Communications Electronics

Signal Bandwidth

Topic Objectives

- Define the bandwidth of a filter

- Define the bandwidth of a signal

- Measure the bandwidth of a signal

What is Bandwidth?

- The term bandwidth can be used in different ways

    - Bandwidth of a filter
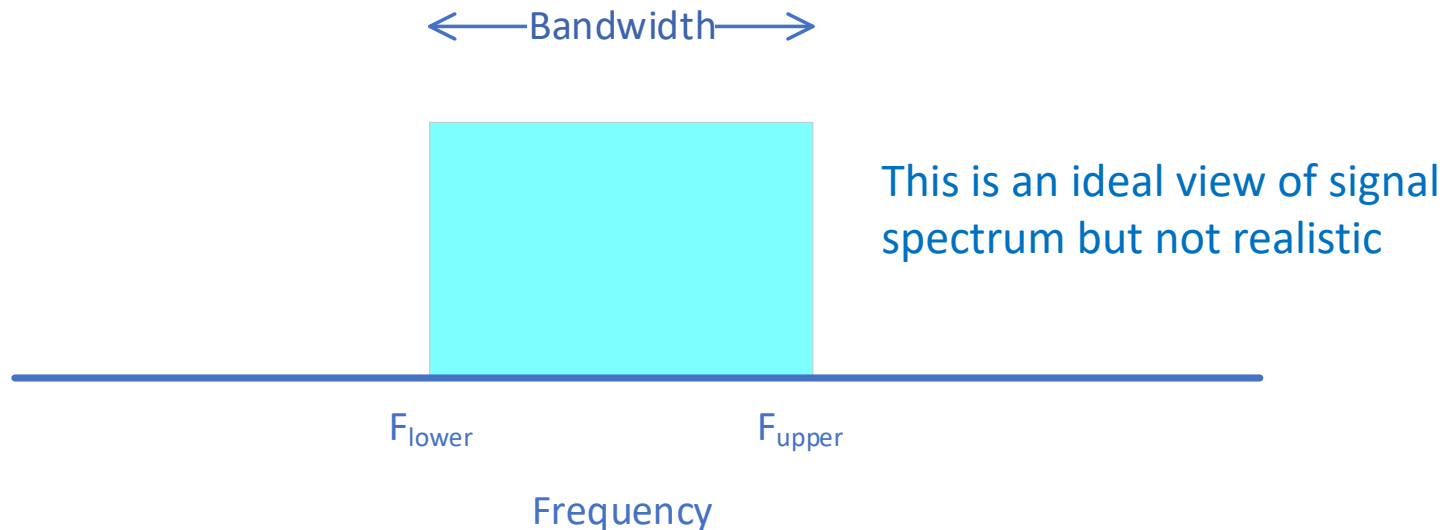   - Bandwidth of a signal

What is the Bandwidth of a <u>Signal</u>?

- In simple terms:

  - Bandwidth is the portion of the spectrum occupied by a signal

  - The frequency range over which a receiver or transmitter operates

  - If all the energy is contained between two frequencies, f_{upper} and f_{lower} then:

$$BW = f_{upper} - f_{lower}$$

What is the Bandwidth of a <u>Signal</u>?

- Simple definition -- The amount of spectrum occupied by all of the signal energy

$\longleftarrow$ Bandwidth $\longrightarrow$

This is an ideal view of signal spectrum but not realistic

F_{lower} F_{upper}

Frequency

$$BW = f_{upper} - f_{lower}$$

What is the Bandwidth of a <u>Signal</u>?

- The definition of Bandwidth is usually how much spectrum is occupied by a percentage of the total energy
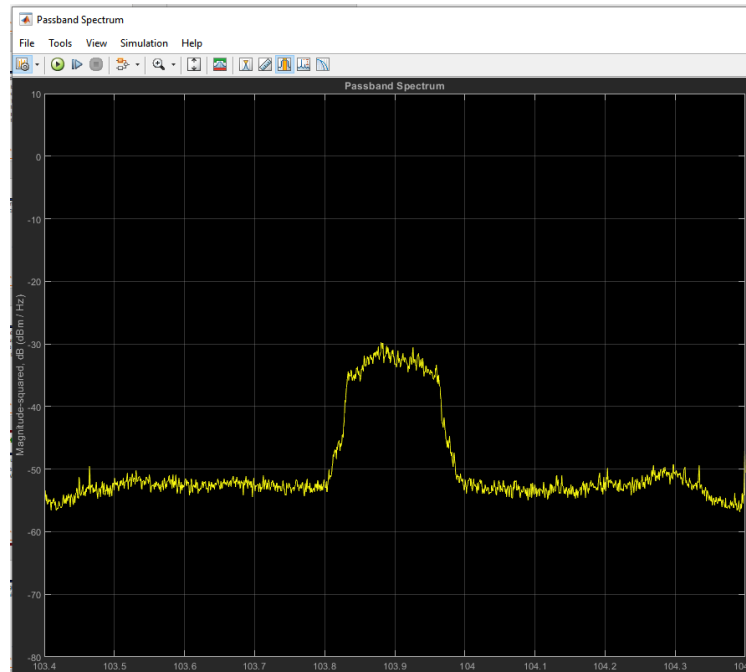 - 90% and 99% are common
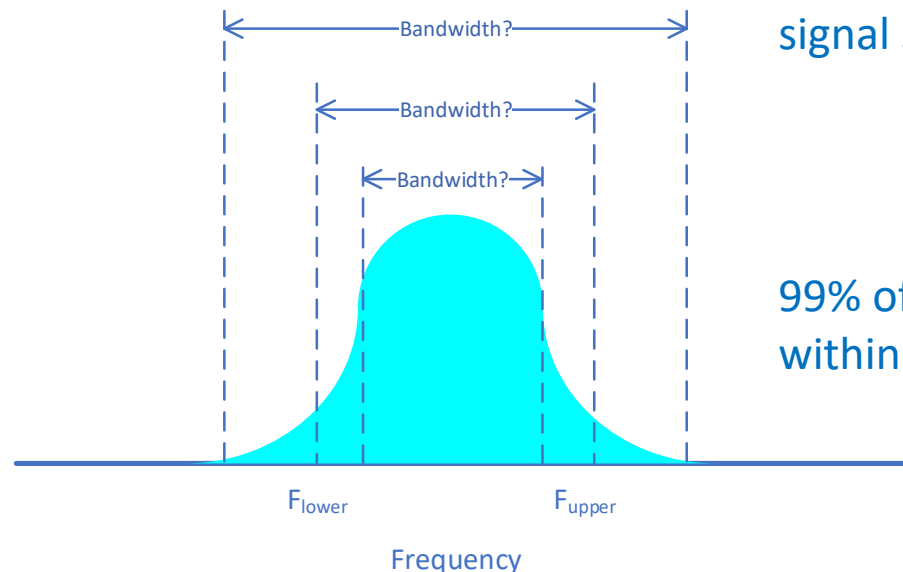
This is a more realistic view of a signal spectrum

99% of the energy is contained within xx kHz of spectrum

Bandwidth?

