

Abstract

Railway signaling is the baseline safety system controlling the movements of trains. It is the safety critical part of the train control function of the railway. Railway line safety methods are going to be implemented for Meiso-Dewanle new project as it's specified in the preliminary design document. The safety methods of the project contain of Track-circuit block system, computer interlocking system and lightning protection system. This all methods concentrate on controlling Wayside signals, Switches and power line protection system for safe train transport by controlling and signaling equipments situated at fields. For safe transit at the end of each blocks the driver expected to see the color of Wayside signals from some KM distance before the signal .But Field signals have limitations for sight hindering natural or artificial circumstances. Cab signal system provides block occupancy necessary information immediately for the driver and guides him to function the train with a full knowhow of the dynamic line situations ahead of him. Speed controlling is the very mechanism of avoiding danger and by giving line status data's timely, Cab signal helps the train operator to derive safely.

This thesis done on cab signaling partly due to: to exploit the wide application of cab signaling for its safety protection mechanism for Semi-Automatic block system. And, in addition, its physical location closeness to the train operator is also the other reason. Design of Cab signaling for Meiso-Dewanle have implemented using Ac 25 Hz coded track circuit communication system. Wayside signal at stations are grouped into 8 groups and encoded using Extended hamming codes for error detection, modulated with Bpsk modulation for good error probability, Transmitted through the rails to the cab for decoding and demodulation for better signal detection.

Mat lab simulation for the encoding, decoding, modulation/demodulation, transmission, and band filter have included in this thesis. Transmission parameter design analysis on amplitude and phase of the signal also carried out in the simulation part.

The transmission of the signal is affected by rail resistance, rail inductance and most importantly by ballast resistance. Distributed rail model for the rail and Lumped model for the train length with rail and ballast impedance have used in the thesis to calculate the accurate values of the current in the leading wheels of the train. The worst ballast resistance also used to calculate the maximum safe working length of the track circuit which is 1.2KM.

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List of Abbreviation

ATP-----	Automatic Train Protection
CCECC-----	China Civil Engineering Construction Corporation
CREEC-----	China Railway Eryuan Engineering Group Corporation
Hr-----	Hour
KM-----	Kilo Meter
MIT-----	Massachusetts Institutes of Technology
E-----	Encoding
G-----	Generator matrix
H-----	Parity check matrix
I_k -----	$k \times k$ Identity Matrix
F_q -----	stands for the finite field with q elements
F_q^n -----	stands for the finite field with q elements of with length n
C-----	code
d -----	hamming distance
r -----	error vector
s -----	syndrome of a code C
$P_{cd}(p)$ -----	probability correct decoding
$P_{de}(p)$ -----	probability of decoding error
$P_{df}(p)$ -----	probability of decoding failure
P_{err} -----	probability of error
BPSK-----	binary phase shift keying
$S(t)$ -----	BPSK signal

D_p -----phase deviation
 $m(t)$ -----message signal
PSD----- Power Spectral Density
 T -----bit period
 $r(t)$ -----received signal
 E -----signal power
 $p(z|+a)$ -----Conditional probability of $+a$ being z received
 $p(z|-a)$ -----Conditional probability of $-a$ being z received
 z -----Signal amplitude output of the coherent demodulator
 f_c -----frequency of the carrier waveform
 V_s -----sending end/track circuit voltage
 I_s -----sending end/track circuit current
 V -----output voltage of the track circuit
 I -----output current of the track circuit
 V_r -----Receiving end voltage
 I_r -----Receiving end Current
 $Z_{rail \Delta X}$ -----impedance value for small interval ΔX
(IRJs)-----insulated rail joints
JTCs -----Joistless track circuits
TCR -----track-circuit-reader
 B_e -----the magnetic-induction intensity
 $\phi_{e(x, x_1, z_0, t)}$ -----Magnetic flux in induction coils of a TCR antenna
 $\Phi_1(x, x_1, t)$ -----magnetic flux in each induction coil of a TCR antenna
 $\Phi_2(x, x_1, t)$ -----magnetic flux in each induction coil of a TCR antenna

$I_c(x, x_1, t)$ ----- the self-inductance current in the coils

ω_l : -----Lower cutoff frequency;

ω_u -----upper cutoff frequency;

ω_0 -----Center frequency;

B -----bandwidth;

$Q \equiv \frac{\omega_0}{B}$ -----Quality factor;

L -----inductance a receiving antenna coil

$N = qm$ -----Number of turns

a -----radius of the receiving antenna wire

l_{coil} -----width of the receiving antenna coil

\bar{Z}_{coil} -----Impedance of the receiving antenna coil

Chapter 1.Introduction

1.1 Background

Railway transportation system had been used as a major freight and passenger transport to the eastern part of Ethiopia from 1917 to 2010. The system comes to existence during the reign of Emperor Menelik II and covers a total of 781km powered by diesel engine and jointly owned by Ethiopia and Djibouti.

The mobility need of the country population and the development of transportation system are far from compatibility. Therefore; the country is in need of modern, Safer, economic, time saving and long lasting transportation which will ease import-export system and result fast development of the country's economy. To this end, the government of Ethiopia has embarked on railway system. The route of Ethiopia - Djibouti line is subdivided for better project accomplishment and it includes the MIESO-DAWANL section as one part.

[1]Survey and Design Commission Contract for MIESO-DAWANLE Section of New Ethiopia Railway signed by and between Kunming Investigation, Design and Research Institute Co., Ltd. of CREEC and CCECC MIESO-DAWANL Railway Project Management Department on June 20, 2012. Study scope encompasses MIESO (excluded) - DIRE DAWA (included), with a total length of 134.322 km. The route is led from the west side of MIESO town, stretches northeastward, passes through MULU, DELADU, AFUDEM and ADELE and arrives at BIKE. After leaving the BIKE station, the route turns to the southeast to pass GOTA, then turns to the east to pass ERER, MEGALA and HURSO and ends at MELKA town, on the north side of which the DIRE DAWA station is located.

The purpose of this thesis is to design safety cab signaling system from MIESO-DAWANLE to make the route safer so that unnecessary time delay can be reduced and optimum traffic flow will be achieved.

[2]Railway signaling is a system used to safely direct railway traffic in order to prevent trains from colliding. Trains move on fixed rails so they are uniquely susceptible to collision; the weight of trains and momentum makes it difficult to stop before reaching the impending obstacle. According to train's safety methods implementation is carried out in railway lines .The simplest form of safety operation is to run the system with respect to a timetable and to divide railway lines into sections known as blocks so that only one train is permitted in each block at a time. The other method is to implement signaling equipment's or circuits that give visual indications for the driver. Track circuit operating Wayside signals function on this basis. An alternative method uses axle counters for determining the occupied status of a block located at its beginning and end that count the number of axles entering and leaving. Train position identifying method install Transponder b/n rails as another safety measures. Computer based interlocking system commands switches to lock to the specified route so that level transit and safety at turnouts will be guaranteed.

Cab signaling system communicates track status information to the train cab (driving position), where the train driver can see the information. The simplest systems display the trackside signal aspect, while more sophisticated systems also display allowable speed and dynamic information about the track ahead. In modern systems, a train protection system is usually overlaid on top of the cab signaling system to warn the driver of dangerous conditions, and to automatically apply the brakes and bring the train to a stop if the driver ignores the dangerous condition. Cab signaling systems range from simple coded track circuits, to transponders that communicate with the cab, and Communication-Based Train Control Systems.

[3] The ATP signaling codes contained in the track circuits are transmitted to the train. They are detected by pick-up antennae (usually two) mounted on the leading end of the train under the driving cab. This data is passed to an on-board decoding and safety processor. The permitted speed is checked against the actual speed and, if the permitted speed is exceeded, a brake application is initiated. In the more modern systems, distance-to-go data will be transmitted to the train as well. The data is also sent to a display in the cab which allows the driver of a manually driven train to respond and drive the train within the permitted speed range.

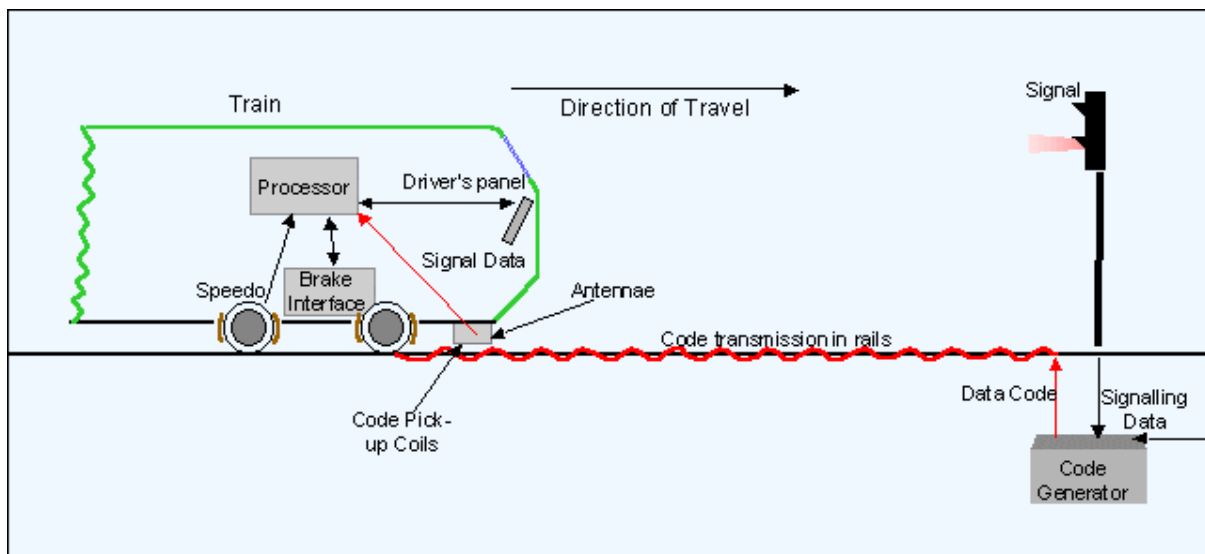


Figure 1.1 ATP code transmission using track circuit

[4] Signals under the heading of Cab Signal are of several forms. These are traditional color light forms in miniature. There are position light and numerical forms as well. Digital forms with numbers and sometimes letter and graphic forms are increasingly commonplace. Such focus on speed limit messages. All of these forms are located on-board the train and receive impulses from track circuits and other means including transponders. Frequently various aspects of train control are added to cab signals (or cab signals become part of train control). A sound dimension is also a common feature of Cab Signals.

On this very end ERC is under construction of MIESO-DAWANLE 134.32Km railway line in eastern part of the country. But, the signal system of Mieso-Dire Dawa Railway includes

[5] block system, computer interlocking system and integrated lightening protection system. And I thought the design is not efficient in considering other types of safety signals (cab signal). Due to this I am interested to work my thesis on cab signals which receive data from track circuit that assure more safety for the line. And I try to encompass:

I. Warning Signals.

II Wayside signals and station turnout signals.

1.2 Statement of the problem

[6] Practical experience proved that there had to be some way of preventing trains running into each other. It's so difficult stopping a train within the driver's sighting distance. The least train interval is braking distance plus safety distance this is due to: Inexperience, bad brakes and the low adhesion levels which exists on the railway between steel wheel and steel rail for traction and braking - this will induce a problem which effects stopping a train within braking distances impossible. An Intercity train travelling at 100 mph (160 km/hr) will take more than a mile to stop. Even for a signaling system with enforcement (ATP) like the London Underground, there is a risk that a train could pass stop signal, then be stopped by the ATP enforcement system and still hit the train in front.

[7] Proper automatic target braking is possible only when both static and dynamic speed Profile is calculated. This requires the transmission of movement authorities, which Define braking targets by distance and speed. [8] To achieve higher safety, location dependent stop warning was introduced to warn the driver that the train is approaching a signal which shows a Stop aspect. A train approaching a tunnel, a bridge, Grade points or turnouts needs a wayside warning signal unless otherwise accidental consequence may be severe. But in cases when this wayside signal is not in a clear sight for the driver for different reasons like, Fog or Dwarf signal height..., the replication of the warning signal at the cab will add another safety assurance for the trains.

1.3 Objective

1.3.1 General Objective

The general objective of this Thesis is to design best cab signal Model for train's safety, and to maximize line's traffic as well as to reduce unnecessary time delay by avoiding possible conditions that lead to an accident.

1.3.2 Specific Objective

The specific objective of this thesis is to Design appropriate Cab signaling indications for the driver for the following railway line conditions:

- i. Wayside, Barriers and Warning signals
- ii. Station Turnout points signals.

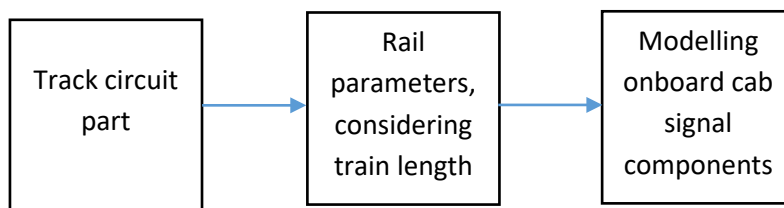
1.4. Research method

First I collected meiso-dire dewa preliminary design document and identified that the system is inefficient in considering cab signal aids. After, I decided the possible communication means for communication between the wayside equipment and the cab. Then, track circuit based communication is used for the implementation of cab signaling.

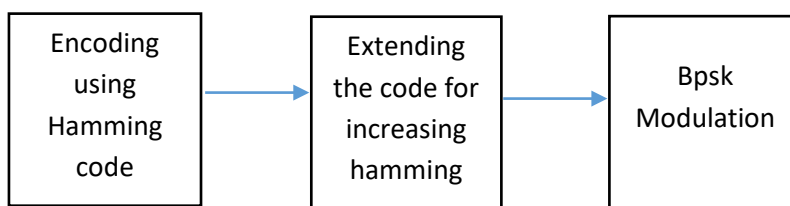
The next part included collecting books and researches done before relating with my topic which helped me through to have a detail understanding on what I should do and the extent of my scope. My research is done by separating the system into three subdivided components and modelling this systems separately. The subparts include: The track circuit transmitter, the rail parameter and the cab signaling onboard components.

- I. Track circuit Transmitter:-Encoding using hamming code and extension of the code implemented, Bpsk modulation technique is used for analog transmission of digital signal.
- II. The Rail parameters: transmission line theory and two port network analysis is used to Modell the rail parameters.
- III. Joistless track circuit antenna model is used to model antenna parameters, Band pass filter design to a void interference, a coherent Bpsk demodulation scheme implemented for accurate signal detection ,and syndrome decoding table is used for decoding the received signal.

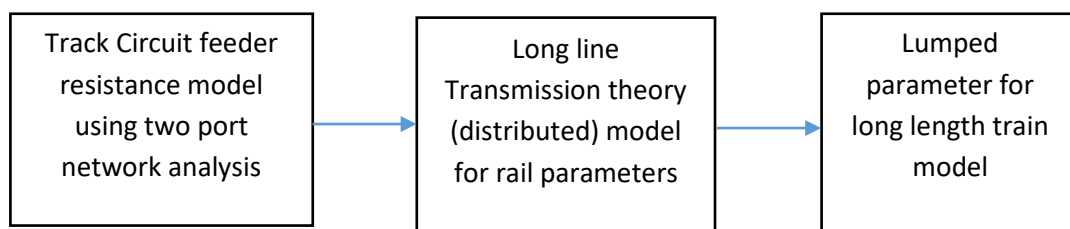
Modelling the System separating into three parts



1. Track circuit Part



2. Track circuit to train (rail parameter)



3. Cab signaling components

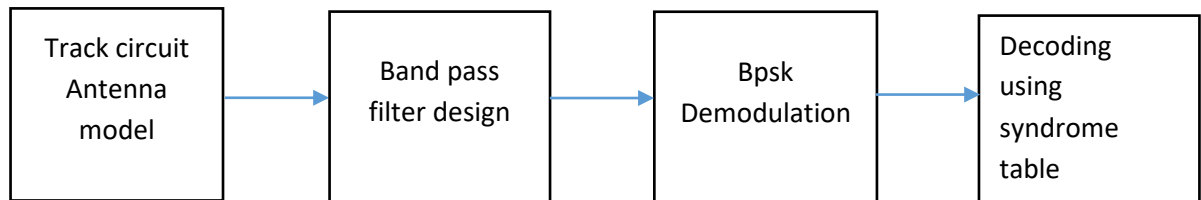


Figure 1.2 Research Methods

After modelling the system, matlab simulation is conducted, then simulation results have analyzed and based on the results conclusion are made at the end.

1.5 Thesis limitation

On this thesis cab signaling focus only on sending wayside signals to the cab. Their influential role on safety was the first thing I considered to implement the research on this dynamic wayside signals. Static data transmission to the cab, like gradient and others is not considered because I choose to work my research in detail on the dynamic one. Braking distance range for different train speed is considered from standards b/c I couldn't find the speed profiles for the meiso-dire dewa line, and the design puts into consideration to send wayside signals to the cab for safe braking distances. Track circuit voltage output voltage value is not included in preliminary project design so that I used 220 volt for the Chinese standard b/c the company working on the project is Chinese company. Rail parameters like ballast resistance, rail resistance, rail inductance, train shunt admittance have taken from standards due to information shortage from ERC.

1.6 Thesis contribution

This thesis contributes safety assured train cab signal communication aids to the driver of the train so that the driver could easy operate the train with full knowhow of the signal condition ahead of him. Matlab results shows how rail parameters change affect the performance of the normal operation of the track circuit, and in times this conditions are affected due to different factors, a quick response for maintenance will be done to avoid unwanted working conditions for the track circuit. This thesis used Bpsk demodulation means and gives an insight for others who wants to do researches on communication to consider it for better error handling performance. This thesis considers the train length which affects the voltage drop of the track circuit along the rails so that communication distance b/n the track circuit and the relay coil will be analyzed from this train length view. Cost minimization- b/c the research is mainly

used components already included in the project for other purposes, it doesn't incur another cost.

1.7. Thesis Organization

This thesis is organized into 5 chapters. The first chapter is about the Introduction part which includes the background, statement of the problem, thesis objective, research methods, thesis limitation, thesis contribution and thesis organization of the thesis.

The second chapter is about literature review explains about encoding decoding technique, Bpsk modulation/Demodulation, transmission line models, Track circuit antenna and band pass filter. At the end it gives a review on a research done before.

Chapter 3. this part is about mathematical modelling and design which uses encoding, Bpsk modulation, distributed and lumped transmission models, track circuit antenna models and band pass filter models for design.

Chapter 4. this chapter include all simulation for the designs implemented in chapter 3.

Chapter 5 is the last part and gives conclusion based on the results obtained in the above two chapters. And also this chapter gives recommendation on the performance of the model and its parameters.

Chapter.2.Literature Leview

2.1 Codes and hamming distance

[n; k] block codes, that is the message words, have a fixed length of k symbols and the encoded words have a fixed length of n symbols both from the same alphabet Q. [9]The central concept in detecting or correcting errors is redundancy. To be able to detect or correct errors, we need to send some extra bits with our data. These redundant bits are added by the sender and removed by the receiver.

[10]Let Q be a set of q symbols called the alphabet. Let Q^n be the set of all n-tuples $x = (x_1, \dots, x_n)$, with entries $x_i \in Q$. A block code C of length n over Q is a non-empty subset of Q^n .

The elements of C are called Codewords. If C contains M codewords, then M is called the size of the code. We call a code with length n and size M an (n, M) code. If $M = q^k$, then C is called an [n; k] code. For an (n, M) code defined over Q, the value $n - \log_q M = n$ is called the

redundancy. The information rate is defined as $R = \log_q \frac{M}{n}$

Let C be an [n; k] block code over Q. An encoder of C is a One-to-one map

$$E: Q^k \rightarrow Q^n \text{-----} 2.1$$

Such that $C = E(Q^k)$. Let $c \in C$ be a codeword. Then there exists a unique $m \in Q^k$ with $c = E(m)$. This m is called the message or source word of c. In order to measure the difference between two distinct words and to evaluate the error-correcting capability of the code, we need to introduce an appropriate metric to Q^n . A natural metric used in Coding Theory is the Hamming distance.

For $x = (x_1, \dots, x_n); y = (y_1, \dots, y_n) \in Q^n$, the Hamming distance $d(x; y)$ is defined as the number of places where they differ:

$$d(x, y) = | \{ i \mid x_i \neq y_i \} |$$

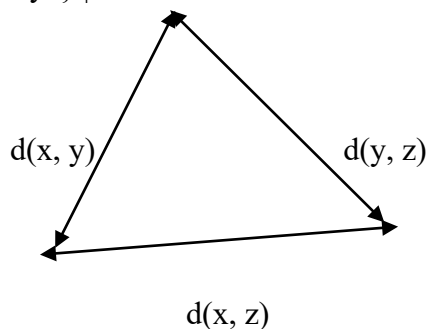


Figure 2.1 hamming distance

The Hamming distance is a metric on Q^n , that means that the following properties hold for all $x, y, z \in Q^n$:

- (1) $d(x, y) \geq 0$ and equality holds if and only if $x = y$,
- (2) $d(x, y) = d(y, x)$ (symmetry),
- (3) $d(x, z) \leq d(x, y) + d(y, z)$ (triangle inequality),

the minimum distance of a code C of length n is defined as

$$d = d(C) = \min \{ d(x; y) \mid x, y \in C; x \neq y \} \text{-----2.2}$$

If C consists of more than one element, and is by definition $n+1$ if C consists of one word.

We denote by (n, M, d) a code C with length n , size M and minimum distance d .

The main problem of error-correcting codes from "Hamming's point view" is to construct for a given length and number of codewords a code with the largest possible minimum distance, and to find efficient encoding and decoding algorithms for such a code.

2.1.1 Linear Codes

A linear code C is a linear subspace of F_q^n , where F_q stands for the finite field with q elements. The dimension of a linear code is its dimension as a linear space over F_q . We denote a linear code C over F_q of length n and dimension k by $[n, k]_q$, or simply by $[n, k]$. If furthermore the minimum distance of the code is d , then we call by $[n, k, d]_q$ or $[n, k, d]$ the parameters of the code. It is clear that for a linear $[n, k]$ code over F_q , its size $M = q \cdot k$. The information rate is $R = k/n$ and the redundancy is $n - k$.

For a word $x \in F_q^n$, its support, denoted by $\text{supp}(x)$, is defined as the set of nonzero coordinate positions, so $\text{supp}(x) = \{i \mid x_i \neq 0\}$. The weight of x is defined as the number of elements of its support, which is denoted by $\text{wt}(x)$. The minimum weight of a code C , denoted by $\text{mwt}(C)$, is defined as the minimal value of the weights of the nonzero codewords:

$$\text{mwt}(C) = \min \{ \text{wt}(c) \mid c \in C; c \neq 0 \} \text{-----2.3}$$

in case there is a $c \in C$ not equal to 0, and $n + 1$ otherwise.

Note: The minimum distance of a linear code C is equal to its minimum weight.

Suppose C is an $[n, k, d]$ code, then, for any $r, 1 \leq r \leq k$, there exist subcodes with dimension r . And for any given r , there may exist more than one subcode with dimension r . The minimum distance of a subcode is always greater than or equal to d . So, by taking an appropriate subcode, we can get a new code of the same length which has a larger minimum distance.

2.1.2 Generator matrix and systematic encoding

Let C be an $[n, k]$ linear code over F_q . Since C is a k -dimensional linear subspace of F_q^n

, there exists a basis that consists of k linearly independent codewords, say g_1, \dots, g_k .

Suppose $g_i = (g_{i1}, \dots, g_{in})$ for $i = 1, \dots, k$. Denote

$$G = \begin{pmatrix} g_1 \\ g_2 \\ \cdot \\ \cdot \\ g_k \end{pmatrix} = \begin{pmatrix} g_{11} & g_{12} & \cdot & \cdot & g_{1n} \\ g_{21} & g_{22} & \cdot & \cdot & g_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ g_{k1} & g_{k2} & \cdot & \cdot & g_{kn} \end{pmatrix} \quad \text{-----2.4}$$

Every codeword c can be written uniquely as a linear combination of the basis elements, so $c = m_1g_1 + \dots + m_kg_k$ where $m_1, \dots, m_k \in F_q$. Let $m = (m_1, \dots, m_k) \in F_q^k$. Then $c = mG$. The encoding

$$E : F_q^k \rightarrow F_q^n ;$$

from the message word $m \in F_q^k$ to the codeword $c \in F_q^n$ can be done efficiently by a matrix multiplication. $c = E(m) := mG$:

A $k \times n$ matrix G with entries in F_q is called a generator matrix of an F_q linear code C if the rows of G are a basis of C .

the generator matrix G of the Hamming code has the following form $(I_k | P)$, where I_k is the $k \times k$ identity matrix and P a $k \times (n - k)$ matrix.

Let C be an $[n, k]$ code. The code is called systematic at the positions (j_1, \dots, j_k) if for all $m \in F_q^k$ there exists a unique codeword c such that $c_{j_i} = m_i$ for all $i = 1, \dots, k$. In that case, the set $\{j_1, \dots, j_k\}$ is called an information set. A generator matrix G of C is called systematic at the positions (j_1, \dots, j_k) if the $k \times k$ submatrix G' consisting of the k columns of G at the positions (j_1, \dots, j_k) is the identity matrix. For such a matrix G the mapping $m \rightarrow mG$ is called systematic encoding.

2.1.3 Parity check matrix

There are two standard ways to describe a subspace, explicitly by giving a basis, or implicitly by the solution space of a set of homogeneous linear equations. Therefore there are two ways to describe a linear code. That is explicitly as we have seen by a generator matrix, or

implicitly by a set of homogeneous linear equations that is by the null space of a matrix. Let C be an F_q -linear $[n, k]$ code. Suppose that H is an $m \times n$ matrix with entries in F_q . Let C be the null space of H . So C is the set of all $c \in F_q^n$ such that $Hc^T = 0$. These m homogeneous linear equations are called parity check equations, or simply parity checks. The dimension k of C is at least $n - m$. If there are dependent rows in the matrix H , that is if $k > n - m$, then we can delete a few rows until we obtain an $(n - k) \times n$ matrix H' with independent rows and with the same null space as H . So H' has rank $n - k$.

An $(n - k) \times n$ matrix of rank $(n - k)$ is called a parity check matrix of an $[n, k]$ code C if C is the null space of this matrix.

Suppose that the codeword c is transmitted and $r = c + e$ is received. Then e is called the error vector and $wt(e)$ the number of errors. Now $Hr^T = 0$ if there is no error and $Hr^T \neq 0$ for all e such that $0 < wt(e) < d$. Therefore we can detect any pattern of t errors with $t < d$. The vector Hr^T is called the syndrome of the received word. We show that every linear code has a parity check matrix and we give a method to obtain such a matrix in case we have a generator matrix G of the code.

Suppose C is an $[n, k]$ code. Let I_k be the $k \times k$ identity matrix. Let P be a $(n - k) \times n$ matrix. Then, $(I_k | P)$ is a generator matrix of C if and only if $(-P^T | I_{n-k})$ is a parity check matrix of C .

Proof. Every codeword c is of the form mG with $m \in F_q^k$.

Suppose that the generator matrix G is systematic at the first k positions. So $c = (m, r)$ with $m \in F_q^k$ and $r = mP$. Hence for a word of the form $c = (m; r)$ with $m \in F_q^k$ and $r \in F_q^{n-k}$ the

following statements are equivalent:

- c is a codeword;
- $-mP + r = 0$;
- $-P^T m^T + r^T = 0$;
- $(-P^T | I_{n-k})(m, r)^T = 0$;
- $(-P^T | I_{n-k}) C^T = 0$

Hence $(-P^T | I_{n-k})$ is a parity check matrix of C .

2.1.4 Decoding and the Error Probability

Let C be a linear code in F_q^n of minimum distance d . If c is a transmitted codeword and r is the received word, then $\{i \mid r_i \neq c_i\}$ is the set of error positions and the number of error

positions is called the number of errors of the received word. Let $e = r - c$. Then e is called the error vector and $r = c + e$. Hence $\text{supp}(e)$ is the set of error positions and $\text{wt}(e)$ the number of errors. The e_i 's are called the error values.

[11] $e(C) = \lfloor (d(C) - 1)/2 \rfloor$ is called the error-correcting capacity or decoding radius of the code C .

A decoder D for the code C is a map

$$D : F_q^n \rightarrow F_q^n \cup \{*\} \text{ -----2.5}$$

such that $D(c) = c$ for all $c \in C$.

If $E : F_q^k \rightarrow F_q^n$ is an encoder of C and, $D : F_q^n \rightarrow F_q^n \cup \{*\}$ is a map such that $D(E(m)) = m$ for all $m \in F_q^k$, then D is called a decoder with respect to the encoder E .

If E is an encoder of C and D is a decoder with respect to E , then the composition $E \circ D$ is a decoder of C . It is allowed that the decoder gives as outcome the symbol $*$ in case it fails to find a codeword. This is called a decoding failure. If c is the codeword sent and r is the received word and

$D(r) = c' \neq c$, then this is called a decoding error. If $D(r) = c$, then r is decoded correctly.

Notice that a decoding failure is noted on the receiving end, whereas there is no way that the decoder can detect a decoding error.

[12] A complete decoder is a decoder that always gives a codeword in C as outcome. A nearest neighbor decoder, also called a minimum distance decoder, is a complete decoder with the property that $D(r)$ is a nearest codeword. A decoder D for a code C is called a t -bounded distance decoder or a decoder that corrects t errors if $D(r)$ is a nearest codeword for all received words r with $d(C, r) \leq t$ errors.

[13] If D is a t -bounded distance decoder, then it is not required that D gives a decoding failure as outcome for a received word r if the distance of r to the code is strictly larger than t . In other words: D is also a t' -bounded distance decoder for all $t' \leq t$.

A nearest neighbor decoder is a t -bounded distance decoder for all $t \leq \rho(C)$, where $\rho(C)$ is the covering radius of the code. A $\rho(C)$ -bounded distance decoder is a nearest neighbor decoder, since $d(C, r) \leq \rho(C)$ for all received words r .

Let r be a received word with respect to a code C . A coset leader of $r + C$ is a choice of an element of minimal weight in the coset $r + C$. The weight of a coset is the minimal weight of an element in the coset.

Let r be a received word. Let e be the chosen coset leader Of the coset $r + C$. The coset leader decoder gives $r - e$ as output

[14] Let C be a binary linear code with parity check matrix H , let c be the sent codeword, and let r be the received vector. Then we have $Hc^T = 0$. If we have $Hr^T = 0$, then r is also a codeword. It should therefore be reasonable for a decoder to check this. A decoder based on this idea calculates the syndrome

$$s = Hr^T \text{-----2.6}$$

Which is an $(n - k)$ -dimensional vector. Define the error vector $e = c + r$. Then we get $s = H(c^T + e^T) = Hc^T + He^T$.

Since we have $Hc^T = 0$, this finally becomes $s = He^T$,

Let C be a code of dimension k . Let r be a received word. Then $r + C$ is called the coset of r .

Now the cosets of the received words r_1 and r_2 are the same if and only if $r_1H^T = r_2H^T$.

Therefore there is a one to one correspondence between cosets of C and values of syndromes.

Furthermore every element of F_q^{n-k} is the syndrome of some received word r , since H has rank $n - k$. Hence the number of cosets is q^{n-k} .

[15] One of the most fundamental models of a communication channel is the binary symmetric Channel (BSC). In this channel, every bit of a transmitted message has the same probability p of being changed to the other bit. So, a 0 will change to a 1 with probability p and will stay unchanged with probability $1-p$. The number $1-p$ is called the reliability of the BSC. We also assume that errors occur randomly and independently (not always a realistic assumption but will work well for many situations). We will always assume that we work with a BSC with a fixed reliability.

For every decoding scheme and channel one defines three probabilities $P_{cd}(p)$, $P_{de}(p)$ and $P_{df}(p)$, that is the probability of correct decoding, decoding error and decoding failure, respectively. Then

$$P_{cd}(p) + P_{de}(p) + P_{df}(p) = 1 \text{ for all } 0 \leq p \leq 1/2$$

So it suffices to find formulas for two of these three probabilities. The error probability, also called the error rate is defined by $P_{err}(p) = 1 - P_{cd}(p)$.

$$\text{Hence } P_{err}(p) = P_{de}(p) + P_{df}(p):$$

[16] The probability of correct decoding of a decoder that corrects up to t errors with $2t + 1 \leq d$ of a code C of minimum distance d on a binary symmetric channel with cross-over probability p is given by

$$P_{cd}(p) = \sum_{w=0}^t \binom{n}{w} p^w (1-p)^{n-w} \text{-----2.7}$$

Let C be a linear code of length n . Let $v \in F_q^n$. The extended code $C^e(v)$ of length $n + 1$ is defined as follows. For every codeword $c = (c_1, \dots, c_n) \in C$, construct the word $ce(v)$ by adding the symbol $c_{n+1}(v) \in F_q$ at the end of c such that the following parity check holds

$$v_1c_1 + v_2c_2 + \dots + v_nc_n + c_{n+1} = 0:$$

Now $C^e(v)$ consists of all the codewords $ce(v)$, where c is a codeword of C . In case v is the all-ones vector, then $C^e(v)$ is denoted by C^e .

