Wireless Communication Security Education using Laboratory Tasks

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ABSTRACT: *Wireless communication security is a crucial issue for which we need some laboratory tasks to educate the students about antenna, propagation effects and wireless link designs. Applied studies education is useful to the students while involved in the information system education practices. The education pattern involves the focus on linking theory and practice with limited resources, taking into account available infrastructure at selected institutions. The teaching is designed by combining different methods such as simulation, measurements and practical demonstration. Students are likely to get practical experience in security, signals and measurements, antenna parameters and signal propagation effects. We advocated these issues in this paper.*

Keywords: Teaching Wireless Communications, Practical Teaching, Simulation, Measurements And Demonstration in Wireless Communications Education

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1. Introduction

Wireless communications are very important part of the telecommunication curriculum. Understanding fundamentals of this subject lays down foundation for understanding of numerous applications ranging from radio frequency identification and near filed communications to more sophisticated systems such as global positioning systems, wireless local area networks or cellular systems. Applied studies incorporate knowledge of all aspects of telecommunication systems as academic studies however with less involved mathematical foundation and with more practice oriented instruction. It is therefore of great importance to design laboratory exercises that support theory by illustrating, demonstrating, simulating or measuring and implementing real world examples. This is not always easy due to limited resources in terms of appropriate hardware, software and instruments. A number of papers deal with practical instruction in engineering education in the field of wireless communications. In order to emphasize the importance of the subject of wireless communication education and the need to pay special attention to practical instruction we here mention some of the work in this field. Although the purpose is the same (teaching and demonstrating concepts, facilitating learning and inspiring interest in the subject) our approach does not directly build on the work in the quoted references. We are oriented towards applied studies, introductory wireless lab classes, low cost solutions, use of available free software and special attention has been given to designing gradually more involving learning tasks. In [1] the authors present a Wireless Communication System Laboratory Course for graduate and senior level undergraduate students. This course covers broad range of subjects and is designed to maintain high students' motivation by including the use of popular wireless devices such as cell phones, notebook computers, Bluetooth devices. In [2] authors present teaching wireless communication and networking fundamentals using Wi-Fi projects. The authors have concluded that Wi-Fi projects are easy to use and set up for demonstrations, low cost, facilitate an interactive hands-on learning experience, useful and challenging in sense of motivating students to test their knowledge. When it comes to radio link design several papers propose various software tools [3], [4].

This paper presents four introductory laboratory exercises for the third year course in Mobile communications at the Electronics and Telecommunications (ELITE) study program at the School of Electrical and Computer Engineering of Applied Studies in Belgrade (VISER). The students are introduced step by step to subjects covering fundamental of RF signal measurements, antenna parameters and wireless channel propagation effects. The Mobile communication course has been introduced in 2007 in the curriculum. Over the years the laboratory sessions have evolved from pure software simulation covering the basic points of wireless link design to the contemporary laboratory that involves measurement equipment and practical realizations. Here we present this introduction to the subject that includes measurements of RF signal characteristics, examining antenna parameters, simulation and calculation of propagation losses and implementation of point to point Wi-Fi link.

The goal of the presented exercises is to approach topics in wireless communications from different perspectives and in different settings with progressively increasing complexity of the studied example. Pedagogically, this means that students are motivated to constantly review previously acquired knowledge and build on it which leads to better understanding and memorizing of theoretical knowledge. Also, since real world examples are demonstrated, the students are encouraged to integrate previously acquired knowledge in various communication courses.

