Synergizing RF Technology for Dynamic Vehicle Speed Detection and Comprehensive Sensor Telemetry: A Cost-Efficient and Low-Power Paradigm

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Abstract— With improvements in detection technologies, it is now simpler than ever to find those who are traveling too fast, failing to buckle their seatbelts, or falling asleep in driverless vehicles. But building more robust solutions is crucial in nations like India where people are skilled enough to get around sophisticated systems like number plate identification with just some reflector tape that they can buy on Amazon or Flipkart. To address these situations, an active RFID system is proposed that will log the information needed to execute safety guidelines every two to three minutes and send it to a receiver that can be deployed about five kilometers away. System installation from the manufacturer may be made mandatory, and stringent registration during RC registration may be required. Slowing down or fastening their seatbelts close to checkpoints can be used to trick the detector cameras. Using this method such incidents are easily detected because the system can track the behavior of the car from starting the ignition. Low accuracy caused by weather circumstances like fog, smog, and under or overexposed lightning conditions become essentially nonexistent with this system because it is based on radio wave technology and low-distance data collection. As a result, this system compels the entity to obey all safety guidelines with the greatest accuracy while moving at an optimal speed.

Keywords—*IoT, RF, OBD-II, ASK Modulation, RFID*

Introduction

Vehicular collisions have become a great concern in today's times. Humans, in general, tend to push their limits to any extent. If a human is given a chance to break the speed laws, he will excel to a speed the vehicle can persist. (2,40,828 out of 4,03,116 instances) [1] deaths in 2021 were caused by over-speeding, which accounted for 59.7% of all accidents. Similarly, 16,397 of the 19,811 car occupants who died last year who were killed were not wearing seatbelts. With advanced methodologies like Number Plate detection systems, there has been a check of the lawbreakers but it has been quite expensive on the processing side to maintain and run the systems [2]. Such systems fail in foggy or poor lighting conditions so several other algorithms are deduced to increase the readability of characters [3]. In countries like India, where number plates are found to be broken, damaged, or discolored it becomes challenging to track the vehicle details [4]. Multiple solutions can be used to bypass multi-million-dollar traffic systems. Fig. 1 shows a cheap method of using reflective spray on the number plate to make it invisible. In our proposed system, we use the OBD-II interface of the vehicle that stores, manages, and forwards this information to a receiver to check for law breaks [5]. It stores the data in a data log, modulates it, and sends it using an RF modem, installed on the car, to a receiver installed at an interval of 5-10 km [6]. With advancements in automated cars, drivers have become much more prone to dozing off in cars. Our systems can be merged with various machine-learning algorithms that will detect the sleepy state of the drivers and alert the drivers [7].

Fig. 1 Before and After using reflector tape to bypass speed cameras

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Literature Review

The technology defined in [8], employs an RF gun to measure vehicle speed and take pictures of moving objects going faster than the speed limit. From these photos, the system harvests license plates, updates them in a database, and sends the data to the closest traffic control facility. Additionally, the owner of the car receives information about the fine based on the local government regulations in place, and repeat offenders face a double fine. The system offers a straightforward software solution for gathering license plate data and reducing speeding.

According to [9], a similar image processing algorithm is used with much more sophisticated processing to extract the number plates in low-light conditions. A car image is first captured, followed by grayscale, binarization, plate localization, and character segregation. The returned characters are then checked with the character dataset. If the number of characters returned is less than the desired values, the threshold value for grayscale is either increased or decreased by two times, depending on the light conditions. However, the computational complexity or effectiveness of the suggested system is not thoroughly assessed in the research.

According to [10], proposes a very similar methodology as our proposed model that uses a hardware module on the car that sends data to a web server using a GPRS module. The system gathers and evaluates vehicle data, creates maintenance schedules, and assesses driver performance. The paper's main focus is on transmission rate and accuracy rather than actual law implementation.

The system for real-time monitoring of commercial vehicle security is suggested in [11], with a particular emphasis on the identification of unusual driving patterns and probable criminal activity. It suggests an algorithm that uses GPS and onboard sensors (sampled from OBD-II) to track the driver's choice of route and car-following behavior continually. The study emphasizes the significance of identifying robbery, hijacking, and technical issues in commercial vehicle events. The method is also tested in the study using a microscopic traffic simulation model, with a particular emphasis on the traffic signal's effect zone and dynamic modification depending on link volume in real-time.

