EE 340: Communications Laboratory
Autumn 2015

Lab 1: Familiarization with GNU Radio and complex signals

Legends used

Question/observation: Show it to the TA and explain (carries marks)

Recall/ try to reason out/ useful information

Caution (be very careful!)

Additional information / weblink

Lab objectives

- Learning GNU Radio Software
- Understanding the concept of upconversion of a baseband signal using carrier to make it a passband signal
- Becoming familiar with the concept of “real" vs. “complex" signals or double-sideband vs. single-sideband signals.

Lab Task 1: GNU Radio Tutorial

- Download and carefully go through the GNU Radio video tutorial available at your desktop, also available at:

http://wel.ee.iitb.ac.in/teaching_labs/Communication/Videos/gnuradio1.mp4

NOTE: Each step in the tutorial is important, please don't miss anything

Lab Task 2: Sine wave Generation

- Use a 500 Hz sine wave source in GNU Radio
  - Use "float" as the output data type

Give the output to SCOPE and FFT sinks to observe the signal in time and frequency domains.

  - Make sure that the waveforms are displayed in a single window with multiple tabs.

- Use audio sink block and play the 500 Hz tone on your audio device
  - Ensure the frequency of the signal you hear is correct (check with TAs) by ensuring correct sample rates!

Lab Task 3: Sine wave Upconversion

- Multiply a 500 Hz sine wave (message signal) with a 10 kHz sine wave (carrier wave) , i.e.

$$\cos(2\pi\times 500t).\cos(2\pi\times 10^4 t)$$

Make sure that you are NOT using complex signals

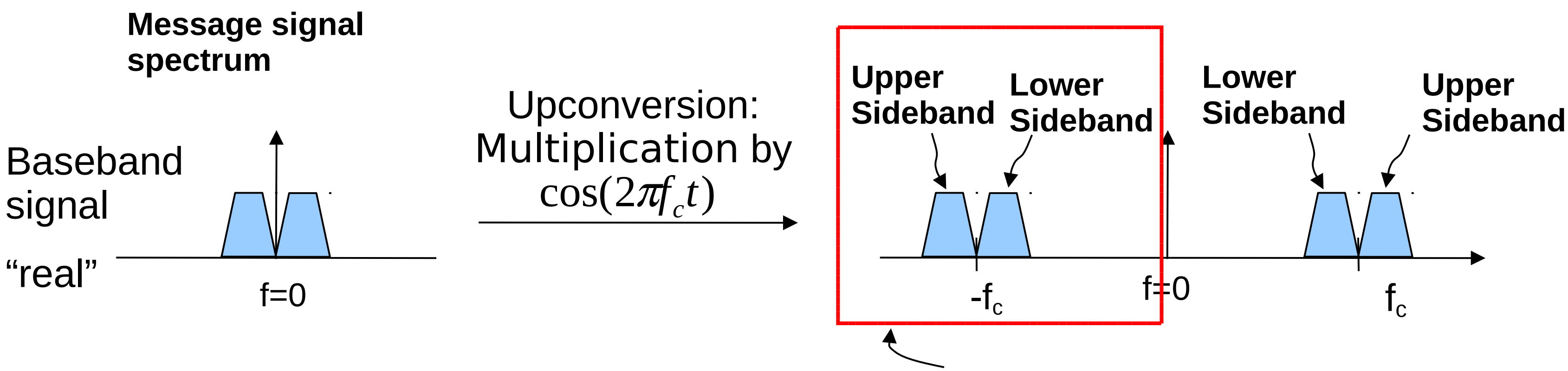
- Again observe the signal in time and frequency domains (in two separate tabs of a single display window)

Justify the observed spectrum mathematically

- This process is called "up-conversion" as the message signal (f_m = 500 Hz) is shifted to higher frequencies using a carrier frequency (f_c =10 kHz) to get $f_c \pm f_m$ Hz

Double Sideband Modulation

- This translation of spectrum of the “message signal" from baseband to a carrier frequency is called upconversion or carrier modulation.
  - As observed in your simulation, there are two tones: One at 9.5kHz and another one at 10.5kHz
  - These are called the two sidebands of the signal



