#1 DESIGN GOAL $G_{TU} = 10\,dB$ FROM 1–2 GHz
$F < 4\,dB$

NOTE: $G_0 = |S_{21}|^2 = \begin{cases} 14\,dB & f=1 \\ 11.8\,dB & f=1.5 \\ 10\,dB & f=2 \end{cases}$

$$G_{S\max} = \frac{1}{1-|S_{11}|^2} = \begin{cases} 2.29\,dB \\ 1.94\,dB \\ 1.86\,dB \end{cases}$$

$$G_{L\max} = \frac{1}{1-|S_{22}|^2} = \begin{cases} 4.25\,dB \\ 3.74\,dB \\ 3.59\,dB \end{cases}$$

FOR SIMPLICITY, SINCE $|S_{11}| < .64$ OVER THE ENTIRE RANGE, LET'S MAKE $G_S = 1$
I.E. NO MATCHING NETWORK ON INPUT SIDE.

THUS, WE REQUIRE $G_{L\,des} = \begin{cases} -4\,dB \text{ @ } 1\,GHz \\ +0\,dB \text{ @ } 2\,GHz \end{cases}$

THE CONSTANT LOAD CIRCLES: $C_L = \dfrac{g_L S_{22}^*}{1-(1-g_L)|S_{22}|^2}$

$$R_L = \frac{\sqrt{1-g_L}\,(1-|S_{22}|^2)}{1-(1-g_L)|S_{22}|^2}$$

| $f$ | $C_L$ | $R_L$ |
|---|---|---|
| 1 | $0.25\angle 30^\circ$ | 0.74 |
| 2 | $0.48\angle 43^\circ$ | 0.49 |

FOR 4dB NOISE FIGURE, WE HAVE THE FOLLOWING NOISE CIRCLES

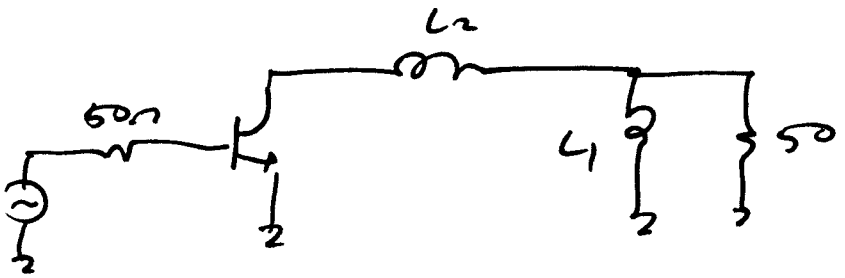
| $f$ | $N$ | $C_F$ | $R_F$ | |
|---|---|---|---|---|
| 1 | 1.245 | $0.214\angle 23^\circ$ | 0.705 | (BLUE) |
| 1.5 | 1.448 | $0.18\angle 61^\circ$ | 0.737 | (GREEN) |
| 2 | 0.859 | $0.22\angle 88^\circ$ | 0.648 | (PURPLE) |

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, $F_{50} = F_{min} + \frac{4R_N}{Z_0} \frac{|\Gamma_{opt}|^2}{|1+\Gamma_{opt}|^2}$

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 dB AND 0 dB GAIN CIRCLES ARE PLOTTED FOR THE LOAD AT 1GHz AND 2GHz. ANY LOAD IMPEDANCE ON THE −4 dB CHART THAT MOVES TO THE 0 dB CHART FROM 1–2 GHz IS AN ACCEPTABLE SOLUTION.

