

# 1 | Determining the Complex Relative Permittivity

From worksheet ?? it is known that to find the complex relative permittivity,  $\epsilon_0$ , a set of at least six measurements are needed. Three with vertical polarization and three with horizontal polarization. So the first part of this worksheet will be about the performed measurement the next part will be data manipulation to find  $\epsilon_0$  for both the gym and the parking lot.

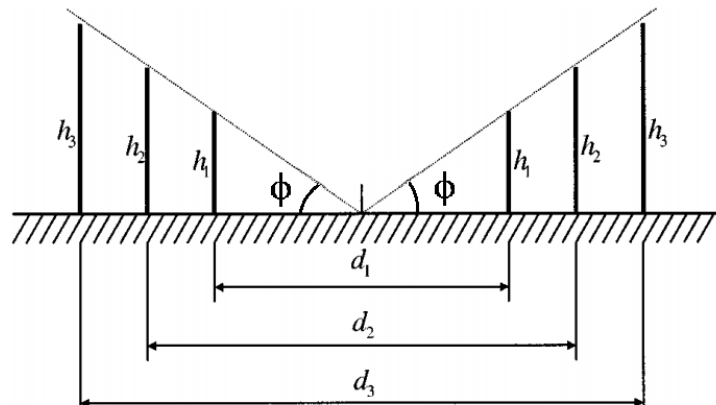
## 1.1 Measurement

### 1.1.1 Procedure

1. Decide frequency and incidence angle
2. Decide measurement setup, including  $P_t$  heights and distances between transmitter and receiver for all three measurements points
3. Determine  $G_t$ ,  $G_r$ ,  $L$ ,  $\alpha_t$ ,  $\alpha_r$  for both horizontal and vertical cases
4. Calculate  $\lambda$ ,  $k$ ,  $r_1$ ,  $r_2$
5. Measure  $P_r$  in all six cases
6. Find intersection point using ?? for both horizontal and vertical polarization
7. Calculate the complex relative permittivity using ??

### 1.1.2 Setup

So first it is decided to use both 858MHz and 2580MHz as frequencies as both of these are used in the extensive measurement campaign performed in the project. The incidence angle are chosen to 45 degree, based on the simplification of height distance relation. The setup used is the same as for the campaign and can be found in the measurement journal. Though only the patch antennas are used for this. The height and distances are calculated so the follows the description seen on Figure 1.1.



**Figure 1.1:** Illustration of the three distances and heights needed. Figure taken from [?].

	Height	Distance	Power
<b>Point 1</b>	0.5m	1m	0dBm
<b>Point 2</b>	1m	2m	0dBm
<b>Point 3</b>	2m	4m	0dBm

**Table 1.1:** Height distance for the different measurement points.

### 1.1.3 Pre-processing

Based on a measurement performed in Satimo Starlab all gains for the antenna can be found. These are summarized in Table 1.2

Frequency	858 MHz		2580 MHz	
Polarization	Vertical	Horizontal	Vertical	Horizontal
<b>Gain angle 0</b>	-3.5745 dB	-3.6360 dB	4.3624 dB	4.3446 dB
<b>Gain angle 45</b>	-4.8326 dB	-6.9685 dB	-2.6601 dB	-3.5324 dB

**Table 1.2:** Gains for the patch antennas.

From the linkbudget worksheet it is found that L is 0.9 dB for 858 MHz and 1.6 dB for 2580 MHz.

The last parameters can then be calculated and are summarized in ??

Parameter	Description	Magnitude
$\lambda_{858MHz}$	Wavelength for 858 MHz	0.3497 m
$\lambda_{2580MHz}$	Wavelength for 2580 MHz	0.1163 m
$k_{858MHz}$	Wave number for 858 MHz	17.9699
$k_{2580MHz}$	Wave number for 2580 MHz	54.0354
$r_{1,1}$	Direct distance for point 1	1 m
$r_{1,2}$	Length of reflected path for point 1	$1\sqrt{2}$ m
$r_{2,1}$	Direct distance for point 2	2 m
$r_{2,2}$	Length of reflected path for point 2	$2\sqrt{2}$ m
$r_{3,1}$	Direct distance for point 3	4 m
$r_{3,2}$	Length of reflected path for point 3	$4\sqrt{2}$ m

**Table 1.3:** Remaining parameters needed for calculation

#### 1.1.4 Measured data

At the each measurement point is gathered 10 measurements and the means are shown in Table 1.4.

Frequency	Polarization	Point	Power received in the gym	Power received on the parking lot
858 MHz	Horizontal	1	-41,38	-40,561
858 MHz	Horizontal	2	-48,51	-47,188
858 MHz	Horizontal	3	-57,195	-53,858
858 MHz	Vertical	1	-37,55	-38,7
858 MHz	Vertical	2	-44,986	-46,109
858 MHz	Vertical	3	-51,463	-50,34
2580 MHz	Horizontal	1	-39,148	-35,484
2580 MHz	Horizontal	2	-45,63	-43,502
2580 MHz	Horizontal	3	-50,888	-47,314
2580 MHz	Vertical	1	-40,145	-36,232
2580 MHz	Vertical	2	-45,33	-41,253
2580 MHz	Vertical	3	-51,079	-47,219

**Table 1.4:** Measured data

### 1.1.5 Post-processing