2. Introducing RF Signals, Noise and Distortion Measurement in the Frequency Domain

Although this topic has been covered in the second year telecommunication courses at ELITE study program, due to importance of the subject and need that students get working knowledge of measurements with spectrum analyzer instrument, this topic has been repeated in the third year Mobile communications course. In the telecommunications courses preceding this courses software, combined, and hardware realization of spectral analysis laboratory sessions have been introduced in order that students master this complex and important subject. Details of this have been presented in [5]. In Mobile communications course students revise and expand their knowledge. The exercise consists of connecting signal generator and spectrum analyzer with coaxial cable and performing measurements. In the first part of measurements students use SMA and in the second part BNC connectors respectively. Frequency of the RF carrier (f_{c_in}) is measured, as well as the signal (L_{c_in}) and noise (N) levels. Based on the measurements the carrier frequency error (FE) is calculated (relative to the frequency f_{c_out} set by the signal generator). The RF carrier frequency (f_{c_out}) is varied and the output signal level (L_{c_out}) is kept constant. The attenuation of the cables and connectors (ΔL) is calculated.

f_{c_out} [Hz]	100 M	300 M	3 G	10 G
L_{c_out} [dBm]	0	0	0	0
f_{c_in} [Hz]	100000052.1	300000243.2	3000002426.1	10000007980.5
L_{c_in} [dBm]	−0,77	−1,40	−5,88	−13,08
N [dBm]	−75	−75	−70	−70
ΔL [dB]	0,77	1,40	5,88	13,08
FE [ppm]	0,521	0,811	0,801	0,798

Table 1. Results for the RF Measurements Experiment

The results are reported in the form of tables and graphs. Table I shows results obtained for the RF carrier measurements and SMA connector.

L_{out} [dBm]	L_{in} [dBm]	ΔL_{2nd} [dB]	ΔL_{3rd} [dB]
0	−2,56	−52,24	−80,85
2	−0,56	−52,67	−77,61
4	1,45	−52,37	−73,02
6	3,49	−52,50	−80,24
8	5,50	−52,51	−75,85
10	7,50	−50,37	−72,44

Table 2. Results for the Harmonic Distortion Measurements

Students observe cable and connector losses as a function of frequency. The differences between BNC and SMA connector

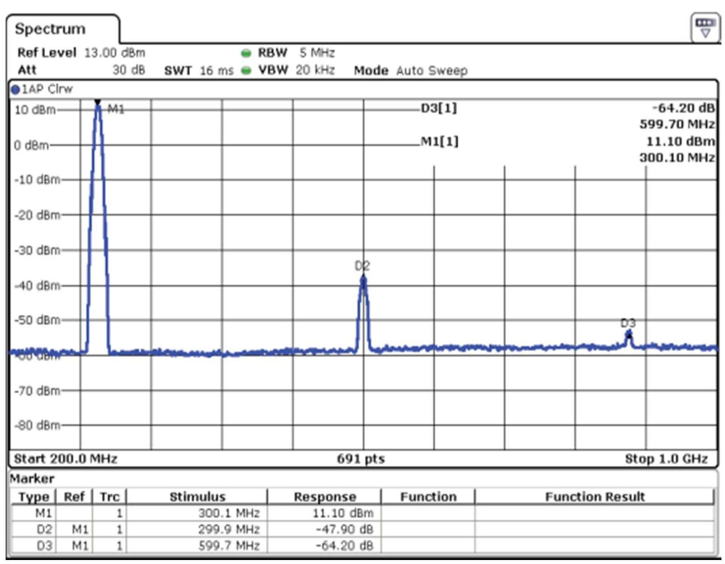

Figure 1. Harmonic distortion measurements

losses are becoming distinct at higher frequencies. Subsequently students perform signal harmonic distortion measurements. An example of the harmonic distortion measurement, that is, the level of the second and third harmonic components and the fundamental is shown in Figure 1. This figure shows image captured by spectrum analyzer for RF carrier frequency 300 MHz and signal level (L_{out}) of 14dBm. Students further change output signal level and record level differences between the harmonics and the fundamental. This is shown in Table 2. The results were obtained with signal generator Agilent E8257D and spectrum analyzer Rohde Schwarz FSV.

