lab4

November 9, 2022

1 Design of a Stepped impedance low-pass filter

1.1 SPECS

- **Maximally Flat**
- Stepped Impedance:
    - $Z_{Low} = 10\Omega$
    - $Z_{High} = 150\Omega$
- Substrate:
    - GIL Technologies GML-1000
        * $H = 0.762$
        * $E_r = 3.2$
        * $\tan_d = 0.003$
- Order of the Filter: **7** ^{nth}
- Cut-off Frequency: $f_c = 2.0\ GHz$

$$\left|\frac{w}{w_c}\right| - 1 = 0.1N,\ \ N = 7\ e\ w_c = 2 \cdot \pi \cdot\ 2\ GHz$$

$$\frac{w}{2 \cdot \pi \cdot\ 2\ GHz} = 0.7 + 1$$

$$w = 3.4\ GHz$$

```
!pip install numpy
import numpy as np
z_high = 150
z_low = 10
H = 0.762
E_r = 3.2
tan_d = 0.003
n = 7
f_c = 2e9
w_c = f_c * 2 * np.pi
R_0 = 50
lightspeed = 3e8 #approximation in vacuum should be changed based on substrate
wavelength = lightspeed/ f_c
```

```
[3]: attenuation_w   =   ((n/10)+1 )* w_c #Quando a atenuação e maior que 20dB
     attenuation_f   =   ((n/10)+1 )* f_c #Quando a atenuação e maior que 20dB

     print(f"Freq Attenuation is more than 20dB: {attenuation_f:e} Hz")
     print(f"                                   : {attenuation_w:e} rad/s")
```

```
Freq Attenuation is more than 20dB: 3.400000e+09 Hz
                                   : 2.136283e+10 rad/s
```

Since our filter is maximally flat we will use the values from the table provided in slide 17 of *Microwave Filter Design 2*

N	g_0	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8
...	...	...	...	...	...	...	...	...	...
7	1.0000	0.4450	1.2470	1.8019	2.0000	1.8019	1.2470	0.4450	1.0000

```
[4]: g_list = [1.0000, 0.4450, 1.2470, 1.8019, 2.0000, 1.8019, 1.2470, 0.4450, 1.
     ↪0000]
     C_list = []
     L_list = []
     i = 0
     for g in g_list:
         if(i <= 0 or i==n+1):
             print(" ")
             #print("Do Nothing")
         elif(i % 2 == 0 and i > 0):
             #print("par")
             L_list.append((R_0*g)/w_c)
         elif(i % 2 == 1 and i > 0):
             #print("impar")
             C_list.append(g/(R_0*w_c))
         #print(g)
         #print(f"i={i}")
         i+=1

     i = 1
     for c in C_list:
         print(f"C{i} = {c:.3e} F")
         i+=1
     i=1
     print(" ")
     for l in L_list:
         print(f"L{i} = {l:.3e} H")
         i+=1
     print(" ")
     beta = (2*np.pi)/wavelength
```

```python
print(f"{beta = :.3f}")
print(f"{wavelength = :.3f}")
microstrip_l_list = []
microstrip_betal_list = []
i = 0
for g in g_list:
    if(i % 2 == 0 and i >= 1 and i <= n):
        #print(f"Bobine")
        microstrip_l_list.append((((g*R_0)/z_high)/beta)
        microstrip_betal_list.append((g*R_0)/z_high)
    if(i % 2 == 1 and i >= 1 and i <= n):
        #print("Condensador")
        microstrip_l_list.append((((g*z_low)/R_0)/beta)
        microstrip_betal_list.append((g*z_low)/R_0)
    i+=1

# Speed of wave in substrate is needed for this calculation
#i=1
#print(" ")
#for l in microstrip_l_list:
#    print(f"Lengh {i} = {l:.3e} m")
#    i+=1

i=1
print(" ")
for l in microstrip_betal_list:
    if(i % 2 == 1): string = f"Capacitor {i}  Z_0={z_low} "
    else: string = f"Inductor  {i}  Z_0={z_high}"
    print(f"{string} Angle = {l:.3f} rads or {l * (180/np.pi):.3f} degrees")
    i+=1
```

```
C1 = 7.082e-13 F
C2 = 2.868e-12 F
C3 = 2.868e-12 F
C4 = 7.082e-13 F

L1 = 4.962e-09 H
L2 = 7.958e-09 H
L3 = 4.962e-09 H

beta = 41.888
wavelength = 0.150

Capacitor 1  Z_0=10  Angle = 0.089 rads or 5.099 degrees
Inductor  2  Z_0=150 Angle = 0.416 rads or 23.816 degrees
```

```
Capacitor 3  Z_0=10  Angle = 0.360 rads or 20.648 degrees
Inductor  4  Z_0=150 Angle = 0.667 rads or 38.197 degrees
Capacitor 5  Z_0=10  Angle = 0.360 rads or 20.648 degrees
Inductor  6  Z_0=150 Angle = 0.416 rads or 23.816 degrees
Capacitor 7  Z_0=10  Angle = 0.089 rads or 5.099 degrees
```

[4]:
```
!pip install scikit-rf
!pip install matplotlib
```

```
Requirement already satisfied: scikit-rf in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (0.24.0)
Requirement already satisfied: pandas~=1.1 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from scikit-rf)
(1.5.1)
Requirement already satisfied: scipy~=1.7 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from scikit-rf)
(1.9.3)
Requirement already satisfied: numpy~=1.21 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from scikit-rf)
(1.23.4)
Requirement already satisfied: python-dateutil>=2.8.1 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
pandas~=1.1->scikit-rf) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
pandas~=1.1->scikit-rf) (2022.6)
Requirement already satisfied: six>=1.5 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from python-
dateutil>=2.8.1->pandas~=1.1->scikit-rf) (1.16.0)

[notice] A new release of pip
available: 22.2.2 -> 22.3.1
[notice] To update, run:
pip install --upgrade pip
Requirement already satisfied: matplotlib in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (3.6.2)
Requirement already satisfied: kiwisolver>=1.0.1 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (1.4.4)
Requirement already satisfied: numpy>=1.19 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (1.23.4)
Requirement already satisfied: pyparsing>=2.2.1 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (3.0.9)
Requirement already satisfied: packaging>=20.0 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (21.3)
```

Requirement already satisfied: python-dateutil>=2.7 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (2.8.2)
Requirement already satisfied: cycler>=0.10 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (0.11.0)
Requirement already satisfied: fonttools>=4.22.0 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (4.38.0)
Requirement already satisfied: contourpy>=1.0.1 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (1.0.6)
Requirement already satisfied: pillow>=6.2.0 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from
matplotlib) (9.3.0)
Requirement already satisfied: six>=1.5 in
/home/gitpod/.pyenv/versions/3.8.13/lib/python3.8/site-packages (from python-
dateutil>=2.7->matplotlib) (1.16.0)

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```
[8]: #Plot VNA Result

     import skrf as rf
     ntwk = rf.Network('data/filtro SI 2GHz-ERF.s2p')
     s = ntwk.s
     %matplotlib inline
     from pylab import *
     rf.stylely()
     ntwk.plot_s_db()
```