

Improvement in Speed of Trains in Poor Visibility & Advancement of Train Transport Signaling Mechanism

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Abstract

The Railway system is heavily hampered by poor weather conditions like fog, smog and heavy rainfall especially in Northern India. These factors lead to poor visibility and reduces the average speed of trains which is the main reason for their delay, particularly in winter season. The average speed of the train is kept low so that the locomotive pilot can easily watch out signals and control the movement of the train. This paper focuses on techniques to boost the average speed of trains during low visibility by improving the transport signaling mechanism using wireless communication mechanisms using pulse code modulated signals.

Keywords: Armstrong transmitter, block signaling, cab signaling, detonators, GPS, pulse code modulation, RADAR, terrain mapping, TPWS.

1. Introduction

Indian Railways (IR) is one of the most important national transportation facility for goods as well as for people from one place to another. It is the property of the Government of India and is operated through Ministry of Railways. The rail network is densely spread all over the country comprising of 1,99,630kms of total track and 92,081kms of running track. It is the fourth largest rail network in the world containing approximately 7,216 working stations. Indian Railways provide transportation for about 22 million passengers daily generating a revenue of INR 1.638 trillion.

This public sector helps the people of India and provides the cheapest mode of transportation but is heavily affected during winters mainly in the North & North Central Region. Weather conditions like fog and heavy rain reduces the visibility and impedes the movement of trains. Since, the visibility is low, the locomotive pilot has to drive slowly which causes train delays and is a major concern for Indian Railways. Many remedies for the improvement of visibility and speed of trains in foggy conditions were introduced but remained unsuccessful and due to this, it was seen that the average of speed of Indian Railways could not go beyond 60 km/ hr in such conditions. Improvement of such a big rail network is necessary for the advancement and development of Railways which can be done mainly by boosting up the speed of trains and increasing the visibility for loco pilots in dense weather conditions. The Research Design & Standard Organization (RDSO) of Indian Railways is trying to find remedies for this problem but has not achieved much success in this field yet and hence, the railways and passengers are suffering a lot.

2. Rail Route Signaling

Generally, a rail route from one place to another consists of railway tracks, with each track supported by a traffic light pole for

signalling the train and controlling the rail traffic accordingly. These traffic light poles are usually present at an interval of 1km each and signals the train to control its motion.

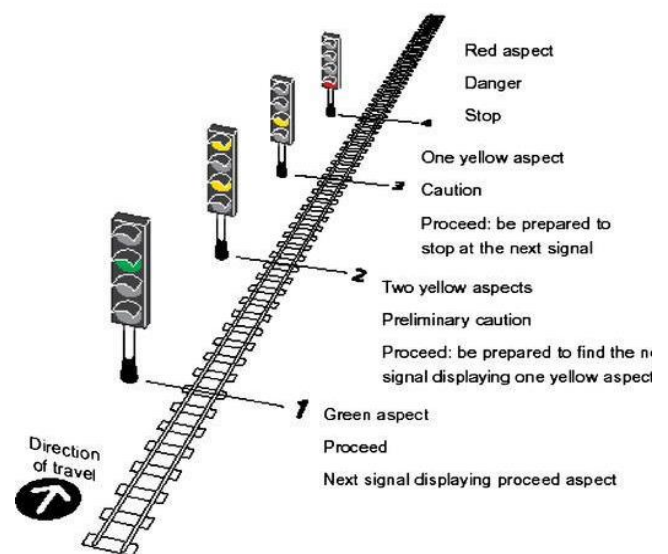


Fig. 1. Multi-Aspect Rail Route Signaling. [1]

These signals use high quality LED lights to signal the driver so that it can be observed even from large distances. Generally, a high-speed train on application of brakes requires a 300m track to completely come to halt. Thus, it is important for a loco pilot to see the signal from more than 300m which is the normal visibility of a person. But in foggy conditions, the visibility is reduced to less than 20m and thus, the speed is kept low so that the train can be stopped easily without the application of emergency brakes. The signalling process consists of coloured signalling using multi-colour lights which are automatically controlled. There are mainly three modes of traffic signal poles:

- Two aspect pole signalling have a red and green light at the bottom and top of the lamp holder respectively.
- Three aspect pole signalling, using an additional amber lamp in the middle stating a hold signal for the train.
- Multiple aspect pole signalling using four lamps to signal the driver for speed increase and braking techniques, mainly used by high speed trains.

