Lab 4

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
```

```
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
```

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

[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()
```