BJT_Oscillator

Where To Find This Example

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Design Notes

BJT Feedback Oscillator Design

This example shows a simple oscillator design using a NEC68630 nonlinear device model with the collector grounded to provide the negative resistance. A coaxial line is used in the resonator design to adjust the frequency of oscillation. This example shows how a designer should start his or her analysis using linear simulation to find conditions appropriate for oscillation. Once these are found, the designer can perform a non-linear simulation to predict output frequency, output power, and phase noise of the oscillator.

This oscillator also serves as a good example for demonstrating how the NDF measurement is used to check a circuit's stability.
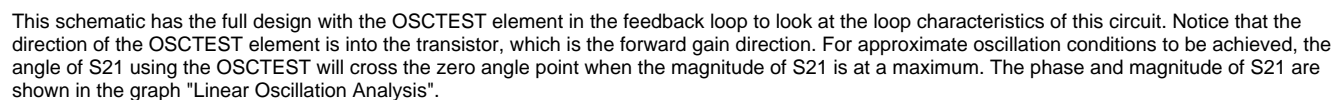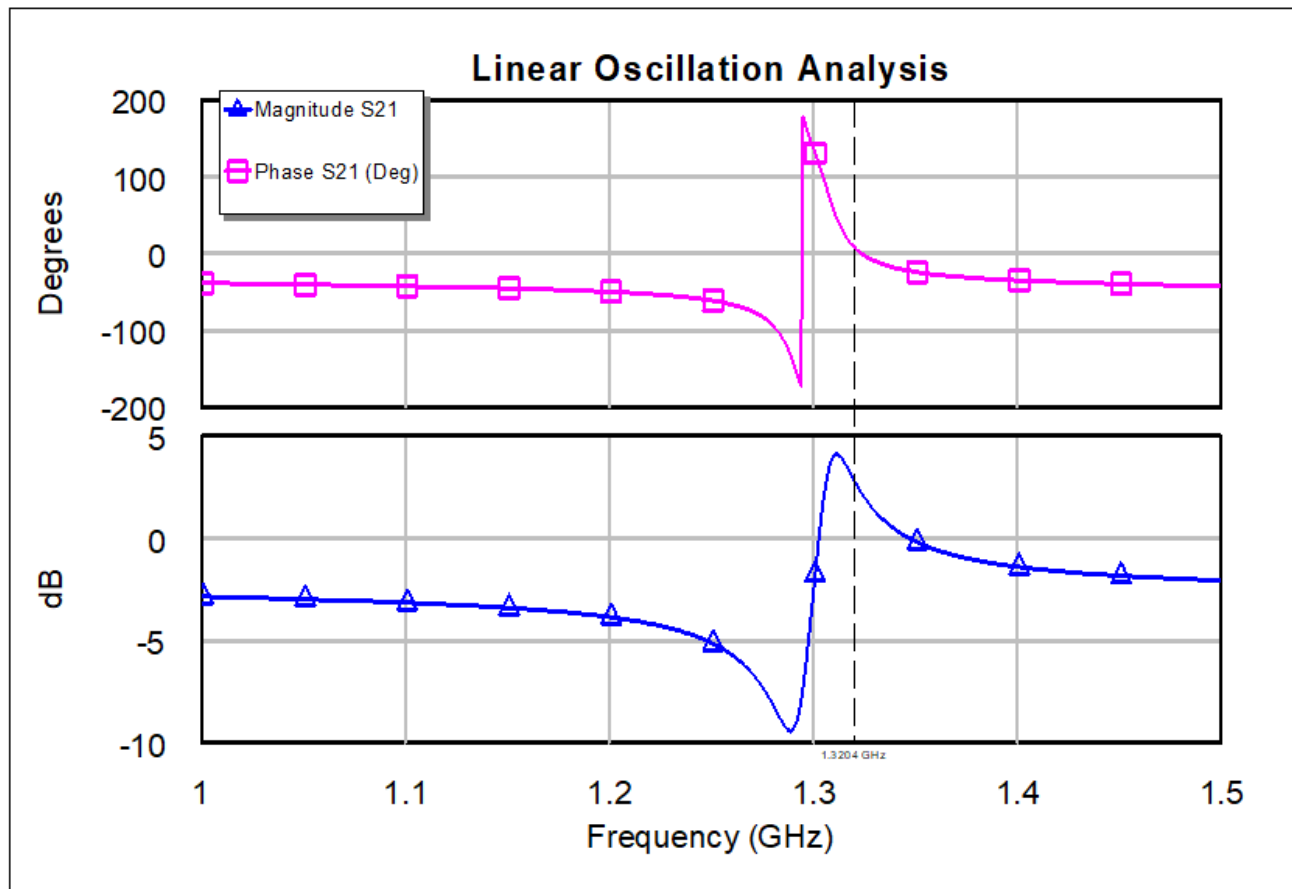
Overview

The AWR Design Environment (AWRDE) has some extremely powerful capabilities for analyzing oscillators. However, the designer should follow a suggested design procedure to effectively simulate this type of circuit. Many times designers piece together their circuit and expect the nonlinear simulation to give good results immediately without first analyzing the linear results to get a feeling of how the circuit will behave.

