SMITH CHART EXAMPLES

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ASU

Smith Chart for the Impedance Plot

It will be easier if we normalize the load impedance to the characteristic impedance of the transmission line attached to the load.

$$z = \frac{Z}{Z_o} = r + jx$$

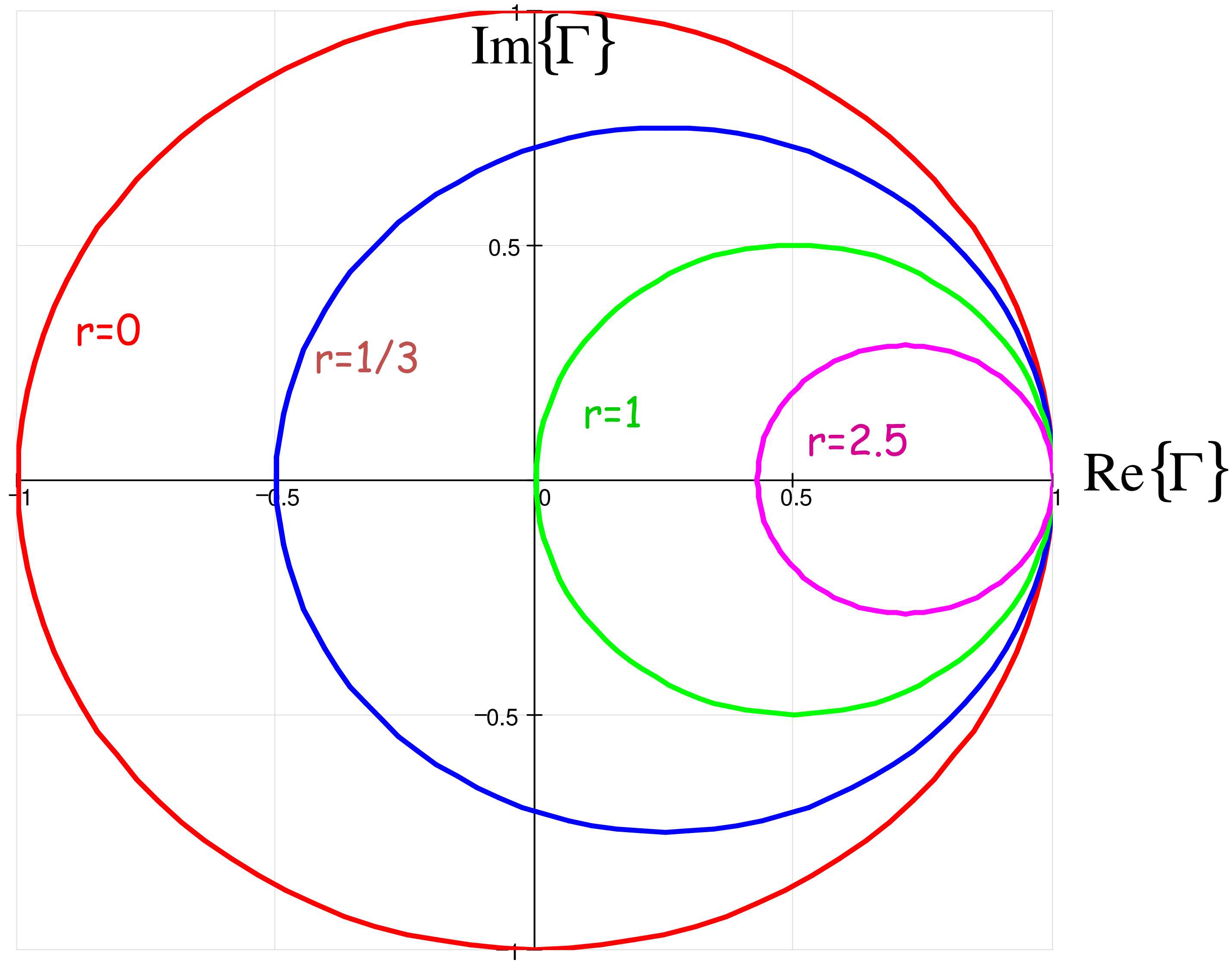
$$z = \frac{1+\Gamma}{1-\Gamma}$$

Since the impedance is a complex number, the reflection coefficient will be a complex number

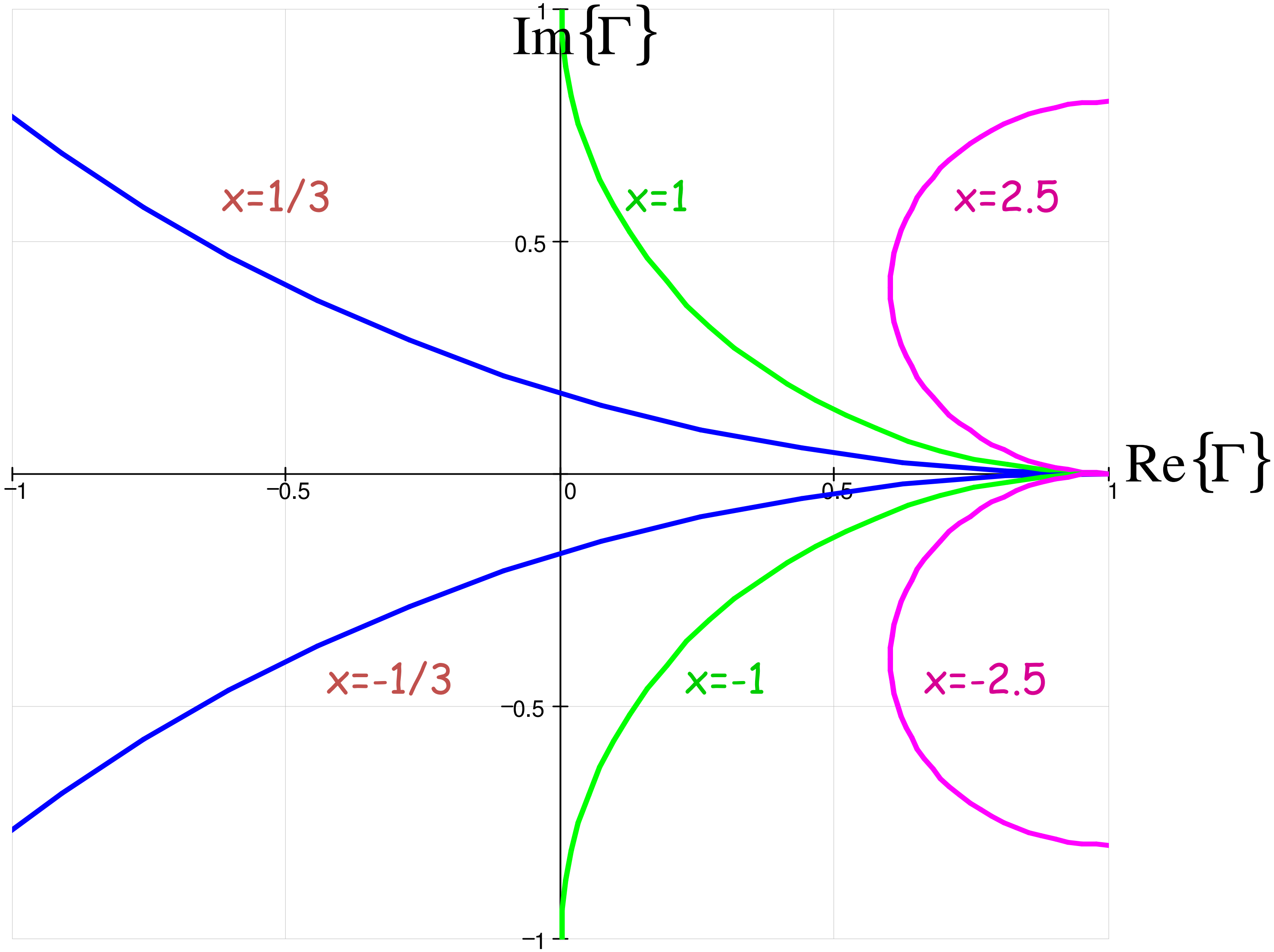
$$\Gamma = u + jv$$

$$r = \frac{1-u^2-v^2}{(1-u)^2+v^2} \qquad x = \frac{2v}{(1-u)^2+v^2}$$

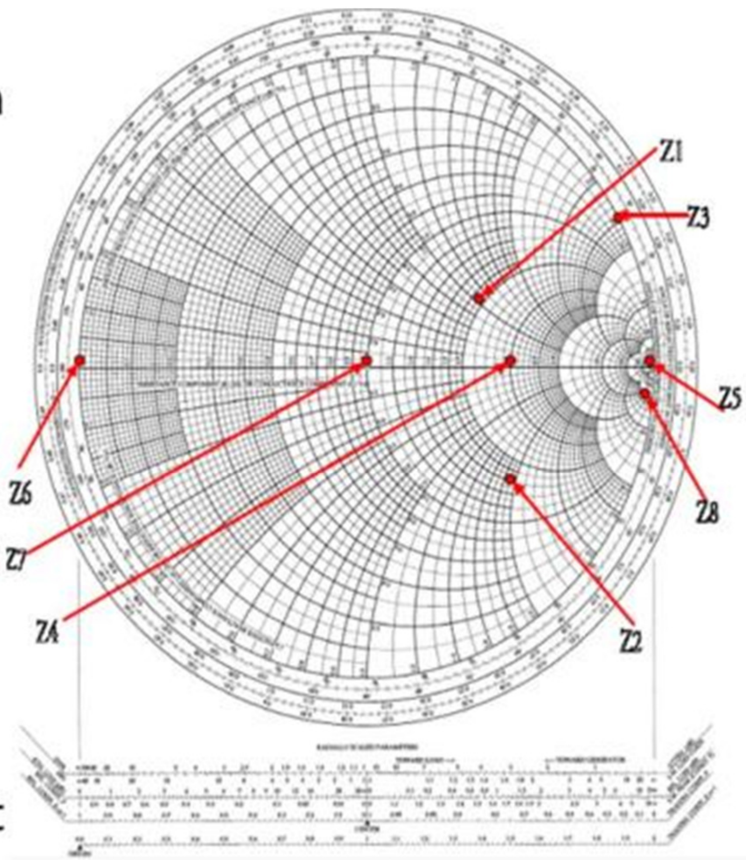
Real Circles



Imaginary Circles



- Impedance divided by lin impedance (50 Ohms)
  - Z1 = 100 + j50
  - Z2 = 75 -j100
  - Z3 = j200
  - Z4 = 150
  - Z5 = infinity (an open circuit)
  - Z6 = 0 (a short circuit)
  - Z7 = 50
  - Z8 = 184 -j900