Along with this, the loco pilots are provided with a signalling book which educates the driver about the various signalling techniques followed by them on the route. It generally contains information about the traffic signals and their distance information from certain stations.

Many signalling techniques are used for the monitoring of trains and guide them through stations. Some of these techniques are:

2.1. Time Table Schedule

It is one of the simplest form of signalling technique in which the train follows a certain predefined time-table and the loco pilot runs it accordingly. Every train is bound to follow the schedule and runs on the track in which they are given possession. Earlier, this system was much prevalent in railways, but with passage of time and advancement in the field of technology, this technique became obsolete. The major disadvantages of this system are:

- No information about the clearance of the track ahead is reported.
- The system is not flexible i.e. trains cannot be added, delayed or rescheduled.
- The system is inefficient and prone to accidents.

2.2. Block Signalling

A rail route consists of thousands of kilometres of railway track which is divided into blocks to take several precautions. These blocks are divided such that in a particular period of time, only one train is allowed in each block. This helps the railways to isolate the moving trains and avoid accidents by collision of trains. This system forms the basis of most of the safety systems used by Indian Railways to avoid accidents.

Earlier, block signalling was controlled by a signalman who signals the train driver manually about the clearance of the block. The signalman uses a stopwatch to assume that the preceding train moving at a certain speed has crossed the block in a certain time. Calculating this, he signals the succeeding train to move into the desired block. But the disadvantage of this system was that, the signalman has no knowledge about the preceding train. If the train has stopped in the block, it could result in collision.

By the introduction of electric telegraph, the train driver used to signal the signalman about its clearance from the block and the system became much more efficient. Still, automation in this system was required for the improvement in quality of movement of trains.

Generally, five types of block signalling are in use:

- Manual Signalling.
- Permissive & Absolute Block Signalling.

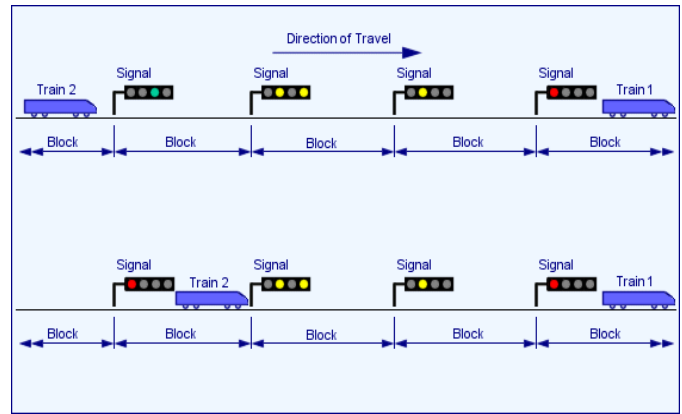


Fig.2. Two Train Block Signaling Layout. [2]

- Automatic Block Signalling.
- Fixed Block Signalling.
- Moving Block Signalling.

Permissive & Absolute Block Signalling refers to the phenomenon in which two or more trains enter the same block in the same time period, keeping a safe distance at a slow speed, so that the brakes can be applied easily without colliding.

Automatic Block Signalling refers to the mechanism in which the trains are signalled automatically about the clearance of the upcoming block and are allowed to enter or exit the block safely, without the instruction of the signalman.

Fixed Block Signalling refers to the signalling process in which the block is fixed from one point to another, known as starting and ending point respectively. The disadvantage of fixed block is that faster moving trains occupies the whole block and succeeding trains have to bear their speed.