The design in this example starts with a linear simulation of the circuit with the OSCTEST element to break the feedback loop to look for approximate oscillation conditions. Since this is a linear type of analysis, the circuit can easily be tuned or optimized to find the appropriate element values. Once the appropriate linear oscillation conditions have been determined, then the nonlinear simulation can be performed. The OSCTEST element is removed and the OSCAPROBE is used to determine the nonlinear characteristics of the oscillator.

A supplemental schematic is added with no OSCTEST or OSCAPROBE, to show how the NDF measurement detects the oscillator's instability as the coax line's length is varied over a wide range.
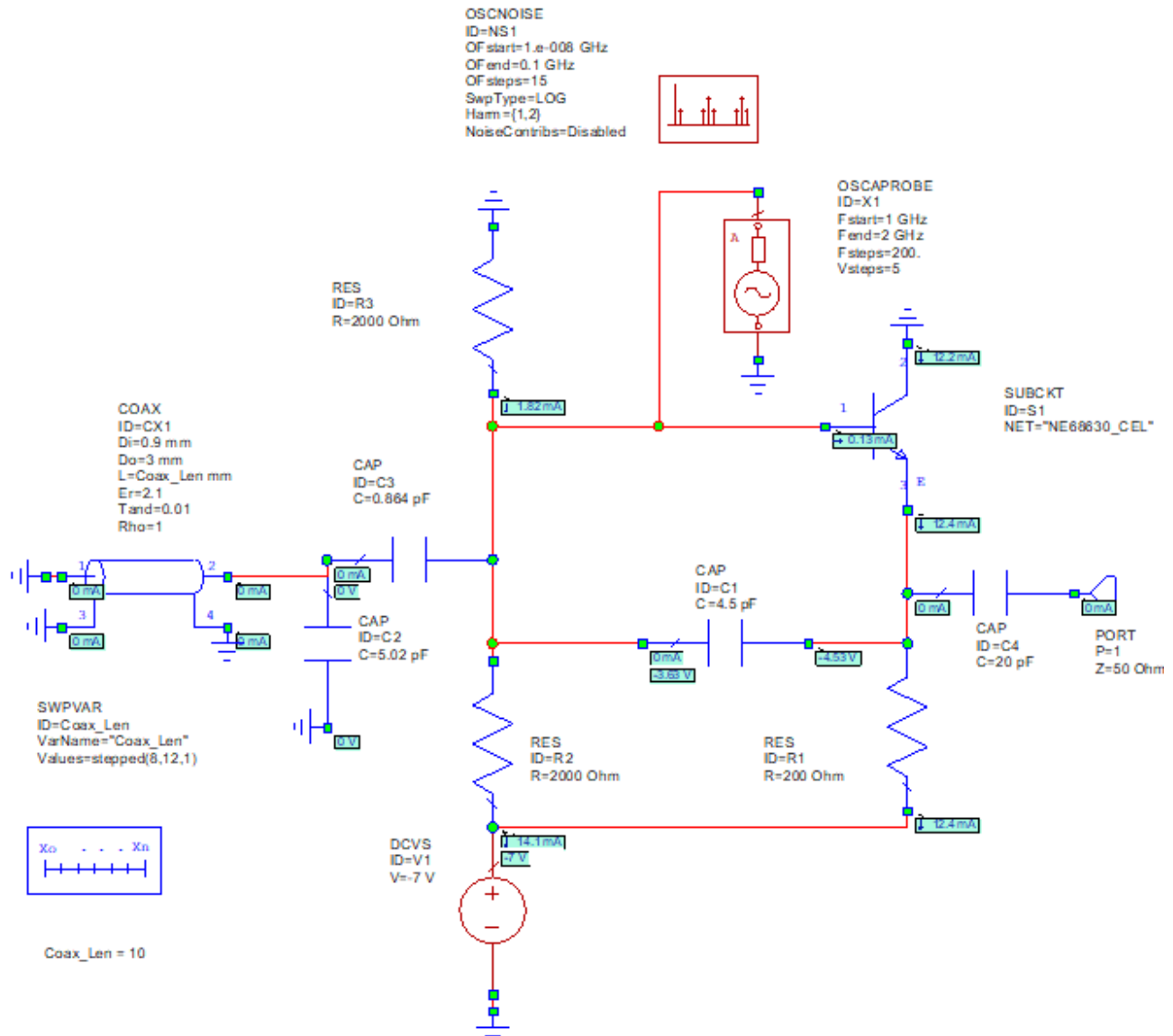
Step_1_Linear_Oscillator schematic

