POZNAŃ UNIVERSITY OF TECHNOLOGY

Multi-path Propagation

Simulating multi-path propagation in radio telecommunication channel in a closed environment using Python programming language

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1. Abstract

One of the key aspects of the signal propagation in radiotelecommunication is multi-pathing, which is a main reason standing behind fast fading. However today we will mainly focus on trying to simulate simple case of multi-pathing in a closed room with the use of Python programming language.

2. Introduction

For the first part of the exercise, we'll be conducting our simulation in the simplest room possible, with only 4 walls and no obstacles between receiver and transmitter. As in the *Figure 1* our receiver will be traveling in a lane parallel to the wall next to which transmitter is standing.

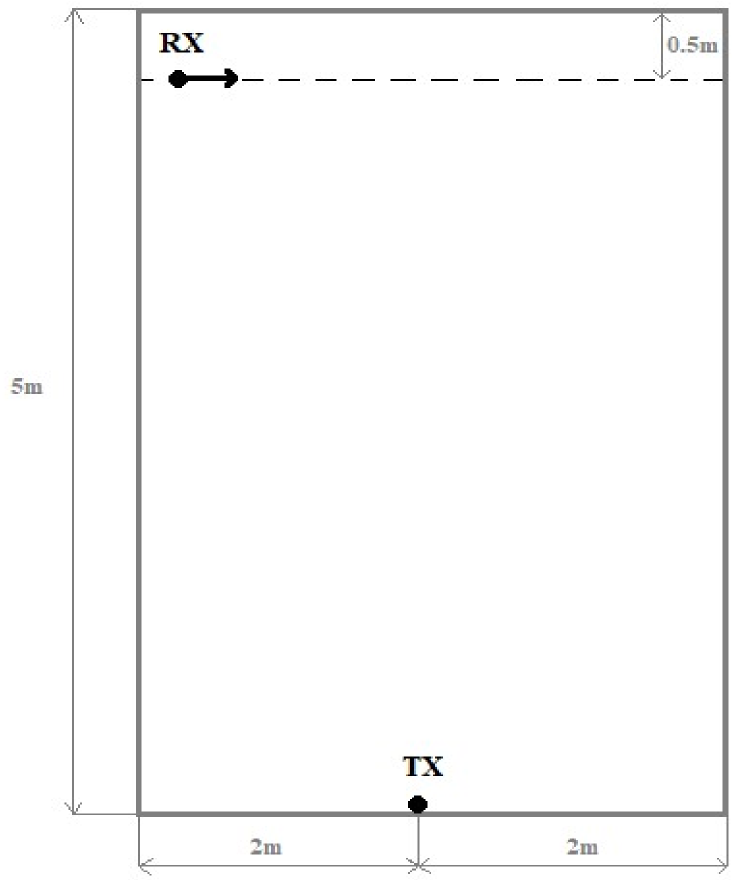

Fig. 1

In the second part, we'll be trying to simulate diffraction in the shadow region, thus we'll add some additional space to the room in figure one. The point is to stop Line of Sight and have our signal bend on a knife-like edge of an obstacle, in this case, a corner of a wall.