Moving Block Signalling uses GPS system to control the block of a train variably with the speed of the train and is considered as the most efficient block signalling mechanism.

2.3. Centralized Traffic Control

Centralized Traffic Control (CTC) controls the movement of trains on tracks according to the availability of lines and speed. The system uses a central base station which coordinates with all other trains and guides their movements accordingly. [3] It mainly controls rail road interlocking and traffic flow in particular areas.

2.4. Train Detection

Train detection techniques are required to analyse whether a rail track is occupied by a train or not. To check the presence of a train on the rail track, two techniques are used:

- Track Circuits
- Axle Counters

In track circuits, the rail tracks are isolated between sections by a relay. If there is no train, the circuit is completed and the relay is energised. In the presence of trains, the circuit act as short-circuit and the relay is de-energised. Hence, it gives the information about the presence of other trains on the track.

In axle counters, a counter is installed at the start and end of each block. It counts the number of axle that enter and leave the block. If these two are equal, the block is clear.

3. Safety Systems

Along with improvement in speed and luxury of the trains, the Railway Authorities are also responsible for the safety of trains and passengers on the tracks. Several safety devices and mecha-

nisms were invented for the security of trains which are installed and are being used effectively nowadays. Some systems act only at Signal being Passed at Danger (SPAD) whereas some include audio/ visual notifications. [4] In-Cab Signalling is the most effective safety system in fog and is used for application of automatic brakes whenever a signal is missed. Some of the rail safety technologies are:

3.1. Cab Signalling

It is used for in-cab communication and signalling for the loco pilot so that he can control the train accordingly. It gives information about the maximum allowable speed and safe braking distance along with information about the route ahead and clearance of track. The main use of cab signalling is that it is the base-line of most of the safety systems installed.

In-cab equipment consists of a transmitter and control panel to control the train according to the signal obtained. The signal transmission is done with the help of balise which is a form of electronic beacon or transponder.

3.2. Train Protection & Warning System

TPWS is used to inform the train driver about certain aspects and apply emergency brakes in case of danger. These aspects include:

- Passing of signal without authority.
- Passing a signal at speeds higher than prescribed.
- Approach buffer stop too fast.
- Approach a reduction in speed which is too fast.

On-track system is installed for checking these aspects and information is conveyed to the driver or the brakes are applied automatically. [5] The on-track equipment consists of:

- TPWS receiver
- TPWS control panel.
- TPWS acknowledgement button.
- TPWS isolation switches.

Magnetic loops are installed in between the tracks which observe the changes in magnetic field to calculate the approximate speed of the locomotive. This calculated speed is compared with the maximum permitted speed and signals are generated accordingly.

4. Technologies Used

The Indian Railways is the cheapest mode of transport available in the country. Advancement in the rail technology has led to the development of tracks, electrification of lines, improvement in the quality of service provided in coaches and boosting of maximum speed of the trains. These factors have led to the improvement of railway standards but the major issue still remains the same. The railway is still finding a way to cope up with speed in foggy weather and how to increase the average speed of the train in winters, mainly in Northern India. Many methods were proposed for the improvement of speed and vision in dense foggy conditions but not all were efficient. Some of the major techniques used by the Indian Railways to fight fog and keep the trains in motion are:

4.1. GPS Based Fog Safety Device

In 2010, Indian Railways introduced a Global Positioning Satellite (GPS) based fog safety device as a remedy to the problems caused due to dense fog in Northern India. This device provided in-cab assistance to the loco pilot and generates information about the upcoming traffic signals.

GPS based fog safety device uses a wireless GPS module to access the data about the upcoming traffic pole and intimate it to the



Fig. 3. GPS based fog safety device.

loco pilot with the help of a global positioning satellite. It is capable of providing the information like the distance of the traffic light pole from the train, the signal status at the traffic light pole and the upcoming road crossings which occur when a railway line crosses the road.