PORT
P=2
Z=50 Ohm

PORT
P=1
Z=50 Ohm

RES
ID=R3
R=2000 Ohm

0 mA

0 mA

0 mA 0 mA
0 V 0 V

12.2 mA

COAX
ID=CX1
Di=0.9 mm
Do=3 mm
L=10 mm
Er=2.1
Tand=0.01
Rho=1

1.82 mA

1

0.13 mA

0.13 mA

SUBCKT
ID=S1
NET="NE68630_CEL"

CAP
ID=C3
C=0.864 pF

2

-3.63 V

OSCTEST
ID=OD1

3

12.4 mA

1

0 mA

2

0 mA

0 mA

0 V

CAP
ID=C2
C=5.02 pF

0 mA

0 V

3

0 mA

4

0 mA

0 mA

-3.63 V
ID=C1
C=4.5 pF

-4.53 V

0 mA

CAP
ID=C4
C=20 pF

0 mA

PORT
P=3
Z=50 Ohm

0 V

RES
ID=R2
R=2000 Ohm

RES
ID=R1
R=200 Ohm

12.4 mA

DCVS
ID=V1
V=-7 V

14.1 mA

-7 V

+
−

This schematic has the full design with the OSCTEST element in the feedback loop to look at the loop characteristics of this circuit. Notice that the direction of the OSCTEST element is into the transistor, which is the forward gain direction. For approximate oscillation conditions to be achieved, the angle of S21 using the OSCTEST will cross the zero angle point when the magnitude of S21 is at a maximum. The phase and magnitude of S21 are shown in the graph "Linear Oscillation Analysis".

Linear Oscillation Analysis

This design is very sensitive to the capacitor C1. Try tuning on its value and watch the linear results change and see how it is possible to get away from the linear oscillation approximation. The original design value is 4.5 pF. Notice with the marker that the approximate oscillation frequency with this circuit is 1.32 GHz.
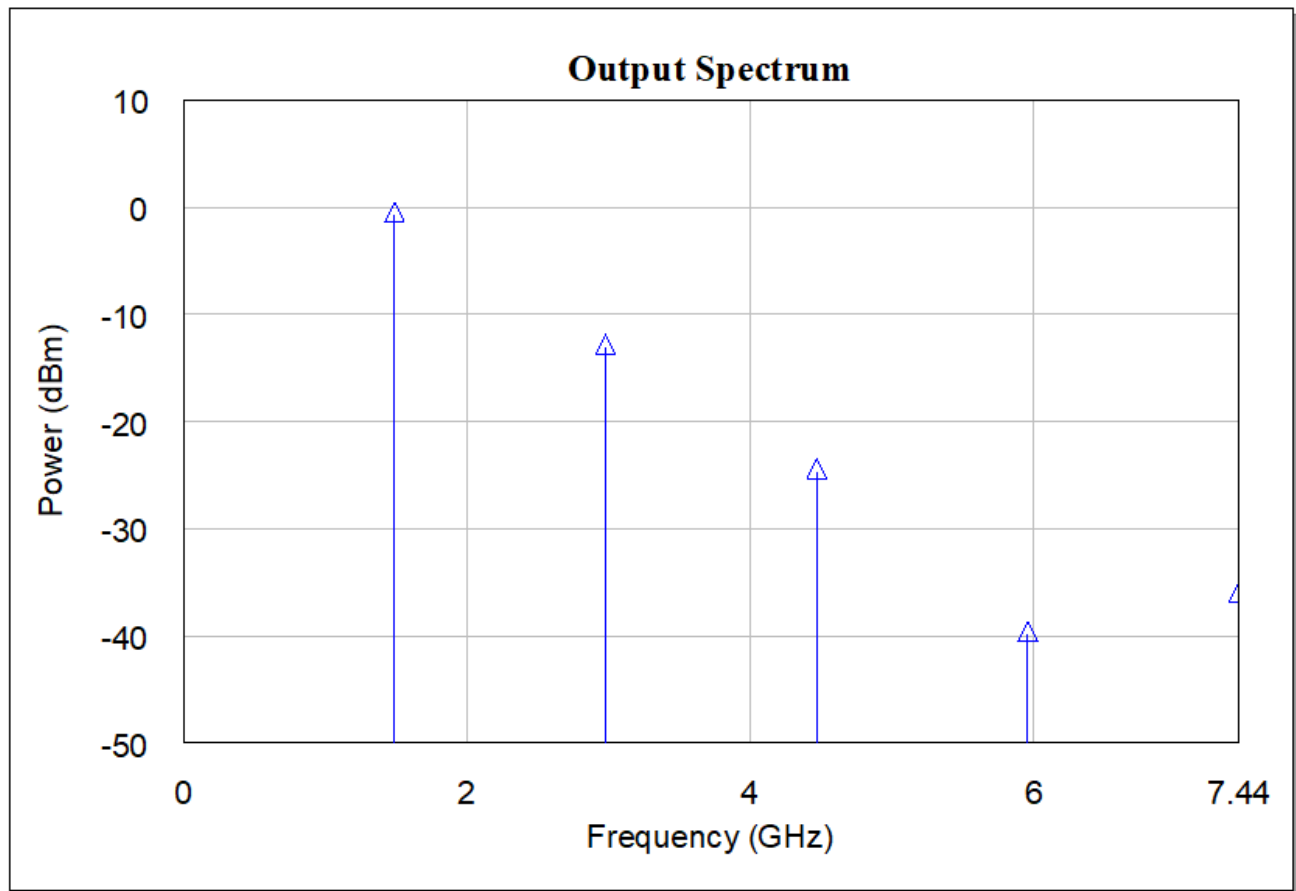
Step_2 Nonlinear Oscillator schematic

