the receiver program `recordTwoAntennas.grc`.
- Tune the receiver RX1 gain such that received signal level is -40 dB and make a note of the gain value.
  2.46GHz 27dB 5.8GHz
- Repeat the measurement for RX2 and both for the other frequency.

2,4

(42) Record the gain you had to set in Gnuradio program to achieve this signal level: for both receivers at both frequencies.

	RX1	RX2
2.46GHz	27dB	30dB
5.8GHz	43dB	31dB

4.1.3 Transmitter and receiver preparation

- Repeat this measurement for 2.46 and 5.8 GHz.
- Start with the frequency in 2.46 GHz band.
- Connect to generator USRP TX/RX antenna
- Open at the generator laptop `transmitSinus.grc`.
- Check that the frequency and the gain are correct.
- Connect to receiver USRP both RX to antennas.
- Open the `recordTwoAntennas.grc` program at the receiver computer.
- Check that the frequency and the gains are correct.
- Comment the recording block in the `recordTwoAntennas.grc` Gnuradio program.
- Start the transmitter and receiver.
- See what windows will open.
- Put the transmitter antenna somewhere on the side of receiver antenna.
- Adjust the receiver frequency until you see the transmitted sinus. Record the offset. 1,5kHz
- Play with the receiver antennas for a while. For example move the other antenna slowly and see what happens to the time domain sum signal. Try to get the sum signals out of phase. This is basically what happens in multipath fading whi one multipath component.
- Check and record the frequency offset with the other frequency band.

(43) List what measurement windows where opened at the receiver.

(44) Take screenshot of the case when the signals from both antennas compensate each other.

(45) How this distance is related to the wavelength of the frequency you are using?

4.2 Hallway measurement

4.2.1 Hallways measurement preparation

Transmitter setup:

- The path loss measurement is done by moving the cart with transmitting signal generator, on the hallway.
- Examine the hallway. Write down objects or changes on the path (with the distance) that you think might vary the measured signal power.
- Note the measurement marks on the floor.
- Move the cart into hallway to the 0 meter measurement point.
- Open at the generator laptop `transmitSinus.grc`.
- Check that the frequency and the gain are correct.

Receiver setup:

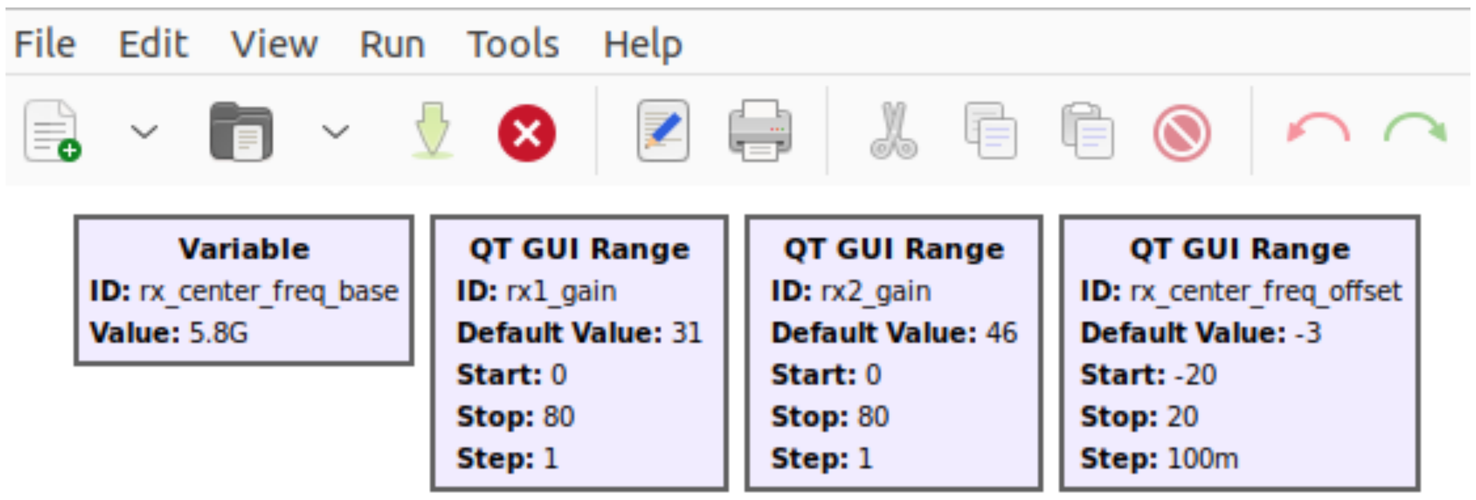

Figure 2: Receiver adjustments.

- Set the receiver antennas to be at the one wavelength away.
- Open the `recordTwoAntennas.grc` program at the receiver computer.
- Check that the frequency and the gains are correct. Adjust the defaults in the GNURadio Companion.
- Enable the data recording block and set the target file and name such that you can find it at the computer.
- Prepare a stopwatch to record the time your measurement takes.

4.2.2 Measurement

- Start the `recordTwoAntennas.grc` to record data.
- Start the transmitter (in the hallway) to transmit the signal.
- Start to move the transmitter slowly. Start the stopwatch at the same time.
- On the floor are marks every one meter. Move towards the hallway with constant speed of one meter in every 10 seconds. The pace can be difficult to follow because it is slow, however, do not stop if you went too fast, but move at all times, in slow steady pace.
- When you are in end of the hallway stop the transmitter transmission and stopwatch

- The length of the measurement path is 10 meters; therefore, end time minus start time should be about 100 seconds. If the time was more than 20 seconds different, make new measurement.
- Stop the receiver program.
- In the file `pathloss.m` is a demo code that analyses the recorded data.
- Set your recorded file name into `pathloss.m` and run the code in octave to validate that your recording was without problems.
- Validate from assistant the correctness of your measurement.

(46) Take up the sampling rate of the recorded data.

4.2.3 5.8 GHz measurement

Make/repeat Transmitter and Receiver setup and measurement for 5.8 GHz frequency.

4.3 Post measurement questions

- In the measurement file every first two samples are IQ samples from antenna 1 and next two samples IQ samples from antenna 2.
- In the file `pathloss.m` is example how you can load the samples into Matlab(Octave) workspace.
- filter out the transmitted sinus signal for both antenna signals.
- Plot the received signal power from

(47) From antenna 1.

(48) From antenna 2.

(49) Plot both antenna signal powers on the same plot.

- Plot the same plot but Instead of samples or time use on x axis distance.
  - you can convert the samples to distance by assuming that you moved at steady pace and the sampling rate is the one you took up during the measurement.

(50) Plot on one figure the received power of both antennas, selection combining receive diversity method with the two antennas, and the theoretical model derived in the preliminary exercise as function of time t.

(51) Plot on this figure received signal power after moving average window. (to see more clearly the slow fading.)

Hint: Moving the cart did not start when the measurement started. Use the start and end times of the measurement to remove the unwanted measurement data. Approximately every 10th second in the measurement data corresponds one meter on the hallway, not the distance to the measurement point.

Explain the things you see in the fading curves.

(52) Can you see the impact of fast and slow fading? Explain how you can recognize them.

(53) Can you explain any slow/shadow fading effects caused by observation made of the hallway?

(54) How much is the diversity gain achieved compared to individual signals from antenna 1 and 2. (The average signal power)

(55) Zoom to some part of the measurement curve to illustrate the function of selection combining.

(56) How well the calculated path loss model goes together with the measured path loss curve.

(57) Include into your answer what measurement location you were using.

- Notice: that the from different measurement locations in laboratory the geometry will be different than in the plot in preliminary exercises.
- If at your measurement point some part of the measurement had line of sight connection is it visible from in the measured data?

(58) Any own observation on the measurement or the results.