# Design Goal 2

\[ G_{TV} = 10 \, \text{dB} \quad \text{from} \quad 0 - 2 \, \text{GHz} \quad F < 4 \, \text{dB} \]

**Note:**

\[
G_0 = |S_{21}|^2 = \begin{cases} 
14 \, \text{dB} & f = 1 \\
11.8 \, \text{dB} & f = 1.5 \\
10 \, \text{dB} & f = 2 
\end{cases}
\]

\[
G_{s\max} = \frac{1}{1 - |S_{11}|^2} = \begin{cases} 
2.29 \, \text{dB} \\
1.94 \, \text{dB} \\
1.86 \, \text{dB} 
\end{cases}
\]

\[
G_{l\max} = \frac{1}{1 - |S_{21}|^2} = \begin{cases} 
4.25 \, \text{dB} \\
3.74 \, \text{dB} \\
3.59 \, \text{dB} 
\end{cases}
\]

For simplicity, since \( |S_{11}| < 0.64 \) over the entire range, let's make \( G_0 = 1 \), i.e., no matching network on input side.

Thus, we require \( G_{l\max} = \begin{cases} 
-4 \, \text{dB} @ 1 \, \text{GHz} \\
0 \, \text{dB} @ 2 \, \text{GHz} 
\end{cases} \)

The constant load circles:

\[ C_l = \frac{9L S_{22}^*}{(1 - (1 - 9L) |S_{22}|^2)} \]

\[ R_l = \frac{\sqrt{1 - S_{22}^* (1 - |S_{22}|^2)}}{1 - (1 - 9L) |S_{22}|^2} \]

<table>
<thead>
<tr>
<th>( f )</th>
<th>( C_l )</th>
<th>( R_l )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.25 , \text{dB}</td>
<td>0.74</td>
</tr>
<tr>
<td>2</td>
<td>0.48 , \text{dB}</td>
<td>0.49</td>
</tr>
</tbody>
</table>
For a noise figure, we have the following noise circles:

<table>
<thead>
<tr>
<th>f</th>
<th>N</th>
<th>CF</th>
<th>RF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.245</td>
<td>0.214</td>
<td>82°</td>
</tr>
<tr>
<td>1.5</td>
<td>0.448</td>
<td>0.18</td>
<td>61°</td>
</tr>
<tr>
<td>2</td>
<td>0.859</td>
<td>0.22</td>
<td>88°</td>
</tr>
</tbody>
</table>

These circles are plotted on the Smith chart. The optimum source impedances are also shown. Notice that the origin is inside these circles so the noise will be lower across the band without a matching network. In fact, \( F_{50} = \tilde{F}_{\text{min}} + \frac{4R_N}{20} \frac{\left| \Gamma_{\text{opt}} \right|^2}{1 + \left| \Gamma_{\text{opt}} \right|^2} \)

And this is much less than the spec so we can safely ignore noise with a 50Ω input source. Since the device is assumed unilateral, the load can be chosen independently to give best gain performance.

On the Smith chart, the -4.08 and 0.03 gain circles are plotted for the load at 16GHz and 26GHz. Any load impedance on the -4.03 chart that moves to the 0.03 chart from 1-2.6GHz is an acceptable solution.
The following arch is chosen (L-L match)

\[
\begin{align*}
L_2 & \quad 50 \\
\quad 50 & \quad 0 \\
\quad 2 & \quad 1 \quad 2 \\
0.08 & \quad 0.16 \\
0.08 & \quad 0.16 \\
L_1 & = \frac{Z_0}{0.9 \cdot \omega L} = 4.92 \text{ nH} \\
L_2 & = \frac{0.08 Z_0}{\omega} = 318 \text{ pH}
\end{align*}
\]

We desire to find a point on the \((1+jb)\) circle (shown in red) such that a series reactance will move it to the constant gain circle in such a way that \(b_1/b_2 = 2\) (ratio in freq). By trial and error we find that \(1-0.9j\) at 2GHz requires \(0.08j\) of series reactance and \(1-1.8j\) at 16GHz requires about \(0.16j\) of series reactance, exactly in the correct proportion:

A simulation of the obtained gain over the entire band is shown in the following page. The gain deviates by 0.1dB at the band edges and 0.3dB near the center.
* BPTM 65nm NMOS

```plaintext
model nmos bsim4\n  \binunit = 1            \paramchk= 1            \mobmod = 0            \geomod = 1            \
capmod = 2            \igcmod = 1            \igbmod = 1            \
diomod = 1            \rdsmod = 0            \rbodymod= 1            \rgatemod= 1            \
permod = 1            \acnqsmod= 0            \trnqsmod= 0            \ 
  \tnom = 27            \toxe = 1.7e-9            \toxp = 1e-9            \toxm = 1.7e-9            \
dtox = 0            \epsrox = 3.9            \wint = 5e-009            \lint = 1.6e-008            \
  \l = 0            \wl = 0            \lln = 1            \wln = 1            \
  \lw = 0            \ww = 0            \lwn = 1            \wwn = 1            \
  \lwl = 0            \wwl = 0            \xpart = 0            \toxref = 1.7e-9            \
  \vth0 = 0.22            \k1 = 0.43            \k2 = 0.01            \k3 = 0            \
  \k3b = 0            \w0 = 2.5e-006            \dvt0 = 3.5            \dvt1 = 0.55            \
  \dvt2 = -0.032            \dvt0w = 0            \dvt1w = 0            \dvt2w = 0            \
  \dsub = 1            \minv = 0.05            \voffl = 0            \dvtp0 = 1.2e-008            \
  \dvtp1 = 0.1            \lpe0 = 5.75e-008            \lpeb = 2.3e-010            \xj = 2.5e-008            \
  \ngate = 5e+020            \ndep = 2.6e+018            \nsd = 1e+020            \phin = 0            \
  \cdsc = 0.0002            \cdscb = 0            \cdscd = 0            \cit = 0            \
  \voff = -0.15            \nfactor = 2            \eta0 = 0.24            \etab = 0            \
  \vfb = -0.55            \u0 = 0.06            \ua = 1e-010            \ub = 1e-017            \
  \uc = -3e-011            \vsat = 1.2e+005            \a0 = 1.5            \ags = 1e-020            \
  \al = 0            \a2 = 1            \b0 = -1e-020            \bl = 0            \
  \keta = 0.04            \dwg = 0            \dwb = 0            \pclm = 0.12            \
  \pdiblc = 0.02            \pdiblc2 = 0.02            \pdiblc = -0.005            \drout = 0.5            \
  \pvag = 1e-020            \delta = 0.01            \pscbe1 = 8.14e+008            \pscbe2 = 1e-007            \
  \fprout = 0.2            \pdits = 0.2            \pditsd = 0.23            \pditsl = 2.3e+006            \
  \rsh = 5            \rdsw = 160            \rsw = 150            \rdw = 150            \
  \rdswmin = 0            \rdwmin = 0            \rswmin = 0            \prwg = 0            \
  \prwb = 6.8e-011            \wr = 1            \alpha0 = 0.074            \alphal = 0.005            \
  \beta0 = 30            \agidl = 0.0002            \bgidl = 2.1e+009            \cgidl = 0.0002            \
  \egidl = 0.8            \
  \aigbacc = 0.012            \bigbacc = 0.0028            \cigbacc = 0.002            \
  \nigbacc = 1            \aigbinv = 0.014            \bigbinv = 0.004            \cigbinv = 0.004            \
  \eigbinv = 1.1            \nigbinv = 3            \aigc = 0.012            \bigc = 0.0028            \
  \cigc = 0.002            \aigsd = 0.012            \bigsd = 0.0028            \cigsd = 0.002            \
  \nigc = 1            \poxedge = 1            \pigcd = 1            \ntox = 1
```