OSCNOISE
ID=NS1
OFstart=1.e-008 GHz
OFend=0.1 GHz
OFsteps=15
SwpType=LOG
Harm={1,2}
NoiseContribs=Disabled

OSCAPROBE
ID=X1
Fstart=1 GHz
Fend=2 GHz
Fsteps=200.
Vsteps=5

RES
ID=R3
R=2000 Ohm

SUBCKT
ID=S1
NET="NE68630_CEL"

12.2 mA

1.82 mA

0.13 mA

COAX
ID=CX1
Di=0.9 mm
Do=3 mm
L=Coax_Len mm
Er=2.1
Tand=0.01
Rho=1

CAP
ID=C3
C=0.864 pF

E

12.4 mA

CAP
ID=C1
C=4.5 pF

0 mA
0 V

0 mA

0 mA

0 mA

CAP
ID=C2
C=5.02 pF

0 mA

CAP
ID=C4
C=20 pF

PORT
P=1
Z=50 Ohm

0 mA

3.83 V

4.53 V

SWPVAR
ID=Coax_Len
VarName="Coax_Len"
Values=stepped(8,12,1)

Xo . . . Xn

RES
ID=R2
R=2000 Ohm

RES
ID=R1
R=200 Ohm

12.4 mA

DCVS
ID=V1
V=-7 V

14.1 mA
-7 V

+
−

Coax_Len = 10

Now that the linear analysis shows that this circuit should oscillate at 1.32 GHz, non-linear oscillator characteristics can be simulated. The OSCTEST element is removed and the OSCAPROBE is hooked into the feedback loop. With this element, the simulator can determine the large signal oscillation frequency, output power and phase noise. Information from the linear analysis is used for setting up the OSCAPROBE element. The user has to specify the frequency range that probe will use search between when looking for oscillations. Please use the help for this model for more information on each of the probe's parameters.
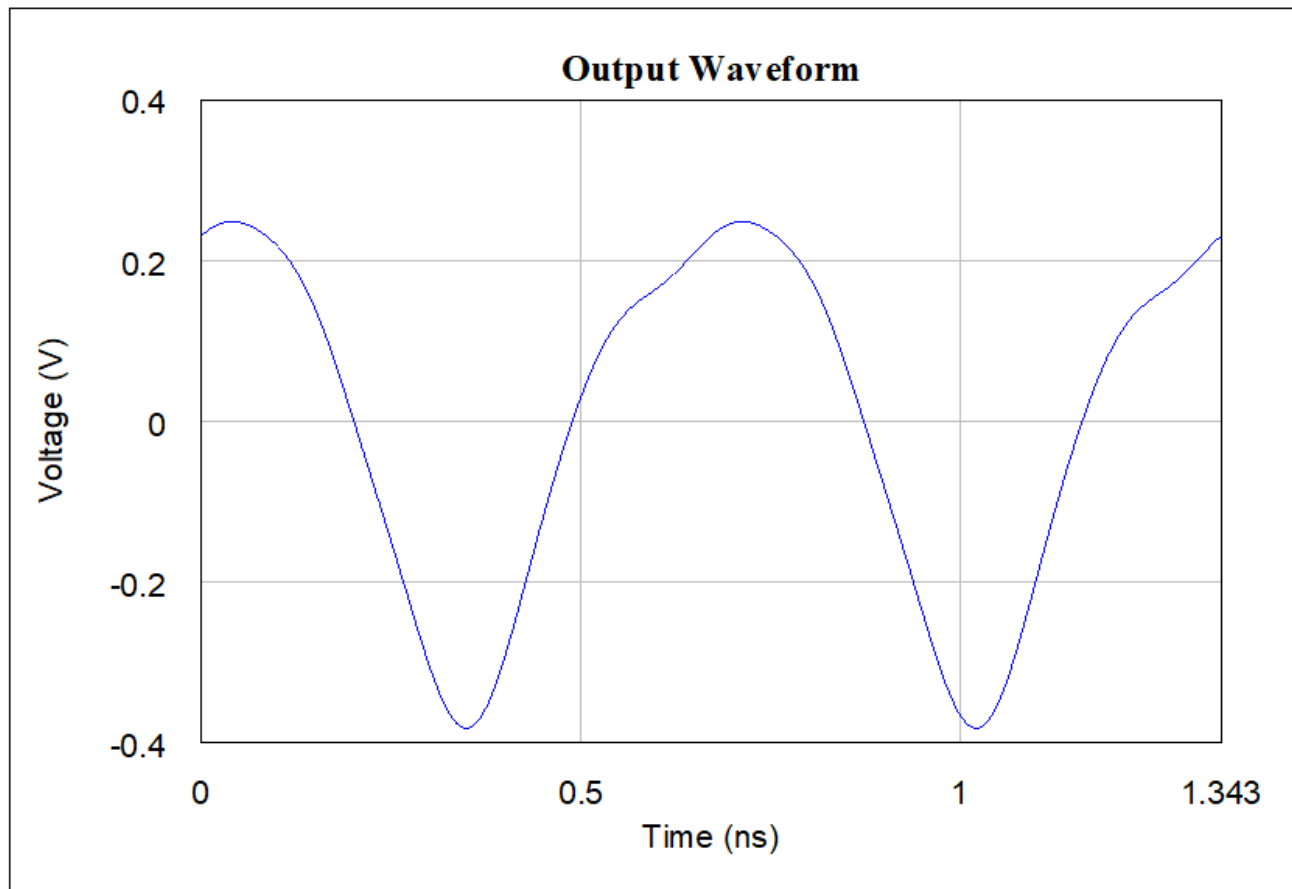
In this design, the coax line in the resonator can be used to set the frequency of oscillation. To help determine the appropriate length of the line to get the right oscillation frequency, the length of this line has been setup as a swept variable to sweep from 8 to 12 mm. The graph "Oscillation Frequency" shows a plot of the oscillation frequency versus the coax line length. You can see that a fairly linear change in oscillation frequency can be achieved by changing this length. Additionally, notice that when the length is 10 mm (same length as the linear schematic); the oscillation frequency is approximately 1.325 GHz, very close to the linear approximation.

