DEVELOPMENT OF ONLINE SPEED TRAP SYSTEM (DOSTS).

MAIZUL BIN HJ. ISHAK

A project report submitted in partial fulfillments of the requirements for the award of the degree of Master of Engineering (Electrical – Electrical Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MAY 2006

ABSTRACT

By generating TTL square wave of the output of a Doppler speed sensor principle and its' datasheet specification of DRS1000, connected to frequency to voltage converter circuit, PIC 16F877 micro controller with Analog to Digital converter circuit and web camera, a prototype of the Development of Online Speed Trap System (DOSTS) which being created and programmed to detect the signal and calculate the vehicle's speed. All the data will be sending to GUI (at PC) through serial communication interface (RS232). A development programming of Visual Basic (VB) GUI will gather all the important of information or data as usual as required by the police traffic department for displaying it on the PC monitor. The work in this project is to study, evaluate and compare the output of Doppler principle especially DRS1000`s output, detecting for speed of the vehicles will be the main focus. The study of the output Doppler principle will lead to be used in the VB GUI. As a conclusion, the speed and image of car models using the same of output of DRS 1000, Doppler sensor is verified via programming of VB GUI in term of various speeds.

ABSTRAK

Dengan menjanakan gelombang *square TTL*, sebagai output daripada sensor kelajuan, Doppler; berdasarkan diatas prinsip dan datasheet spesifikasi DRS1000, ianya dihubungkan kepada litar pertukaran frekuansi kepada voltan, *PIC 16F877 microcontroller* dengan litar pertukaran Analog kepada Digital dan kamera web; satu prototaip daripada Pembangunan Sistem Perangkap Laju Secara Diatas Talian telah dicipta dan diprogramkan untuk mengesan isyarat dan juga mengira kelajuan kenderaan. Kesemua data tersebut akan dihantar ke *GUI* (di komputer) dengan melalui antaramuka komunikasi Sesiri (RS232). Suatu pembangunan berprogram daripada *Visual Basic (VB) GUI* akan mengumpulkan kesemua maklumat atau data yang penting seperti yang biasa dikehendaki oleh pihak jabatan polis trafik dengan tujuan untuk paparan di monitor komputer. Kerja-kerja didalam projek ini adalah bertujuan untuk pembelajaran, penilaian dan pembezaan output daripada prinsip *Doppler* teristimewanya output daripada DRS1000, yang mana pengesanan kelajuan kenderaan menjadi fokus utama. Pembelajaran mengenai output daripada prinsip *Doppler* ini akan menjadi teraju utama untuk digunakan didalam *VB GUI*. Sebagai kesimpulannya, imej dan kelajuan model kereta yang menggunakan output yang sama dengan DRS1000, sejenis sensor *Doppler* disahkan melalui pengaturcaraan *VB GUI* didalam pelbagai kelajuan.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS/SYMBOLS

f	-Frequency (Hz)
f_0	- a function of radar transmit frequency (Hz)
f_t	- a function of radar transmit frequency (Hz)
c	- A speed of light (in vacuum: 299,792,458 m/sec @ 1,079,252,848.8 km/h)
V	- Velocity
Vt	- Target velocity
Vp	- Patrol velocity
Vrelative	- Target relative speed to radar
F0	-Frequency 35.5 ± 0.1 GHz (Ka Band)
θ	- offset angle of sensor relative to direction of target motion
Fd	- Doppler Shift, Hz.

CHAPTER 1

INTRODUCTION

1.1 Overview

In our modern civilization, speed trap system or vehicle detection and surveillance technologies can be described as containing three components:

i. Transducer

ii. A signal processing device

iii. A data processing device

The function of the transducer is to detect the passage or presence of a vehicle. The signal-processing device typically converts the transducer output into an electrical signal and while the data processing device usually consists of computer hardware and firmware that converts the electrical signal into traffic parameters. In this case, traffic parameters mean vehicle presence, count, speed, class, gap, headway, occupancy, weight and link travel time [1].

