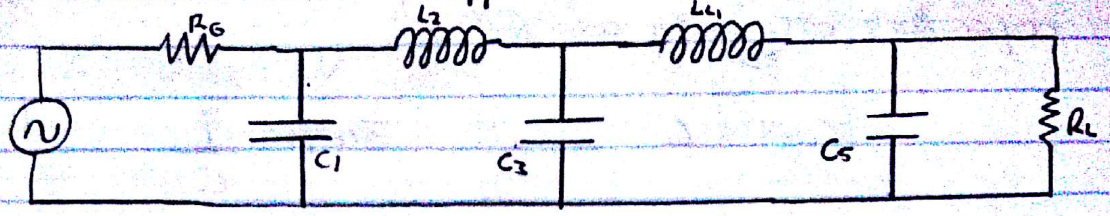
RF ELECTRONICS HOMEWORK 1 FERGAL LONERGAN

DESIGN NUMBER 3 0.5dB Ripple 2GHz 20dB@3.2GHz



Element	Normalised value
RG	1
C1	1.7058
L2	1.2296
C3	2.5408
L4	1.2296
C5	1.7058
RL	1

The filter that satisfied our specifications was the N=5 Chebyshev 0.5dB ripple filter
our denormalised element values are:

Element	denormalisation equation	denormalised value
RG	1×50	50 Ω
C1	$\frac{1}{2\pi(2\times10^9)} \frac{1.7058}{50}$	2.714 pF
L2	$\frac{50(1.2296)}{2\pi(2\times10^9)}$	4.892 nH
C3	$\frac{2.5408}{50(2\pi)(2\times10^9)}$	4.044pF
L4	Same as L2	4.892nH
C5	same as C1	2.714pF
RL	same as RG	50 Ω

As our circuit had to match our 50Ω LOAD AND INPUT IMPEDANCE we had to choose an odd ordered filter

Now we have a lumped element filter design we can use Richard's Transformation to convert it to a microstrip implementation. For this we use our normalised values for our capacitors and inductors and resistors

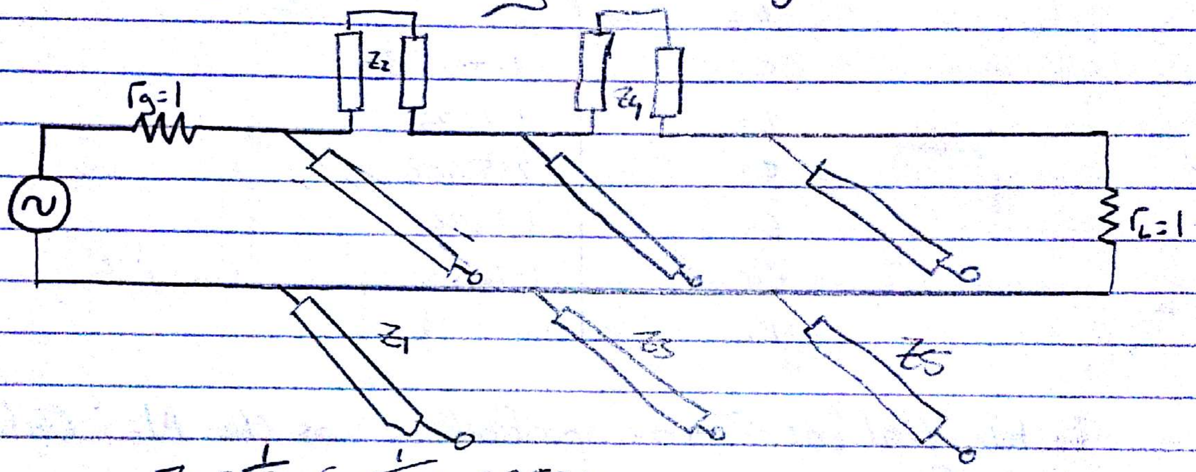
We replace inductors with shorted stubs of length $\frac{\lambda}{8}$ and capacitors with open stubs of length $\frac{\lambda}{8}$.

