

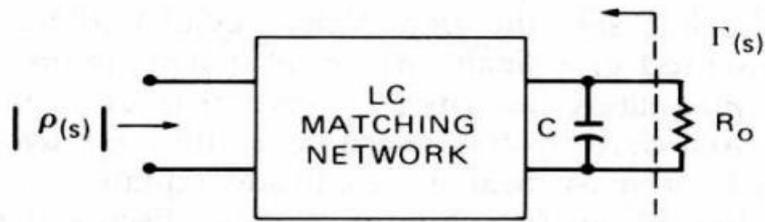
# ***FANO MATCH DESIGN AID***

## ***WITH DESIGN EXAMPLE***

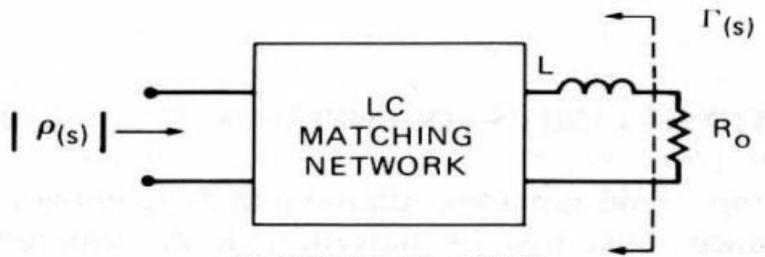
# BACKGROUND

- Load  $Q$  sets the achievable impedance match limit for a given bandwidth
- Canonic BP match obtained from LP prototype
- These are normalized in frequency and impedance
- The LP to BP transformation maps lowpass series inductors to series LC branches and shunt capacitors to parallel LC branches.
- Practical design are obtained by frequency and impedance scaling the normalized solutions
- The Fano Match design aid does all this
- R.M. Fano (MIT Research Lab) pioneered optimum matching network design
- H.W. Bode (Bell Labs) quantified the achievable match limits. This is load  $Q$  and BW dependent