Speed Trap is a set of equipment that being used by government sector or private sector such as the Royal Police in order to capture and measure the speed of vehicles movement which over the speed limit at the certain area [2]. There are two types of techniques for speed trap system that widely used in the worldwide market:

i. Speed trap using lasers technology technique called Laser Radar Speed Trap.

ii. Speed trap using microwaves technology technique called Microwave Radar Speed Trap.

Each technique has their own advantages and disadvantages, which will be discuss later. The aim of this proposal is to study the output speed sensor, DRS1000 to be implement in a speed trap system in order to build a model, which uses the microwaves technology technique (Ka Band Type) [3], [4].

1.2 Project Background

In this project proposal, Doppler Effect or Doppler principle is one of technique from microwave technology technique appearing in continuous wave (CW) is being implemented in the model. A company named, GMH Engineering, Utah, U.S.A had produced a large of worldwide market sales regarding on Doppler speed sensor – **DRS1000** (microwaves technology technique – Ka Band type)**.** The output of this sensor, which is fixed in TTL square wave – fixed output 100 Hz/Mph or 62.138 Hz/Kph (Kmh), was generated using frequency generator as the speed of vehicles to be used with other hardware in the DOSTS prototype [3], [4].

The output of sensor then being connected and sent the data to Frequency to Voltage circuit in order to convert the TTL square wave frequency to voltage within high (5 Volt) or low (0 Volt). Then the data will be sent to PIC 16F877 microcontroller with Analog to Digital converter in order to be calculated and convert to digital output. Digital output data then being send to VB GUI at computer through serial communication port (RS232). Image also can be captured using the web camera as the camera model which being connected using the Universal Serial Bus (USB port). A develop programming of Visual Basic (VB) GUI will gathered all the important of information or data that usually required by the police department for issuing the over speed limit's summon.

1.3 Project Objectives

Below are several projects' objectives to be considered to:

1) Study the Doppler principles and its applications in vehicle speed detection or measurement.

2) Implement and design a simple speed trap prototype using the output of Doppler speed sensor (DRS1000).

3) Develop VB Graphical User Interface (GUI) that will appear the image, operator's detail, present time and date at computer.

4) Capture image of speeding vehicle in term of speed and the image will appear on VB GUI at computer by using web camera as camera model.

1.4 Scope of Project

The scopes of this project are:

1) To study the possibility used from Doppler principles and its applications in term of vehicle speed detection or measurement.

2) To generates the output of speed sensor- DRS1000, for varies vehicle speeds using signal generator

3) To convert signal that being generated in term of speed of vehicles and display at GUI using Visual Basic 6.0 (VB).

4) To interface web camera and computer for displaying the image that being captured on VB GUI.

5) To produce results that usually being required by police department such as date, time, speed limit, speed captured, operator data and etc.

1.5 Research Methodology

1.5.1 Overview

This chapter will describe about the processes from the beginning of this project until the end. First part will describe about the general knowledge of flow diagram and the second part will describe the operation of the project.

1.5.2 Project and Operation Concept Flow Diagram

By referring to figure 3.1 and figure 3.2 show that the flow diagram of how to start this project and the operation concept flow diagram of this project. Firstly, study the DRS1000 application by referring to its` datasheets [3], [4].

All the circuits were joined and connected using protoboard and being test using digital oscilloscope, multimeter and etc. After success being tested, Printed Circuit Board (PCB) design was done by using any kind of suitable PCB designer software. In this project, Protel DXP 2004 and EAGLE version 4.15 are introduced. After PCB fabrication process success, all the circuits were test again in term of to get the exact result and analysis.

