DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

COMMUNICATION-BASED TRAIN POSITIONING CONTROL SYSTEM BY USING EXISTING RADIO SYSTEM

by
Mehmet CANPOLAT

Ekim, 2019
İZMİR

COMMUNICATION-BASED TRAIN POSITIONING CONTROL SYSTEM BY USING EXISTING RADIO SYSTEM

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"COMMUNICATION-BASED TRAIN POSITIONING CONTROL SYSTEM BY USING EXISTING RADIO SYSTEM"** completed by **MEHMET CANPOLAT** under supervision of **ASSOC. PROF. DR. REYAT YILMAZ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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COMMUNICATION-BASED TRAIN POSITIONING CONTROL SYSTEM BY USING EXISTING RADIO SYSTEM

ABSTRACT

In all railway communication system, radio device is commenly used. In open area data communication is achieved by RF transmitters/receivers and in closed enviroments like tunnel through a leaky feeder cable. Signalling systems are designed for vehicles with specific technology on the railway. Not every vehicle on railway can be monitored and this causes accidents. In addition, high-cost infrastructure is required for instant vehicle tracking in buildings such as tunnels. In this study, a railway vehicle tracking system is introduced and designed which enhances system security and minimizes data loss, using the existing radio infrastructure for communication in railway systems.

In this thesis, location information was obtained with the axle counter sensors on the vehicle and the rfid transmitter circuits on the line. All railway systems have radio infrastructure and communication is provided in tunnels using 433 MHz transceiver circuits suitable for this infrastructure. 2.4 GHz transceiver circuits were used to back up this location information. All these systems are practical, cost-appropriate and designed to be installed on every vehicle. Consequently, instant tracking of every vehicle on the railway will be possible.

As a result of this study, the location information of the vehicle cruising on the line is displayed instantly in the mapping interface located in the control center. When any of the transceiver circuits operating at 433 MHz and 2.4 GHz frequency band is off, data can be obtained from the other frequency band without data loss. In this way, vehicles can be tracked instantaneously and the system can operate as a redundant system itself.

Keywords: Railway, communication, signalization, location information

MEVCUT TELSİZ SİSTEMİNİ KULLANARAK HABERLEŞME TABANLI TREN KONUM KONTROL SİSTEMİ

ÖZ

Tüm demiryolu sistemlerinde haberleşme için telsiz cihazları kullanılmaktadır. Açık alanlarda RF vericiler/alıcılar, tünel gibi kapalı ortamlarda sızdırıcı kablo vasıtasıyla veri iletişimi sağlanmaktadır. Sinyalizasyon sistemleri demiryolu üzerinde bulunan belirli teknolojiye sahip araçlar için tasarlanmaktadır. Her aracın takibi yapılamamakta olup bu durum kazalara neden olmaktadır. Ayrıca tünel vb. yapılarda anlık araç takibinin yapılabilmesi için yüksek maliyetli altyapı gerekmektedir. Bu çalışmada, raylı sistemlerde öncelikle haberleşme için bulunan mevcut telsiz altyapısının kullanıldığı birbirini yedekleyen, sistem güvenliğini artıran ve veri kaybını minimal seviyeye getiren demiryolu araç takip sistemi tasarlanmıştır.

Bu tez çalışmasında, araç üzerinde bulunan aks sayıcı sensörler ve hat üzerine yerleştirilen rfid verici devreler ile konum bilgisi alınmıştır. Tüm demiryolu sistemlerinde telsiz altyapısı bulunmakta olup bu altyapıya uygun 433 MHz alıcı-verici devreler kullanarak tünel vb. yapılarda haberleşme sağlanmıştır. Bu konum bilgilerini yedeklemek amacıyla 2,4 GHz alıcı-verici devreleri kullanılmıştır. Tüm bu sistemler pratik, maliyeti uygun ve her araca montajı yapılacak şekilde tasarlanmıştır. Bunun sonucunda demiryolu üzerinde bulunan her aracın anlık takibi yapılabilecektir.

Bu çalışma sonucunda hat üzerinde seyir halinde olan araçların konum bilgileri kontrol merkezinde bulunan haritalama arayüzünde anlık olarak görüntülenmiştir. 433 MHz ve 2,4GHz frekans bantlarında çalışan alıcı-verici devrelerin herhangi bir tanesi çalışmadığında veri kaybı yaşanmadan diğer frekans bandından veri elde edilmektedir. Böylelikle araçlar anlık olarak takip edilebilmekte ve sistem kendi içerisinde yedekli olarak çalışabilmektedir.

Anahtar Kelimeler: Demiryolu, haberleşme, sinyalizasyon, konum bilgisi

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CHAPTER ONE
INTRODUCTION

It is seen that public transportation has started to be formed due to rapid population growth, urbanization, air pollution and many other reasons. Public transport, which has been used primarily in big cities, has become a fast, safe and timely way to get to their destination. Rail systems, public transportation systems in terms of both speed and passenger transport because of the other public transportation stands out compared to other vehicles. The importance of signaling system in tram, light metro and subway vehicles which are used in rail systems is known to be very great. The reason for this is considered to be a safe transportation and to prevent accidents.

In this first part of the study, the histories of rail transportation systems in Turkey and with the world are described in detail. In addition, the importance of rail transportation systems in public transportation systems is explained. The first emergence of rail transport systems was in the early 1800s. The rail system, which has emerged as an alternative to the road in England, has developed rapidly over the years. In Turkey, the use of rail transport system was first introduced in the 1850s. Over the years, in addition to locomotives, commuter trains, subways, trams and light rail vehicles have been developed. Rail transportation systems, which have the advantage of cost and passenger capacity among all public transportation vehicles, have become the most preferred means of transportation in urban areas.

After the rapid development of railway transportation, safety and speed issues became prominent and became a necessity. In order to fulfill these requirements, a signaling system has been developed. Rail transportation systems, which were initially managed by pointers and illuminated signals, continued to serve with signaling systems developed using computers and electronic cards with the increasing number of trains and passengers.

In the third chapter, signaling systems used in rail transportation are discussed in detail. Moreover, the importance of signaling system and basic elements of the signaling system that is field equipment and central interlocking, are explained. There are many signaling systems used worldwide. GSMR system is used on the basis of the signaling system abroad. The foundation of one of the signaling system of the metro rail transportation in Turkey is based on a fixed block systems. GPS system is used in vehicles passing over tram and level crossing. GPS and fixed block systems are more preferred because of the high cost of the infrastructure to be used for GSMR system (Dönmez, 2014).

In the fourth chapter, wired and wireless communication technologies are examined under the title of communication systems. Wireless communication technology used in rail transportation systems is mainly discussed.

In the application part of this study, described in the detail of equipment are used in the project. Vehicle location information is obtained with two different methods. One of the methods is applied in the vehicle and the other of methods is applied in the line. The obtained data packages are transferred from vehicle to the control center by the transceiver circuits connected to the control units. After processing the data from the control center, it is sent from the serial port to the mapping software. Location information is processed from the data received into the mapping software, showing the locations of the vehicles on the mapping.

When the system we have developed is compared with the GSMR and GPS systems, each has different advantages and disadvantages. When we look at the system we have developed, it is seen as an advantage to place modules in each vehicle, using the existing wireless system for the system infrastructure and avoiding the need for wiring in order to keep the costs low and to monitor the vehicles instantly. When the GSMR system is considered, it is known that the modules cannot be placed in each vehicle and the cost is high due to the installation of system-specific infrastructure. When the GPS system is considered, it is seen as an advantage that modules can be installed in each vehicle, but it is an important disadvantage that it is not possible to follow the underground lines (Karayanık, 2017).

CHAPTER TWO
RAIL TRANSPORTATION SYSTEMS

2.1 Historical of Rail Transportation Systems

Looking at the revolutions in history, first BC around 8000 it is observed that the Agricultural Revolution took place. With the Agricultural Revolution, mankind began to move from nomadic life to settled life and then has started to adopted land as a capital. In order to make efficient use of this capital, animal power has been used over time and tools have been developed. In 1765, the Industrial Revolution and the French Revolution emerged and the process of fabrication began. The new technologies that emerged with the Industrial Revolution brought along a new field of production and lifestyle (Günay, 2002).

By fabrication process, the requirements of producing and raw material have also started to increase. This situation has brought transportation to a different and important point. Nicolas Cugnot in 1769 and William Murdock in 1786 tried to reach the highway by using steam power. In 1801, Richard Trevichick has found a locomotive operating with steam power and tried this vehicle on the railway track. However, the rails could not weigh of the locomotive (MEB, 2011). The locomotives has been tried to carry firstly on the wood and then on the metal rails. In 1820, rails which are used today and made of steel started to be used. The wheels of the first produced locomotives have a serrated surface. As shown in Figure 2.1, the third rail line was installed by John Blenkinsop in 1812 and the locomotive was moved by contact with this rail line. In 1823, Christopher Blackett showed that on a smooth railway the locomotive and the load drawn from behind could be moved on the rails (Berkmen, 1963).

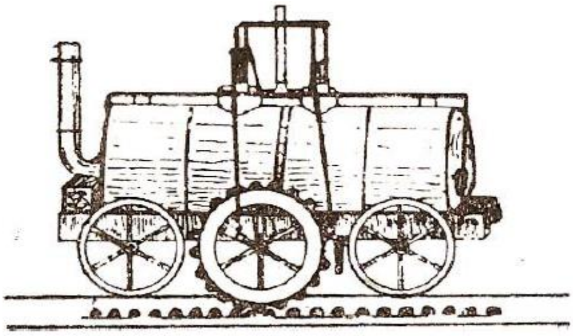
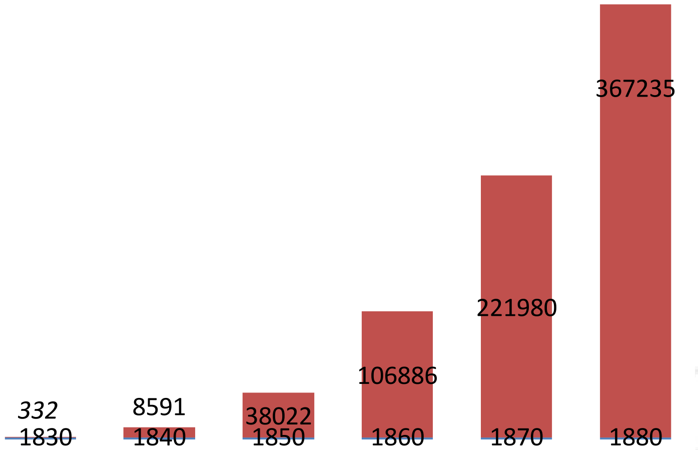


Figure 2.1 The train and 3 railway line (Berkmen, 1963)

After all these developments, the first successful work on the railway was made by George Stephenson, a mechanical engineer, in 1829 in England to build a more robust rail and a locomotive capable of going on rails. This locomotive was called "ROCKET", was able to pull 12942 kg load at 22 km / h. Following this successful project, Stephenson was asked to build a line between Liverpol and Manchester, which was commissioned on 15 September 1830 (Smiles, 1959).

In the following years, developments in the construction and transportation of railways were observed in the Western states. The first railway line was established in 1832 in France. The first railway line between Etienne-Lyon, the first railway line established in Germany in 1835, between Nuremberg-Furth and the first railway line established in Belgium in 1835 was opened between Brussels and Malines. In 1852, it is known that there are only three cities in England where the railway is not installed. Railway transportation, which paved the way for industrialization and developed rapidly over time, as seen in Table-2.1, the length of the world railways is 332 km in 1830, 38022 km in 1850 and 367235 km in 1880. Looking at the following years, it is seen that the length of railways reached 612200 km in 1890, 860000 km in 1905, and 1110000 km in 1913 (MEB, 2011).

Table 2.1 Total railway length in the world between 1830-1880 (km) (Bruckmüller & Hartmann, 2001)



In addition to all this, considering the year of between 1947 and 1948, that the railways with the countries neighboring Turkey lengths are shown in Table 2.2 (Yücel & Taşar, 2016).

Table 2.2 1947 - 1948 existing railway length of year in Turkey neighboring countries (Yücel & Taşar, 2016)

Country	Railway Length	Railway Falling Every 100 Kilometers
Czechoslovakia	10527	7.5
Yugoslavia	9471	3.8
Romania	11216	5.8
Bulgaria	3405	3.1
Greece	2650	2
Syrıa & Lebanon	1100	0.9
Palestıne & Jordan	1003	0.8
Iranian	1500	0.1
Egypt	3619	0.4

2.2 Turkey History of Rail Transport System

The first railway in Turkey founded in 1837, at the request of Kavalalı Mohamed Ali Pashathe, British governor of Egypt, began to be established between Cairo and İskenderiye and was completed in 1854. During the Ottoman period, the right of established the railways to the British, French and German, on the conditions that the profit per kilometer of rail was gained and the operating right of mines was granted (Pamuk, 1994). The second railway line started to be established in 1857 between Çernavoda and Constanta in Rumelia in order to develop in the agricultural area and was completed in 1860 (Özdemir, 2001). The work progressing rapidly until the Second World War slowed down due to the war, but the work continued. The railway was completed in Kayseri in 1927, in Sivas in 1930, in Malatya in 1931, in Nigde in 1933, in Elazığ in 1934 and in 1935, in Diyarbakır in 1939 and in Erzurum in 1939 (MEB, 2011).

After the railway line has been established within the boundaries of Turkey, had been started o construction of the line extending from Turkey to abroad. The first abroad railway was the 2383 km Vienna - Istanbul rail line, which was completed in 1888. Known as Orient Express, this line was starting from Istanbul to Edirne, Plovdiv, Nis, Thessaloniki, Belgrade, Sarajevo and then was stretching to Vienna. After the completion of this line, two different railway projects that had been acknowledged as important, Istanbul - Baghdad and Istanbul - Hejaz lines have been planned and completed. At the period of 2nd Abdulhamid came to the importance of railways was increased and project work had been started. Some of these are known as Anatolian Railways (1888), Baghdad Railway (1889), Jaffa-Jerusalem Railway (1889), Thessaloniki-Monastery Railway (1890), Beirut-Damascus Railway (1890), Thessaloniki-Istanbul Railway (1892). In these projects, although the policy of progress was followed by granting concessions to foreigners, the idea of accelerating military power has been prioritizied (Akbulut, 2010).

In the Republican period, it is seen that the importance of transportation in terms of both internal and external security has increased. In other words, from the perspective of external security, it was possible to reduce the distance to the borders of the country by rail transport. In terms of internal security, railways were important in order to overcome the problems of public within the borders of the country and to provide unity. In line with these objectives, it is seen that major progress has been made by the railway projects that mainly started in 1924 and completed in 1939. Between these years, the railway length was 191%, the number of trains 304%, the number of passengers 203%, railway income increased by 155% (Şen, 2003).

As a result, the railway length which was 4136 km, before the Republican period, gained speed during the Republican period and approximately 3764 km of new railway lines were constructed. After the 1950s, which was accepted as the post-republic period, the work continued in a similar way and a further 972 km of operational length was increased and a total of 8872 km of roads were opened for use. In the period between 1950 and 2010, the completed railway length had been calculated as 9594 km. In other words, an average of 134 km of railways line has been constructed in railways, which developed rapidly during the early years of the Republic, but after the 1950s this figure decreased to 16 km. Railway transportation, which gained momentum since the beginning of the 21st century, has increased to 135 km of line construction. Table 2.3 shows the railways length by years (TCDD, 2010).

