A Study on Urban Maglev Railway Signaling System Optimization

H.S. YUN1, J.S MOOM2, I.J. LEE3, E.S. KWAK4
1KRNA, Daejeon, Korea; 2KRNA, Daejeon, Korea; 3KRNA, Daejeon, Korea; 4KRNA, Daejeon, Korea

Abstract

It is impossible to detect train by using the most fundamental and essential track circuit for detecting train and install devices such as tachometer since magnetic levitation train runs by being levitated and propelled on track (guide way) different from train using conventional wheels. Accordingly, it is necessary to study separate facility to embody signaling system which enables train to be operated safely by detecting the location and measure the speed of train and develop equipment to transmit and receive information with instead of using conventional track and wire cable. Hence, this thesis suggests the plan for optimization of signaling system of magnetic levitation train to realize safe train operation by carrying out safe transmission and receipt of information between wayside and on-board, detecting the absolute location of train using Tag and DGPS and measuring speed and distance using Doppler sensor.

Introduction

Signaling system is an integrated system, which integrates technologies of computer, communication and control, etc. and is interfaced with the fields of civil engineering, track, architecture and electric power. And it is the system to ensure rapidness, correctness and safety of train operation by interconnecting the technologies of system engineering, element and reliability systematically. Especially, it is urgent to develop system engineering for signaling system and key element technology of magnetic levitation train not only because the signaling system of magnetic levitation train has big difference in its driverless automatic operation system, wireless communication system between train and wayside and detecting method of train but also the research for magnetic levitation train has been progressed putting priority on the development of rolling stock. Currently, large corporations take part in the domestic signal business through the collaboration with overseas signal companies rather than development of key technology due to the insufficiency of economic feasibility, and small and medium industries are under difficult situations in development of signaling system due to the lack of manpower and fund to invest in technology development. Commercialization of urban magnetic levitation train, which has advantage and excellence such as provision of various services and reduction of construction cost, has started under the leadership of the government according to the rising of expectation of the nation. Signaling system is divided into on-board and wayside, automatic train stop equipment currently being used in manual operation is the main result of development in on-board, and the wayside has switching equipment, track circuit equipment and centralized train control system etc. in part of the development result, however, researches for the development of optimal system through systematic analysis and buildup of technologies necessary for constructing the system for driverless operation are in progress under the initiatives of the government, research institutes and private enterprises. Research on moving block method and method of transmitting and receiving information between the wayside and train for high density operation are currently in the state of entering development and test. Particularly, the level of technology for signaling system lacks experience in designing, manufacturing and installing since there is no magnetic levitation train designed, manufactured, installed and operated. However, it is very important to construct signaling system of magnetic levitation train and to accomplish independence in technology by successfully achieving integrated engineering where technologies are systematically combined through joint technology development by industry, academic fields and research institutes for signaling system of magnetic levitation train of which demand is expected to be bigger in the future. Hence, in order to develop technology for signaling system to satisfy safety, reliability and effectiveness necessary for signaling system of magnetic levitation train, this thesis discusses trend of technology and method of configuration to apply in signaling system of magnetic levitation train by putting the status of research and development in the center for CBTC system which is currently in progress in the country for technology development of control equipment for integrated operation of signaling system, technology development of automatic train control equipment, of communication
equipment and technology development for testing and evaluation of signaling system of magnetic levitation train which are major technologies.

Main discourse

Automation in control of train in addition to high-speed operation of train has been required and progressed rapidly in the recent railway industry. Accordingly, research on train control system using radio has been progressed since long before, and it is currently actual situation that development of various systems is required.

Wireless communication means to transmit and receive data through electromagnetic wave of radio frequency without using cable to be connected.

Safety of system is given by communication protocol, and use of wireless system may affect availability of signaling system that can be called barometer of safety, so development of wireless system is quite limited due to combination of safety and availability and problem of fail-safe communication in wireless environment.

Research and development and testing of radio based train control system is actively in progress in the country, and it is developed currently up to the step of test line operation based on the excellent and abundant domestic technology of communication infrastructure.