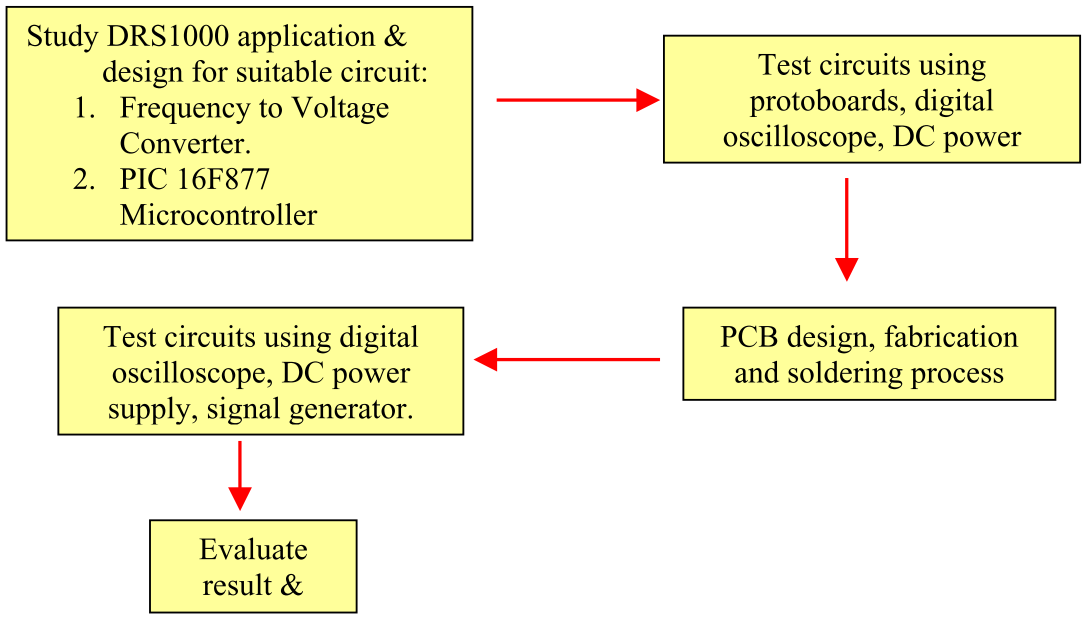

Figure 1.1: Project Flow Diagram

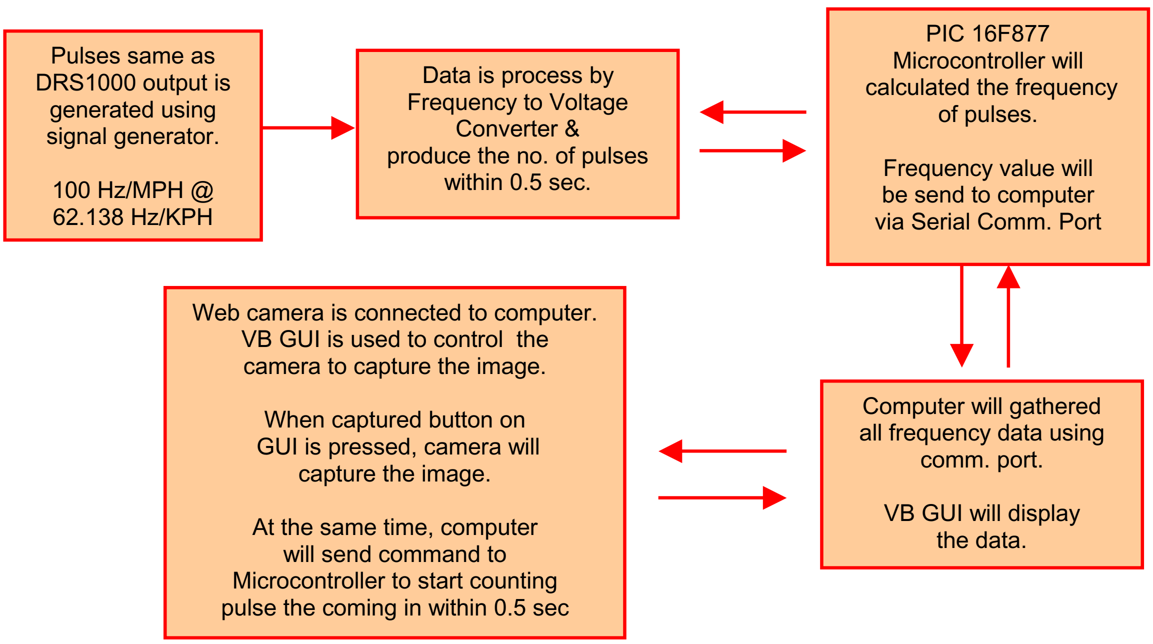

Figure 1.2: Operation Flow Diagram

A signal generator is used to generate varies speed as same as DRS1000 output, which in TTL square wave. Computer is used as a tool to provide and gathered all the data and appeared them through VB GUI. Web camera will focus the image and capture it as a proof of speeding car in DOSTS prototype. Detailed information will be discuss and shown at Result & Analysis chapter later.

1.6 Literature Review

1.6.1 Description of Laser Radar Speed Trap

Laser radars, also referred to as ladar or lidar, using pulsed laser light instead of continuous microwaves (CW) to sense a target. Lasers are extremely pure (coherent) light waves, similar to only one (pure) color of light. Notify that white light consists of multiple wavelengths (colors) with random (non-coherent) phases. Theodore Maiman of Hughes Aircraft Company (California) built the first working laser using a ruby rod pumped by a flash lamp in May of 1960 [1]. Traffic laser used solid-state diodes to generate laser light. Below are the meaning and short form for the important words in Laser Technology technique:

i. LASER - **L**ight **A**mplification by **S**timulated **E**missions of **R**adiation

ii. RADAR - **RA**dio **D**etection **A**nd **R**anging

iii. LADAR - **LA**ser **D**etection **A**nd **R**anging

iv. LIDAR - **LI**ght **D**etection **A**nd **R**anging

Laser radars transmit pulsed laser light to measure target range. The time it takes for a laser light pulse to travel (at the speed of light) from the laser to the target and back is used to compute the distance from the laser to target and back (distance pulse travels = speed of light x