Kaunas University of Technology
Faculty of Mechanical Engineering and Design

Elevation of Motorcycle Safety Using a FMCW Radar and a Side Stand Retracting Assembly

Master's Final Degree Project

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Assoc. prof. Dr. Saulius Japertas
Supervisor

Kaunas, 2018

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Reviewer

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Declaration of Academic Integrity

I confirm that the final project of mine, Ashwin Raj Rammohan, on the topic "Elevation of motorcycle safety using a FMCW radar and a side stand retracting assembly" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarised from any printed, Internet-based, or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this project.

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KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Study programme Vehicle Engineering(621E20001)

TASK ASSIGNMENT FOR FINAL DEGREE PROJECT OF MASTER STUDIES

Given to the student:

1. Title of the Project:

   Elevation of motorcycle safety using a FMCW radar and a side stand retrieving assembly

   Approved by the Dean Order No. V25-11-6, 12 April 2018

2. Aim and Tasks of the Project: The main aim of the research is to design a motorcycle concept with the radar element attached to it and perform flow analysis to deduct the velocity profiles, lift and coefficient of drag values of the formed body.

3. Initial Data: Literature review of FMCW radar , proposed model of the radar component with external auiliary transmitter antenna,design with possible dimensions and deduction of values using preliminary design subjected to a flow analysis.

4. Main Requirements and Conditions: Design of the motorcycle to be dimensionally symmetric, the side stand retractable assembly to be cost efficient,the complicated assembly to be entity converted into a single bofy for flow analysis.

5. Structure of the Text Part: Introduction, summary, literature review on FMCW radar, Theoretical essay on the radar utilized, matlab and Simulink coding for the radar component, design of the radar on motorcycle and the side stand assembly, flow analysis of the motorcycle with the radar component.

6. Structure of the Graphical Part: Results of the matlab and simulink models of the radar designed, streamline, velocity contours of the motorcycle subjected to flow analysis with the radar attached.

7. Consultants of the Project: Assoc Prof Dr Saulius Japertas

Student ....Ashwin Raj Rammohan..
(Name, Surname, Signature, date)

Supervisor .... Assoc. Prof. Dr. Saulius Japertas ....
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Programme Director of the Study field ______________________________
(Name, Surname, Signature, date)

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Study field and area (study field group): Transport Engineering (E12), Engineering Science.

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SUMMARY

The preliminary objective of this master thesis study is the overall enhancement of motorcycle safety on a broader and generic sense, with the inclusion of a FMCW radar for target vehicle’s range and speed estimation. The loss of peripheral vision occurring at high speeds of commute is substituted by the graphical display provided by the radar which in addition to the side stand retriever assembly contributes to colossal safety and thus eradicates the accident rates along with potential fatalities.

The designing and analysis softwares employed for the model fabrication and analytical studies are solidworks, matlab and ansys respectively.

The flow analysis is run to perform a brief analytical study on the radar module with the motorcycle involved and to calculate the values of coefficient of drag and lift.

Ashwin Raj Rammohan. Motociklų saugos gerinimas panaudojant FMCW radaro ir šoninės atramos mazgų montavimą. Magistro baigiamasis projektas / vadovas / doc. dr. Saulius Japertas; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.
Studijų kryptis ir sritis (studijų krypčių grupė): Transporto inžinerija (E12), Inžinerijos mokslai.
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Kaunas, 2018. Puslapiųsk 45. p.

Santrauka

Pagrindinis šio magistrinio darbo tikslas – iš esmės padidinti motociklo saugumą bendra ir plačiąja prasme, panaudojant FMCW radarą tam, kad įvertinti transporto priemonės atstumą iki taikinio bei tos transporto priemonės greitį. Periferinės regos praradimas transportui judant dideliu greičiu kompensuojamas grafiniu monitoriumi, kuris pateikia vaizdą iš radaro. Tai kartu su šoninės stovėjimo svirties montavimu stipriai padidintų važiavimo saugumą bei iš esmės sumažintų nelaimingų atsitikimų ir netekčių skaičių kelyje.
Darbe modelio projektavimui ir skaitmeniniam modeliavimui bei analizei atitinkamai naudojamos tokios programinės priemonės: solidwork, matlab ir ansys.
Srauto analizė atliekama tam, kad galima būtų greitai atlikti radiolokacinio modulio, sumontuoto motocikle, tyrimą bei įvertinti pasipriešinimo ir keliamosios jėgos koeficientus.

Introduction

‘Mobility, the commutation of goods and services from one initiation point to the desired destination’ according to Todd Litman , might be one of the biggest discoveries achieved by the feet of mankind, with the only price being paid in terms of avoidable and unavoidable fatalities occurring due to bountiful reasons. The ultimate objective of this research project is to find the occurrence of the ‘tunnel vision’ phenomenon in any desired locomotive medium at varying speeds and to hinder the former process by engineering application of exclusive Radar Navigation and Ranging techniques. The radar model that is to be incorporated is a frequency modulation continuous wave radar system with an external auxiliary antenna construction for easy and effective built, onto the vehicle’s frame which is the mudguard in this case. The adoption of this concept will ensure the deterioration of road fatalities to a significant extent mainly due to the elimination of tunnel vision in motorcycles. This system is employed in conjugation with that of a side stand retriever assembly for enhancing the overall safety features of the motorcycle. Hence radio detection and ranging technique aids in the successful substitution of the lost peripheral vision by graphical display units providing speed, and range determination of target bodies. The flow analysis is carried out using Ansys simulation software to get a glimpse of the velocity, pressure and streamline contours influencing the motorcycle design and to plot the coefficient of drag, lift values that would prevail in the designed model.

Objective: The chief objective is to design and assemble the FMCW radar and the side stand retracting assembly onto the concept vehicle to perform flow analysis and to determine the coefficient of drag and lift values.

Individual tasks:

- To research the literature review and predecessing advancements made in the field of radar applications
- To provide a brief theoretical format of the radar system and its components
- To design the radar block modules using matlab and Simulink software applications.
- To design the retractable side stand assembly with the aid of solidworks software.
- To design the concept motorcycle and the auxiliary radar antenna mounted on its mudguard fender.
- To design the motorcycle concept in simpler terms of one part, one body to perform flow analysis.
- To perform ansys flow analysis and thereby derive the coefficient of drag and lift values.

1. Literature review

Heinrich Hertz in the end of 19th century discovered that objects of metallic composition reflected radio waves through his experiments. This was previously indicated by James Clerk Maxwell during his experimental task on electromagnetism. Irrespective of the fact that this phenomenon was already discovered, its proposition was made available only during the early 20th century. This conceptual radar system was first utilized by the Germany based inventor Christian Hulsmeyer in his ship detection device of negligible complexity which was designed to aid his vessel in dodging collisions in fog. The following two decades witnessed the evolution of various systems with immense similarity. This is the inception of the radar system and the corresponding device is the predecessor of the current radar technology used for modern applications.

A group of innovative heads including Eric j knapp, Jorge Salazar, Rafael H Medina, Akilesh Krishnamurthy and Russell Tessier developed an array for Phase tilting radar at the Engineering Research centre for CASA abbreviated as Collaborative Adaptive Sensing of the Atmosphere for utilization of networks in distribution, collaboration and adaptive sensing techniques. The T/R module, elements of passive antenna and controller array were designed and elaborated in detail in their contribution to the advancement of radar technology [5].

The doppler weather radar by Richard J Doviak reveals the inception and advancement of integral weather echo characteristics namely signal to noise ratio (SNR), range correlation, signal statistics and so on. He equates the echo power loss caused by the finite receiver bandwidth and its relation to the range weighting function. This type of radar is exclusively used in weather sensing and measurement fields. He thereby devised a novel formula that bridges a relation between the width of the spectrum and the shear of radial velocities in addition to the turbulence, antenna rotation’s signal decorrelation and signal processing biases which is presented [6].

RISAT-1, India’s novel autochthonous all weather Radar imaging satellite is the Indian pioneer which utilizes the synthetic aperture radar (SAR) technique whose images promote agriculture and management of disaster due to its day and night, all weather observing capacity. It also is the foremost remote sensing satellite using microwaves and can enhance the ISRO’s potential for geographic surveillance especially during the natural calamities like floods, cyclones, landslides etc [7].

The 5th European Radar Conference included a radar technology developed by Ville Viikari, Timo Varula and Mikko Kantanen which was designed for the detection of low

Friction spots on civilian roads caused due to the backscattering properties of the material asphalt at all physical conditions (including dry, wet and icy states). They formulated the result of accurate water and ice detection by making use of a dual polarized 24 GHz and 77 GHz radar systems respectively.

Enoch R Yeh, Junil Choi, Nuria G Prelcic, Chandra R Bhat and Robert W Heath Jr combinedly examined Dedicated Short Range Communication (DSRC) and thereby devised the relationship between automobile radar's inherent security issues and the technologies corresponding to the former (DSRC). They discovered the vulnerability leading to potential road fatalities resulted by an external spoof attack. Considering the fact that the DSRC displays inherent pliancy to spoofing attacks and its incompetence to tackle similar traditional Wi-Fi based attacks, they incorporated both radar and DSRC units into a single module and hence theoretically reduced the insecurity of the vehicular system, safety wise [8].

R H Rasshofer and K Gresser together framed a model of the radar and lidar systems which were comparatively cheaper than the existing models and to eliminate the disadvantages of individual sensors employed in their paper 'Automotive Radar and Lidar Systems for Next Generation Driver Assistance Functions' by utilizing data fusion techniques [9]. An Intelligent transport system in general is defined as a technology, an application or a platform intended to improve the transportation quality, in addition to the outcome achievement of monitoring, managing and thereby enhancing transportation systems.

The constitutional framework of intelligent transportation systems can be carried out in many ways, for instance telematics and camera designs that capture contrast information on rudimentary systems employed for efficiently managing traffic or public transportation fleets. Some exploit wireless and RFID [2] radio wave technologies for signal conduction across geographic areas. These systems may be framed for varied objectives ranging from traffic volume orientation to strengthening of traffic law enforcement. Some counterpart modules may be directed at reducing carbon emissions, enhancing individual vehicle and fleet efficiency, or promoting the quality of life for pedestrians, residents, bicyclists via discrete traffic outcomes. Some facets of an intelligent transportation system can be enforced to commercial targets, such as swift shipping, more efficient fleet operations and secured jobs in transportation industries.

The genre of Intelligent transport systems chiefly comprises of the following categories such as,

- Advanced Traffic Management Systems (ATMS);
- Advanced Traveler Information System (ATIS);

- Commercial Vehicle Operations (CVO);
- Advanced Public Transportation Systems (APTS);
- Advanced Vehicle Control Systems (AVCS) [22].

Out of all the above mentioned ITS subdivisions and derivatives, the chosen field of study precisely falls under the category of Advanced Traveler Information Systems [22].

1.1 Tunnel vision

Irrespective of the fact that tunnel vision correlates to a lot of impairments in general, it leans to the side of vision impairment in the chosen field of study. When an automobilist operates the vehicle at speeds above the recommended standards, a phenomenon referred to as the tunnel vision occurs where the operator tends to lose the peripheral vision and the imaging senses working in such a way that constriction of the visual field occurs. This anomaly is referred to as the Tunnel Vision.

Human eyes are capable of Transmitting in excess of 200 frames per second where the optic nerves are responsible for doing so in less than 0.005 seconds per picture which is exponentially high when compared to the normal image processing capability of the human, being 13 to 15 frames per second psychologically [3]. This difference also contributes and is worsened when the tunnel vision phenomenon occurs.

Similar to the principles of any active cognitive processes, the human mind purposely ignores the peripheral visual input in order to focus exclusively on survival by dealing with what is immediately in front of the driver, when the speed of the automobile advances the critical tunneling speed, especially in the case of a motorcycle, and hence this phenomenon is common among MotoGP, Daytona and other race enthusiasts and also occurs in cars depending on certain conditions which is inevitable as stated above and exists without a proper engineering solution. The Drivers still base their visual skills to try and eliminate the drawbacks caused by tunnel vision which has to be eradicated engineering wise.

Basic biological causes of peripheral vision loss include:

- Glaucoma
- Retinitis pigmentosa
- Eye strokes or occlusions
- Detached retina

- Brain damage from stroke, disease or injury
- Neurological damage such as from optic neuritis
- Compressed optic nerve head (papilledema)
- Concussions or head injuries [4],

Which are omitted as they are the biological and not automobile induced tunnel vision. Hence an engineering way to eliminate the tunnel vision phenomenon while driving has to be devised.

1.2 Theory of the existing radar module

The basic radar system (Fig. 2.1) comprises of a limited number of intrinsic components, constructed together in assimilation to make use of all the contributing component's functions and hence to achieve the primary objective of obstacle detection.

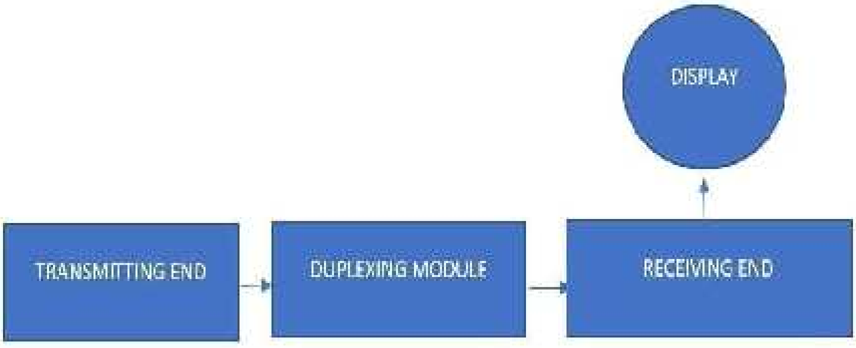


Figure 2. 1 Basic block diagram of a radar system

Prior to the investigation of the various vital characteristics of a general radar system, the chief categories of the existing radar modules depending on their nature of operation and chiefly on its waveform nature can be assorted as follows.