Bandwidth?

Bandwidth?
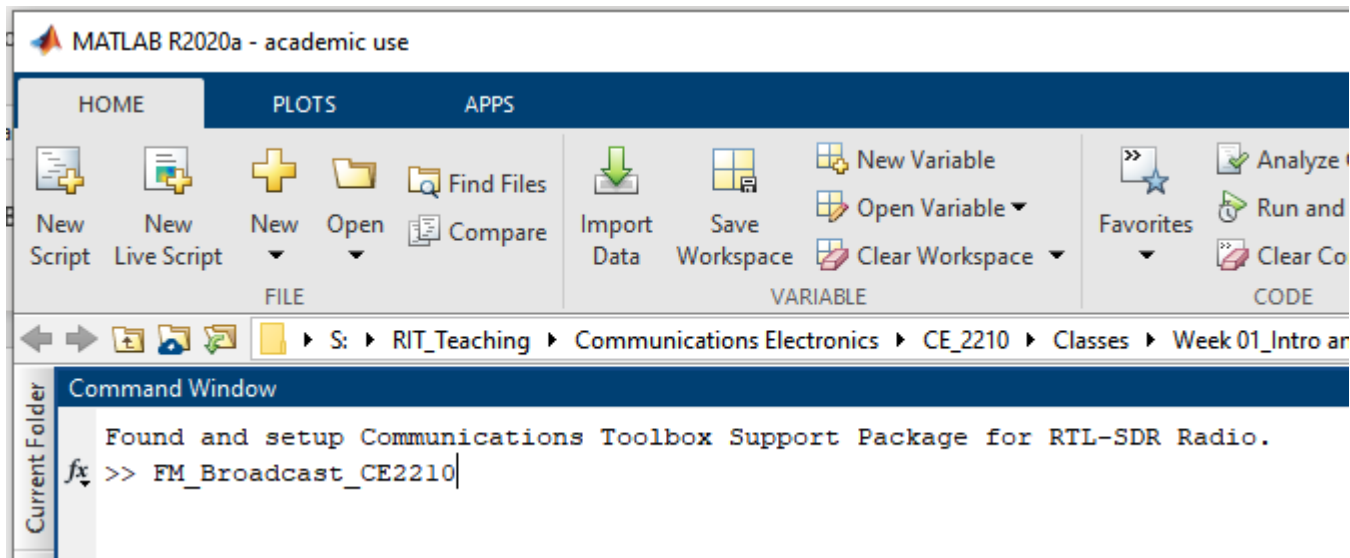
F_{lower}

F_{upper}

Frequency

How do you measure Signal Bandwidth?

- Usually measured on a spectrum analyzer

- We can use our RTL-SDR receiver and the SIMULINK spectrum analyzer!

Signal Bandwidth Example

- Run the FM Broadcast demonstration file after plugging in the RTL-SDR and connecting an antenna – "FM_Broadcast_CE2210"
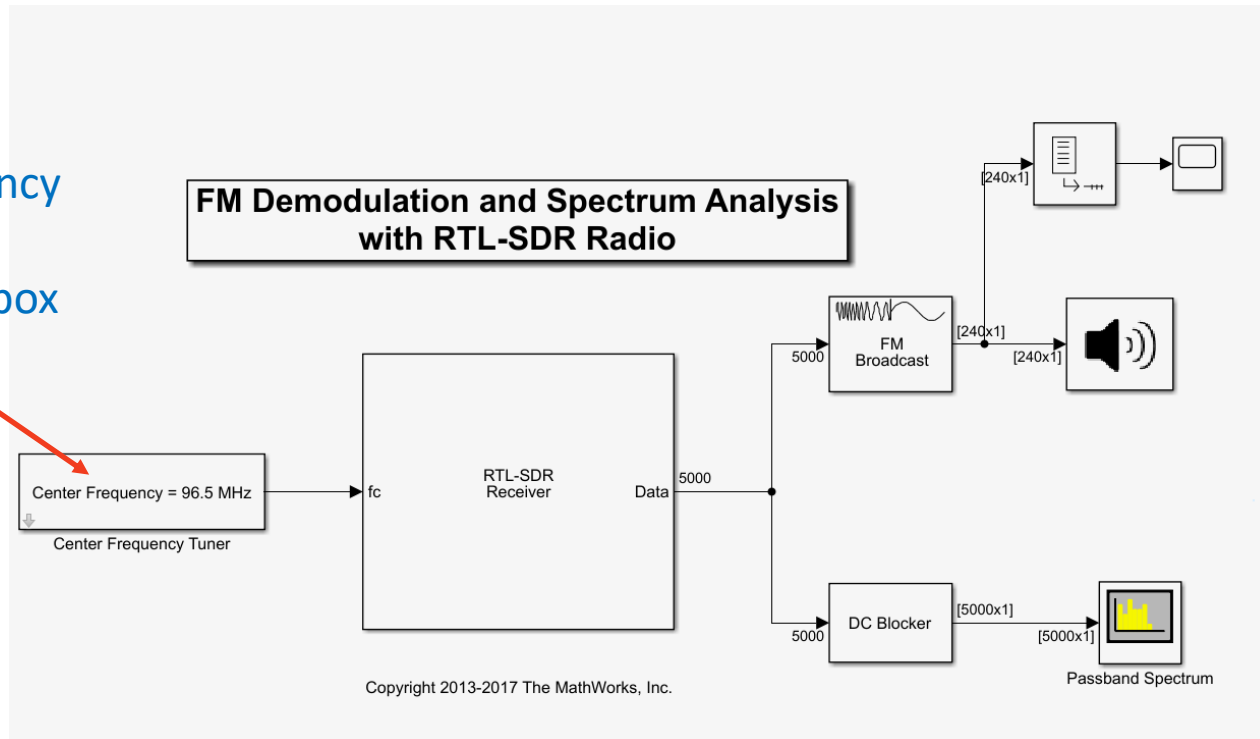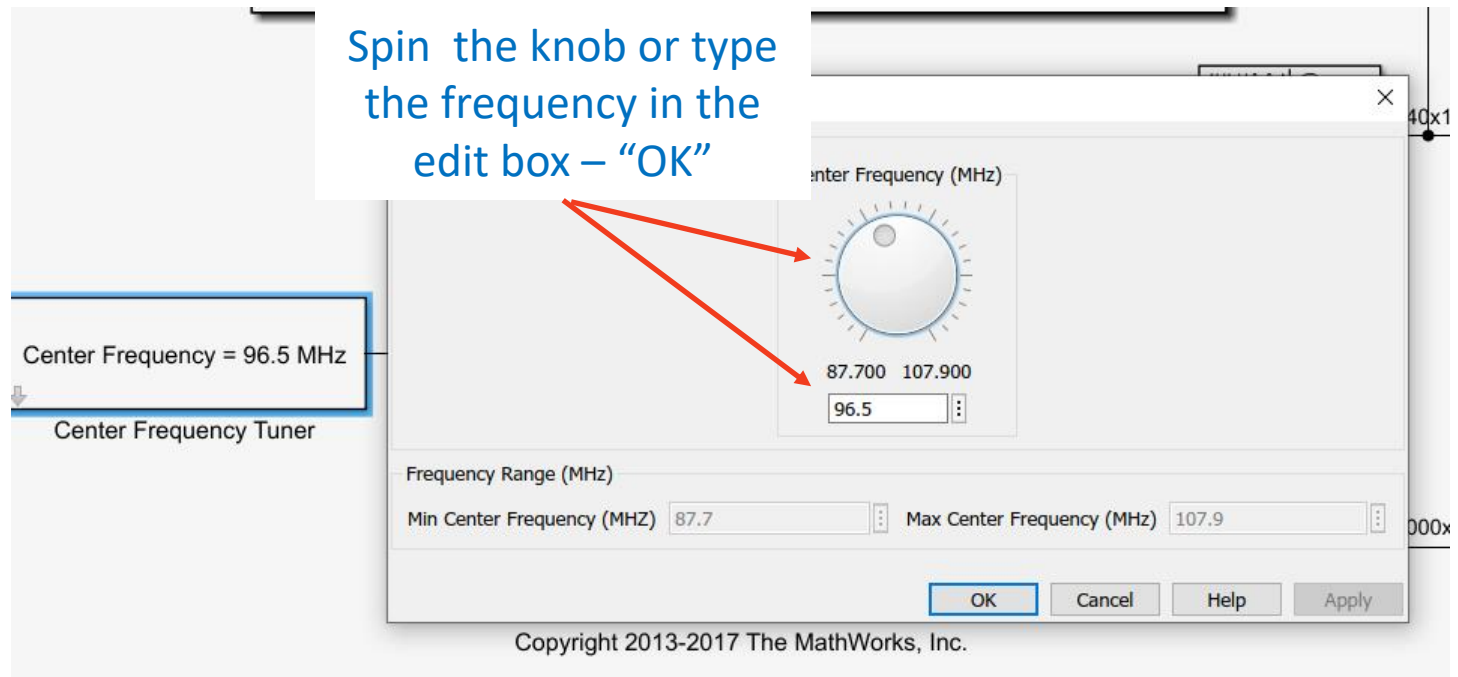
Signal Bandwidth Example