It is a portable instrument which simply uses GPS technology to provide information to the loco pilot. The average distance up to which it works is calculated to be 4km. The cost of installing a fog safety device in a train is about INR40000.

Benefits of installing GPS based fog safety device are:

- Improving the safety of passengers in fog.
- The driver is pre-alerted about the upcoming signal.
- The average speed can be increased with the help of proper functioning of this device.

This device was installed in many trains in Northern Railways (NR) and North Central Railway (NCR) region but the output obtained was not satisfactory and the average speed of the trains cannot be increased by more than 60km/hr. The two major drawbacks of the fog safety device are:

- The device is unable to read the correct distance of the traffic light pole and hence the speed cannot be increased.
- The prediction of the signal status is not always correct and hence the driver has to keep a watch at the signal and thus the average speed cannot be increased.

This device is still in use in many trains but the average speed and virtual visibility of these train and train drivers respectively could not be improved. So, other technologies came in use.

4.2. Detonators

A Railway Fog Signal Detonator is a coin shaped device filled with detonating material which makes a loud sound on application of high pressure which intimates the loco pilot about the approaching traffic signal. These detonators are kept on the railway tracks and secured by lead strips attached to it. It was first invented in 1841 by an English Scientist Edward Alfred Cowper.

Reports state that most of the accidents in foggy zones occur due to overshooting of signals by the train drivers. To avoid these accidents and ensure passenger safety, the station masters are provided with these detonators and given the responsibility of placing them at appropriate distances so that the loco pilot can drive safely without overshooting these signals.

On high speed lines, where high speed trains with an average speed of 100km/hr run, these detonators are placed on both the rails of the track to make the sound louder and more audible. The best property of these detonators is that they are triggered by pressure and not by impact. This makes them easy for transportation since they cannot be triggered with vibrations or small impacts.



Fig. 4. Railway Fog Signal Detonator.

The formula of the compound in the detonator by mass as stated by Military and Civilian Pyrotechnics is:

- Potassium Chlorate (40%)
- Sulphur (16%)
- Sand- 60 mesh (37%)
- Binder (5%)
- Neutralizer (2%)

This mixture compound in the given ratio form the detonating material for the fog signal detonator. [6] The major uses of this detonator are:

- A caution signal or warning for the driver about the approaching signals in dense fog when the signals are difficult to observe.
- A warning of an obstacle or train stopped ahead in the line because of any accidents. The train crew only keep these detonators on the track as a precautionary signal.
- A warning for engineers and workers, working on the line of an approaching train.
- A signal to stop the train in case of an emergency.

This technology is the most popular technology used in Indian Railways nowadays. But the major disadvantage of this technology is that it does not give information about the signal status and hence the average speed is reduced to observe the signal correctly. Secondly, it can cause confusion to the loco pilot if two detonators blast at the same time on a two-way track if two different trains pass at the same time. The major drawback of this method is that it requires manual labour and hence it is difficult to put these detonators on rails when there is such a large network ranging to thousands of kilometres.

4.3. TRI-NETRA

TRI-NETRA stands for Terrain Imaging for diesel drivers- Infra-red, Enhanced Optical & Radar Assisted System. It was developed by Development Cell under the guidance of Member Mechanical, Railway Board. The design and specifications of this system is approved by Research Designs & Standards Organisation (RDSO). This system is based on the technology adopted by fighter planes to see through clouds in darkness and fly. Similar technology is used by naval ships for mapping of ocean floors and navigating it properly. [7]

This technology comprises of 3 components namely:

- High resolution optical video camera.
- High sensitivity infra-red video camera.
- Radar based terrain mapping system.



Fig. 5. TRI-NETRA (Terrain Imaging for diesel drivers-Infra-red, Enhanced Optical & Radar assisted system).



Fig. 6. Composite Image generated by TRI-NETRA system.