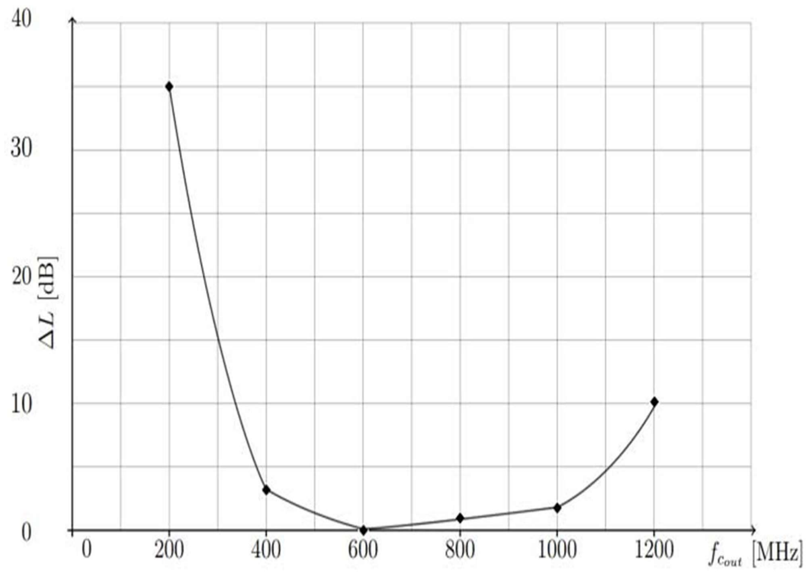

Figure 2. Results for the antenna bandwidth estimation

3. Examining Design and Antenna Characteristics

The goal of this exercise is that students get familiar with antennas and their characteristics which is achieved by measurements

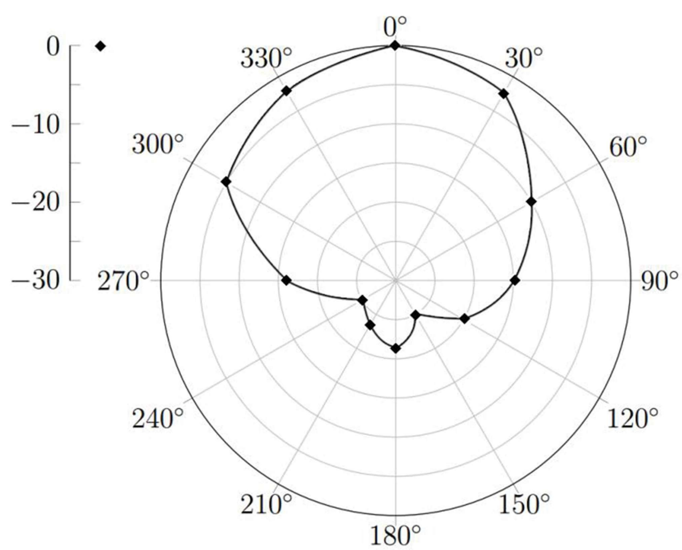

Figure 3. Estimated antenna radiation pattern

using signal generator, spectrum analyzer and printed log-periodic antennas. In the introductory part students are instructed about general antenna design and parameters as well as particularities of printed log periodic antennas. The first task consists of estimating antenna bandwidth. This is done by connecting one antenna to signal generator and using it as a transmitter and the second antenna to spectrum analyzer and using it as a receiver. The transmitting frequency is changed for constant signal level and the received signal level is measured.

The obtained results are shown in Figure 2 where normalized received signal level with respect to frequency is plotted.

The second part of the exercises cosniders estimating antenna radiation pattern by using the same setup. The receiving antenna is rotated and normalized antenna pattern is sketched. An example of obtained results is shown in Figure 3.