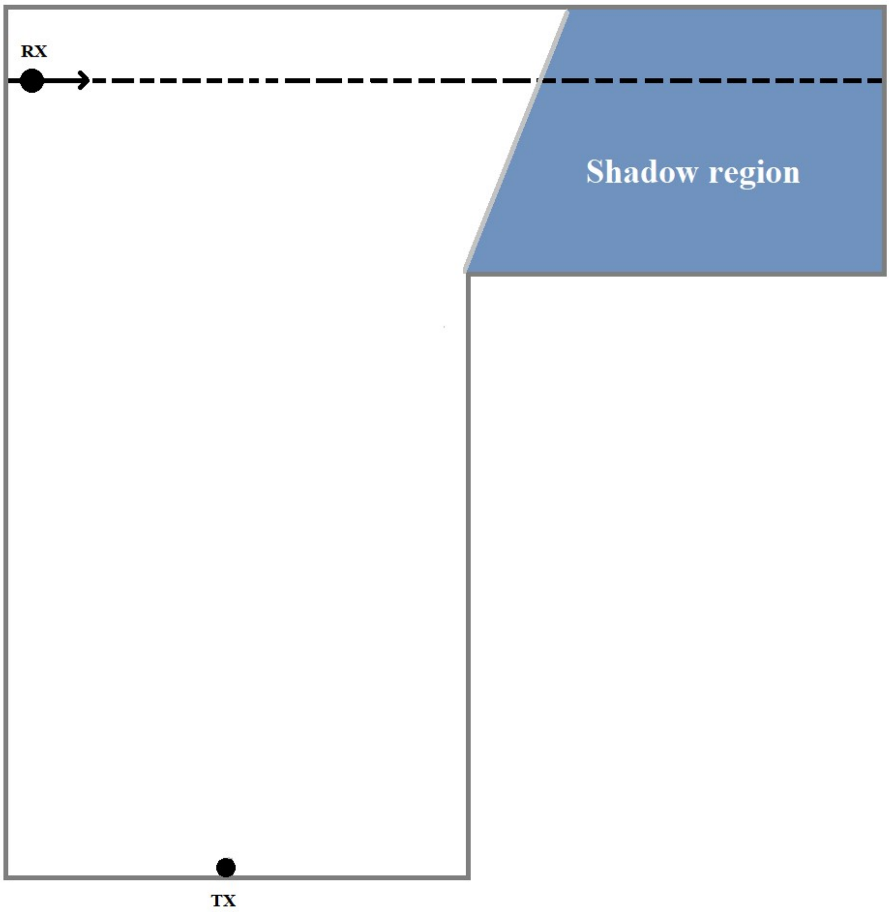

Fig. 2

3. Assumptions

We'll be working with the signal with frequency f_c = 2.4GHz.

As we're simulating a situation in a space created fully by us, we have to assume few things before the calculations in order to avoid confusion. For calculating the reflectances we'll be using Recommendation ITU-R P.2040-1 formulas, which require us to establish from what our room is build.

For that we assume:

$$Concrete\ floor, ceiling, right\ wall, permittivity = 5.31$$

$$Left\ wall\ with\ wooden\ wardrobe, permittivity = 1.99$$

$$Wall\ behind\ receiver\ has\ glass\ windows, permittivity = 6.27$$

We also need to assume how big is the room we're making simulations in:

$$length = 5m$$

$$width = 4m$$

$$height = 2.5m$$

$$height\ of\ transmitter\ and\ receiver = 1m$$

$$length\ of\ additional\ room = 2m$$

$$width\ of\ additional\ room = 1.5m$$

4. Simulating received-to-transmitted power ratio P_R/P_0 in different scenarios

In this part of the project we'll be mainly using equation for P_R/P_0 provided below:

$$\frac{P_R}{P_0} = \left| \sum_{i=0}^{n} \frac{a_i}{d_i}\ e^{j\varphi_i} \right|^2$$

Where a_i is the total reflectance of the ray, d_i is the total path travelled and

$$\varphi_i = \frac{-2\pi f_c d_i}{c}.$$

In addition to that, we'll be using P-2040 formula for reflectance.

$$R_{eTE} = \frac{\cos(\theta) - \sqrt{\eta - \sin(\theta)^2}}{\cos(\theta) + \sqrt{\eta - \sin(\theta)^2}}$$

Where η is the real part of the permittivity and θ is the incident angle.

a) Line of Sight path only

As we can observe, since we have no additional beams that would interfere with each other, the line in pretty simple and power is increasing with the receiver getting closer to the transmitter and decreasing as it goes away.