According to [12], the model uses the OBD-II, which is a standardized hardware interface that is used to diagnose and report a vehicle's self-diagnostic and reporting capabilities. It is a 16-pin connector that can be found in the passenger compartment of the vehicle, usually near the center console, to obtain the required information. The model then stores, manages, and forwards this information to a receiver to check for errors, malfunctions, and warnings.

In [13], the system is based on car telemetry data and uses machine learning techniques for monitoring and early warning of driver sleepiness. When compared to other biometric and camera-based methods, the proposed method is much more effective. An AI-driven system is proposed that focuses on the driving of the pilot and deduces his sleepy state. The sliding window strategy for collecting behavior and extracting persistent information for classification, as well as the architecture design process, are discussed.

According to [14], it proposes an e-sticker using a special RFID protocol. The e-sticker may take the place of many stickers, including the parking, inspection, and registration stickers. Patrol police, inspection facilities, and authorized offices may see it. The system is made up of monitoring and data collection modules (readers and tags), both of which consume little power to increase battery life. The e-sticker makes use of a unique active RFID protocol and the nRF24LE01 chip for vehicles, as it has extremely low power consumption. The model provides a single-chip solution for the RF TX-RX, CPU, memory, and converter, along with the proprietary software. The hardware and software architecture of the e-sticker system are also covered in the study.

The goal in [15] was to categorize RFID tags according to their roles, standards, and frequencies to find the optimal data format for RFID tags. The evaluation highlighted how the local processing approach differs from the worldwide EPC standard for data-on-network. Through the examination of several data formats, such as CSV and XML, and compression techniques, the best format for storing data on RFID tags was determined. They subjected the data stored on RFID tags to potential local processing without a network connection or central database based on the findings for better readability.

The approach described in [6], which improves data accuracy and frequency performance, is based on RFID and is used for car maintenance services. For increased range and frequency, it makes use of RFmodems and Electronic Control Unit data. It sends the ECU data using the RF modem and alerts the user if maintenance is required. Along with autonomous toll collection, theft detection, and broadcasting traffic patterns, it has potential uses that go beyond vehicle maintenance.

Problem Statement

Building more robust solutions is crucial in nations like India, where people are skilled enough to get around sophisticated systems like number plate identification cameras with just some nano reflector tape that they can buy on Amazon or Flipkart. As a result, accidents have increased significantly in frequency. Although there have been multiple solutions, like speed cameras and seat belt detectors, they fall inefficiently in low-light or foggy conditions or can be bypassed by simply doing the needful in the camera zone or nearby check posts. Furthermore, installing speed cameras with infrared technology and also trying to process the defaulters through their number plates is a tedious task on the servers and is very cost-efficient due to the complex image processing algorithms working in place.

I. Proposed Work

The proposed project looks to solve the problem by implementing a low-cost RFID solution that will be directly onboarded on the vehicle and will dynamically capture data from the car’s onboard modem and diagnostics (ODBII). ODB-II is already capable of capturing speed data, so we just need to add a few other sensors to track functions like seat belts, drowsiness, and others as per requirements. We can also add a GPS module to accurately store the latitude and longitude data to find the exact location of a law break. The system can store the required data redundantly in a data log at intervals of 5 minutes or so; thus, there will be no chance left for the pilot to bypass the system as he will be tracked throughout the journey. Once he reaches a receiver checkpoint, which sends streams of request signals, the RF Modem converts the data into RF signals and sends a burst of RF waves that are captured by the receiver and processed forward. With the RF modem, an active RFID is attached that stores the unique identification of the vehicle, thus nullifying the methodology of license plate scanning. If the car is found to be in default, the backend system can log the fine amount to his bank account (such systems are already up and running) or break out of any storing or processing. The solution uses RF signals in a short to medium range, so it will be capable of working even in foggy or low-light conditions. The above can be made as a proprietary device installed by the vehicle manufacturer. Also, it needs to be compulsorily activated with the unique identification tag at the RTO office, just like Fast Tag.