Hence, Transmitter, receiver and the mediating duplexer are the chief working components constructed in relation with each other forming the radar system. The display acts as the radarscope and forms the interface with which the operator allegedly acquired knowledge through effective communication of the obstacles, in case of a normal radar.

The chief variables that are to be taken into consideration while designing a radar system for any desired application genre are stated below.

1.3 Components and their respective functions

The theory of the system comprises of the required objectives to be met by the design process through which the radar system is formulated. In general, the most radar systems are fabricated revolving a central Frequency Modulated Continuous Wave Radar (FMCW).

Table 2. 1FCW requirements for the radar sensor

PARAMETER OF THE SENSOR	NECESSARY CONDITION
Azimuth field of view	It should be greater than 18 degrees
Elevation field of view	It should lie between the values of 4 and 8
Operating range	5-200 meters
Range rate limits	Should be between 35 and 70 m/s
Azimuth resolution	Should be lesser than 1.5 degrees
Range resolution	It should be lesser than 1 meter
Accuracy of range rate	It should be lesser than 0.25 m/s
Rate of data update	It should be greater than 10 Hertz
Sidelobe attenuation	It should be greater than 25dB

The forward collision avoidance system in the formulated concept of tunnel vision eliminating radar system is depicted in figure 2.2.

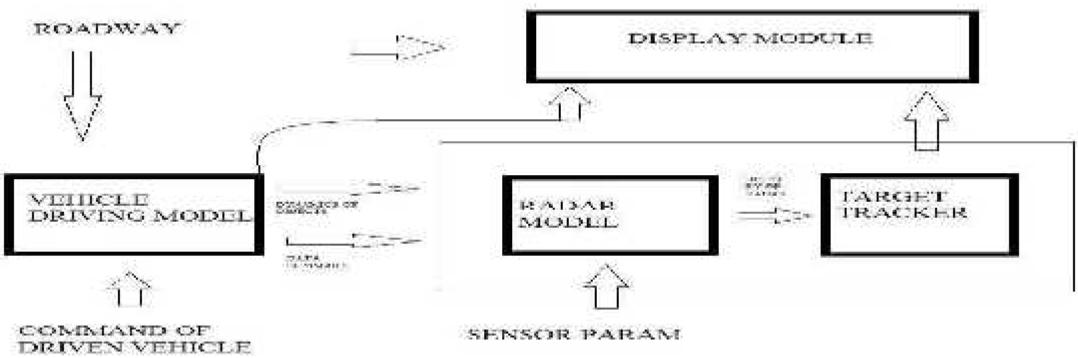


Figure 2. 2 Simulated forward collision warning system

The integral module that is mandatory in this case, is the Forward Collision Avoidance System (FCW) as the motorcycle involved is more prone to a forward collision which occurs with greater probability, when the automobile is operated at elevated speeds.

1.4 Devices involved

1.4.1 Radar sensor

The Radar sensor employed in this motorcycle application is the FMCW radar sensor which is a pioneer in radar sensing applications and is involved in the determination of speed, position, distance measurement from the target obstacle, level gauging, anti-collision, surveillance and also recommended for security purposes. There is a wide classification of sensors ranging from 24 GHz to 79 GHz which are the most common types that are made use of, for automotive sensing applications.

Figure 2. 3 Radar Sensor involved in the FMCW radar system. [21]

Unlike the other electromagnetic waves such as laser beams, infrared and ultrasound, radars exhibit consistency in accurately measuring the required parameter despite the abnormal weather conditions such as dust, smoke and fog. Unlike the single spot measuring restriction of a laser beam, the FMCW radar caters implicates vital information of the measured surface.

1.4.2 Radar display

The Type one forms the raw video displays which are general oscilloscopes that display the identified and multiplied target signal along with the receiver noise. It requires human operation to interpret the various target noise and clutter. Synthetic video displays formulate the type two category, utilizing a computer assistance to enhance the display as a result of noise elimination, clutter and thus by creating its own symbol. [17]

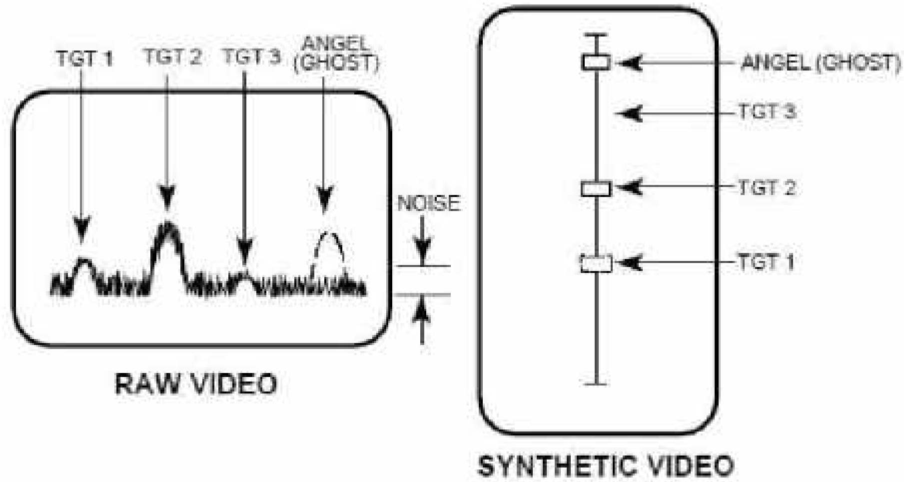


Figure 2. 4 Type of Radar Display utilized [21]

The design of the radar system is brought upon in such a way that the display elements comprises of a Plan Position Indicator supported by a graphical user interface run by a microprocessor.

1.4.3 Radar antenna

The collision avoidance system of the formulated concept desires a high frequency operation antenna and hence a petite built which can be incorporated into the motorcycle structure with ease, and also with nullified performance hindrances due to such construction. 77 GHz is preferred for Long Range Radar detection, up to 150 m in front of the vehicle. Many requirements need to be satisfied in designing such antennas [18]

The type of antenna that the system utilizes in the design phase resembles an exterior auxiliary, isotropic antenna.

PARAMETER INVOLVED	BEARABLE VALUES
Temperature	-50<optimal operation<60 degree Celsius
Relative Humidity (RH)	0<steady performance<95 %
Wind Speed	Up to 67 m/s
Load posed by external weather conditions (ice, hail, snow etc)	up to 300 kg/square meter

Table 2. 2 Parameters involved with the radome module

Service	Typical Frequency	Tx*	Rx*	Direction of Radiation
AM Radio FM Radio	Approximately 1 MHz 88 MHz to 108 MHz		Yes Yes	Horizontal Horizontal
In-vehicle TV	50 MHz to 400 MHz		Yes	Horizontal
Digital Audio Broadcasting (DAB)	100 MHz to 400 MHz		Yes	Horizontal
Remote Keyless Entry (RKE)	315 MHz/ 413 MHz/ 434 MHz		Yes	Horizontal
Tyre Pressure Monitoring System (TPMS)	315 MHz/ 413 MHz/ 434 MHz	Yes	Yes	Intra-vehicular
Cellular Phone (provision of Internet via HSPA)	850 MHz 900 MHz 1800 MHz 1900 MHz 2100 MHz	Yes	Yes	Horizontal
Satellite Navigation (GPS)	1.575 GHz		Yes	Satellite
Satellite Digital Audio Radio Service (SDARS)	2.3 GHz		Yes	Satellite
IEEE 802.11 b/g/n (Wi-Fi)	2.4 GHz	Yes	Yes	Horizontal
Bluetooth	2.4 GHz	Yes	Yes	Intra-vehicular
WiMAX Electronic Toll Collection (ETC)	2.3 GHz/2.5 GHz/3.5 GHz 5.8 GHz (or 900 MHz)	Yes Yes	Yes Yes	Horizontal Overhead
V2V* and VII*	5.9 GHz	Yes	Yes	Horizontal
Collision Avoidance Radar	24 GHz and 77 GHz	Yes	Yes	Forward

Table 2. 3 Types of radar system antennas based on characteristic features [18]

This type of antenna can be used for ground, Arial, and underground usage contributed by its excellent outer structure.

1.4.4 Regulations of automotive radar frequencies by international government agencies

The momentum in terms of automotive radar technology has been in proliferation for the past few decades. Regulation of the 76 to 77 GHz frequencies was governed by the European standards (ETSI EN 301 091) around 1990 which was designated for Intelligent Transport Systems in countries such as Japan, United States of America and Europe.

The Federal Communications Commission (FCC) commissioned Ultra Wide Band sensors targeted at the North American market (NAFTA) in 2002 considering the former's efficient short range appliances resulting due ti its inexpensive nature coupled with immense range resolution. FCC allocated the range lying between 22 GHz to 29GHz for automotive short range applications aiding UWB with a value of -41.3 dBm/MHz as its mean power density.

The Short range Automotive Radar Frequency Consortium (SARA) was established by the chief European car manufacturers of the 2002 period which supported the European UWB regulation of 24 GHz automotive radar as its primary motto. This resulted as a concession targeted to nullify the objections of the earth observation organizations and the telecom community.

The European commission's official community pronounced the allocation of range interval from 21.65 to 26.65GHz for UWB short range radar on the 17th of January 2005 with permitted marketing strategies formulated to the projected period of 8 years. The infiltration rate is barred to 7 percentage of all cars in every European nation with the expectation of unhindered short range radar sensor fabrication and exclusive usage, without diminishing the military, scientific and commercial counterparts.

The commission of European Union designated the frequency range of 77 GHz to 81 GHz for UWB Short Range Radar with authorized management since 2005. With the inevitable replacement with the former frequency range in Japan and North America, the SRR transitory will alter the usage to 79 GHz from the traditional 24 GHz module.

2 Methodology of the project

2.1 Matlab designing of the automotive radar system

The Frequency modulated continuous wave radar used in the motorcycle is mathematically designed using the mat lab coding technique for effective and competent mathematical modelling of the core system. The code is written in the coding software to generate the working attributes of the radar as a whole system using the following mathematical boundary conditions adopted depending on the radar system in selection.

System Criterion	Equivalences	Units
Operating Frequency	77	GHz
Maximum Target Range	500	m
Range Resolution	1	m
Maximum target Speed	230	Km/hr
Sweep Time	7.33	µs
Sweep Bandwith	150	MHz
Maximum Beat Frequency	27.30	MHz
Sampler Rate	150	MHz

Table 3. 1Operating conditions of the FMCW radar

The radar is formulated in such a way that the signal revived remains to be a time delayed facsimile of the signal transmitted in such a way that the delay is directly proportional to the range as the signal remains in a state of constant sweep along a frequency band. The frequency difference correlates in such a way amidst the transmitted and the received signal that it a constant at any occasion of the seep which is referred to as the beat frequency. The etymologic derivation of the delay time can be carried out succeeded by the translation of the latter to the range due to its sweep being linear in nature.

In the FMCW radar composition the maximum monitoring capacity of the radar is precisely 500 meters with the dispensation of two, one meter apart targets. The wave form patterns are acquired from these technicalities.

```
clc
clear all
fq= 77e9;
c= 3e8;
lambda = c/fq;
range_supr = 500;
tm = 10*range2time(range_supr,c);
range_res = 1;
bw = range2bw(range_res,c);
swp_slope = bw/tm;
fr_supr = range2beat(range_supr,swp_slope,c);
v_supr = 500*1000/3600;
fd_supr = speed2dop(2*v_supr,lambda);

fb_supr = fr_supr-fd_supr;
fs = max(2*fb_supr,bw);
waveform = phased.FMCWWaveform('SweepTime',tm,'SweepBandwidth',bw,...
    'SampleRate',fs);
sig = waveform();
subplot(211); plot(0:1/fs:tm-1/fs,real(sig));
xlabel('Time (s)'); ylabel('Amplitude (v)');
title('FMCW signal'); axis tight;
subplot(212); spectrogram(sig,32,16,32,fs,'yaxis');
title('FMCW signal spectrogram');
car_dist = 50;
car_speed = 96*1000/3600;
car_rcs = db2pow(min(10*log10(car_dist)+5,20));

cartarget = phased.RadarTarget('MeanRCS',car_rcs,'PropagationSpeed',c,...
    'OperatingFrequency',fq);
carmotion = phased.Platform('InitialPosition',[car_dist;0;0.5],...
    'Velocity',[car_speed;0;0]);
channel = phased.FreeSpace('PropagationSpeed',c,...
    'OperatingFrequency',fq,'SampleRate',fs,'TwoWayPropagation',true);
ant_aperture = 6.06e-4;
ant_gain = aperture2gain(ant_aperture,lambda);

tx_ppower = db2pow(5)*1e-3;                        % in watts
tx_gain = 9+ant_gain;                              % in dB
```

Figure 3. 1Matlab coding for the FMCW radar

2.1.1 Radar Signal Simulation

The concept of the Frequency Modulated Continuous Wave radar confides in the range measurement by explicit auditing of the beat frequency in the dechirped signal. The received signal and the transmitted signal are blended together to extract the desired frequency of the radar module. Subsequently after the successful mixing of the end to end signals, the dechirped signal incorporates only the definitive frequency components that correlates to the target range.

The range of the Doppler is determined precisely with the aid of these following actions

- The FMCW radar signal is generated by the waveform generator.

- The transmitter in coordination with the antenna aids in the radiation followed by the amplification of the signal to space.
- The proliferation of the signal targeted to the mark gets reflected by the target and commuted back to the radar.
- The signal is accumulated by the receiving antenna.
- The acquired signal is dechirped and cured in a buffer.
- As soon as the sufficiency of the collected sweeps reaches a desired value in the buffer, The estimation of the range and speed of the targets becomes apparently effortless with the help of these results. The range and speed of the target can also be depicted as a figure to provide with an intuitive signal of the targets stance in terms of speed and range.

2.2 Simulink model of the automotive radar system

In order to provide an interactive, graphically modelled environment for the code created and to eventually control the entire systematic operation of the radar system the Simulink add on product of the matlab is made use of, as a part of the methodology.

The Simulink model of the FMCW radar system makes use of liner in addition to a couple of nonlinear systems modelled in continuous time carried exclusively by the graphical user interphase provided. The overall Simulink model of the FMCW radar is depicted as follows.