Researches relating to CBTC in progress in the form of research and development in the country are Technology development of intelligent train control system led by Korea Railroad Corporation and its application to heavy electric railway under review, Technology development of Korean model of light electric railway led by Korea Railroad Research Institute and technology development of train control system as a part of development project of commercialized model of rolling stock of magnetic levitation train carried out by Private Company, and the characteristics of these technology developments are not so different in the fundamental principle and method of application due to development of communication based train control system.

CBTC system is defined as the system using continuous bi-directional data link of wayside and onboard equipment. Data link is the system to decide the location of train and control the location speed and direction without conventional physical track circuit by using pattern belt, leakage coaxial cable, inductive loop or radio frequency, and etc.

It is found possible in this thesis to suggest system configuration method applicable to the model line of commercialization project of urban magnetic levitation train through analysis of research project to be progressed in the future by analyzing characteristics, merits and demerits of CBTC currently under development in the country.

Technology to control operation of train should be considered as different concept from the conventional train due to the characteristics that the magnetic levitation train runs levitating on the rail (guide way) without wheel quite different from the conventional train using wheel, and such point of view has been fully considered also in the country in research and development of signaling system. Communication based train control system has various kinds of merits in the aspects of construction of signaling facility or maintenance and repair in the fact that it is possible to embody train location detection on the ground without using track circuits. In this research, examples of wireless communication system for CBTC in and out of the country and applicable standards were investigated, and radio frequency and construction method of wireless network to be considered for application of train control system using radio in the country were reviewed.

<table>
<thead>
<tr>
<th>New York</th>
<th>San Francisco</th>
<th>Other North America</th>
<th>UK</th>
<th>Europe</th>
<th>Asia</th>
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<td>Docklands</td>
<td>Paris Line 14</td>
<td>Kuala Lumpur</td>
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<td>Muni</td>
<td>Vancouver</td>
<td>Jubilee</td>
<td>Paris Line 13</td>
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<td></td>
<td>Morgantown</td>
<td></td>
<td>Gyeongsan (Korea)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Examples of CBTC system constructed in and out of the country
Half duplex system is the mainstream if we see major radio and network system manufacture of the work and major specification. Full duplex system in general is the communication system used for the purpose of mobile commutation service, where commercial frequency can be operated by common carrier, point to point, or relay between station and station. And, link configuration of transmission and receipt is clearer than half duplex system since transmission and receipt is performed at the same time, however, it is more efficient to adopt half duplex system in case of wireless communication system for CBTC if synthetically considering economic feasibility and frequency environment etc. considering capacity of transmission data.

Selection of radio frequency
Use of radio communication may be promoted or restricted considerably by internationally agreed protocol and according to the laws and regulations for radio wave distributed corresponding to the actual circumstances of each country because limited resource called frequency of radio communication should be distributed and used efficiently. Accordingly, decision of frequency band to be applied to radio communication in reviewing required specification for wireless based train control system is the priority to progress, and consideration for domestic laws and regulation radio wave, frequency environment and direction of future policy in the frequency band is very important for it.

Radio frequency for CBTC
Radio frequency band of ISM band of 2.4GHz is used for CBTC. Frequency of 900MHz band is used in the part of system; however, various restrictive conditions exist in allotment of frequency resource since mobile communication provider uses this frequency band. ISM band is the band allotted to industry, science and medical purpose, and Range of use has the trend of spreading to the overall daily life such as for transmission of voice, image and data within the small zone and remote control of equipment etc., since extremely low power radio station emitting radio wave of lower power is not required to receive permission according to the use of radio wave due to the recent trend of increasing demand of various kinds of radio station because of the rapid development of radio communication technology. Particularly, overflowing of corresponding frequency in 2.4GHz band is worried about in proportion to the excellence of application technology, consolidation of laws and system, and explosive growth etc. However, even the large common carrier progresses service business of commercial purpose and problems of conflicting area occurred partially is properly avoided and solved through mutual adjustment because it has excellent technical performance and flexibility in spite of such problem. And, even in the extreme situation that collision is inevitable, the probability of occurrence of serious problems is very low since higher band already allotted can be utilized.