THE FOLLOWING ARCH IS CHOSEN (L-L MATCH)




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 $1-0.9j$

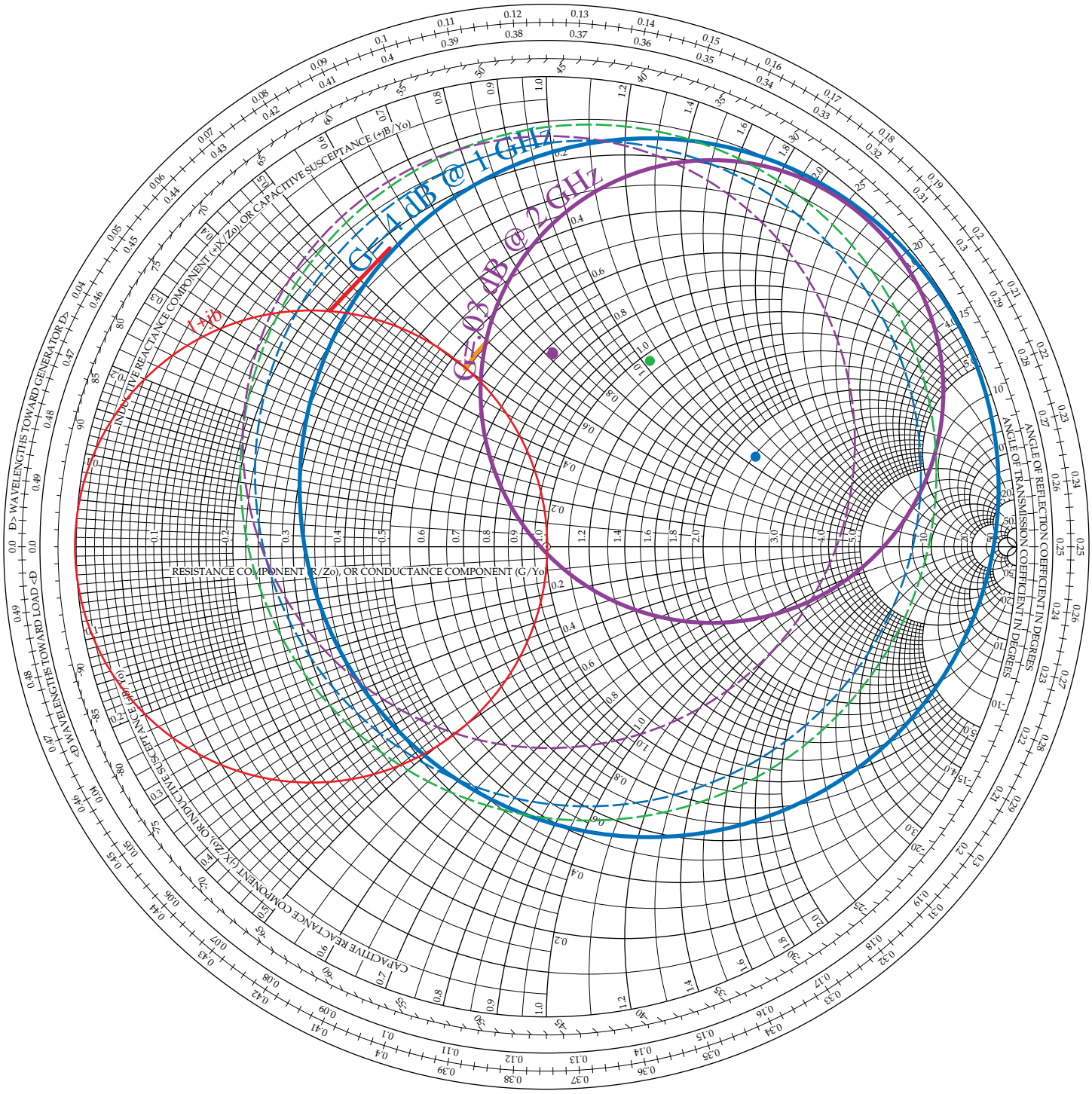
0.08j → AT 2GHz REQUIRES .08j OF SERIES REACTANCE AND $1-1.8j$ AT 1GHz REQUIRES