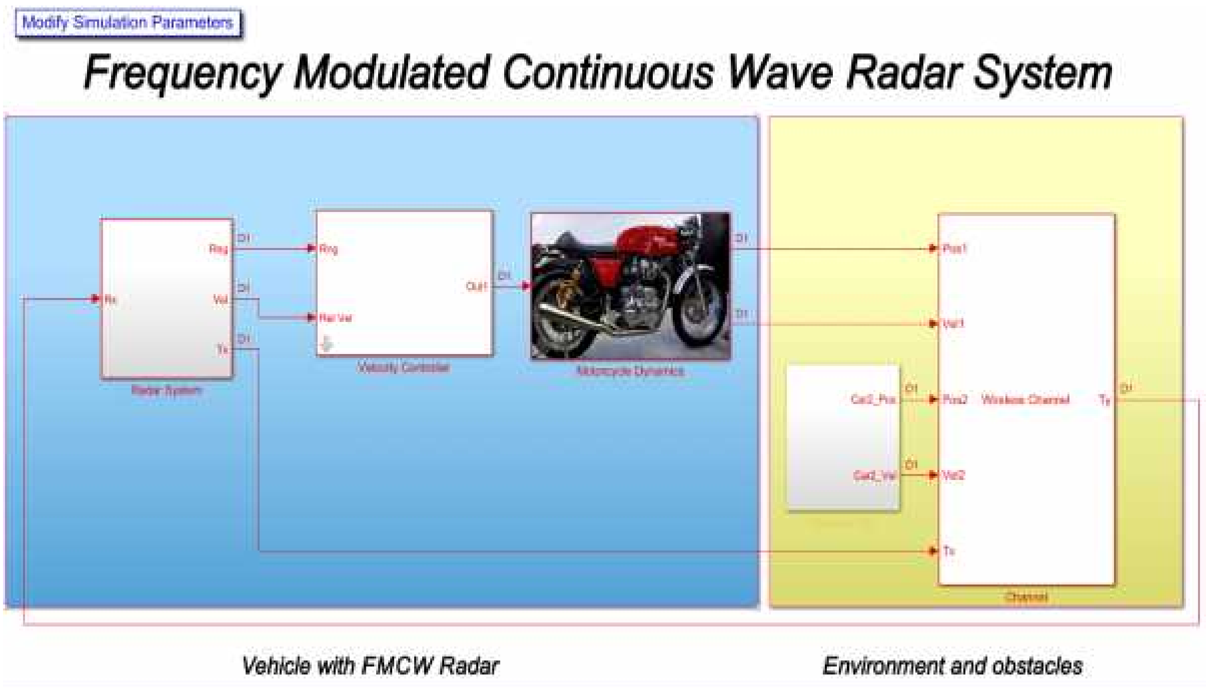


Figure 3. 2 FMCW radar system using Simulink

The large scale box highlighted in blue represents the thorough fabrication of the entire system in use consisting chiefly of the radar systems in conjugation with the velocity controller and the dynamics of the motorcycle which adds definition to its vehicular nature.

The sub block diagram represented by the yellow colour represents the target vehicle and other possible or potential hurdles and physical interferences that have to be briefed to the commuter using the vehicle with the built in radar system.

The blocks are in relations with one another using the lines corresponding to ‘Tx’ denoting the transmitter and ‘Rx’ denoting the receiver.

In order to experiment the efficiency of the radar system in use, the target vehicle is assumed to be a car which is denoted as ‘C2’ of which the precise vehicular speed, range, overview are to be determined.

2.2.1 Radar system

The radar system employed in chosen vehicle comprises of the following components constructed in conjugation with each other to attain the desired output.

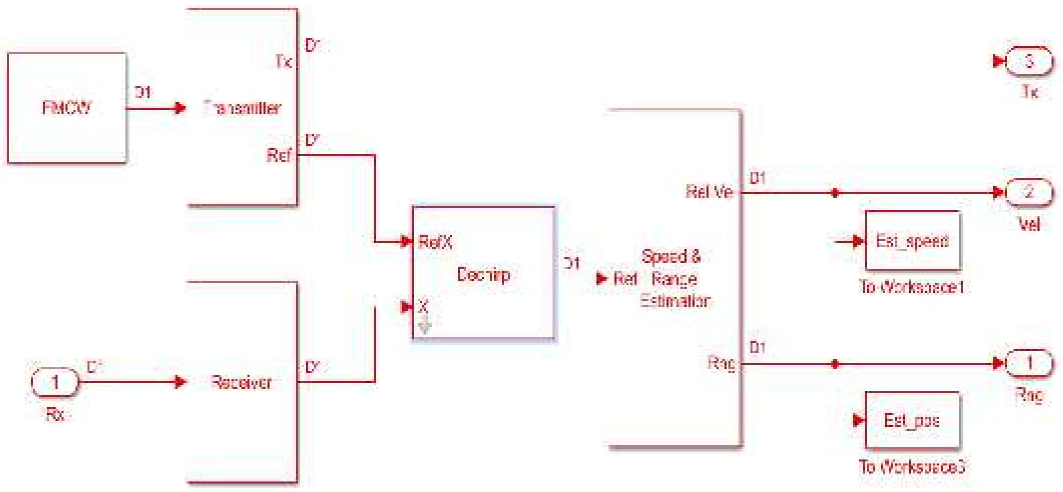


Figure 3. 3 Overall radar system designed in Simulink

The transmitter and the receiver antennas are located in such a way that the signal generated is allowed to propagate from the transmitter end and eventually attains the receiver end after the bombardment of the signal onto the target surface.

The De-chirp allows the mixing of the reference signal along with that of the input signal by taking the reference signal from the transmitter with that of the signal given to the receiver.

The dechirped signal is then fed into the block responsible for the determination of the speed and range estimation. These values are then sent to individual work stations depicted above responsible for individual calculation and explicit appraisal of the necessary target attributes.

2.2.2 Transmitter and receiver antenna blocks

The sub blocks of the transmitter array block and the receiver array block are as follows

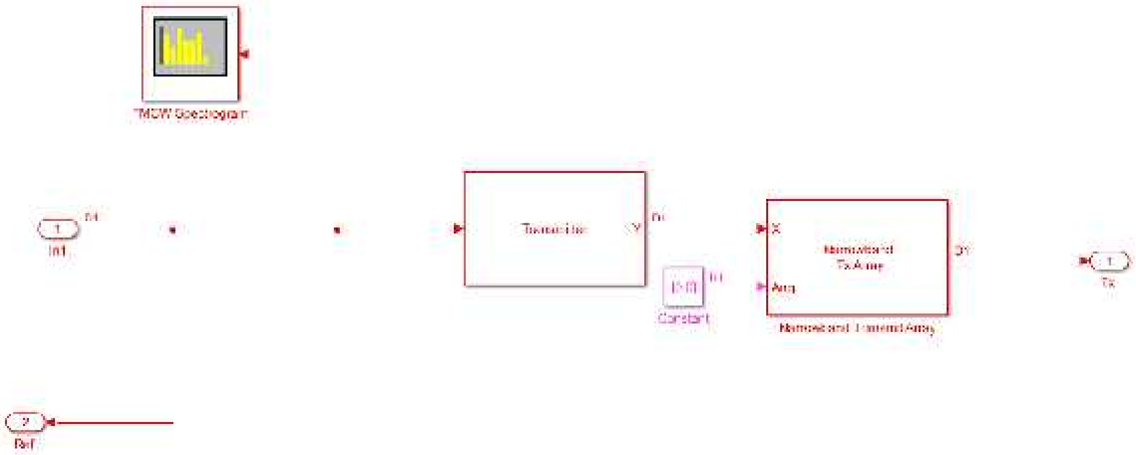


Figure 3. 4 Transmitter antenna block in Simulink

Here the figure3.4 illustrates the flow of the spectral signal to the transmitter model after which it is associated with a gain as a result of the amplification phenomenon. 'IN 1' refers to the inlet from which the signal travels and 'Tx' refers to the transmitter of the module.

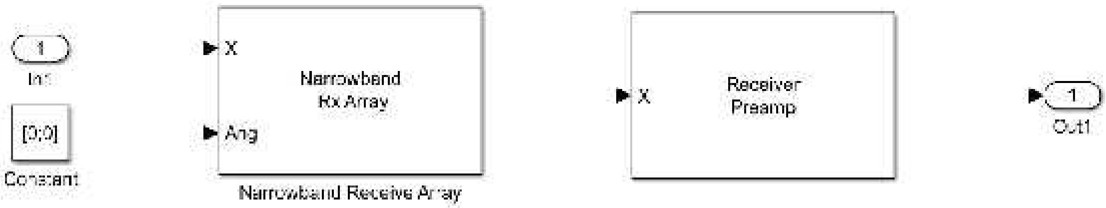


Figure 3. 5 Receiver Block design in Simulink

This design is analogously unique when compared to most of the other automotive radar systems since the common automotive radars belonging to the pulsed wave radar systems, whereas the continuous type is made use of in this concept. This operation principle requires the use of a special microcontroller type that can easily be fixed in a motorcycle due to its nature of being handy and readily portable. The figure 3.5 represents the receiver module of the overall radar complexity consisting of individual phase ray system blocks as illustrated above.

The integral module that is mandatory in this case, is the Forward Collision Avoidance System (FCW) as the motorcycle involved is more prone to a forward collision which occurs with greater probability, when the automobile is operated at elevated speeds.

2.3 Methodology of the retractable stand assemblage used in motorcycle

2.3.1Proposed method

The basic working principle of a motorcycle is the rotation of the pinion that eventually drives the vehicle itself from the power spawn upon by the engine, which is an established fact and also the basis for the dynamics of the 'Retractable stand assemblage'. This side stand retrieving assembly makes use of the power generated by the engine bestowed upon it by its relating connection with that of the chain drive. This simple yet efficient system consist of the following integral constituents.

- Axle
- Pinion gear
- Lifting crowbar
- Pushing crowbar

2.3.2Principle of operation

The retractable stand assemblage retrieves the former instantaneously during the scenario when the commuter forgets to push back the side stand during the high speed transit. Its working principle is stationed on the dynamics of the vehicle itself where the power originated in the engine of the particular vehicle is disseminated to the retrieving entity through a pinion that connects to the chain drive of the system. Hence the rotary advancement of the pinion is translated to the linear motion of the chain, which again is converted to rotary advancement by the wheel's sprocket and thus retrieving the motorcycle stand.

The sprocket is positioned between the pinions of the chain drive and hence forms the key integral part of the systems operation. The sprocket, being a commodity of utmost importance is specifically designed to rotate and therefore power the lifting crowbar connected to the stand bringing upon the incitation of the pushing crowbar to revive the stand.

The anticlockwise rotation of the inciter assemblies lead to the absorption of the power by the designed system and eventually leads to the revival of the stand to its resting position by the guidance of the pushing crowbar.

To achieve a luminous apprehending of the system involved, a careful examination of the assembly's essence during the chief two working conditions are discussed as follows to shed more light on the effervescent of the module's application

2.3.3 Assemblage at rest

At the point when the motorcycle is motionless, the commuter impels the side stand of the vehicle to ground, the pushing crowbar that is turned at the focal point of the side stand gets drawn in with the inciter gatherings' lifting rod.

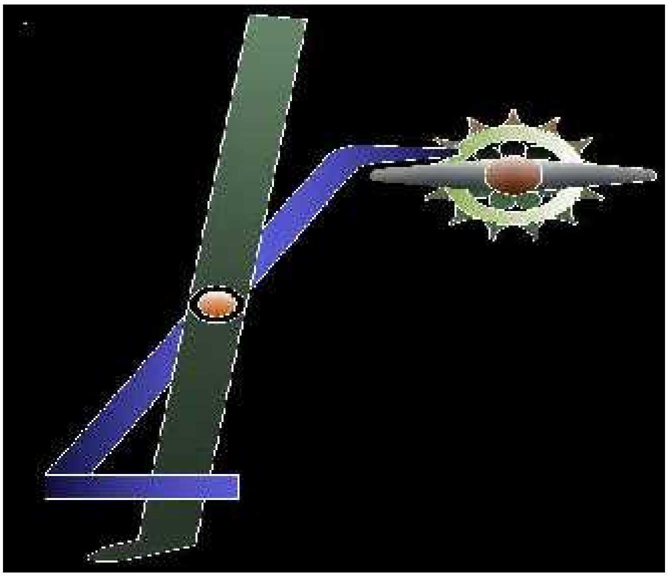


Figure 3. 6 Side stand retriever Assemblage at rest

The length and size of the pushing crowbar is determined on the mode of application, i.e. the individual motorcycle model and genre involved onto which the assemblage has to be mounted on.

2.3.4 Assemblage during motion

At the point when motorcycle is locomotion, Engine's pinion conducts energy to the posterior wheel by the chain drive. The inciter gathering which is kept at the focal point of the chain drive turns as the sprocket draws in with chain drive. Henceforth when the sprocket pivots, the lifting lever mounted with hub turns in such a way to enable the captivation of the lighting crowbar and the pushing crowbar to push the stand, with the utilization of a C molded clipping gadget or a stand holder. The spring strained in the side stand at that point gets compacted rapidly thus retrieving the stand.