- Then, normalize and plot The points are plotted as follows:
  - z1 = 2 + j
  - z2 = 1.5 -j2
  - z3 = j4
  - z4 = 3
  - z5 = infinity
  - z6 = 0
  - z7 = 1
  - z8 = 3.68 -j18S

Normalized Admittance

$$y = \frac{Y}{Y_o} = YZ_o = g + jb$$

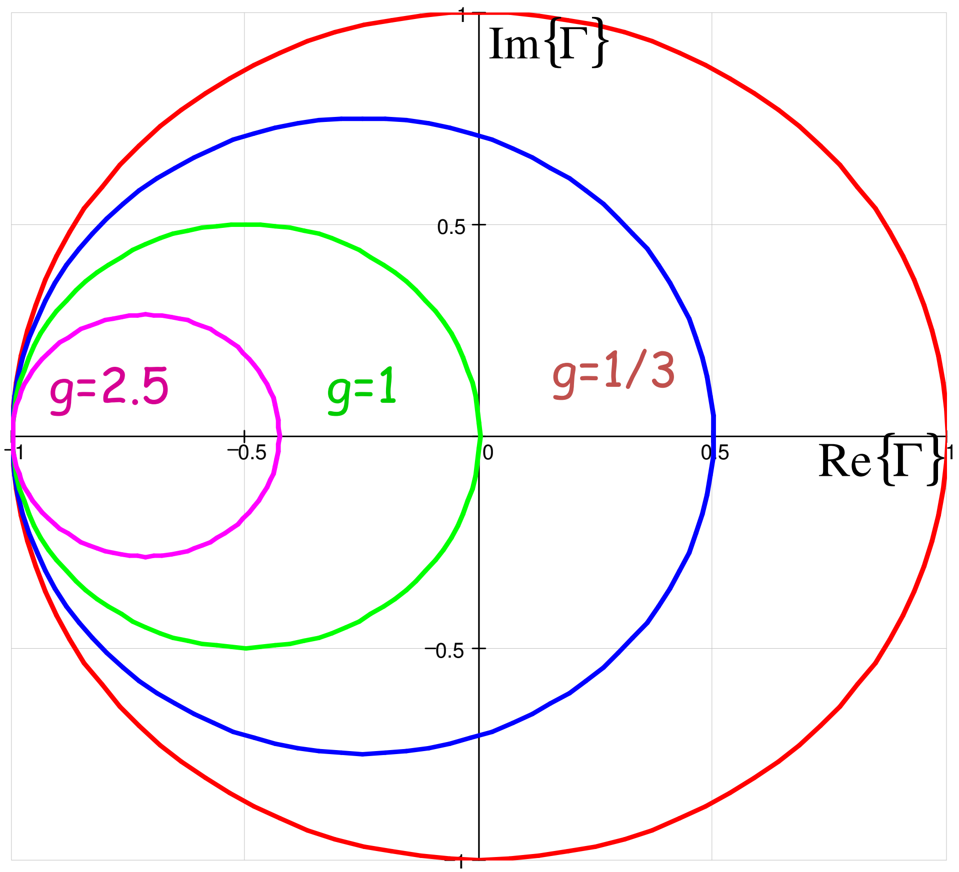
$$y = \frac{1-\Gamma}{1+\Gamma}$$

$$g = \frac{1-u^2-v^2}{(1+u)^2+v^2} \quad \Rightarrow \quad \left(u + \frac{g}{1+g}\right)^2 + v^2 = \frac{1}{(1+g)^2}$$

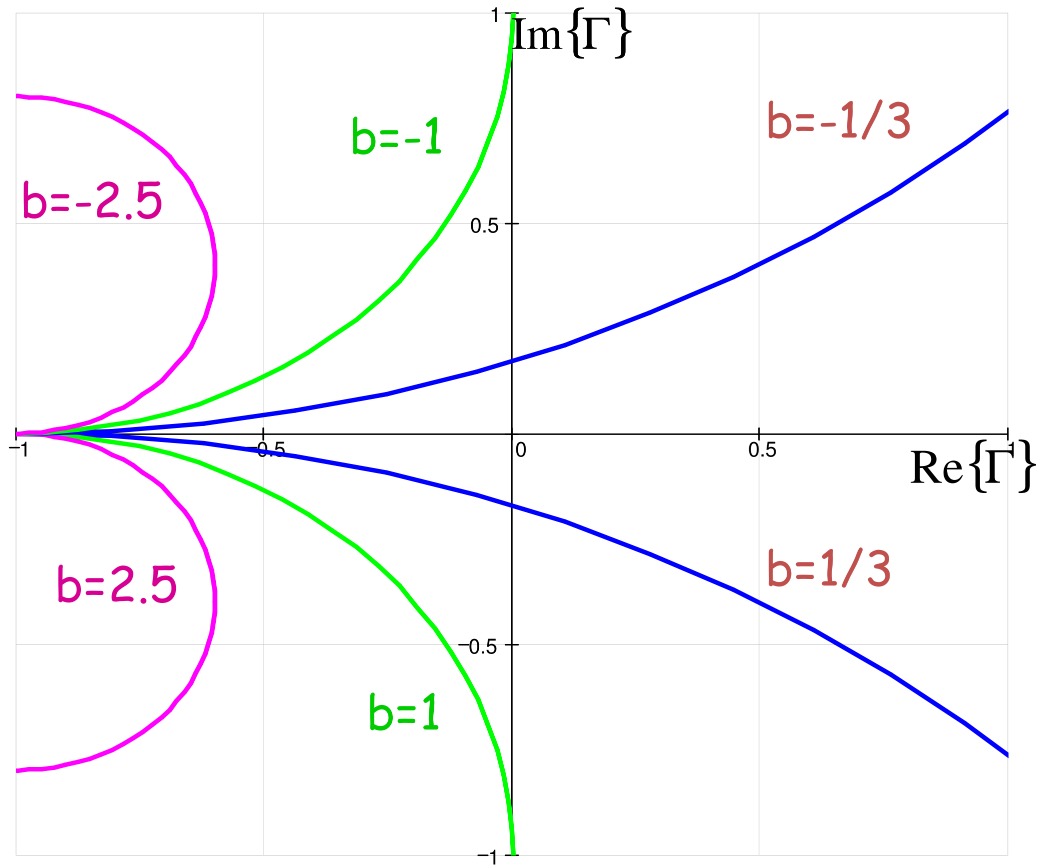
$$b = \frac{-2v}{(1+u)^2+v^2} \quad \Rightarrow \quad (u+1)^2 + \left(v + \frac{1}{b}\right)^2 = \frac{1}{b^2}$$