- ### Set the receiver frequency

Select the frequency
of an FM station
Double Click the box

**FM Demodulation and Spectrum Analysis
with RTL-SDR Radio**

Center Frequency = 96.5 MHz
Center Frequency Tuner

fc   RTL-SDR
          Receiver   Data   5000

5000   FM
       Broadcast

[240x1]

[240x1]
[240x1]

5000   DC Blocker   [5000x1]

[5000x1]
Passband Spectrum

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Signal Bandwidth Example

- Set the receiver frequency

Spin the knob or type the frequency in the edit box – "OK"
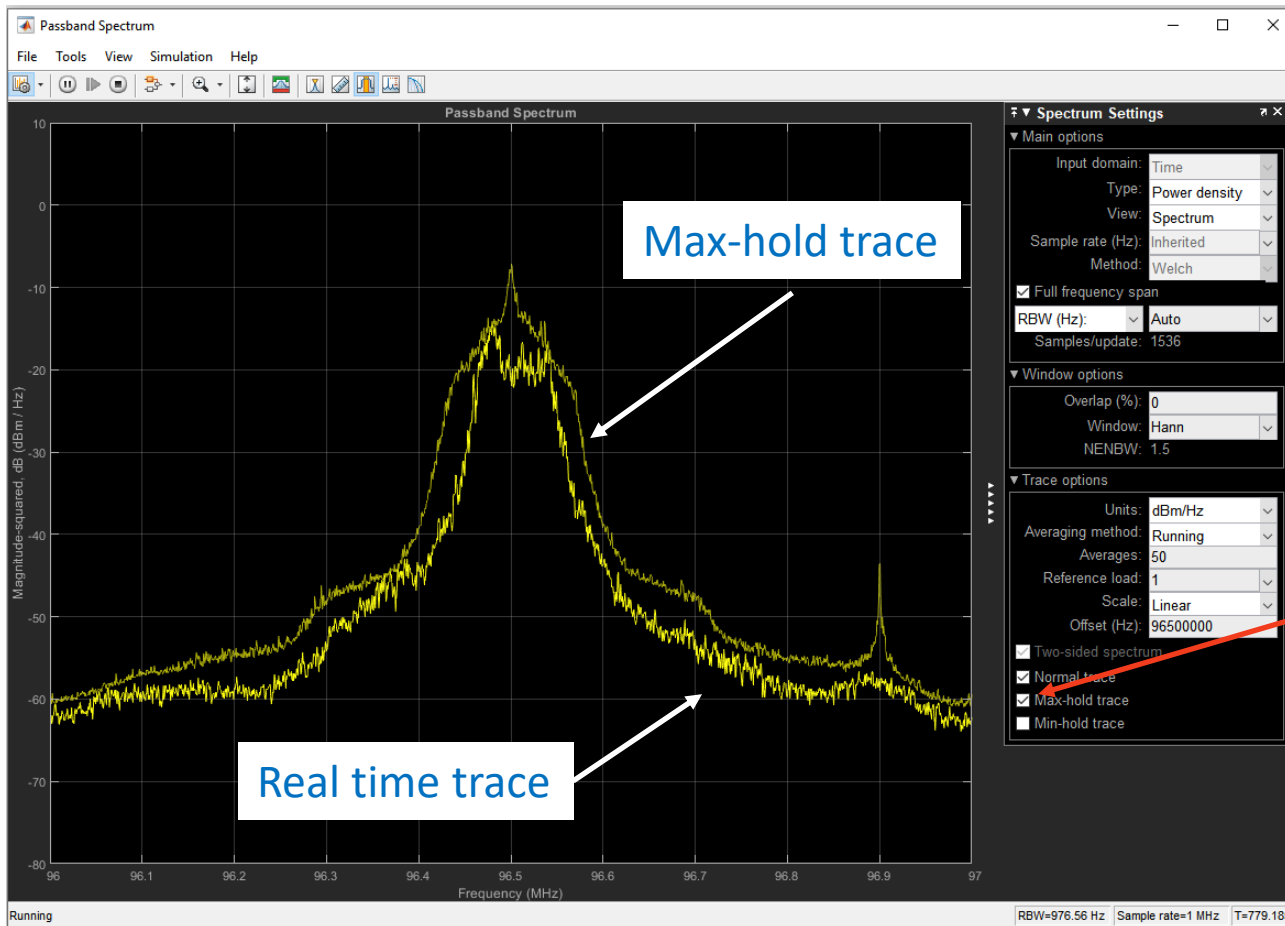
Signal Bandwidth Example