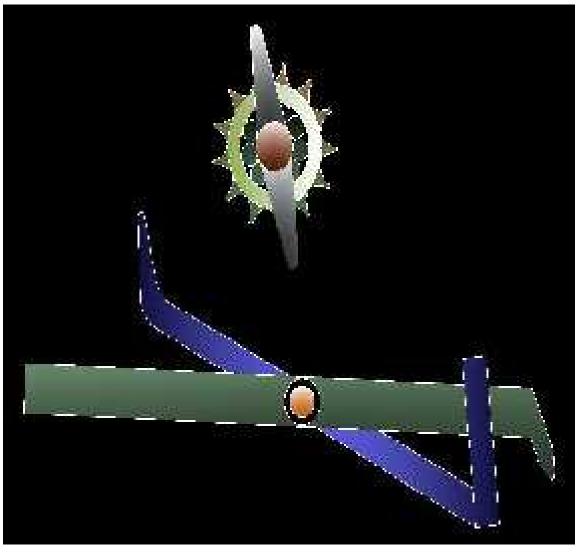
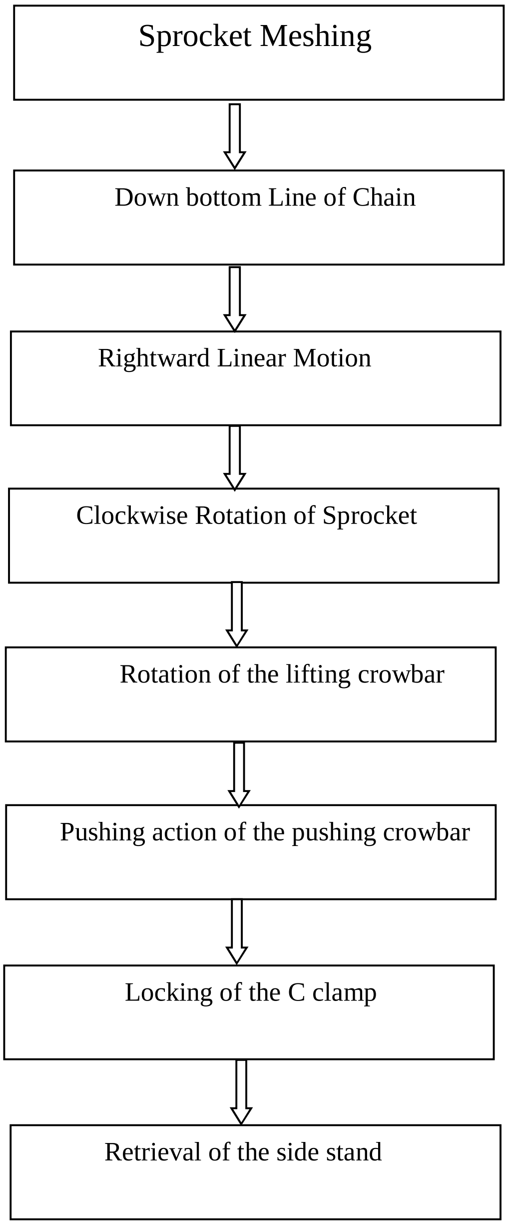


Figure 3. 7 Side stand retriever assemblage during motion

The overall operational flow of the ‘retractable stand assemblage ‘is depicted as follows



3 Design of individual models using solidworks

The designing software employed for the individual part components and their overall assembly is solid works which explains the boundary conditions better that its counterparts and facilitates easier meshing of the part assembly.

3.1 Design of the retractable stand assemblage

The overall design of the retractable side stand assemblage consisting of designing the following integral components individually.

3.1.1 Design of the axle and the lifting crowbar

Axle is the metallic pole made up of mild steel interfacing the lifting crowbar and sprocket midway. The pivot is welded halfway to the sprocket which is held in position by a fixture, welded to the edge. The holder is utilized to counteract vibration and to offer help to the axle. The holder has little metallic tube and a rectangular metal plate. The metal plate is welded opposite to the tube.
The opposite end of the metal plate is welded at the casing. The entire metallic individuals from holder are of mild steel. The one end of pivot is welded with sprocket and opposite end with lifting crowbar to enable the flow of power transmission from sprocket to lifting crowbar.

Table 4. 1 Specifications of axle

MATERIAL	Mild Steel
SHAPE	Cylindrical rod
LENGTH	50mm
DIAMETER	13mm
INNER DIAMETER OF SUPPORTING AXLE	15 mm
OUTER DIAMETER OF SUPPORTING AXLE	17mm
LENGTH	30mm
THICKNESS	3mm

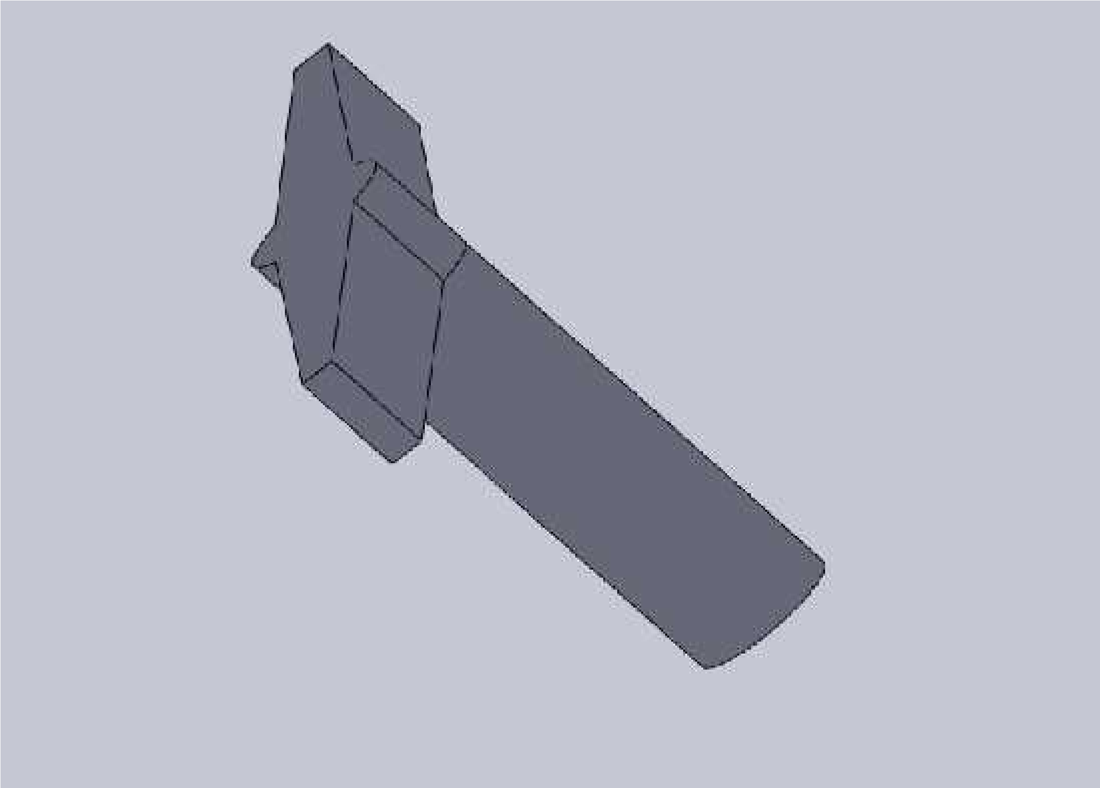


Figure 4. 1 Solidworks model of the axle and the lifting crowbar

3.1.2 Lifting crowbar

Lifting crowbar is the third significant segment of the framework which briefly is a rectangular pole made of mild steel-pole that comprises of two lifting crowbars mounted onto the edge of the assembly. The lifting lever ought to be parallel to the pinion gear fabricated with two metal bars, where both are welded at either sides of the pivot.

3.1.3 Pushing crowbar

Pushing crowbar is the component pivoted centrally to the side stand. The pushing crowbar is a metallic rectangular plate, with a bent rear denoting a ‘C’ in structure and is welded with a small piece of rectangular rod. This small piece of rod is employed by the lifting crowbar to successfully dive the engagement and to process smooth retrieval.

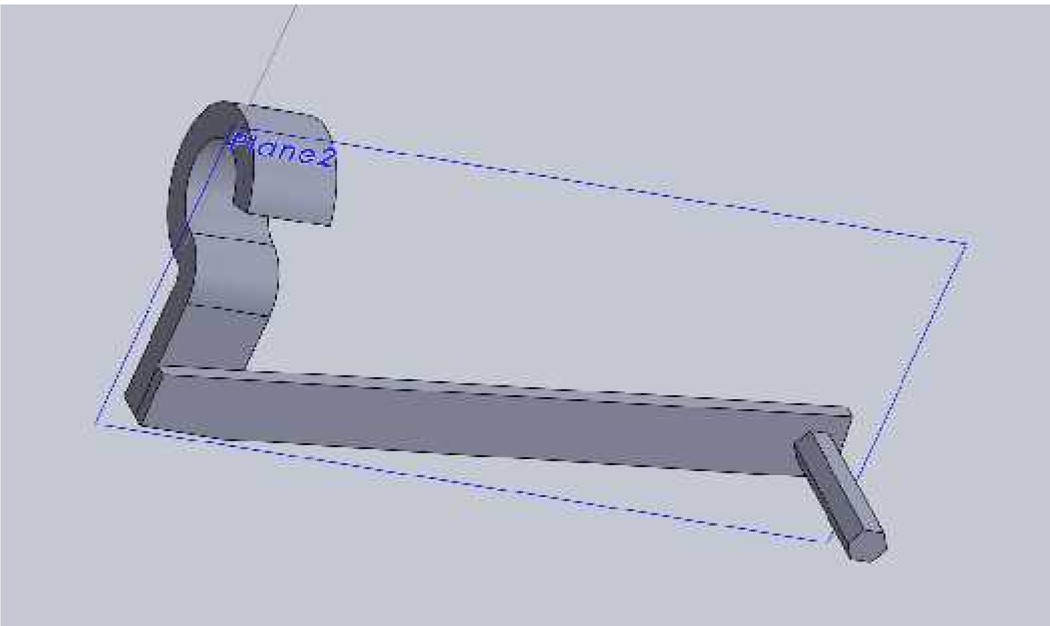


Figure 4. 2 Solidworks model of the pushing crowbar

Table 4. 2 Specifications of Pushing crowbar

MATERIAL UTILIZED	Mild Steel
LEVER LENGTH	180mm
THICKNESS	3mm
HOLE DIAMETER	8mm
LENGTH	30mm
THICKNESS	10mm
CLAMP DIAMETER	28mm
STAND DIAMETER	25mm
PIVOTED ANGLE	55deg
BOLT DIAMETER	8mm

The overall assembly of the sprocket stand retriever system is depicted in the following solid works model.

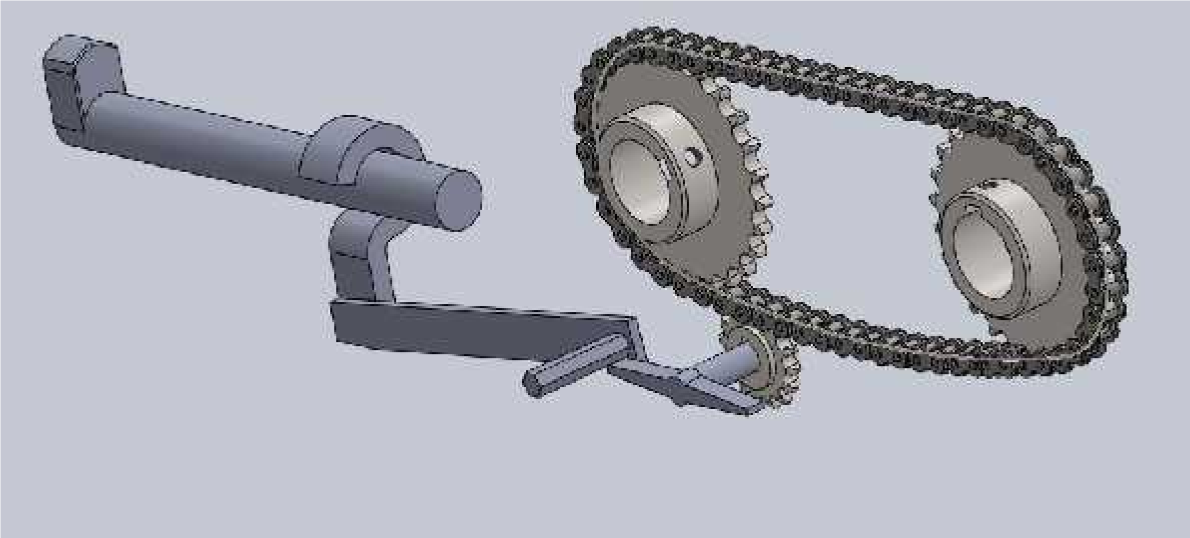


Figure 4. 3 Overall assembly of the sprocket stand retriever system

The assembly is constructed in such a way that the total number of components constituted in the assemblage is 71 resolved components fixed with each other via 5 mates. The individual components included and hence forming the assembly are the chain drive with the sprockets, the connected pinion gear to which the axle and the lifting lever are attached, the pushing lever with the ‘C’ clamp enclosing the side stand of the motorcycle and henceforth coordinating each other as desired to bring about the overall operation of retracting the side stand if left unattended during the commutation of the motorcycle which is illustrated in the figure 4.3.

3.2 Solidworks design of the FMCW radar attached to the motorcycle

The FMCW radar constitutes of the transmitter, receiver, mixer and the microcontroller as a sensor in whole which can be attached in a varied combinations according to the specifications of the bike onto which it is to be anchored. Irrelevant to the fact that the sensor in whole is enclosed and cased on to a small dome, an external supplementary antenna is provided for auxiliary range detection during adverse weather conditions and for augmented understanding of the design as an anchor to the motorcycle. The solidworks software is employed for the inception of the complete motorcycle assembly with the antenna system attached with it which is illustrated in the figure 4.4 .