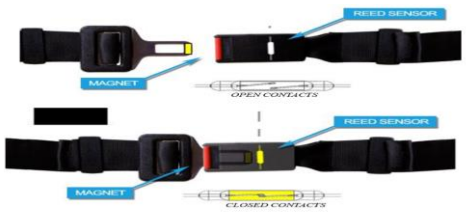
Architechture Requirements

A. VSS (Vehicle Speed Sensor)

A Vehicle Speed Sensor is used to measure the real-time speed of the vehicle using a Hall Effect that uses a voltage baseline to calculate the speed. Mounted on the gearbox, it uses an on-off nature based on the shaft rotation to send digital rectangular waves for speed calculation. As per the proposed research, speed data is an extremely important factor. [16]

B. Speed Belt Buckle Sensor using Reed Switch

Seat Belt Buckle Sensor that uses a magnetic circuit technology that completes when a seat belt is latched. This activates a Reed Switch to close its contacts and send a signal to the OBD-II interface.



C. OBD-II (On-Board Diagnostics ver. 2)

On-board diagnostics is a module installed on a vehicle that stores telemetry data that can be used to report the diagnostics of the vehicle. It has multiple types of data ranging from engine health to the speed of the vehicle. It communicates with the control unit using the CAN protocol, also known as the Control Area Network [18]. It has a 16-bit connector that can be used to attach a data cable to access the data retrieved from various sensors. It has a DTC (Diagnostic Trouble Code) and PID (Parameter ID). DTC specifies the issue in the car, like Pxxxx, which means a powertrain error. PID has specific codes for data [19].

D. Active RFID Tag

An active RFID (Radio Frequency Identification) Tag is used to provide data for the identification purposes of the car [20]. These data include chassis number, engine number, license plate number, etc.

Fig. 2 depicts the working of the reed switch. [17].

Fig. 2 Buckled and Unbuckled Seat Belt

The active tag practices two-way communication. It sends its data to the RF modem to be forwarded to the receiver and also sends request signals for data from the ECU or the OBD-II. Active RFID tags have a higher transmission range as they are coupled with a battery source for better range. They remain dormant unless an RF signal activates them. To standardize the procedure, the tags should be compulsorily registered with all the details during RC registration.

E. ELM327 OBD Scanner

To translate the data from OBD-II we need a special microcontroller termed the ELM327 OBD Scanner, which can use multiple connection methods like USB, Bluetooth, RS-232 serial port, or WIFI [21]. For our purpose, we propose the RS-232 port that will transfer data from the OBD-II interface or the ECU data to the RF modem based on signals provided by the Active RFID tag. Despite USB being faster, RS-232 remains simpler and adequate for short-distance point-to-point communication.