It should be based on the 2.4GHz ISM band to be used in wireless system for communication based train control in principle and coordinated with the existing radio frequency band used in image transmission and real time broadcasting service, however, it is necessary to take a step of process for deciding the use for identification of moving subject considering stable system configuration afterwards while complying with domestic regulations of radio wave and at the same time to take a step of applying for opening radio station. That is, it is expected to satisfy all requirement corresponding to domestic radio wave regulations and standard of equipment specification through discussion with related authorities since train control by radio is a very important field in the aspect of its public nature, and complementary plan should be studied in the future in preparation for the case of intentional emission of strong jamming wave.

Eventually, problem may not occur naturally in operation of the system using 2.4GHz ISM band, however, artificial and malicious external attempt should be blocked in advance if possible or it should be deliberately considered to work out measures so that, if inevitable, immediate identification of situation and action can be taken.

Construction of train control network
Whole train control network configuration is largely divided into control facility and interconnecting equipment of station, signaling facility, wayside access point and on-board radio facility, transmission method between wayside access point and on-board radio facility is based on the standard of IEEE 802.11b, and link between wayside access point is connected through optical cable network and transmits information between on-board facility and central control facility.
It should be reviewed whether interconnection of APs between station and station should be done with radio or cable between as shown on Fig.1. It is desirable to connect AP and AP between stations through cable backbone network as shown on Fig.1. Construction with wireless is to apply technology of grasping location of train by measuring the time of arrival according to the distance in communication between radio equipment of front and rear ends of train and railway track side equipment.[1]

Half duplex system of spread spectrum method is used mainly in the section of wireless link in the main specification of wireless communication system. We can see the trend that holistic approach is progressed with half duplex backbone of spread spectrum method.

CBTC has the following merits as the system of controlling train by using wireless communication instead of conventional track circuits.

- Detecting instruments such as track circuits are not necessary since location detection of train in CBTC is automatically carried out on the train. Tag is used on the wayside for this purpose.
- High frequency radio communication is used in transmission and receipt between wayside and train, and high speed and large quantity of information is possible as the system that information of location detecting sensor mounted on the train and speed are transmitted to the wayside, and the running permission location is transmit to the train from the wayside.
- It is possible to embody train control function in the on-board system to prevent excess of speed and overrun by calculating braking curve enabling to stop within the permitted location together with brake performance, track inclination and speed. [2]

**CBTC communication configuration**

Communication system among constituents of CBTC is designated the mixed communication infrastructure to perform smooth radio communication between train running along the track and wayside as shown in Fig.2 and smooth cable communication between automated train supervision system (ATS) and zone controller. Especially, radio system between them includes wireless link between fixed station on the wayside and mobile station on the train and interface part of wireless link and each network, and functions as key network for train control.

CBTC system detects train location through on-board equipment without connection with track circuit. It transmits location information of train and other train status information to the wayside controller through wireless data link between train and wayside. It decide the limit of operation of each train equipped with CBTC based on location information and the matters inputted from interlocking equipment on the wayside. It transmits operation information and other train control data to the corresponding train through radio link between train and wayside.
Requirement of CBTC radio system

Wireless link should be ceaselessly stable in geography or time over all sections. Data handling capacity should have enough surpluses more than the required quantity of communication necessary in operation of CBTC system. Seamless roaming should be realized through stable handover in the high-speed train operation condition. Target performance wireless communication system for CBTC is set up in Table 2 considering the technical requirement as above for CBTC. [5][6]

<table>
<thead>
<tr>
<th>Item</th>
<th>Target function</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission speed of radio data</td>
<td>1Mbps or higher</td>
<td></td>
</tr>
<tr>
<td>Maximum allowable speed for high speed roaming</td>
<td>100km/h or higher</td>
<td></td>
</tr>
<tr>
<td>Data link error rate</td>
<td>1% or less</td>
<td>BER10-4 or lower</td>
</tr>
<tr>
<td>Net response time of mixed link</td>
<td>0.2sec or shorter</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Specifications of CBTC communication system (a part of IEEE Std 1474.1)