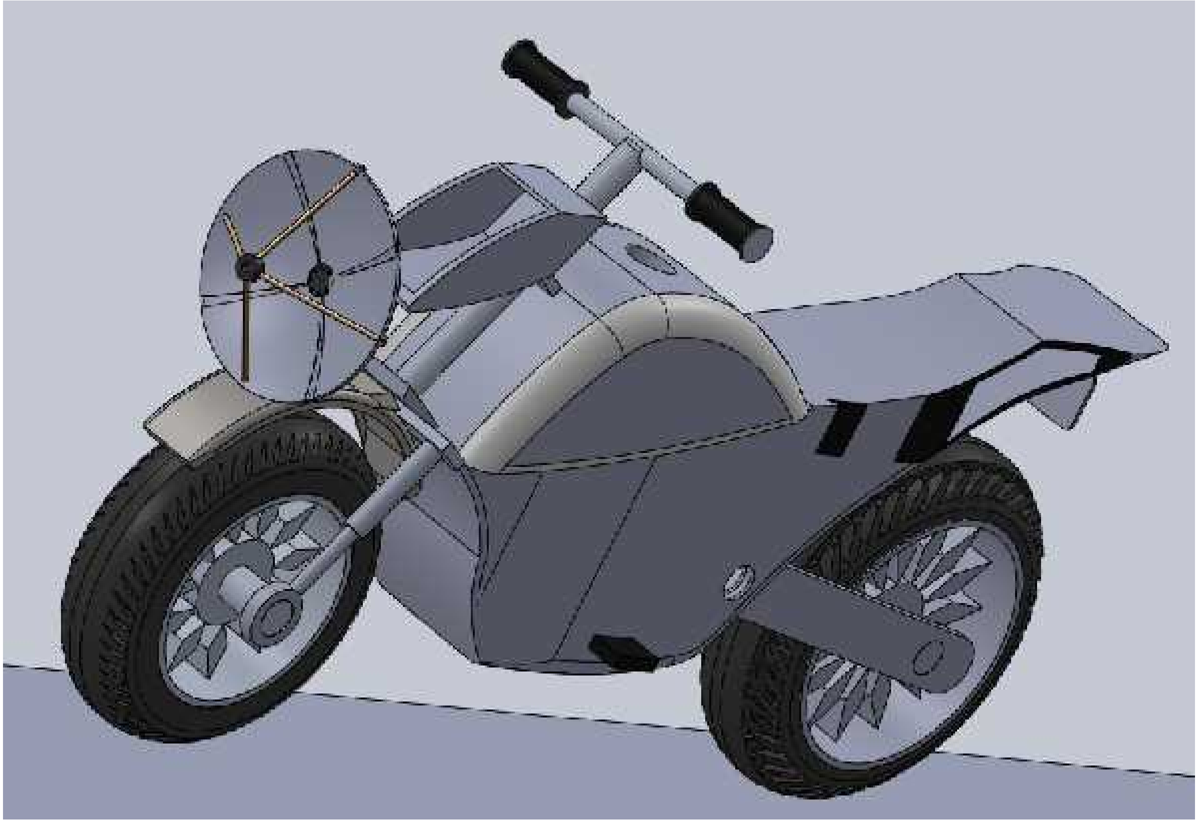


Figure 4. 4 Solidworks model of the antenna attached to the motorcycle concept

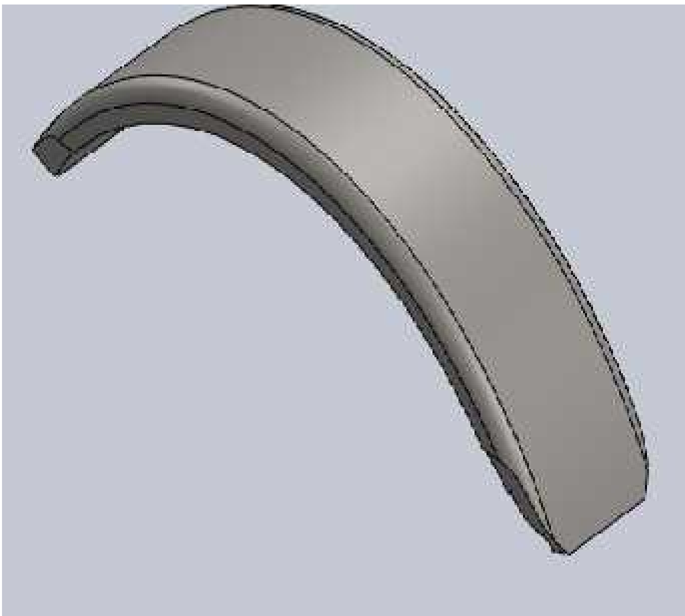
To authenticate the theory that the radar model can be attached and incorporated in any motorcycle genre such as a dual sport, cruiser, sport touring motorcycles etc., a general concept of a high speed motorcycle is designed and developed to withheld the antenna component rather than a specialized model of a motorcycle belonging to any of the vehicular genre.

The concept bike has a simple design assembly consisting of 56 components and bodies altogether coupled as an assembly. The auxiliary radar antenna can be attached in a number of places in and around the motorcycle design and is selected to be mounted on the front mudguard after meticulous examination of the relevant parts on which it can be mounted on for efficient operation of the radar component considering a varied number of external factors and conditions.

The mudguard is altered in such a way that a fender cap with two fixtures supporting two connecting high carbon steel rods which are mounted on them in conjugation with their connection to the antenna element via a grip bracket. The alteration made in the mudguard element and its original design are illustrated as follows for understanding the concrete fixture of the antenna module.

Figure 4. 5 Mudguard after the alteration for the radar mount

Figure 4. 6Mudguard before the alteration for the radar mount



The complete assembly is hence illuminated in figure 4.4 and is later fed to an analysis software for the determination of the coefficient of drag and lift of the model designed and to thereby verify the aerodynamics of the design module and to examine whether the attachment onto the vehicle affects its performance whatsoever.

3.3 Ansys flow simulation of the designed model

The ‘Ansys’ software is employed for the flow study of the motorcycle designed and onto which the radar module is installed. This study is of immense value as it predicts whether the attachment involved actually affects the motorcycle medium in terms of velocity, streamlines and airflow during operation either significantly or insignificantly .

The model designed in solidworks tenders to be over complicated for analytical study of flow due to its intricate parts and exaggerated assembly features. The direct importation of the model will render the flow analytical study and hence craves the simplification of the assembly model into one solid body. This simplification involve the design of the whole multiple assemblies into an individual solid body rendering the complications of its mother design as portrayed in the figure 4.7.

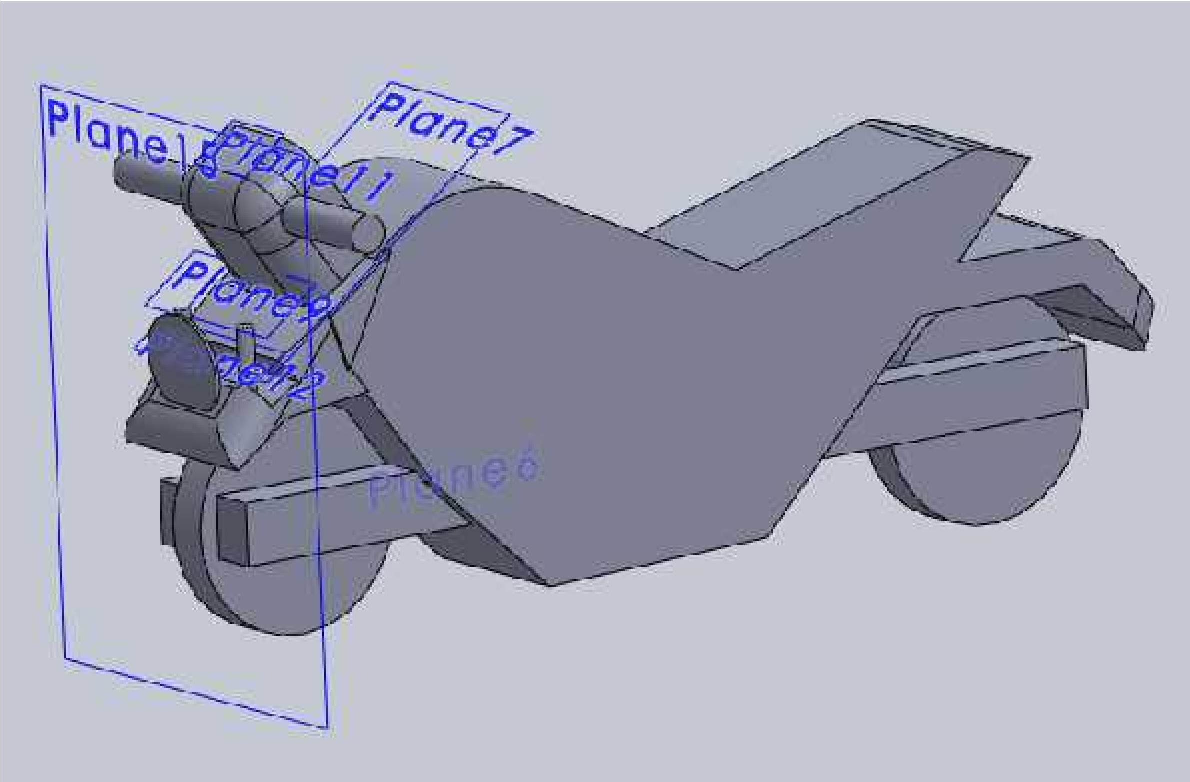


Figure 4. 7 Simplified motorcycle design with the radar antenna attachment

This figure 4.7 is a simpler representation of the complex assembly consisting of the concept motorcycle with the radar components involved and hence renders any change from its basic design features. The surfaces of the mudguard, handlebars and the motorcycle head (on which the head on display is mounted) are filleted to provide minimal traction, thus enhancing the aerodynamic features of the overall vehicular body.

The boundary conditions required to be satisfied to promote the desired flow analysis are illustrated in the table 4.3.

Table 4. 3 Boundary conditions required for the flow analysis

Boundary condition	**Admission value**	**Units**
Enclosure dimensions		
Velocity magnitude	115	m/s
Direction specification	Normal to boundary	nil
Flow	Viscous- Laminar	Nil
Velocity specification method	Magnitude, normal to boundary	Nil
Density	1.255	Kg/m^3
Depth	1	m
Length	1	m
Temperature	288.16	K
Viscosity	1.7894e-05	Kg/m-s
Enclosure	(x,y,z,-x,-y,-z);(0.25,0.25,0.25,0.25,0.25,1)	m

The results generated of the flow simulation are illustrated in the form of numerical data and graphical representation which are depicted in the results section.

4 Calculations

4.1Basic equations for automotive radar power

When the theory of scientific echolocation is considered, the required targets positional apprehension can be achieved up to a certain obtainable space depending on the power of the radar involved. The distance of the target to be detected in general is denoted as D_0, which is derivable through the acclaimed formula,

$$D_0 = \sqrt[4]{\frac{P_t G_A^2 \sigma_{tg} \lambda^2}{64 \pi^3 P_{r\ min}}}\ , \quad m \quad (1)$$

Where:

P_t – Power value of the transmitter in W;

G_A – Gain of the antenna;

σ_{tg} – effective target area, equal to $1m^2$;

λ – wave-length;

Wavelength is calculated by the formula

$$\lambda = \frac{c}{f} = (3\times10^8)/ 77\times10^9 = 3.859e\text{-}3$$

$P_{r\ min}$ – sensitivity of the receiver which is denoted in W.

Considering radio wave attenuation, L_{atm}, constituted in the earth atmosphere, the distance at which the target is determined, D_{atm},

$$D_{atm} = \sqrt[4]{\frac{P_t G_A^2 \sigma_{tg} \lambda^2}{64 \pi^3 P_{r\ min} L_{atm}}}\ , \quad m$$

Power of the transmitter, P_t , W		Distanve of the target vehicle D_0 , m
Radar Type 1	Radar Type 2	
1.08×10^{-7}	1.08×10^{-4}	30
3.41×10^{-7}	3.41×10^{-4}	40
8.33×10^{-7}	8.33×10^{-4}	50
1.73×10^{-6}	1.73×10^{-3}	60
3.2×10^{-6}	3.2×10^{-3}	70
5.46×10^{-6}	5.46×10^{-3}	80
8.75×10^{-6}	8.75×10^{-3}	90
1.33×10^{-5}	1.33×10^{-2}	100
1.95×10^{-5}	1.95×10^{-2}	110
2.76×10^{-5}	2.76×10^{-2}	120
3.81×10^{-5}	3.81×10^{-2}	130
6.75×10^{-5}	6.75×10^{-2}	150
2.13×10^{-4}	2.13×10^{-1}	200
5.21×10^{-4}	5.21×10^{-1}	250

Table 5. 1 Calculated values of detection distance for various power and radar frequencies

4.2 Calculation of free space loss

The free space loss is denoted as L, which can be computed by the formula,

$L = (4\pi\, d\, f\, /c)^{2}$

$= (4\,\pi \times 500 \times 10^{-3} \times 77.9/\ 3\times10^{8})$ (where the maximum detectable distance is 500 m)

=1.631e-6

4.3 Cost estimation of the retractable stand assembly

INTRINSIC COMPONENT	MATERIAL EMPLOYED	ESTIMATED PRICE IN USD	RELEVANT PRICE IN EURO
INNER CHAIN	STAINLESS STEEL	108.68	92.687
OUTER CHAIN	STAINLESS STEEL	228.92	195.232
PINION GEAR	PLAIN CARBON STEEL	6.35	5.415
LIFTING LEVER AND AXLE	PLAIN CARBON STEEL	4.30	3.667
PUSHING LEVER	CF8 STAINLESS STEEL CAST	25.32	21.593
SIDE STAND	PLAIN CARBON STEEL	15.39	13.125
SPROCKET (2)	PLAIN CARBON STEEL	41.75	35.606
WELDING AND ANODIZING COST	NIL	0.07	0.059
TOTAL COST	NIL	430.78	367.384

Table 5. 2 Cost estimation of the side stand retracting assembly

The overall price estimate in euros including the already existing outer and inner chain drive contained in the motorcycle assembly is 367.35 euros (approximately). In order to incorporate the sprocket stand retriever system designed, the outer and the inner chain drives can be excluded due to their inevitable presence in the motorcycle as the power transmission medium from the engine to the flywheel. Hence excluding the price estimates of the combined outer and inner chain drives, the overall cost approximated for the installation of the devised assembly is (367.388 – 287.919) € which is 79. 469 euros in total.