Scanned by CamScanner

Our normalized characteristic impedances for our inductors and capacitors are given as follows:

$$Z(\text{ind}) = L \qquad Z(\text{cap}) = \frac{1}{C}$$

Now redrawing our circuit using stubs we get:



$Z_1 = \frac{1}{C_1} = \frac{1}{1.7058} = 0.5862$

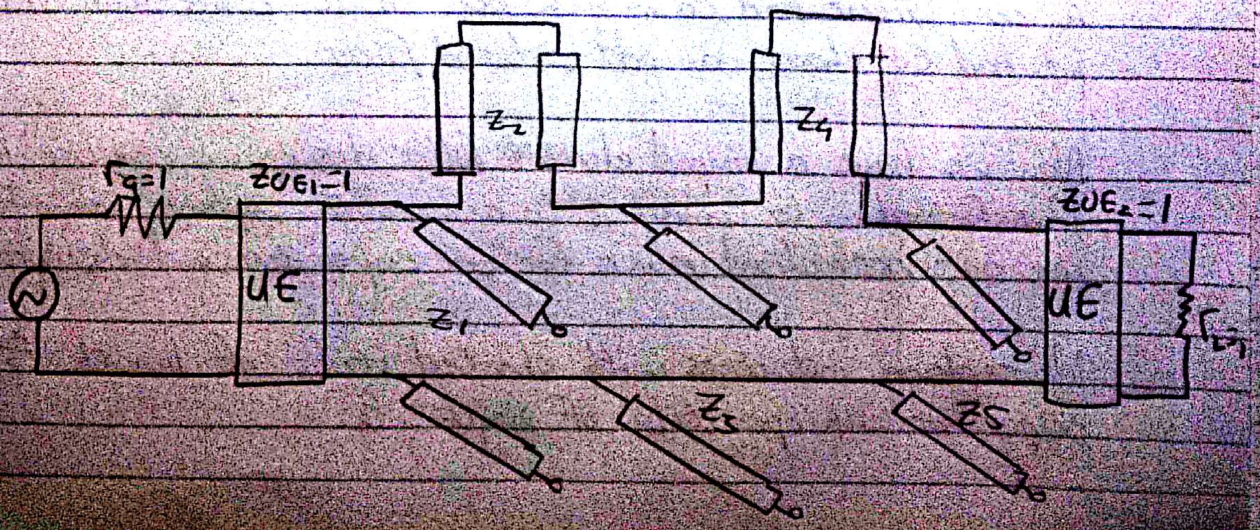
$Z_2 = L_2 = 1.2296$

$Z_3 = \frac{1}{C_3} = \frac{1}{2.5408} = 0.3936$

$Z_4 = L_4 = 1.2296$

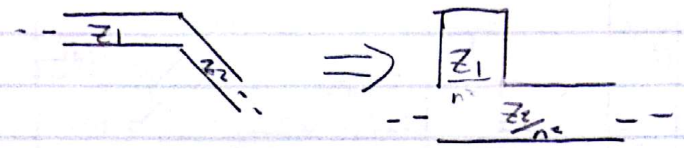
$Z_5 = \frac{1}{C_5} = \frac{1}{1.7058} = 0.5862$

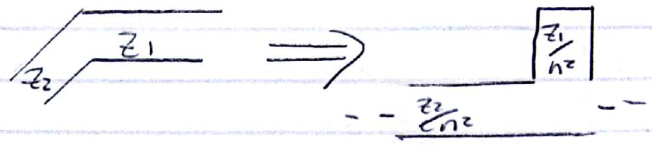
We use Kuroda Identities to convert our short circuit stubs into open circuit stubs as short circuit stubs are difficult to manufacture. To do this we must also introduce two unit elements at the input and output of the filter.

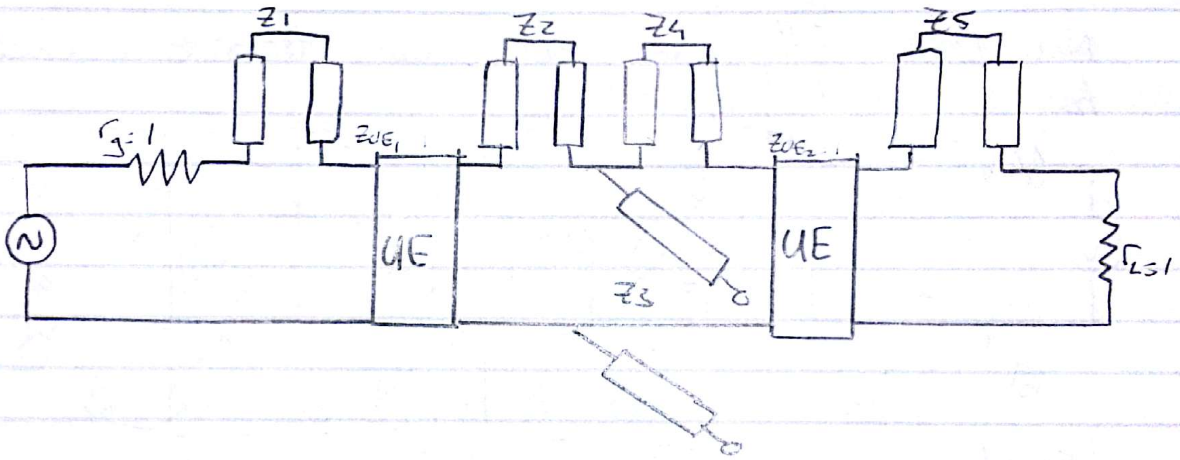


We can now transform our design using the following two identities:

$$n^2 = 1 + \frac{Z_2}{Z_1}$$







$$n^2 = \frac{1+Z_1}{Z_{UE_1}} = 1 + \frac{1}{1.7058}$$

$$Z_{UE_1} = \frac{Z_1}{n^2} = \frac{\frac{1}{1.7058}}{1+\frac{1}{1.7058}} = 0.3696$$

$$Z_1 = \frac{Z_{UE1}}{n^2} = \frac{1}{1+\frac{1}{1.7058}} = 0.6304$$

$$Z_2 = 1.2296$$

$$Z_3 = \frac{1}{2.5408} = 0.3936$$

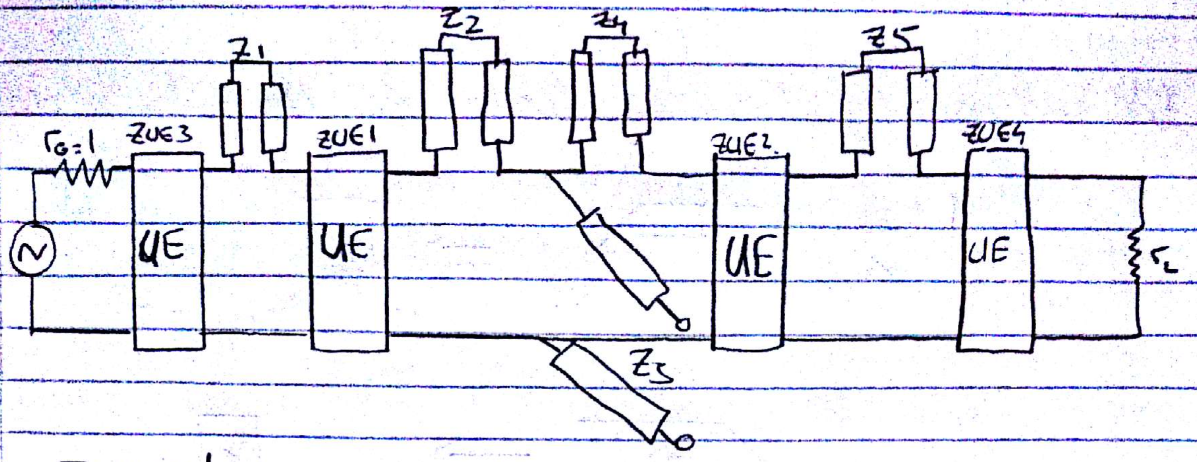
$$Z_4 = 1.2296$$

Similarly as above

$$Z_{UE2} = \frac{Z5}{n^2} = \frac{\frac{1}{1.7058}}{1+\frac{1}{1.7058}} = 0.3696$$

$$Z5 = \frac{Z_{UE2}}{n^2} = \frac{1}{1+\frac{1}{1.7058}} = 0.6304$$

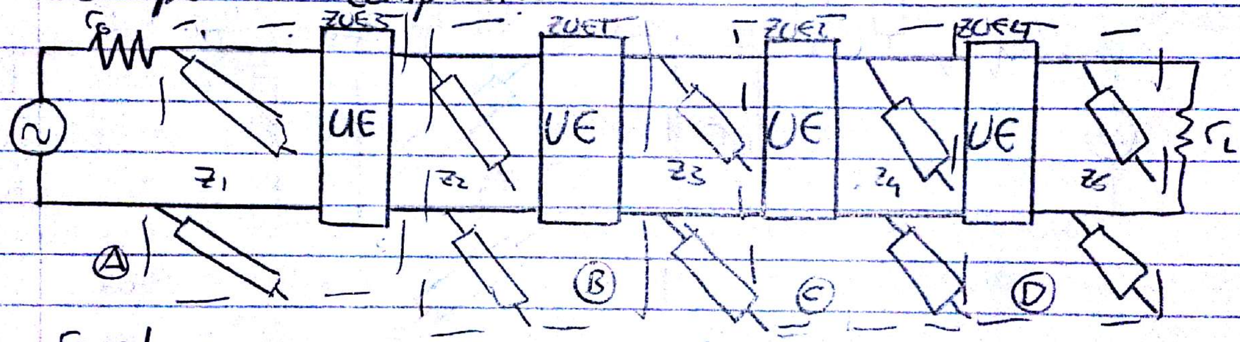
Again we add in unit elements to our circuit, at the input & output