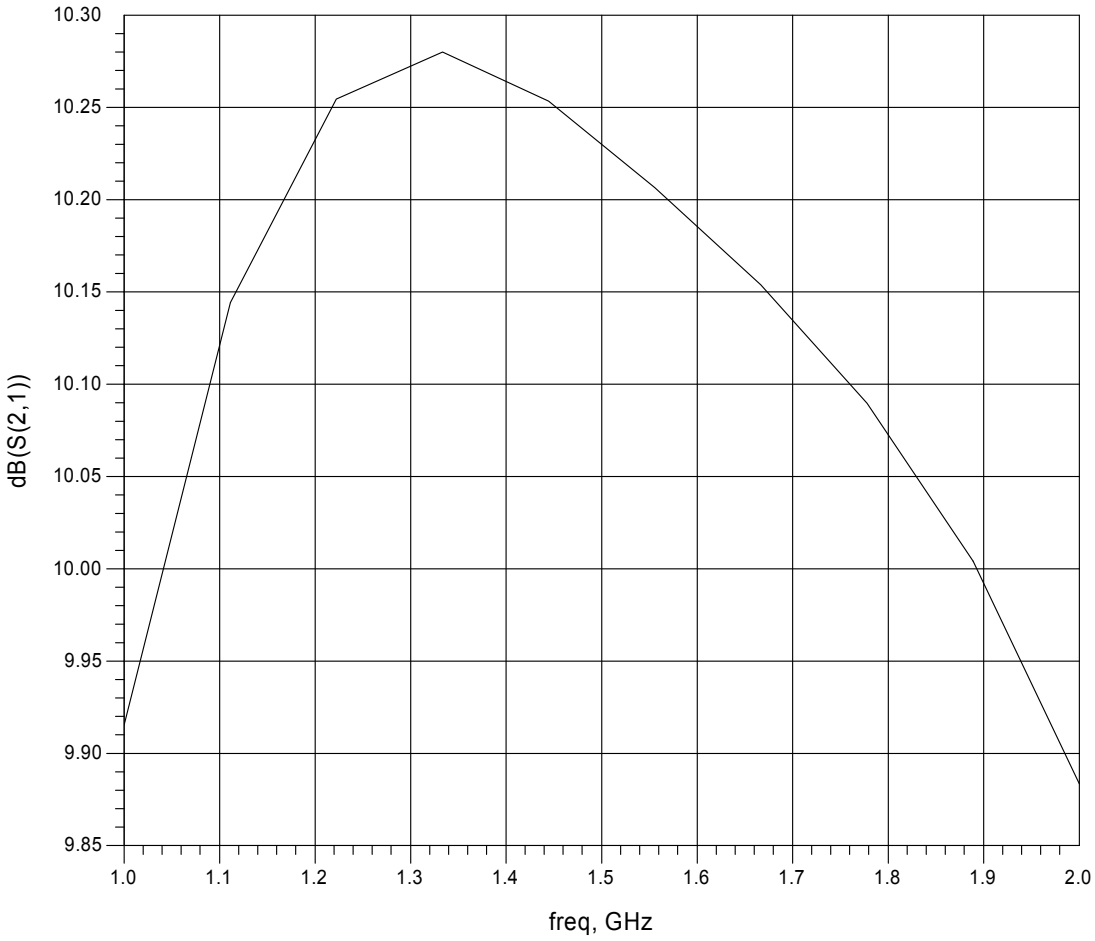
0.16j → ABOUT 0.16j OF SERIES REACTANCE, EXACTLY IN THE CORRECT PROPORTION:

$$L_1 = \frac{Z_0}{0.9\cdot\omega} = 4.42\,nH$$

$$L_2 = \frac{0.08\,Z_0}{\omega} = 318\,pH$$

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

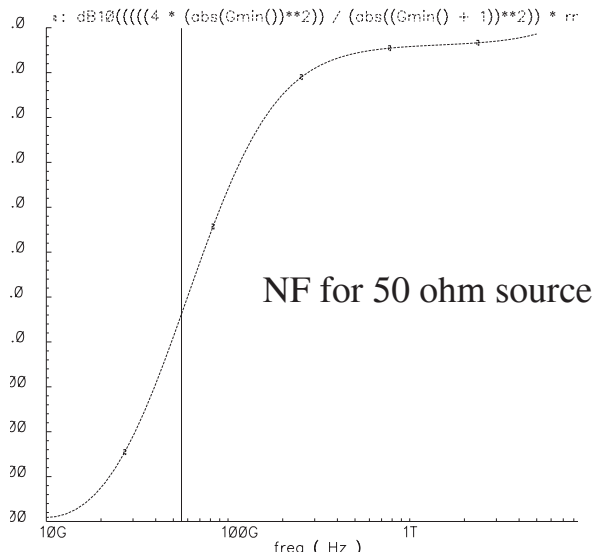

G=4 dB @ 1 GHz
G=0.3 dB @ 2 GHz
(1+j0)
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE (-jB/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD

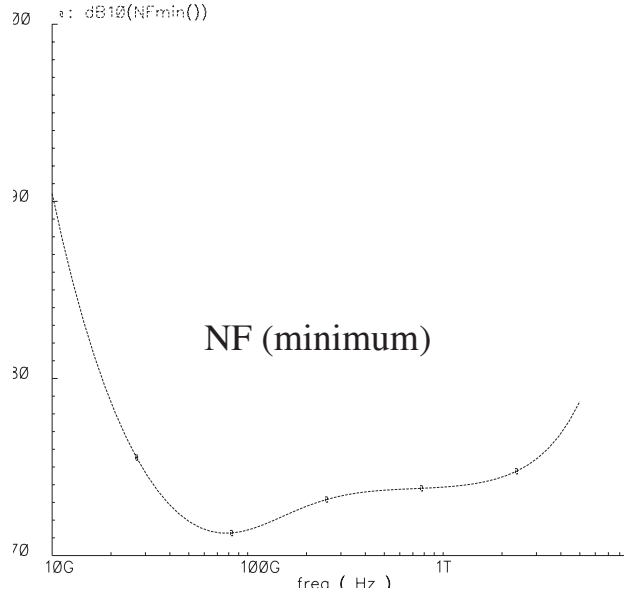

10.30
10.25
10.20
10.15
10.10
10.05
10.00
9.95
9.90
9.85
dB(S(2,1))
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
freq, GHz

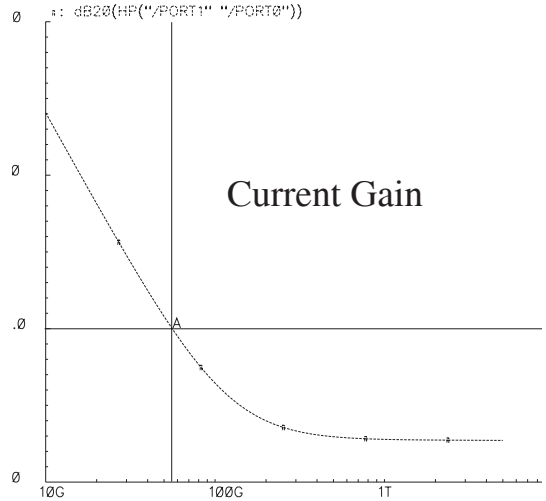
```
* BPTM 65nm NMOS

model  nmos  bsim4\
\
binunit = 1            paramchk= 1            mobmod  = 0          \
capmod  = 2            igcmod  = 1            igbmod  = 1            geomod  = 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
 \
ll      = 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
 \
a1      = 0            a2      = 1            b0      = -1e-020      b1      = 0
 \
keta    = 0.04         dwg     = 0            dwb     = 0            pclm    = 0.12
 \
pdiblc1 = 0.02         pdiblc2 = 0.02         pdiblcb = -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        alpha1  = 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
 \
\
```