- Open the spectrum analyzer
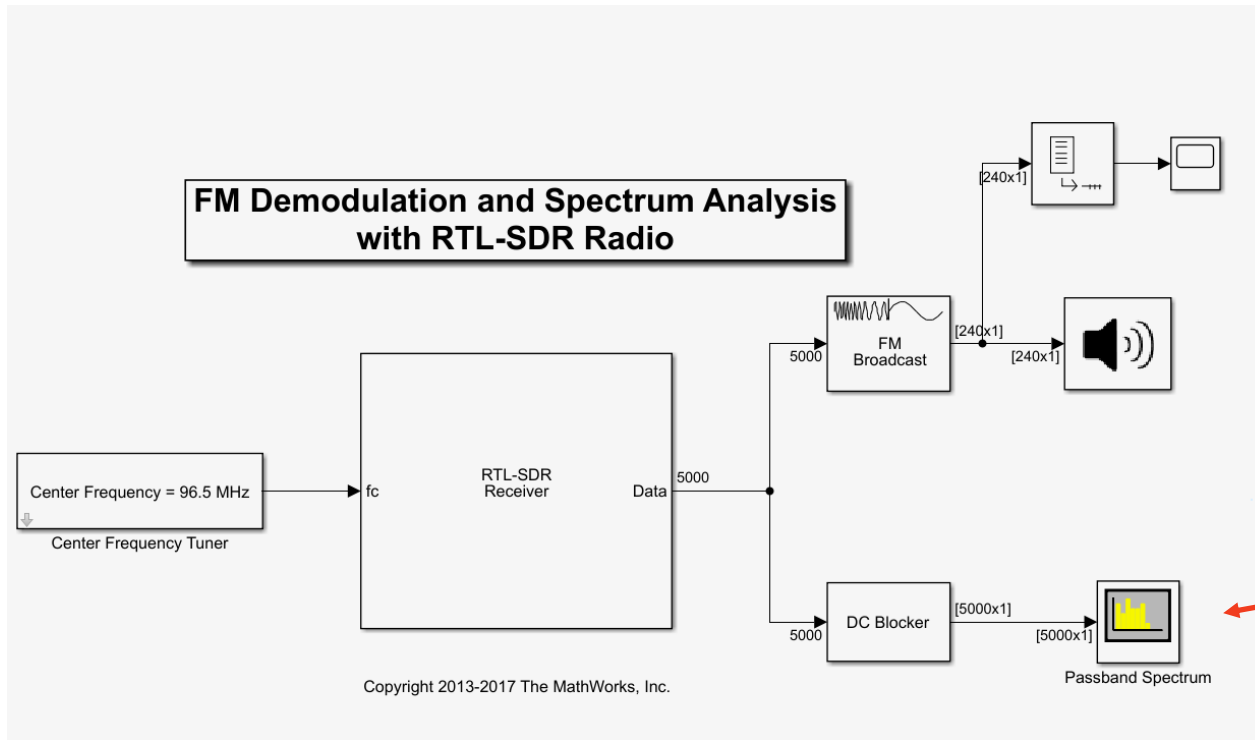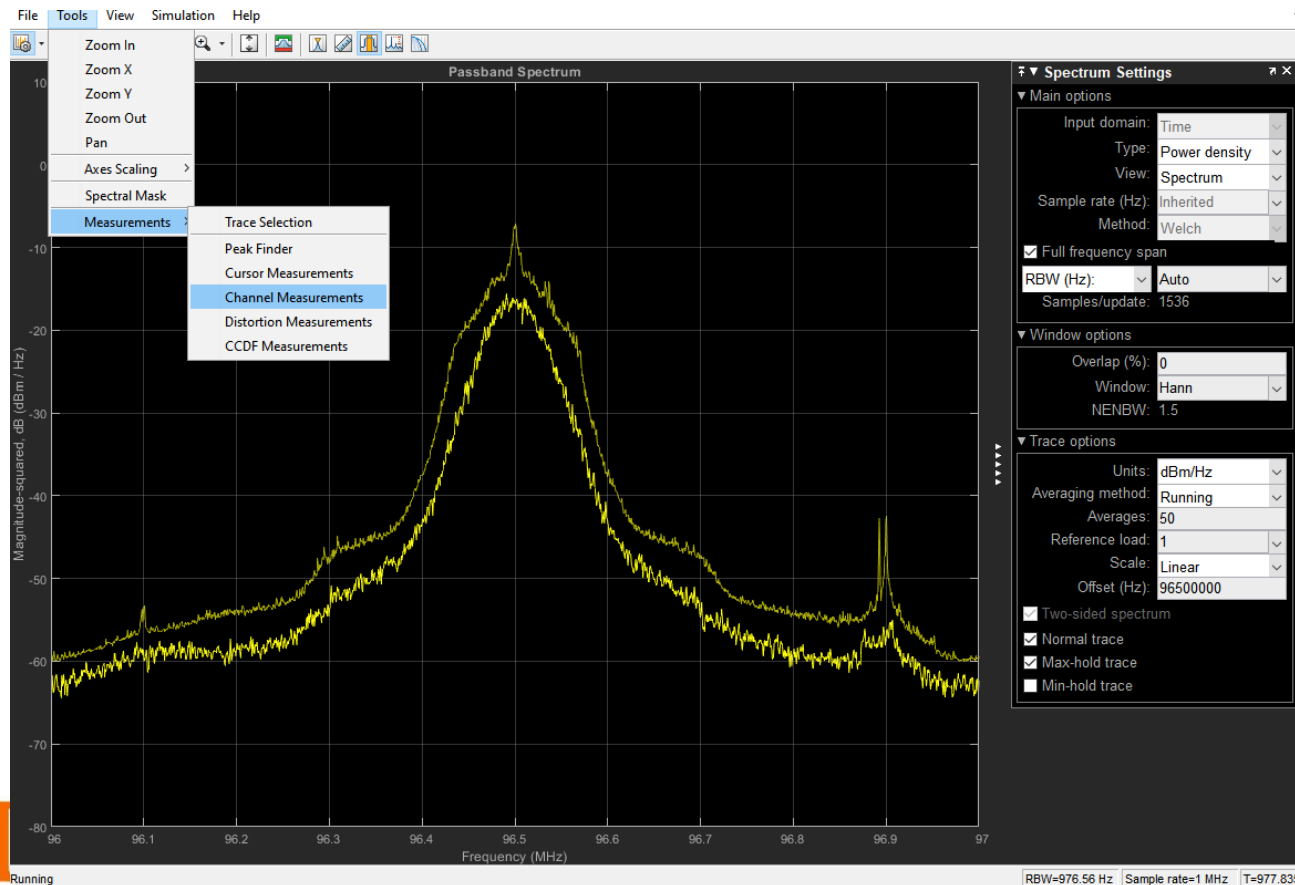