$Z_{UE3} = 1$

$Z_{UE4} = 1$

Now we can fully convert our circuit design so it exclusively has open stub components



$r_{g1} = 1$

$r_L = 1$

$z_3 = \frac{1}{2.5408} = 0.3936$

(A) $n^2 = 1 + \frac{Z_{UE3}}{Z_1} = 1 + \frac{1}{0.6304}$

$z_1 = Z_{UE3} \times n^2 = (1)(1 + \frac{1}{0.6304}) = 2.5863$

$Z_{UE3} = z_1 \times n^2 = 0.6309(1 + \frac{1}{0.6304}) = 1.6304$

(B) $n^2 = 1 + \frac{Z_{UE1}}{Z_2} = 1 + \frac{0.3696}{1.2296}$

$z_2 = Z_{UE2} \times n^2 = 0.3696(1 + \frac{0.3696}{1.2296}) = 0.4807$

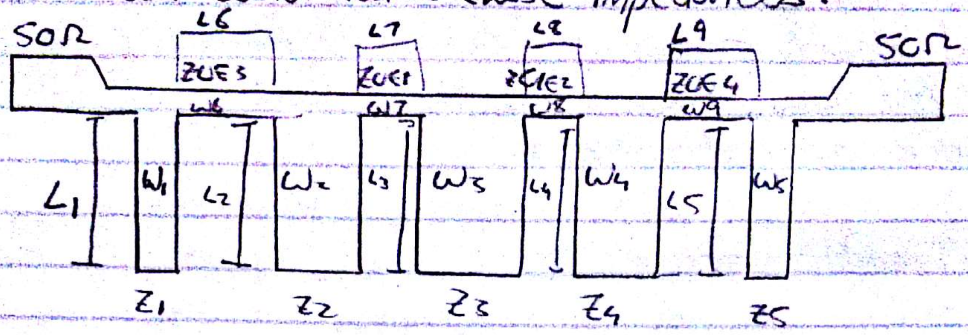
$Z_{UE1} = z_2 \times n^2 = 1.2296(1 + \frac{0.3696}{1.2296}) = 1.5992$

(A) is the same as (D) and (B) is the same as (C)

$\Rightarrow$ $Z_4 = 0.4807$ $\quad$ $Z_5 = 2.5863$

$Z_{UE2} = 1.5992$ $\quad$ $Z_{UE4} = 1.6304$

Now we can denormalise these impedances:



$R_G = 50\Omega$
$Z_1 = 129.32\Omega$
$Z_2 = 24.04\Omega$
$Z_3 = 19.68\Omega$
$Z_4 = 24.04\Omega$
$Z_5 = 129.32\Omega$
$Z_{OE1} = 79.96\Omega$
$Z_{OE2} = 79.96\Omega$
$Z_{OE3} = 81.52\Omega$
$Z_{OE4} = 81.52\Omega$
$R_L = 50\Omega$

The electrical lengths of all lines is:
$\frac{\lambda}{8} \cdot \frac{2\pi}{\lambda} = \frac{\pi}{4}$

We use TXLINE TO Find the widths (From MICROWAVE OFFICE)