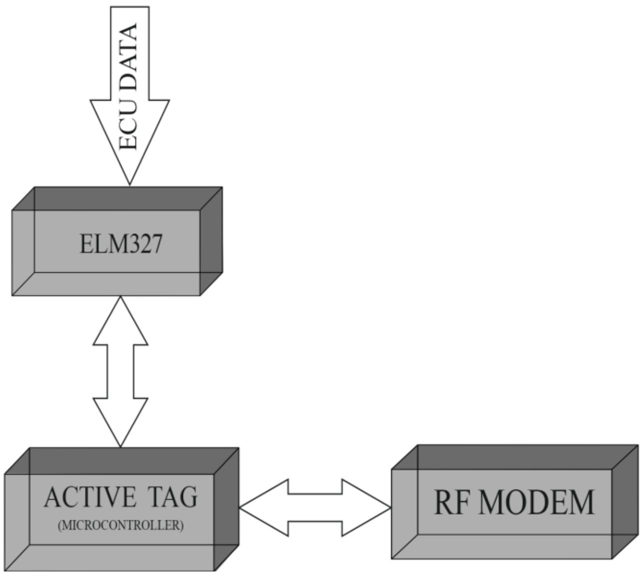


Fig. 3 **depicts an RS-232 port..**

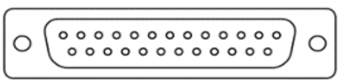
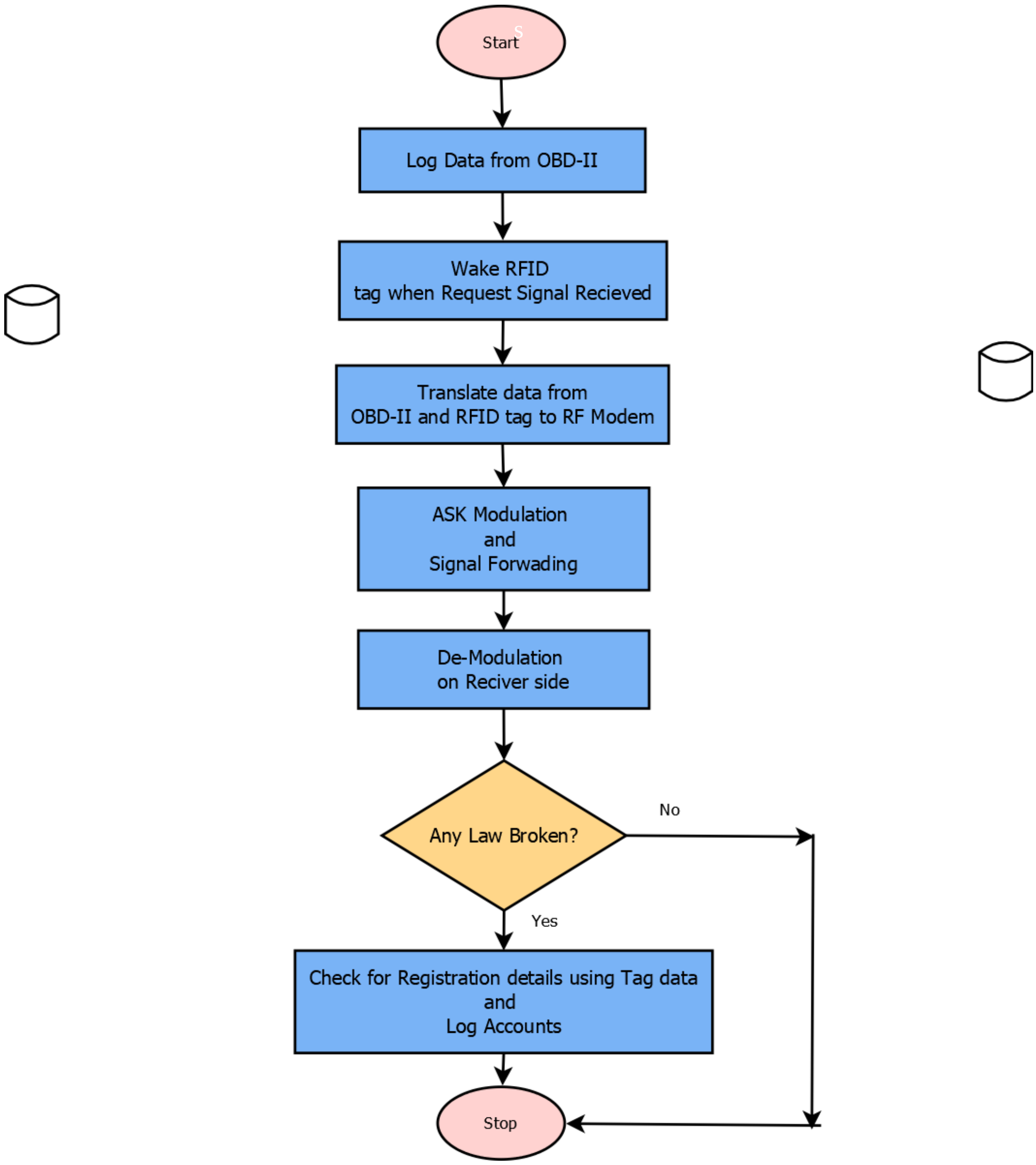