Finally, additional characteristics of the oscillator are determined in this example, as shown in the graphs listed below. These are all simulated over the swept coax line and the results are set to be tunable. Open up the tuner, change the value of Coax_Len, and watch all of these graphs change based on the length of coax line simulated:
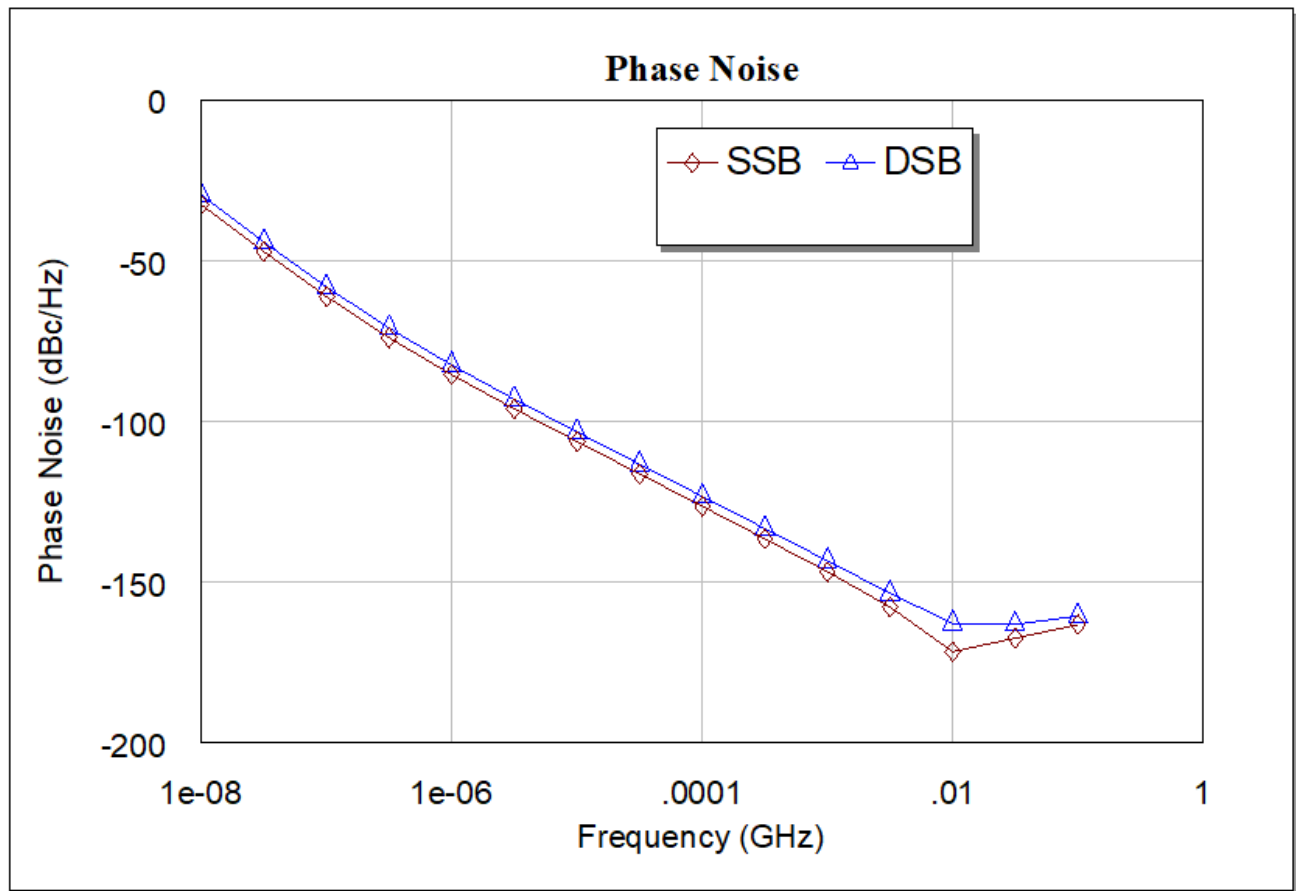
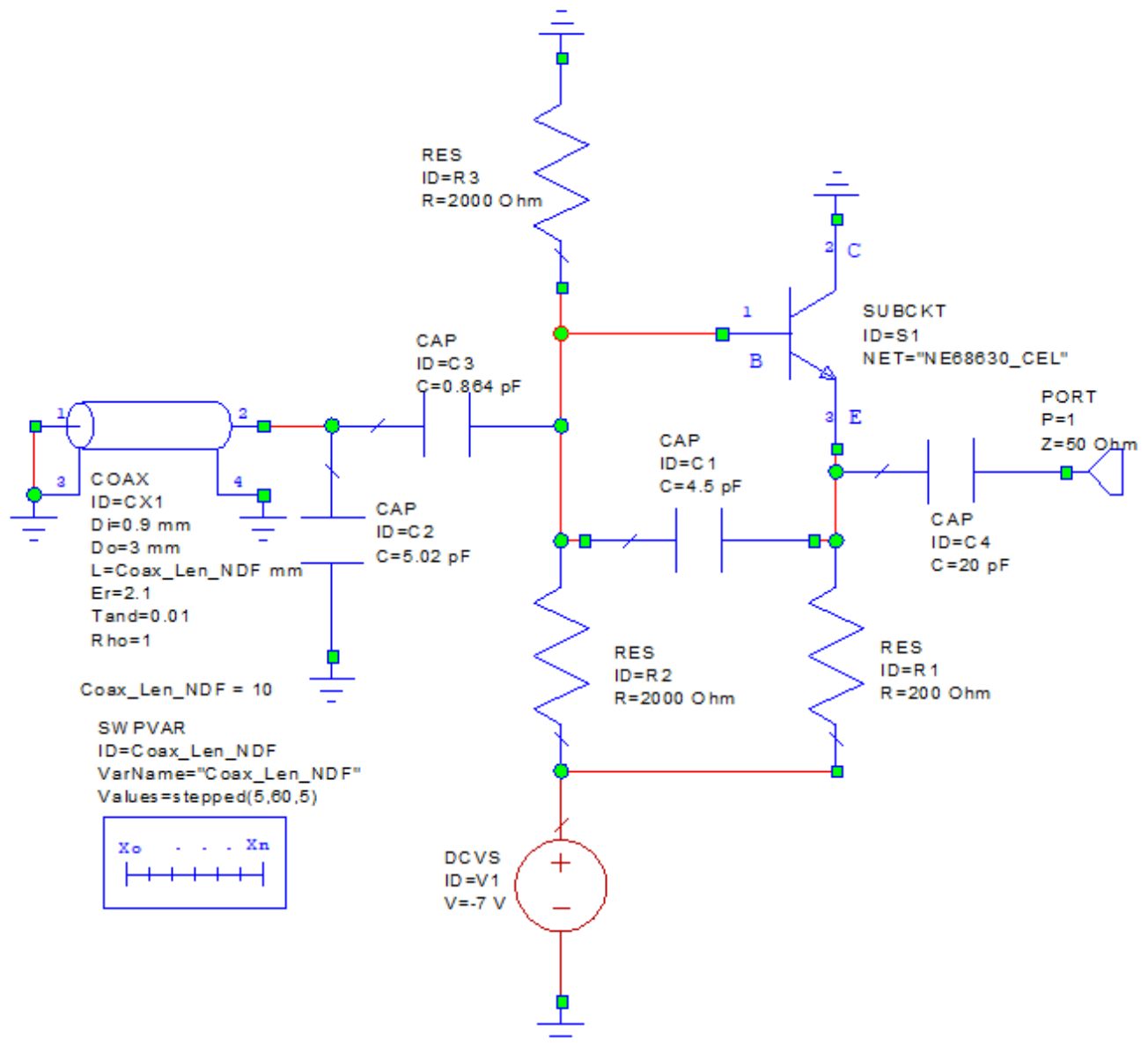- "Output Spectrum" - The output power spectrum of the oscillator.