These are equations for circles on the (u,v) plane

Real admittance

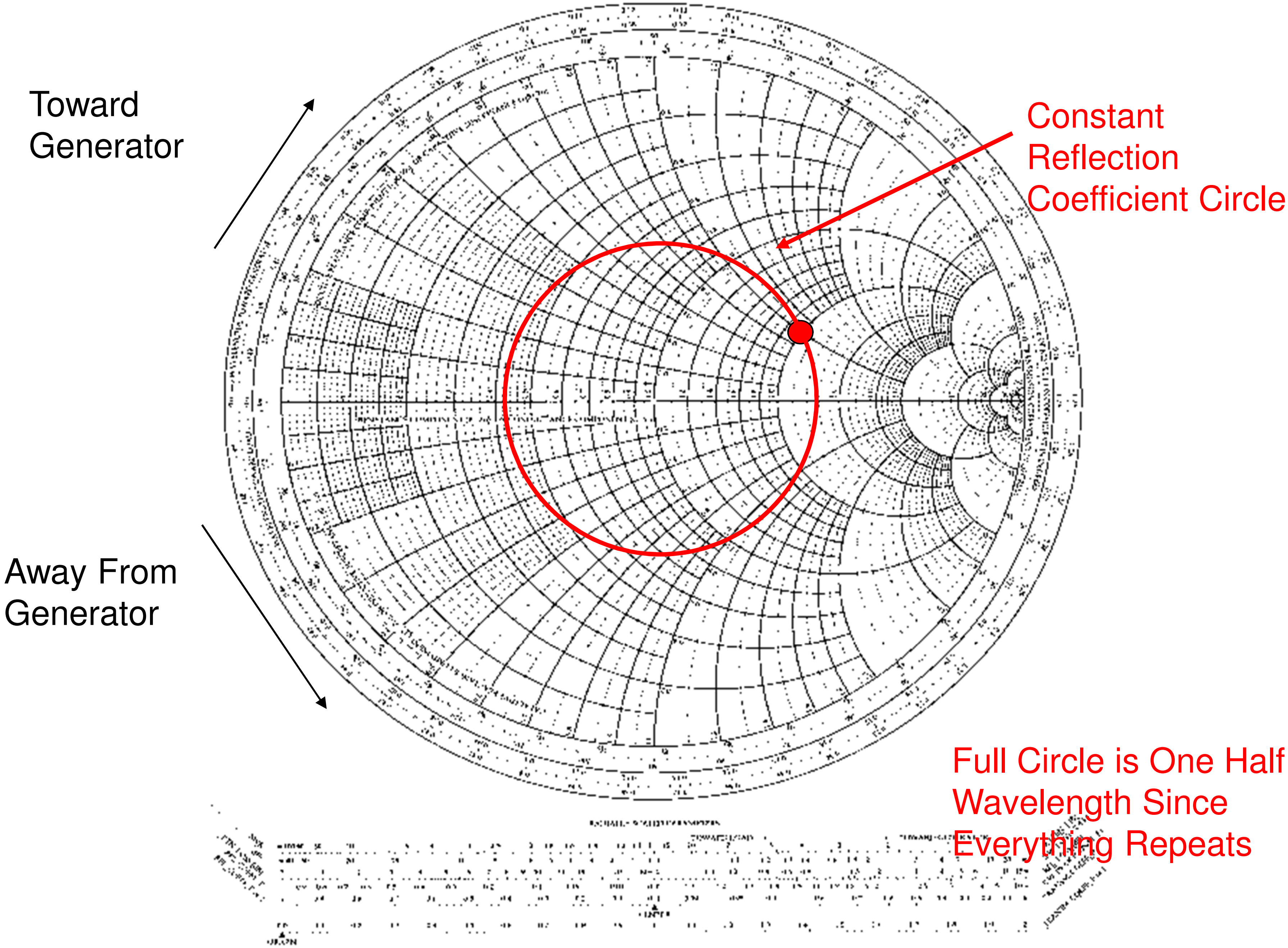


Complex Admittance

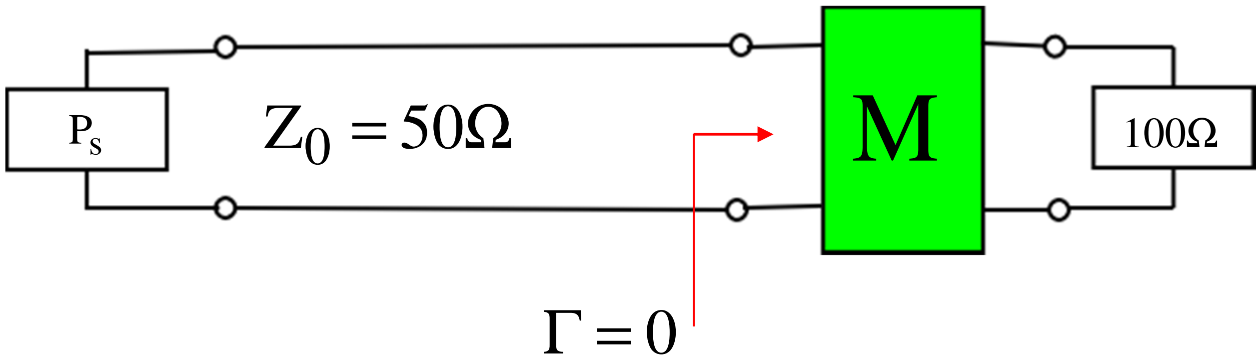


Matching

- For a matching network that contains elements connected in series and parallel, we will need two types of Smith charts
  - impedance Smith chart
  - admittance Smith Chart
- The admittance Smith chart is the impedance Smith chart rotated 180 degrees.
  - We could use one Smith chart and flip the reflection coefficient vector 180 degrees when switching between a series configuration to a parallel configuration.


Toward Generator
Away From Generator
Constant Reflection Coefficient Circle
Full Circle is One Half Wavelength Since Everything Repeats

Matching Example

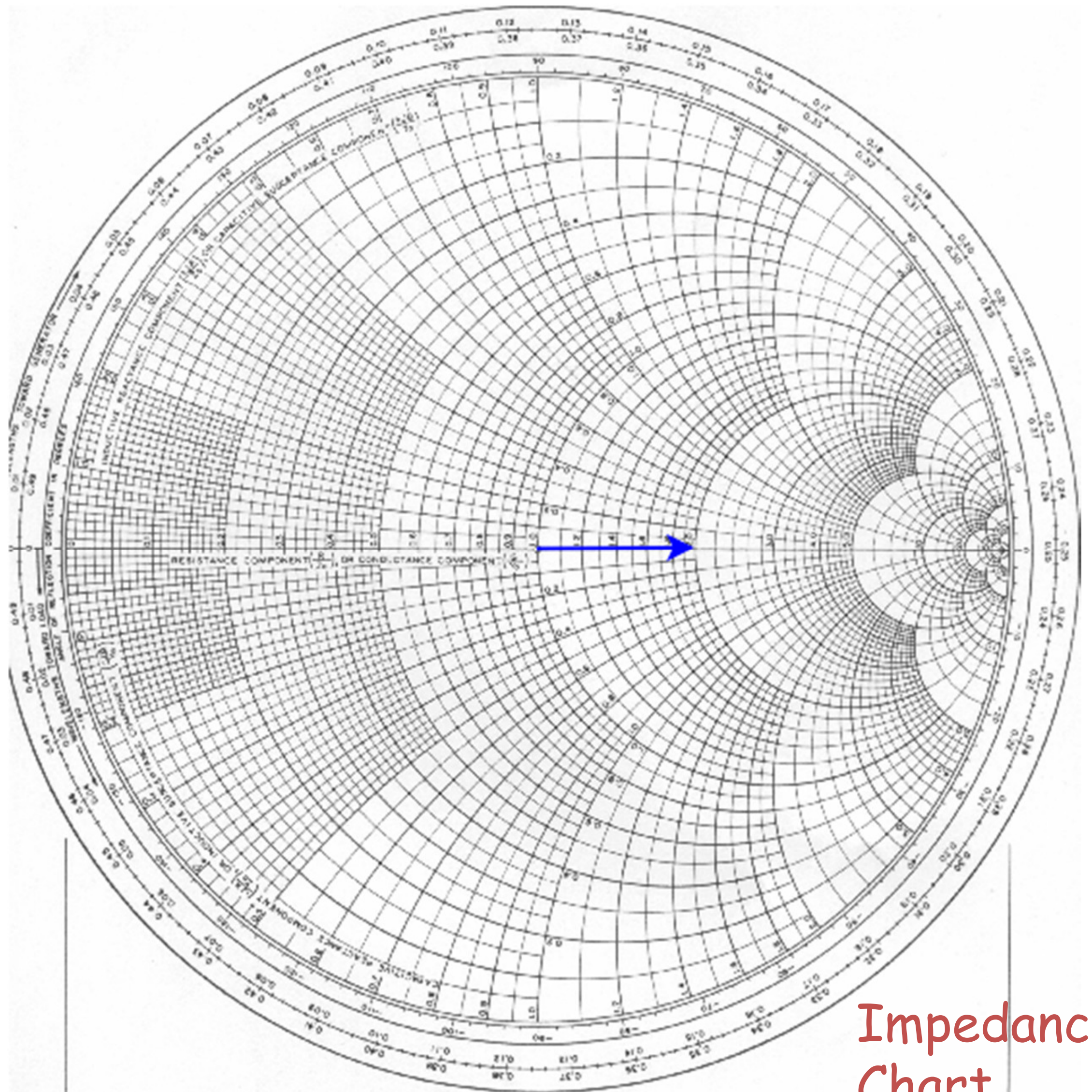


Match 100Ω load to a 50Ω system at 100MHz

A 100Ω resistor in parallel would do the trick but ½ of the power would be dissipated in the matching network. We want to use only lossless elements such as inductors and capacitors so we don't dissipate any power in the matching network

Matching Example

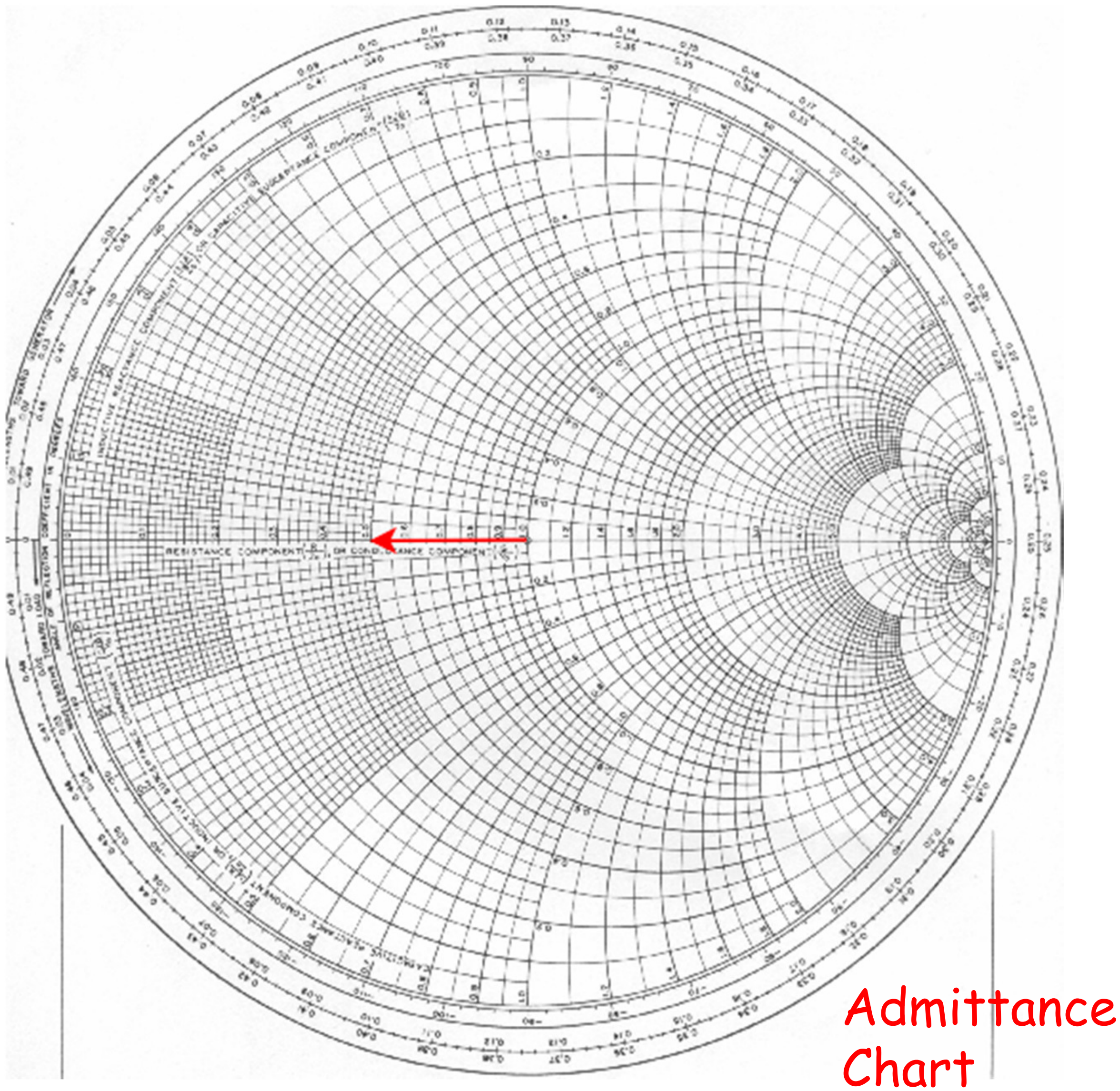
- We need to go from z=2+j0 to z=1+j0 on the Smith chart
- We won't get any closer by adding series impedance so we will need to add something in parallel.
- We need to flip over to the admittance chart



