Introduction to Modulation: Double Sideband (DSB) and Single Sideband (SSB)

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Overview

- Review of AM
- Double Sideband (DSB)
- Single Sideband (SSB)
- Locating and Demodulating Sideband Signals
Sideband Modulation

- Where’s the intelligence?
  - A signal carries useful information only when it changes.
  - Change of **ANY** carrier parameter produces sidebands.
  - The intelligence or information is in the sidebands.

- Why not just send the sidebands or just a sideband?
AM Review

- AM review:
  - Carrier is modulated by varying amplitude linearly proportional to intelligence (baseband) signal amplitude.

- Block Diagram

\[ x(t) \xrightarrow{m} x \xrightarrow{+} x_{AM}(t) = A_c [1 + mx(t)] \cos \omega_c t \]
AM: Time Domain

- AM in the Time Domain

![Graph showing unmodulated and 100% modulated carrier waves.](image)
AM: Frequency Domain

- AM in the Frequency Domain

![Graph showing carrier and sidebands](image)
Double Sideband Modulation (DSB)

- Let’s just transmit the sidebands

\[ x(t) \rightarrow m \rightarrow x \rightarrow + \rightarrow x_{DSB}(t) = A_c m x(t) \cos \omega_c t \]
DSB: Time Domain

- Double Sideband in the Time Domain
DSB: Frequency Domain

- Double Sideband in the Frequency Domain

carrier was here

lower sideband

upper sideband
Example of a DSB Signal
Demodulating DSB

- Will the AM envelope detector work? **NO!**
Demodulating DSB

- Need a synchronous detector

\[ A_c x(t) \cos^2 \omega_c t = \frac{A_c x(t)}{2} [1 + \cos 2\omega_c t] \]

- This is provided by the USRP

\[ x_{DSB}(t) = A_c x(t) \cos \omega_c t \]

\[ x_{DSB}(t) = A_c x(t) \cos \omega_c t \]

This should give baseband signal output
**Demodulating DSB**

- **Problem:** carrier is not perfectly synchronized with local oscillator

\[ x_{DSB}(t) = A_c x(t) \cos[(\omega_c + \Delta w)t + \Phi] \]

- **Demo:** output = I+Q

Results in amplitude variations.
AM versus DSB: Power Considerations

- Do the math – for tone modulation:
  - AM: \( P_{AM} = 0.5A_c^2 + 0.25m^2A_c^2 \)
  - For AM, less than 33% of the power is in the sidebands
  - For DSB, 100% of the power is in the sidebands

Efficiency, \( \eta = \frac{\frac{1}{4} m^2 A_c^2}{\frac{1}{2} A_c^2 + \frac{1}{4} m^2 A_c^2} = \frac{m^2}{2 + m^2} < \frac{1}{3} \)
DSB Spectrum

- Note: the upper and lower sidebands are the same
- Do we need both of them?

![Graph showing DSB Spectrum with upper and lower sidebands marked.]
A sideband signal is obtained by adding a sideband filter to capture the upper or lower sideband.
Example of a LSB Signal
Comparison of DSB and SSB

- **Power:** SSB requires half of the power of DSB
- **Bandwidth:** SSB requires half of the bandwidth of DSB
- **Complexity:** SSB modulators/demodulators are more complex
A data file is captured using the USRP with a decimation factor of 8 (64Msps/8=8Msps)

Using the following MATLAB commands:

```
>> oursig=read_complex_binary('data_complex.dat');
>> N=length(oursig);
>> fs=8000000;
>> ourspectrum=fft(oursig);
>> ourspectrum=fftshift(ourspectrum);
>> fvalues=(fs/N)*[-N/2+1:N/2];
>> plot(fvalues,abs(ourspectrum));
```
Looking at Signal

The following plot results:
Finding LSB Signals

- The data file: hf_7200khz_256_complex.dat contains 256KHz of spectrum centered at 7.2MHz
- Using MATLAB we can plot this spectrum:

```matlab
>> hfsig = read_complex_binary('hf_7200khz_256_complex.dat');
>> N = length(hfsig);
>> fs = 256000;
>> hfspectrum = fft(hfsig);
>> hfspectrum = fftshift(hfspectrum);
>> fvalues = (fs/N)*[-N/2+1:N/2];
>> plot(fvalues, abs(hfspectrum));
```
Finding LSB signals

- This results in:
Finding LSB Signals

- Expanding on a range of frequencies:
Listening to this Signal

- Use the program: `ssb_rcv_file.py`
- Download this file and the data file
- Run the program with:
  ```
  ./ssb_rcv_file.py hf_7200khz_256_complex.dat 30000 1500 1
  ```

You should hear a signal – find other signals by changing the frequency offset