These three components act as three eyes of the locomotive pilot and help him see the terrain ahead in poor weather conditions like heavy rains, dense fog and night-time. A display unit is installed inside the cabin of the loco pilot which combines the data from these components and construct an image of the train ahead. This image helps the loco pilot to analyse the situation ahead and get a clear view of the track in poor visibility conditions.

The system comprises of two high resolution optical video camera and one high sensitivity infra-red video camera which records the image of the terrain ahead of the engine and feeds it to the radar-based terrain mapping system. The terrain mapping system combines these images and creates a composite image which gives a clear view of the terrain ahead. This system improves the visibility of the loco pilot which in turn increases the average speed of the train. The clear view of the terrain ahead helps the loco pilot to keep a safe braking distance and drive safely. The visibility is improved by up to 100m which makes the traffic signals clear.

TRI-NETRA system is under observation by the Indian Railways Ministry, which is analysing the output of the newly invented system. The trains, installed with this system have shown good output and were able to increase the average speed considerably. [8]

Along with these three technologies, LED Fog Lights is also considered as a measure by the Indian Railways to fight fog and improve the average speed and visibility of the train and loco pilot respectively. LED Fog Lights produces high quality light which does not diffuse easily in dense fog and increases visibility of the loco pilot. This technology is still under trial stage and its output efficiency is still monitored.

5. Proposal

Improvement in the speed of trains in foggy conditions can only be provided by improving the vision of the loco pilot. Since, this is difficult due to adverse weather conditions, the signals can be automated such that instead of viewing the signals outside at the traffic light pole, the loco pilot can read them simply on a display fitted inside the locomotive engine. Introduction of this technique will lead to higher virtual visibility of the signals and hence, the

speed of the locomotive can be increased considerably. To keep a check on the tracks high resolution surveillance cameras will be installed at traffic light poles which will keep a check on the tracks and report the description of the clearance of the tracks. Along with this medium range RADAR systems can be installed at the centre of the engine in the front to map the path and detect obstructions which may lead to accidents.

Improving the virtual visibility of the loco pilot can be achieved by automating the signalling mechanism and displaying it in the engine itself along with the traffic lights present along the track. This can be achieved by digitizing the signals and then modulating it before transmission. At the receiver end, these signals can be decoded, demodulated and then the original signal can be reconstructed from it. The various techniques which can be used to realize automation of the signals occur at both the transmitting and receiving station as follows:

5.1. Transmitting Station

A traffic light pole is generally present at an interval of 1km along the given track. It consists of 4 lights, each stating a meaning to the loco pilot for navigating through the track properly. The 4 signals are:

- RED- Stating the train to stop.
- YELLOW- Stating the train that the signal is about to change to red.
- DOUBLE YELLOW- Stating the train to move slow as the signal will change to yellow and then red.
- GREEN- Stating the train to move at a good speed.

These 4 signals can be digitized using a DAC circuit. The signals that are required to be transmitted consist of the status of traffic light pole. These signals can be converted into analog signals from the respective digital signals and transmitted easily using FM modulation techniques. The respective digital signals of each traffic signal output can be changed into analog signals by varying the amplitude level of each bit and then transmitted as a single waveform message signal. The digital codes of each colour represented by the traffic pole can be seen in Table 1.

After conversion of the digital signal into an analog signal, the signal can be transmitted using frequency modulation technique in order to successfully be retrieved by the train. This signal is transmitted by using FM Armstrong Transmitter whose carrier frequency can be varied depending on the frequency of the train's receiver.

The usage of this communication technique is an example of ground communication. Due to this, usage of frequency bandwidth in GHz range proves to be extremely efficient as attenuation in such a small range that is required in ground communication is easily incorporated. Furthermore, the communication takes place in a 1km radius placing the receiver and transmitter comfortably within their respective line of sight.