Let C be an $[n; k]$ code. Then it is clear that $C^e(v)$ is a linear subspace of F_q^{n+1} , and has dimension k . So, $C^e(v)$ is an $[n+1; k]$ code. Suppose G and H are generator and parity check matrices of C , respectively. Then, $C^e(v)$ has a generator matrix $G^e(v)$ and a parity check matrix $H^e(v)$, which are given by

$$G^e(v) = G \begin{pmatrix} | & g_{1n+1} \\ | & g_{2n+1} \\ | & \cdot \\ | & \cdot \\ | & g_{kn+1} \end{pmatrix} \quad H^e(v) = \begin{pmatrix} v_1 & v_2 & \cdot & \cdot & \cdot & v_n & | & 1 \\ \hline 0 & & & & & & & \\ & & & H & & & & \\ & & & & & & & 0 \end{pmatrix}$$

where the last column of $G^e(v)$ has entries $g_{in+1} = -\sum_{j=1}^n g_{ij}v_j$ -----2.8

2.2 Binary Phase-Shift Keying (BPSK)

2.2.1 BPSK Generation

[17] A PSK bandpass modulated signal is generally represented by

$$\text{Re}\{g(t)e^{iWct}\} = \text{Re}\{A_c e^{i(\theta+Wct)}\} = \text{Re}\{A_c e^{i\theta} e^{iWct}\} = A_c \cos(\theta+Wct) =$$

$$A_c \cos[W_c t + D_p m(t)], \text{ Where } \theta(t) = D_p m(t)$$

In BPSK $m(t)$ is a polar baseband data signal. For convenience, let $m(t)$ have a peak values of ± 1 and a rectangular pulse shape.

We now show that BPSK is also a form of AM-type signalling, in fact expanding the preceding equation we get

$$\cos(a + b) = \cos a \cos b - \sin a \sin b$$

$$S(t) = \{ A_c \cos[D_p m(t)] \} \cos(w_c t) - \{ A_c \sin[D_p m(t)] \} \sin(w_c t)$$

From equation above we can see that it corresponds to a quadrature modulation

Scheme

Now recalling that $m(t) = \pm 1$ and that $\cos(x)$ and $\sin(x)$ are even and odd functions of x we get:

$$\cos[D_p \cdot (+1)] = \cos[D_p \cdot (-1)] = \cos[D_p]$$

$$\sin[D_p \cdot (+1)] = -\sin[D_p \cdot (-1)]$$

we see that the representation of BPSK signal reduces to:

$$S(t) = \cos(\omega_c t) \cos(D_p) - A_c \sin(\omega_c t) \sin(D_p) \cdot m(t) =$$

$$= \underbrace{[A_c \cos(D_p)] \cos(\omega_c t)}_{\text{Pilot Carrier Term, } m(t) \text{ is not present}} - \underbrace{[A_c \sin(D_p)] m(t) \sin(\omega_c t)}_{\text{data term}}$$

Pilot Carrier Term, $m(t)$ is not present

data term

The level of the pilot carrier term is set by the value of the peak phase deviation constant, $\Delta\theta = D_p$.

For digital angle-modulated signals, the digital modulation index h is defined by

$$\frac{2\Delta\theta}{\pi} = \frac{2D_p}{\pi}$$

where $2\Delta\theta = 2D_p$ is the maximum peak-to-peak phase deviation (radians) during the time required to send one symbol, T_s .

$$h = \frac{2\Delta\theta}{\pi} = \frac{2D_p}{\pi}$$

$$2 \quad 2\pi$$

$$1 \quad \pi$$

For binary signaling, the symbol time is equal to the bit time ($T_s = T_b$). The level of the pilot carrier term is set by the value of the peak deviation, which is $\Delta\theta = D_p$ for $m(t) = \pm 1$. The value of m is determined by the input data bit stream converted in NRZ for example. If D_p is small, the pilot carrier term has a relatively large amplitude compared to the data term;

consequently, there is a very little power in the data term (which contains the source information). To maximize the signaling efficiency (so that there is a low probability of error), the power in the data term needs to be maximized. This is accomplished by letting $\Delta\theta = D_p = \pi/2$ radians, which corresponds to a digital modulation index of $h = 1$. For this optimum case of $h = 1$, the BPSK signal becomes

$$S(t) = -A_c m(t) \sin(\omega_c t)$$

Therefore the modulated signal is

$$\operatorname{Re}\{g(t)e^{i\omega_c t}\} = \operatorname{Re}\{iA_c e^{i\theta} e^{i\omega_c t}\} = \operatorname{Re}\{iA_c m(t) \cos(\omega_c t) - A_c m(t) \sin(\omega_c t)\}$$

$$\left. \begin{aligned} S_1(t) &= +A_c \sin \omega_c t & m(t) &= +1 \\ S_2(t) &= -A_c \sin \omega_c t & m(t) &= +1 \end{aligned} \right\} \text{-----2.9}$$

$$g(t) = A m(t)$$

In figure below are reported the phase $S_i(t) = \pm 1$ and quadrature $q(t) = 0$ components of the baseband modulating signal $g(t)$ plus the constellation diagram

[18] A binary PSK system is characterized by a signal space that is one-dimensional (i.e. $N=1$), and has two message points (i.e. $M=2$)

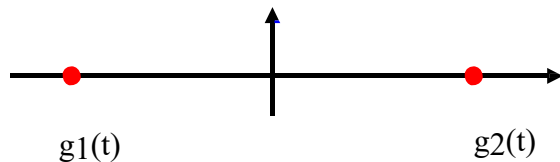


Figure 2.2 constellation diagram for BPSK

[19] When the modulating wave shape is rectangular and the symbol 0,1 are equally probable, the Power Spectral Density (PSD) for the baseband complex envelope is

$$A^2 T \left(\frac{\sin(\pi f T)}{\pi f T} \right)^2$$

$$\text{PSD}(s(t)) = 1/4 [P_g(f-f_c) + P_g(f+f_c)] = \frac{A_c^2 T}{4} \left(\frac{\sin(\pi(f-f_c)T)}{\pi(f-f_c)T} \right)^2 + \frac{(\sin(\pi(f+f_c)T))^2}{\pi(f+f_c)T}$$

$$\frac{A^2 c T}{4} \{ \text{sinc}(\pi(f-f_c)T)^2 + \text{sinc}(\pi(f+f_c)T)^2 \} \text{-----2.10}$$

The symbols, $s_1(t)$ and $s_2(t)$ representing the ones and zeros respectively, are then,

$$\begin{aligned} S_1(t) &= +A_c \cos \omega_c t & \text{when } m(t) &= -1 \\ S_2(t) &= -A_c \cos \omega_c t & \text{when } m(t) &= +1 \end{aligned}$$

Using the duplication formula $\cos^2(x) = \frac{1+\cos 2x}{2}$, $\sin^2(x) = \frac{1-\cos 2x}{2}$

[20] the energy transmitted during one bit period = $\frac{2\pi}{w}$

$$\int_0^T |S(t)|^2 dt = \int_0^T A_c^2 \sin^2(\omega_c t) dt = A_c^2 \int_0^T \frac{1-\cos 2x}{2} dt = A_c^2 \left[\frac{T}{2} - \frac{1}{2} \int_0^T \cos(2\omega_c t) dt \right] = \frac{A_c^2 T}{2} - A_c^2 \frac{1}{2} \left[\frac{\sin(2\omega_c t)}{2\omega_c} \right]_0^T = A_c^2 \frac{T}{2}$$

Where $s(t) = A_c \sin(\omega_c t)$, $T = \frac{2\pi}{w}$, $\omega_c = n w$ with $n=1,2,3,4\dots$

$$C = \frac{E}{T} = \frac{A_c^2}{2} \text{ [w]}$$

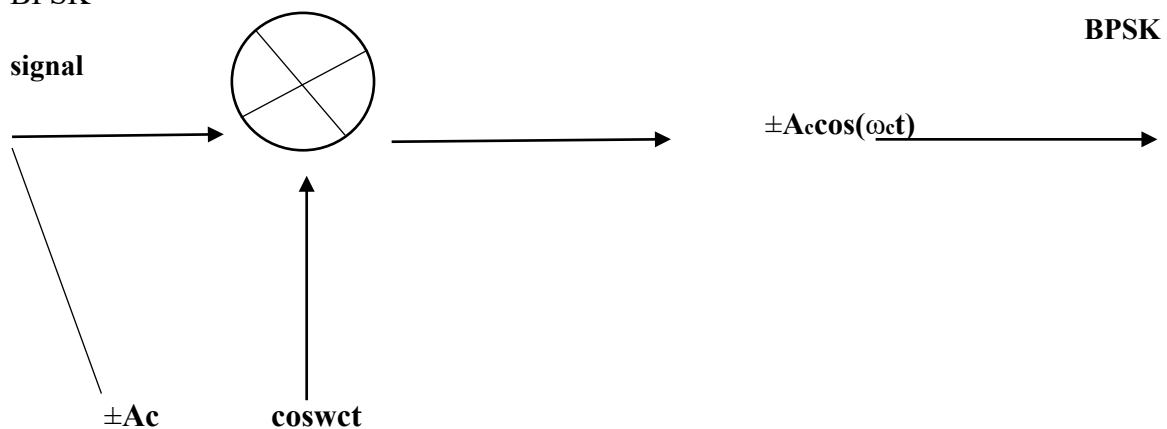
The value A_c of the carrier is given by: $A_c = \sqrt{\frac{2\pi}{T}} \text{ [V]}$

Substituting this value of A_c into equation of $s(t)$ we get:

$$\begin{aligned}
 S_1(t) &= +A_c \cos \omega_c t = +\sqrt{E} \sqrt{\frac{2}{T}} \cos \omega_c t & \text{when } m(t) = +1 \\
 S_2(t) &= -A_c \cos \omega_c t = -\sqrt{E} \sqrt{\frac{2}{T}} \cos \omega_c t & \text{when } m(t) = -1
 \end{aligned}
 \tag{2.11}$$

This form of BPSK is referred to as phase-reversal keying since the two carrier signals representing the logic ones and zeros are exactly 180° out of the phase i.e. the phase modulation index h=1. A more general form of BPSK occurs when the phase difference between the two signals is other than 180°. This creates a residual carrier term that allows carrier tracking by a phase-lock loop (PLL). Unless stated otherwise, BPSK will refer to 180° mode.

A method of generating BPSK is shown in figure below. A bit sequence represented by ±A_c is applied to a balanced modulator, resulting in an output of ±A_ccos(ω_ct) which is a BPSK



2.3 BPSK modulator

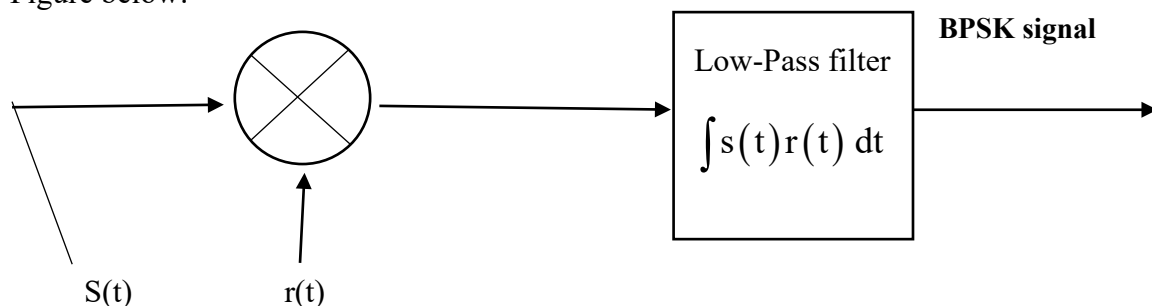
2.2.2 BPSK Detection by a Correlation Receiver

When binary PSK modulation is used at the transmission end, then a receiver employing coherent demodulation must be employed since the information is contained in the carrier phase.

A correlation receiver performs coherent demodulation. Correlation, C(t), of two signals, r(t) and s(t), over a period, T, is defined mathematically as:

$$C(t) = \int_0^t r(t)s(t) dt \quad 0 < t < T \tag{2.12}$$

Correlation is implemented in hardware by a multiplier and an integrator, as shown in Figure below:



2.4 Hardware implementation of correlation

The correlation receiver is so called because it correlates the received signal, composed of signal plus noise, with a replica of the signal. For the correlation to be achieved, it is necessary for the receiver to be phase locked to the carrier as discussed earlier. The purpose of the correlation receiver is to reduce the received symbol to a single point or statistic that will be used by the decision device to determine which symbol has been transmitted. In practice, the single point is a fixed voltage obtained by a S/H device. The decision device is a voltage comparator that is set such that if the voltage point is above a certain level, the comparator indicates a one is received; if the voltage is below this level, a received zero is indicated, the case for no noise will be treated first. Functionally and conceptually, the correlation receiver is composed of the receiver and bit synchronizer. The correlation receiver and the matched filter are equivalent. Specifically, the integrator and the S/H, at $t=T$, are equivalent to a matched filter, sampled at the output. Since there is no discrete carrier term in the ideal BPSK signal, a PLL may be used to extract the carrier reference only if a low level pilot carrier is transmitted together with the BPSK signal otherwise is needed a coherent detection. However, the 180° phase ambiguity must be resolved, this can be accomplished by using differential coding at the transmitter input and differential decoding at the receiver output

No Noise

An exact replica of the carrier multiplies the received symbol, and the output of the Multiplier is applied to an integrator. The output of the multiplier is given by:

$$+\sqrt{E} \sqrt{\frac{2}{T}} \cos w_c t \times \sqrt{\frac{2}{T}} \cos w_c t = \frac{2}{T} E \cos 2w_c t = +\sqrt{E} \frac{2}{T} \left[\frac{1+\cos 2x}{2} \right] = \pm \sqrt{E} \frac{2}{T} \left[\frac{1}{2} + \frac{1}{2} \cos 2w_c t \right]$$

The output of the multiplier, $e_m(t)$, is applied to integrator. The integrator will integrate the double frequency term over an integer number of cycles therefore deleting this term. In practice, a low pass filter follows the integrator to ensure that this term is deleted from the output. The output $a(t)$, is:

$$\pm \sqrt{E} \frac{2}{T} \int_0^t \left[\frac{1}{2} + \frac{1}{2} \cos 2w_c t \right] dt = \pm \sqrt{E} \frac{1}{T} t$$

the output of the correlator is either a positive- or negative-going ramp function (Triangular function).

The S/H device is usually set to sample the ramp whenever it reaches a maximum value, which ideally occurs whenever $t=T$. the upper limit of the integrator is also set to T . For the no noise case, the output of the integrator at $t=T$ is:

$$A(t=T) = \pm \sqrt{E} \frac{2}{T} \int_0^T \left[\frac{1}{2} + \frac{1}{2} \cos 2w_c t \right] dt = \pm \sqrt{E} \frac{1}{T} T = \pm \sqrt{E} \text{-----} 2.13$$

The S/H device is clocked to sample the output of the integrator whenever the maximum voltage is expected. For this case, the S/H samples at $t=T$ and the output voltage $b \pm E$ is applied to the threshold device, which normally triggers out a crisp waveform representing a one if the voltage is greater than zero or a zero if the voltage is less than zero.

with Noise

The case when the received signal is contaminated with additive white Gaussian

Noise (AWGN) is now considered. Let the white noise have a power spectral density (PSD) given by $N_0/2$. The received modulated baseband signal in input to the correlator receiver is now given by

$$S(t) = \pm\sqrt{E} \sqrt{\frac{2}{T}} \cos\omega_c t + n(t) \text{ -----2.14}$$

Where $n(t)$ is white Gaussian noise.

The output of the integrator at $t=Tb$ due to the signal part of $s(t)$ will be the same as before, $\pm a$. For the low-noise case, the output of the integrator might look similar to the ramp shown in figure below on the left; and for the high-noise case, the ramp on the right figure is indicative about what the output might look like.

Let the baseband sampled voltage outgoing by the integrator at $t=T$, can be represented by z , then $z = \pm\sqrt{E} + N$

It can be shown that N is a Gaussian random variable with zero mean μ and variance σ^2 given by: $\sigma^2 = N_0/2$

Therefore, the output random variable voltage, z , outgoing from the integrator is also a Gaussian random variable. Then z will have a variance of $N_0/2$ and a mean of $a = \pm\sqrt{E}$, depending upon which symbol has been received.

Letting $a = \sqrt{E}$

The conditional probability density function for z , gives an information about the correspondence of symbol with $\pm a$. Precisely it gives an indication if a one or a zero has been transmitted:

$$\left. \begin{aligned} p(z|-a) &= \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{1}{2}\left(\frac{z-\sqrt{E}}{\sigma}\right)^2} \\ p(z|+a) &= \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{1}{2}\left(\frac{z+\sqrt{E}}{\sigma}\right)^2} \end{aligned} \right\} \text{-----2.15}$$

Maximum value for $p(z|a)$ function, is reached when $z=a$.

The plot for these two functions is shown in figure below, this figure shows that the sampled output voltage z will fall somewhere along the x axis. Points $\pm a$ represents the more density probability places for z

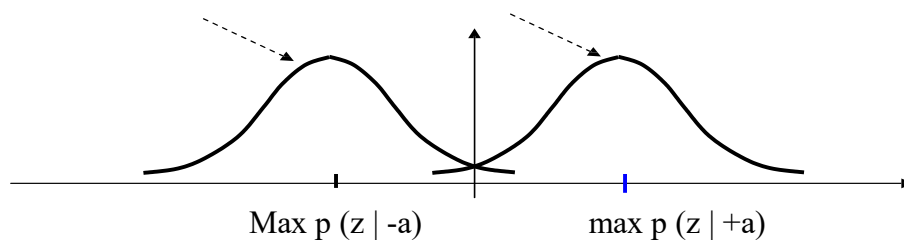


Figure 2.5 Conditional probability density functions

The baseband signal constellation for a BPSK is shown below, we can observe the jitter around $\pm a$ points due to the noise presence.

At the end of each symbol period when the integrator output voltage is sampled, the receiver must decide which symbol was sent based on the sampled voltage z . For maximum likelihood detection, conceptually, the statistic z is substituted into conditional probability density function already seen, and the function with the largest value indicates which symbol have the maximum possibility to have been transmitted.

.Probability of error

[21]The bit error probability can be derived from the formula for general binarySignals

$$P_b = Q\left(\sqrt{\frac{E_1 + E_2 - 2\rho_{12}\sqrt{E_1 E_2}}{2N_0}}\right)$$

$$\rho_{12} = -1 \text{ and } E_1 = E_2 = E_b$$

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right), \text{ (coherent Bpsk) -----2.16}$$

[6]The test is implemented by forming a ratio between two densities, such as:

$$\frac{P(z|+a)}{P(z|-a)} = \frac{P(z|\sqrt{E})}{P(z|-\sqrt{E})} = \frac{\frac{\pi}{\sqrt{2\pi\sigma^2}} e^{-\frac{1}{2}\left(\frac{z-\sqrt{E}}{\sigma}\right)^2}}{\frac{\pi}{\sqrt{2\pi\sigma^2}} e^{-\frac{1}{2}\left(\frac{z+\sqrt{E}}{\sigma}\right)^2}} = \frac{\pi}{\sqrt{2\pi\sigma^2}} e^{\left(\frac{1}{2}\left(\frac{z+\sqrt{E}}{\sigma}\right)^2 - \frac{1}{2}\left(\frac{z-\sqrt{E}}{\sigma}\right)^2\right)}$$

Assuming each symbol is equally likely and the cost of all errors is the same, the received point z is substituted as Gaussian random variable. Therefore a value for

$z > 1$, choose the symbol corresponding to $+a$;

$z < 1$, choose the symbol corresponding to $-a$.

Fundamentally, this test computes the value for each conditional probability density function at instant and selects the density with the largest value in that time instant.

2.2.3 Band width for Bpsk

[22]Two-level PSK (BPSK)

– Uses two phases to represent binary digits

$$S(t) = \begin{cases} A \cos(2\pi fct) & \text{binary 1} \\ A \cos(2\pi fct + \pi) & \text{binary 0} \end{cases}$$

$$\begin{cases} A \cos(2\pi fct) & \text{binary 1} \\ -A \cos(2\pi fct) & \text{binary 0} \end{cases}$$

$$B = f_b \text{-----2.17}$$

2.3 Transmission Line theory-Matrix Representation

2.3.1 Feed Resistance Voltage Drop - two port network analysis

[23]

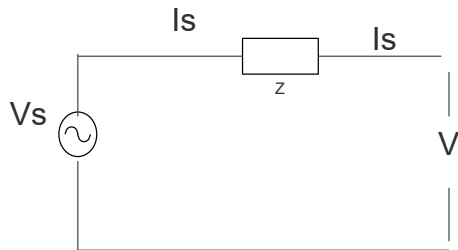


Figure 2.6 Feeder impedance

$$A = \left. \frac{V_s}{V} \right|_{I_1=0} = 1, V_s = V_1 = 1$$

$$B = \left. \frac{V_s}{I_s} \right|_{V_1=0} = Z \Delta x$$

$$C = \left. \frac{I_s}{V_1} \right|_{I_1=0} = 0$$

$$D = \left. \frac{I_s}{I_s} \right|_{V_1=0} = 1$$

2.3.2 Rail Parameter Design using A Distributed Model

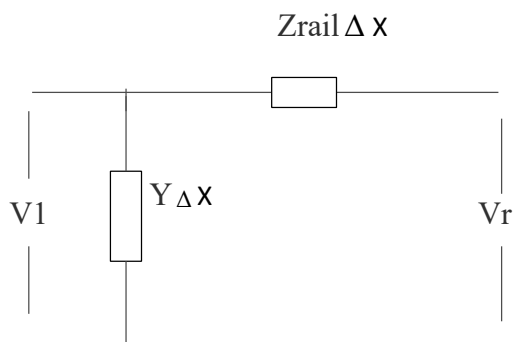


Figure 2.7 Rail parameter-distributed line model, sending/receiving end voltages

[23] We can write a matrix representation to describe the sending end voltage and current by receiving end voltage and current.

$$V = AV_R + BI_R$$

$$I = CV_R + DI_R$$

I: Sending end current

I_R : Receiving end current

V: Sending end voltage

V_R : Receiving end voltage

$$\begin{pmatrix} V \\ I \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_R \\ I_R \end{pmatrix}$$

A, B, C, and D are parameters to be found Purposes of Equivalent Circuit

- To calculate the voltage at the receiving end when the sending end voltage is known or vice versa.
- This is used to find the voltage difference between sending and receiving end.

A Distributed Model

Series impedance and shunt admittance values are given as per-length and are uniformly distributed along the transmission lines.

- A distributed model accounts for this distributed nature of transmission-line parameters.
- This model provides exact transmission line equations and is suitable for long-length transmission lines.

It is important that the voltage at the load is kept constant in daily operation.

- Starting from the load, the receiving end of the line is located at $x = 0$ and the sending end is at $x = \ell$.

- At the incremental length Δx of the line, we are interested to find relationship between sending end voltage $V(x+\Delta x)$ and sending end current $I(x+\Delta x)$ to the receiving end voltage $V(x)$ and current $I(x)$.

$$I(x + \Delta x) = I(x) + y \Delta x V(x + \Delta x), \quad yV(x + \Delta x) = \frac{I(x + \Delta x) - I(x)}{\Delta x}$$

$$\frac{dI}{dx} = yV, \quad V(x + \Delta x) = V(x) + z \Delta x I(x)$$

$$\frac{V(x + \Delta x) - V(x)}{\Delta x} = zI(x), \quad \frac{dV}{dx} = zI$$

$$\left. \begin{array}{l} \frac{dI}{dx} = yV \\ \frac{dV}{dx} = zI \end{array} \right\} \begin{array}{l} \text{-----1} \\ \text{-----2} \end{array}$$

Form 1 and 2

$$\frac{d^2V}{dx^2} = z \frac{dI}{dx} = zyV$$

$\gamma = \sqrt{zy}$, γ is called propagation constant (1/m).

$$V=K_1e^{\gamma x}+K_2e^{-\gamma x}$$

$$I=\frac{1}{z}V\frac{dV}{dx}=\frac{K_1\gamma e^{\gamma x}}{z}+\frac{K_2\gamma e^{-\gamma x}}{z}$$

We can find the constants k_1 and k_2 from the fact that at the receiving end of the line ($x=0$), $V = V_R$ and $I = I_R$.

$$V_R=K_1+K_2$$

$$K_1=\frac{V_R+I_R(z/\gamma)}{2}, K_2=\frac{V_R-I_R(z/\gamma)}{2}$$

$$\frac{z}{\gamma}=\frac{z}{\sqrt{zy}}=\sqrt{\frac{z}{y}}=Z_c, z=Z_{rail}$$

$$K_2=\frac{V_R-Z_c I_R}{2}, K_1=\frac{V_R+Z_c I_R}{2}$$

• Substitute k_1 and k_2 , we have the voltage and current equations at any point x from the load as follows.

$$V=V_R\left(\frac{e^{\gamma x}+e^{-\gamma x}}{2}\right)+Z_c I_R\left(\frac{e^{\gamma x}-e^{-\gamma x}}{2}\right) \text{-----2.17}$$

$$I=I_R\left(\frac{e^{\gamma x}+e^{-\gamma x}}{2}\right)+\frac{V_R}{Z_c}\left(\frac{e^{\gamma x}-e^{-\gamma x}}{2}\right) \text{-----2.18}$$

$$V=V_R \cosh(\gamma x)+Z_c I_R \sinh(\gamma x), I=I_R \cosh(\gamma x)+\frac{V_R}{Z_c} \sinh(\gamma x)$$

$$\begin{pmatrix} V \\ I \end{pmatrix} = \begin{pmatrix} \cosh(\gamma x) & Z_c \frac{\sinh(\gamma x)}{Z_c} \\ \frac{\sinh(\gamma x)}{Z_c} & \frac{\sinh(\gamma x)}{Z_c} \end{pmatrix} \begin{pmatrix} V_R \\ I_R \end{pmatrix}$$

2.3.3 Lumped Model (For Train Shunt and rail Impedance Model)

[24] This is also known as the nominal π model as shown below. The admittance and impedance Z shown are shown for the whole line, per-phase (and not per mile).

For the "pi" model shown we have the following model:-

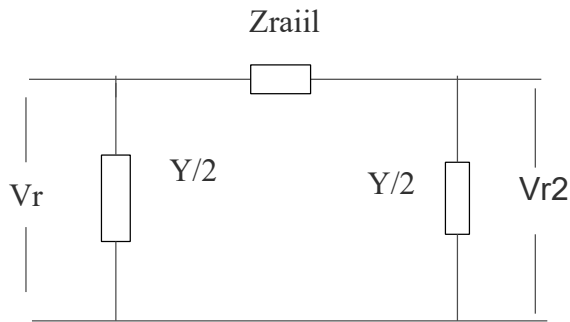


Figure 2.8 train and rail parameters with Lumped model

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} \frac{ZY}{2} + 1 & Z \\ Y[1 + \frac{ZY}{4}] & \frac{ZY}{2} + 1 \end{bmatrix} \begin{bmatrix} V_{r2} \\ I_{r2} \end{bmatrix}$$

For the train shunting the track circuit voltage, $I_{r2} = 0$

$$V_R = \left[\frac{ZY}{2} + 1 \right] V_{r2} + Z I_{r2}$$

$$I_R = Y \left[1 + \frac{ZY}{4} \right] V_{r2} + \left[\frac{ZY}{2} + 1 \right] I_{r2}$$

$$V_R = \left[\frac{ZY}{2} + 1 \right] V_{r2}$$

$$I_R = Y \left[1 + \frac{ZY}{4} \right] V_{r2}$$

$$\frac{V_R}{I_R} = \frac{\frac{ZY}{2} V_{r2}}{Y \left[1 + \frac{ZY}{4} \right] V_{r2}} = \frac{2Y + 4}{4Y + ZY^2} = Z_S \text{-----2.19}$$

2.4 The Purpose of Track Circuits

[25]The track circuit is a device designed to continuously prove the absence of train from a given section of track; it cannot absolutely prove the presence of a train, since its designed failure mode is to give the same indication as if a train is present.

By proving the absence of a train, a clear track circuit can be used to confirm that it is safe to set a route and permit a train to proceed.

2.4.1 Fundamental Design Principle

A section of railway track is electrically defined by the provision of insulated rail joints (IRJs), or equivalent, in the rails at either end as shown in Figure B2. A source of electrical energy is connected, via a series impedance, across the rails at one end and a detector, which is receptive to the particular form of electrical energy, is connected across the rails at the other end.

With no train within its boundaries, the detector senses the transmitted electrical energy and energises the repeater circuit. This conveys the absence of a train to the signaling system (ie. track circuit clear). A train within the track circuit will cause the rails to be short circuited such that the detector no longer sees sufficient electrical energy; it therefore changes state and informs the signalling system (ie. track circuit occupied). It can be seen that an electrical short circuit between the rails, caused other than by a train, or any disconnection within the circuit, will fail the track circuit and inform the signalling system that the track circuit is occupied. Such a circuit configuration incorporates a high degree of “fail safe”; it does, however, depend upon good electrical contact between the wheel sets of the train and the rails upon which they run. It also depends upon a continuous low impedance path between the steel tyres of each wheel via the connecting axle.

Track circuits apply this basic principle in a variety of ways for various reasons. The source of electrical energy may be d.c., a.c. at power frequencies, a.c. at audio frequencies, or a series of impulses. The detector may be a simple relay, a more complex a.c. vane relay or a receiver tuned to a particular frequency or pattern of signals. Additional items may have to be added to overcome the problems arising from sharing the rails with heavy currents created by an electric traction system.

2.4.2 Electrical Behaviour of Railway Track

2.4.2.1 Ballast Resistance

Ballast resistance is the resistance between the two rails of a track circuit and comprises of leakage between the rail fixings, sleepers and earth. The value of this resistance is dependent upon the condition of any insulations, cleanliness of the ballast and the prevailing weather conditions.

The ballast resistance is inversely proportional to track circuit length and is expressed as ohm kilometers, typical values being in the range 2 to 10 Ω km. Lower values may be obtained in wet conditions with bad drainage and/or contamination with conductive materials. Higher values may be obtained in dry/clean conditions or during frosty weather. A reliable track circuit must therefore be able to operate over a wide variation of ballast resistance.

Most simple explanations of track circuit operation portray ballast resistance as a single resistance connected between the rails as shown in Figure B3. Whilst such a representation is useful in explaining the simple behavior of d.c. track circuits, it is important to understand that the model's limitations make it unsuitable to explain many of the more complex phenomena demonstrated by track circuits. For the types of track circuit used, the reactance of the ballast can be considered as negligible.

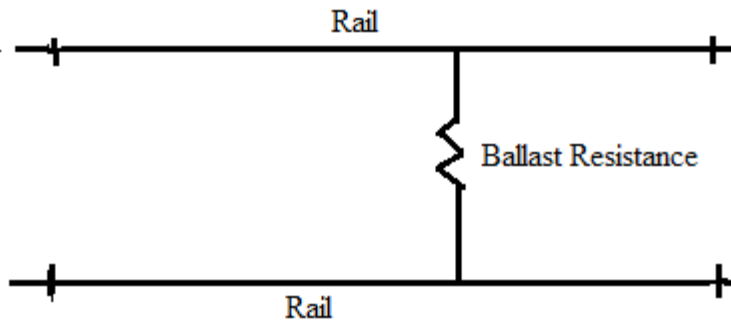


Figure 2.9 Ballast resistance

When considering other than the simple case, a more accurate model would represent the ballast resistance as a series of resistances between each rail and earth as shown in Figure B4. Although there is a further component of resistance between the rails independent of earth, it is high compared to the rail–earth resistance and can be discounted for most calculations.

2.4.2.2 Rail Impedance

The d.c resistance of rail is very low, around $0.035\Omega/\text{km}$, although this is increased to approximately $0.25\Omega/\text{km}$ by the relatively higher resistance of galvanised iron bonds in jointed track. The inductance of rail can raise the overall impedance per rail from approximately $0.3\Omega/\text{km}$ (50Hz) to, in the case of reed track circuits, $2.5\Omega/\text{km}$ (400Hz) and for TI21 track circuits, $10\Omega/\text{km}$ (2 kHz). These impedance values may be increased further by large traction currents, due to the rail being driven toward saturation. When considering a.c. track circuits, rail inductance must be taken into account by application of the further complex model including rail inductance as shown in Figure B5. Although of little consequence at power frequencies, audio frequency track circuits exhibit a steep decline in rail voltage as distance from the transmitter increases. Since the ballast resistance is now distributed throughout the length, detailed calculation requires the use of hyperbolic functions.

These effects can usually be ignored when considering the operation of a.c. power frequency track circuits, where rail voltage can be expected to decline very little between the feed and relay ends.

2.4.2.3 Rail to Rail Capacitance

Although an even more complete picture would include rail–to–rail capacitance, this is very small and of marginal significance relative to track circuit operation at audio frequencies.

Workable Lengths of Track Circuits

It can be seen that the workable length of a track circuit is limited by three factors:

- the declining value of ballast resistance;
- the increasing value of rail impedance;
- Immunisation / Electrification requirements, including electromagnetic compatibility with trains.

As the various types of track circuit feed/transmitter produce differing power outputs, and as rail impedance is frequency related, it follows that the maximum workable length will vary with design type and with the minimum ballast resistance at which the track circuit is expected to remain functional.

2.4.2 Track Circuit Clear

The ballast resistance forms an additional load in parallel with the relay. As the ballast resistance falls due to wet weather, the current drawn from the feed increases. This will cause the voltage across the feed resistor to increase, so reducing the rail and relay voltages. If this reduction causes the relay voltage to fall below the relay pick-up value, the track circuit will not clear after an occupying train has departed. A further reduction of the relay voltage to below relay drop-away value will fail the track to the occupied state without the passage of a train.

Reducing the value of feed resistance has the effect of increasing the current fed into the rails and raising the rail/relay voltage. Long feed end leads insert additional non-adjustable feed resistance and thereby reduce the effectiveness of the adjustable feed resistance. Long relay end leads reduce the ratio of relay voltage to rail voltage by potential divider action; the effect is to cause the track circuit to indicate occupied at a higher ballast resistance. It therefore imposes a shorter maximum workable length.

2.4.3 Track Circuit Occupied

When the track circuit is occupied by a train, a short circuit current will flow from the feed end equipment, which is limited by the value of the feed resistance and the characteristics of the feed end equipment itself. The feed end equipment is designed to cope with this worst case power dissipation.