Table 2.3 Railways length (Türkiye Cumhuriyeti Devlet Demiryolları, 2010)

Railway Constructions (Outlines)	**KM**	**Average annual road construction (KM)**
Before the Republic	4136	66
Republican Period		
1923-1950	3764	134
1951 and later	972	16
End of 2010 total outline path length	8722	
End of 2010 high speed train line	872	
Total outline length	9594	135
End of 2010 station roads	2346	
Total path length	11940	

2.3 Location of Rail Transportation in Public Transportation Systems

In order to provide transportation in big cities, solutions are produced with different means of transportation. These vehicles, which are referred to as public transport, are classified under different classes as A, B and C. These are defined as follows (Vuchic, 2015);

- **Class C:** Class C, referred to as street public transport, is used for situations where traffic is mixed. In this case, it is possible for public transport to lose time during pick-up and drop-off of the passengers due to the intensity of traffic. This class includes buses and trams.

- **Class B:** Class B, which is expressed as semi-speed in public transportation, includes buses and light rail transportation vehicles serving on side roads, separated roads and streets. It is far from the traffic density with the roads reserved for these vehicles.

- **Class A:** The vehicles in this class provide fast and safe service to its passengers.

As public transportation vehicles, monorail, driverless human carriers, tram, light subway, metro, metrobus, bus, minibus, taxi are listed as. Table 2.4 shows the classification of public transport by categories.

Table 2.4 Classification of public transportation modes by categories (Vuchic, 2015)

Public transportation modes	General categories
Ring bus	Street transport
Regular bus	
Express bus / tram	
Trolley bus	Semi-speed transportation
Tram / Street tram	
Fast bus transportation	
Light rail transportation	
AGT ring service	
Quick access with automatic guidance	
Fast transportation	
Light rail fast transport	
Rubber Wheel	Fast transportation
Monorail	
Fast transportation by rail / metro	
Regional railway	
Cable car	
Gear Rail	Special public transportation
Funicular	
Aerial tramway	
Ferry	
Sea Bus	

Cost issues related to the preference of public transport come to the fore. In this case, when the public transportation vehicles are compared according to their capacity and costs, the vehicles serving the most passengers with the lowest cost are seen as subways. This comparison is shown in Figure 2.2 (Murteza, 2010).

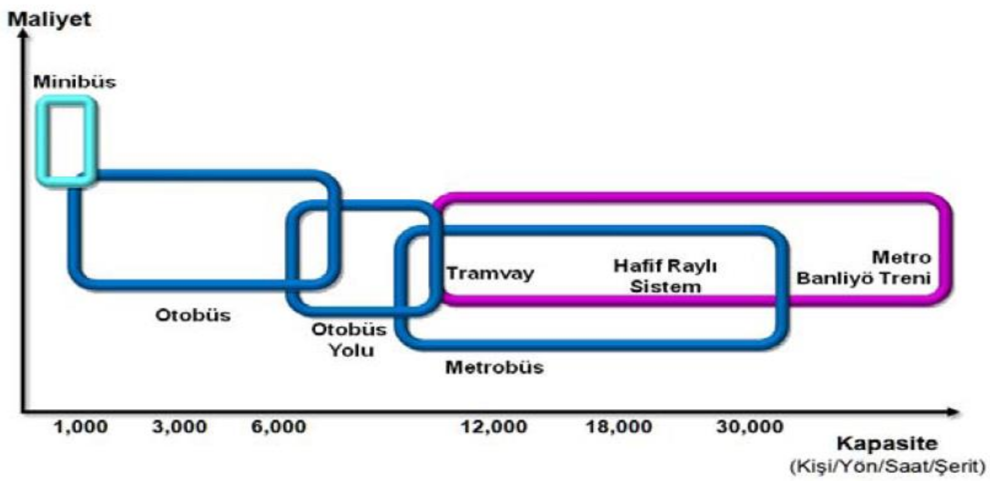


Figure 2.2 Comparison of capacity and costs of public transport (Murteza, 2010)

In this study, subway, trams and light rail systems, which are known as fast transportation vehicles, will be discussed. The metro system is known as a high-capacity, fast, safe, electric public transport system that operates independently of traffic, roads and pedestrians. Compared to other public transportation vehicles, the subway is distinguished by its own route. In addition, the intervals are scheduled at the specified frequency during the day (Öztürk, 1989; Vuchic, 2015). For example, 6-way wagons are used in 120-130 meters platforms on the M1 line in İzmir Metro. Approximately 1500-1700 passengers can be transported with these wagons.

As a result of technological developments, public transportation vehicles used in the city begin to show diversity. From the framework of rail transportation systems, the diversity of transportation starts with tram, continues with light rail systems and ends with metro. Table 2.5 shows a detailed technical comparison of tramway, light rail and subway systems (Arlı, 2010).

Table 2.5 Technical comparison of urban rail vehicles (Arlı, 2010)

Vehicle Feature	**Tram**	**LRS**	**Metro**
Vehicle Capacity (Passenger)	100-250	110-250	140-280
Vehicle height (m)	14-35	14-54	15-23
Vehicle width (m)	2.2-2.7 (2.4)	2.2-3.0 (2.65)	2.5-3.2 (2.9)
Number of Vehicles	1-3	1-4	1-10
Train capacity (passenger)	100-500	100-750	140-2400
Line capacity (thousand passengers/hour)	4-15	6-20	10-70
Maximum Speed (km / h)	60-70	60-100	80-100
Normal operating speed (km / h)	12-20	20-45	25-60
Station range (m)	300-500	500-1000	500-2000
Vehicle Control	Manual / Audio	Manual / Signal	Signal / Automatic Control
Fee collection	in Car	Vehicle / station	at the station
Energy supply	Catenary	Catenary	Catenary - 3rd rail
Reliability	Low-medium	High	Very high

In Figure 2.3, when viewed in Turkey until 2017 to use the rail system in the city, serving and many railway lines are shown at the project stage.

Figure 2.3 Belonging to the project and stages of rail transport system in Turkey (Pektaş, 2017)

CHAPTER THREE
RAILWAY SIGNALIZATION SYSTEMS

Controlling, analyzing and directing trains has been an important issue since railways have been establihed. Any error that may arise from this control mechanism can lead to incidents that may result in both pecuniary loss and intangible damages (Diana et al., 2001). Because of the rapid technological development and the rising needs the expectations from the control mechanism have increased. (Janczura, 1998).

3.1 History of Signalization Systems in Rail Transport

The most important issue that was taken into consideration in the early life stage of the railway transportation was known as the speed of transportation. The rapid end-to-end travel of the country is seen as crucial to the movement of military forces. When a comparison is made with the current developed rail transportation systems, since the number and the speed of the trains were very low, and the range of vision in the case of a possible stopping or the accident were wide, generally people has not attached importance to the signalization. However, with the increasing technology, increasing needs of trains and the number of locomotives added to trains, accidents and other problems started to outbreak. In order to prevent these situations, people who gave signs by hand or flag, that is, pointers were used. The pointers on the railway line has provided the necessary guidance for the trains. For example it had helped for making a safe stopping motion and facilitates the passage of trains at intersections and stations. However, this system, which was created with the help of pointers, it has not been usefulness because of the increasing number of trains, and the increasing weight of load that transported by the train, (Söyler & Açıkbaş, 2005).

At the 1840s, with the both security and cost issues has came to the forefront, according to the certain time intervals train movement method was started to be applied. Each train has been given a certain period of time interval based on its' route. However, this method does not take into account other trains which come from the opposite direction or been at the railway line. For this reason, distance range method had been started to use. In this method, the railways are divided into specific blocks and signs are placed at the beginning of each block, to separate off block from other blocks. With these signs, the machinists were able to see whether there was another train in front of them at the same railway line. As a result of using this method for a while, a fixed-line signals system has emerged. In this period, with the discovery of telegraph, signal operator has emerged as a professional occupation. Signal operators directed the machinists with visual control of the condition of the trains in front of them and at the same railway line. Signal operators, working in coordination with the station officer, must first obtain permission from the officer for the train that wants to enter the station. And then, by the signal circuit is activated by the officer's, train passes are made (Ürün & Gülbahar, 1972).

By the 1900s, the distance method and then the block system had emerged. The block system is divided into five groups. These groups are; manually operated by control operators, both controlled and manually operated blocks, semi-automatic blocks, fully automatic blocks and mechanical blocks (Gülener, 2009). Thanks to these advances, signalization systems have started to be developed in order to monitor the movement of transportation vehicles in railway systems and to provide safe transportation (Rumsey, 2006).

At 1955 in Turkey, for the first time, signalization system which was in the Sirkeci - Halkalı suburb has been used. The signalization systems, which were used in Ankara - Haydarpaşa line in 1968, showed a rapid development until the beginning of 2000s. In these years, totally the length of all lines reached 9000 km and at the 20-25% of these lines has been used signalization system (Söyler & Açıkbaş, 2005).

3.2 Importance of Signaling System

As the traffic density in rail transportation systems increases due to various reasons, the need for signaling system has emerged. In the early days when rail lines and vehicles emerged, signs and markers were used as the signaling system. In this way, the speed of the trains increased and they started to travel more safely. However, these signs and pointers became insufficient over time and the need for remote control of the scissors on the line arose and the use of symphores, ie mechanical signals, began to be used. The pulleys, pulleys and steel wires are simplified to be controlled by providing electricity to make them safer. In the future, with the development of technology, signaling system has been developed by using computer and electronic cards. The equipment on the line of this system is known as electrically operated light signals and shears, magnetically operated train stop brakes. As a result of all these developments, the number of personel used in the operation of rail transportation systems has decreased and a fast and safe service has been started to be provided (Can, 2001).

The benefits of the signaling system are listed as follows (Ürün & Gülbahar, 1972);

- Increased railway capacity,
- Decreasing the number of 15ersonel,
- Increased safety and security,
- Reduction of operating and transportation times,
- Facilitation of railway management.

3.3 Basic Elements of Signalization

The signalization system consists of two basic elements. The first of these is known as field equipments. The other is known as central interlocking. All these basic elements are described in detail below.

3.3.1 Field Equipment

Field equipment, which is one of the basic elements of the signalization system, is divided into five groups as signal circuits, track circuits, switches, relays and on-board equipment.

3.3.1.1 Signal Circuits

Signal circuits, which is one of the field equipment in the signalization system, are as the general definition of the lights that helps the machinists to comply the rules and to take information about the state of the line. The signals on the right side of the line and naturally to the right of the trains' flow direction indicate that the block in front of the train is empty or busy (Yıldırım et al., 2010).

3.3.1.1.1 Basic Definitions and Symbols Used in Signalization System. The most commonly used definitions and symbols in the signalization system are defined as follows (MBE, 2013):

a) Braking distance: The braking distance, which is represented by the letter "D" and is the distance measured in meters. Braking Distance is the distance between the point of making a full brake application and the point of the train stop (Barney et al., 2001:23). For example, the approximate stopping distance of a train with a speed of 160 km / h is calculated as 2039 meters. The braking distance is determined as 400, 700 and 1000 meters by the Turkish State Railways (TCDD) (TCDD Report). The basic logic of this calculation is based upon to speed and braking percentages. It is also necessary to known that the acceleration of the train in determining the braking distance. With another word, acceralation coefficient is important.

b) Point of view: The point of view, represented by the letters “GN” meter (in Turkish), is defined as the point where the machinist or driver starts to brake to stop at the red light. If same example is used, for a train with a speed of 160 km / h point of view is calculated as 450 meters.

c) View: It is represented by the letter "G" is defined as the distance from the point of view to the first warning signal. This warning signal is determined as yellow light.

d) Overlap: Overlapwhich is represented by the letter "D" and is the distance measured in meters. In its simplest form, the "overlap" is a distance allowed for the train either in bad weather or in the event of a malfunction on the train, to stop in should it pass a signal. In other words, it is a distance that, protects the machinist when the signal was passed. It is impossible to predict when a dmachinist react to a stop signal or braking distance for different train types, generally 185 metres is used as a standard value (Kaykacmakine, 2015).

e) Length of the train: The length of the train is represented by the letter "L" and is measured by meter. Length of is determined based upon the passenger capacity and carrying loads.

f) Travelled distance: The travelled distance is represented by the letter "X", which is the unit of measurement in meters. Travelled distance is defined as the minimum distance between trains that follow each other on the same line.

g) Time of travel: The time in which the unit of measurement, in seconds, is represented by the letter "T", is defined as the time taken for the trains to travel the distance of each other.

h) Limit distance: The limit distance, which is represented by the letters "LM" , is the distance in which the trains on the same line can travel safely without touching each other.

3.3.1.1.2 Signal Notifications. The signals used in the signalization system are referred to as colored and illuminated signs that inform the machinist or driver in case the blocks on the rail line in front of him are empty or busy in order to ensure the safety of the railway transportation. The meaning of these signs is explained as follows (Saygın et al., 2009);

• Red signal: means that there is another train on the line that a train is going to, or that the rail block is busy for another reason.

• Yellow signal: Its' mean for the machinist is that there is another train after two blocks on the same line, or that the next signal that the train will see on the line is red and should slow down.

• Green signal: means that there is no other train on the line and that the next signal does not indicate any obstacles to the movement of the train.

3.3.1.1.3 Signal Types. There are traffic lights, ie signals, which allow the control of the movement of the trains in a certain way in each block, scissors zones, station entrances and exits separated by certain lengths on the line (Söyler & Açıkbaş, 2005). Signal types are divided into two according to their appearance and function (TCDD, 2003);

- **Signal types according to their appearance**

According to their appearance, the signals are divided into dwarf and high color signals. These signals are used in railways in different ways as double, triple and quadruple. In Turkey, the color signals can be of three different types;

a) 2 - Aspect Signalling: They are defined as signals having two different color types. The colors of these signals are usually used in red and green.
b) 3 - Aspect Signalling: They are defined as signals having three different color types. The colors of these signals are used in red, yellow and green. This type of signal can be used to indicate one or two states at the same time.
c) 4 - Aspect Signalling: This type of signal can display one or two states at the same time. for example; The colors of these signals could be red, yellow, red and yellow, green and yellow, yellow, yellow and green.

Some examples of these types of signals are given in Figure 3.1.

Figure 3.1 Signal types (Milli Eğitim Bakanlığı, 2013)

Figure 3.2 shows an example of a signal pattern in a three-state region. When approaching the red light in a three-state zone, the signals are listed in the order of sight of the machinist or driver as follows.

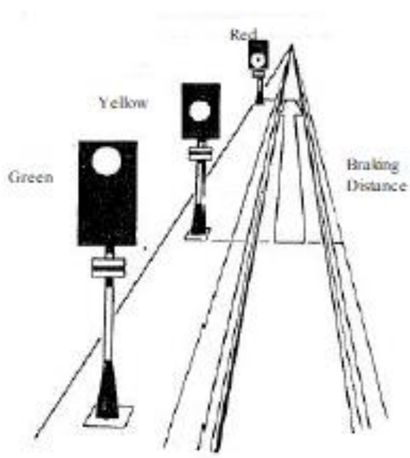


Figure 3.2 Aspect signalling (Hall, 1996)

- **Signal Types According to Functions**

Signals according to their functions are listed as follows;

- Input signals
- Output signals
- Block signals
- Approach signals
- Protection signals
- Repeat signals

In this section, the most commonly used input, output, block and approach signals are explained in detail.