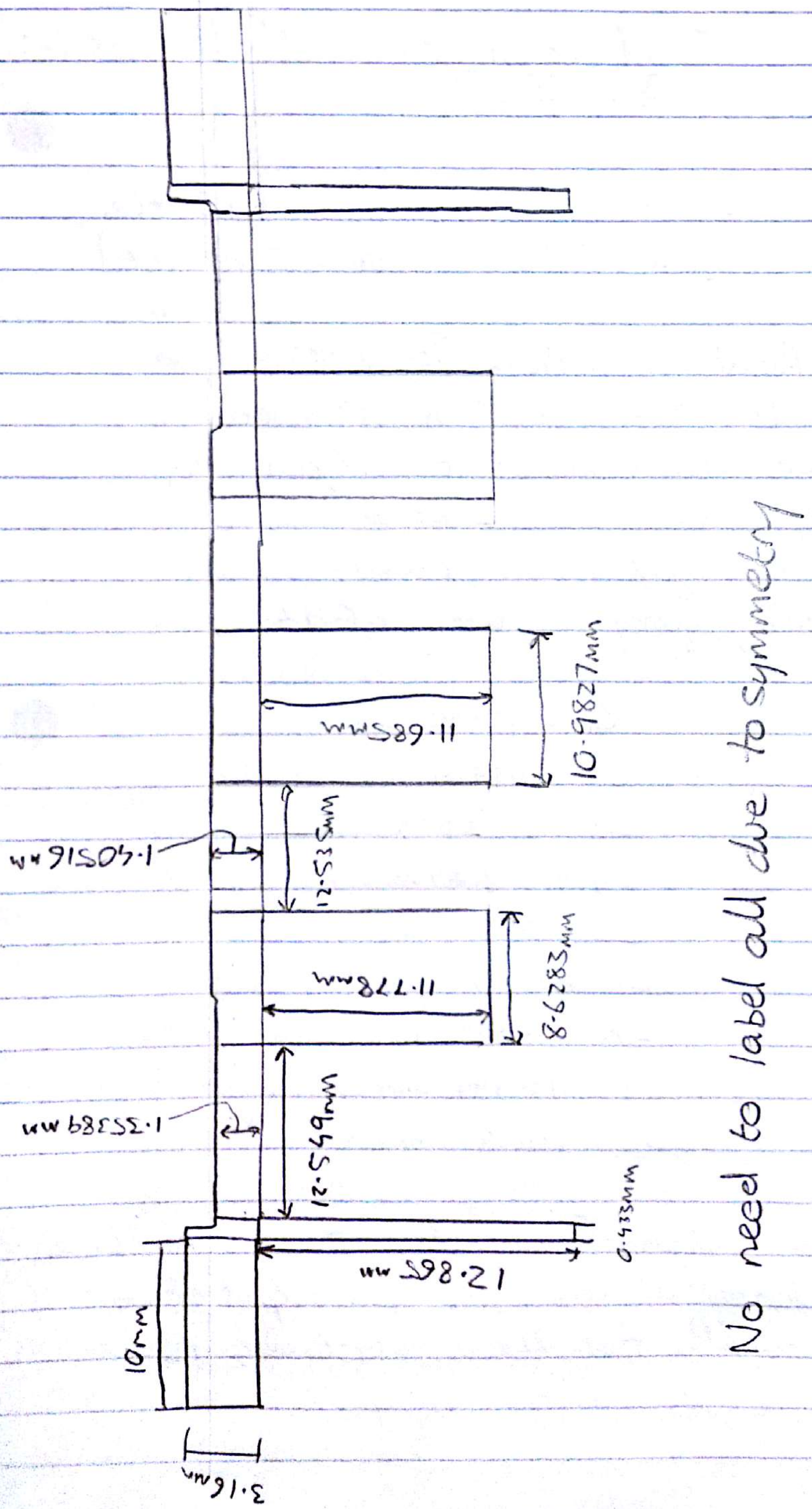
Relative Permittivity	$\varepsilon_r = 2.55$
Substrate thickness	$h = 1.14$mm
Conductor thickess	$t = 18\mu m$
Conductor:	Copper
Loss Tangent	0.001
Cutoff frequency	$W_c = 2$GHz

$W_1 = 0.43276$ mm — $L_1 = 13.5425$ mm
$W_2 = 8.6283$ mm — $L_2 = 12.3974$ mm
$W_3 = 10.9827$ mm — $L_3 = 12.2997$ mm
$W_4 = 8.6283$ mm — $L_4 = 12.3974$ mm
$W_5 = 0.43276$ mm — $L_5 = 13.5425$ mm
$W_6 = 1.35389$ mm — $L_6 = 13.2091$ mm
$W_7 = 1.40516$ mm — $L_7 = 13.1949$ mm
$W_8 = 1.40516$ mm — $L_8 = 13.1949$ mm
$W_9 = 1.35389$ mm — $L_9 = 13.2091$ mm

As in our Lab design we add 10mm of microstrip transmission Line of 50Ω charateristic impedance at the input and output of our filter. Using TXLine the width for these sections is 3.16mm

I then ran my microstrip circuit and compared it to my lumped element circuit in AWR. I tuned all the lengths, apart from the two 10mm TLs, by a factor of 0.95 to give a more accurate match.

New lengths are



My First graph shows the frequency response. It doesn't match well enough so we scale our lengths by 0.95.