The train shunt resistance is in parallel with the ballast resistance. With any given value of feed resistance, the relay will operate at particular values of combined ballast/train shunt resistance. Thus, higher ballast resistance will require a lower value of train shunt resistance to operate the relay and vice versa.

The minimum permitted drop shunt resistance is 0.5Ω (0.3Ω on certain impedance bond track circuits). During very dry weather or severe frost conditions, the ballast resistance increases towards its natural maximum and will offer only a small contribution towards the overall shunt. Thus, when a 0.5Ω (0.3Ω) shunt is placed across the rails, it must still reduce the relay voltage to below drop-away value. It should also be noted that the track relay is dropped by short circuit rather than disconnection. Therefore, the drop-away time of the relay is increased due to the inductive circuit prolonging the decay of the coil current.

2.5 Track Circuit Antenna

Jointless track circuits (JTCs) are a key component of train control systems (TCSs) and are used for train detection. Through electromagnetic induction, JTC currents in the rails can induce voltages in track-circuit-reader (TCR) antennae, enabling continuous transmission of train control information.

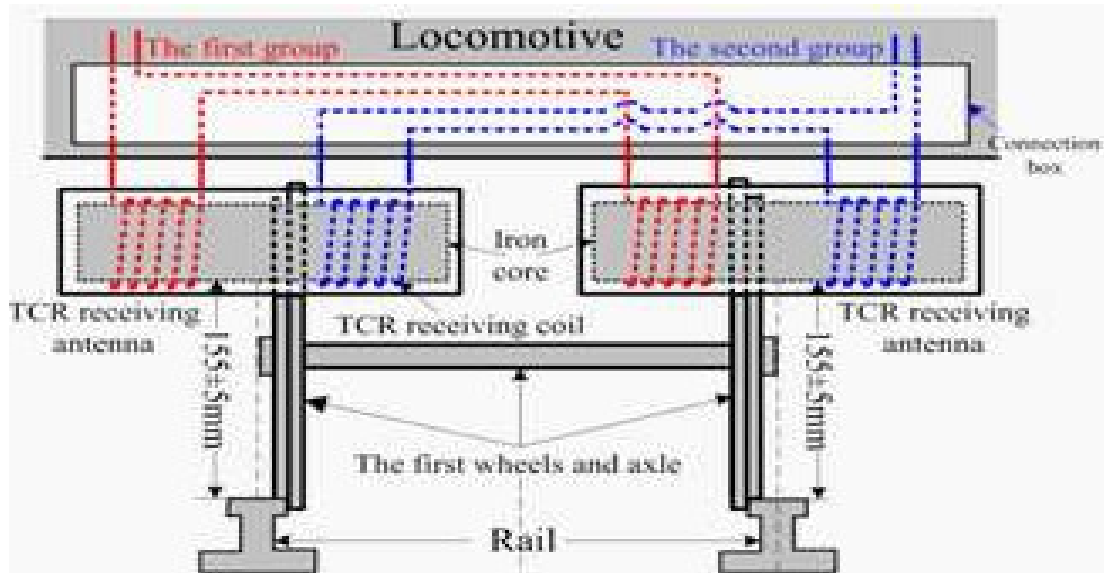
2.5.1 Work Principle and Structures of JTC and TCR

[26]JTCs consist essentially of a transmitter, a transmitting cable, transmitting electrical tuning units, track lines with two rails, a receiving cable, and a receiver. The TCR is an onboard device that consists of TCR antennae, TCR transmission cable, and TCR host computer.

According to installation specifications, one TCR antenna is installed ahead of the leading locomotive wheels and over each rail. As shown in Figure 2.10, the two antennae are perpendicular to their respective rail. The performance and internal structure of the two Antennae are identical; both comprise an iron core about which two independent coils are wound. In a given antenna, each coil is in series with a similarly positioned coil from the

other antenna to make a diploid redundant structure, which improves the reliability of the TCR antennae.

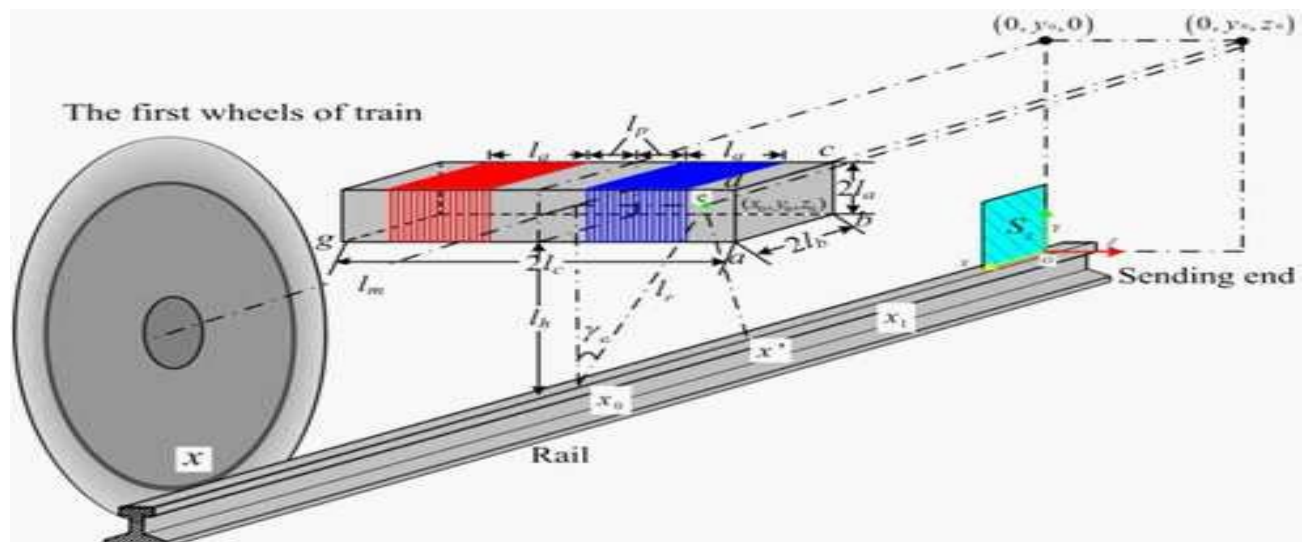
To control train speed and detect train occupancy, the transmitter generates a JTC signal containing train target speed. The signal goes through the transmitting cable, and then through the rails into the receiving end of JTC.



2.10 Basic structure and position of TCR antennae.

2.5.2 Calculation of Magnetic Flux in TCR Antenna

As shown in Figure 5, we take O to be the origin of a Cartesian coordinate system. The dimensions of the TCR antenna are $ab = 2lb$, $ad = 2la$, and $ag = 2lc$, the widths of the coils are lq , the number of turns is qm , the distance from the iron-core center to the inner edge of the coils is lp , the height from the lower edge of the iron core to the rail surface is lh , the horizontal distance from the leading-wheel axle center to the TCR antenna center is lm , and $e(x_0; y_0; z_0)$ is an arbitrary point on the TCR-antenna induction coils.

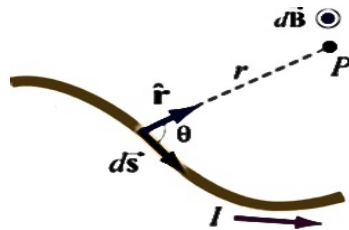


2.11 Coordinate system for TCR antenna, rails, and leading wheels.

The Biot-Savart law [22, 23] gives the magnetic-induction intensity B_e [24] generated by the JTC current in the rails from x to x_1 ($x_1 \geq 0; x \geq 0$) at the arbitrary point $e(x_0; y_0; z_0)$ as

Biot-Savart Law

[27] Currents which arise due to the motion of charges are the source of magnetic fields. When charges move in a conducting wire and produce a current I , the magnetic field at any point P due to the current can be calculated by adding up the magnetic field contributions, $d\vec{B}$, from small segments of the wire $d\vec{s}$, (Figure 9.1.1).



2.12 Magnetic field $d\vec{B}$ at point P due to a current-carrying element $d\vec{s}$. Magnetic field $d\vec{B}$ at point P due to a current-carrying element $I d\vec{s}$

These segments can be thought of as a vector quantity having a magnitude of the length of the segment and pointing in the direction of the current flow. The infinitesimal current source can then be written as $I d\vec{s}$.

Let r denote as the distance from the current source to the field point P , and the corresponding unit vector. The Biot-Savart law gives an expression for the magnetic field contribution, $d\vec{B}$, from the current source, $I d\vec{s}$,

$$d\vec{B} = \frac{\mu_0 I d\vec{s} \times \hat{r}}{4\pi r^2} \text{-----2.20}$$

Where μ_0 is a constant called the permeability of free space:

$$\mu_0 = 4\pi \times 10^{-7} \text{ T.m/A}$$

Notice that the expression is remarkably similar to the Coulomb's law for the electric field due to a charge element dq :

$$d\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} \hat{r}$$

Adding up these contributions to find the magnetic field at the point P requires integrating over the current source,

$$\vec{B} = \int_{\text{wire}} d\vec{B} = \frac{\mu_0 I}{4\pi} \int_{\text{wire}} \frac{d\vec{s} \times \hat{r}}{r^2}$$

The integral is a vector integral, which means that the expression for $d\vec{B}$ is really three integrals, one for each component of $d\vec{B}$. The vector nature of this integral appears in the cross product $I d\vec{s} \times \hat{r}$. Understanding how to evaluate this cross product and then perform the integral will be the key to learning how to use the Biot-Savart law. [28]

$$B_e(x, x_1, t, x_0, y_0, z_0) = \frac{\mu_0 \mu_r}{4\pi} \int_{x_1}^x I_d(x, x', t) (y_0^2 + z_0^2)^{1/2} \left(\sqrt{(x_0 - x')^2 + y_0^2 + z_0^2} \right)^{-3} dx \text{-----2.21}$$

Where μ_0 is the permeability of vacuum and μ_r is the relative permeability of the iron core. The corresponding magnetic $\phi_{e(x, x_1, z_0, t)}$ of Sz is

$$\phi_{e(x, x_1, z_0, t)} = \frac{q_m}{l_q} \int_{l_h}^{l_h+2l_a} \int_{x-l_m-l_b}^{x-l_m+l_b} B_e(x, x_1, t, x_0, y_0, z_0) y_0 (y_0^2 + z_0^2)^{-1/2} dx_0 dy_0 \text{-----2.22}$$

Let the total magnetic flux in each induction coil of a TCR antenna be $\Phi_1(x, x_1, t)$ and $\Phi_2(x, x_1, t)$, where

$$\begin{aligned} \Phi_1(x, x_1, t) &= \Phi_{11}(x, x_1, t) - \Phi_{12}(x, x_1, t) = \Phi_2(x, x_1, t) \\ &= \Phi_{22}(x, x_1, t) - \Phi_{21}(x, x_1, t) \end{aligned}$$

With $\Phi_{11}(x, x_1, t)$ and $\Phi_{22}(x, x_1, t)$ being the total self-magnetic flux of each induction coil in a TCR antenna. According to Eq. (13), they can be expressed as [25]

$$\phi_{11}(x, x_1, t) = \phi_{22}(x, x_1, t) = \int_{l_p}^{l_p+l_q} \phi_{e(x, x_1, z_0, t)} dz_0 \text{-----2.23}$$

The fluxes $\Phi_{12}(x, x_1, t)$ and $\Phi_{21}(x, x_1, t)$ are the mutual magnetic fluxes of the two induction coils in one TCR antenna and can be expressed as [25]

$$\Phi_{12}(x, x_1, t) = \Phi_{21}(x, x_1, t) = I_c(x, x_1, t) M_c \text{-----2.24}$$

Where $I_c(x, x_1, t)$ is the self-inductance current in the coils:

$$I_c(x, x_1, t) = \frac{1}{\bar{Z}_{coil}} \frac{d\phi_{11}(x, x_1, t)}{dt} \text{-----2.25}$$

\bar{Z}_{coil} is the impedance of one coil and M_c (H) the mutual-induction coefficient of the two coils in one TCR antenna.

$$M_c = \int_{l_p}^{l_p+l_q} \int_{l_h}^{l_h+2l_a} \int_{x-l_m-l_b}^{x-l_m+l_b} [M_{ab}(x_0, y_0, z_0) + M_{bc}(x_0, y_0, z_0) + M_{cd}(x_0, y_0, z_0) + M_{da}(x_0, y_0, z_0)] dx_0 dy_0 dz_0 \text{-----2.26}$$

Where $M_{ab}(x_0, y_0, z_0)$, $M_{bc}(x_0, y_0, z_0)$, $M_{cd}(x_0, y_0, z_0)$, and $M_{da}(x_0, y_0, z_0)$ (H/m^3) are the magnetic-induction coefficients at the arbitrary point $e(x_0, y_0, z_0)$ in one coil in the directions ab, bc, cd, and da. These coefficients connect the self-inductance current $I_c(x, x_1, t)$ of the other coil of the same TCR antenna (Figure 6). They are given by

$$M_{ab}(x_0, y_0, z_0) = \frac{q_m \mu_0 \mu_r}{4\pi(z_0 + l_p)} \left(\frac{e_1 a_1}{ea_2} - \frac{e_1 b_1}{eb_2} \right) \text{-----2.27}$$

$$M_{bc}(x_0, y_0, z_0) = \frac{q_m \mu_0 \mu_r}{4\pi(z_0 + l_p)} \left(\frac{e_2 b_1}{eb_2} - \frac{e_2 c_1}{ec_2} \right) \text{-----2.28}$$

$$M_{cd}(x_0, y_0, z_0) = \frac{q_m \mu_0 \mu_r}{4\pi(z_0 + l_p)} \left(\frac{e_3 c_1}{ec_2} - \frac{e_3 d_1}{ed_2} \right) \text{-----2.29}$$

$$M_{da}(x_0, y_0, z_0) = \frac{q_m \mu_0 \mu_r}{4\pi(z_0 + l_p)} \left(\frac{e_4 d_1}{ed_2} - \frac{e_4 a_1}{ea_2} \right) \text{-----2.30}$$

Where ea_2 , eb_2 , ec_2 , and ed_2 are the distances from $e(x_0, y_0, z_0)$ in one coil to a_2 , b_2 , c_2 , and d_2 in the other coil of the same TCR antenna, respectively. They are given by

$$ea_2 = \sqrt{(x_0 - x + l_m - l_b)^2 + (y_0 - l_h)^2 + (z_0 + l_p)^2}$$

$$ec_2 = \sqrt{(x_0 - x + l_m + l_b)^2 + (y_0 - l_h - 2l_a)^2 + (z_0 + l_p)^2}$$

$$eb_2 = \sqrt{(x_0 - x + l_m + l_b)^2 + (y_0 - l_h)^2 + (z_0 + l_p)^2}$$

$$ed_2 = \sqrt{(x_0 - x + l_m - l_b)^2 + (y_0 - l_h - 2l_a)^2 + (z_0 + l_p)^2}$$

e'_1 , e'_2 , e'_3 and e'_4 are the perpendicular points of $e(x_0, y_0, z_0)$ in the directions of ab , bc , cd , and da , respectively. The quantities a_1, b_1, c_1 , and d_1 are located in the same coil as e , and $e'_1 a$, $e'_1 b$, $e'_2 b$, $e'_2 c$, $e'_3 c$, $e'_3 d$, $e'_4 d$ and $e'_4 a$ are the distances from e'_1 to a , e'_1 to b , e'_2 to b , e'_2 to c , e'_3 to c , e'_3 to d , e'_4 to d , e'_4 to a , respectively. They satisfy

$$e'_1 a = e'_3 d = |x_0 - x + l_m - l_b| \quad e'_2 b = e'_4 a = |y_0 - l_h|$$

$$e'_1 b = e'_3 c = |x_0 - x + l_m + l_b| \quad e'_2 c = e'_4 d = |y_0 - 2l_a|$$

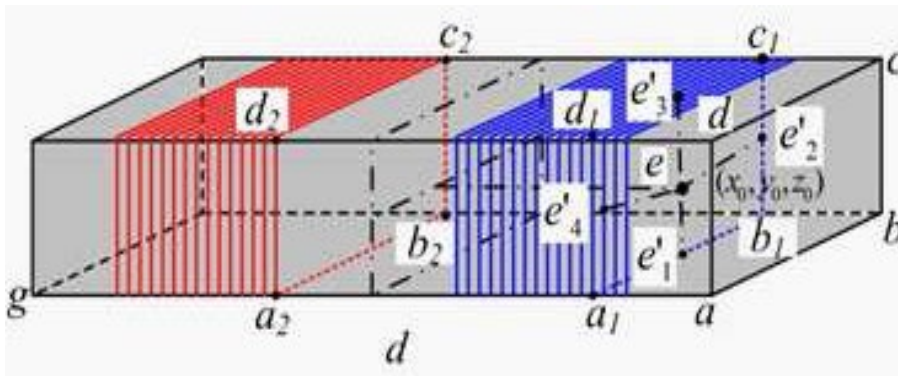


Figure 2.13 Coordinate system of TCR antenna.

When a train enters a track circuit, the JTC signal is shunted by the leading wheels and axle of the locomotive, following which most of the JTC signal flows back into the transmitter with only a small portion entering the receiver. Simultaneously, voltage is induced electromagnetically in the TCR antenna by the JTC and then transmitted into the TCR host computer through the TCR transmission cable. The train target speed is obtained demodulation and decoding in the TCR host computer and then transmitted to the vital computer for train control.

2.6 Band-Pass filters

[29] A band pass filter allows signals with a range of frequencies (pass band) to pass through and attenuates signals with frequencies outside this range.

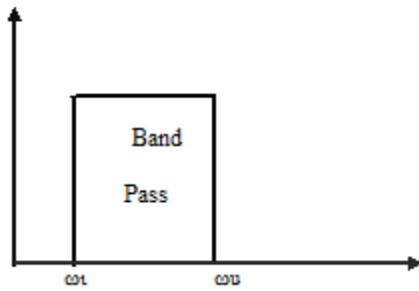


Figure 2.14 Band pass filter

ω_u : Lower cutoff frequency;
 ω_l : upper cutoff frequency;

$\omega_0 = \sqrt{\omega_u \omega_l}$ center frequency;

$B = \omega_u - \omega_l$ bandwidth;

$Q = \frac{\omega_0}{B}$ Quality factor;

As with practical low-pass and high-pass filters, upper and lower cut-off frequencies of practical band-pass filter are defined as the frequencies at which the magnitude of the voltage transfer function is reduced by $\frac{1}{\sqrt{2}}$ (or -3 dB) from its maximum value.

Second-order band-pass filters:

Second-order band pass filters include two storage elements (two capacitors, two inductors, or one of each). The transfer function for a second-order band-pass filter can be written as

$$H(j\omega) = \frac{K}{1 + jQ\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)}, \quad |H(j\omega)| = \frac{|K|}{\sqrt{1 + Q^2\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2}}, \quad \angle H(j\omega) = -\tan^{-1}\left[Q\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)\right]$$

The maximum value of $|H(j\omega)| = |K|$ is called the filter gain. The lower and upper cut-off frequencies can be calculated by noting that $|H(j\omega)| = \frac{|K|}{\sqrt{2}}$ and solving for

This procedure will give two roots: ω_l and ω_u

$$H(j\omega) = \frac{1}{\sqrt{2}} |H(j\omega)|_{\max} = \frac{K}{\sqrt{2}} = \frac{K}{\sqrt{1 + Q^2\left(\frac{\omega_c}{\omega_0} - \frac{\omega_0}{\omega_c}\right)^2}} \quad \text{-----2.31}$$

$$Q^2\left(\frac{\omega_c}{\omega_0} - \frac{\omega_0}{\omega_c}\right)^2 = 1, \quad Q\left(\frac{\omega_c}{\omega_0} - \frac{\omega_0}{\omega_c}\right) = \pm 1$$

The above equation is really two quadratic equations (one with + sign in front of fraction and one with a \pm sign). Solving these equations we will get 4 roots (two roots per equation). Two of

these four roots will be negative which are not physical as $\omega_c > 0$. The other two roots are the lower and upper cut-off frequencies (ω_l and ω_u , respectively):

$$\omega_l = \omega_o \sqrt{1 + \frac{1}{4Q} - \frac{\omega_o}{2Q}} \quad \omega_u = \omega_o \sqrt{1 + \frac{1}{4Q} + \frac{\omega_o}{2Q}}$$

Bode plots of a second-order filter is shown below. Note that as Q increases, the bandwidth of the filter become smaller and the $|H(j\omega)|$ becomes more peaked around ω_o

Asymptotic behavior:

At low frequencies, $\omega/\omega_o \ll 1$, $|H(j\omega)| \propto \omega$ (a +20dB/decade line), and $\angle H(j\omega) \rightarrow 90^\circ$.

At high frequencies, $\omega/\omega_o \gg 1$, $|H(j\omega)| \propto 1/\omega$ (a -20dB/decade line), and $\angle H(j\omega) \rightarrow -90^\circ$

$\omega = \omega_o$, $|H(j\omega)| = K$ (maximum filter gain), and $\angle H(j\omega) \rightarrow 0^\circ$. There are two ways to solve second-order filter circuits. 1) One can try to write $H(j\omega)$ in the general form of a second-order filters and find Q and ω_o . Then, use the formulas above to find the lower and upper cut-off frequencies. 2) Alternatively, one can directly find the upper and lower cut-off

frequencies and use $\omega_o = \sqrt{\omega_u \omega_l}$ to find the center frequency and $B \equiv \omega_u - \omega_l$ to find the

bandwidth, and $Q \equiv \frac{\omega_o}{B}$ to find the quality factor The two examples below show the two

methods. Note that one can always find ω_o and K rapidly as $H(j\omega)$ is purely real and

$|H(j\omega)| = K$

2.6.1 Series RLC Band-pass filters

Using voltage divider formula, we have

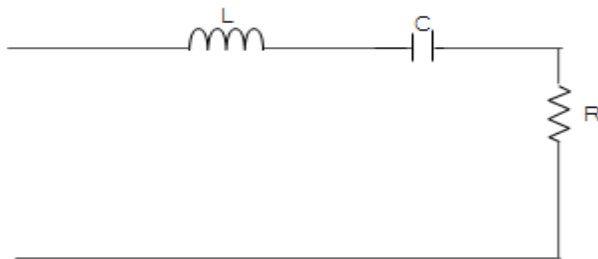


Figure 2.15 RLC series filter

$$V_{in} = L \frac{dI}{dt} + \frac{1}{C} \int I dt + IR$$

$$V_{in}(s) = sLI(s) + \frac{I(s)}{sC} + I(s)R \quad \text{-----1}$$

$$V_{out} = IR, \quad V_{out}(s) = I(s)R \quad \text{-----2}$$

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{I(s)R}{sLI(s) + \frac{I(s)}{sC} + I(s)R},$$

$$= \frac{R}{sL + \frac{1}{sC} + R}, \quad \text{sub } s = j\omega$$

$$H(j\omega) = \frac{R}{R + j\omega L + \frac{1}{j\omega C}}$$

$$\frac{V_o}{V_i} = \frac{R}{R + j\omega L + (1/j\omega C)} \text{-----2.32}$$

There are two approaches to find filter parameters K , ω_o , ω_u , ω_l .

Method 1: We transform the transfer function in a form similar to general form of the Transfer function for second order bandpass filters:

$$H(j\omega) = \frac{K}{1 + jQ\left(\frac{\omega}{\omega_o} - \frac{\omega_o}{\omega}\right)}$$

Note that the denominator of the general form is in the form $1 + j \dots$. Therefore, we divide top and bottom of transfer function of series RLC bandpass filters by R :

$$H(j\omega) = \frac{1}{1 + jQ\left(\frac{\omega L}{R} - \frac{R}{\omega RC}\right)} \text{-----2.32}$$

Comparing the above with the general form of the transfer function, we find $K = 1$. To find Q and ω_o , we note that the imaginary part of the denominator has two terms, one positive and one negative (or one that scales as ω and the other that scales as $1/\omega$) similar to the general form of transfer function of 2nd-order band-pass filters (which includes $Q\omega/\omega_o$ and $Q\omega_o/\omega$). Equating these similar terms we get:

$$\frac{Q\omega}{\omega_o} = \frac{\omega L}{R} \rightarrow \frac{Q}{\omega_o} = \frac{L}{R}$$

$$\frac{Q\omega_o}{\omega} = \frac{1}{\omega RC} \rightarrow Q\omega_o = \frac{1}{RC}$$

We can solve these two equations to find:

$$\omega_o = \frac{1}{\sqrt{LC}} \qquad Q = \frac{\omega_o}{R/L} = \sqrt{\frac{L}{R^2 C}}$$

The lower and upper cut-off frequencies can now be found from the formulas on.

Method 2: In this method, we directly calculate the filter parameters similar to the procedure followed for general form of transfer function. Some simplifications can be made by noting:

1) At $\omega = \omega_o$, $H(j\omega)$ is purely real and 2) $K = H(j\omega=j\omega_o)$. Starting with the transfer function for the series RLC filter:

$$H(j\omega) = \frac{1}{1 + j\left(\omega L - \frac{1}{\omega C}\right)}$$

We note that the transfer function is real if coefficient of j in the denominator is exactly zero (note that this happens for

$$\omega_o L - \frac{1}{\omega_o C} = 0 \rightarrow \omega_o = \frac{1}{\sqrt{LC}}$$

Also

$$K = H(j\omega=j\omega_0) = \frac{R}{R} = 1$$

The cut-off frequencies can then be found by setting:

$$|H(j\omega)| = \frac{|K|}{2} = \frac{1}{\sqrt{2}}$$

$$\left(\frac{\omega_0 L}{R} - \frac{1}{\omega_0 RC}\right)^2 = 2$$

which can be solved to find ω_u and ω_l . Input and Output Impedance of band-pass RLC filters

$$Z_i = j\omega L + (1/j\omega C) + R = j\left(\omega L - \frac{1}{\omega C}\right) \text{ occurs at } \omega = \omega_0$$

$$Z_o = (j\omega L + \frac{1}{j\omega C}) || R \rightarrow Z_o |_{\max} = R$$

$$L = \frac{1}{625C} \dots\dots\dots 2.33$$

$$Q = \sqrt{\frac{L}{R^2 C}}, Q^2 = \frac{L}{R^2 C}, \dots\dots\dots 2.34$$

2.7 Other research

[30]A master’s study on “Preview information for locomotive in cab displays for high speed trains” by Jacob Einhorn, focuses was to examine whether the proposed information aiding cab display improved safety and efficiency of train operation over an existing display, and, if so, to show how much of the provided preview information was useful. The researcher used MIT/VOIP simulator for acquisition of data into log file- the time and location of any change in signal or failure scenario is automatically recorded, along with the train’s location at the time of the change. Thus for each trip the simulator provides a log file that can be used to analyze the dependent variables of interest-namely, speed limit, reaction time and distance, station stopping accuracy and schedule deviation. MIT and Volpe National Transportation center engineers were involved in the research for data acquisition. And Analyzing was based on comparison between the dependent and independent variables.

3. MATHEMATICAL MODELLING AND DESIGN

3.1. Signals at Dire Dewa station

[31] Attachment: signal display meanings.

I. Home color-light signal

- (1) One green light – allow the train to pass through the station along main line at regulated speed;
- (2) One yellow light – allow the train to enter main line in the station through straight turnout before stop;
- (3) Two yellow lights – allow the train to enter main line in the station through side turnout before stop;
- (4) One red light – forbid the train from passing the signal;
- (5) One green light and one yellow light – allow the train to enter the station through straight turnout and then pass over the subsequent open signal before stop.

II. Starting color-light signal

- (1) One green light – allow the train to depart from the station;
- (2) One red light – forbid the train from passing the signal;
- (3) One pale light – allow shunting past the signal.

III. Route color-light signal

- (1) One green light – allow the train to depart from the station along main line;
- (2) One yellow light – allow the train to run in front of the subsequent signal before stop;
- (3) One green light and one yellow light – allow the train to pass over the signal at regulated speed;
- (4) One red light – forbid the train from passing the signal;
- (5) One pale light – allow shunting past the signal.

IV. The calling-on signal from home and route color-light signals displays one red light and one pale light – allow the train to continue running in front of the signal and into the station or through receiving route at a speed of no more than 20 km/h before stop at any time.

V. Distant color-light signal

- (1) One green light – meaning main signal is open;
- (2) One yellow light – meaning main signal is closed;

VI. Shunting color-light signal

- (1) One pale light – allow shunting past the signal;
- (2) One blue light – forbid shunting past the signal.

General signal aspects used:

1. One green light
2. One yellow light
3. Two yellow light
4. One red light

5. One green and one yellow light
6. One pale light
7. One red and one pale light
8. One blue light

NOTE: For 8 signal aspects, we need 3 bits and for each signal speed level message transmission another 1 bit is needed-means total 4 bits.

3.1.2 Encoding the message signals using hamming codes:

The encoding:

$$F_q^k = F_q^n$$

From the message word $m \in F_q^k$ to the codeword $c \in F_q^n$ can be done Efficiently by a matrix multiplication.

$$c = E(m) := mG: \text{-----}3.1$$

4bit-Message words

$$m = \begin{pmatrix} 0000 & 0001 & 0010 & 0011 \\ 0100 & 0101 & 0110 & 0111 \\ 1000 & 1001 & 1010 & 1011 \\ 1100 & 1101 & 1010 & 1111 \end{pmatrix}$$

The generator matrix G of the Hamming code has the following Form (I|P),

Where I_k is the $k \times k$ Identity matrix and P a $k \times (n - k)$ matrix

$$G = \begin{pmatrix} x1 & x2 & x3 & x4 & p1 & p2 & p3 \\ 1 & 0 & 0 & 0 & x & x & x \\ 0 & 1 & 0 & 0 & x & x & x \\ 0 & 0 & 1 & 0 & x & x & x \\ 0 & 0 & 0 & 1 & x & x & x \end{pmatrix}$$

$$P1 = x1 + x2 + x4 \text{-----}3.2$$

$$P2 = x1 + x3 + x4 \text{-----}3.3$$

$$P3 = x2 + x3 + x4 \text{-----}3.3$$

Therefore the generator matrix will be

$$G = \begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$H = [P^T | I_{n-k}]$$

$$H = \begin{pmatrix} 1 & 1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \end{pmatrix}$$

Then

$$C = E(m) := mG:$$

$$C = \left\{ \begin{array}{l} 0000000, 0001111, 0010011, 0011100 \\ 0100101, 0101010, 0110110, 0111001 \\ 1000110, 1001001, 1010101, 1011010 \\ 1100011, 1101100, 1110000, 1111111 \end{array} \right\}$$

The codes has min distance 3

To increase the min distance, let's extend the codes

$$G^e(v) = \left(\begin{array}{c|c} & \begin{matrix} g_{1n+1} \\ g_{2n+1} \\ \cdot \\ \cdot \\ g_{kn+1} \end{matrix} \end{array} \right) \text{-----3.4}$$

$$G = \begin{matrix} & \begin{matrix} i \\ j \rightarrow \end{matrix} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \end{matrix} \downarrow & \begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix} \end{matrix}$$

$$g_{in+1} = - \sum_{j=1}^n g_{ij} v_j, \quad V_j \text{ is all one's row matrix.}$$

$$g_{18} = (g_{11} + g_{12} + g_{13} + g_{14} + g_{15} + g_{16} + g_{17}) \\ = (1 + 0 + 0 + 0 + 1 + 1 + 0) = 1$$

$$g_{28} = (g_{21} + g_{22} + g_{23} + g_{24} + g_{25} + g_{26} + g_{27})$$

$$= (0+1+0+0+1+0+1)=1$$

$$g_{38} = (g_{31}+g_{32}+g_{33}+g_{34}+g_{35}+g_{36}+g_{37})$$

$$= (0+0+1+0+0+1+1)=1$$

$$g_{48} = (g_{41}+g_{42}+g_{43}+g_{44}+g_{45}+g_{46}+g_{47})$$

$$= (0+0+0+1+1+1+1)=0$$

Therefore

$$G^e = \begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \end{pmatrix}$$

Then, the extended hamming codes are given as below

$$C^e = E(m) := m G^e:$$

$$C^e = \left\{ \begin{array}{cccc} 00000000 & 10001101 & 01001011 & 11000110 \\ 00100111 & 10101010 & 01101100 & 11100001 \\ 00011110 & 10010011 & 01010101 & 11011000 \\ 00111001 & 10110100 & 01110010 & 11111111 \end{array} \right\}$$

The parity check matrix of the extended code will be:

$$H^e(v) = \left(\begin{array}{cccccc|c} v_1 & v_2 & \cdot & \cdot & \cdot & v_n & 1 \\ \hline & & & H & & & \cdot \\ & & & & & & \cdot \\ & & & & & & 0 \end{array} \right) \text{-----3.5}$$

$$H^e(v) = \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \end{pmatrix}$$

3.1.2 Correct Decoding Probability

$$p = [];$$

for SNR=0:1:10

$$\text{snr} = 10.^{(\text{SNR}/10)};$$

$$T=0.5*\text{erfc}(\text{sqrt}(\text{snr}));$$

$$p=[p \ T];$$

end

$$p=[0.0786 \ 0.0563 \ 0.0375 \ 0.0229 \ 0.0125 \ 0.0060 \ 0.0024 \ 0.0008 \ 0.0002 \ 0.0000 \ 0.0000]$$

