University of Leeds
School of Electronic and Electrical Engineering

ELEC5333M - Wireless Communication System Design

Group Lab Report

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1 Introduction

This report presents the work carried out across five simulation-based laboratories using Keysight ADS, each examining a different subsystem within a wireless communication link. Together, these studies explore how theoretical concepts introduced in the module appear in practical design scenarios, and how subsystem behaviour influences overall system performance.

The laboratories cover core RF functions including link budgeting, amplifier linearity, filtering, transistor operation and antenna radiation. For each task, simulations are used not only to obtain quantitative results but to interpret them in the context of the underlying theory. This approach allows the accuracy and limitations of the models to be assessed, and highlights how design choices at one stage can constrain or improve the behaviour of the complete link.

The purpose of the report is therefore twofold: to document the simulation methods and key findings from each laboratory, and to form a coherent view of how these individual results connect to broader wireless system design. The following sections outline the methodology, present and discuss the main results, and reflect on the implications for real RF subsystem design.

2 System-Level Results and Analysis

2.1 Link Budget and Propagation (Lab 1)

This laboratory introduces the fundamentals of link budgeting by examining how transmitted power, antenna gains and propagation conditions determine the strength of a received signal. By modelling a complete transmitter–channel– receiver chain in ADS, the exercise demonstrates how analytical predictions can be compared directly with simulated results, establishing a clear understanding of how frequency, distance and system parameters influence overall link performance. These concepts form the foundation for later laboratories, where distortion, filtering, noise and wider RF system behaviour are investigated.

The theoretical background draws on the Friis transmission relationship and the free–space path loss model, which describe how power decays with distance and frequency. Received power is obtained by combining transmitter power, antenna gains and propagation loss in decibel form. Antenna directivity is central, with higher frequency systems relying on significant antenna gain to counter increased path loss. Free–space propagation assumes an unobstructed line–of–sight link, providing a controlled baseline for analysis. ADS then allows this ideal behaviour to be compared against scenarios that include additional losses such as atmospheric absorption or building penetration.

Before validating the system performance using ADS, each scenario was first evaluated using the link-budget equations provided in the Lab 1 handbook [?]. The received power is obtained using:

$$P_r(dBm) = P_t(dBm) + G_t(dBi) + G_r(dBi) + 20\log_{10}\left(\frac{\lambda}{4\pi R}\right),$$

with antenna gains and parabolic reflector diameters calculated using:

$$G_x(dBi) = 10\log_{10}\left(\eta\frac{\pi^2 d^2}{\lambda^2}\right).$$

These expressions provide a baseline prediction for each wireless link prior to introducing simulation tools or additional channel impairments.

Exercise A: 700 MHz Terrestrial Broadcast Link
For a carrier frequency of 700 MHz, the wavelength is:

$$\lambda = \frac{3\times10^8}{700\times10^6} = 0.43 \text{ m}.$$

The transmit power of 5 kW corresponds to

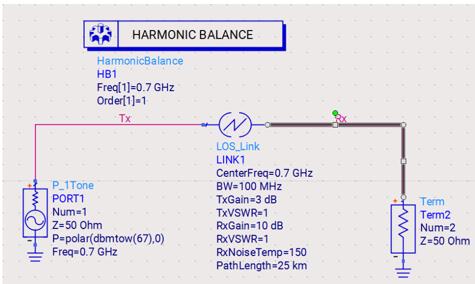
$$P_t = 10\log_{10}(5\times10^6) = 66.99 \text{ dBm}.$$

The free-space loss over 25 km is

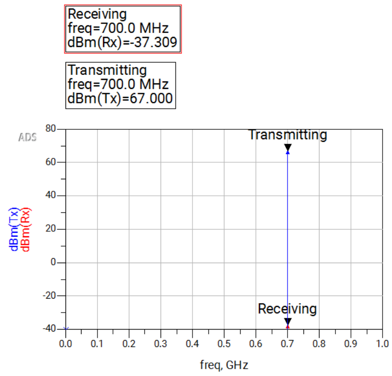
$$\text{FSPL} = 20\log_{10}\left(\frac{0.43}{4\pi \cdot 25 \times 10^3}\right) = -117.30 \text{ dB}.$$

The received power is therefore

$$P_r = 66.99 + 3 + 10 - 117.30 = -37.31 \text{ dBm}.$$



(a) ADS link-budget circuit for Lab 1 Exercise A.



(b) Simulated received-power results for Lab 1 Exercise A.

Figure 1: ADS schematic and simulation results for the Lab 1 link-budget scenario.

Exercise B: 38 GHz Backbone Link.