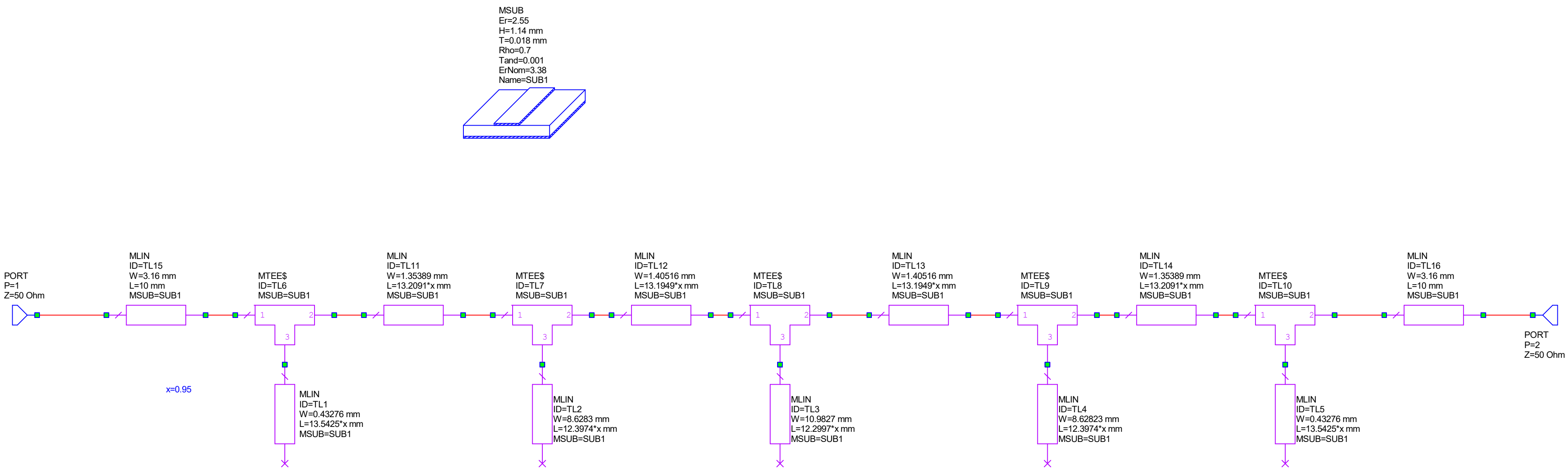
The second graph confirms our design matches our filter specifications. We see our cut-off frequency is at 2GHz and the insertion loss at 3.2GHz is around 43dB. We were asked to design a circuit with a minimum insertion loss at 3.2GHz of 20dB so our filter fulfils the specifications.

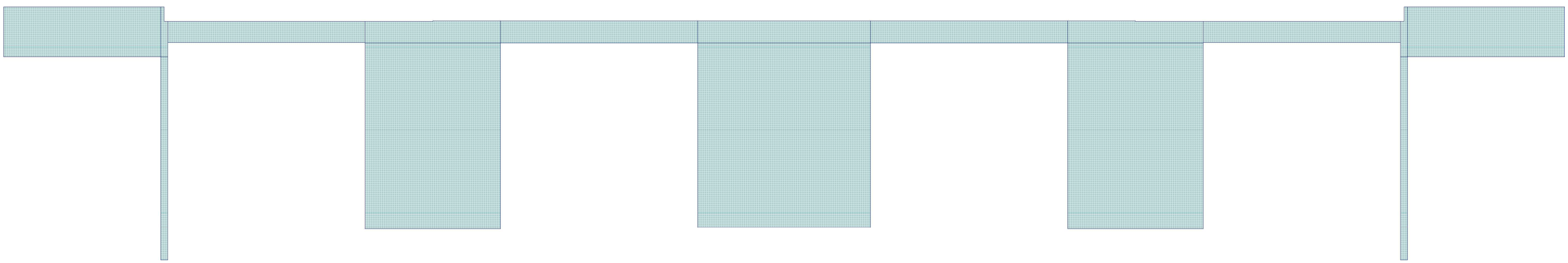
- My third graph compares our filter to the stepped impedance implementation filter we designed for last weeks lab. Both filters had to fulfil the same specifications.

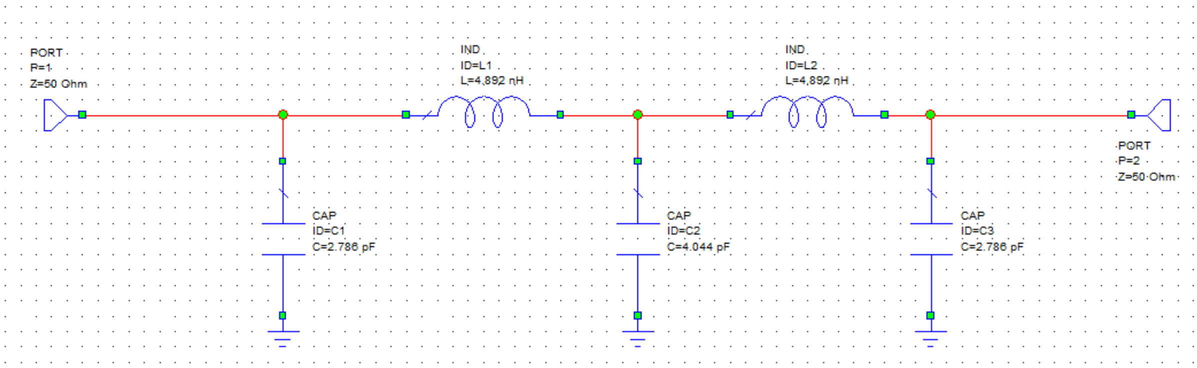
We see both circuits fulfil the specifications however our stepped impedance implementation filter gives a much lower insertion loss of dB, in comparison to the ~43dB we get using the Richard transformations. This is due to us using a lot of simplifying assumptions in our stepped impedance implementation filter that we didn't use in our Richard's Transformation filter. Therefore the Richard's transformation filter is much more accurate.