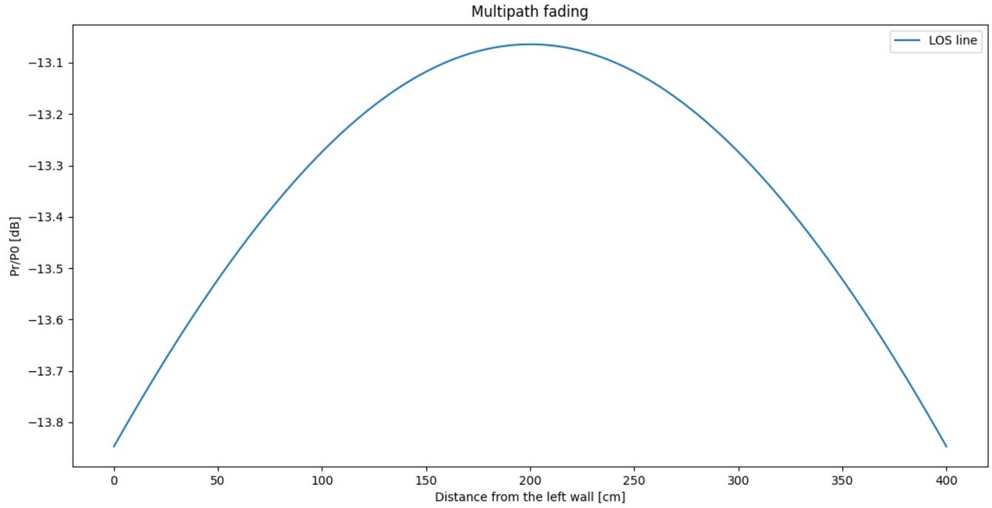

Fig. 3

b) Line of sight and two additional once reflected paths

Since we added more rays, depending on the phase of each one they can either amplify or attenuate our signal. It’s the first example in which we can observe fast fading.