time). Target range from laser half of this distance (Range = 0.5 x speed of light x time). The change in target range over time (1/3 second typical) equals target velocity. Laser radar must transmit a minimum of 2 pulses to get at least 2 range measurements at 2 different times to compute speed. In reality laser radars transmit tens to hundreds of pulses per second [1], [2].

Lasers are optical focusing devices (lenses, prisms, and/or mirrors) used to collimate laser energy into a narrow beam. Some models use the same aperture for transmit and receive; some use separate apertures (one for transmit and one for receive). The LTI Marksman 20-20 laser radar that being present used in Malaysia, has two separate apertures; one on top of the other (top aperture transmits). The LR 90-235/p (Europe) has two separate apertures: side-by-side.

Figure 1.3 (a)

Figure 1.3(b)

Figure 1.3 (a) & Figure 1.3 (b): LTI Marksman 20-20 equipment.

Lasers use a semiconductor diode (typically 3 diodes) to generate laser light. Most traffic lasers emit laser light around 904 nm wavelengths. Other wavelengths are possible; for example aluminum gallium arsenide (AlGaAs) diodes emit light at a wavelength of 850 nm (some fiber optics use this wavelength). Gallium arsenide (GaAs), classified as an injection laser, emits light between 880 nm to 900 nm between the temperatures of -20 and 140 degrees Fahrenheit. Other wavelengths are possible using other materials or alloys [5].

1.6.2 Description of Microwave Radar Speed Trap

The word, radar (rã´där) is a *noun.* Radar mean:

- Acronym for RAdio Detection And Ranging.

- A remote sensor that emits electromagnetic waves (radio, microwave, or light) in order to measure reflections for detection purposes (presence, location, motion, etc.).