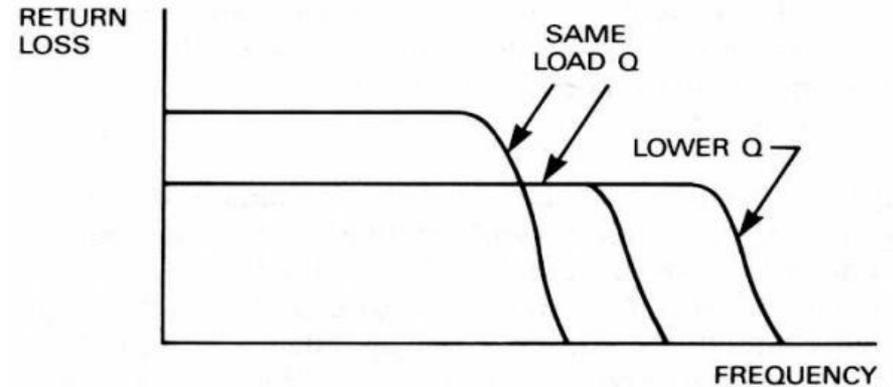
# LOAD Q vs BANDWIDTH



(a) PARALLEL RC LOAD



(b) SERIES RL LOAD

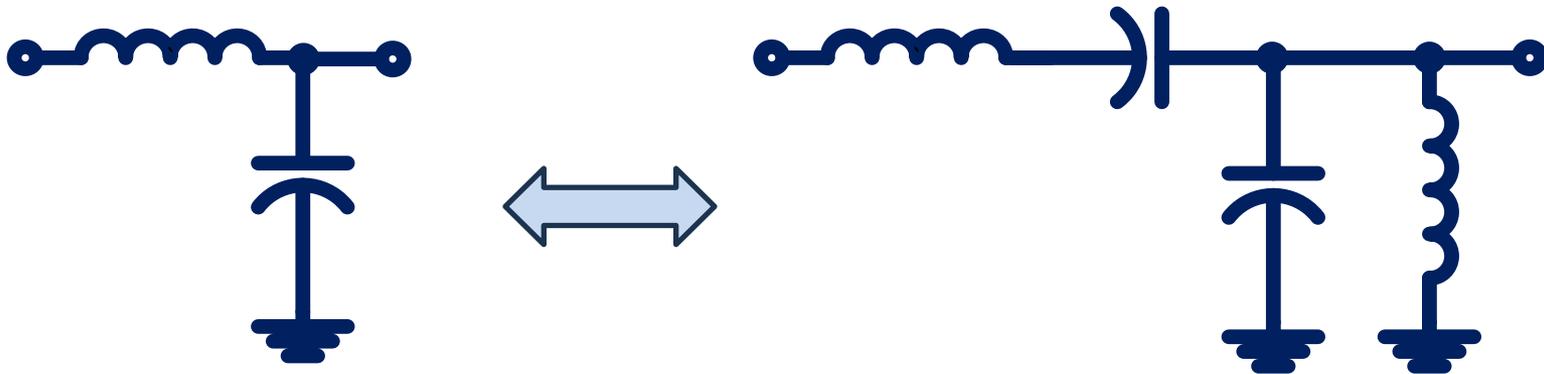


$$Q_{LP} = \frac{Q_{BP}}{Q_{TRANSFORM}}$$

$$Q_{TRANSFORM} = \frac{\sqrt{F_1 F_2}}{(F_2 - F_1)}$$

# LOWPASS TO BANDPASS

*LP SERIES L MAPS TO BP SERIES LC PAIR*  
*LP SHUNT C MAPS TO BP SHUNT LC PAIR*



*LOWPASS PROTOTYPE*

*CANONIC BANDPASS*

*BASIC LADDER NETWORKS*

# LOAD Q CALCULATION

Fano Match

FANO Q CALC NORTON HELP

## Q CALCULATOR

Type of Load

Series RL      Freq L  MHz      R =   $\Omega$

Shunt RC      Freq H  MHz      L =  nH

Series RC

Shunt RL

     Q =

IDEAL MATCH LIMITS

-----

Q calculated = 2.4  
Transform Q = 1.9  
Bandwidth = 51.6 %  
Loss [Bode] = -0.03 dB  
VSWR [Bode] = 1.18:1

# FANO MATCH

Fano Match

FANO Q CALC NORTON HELP

## FANO BROADBAND MATCH

Lower Freq. =  MHz  
Upper Freq. =  MHz  
Load R =   $\Omega$   
Load Q =

<http://k5tra.net>

Net.Order:  2  4  6  8  10  
LC Absorption:  1 Sided  2 Sided  
Load Form:  Series  Parallel

Bandwidth = 51.64 %  
Network order = 4  
Fano Parameters: a = 1.1760, b = 0.3347