Output Spectrum

- "Output Waveform" - The output waveform in the time domain, over two periods of oscillation.

Output Waveform

- "Phase Noise" - The phase noise of the oscillator. Note that the frequency for the phase noise is the frequency offset from the oscillator fundamental frequency. Also notice the 3dB relationship between the SSB and the DSB phase noise.
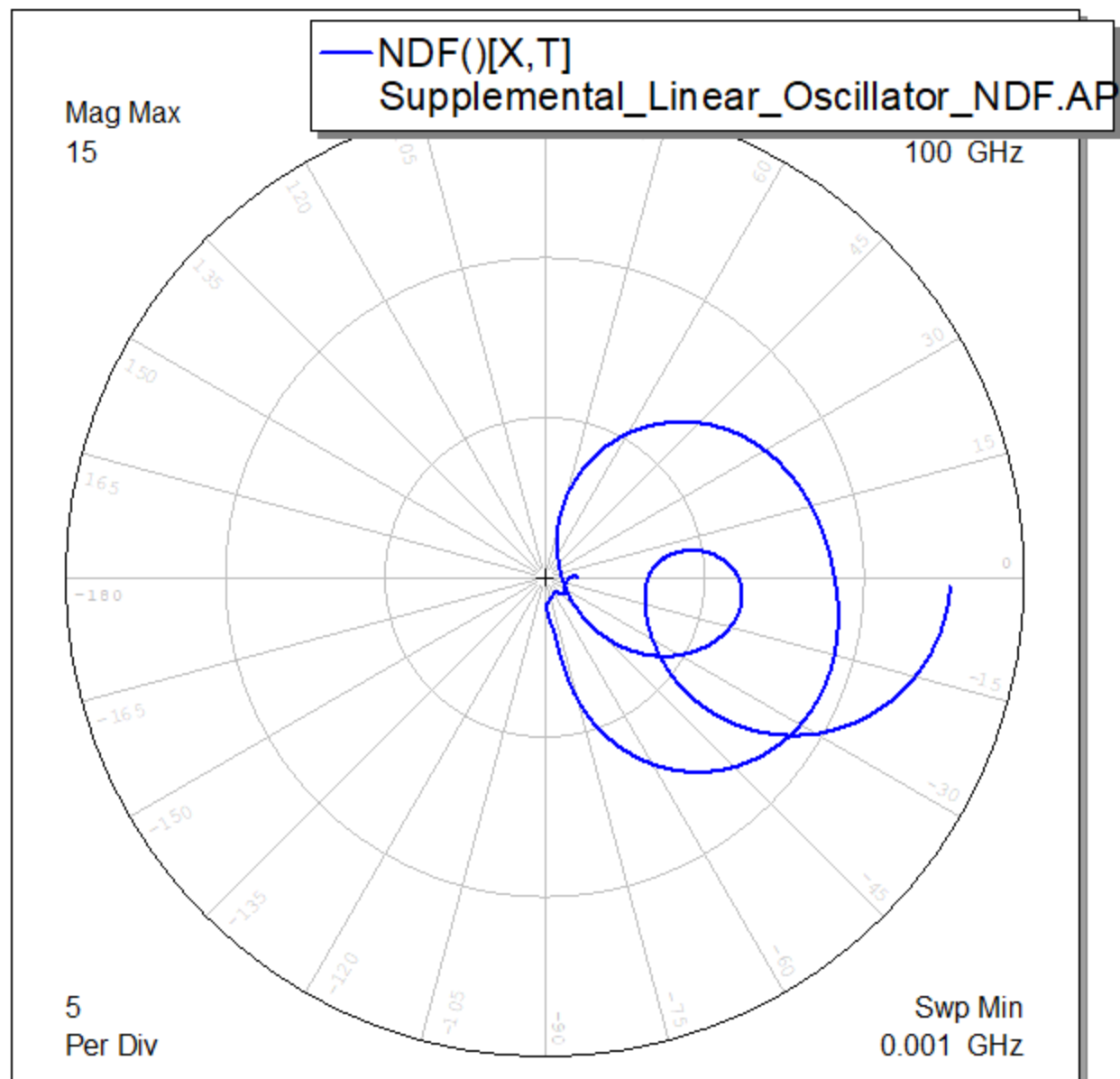
Supplemental_Linear_Oscillator_NDF schematic

RES
ID=R3
R=2000 Ohm

CAP
ID=C3
C=0.864 pF

SUBCKT
ID=S1
NET="NE68630_CEL"

C

B

E

1

2

3

PORT
P=1
Z=50 Ohm

COAX
ID=CX1
Di=0.9 mm
Do=3 mm
L=Coax_Len_NDF mm
Er=2.1
Tand=0.01
Rho=1

1   2

3   4

CAP
ID=C2
C=5.02 pF

CAP
ID=C1
C=4.5 pF

CAP
ID=C4
C=20 pF

Coax_Len_NDF = 10

SWPVAR
ID=Coax_Len_NDF
VarName="Coax_Len_NDF"
Values=stepped(5,60,5)