- Radiolocation.

- Field disturbance sensor.

All stationary microwave traffic radars measure on-coming traffic; some models also (and/or) measure going (receding) traffic. Almost, all-moving mode radars can operate from a stationary position or a moving patrol car. Moving mode radars usually require a minimum patrol car speed for moving mode operation. All moving mode radars (in moving mode) measure on-coming (opposite lane) traffic; some can also (and/or) measure receding (opposite lane) traffic (requires aft antenna). Some moving mode radars can measure targets traveling in the same-lane (direction) as the patrol car (front and/or rear antenna). Same-lane radars require a minimum speed difference (2 mph or MORE) between the target and patrol car. Moving radars also measure patrol car speed (ground speed), most also display patrol measured speed. Many radars track only one target at a time; some models have the option to track and display two targets. In this case, the strongest (may be closest or largest) target (echo) and the fastest (or a faster) target in the beam [1], [3].

Most microwave traffic radars have a relatively wide beam (9 to 25 degrees) that easily covers several lanes of traffic at a relatively short. Detection range (in the beam) varies with radar and target reflectivity and may be as low as 100 feet (30 meters) or less to 1 mile (1.6 kilometers) or more. Radar may track a distant large target instead of a closer small target without any indication to the operator that targets the radar is tracking. Usually, radar should be located as close to the road in order to achieve accurate measurement [4].

1.6.3 Different Types of Radar Frequencies

There are several types of radar with different types of frequencies that stated such as:

1. S Band Radar
2. X Band Radar
3. Ku Band Radar
4. K Band Radar
5. Ka Band Radar
6. Wide Ka Band Radar

1.6.4 S Band Radar (obsolete)

Automatic Signal Co. built one of the first traffic radars in 1947 for the state police in U.S.A. Early radars were bulky and heavy systems (vacuum-tube technology) that usually consisted of three or more separate pieces of equipment, an antenna (sometimes 2 antennas - separate transmit and receive), a 45 pound (20 kg) box (the tube transmitter, receiver and processor), a strip chart pen recorder for a permanent record, and a needle meter calibrated in mph. Sometimes the antennas mounted on a tripod and sometimes on the hood or fender of a patrol car. Some of the early 1960s' models mounted the antennas in the back windshield of the patrol car [1], [4].

The first traffic radars transmitted at 2.455 GHz in the S band (2 - 4 GHz). Note that many microwave ovens transmit at about 2.45 GHz, and low power unlicensed wireless communications transmit from 2.400 - 2.4835 GHz. S band radar antenna beam widths varied from 15 to 20 degrees depending on model. These radars operated from a stationary position only and measured receding as well as approaching targets to an accuracy of about ± 2 mph. The maximum detection range was an unimpressive 150 to 500 feet (45 to 150 meters); vacuum-tube receivers do not have the sensitivity of solid-state receivers. Radar with a 150-feet detection range would have less than 1.5 seconds to measure a target traveling 68 mph (100 feet/second or 109 kmh). Nowadays, the S band radars are obsolete [1], [4].

1.6.5 X Band Radar

X band radars have been around since 1965 and operate on a single frequency (one 50 MHz channel). Radars in the X band have better all weather performance (less signal attenuation in bad weather) than K or Ka bands. X band radars tend to have wider beams than K or Ka radars. Some European countries use X band traffic radars that transmit at 9.41 GHz or 9.90 GHz [1], [4].

1.6.6 Ku Band Radar

The Federal Communications Commission (FCC) has allocated 13.45 GHz in the Ku band for traffic radar use in the United States; however Ku radars are not sold or used in the U.S. Some European countries are reported to use Ku band (13.45 GHz) traffic radars.