- **Input Signals:** Input signals, which have a total of two at each entrance of the station, are controlled directly from the center. Figure 3.3 shows a station with input signals consisting of four high signals.

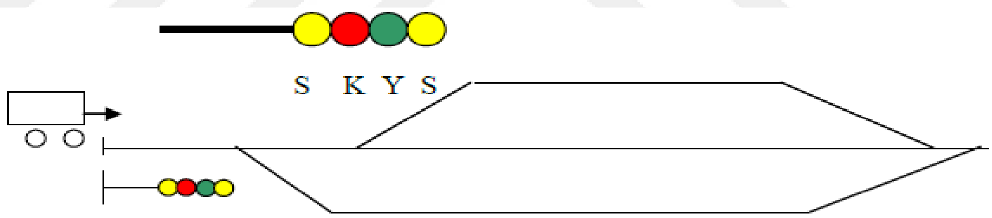


Figure 3.3 Input signals (MEB, 2013)

- **Outputsignals:** Output signals, which have a total of two at each exit of the station, are controlled directly from the center. Figure 3.4 shows a station with output signals consisting of three-color high signals on a double-track railway.

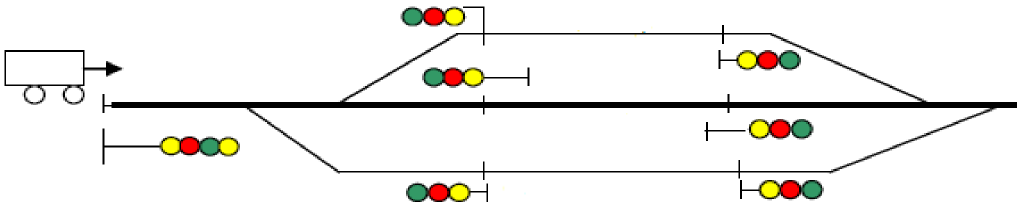


Figure 3.4 Output signals (MEB, 2013)

• **Block Signals:** These are defined as triple high signals at the beginning of the blocks separated according to certain distances on the line outside the stations. The function of the block signals is automatically to change color according to the state of the next signal. The length of the blocks varies according to the length of the line. Figure-3.5 shows part of the line with block signals consisting of triple high signals.

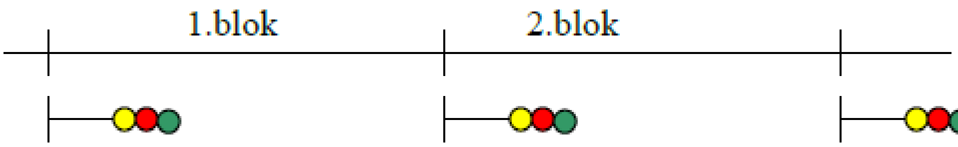


Figure 3.5 Block signals (MEB, 2013)

Figure 3.6 shows how the block signals give a color with more than one train movement.

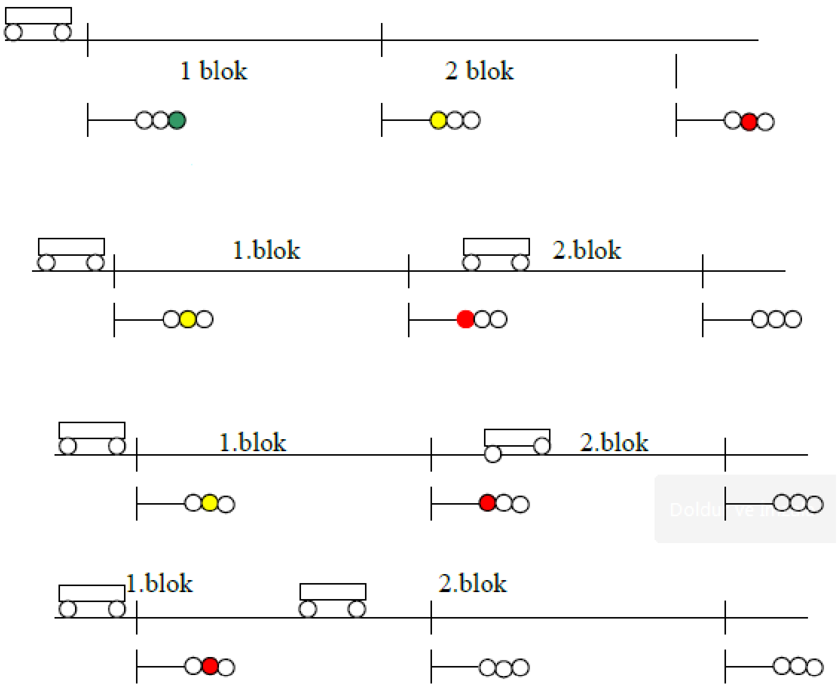


Figure 3.6 Colors of block signals according to train movements (MEB, 2013)

• **Approach signals:** The approach signals positioned at all station, before the input signals, are defined as block signals that are remote controlled. Figure 3.7 is an example showing the approach signal before the input signal at a station.

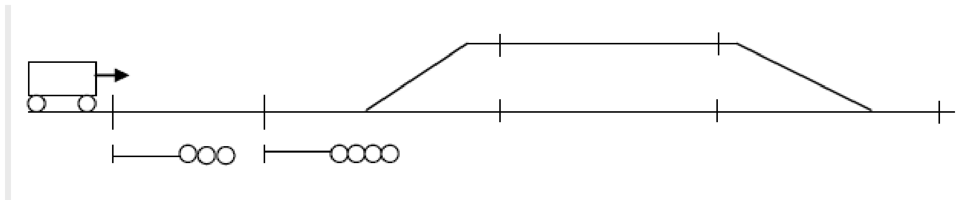


Figure 3.7 Approach signals (MEB, 2013)

3.3.1.1.4 Block Signal Circuits. In order to use block signals, the track circuits have to been actively used. As shown in Figure 3.8, when a train enters the block, the relay contacts take a closed position and signal as a short circuit. With this information, the signal turns red and stays on until the train leaves the block.

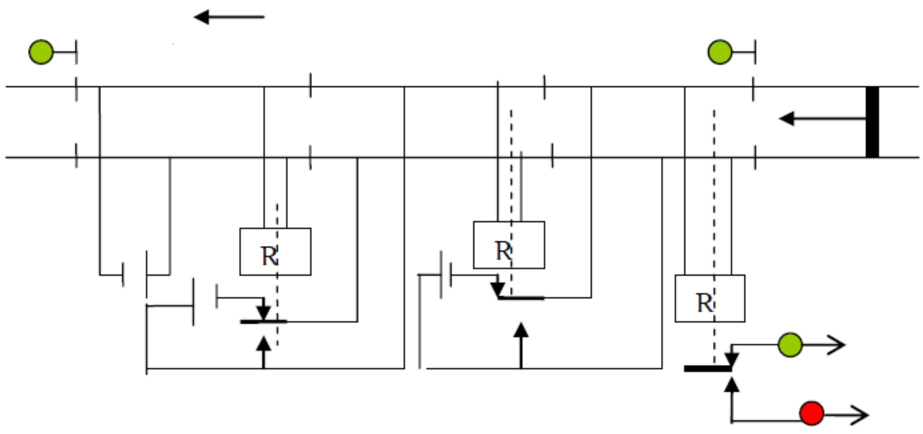


Figure 3.8 Block signal circuits (MEB 2013)

Figure 3.9 illustrates the by 2-block and 3-signal decleration design, related to the block signal circuit. The T relay in this example is used for control purposes. When the line is empty, the signal turns green. With a train moves at the right direction, short circuit position information is received from relay R contacts and the signal turns red. By the train moves to the last block, the relay T contacts are turned on and the red signal turns yellow. When the train leaves the block completely, the contacts of the other relay T are turned on and the yellow signal turns green.

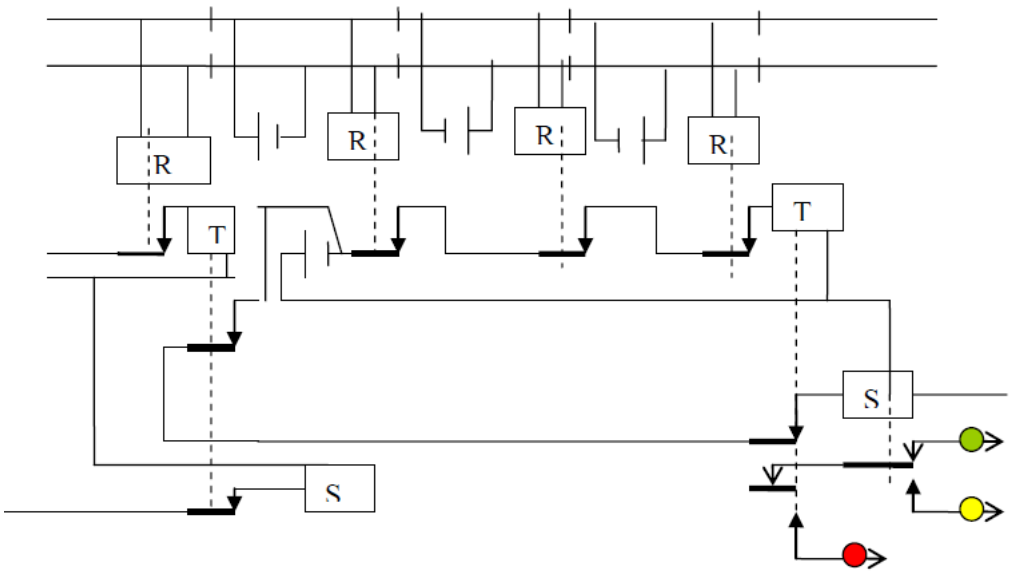


Figure 3.9 Block signal circuit (MEB, 2013)

3.3.1.2 Track Circuits

Track circuits known as electronic equipment, which provide the position information of trains on the line, are divided into two as AC and DC. DC track circuits are used in Turkey. The operating principle of the DC track circuits is based on the correct voltage supply of 1.5 to 12 V to the rail blocks divided on the line. When a train passes over these rail blocks, a short circuit occurs and the position of the relay connected to the rail block changes to closed. Thus, the presence of a train on the rail blocks is understood. Figure 3.10 shows an example of DC track circuit (MEB, 2013; EMO, 2019)

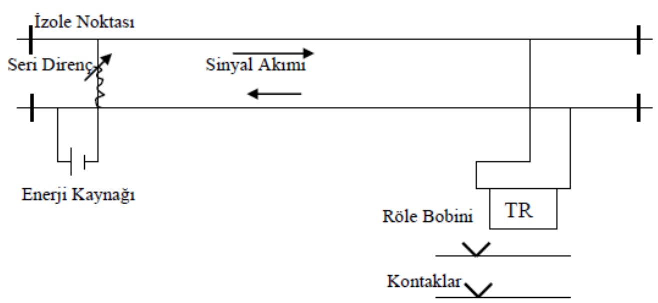


Figure 3.10 DC track circuit (MEB, 2013)

Track circuits are divided into four categories as isolated, coded, axle counter and mobile block track circuits.

3.3.1.2.1 Isolated Track Circuits. Track circuits at the blocks separated by isolated algebras apply voltage to these blocks. By checking this voltage, the presence of trains is monitored. When the subject is examined in detail, the supply voltage is applied on one side of the blocks and at the other side the incoming voltage is controlled. If the supply voltage applied is the same as the incoming voltage, it indicates that there is no train on this block. Similarly, when the train is on the block, when the rails are short-circuited, the incoming voltage is measured at approximately zero and it is understood that there is a train on this block. As a result, the train sensing system, which works as an inverse logic, when it shows that there is voltage it means that there isn't any train on the block, when there is no voltage, it means that there is a train on the block. The reason of this is known as safe working on the block. If any voltage is not measured back on the supply voltage due to cable break, short circuit, equipment failure and the like, it is assumed that there is a train on this block. In this case, even if a malfunction occurs in the system, it is possible to prevent accidents by creating a safe and secure environment (Söyler & Açıkbaş, 2005).

Figure 3.11 shows the principle electrical scheme of the isolated track circuit, and Figure 3.12 shows the principle scheme of the isolated track circuit. On these schemes an accumulator, a current limiting rheostat, a line relay, and a secondary circuit to the signals are located in a block above the line. If there is a train on this block, the resistance of the wheel and axle remains smaller compared to the resistance of the rail and relay, and the circuit is thus completed. In this case, the relay switches to the short-circuit position via the parallel connection and is de-energized. The same applies to the battery and goes into the discharge state. In order to prevent this situation, the current limiting rheostat is connected to the accumulator in series (Saygın et al., 2009).

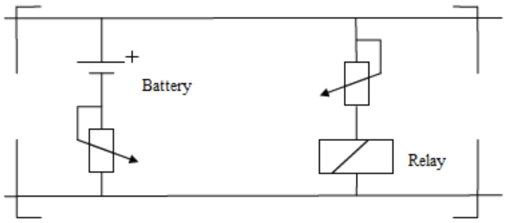


Figure 3.11 Principle electrical diagram of isolated track circuit (MEB, 2013)

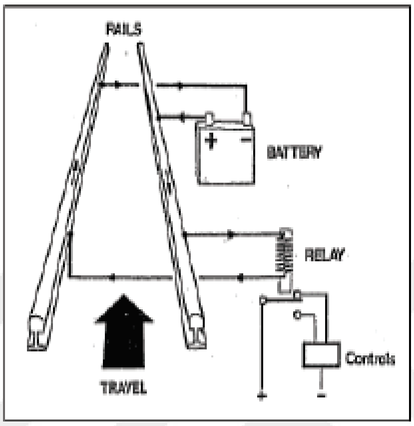


Figure 3.12 Principle diagram of isolated track circuit (MEB, 2013)

Iron bars which are made of mild steel and which connect the two ends of the rails to each other are called algebra. The number of holes on the algebras are 4 or 6. Figure 3.13 shows an algebra and an algebra block. Isolated algebra is used in the areas where the signals are on the line and where the blocks are separated. Their purpose is to prevent algebras from touching each other. An example of Isolated Algebra is given in Figure 3.14 (TCDD, 2003).

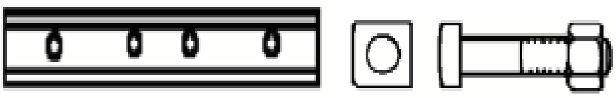


Figure 3.13 Algebra and Algebra Blok (MEB, 2013)

Figure 3.14 Insulated algebra (MEB, 2013)

3.3.1.2.2 Coded Track Circuits. The coded track circuit delivers the voltage generated by the transmitter to the rail at regular intervals and feeds the track circuit. This voltage, which is given at regular intervals, is controlled by the receiver. The coded repeater monitors the codes on the relay regularly. It starts to work by transmitting the codes that are obtained by the demodulator regularly to the code repeater relay. In coded track circuits, the most preferred carrier wave varies between 2.5 Hz and 4 Hz (MEB, 2013).