nmos65.scs Thu Apr 24 09:11:53 2003 1
xrcrg1 = 12  xrcrg2 = 5  
gso   = 5.458e-010  cgdo  = 5.458e-010  cgbo  = 2.56e-011  cdg1  = 2.653e-10  
csl   = 2.653e-10  cappas = 0.03  cappad = 0.03  acde  = 1  
om  = 15  noff  = 0.9  voffcv = 0.02  
kt1  = -0.11  kt1l  = 0  kt2  = 0.022  ule  = -1.5  
uai  = 4.31e-009  ubl  = 7.61e-018  ucl  = -5.6e-011  prc  = 0  
at  = 33000  
fnoimod = 1  tnoimod = 0  
ss   = 0.0001  jsws  = 1e-011  jswgs = 1e-010  njc  = 1  
ijthsld= 0.01  ijthsrew= 0.001  bvs  = 10  xjbvs = 1  
jsd  = 0.0001  jswd  = 1e-011  jswdg = 1e-010  njd  = 1  
ijthdld= 0.01  ijthdrew= 0.001  bvd  = 10  xjbvd = 1  
pbs  = 1  cjs  = 0.0005  mjs  = 0.5  pbsws = 1  
cjsws = 5e-010  mjsws = 0.33  pbswgs = 1  cjswgs = 3e-010  
mjswgs = 0.33  pbd  = 1  cjd  = 0.0005  mjd  = 0.5  
pbwd  = 1  cjswn = 5e-010  mjswn = 0.33  pbswgd = 1  
cjswgd = 5e-010  mjswgd = 0.33  tpb  = 0.005  tcj  = 0.001  
npbsw = 0.005  tpcsw = 0.001  tpbwgs = 0.005  tcjswg = 0.001  
xnis  = 3  xtid = 3  
dmci  = 0e-006  dmcg  = 0e-006  dmdg  = 0e-006  dmcgt = 0e-007  
dw  = 0.0e-008  xgw  = 0e-007  xgl  = 0e-008  
grh  = 0.4  gbmin = 1e-010  rbpb  = 5  rbpd  = 15  
rbbp = 15  rbdb  = 15  rbsb  = 15  ngcon = 1  

// Library name: cad217
// Cell name: fet45
// View name: schematic
PORT1 (net023 0) port r=50 num=2 dc=800.0m type=sine
PORT0 (net015 0) port r=50 num=1 dc=730.431m type=sine
L0 (net6 net023) inductor l=100n
V0 (net6 0) vsource dc=1 type=dc
M3 (net023 net015 0 0) nmos w=1u l=65.000n as=1u*.2u ad=1u*.2u ps=1.4u \ 
   pd=1.4u nrd=.2 nrs=.2 m=2
M2 (net023 net015 0 0) nmos w=1u l=65.000n as=1u*.2u ad=1u*.2u ps=1u pd=1u \ 
   nrd=.2 nrs=.2 m=48
simulatorOptions options reltol=1e-3 vabstol=1e-6 iabstol=1e-12 temp=27 \ 
   tnom=27 scalem=1.0 scale=1.0 gmin=1e-12 rforce=1 maxnotes=5 maxwarns=5 \ 
   digits=5 cols=80 pivrel=1e-3 ckptclock=1800 \ 
   sensfile="../psf/sens.output"
dcOp dc write="spectre.dc" maxiters=150 maxsteps=10000 annotate=status 
dcOpInfo info what=oppoint where=rawfile 
dc dc dev=PORT0 param=dc start=0 stop=.9 lin=100 oppoint=rawfile \ 
   maxiters=150 maxsteps=10000 annotate=status sp sp ports=[PORT0 PORT1] start=10G stop=5000G donoise=yes oprobe=PORT1 \ 
   iprobe=PORT0 annotate=status 
modelParameter info what=models where=rawfile 
element info what=inst where=rawfile 
outputParameter info what=output where=rawfile 
saveOptions options save=allpub
Current Gain

Note: k-factor > 1 until "kink"

NF for 50 ohm source

NF (minimum)