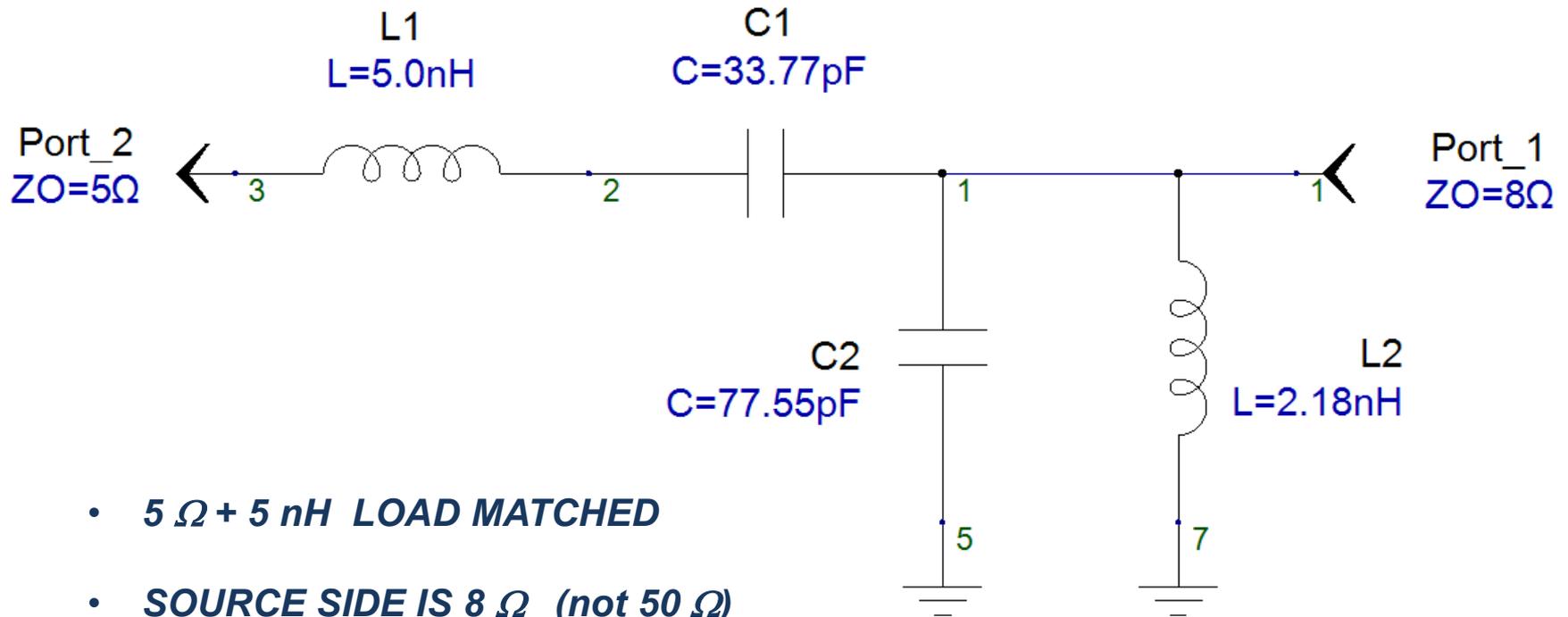
Loss [Max] = -0.24 dB  
Loss [Min] = -0.08 dB  
Loss [Bode] = -0.03 dB