Fig. 3RS-232 Port

F. RF Modem

Transmitting data dynamically from an active tag is extremely complex as it requires RF waves to get changed, so we use a short-range (<=300 m) RF transceiver modem that can send data from the OBD to a receiver installed at traffic poles, gas stations, toll plazas, etc. We need efficient two-way communication between the receiver and the vehicle module; thus, we use the aforementioned modems. Such modems generally provide a data rate of ~2 Mbps, which will be enough for our data transmission. RF modems have communication methods like ASK, FSK, FHSS, PSK, etc. For demonstration purposes, we use ASK modulation and demodulation. The RF module is so chosen that it takes up micro amounts (~0.1 µA) of current in the standby stage with milliseconds (<6 ms) of wakeup delay and a very sensitive antenna (-115 dB) [22]. This enables the model to use the minimum amount of power, resulting in a longer battery life. Fig. 4 depicts the basic module for the vehicle that receives data from the OBD-II, after receiving acknowledgment from the active RFID tag, and forwards it to the RF modem, which modulates the data to send to an installed receiver. The frequency used is 433 MHz, as it has a longer, more reliable transmission range.

Fig. 4 Communication between ELM327 scanner, Active RFID and RF Modem



II. Data Flow

The flowchart in Fig. 5 depicts the collection and processing of telemetry data.

Fig. 5 Data Flow and Algorithm

III. Design and Implementation

A. *Base or Reciever Module*

The base module can be installed in place of speed cameras, as they are costlier and do not work in abnormal lighting conditions. The receivers can be installed on traffic lights, toll booths, gas stations, etc.

The module continuously sends an activation signal for the RFID tag that remains dormant for most of the journey. After receiving data from the RF modem, it demodulates the data into digital signals for processing. The base computer checks through the data for any overspeeding or drowsiness. If any drowsiness is found, the nearby authorities are immediately informed to get the driver and the vehicle into custody. If any over-speeding or seat belt default is detected, the car owner's details are scavenged from the database and logged with a fine that may increase with each successive law break.

The system also sends a message to the owner, which informs him about the penalty he has to pay for the offense committed. The system will generally have extremely low false positives as the data is being collected directly from the car instead of images from speed cameras. Fig. 6 shows the module for the server side.

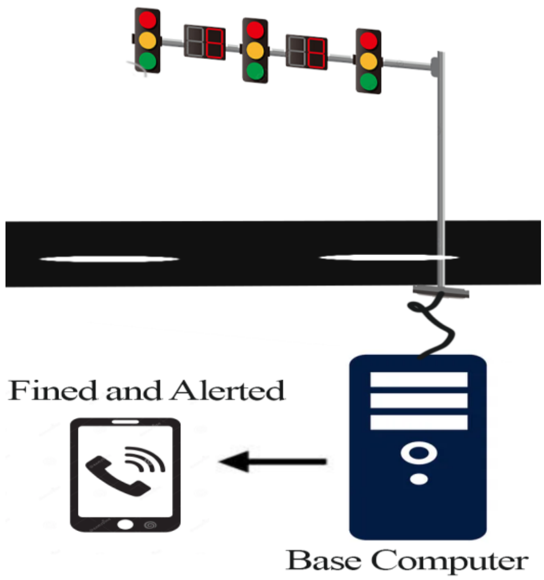
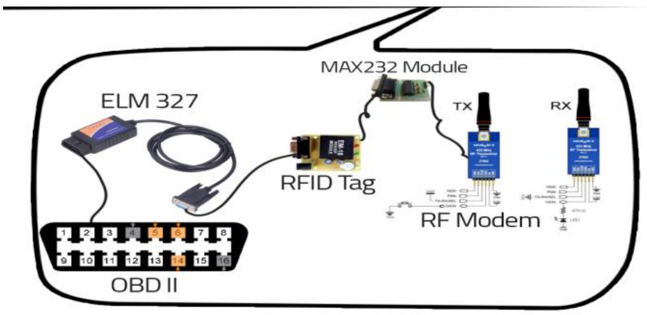


Fig. 6 Base Module

B. *Vehicle Module*

The vehicle module will be installed by the manufacturer and needs to be registered at the RTO office during vehicle registration. The OBD-II of the car logs all the telemetry and

and maintenance data of the car, but as we require only a specific amount of data, we fetch the required sensor data and store it in a data logger.