In this exercise, the objective is to determine the diameter of the transmit parabolic antenna required to achieve a received power of −50 dBm. The carrier frequency is 38 GHz, giving a wavelength of

$$\lambda = \frac{3 \times 10^8}{38 \times 10^9} = 7.89 \times 10^{-3} \text{ m}.$$

The receiver uses a 15 cm dish with efficiency $\eta = 0.55$. Its gain is

$$G_r = 10\log_{10}\left(\eta\frac{\pi^2 d_r^2}{\lambda^2}\right) = 10\log_{10}\left(0.55\frac{\pi^2(0.15)^2}{(7.89 \times 10^{-3})^2}\right) = 32.92 \text{ dBi}.$$

The free–space loss over $R = 10$ km is

$$\text{FSPL} = 20\log_{10}\left(\frac{\lambda}{4\pi R}\right) = -144.04 \text{ dB}.$$

Atmospheric absorption adds a further 10 dB attenuation. The system transmit power is 100 mW, corresponding to

$$P_t = 10\log_{10}(100) = 20 \text{ dBm}.$$

The link budget expression becomes

$$P_r = P_t + G_t + G_r + \text{FSPL} - 10.$$

Setting the target received power $P_r = -50$ dBm and solving for G_t gives

$$-50 = 20 + G_t + 32.92 - 144.04 - 10,$$

$$-50 = -101.12 + G_t,$$

$$G_t = 51.12 \text{ dBi}.$$

The corresponding transmit-antenna diameter follows from the parabolic reflector gain expression:

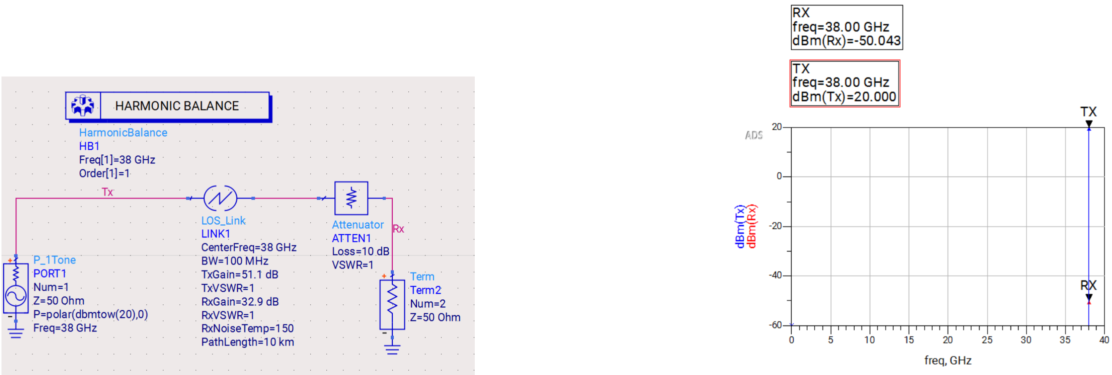
$$G_t = 10\log_{10}\left(\eta\frac{\pi^2 d_t^2}{\lambda^2}\right),$$

$$d_t = \lambda\sqrt{\frac{10^{G_t/10}}{\eta\pi^2}}.$$

Substituting $\eta = 0.55$, $\lambda = 7.89 \times 10^{-3}$ m and $G_t = 51.12$ dBi,

$$d_t = 7.89 \times 10^{-3}\sqrt{\frac{10^{5.112}}{0.55\pi^2}} = 1.22 \text{ m}.$$

Thus, a transmit-antenna diameter of approximately **1.22 m** is required to achieve a received power of -50 dBm under the stated conditions.



(a) ADS circuit schematic for Lab 1 Exercise B.

(b) Simulation results for the 38 GHz backbone link.

Figure 2: ADS schematic and simulation results for the 38 GHz backbone link (Exercise B). The simulated received power of -50.04 dBm matches the analytical prediction.

Atmospheric attenuation varies strongly with frequency due to absorption by oxygen and water vapour, creating alternating low–loss transmission windows and high–loss absorption bands (see Fig. 3). The 38 GHz region lies within a relatively favourable window, while bands near 22 GHz and 60 GHz experience much higher loss. The 10 dB attenuation term used in this exercise reflects one point on this wider frequency–dependent attenuation spectrum and highlights the need to account for atmospheric absorption when designing long-distance links.