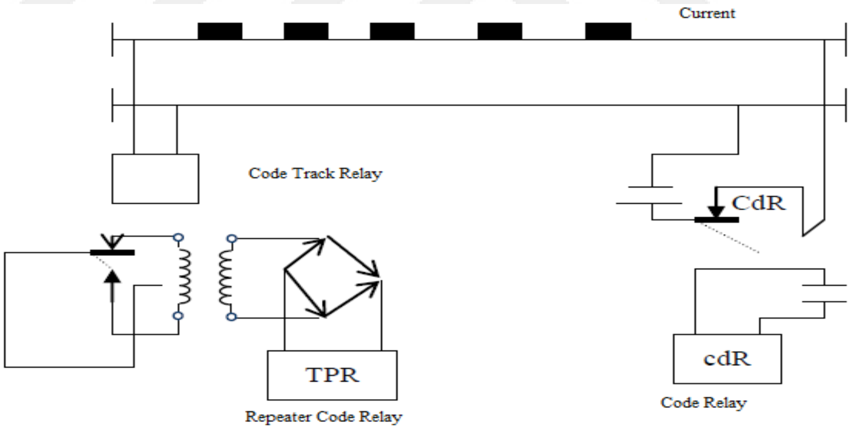


Figure 3.15 Coded Track Circuit (MEB, 2013)

In coded track circuits, also frequency is used besides DC voltage. The rails at the coded rail regions are separated by capacitive separators instead of isolated algebra. Figure 3.16 shows an example of a simple audio frequency track circuit. At one end of the block on the line the sound frequency is transmitted to the rail using the transmitter and at the other end the frequencies transmitted using the receiver are received and measured. The measurement of frequency is based on the method of comparing incoming and outgoing frequencies. When any deviation occurs in this measurement, from the fail-safe logic the presence of a train on the block is considered and this block is locked. Coded track circuits operating with sound frequency are widely used in fixed block systems installed in recent years. The purpose of this system is to detect the train within short distances. As an example, Ankaray rail systems and Taksim - 4. Levent Istanbul Metro is shown (Söyler & Açıkbaş, 2005).

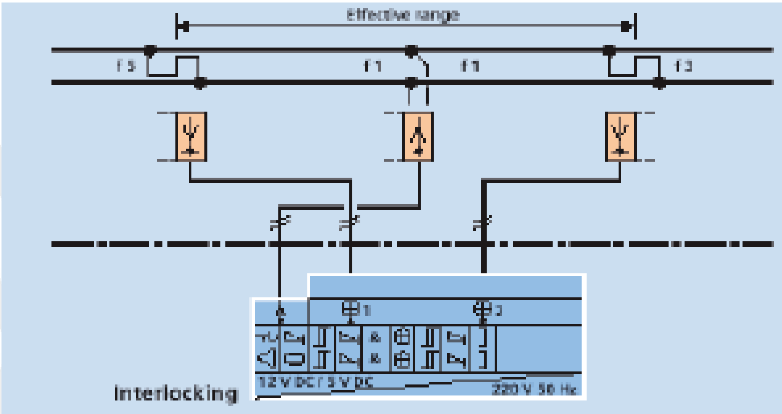


Figure 3.16 Example of a simple audio frequency track circuit (MEB, 2013)

3.3.1.2.3 Track Circuits with Axle Counter. Other type of track circuits is known as axle counter track circuits. With these circuits, which count the number of wheels of the trains, with another word the number of axles, entering and exiting the block on the line, it is understood whether the train is in the designated area. Also, the number of axles entering and leaving the specified block is controlled as a ratio. In cases where this ratio is not equal, it is assumed that there is a train on the block considering on the fail-safe logic. This system is generally used in intercity rail systems. The reason for this is known as not using isolated algebra in the track circuits system with axle counter. Compared to other track circuits, it can be made easier to maintain. As an example, the system used in Bursaray line is seen. In Figure 3.17, an example is given about the track circuit with axle counter (Söyler & Açıkbaş, 2005).

Figure 3.17 Track circuit with axle counter (MEB, 2013)

3.3.1.2.4 Dynamic Block Track Circuits. Dynamic block track circuits are based on the distance and braking force and curved slope parameters in the determined area. The distance in front of each train is automatically adjusted by the computer program in the controlled center. In this way, the speed control of the trains can be controlled remotely. In this system, the distance is controlled by the track circuit, which increases the capacity of the line. When these features are taken into consideration, it is more advantageous to use this system in which the trains can turn within 90 seconds period. As an example, the moving block system used in Ankara Subway is shown (Söyler & Açıkbaş, 2005).

In railways with dynamic block system, the line is divided into certain intervals. All these sections have communication system but they are controlled by computer. In line with this system, the position information, speed and direction of each train are sent to the main system center. All necessary calculations are made here. Then the necessary information is transmitted to the train on the same line. Every train in this system sends status information continuously via radio connection. Figure 3.18 shows an example of this system. This system is called communication-based train control (TCDD, 2003).

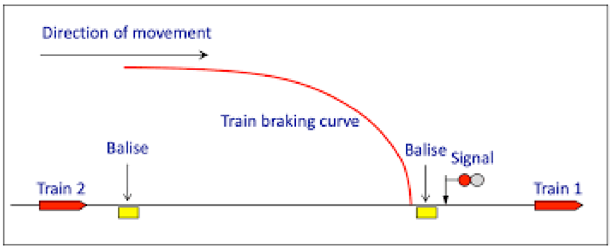


Figure 3.18 Dynamic block system diagram (MEB, 2013)

3.3.1.3 Switches

The movements of the trains to different directions along the line are provided with the switches. According to the fail-safe logic in the signaling system, If there is a train in the area or a suspicious situation occurs the command system does not work (Can, 2001). In Figure 3.19, a simple switch signalization application is given as an example.

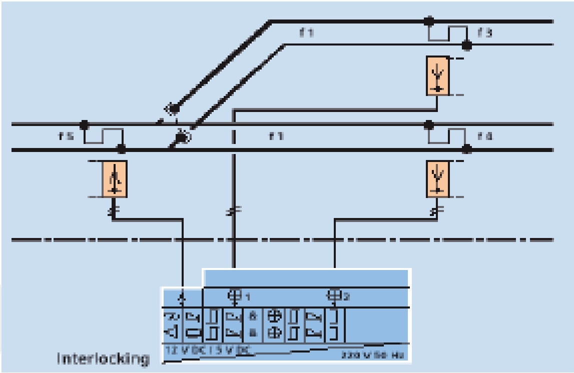


Figure 3.19 A simple switch signaling application (MEB, 2014)

.

The switches are called in two different ways; left and right. When viewed from the tongue end of the switchs, this switch is referred to as the left switches when the line of retention is on the left side of the main line, and the right switches when it stays to the right. In terms of switch circuits, serial and parallel line circuits come to the forefront. Nowadays, generally serial switch line circuits are used. The reason for this is that the relay is de-energized in case of any break in the circuit and it means that there is a defect in the system. The change of direction of the trains on the line by means of scissors is called scissor arrangement (MEB, 2014).

Switches are divided into two different groups according to their direction and the work they perform (Karaca, 2019).

I. Switches according to their directions

a) Right switches

b) Left switches

c) Symmetrical switches

d) Curved switches

II. Switches according to construction and occupation

a) Simple switches

b) Combined switches

• Right combined switches

• Left combined switches

• Right-left combined switches

• Left-right combined switches

• Symmetrical combined switches

c) Cross switches

• Half (simple) cross switches

• Full (combined) cross switches

3.3.1.3.1 Direction of the Switches.

a) Right switch: The switch used when a train passes from the current line to the right is known as the right switch.

b) Left switch: It is known as a left switch that used when a train passes from its current line to the left.

c) Symmetrical switch: The switch that used when a train passes from the current line to both the right and left, it is known as symmetrical scissors. Symmetrical switches are shown as an example in Figure 3.20.

d) Contour Switches: known as the switch used in the curved region.

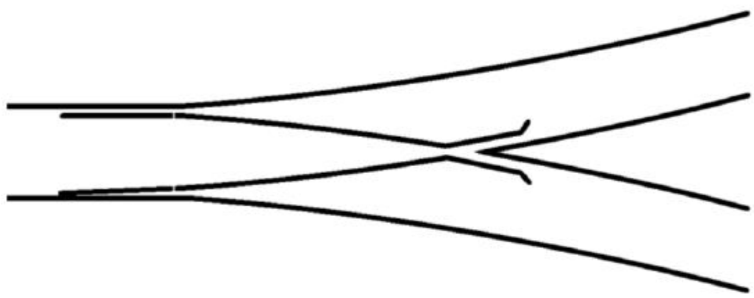


Figure 3.20 Simple switch (Karaca, 2019)

3.3.1.3.2 Switches Based upon Construction and Occupation.

a) **Simple switch:** With simple switch, a train can only change two different ways. In other words, a train is guided by simple switch to the other road on which the train uses, and vice versa. In addition, simple switch do not have a locking system. Figure 3.21 shows an example simple switch (MEB, 2014).

Figure 3.21 Simple Switches (MEB, 2014)

b) **Compound Switches:** Compound switches consist of simple nested switches. By using compound switches, it is possible to make the transition of a train from the existing line to three different directions. In other words, a total of three different directions are used as the line currently used by the train and in addition two slings. Compound switches are generally preferred in warehouse and station sites and are not used in operating lines. Figure 3.22 shows an example compound switches (MEB, 2014).

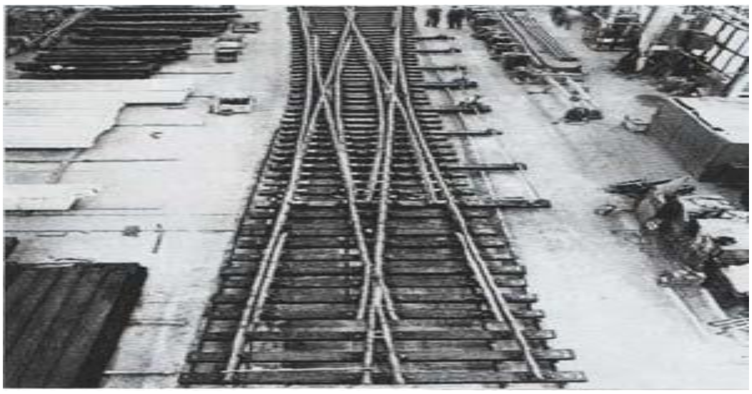


Figure 3.22 Compound switches (MEB, 2014)

In addition to these, there are five different types of compound switches:

• Right compound switches

• Left compound switches

• Right-left compound switches

• Left-right compound switches

• Symmetrical compound switches

Figure 3.23 shows the drawing of the compound switches types.

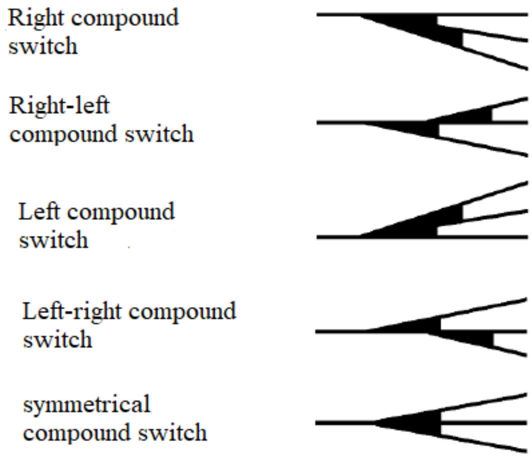


Figure 3.23 Comound switches (Karaca, 2019)

c) Cross Switches

The cross switches provide transitions in more than one direction and are generally used to provide transitions on two intersecting lines. The cross switches are able to handle the orientation of three or four simple switch simultaneously. For this reason, it is frequently used in storage areas, yard areas and maneuvering areas. In addition, cross-switches do not have the ability to change direction. Figure 3.24 shows an exemplary cross-cut (MEB, 2014).

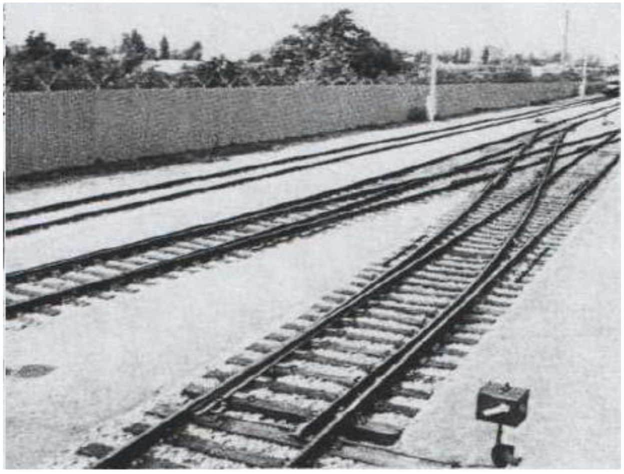


Figure 3.24 Cross switch (MEB, 2014)

In addition to these, there are two different types of cross-switches;

- Semi Cross Switches: This type of cross switches has four tongue and hub. Figure 3.25 shows the semi crossed switches and maneuvering directions.

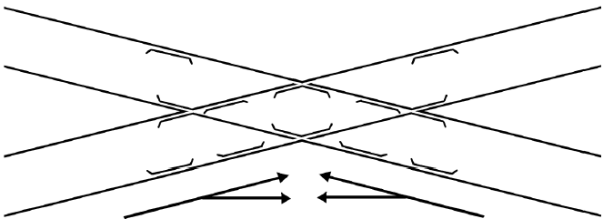


Figure 3.25 Semi Cross Switch (Karaca, 2019)

- Full cross switches: This type of cross switches has eight latch and hubs. Compared to half crossed switches, the maneuverability of this type of switchesappears to be greater. Figure 3.26 shows the half-crossed switches and maneuvering directions.

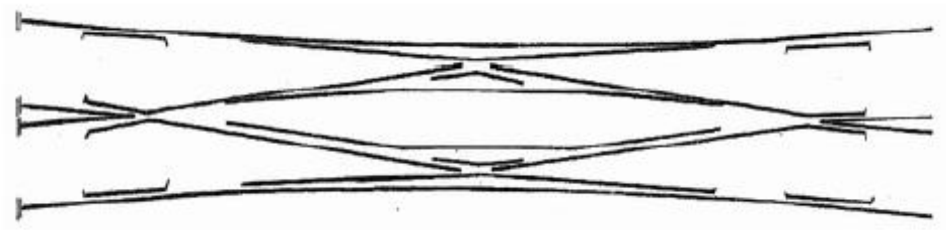


Figure 3.26 Full cross switches (Karaca, 2019)

3.3.1.4 Relays

Centralized Traffic Control - With CTC, train traffic is managed and dispatched. There are relays in the circuits used in this system which serve as locking along the line. These relays, which are known to be of vital importance, are not touched again after necessary adjustment and maintenance. In addition, there are relays which are controlled by the dispatcher at the head of the control machine. When the number of contacts of the relays used in the systems is insufficient, repeater contacts of these relays are used. In terms of the internal structure of the locking circuits, relay circuits can be installed between different battery poles. An example is the completion of the circuit by connecting a contact of the relay connected to the positive pole of one battery to the negative pole of another battery located at a distance. For these two battery groups, they are required to have the same voltage and maintain their current voltage. Relay electrical expressions are shown in Figure 3.27 (MEB, 2011).