5 Results

5.1 Results obtained from the matlab modelling of the radar

The results are shown in the form of figures derived by the Simulink models and matlab coding of the FMCW radar system, in which the figure represents the portrayal of the frequency spectrum. Here the x axis depicts the time intervals and the y axis corresponds to the variation in amplitude created during the varying time period. The fluctuations of the transmitted radar signal are enormous throughout a time interval of three seconds. The inconstancy of the FMCW signal also varies during the time interval of every 1.5 to 2 seconds. This result is generally employed in calculating the sweep time of the generated signal with the sweep being linear in nature.

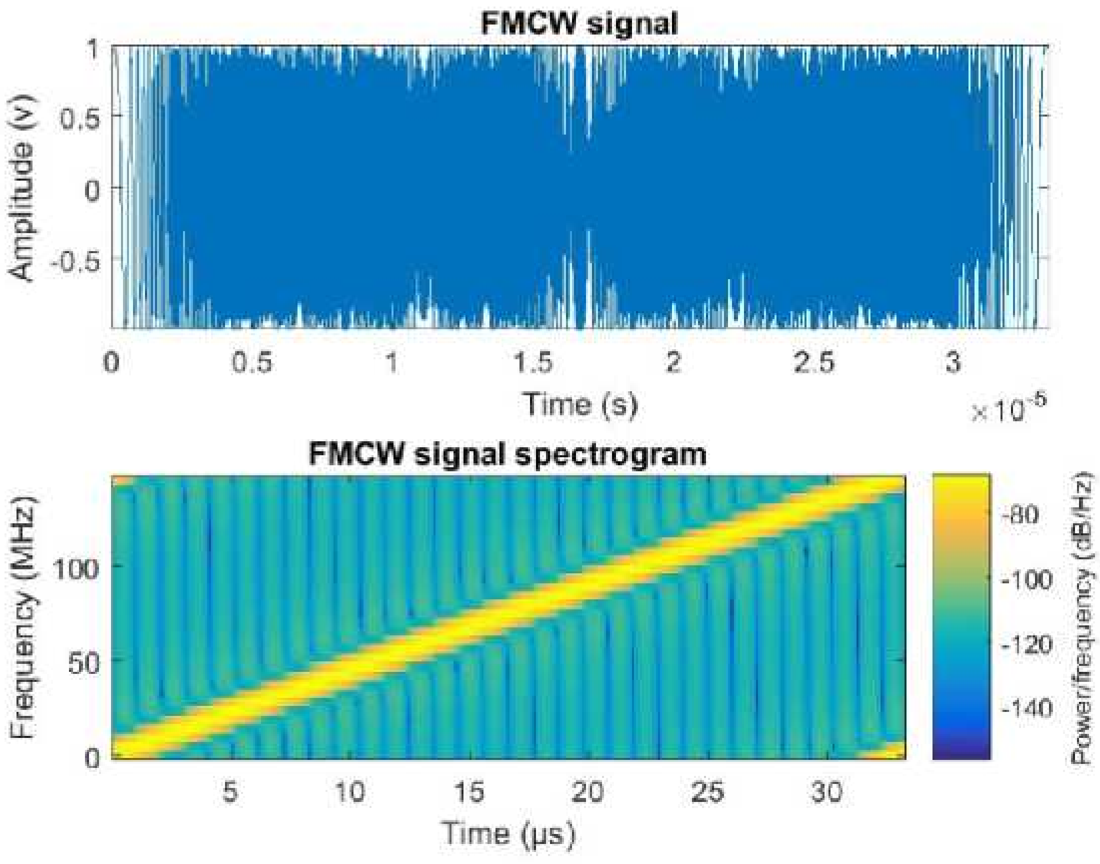


Figure 6. 1 FMCW spectrogram plotted as a result of matlab coding

The graph plotted between frequency and the time period denotes that the frequency steadily escalates with the time inflation depicted in figure 6.1. The colored signal in yellow denotes that the signal processed has a higher frequency of 77 to 85 GHz. This tallies with the frequency generational capacity of the employed radar system which happens to be 77 GHz.

Figure 6.2 demonstrates the natures of the received signal and the de-chirped signal using the spectrum analyzer. This spectrum analyzer mimics the representational values of a spectroscope. From the matlab generated graph, it is deductible that the signal received belongs to the wideband composition of the spectrum whereas the de-chirped signal is of the narrow band. The received signal is illustrated as channel 1 whereas the de-chirped signal is denoted as the 2nd channel.

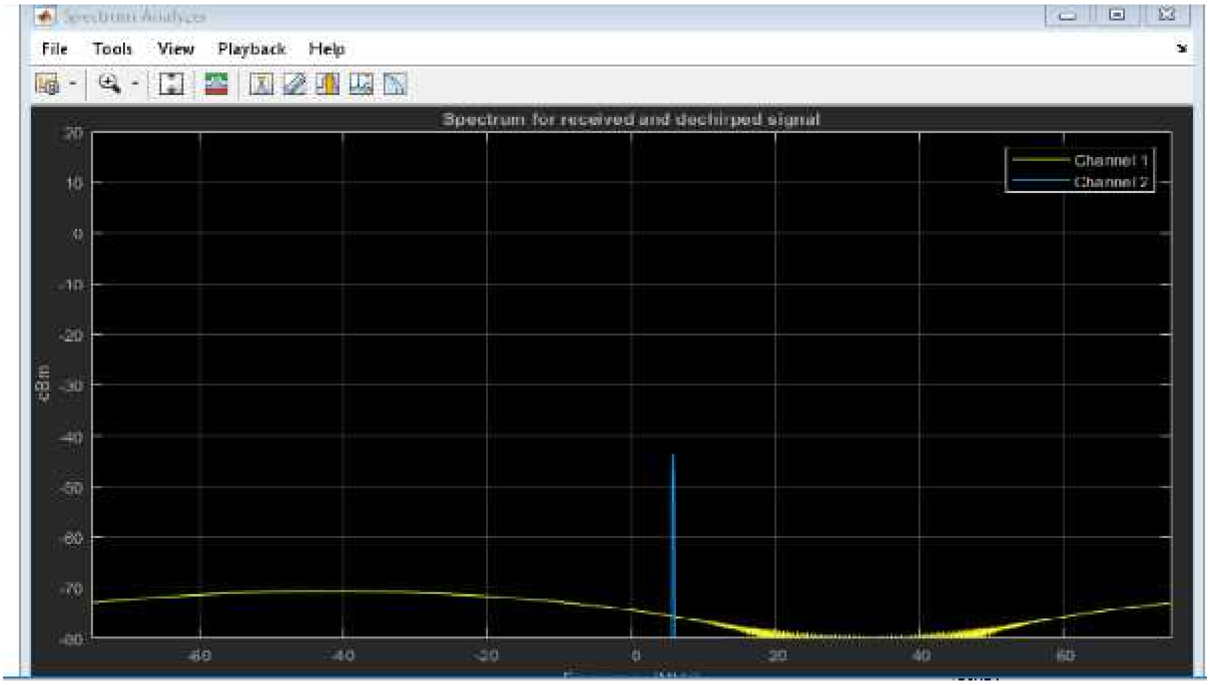


Figure 6. 2 Spectrum for recieved signal and de-chirped signal

The figure 6.3 corresponds to the matlab code aiding the generation of the speed response pattern. This is one of the key integral parts of the radar design as it helps the commuter to achieve a relation between the position, speed and the velocity with which the target vehicle commutes. The display illustrated is generated with attributes such as the power, speed and range of the target vehicle. The technique involved in generating the speed- response pattern is the Multiple Signal Classification (MUSIC algorithm) which depicts that the target vehicle is at a distance of almost 42 meters from that of the in use vehicle. The speed determination also states that the vehicle must be almost stagnant due to its negligible speed output.

This response pattern generated aids in the precise measurement of the target vehicle position via the highlighted bluish yellow line referred to as the ‘line of sight’.

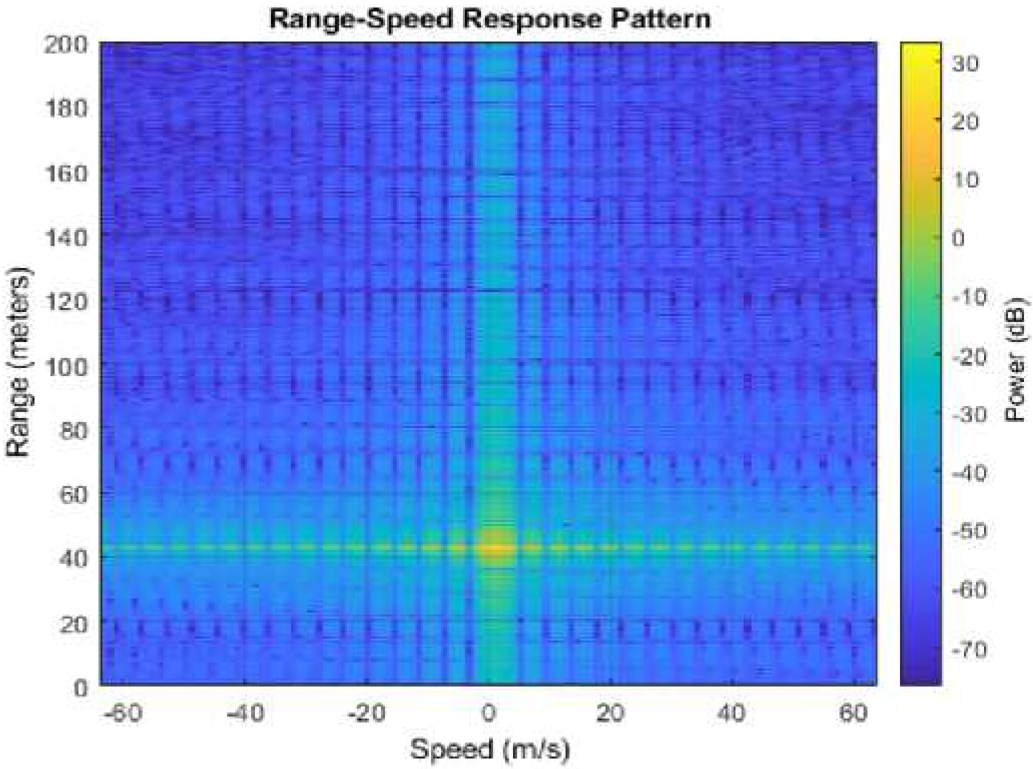


Figure 6. 3 Range and speed response graph from matlab coding

Simulink results of the FMCW radar

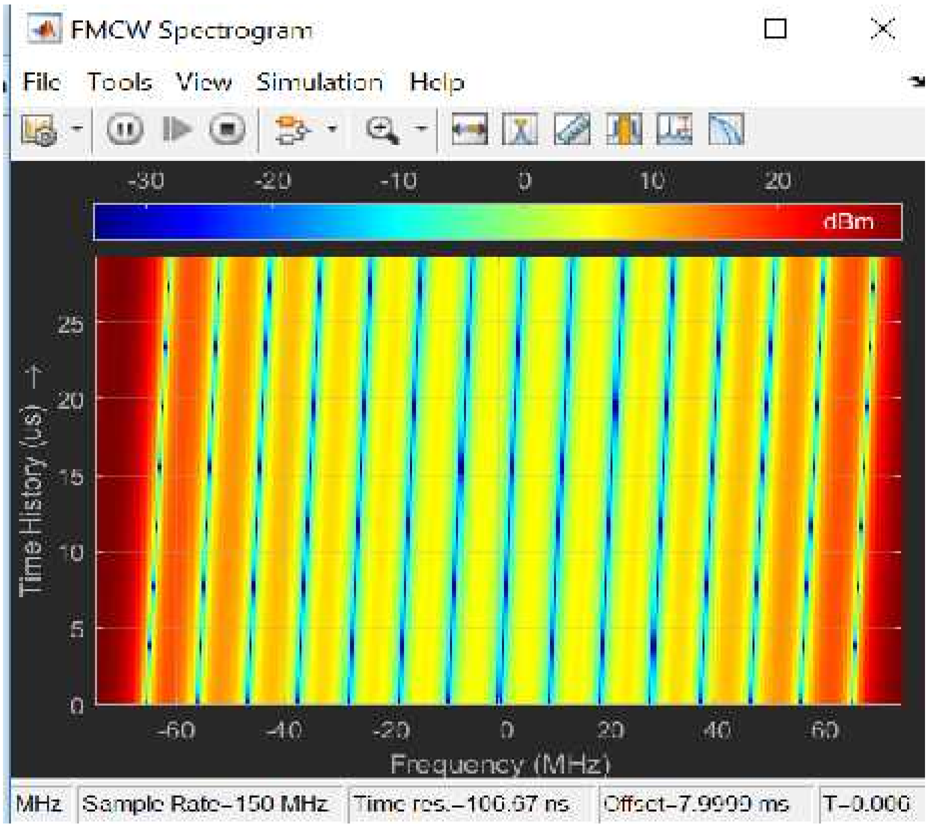


Figure 6. 4 FMCW spectrogram resulted due to the Simulink model

The FMCW spectrogram shows the relation between the frequency of the signal and the sweep time taken by the signal to propagate to and forth the target. The figure 6.4 represents the spectrogram signal and the signals nature resulted by the simulink modelling of the FMCW radar.