Double click the Spectrum Analyzer

Signal Bandwidth Example

- Max-Hold Trace will save the largest value over time
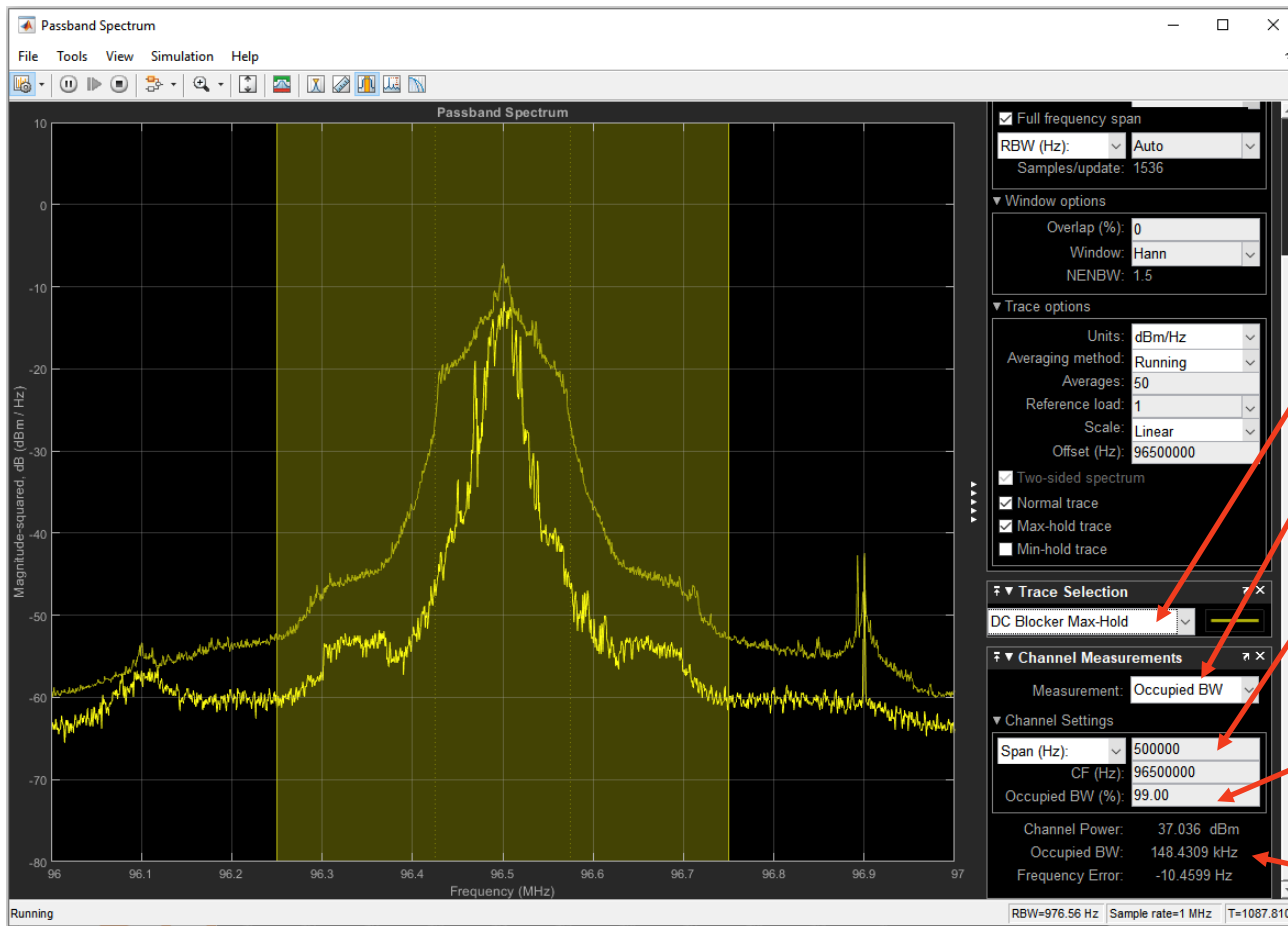
- Shows how wide it could be over time

Signal Bandwidth Example

- Select Tools/Measurements/Channel Measurements

Signal Bandwidth Example

- Set up the channel measurement for Occupied Bandwidth

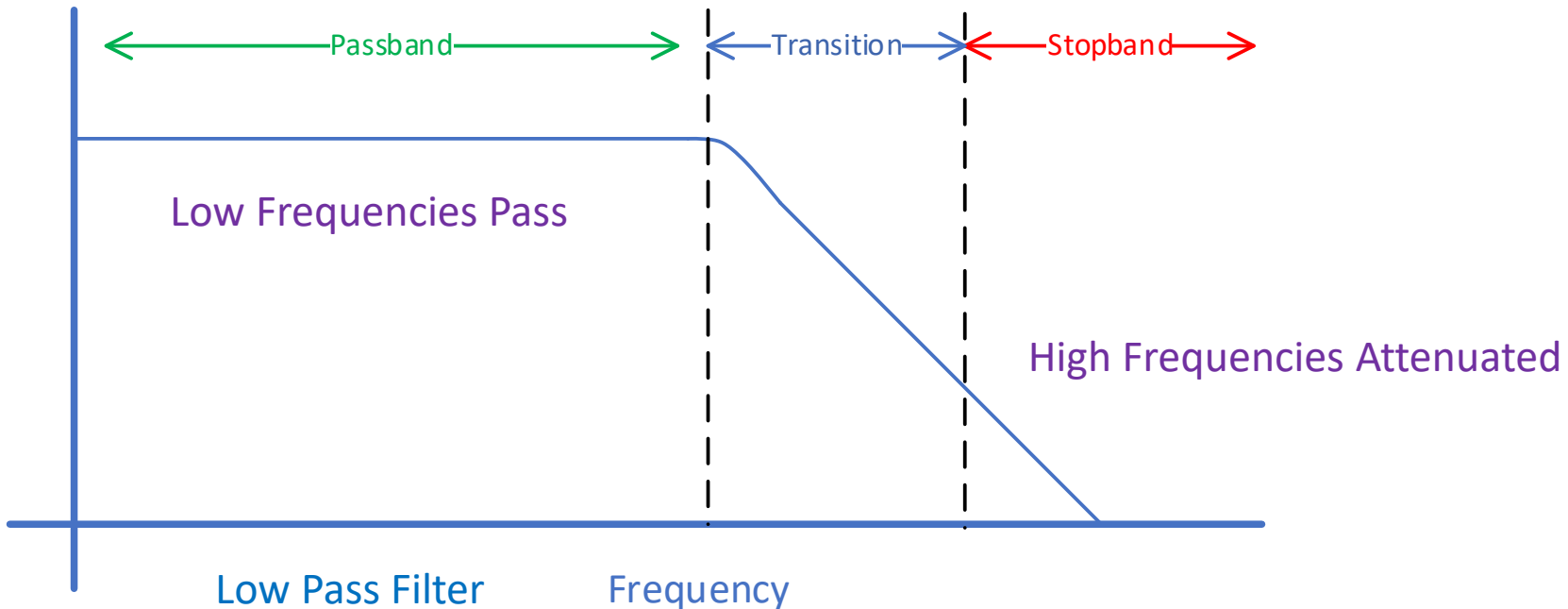In Trace Selection
Select DC Blocker Max-Hold