Impedance Chart

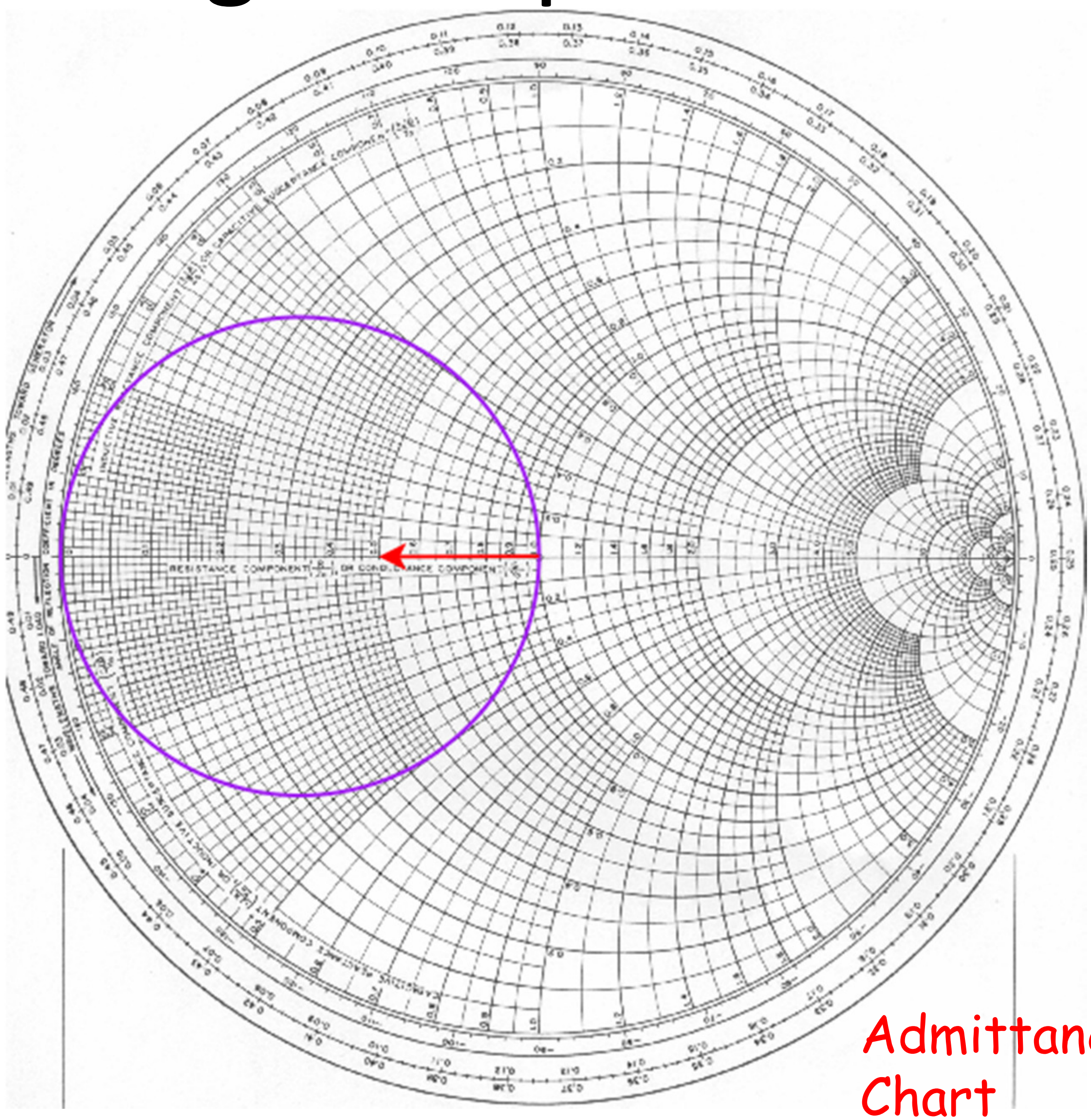
Matching Example

- y=0.5+j0
- Before we add the admittance, add a mirror of the r=1 circle as a guide.



Matching Example

- y=0.5+j0
- Before we add the admittance, add a mirror of the r=1 circle as a guide
- Now add positive imaginary admittance.



Admittance Chart

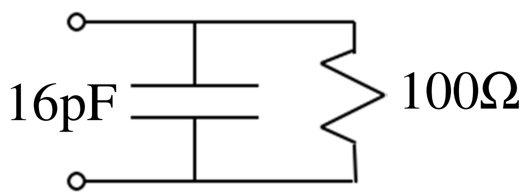
Matching Example

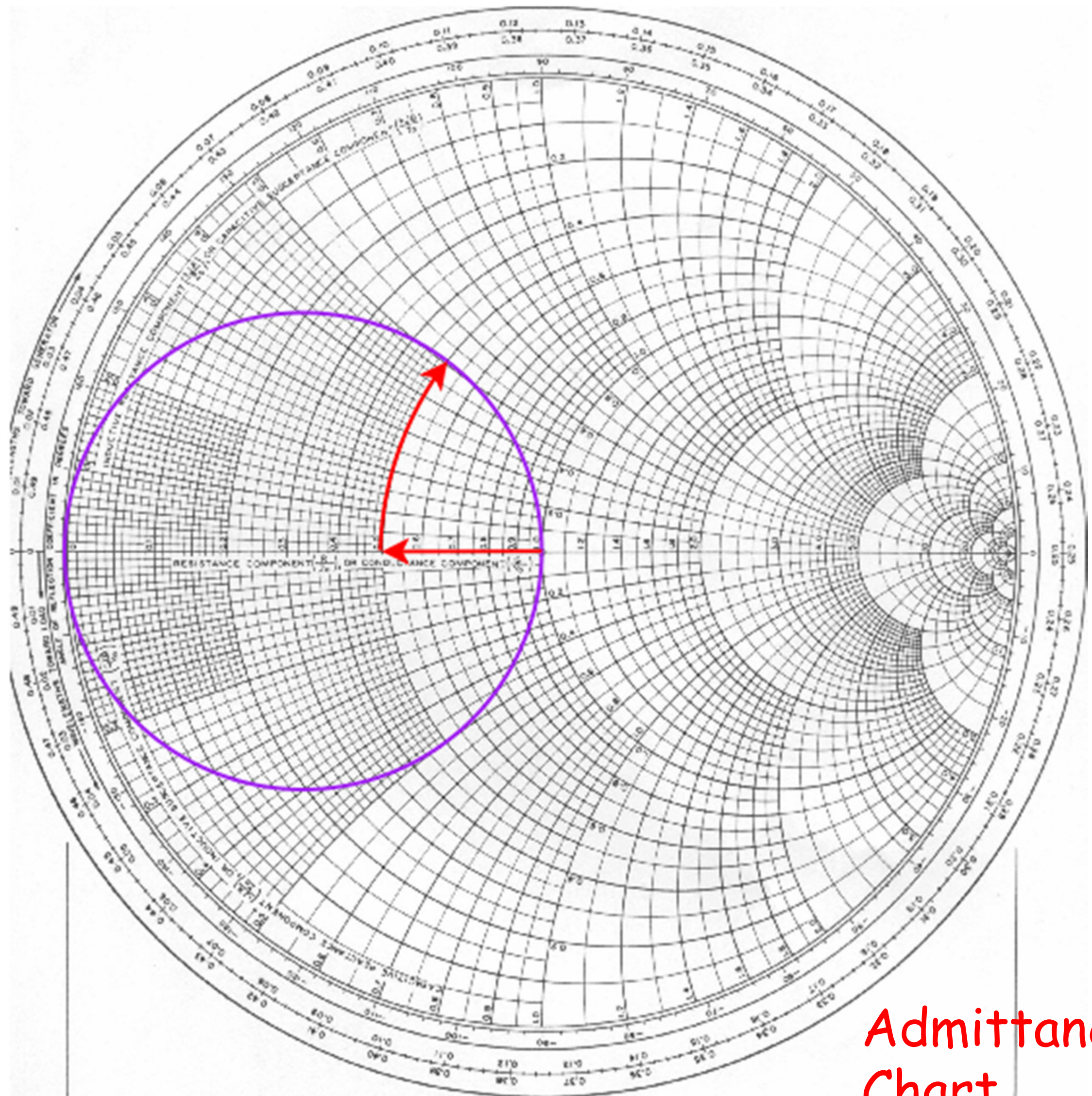
- y=0.5+j0
- Before we add the admittance, add a mirror of the r=1 circle as a guide
- Now add positive imaginary admittance jb = j0.5

