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Amplitude Modulated Radio Applications in Aviation

Abstract:

Amplitude modulation is widely used in aviation because AM is not subject to the capture effect. In this project, we will use the matlab to simulate the conditions of AM's immunity to the capture effect.

Background:

Amplitude modulation is one way of transmitting radio signals across large distances. While FM has many advantages, AM is typically used in aviation. The reason for this is the capture effect.

In telecommunication, the capture effect is a phenomenon associated with FM reception in which only the stronger of two signals at, or near, the same frequency will be demodulated.The capture effect is defined as the complete suppression of the weaker signal at the receiver limiter (if it has one) where the weaker signal is not amplified, but attenuated. When both signals are nearly equal in strength, or are fading independently, the receiver may switch from one to the other and exhibit picket fencing. In many commercial applications, it's fantastic that you can achieve remarkable clarity using FM radios while also segregating the channels very easily thanks to the capture effect. However, in aviation applications, radio is used to transmit voice signals which don't require lots of clarity. More importantly, the capture effect is very detrimental as "locking on" means emergency signals can't be intercepted in many situations!

Amplitude modulation, or AM radio, transmission is not subject to the capture effect. This is one reason that the aviation industry has chosen to use AM for communications rather than FM, allowing multiple signals to be broadcast on the same channel.

In this project we simulated an AM radio receiver in matlab and observed the effects of a signal sent outside (but near) the carrier frequency of a main signal. We want to note the distance in frequency space these signals can be heard reliably. We built a DSB-SC receiver in matlab that could demodulate a signal at carrier frequency fc using a down-mixer. This will hopefully give us the best chance of detecting "fringe" signals near fc that could be distress signals. The DSB-SC radio sections will take the signal and multiply by a cosine wave at fc.

In order to test the effectiveness of fringe signals, we generate two signals. One, the primary signal, will be a simple audio message that can be carried at fc. Another "Mayday" message can be carried at fc + Δfc where Δfc can be adjusted experimentally. One way to test the effectiveness of the "Mayday" signal will be to make the primary signal unit amplitude and the “Mayday” signal a sine wave. Then, we plot Δfc as a function of peak amplitude of the demodulated signal. This will give us an empirical measure of the strength of these fringe signals in an AM . We also used actual audio signals and had a team member try to make out the “Mayday” signal as a function of Δfc. These two criteria will determine how well our radio would work in a real aviation situation.

In addition, we will also generate two FM modulation signals with different carrier frequencies using the sound files as in the AM radio. Using these methods, we can get a clear impression of the capture effect and the difference between AM and FM radio.

Simulation:

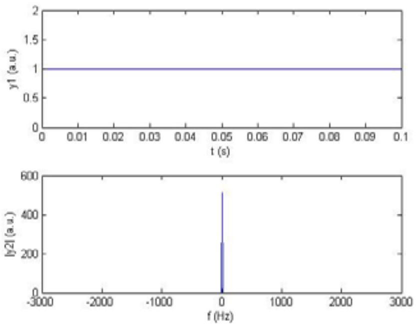
Our simulation strategy began with Professor Landman’s DSB-SC matlab code. We changed it so that it became a function that accepted five parameters, the sampling frequency, the two audio signals, and their respective carrier frequencies. From there it generates modulates the two signals according to their carrier frequencies and also determines a new sampling frequency at the double the sum of the sampling frequency and the maximum of the two carrier frequencies. To simulate the signals mixing in the air, we add them together. We used a down-mixer to demodulate the new signal, sampling at the new sampling rate, and low pass filter the signal at 15kHz. Finally, we plot the time and frequency magnitudes of the two input signals and the final signal, as well as play the final signal as a sound.

For the FM radio, we used Professor Landman’s modulation code and then added some demodulation code from the internet. We did not plot the outputs, since we only want to qualitatively see the effects of the capture effect at a frequency difference where an AM radio can pick up the signal but an FM cannot.