For SNR=1 and correcting 1 error t=1

$$P_{cd}(p) = \sum_{w=0}^t \binom{n}{w} p^w (1-p)^{n-w};$$

$$=p^0(1-p)^8+p(1-p)^7=(1-0.0563)^8+8*0.078(1-0.0563)^7=0.629+0.3007=0.9292$$

3.2 Bpsk signal modulation/Demodulation

$$\int_0^T |S(t)|^2 dt = \int_0^T A_c^2 \sin^2(wct) dt = A_c^2 \int_0^T \frac{1-\cos 2x}{2} dt = A_c^2 \left[\frac{T}{2} - \frac{1}{2} \int_0^T \cos(2wct) dt \right] = \frac{A_c^2 T}{2} - A_c^2 \frac{1}{2} \left[\frac{\sin(2wct)}{2wc} \right]_0^T = A_c^2 \frac{T}{2}$$

$$\frac{A_c^2 T}{2} = \frac{0.64^2 (0.08)}{2} = 0.016w$$

$$\frac{A_c^2 T}{4} = \frac{0.64^2 (0.08)}{4} = 0.008w$$

$$\frac{A^2 c T}{4} \{ \text{sinc}(\pi(f-f_c)T)^2 + \text{sinc}(\pi(f+f_c)T) \} =$$

$$0.008 (\text{sinc}(\pi(f-25)0.08) + \text{sinc}(\pi(f+25)0.08)) = 0.008(\text{sinc}(0.25(f-25)) + \text{sinc}(0.25(f+25)))$$

$$\sqrt{E} = \sqrt{0.016} = 0.128,$$

$$1 \quad + \sqrt{E} \sqrt{\frac{2}{T}} \cos wct \times \sqrt{\frac{2}{T}} \cos wct = \frac{2}{T} E \cos 2wct = + \sqrt{E} \frac{2}{T} \left[\frac{1+\cos 2x}{2} \right] = \pm \sqrt{E} \frac{2}{T} \left[\frac{1}{2} + \frac{1}{2} \cos 2wct \right] = 0.128 * 2 / 0.08 [1/2 + 1/2 \cos 2wct] = 3.2 [1/2 + 1/2 \cos 2wct] = [1.6 + 1.6 \cos 2wct]$$

$$2 \quad \pm \sqrt{E} \frac{2}{T} \int_0^t \left[\frac{1}{2} + \frac{1}{2} \cos 2wct \right] dt = \pm \sqrt{E} \frac{1}{T} t$$

$$3 \quad a(t=T) = \pm \sqrt{E} \frac{2}{T} \int_0^T \left[\frac{1}{2} + \frac{1}{2} \cos 2wct \right] dt = \pm \sqrt{E} \frac{1}{T} T = \pm \sqrt{E} = 0.11514$$

$$4 \quad S(t) = \pm \sqrt{E} \sqrt{\frac{2}{T}} \cos wct + n(t)$$

$$5. \quad z = \pm \sqrt{E} + N$$

But

Received Bpsk signal is

$$0.5757\sin(\omega t - 94.22^\circ) = 0.5757\sin(\omega t - 94.83^\circ), \text{ let } b = \omega t - 4.83$$

$$0.5757\sin(b - 90^\circ) = 0.5757(\sin b \cos(90^\circ) - \sin(90^\circ) \cos b) = -0.5757 \cos b = 0.5757 \cos(\omega t - 94.83^\circ)$$

$$+ \sqrt{E} \sqrt{\frac{2}{T}} \cos(\omega t - 4.83^\circ) \times \sqrt{\frac{2}{T}} \cos(\omega t - 4.83^\circ) = \frac{2}{T} E \cos^2 \omega t = + \sqrt{E} \frac{2}{T} \left[\frac{1 + \cos 2x}{2} \right] = \pm \sqrt{E} \frac{2}{T} \left[\frac{1}{2} + \frac{1}{2} \cos 2(\omega t - 4.83^\circ) \right] = 2.8785 \left[\frac{1}{2} + \frac{1}{2} \cos(\omega t - 8.9^\circ) \right] = 1.439 + 1.439 \cos(\omega t - 4.83^\circ)$$

$$\int_0^{0.08} 1.439 + 1.439 \cos 2(\omega t - 4.83^\circ) dt = 1.439 * 0.08 + 2 * 1.43 * 2 \cos 2(\omega t - 4.83^\circ) \Big|_0^{0.08}$$

By using low pass filter, the second part will be rejected and, the demodulated signal will be:

0.115 for +1 and -0.115 for -1

For additive White gaussian noise the demodulated signal will be calculated using the following matlab code:

```
SNR=[0:1:10]';
snr=10.^(SNR/10);
x=[ 1 0 1 1 0 1 0 0];           % Binary Information
bp=0.08;                       % bit period
disp(' Binary information at Transmitter :');
disp(x);
bit=[];
for n=1:1:length(x)
    if x(n)==1;
        se=ones(1,100);
    else x(n)==0;
        se=-1*ones(1,100);
    end
    bit=[bit se];
end
t1=bp/100:bp/100:100*length(x)*(bp/100);
```

```

subplot(5,1,1);
plot(t1,bit,'lineWidth',2.5);grid on;
axis([ 0 bp*length(x) -1, 1]);
ylabel('amplitude(volt)');
xlabel(' time(sec)');
title('transmitting information as digital signal');
F=[];
for (i=1:1:length(x))
n= 1/sqrt(2)*(randn(1,800)+j*randn(1,800));
end
F=[F n]
t5=bp/100:bp/100:bp*length(x);
subplot(5,1,2);
plot(t5,F)
axis([ 0 bp*length(x) -10,10]);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for noise');
% Binary-PSK modulation
br=1/bp; % bit rate
f=br*2; % carrier frequency
t2=bp/100:bp/100:bp;
ss=length(t2);
m=[];
for (i=1:1:length(x))
if (x(i)==1)
y=-0.4294*cos(2*pi*f*t2-203.38);
else

```

```

        y=-0.4294*cos(2*pi*f*t2-203.38+pi);
    end

    m=[m y];
end
t3=bp/100:bp/100:bp*length(x);
subplot(5,1,3);
plot(t3,m);
axis([ 0 bp*length(x) -5,5]);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for binary PSK modulation coresponding binary information');
for k=1:length(SNR),
    if k==1,
        Bpsk= m+ sqrt(snr(k))*F; %snr is Eb/N0 in BER equations
    subplot(5,1,4);
    plot(t3,Bpsk )
    legend('real part of signal','data'),
    title('BPSK signal in noise'),pause
    end
end

r=real(Bpsk);
% Binary PSK demodulation
mn=[];
A=5;%sqrt(2/bp)
for n=ss:ss:length(m)
    t=bp/100:bp/100:bp;
    y=-A*cos(2*pi*f*t2-204.6296); % carrier signal
    mm=y.*r((n-(ss-1)):n);

```

```

t4=bp/100:bp/100:bp;
z=trapz(t4,mm) % intregation
if(z>0)
a=1;
else
a=0;
end
mn=[mn a];
end
disp(' Binary information at Reciver :');
disp(mn);
% Representation of binary information as digital signal which achived
%after PSK demodulation
bit=[];
for n=1:length(mn);
if mn(n)==1;
se=ones(1,100);
else mn(n)==0;
se=-1*ones(1,100);
end
bit=[bit se];
end
t4=bp/100:bp/100:100*length(mn)*(bp/100);
subplot(5,1,5)
plot(t4,bit,'LineWidth',2.5);grid on;
axis([ 0 bp*length(mn) -1, 1]);
ylabel('amplitude(volt)');
xlabel(' time(sec)');

```

title('received information as digital signal after binary PSK demodulation');

grid on;

3.3 Voltage and Current at the Train

3.2. Receiving end current design considering Train length

$$A = \left. \frac{V_s}{V_1} \right|_{I_1=0} = 1, V_s = V_1 = 1$$

$$B = \left. \frac{V_s}{I_1} \right|_{V_1=0} = Z \Delta x$$

$$C = \left. \frac{I_s}{V_1} \right|_{I_1=0} = 0$$

$$D = \left. \frac{I_s}{I_1} \right|_{V_1=0} = 1, I_1 = I_s$$

$$V_R = \frac{V}{\cosh(\gamma x) + \frac{Z_c}{Z_s} \sinh(\gamma x)},$$

$$V = V_s - Z \Delta x I_s$$

$$V_R = \frac{V_s - Z \Delta x I_s}{\cosh(\gamma x) + \frac{Z_c}{Z_s} \sinh(\gamma x)}$$

$$= \frac{V_s - Z \Delta x I_s}{\cosh(\gamma x) + \frac{Z_c}{Z_s} \sinh(\gamma x)}$$

$$I_s = \frac{V_R}{Z_c} \sinh(\gamma x) + I_R \cosh(\gamma x)$$

$$\frac{V_s - Z \Delta x \left(\frac{V_R}{Z_c} \sinh(\gamma x) + I_R \cosh(\gamma x) \right)}{\left(\cosh(\gamma x) + \frac{Z_c}{Z_s} \sinh(\gamma x) \right)}$$

$$I_R = \frac{V_R}{Z_s} \text{ and}$$

$$V_R = \frac{V_s}{\cosh(\gamma x) + \frac{Z_c}{Z_s} \sinh(\gamma x) + Z \Delta x \left(\frac{\sinh(\gamma x)}{Z_c} + \frac{\cosh(\gamma x)}{Z_s} \right)} \text{-----3.6}$$

, where $Z_s = \frac{2Y + 4}{4Y + ZY^2}$, lumped parameter design for 0.8km train length admittance and rail impedance.

$$V = V_R \cosh(\gamma x) + Z_c I_R \sinh(\gamma x),$$

$$I_R Z_s = V_R, V = I_R Z_s \cosh(\gamma x) + Z_c I_R \sinh(\gamma x)$$

$$I_R = \frac{V}{Z_s \cosh(\gamma x) + Z_c \sinh(\gamma x)}$$

$$= \frac{V_s - Z \Delta x I_s}{Z_s \cosh(\gamma x) + Z_c \sinh(\gamma x)}$$

$$= \frac{V_s - Z \Delta x I_s}{Z_s \cosh(\gamma x) + Z_c \sinh(\gamma x)}$$

$$I_s = I = \frac{V_R}{Z_c} \sinh(\gamma x) + I_R \cosh(\gamma x)$$

$$= \frac{V_s - Z \Delta x \left(\frac{V_R}{Z_c} \sinh(\gamma x) + I_R \cosh(\gamma x) \right)}{(Z_s \cosh(\gamma x) + Z_c \sinh(\gamma x))}$$

$V_R = I_R Z_s$, then

$$I_R = \frac{V_s}{(Z_s \cosh(\gamma x) + Z_c \sinh(\gamma x) + Z \Delta x \left(\frac{Z_s}{Z_c} \sinh(\gamma x) + \cosh(\gamma x) \right))}$$

$$V_R = \frac{V_s}{\cosh(\gamma x) + \frac{Z_c}{Z_s} \sinh(\gamma x) + Z \Delta x \left(\frac{\sinh(\gamma x)}{Z_c} + \frac{\cosh(\gamma x)}{Z_s} \right)}$$

$$I_R = \frac{V_s}{(Z_s \cosh(\gamma x) + Z_c \sinh(\gamma x) + Z \Delta x \left(\frac{Z_s}{Z_c} \sinh(\gamma x) + \cosh(\gamma x) \right))} \dots \dots \dots 3.7$$

$R_{rail} = 0.15 \Omega, Z_{rail} = 0.2 \Omega, z = R_{rail} + jL_{rail} = 0.15 \Omega + j0.2 \Omega, R_{ballast} \text{ b/n } 2-10 \Omega, \text{ take } 5 \text{ ohm}$

take $5 \Omega, y = \frac{1}{R_{ballast}} = 0.2, x = 1 \text{ km}$

Using matlab,

```
vs=220;
Z1=0.5;%feeder resistance
Zr=complex(0.12,0.16);%0.8*(r+jl),0.8km-train length
ys=1.2;%shunt admittance of the train and ballast resistance
Zs=(2*ys*Zr+4)/(4*ys+Zr*ys^2);
d=1;
l=0.2;
r=0.15;
```

```

m=0.2;
r1=m;
x1=l;
res=r;
z=complex(res,x1);
y=complex(r1,0);
zc=sqrt(z/y);
Y=sqrt(y*z);
%the ABCD parameters hence are
A=cosh(Y*d);
B=sinh(Y*d);
%Z1=Z1-0.005;
%evaluate the value of Vreceiving end and Ireceiving end
Vr=vs/((A+((zc*B)/Zs))+Z1*((B/zc)+(A/Zs)));
Ir=vs/((Zs*A)+(zc*B)+Z1*((Zs*B/zc)+A));
fprintf('voltage at the receiving end=');
disp(Vr);
fprintf('current at the receiving end=');
disp(Ir);
Voltage at the receiving end= 1.0452e+002 -1.6472e+001i

```

Current at the receiving end= 1.321e+002 -2.214e+001i

3.4 Track circuit Parameters Antenna Design

r = Rail to TCR antenna distance

$B_e(x, x_1, t, x_0, y_0, z_0)$ = magnetic field

$$|r| = (\sqrt{(x_0 - x')^2 + y_0^2 + z_0^2})^3,$$

$$\vec{ds} = dx' \hat{i},$$

$$\hat{r} = \frac{(x_0 - x')\hat{i} + y_0\hat{j} + z_0\hat{k}}{(\sqrt{(x_0 - x')^2 + y_0^2 + z_0^2})^3},$$

$$B_e(x, x_1, t, x_0, y_0, z_0) = \frac{\mu_0 \mu_r}{4\pi} \int_{x_1}^x I ds \times \hat{r},$$

$$I ds \times \hat{r} = I dx' \hat{i} \times \frac{(x_0 - x')\hat{i} + y_0\hat{j} + z_0\hat{k}}{(\sqrt{(x_0 - x')^2 + y_0^2 + z_0^2})^3}, \dots \dots \dots 3.8$$

$$= \frac{I(y_0 \hat{k} - z_0 \hat{j}) dx'}{(\sqrt{(x_0 - x')^2 + y_0^2 + z_0^2})^3}$$

$$I \frac{\sqrt{y_0^2 + z_0^2}}{(\sqrt{(x_0 - x')^2 + y_0^2 + z_0^2})^3} dx',$$

$$B_e(x, x_1, t, x_0, y_0, z_0) = \frac{\mu_0 \mu_r}{4\pi} \int_{x_1}^x I ds \times \hat{r},$$

$$= \frac{\mu_0 \mu_r I}{4\pi} \int_{x_1}^x \frac{\sqrt{y_o^2 + z_o^2}}{(\sqrt{(x_o - x')^2 + y_o^2 + z_o^2})^3} dx'$$

Let $a^2 = y_o^2 + z_o^2$

$$B_e(x, x_1, t, x_o, y_o, z_o) = \frac{\mu_0 \mu_r I}{4\pi} \int_{x_1}^x \frac{a}{(\sqrt{(x_o - x')^2 + a^2})^3}$$

Let $(x_o - x') = a \tan \theta$ and $\frac{dx'}{d\theta} = a \sec^2 \theta, dx' = a \sec^2 \theta d\theta$

$$B_e(x, x_1, t, x_o, y_o, z_o) = \frac{\mu_0 \mu_r I}{4\pi} \int \frac{a^2 \sec^2 \theta}{(\sqrt{a^2 \tan^2 \theta + a^2})^3} d\theta$$

$$= \frac{\mu_0 \mu_r I}{4\pi} \int \frac{a^2 \sec^2 \theta}{(\sqrt{a^2 (\tan^2 \theta + 1)})^3} d\theta = \frac{\mu_0 \mu_r I}{4\pi} \int \frac{a^2 \sec^2 \theta}{(\sqrt{a^2 (\sec^2 \theta)})^3} d\theta$$

$$\frac{\mu_0 \mu_r I}{4\pi} \int \frac{a^2 \sec^2 \theta}{(a \sec)^3} d\theta = \frac{\mu_0 \mu_r I}{4\pi} \int \frac{a^2 \sec^2 \theta}{a^3 \sec^3} d\theta = \frac{\mu_0 \mu_r I}{4\pi} \int \frac{1}{a \sec} d\theta$$

$$\frac{\mu_0 \mu_r I}{4\pi a} \int \cos \theta d\theta = \frac{\mu_0 \mu_r I}{4\pi a} \sin \theta, \sin \theta = \frac{(x_o - x')}{\sqrt{(x_o - x')^2 + y_o^2 + z_o^2}}$$

Let's assume I is constant and most of B_e is contributed by the current from x_1 to x , which is measured from midpoint X' to x_1 or to x and equals l .

$(x_o - x') = x_1$

$$B_e = \frac{\mu_0 \mu_r I}{4\pi(\sqrt{(y_o^2 + z_o^2)})} \frac{x_1}{\sqrt{x_1^2 + y_o^2 + z_o^2}} \Bigg|_{-l}^l$$

$$B_e = \frac{\mu_0 \mu_r I}{4\pi(\sqrt{(y_o^2 + z_o^2)})} \left(\left(\frac{1}{\sqrt{l^2 + y_o^2 + z_o^2}} \right) - \left(\frac{-1}{\sqrt{l^2 + y_o^2 + z_o^2}} \right) \right)$$

$$B_e = \frac{\mu_0 \mu_r I}{4\pi(\sqrt{(y_o^2 + z_o^2)})} \left(\frac{2l}{\sqrt{l^2 + y_o^2 + z_o^2}} \right) \dots \dots \dots 3.9$$

$$\phi_e(x, x_1, z_o, t) = \frac{q_m}{l_q} \int_{l_h}^{l_h + 2l} \int_{x-l_m-l_b}^{x-l_m+l_b} B_e(x, x_1, t, x_o, y_o, z_o) \frac{y_o}{\sqrt{y_o^2 + z_o^2}} dx_o dy_o$$

$$B_e = \frac{\mu_o \mu_r I y_o}{4\pi(\sqrt{y_o^2 + z_o^2})} \left(\left(\frac{(X_o - X)}{\sqrt{(X_o - X)^2 + y_o^2 + z_o^2}} \right) - \left(\frac{(X_o - X_1)}{\sqrt{(X_o - X_1)^2 + y_o^2 + z_o^2}} \right) \right) dx_o dy_o$$

$$\phi_e(X, X_1, Z_o, t) = \frac{q_m}{l_q} \int_{lh}^{lh+2la} \int_{x-lm-lb}^{x-lm+lb} \frac{\mu_o \mu_r I y_o}{4\pi(\sqrt{y_o^2 + z_o^2})} \left(\frac{(X_o - X)}{\sqrt{(X_o - X)^2 + y_o^2 + z_o^2}} \right) dx_o dy_o -$$

$$\frac{q_m}{l_q} \int_{lh}^{lh+2la} \int_{x-lm-lb}^{x-lm+lb} \frac{\mu_o \mu_r I y_o}{4\pi(\sqrt{y_o^2 + z_o^2})} \left(\frac{(X_o - X_1)}{\sqrt{(X_o - X_1)^2 + y_o^2 + z_o^2}} \right) dx_o dy_o$$

$$\text{let } x_o - X = -1, \frac{dl'}{dx_o} = 1, \text{ and } b = l^2 + y_o^2 + z_o^2, \frac{db}{dl'} = 2l,$$

$$, x_o - X_1 = 1, \frac{dl'}{dx_o} = 1, \text{ and } c = l^2 + y_o^2 + z_o^2, \frac{dc}{dl'} = 2l$$

$$\frac{q_m}{l_q} \int_{lh}^{lh+2la} \int_{x-lm-lb}^{x-lm+lb} \frac{\mu_o \mu_r I y_o}{8\pi(\sqrt{y_o^2 + z_o^2})} \frac{1}{\sqrt{b}} db dy_o +$$

$$\frac{q_m}{l_q} \int_{lh}^{lh+2la} \int_{x-lm-lb}^{x-lm+lb} \frac{\mu_o \mu_r I y_o}{8\pi(\sqrt{y_o^2 + z_o^2})} \frac{1}{\sqrt{c}} dc dy_o$$

$$- \left(\frac{q_m}{l_q} \int \frac{\mu_o \mu_r I y_o}{4\pi(\sqrt{y_o^2 + z_o^2})} \sqrt{b} dy_o + \frac{q_m}{l_q} \int \frac{\mu_o \mu_r I y_o}{4\pi(\sqrt{y_o^2 + z_o^2})} \sqrt{c} dy_o \right)$$

$$y_o^2 + z_o^2 = b - l^2, \text{ and } y_o^2 + z_o^2 = c - l^2, \frac{db}{dy_o} = 2y_o, \frac{dc}{dy_o} = 2y_o$$

$$- \left(\frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{\sqrt{b}}{b - l^2} db + \frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{\sqrt{c}}{c - l^2} dc \right)$$

$$\text{let } b - l^2 = f, df = db, g = c - l^2, dg = dc$$

$$- \left(\frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{\sqrt{f+l^2}}{f} df + \frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{\sqrt{g+l^2}}{g} dg \right)$$

$$\sqrt{f+l^2} = u, 2u du = df, \sqrt{g+l^2} = v, 2v dv = dg, \text{ sub}$$

$$- \left(\frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{2u^2}{u^2 - l^2} du + \frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{2v^2}{v^2 - l^2} dv \right)$$

$$- \left(\frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \left(\frac{1}{1 - \frac{l}{u}} - \frac{1}{1 + \frac{l}{u}} \right) du + \frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \left(\frac{1}{1 - \frac{l}{v}} - \frac{1}{1 + \frac{l}{v}} \right) dv \right)$$

$$-\left(\frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \left(\left(\frac{u}{u-1} \right) + \left(\frac{u}{u+1} \right) \right) du + \frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \left(\left(\frac{v}{v-1} \right) + \left(\frac{v}{v+1} \right) \right) dv \right)$$

let, $a=u-1$, $da=du$, $u+1=r$, $du=dr$, $h=v-1$, $v+1=s$, $dv=ds$, $dh=ds$

$$-\left(\frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{a+1}{a} da + \frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{r-1}{r} dr + \left(\frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{h+1}{h} dh + \frac{q_m}{l_q} \int \frac{\mu_o \mu_r I}{8\pi} \frac{s+1}{s} ds \right) \right)$$

$$-\left(\frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} (a-1 \times \ln|a| + r+1 \times \ln|r|) + \frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} (h+1 \ln|h| + s-1 \ln|s|) \right)$$

$$-\left(\frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} ((\sqrt{l^2+y_o^2+z_o^2}+1)-1 \ln|\sqrt{l^2+y_o^2+z_o^2}+1|) + \frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} ((\sqrt{l^2+y_o^2+z_o^2}-1)+1 \ln|\sqrt{l^2+y_o^2+z_o^2}-1|) \right) + \frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} ((\sqrt{l^2+y_o^2+z_o^2}-1)+1 \ln|\sqrt{l^2+y_o^2+z_o^2}-1|) + \frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} ((\sqrt{l^2+y_o^2+z_o^2}+1)-1 \ln|\sqrt{l^2+y_o^2+z_o^2}+1|))$$

=

$$-\frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} ((2\sqrt{l^2+y_o^2+z_o^2})+1 \ln|\sqrt{l^2+y_o^2+z_o^2}-1| - 1 \ln|\sqrt{l^2+y_o^2+z_o^2}+1|)$$

$$-\frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} ((2\sqrt{l^2+y_o^2+z_o^2})+1 \ln|\sqrt{l^2+y_o^2+z_o^2}-1| - 1 \ln|\sqrt{l^2+y_o^2+z_o^2}+1|)$$

$$\phi_c(x, x_1, z_o, t) = -\frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} ((4\sqrt{l^2+y_o^2+z_o^2})-2 \ln|\sqrt{l^2+y_o^2+z_o^2}+1| + 2 \ln|\sqrt{l^2+y_o^2+z_o^2}-1|) \Big|_{1.35}^{1.65} \Big|_{0.47}^{0.67} \quad \text{-----3.10}$$

$$\phi_{11}(x, x_1, t) = \phi_{22}(x, x_1, t) =$$

$$\int_{l_p}^{l_p+l_q} \phi_c(x, x_1, z_o, t) dz_o = -\frac{q_m}{l_q} \frac{\mu_o \mu_r I}{8\pi} ((4\sqrt{l^2+y_o^2+z_o^2})-2 \ln|\sqrt{l^2+y_o^2+z_o^2}+1| + 2 \ln|\sqrt{l^2+y_o^2+z_o^2}-1|) \Big|_{1.4}^{1.6} \Big|_{0.47}^{0.67} dz_o$$

But

$$x_o - x = -l = -(l_m - l_b) = 1.5m \text{ and } x_o - x_1 = l =$$

Let $q_m=20$, $l_q=l_{coil}=10cm$, $l=1.5m$, $l_h=47cm$, $l_h+2l_a=67$, $z_0=20cm$, $l_b=0.15m$
 $\mu_o \mu_r = 2.3 \times 10^{-2}$

$$M_c = \int_{l_p}^{l_p+l_q} \int_{i_n}^{l_n+2l_a} \int_{x-l_m-l_b}^{x-l_m+l_b} [M_{ab}(x_o, y_o, z_o) + M_{bc}(x_o, y_o, z_o) + M_{cd}(x_o, y_o, z_o) + M_{da}(x_o, y_o, z_o)] dx_o dy_o dz_o$$

$$M_{ab}(x_o, y_o, z_o) = \frac{q_m \mu_o \mu_r}{4\pi(z_o+l_p)} \left(\frac{e_1 a_1}{ea_2} - \frac{e_1 b_1}{eb_2} \right)$$

$$M_{bc}(x_0, y_0, z_0) = \frac{q_m \mu_0 \mu_r}{4\pi(z_0 + l_p)} \left(\frac{e_2' b_1}{e b_2} - \frac{e_2' c_1}{e c_2} \right)$$

$$M_{cd}(x_0, y_0, z_0) = \frac{q_m \mu_0 \mu_r}{4\pi(z_0 + l_p)} \left(\frac{e_3' c_1}{e c_2} - \frac{e_3' d_1}{e d_2} \right)$$

$$M_{da}(x_0, y_0, z_0) = \frac{q_m \mu_0 \mu_r}{4\pi(z_0 + l_p)} \left(\frac{e_4' d_1}{e d_2} - \frac{e_4' a_1}{e a_2} \right)$$

Using the following matlab codes

```
Flux1=@(x,y,z) 1./(z+0.05).*abs(x-0.15)./(sqrt((x-0.15).^2+(y-0.47).^2+(z+0.05).^2));
```

```
Field1= triplequad(Flux1,-0.1,0.1,0.47,0.67,0.05,0.15)
```

```
Flux2=@(x,y,z) 1./(z+0.05).*abs(x+0.15)./(sqrt((x+0.15).^2+(y-0.47).^2+(z+0.05).^2));
```

```
Field2= triplequad(Flux2,-0.1,0.1,0.47,0.67,0.05,0.15)
```

```
Flux3=@(x,y,z) 1./(z+0.05).*abs(y-0.47)./(sqrt((x+0.15).^2+(y-0.47).^2+(z+0.05).^2));
```

```
Field3= triplequad(Flux3,-0.1,0.1,0.47,0.67,0.05,0.15)
```

```
Flux4=@(x,y,z) 1./(z+0.05).*abs(y-0.17)./(sqrt((x+0.15).^2+(y-0.17).^2+(z+0.05).^2));
```

```
Field4=triplequad(Flux4,-0.1,0.1,0.47,0.67,0.05,0.15)
```

```
Flux5=@(x,y,z) 1./(z+0.05).*abs(x+0.15)./(sqrt((x+0.15).^2+(y-0.17).^2+(z+0.05).^2));
```

```
Field5= triplequad(Flux5,-0.1,0.1,0.47,0.67,0.05,0.15)
```

```
Flux6=@(x,y,z) 1./(z+0.05).*abs(x-0.15)./(sqrt((x-0.15).^2+(y-0.17).^2+(z+0.05).^2));
```

```
Field6= triplequad(Flux6,-0.1,0.1,0.47,0.67,0.05,0.15)
```

```
Flux7=@(x,y,z) 1./(z+0.05).*abs(y-0.17)./(sqrt((x-0.15).^2+(y-0.17).^2+(z+0.05).^2));
```

```
Field7= triplequad(Flux7,-0.1,0.1,0.47,0.67,0.05,0.15)
```

```
Flux8=@(x,y,z) 1./(z+0.05).*abs(y-0.47)./(sqrt((x+0.15).^2+(y-0.47).^2+(z+0.05).^2));
```

```
Field8= triplequad(Flux8,-0.1,0.1,0.47,0.67,0.05,0.15)
```

```
Field1 = 0.0169, Field2 = 0.0169,Field3 = 0.0112    Field4 = 0.0243,Field5 = 0.0091, Field6 = 0.0091
```

```
Field7 = 0.0243,Field8 = 0.0112
```

$$M_{ab} + M_{bc} + M_{cd} + M_{da} = \frac{q_m \mu_0 \mu_r}{4\pi} (\text{Field1} - \text{Field2} + \text{Field3} - \text{Field4} + \text{Field5} - \text{Field6} + \text{Field7} - \text{Field8}) = 0$$

$$\phi_{11}(x, x_1, t) = \phi_{22}(x, x_1, t) = \int_{l_p}^{l_p+l_q} \phi_e(x, x_1, z_o, t) dz_o \text{-----3.11}$$

$$\int_{l_p}^{l_p+l_q} \phi_e(x, x_1, z_o, t) dz_o = -\frac{qm \mu_o \mu_r l}{l_q 8\pi} ((4\sqrt{l^2 + y_o^2 + z_o^2}) - 2l \ln \left| (\sqrt{l^2 + y_o^2 + z_o^2} + 1) \right| + 2l \ln \left| (\sqrt{l^2 + y_o^2 + z_o^2} - 1) \right|) \Big|_{1.4}^{1.6} \Big|_{0.47}^{0.67} dz_o$$

$$\text{Let Self_flux} = ((4\sqrt{l^2 + y_o^2 + z_o^2}) - 2l \ln \left| (\sqrt{l^2 + y_o^2 + z_o^2} + 1) \right| + 2l \ln \left| (\sqrt{l^2 + y_o^2 + z_o^2} - 1) \right|)$$

Integrating using the following matlab code,

x=1.5;

y=0.47;

b=0.15;

x1=x+b;

x2=x-b;

y1=y;

y2=y+2*b;

T1=x1.^2+y2.^2;

T2=x1.^2+y1.^2;

T3=x2.^2+y2.^2;

T4=x2.^2+y1.^2;

selfflux1=@(z) (4*sqrt(T1+z.^2)- 2*x1*reallog(sqrt(T1+z.^2)+ x1)+ 2*x1* reallog(sqrt(T1+z.^2)- x1));

selfflux2=@(z) -(4*sqrt(T2+z.^2)- 2*x1*reallog(sqrt(T2+z.^2)+ x1)+ 2*x1* reallog(sqrt(T2+z.^2)- x1));

selfflux3=@(z)-(4*sqrt(T3+z.^2)- 2*x2*reallog(sqrt(T3+z.^2)+ x2)+ 2*x2* reallog(sqrt(T3+z.^2)- x2));

selfflux4=@(z) (4*sqrt(T4+z.^2)- 2*x2*reallog(sqrt(T4+z.^2)+ x2)+ 2*x2* reallog(sqrt(T4+z.^2)- x2));

Self_flux=quad(selfflux1,0.05,0.15)+ quad(selfflux2,0.05,0.15)+ quad(selfflux3,0.05,0.15)+ quad(selfflux4,0.05,0.15)

self_flux=0.0531

$$\phi_{11}(x, x_1, t) = \phi_{22}(x, x_1, t) = \frac{N \mu_0 \mu_r I}{l_q 8\pi} * \text{Self_flux} = \frac{N \times 2.5 \times 10^{-1}}{0.1 \times 8 \times 3.14} \times I (0.0531) = 0.00528 \times I * N$$

at $x=1.5\text{km}$, $I=1.4931e+002 -2.353e+001i = 151.15\cos(\omega t + \theta)$, $\theta = \underline{-8.9^\circ}$

$$\phi_{11}(x, x_1, t) = \phi_{22}(x, x_1, t) = (0.00528 * N) * (133.84\cos(\omega t - 9.51^\circ)) = 0.798 \cos(\omega t - 9.51^\circ) \times N$$

Voltage induced in the coil is:

$$\varepsilon = - \frac{d\phi_{11}(x, x_1, t)}{dt} \text{-----} 3.12$$

$$\varepsilon = - \frac{d\phi_{11}(x, x_1, t)}{dt} = 0.7066 \sin(\omega t - 9.51^\circ) \times N$$

$$I_c(x, x_1, t) = \frac{1}{\bar{Z}_{\text{coil}}} \frac{d\phi_{11}(x, x_1, t)}{dt}$$

From band pass filter design- $L=6.2698$, $\bar{Z}_{\text{coil}} = j\omega L$,

$\omega = 2\pi f = 2 \times 3.14 \times 25 = 157$ and L from band pass filter design, we have 4Hr

$$\bar{Z}_{\text{coil}} = j\omega L = 157 * 3.1347 = 492.179 \Omega$$

[32] $L = N^2 \frac{2 \times \ell_{\text{coil}} \times \mu}{\pi} [\ln(\ell_{\text{coil}}/a) - 0.77401]$, ℓ_{coil} = length of coil, a =radius of coil wire

Where the constant of proportionality μ (in Henry's/meter) is the magnetic permeability of the environment outside the conductor ($\mu = \mu_0 \mu_r$)

$$N = \sqrt{\frac{L \times \pi}{2 \ell_{\text{coil}} \times \mu [\ln(\ell_{\text{coil}}/a) - 0.77401]}} \text{-----} 3.13$$

$$= \sqrt{\frac{6.269 \times 3.14}{2 \times 0.3 \times 2.1 \times 10^{-1} [\ln(0.3/2.03 \times 10^{-3}/2) - 0.77401]}}$$

$N=5$ turns

$$\varepsilon = - \frac{d\phi_{11}(x, x_1, t)}{dt} = 0.7066 \sin(\omega t - 9.51^\circ) \times N$$

$$\varepsilon = -3.99 \sin(\omega t - 9.51^\circ) \text{ V}$$

$$\bar{Z}_{\text{coil}} = j\omega L = 157 * 3.1347 = 492.179 \Omega$$

$$I_c(x, x_1, t) = \frac{3.53 \sin(\omega t - 98.9^\circ)}{492.179} = 7.18 \sin(-94.22^\circ)$$

3.4 Band pass filter design

3.4.1 Series RLC filter:

$$H(j\omega) = \frac{1}{1 + j(\omega L - \frac{1}{\omega C})}$$

We note that the transfer function is real if coefficient of j in the denominator is exactly zero (note that this happens for

$$\omega_0 L - \frac{1}{\omega_0 C} = 0 \rightarrow \omega_0 = \frac{1}{\sqrt{LC}} \text{-----3.14}$$

Also

$$K = H(j\omega = j\omega_0) = \frac{R}{R} = 1$$

The cut-off frequencies can then be found by setting:

$$|H(j\omega)| = \frac{|K|}{2} = \frac{1}{\sqrt{2}}$$

$$\left(\frac{\omega_0 L}{R} - \frac{1}{\omega_0 R C}\right)^2 = 2$$

Which can be solved to find ω_u and ω_l . Input and Output Impedance of band-pass RLC filters

$$Z_i = j\omega L + (1/j\omega C) + R = j(\omega L - \frac{1}{\omega C}) \text{ occurs at } \omega = \omega_0$$

$$Z_o = (j\omega L + \frac{1}{j\omega C}) || R \rightarrow Z_o |_{\max} = R$$

$$L = \frac{1}{625C} \text{-----3.15}$$

$$Q = \sqrt{\frac{L}{R^2 C}} = Q^2 = \frac{L}{R^2 C}$$

$$L = Q^2 R^2 C \text{-----3.16}$$

3.4.2 Finding R, L and C for $Q=2$

L in single coil is 3.13, for two=6.2698H

$$\dot{I}. L = Q^2 R^2 C, Q=2, L=6.2698H$$

$$C = \frac{1}{625L}, C = 2.55 \times 10^{-4}$$

$$L=Q^2R^2C, R=\sqrt{\frac{L}{Q^2C}}=78.36\Omega,$$

$$V_i=2\varepsilon$$

At 1 km

$$V_o=\frac{V_i}{R+j\omega L+(1/j\omega C)}R, \frac{V_i}{R+j\omega L+(1/j\omega C)}=\frac{7.07\sin(-9.51^\circ)}{962.29(85.32)}$$

$$=7.347\sin(-94.83^\circ)\text{mA}$$

$$V_o=7.347\sin(-94.83^\circ)\times R=8.29\times 10^{-3}\text{C}\times 78.36=0.5757\sin(\text{wct}-94.83^\circ)$$

Chapter 5 Conclusion and Recommendation

5.1 Conclusion

Cab signaling codes are coded for signal aspects under the Home color-light signal, Starting color-light signal, Route color-light signal, The calling-on signal, Distant color-light signal, and Shunting color-light signal, putting into 8 categories. Total of 16 codes are encoded and, 8 are used to communicate the 8 different aspects. Except for The calling-on signal and Shunting color-light signal, another 5 signaling codes are provided to communicate the permitted speed profile for the line. The total 15 codes are chosen on their performance level so that long consecutive either ones or zeros are dropped from the codes' list.