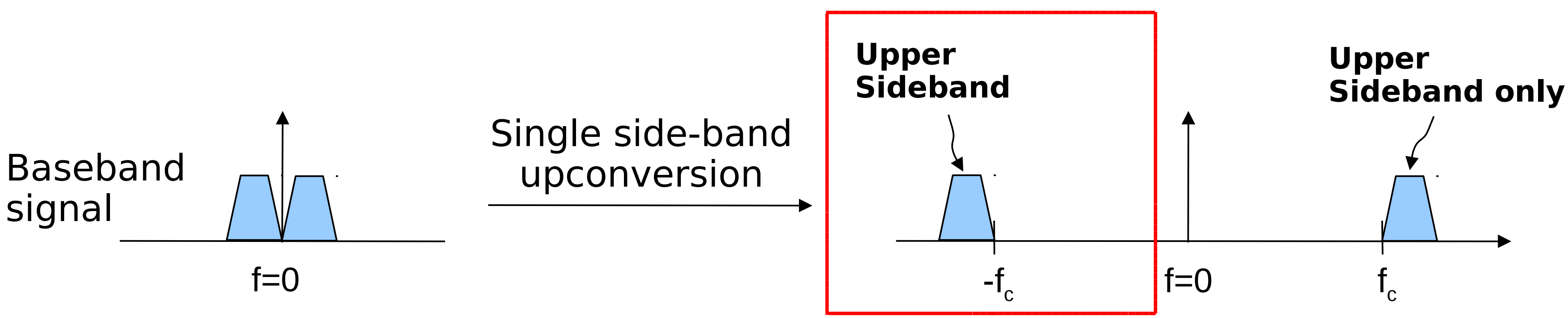
The negative frequency spectrum is not shown in the GNU Radio FFT plot if the signal is “real”: For “real” signal it is just the mirror image of signal for positive frequencies

Lab Task 4: Single-sideband upconversion

- Multiply the signal i.e. $\cos(2\pi \times f_m \times t)$ with $\cos(2\pi \times f_c \times t)$
- Multiply 90-degree shifted version of the shifted signal, i.e.

$$\cos(2\pi \times f_m \times t - \tfrac{\pi}{2}) = \sin(2\pi \times f_m \times t) \text{ with } \sin(2\pi \times f_c \times t)$$

- Take the difference of the two resulting signals and observe the frequency spectrum (on an FFT plot)
  - Justify the observed spectrum mathematically.
- This process is called “single-sideband up-conversion" as the signal of interest is up-converted but only for one of the sidebands, which is more bandwidth efficient but requires the complex baseband signal.
- If you take the sum of the above two signals instead of the difference, what will you get?



“New” Concept: Complex Signals

- If you select the sine wave source output as complex, the output is actually $e^{j2\pi \times f \times t}$

- However, complex signals are “not present” in real world.
- Basically, it is easy to represent two independent/orthogonal real signals as a single complex signal, such as

$$\cos(2\pi ft) \text{ and } \sin(2\pi ft) \quad \text{using} \quad \mathrm{e}^{j2\pi ft} = \cos(2\pi ft) + j\sin(2\pi ft)$$

- Complex signals can also be used to represent the signals that contain information in phase (in addition to amplitude, for which the spectrum is asymmetric about the Y-axis (you will learn more about this later)
  - Can be used for carrying more information

Lab Task 5: Single sideband upconversion using complex signals

- Generate a “complex” 500 Hz “sine wave” f_m using signal source block, select output type as complex
- Similarly, generate a “complex” 10 kHz “sine wave” f_c
- ✓ Multiply the two, observe the FFT spectrum of the real part of the resulting signal
- ✓ Show analytically this operation the same thing as single sideband upconversion

Lab Task 6: Hilbert Transform

- Hilbert transform, H(*f*) = -*j* signum (*f*), shifts any real signal by 90 degrees.
- Hilbert transform block in GNU radio provides the signal and its Hilbert transform as the real and the imaginary parts, respectively, in its complex output.
  - It is basically a discrete time filter and can only implement the approximation of an *ideal* Hilbert transform. More number of taps are required for better approximation.
  - It also adds certain delay to the transformed signal. Therefore both the signal (real part) and its transformed version (imaginary part) should be taken from the output of this block to get matched delays.

✓ Use the Hilbert Transform block to perform (with default parameters) the single-sideband up-conversion of an arbitrary signal, such as triangular wave.

  The observed spectrum should have power mainly in the upper sideband

What will you do to get power in mainly the lower sideband?