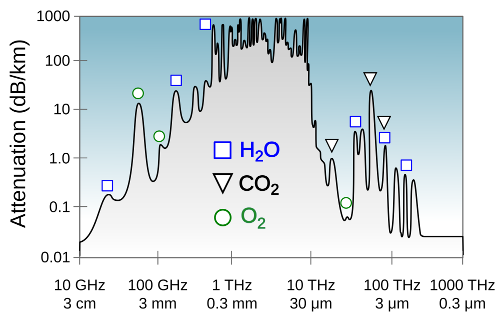


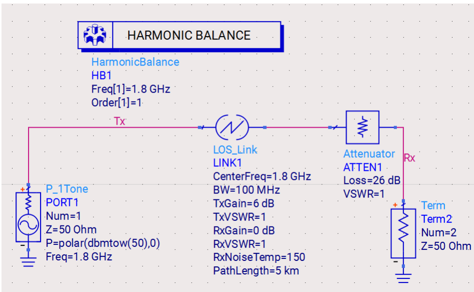
Figure 3: Atmospheric attenuation vs frequency, showing absorption features from oxygen and water vapour [?].

Exercise C: 1.8 GHz Cellular Link. The wavelength at 1.8 GHz is

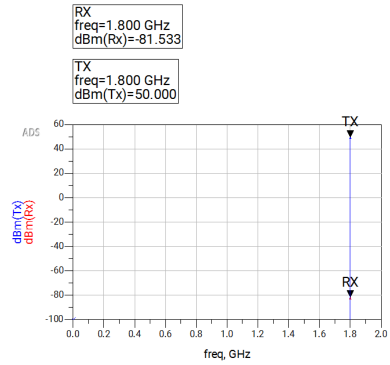
$$\lambda = 0.167 \text{ m}.$$

Transmitter power, antenna gains and free-space loss are combined as before, with an additional 26 dB attenuation term accounting for fading margin (20 dB) and building penetration (6 dB):

$$P_r = P_t + G_t + G_r + \text{FSPL} - 26 \text{ dB}.$$



(a) ADS circuit schematic for Lab 1 Exercise C.



(b) Simulation results for the 1.8 GHz cellular link.

Figure 4: ADS schematic and simulation results for the 1.8 GHz cellular link (Exercise C).

Exercise D: GEO Satellite Downlink. For a 12 GHz carrier,

$$\lambda = \frac{3 \times 10^8}{12 \times 10^9} = 0.025 \text{ m}.$$

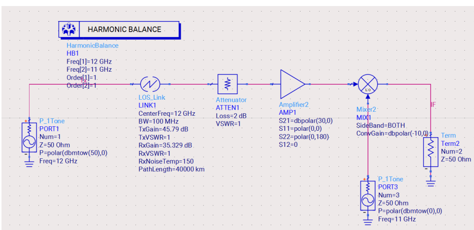
The spacecraft and ground-station dish gains follow from

$$G = 10 \log_{10} \left(0.6 \frac{\pi^2 d^2}{\lambda^2} \right),$$

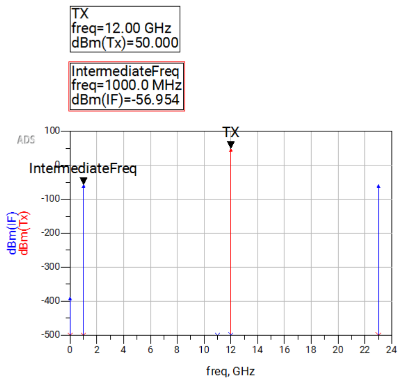
using diameters of 2 m and 0.6 m respectively. The free-space loss over 40,000 km is added along with atmospheric absorption (2 dB), low-noise-amplifier gain (30 dB) and mixer conversion loss (10 dB):

$$P_{IF} = P_t + G_t + G_r + \text{FSPL} - 2 \text{ dB} + 30 \text{ dB} - 10 \text{ dB}.$$

This predicts the IF power prior to validating the chain using ADS.



(a) ADS circuit schematic for Lab 1 Exercise D.



(b) Simulation results for the GEO satellite downlink.

Figure 5: ADS schematic and simulation results for the GEO satellite downlink (Exercise D).

2.2 Amplifier Linearity and Intermodulation (Lab 2)

2.3 Filter Behaviour (Lab 3)

2.4 Transistor Characteristics (Lab 4)

2.5 Time-Domain Distortion and Antenna Performance (Lab 5)

3 Cross-Subsystem Discussion

- How link budget results define required amplifier gain and noise margin.
- How amplifier linearity and filter behaviour interact in a real chain.
- How device-level characteristics feed into system-level performance.
- Limitations of the simulations (ideal models, omitted noise sources, parasitics, EM simplifications).

4 Conclusion

- What was demonstrated,
- What was learned about subsystem behaviour,
- How the results relate to practical wireless system design.