Occupied BW

Set Span 500e3
Center Freq – Your station

Set Desired % Power
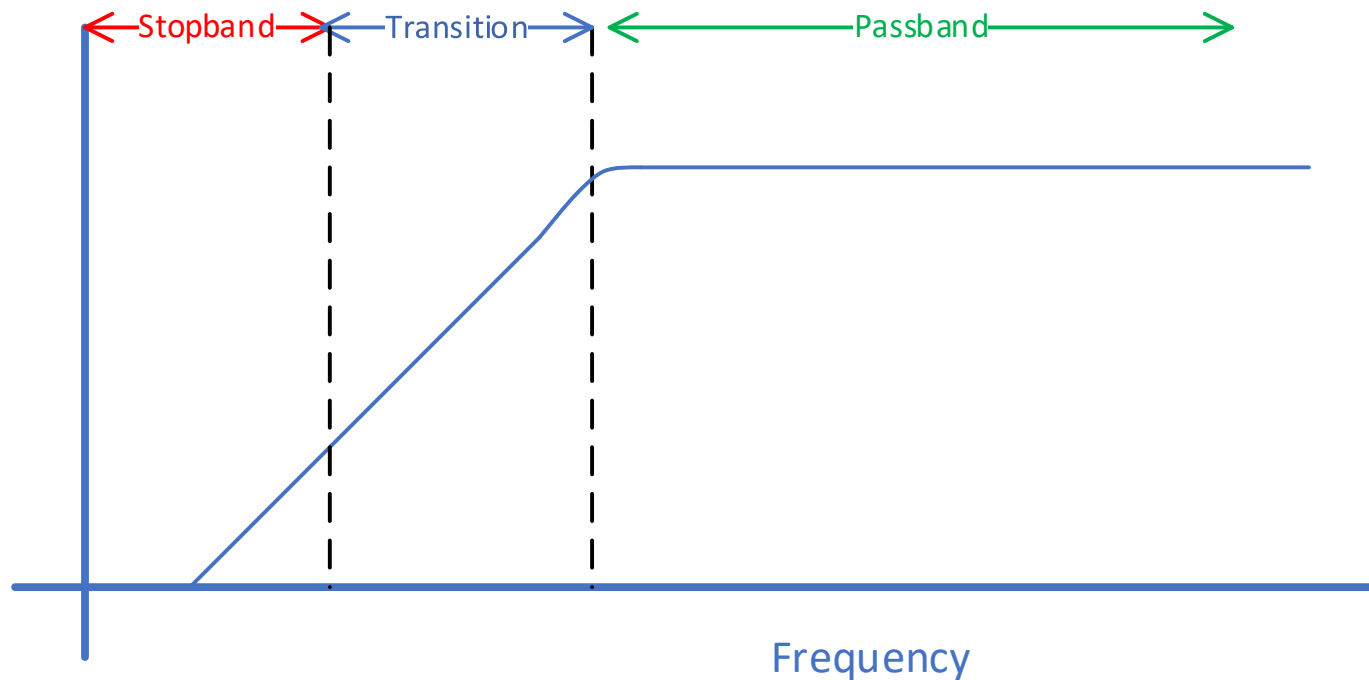(e.g. 99)

Read Occupied BW

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What is Filter Bandwidth?

- Filters can be described by their regions
  - Passband – Frequencies pass with little attenuation
  - Transition band – Frequencies begin to be attenuated
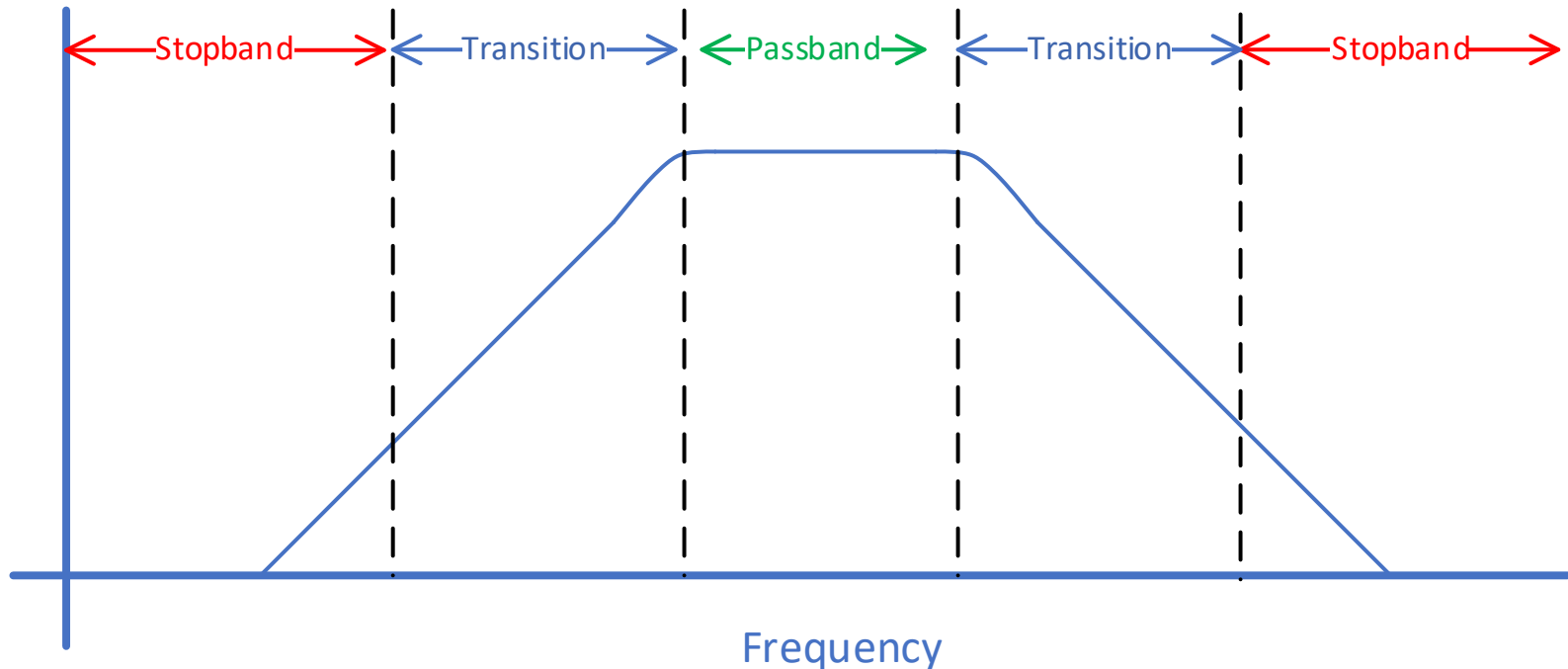 - Stop band – Signals are highly attenuated

High Pass Filter

- High pass filters attenuate low frequencies and pass higher frequencies

Stopband ⟷ Transition ⟷ Passband

Frequency

Bandpass Filter

- Bandpass filters pass a range of frequencies between and upper and lower frequency

What is Filter Bandwidth?