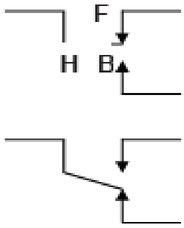


Figure 3.27 Electrical Representations of Relay (MEB, 2011)

• H (heel): heel,

• F (front): front contact,

• B (back): rear contact,

• Energetic position; front contact closed, rear contact open,

• Non-energized position; front contact open, rear contact closed.

3.3.1.5 On Board Equipments

With electronic units in the trains, information from the signaling system is received and the train is controlled with this information. These equipments, which provide the movement of the trains according to all the light signals on the line, are considered as the most important component of all systems. On-board equipment when the machinist or driver drives the train, warns the machinist or driver firstly, when either the speed limit or the various safety rules are obeyed. In addition, the trains ensure that the train stops in the event of a coupling breakage, opening of doors outside the station, a failure in the braking system and the like, or a perceived obstacle in the signal system and exceeding the defined maximum speed.

In addition to this, it is possible to activate the safety methods and stop the trains in automatic systems without the need of alerting the machinists or drivers. When the accidents that occur in railway systems are examined, it is seen that most of the accidents are caused by turning off the equipment on the train and driving manually (Söyler & Açıkbaş, 2005). Figures 3.28, 3.29, 3.30 and 3.31 show some of the on-board equipment.

Figure 3.28 Automatic train stop system (Savronik, 2019)

Figure 3.29 Train control computer (Savronik, 2019)

Figure 3.30 Speed sensing unit and speed indicator unit (Savronik, 2019)

Figure 3.31 Data recording unit (Savronik, 2019)

3.3.2 Central Interlocking

Another basic element of the signaling system is known as the central interlocking. The central interlocking of electronic cards, which is operated by logic functions, is known as the brain of the system. Central intercommunication, which sends and receives commands by communicating with field equipment, determines the routes of the trains (Karayanık, 2017).

In all systems, electronic locking system is known as more reliable and faster than relay locking circuits. In addition, this system has the ability to lock both the computer and fully electronic. The modular hardware and software in the electronic locking system makes it easy to implement changes in the line plan. Interfaces forming this system are known as station control panel, locking processor, input and output control unit and signals on the line (Can, 2001).

The information of the equipment on the whole line is collected in the control center. Using this information, it is decided which block a train should enter. In addition, the exit of the train entering a block or a truss zone is monitored and the area in which the train is locked until this train leaves. Thus, no other maneuvering or operations can be made within this area. In addition, it is not possible for trains to enter the unauthorized block. Otherwise, ATC (Automatic Train Control) and ATP (Automatic Train Protection) systems intervene and stop the train and prevent possible collisions and similar events (Söyler & Açıkbaş, 2005).

Relays are used in the systems used before the central locking system. In other words, when a train arrives on the block, the relay controlling the block is provided to provide information flow and prevent the execution of other commands. Nowadays, software interlocking system is used according to fail-safe logic in new systems. Central locking systems include at least 2 industrial computers. The information that comes to and from these computers is primarily compared. When a difference is observed as a result of this comparison, the command is not implemented (Yıldırım, 2010).

The locking functions of the central system are listed as follows (Karayanık, 2018);

- Blocking all other blocks except the route of the train going on the line,
- Considering the change of the route of the train going on the line, blocking all other blocks outside the route and positioning the light signals and trusses on the route that the train will follow to the correct position,

• Following the light signals on the whole line and adjusting the trains according to their position,

• Light signals and scissors for the next train after the trains on the line leave the blocks.

The central interlocking table is known as the table in which the operations necessary for the realization of a specified route are arranged. Figure 3.32 shows an example of a station and Table 3.1 shows the central interlocking table prepared for the route 1BT-2ST.

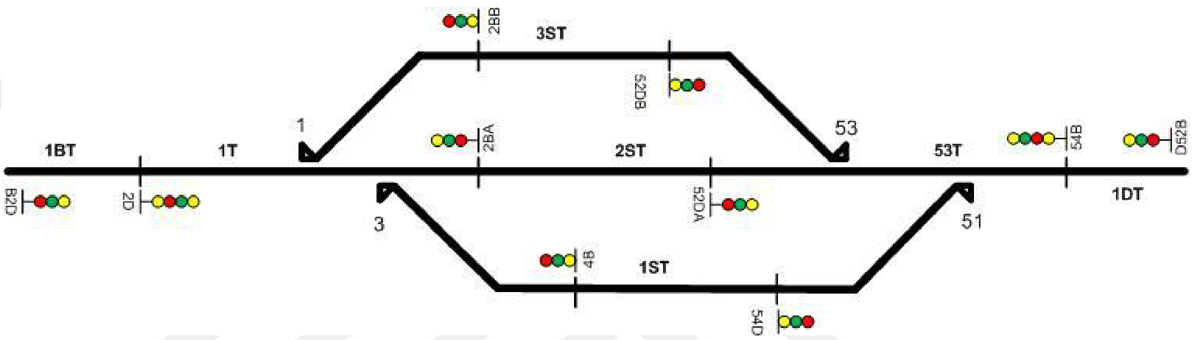


Figure 3.32 An example station (Eriş, 2011)

Table 3.1 Central interlocking table (Eriş, 2011)

		Signal Status				
Route	Signal No.	Colour	Prerequisite	Switch	Signal Lock	Route Lock
		G	52DA G, Y			
1BT-2ST	2D	Y	52DA R	1(N)	2BA,2BB	001BT-1T-2ST
		YR		3(N)	4B,54B1	

CHAPTER FOUR
COMMUNICATION SYSTEMS

4.1 Communication

Communication is defined as the transmission of audio, image, video, data and similar information from a designated point to another point in a more secure and high-efficiency manner. The communication system consists of four different circuits, the source on which the information is generated, the sender, the communication area and the receiver. The main conditions that ensure the quality of information in communication are listed below (Karakuş, 2011);

- The capacity of the communication area,
- Considerations such as comprehension, recognition, feeling and delay in voice transmission,
- In image transmission, adherence to the original image,
- The number of picture frames per second required for eye detection in video conference transmission,
- Bit error rate in data transmission.

4.1.1 Communication System Components

The communication system consists of four different components. Figure 4.1 shows an example of these components.

Figure 4.1 Communication system components (Karakuş, 2011)

4.1.1.1 Transmitter

The transmitter, one of the building blocks of the communication system, is known as an electronic circuit that transmits information into the desired format. Today, the frequency range is determined for each of the transmitters used for radio and television broadcasts. The reason for this is known to be the confusion of the information sent by the transmitters. In addition, the transmitters can transmit information in accordance with their power. For example, the power of the radio transmitters ranges from 2 to 600 watts and the power of the radio transmitters ranges from 1000 to 10 K watts. Figure 4.2 shows the block diagram of a transmitter (MEB, 2011).

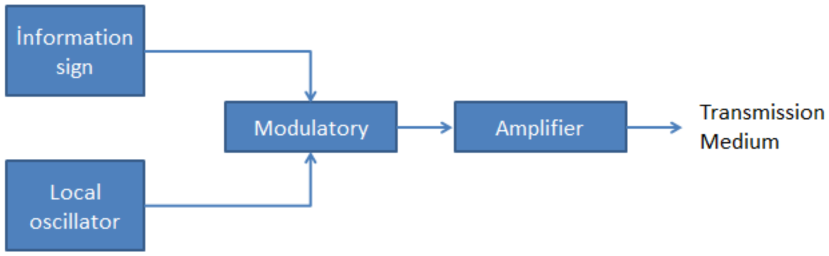


Figure 4.2 Block diagram of a transmitter (MEB, 2011)

4.1.1.2 Transmission Medium

The transmission medium is defined as the area through which information is transmitted between the transmitter and the receiving source. As an example of this situation, the information coming from the television transmitting antennas to the antennas in the houses is used the air as the transmission medium and then the transmission of the information to the televisions. Today, the most commonly used transmission environments are listed as follows.

- Copper cables; twisted pair and coaxial cables,
- Waveguides,
- Fiber optic cables,

- Natural environments such as air, space and water.

4.1.1.3 Distortion and Noise from Transmission Medium

Any information from the transmitter source to the receiver is subject to various distortions. Some of the causes of these disturbances are caused by the transmitter and some by the transmission medium. There may be signal attenuation, delay distortion, intermodulation distortion, noise that may occur in a transmission medium (MEB, 2011).

4.1.1.4 Receiver

The receiver is defined as electronic circuits in which the information sent by the transmitter source is collected and changed back to the desired information format (MEB, 2011). Figure 4.3 shows the block diagram of a receiver.

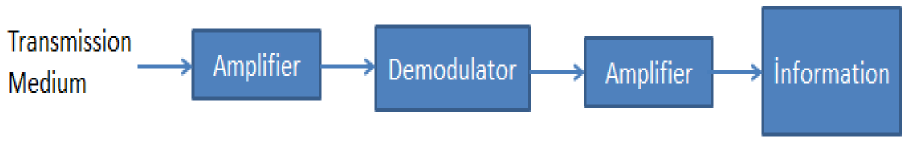


Figure 4.3 Block diagram of a receiver (MEB, 2011)

4.1.2 History of Communication Systems

The concept of communication is known as one of the most important needs of human beings. In ancient times, people tried to communicate through smoke by fire, and by using instruments such as drums, pipes and whistles, through sound.

Looking at the developments in the world (Karakuş, 2011);

- Around 3000 BC a writing system called Egyptian hieroglyph was found. These articles consist of human, animal and article forms.

- Papirus was discovered by Egyptians in 1045 BC. Later, in China, the inventor named Pi Cheng invented the printing press and published the book for the first time.
- In 1820, the Danish scientist Oersted discovered the electromagnetic current and helped form the cornerstone of modern communication tools.
- In 1826, his photograph, one of the most common means of communication, was discovered by French Niepce.
- In 1873 Maxwell invented electromagnetic wave equations.
- In 1876, Graham Bell, a Scottish researcher, succeeded in transmitting the first human voice through electrical wires.
- In 1877, American researcher Edison invented the first instrument for recording sound, which he called the FonoGraf.
- In 1896, the Italian Marconi succeeded in broadcasting in Morse code.
- In 1922, German scientist Korn invented the first fax machine capable of sending photos from electrical wires.
- In 1926, the Scottish scientist Logie Baird developed a device called Tele-Vision, which was able to transmit the image of the human face over multiple distances by radio waves.
- In 1946, American scientists Eckert and Mauchly invented the world's first computer to calculate the military. This computer, called ENIAC, is known to weigh approximately 30 tons.
- In 1962, Americans launched the world's first communication satellite, TELSTAR, into space. Thanks to this satellite, telephone calls, television and radio broadcasts have been started.

Looking at the developments in Turkey (EMO, 2019);

- In 1840, Türk Telekom was founded by Sultan Abdülmecit under the name Postahane-i Amirane.
- In 1847, the first telegraph reception and reception was successfully completed.
- In 1929, intercity single circuit communication was realized between Ankara and Istanbul.

- In 1940, two single-channel overhead multiplexer systems were communicated between Ankara and Istanbul.
- Fiber optic cable, which increased the channel capacity in communication in 1985, was laid underground in Ankara for the first time and a 140 Mb / s system at 1310 nm wavelength was put into service.
- In 1990, TURKSAT National Communication Satellites agreement was signed with the French Aerospatiale company.
- Turkey met with GSM technology in 1994.
- It is Turkey's first satellite launched into space in 1994. Turksat.
- In 1996, Turkey's second satellite was launched Turksat 1C space.
- In 1997, digital line multiplexing systems were introduced to optimize the use of the audio frequency cable network.

4.1.3 Types of Communication Systems

In communication technology, a transmission medium is needed to transfer information using transmitters and receivers. This transmission medium is divided into two parts as wired and wireless.

4.1.3.1 Wired Communication

In communication technology, wired communication is provided by twisted pair, coaxial and fiber optic cables (Brahms, 2019).

• **Twisted Pair Cables:** They are used in telephone lines. The most important feature of this cable is that it enables the transmission of data without being affected by electromagnetic waves and radio frequencies.

• **Coaxial Cables:** They are used in television lines. Looking at the internal structure of this cable, there is a copper cable with insulation in the middle and a larger cable surrounding it. During communication, the data is passed through the copper cable in the middle of the cable. The wider cable outside has a protective function against electrical influences. Coaxial cables can transfer data up to 10 Mbit.

• **Fiber optic cables:** Fiber optic cables, which are made of thin glass, are used for data transmission over wideband ranges. The most important feature of these cables is the transmission of data over long distances without any loss.

4.1.3.2 Wireless Communication

The age of wireless communication has begun with the new needs and devices that emerged as a result of the rapid progress of technology. Wireless communication uses transmission environments such as air, water and space. In wireless technologies, data transmission is provided by infrared, radio frequencies, bluetooth and microwave, which are collected under the heading of electromagnetic waves. Figure 4.4 shows the order of electromagnetic waves according to their wavelengths. Certain band ranges of electromagnetic waves are licensed by the Federal Communication Commissin (FCC) to different institutions or organizations. Parts outside this band gap are used in areas such as industry, science and medicine without restriction. Figure 4.5 shows the frequency ranges related to radio waves and their usage areas (Söylemez, 2014).

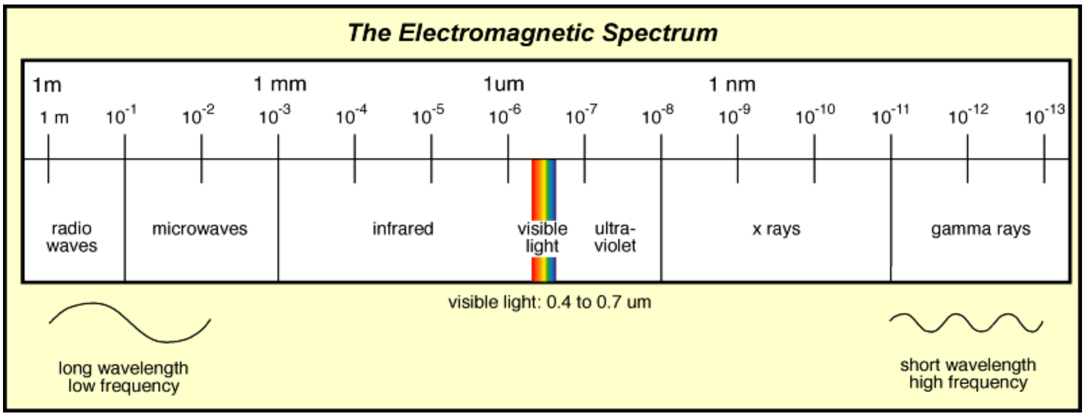


Figure 4.4 Order of electromagnetic waves by wavelength (Söylemez, 2014)

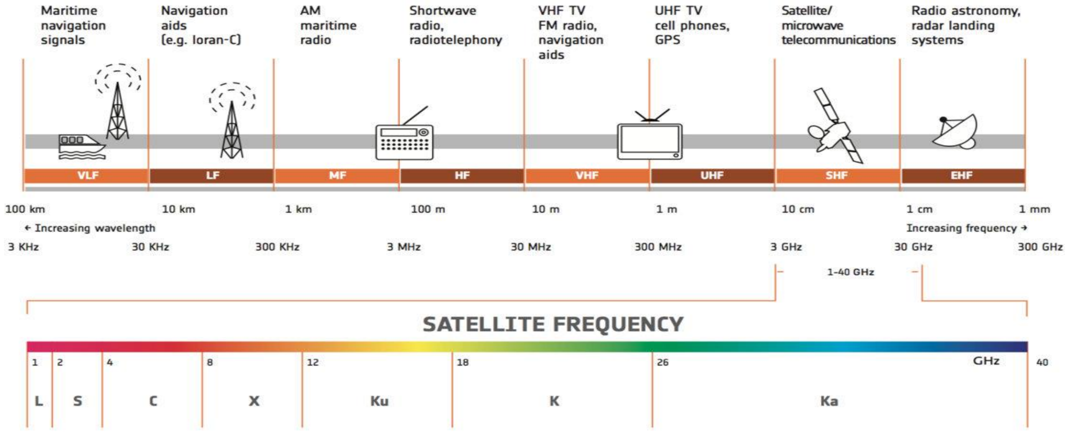


Figure 4.5 Radio waves and frequency ranges (Söylemez, 2014)

- **Infrared:** A type of wireless communication in which data is transmitted using light and wave methods. This wavelength used for short distances and it does not pass through walls and similar obstacles. For this reason, in the communication using infrared, the transmitter and receiver must be close to each other and must be directly visible. This wavelength is preferred for personal computers and ancillary equipment and for devices operating with remote control. Infrared data transfer at 900 MHz is provided (Söylemez, 2014).