1.6.7 K Band Radar

K band radars have been around since 1976 and operate on a single frequency (one 200 MHz channel). These radars generally have more narrow beams than X band radars, and wider beams than Ka band radars. Detection range decreases with moisture

Some World War II radars operated in the K band around 24.1 GHz (in the limits of K band traffic radar), which also happens to be in the water vapor absorption band (centered at about 22.24 GHz); signals in the absorption band tend to become absorbed by moisture in the atmosphere and do not have the range that other frequency bands offer. For short range applications the effects may be tolerable on relatively clear dry days [1], [4].

1.6.8 Ka Band Radar

In 1983 the U.S. FCC allocated the spectrum from 34.2 - 35.2 GHz (Ka band) for traffic radar use, that same year Ka band photo (Across the Road) radars started appearing in the United States. Nine years later in 1992 the FCC expanded the Ka band spectrum allocated for traffic radar use to 33.4 - 36 GHz. Ka band radars typically have more narrow beams than X or K band radars. Target detection range dependents on moisture in the atmosphere (rain or humidity), the more moisture the less range.

Many models have a frequency tolerance of ± 100 MHz (200 MHz bandwidth); some models have a tolerance of ± 50 MHz (100 MHz bandwidth). An advantage of 100 MHz bandwidth over a 200 MHz bandwidth (besides less chance of interference) is more radar channels can be squeezed in the (Ka) band. The bandwidth allocated to Ka band traffic radar is 2.6 GHz (36-33.4 GHz), or 2,600 MHz. Radar with 200 MHz bandwidth has 13 channels (2600/200). Radar with 100 MHz bandwidth has 26 channels (2600/100). At minimum 2 radars operating close to each other should be separated by at least 2 channels (the greater the separation the less chance of interference) [1], [4].

.

1.6.9 Wideband (Ka) Radar

Wideband radars (Ka band) operate on a single fixed frequency (operator selects one of several available), and/or in a frequency hop mode. In frequency hop mode the radar dwells on a fixed frequency for a fraction of a second (on the order of 1/10 of a second or more) and hops to another frequency. The radar cycles between a numbers of different frequencies. Wideband radars are intended to defeat radar detectors [1], [4].

1.7 Differential between Microwave Radar and Laser Radar

In microwave traffic radars application, it's required the operator to aim exactly (only general direction) at one particular target, and is most effective when traffic is light. Many microwave radars can be used from a moving patrol car. Traffic laser radars can function in dense (or light) traffic, and require the operator to select (aim crosshairs at) a particular target. Laser radars are not designed to operate from a moving patrol car. Typically microwave radars have longer detection range than laser light systems. Table 1 below shows the differential Between Microwave Radar and Laser Radar requirement for application [1], [2].

Table 1.1: Differential between Microwave Radar and Laser Radar

Microwave Radar	**Laser Radar**
Stationary, Moving	Stationary only
Easy Aim	Exact Aim Required
Continuous Instant-on Intermittent (Pulsed)	Instant-on only
Light-Moderate Traffic	Light-Dense Traffic
Short-Long Range Targets Detection range decreases with rain, humidity, fog (K / Ka bands)	Short Range Targets Detection range decreases with fog, rain, dust, smoke, CO_2, humidity
Measures Speed only some models measure / display Strongest and/or Fastest targets	Measures Speed and Range some models do not display Range
Inside or Outside Patrol Car antennas can be mounted / used inside or outside patrol car	Outside Patrol Car Use Should not be operated from behind glass / windshields etc.

1.8 Layout of Thesis

This section outlines the structure of the thesis.

Chapter 2 deals with the concept of Doppler, history of Doppler, the actual DRS1000 concept which being implement into DOSTS prototype project and also examples of calculations.

Chapter 3 discusses about the information for project design of DOSTS prototype, which can be divided into two categories:

i) Schematic Design

ii) Software Development

Chapter 4 explains the result and analysis for actual DOSTS prototype project including the DOSTS Matlab simulation that based on DRS1000 datasheet & application.

Chapter 5 concludes the topics and suggests recommendation for future works, which can be done due to small improvements or large improvements.