$$jb = j0.5$$

$$\frac{j0.5}{50\Omega} = j2\pi(100\text{MHz})C$$

$$C = 16\text{pF}$$

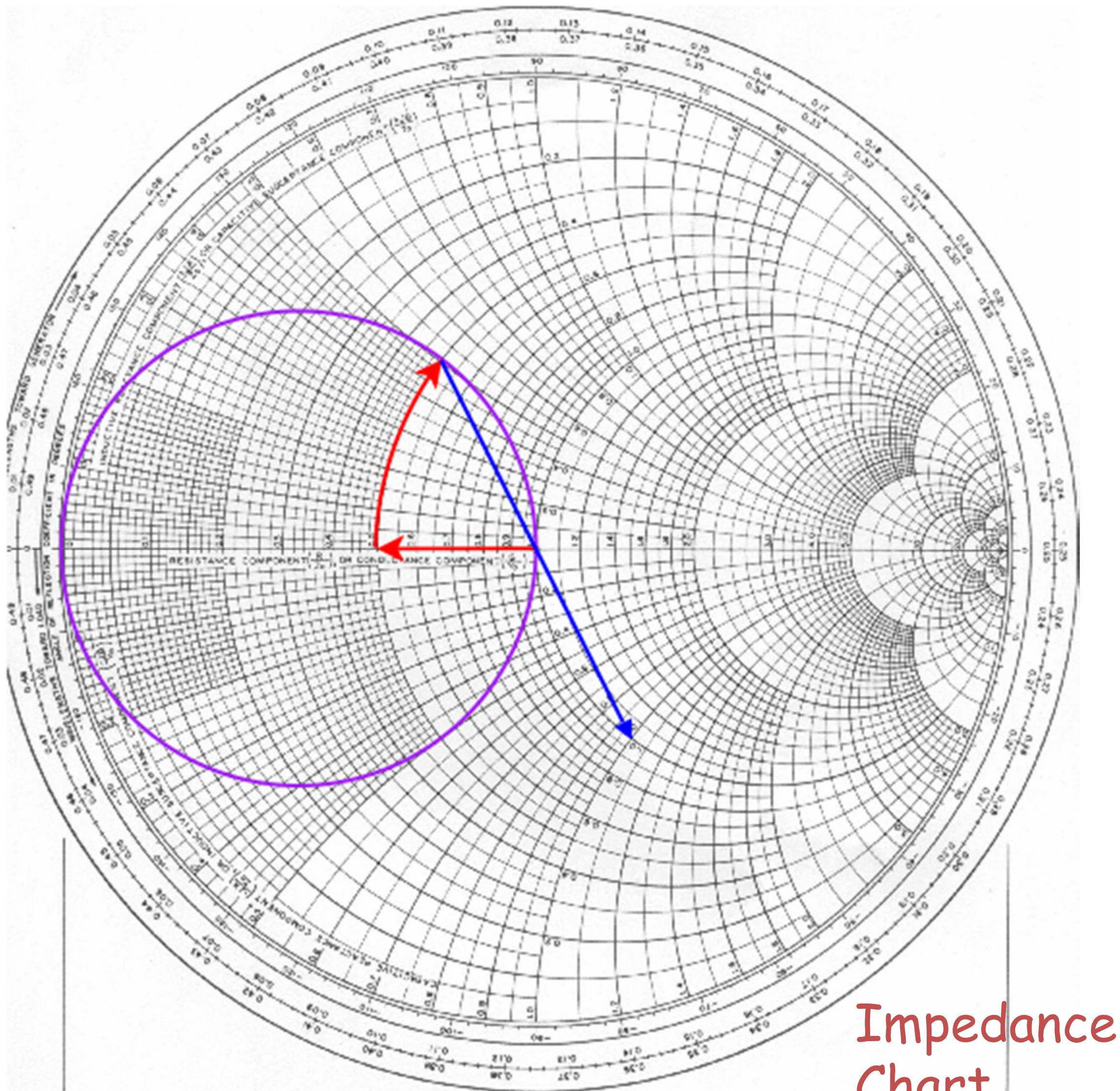




Admittance Chart

Matching Example

- We will now add series impedance
- Flip to the impedance Smith Chart
- We land at on the r=1 circle at x=-1



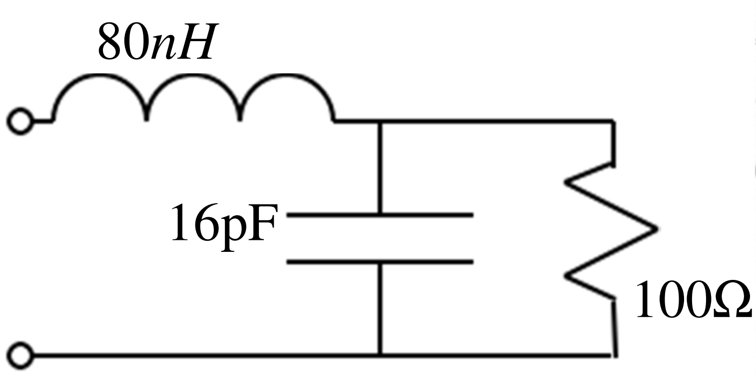
Matching Example

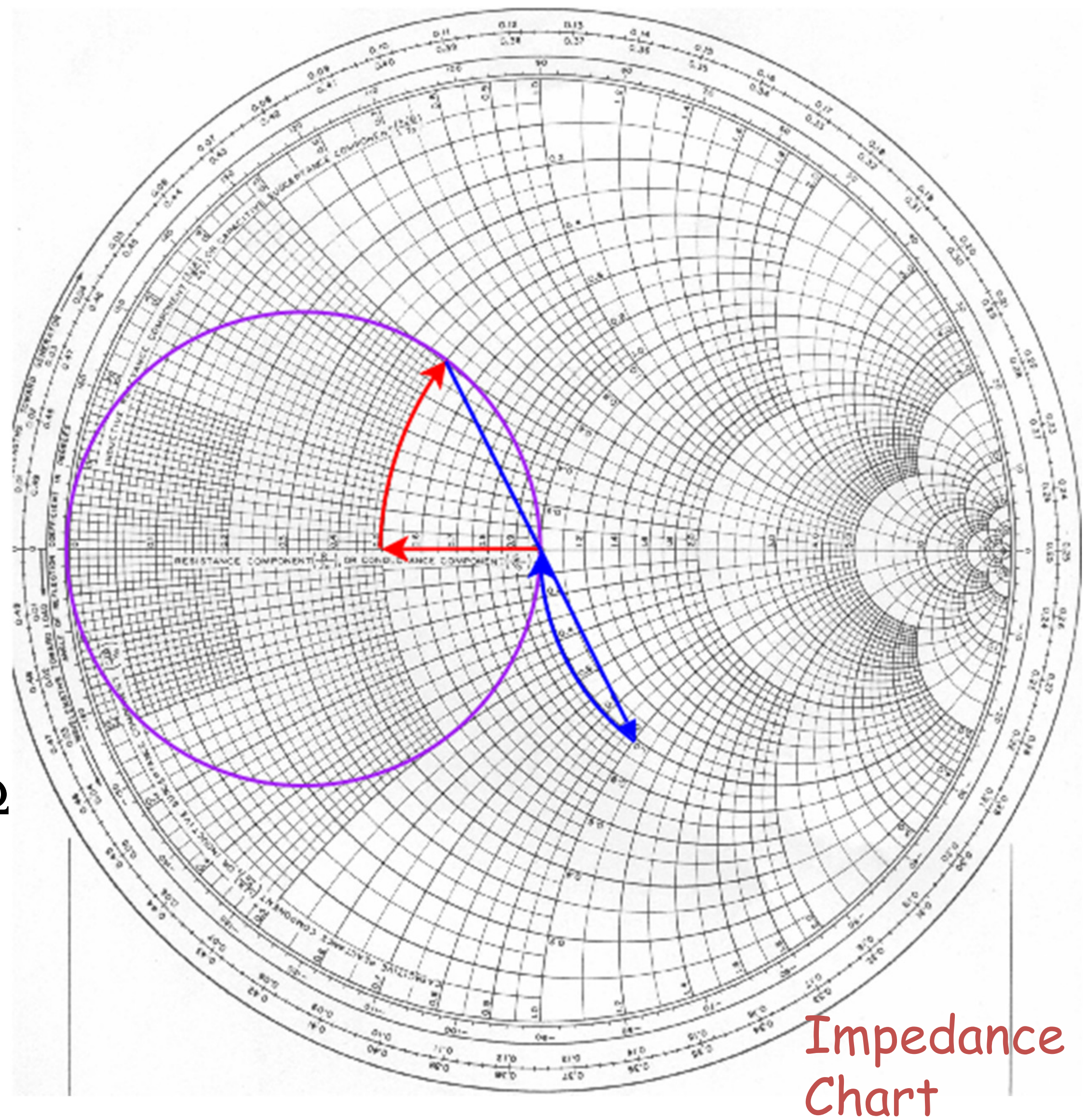
- Add positive imaginary admittance to get to z=1+j0