- Implementing the stepped impedance design of our filter is a lot more straightforward to manufacture than our Richard's transformation filter.

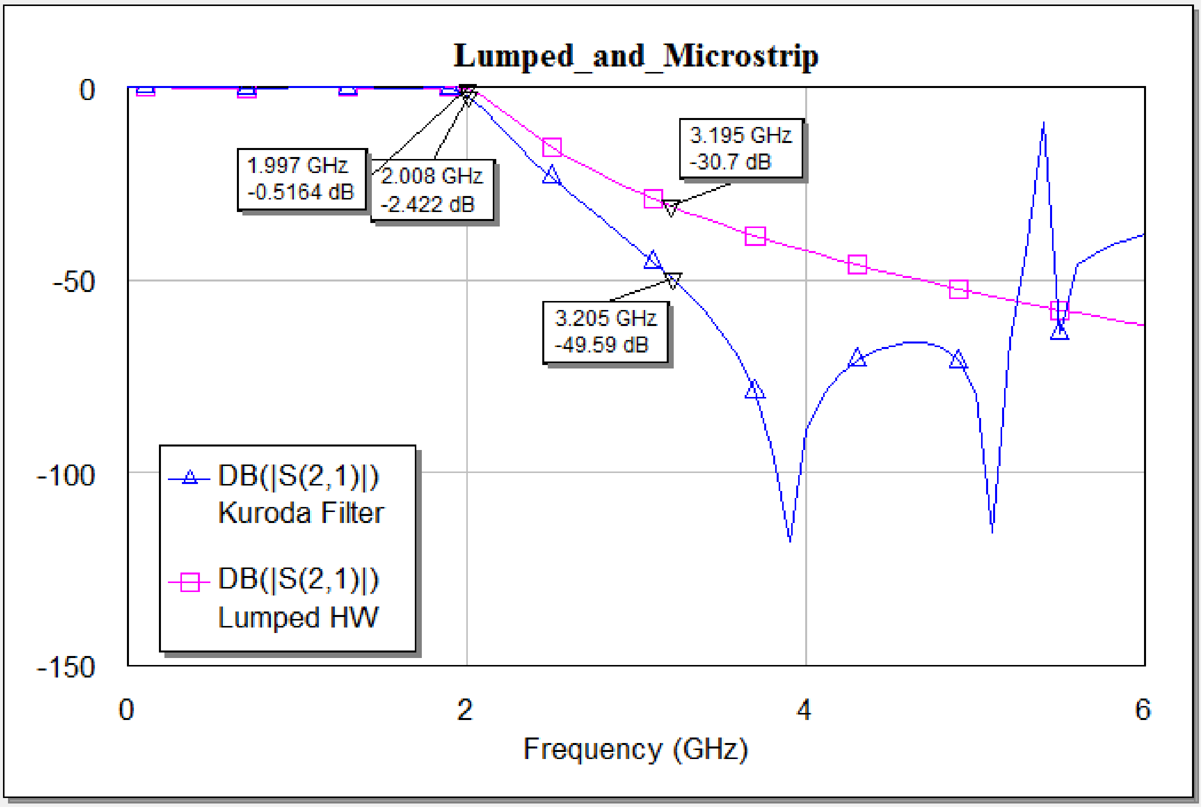
I would conclude in saying that a far more practical solution than using the Richard's transformation design would be to design a higher order stepped impedance filter, As the 43dB insertion loss is really quite excessive and not merited for these specifications.