4. Creating and Investigating Characteristics of Communication System in Radio Mobile Software

The goal of this exercise is to introduce students to the use of Radio Mobile software tool [6] for investigating characteristics of wireless communications system. The laboratory exercise includes investigating radio link equipment characteristics and electromagnetic waves propagation effects. The students observe the impact of the transmitter power, antenna gain and radiation pattern, terrain profile on the performance of the communication link including Fresnel zones. This exercise demands that students are familiar with data needed to perform a basic link performance such as coordinates of the transmitter and receiver, radiated power, operating frequency band, antenna radiation pattern as well as with theoretical foundations of the wireless link budget analysis. Some of these parameters were introduced in the previously described lab sessions.

The example in Figure 4 shows the terrain profile between two locations that were chosen for the point to point link that will be realized and examined in the next laboratory exercise.The figure shows line of sight as well as Fresnel zones and predicted values for the path loss and received power for the realistic parameters. The simulation takes into account terrain profile and detailed data on clutter is not taken into account.

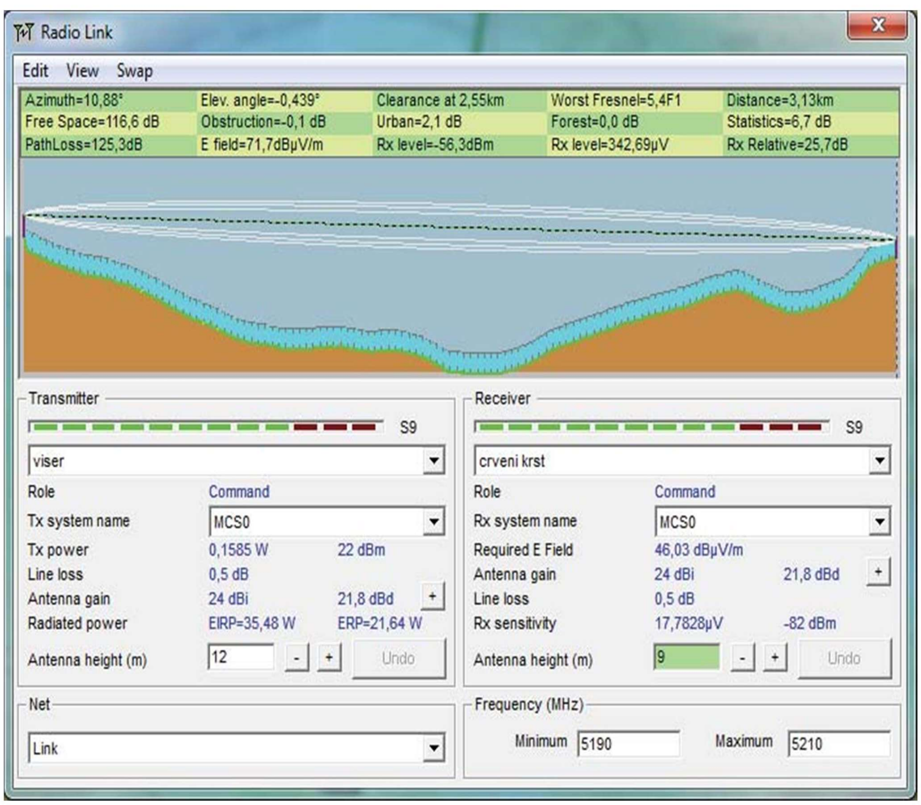

Figure 4. Results for the radio link simulation in Radio Mobile software

The antenna parameters and transmitter power as well as receiver sensitivity were taken from the manufacturer's web site [7]. The coverage map when the transmitter is at VISER school building is shown in Figure 5. The students can observe that we use highly directional antennas and that for point to point links antennas have to be aligned. Also due to this property influences of other sources of interference are limited.