$$jx = j1.0$$

$$(j1.0)50\Omega = j2\pi(100\text{MHz})L$$

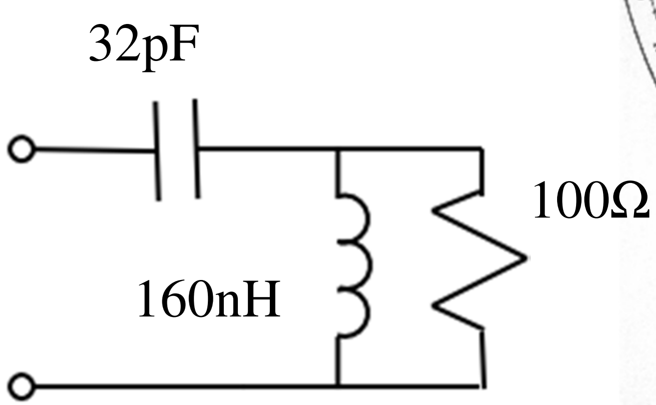
$$L = 80\text{nH}$$

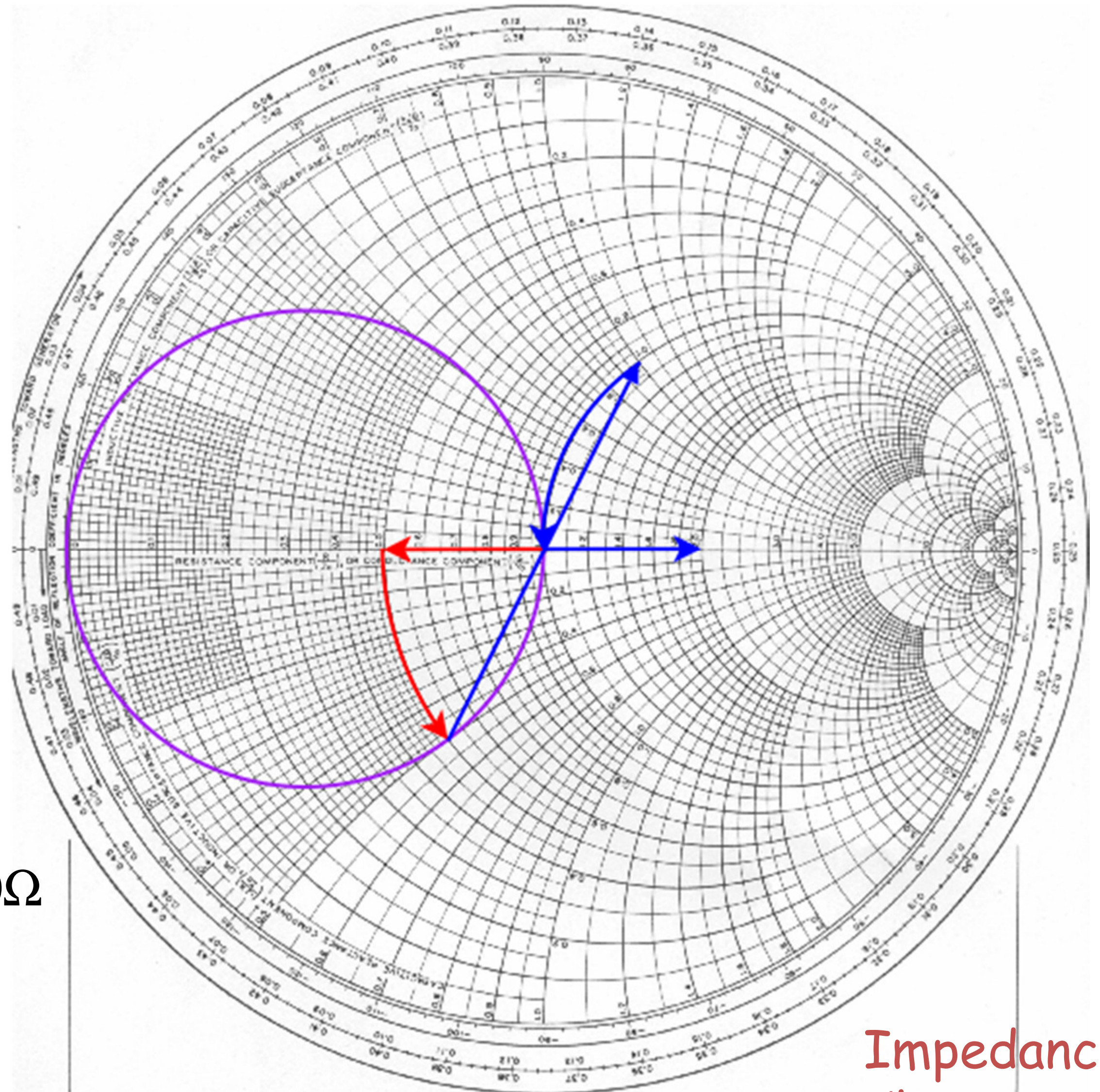




Matching Example

- This solution would have also worked





Impedance Chart

Mainstream vs. RF Electronics

Mainstream electronics

Microprocessors, memories, consumer electronics

Transistor types
- Bipolar: BJT (few Applications)
- FET: MOSFET (Standard)

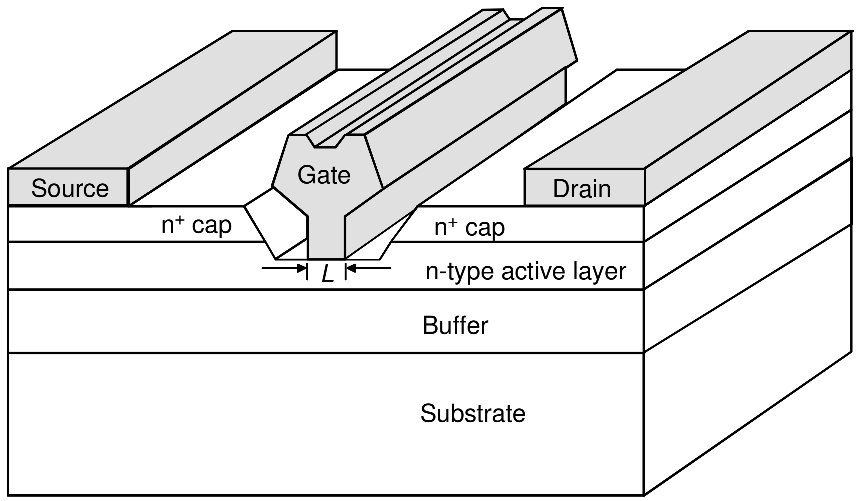
Semiconductors
- Si

RF Electronis

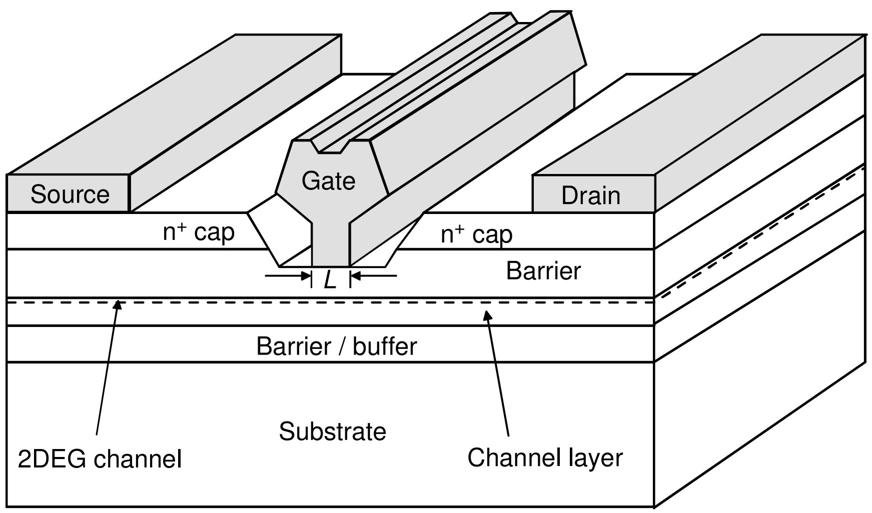
(HF, GHz, microwave electronics)

Transistor types
- Bipolar
  - HBT (Heterojunction Bipolar Transistor)
  - BJT (Bipolar Junction Transistor)
- FET
  - MESFET (Metal Semiconductor FET)
  - HEMT (High Electron Mobility Transistor)
  - SIT (Static Induction Transistor)
  - MOSFET (Metal Oxide Semiconductor FET)

Semiconductors
- III-V's (GaAs, InP AlGaAs, InGaAs, InAlAs, …)
- Si
- SiGe
- Wide bandgap materials (SiC, GaN, AlGaN)



MESFET
Metal-Semiconductor FET



HEMT
High Electron Mobility Transistor
Channel: twodimensional electron gas (2DEG) at the inter-face channel layer - barrier

E. Simulation Examples

- Example #1

  This Example gives comparison of the device output characteristics of a single quantum-well structure when using drift-diffusion and energy balance models