Data transmission speed

Transmission quantity of duplex data from one train in a general CBTC system shows approx. 8Kbps in average. Therefore, if communication should be carried out with a train composed of 10 cars through wireless link in the CBTC system, it requires the rate of treatment of 80Kbps in the wireless link. Here, it requires net treatment rate of wireless link of 200Kbps increased by 2.5 times considering surplus since net treatment rate decreases in the packet communication system. Transmission speed of 543Kbps is required in order to secure wireless link of 200Kbps deduced above in wireless LAN of CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) system according to the standard of IEEE 802.11b, and in case transmission speed of CBTC is 1Mbps, it becomes approx. 2 times. High speed roaming should be possible based on 100km since it should satisfy 100km/hr the maximum speed urban magnetic levitation propulsion train, and its realization is found possible without any problem in the level of current technology. [2]

Error rate of data link

Momentary interruption may occur during operation of wireless communication system in the link between wayside equipment and on-board radio equipment. Standard of target performance of 1% or
less in most CBTC projects in advanced countries is suggested for this problem, and such level is reported that it did not give any impact on actual quality of wireless communication. At this time, average bit error rate (BER) should be set in designing performance of wireless communication instruments; commercialized product has BER$10^{-4}$~BER$10^{-6}$ in general, and BER$10^{-4}$ allow some additional errors due to high bit error allowable rate compared to BER$10^{-6}$, but instead sensitivity of receipt is more improved. Even so, if BER is raised so high, reliability of data falls, so it should be sustained under a certain level. Considering this, it should be decide not more than maximum BER$10^{-4}$.

The bigger the margin of wireless link system, the smaller the error rate of data link, however, it is necessary to confirm through site test for each corresponding section and take the measure such as adjustment of antenna arrangement or addition of relay equipment in case the performance is not sufficient since lot of variables exist according to the performance limit and actual radio environment of the site.

Net response time of mixed link
It means the time for connection from wireless network to cable network as the net data link time excluding information processing time of CBTC equipment, and in the wireless network also includes the time required in in-line communication connected to router and channel service unit (CSU) or optical transmission equipment and wireless equipment and off-line communication between ground radio equipment and onboard radio equipment.

Considering that target performance of total CBTC communication system is no more than max. 1 sec, and delay time of communication between wayside and train including information processing time of CBTC in required lower than 0.5sec, net communication response time between communication systems for train control should not exceed max. 0.2 sec.

Matters to be considered in construction of new system
The followings should be considered in construction of CBTC communication system.
1) Minimize the burden of handover between wayside stations according to the movement of onboard station and correspond to high speed running of train effectively by constructing whole communication network as a single subnet network including wireless network.
2) Improve the reliability of communication by securing redundancy in communication path among automated train supervision system (ATS), ground equipment and onboard equipment.
3) And recovery of path in occurrence of error in transmission path should be fast and etc.

Types of communication system
CBTC communication system is divided into control network and data network, and data network is divided again into wireless LAN between ground and train and cable LAN where track side, control station and central station. At this time, interface standard applied to each network should apply opened standard to make integration and extension of network easy.

1) Control network
   IEEE1473-L standard, which has small data transmission quantity as control network for train control but high reliability and high real time performance capacity, is suggested.
2) Data network among railway track side, control station and central station
   IEEE802.3 standard standardized as IP based Ethernet cable LAN interface is suggested. It is a network to connection between ground systems, and to connect in formations according to wireless communication with cable LAN through backbone network. Backbone network can be constructed by using cable or radio; however, it is desirable to construct cable communication network based on optical cable considering stability and reliability of the system.

Radio network between wayside and onboard
It is based on IP based Etherton interface function as IP based spread spectrum technology and half duplex communication system, and should be possible to support communication with CBTC subsidiary systems such as onboard equipment applying serial comminication and IEEE1473-L stabdard as shown in Fig. 3.

Because the method of constructing wireless communication network for transmission of data between wayside and train in CBTC has merits of copmatibility, extenability and economic feasibility since generel purpose product of open standard of IEEE802.11b can be used if wireless LAN is used, this should be based on. Wireless LAN system is the system to embody wireless link between wayside equipment (wayside rasio station) and onboard equipment (mobile radio station) by applying wireless LAN. At this time it has the merit that wireless network configuration becomes simple since
routing between wayside equipments is not performed, and the wayside equipment with Access Point in the center is limited to play the roll of relay between train and equipment of control station only.