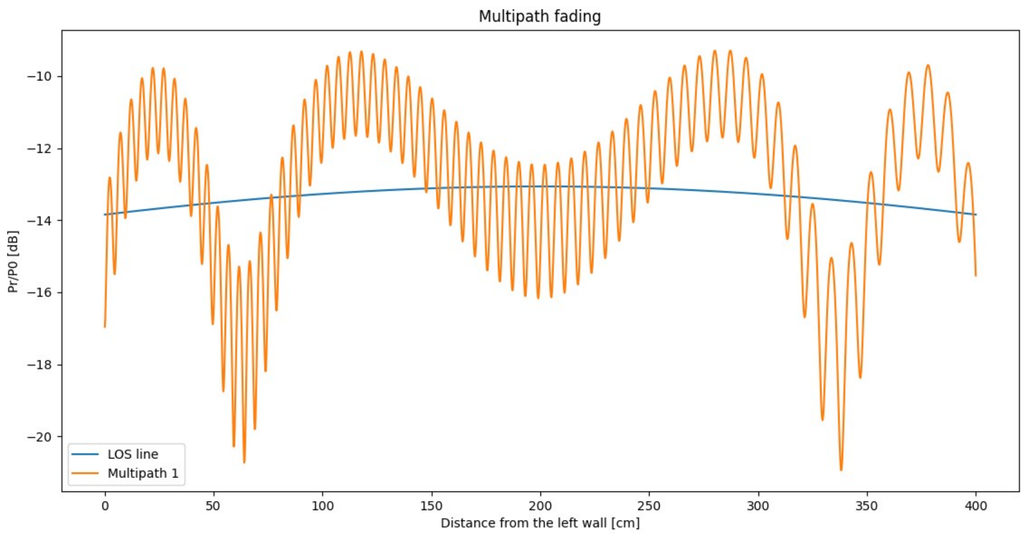

Fig. 4

c) LOS, two once reflected path, and two twice reflected paths

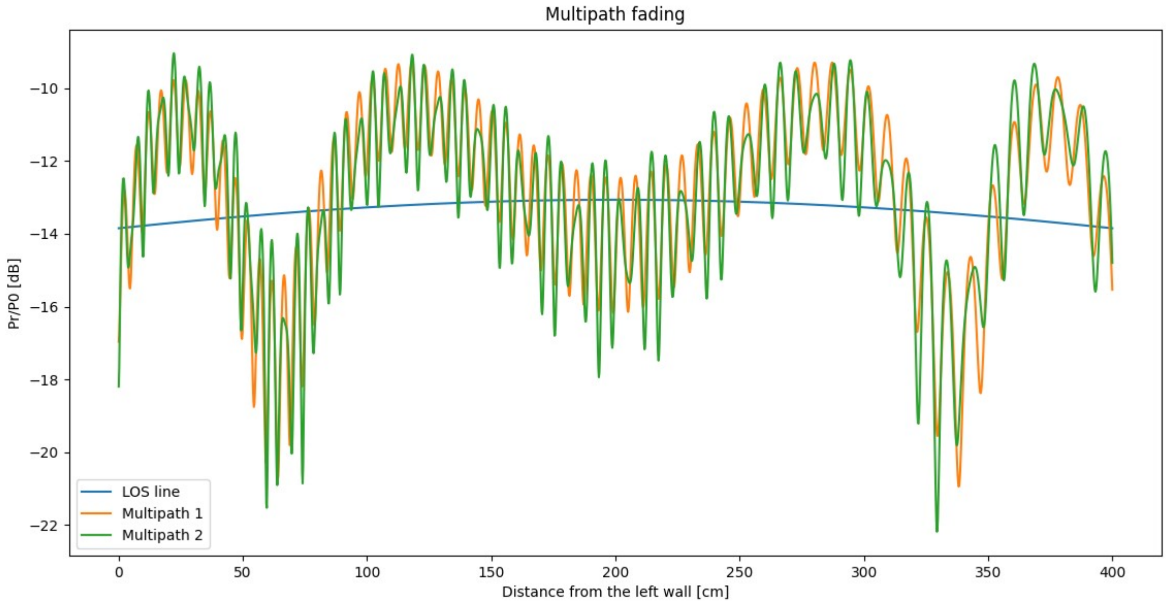

Fig. 5

d) Simulating diffraction in the shadow region using Deugant model

For the Deugant model we assume that we have an obstacle with a knife-like edge which diffracts our ray as presented on the image below.

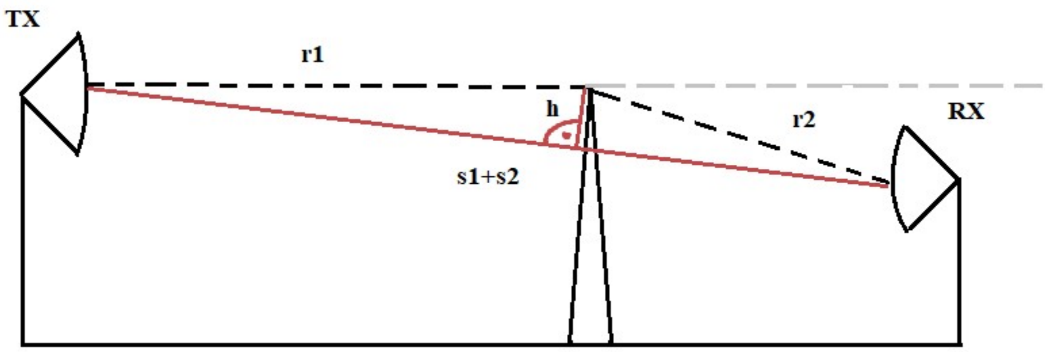

Fig. 6

First we have to calculate variable ***v*** from the equation below:

$$v = h * \sqrt{\frac{2f_c}{c} * \frac{s_1 + s_2}{r_1 * r_2}}$$

And then we substitute it into the equation:

$$C = 6.9 + 20\log\left(\sqrt{(v-0.1)^2+1} + v - 0.1\right)$$

which gives us the attenuation of the LOS ray.

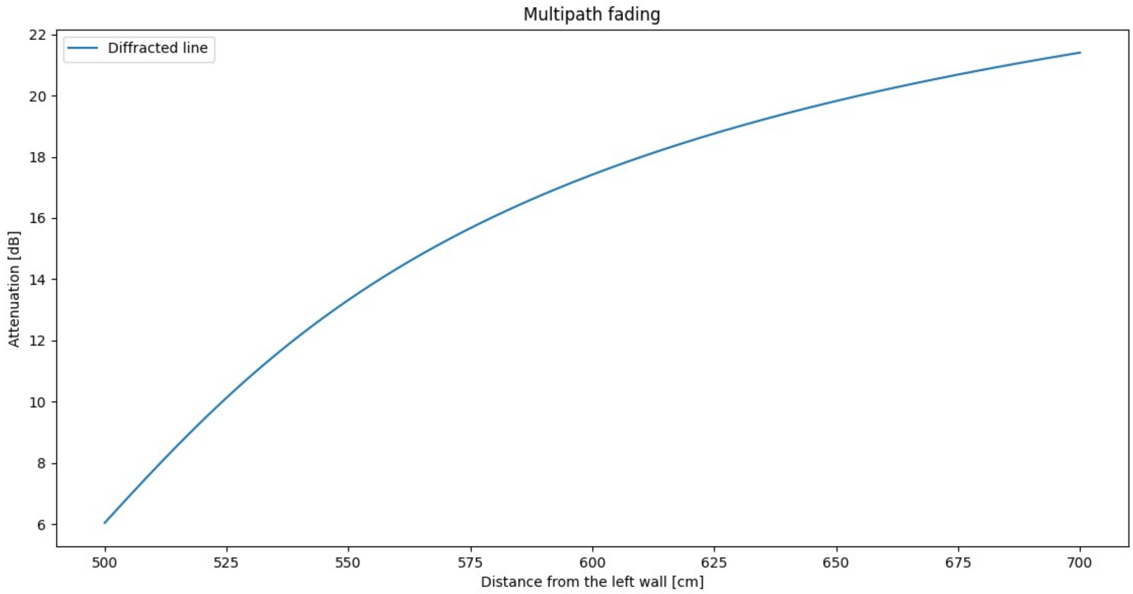

Fig. 7

As we can observe, along with getting deeper into the shadow region presented in **Fig.2** the attenuation gradually rises.