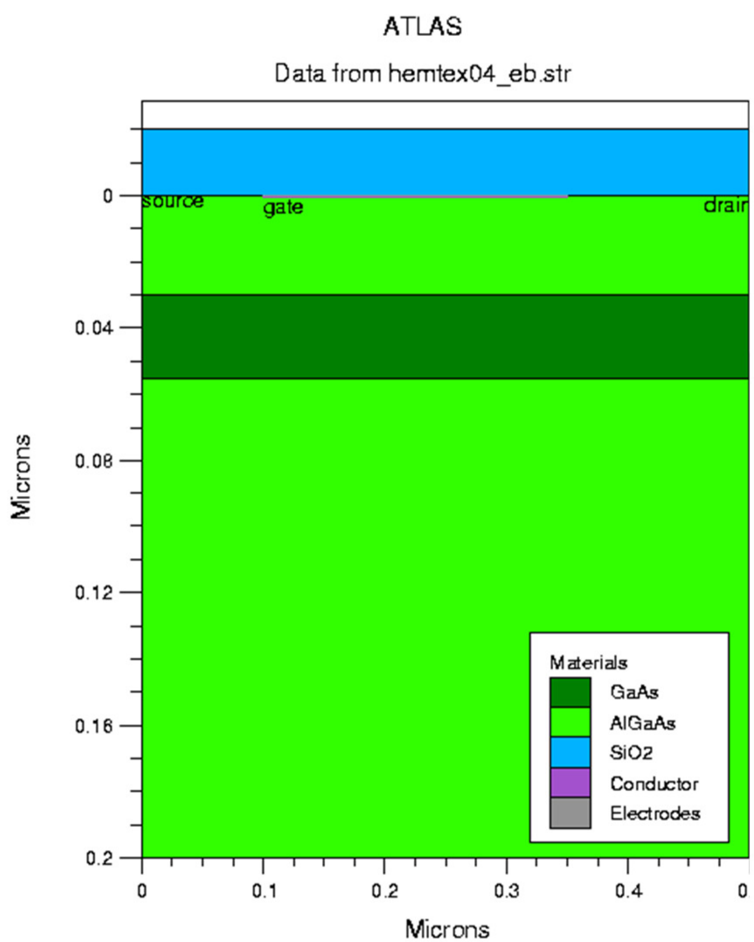
- Example #2

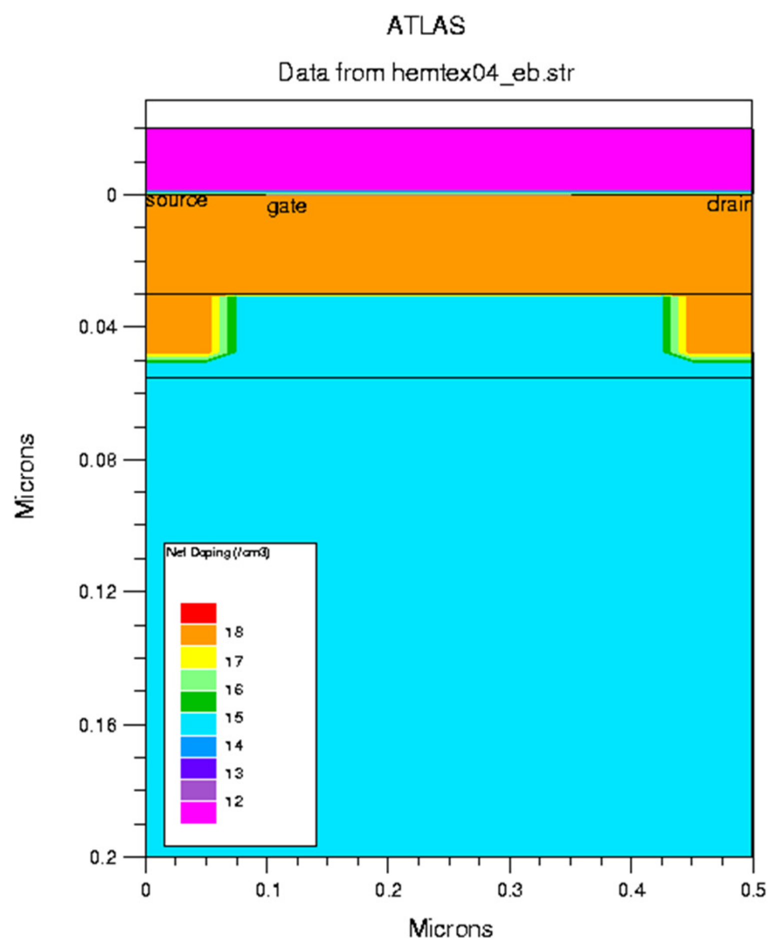
  Simulation results of a pseudomorphic HEMT structure: device transfer and output characteristics with extraction of some significant device parameters, such as threshold voltage, maximum saturation current, etc.

- Example #3

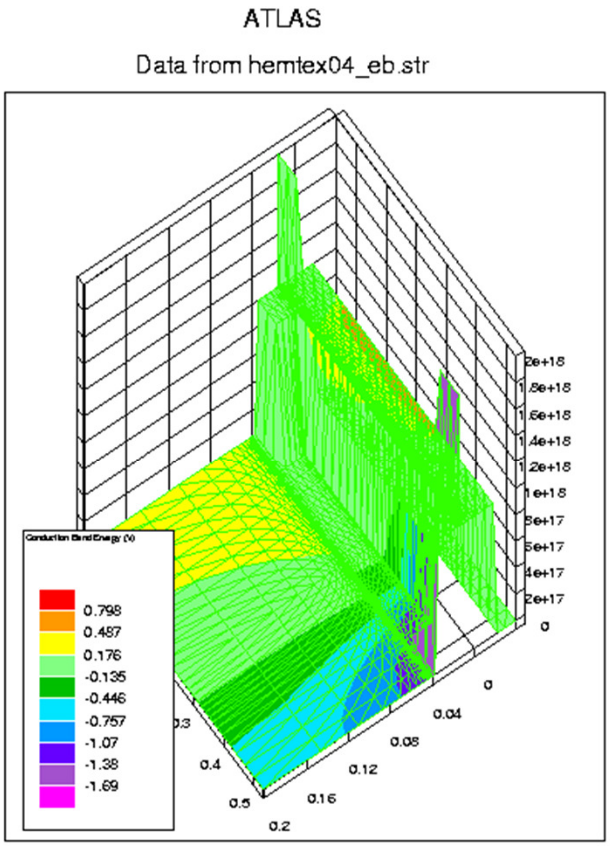
  This is a follow-up of Example #2, in which AC analysis is performed and the device S-parameters calculated.

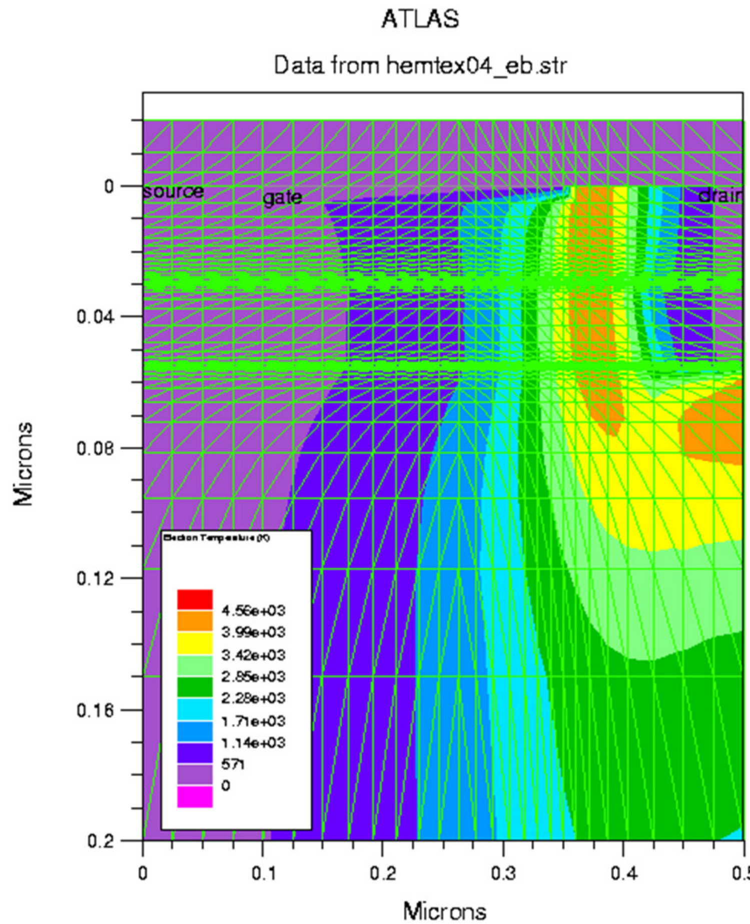
Example 1


ATLAS
Data from hemtex04_eb.str
source
gate
drain
Microns
0
0.04
0.08
0.12
0.16
0.2
0
0.1
0.2
0.3
0.4
0
Microns
Materials
GaAs
AlGaAs
SiO2
Conductor
Electrodes

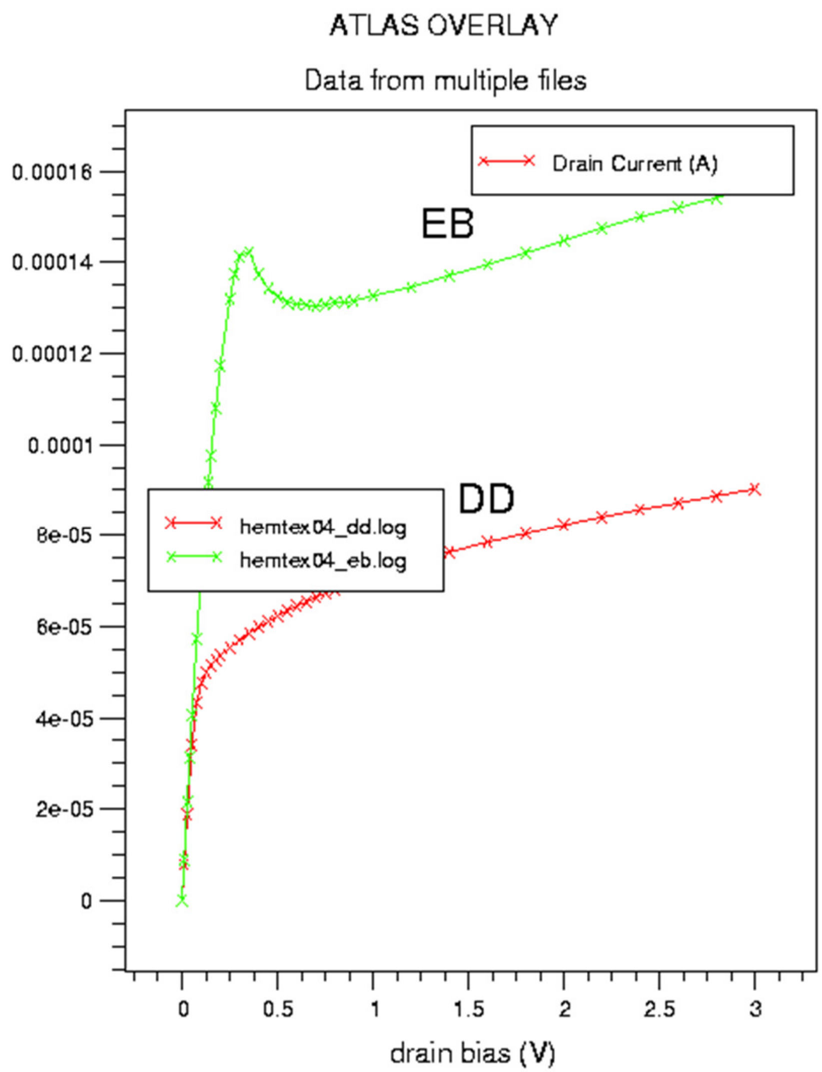

ATLAS
Data from hemtex04_eb.str
source
gate
drain
Microns
0
0.04
0.08
0.12
0.16
0.2
0
0.1
0.2
0.3
0.4
0.5
Microns
Net Doping (/cm3)
18
17
16
15
14
13
12