Dechirped signal spectrogram

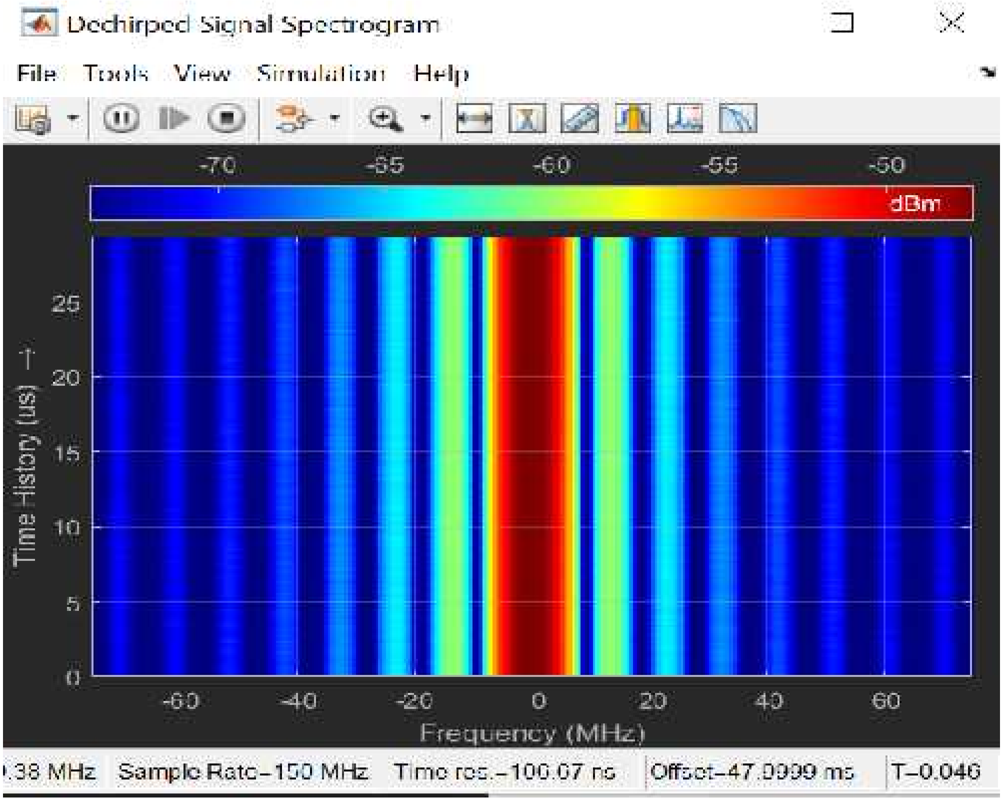


Figure 6. 5 Dechirped signal spectrogram by the Simulink model

The above depicted figure 6.5 shows the nature of the dechirped signal after the mixing of the received and the transmitted signals.

5.2 Results of the flow simulation in ansys

The flow simulation involves subjecting the reference model designed mimicking the original solidworks model of the entire motorcycle assembly with the radar component attached to it, to the flow analysis. This analysis is executed to find the influence of contrasting parameters on the motorcycle with the FMCW radar attached to it, such as pressure, velocity, momentum etc.

The flow analysis is predominantly executed to find the way with which the designed module is affected during normal driving conditions, as well as to find the drag coefficient acting against the motion of the vehicle, during the commutation of the automobile.

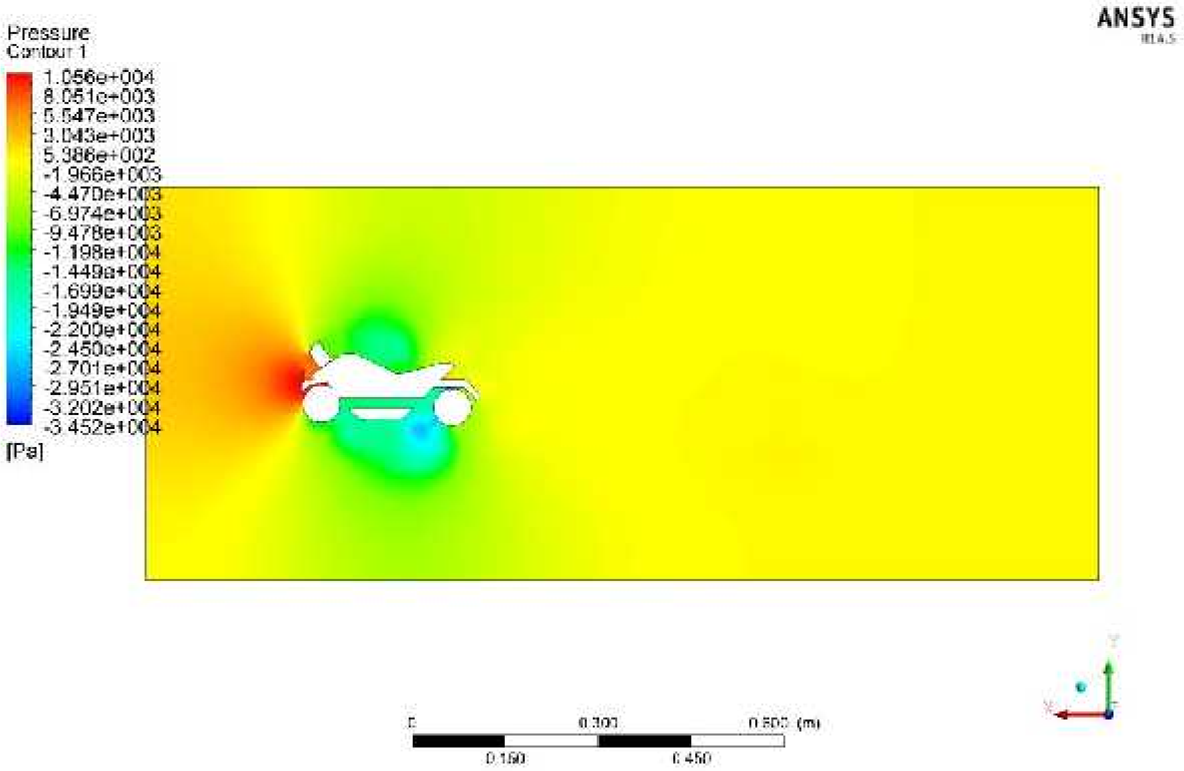


Figure 6. 6 Pressure contour results on and around the motorcycle design

The varied pressure forces potentially acting on the motorcycle is depicted in the figure generated as an aftermath of the flow analysis. The diagrammatic representation states that the maximum pressure acts near the antenna complication, mounted on the motorcycle mudguard which happens predominantly when it has an upright azimuth angle. The minimum pressure can be found to reside near the rear wheel and the mudguard of the motorcycle component.

The pressure contour is succeeded by the velocity contour in order to determine the nature of the vehicle's relative velocity acting on its overall surface of its body. The relative velocity is marginally lesser around the exteriors of the motorcycle frame due to its design but contributes to the overall desired velocity profile of the vehicle.

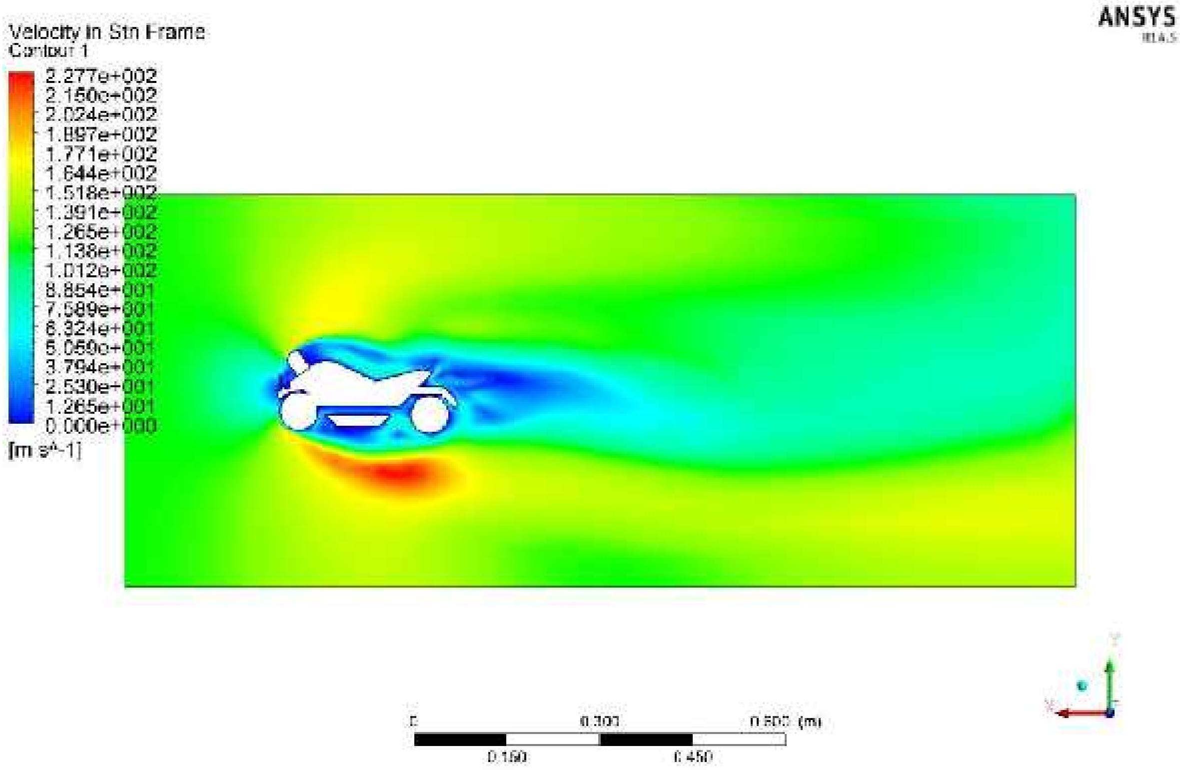


Figure 6. 7 velocity contour results on and around the motorcycle design

The hypothesis of streamlines is significant during the aerodynamic study of any vehicle, be it in air or ground medium. The streamlines shed light on the affiliation between pressure and velocity contained by the body using Bernoulli's equation. The streamline schemas are generated for three cases involving various frame rates.

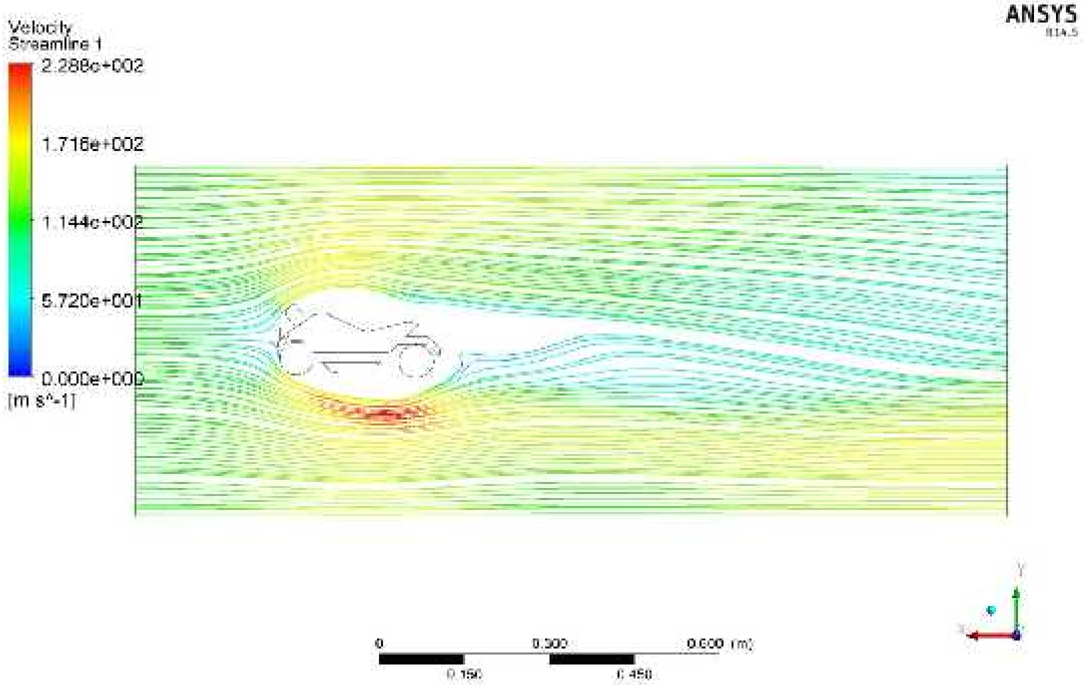


Figure 6. 8 Velocity streamline result at 100 frames generated by the flow analysis

The figure 6.8 depicts the streamlines generated for the modelled medium at a frame rate of 100 units during a predominant period of time.

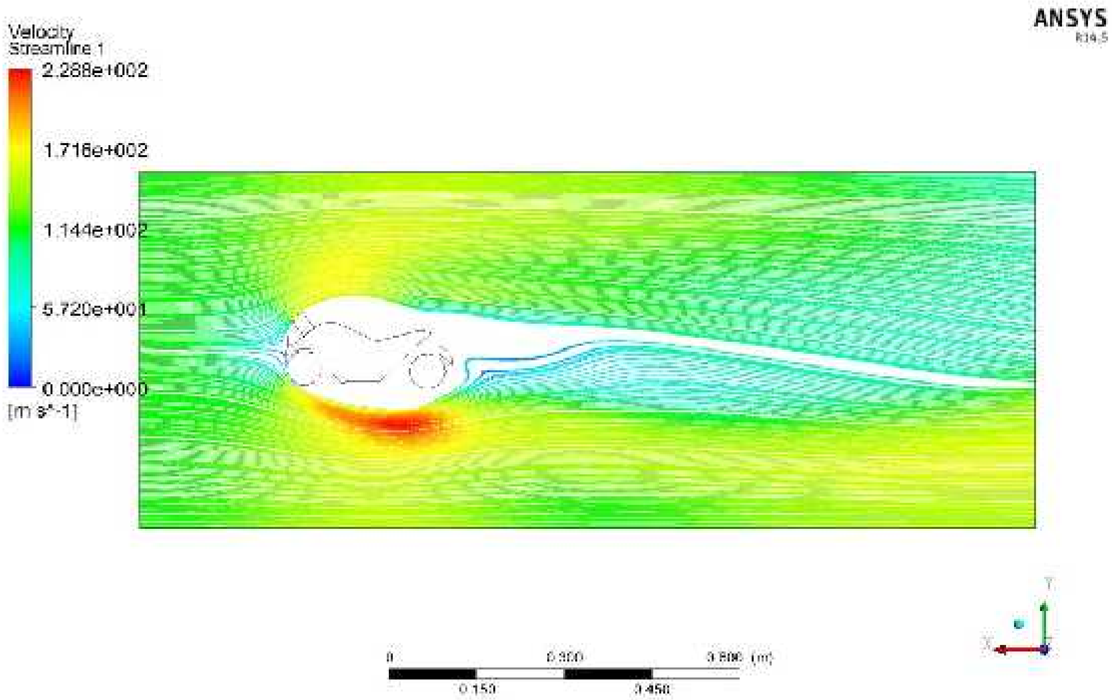


Figure 6. 9 Velocity streamline result at 500 frames generated by the flow analysis

The figure 6.9 illustrates the same notation of streamlines for a contrasting condition of 500 frames.