- The 3 dB bandwidth of a low pass filter is the frequency where the amplitude response is lower than the pass band response
    - Other attenuation levels sometimes are used (e.g. 60 dB Bandwidth)
   - Similar approach for high pass filters
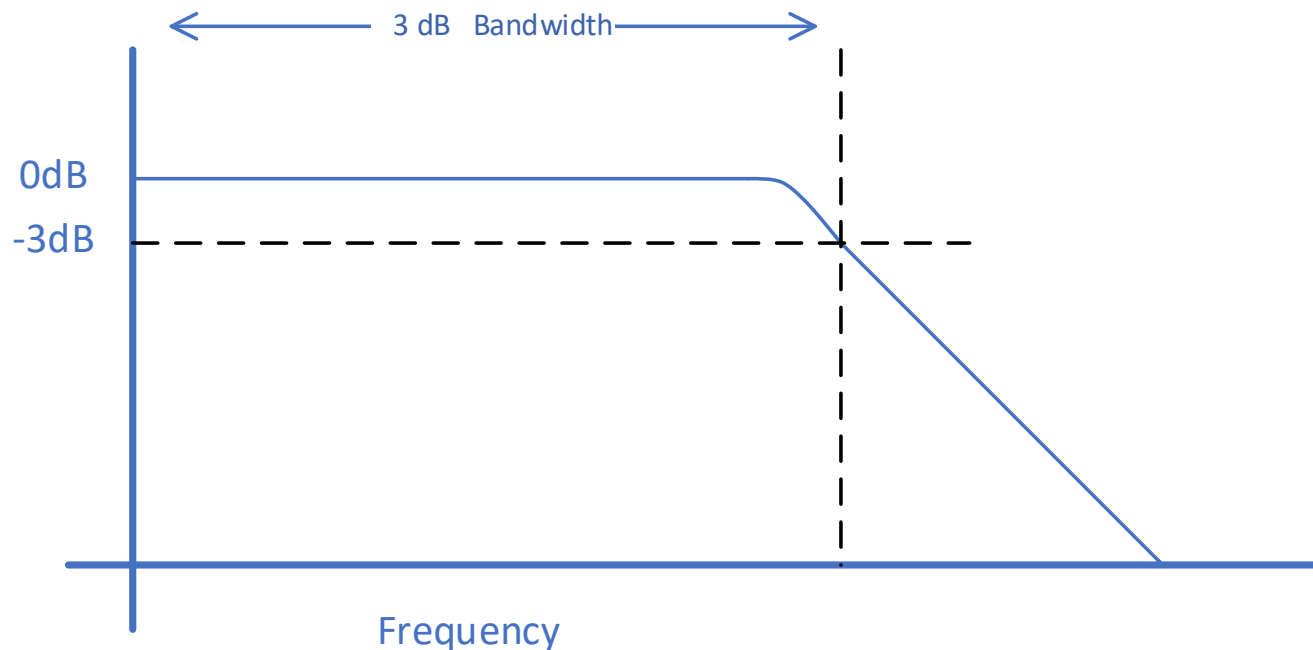
What is Filter Bandwidth?

- The 3 dB bandwidth of a band pass filter is the difference in frequencies where the amplitude response is lower than the pass band response by 3 dB
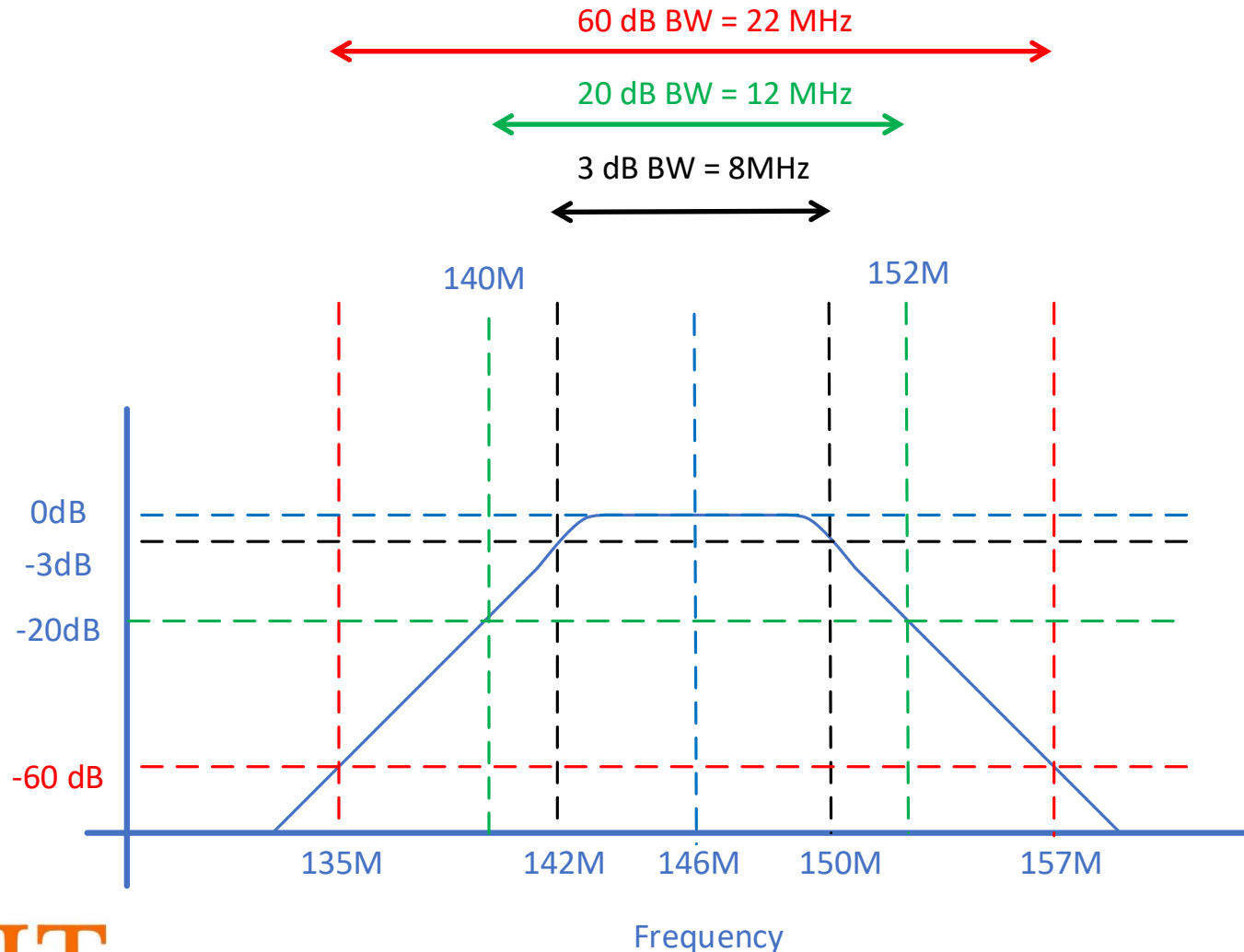 - 60 dB bandwidth is shown
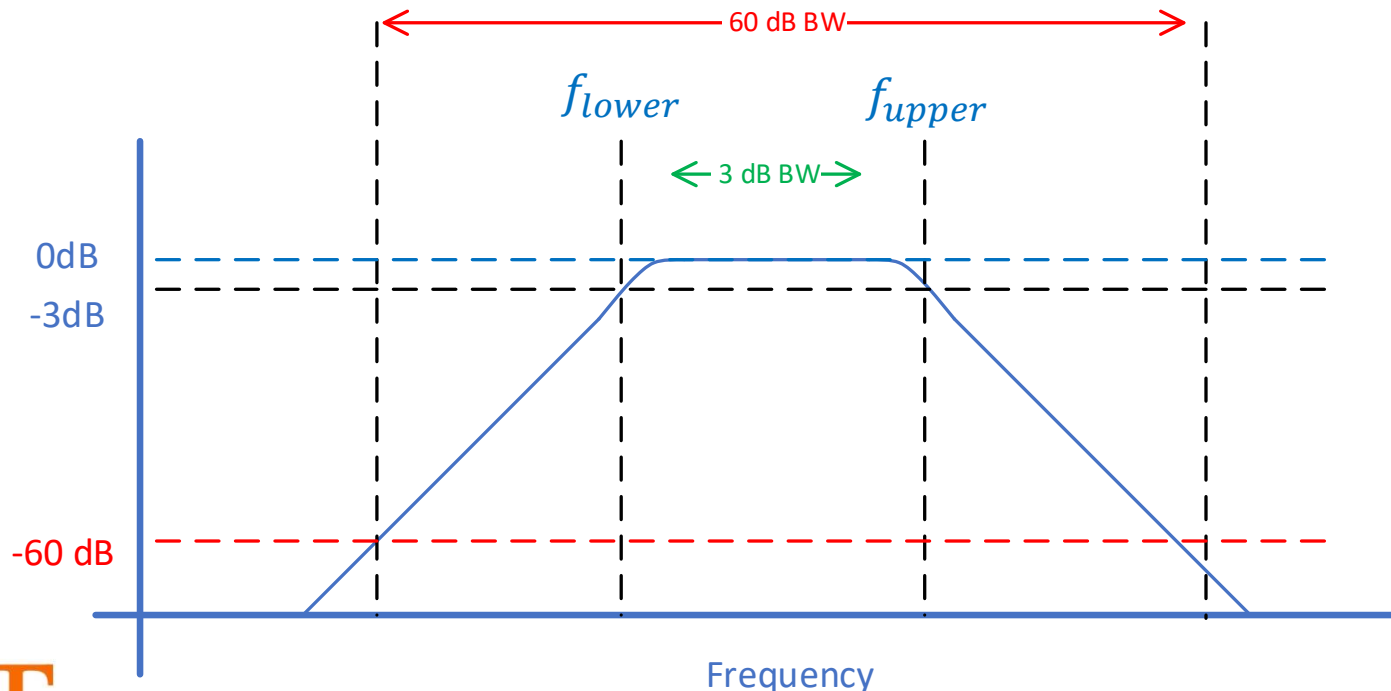
A Bandpass Filter Example