Figure 3: Radio network interface

Method of wireless network configuration
In order to secure reliability and safety of wireless network, it should be constructed in duplex system as shown in Fig. 4.

Duplication of wireless network is divided into duplication of wayside wireless system and duplication of radio system mounted on the train. Wayside wireless system enables to construct communication network between train and wayside system and central control station by forming cell of a certain range according to the electric field strength and pattern characteristics of antenna and providing wireless network to the onboard wireless system located in such cell. That is, double wayside wireless systems are installed to cover up and down tracks of train in one cell, and each system is set up in so that it may have different radio channel and different ID. For example, it is managed by dividing the network into the left wayside wireless equipments as odd network and right wayside wireless equipment as even network providing each cell with serial number if it is assumed that the train moves up line. The fore end train is set up with configuration corresponding to the odd network and the rear end train is set up configuration corresponding to the even network.

Therefore, in normal operation situation, effective data is processed in the up line train by being interlocked with the odd network and the down line train by being interlocked with the even network, however, odd network and even network are integrated into one network actually and fore and rear radio equipment are left all in linked state on radio all the time no matter it is up line or down line. If occurrence of trouble may cause failure of wireless link in the fore end train of the up line, control station detects it reads the data from the wireless equipment of the rear end train immediately and process it as effective data.

Effect of increasing sustaining time of wireless link and improving availability can be obtained by such duplication since communication connection is maintained without separate restoration time even in the case that failure of one wireless link is caused by occurrence of trouble.[7]

Figure 4: Duplication of radio network
High speed roaming
It is quite important that the communication is maintained without disconnection while train is moving from one communication section to neighboring communication section, and it is necessary to specify correctly cell coverage and roaming between onboard mobile station and wayside wireless base station.

Roaming is carried out in way that onboard system automatically set the communication channel and hand over by comparing the Received Signal Strength received from the neighboring wayside and selecting the cell with more dominant Received Signal Strength.

At this time, threshold value (generally, threshold value of circuit quality) hysteresis margin in addition to received signal strengths are used as decision criteria of handover.

Minimum allowable sensitivity of receipt in IEEE 802.11b standard of wireless LAN is reported as -80dBm, and if the hysteresis margin for stable roaming 15dB, allowable value of receipt sensitivity for calculating cell distance, i.e. the distance of base station to install antenna, is -65dBm acell distance.

That is, distance to install AP should be set up so that receipt sensitivity may not become smaller than -65dBm considering the loss of wave path according to the distance.

It is necessary to apply method of approach to communication range and roaming standard by analyzing its characteristics through numerical simulation firstly, and confirming numerical simulation result through reduced model test in the laboratory level secondly, and then lastly calculating optimum distance through repetition of test after installing radio equipment on the actual wayside.[3],[4]

Detection of location and speed of train
Transponder tag
Transponder tag is suggested in order to confirm location information in the onboard equipment. Tag holds the value corresponding to the location information and transmits it by wireless at the moment of encounter with onboard antenna installed on the train. Transponder tags will be installed on the side of railway track according to the record in the database of ATP equipment. Equipment to read transponder receives own unique code identification number of transponder if the train passes the transponder installed on the side of railway track according its operation. Equipment to read transponder transfers transponder ID to ATP equipment for processing. ATP equipment checks whether received ID is effective based on the following principles.
- Transponder ID exists in the database of ATP.
- Received transponder ID is based on the transponder ID received previously.
- Transponder ID should be received with the proper distance after the previous transponder.
- Location of railway track side connected with verified and unique transponder ID is received based on the designated track data.
- Transponders are located on the designated location, by dividing the block in order to minimize undesignated points, and surrounding wayside switching equipment and station.
- The principle of the number of transponder tag to be arranged is as follows.
  - Identification number of each tag on the location of wayside should be unique.
  - There should be any gap in numbering sequence.