5.2. Receiving Station

As the safe braking distance of a high-speed train is about 200m, the transmitting signal is generated in the range of 600m so that it can be easily received at the receiving station. The receiving station is installed at the roof of the loco motive engine so that the transmitted signal can be received and reconstructed for the loco pilot. The receiving antenna senses the incoming signal and RF amplifier is used to amplify the signal to improve the SNR. This signal then converted to an intermediate frequency upon which further processes can take place. The signal is then processed in order to get the original waveform transmitted by the receiver. The analog waveform is then converted into a digital signal by using an ADC. This digital message received is then used to determine the action required to be taken by the loco pilot, i.e. stop the train if the digital signal is 00, which means red colour, slow down the train if the digital signal is 01, which means yellow colour, etc.

Table 1. Pulse Codes for equivalent traffic signals

Traffic Light Status	Signal Transmission	Digital Code
RED	STOP	00
YELLOW	Slow Down	01
DOUBLE YELLOW	Keep Moving	10
GREEN	GO	11

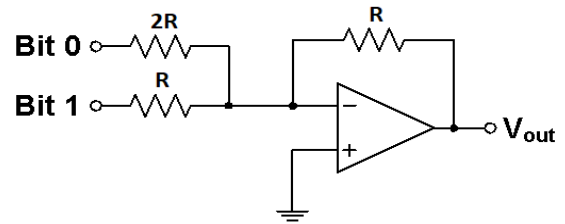


Fig. 7. DAC Circuit.

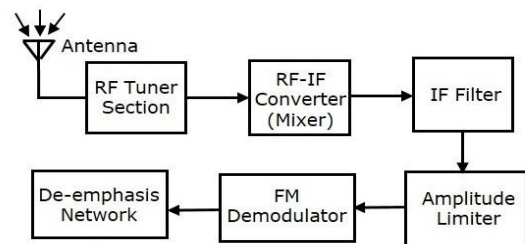


Fig. 8. FM Receiver Block Diagram

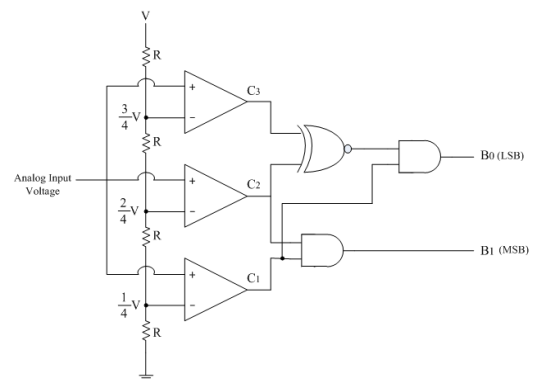


Fig. 9. ADC circuit.

Now, this technique is a solution to the partial visibility of traffic signals by the loco pilot. But the problem arises that the transmitted signal is created in the vicinity of 600m and can be received by any train crossing this region, which can lead to severe accidents. To avoid this, each train is allotted with a particular range of bandwidth such that the signal transmitted is of a particular frequency, which lies in the bandwidth of the respective train. In particular, each train is allotted with a bandwidth of 5MHz which is shared by no other train. The transmitted signal is set to frequency which lies in this bandwidth so that it can be detected by this particular train only. Thus, the carrier signal modulates the given codes at a frequency which lies in the bandwidth region of the train.

To identify the uniqueness of the train such that the transmitter generates the signal of that particular frequency, two methods can be used. These methods are as follow:

5.2.1. GPS Method

In this method, a GPS module is interfaced with arduino and is installed inside the cabin of the driver. This module can then be coded to produce the following outputs about the particular train like:

- Latitude
- Longitude
- Speed
- Direction (in degrees)
- Date.

These parameters can be used to detect the exact position of the train in a block.

A server is setup which comprises of the latitude and longitude of all the traffic light poles present along the tracks. Thus, the latitudes and longitudes of the traffic light poles can be compared with that of the train, and the nearest upcoming pole can be intimated to generate a particular frequency signal for the approaching train. This system of identification has its own advantages as it is easy to construct and install and is very cheap.