VSWR [Max] = 1.61:1  
VSWR [Min] = 1.32:1  
VSWR [Bode] = 1.18:1

G[0] = 1.00000  
G[1] = 1.25664  
G[2] = 0.48723  
G[3] = 1.60597

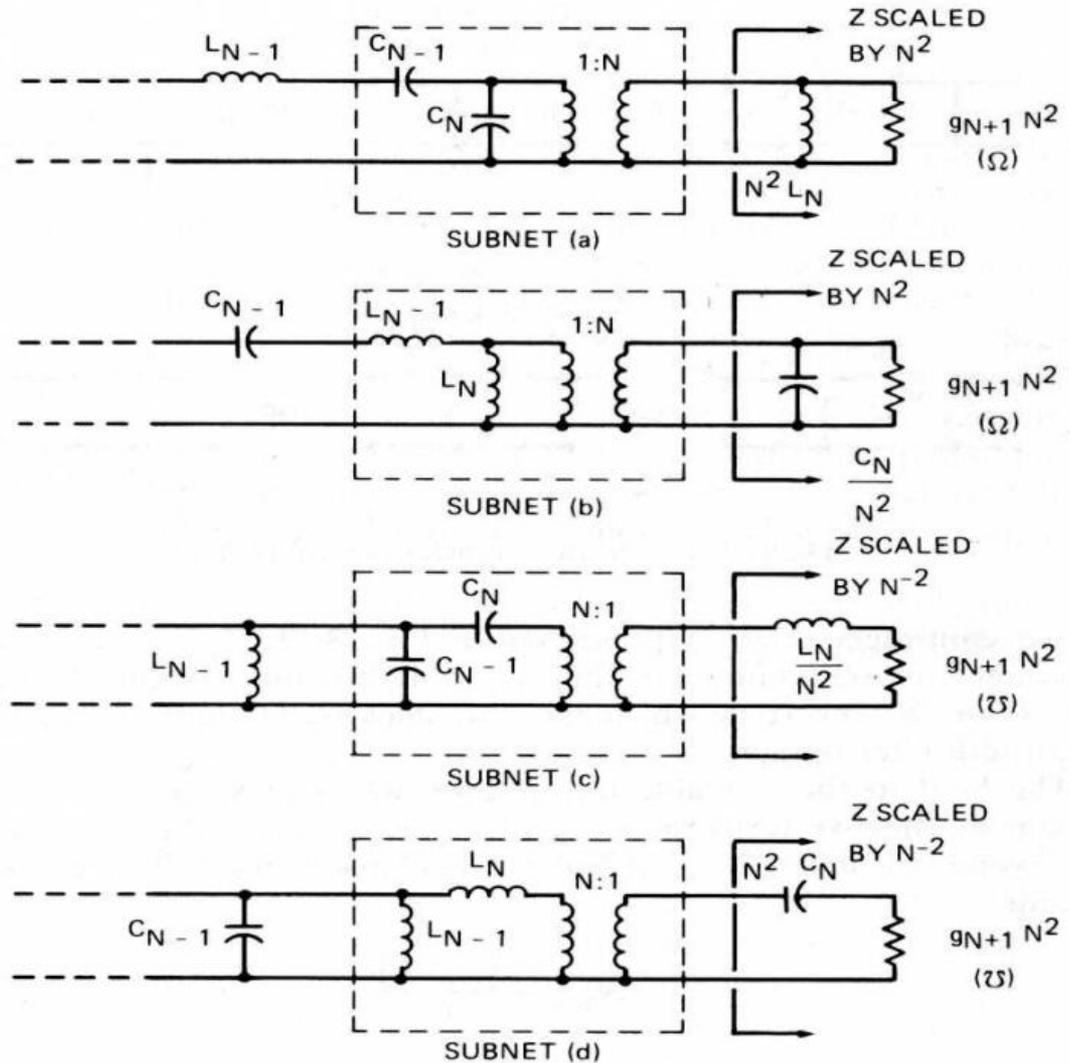
FANO-BANDPASS  
-----  
R = 5.0 Ohm  
Ls = 5.00 nH  
Cs = 33.77 pF  
Lp = 2.18 nH  
Cp = 77.55 pF  
R = 8.0 Ohm