We can present it along the paths from previous simulations to observe how diffraction influences strength of our signal.

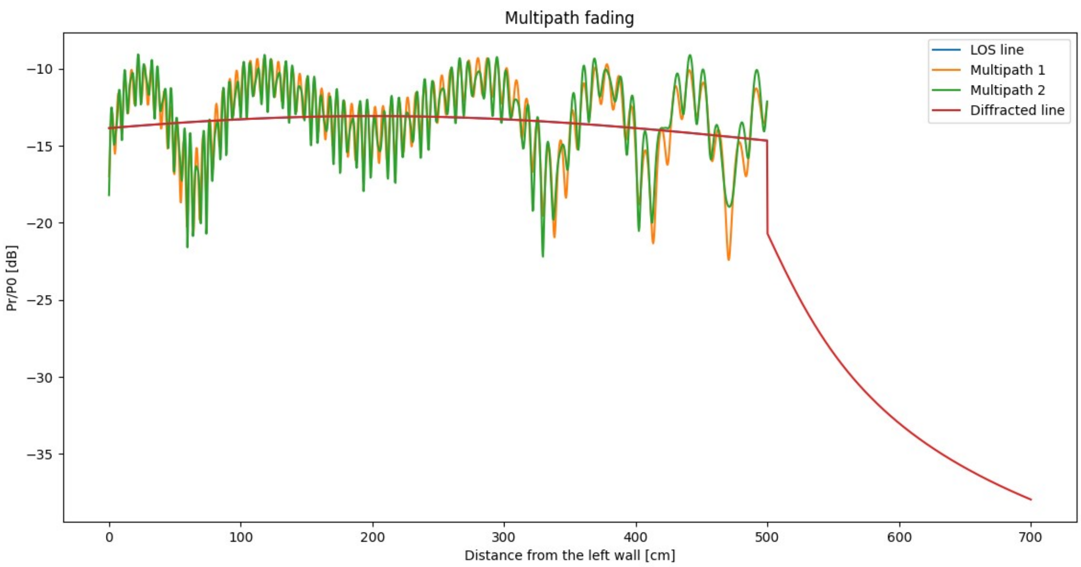

Fig. 8

5. Simulating Power Delay Profile

Additionally to the previous simulations we can present how Power Delay Profile of the signal looks in a particular spot on our d axis.

The idea of Power Delay Profile is to represent the signal as a function of the propagation delays of the respective multipaths.