![Figure 5: Example of Tag installation](image)

Dynamic Grobal Positioning System
GPS is a location determination and detection system called Grobal Positioning System or NAVSTAR (Navigation System with Timing and Ranging), and it is composed of space field, control field and user field. Space field is composed of GPS satellite to transmit navigation message necessary to
calculate location continuously to users through carrier wave. Control field estimates the location of satellite by tracing and watching GPS satellite as correctly as possible through several observation and control station distributed around the world, and sends various kind of correction information to satellite. User field is composed of GPS receiver to receive GPS satellite signals and calculate location and various kinds of equipment developed to achieve various specific purpose by allying it. GPS system is applied widely in the fields of geographic information, navigation of airplane, navigation of space, navigation of vessel, automobiles, and military etc. GPS system is classified into single global positioning system which has location accuracy of 30~40m level and differential global positioning system (DGPS) which has location accuracy of few meter level, and carrier wave correction differential global positioning system, which has location accuracy of few centimeter level.

 Cause of error in global positioning system
  · Error caused by ionospheric layer
  · Error caused by tropospheric refraction
  · Error in orbit and clock of sattlite
  · Error of multiple path
  · Cycle slip

DGPS is comparatively very expesive in its installation cost, on the other hand, accuracy of location determination is exceptionally higher than general GPS system. Installation of DGPS is suggested as a subsidiary equipment for location detection to be applied in onboard signal system of magnetic levitation train in order to confirm the location of train by using such high accuracy of distance. If magnet levitation train is reset due to trouble occurred in the system of magetic levitation train operating by application of DGPS, it is impossible to know the location of train on the ground until the wayside tag is deted by ruuning. It is possible to confirm the absolute location of train if DGPS equipment is installed in signal system in the way to complement this problem, even though the train is reset. And interface should be embodied by using hard ware anbd software such as wayside tag and track possession of virtual block etc.

**Doppler Rader Sensor**
Magnetic levitation train cannot be equipped with tachometer since wheel axle, which conventional wheel type train has, does not exist in magnetic levitation train. Application of dopper dadar sensor to replace tachometer for this purpose is suggested. Uniform concrete surface without irregularity facing the train is the optimum condition for installation of DRS (Doppler Rader Sensor) in order to measure the speed of magnetic levitation train and receive errorless signal, and instalation of the locationn where swaying can be minimized can the best condition to detect. Table 3 represents Doppler Rader sensor’s performance.

<table>
<thead>
<tr>
<th>Speed measurement</th>
<th>Typical</th>
</tr>
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<tbody>
<tr>
<td>Statistical error</td>
<td>0 km/h-100 km/h &lt;0.4 km/h 1σ limit</td>
</tr>
<tr>
<td></td>
<td>100 km/h-600 km/h &lt;0.4 % 1σ limit</td>
</tr>
<tr>
<td>Error by variation of the ground (calibration shift)</td>
<td>0-600 km/h &lt;1 km/h.</td>
</tr>
<tr>
<td>Dynamic error</td>
<td>Delta v = 0.65 km/h</td>
</tr>
</tbody>
</table>

*Table 3 : Doppler Rader Sensor's performance*
It is found as the result of technical review that application on the bottom of bogie did not cause any awaying while running, however, possibility of error occurrence due to unstable doppler signal level caused by irregularity of track is big. If it is installed on the side of bogie, it is possible to get stable data of speed and distance since doppler signal level is kept stable and uniform surface of concrete can be used as facing surface. However, it requires attention in installation since unstable factors in installation such as linear motor, electromagnet and etc. are located close to it.

Distance error of approx. 1% occurred as a result of comparison of actual distance measurement test and the distance detected using pulse of doppler sensor, which is found smaller than the error of 2% possible to occur using tachometer in wheel type. This error can be compensated by distance correction logic by using Transponder in operation of ATP and ATO.

The following table shows the result for distance compare test in test line.