# INITIAL CANONIC BP MATCH

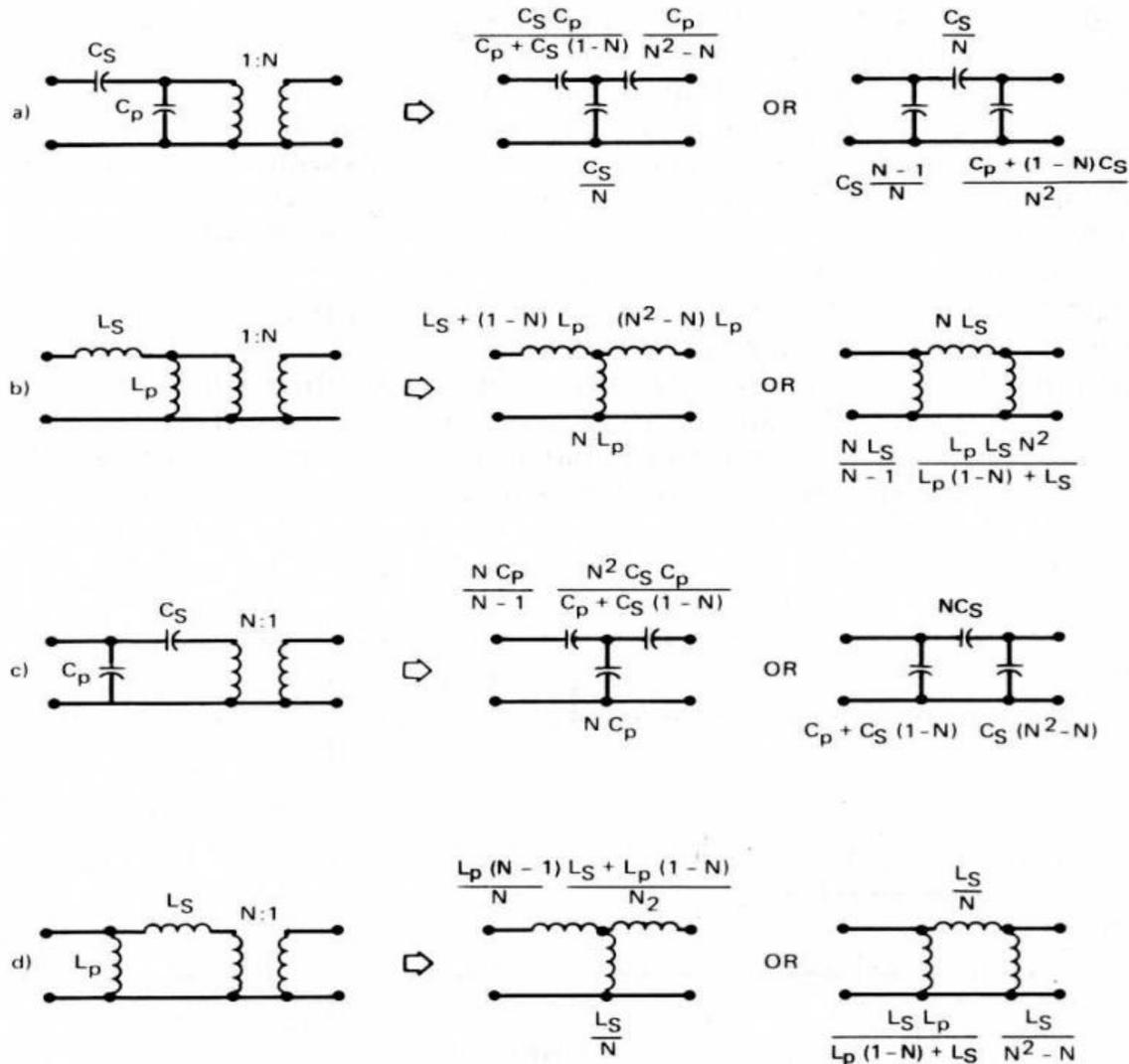


# NORTON IMPEDANCE TRANSFORMATION

***AN IDEAL TRANSFORMER  
CASCADED WITH A PAIR  
OF L's or C's CAN BE  
REPLACED WITH AN  
EQUIVALENT NETWORK  
OF L's or C's***



# NORTON EQUIVALENT NETWORKS



T.Apel

# NORTON TRANSFORMER CALCULATION

Fano Match

FANO Q CALC NORTON HELP

## NORTON TRANSFORMER

Series

Shunt

Max/Min

Desired Z

L Type

C Type

Up

Down

**T Norton**

< LOAD SIDE >

**π Norton**

**CALCULATE** # Elements After Norton

L,C, or R	INITIAL	SCALED
<input type="text" value="L"/>	<input type="text" value="2.18"/>	<input type="text" value="13.574"/>
<input type="text" value="R"/>	<input type="text" value="8.0"/>	<input type="text" value="49.814"/>

-----

System reference = 8.03 Ohms  
 Series element = 33.77 pF  
 Shunt element = 77.55 pF  
 Zin limit available = 87.26 Ohms  
 Transform up to 50.00 Ohms  
 Element values (from load side) :