Example 1 (cont'd)

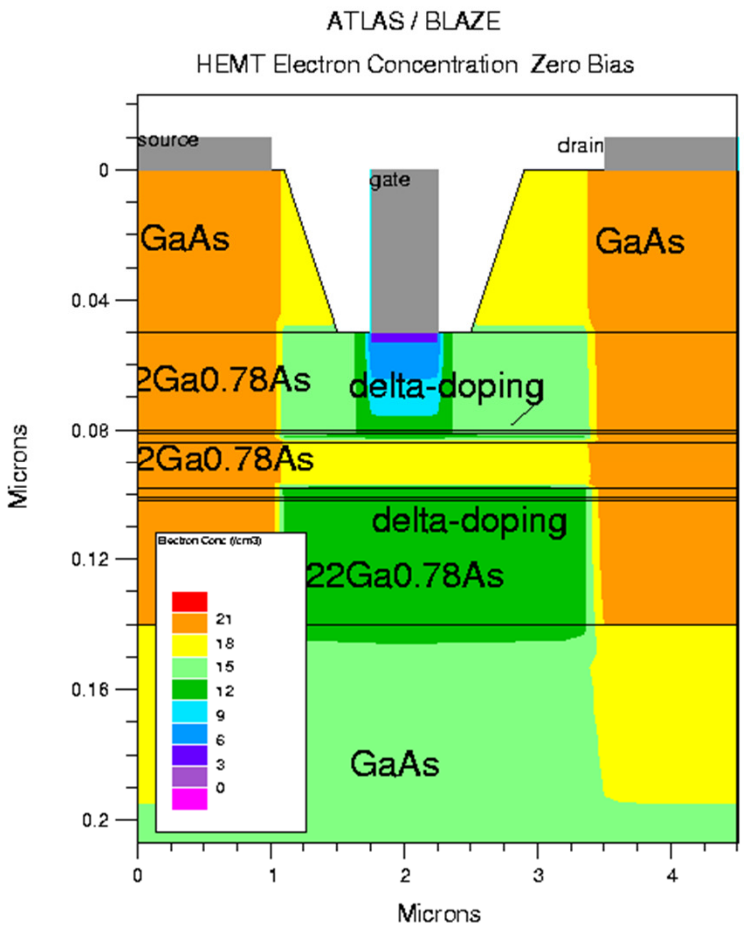


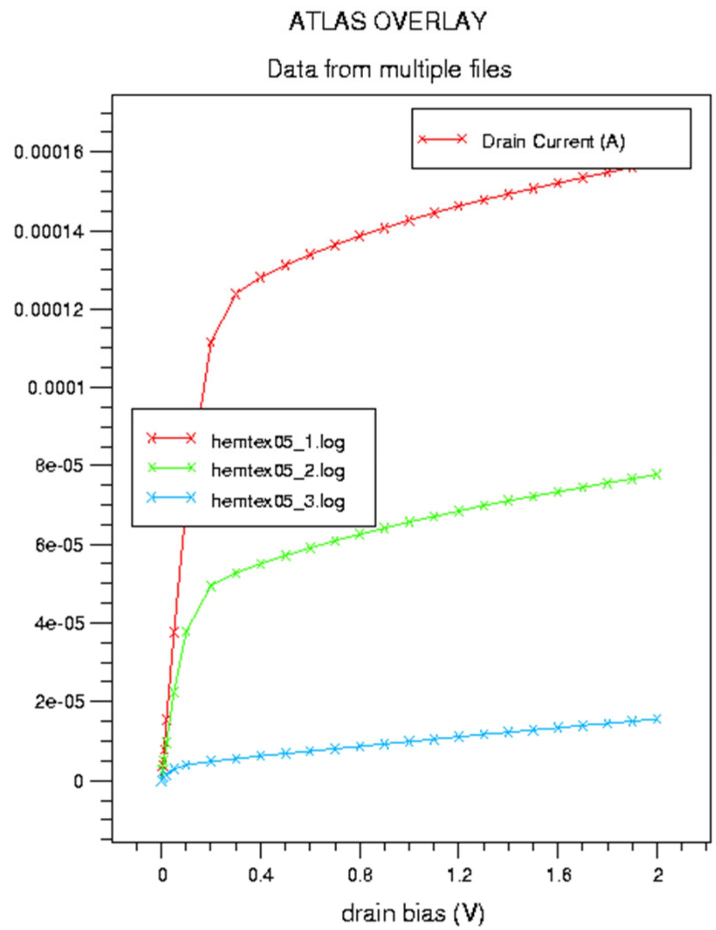


Example 1 (cont'd)

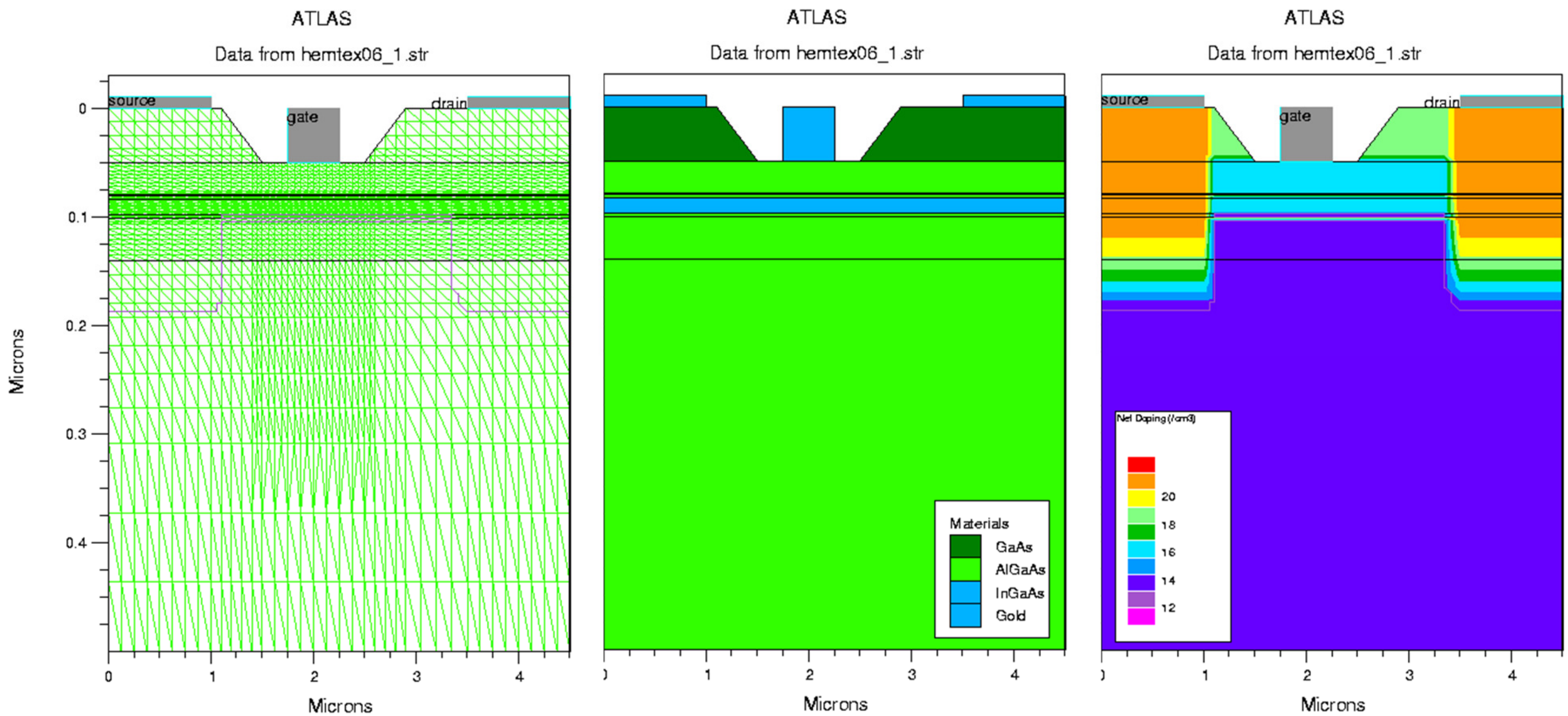


Example 2


ATLAS / BLAZE
HEMT Electron Concentration Zero Bias
source
drain
gate
GaAs
GaAs
2Ga0.78As
delta-doping
2Ga0.78As
delta-doping
22Ga0.78As
GaAs
Electron Conc (/cm3)
21
18
15
12
9
6
3
0
Microns
Microns
0
0.04
0.08
0.12
0.16
0.2
0
1
2
3
4


ATLAS OVERLAY
Data from multiple files
Drain Current (A)
hemtex05_1.log
hemtex05_2.log
hemtex05_3.log
0.00016
0.00014
0.00012
0.0001
8e-05
6e-05
4e-05
2e-05
0
0
0.4
0.8
1.2
1.6
2
drain bias (V)

Example 3


ATLAS
Data from hemtex06_1.str
source
gate
drain
Microns
Materials
GaAs
AlGaAs
InGaAs
Gold
Net Doping (/cm3)
20
18
16
14
12

Example 3 (cont'd)