<table>
<thead>
<tr>
<th>No.</th>
<th>Sensor type</th>
<th>Installation position</th>
<th>Actual Distance(m) (A)</th>
<th>Distance of pulse in doppler sensor(m)(B)</th>
<th>Distance of 485 in doppler sensor(m)(C)</th>
<th>A-B</th>
<th>A-C</th>
<th>MAX Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DRS-05</td>
<td>Side</td>
<td>132.28</td>
<td>134.06</td>
<td>133.50</td>
<td>-1.78</td>
<td>-1.22</td>
<td>15</td>
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<tr>
<td>2</td>
<td>DRS-05</td>
<td>Side</td>
<td>233.78</td>
<td>-</td>
<td>235.70</td>
<td>-</td>
<td>-1.92</td>
<td>30</td>
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<td>3</td>
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<td>Side</td>
<td>93.89</td>
<td>90.49</td>
<td>90.10</td>
<td>3.40</td>
<td>3.79</td>
<td>5</td>
</tr>
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<td>4</td>
<td>DRS-05</td>
<td>Side</td>
<td>52.04</td>
<td>50.40</td>
<td>50.10</td>
<td>1.64</td>
<td>1.94</td>
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<td>5</td>
<td>DRS-05/1</td>
<td>Under</td>
<td>80.40</td>
<td>80.79</td>
<td>-</td>
<td>-0.39</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>DRS-05/1</td>
<td>Under</td>
<td>127.80</td>
<td>126.33</td>
<td>-</td>
<td>1.47</td>
<td>-</td>
<td>21</td>
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<td>7</td>
<td>DRS-05/1</td>
<td>Under</td>
<td>129.98</td>
<td>128.52</td>
<td>-</td>
<td>1.46</td>
<td>-</td>
<td>21</td>
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<td>8</td>
<td>DRS-05/1</td>
<td>Under</td>
<td>57.70</td>
<td>59.12</td>
<td>-</td>
<td>-1.42</td>
<td>-</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 4: Distance compare test sample(Test line of kimm)

**Conclusion**

Until now, configuration of wireless communication equipment of CBTC signaling system to be applied to magnetic levitation train, and the configuration method of train location and train speed detection equipment are suggested. As a method for optimum configuration of wireless communication system in order to embody CBTC system effectively, backbone network is constructed as cable network of IEEE 802.3 standard by using optical cable, whole communication network is constructed as single subnet network with ring topology in order to minimize network mobility burden in high speed roaming and secure seamless connection of ground wireless communication network and multiplication.

Wireless network between wayside and train, which is wireless LAN system of IEEE 802.11 standard spread spectrum technology and half duplex system, supports communication with CBTC subsidiary system and interconnecting equipment such as onboard equipment where IP based Ethernet interface function is bases on and serial communication and IEEE 1473-L standard are applied, an makes integration of communication network easy.

And, the method of keeping sustenance of communication without separate restoration work even in the case of sectional disorder is suggested as the method for optimization for securing reliability and stability of wireless network by duplication through dividing the wireless network into up line and down line.

It will be necessary to study on effective cell design and roaming technology in order to secure seamless roaming in high speed train operation in the future.

Conventional track circuit cannot be used since magnetic levitation train levitates without contact with rail different from the wheel type train. Therefore, It is very important to develop and apply equipment that has not only capability of train detection more than track circuit but also reliability and stability. For this purpose, installation of transponder tag, which operates without power and has excellent responding capacity to movement, is suggested. Transponder tag is the facility already applied and used in the conventional wheel type train, so the reliability and the stability are proven.
Magnetic levitation train should be equipped with unique facility since tachometer used in wheel type train cannot be used due non-existence of wheel, so doppler sensor using doppler effect is suggested to use. Doppler sensor has excellent detection capacity also in high speed and is used in wide range, so it is expected to exhibit excellent capacity as the speed detection facility for magnetic levitation train. It should be constructed as the facility without trouble in operation of train by sufficient technical review at the stage of commercialization since magnetic levitation train does not have commercialized result, and considering not only reliability, stability but also availability and maintainability.

In addition to the technical review for location detection facility and speed detection facility, in-depth research on interface embodiment with vital facility such as interlocking equipment is necessary.

Acknowledgements

This research was supported by a grant from the Urban Maglev Program funded by the Ministry of Construction & Transportation of the Korean government.

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