- **Radio Frequency:** Compared to infrared, radio frequencies have the ability to pass through walls and similar obstacles and have a wider bandwidth. As shown in Figure-4.6, the 900 MHz frequency range is reserved for WLAN use, the 2.4 GHz frequency range for wireless telephone devices and the 5 GHz frequency range for the use of computers and similar devices (Söylemez, 2014).

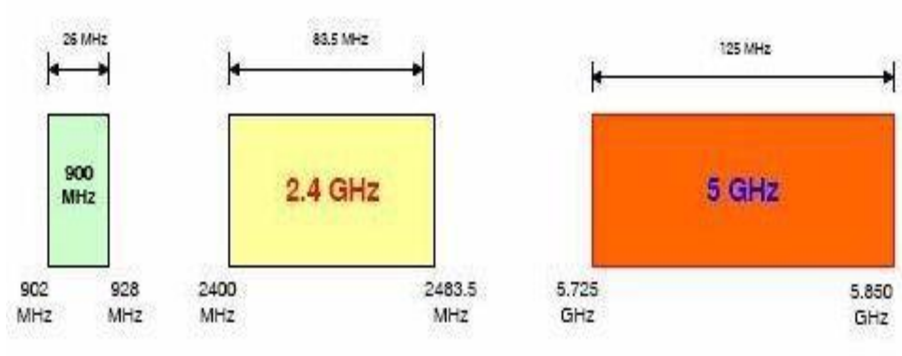


Figure 4.6 Radio frequency fand intervals (Söylemez, 2014)

- **Bluetooth:** Bluetooth, first found by Erikson, is known as a wavelength used in short distances. A data transmission of approximately 1 Mbps is provided via Bluetooth. For Bluetooth-enabled devices, the devices must be identified to each other to ensure data transfer (Brahms, 2019).

- **Microwaves:** It is known as a wavelength where data flow is achieved at very high speeds compared to other wavelengths. Stations are used to provide data flow with microwaves. This is known as the fact that this wavelength can move along a straight line and interrupt communication with walls and similar obstacles (Brahms, 2019).

4.1.4 Communication in Transportation Systems

As a result of technological developments and population growth, the increase in the number of vehicles in traffic has become an important factor. In order to prevent this situation, there is a significant increase in public transport. In addition, intelligent transportation systems are being developed in order to ensure that all vehicles can proceed in an orderly and safe manner. The purpose of intelligent transportation systems, which use computer, communication and electronic technologies together, is determined to increase the safety of traffic and shorten travel times (Raut & Devane, 2017).

Intelligent transportation systems are developed under three different factors: road, passenger and vehicle. Wired and wireless communication systems are used to transfer all data related to these factors to the required systems. Fiber optic cables, copper cables, ethernet cables (CAT5 and CAT6) are used in wired communication. Wired communication is not preferred much because of the distance between land and rail transportation within the smart transportation systems (Tufan, 2014).

Air is the most commonly used communication medium in wireless communication technology used in intelligent transportation systems. In this communication, three different protocols are used to ensure the data flow between the transmitter and receiver. The first protocol is known as a communication protocol in which there is a transmitter and a receiver in the system. In this protocol, the transmitter is only capable of sending data to the receiver and the communication direction is expressed as simplex. The second protocol is based on the principle that the transmitters within the system can operate as receivers and the receivers as transmitters. Similar to the first protocol, a transmitter and a receiver in the system can provide data transmission and the communication direction is expressed as full duplex. The third protocol is based on the ability of all transmitters and receivers in the system to transfer data to each other. The communication aspect of this protocol is defined as full duplex (Sarıkaş et al., 2018). Figure 4.7 shows the types of wireless communication technologies.

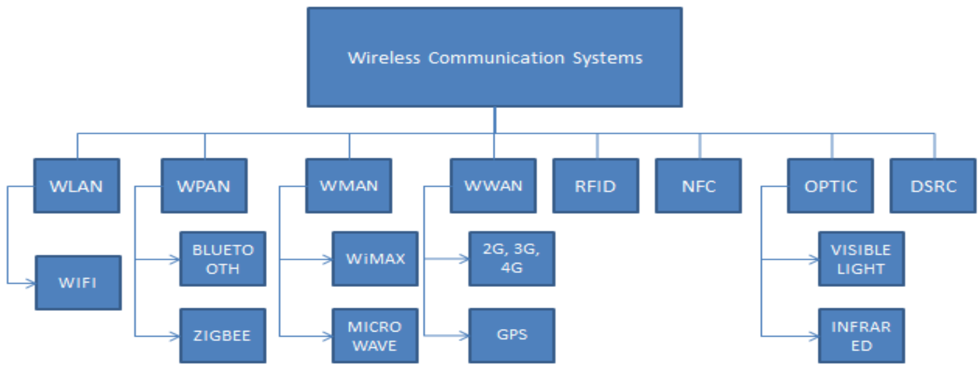


Figure 4.7 Types of wireless communication technologies (Sarıkaş, Yayla & Polat, 2018)

RFID (Radio Frequency Identification), which is one of the wireless communication technologies, is used to identify all objects within the transportation as singular and plural. All data for objects is automatically saved. RFID consists of two basic parts: tag and reader. The label, divided into active and passive, consists of a microchip and an antenna connected to the microchip, in which data from the objects are stored. In smart transportation systems using RFID, where the location information of vehicles, electronic ticket fare collection, order and collection operations in freight management system and logistics tracking are provided (Yüksel & Zaim, 2008).

CHAPTER FIVE
THE IMPLEMENTATION OF COMMUNICATION-BASED TRAIN CONTROL SYSTEM

5.1 System Block Diagram

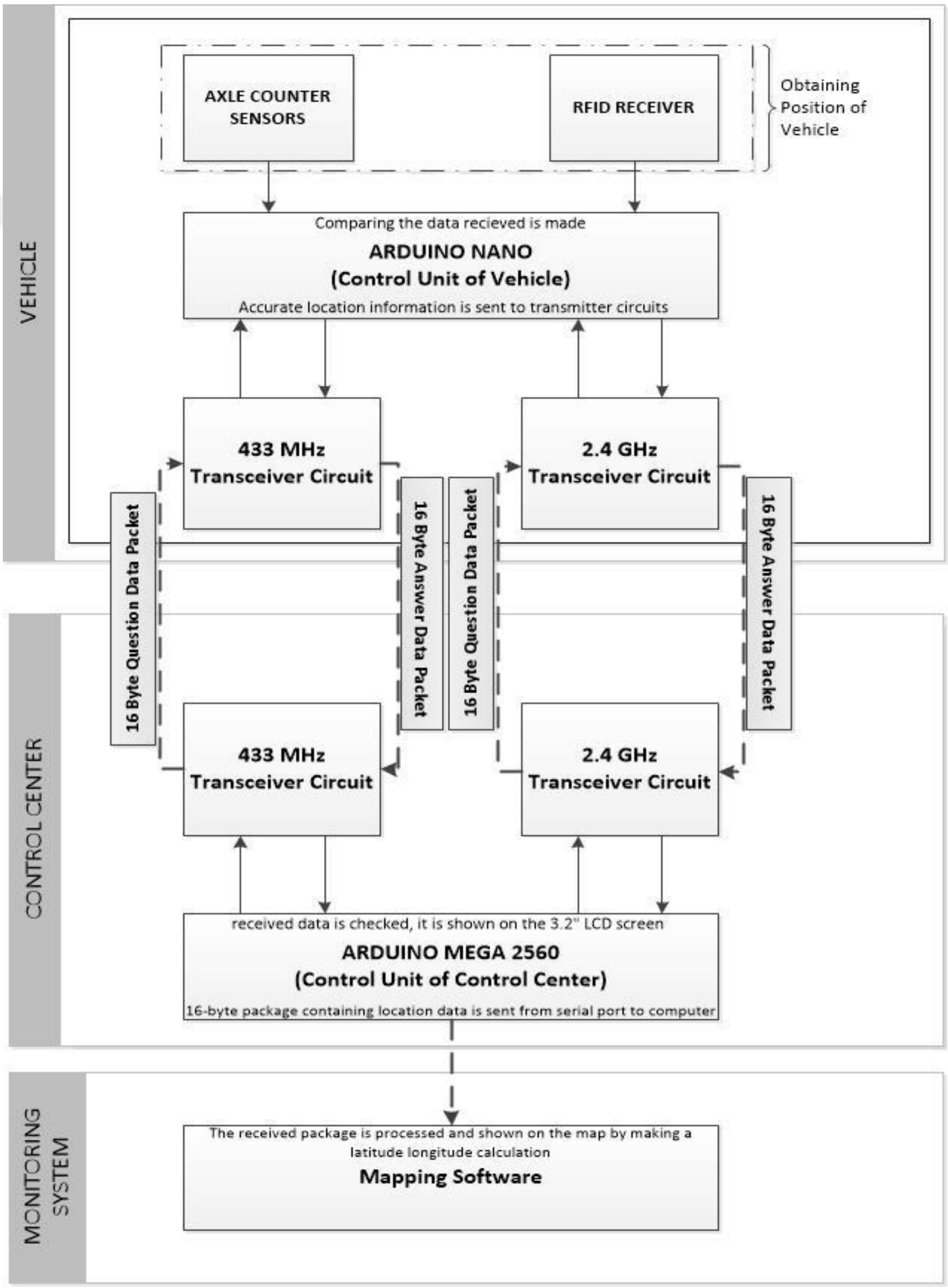


Figure 5.1 Block diagram of the introduced system

The introduced system consists of three main headings: vehicle, control center and monitoring system. The first part of the vehicle is obtained location information and transferred to the control center. The location information received in the control center is proccessed and sent to the mapping software via serial port. Finally, the location information received is tracking instantly over the map.

5.2 Purpose of the Project

Radio system is used for communication in all railway systems. In the open area, data communication is made by rf transmitters, in closed environments as tunnel etc., data communication is made by means of a leaky feeder cable. The project aimed to obtain the location information of all kinds of vehicles on the railway using the existing radio infrastructure. The system is designed for two-way data communication, which backs up each other for location information, increases system security and minimizes data loss.

5.3 Importance of the Project

The project is intended to obtain and transfer location information. An important part of the signalling system in railway systems is the acquisition of location information ant its transfer to the control center. The project sheds light on the local signalling system.

The project aims to use the existing radio infrastructure. In this way, in cases data communication can not be done or installing infrastructue at high cost in tunnel etc. places, data communication will be possible without interruption by means of existing leaky feeder cables.

The equipment can be added to every vehicle on the railway with practical and low costs. In this way, the system was designed in a way to monitor and control the vehicles such as coal trains, wagons, maintenance vehicles (unimog, grinding etc.).

As a result, every vehicle on the railway will able be tracked and the accident rate will be reduced to a minimum.

The position information of the vehicles, together with the control center, is designed to be visible to the vehicle on the route, the manual switch operator and the stations. Thus, control will be provided by more than one person.

In addition to the radio infrastructure, the system was backed up with the 2.4 GHz wifi system. With this system, it is aimed to both back up the system and gain the bandwidth. With the obtained bandwidth, systems that can send line status information (line collapse, bridge tunnel entrances and exits) to the vehicles traveling on the route can be added and the systems which can transfer camera images from the vehicles on the route to the control center.

5.4 Method of the Project

The project is based on the logic of locating the vehicles on the railway and transmitting this data to the relevant units.

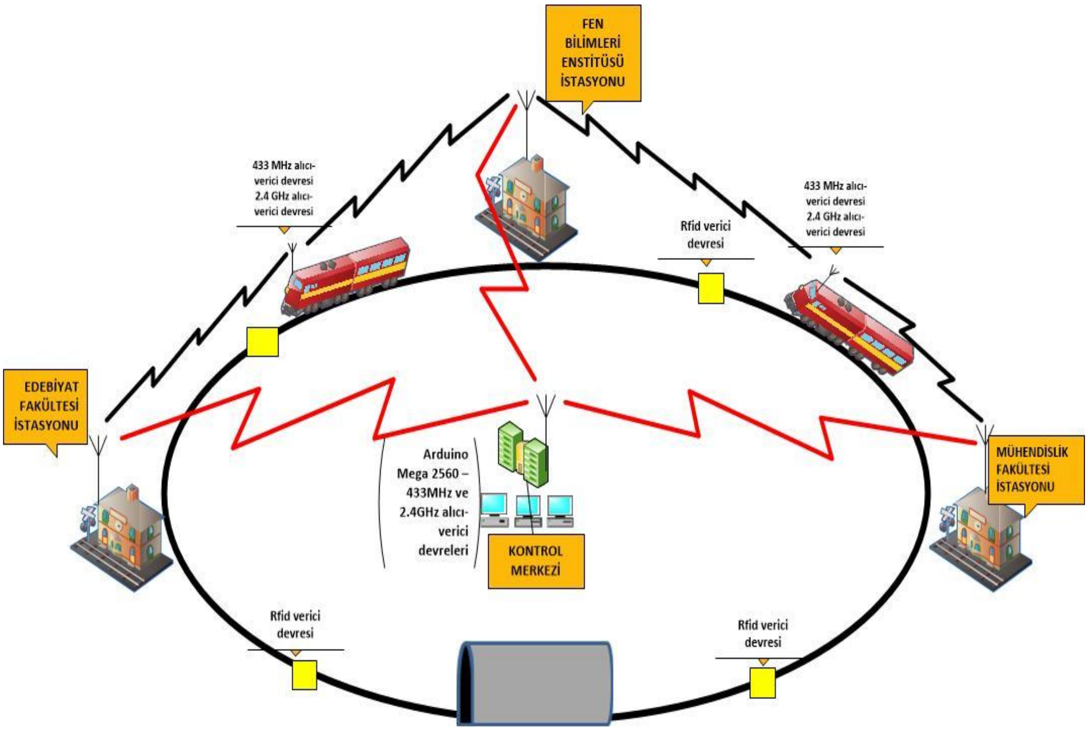


Figure 5.4.2 Planned communication structure

In order to obtain the positions of the vehicles, the axle counter placed on the vehicles and the rfid transmitters placed on the line were used. Axle counter sensors provide the vehicle's current location information. The rfid transmitter, whose position is predetermined on the line, transmits the location information to the vehicle passing over it.