Cab signaling for wayside signals has modelled and have an operating performance over 1.2kms withstanding variable track conditions. Based on the fact that communication distance is greatly affected with the decreasing value of ballast resistance, for worst atmospheric conditions like heavy rain, and the increasing property of rail impedance, the safe communication distance is not more than 1.2 kms. Ballast impedance up to 0.25ohm is considered for lower level and any decrease below this will affect directly the communication distance. For this ballast value, The Induced voltage level is 5.7466volt with 1.2377⁰ phase shift tolerance b/n the demodulator and the received signal and the design result confirms that this numbers are safe for Bpsk signal detection for SNR ratio of 0 upto 1.2 kms.

Increasing the X, Y, Z parameters of the receiving antenna has a direct effect on increasing the flux produced by the current in the rails. Due to that, increasing this parameters can be done unless otherwise cost and physical restriction imposed on the dimension is obliged. Considering this restrictions, 30cm for X, Y parameters and, 15 cm for the Z parameters is designed in the modelling of antenna dimension parameters.

The feeder resistance in the design, which adds another voltage drop for the system, has a negative impact on the receiving voltage level. But the research used this feeder resistance for compensation of the decreasing value of ballast resistance for the worst condition so that, since feeder resistance values are adjustable, in times of low ballast value the feeder resistance value can be reduced to 0 to compensate voltage drop in the ballast resistance. Feeder resistance values are from 0 - 0.5 ohm.

The high value of the inductance impedance is due to the large value of the flux produced by the rail current. For low inductance values the flux produced will be low in turn reduce the induced voltage in the antenna coils which means track circuit communicating distance is short. For that matter, large Inductance impedance value of around 1000 ohm have used in the design and to get this value Iron-Cobalt alloy high relative permittivity material is used.

Due to low track circuit frequency (25 Hz) value the bit rate is designed to be 12.5 Hz and this affects the bandwidth so that the bandwidth level should not be less than the bit rate for Bpsk modulation technique. As per this, band width of not more than 12.5 Hz is designed to avoid interference from the likes of traction current of 50 Hz.

One bit error of the encoded signal can be handled and decoded correctly, considering this the decoder design will be error correcting for 1 bit and error detection for 2 bit errors. For more than 2 errors the decoder can't detect an error.

5.2 Recommendation

The frequency value of the track circuit is 25 Hz and this limits the bit rate to be at least below 25 Hz for Bpsk modulation, even for integer multiple of bit rate compared to the carrier, the bit rate value will be 12.5 Hz and below. With the design bit rate 12.5 Hz, for transmission of 16 bits the total time required is at least 1.28secs. On this interval the train spans 42.6meters for maximum speed of 120km/hrs. - Which is a long distance for transmission of the next signal. And more seriously there is a phase change of around 1.248^0 b/n the starting to the end of two 8 bit codes.

On the above basis the track circuit operating frequency should be changed for quick signal transmission and to make the phase shift variation to be approximately 0^0 b/n the starting to the end of the code transmission-This increases the transmission length. For higher level of carrier frequency this criteria is achieved without violating the Bpsk bandwidth requirement.

The other part, phase shift, which is available due to rail parameter like inductance can be avoided by designing compensator capacitors b/n the rails to compensate phase shift values. This is a recommendation I suggest for further design implementation which adds a value for better Bpsk performance.

The other recommendation is b/c of the design do not include static data transmission, other researchers to conduct another research on this area so that the cab signal capability on delivering line information to the driver can be enhanced.

Table for normal condition-ballast resistance Of 5 ohm, inductance 0.2ohm/km, rail resistance 0.15ohm/km, shunt train and ballast admittance 0.6 over for each 100m interval

e	Vof	Abs e	Ang(e)	Abs vof	Ang vof	Ph.dev. (e)	Mag.dev(e)	Mag.dev (Vof)	Ph.dev.(e)
8.5097 - 0.2320i	0.0378 - 0.6935i	8.5129	-91.5625	0.6945	- 176.9260	0	1.0000	0	1.0000
8.3553 - 0.3482i	0.0273 - 0.6817i	8.3625	-92.3877	0.6823	- 177.7512	-0.8252	1.0180	-0.8252	1.0180
8.2004 - 0.4592i	0.0172 - 0.6699i	8.2133	-93.2064	0.6701	- 178.5699	-0.8187	1.0182	-0.8187	1.0182
8.0455 - 0.5649i	0.0076 - 0.6580i	8.0653	-94.0186	0.6580	- 179.3821	-0.8121	1.0183	-0.8121	1.0183
7.8907 - 0.6656i	-0.0016 - 0.6461i	7.9187	-94.8241	0.6461	- 180.1876	-0.8055	1.0185	-0.8055	1.0185
7.7362 - 0.7613i	0.0104 - 0.6341i	7.7735	-95.6230	0.6342	- 180.9865	-0.7989	1.0187	-0.7989	1.0187
7.5822 - 0.8521i	-0.0188 - 0.6222i	7.6299	-96.4152	0.6225	- 181.7787	-0.7923	1.0188	-0.7923	1.0188
7.4289 - 0.9381i	-0.0268 - 0.6103i	7.4879	-97.2009	0.6109	- 182.5644	-0.7856	1.0190	-0.7856	1.0190
7.2765 - 1.0195i	-0.0345 - 0.5985i	7.3475	-97.9799	0.5995	- 183.3434	-0.7791	1.0191	-0.7791	1.0191
7.1251 - 1.0964i	-0.0417 - 0.5867i	7.2090	-98.7525	0.5882	- 184.1160	-0.7726	1.0192	-0.7726	1.0192
6.9749 - 1.1689i	-0.0486 - 0.5749i	7.0722	-99.5186	0.5770	- 184.8821	-0.7661	1.0193	-0.7661	1.0193
6.8260 - 1.2372i	-0.0552 - 0.5633i	6.9372	- 100.2783	0.5660	- 185.6418	-0.7597	1.0195	-0.7597	1.0195
6.6785 - 1.3013i	-0.0614 - 0.5517i	6.8042	- 101.0317	0.5551	- 186.3952	-0.7534	1.0196	-0.7534	1.0196

Table for normal condition-ballast resistance Of 0.25 to 0.33 ohm interval, inductance 0.2ohm/km, rail resistance 0.15ohm/km, shunt train admittance 0.6 over 1.2km distance

e	Vof	Abs e	Ang(e)	Abs vof	Ph.dev.(e)	Ph.dev.(e)	Mag.dev(e)	Ph.dev.(vof)	Mag.dev(vof)
5.1089 - 2.4319i	-0.1637 - 0.4316i	5.6582	-115.4679	0.4616	-200.8314	0	1.0000	0	1.0000
5.0551 - 2.4495i	-0.1655 - 0.4274i	5.6173	-115.8665	0.4583	-201.2300	-0.3986	1.0073	-0.3986	1.0073
5.0017 - 2.4663i	-0.1673 - 0.4231i	5.5767	-116.2606	0.4550	-201.6241	-0.3941	1.0073	-0.3941	1.0073
4.9487 - 2.4821i	-0.1689 - 0.4189i	5.5363	-116.6503	0.4517	-202.0138	-0.3897	1.0073	-0.3897	1.0073
4.8963 - 2.4972i	-0.1705 - 0.4148i	5.4963	-117.0358	0.4484	-202.3993	-0.3855	1.0073	-0.3855	1.0073
4.8443 - 2.5114i	-0.1720 - 0.4106i	5.4566	-117.4171	0.4452	-202.7806	-0.3813	1.0073	-0.3813	1.0073
4.7928 - 2.5248i	-0.1734 - 0.4065i	5.4171	-117.7945	0.4420	-203.1580	-0.3773	1.0073	-0.3773	1.0073
4.7417 - 2.5376i	-0.1748 - 0.4025i	5.3780	-118.1679	0.4388	-203.5314	-0.3735	1.0073	-0.3735	1.0073
4.6912 - 2.5495i	-0.1761 - 0.3984i	5.3392	-118.5376	0.4356	-203.9011	-0.3697	1.0073	-0.3697	1.0073
4.6411 - 2.5609i	-0.1773 - 0.3944i	5.3007 5.2625	-118.9037	0.4325	-204.2671	-0.3660	1.0073	-0.3660	1.0073
4.5915 - 2.5715i	-0.1785 - 0.3905i	5.2625	-119.2661	0.4294	-204.6296	-0.3624	1.0073	-0.3624	1.0073

Table for normal condition-ballast resistance Of 5ohm, inductance 0.2-0.3 ohm/km interval, rail resistance 0.15ohm/km, shunt train admittance 0.6 over 1.2km distance

e	Vof	Abs e	Angle	Abs vof	Ang vof	Mag.dev.(e)	Ph dev.(e)	Ph dev.(vof)	Mag.d ev.(vof)
6.6785 - 1.3013i	-0.0614 - 0.5517i	6.8042	-101.0317	0.5551	-186.3952	1.0000	0	0	1.0000
6.6581 - 1.3540i	-0.0658 - 0.5504i	6.7943	-101.5010	0.5543	-186.8645	1.0014	-0.4694	-0.4694	1.0014
6.6368 - 1.4062i	-0.0702 - 0.5490i	6.7842	-101.9691	0.5535	-187.3326	1.0015	-0.4681	-0.4681	1.0015
6.6148 - 1.4579i	-0.0745 - 0.5476i	6.7736	-102.4358	0.5526	-187.7993	1.0016	-0.4667	-0.4667	1.0016
6.5921 - 1.5091i	-0.0788 - 0.5461i	6.7627	-102.9011	0.5517	-188.2646	1.0016	-0.4653	-0.4653	1.0016
6.5687 - 1.5598i	-0.0831 - 0.5445i	6.7514	-103.3650	0.5508	-188.7285	1.0017	-0.4639	-0.4639	1.0017
6.5446 - 1.6100i	-0.0874 - 0.5429i	6.7398	-103.8274	0.5499	-189.1909	1.0017	-0.4624	-0.4624	1.0017
6.5199 - 1.6596i	-0.0916 - 0.5412i	6.7278	-104.2883	0.5489	-189.6518	1.0018	-0.4609	-0.4609	1.0018
6.4944 - 1.7086i	-0.0957 - 0.5395i	6.7154	-104.7476	0.5479	-190.1111	1.0018	-0.4593	-0.4593	1.0018
6.4684 - 1.7571i	-0.0998 - 0.5377i	6.7028	-105.2053	0.5469	-190.5688	1.0019	-0.4577	-0.4577	1.0019
6.4417 - 1.8050i	-0.1039 - 0.5358	6.6898	-105.6613	0.5458	-191.0248	1.0019	-0.4561	-0.4561	1.0019

4.1. Bpsk modulation/Demodulation without Noise for input voltage 220volt

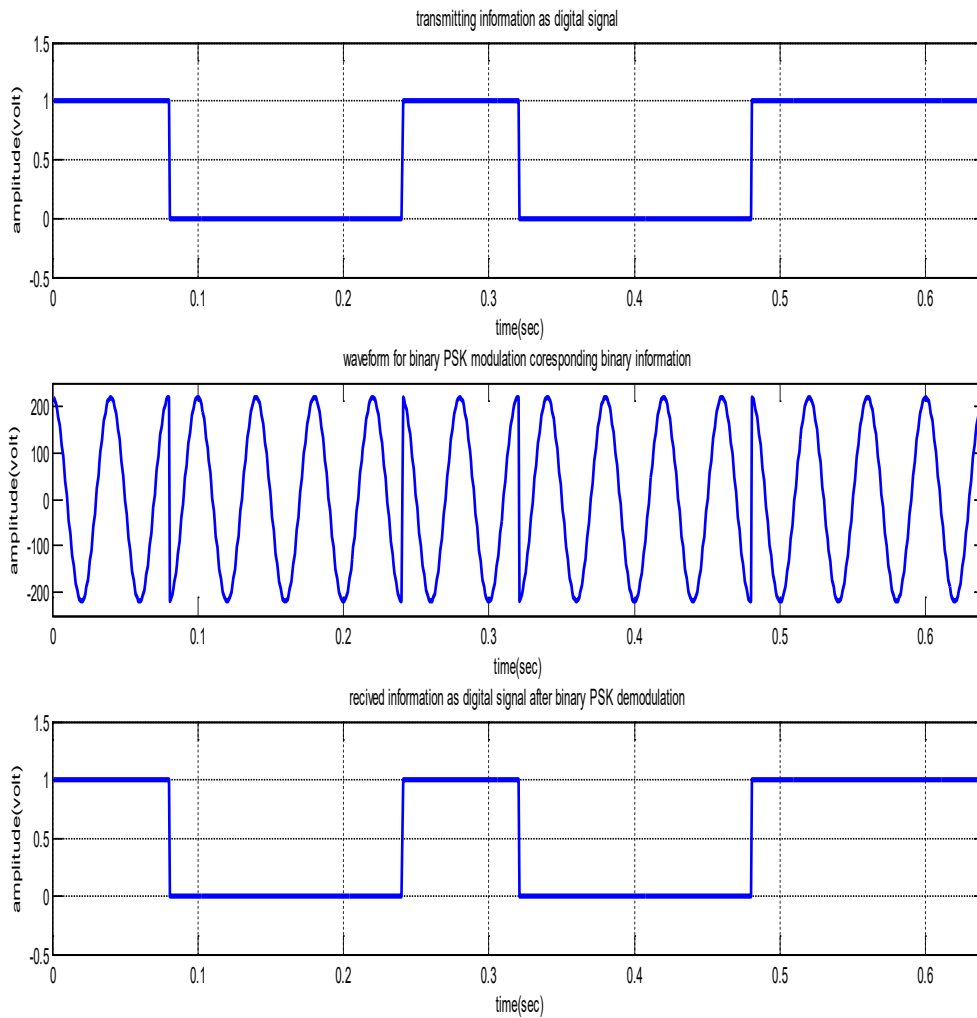


Figure 4.2. Bpsk modulation/ demodulation with Noise for the received voltage of 0.5577volt

