PRACTICE 01 – MEASUREMENTS ON COAXIAL CABLES

1. CALIBRATION OF THE NETWORK ANALYSER (VNA)

Calibrate FULL 2 PORT for 3 times (one for each component of the group). Frequency range: fmin ÷ 1GHz; fmin ÷2 GHz; fmin ÷ 3 GHz. (fmin depends on the particular VNA).

Follow the instructions in the calibration sheet to acquire, save and plot data. **(REPORT)**

2. TRANSMISSION MEASUREMENTS ON COAXIAL CABLE

On the desk, there is a coaxial cable with type-N connectors being **L** its **physical length** (different for each desk). Connect the cable to the 2 ports of the VNA calibrated between fmin and 3 GHz.

Theoretical S21 of the cable is:

$$S21(\omega) = \exp(-\gamma L) = \exp(-\alpha L - j\beta L) = \exp(-\alpha' \,\mathrm{sqrt}(\omega) L - j\,\omega\,\tau)$$

Evaluate the attenuation constant α at 1 GHz **(REPORT)**.

3. S21 PHASE MEASUREMENT

Select Format-Phase. Why do you see a periodic signal between -180° and 180°? **(REPORT).**

The commands

(VNA1 and VNA2) -> RESPONSE-> **SCALE-> Electrical Delay**

(PNA) -> **SCALE -> Electrical Delay**

(FIELD FOX) -> **SCALE/AMPLITUDE ->more => Electrical Delay**

add a (fictious) delay to the signal, thus you are measuring

S21' = S21 $\exp(j\omega\tau')$.

Therefore, the phase of the measured S21' becomes

phase (S21') = $-\omega\tau + \omega\tau'$.

When $-\omega\tau + \omega\tau' = 0$, the phase plot shall become a horizontal line.

The VNA shows the value of τ' (electrical delay) in seconds and the cable length $L0 = c\,\tau'$ (**electrical length of the cable**, with c speed of light in vacuum/air), i.e. assuming a line in vacuum. **(REPORT).**

On the contrary, in the cable there is a dielectric material with constant ε_r, thus he EM field have a phase velocity $v=c/\mathrm{sqrt}(\varepsilon_r)$ and length $L=c\tau'/\mathrm{sqrt}(\varepsilon_r)$.

Thus $L0/L = \mathrm{sqrt}(\varepsilon_r) = n$ (refractive index of the dielectric material)

Measuring L with a meter, evaluate the **permittivity** ε_r and the **refractive index n** for the cable under test **(REPORT).**

4. S21 MAGNITUDE MEASUREMENT (dB)

Select Format-Log mag. Measure **S21(f)** which is decreasing as frequency f increases **(REPORT).**

As we know from theory

mod(S21)dB = 20log10(exp[$-\alpha'$ sqrt(ω)L] =

-20 (log10e) α' sqrt(2π) sqrt(f) L = -8,686 α' sqrt(2π) L sqrt(f).

Execute the regression (**LinearFit**), with the $\sqrt{f}$ on the x-axis, derive the slope and thus the **constant α' with its uncertainty**. Use α' to give also the **attenuation of the cable** at 1 GHz in dB/m with its uncertainty **(REPORT).**

5. CABLE REFLECTION MEASUREMENTS

Connect the coaxial cable to VNA port 1, leaving open the other end.

Plot the magnitude of S11 in dB, being Δf the period of |S11| oscillations. **(REPORT).**

Use Δf to measure **the delay τ** of the cable (τ= 1/(2Δf)) and compare it with the one you evaluated previously **(REPORT).**

Evaluate the **refractive index n** using the formula:

$$n = c / (2 L \Delta f)$$

and compare it with the previous result **(REPORT).**