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# EEE414: Mobile Communications

# Propagation assignment sheet

*value:* 15%

*due date:* Sunday 8th of December, 2019. Please submit your report as a PDF file through the Propagation Assignment submission upload icon on the EEE414 ICE page.

*length:* No more than 20 pages, including figures and references. Please keep in mind that based on a value of 15%, this assignment should take approximately 24 hours to complete, including time spent making the measurements.

**Purpose:** To provide an introduction to practical radio wave propagation and polarization effects by conducting a small scale field trial. Secondarily, to provide insight into the utility and limitations of radio wave propagation theory in a practical situation.

**Background:** As background information to help with your assignment, Chapter 3 of the Rappaport textbook [1] introduces mobile radio propagation. Sections 3.6 and 3.11 (page 79 and 85) may prove helpful in background theory. Note that Figures 3.28 and 3.29 were measurements made at 914MHz. Figure 3.16 compares theory and measured reflection coefficients of a wall with similar properties to concrete. Page 68 of the Agrawal textbook presents some urban propagation theory. Page 30 of the Goldsmith textbook [2] gives an equivalent introduction to that in the Rappaport textbook [1]. Note that the reflection coefficient of a dielectric surface such as the concrete floor changes with moisture content, frequency, angle of incidence, and polarization of the radio wave. With the polarization effects in mind, vertical linearly polarized transmit to vertical linearly polarized receive (V-V) and horizontal linearly polarized transmit to horizontal linearly polarized receive (H-H) analytical theoretical equations were developed to compare directly to the FEKO™ simulations and experimental measurements.

As discussed in the reference by Reddy used in the lectures, the full-wave numerical simulator FEKO™ uses the Method of Moments (MoM) technique to solve the integral form of Maxwell's Equations at discrete positions on a CAD model of some antenna or radio propagation system that has been subdivided into small mesh elements. Here FEKO™ was used to simulate a pair of simple dipole antennas, a pair of the circular waveguide – monopole "cantennas" made from 1 litre FAXE beer cans and a pair of Short Backfire antennas. Both V-

V and H-H cases were simulated in FEKO™. The concrete floor was represented by an infinite sheet in the XY-plane using either the reflection coefficient approximation or the exact Sommerfeld integrals making it appear that a dielectric was filling the entire lower half space below the XY-plane. For each different ground plane condition a different series of 70 simulations were run with 50cm step between successive simulations. Each individual 2.45GHz simulation of the pair of cantennas took 29minutes, making a total of 34hours of computer time for a given series. Thus, a set of 4 different series of simulations in FEKO™ took approximately 6 days of computer time, been considerably longer than the 9 hours spent making measurements this year.

With regard to prior work: V-V measurements were made in CG13W in 2016 and 2017. The ceiling and the walls were more than 8metres away, so the reflections off the ceiling and walls were expected to have little or no effect. In 2017, the cantennas were held 103cm above the floor of CG13W, and V-V measurements were made at 2.45GHz; other than been 6cm lower, this was an exact repeat of the 2016 measurements. The hall CG13W was not available in 2018, so the ground floor corridor of the EE Building was used. Both V-V and H-H measurements were made in 2018 at 108cm above the floor.

The supplied Matlab code *prop2018c.m* implements the relevant theory and plots all the measured data from prior years. Modify this code to produce the graphs you need for your report. All measurements were made in dBm (dB logarithmic scale referenced to 1milliWatt). However, all theoretical, numerical simulation and measured data were normalized to the power level at antenna separation of 1metre to enable direct comparison.

**Instructions:** Plot all of this year's 2.45GHz measured V-V and H-H data on 2D graphs using the provided Matlab m-file, or equivalent. How do the data sets compare? Are there any significant differences between the 2016, 2017 and 2018 data? Was there any significant difference between the measured data from GC13W and the ground floor of the EE Building? Compare the measured data sets to the theoretical Friis Equation / free space LOS propagation model and the 2-ray interference model that accounts for reflection off the floor. How do the measured data sets compare to this analytic theory and the FEKO™ numerical simulations? What are the possible sources of difference between experiment, theory and simulation? What assumptions are made in the theory? What is not accounted for in the theory? Similarly, what is not accounted for in the FEKO™ simulations? Looking across all the theory and FEKO™ results, was $\varepsilon_r$=4.5 or $\varepsilon_r$=7.5 closer to the measured data? What does this indicate about the moisture content of the concrete floor?

Present your report in IEEE journal format.

*hints*:

Why would it be near impossible to use dipole antennas for these measurements that we did using the cantennas and Short Backfire antennas?

What is the gain of the antennas assumed in the 2-ray interference model? What was the gain of the cantenna and Short Backfire antennas derived from the measured data (show all your working)? Can the 2-ray interference model be modified to account for the directionality of the antennas? Does this improve the accuracy of the 2-ray interference model?

What are the implications of any severe fading on signal reception by a mobile receiver? How will the fading effect the bit error rate (BER)? Given the choice between the ISM bands 2.45GHz, 24GHz and 60GHz, which do you think is best for a short range mobile application?

As our measurements were made at 2.45GHz, was there any interference from WiFi, Bluetooth or 4G? Why or why not?

Do you have observations or comments with regard to conducting field trials? References [3] to [7] present results of outdoor field trials that were affected by reflections off buildings and other objects in an urban environment. Could we perform more ideal measurements elsewhere on campus? Where on campus would you recommend? Justify your recommendation.

Example references:

[1] T.S. Rappaport, *Wireless communications: principals and practice*, 1st ed., Prentice Hall, 1995.

[2] A. Goldsmith, *Wireless communications*, Cambridge University Press, 2005.

[3] O. Landron, M.J. Feuerstein and T.S. Rappaport, "A Comparison of Theoretical and Empirical reflection Coefficients for Typical Exterior wall Surfaces in a Mobile Radio Environment," *IEEE Trans. Antennas Propag.*, vol. 44, pp. 341-350, 1996.

[4] Y. Ito, T. Taga, J. Muramatsu and N. Suzuki, "Prediction of line-of-sight propagation loss in inter-vehicle communication environments," *The 18th Annu. IEEE Int. Symp. on Personal, Indoor and Mobile Radio Commun. (PIMRC'07)*, 2007, pp. 1 – 5.

[5] P. Harley, "Short distance attenuation measurements at 900 MHz and 1.8 GHz using low antenna heights for microcells," *IEEE J. on Select. Areas in Commun.*, vol. 7, pp. 5 – 11, 1989.

[6] C. Sommer and F. Dressler, "Using the Right Two-Ray Model? A Measurement-based Evaluation of PHY Models in VANETs," *Int. Conf. on Mobile Computing and Networking (MobiCom 2011)*, Las Vegas, NV, September 2011..

[7] C. Sommer, S. Joerer and F. Dressler, "On the applicability of Two-Ray path loss models for vehicular network simulation," *IEEE Vehicular Networking Conference (VNC)*, 2012.