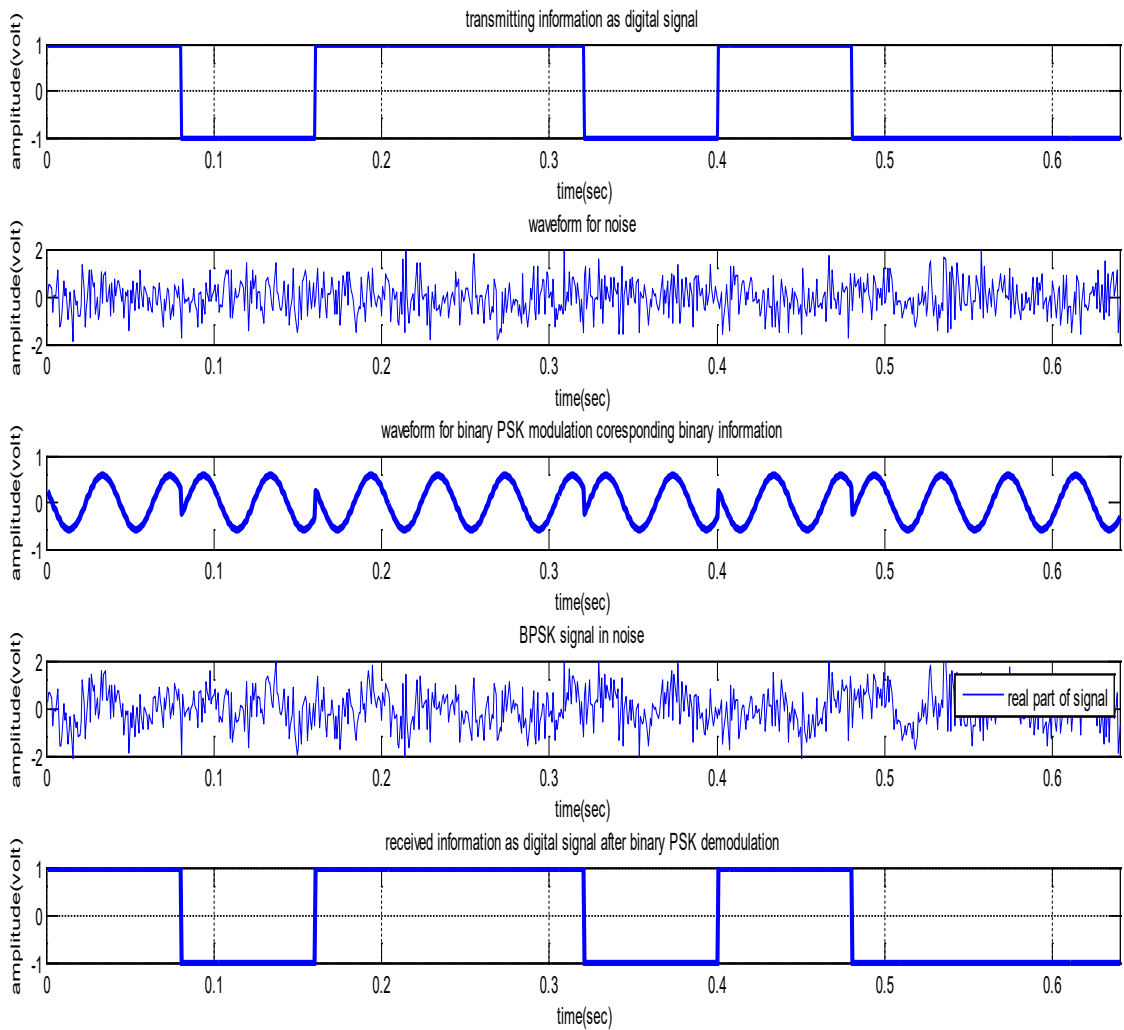


Figure 4.3. Bpsk modulation/demodulation with phase variation of 1.2377^0

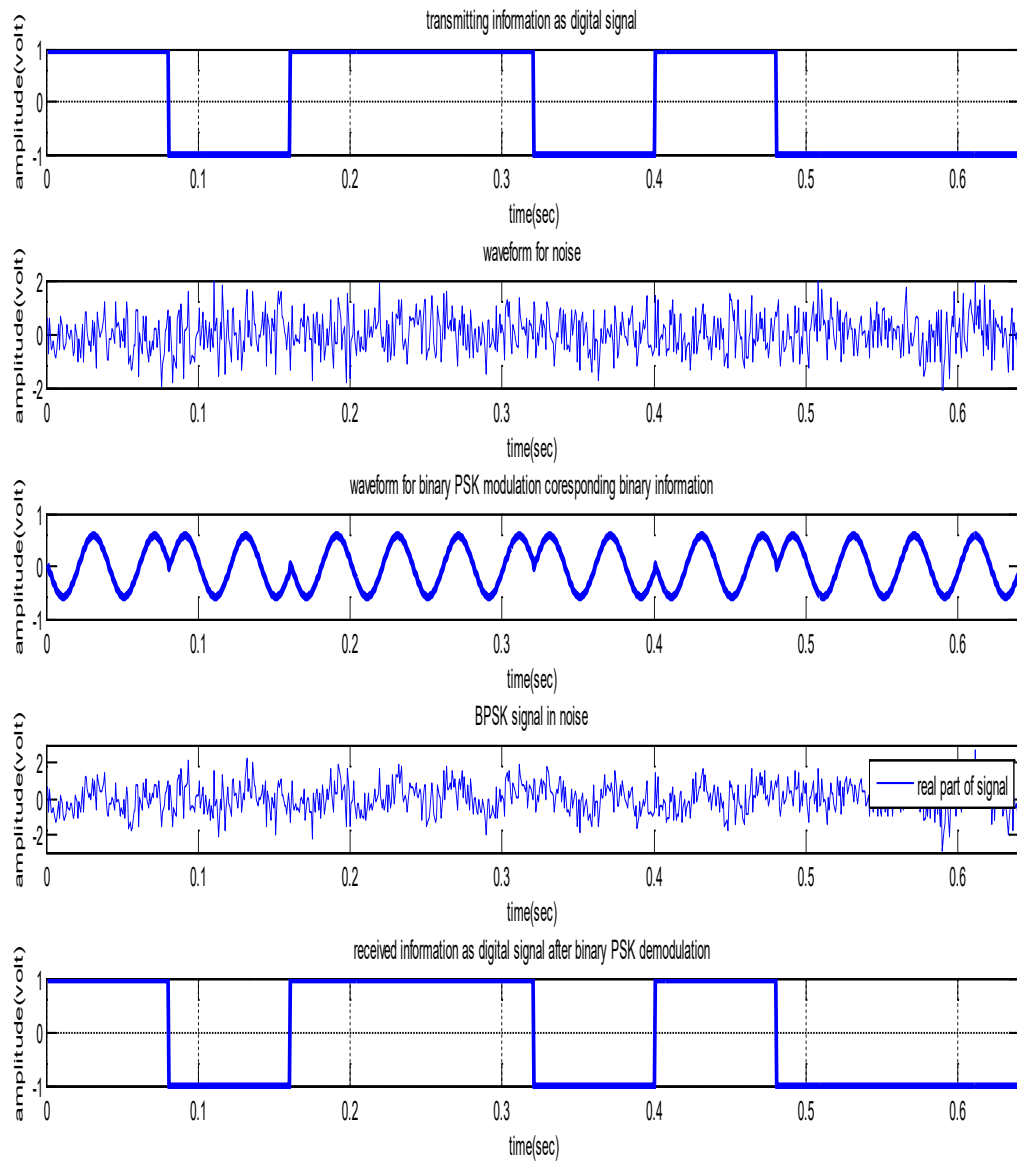


Figure.4.4 Band pass filter gain in db for Q=1, 2, 3

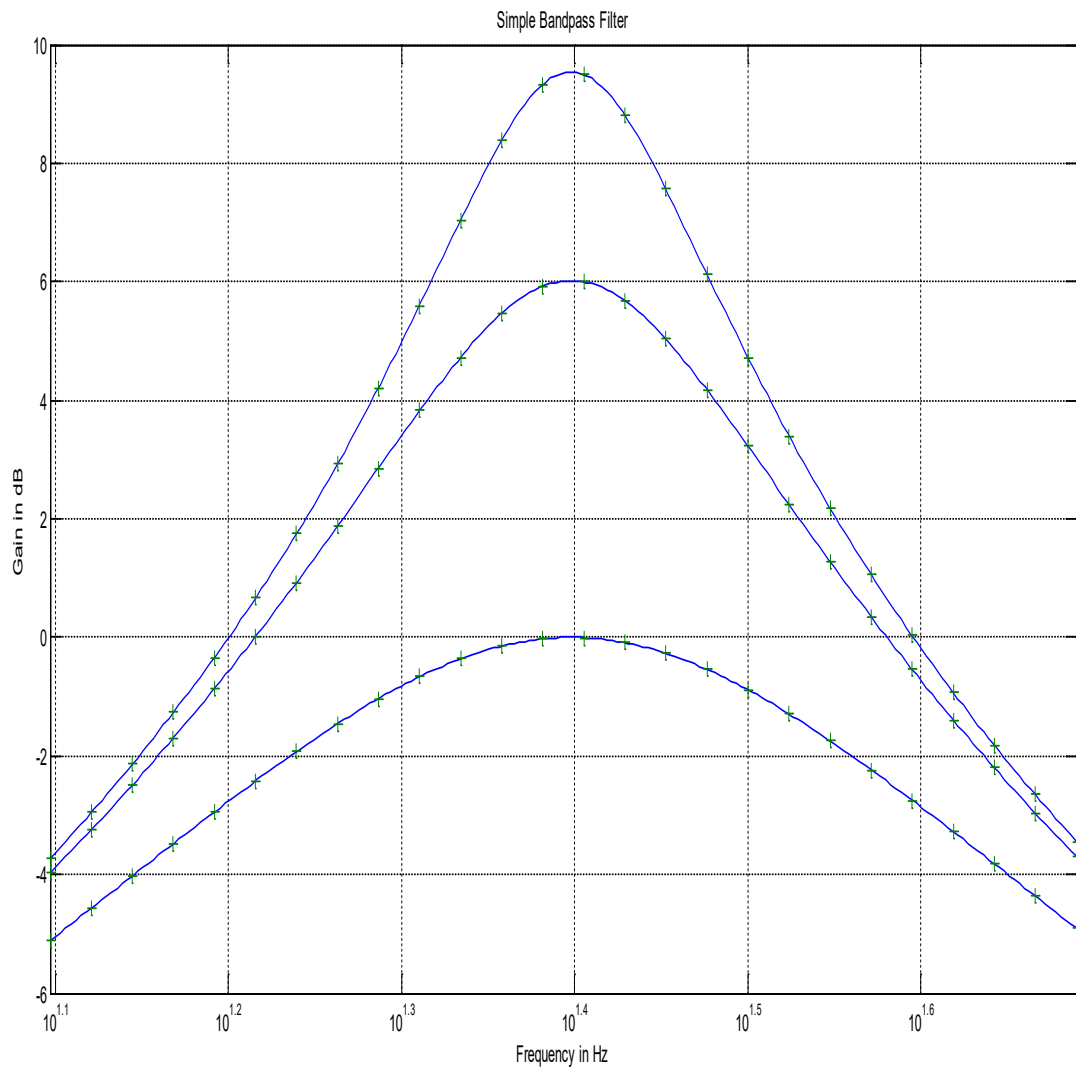


Figure Band pass filter gain in db for Q=1, 2, 3

Figure.4.5. Band pass Filter gain Diagram for Quality factor=2

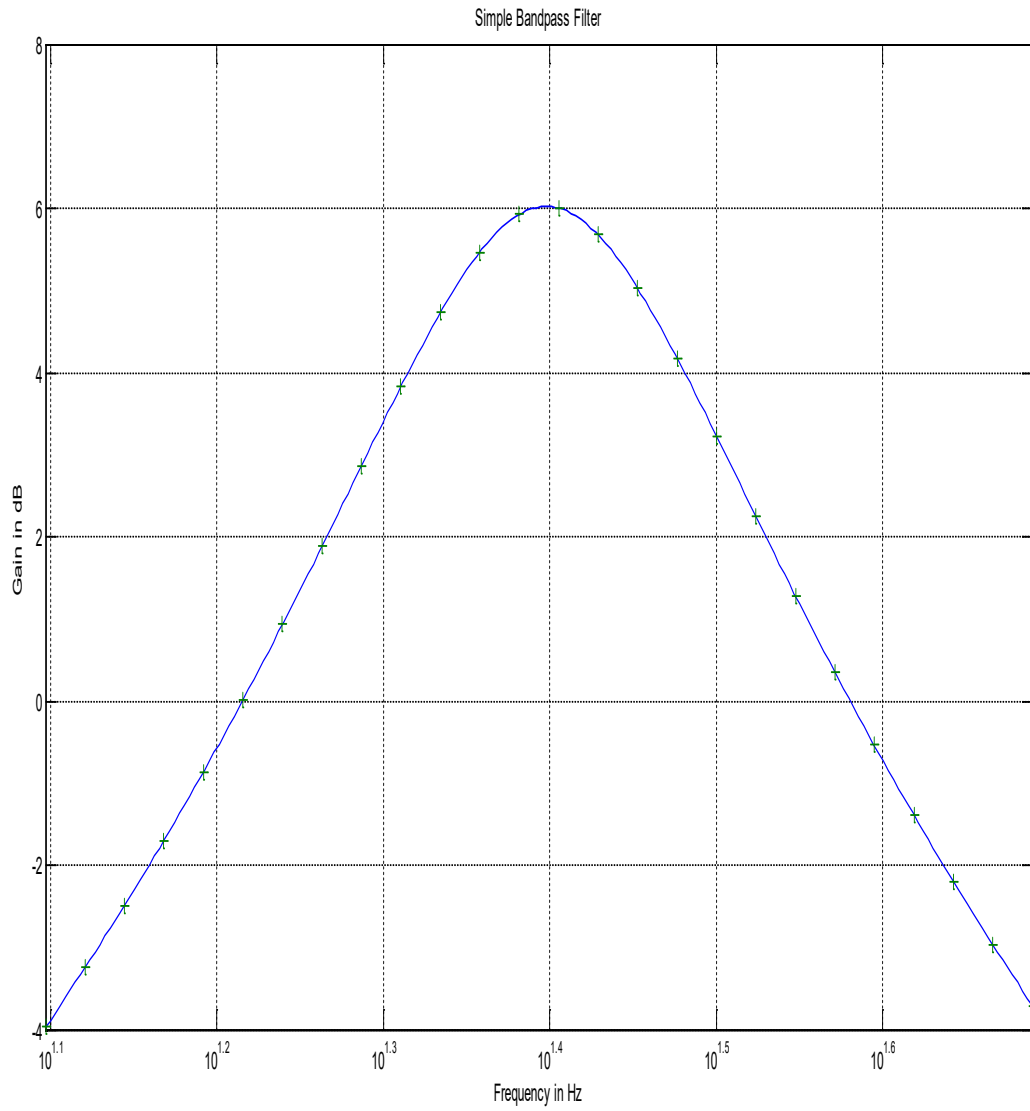


Figure.4.6. Amplitude of the induced TCR antenna voltage for normal condition

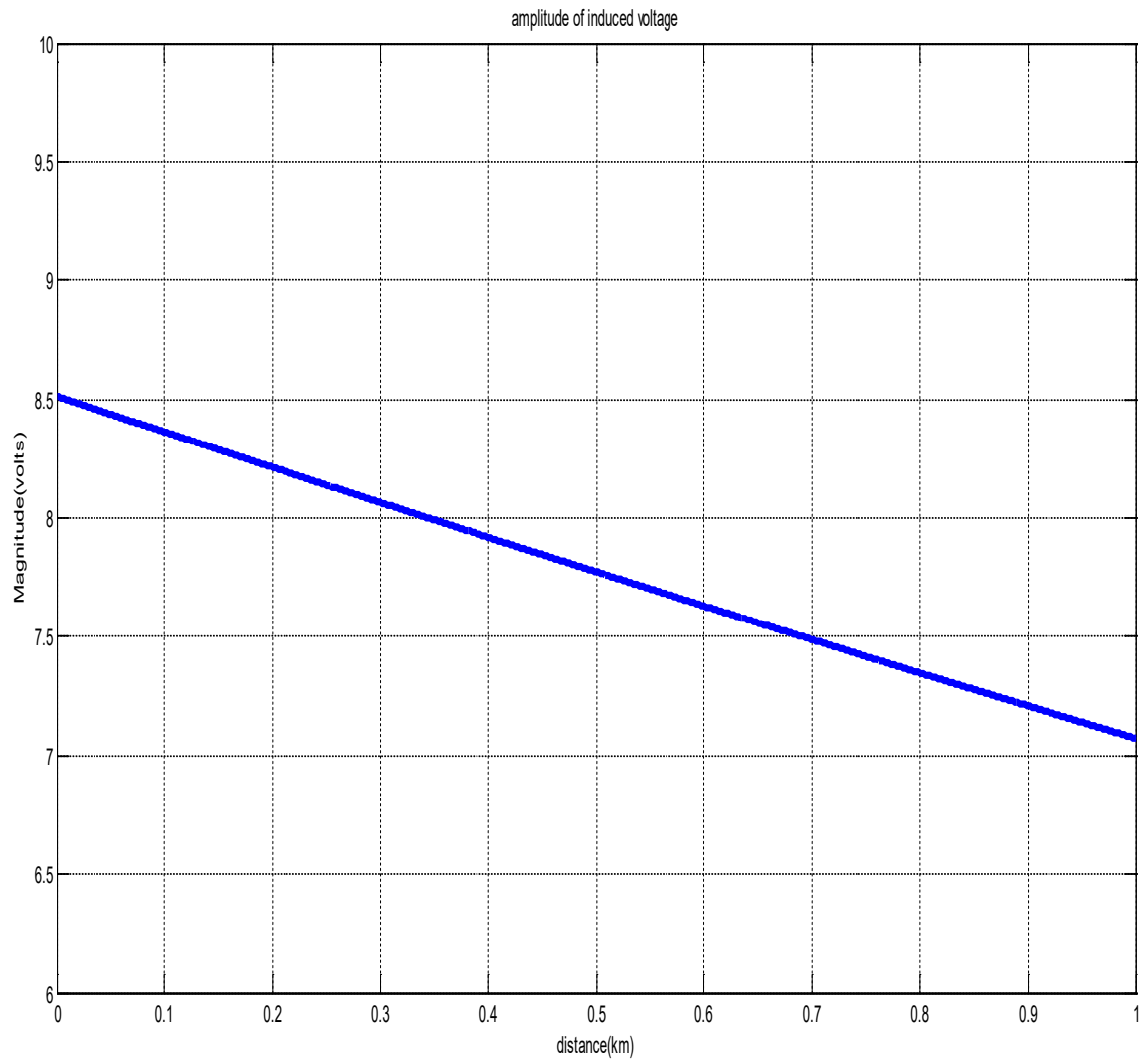


Figure.4.7. Induced voltage phase shift angle for normal condition

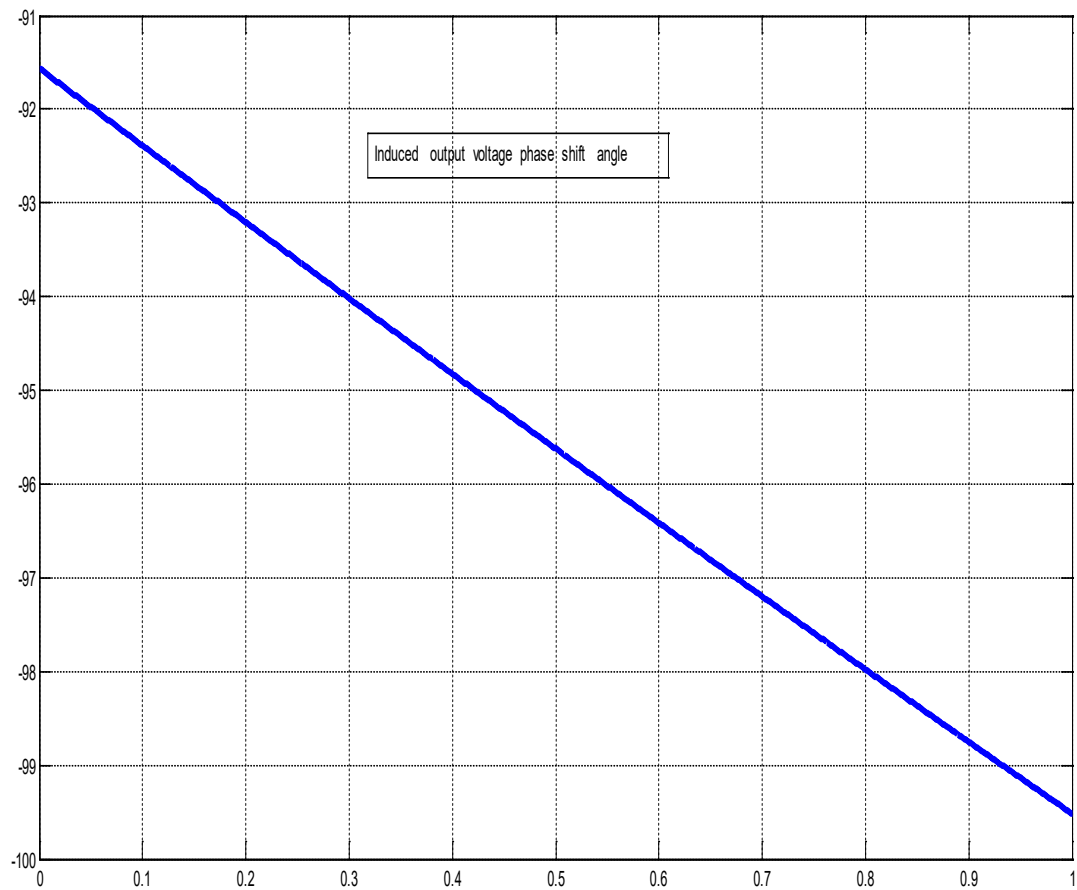


Figure.4.8. Amplitude of Filter's output voltage for normal condition

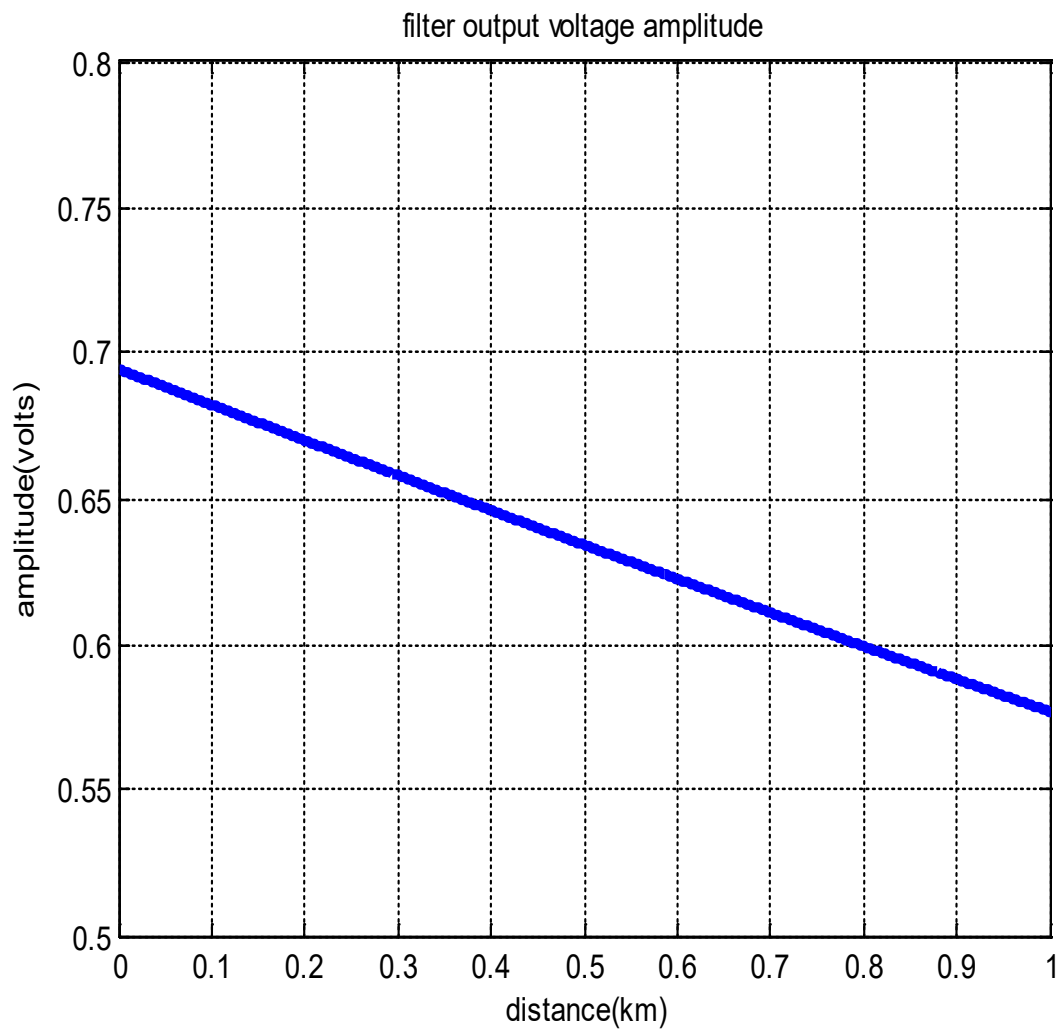


Figure.4.9. Phase angle shift-Filter's output voltage for normal condition

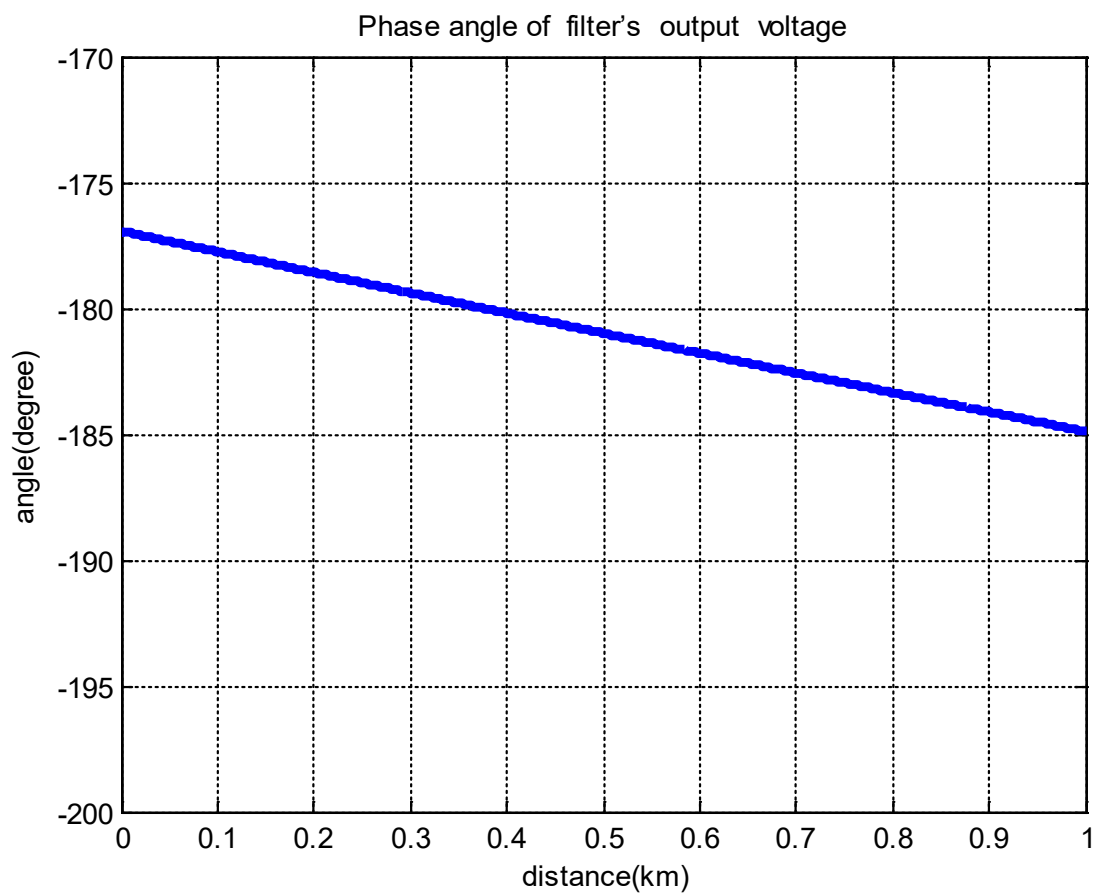


Figure.4.10. Magnitude deviation in each 100 meter for induced voltage

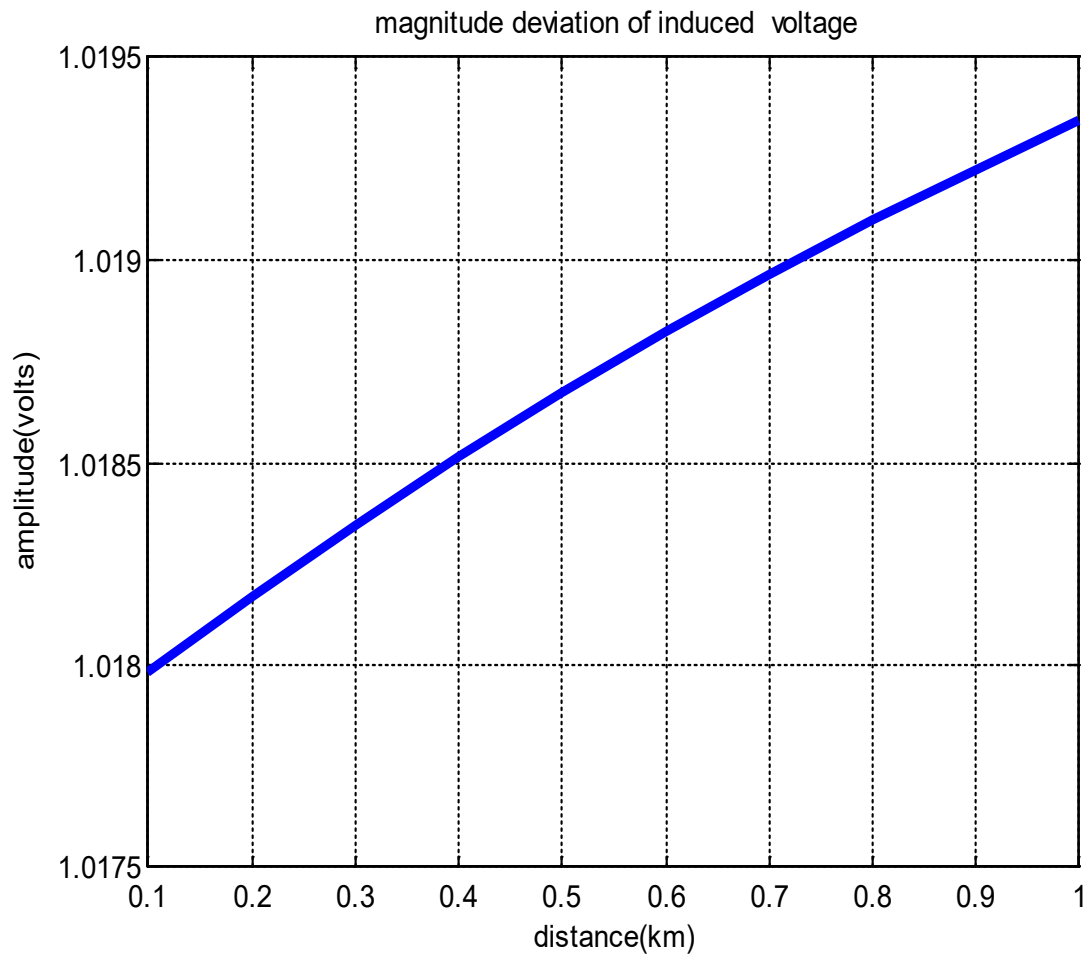


Figure.4.11. Magnitude Deviation for filters output voltage in each 100 meter interval

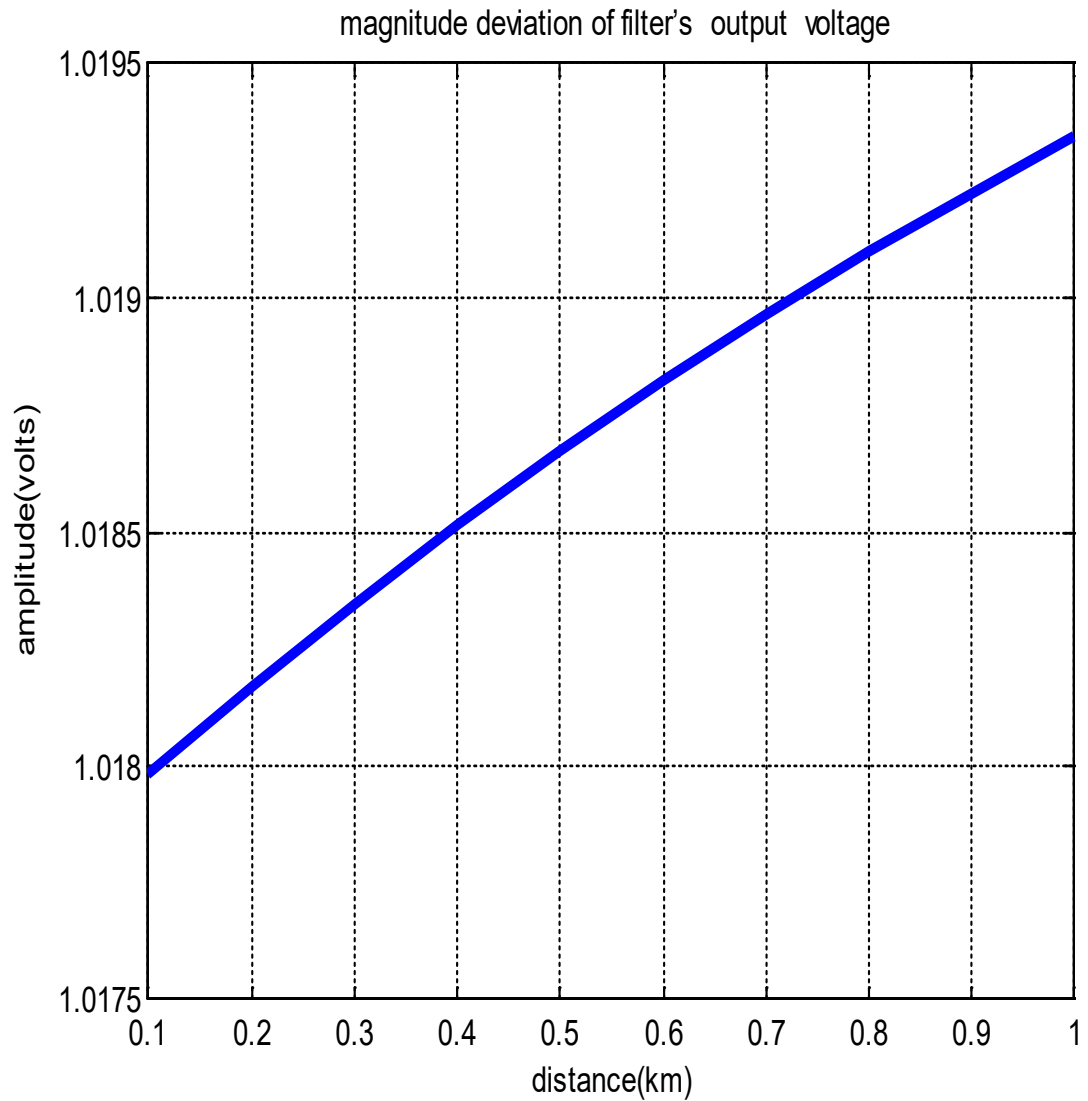


Figure.4.12. Phase angel deviation for each 10 meter distance interval for Filter's output voltage for normal condition

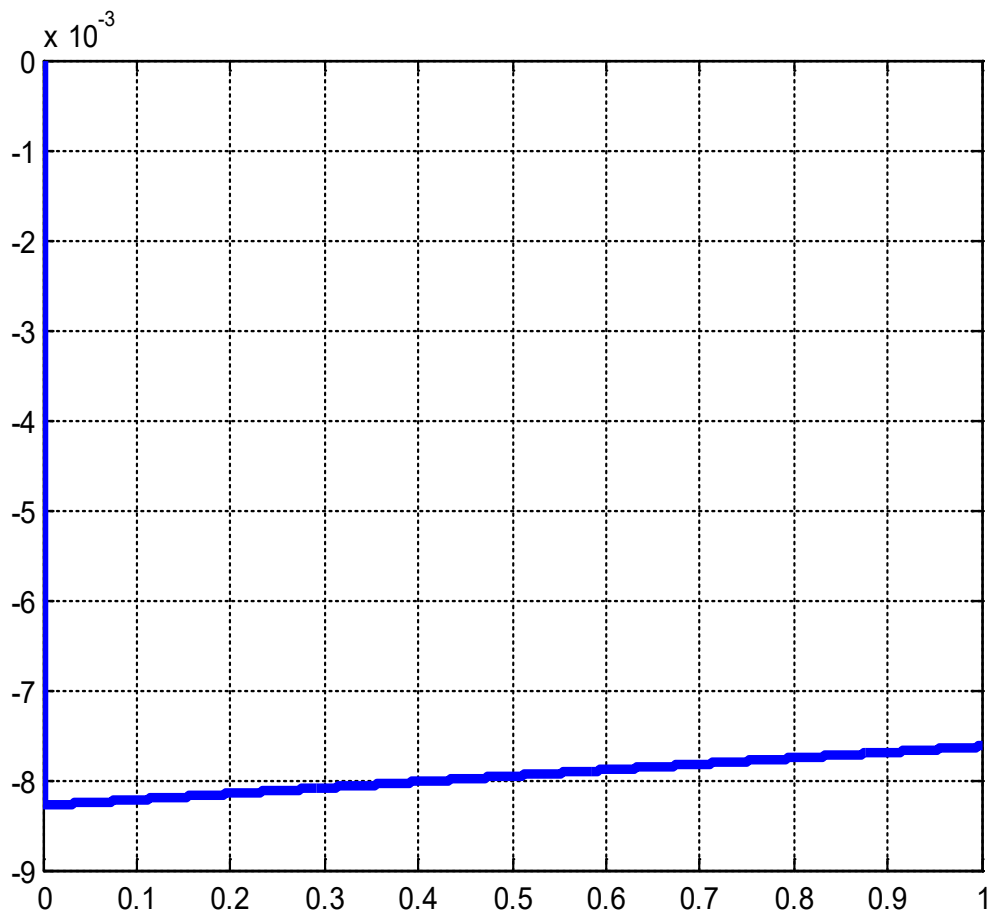


Figure 4.13. Phase angel deviation for each 10 meter distance interval for induced voltage for normal condition

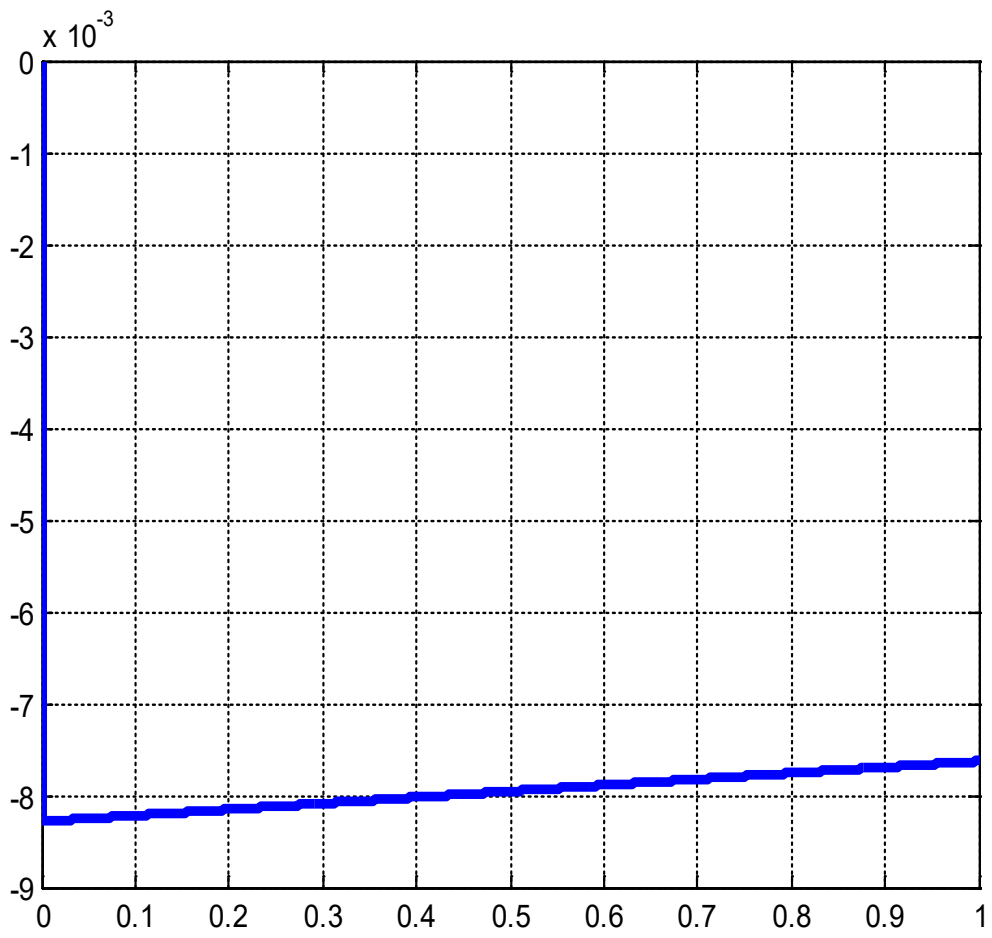


Figure.4.14. Amplitude of Induced voltage for ballast resistance 0.25ohm

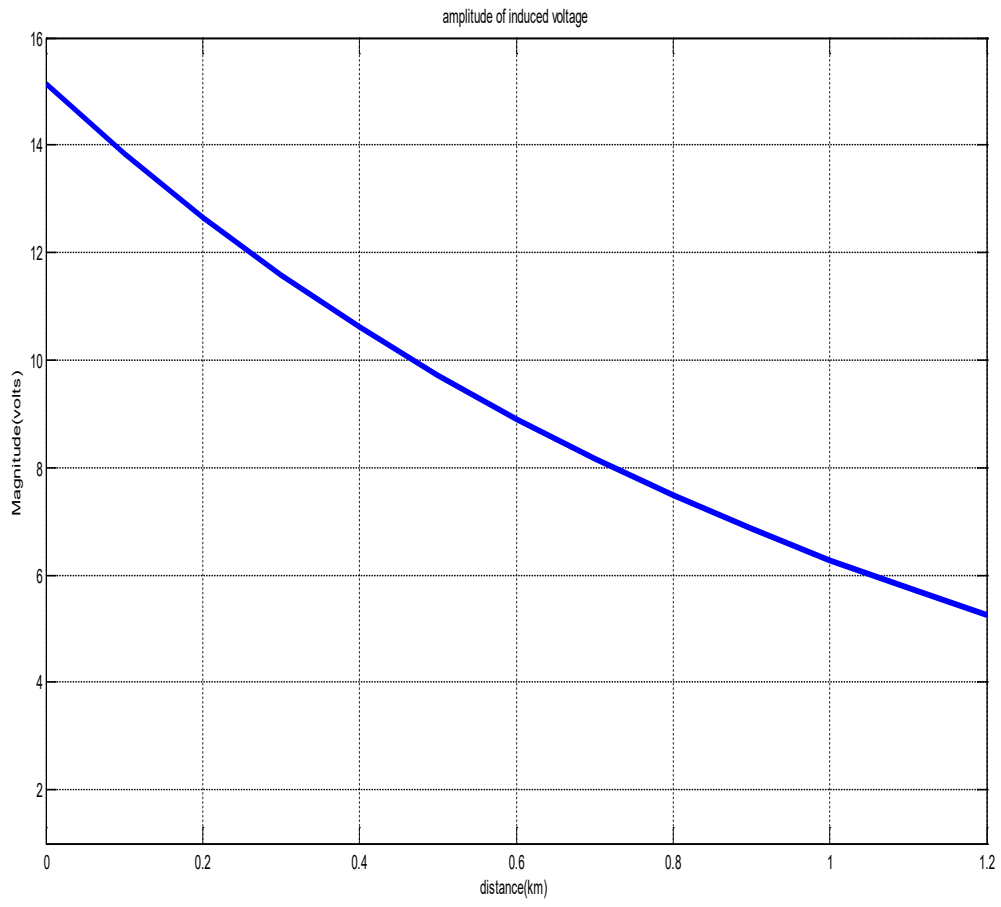


Figure.4.15. Amplitude of Filter's Output Voltage for ballast Resistance of 0.25ohm over the distance 1.2km

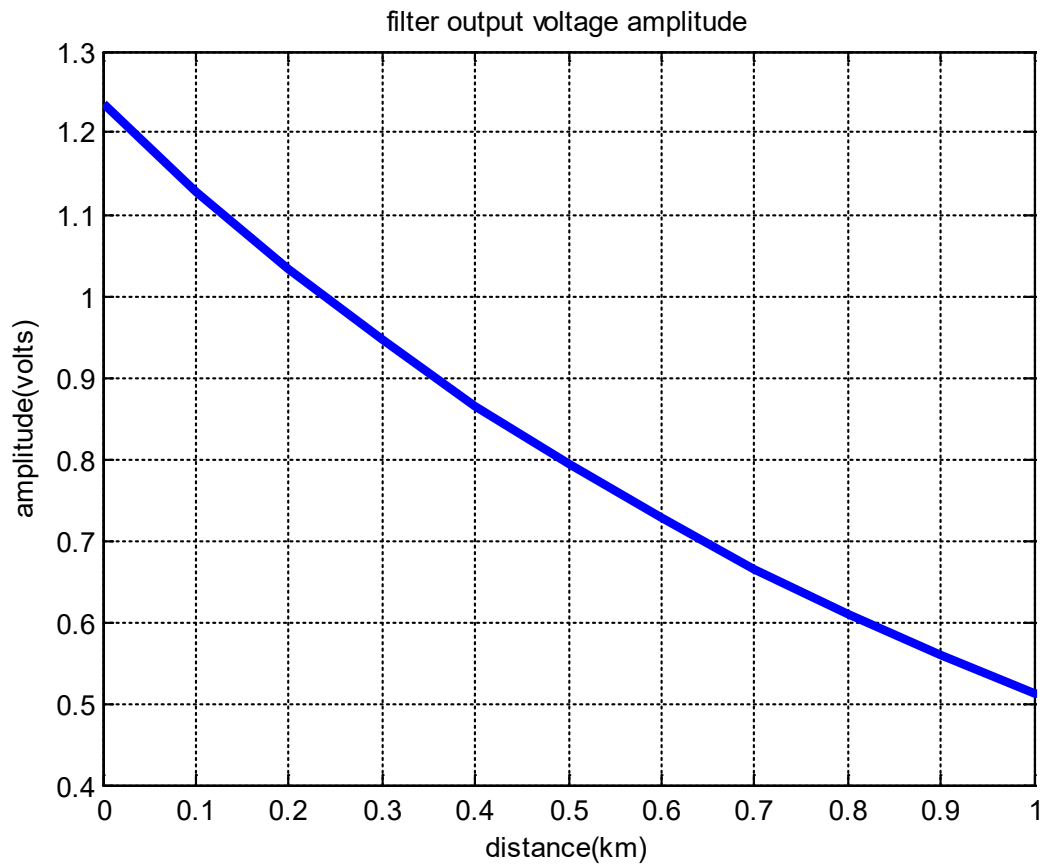


Figure.4.16.Phase Shift angle for induced voltage for ballast resistance of 4ohm over the distance of 1.2km

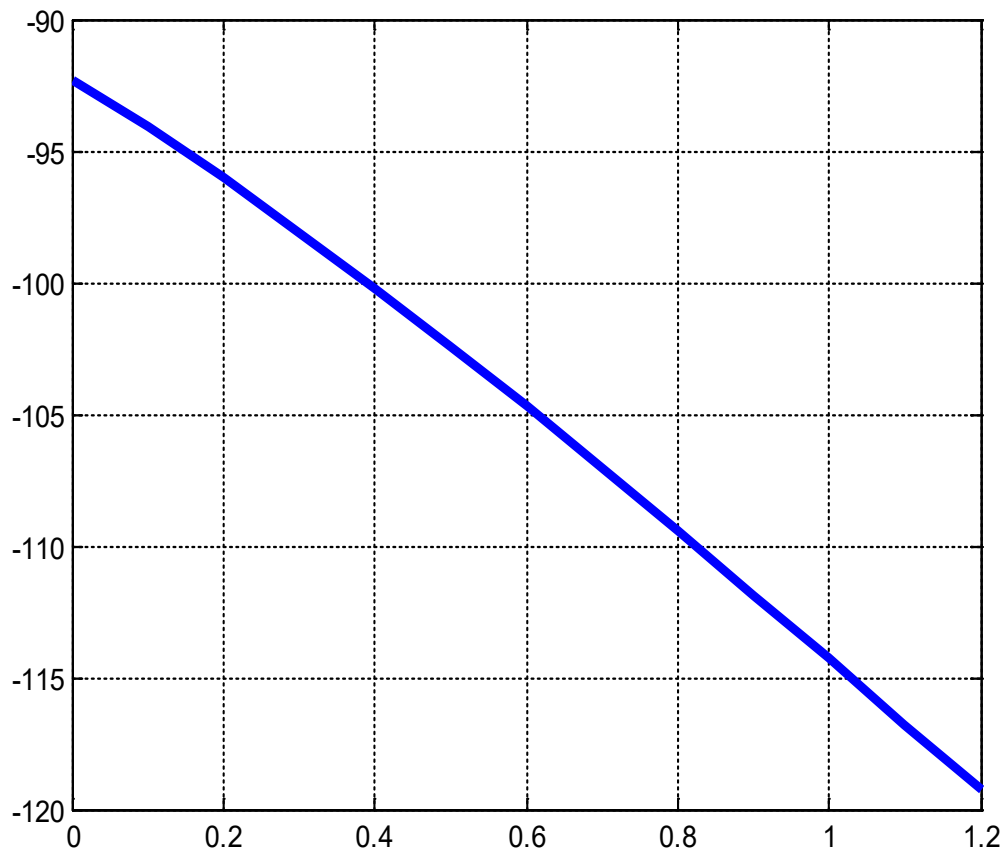


Figure.4.17. Phase Shift angle for filters output for ballast resistance of 4ohm over distance of 1.2km