5.2.2. Surveillance Camera Method

In this method, surveillance cameras are installed at every traffic light pole facing the forwarding rail tracks. Along with this, each train has to be installed with and LED display board, with its train number at the end of the train above the printed 'X'. This number is captured by the camera and the image is processed to obtain the integer number from the image. This integer number is converted into binary equivalent and fed to the upcoming traffic light pole which generates the signal of the required frequency such that it can obtain the signal even in foggy conditions.

These signals can be transferred to the neighbouring traffic poles by the help of inter-connective wires present overhead. Along with the display light boards, unique codes can be printed at the back of the train which can be processed using image processing software and compared with the database to get the details of the train. These details can be sent to the upcoming traffic light pole to deduce the train number and generate the equivalent bandwidth signal.

The advantage of these cameras is that along with the number plate detection mechanism, it can be used to keep a check on the railway tracks for their clearance. It helps to check the presence of hurdles and unwanted things like vehicles, animal cattle and people. With help of these cameras a more efficient safety system can be installed with the railways. These cameras can also check the breakage of cracks in rails and avoid accidents. Thus, incorporating these mechanisms with the system, a fully-fledged system can be built to improve the visibility and speed of the train.

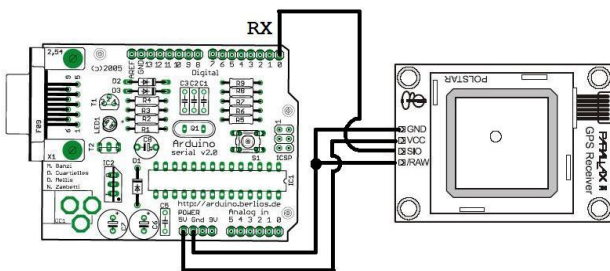


Fig. 10. Circuit design of GPS module interfaced with Arduino UNO [9]

5.2.3. Frequency Adjust Burst Transmission

In this technique, another set of transmitter and receiver is used. The transmitter is provided to the train and the receiver to the traffic signal. The transmitter is used to transfer a digital signal to the traffic signaling pole which denotes the lower frequency limit, say x MHz, of the frequency bandwidth assigned to the train. This signal is again transmitted using PCM technique as shown in fig.7. The signal is then received by the receiver and decoded to inform the traffic signal of the frequency bandwidth of the approaching train by giving it the information of lower bandwidth limit x MHz and upper bandwidth limit $(x+5)$ MHz Using this information, the oscillator of the transmitter is adjusted automatically to transmit the required signal within the bandwidth of the train.

The assignment of frequencies used by the trains' receivers is assigned to them using SPADE system. In this system, the number of frequencies that can be used by the trains in order to receive signals is a fixed amount. These frequencies are present in a pool which is constantly monitored and assigned to the trains. Due to these, the transmitter frequency range required in the traffic signal can be small and hence it will be easier to use. Plus, using this technique, multiple trains which are running at the same time but are far apart from each other can use the same frequency to operate simultaneously. Furthermore, with increase in the number of trains, the confusion of assigning new frequency to a particular train and hence updating transmitter of traffic signal can be avoided.

6. Safety Systems

Along with the newly introduced technology, a safety system is also introduced to protect the fast-moving trains from accidents like collision, derailment and precautionary measures like overshooting of traffic signals and over speeding. [10] These can be done with the help of introduction of following systems:

6.1. Ultrasonic Sensors

High range ultrasonic sensors can be installed at railway crossings to monitor the presence of vehicles and animals on the track in case of incoming trains. [11] The sensor will activate only when the vehicular barrier closes in case of incoming trains and will create a warning sound in case of any presence or non-clearance of track in case of dense fog or rains.

6.2. Miniature RADAR

Miniature models of RADAR can be installed in front of the engine such that they are able to detect the presence of any hurdles that are present on the track at far away distances even in dense fog and heavy rains when the visibility is not good. These miniature RADARs are set fixed, unlike the conventional ones that rotate 360 degrees. The RADAR maps the upcoming hurdle on a display unit, set inside the cabin of the loco pilot and intimates him about them. This system can be very helpful in the safety measure of the train in adverse weather conditions.