'T' type NORTON

-----

C1(pF) = 96.808  
 C2(pF) = 31.08  
 C3(pF) = 20.78

'Pi' type NORTON

-----

C1(pF) = 20.24  
 C2(pF) = 13.53  
 C3(pF) = 4.34

Two elements impedance scaled:

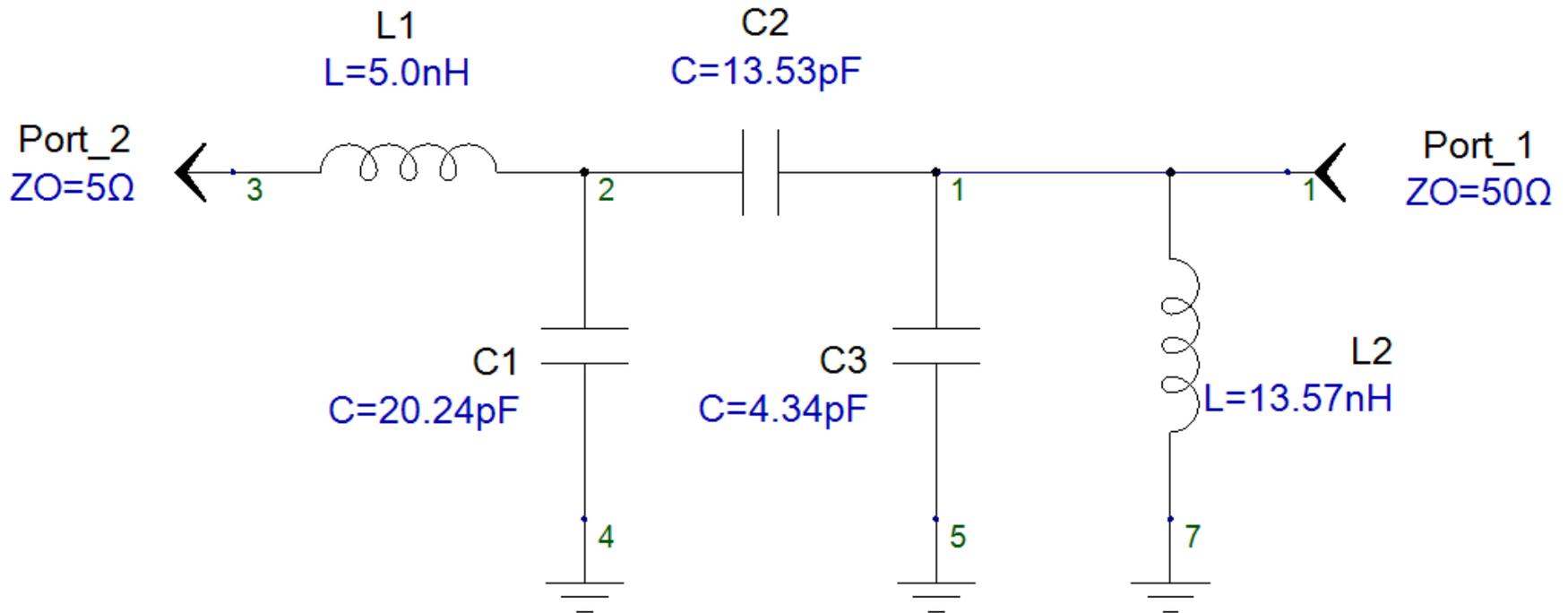
-----

L scaled from 2.18 to 13.574  
 R scaled from 8.0 to 49.814

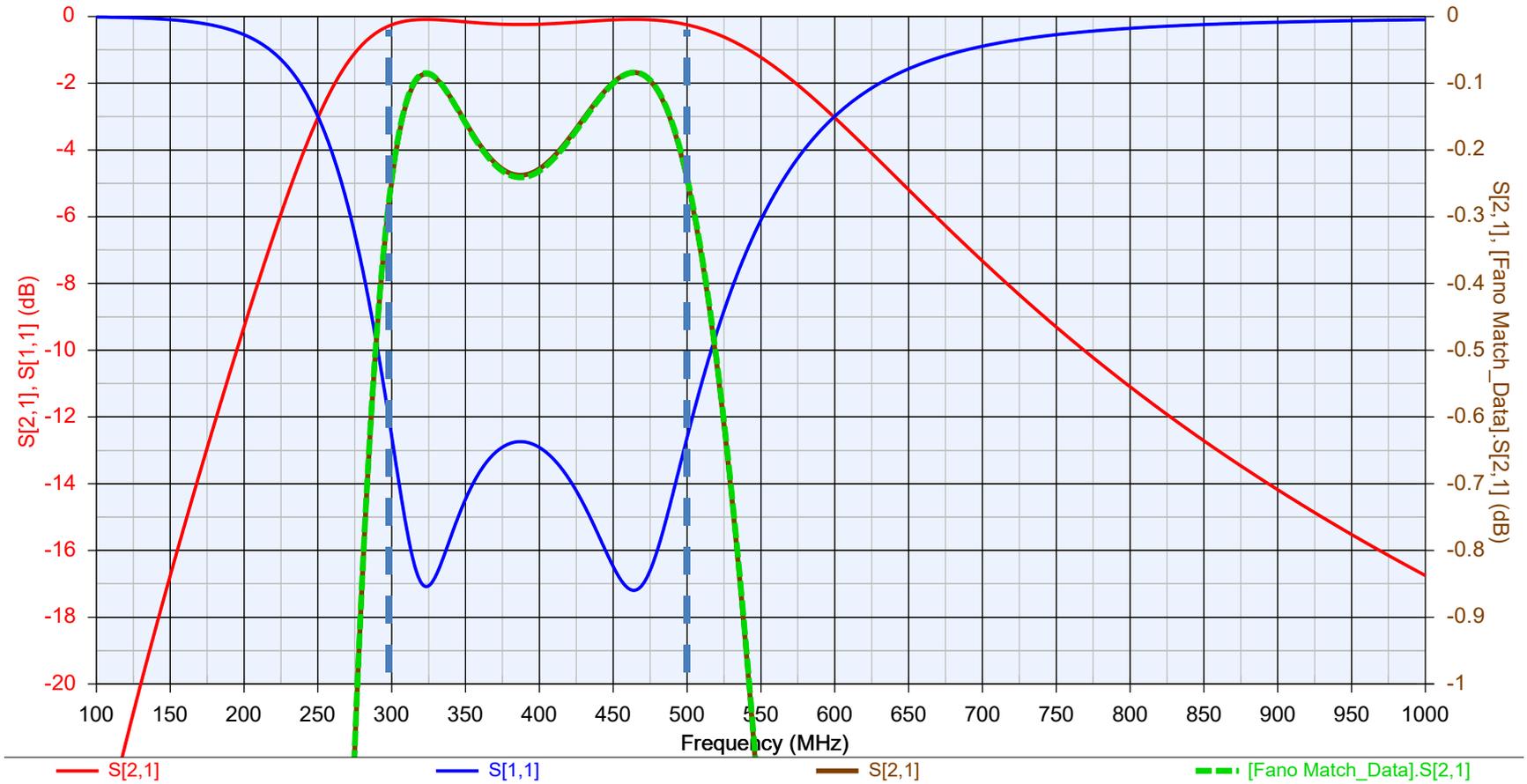
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**WRITE**

