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Development of Velocity Measuring System based on Doppler Shift

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Abstract

This thesis presents development of an automated system made to measure the velocity of a moving vehicle based on Doppler-effect. Here we developed two velocity measuring devices, an analouge high frequency one, to measure the relatively low car velocity and a software defined radio system at relatively low frequency to measure the velocity of the high speed objects, the planes.

The first velocity measuring system consists of three main parts:The frontend part, the back end one and the digital processing part. After we made the analysis and simulation of the system, we started the design of the front end which depends on Gunn diode oscillator as micro wave source used to emit the signal in 24GHz and a Schottky diode reciever used as a mixer or signal detector. The second area is based on detecting/measuring the Doppler shift of the wave reflected from the moving target then displaying the speed of the vehicle after processing its information. The third area represents the add-ons of the system as if the target exceeds a certain configured limit representing a specific speed. It initiates a Java program to take a snapshot of that vehicle, getting the coordinates of its position through Glopal Positioning system (GPS) technology then send all that information through Multimedia Messaging System (MMS) to be tracked by a traffic control system. The modules of the system was working good, the design is really compact assembling a lot of features integrated in small area and most of its components are off shelf components. the other system on Doppler Effect is the most interesting as it's targeting the flying object. The system could be used as a radar to detect planes, moving clouds, meteors. , which can be used as a military or a remote sensing applications. The system uses the Cross Ambiguity Function CAF to extract the Doppler shift and the time delay by comparing two signals received to the system. This time, the system is implemented on a software defined radio developed by Universal Software Radio Peripheral (USRP).

Key words: Doppler shift, Gunn diode, Schottky diode, Horn antenna, Digital signal processing, Global poisoning system, Multimedia Messaging system, Universal Software Radio Peripheral, GNU radio, Cross ambiguity function, Radar.

Contents

List of Figures

List of symbols and abbreviations

AGC	Automatic Gain Control
CFAR	Constant False Alarm Rate
CIC	Cascaded Integrator Comb Filter
CW	Continuous Wave
DDC	Digital Down Converter
DOA	Direction Of Arrival
DSP	Digital Signal Processors
FDOA	frequency-difference-of-arrival
FPGA	Field Programmable Gate Arrays
FSF	Free Software Foundation
GaAs	gallium-arsenide
GNU	GNU Not Unix
GPS	Global Positioning System
GSM	Global System for Mobile
LO	Local Oscillator

NCO	Numerically Controlled Oscillator
PCL	Passive Coherent Location radar
PGA	Programmable Gain Amplifier
RCS	Radar Cross Section
SAR	Synthetic Aperture Radar
SDR	Software Defined Radio
SNR	Signal to Noise Ratio
TDOA	time-difference-of-arrival
TEDs	transferred electron devices
USRP	Universal Software Radio Peripheral

Chapter 1

Introduction

1.1 Motivation

The motivation of this thesis started after the graduation project and almost two years of the practical work in designing and implementing VLSI circuits, The graduation project was designing Low Noise Amplifier (LNA) at the ISM band for Bluetooth application. After that at the Arab Organization Industry AOI in the VLSI design centre the project was to design, implement and testing CMOS integrated intermediate frequency (IF) limiting amplifier [1] where we published a paper in IEEE Conference on it[1]. However, it was better to develop an end to end system.
In this thesis we will develop electronic systems to measure the velocity of moving objects based on the Doppler frequency shift of a reflected wave from a moving object. The concept was phrased by a scientist called Doppler so it was named after him DOPLLER EFFECT. The Doppler shift value increases in proportional to the object speed and the hitting frequency. So basically with low speed objects we need high frequency to let the variance measurable while with high speed objects low frequencies are enough.

In this thesis we are going to develop two systems for the two above situations: namely, one for the low speed and the other for the high speed objects.

[1] http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?tp=&arnumber=1287757&isnumber=28700

Frist system overview

The first system deals with the low speed vehicle. So high frequencies are needed to deal with this targets. Micro wave devices are the right choice for it and the mixers could be used as the correlators to extract the Doppler shift as our signals are analog. Some options could be also added to the system to make it more advanced.

Instead of assigning an agent to hide behind a tree or a big body monitoring the speed of vehicles, taking shots or reporting it through the RF signal, we tried to develop an automated system to do that and more through new technologies and new devices [2].
Our system consists of three main developing parts, the front end, the back end and the digital processing part. After we made the system analysis and simulation, we started the design of the front end. It depends on Gunn-diode oscillator as micro wave source used to emit the signal in 24GHz and a Schottky diode receiver used as a mixer or a signal detector. The second part is based on detecting/measuring the Doppler shift of the wave reflected from the moving target then displaying the speed of the vehicle after processing its information. The third part represents the add-ons for the system as if the target exceeds a certain configured limit representing a specific speed, it initiates a Java program to take a snap shot of this vehicle, getting the coordinates of its position through GPS technology then send all the information through MMS to be tracked by the traffic system.

The second system

In the second system the target -this time- is the flying object. The system could be used as passive radar to detect planes, moving clouds, meteors. , which can be used in a military or a remote sensing application. The system uses the Cross ambiguity function CAF to extract the Doppler shift by comparing two signals received by the system from two different paths, namely, a direct path and a path intersected by the moving object. The platform which the system is running on is GNU radio as a software defined radio (SDR), and the Hardware is Universal Software Radio Peripheral (USRP).
In the high speed application we may use low frequency that can detect the Doppler variance. After down converting the signals we may use the different digital techniques to extract the Doppler shift, this time we used the CAF as the system became digitized.

1.2 Thesis outline

The Thesis consists of five chapters. In brief, chapter 1 gives an introduction to the system and the thesis's outlines. Starting from Chapter 2 we will discus some important concepts about Doppler effect, history, equation and applications then some micro wave devices will be used in the system as Gunn-diode, Schottky-diodes. Also we will review some important concepts about the horn antenna and the Cross ambiguity function which used as the numerical analysis to calculate the speed and range. Chapter 3 will cover the development road map of the Doppler system for low speed targets through the development of the front and back ends ending with the system peripherals and the add-ons of the system. Chapter 4 will cover the development road map of the Doppler system for high speed targets with it's experimental results.
Finally in chapter 5 we will give the conclusion and the future work that may be done to enhance the performance of the systems.

Chapter 2

Thesis Essentials

This chapter will review some important concepts and phenomena's that will be used in building of our Doppler shift system. First we will review Doppler effect starting from its history, equation and applications. Second we will have a look on some microwave devices. Finally, we are going to review some concepts with the antenna theory.

2.1 Doppler effect

"No matter what shape the theory of electromagnetic processes should take, the Doppler Principle ... will remain in any case. "

Albert Einstein

This section covers in its first subsection Doppler Effect's history through getting more details about Christian Doppler, his observations and the development of the conclusions of his observations. In the second subsection we introduce the equation of Doppler shift showing the parameters contributing to this shift. In the third section, we will mention some applications which use this effect in their calculation.

2.1.1 Doppler effect's history

When we are saying Doppler Effect or Doppler shift, we should return back in the history and review the life of that Austrian mathematician and physicist who was born on the 29th