1 | Determining the Complex Relative Permittivity

From worksheet (see complex relative permittivity) it is known that to find the complex relative permittivity, ϵ_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 ϵ_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, α_t, α_r for both horizontal and vertical cases
4. Calculate λ, k, r_1, r_2
5. Measure P_r in all six cases
6. Find intersection point using Equation 1.1 for both horizontal and vertical polarization
7. Calculate the complex relative permittivity using see worksheet Groundwave, equation 2.4

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 they follow the description seen on Figure 1.1.

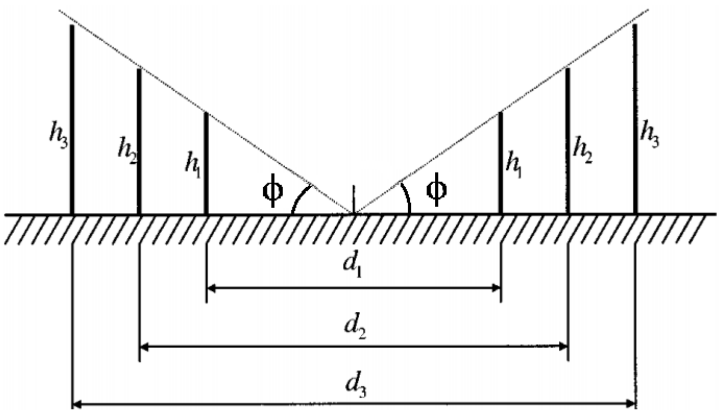

Figure 1.1: Illustration of the three distances and heights needed. Figure taken from [Kim and Narayanan, 2002].

	Height	**Distance**	**Power**
Point 1	0.5m	1m	0dBm
Point 2	1m	2m	0dBm
Point 3	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**
Gain angle 0	-3.5745 dB	-3.6360 dB	4.3624 dB	4.3446 dB
Gain angle 45	-4.8326 dB	-6.9685 dB	-2.6601 dB	-3.5324 dB

Table 1.2: Gains for the patch antennas.

From the link budget 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 Table 1.3

Parameter	Description	Magnitude
λ_{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

When the data is put fed into Equation 1.1, it forms circles the intersection point between the three circles using the same frequency and polarization marks the complex reflection coefficient.

$$\left(\Gamma_{h,v} + \frac{r_r \cos(kr_d)}{\sqrt{\alpha_r}\sqrt{\alpha_t}}\right)^2 + \left(\zeta_{h,v} + \frac{r_r \sin(kr_d)}{\sqrt{\alpha_r}\sqrt{\alpha_t}}\right)^2 = \left(\frac{4\pi r_2 \sqrt{P_d}}{\lambda\sqrt{\alpha_r}\sqrt{\alpha_t}}\right)^2 \tag{1.1}$$

Where:

r_r	is $\frac{r_2}{r_1}$	[1]
r_d	$r_2 - r_1$	[m]
P_d	$\frac{P_r L}{P_t G_t G_r}$	[1]

Bibliography

Kim, H.-S. and Narayanan, R. M. (2002). A New Measurement Technique for Obtaining the Complex Relative Permittivity of Terrain Surfaces. *IEEE Transactions on Geoscience and Remote Sensing*.