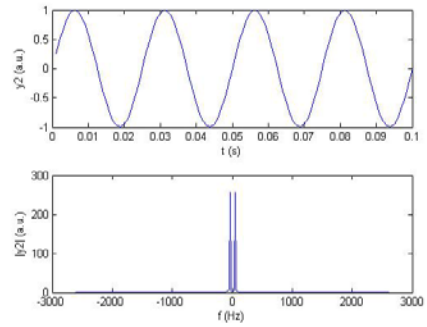
Results:

For the first part of the experiment, we compared the peak amplitude of an output sine wave with inputs 1 for the primary signal and a sine wave for the secondary signal. We begin with fc1 = 1000 = fc2 and we get the following graphs:

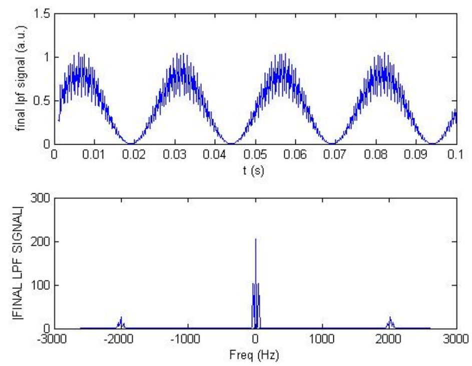
Signal 1: Unity



Signal 2: Sine Wave



Received Signal at Δf = 0

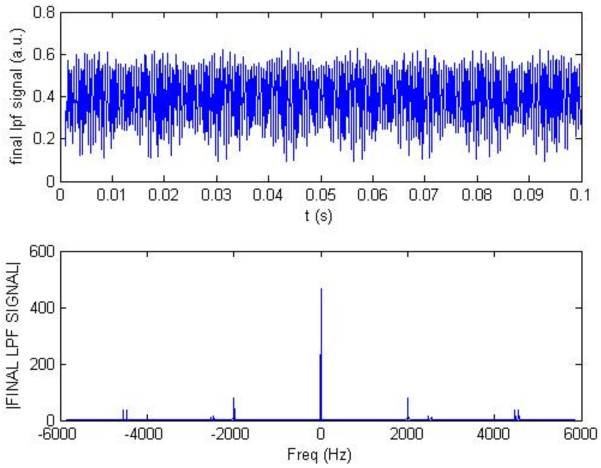


To determine the point where the signal was not capable of transmitting the sine wave, we increased Δf until the change in peak to peak amplitude was $\pm .3\, a.u.$Our results are tabulated below.

Δf (Hz)	m_{peak}(a.u.)
0 (+0%)	1
200 (+20%)	.9
700 (+70%)	.7
1500 (+150%)	.4
2500 (+250%)	.3

As we can see, by our metric, we can still have a clear mayday signal as far away as 2500 Hz from the main band. At this distance, however, there is some significant distortion.

Received Signal at Δf = 2500



By listening to an audio signal, we can easily figure out the difference between AM and FM radio under the capture effect. In amplitude modulation, we used 40kHz as the carrier frequency for the primary signal and therefore demodulated the mixed signal by using the frequency of 40kHz. When the carrier frequency for the mayday signal is 30kHz or above, we can recognize the meaning of the mayday signal. After reducing the carrier frequency for the mayday signal to 20kHz, we can hear the mayday signal but it is difficult to understand it. Then, after reducing the carrier frequency for the mayday signal to 10kHz, it is impossible to understand, but we can still detect another signal modulated by another carrier frequency. In frequency modulation, we still used 40kHz as the carrier frequency for audio signal and demodulated the mixed signal by using a frequency of 40kHz. When the carrier frequency for mayday signal is below 35kHz, the mayday signal is very weak and it is difficult to recognize the existence of another signal.

Sound Quality of MAYDAY Signal

Difference in carrier frequency	Amplitude Modulation	Frequency Modulation
±3%	Very Clear	Noise
±10%	Very Clear	Weak
±20%	Clear	Can not hear
±50%	Difficult to understand	Can not hear
±75%	Audible but Incoherent	Can not hear

Conclusion:

Using the quantitative measurement we determined that at a carrier frequency difference of 250% of the carrier frequency the signal was at 30% of its peak amplitude. This shows the ability of AM radio to receive signals even well outside its assigned frequency. When we tested it qualitatively, we determined that the mayday signal was fairly audible even with carrier frequencies significantly below the operating frequency of the radio. Conversely, the FM radio was barely audible even fairly close to the carrier frequency. From these tests, we have shown that the AM radio has the capability to pick up distress signals readily, unlike its FM counterpart, making it ideal for these aviation applications.

Reference:

"CAPTURE EFFECT" - (http://en.wikipedia.org/wiki/Capture_effect) 4/16/2012

MATLAB code for AM modulation/demodulation - EECE252 matlab session

MATLAB code for FM modulation/demodulation - (http://www.mathworks.com/matlabcentral/fileexchange/11122) 4/16/2012