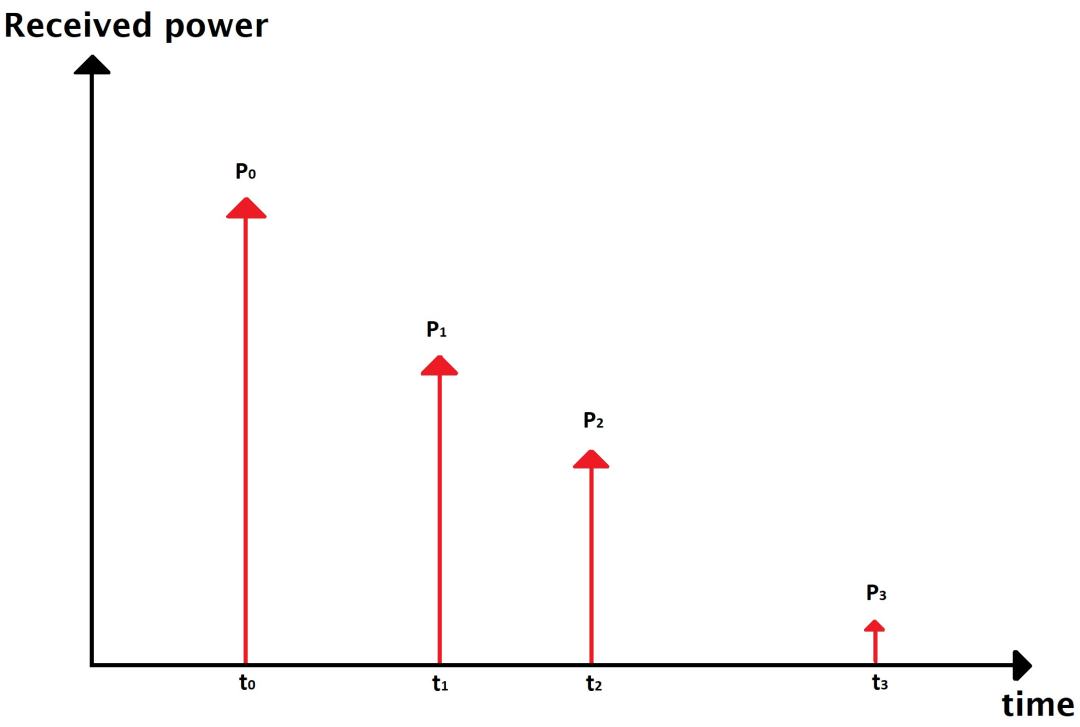

Fig. 9

In order to do that we first calculate how long signal travelled from transceiver to the receiver using equation:

$$t_n = \frac{d_n}{c}$$

where d_n is the length of the path and c is the speed of light.

We also calculate powers of particular paths with the equation:

$$P_{Rn} = \left|\frac{a_n}{d_n}\right|^2$$

Where a_n is the total reflectance of the path.

After sorting all the paths by their time in ascending order we can normalize all the values.

$$Normalized\ power\ P_{Norm} = \frac{P_{Rn}}{P_0}$$

where P_0 is the power with the smallest respective time t_n,

$$Normalized\ time\ \Delta\tau_n = t_n - t_0$$

Before plotting the Power Delay Profile we also assume values of t_0 and P_{Norm0} to be

$$t_0 = 0$$

$$P_{Norm0} = 1$$

With everything calculated we should achieve a graph similar to the one in **Fig.9.**

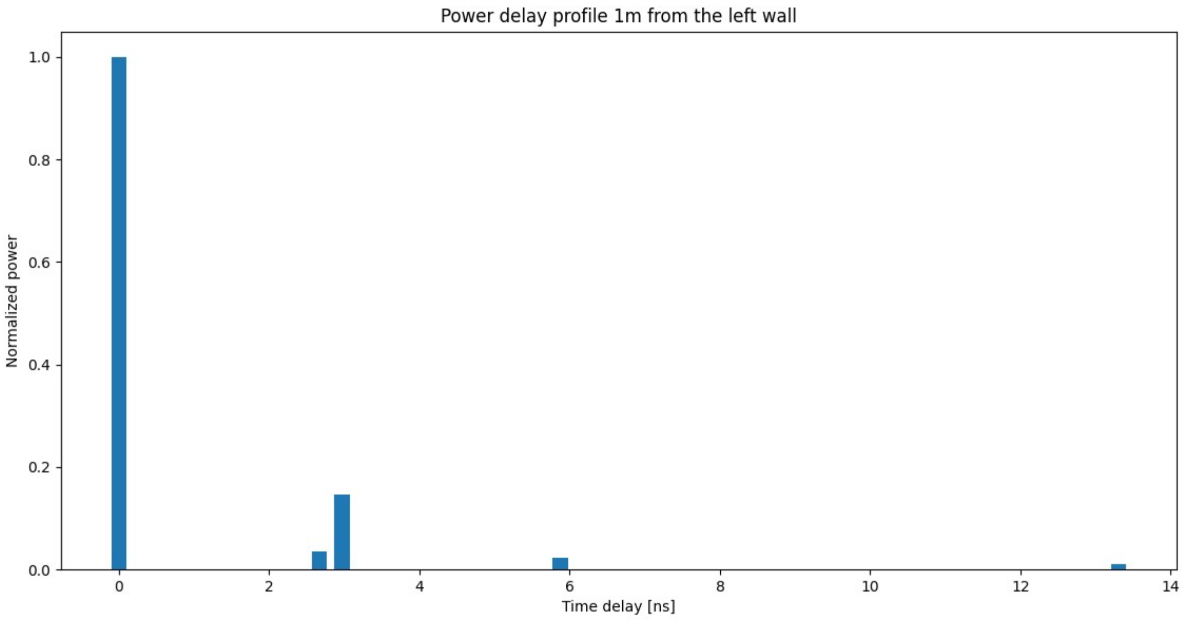

Fig. 10

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