7. Results and Simulations

The frequency tuning done in the transmitter of train can be easily controlled by using Armstrong transmitter. Using this constant frequency value can be set. This value will then get multiplied to the required amount by using the combination of the two multipliers. These multiplication factors are controlled using LC oscillations. These LC oscillations are can be varied to get different multiplier values by using variable capacitors or capacitor banks whose capacitor values can be set according to requirement. [12]

These multipliers' values can be determined according to the output of transmitter required using, the following assumptions and formulas:

$$\Delta f_0 = f_c - f_{c1} \quad (1)$$

$$m_1 = \Delta f_0 / \Delta f_1 \quad (2)$$

$$m_2 = f_c / f_{c1} \quad (3)$$

$$n_1 n_2 = m_1 \quad (4)$$

$$n_2(n_1 f_{c1} - f_{c2}) = f_c \quad (5)$$

where,

f_c = Output frequency required

f_{c1} = Frequency value set as standard frequency (Input)

f_{c2} = Frequency value after first multiplier

Δf_1 = Input change in frequency (After usage of Narrowband Phase Modulator)

Δf_0 = Output change in frequency

m_1 = Multiplication factor required (one shot)

m_2 = Multiplication factor required (actual)

n_1 = Multiplication factor of first multiplier

n_2 = Multiplication factor of second multiplier

Using these equations, the output frequency required can be tuned depending on the multiplication factor used and these multipliers can be adjusted by adjusting their capacitance value. [13]

The circuit in fig.12 is a PSPICE simulation of the proposed FM transmitter which uses Armstrong method for transmission of signals from one place to another. The input is given through the V2 and the frequency multiplied output is obtained from the collector terminal of BJT Q3.

8. Conclusion

The main cause for the low average speed of the Indian Railways in Northern Region is due to low visibility. Though, it is difficult to improve the visibility in dense foggy conditions and heavy rains, better systems are introduced to improve the average speed. The proposal suggests a better way to improve the speed of the trains in dense fog and also keep a check on the clearance of the tracks by incorporating ultrasonic sensors, IR sensors and RADAR system on the loco motive engine as well as traffic light pole. All these systems together form a mechanism technology which help enhancing the speed of train and increase the virtual visibility of the loco pilot. It also provides a base method to rectify the track status along with its clearance.

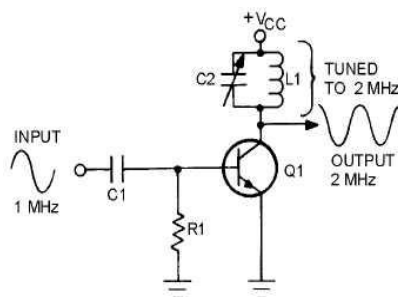


Fig. 11. Circuit design of a simple multiplier.

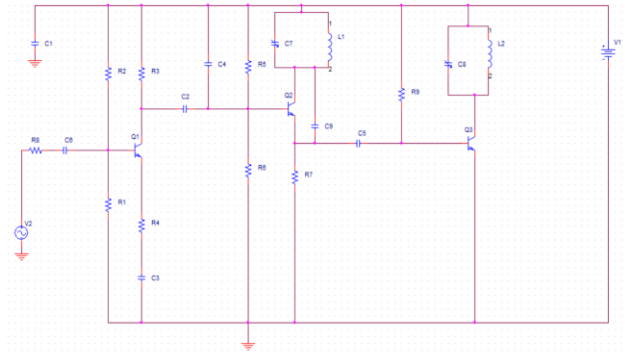


Fig. 12. Circuit design of Armstrong circuit FM Transmitter.

With all these techniques, the pre-existing technologies can be eliminated and this will certainly improve the existing conditions of the Indian Railways.

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