The data obtained are transferred to the control center by the transceiver circuit operating at frequencies of 2.4 GHz and 433 MHz. The data obtained in the control center is compared and the correct information is transferred from the serial port to the mapping software.

5.5 Scope of the Project

The project covers the entire railway system. Communication can be provided by installing transceiver units in all kinds of vehicles on the railway. By placing an axle counter on the vehicle and a rfid antenna on the line, location information is obtained and transferred to the mapping software.

5.5.1 Obtaining Location Data

Two different methods were used to obtain location information in the project. The data obtained as a result of these two methods were compared in the in-vehicle control unit and the error rate was minimized.

5.5.1.1 Obtaining Location Information by Axle Counting Method

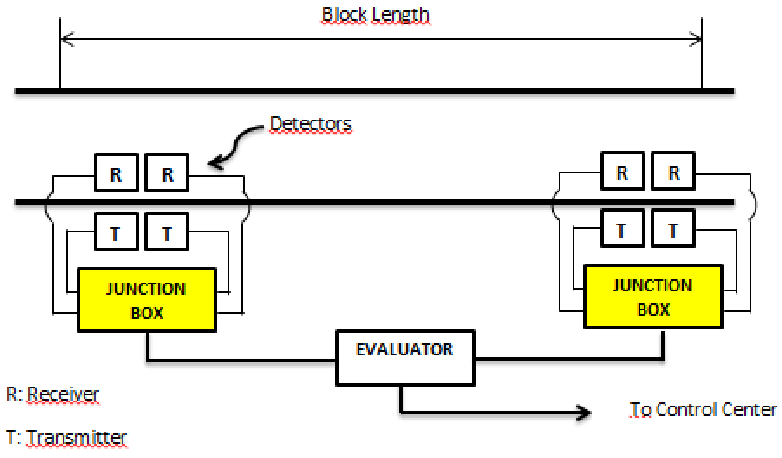


Figure 5.3 Axle counting method

In railway signalling systems, the axle counting system is based on the counting of the vehicle wheel by installing the axle sensors on the rail at station entrances-exits and block entrances-exits and informing that the vehicle is in that block.

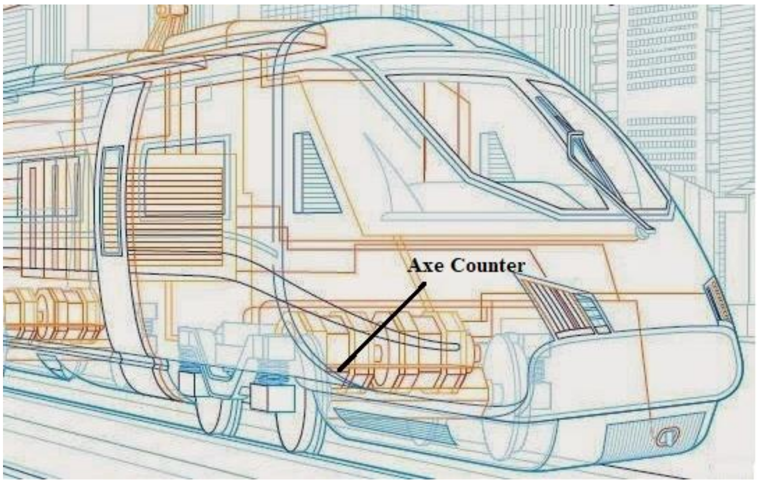


Figure 5.4 View of the mounting location of the axle counter sensors

In the project, different methods were applied. Axle counter sensors are placed on vehicle wheels. Instant location information is obtained by counting vehicle wheel turns.

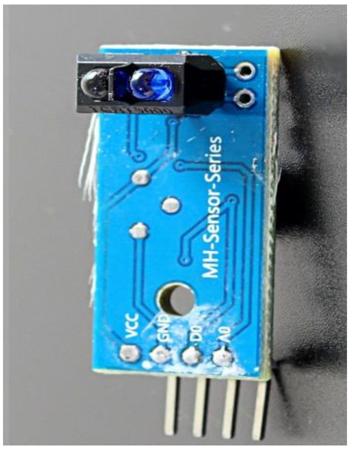


Figure 5.5 View of axle counter circuit (Personel archive, 2019)

The project uses TCRT5000 optical sensors mentioned in Figure 5.5. These sensors can be adjusted analog and digital output. The operation voltage is between 3.3 V – 5 V and these sensors are preferred because of they are suitable for supply voltage section in the application operation and their dimensions (30x16 mm) can fit JPin the vehicle. It has an IR transceiver sensor on it. The IR signal received by the receiving sensors is compared with the LM339 comparator integration, which outputs as 0 and 1. With the adjustable resistance (trimpot) on it, distance and sensitivity can be adjusted.

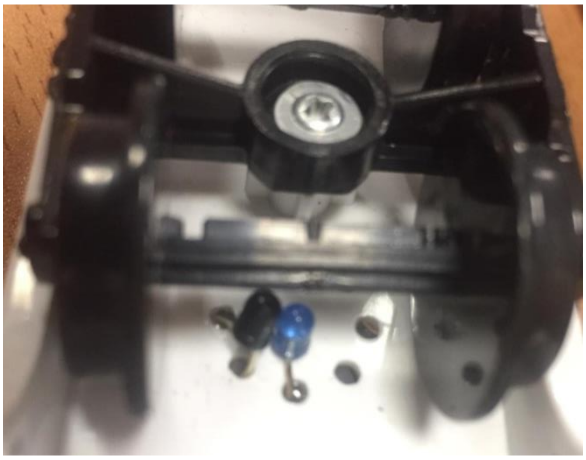


Figure 5.6 Image of the axle counter sensor where is mounted in the project (Personel archive, 2019)

In the application study, the circuit part was placed inside the vehicle and the sensors were placed in the axle area. With the wheel movement sensors begin to detect and count axle movement. Sensors will count four pulses on a full wheel lap. With each pulse perception of the sensor, the vehicle moved 1.57 cm. The number seven pin of the control unit in the vehicle is set as an entry and axle counter information has been forwarded here.

```
// tekerlek okuma rutini
void tekerlek_oku(void)
{
      if ((!digitalRead(tekerlek_sayac))&& (tekerlek_tek_say==0))
          {
            tekerlek_tek_say=1;
              tren_mesafe++;
          }
      if (digitalRead(tekerlek_sayac))
          {
            tekerlek_tek_say=0;
          }
}// tekerlek okuma rutin sonu
```

Arduino nano reads axle pulses with the codes specified in the above code. The distance information obtained here is uploaded to byte 10,11 and 12 on the package sent and transmitted to the center from the 2.4 GHz and 433 MHz transmitting circuits as location information.

5.5.1.2 Obtaining Location Information via RFID Method Over the Line

Due to the weather and rail conditions (rainning, snowing, ice, rails lubrication, crossing the curved rails etc.) of the vehicles moving on railway, measurement errors occur in the data receiving from axle sensors in cases such as sledging-locking-slipping of the vehicle wheels. Taking these situations into account, the position distance is confirmed by taking from the rfid antennas placed on the line at regular intervals. Thus, the acquisition of location information is backed up and the error rate is minimized. In the event of failure of any positioning method, the system will continue to run with the other method.

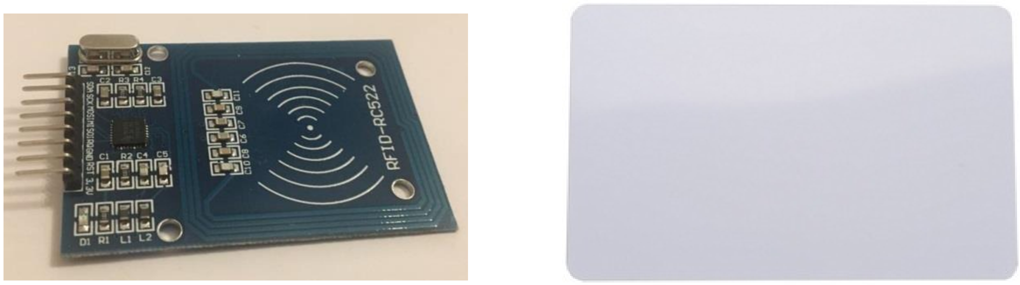


Figure 5.7 View of MFRC522 module and contactless smart card (Personel archive, 2019)

In the project, contactless smart card was used for rfid transceiver circuits in accordance with the MFRC522 module and ISO/IEC 14443A and MIFARE protocol stipulated in Figure 5.7. The operating frequency of the card is 13.56 MHz. This module is preferred because of the operating voltage of the module is 3.3 V and can fit under the vehicle. The RFID card was put under the track at certain distances.

Figure 5.8 View of the mounting location of MFRC522 module (Personel archive, 2019)

In the study, the MRFC module was installed under the vehicle. RFID cards were programmed with distance information. When passing through the vehicle over programmed cards, it transmits the location information to the control unit (Arduino-Nano) in the vehicle via MFRC522 module. The control unit (Arduino-Nano) compares the location information it receives from the MFRC522 module with the location information it receives from the axle counter sensors. The axle counter continues to count the distance information on the value it receives from the MFRC522 module. The actual positioning information obtained is sent to the center via the 2.4 GHz and 433 MHz transmitter.

5.5.2 Communication Systems used in this study

All railway systems uses radio communication. Communication is provided with radio base station in open areas with leaky feeder cables in tunnels. Communication was provided with the transceiver circuits operating at 2.4 GHz and 433 MHz frequency, which were received in accordance with the infrastructure of this system already used in the project. In this project, two sets of transceiver ciruit were used in both frequency bands. One of these sets is mounted in the vehicle and the other is mounted in the control center. Arduino Mega 2560 and 3.2” TFT LCD was used as control unit in the control center. With the control unit (Arduino Mega 2560) in the control center, the control units (Arduino Nano) in the vehicle communicate in both directions through these transceiver circuits. The control center questions all the vehicles on the line, respectively. The obtained position, speed and direction information is sent from the serial port to the mapping software.

Table 5.1 16 Bytes Data Packet Structure

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
PacketHeader					**Region**	**Train Id**	**Speed**	**Route**	**Location**			**Reserve**		**Checksum**	

In the project, communication between the control center and vehicles is provided in packets of 16 bytes and the data packet structure is as specified in the Table-5.1. The first five packets used as packet header. 6th Byte is reserved for area where the vehicle is located, and the 7th Byte is reserved for vehicle id. 8th byte is used for speed information, 9th byte is used for vehicle route information and 10th-11th-12th Bytes are used for positioning information. The 13th and 14th bytes are empty and can be used according to the data to be requested (failure information, emergency code information etc). The 15th and 16th bytes is reserved to check that the data is healthy.

5.5.2.1 Transceiver Circuits Operating at 433 MHz Frequency

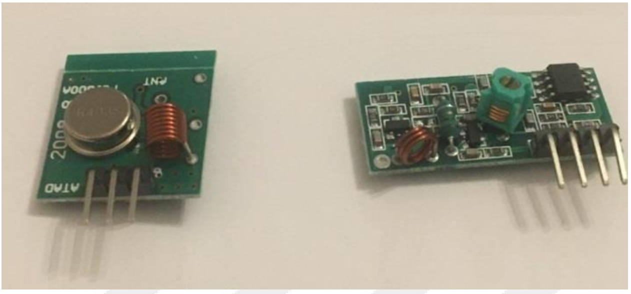


Figure 5.9 View of 433 Mhz transceiver circuit (Personel archive, 2019)

In the project, a set of 433 MHz RF transceiver modules, which are also depicted in the Figure 5.9, were placed inside the vehicle and in the control center and connected to the control units. It has a working capability between 5V – 12V supply voltage is used in the project. Signal communication is provided with ASK/OKK modulation in circuits that can reach 150 meters target in the open air. Circuit receiver has -103 dBm input accuracy.

```
buf[0]='T';
buf[1]='R';
buf[2]='P';
buf[3]='S';
buf[4]='T';

buf[5]=1;
buf[6]=tren_id;
buf[7]=(byte) tren_hizi;
buf[8]=tren_yon;
buf[9]=(tren_mesafe & 0xFF);
buf[10]=(tren_mesafe >> 8) & 0xFF;
buf[11]=(tren_mesafe >> 16) & 0xFF;
buf[12]='A';
buf[13]='B';
buf[14]=chk1;
buf[15]=chk2;
```

After comparing the data from the axle counter and RFID transmitter circuits in Arduino Nano, data is exchanged in packets of 16 bytes as specified in above codes in Arduino Mega 2560 so communication provided between vehicle and control center. The first two byte packet header are programmed as commands for the next three bytes. When sending data from the control center to vehicle, the first five bytes are in the form of a ‘TRDRM’ script. The first five bytes of the package that the tool sends in response after receiving and processing this package are in the form of a ‘TRPST’ script. In other words, the control center requests status information and the vehicle sends location information. It was considered the demands that can be added when designing the system.

5.5.2.2 Transceiver Circuits Operating at 2.4 GHz Frequency

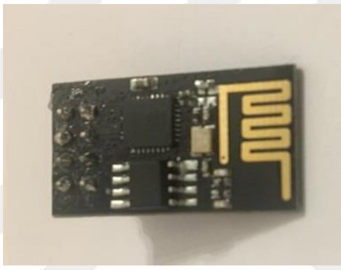


Figure 5.10 View of ESP8266- ESP01 wifi module (Personel archive, 2019)

In addition to the transceiver circuits operating at 433 MHz frequency, the project used the Esp8266-esp01 serial module running on the 2.4 GHz frequency band. With the addition of this system running on the 433 MHz frequency band is backed up. Location information will be seen in the control center without any problems as communication is provided from two different frequency bands in the failures that can be seen in the control center and vehicle or connection problems.

The module operates at 802.11b/g/n wireless standards and supports IPV4, TCP/UDP/HTTP/FTP network protocols. The operating voltage is between 3.0V – 3,6V and is fed in 3.3V in the project. The module is located both in the control center and in the vehicle.

One wireless modem is used for wifi connection.

A password-protected connection with hidden ssid is provided the prevent peripheral devices from being connected.

```
char ssid[] = "STCP";            // your network SSID (name)
char pass[] = "stcp1234";        // your network password
```

IP of the kontrol center and vehicle are predefined in programme. Three vehicle IPs are defined. The centeral Arduino Mega 2560 sends 16 bytes question packages for these three IPs, respectively, via the Esp8266 module. The vehicle that receives the package processed the 16 byte package and responded to the control centre.

```
char trenClient1[] = "192.168.1.3";  // NTP server
char trenClient2[] = "192.168.1.4";  // NTP server
char trenClient3[] = "192.168.1.5";  // NTP server
```

Two ports have been defined for package exchange. The 10002 post is also set for the control center to listen to the vehicles, and the 10003 port is set forthe vehicles to listen to the control center.

```
unsigned int localPort = 10003;  // local port to listen on
unsigned int localPort_send = 10002;  // local port to listen on
```

5.5.3 Control Units

5.5.3.1 Arduino Mega 2560 – 3.2" TFT LCD

Figure 5.11 View of arduino mega 2560 control unit (Personel archive, 2019)

The Arduino Mega 2560 is preferred for the control center. It has the 256 KB Flash Memory, 8 KB SRAM and 4 KB EEPROM Memory is powered by an external 5V AC-to-DC adaptor. There are 54 digital input-output pins. The feature of this controller is access to digital pins through pinMode(), digitalWrite() and digitalRead() functions. There are also 16 analog input pins.