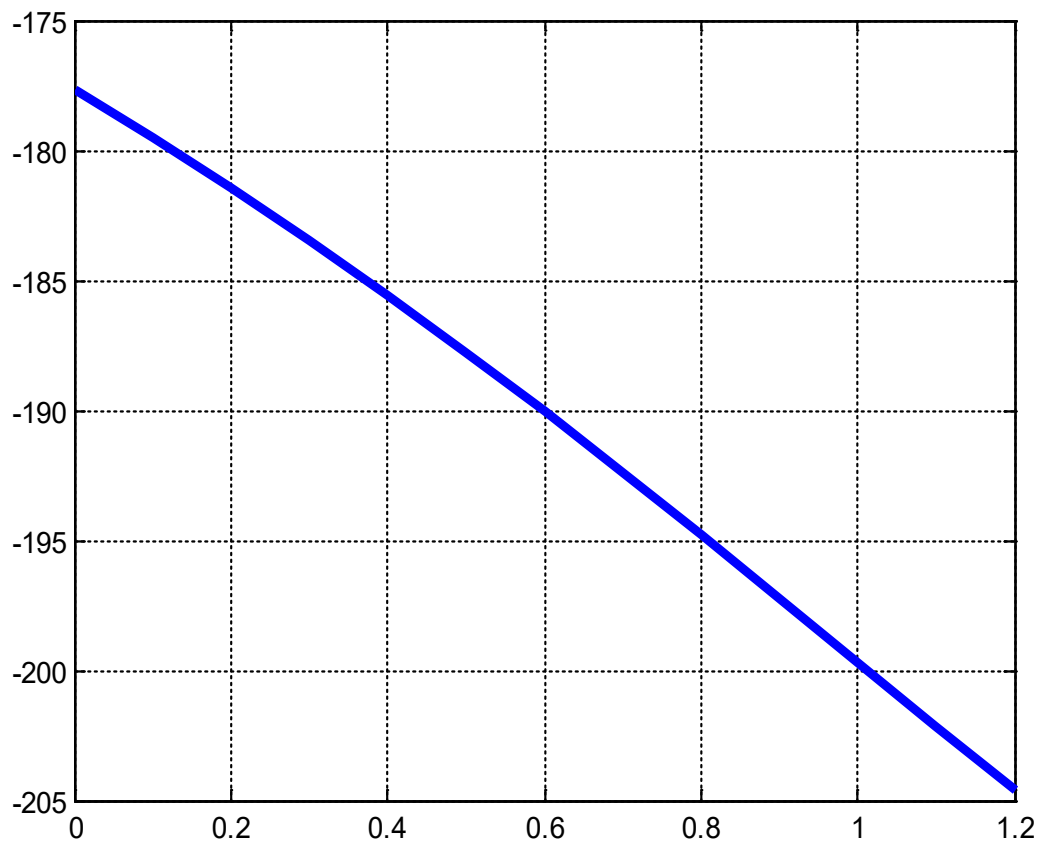


Figure.4.18.Amplitude deviation of induced voltage for ballast resistance of 0.4ohm over 1.2km distance

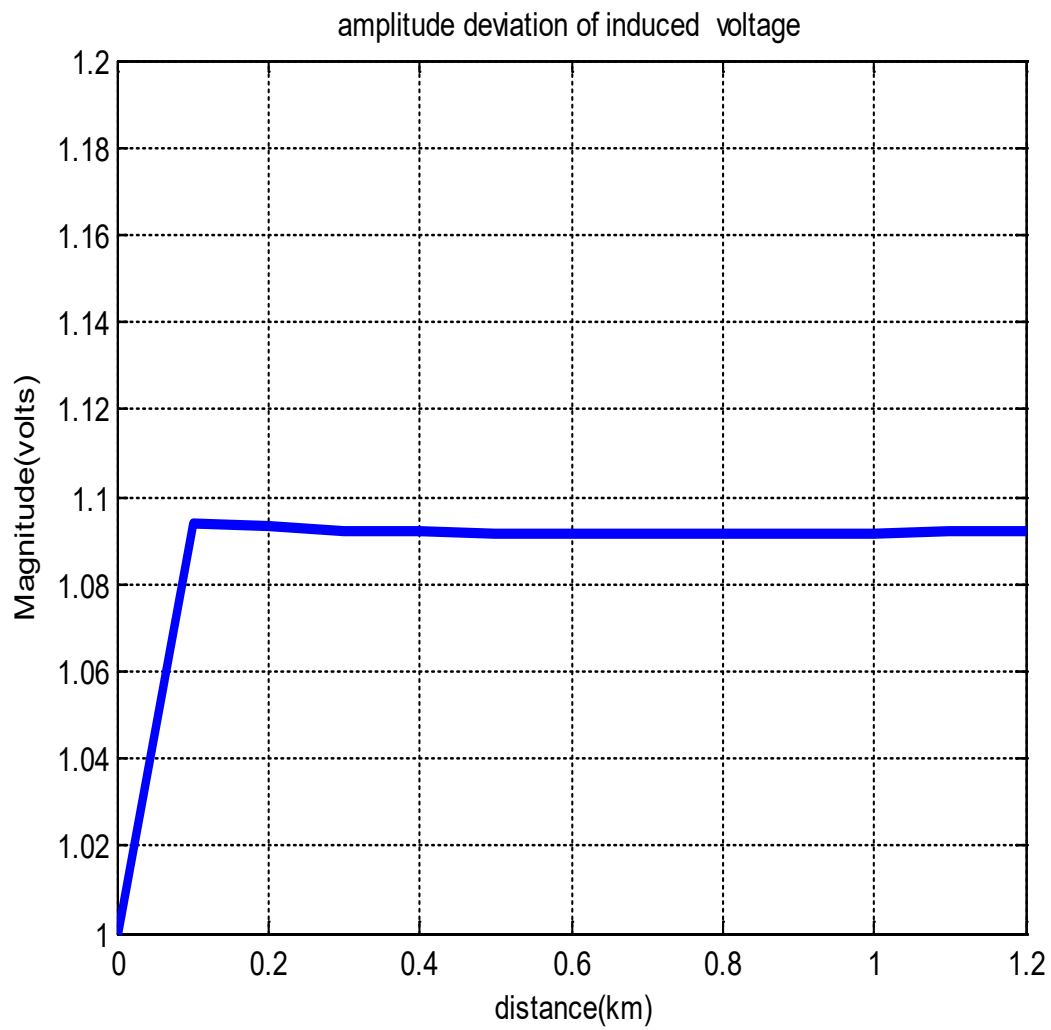


Figure.4.19. Amplitude deviation of filter's output for ballast resistance of 0.4ohm over distance of 1.2

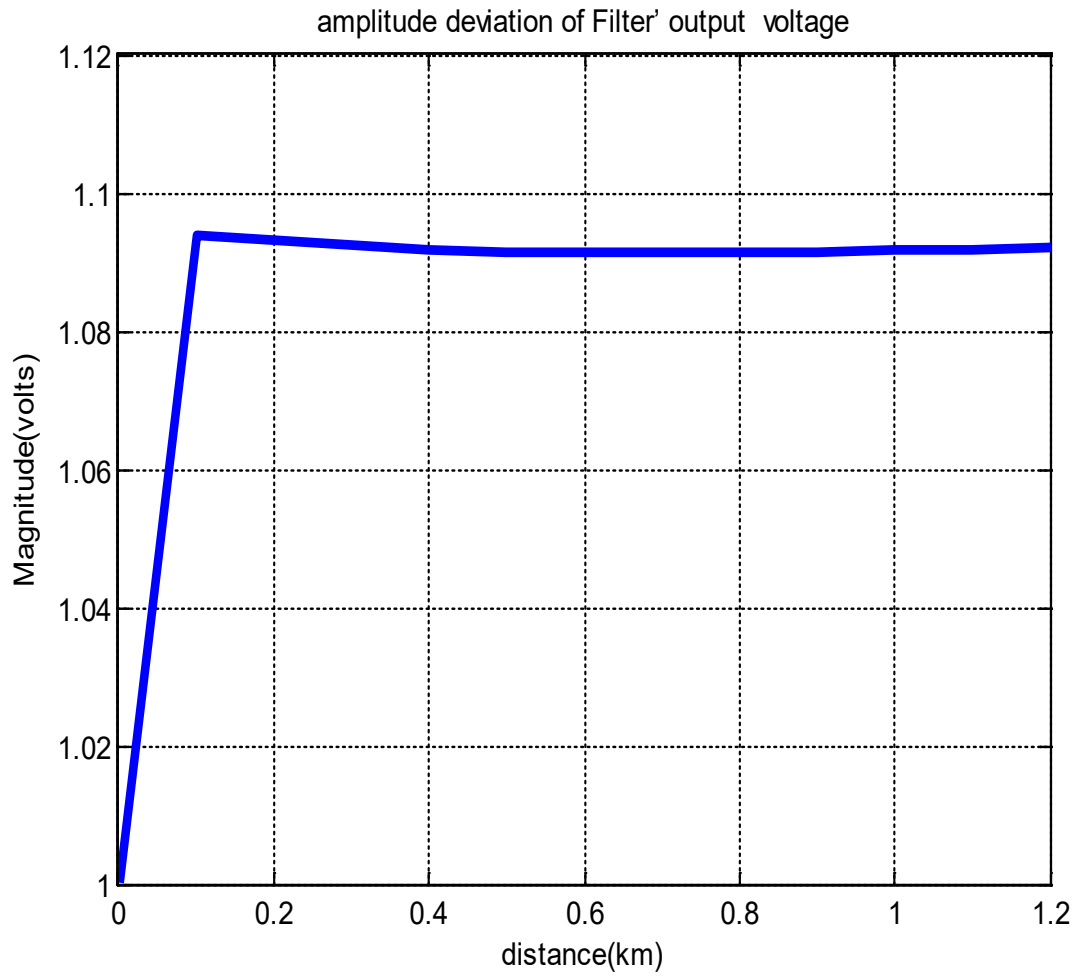


Figure.4.20. Phase Deviation of angel of induced voltage for each 100m for ballast resistance of 4ohm over 1.2km distance

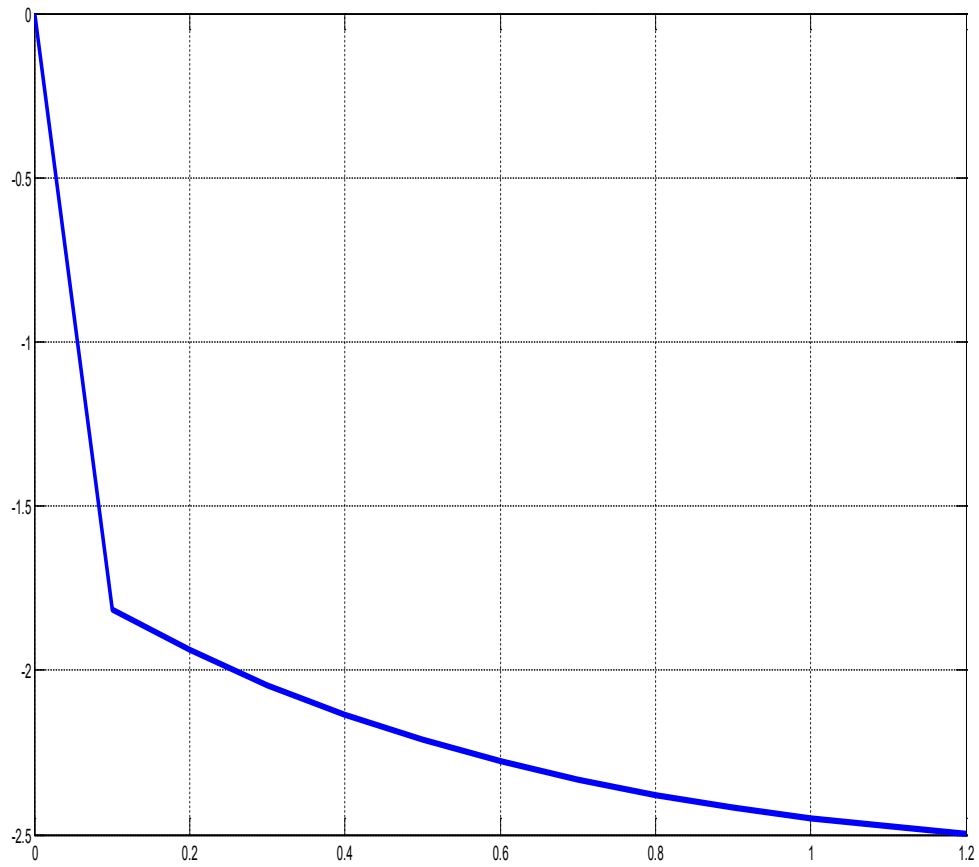
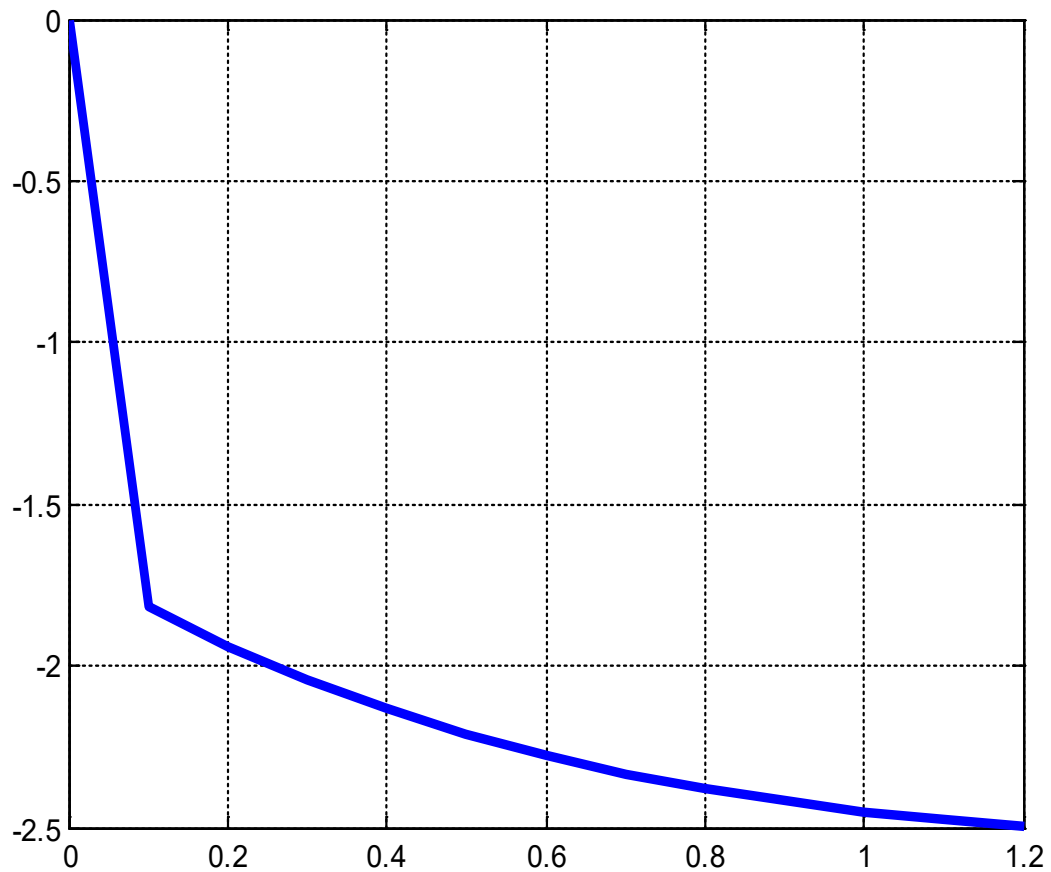


Figure.4.21.Phase Deviation of angel for Filter's output in each 100m for ballast resistance of 4ohm over 1.2km distance



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APPENDIX

A. Encoding using Generator matrix

$n = 7;$
 $k = 4;$
 $p = 2;$

```

In = eye(n);
Ik = eye(k);
Ink = eye(n-k);

L = [1 1 0; 1 0 1; 0 1 1; 1 1 1]
G = [Ik L]
H = mod([-L' Ink],p)
mod(G*H',p)
mod(G*H',p)
de2bi(16)
u = de2bi(0:(2^k - 1),k)
C = mod(u*G,p)
G=G';% extending code

```

```
F=sum(G);
```

```
B=mod(F,2);
```

```
B=B';
```

```
G=G';
```

```
Ge=horzcat(G,B);
```

```
V=ones(1,8);
```

```
W=zeros(3,1);
```

```
N=horzcat(H,W);
```

```
He=vertcat(V,N);
```

```
mod(Ge*He',p);
```

```
Ce = mod(u*Ge,p);
```

B.Decoding Using syndrome table

```
n = 8;
```

```
k = 4;
```

```
p = 2;
```

```
In = eye(n);
```

```
Ik = eye(k);
```

```
Ink = eye(n-k);
```

```
P = [1 1 0 1; 1 0 1 1; 0 1 1 1; 1 1 1 0]
```

```
>> G = [Ik P]
```

```
>> H = mod([-P' Ink],p)
```

```
>> mod(G*H',p)
```

```

>> de2bi(16)
>> u = de2bi(0:(2^k - 1),k)
>> C = mod(u*G,p)
>> N2 = nchoosek(1:n,2)
>> E2 = zeros(length(N2),n);
for i=1:length(N2);
E2(i,N2(i,:)) = 1;
end % All weight 2 error patterns
>> S2 = mod(E2*H',2)
>> trt = syndtable(H);
recd = [ 0 0 1 0 1 1 1 0]; % Suppose this is the received vector.
syndrome = rem(recd * H',2);
syndrome_de = bi2de(syndrome,'left-msb'); % Convert to decimal.
disp(['Syndrome = ',num2str(syndrome_de),...
'(decimal), ',num2str(syndrome),' (binary)'])
corrvect = trt(1+syndrome_de,:) % Correction vector
% Now compute the corrected codeword.
correctedcode = rem(corrvect+recd,2)

```

C.BPSK modulation and demodulation for the No attenuation ,no channel phase shift and no noise case

```

clc;
clear all;
close all;
x=[ 1 0 0 1 0 0 1 1]; % Binary Information
bp=0.08; % bit period
disp(' Binary information at Transmitter :');
disp(x);
%XX representation of transmitting binary information as digital signal XXX
bit=[];

```

```

for n=1:1:length(x)
    if x(n)==1;
        se=ones(1,100);
    else x(n)==0;
        se=zeros(1,100);
    end
    bit=[bit se];
end
t1=bp/100:bp/100:100*length(x)*(bp/100);
subplot(3,1,1);
plot(t1,bit,'lineWidth',2.5);grid on;
axis([ 0 bp*length(x) -.5 1.5]);
ylabel('amplitude(volt)');
xlabel(' time(sec)');
title('transmitting information as digital signal');
% Binary-PSK modulation%
A=220; % Amplitude of carrier signal
br=1/bp; % bit rate
f=br*2; % carrier frequency
t2=bp/99:bp/99:bp;
ss=length(t2);
m=[];
for (i=1:1:length(x))
    if (x(i)==1)
        y=A*cos(2*pi*f*t2);
    else
        y=A*cos(2*pi*f*t2+pi); %A*cos(2*pi*f*t+pi) means -A*cos(2*pi*f*t)
    end
end

```

```

    m=[m y];
end
t3=bp/99:bp/99:bp*length(x);
subplot(3,1,2);
plot(t3,m);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for binary PSK modulation coresponding binary information');
% Binary PSK demodulation
mn=[];
for n=ss:ss:length(m)
    t=bp/99:bp/99:bp;
    y=cos(2*pi*f*t);           % carrier signal
    mm=y.*m((n-(ss-1)):n);
    t4=bp/99:bp/99:bp;
    z=trapz(t4,mm)             % intregation
    if(z>0)                     % logic level = (A+A)/2=0
        %because  $A*\cos(2*\pi*f*t+\pi)$  means  $-A*\cos(2*\pi*f*t)$ 
        a=1;
    else
        a=0;
    end
    mn=[mn a];
end
disp(' Binary information at Reciver :');
disp(mn);
%XXXXXX Representation of binary information as digital signal which achived
%after PSK demodulation

```

```

bit=[];
for n=1:length(mn);
    if mn(n)==1;
        se=ones(1,100);
    else mn(n)==0;
        se=zeros(1,100);
    end
    bit=[bit se];
end
t4=bp/100:bp/100:100*length(mn)*(bp/100);
subplot(3,1,3)
plot(t4,bit,'LineWidth',2.5);grid on;
axis([ 0 bp*length(mn) -.5 1.5]);
ylabel('amplitude(volt)');
xlabel(' time(sec)');
title('recived information as digital signal after binary PSK demodulation');

```

D.modulation/demodulation for real case

```

x=[ 1 0 1 1 0 1 0 0];
SNR=[0:1:10]'; %column vector
%SNR in linear scale
snr=10.^(SNR/10); % Binary Information
bp=0.08; % bit period
disp(' Binary information at Transmitter :');
disp(x);
%XX representation of transmitting binary information as digital signal XXX
bit=[];
for n=1:1:length(x)

```

```

if x(n)==1;
    se=ones(1,100);
else x(n)==0;
    se=-1*ones(1,100);
end
bit=[bit se];
end
t1=bp/100:bp/100:100*length(x)*(bp/100);
subplot(5,1,1);
plot(t1,bit,'lineWidth',2.5);grid on;
axis([ 0 bp*length(x) -1, 1]);
ylabel('amplitude(volt)');
xlabel(' time(sec)');
title('transmitting information as digital signal');
F=[];
for (i=1:1:length(x))
n= 1/sqrt(2)*(randn(1,800)+j*randn(1,800));
end
F=[F n]
t5=bp/100:bp/100:bp*length(x);
subplot(5,1,2);
plot(t5,F)
axis([ 0 bp*length(x) -10,10]);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for noise');
% Binary-PSK modulation
A=5; % Amplitude of carrier signal

```

```

br=1/bp; % bit rate
f=br*2; % carrier frequency
t2=bp/100:bp/100:bp;
ss=length(t2);
m=[];
for (i=1:1:length(x))
    if (x(i)==1)
        y=-0.5757*sin(2*pi*f*t2-94.83);
    else
        y=-0.5757*sin(2*pi*f*t2-94.83+pi);
    end
    m=[m y];
end
t3=bp/100:bp/100:bp*length(x);
subplot(5,1,3);
plot(t3,m);
axis([ 0 bp*length(x) -5,5]);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for binary PSK modulation coresponding binary information');
for k=1:length(SNR),
    if k==1,
        Bpsk= m+ sqrt(snr(k))*F; %snr is Eb/N0 in BER equations
    subplot(5,1,4);
    plot(t3,Bpsk )
    legend('real part of signal','data'),
    title('BPSK signal in noise'),pause
end

```

```

end

% Binary PSK demodulation

mn=[];

for n=ss:ss:length(m)

    t=bp/100:bp/100:bp;

    y=-A*sin(2*pi*f*t-94.83); %-cos4.83          % carrier signal

    mm=y.*Bpsk((n-(ss-1)):n);

    t4=bp/100:bp/100:bp;

    z=trapz(t4,mm)          % intregation

    if(z>0)

        a=1;

    else

        a=0;

    end

    mn=[mn a];

end

disp(' Binary information at Reciver :');

disp(mn);

% Representation of binary information as digital signal which achived

%after PSK demodulation

bit=[];

for n=1:length(mn);

    if mn(n)==1;

        se=ones(1,100);

    else mn(n)==0;

        se=-1*ones(1,100);

    end

    bit=[bit se];

```

```

end

t4=bp/100:bp/100:100*length(mn)*(bp/100);

subplot(5,1,5)

plot(t4,bit,'LineWidth',2.5);grid on;

axis([ 0 bp*length(mn) -1, 1]);

ylabel('amplitude(volt)');

xlabel(' time(sec)');

title('received information as digital signal after binary PSK demodulation');

grid on;

E.demodulation for continuous phase shift deviation of the received signal

x=[ 1 0 1 1 0 1 0 0];

SNR=[0:1:10]'; %column vector ,SNR (Eb/No) values in decibels

%SNR in linear scale

snr=10.^(SNR/10); % Binary Information

bp=0.08; % bit period

disp(' Binary information at Transmitter :');

disp(x);

%XX representation of transmitting binary information as digital signal XXX

bit=[];

for n=1:1:length(x)

    if x(n)==1;

        se=ones(1,100);

    else x(n)==0;

        se=-1*ones(1,100);

    end

    bit=[bit se];

end

t1=bp/100:bp/100:100*length(x)*(bp/100);

```

```

subplot(5,1,1);
plot(t1,bit,'lineWidth',2.5);grid on;
axis([ 0 bp*length(x) -1, 1]);
ylabel('amplitude(volt)');
xlabel(' time(sec)');
title('transmitting information as digital signal');
F=[];
for (i=1:1:length(x))
n= 1/sqrt(2)*(randn(1,800)+j*randn(1,800));
end
F=[F n]
t5=bp/100:bp/100:bp*length(x);
subplot(5,1,2);
plot(t5,F)
axis([ 0 bp*length(x) -10,10]);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for noise');
% Binary-PSK modulation
A=5; % Amplitude of carrier signal
br=1/bp; % bit rate
f=br*2; % carrier frequency
t2=bp/100:bp/100:bp;
ss=length(t2);
m=[];
for (i=1:1:length(x))
if (x(i)==1)
y=-0.5757*sin(2*pi*f*t2-94.44);

```

```

else
    y=-0.5757*sin(2*pi*f*t2-94.44+pi);
end
m=[m y];
end
t3=bp/100:bp/100:bp*length(x);
subplot(5,1,3);
plot(t3,m);
axis([ 0 bp*length(x) -5,5]);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for binary PSK modulation coresponding binary information');
for k=1:length(SNR),
    if k==1,
        Bpsk= m+ sqrt(snr(k))*F; %snr is Eb/N0 in BER equations
    subplot(5,1,4);
    plot(t3,Bpsk )
    legend('real part of signal','data'),
    title('BPSK signal in noise'),pause
    end
end

% Binary PSK demodulation
mn=[];
for n=ss:ss:length(m)
    t=bp/100:bp/100:bp;
    y=-A*sin(2*pi*f*t-94.83); %-cos4.83 % carrier siignal
    mm=y.*Bpsk((n-(ss-1)):n);
    t4=bp/100:bp/100:bp;

```

```

z=trapz(t4,mm)                % intregation
    if(z>0)
a=1;
    else
a=0;
    end
mn=[mn a];
end
disp(' Binary information at Reciver :');
disp(mn);
% Representation of binary information as digital signal which achived
%after PSK demodulation
bit=[];
for n=1:length(mn);
    if mn(n)==1;
        se=ones(1,100);
    else mn(n)==0;
        se=-1*ones(1,100);
    end
    bit=[bit se];
end
t4=bp/100:bp/100:100*length(mn)*(bp/100);
subplot(5,1,5)
plot(t4,bit,'LineWidth',2.5);grid on;
axis([ 0 bp*length(mn) -1, 1]);
ylabel('amplitude(volt)');
xlabel(' time(sec)');
title('received information as digital signal after binary PSK demodulation');

```

```
grid on;
```

F. Transmission over distance

```
clear;
clc;
Ir=[];

Vr=[];

Vo=[];

Pf=[];

Mfd=[];

Pfd=[];

Mf=[];

Md=[ ];

Pd=[ ];

e=[];

p=[];

M=[];

D=[];

vs=220;

m=0.2;
Z1=0.5;
zr=complex(0.12,0.16);
ys=1.2;
Zs =(2*ys*zr+4)/(4*ys+zr*ys^2);
for d=0:0.1:1.2
l=0.2;
r=0.15;
r1=m;
%evaluation of the parameters
xl=l;
res=r;
Zf=complex(78.51,959.08);

z=complex(res,xl);

y=complex(r1,0);

zc=sqrt(z/y);
Y=sqrt(y*z);
L=0.0528;%  $2 * \frac{N}{l_q} \frac{\mu_o \mu_r}{8\pi}$  value
%the ABCD parameters hence are
A=cosh(Y*d);
B=sinh(Y*d);
%Z1=Z1-0.005;
%evaluate the value of Vreceiving end and Ireceiving end
```

```

Vr1=vs/((A+((zc*B)/Zs))+Z1*((B/zc)+(A/Zs)));
Ir1=vs/((Zs*A)+(zc*B)+Z1*((Zs*B /zc) +A));
e1=L*Ir1;
Vof=78.51*e1/ Zg;

Mf1=abs(Vof);

Pfde =angle(Vof);

Pf1= Pfde *180/3.14-90;

M1=abs(e1);

pde=angle(e1);

p1=pde*180/3.14-90;

e=[e e1];

p=[p p1];

M=[M M1];

D=[D d];

Vo=[Vo Vof];

Pf=[ Pf Pf1];

Mf=[ Mf Mf1];

Vr=[Vr Vr1];
Ir=[Ir Ir1];
end
Vr=[Vr]
Ir=[Ir]
E=[e]
Vo=[Vo ]

M=[M]

P=[p]

Mf=[ Mf]

Pf=[ Pf]

for i=0:1:12

if i==0

Pd1=0;

Md1=1;

Pfd1=0;

Mfd1=1;

else

Pd1=P(i+1)-P(i);

Md1=M(i)/M(i+1);

```

```

Pfd1=Pf(i+1)-Pf(i);
Mfd1=Mf(i)/Mf(i+1);

end

Pd=[Pd Pd1];
Md=[Md Md1];
Mfd=[Mfd Mfd1];
Pfd=[Pfd Pfd1];
end
Pd=[Pd]
Md=[Md]
Mfd=[Mfd]
Pfd=[Pfd]

```

G.Transmission for different values of ballast resistance

```

clear;
clc;
Ir=[];

Vr=[];

Vo=[];

Pf=[];

Mfd=[];

Pfd=[];

Mf=[];

Md=[ ];

Pd=[ ];

e=[];

p=[];

M=[];

D=[];

vs=220;

Z1=0.5;

zr=complex(0.12,0.16);

for m=3:0.1:4
d=1.2;
ys=1.04+0.8*m;
Zs =(2*ys*zr+4)/(4*ys+zr*ys^2);
l=0.2;
r=0.15;
r1=m;
%evaluation of the parameters
xl=l;

```

```

res=r;
Zf=complex(78.51,959.08);

z=complex(res,xl);

y=complex(r1,0);

zc=sqrt(z/y);
Y=sqrt(y*z);

L=0.0528;% 2*  $\frac{N}{l_q} \frac{\mu_o \mu_r}{8\pi}$  value
%the ABCD parameters hence are
A=cosh(Y*d);
B=sinh(Y*d);
%Z1=Z1-0.005;
%evaluate the value of Vreceiving end and Ireceiving end
Vr1=vs/((A+((zc*B)/Zs))+Z1*((B/zc)+(A/Zs)));
Ir1=vs/((Zs*A)+(zc*B)+Z1*((Zs*B /zc) +A));
e1=L*Ir1;
Vof=78.51*e1/ Zf;

Mf1=abs(Vof);

Pfde =angle(Vof);

Pf1= Pfde *180/3.14-90;

M1=abs(e1);

pde=angle(e1);

p1=pde*180/3.14-90;

e=[e e1];

p=[p p1];

M=[M M1];

D=[D d];

Vo=[Vo Vof];

Pf=[ Pf Pf1];

Mf=[ Mf Mf1];

Vr=[Vr Vr1];
Ir=[Ir Ir1];
end
Vr=[Vr]
Ir=[Ir]
E=[e]
Vo=[Vo ]

M=[M]

P=[p]

Mf=[ Mf]

Pf=[ Pf]

```

```

for i=0:1:10
if i==0
Pd1=0;
Md1=1;
Pfd1=0;
Mfd1=1;
else
Pd1=P(i+1)-P(i);
Md1=M(i)/M(i+1);
Pfd1=Pf(i+1)-Pf(i);
Mfd1=Mf(i)/Mf(i+1);
end
Pd=[Pd Pd1];
Md=[Md Md1];
Mfd=[Mfd Mfd1];
Pfd=[Pfd Pfd1];
end
Pd=[Pd]
Md=[Md]
Mfd=[Mfd]
Pfd=[Pfd]

```

H. TRansmission for different inductance value

```

clear;
clc;
Ir=[];
Vr=[];
Vo=[];
Pf=[];
Mfd=[];
Pfd=[];
Mf=[];
Md=[ ];
Pd=[ ];
e=[];
p=[];
M=[];
D=[];

```

```

vs=220;

d=1.2;

m=0.2;
Z1=0.5;
zr=complex(0.12,0.16);
ys=1.2;
Zs=(2*ys*zr+4)/(4*ys+zr*ys^2);
for l=0.2:0.01:0.3
r=0.15;
r1=m;
%evaluation of the parameters
xl=l;
res=r;
Zf=complex(78.51,959.08);

z=complex(res,xl);

y=complex(r1,0);

zc=sqrt(z/y);
Y=sqrt(y*z);

L=0.0528;% 2*  $\frac{N \mu_0 \mu_r}{l_q 8\pi}$  value
%the ABCD parameters hence are
A=cosh(Y*d);
B=sinh(Y*d);
%Z1=Z1-0.005;
%evaluate the value of Vreceiving end and Ireceiving end
Vr1=vs/((A+((zc*B)/Zs))+Z1*((B/zc)+(A/Zs)));
Ir1=vs/((Zs*A)+(zc*B)+Z1*((Zs*B/zc)+A));
e1=L*Ir1;
Vof=78.51*e1/Zf;

Mf1=abs(Vof);

Pfde=angle(Vof);

Pf1= Pfde *180/3.14-90;

M1=abs(e1);

pde=angle(e1);

p1=pde*180/3.14-90;

e=[e e1];

p=[p p1];

M=[M M1];

D=[D d];

Vo=[Vo Vof];

Pf=[ Pf Pf1];

Mf=[ Mf Mf1];