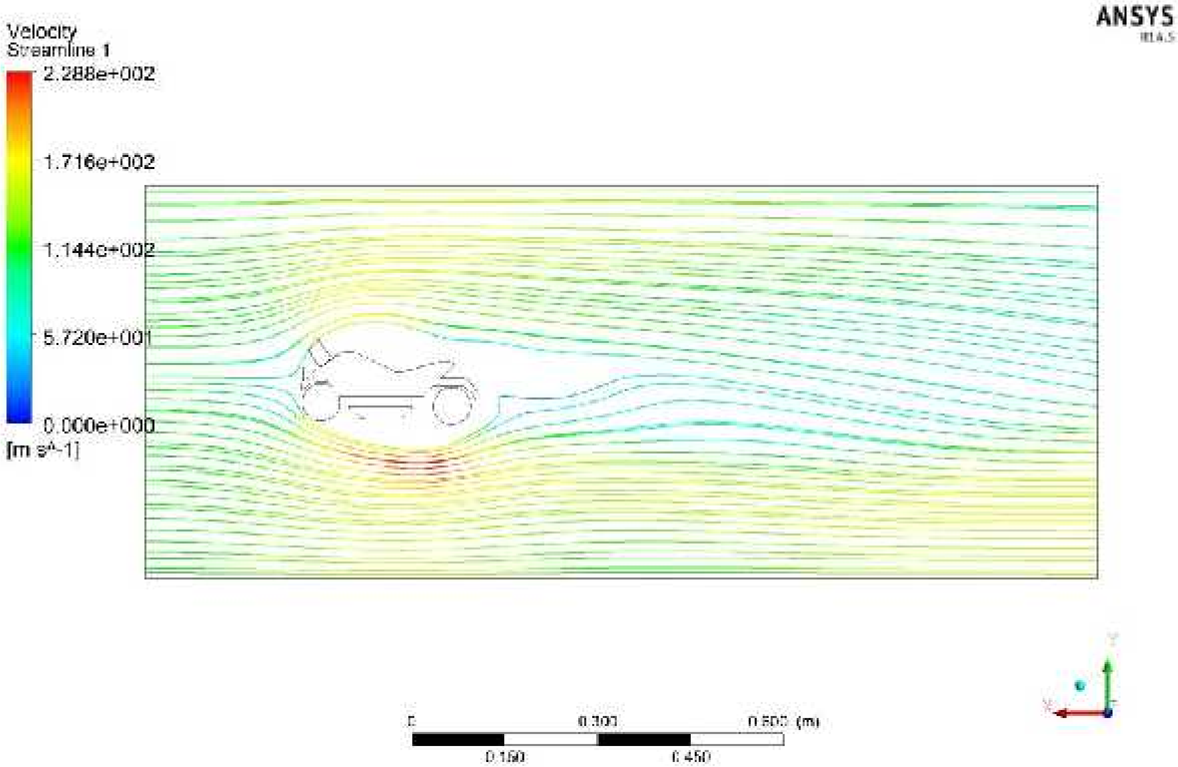


Figure 6. 10 Velocity streamline result at 50 frames generated by the flow analysis

The figure 6.10 depicts the velocity streamlines of the motorcycle medium at a frame rate of 50 units. The value varies on various faces and bodies of the designed motorcycle medium.

The flow analysis is also employed to determine the drag coefficient resulting from the drag force acting against the motion of the body, the lift and the momentum. Values of the drag coefficient and lift are measured precisely by the generation of graphs against iterations.

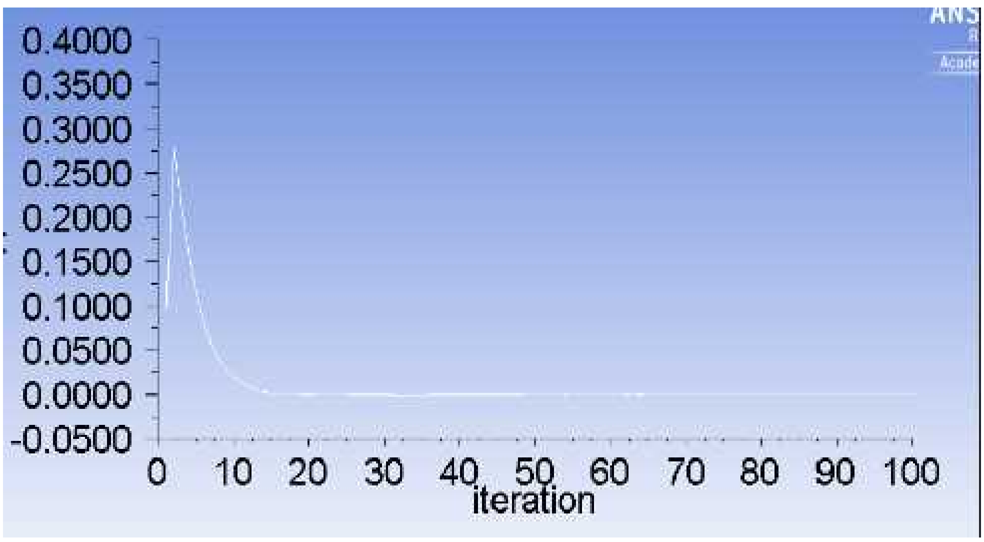


Figure 6. 11 analysis graph plotted between coeffecient of drag and no of iterations

The figure 6.11 depicts the relationship between coefficient of drag and number of iterations. The value of drag coefficient lies between the values 0.2500 and 0.300 which is comparatively lesser for a normal vehicle , hence stating that the body is aerodynamically well designed.

The lesser value of drag is also a result owing to the absence of a human body seated on the motorcycle, which if present will increase the value of drag and hence the coefficient as well.

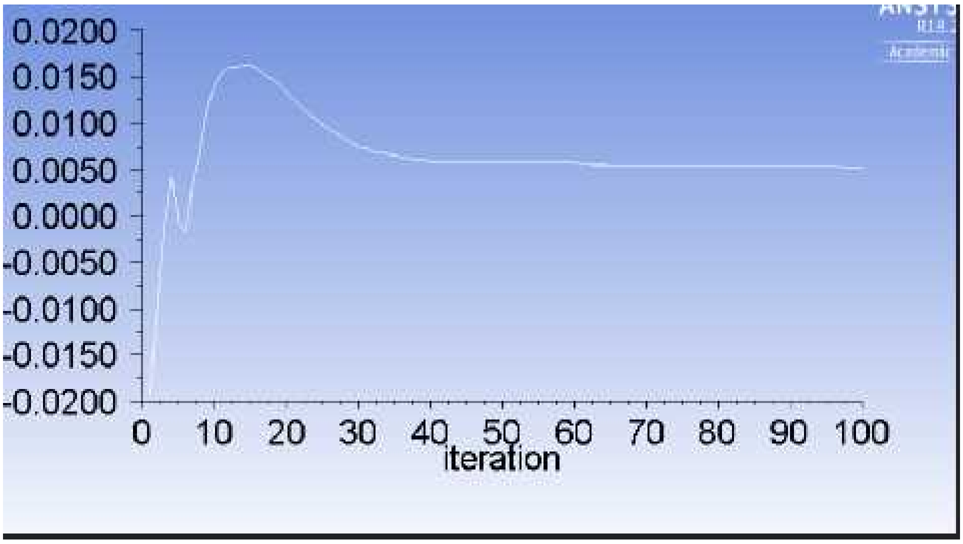


Figure 6. 12 analysis graph plotted between lift and no of iterations

The figure 6.12 represents the correlational existence of lift and the number of iterations. The value of lift created against the designed motorcycle can be found exactly as 0.0150 which is negligible considering the value of the drag coefficient. These results thereby notify that the motorcycle is foolproof in case of its aerodynamically designed model.

Conclusions

- A 77 GHz frequency modulated continuous wave radar is designed as a 3-d model attached to a concept vehicle
- The range and speed of the target vehicle are estimated with a number of given inputs for the radar system which is 40 m/s in this case.
- The sprocket side stand retrieving system is designed as an inexpensive counterpart to the available counterpart safety measures at an astonishingly low cost of 79.46 euros.
- Cross sectional view of the target is depicted as an image for the commuter to observe the surroundings and to increase the factor of safety of the vehicle itself.
- The flow analysis is performed in a simulation software which states that the motorcycle with the attached radar system is aerodynamically designed.
- The coefficient of drag value is derived as a graphical representations during the simulation process and is 0.300 which is desirable for a perfectly streamlined body.
- The lift value obtained is 0.0150 and hence is negligible.

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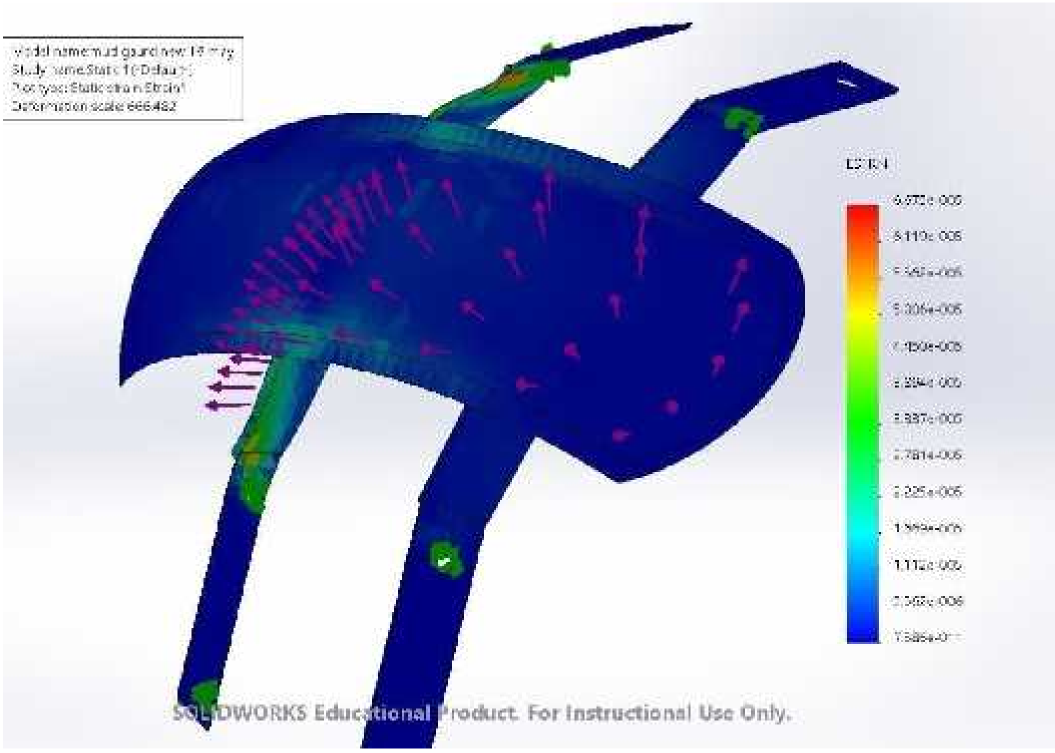
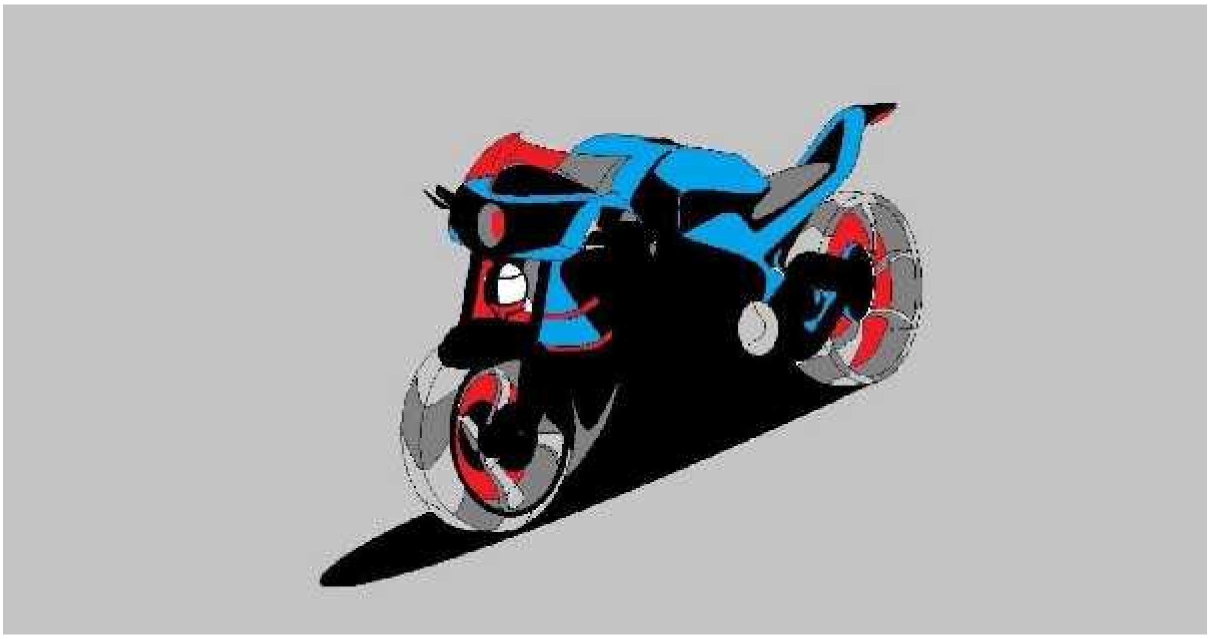
Appendices

1. Stress strain analysis of the mudguard



2. Initial concept of the motorcycle involved with the radar



3. Graph for momentum