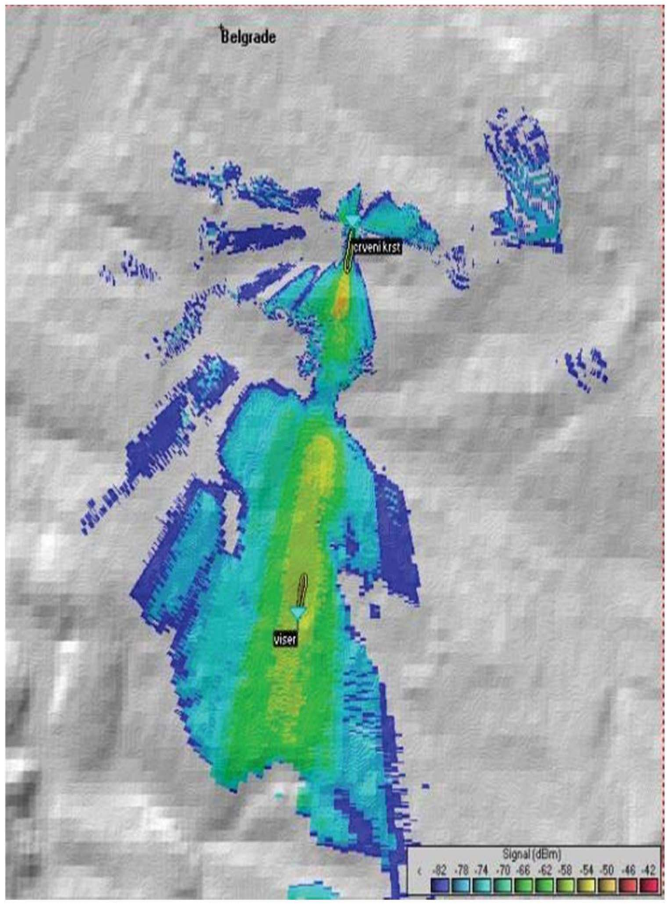

Figure 5. Coverage map obtained by the simulation in the Radio Mobile software

5. Verifying Wireless System Design in Practice

In this lab session students get hands on experience with a practical Wi-Fi point to point link realized between VISER school building and the building that is 3,12 km away. Students first estimate path losses for particular antennas and their locations with Radio Mobile software and compare it to measurements obtained by the MikroTik LHG 5 802.11 wireless device with an integrated dual polarization grid antenna [7].

Students are motivated to integrate their previously acquired knowledge and apply it to real world example. Figure 6 shows obtained received power results for the modulation and coding scheme that uses binary phase shift keying and rate 1/2 convolutional code. This is obtained from the MikroTik LHG wireless device measurements. Students can observe that there is difference in simulation results and results obtained by experiment.

The values predicted by simulation are better than the ones obtained directly from the wireless device due to fact that environment is dense urban environment and simulation does not take into account datasets with clutter height.

Figure 7 shows results for the estimated bitrate. The obtained values are slightly lower than that given in 802.11n specifications. This laboratory session also requires that students are familiar with theory and parameters used in Wi-Fi standard.