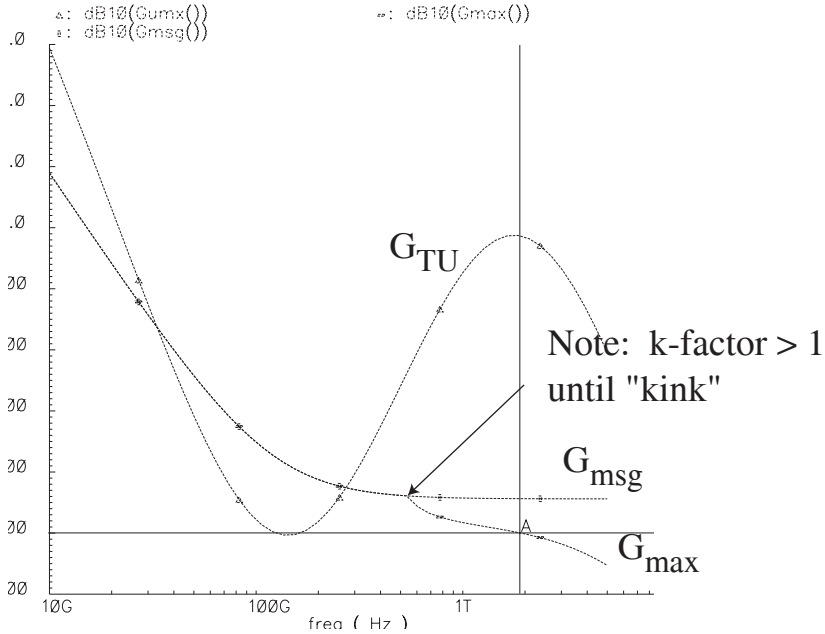
```
xrcrg1  = 12           xrcrg2  = 5          \
cgso    = 5.458e-010   cgdo    = 5.458e-010   cgbo    = 2.56e-011    cgdl    = 2.653e-10
    \
cgsl    = 2.653e-10    ckappas = 0.03         ckappad = 0.03         acde    = 1
 \
moin    = 15           noff    = 0.9          voffcv  = 0.02       \
\
kt1     = -0.11        kt1l    = 0            kt2     = 0.022        ute     = -1.5
 \
ua1     = 4.31e-009    ub1     = 7.61e-018    uc1     = -5.6e-011    prt     = 0
 \
at      = 33000      \
\
fnoimod = 1            tnoimod = 0          \
\
jss     = 0.0001       jsws    = 1e-011       jswgs   = 1e-010       njs     = 1
 \
ijthsfwd= 0.01         ijthsrev= 0.001        bvs     = 10           xjbvs   = 1
 \
jsd     = 0.0001       jswd    = 1e-011       jswgd   = 1e-010       njd     = 1
 \
ijthdfwd= 0.01         ijthdrev= 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
 \
pbswd   = 1            cjswd   = 5e-010       mjswd   = 0.33         pbswgd  = 1
 \
cjswgd  = 5e-010       mjswgd  = 0.33         tpb     = 0.005        tcj     = 0.001
 \
tpbsw   = 0.005        tcjsw   = 0.001        tpbswg  = 0.005        tcjswg  = 0.001
 \
xtis    = 3            xtid    = 3          \
\
dmcg    = 0e-006       dmci    = 0e-006       dmdg    = 0e-006       dmcgt   = 0e-007
 \
dwj     = 0.0e-008     xgw     = 0e-007       xgl     = 0e-008     \
\
rshg    = 0.4          gbmin   = 1e-010       rbpb    = 5            rbpd    = 15
 \
rbps    = 15           rbdb    = 15           rbsb    = 15           ngcon   = 1
 \
\
```

```
// Generated for: spectre
// Generated on: May  2 09:54:27 2003
// Design library name: cad217
// Design cell name: fet45
// Design view name: schematic
simulator lang=spectre
global 0
include "/users/niknejad/instr/217/nmos65.scs"

// 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
```


NF for 50 ohm source
10G
100G
1T
freq ( Hz )


NF (minimum)
10G
100G
1T
freq ( Hz )


Current Gain
A
10G
100G
1T


dB10(Gumx())
dB10(Gmsg())
dB10(Gmax())
$G_{TU}$
Note: k-factor > 1
until "kink"
$G_{msg}$
$G_{max}$
A
10G
100G
1T
freq ( Hz )