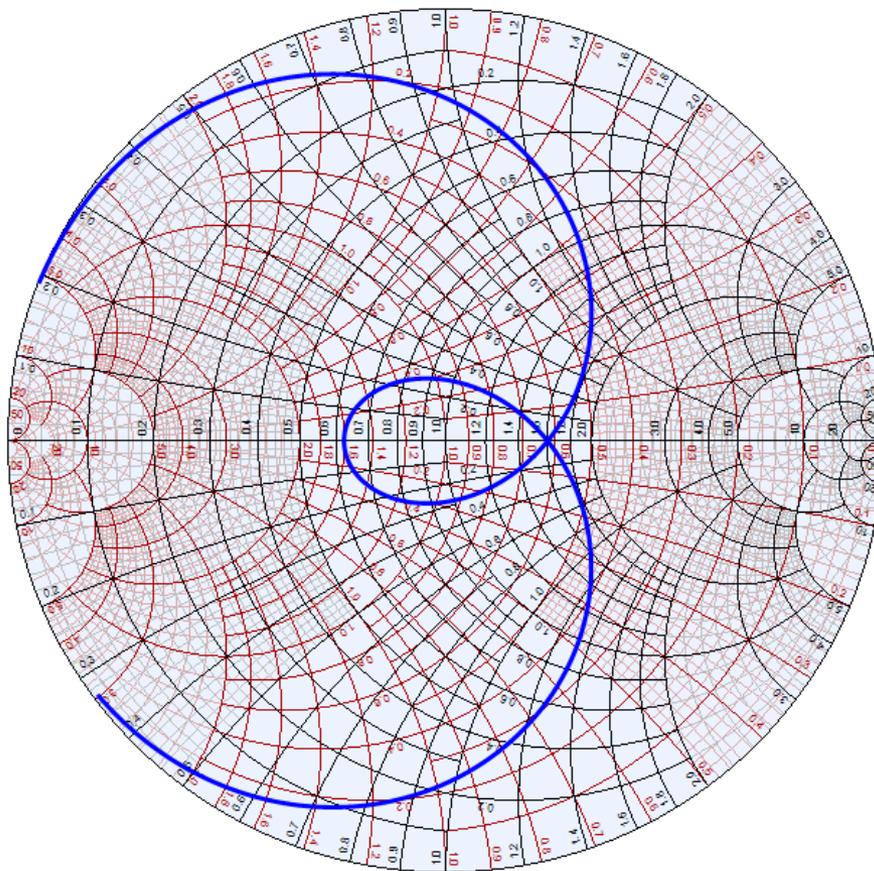
# COMPLETED FANO MATCH



# MATCH PERFORMANCE



# MATCH PERFORMANCE



T.Apel

# FANO MATCH OUTPUT FILE

## FANO IMPEDANCE MATCH

-----  
Lower Frequency = 300 MHz  
Upper Frequency = 500 MHz

Load Z = 5.00 Ohms  
Load Q = 2.433  
Decrement = 0.796  
Transform Q = 1.936  
Bandwidth = 51.64 %  
Network order = 4  
Fano Parameters: a = 1.1760, b = 0.3347

Loss [Max] = -0.24 dB  
Loss [Min] = -0.08 dB  
Loss [Bode] = -0.03 dB

VSWR [Max] = 1.61:1  
VSWR [Min] = 1.32:1  
VSWR [Bode] = 1.18:1

G[0] = 1.00000  
G[1] = 1.25664  
G[2] = 0.48723  
G[3] = 1.60597

## FANO-BANDPASS

-----  
R = 5.0 Ohm  
Ls = 5.00 nH  
Cs = 33.77 pF  
Lp = 2.18 nH  
Cp = 77.55 pF  
R = 8.0 Ohm

## CAPACITIVE NORTON TRANSFORMER

-----  
System reference = 8.03 Ohms  
Series element = 33.77 pF  
Shunt element = 77.55 pF  
Zin limit available = 87.26 Ohms  
Transform up to 50.00 Ohms  
Element values (from load side) :

### 'T' type NORTON

-----  
C1(pF) = 96.808  
C2(pF) = 31.08  
C3(pF) = 20.78

### 'Pi' type NORTON

-----  
C1(pF) = 20.24  
C2(pF) = 13.53  
C3(pF) = 4.34

Two elements impedance scaled:

-----  
L scaled from 2.18 to 13.574  
R scaled from 8.0 to 49.814