**METHOD:**

**Generator Noise in Time and Frequency Domains**

1. Set the generator for a noise (random) signal output with 2Vp-p into a 50 ohm load. Verify your amplitude setting using a sine wave. Set the oscilloscope for sample rate of 250Ms/sec, input R=50, and the bandwidth to 150 MHz.
   1. Measure the p-p, rms, and DC magnitude of the noise waveform using the oscilloscope. Be sure the noise is not clipping. Hint(use the run stop button) Why is it not reading 2vp-p? Calculate the Vp-p to Vrms ratio. What do we use this ratio for?

**476 mV p-p, 88.9 mV rms, -10 mV DC. The signal is random Gaussian noise, so the probabilities of a full voltage swing are very small. The Vpp:Vrms ratio is 5.35. This ratio is the crest factor, which can be used to measure the quality of a signal.**

* 1. Using the Spectrum Analyzer (SA) to estimate the 3dB bandwidth of the noise. Ask for help setting up the SA when you get to this step.

**The 3dB bandwidth of the noise 35 MHz**

* 1. The SA shows the power calculated for all frequencies within the resolution bandwidth (RBW) for the settings you have, P(f)=dBm/RBWHz. From the RBW it calculates P(f)=dBm/Hz assuming P(f) is constant amplitude across the RBW frequency range. Record the SA resolution bandwidth (RBW), power P(f)=(dBm/RBW) , and the power/Hz P(f)=dBm/Hz at 10 MHz.

**RBW = 100 kHz**

**P(f) = -86.23 dBm/Hz**

**P(f) = -36 dBm/Hz @ 10 MHz**

* 1. At what frequency does P(f) dBm/Hz= P(10 MHz) dBm/Hz-3dB? This is the 3dB noise bandwidth of the function generator.

**35 MHz**

* 1. What power in dBm you would measure if the resolution bandwidth was increased by a factor of 10?

**10 dBm**

**RC low pass filter**

1. Make a **RC low pass filter** using a **220pF** capacitor by placing it in parallel with the output of the generator. (Remember the generator output is 50 ohms).
   1. Measure the 3 dB bandwidth of the filter using the oscilloscope (hi-Z input) and a variable frequency sinewave. Compare this to the theoretical 3dB bandwidth.

**Measured 12 MHz, the theoretical is 15 MHz**

* 1. Set the generator back to 2Vp-p noise and look at the signal on the SA. Notice that the 3dB bandwidth of the noise spectrum has been reduced to the 3db bandwidth of the low pass filter.
  2. Re-measure the Vp-p and Vrms at the filter output using the settings from part 1. Why did the measured values change? (Explain by showing what happens to a signal going through a low pass filter- LPF using N0 and H(f)).

**30.4 mV p-p, 4.39 mV RMS, 824 uV DC. Because we’re going through a low pass filter, the higher frequency noise components are being thrown away.**

* 1. Reduce the 3dB bandwidth of the filter by using 440pF of capacitance and remeasure Vp-p and Vrms. Compare these voltages with the voltages measured in 2c. Calculate what you expect the values would be for a bandwidth reduction of ½. P watts =(N0 W/Hz)\*(Bn)

**Coupled LC Bandpass Filter**

1. Build the **Coupled Bandpass filter** shown in reference section and set the scope bandwidth to 20 MHz bandwidth.
   1. Use the scope to measure the center frequency and bandwidth of the filter using a swept sinewave. Record the -3dB, -6dB, -10dB, -20dB, and -40dB frequencies.

**Center = 1.34 MHz**

**-3dB = 1.37 MHz**

**-6dB = 1.47 MHz**

**-10dB = 1.56 MHz**

**-20dB = 1.12 MHz**

**-40dB = 0.67 MHz**

* 1. Set the oscilloscope to 2us/div with 20 MHz bandwidth, the generator output for noise with maximum amplitude. The noise voltage at the output of the filter is much lower since the bandwidth of the filter is small, trigger in the center of the screen, and set the trigger level as high as possible to get a trace. Setting the trigger for single trace mode helps. Note how the signal looks like a sinewave of the center frequency of the filter with amplitude that varies at a much slower rate. This is similar to an AM modulated waveform (Couch fig 5.1). Ask for help from the TA for an explanation of the waveform and setting the trigger correctly.
  2. What is the approximate frequency of the sine wave? The is related to the center frequency of the filter. Estimate the highest frequency in the envelope of the sinewave. This is related to the BW of the filter.

**12.5 MHz**

**50 MHz**

**X3 Frequency Multiplier and Filtered Signals**

1. Change the generator to a square wave with a frequency equal to the center frequency of the filter and connect a probe to the input of the filter to display both the input and output waveforms on the oscilloscope.
   1. The output of the filter should be a sinewave at the center frequency of the filter. Record the amplitude of the output sinewave and compare it to what you would expect from the square wave input. Explain any error. (hint, the filter allows some of the other harmonics through)

**156 mV p-p. This is equal to the magnitude of the first harmonic of the square wave, with some error.**

* 1. Plot the Spectrum of the input and output signals. Consider the first 3 spectral components of the output in your for your plot and calculate the distortion of the output sinewave.
  2. Change the generator frequency to 1/3 the center frequency of the filter. The output of the filter will be a sinewave at 3 times the generator frequency with distortion of f/3, 5\*f/3, 7\*f/3…. This principal of frequency multiplication is used in communication circuitry in transmitters and in receivers.