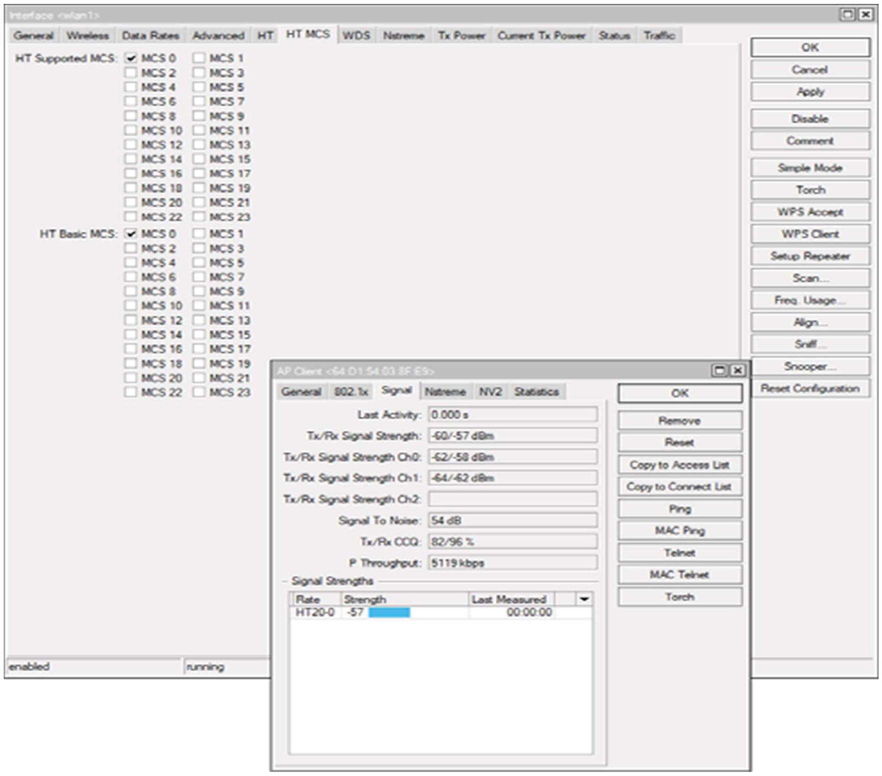

Figure 6. Results for the received signal strength obtained from the wireless MikroTik LHG 5 802.11 device

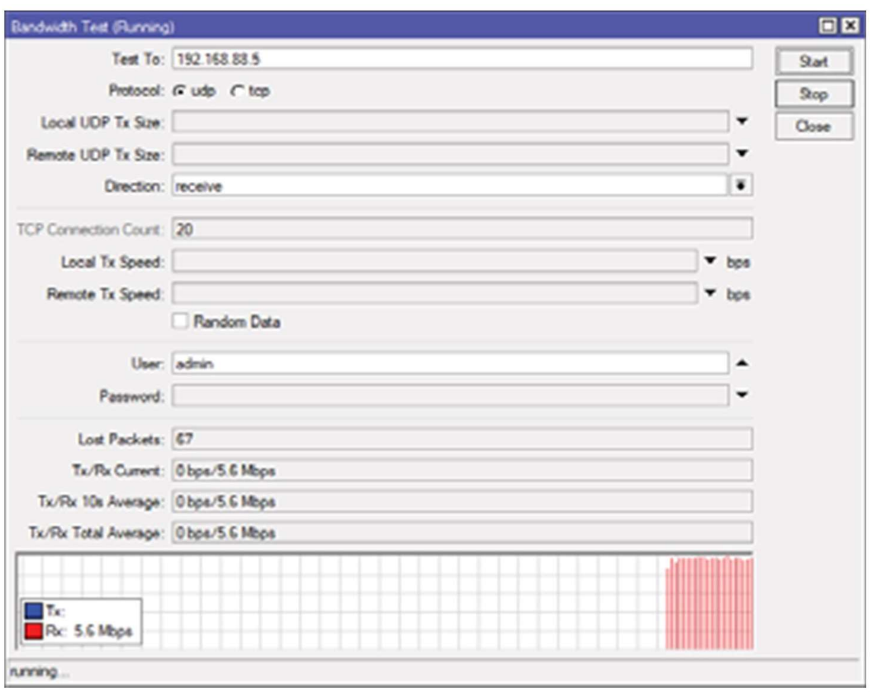

Figure 7. Estimated Link Bitrate Obtained From The Wireless Mikrotik Lhg 5 802.11 Device

6. Conclusion

In this paper we have presented laboratory sessions that introduce students to topics in wireless communications step by step and in an easy to grasp way. They start from simple measurements and observations and end up with practical realization. The communication system elements and parameters are examined individually and as part of the complex system. Some aspects are reinvestigated but in a different setting which makes repetition of knowledge more attractive to students as well as more productive. Also in this way the integration of knowledge from various courses is facilitated. Although topics are covered from the point of view of applied studies and represent introduction to the subject they are fundamental and lend themselves to expansion to higher level of knowledge. This could be used either for broadening course topics or as topics for student projects.

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