

Implementation of Doppler Radar

Application Note

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Executive Summary

Doppler radar is an easy and effective way to measure relative speed. With the ability to make smaller antennas, Doppler can be used in multiple mobile ways. Data obtained can be used for just raw data or in other more integrated ways.

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Introduction

The Doppler Effect has been characterized for a long time now, when it was first observed for sound waves. This effect has been used for very practical purposes by applying it to electromagnetic waves. It is a very useful way to determine speed along with other applications in a system. This application note will go over several ways to implement Doppler radar in a way that is useful for a particular system.

Background

Doppler radar uses the same principles discovered by Christian Doppler when observing sound and applies them to electromagnetic waves. In general, the Doppler Effect is a shift in frequency perceived by a receiver from a signal source due to relative movement of the source and/or receiver. The most obvious way to see how this can affect electromagnetic waves is how astronomers use the color shift from light waves travelling from astral bodies to identify the speed these objects are moving away or toward the Earth.

For a Doppler radar system, a known frequency signal is transmitted from an antenna which is pointed at a reference object. A separate antenna is used to receive the signal that is reflected back from the reference to measure the Doppler shift of the signal. The basic formulas used from here are as follows:

$$f_r = f_o \left(\frac{v \pm v_o}{v \pm v_s} \right)$$

Here f_r is the received frequency, f_o the source, v_s relative speed of the source, v_o the observer speed, and v the speed of the waves in the medium. For practical purposes the difference in frequency is used for calculations.

$$\Delta f = f_r - f_o$$

Figure 1 below shows an example of a basic block diagram for a Doppler module:

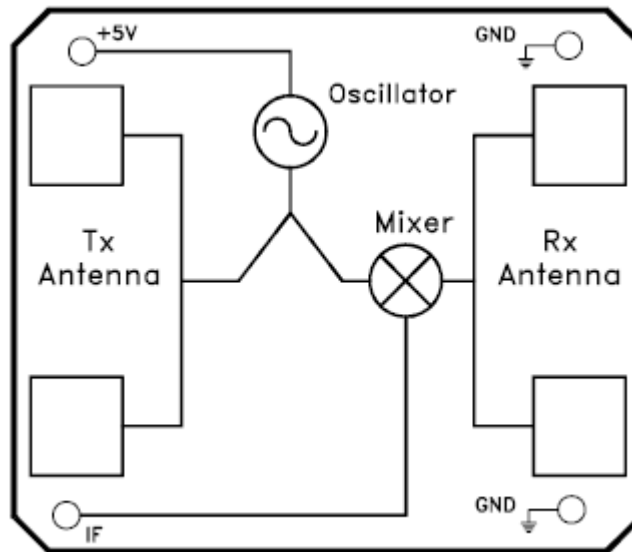


Figure 1: Doppler Module Block Diagram

Implementation

A simple Doppler module, also called a microwave motion sensor, can be easily integrated into multiple types of systems for various purposes. Doppler modules have an internal oscillator used to produce the signal frequency transmitted as the source. The received signal is then mixed with this set signal, which produces an output that is a sinusoid containing the frequency difference between the output and receiver signals.

In most systems, these values need to be recorded or read in a tangible way and this is usually done with some sort of microcontroller. The easiest way for a microcontroller to read data from an analog device is if it outputs a DC level voltage. Some modules have this feature built into them. For those that don't, like the HB100 used in the ECE 480 Design Team 5 project, output just the AC signal. For these modules a frequency-to-voltage circuit must be implemented. An IC, such as the LM2907N, can be used for this specific purpose or any other discrete component circuit. This circuit can be used to calibrate the output data for a specific set of expected frequencies coming from the module to contain it in reference voltage range.

Sampling of this data and the manipulation of it through code is needed to take this raw data and make it useful for the system. To find speed from the output signal of the module the equation

$$\Delta f = \frac{2 * v}{\lambda}$$

$$\lambda = \frac{c}{f_o}$$

is used, where c is the speed of light, f_o is the signal frequency, and v is the speed of value to the application. This can easily be implemented into code since we would know what frequencies correspond to what DC voltage level from designing and testing the frequency-to-voltage circuit. When the microcontroller converts this analog signal to a digital one, it obtains a hexadecimal number. This hexadecimal number needs to be adjusted to the reference voltage and bit resolution of the ADC port. An example of this code, written in C, can be found in Figure 2 below with a 5 volt reference.

```
ConvertADC(); //perform ADC conversion
while(BusyADC()); //wait for result
adc_result = ReadADC(); //get ADC result
data = (adc_result/1024)*5;
```

Figure 2: Sample C Code

The value obtained from this can then be manipulated using Doppler equations to find the speed of the target object. The HB100 uses a source signal with a frequency of around 10 GHz and some common speeds corresponding to the difference can be seen below in Figure 3.

10.5 GHz Source	
ΔF	Speed (mph)
50	1.597885714
100	3.195771429
150	4.793657143
200	6.391542857
250	7.989428571
300	9.587314286
350	11.1852
400	12.78308571
450	14.38097143
500	15.97885714
550	17.57674286
600	19.17462857

Figure 3: Speed Values

The values found in Figure 3 are only true with the source object or target object being stationary. Most systems implement Doppler radar in this way. If a moving target's speed is what is necessary then the source is stationary and pointed toward the moving target object, like in the case of a police radar gun. If the speed of the moving object which contains the source of the signal wave is required then signal needs to be emitted toward an object that always doesn't move. As an example, airplanes use a Doppler system that reflects a signal off the physical ground to keep track of the plane's speed. This is also the case for ECE 480 Design Team 5's project. When the Doppler measurement system is mobile the ground is the most practical reference.

Conclusion

Using the Doppler Effect is a great way to measure relative speed. This can have many types of applications, from just recorded the raw speed to motion sensing in security equipment. Design Team 5 is using Doppler radar to effectively measure a skier or snowboarders top and average speed using the principles contained in this document.

References

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