MSUB
Er=2.55
H=1.14 mm
T=0.018 mm
Rho=0.7
Tand=0.001
ErNom=3.38
Name=SUB1
PORT
P=1
Z=50 Ohm
MLIN
ID=TL15
W=3.16 mm
L=10 mm
MSUB=SUB1
MTEE$
ID=TL6
MSUB=SUB1
MLIN
ID=TL11
W=1.35389 mm
L=13.2091*x mm
MSUB=SUB1
MTEE$
ID=TL7
MSUB=SUB1
MLIN
ID=TL12
W=1.40516 mm
L=13.1949 mm
MSUB=SUB1
MTEE$
ID=TL8
MSUB=SUB1
MLIN
ID=TL13
W=1.40516 mm
L=13.1949*x mm
MSUB=SUB1
MTEE$
ID=TL9
MSUB=SUB1
MLIN
ID=TL14
W=1.35389 mm
L=13.2091*x mm
MSUB=SUB1
MTEE$
ID=TL10
MSUB=SUB1
MLIN
ID=TL16
W=3.16 mm
L=10 mm
MSUB=SUB1
PORT
P=2
Z=50 Ohm
x=0.95
MLIN
ID=TL1
W=0.43276 mm
L=13.5425*x mm
MSUB=SUB1
MLIN
ID=TL2
W=8.6283 mm
L=12.3974*x mm
MSUB=SUB1
MLIN
ID=TL3
W=10.9827 mm
L=12.2997*x mm
MSUB=SUB1
MLIN
ID=TL4
W=8.62823 mm
L=12.3974*x mm
MSUB=SUB1
MLIN
ID=TL5
W=0.43276 mm
L=13.5425*x mm
MSUB=SUB1

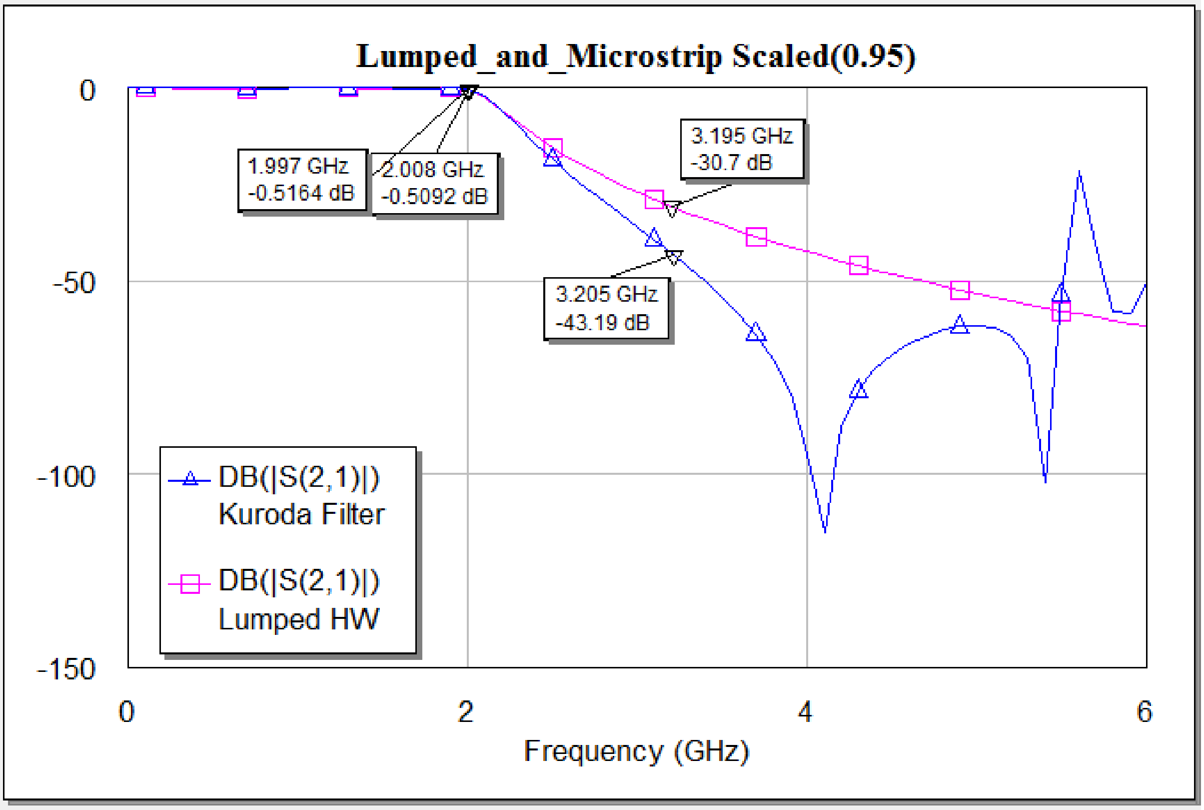




Circuit 1



Graph 1



Graph 2

Graph 3