- What is the 3, 20 and 60 dB BW's of this bandpass filter?

A Bandpass Filter Example

RIT **EEET-313 Communications Electronics**
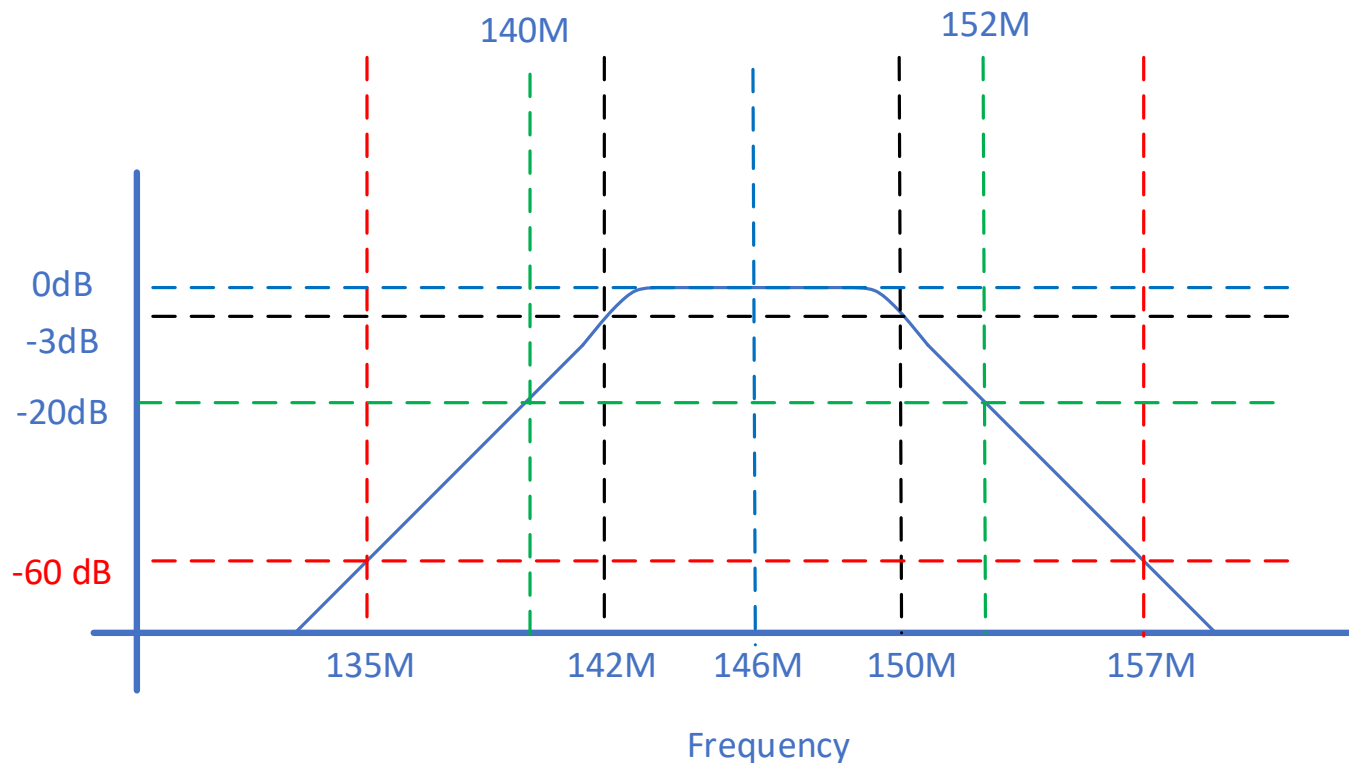
Be clear on what you mean by Bandwidth!!!

- When speaking of bandwidth, be clear on what you mean by bandwidth
    - 3 dB, 60 dB, 90%, 99% etc..