The Arduino Mega 2560 is used for center control units in the project. It communicates with over-line vehicles via 433 MHz and 2.4 GHz transceiver circuits. Sends 16 bytes of data. In 2.4 GHz wifi communication, it listens to over-the-line vehicles form its 10002 ports. It sends the data it receives from the 433 MHz and 2.4 GHz receiver circuit from the serial port to the mapping software.

Communication datas are monitored instantaneously, such as whether 433 MHz and 2.4 GHz connections are active via 3.2” TFT LCD screen, whether data is exchanged or not.

Figure 5.12 View of the data communication on TFT LCD screen of Arduino Mega 2560 module (Personel archive, 2019)

The TFT LCD screen of Arduino Mega 2560 module which is used as a control unit in the control center, is programmed in the upper right corner so that the vehicle location, speed and id information can be seen instantaneously. By calculating from the latest data, the position is projected onto the screen in speed and id.

The connection of the three vehicles at the 433 MHz frequency is TREN1, TREN2 and TREN3 shaped and the connection at the 2.4 GHz frequency is programmed as WIFI1, WIFI2 and WIFI3. The connection status is shown on the screen in the green and red. The green connection color indicates that vehicle communication with the center is provided. If the connection is red, it means that the connection is disconnected or the vehicle-control center communication cannot be provided.

5.5.3.2 Arduino Nano

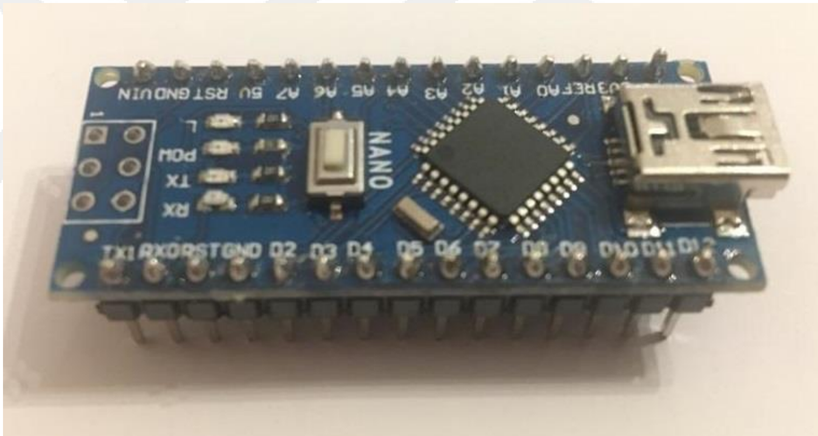


Figure 5.13 View of the Arduino Nano control unit (Personel archive, 2019)

Arduino Nano control unit was used in the project both in order to fit in size and due to its technical features. There are 14 digital input-output pins and 9 analog input pins. Thanks to the 5V operating voltage, it is ensured that it works with the feeding units that can be placed on the vehicle. It has 32 KB Flash Memory, 2 KB SRAM, 1 KB EEPROM memory.

The Arduino Nano, which is used as an on-vehicle control unit, is connected to 433 MHz transceiver circuits, 2.4 GHz transceiver circuits and the RFID receiver circuit. Data from axle counter sensors and data from RFID transmitters are compared and verified. On the 16 byte package receiving from the control center, The location information is processed into the package and the transmitters working at 433 MHz and 2.4 GHz frequency and location information are sent to the control center.

5.5.4 Power Supply Units

Control center and in-vehicle control units, transceiver circuits and various supply units for the vehicle have been used.

5.5.4.1 18650 Rechargeable High DrainFlat Top Batteries

Figure 5.14 Image of the rechargeable high drain flat top battaries (Personel archive, 2019)

The vehicle needs a feed for the control unit (Arduino Nano) and transceiver circuits (2.4 GHz and 433 MHz transceiver circuits, RFID receiver circuit). In order to meet these needs, it has been taken into consideration that it can fit into the vehicle and suitable current to be used in the study. So these types of rechargeable batteries are preferred. Two batteries are used in the vehicle. These batteries connected serial and 7.2 Volt voltage were obtained.

.

3.3 V (2.4 GHz transceiver circuits and RFID receiver circuit) and 5V (Arduino Nano and 433 MHz transceiver circuit) voltages are required in the vehicle. An adjustable voltage regulation circuit (LM2596) was used to ensure these voltage values. With the voltage adjustment trimpot, 3.3V and 5V voltages were obtained and the systems in the vehicle were fed.

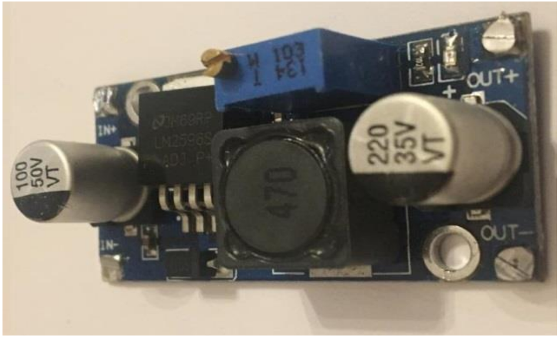


Figure 5.15 View of the LM2596 regulation circuit (Personel archive, 2019)

The regulated card supports the input voltage 4-35V. 1.25V – 30V output voltage can be adjusted. The input voltage must be at least 1.5 V higher than the output voltage. For this reason, two batteries were used and 7.2V was obtained. In addition, 3A output current can be taken from the output of the regulated card.

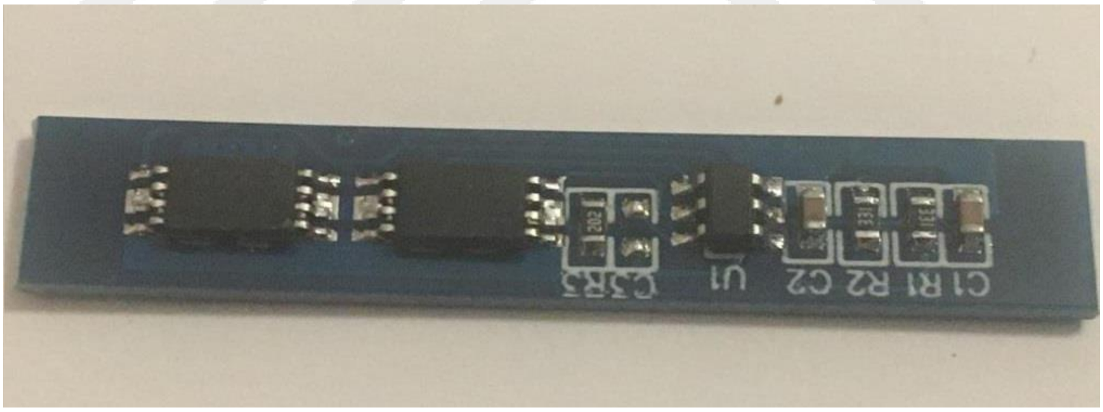


Figure 5.16 View of the battery charge modüle (Personel archive, 2019)

2S 5A Li-ion Lithium Battery 18650 Charge protection plate 7.4 V 8.4 V Surface Module is used to charge the on-board batteries without removing them from the vehicle.

In addition, three 1.5 V AA batteries are used to prevent vehicle motor interference.

5.5.5 The Mapping Software

The Arduino Mega 2560 control unit in the control center collect all the data and transfer it from the serial port to the computer. The interface program written in c sharp programming language is processed from the serial port. After the latitude and longitude calculations are made, the map shows the instant position of the vehicle.

```
if (dataLength >= 16)
   {
       if (komut == "")
    {

       komut = data1.Substring(0, 5);
       textBox1.Text = komut + textBox1.Text + "\n";
       if (komut == "TRPST")
       {
           gelen_komut++;
           label2.Text = gelen_komut.ToString();

           textBox2.Text = textBox2.Text + komut + "\n";
           int metre = (byte)data2[10];
           int metre1 = (((byte)data2[11])*256);

           metre = metre + metre1;
           label3.Text = metre1.ToString();
           label4.Text = metre.ToString();

           string hexString = BitConverter.ToString(data2);
           textBox3.Text  = hexString;
           int metre3 = (int)data2[12];

           textBox2.Text = textBox2.Text + "Tren metre =" + metre.ToString() + " " + "\n";
           Class1.mesafe = metre;

           data1 = data.Substring(14, (data.Length - 14));
           data = data1;
           komut = "";
       }
       else
       {
           data1 = data.Substring(1, (data.Length - 1));
           data = data1;
           komut = "";
       }
    }
    else
    {
       data1 = data.Substring(1, (data.Length - 1));
       data = data1;
       komut = "";
    }

} /* data boyutu 16 ve uzeri ise gir  */
else
{
    textBox2.Text = textBox2.Text + data1.Length.ToString();
}

}
```

C sharp programming language is used for mapping software. After verifying the first 5 bytes of data from the serial port with the code specified in above codes, it takes the location information contained in the 10th, 11th and 12th bytes. It calculates the location on the map and send to interface.

Figure 5.17 View of the map of the vehicle tracking system (it was created by utilizing the Google Earth, 2019)

5.6 Advantages of the Project

The most important advantage of the project was that simple practical equipment could be added to each vehicle (steam, coal, diesel and electric trains, line maintenance vehicles, freight wagons etc.) used on the railway to control the location information from the center or the vehicle. In this way, every vehicle on the railway will be monitored from the system. This is significant share in lowering the accident rate.

In the majority of the signalling systems used in the world, vehicle position works according to block line logic. Vehicles can be tracked instantaneously in the project. Each vehicle processed the requested information and sent it to the control center in response to the question package it receives. The mapping software shows the instantaneous location information of the vehicle by processing incoming packages.

GPS system for wireless communication railways is used. There are solutions such as detection sensors in the tunnel, but there is no instant tracking of vehicles. Thanks to the presency of radio communication in the tunnel and the use of this infrastructure in the project, the tunneling vehicles will be monitored instantaneously.

Axle counter sensors are backed up with rfid antennas on the line while location information is obtained. If one of the two systems is defective, vehicle location information will be accurately displayed in the mapping software thanks to data from the other system.

Two different systems were used for communication system. In case of failure of any system due to circuits running at 433 MHz and 2.4 GHz frequency, data will be taken from the other system without loss of data. The system is backed up at different frequencies.

The system is very cost-effective compared to other systems. The cost of failure maintenance is very low because there is no cable connection along the line. It is simple, practical and cost-effective in equipment to be installed in vehicles.

The project was designed not only for obtaining location information, but also as a project in which the entire signaling system could be placed within this communication structure. The system can be programmed according to the demands. If desired, the driver of the vehicle can be informed of the location of the vehicle in front and the status of the equipment on the line.

Any IP-based system can be added to the system. IP-based systems such as emergency call phones, IP phones, passenger information systems etc. can be added. Since high bandwidth is used, in-vehicle camera images can be transferred to the center if desired.

5.7 Result of the Project

The vehicle position tracking system which is an important part of signalling system was successful. The vehicle is monitored instantaneously in the mapping interface programme. The study which uses systems suitable for today’s technology is very cost-effective. Equipment used in the study can be practically mounted and does not require any auxiliary external equipment. In the other words, the equipment can be mounted on every vehicle on the track so every vehicle can be monitored.

CHAPTER SIX
CONCLUSION

Two methods are used for vehicle position information, which is the most important part of the signaling system. Axle counter sensors used in the signaling system are positioned on the rail. In the project, it was placed in the vehicle. With the movement of the vehicle wheel, the counter starts counting and position information is obtained. In theory, although the error rate of the axle counter is very low, in practice, the axle counter does not count in some cases, as there are situations such as locking and sliding of the wheels while passing through the curved areas of the vehicles and the areas where automatic lubrication systems are used. Some other cases also can cause error. These are sudden braking and starting. Therefore, RFID transmitter circuits are located in apredetermined position on the line. As the driving vehicle passes over RFID transmitter circuits, the control unit (Arduino Nano) in the vehicle compares the data from the axle counter sensors and the RFID receiver. The axle counter sensors continue to overwrite the correct position information from the RFID receiver. The correct data is sent to the control center. Position information in the system is also backed up and error rate is minimized.

The project aimed to use the common communication infrastructure on the entire railway. Thus, the system can be integrated into the whole railway network. 433 MHz transceiver circuits suitable for the existing radio infrastructure were used. One of the reasons for the use of this communication infrastructure is the fact that the positions of vehicles traveling on the line in closed areas such as tunnels can be monitored instantly by means of a leaky feeder cable inside the tunnel.

In the railway signaling system, GSMR and GPS systems are used for instant tracking of vehicles in navigation. GPS system does not work in places such as tunnels. While trying to find various solutions for this problem in tunnels, instant tracking of vehicles cannot be performed. In addition, In the GPS system data can be received min. in each 3sec.In the GSMR system, instant vehicle tracking can be done in the tunnel. But the cost of the system is quite high. The introduced system works under all conditions and is very advantageous in terms of cost compared to other systems.

In addition to transceiver circuits operating at 433 MHz frequency, transceiver circuits operating at 2.4 GHz frequency were accommodated in the system. With that, in case of any failure of the transceiver circuits operating at 433MHz frequency, the system continues to operate over the other transceiver circuits.

The 2.4GHz frequency transceiver circuits used in the project provides more bandwidth to the system and can be used in accordance with the requests.(In-car camera view, receiving data from the line equipment in front of the vehicle, viewing the position information of the vehicles in front of the vehicle, etc.).

Arduino nano was used as a control unit in the application thanks to both the hardware and the fact that it can fit in the vehicle. This control unit receives a 16 byte query packet from the control center. The control unit check wheather the value comes from the axle counter sensor fit the value comes from the RFID receiver circuit. If it does not show the same position then the axle counter is set according to the RFID value.

In the control center, arduino mega 2560 was used. This controller listens to the entire system through port 10002. It sends 16 byte query packets to the vehicles respectively. It sends 16 bytes of data from the vehicles through the serial port to the mapping software.

C sharp programming language is used for mapping interface. In this program, location information is taken from 16 bytes of data coming from serial port. The received position information is shown on the map by calculating latitude and longitude. Thus, vehicles are monitored instantly in the control center.

As a result, a vehicle tracking system is introduced and designed where every vehicle (unimog, wagon, coal train, maintenance vehicles etc.) on the railway can be monitored instantaneously without adhering to environmental conditions (tunnel, bridge, etc.). One of the objectives of the system is to use the existing radio infrastructure of all railways, thus minimizing the cost of infrastructure. The system is backed up both when obtaining location information and providing communication, and the error rate is minimized. This secure vehicle tracking system is the most important part of the signaling system. Consequently, this study provides the basis for a low cost, domestic, safe and instantaneous monitored signalling system.

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