Xo   . . .   Xn

RES
ID=R2
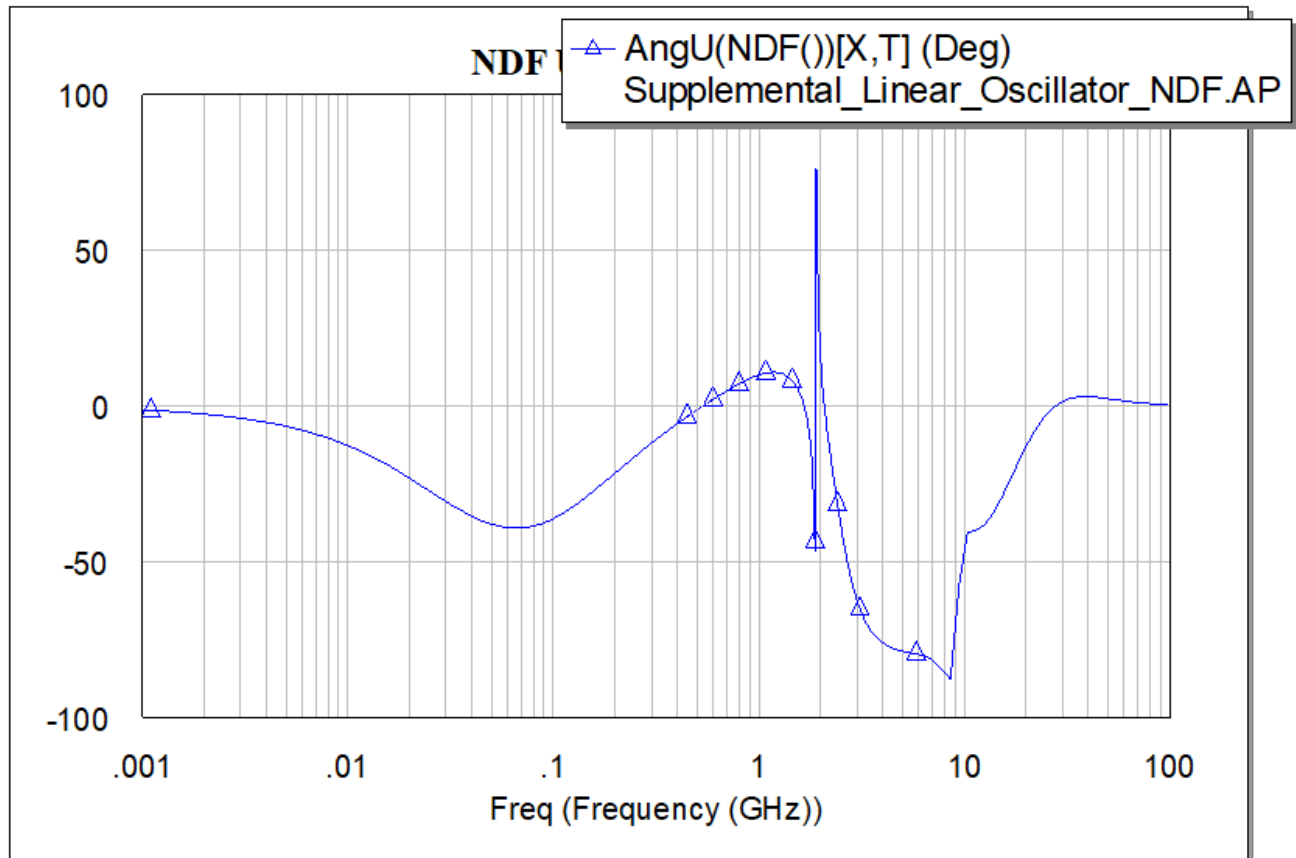R=2000 Ohm

RES
ID=R1
R=200 Ohm

DCVS
ID=V1
V=-7 V

+

−

In this schematic, the oscillator circuit is drawn without additional measurement or simulation control elements, except for a SWPVAR block that varies the coax line length over a range so wide that the oscillator will not work at the extremes.

The complex NDF measurement approaches constant real values as frequency approaches 0 or infinity. Instability is indicated when NDF encircles the origin of a polar plot as frequency is swept from very low to very high (see the "NDF Polar" graph).

In other words, if the phase of NDF decreases by more than 360 degrees, the circuit is unstable (see "NDF Unwrapped Angle" graph).

NDF ━━ AngU(NDF())[X,T] (Deg)
Supplemental_Linear_Oscillator_NDF.AP

After the simulation is completed, open the NDF graphs and the tuner, then use the slider for the Coax_Len_NDF variable to see how the NDF measurement varies with the coax line length.

The frequency sweep must be set carefully, to ensure that encirclements of the origin can be detected, and that the unwrapped phase of NDF is continuous. Note that the frequency sweep set on this schematic is irregular to ensure sufficient resolution where necessary.