To translate the data from the OBD-II to the data logger, we use an ELM327 OBD scanner that is attached to the OBD port using the RS-232 port. The data logger is connected to an Active RFID tag that, when activated, sends a request signal to fetch the data and forward it to the RF modem for ASK modulation at a frequency of 433 MHz.

There is a voltage difference in communication between RFID and the RF modem, so we use the MAX-232 [23] IC to adjust the voltage to and fro of the communication, i.e., RFID to RF modem and vice versa. Fig. 7 shows the implementation of the module fixed into the vehicle.

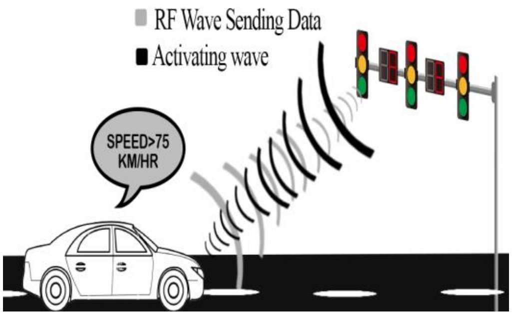


Fig. 8 Vehicle Module and Base Module Communication

IV. IMPLEMENTATION AND RESULTS

The receiver module continuously sends activating signals to find a vehicle in range. As soon as the vehicle module receives the signal, the RFID tag gets activated, and data from OBD-II gets forwarded to the RF modem. The modem modulates the data and sends it to the receiver.

The ELM 327 reads the data from the OBD-II module, which is connected to the RFID tag, and forwards it to the RF modem. While sending the data, we also send the unique identification details stored in RFID that may be required for processing. The voltage difference between the RFID tag and the RF modem is rectified (step up or step down) using the MAX 232 module. The data provided to the RF modem is modulated into RF waves and sent to the RF receiver installed at places like traffic light poles.

The base station processes the data and alerts the officials or the driver as per the requirements.

Fig 6, 7, and 8 show the base module, vehicle module, and communication between the vehicle and receiver module, respectively.

A basic logical implementation of the above scenario has been implemented in Python. A sample of data is generated that is converted, modulated, sent as an ASK wave, received as a wave, demodulated, and processed.

A. The Implemented Algorithm

1) Random Data Generated and stored in Machine Readable form (implied OBD-II)

```
def generate_obd_data():
    i=0;
    dt=simulated_data["SPEED"]
    while(i<10):
        data.append(int(random.uniform(dt[0], dt[1])))
        # rf.append(int(random.uniform(dx[0], dx[1])))
        i=i+1
    return data
```

***Fig**. 9*

2) Conversion to Machine Level Format

```
def convert_to_bin():
    for num in data:
        x=bin(num)
        x=x[2:]
        bin_list.append(x)
    dx=simulated_data["RFID"]
    print(f"\n\nRFID of the Vehicle used for identification {dx} \n")
    bin_list.append(dx[2:])
```

Fig. 10

3) ASK Modulation for Transmisson (RF Module on Vehicle)

```
# Parameters
bit_rate = 1000  # bits per second
carrier_freq = 1000  # carrier frequency in Hz
# Calculate the total duration of the transmission
total_duration = len(bit_seq) / bit_rate
# Time vector with a higher sampling rate
t = np.linspace( start: 0, total_duration, int(total_duration * 1000))
carrier = np.sin(2 * np.pi * carrier_freq * t)
# ASK modulation
ask = carrier * bit_seq
print("\n\n--------The amplitudes of Modulated Signals which are se
print(ask)
plt.subplot(211)
plt.plot( *args: t, ask)
plt.xlabel('Time (s)')
plt.ylabel('Amplitude')
plt.title('ASK Sending Signal')
plt.grid()
plt.show(block=False)
print("---------------------------------------------")
return(ask)
```