```

```

Vr=[Vr Vr1];
Ir=[Ir Ir1];
end
Vr=[Vr]
Ir=[Ir]
E=[e]
Vo=[Vo ]

M=[M]

P=[p]

Mf=[ Mf]

Pf=[ Pf]

for i=0:1:10
if i==0
Pd1=0;
Md1=1;
Pfd1=0;
Mfd1=1;
else
Pd1=P(i+1)-P(i);
Md1=M(i)/M(i+1);
Pfd1=Pf(i+1)-Pf(i);
Mfd1=Mf(i)/Mf(i+1);
end
Pd=[Pd Pd1];
Md=[Md Md1];
Mfd=[Mfd Mfd1];
Pfd=[Pfd Pfd1];
end
Pd=[Pd]
Md=[Md]
Mfd=[Mfd]
Pfd=[Pfd]

```

I Simulation for Induced and Filter output voltage

```

clear;
clc;
Ir=[];

Vr=[];

Vo=[];

Pf=[];

```

```

Mfd=[];

Pfd=[];

Mf=[];

Md=[ ];

Pd=[ ];

e=[];

p=[];

M=[];

D=[];

vs=220;

d=1;

m=0.2;
Z1=0.5;
zr=complex(0.12,0.16);
ys=1.2;
Zs=(2*ys*zr+4)/(4*ys+zr*ys^2);
for d=0:0.1:1.2
l=0.2;
r=0.15;
r1=m;
%evaluation of the parameters
xl=l;
res=r;
Zf=complex(78.51,959.08);

z=complex(res,xl);

y=complex(r1,0);

zc=sqrt(z/y);
Y=sqrt(y*z);

L=0.0528;% 2*  $\frac{N \mu_o \mu_r}{l_q 8\pi}$  value

%the ABCD parameters hence are
A=cosh(Y*d);
B=sinh(Y*d);
%Z1=Z1-0.005;
%evaluate the value of Vreceiving end and Ireceiving end
Vr1=vs/((A+((zc*B)/Zs))+Z1*((B/zc)+(A/Zs)));
Ir1=vs/((Zs*A)+(zc*B)+Z1*((Zs*B/zc)+A));
e1=L*Ir1;
Vof=78.51*e1/Zf;

Mf1=abs(Vof);

Pfde =angle(Vof);

Pf1= Pfde *180/3.14-90;

M1=abs(e1);

```

```

pde=angle(e1);
p1=pde*180/3.14-90;
e=[e e1];
p=[p p1];
M=[M M1];
D=[D d];
Vo=[Vo Vof];
Pf=[ Pf Pf1];
Mf=[ Mf Mf1];
Vr=[Vr Vr1];
Ir=[Ir Ir1];
end
Vr=[Vr];
Ir=[Ir];
E=[e];
Vo=[Vo ];
M=[M];
P=[p];
Mf=[ Mf];
Pf=[ Pf];
dp=0:0.1:length(d);
figure(1);
plot(dp,M,'LineWidth',3.5);grid on;
axis([ 0 1 6 10]);
ylabel('Magnitude(volts)');
xlabel('distance(km)');
title('amplitude of induced voltage');
figure(2);
plot(dp,P,'LineWidth',3.5);grid on;
axis([ 0 1 -90 -100]);
ylabel('angle(degree)');
xlabel(' distance(km)');
title('Phase angle of induced output voltage');

```

```

figure(3);
plot(dp,P,'LineWidth',3.5);grid on;
axis([ 0 1 -80 -100]);
ylabel('angle(degree)');
xlabel(' distance(km)');
title('Phase angle of induced output voltage');
figure(4);
plot(dp,Mf,'LineWidth',3.5);grid on;
axis([ 0 1 0.5 0.8]);
ylabel('amplitude(volts)');
xlabel(' distance(km)');
title('filter output voltage amplitude');
for i=0:1:1000
if i==0
Pd1=0;
Md1=1;
Pfd1=0;
Mfd1=1;
else
Pd1=P(i+1)-P(i);
Md1=M(i)/M(i+1);
Pfd1=Pf(i+1)-Pf(i);
Mfd1=Mf(i)/Mf(i+1);
end
Pd=[Pd Pd1];
Md=[Md Md1];
Mfd=[Mfd Mfd1];
Pfd=[Pfd Pfd1];
end
Pd=[Pd];
Md=[Md];
Mfd=[Mfd];
Pfd=[Pfd];
figure(5);
plot(dp,pd,'LineWidth',3.5);grid on;

```

```

axis([ 0 1 -1 -1]);
ylabel('angle(degree)');
xlabel(' distance(km)');
title('Phase shift angle deviation of Filter' output voltage');
figure(6);
plot(dp,Pfd,'LineWidth',3.5);grid on;
axis([ 0 1 -1 -1]);
ylabel('angle(degree)');
xlabel(' distance(km)');
title('Phase shift angle deviation of Filter' output voltage');
figure(7);
plot(dp,Md,'LineWidth',3.5);grid on;
axis([ 0 1 1.017 1.0195]);
ylabel('angle(degree)');
xlabel(' distance(km)');
title('Phase shift angle deviation of Filter' output voltage');
figure(8);
plot(dp,Mfd,'LineWidth',3.5);grid on;
axis([ 0 1 1.0.17 1.0195]);
ylabel('angle(degree)');
xlabel(' distance(km)');
title('Phase shift angle deviation of Filter' output voltage');

```

I. receiver voltage Plot for ballast resistor of 4ohm over 1.2km distance

```

clear;
clc;
Ir=[];
Vr=[];
Vo=[];
Pf=[];
Mfd=[];

```

```

Pfd=[];

Mf=[];

Md=[ ];

Pd=[];

e=[];

p=[];

M=[];

D=[];

vs=220;

m=4;
Z1=0.5;
zr=complex(0.12,0.16);
ys=4.24;
Zs =(2*ys*zr+4)/(4*ys+zr*ys^2);
for d=0:0.1:1.2
l=0.2;
r=0.15;
r1=m;
%evaluation of the parameters
xl=l;
res=r;
Zr=complex(78.51,959.08);

z=complex(res,xl);

y=complex(r1,0);

zc=sqrt(z/y);
Y=sqrt(y*z);
L=0.0528;%  $2 * \frac{N \mu_0 \mu_r}{l_q 8\pi}$  value
%the ABCD parameters hence are
A=cosh(Y*d);
B=sinh(Y*d);
%Z1=Z1-0.005;
%evaluate the value of Vreceiving end and Ireceiving end
Vr1=vs/((A+((zc*B)/Zs))+Z1*((B/zc)+(A/Zs)));
Ir1=vs/((Zs*A)+(zc*B)+Z1*((Zs*B /zc) +A));
e1=L*Ir1;
Vof=78.51*e1/ Zr;

Mf1=abs(Vof);

Pfde =angle(Vof);

Pf1= Pfde *180/3.14-90;

M1=abs(e1);

pde=angle(e1);

p1=pde*180/3.14-90;

```

```

e=[e e1];
p=[p p1];
M=[M M1];
D=[D d];
Vo=[Vo Vof];
Pf=[ Pf Pf1];
Mf=[ Mf Mf1];

Vr=[Vr Vr1];
Ir=[Ir Ir1];
end
Vr=[Vr];
Ir=[Ir];
E=[e];
Vo=[Vo ];

M=[M];

P=[p]

Mf=[ Mf]

Pf=[ Pf];

dp=0:0.1:1.2;

%figure(1);

%plot(dp,M, 'LineWidth',3.5);grid on;

%axis([ 0 1.2 1 16]);

%ylabel('Magnitude(volts) ');

%xlabel('distance(km) ');

%title('amplitude of induced voltage');

%figure(2);

%plot(dp,P, 'LineWidth',3.5);grid on;

%axis([ 0 1.2 -90 -100]);

%ylabel('angle(degree)');

%xlabel('distance(km)');

%title('Phase angle of induced output voltage');

%figure(3);

%plot(dp,Pf, 'LineWidth',3.5);grid on;

```

```

%axis([ 0 1.2 -80 -200]);
%ylabel('angle(degree)');
%xlabel('distance(km)');
%title('Phase angle of induced output voltage');
%figure(4);
%plot(dp,Mf,'LineWidth',3.5);grid on;

%axis([ 0 1 0.4 1.3]);
%ylabel('amplitude(volts)');
%xlabel('distance(km)');
%title('filter output voltage amplitude');

for i=0:1:12
if i==0
Pd1=0;
Md1=1;
Pfd1=0;
Mfd1=1;
else
Pd1=P(i+1)-P(i);
Md1=M(i)/M(i+1);
Pfd1=Pf(i+1)-Pf(i);
Mfd1=Mf(i)/Mf(i+1);
end

Pd=[Pd Pd1];
Md=[Md Md1];
Mfd=[Mfd Mfd1];
Pfd=[Pfd Pfd1];
end
Pd=[Pd];
Md=[Md];
Mfd=[Mfd];
Pfd=[Pfd];
%figure(5);

%plot(dp,Pd,'LineWidth',3.5);grid on;

%axis([ 0 1.2 0 -5]);

```

```

%ylabel('angle(degree)');
%xlabel('distance(km)');
%title('Phase shift angle deviation of Filter' output voltage');
%hold on
%figure(6);
%plot(dp,Pfd,'LineWidth',3.5);grid on;
%axis([ 0 1.2 -1 -1]);
%ylabel('angle(degree)');
%xlabel(' distance(km)');
%title('Phase shift angle deviation of Filter' output voltage');
%hold on
%figure(7);
%plot(dp,Md,'LineWidth',3.5);grid on;
%axis([ 0 1.2 1 1.2]);
%ylabel('Magnitude(volts)');
%xlabel(' distance(km)');
%title('amplitude deviation of induced voltage');
figure(8);
plot(dp,Mfd,'LineWidth',3.5);grid on;
axis([ 0 1.2 1 1.12]);
ylabel('Magnitude(volts)');
xlabel('distance(km)');
title('amplitude deviation of Filter' output voltage');

```

J.Bandpass filter gain for different quality factor

```

a = [1 12.5 625];
b = [25 0];
w1 = logspace(1.097,1.69, 26); w2 = logspace(1.097, 1.69, 200);
h1 = freqs(b, a, w1); h2 = freqs(b, a, w2);
mag1 = abs(h1); mag2 = abs(h2);

```

```

db1 = 20*log10(mag1); db2 = 20*log10(mag2);
semilogx(w2, db2, w1, db1, '+');
title ('Simple Bandpass Filter');
xlabel ('Frequency in Hz');
ylabel ('Gain in dB');
grid on;
a = [1 25 625];
b = [25 0];
w1 = logspace(1.097,1.69, 26); w2 = logspace(1.097, 1.69, 200);
h1 = freqs(b, a, w1); h2 = freqs(b, a, w2);
mag1 = abs(h1); mag2 = abs(h2);
db1 = 20*log10(mag1); db2 = 20*log10(mag2);
semilogx(w2, db2, w1, db1, '+');
title ('Simple Bandpass Filter');
xlabel ('Frequency in Hz');
ylabel ('Gain in dB');
grid on;
a = [1 8.33 625];
b = [25 0];
w1 = logspace(1.097,1.69, 26); w2 = logspace(1.097, 1.69, 200);
h1 = freqs(b, a, w1); h2 = freqs(b, a, w2);
mag1 = abs(h1); mag2 = abs(h2);
db1 = 20*log10(mag1); db2 = 20*log10(mag2);
semilogx(w2, db2, w1, db1, '+');
title ('Simple Bandpass Filter');
xlabel ('Frequency in Hz');
ylabel ('Gain in dB');
grid on;

```


Abstract

Railway signaling is the baseline safety system controlling the movements of trains. It is the safety critical part of the train control function of the railway. Railway line safety methods are going to be implemented for Meiso-Dewanle new project as it's specified in the preliminary design document. The safety methods of the project contain of Track-circuit block system, computer interlocking system and lightning protection system. This all methods concentrate on controlling Wayside signals, Switches and power line protection system for safe train transport by controlling and signaling equipments situated at fields. For safe transit at the end of each blocks the driver expected to see the color of Wayside signals from some KM distance before the signal .But Field signals have limitations for sight hindering natural or artificial circumstances. Cab signal system provides block occupancy necessary information immediately for the driver and guides him to function the train with a full knowhow of the dynamic line situations ahead of him. Cab signaling also solves the "short circuit adjacent line" problem, other than a train's axle, for the reason Track circuit is communicating "Red" Wayside signal. Only stopping the train before the block can be adjusted to enter the block with minimum speed using transponder aided cab signal to avoid unnecessary time delay and, in turn, this maximizes line traffic flow efficiency. For different grade points, level crossings and for unexpectedly occurring line barriers cab signal works as the close informant of the driver. Speed controlling is the very mechanism of avoiding danger and by giving line status data's timely, Cab signal helps the train operator to derive safely.

Design of Cab signaling for Meiso-Dewanle considered partly due to: to exploit the wide application of cab signaling for its safety protection mechanism for Semi-Automatic block system, and, for future cases, when the line becomes fully automatic it substitutes the function of Wayside signals totally. And, in addition, its physical location closeness to the train operator also the other reason for implementing Cab signaling.

The signal display time, for safe operation, at the Cab will be analyzed and modeled using speed versus braking distance non-linear optimization problem solving Technique for different line conditions described above. Exact calculation of (braking + safety distance) for controlling speed will be solved and simulated using Matlab simulation. Finally, Cab signaling indication time-interval, communicating devices and means of communication with the Cab, design will be implemented according to the model.

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List of Abbreviation

ATP =Automatic Train Protection

CCECC= China Civil Engineering Construction Corporation

CREEC= China Railway Eryuan Engineering Group Corporation

Hr =Hour

KM =Kilo Meter

MIT= Massachusetts Institutes of Technology

1. Introduction

Railway transportation system had been used as a major freight and passenger transport to the eastern part of Ethiopia from 1917 to 2010. The system comes to existence during the reign of Emperor Menelik II and covers a total of 781km powered by diesel engine and jointly owned by Ethiopia and Djibouti.

The mobility need of the country population and the development of transportation system are far from compatibility. Therefore; the country is in need of modern, Safer, economic, time saving and long lasting transportation which will ease import-export system and result fast development of the country's economy. To this end, the government of Ethiopia has embarked on railway system. The route of Ethiopia - Djibouti line is subdivided for better project accomplishment and it includes the MIESO-DAWANL section as one part.

[1]Survey and Design Commission Contract for MIESO-DAWANLE Section of New Ethiopia Railway signed by and between Kunming Investigation, Design and Research Institute Co., Ltd. of CREEC and CCECC MIESO-DAWANL Railway Project Management Department on June 20, 2012. Study scope encompasses MIESO (excluded) - DIRE DAWA (included), with a total length of 134.322 km. The route is led from the west side of MIESO town, stretches northeastward, passes through MULU, DELADU, AFUDEM and ADELE and arrives at BIKE. After leaving the BIKE station, the route turns to the southeast to pass GOTA, then turns to the east to pass ERER, MEGALA and HURSO and ends at MELKA town, on the north side of which the DIRE DAWA station is located.

The purpose of this thesis is to design safety cab signaling system from MIESO-DAWANLE to make the route safer so that unnecessary time delay can be reduced and optimum traffic flow will be achieved.

2. Background

[2] Railway signaling is a system used to safely direct railway traffic in order to prevent trains from colliding. Trains move on fixed rails so they are uniquely susceptible to collision; the weight of trains and momentum makes it difficult to stop before reaching the impending obstacle. According to train's safety methods implementation is carried out in railway lines. The simplest form of safety operation is to run the system with respect to a timetable and to divide railway lines into sections known as blocks so that only one train is permitted in each block at a time. The other method is to implement signaling equipments or circuits that give visual indications for the driver. Track circuit operating Wayside signals function on this basis. An alternative method uses axle counters for determining the occupied status of a block located at its beginning and end that count the number of axles entering and leaving. Train position identifying method install Transponder b/n rails as another safety measures. Computer based interlocking system commands switches to lock to the specified route so that level transit and safety at turnouts will be guaranteed.

Cab signaling system communicates track status information to the train cab (driving position), where the train driver can see the information. The simplest systems display the trackside signal aspect, while more sophisticated systems also display allowable speed and dynamic information about the track ahead. In modern systems, a train protection system is usually overlaid on top of the cab signaling system to warn the driver of dangerous conditions, and to automatically apply the brakes and bring the train to a stop if the driver ignores the dangerous condition. Cab signaling systems range from simple coded track circuits, to transponders that communicate with the cab, and Communication-Based Train Control Systems.

ATP [3] signaling codes contained in the track circuits are transmitted to the train by transponder installed between the rails. They are detected by pick-up antennae (usually two) mounted on the leading end of the train under the driving cab. This data is passed to an on-board decoding and safety processor. The permitted speed is checked against the actual speed and, if the permitted speed is exceeded, a brake application is initiated. In the more modern systems, distance-to-go data will be transmitted to the train as well. The data is also sent to a display in the cab which allows the driver of a manually driven train to respond and drive the train within the permitted speed range.

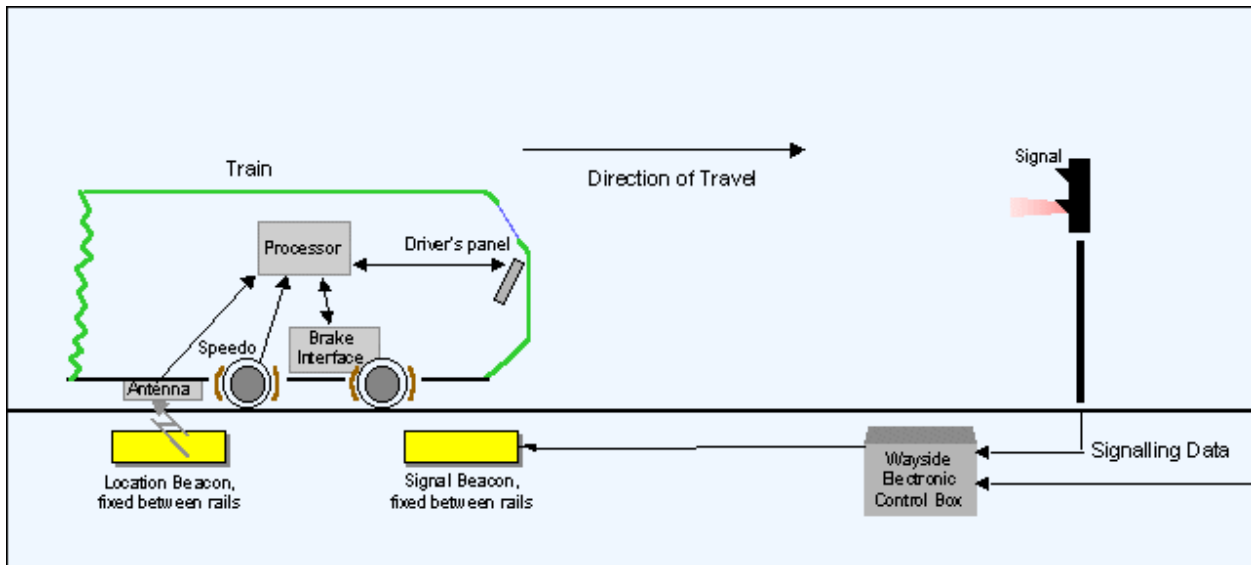


Fig 1 signaling diagram for signal flow from wayside signal to cab display through balises

[4] Signals under the heading of Cab Signal are of several forms. These are traditional color light forms in miniature. There are position light and numerical forms as well. Digital forms with numbers and sometimes letter and graphic forms are increasingly commonplace. Such focus on speed limit messages. All of these forms are located on-board the train and receive impulses from track circuits and other means including transponders. Frequently various aspects of train control are added to cab signals (or cab signals become part of train control). A sound dimension is also a common feature of Cab Signals.

On this very end ERC is under construction of MIESO-DAWANLE 134.32Km railway line in eastern part of the country. But, the signal system of Mieso-Dire Dawa Railway includes

[5] block system, computer interlocking system and integrated lightning protection system. And I thought the design is not efficient in considering other types of safety signals (cab signal). Due to this I am interested to work my thesis on cab signals which receive data from transponders that assure more safety for the line. And I try to encompass:

I. Level/Grade Crossing Sound Signals.

II. Barriers & Warning Signals.

III Turnout signals.

IV. Line short circuit signals: due to water or metal bar.

3. Statement of the problem

[6] Practical experience proved that there had to be some way of preventing trains running into each other. It's so difficult stopping a train within the driver's sighting distance. The least train interval is braking distance plus safety distance this is due to: Inexperience, bad brakes and the low adhesion levels which exists on the railway between steel wheel and steel rail for traction and braking - this will induce a problem which effects stopping a train within braking distances impossible. An Intercity train travelling at 100 mph (160 km/hr) will take more than a mile to stop. Even for a signaling system with enforcement (ATP) like the London Underground, there is a risk that a train could pass stop signal, then be stopped by the ATP enforcement system and still hit the train in front.

[7] Proper automatic target braking is possible only when both static and dynamic speed Profile is calculated. This requires the transmission of movement authorities, which Define braking targets by distance and speed. [8] To achieve higher safety, location dependent stop warning was introduced to warn the driver that the train is approaching a signal which shows Stop aspect. But for the conditions like "adjacent rails' short circuit "- due to water or metal bar, other than a train's axle, makes Track circuit to communicate "Red" wayside signal for a train not to enter the block section ahead and this will result unnecessary time delay which has a negative impact on a time-table schedule. A train approaching a tunnel, a bridge, Grade points or turnouts needs a wayside warning signal unless otherwise accidental consequence may be severe. But in cases when this wayside signal is not in a clear sight for the driver for different reasons like, Fog or Dwarf signal height..., the replication of the warning signal at the cab will add another safety assurance for the trains.

4. Literature review

[9]A master's study on "Preview information for locomotive in cab displays for high speed trains" by Jacob Einhorn, focuses was to examine whether the proposed information aiding cab display improved safety and efficiency of train operation over an existing display, and, if so, to show how much of the provided preview information was useful. The researcher used MIT/VOIP simulator for acquisition of data into log file- the time and location of any change in signal or failure scenario is automatically recorded, along with the train's location at the time of the change. Thus for each trip the simulator provides a log file that can be used to analyze the dependent variables of interest-namely, speed limit, reaction time and distance, station stopping accuracy and schedule deviation. MIT and Volpe National Transportation center engineers were involved in the research for data acquisition. And Analyzing was based on comparison between the dependent and independent variables.

5. Research Questions

5.1 General research questions

- What are the different safety methods included in the Preliminary ERC Meiso-Dewanle project and their limitation on safety?
- Is there any clarified plan for implementing cab signaling in the Preliminary ERC Meiso- Dewanle project?
- What conditions make Cab signaling safety protection needed for the line?
- What methods and technique will be used for modeling and simulation of Cab signaling?
- What devices and communication means used to communicate with the Cab receiver?

5.2 Specific research questions

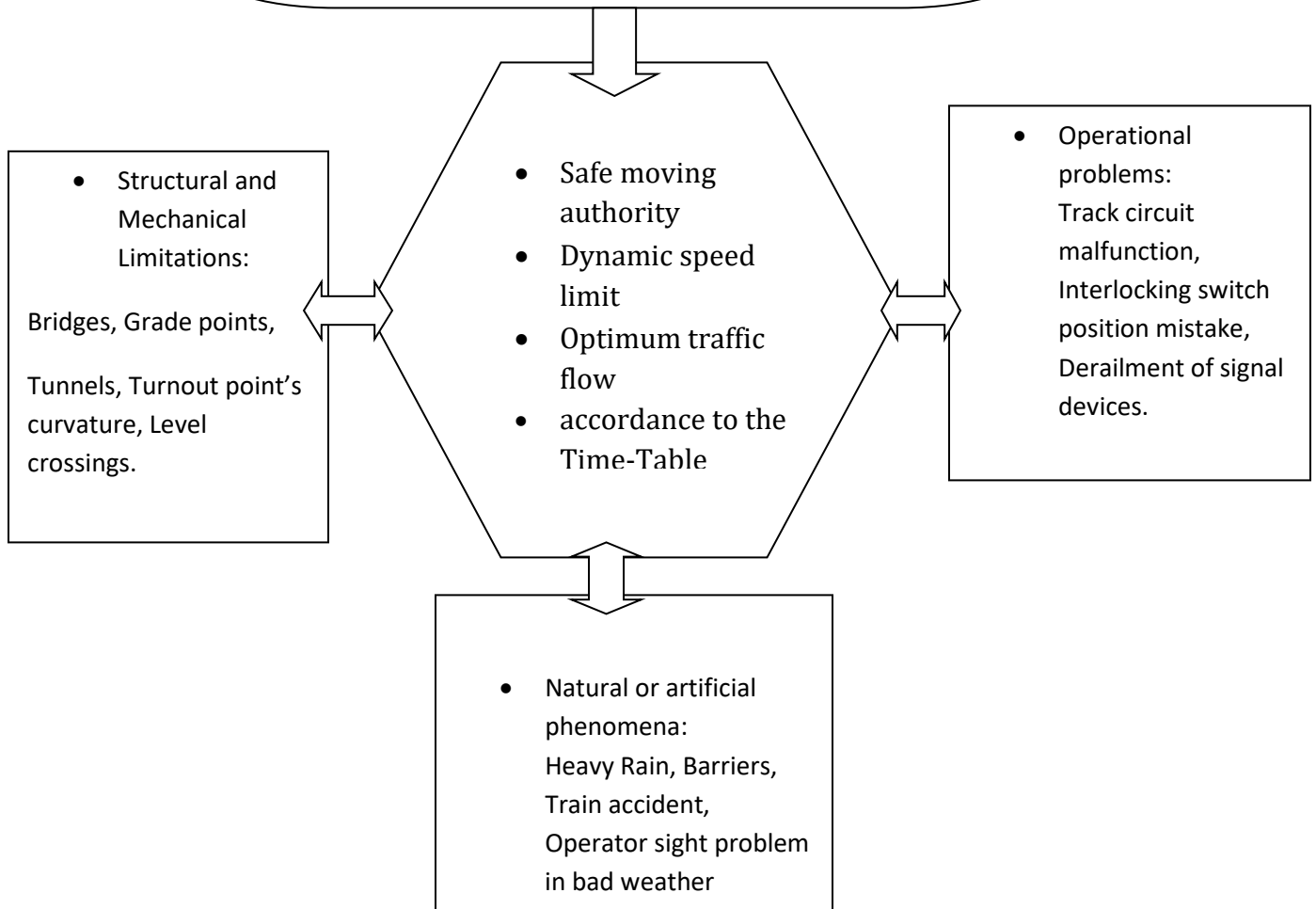
- Does cab signaling used to replicate the Wayside signal aspect?
- Can Cab signaling safety method used as indicator for turnout points, level crossings and line barrier intervention?
- How can Cab signaling help the train's operator for speed controlling?
- How can Cab signaling solve unwanted short circuit problems?
- Does Cab signaling promote in solving delay time and traffic flow problems?
- Does Cab signaling consider different grade points for modeling?
- Why transponders used as data transmitter for the on-board receiver device?

7. Conceptual Framework

Railway transport becomes a major transportation system because of for its strict speed controlling mechanism that can assure safety. This is prominently due to a simple problem in the system consequences a series disastrous accident on the passengers and a huge amount of material damage. Railway safety method attributes different types and locomotive Cab signaling safety assurance takes an evitable place. Cab signaling provides track status information to attain a certain outcomes that can be ascertained as safety values .This outcomes cab be described as questions: What is the safe moving authority? What is the dynamic speed limit? How optimum traffic flow will be achieved? And how it avoids unnecessary time delay ? There are cluster of variables that influence these outcomes are Structural and Mechanical Limitations, Operational problems, and Natural or artificial phenomena.

The significance of this thesis is to have a well designed safety locomotive cab signal model which informs relevant line information for the driver timely so that the driver can easily make accurate speed controlling mechanisms for safe-operation of the train. The Model will also avoid unnecessary time delay resulted due to unclear site Wayside signals, and non-operational adjacent line short circuit problems. Helping the driver to work in a strong accordance with the time-table, in addition, Optimum traffic flow on the line can be easily achieved.

Locomotive cab signaling for safe Train Transit



7. Objective

7.1 General Objective

The general objective of this Thesis is to design best cab signal Model for train's safety, and to maximize line's traffic as well as to reduce unnecessary time delay by avoiding possible conditions that lead to an accident.

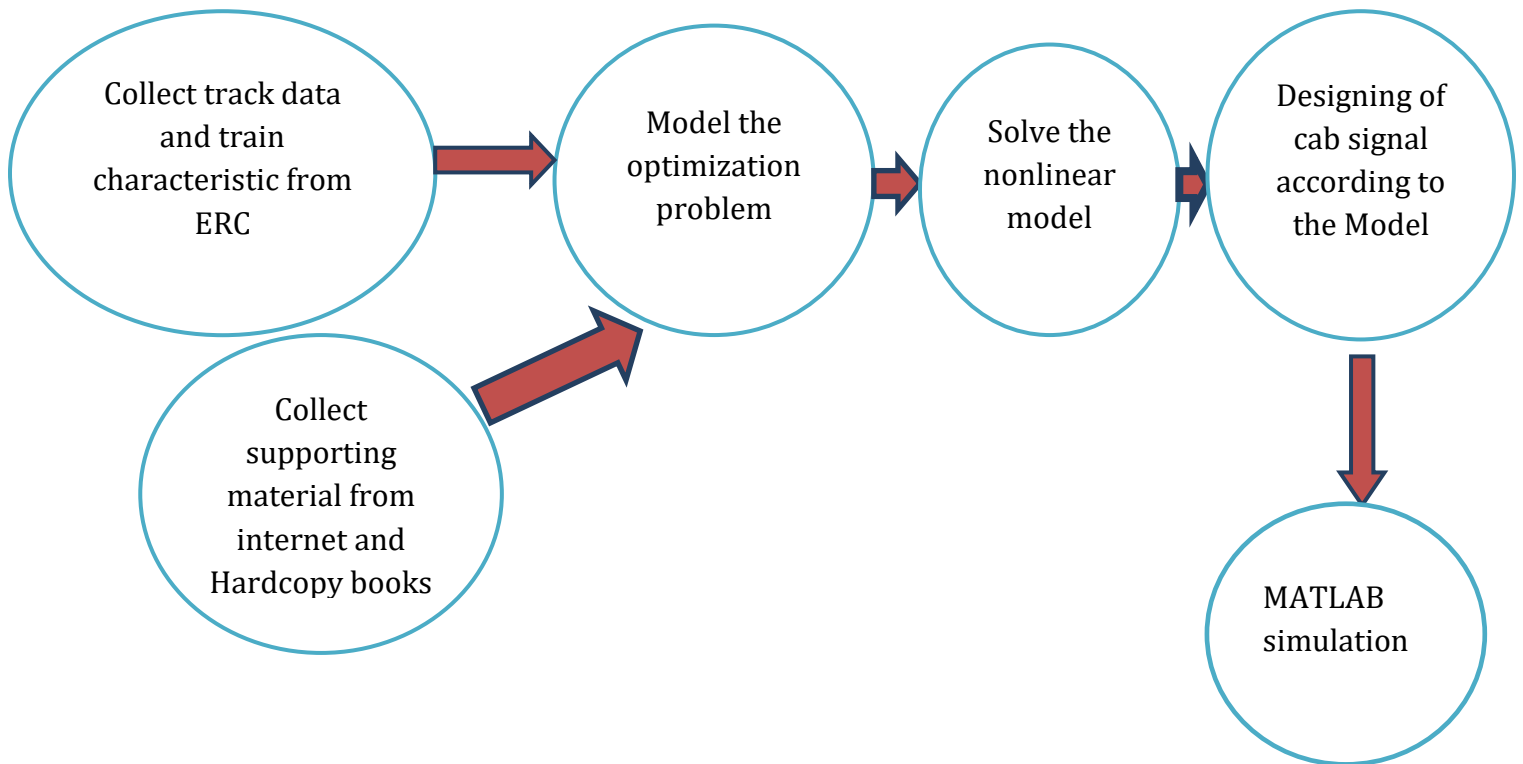
7.2 Specific Objective

The specific objective of this thesis is to Design appropriate Cab signaling indications for the driver for the following railway line conditions:

- Level/Grade Crossing.
- Wayside, Barriers and Warning signals
- Turnout points.
- Line short circuit -due to water or metal bar other than a train's axle.

8. Methodology

- ✚ Collecting track characteristic, Preliminary Design document, supporting materials (books, thesis, and journals).
- ✚ Reviewing the collected document
- ✚ Based on the analyzed information Mathematical Model will be developed and Design of cab signal which optimizes track efficiency will be made.
- ✚ Optimization problem will be solved by appropriate nonlinear constrained optimization problem solving technique. Mostly nonlinear constrained optimization problem is complex, computer aided program will be applied.
- ✚ The model will be simulated by MATLAB and the simulation result will be analyzed.
- ✚ The final part of the work is discussion of the whole result obtained and recommendation for future work.



9. Scope of the study

This Thesis only looks for implementing safety aids using cab signal from Meiso-Dewanle line. It tries to model systems for line conditions:

- Level/Grade Crossing
- Wayside Signal, Barriers and Warning signals
- Turnout points/Switch points
- Line short circuit.

System modeling using speed limit v braking distance relationship will be analyzed to find the minimum cab signal display time for the above specified conditions. Because different Grades can be available, consideration of each section may be taken, or maximum grade point is going to be used for modeling for general case, if grade values difference is not significant.

11. Thesis Budget

Item	Quantity	Unity	Price/unity	Total price
Paper	6	Package	130	780
CD-RW	18	Each	20	360
Flash Disk (16 GB)	1	Each	400	400
Photo copy and printing for supporting material	7000	Page	0.75	5250
Software	-	-	-	2000
Internet cost	-	-	-	3000
Transportation Cost During Data Collection and Site visit to Meiso and Dewanle	-	-	-	10000
Printing Thesis	7	Each	110	600
Thesis Binding	7	Each	20	100
Sub Total				22490
Contingency (10%)				2249
Final total				24739

Reference

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Graduate Committee

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Date