Fig. 11

ASK Demodulation at Reciever (Reciver Module)

```
for amplitude in signal:  #demodualtion
    if amplitude != 0:
        binary_data.append(1)
    else:
        binary_data.append(0)
ch = ""
rfid = binary_data[len(binary_data)-16:]
binary_data = binary_data[:len(binary_data)-17]
dem_seq = []          #combine bits
for i in binary_data:
    if len(ch)!=8:
        ch=ch+str(i)
    else:
        ch=ch[1:]
        dem_seq.append(ch)
        ch = ""
        ch=ch+str(i)
dem_seq.append(ch)
```

```
for i in demodulated_data:
    y=i[::-1]
    for j in y:
        dec = dec + (2 ** k) * int(j)
        k = k + 1
    dec_form.append(dec)
    k = 0
    dec=0
print("\n\n-------Converting binary data to
print(dec_form)
rfid=[str(i) for i in rfid]
rfid="".join(rfid)
print("\n\n\n-------Final Output--------")
for i in dec_form:
    if(i>75):
        print(f"User was OverSpeeding. His S
        break
```

Fig. 12

4) Processing of Received Information (Base Computer)

Fig. 13

```
[112, 67, 66, 61, 115, 14, 37, 86, 69, 108]


-------Final Output--------
User was OverSpeeding. His Speed was 112. Fine 1000 for RFID
 0101010010101010
```

B. ASK Wave

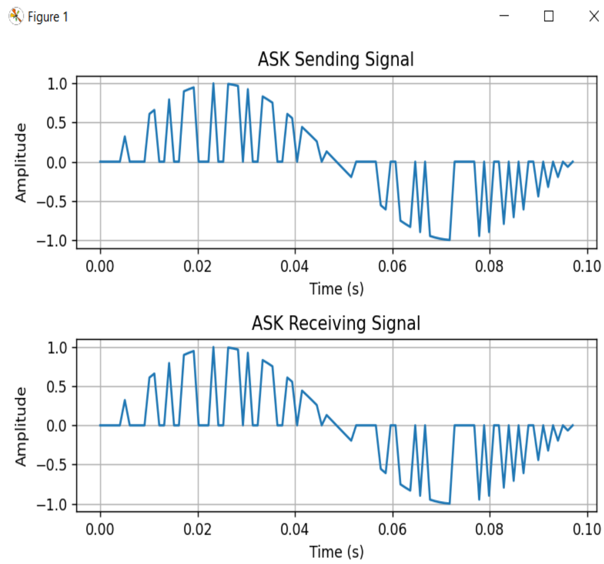


Fig. 14

C. *Results*

```
RFID of the Vehicle used for identification
0b0101010010101010

---------Generate OBD dataset--------------
Data from Speed Sensor:
[112, 67, 66, 61, 115, 14, 37, 86, 69, 108]


Store the OBD data in Binary Format
['1110000', '1000011', '1000010', '111101', '1110011', '1110
', '100101', '1010110', '1000101', '1101100', '
0101010010101010']
----------------------------------------------


-------Modulate The Data for Transmission through RF Modem
---------
--------Bit format converted to 8 bit--------
['01110000', '01000011', '01000010', '00111101', '01110011
', '00001110', '00100101', '01010110', '01000101', '01101100
', '00101010010101010']


----------Generate bit sequence----------
[0, 1, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 1, 0, 1, 0, 0
, 0, 0, 1, 0, 0, 0, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1, 0, 0, 1, 1
, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1
, 0, 1, 1, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 1, 1, 0, 0
, 0, 0, 1, 0, 1, 0, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 0]
----------------------------------------------


----------Demodulated Data------------
Binary Form:['1110000', '1000011', '1000010', '0111101', '
1110011', '0001110', '0100101', '1010110', '1000101', '
01101100']


-------Converting binary data to decimal form--------
```

Fig. 15

V. Conclusion

The system will use the accurate data directly from the vehicle to keep a check on the lawbreakers. The proposed system aims to reduce the overall false positives that frequently occur due to incorrect data generation through thecurrent image processing algorithms. Drivers who try to bypass the systems by using fake number plates will also get scanned due to the RFID tags in place that will use RF waves that cannot be altered.

VI. Future Scope

We aim to integrate the above system with toll collection systems that will directly deduct the fine amount from their FastTags, enabling a smoother implementation of the system. Also, devices to keep a check on tampered vehicle modules can also be proposed. The above system needs to be incorporated with message collision detection systems to reduce the data loss in the transmission of frames from multiple vehicles simultaneously.

VII. Acknowledgment

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