Headway Comparison between ATS and ERTMS/ETCS system

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Abstract : The present headway on KNR lines varies from 6 to 10 minutes. Therefore, KNR would like to reduce the headway of all the lines by 4 minutes with the implementation of ERTMS/ETCS on-board system. In Korea, thanks to the operation of the High Speed Line in 2004, the bottleneck phenomenon will occur only in a few sections such as Seoul-Siheung, which will be the common route between KTX and conventional trains. Therefore, we will analyze expected braking distance and running time depending on characteristics of conventional passenger and freight trains and high speed train will be operated within electrified conventional line for comparing the headways of ATS trackside and ETRMS/ETCS on-board system within the Seoul-Siheung section.

Keywords: Train Control System, Simulation, Modeling, Headway, Automatic Train Protection

1. INTRODUCTION

The railroad signaling system is the core of railroad system in that it realizes protection between running trains by checking the capacity of a railroad line and safety of a train in accordance with the condition of the front train. It thus plays an important role in making it possible for various trains to be safe, speedy and accurate on the same railroad line.
As the number of passengers and the speed of trains increase due to improvement of users' environment, a new signaling system is called for the high speed of trains and the high density of train operation. In particular, a plan has been established to replace railroad system between the operation sections of classical lines of KTX(Korea Train Express) such as Kyoungbu line, Honam line and the Electrification line of main railroad network from Trackside signaling to on-board signaling of ERTMS/ETCS (European Railway Traffic Management System/European Train Control System) for a high-speed and high-density operation of trains. Therefore, it is expected that it may decrease the cost of maintenance and also improve operation safety and effectiveness ([1],[2]).
But KNR(korean National Railroad) plans to open KTX in 2004 and operate it together with conventional trains on some sections. In this case, it is critically required that the line capacity reach saturation in the bottleneck sections of some existing lines. We also have to ensure the improved speed and safe operation between existing operational sections of the high-speed Railway.

The current paper analyzes line capacity change by applying ATS Trackside signaling, which is expected to be operated between the existing train and KTX from 2004, and on-board signaling of ERTMS/ETCS, which is going to be used in the future. This analysis was carried out in Secoul-Siheung section, where an extreme bottleneck is seen as most of the trains in Korea go through this section.

2. FEATURES OF TRACKSIDE SIGNALING AND ON-BOARD SIGNALING

The Trackside signaling used in Korea has been built up with ABS (Automatic Block System) and a signaling lamp at every block section. The operators run the system and choose one of the options (Acceleration, Deceleration or Breaking) after simply checking the front signaling lamp with eyes. This controls the train speed according to the limited speed given by signaling lamp at every block section manually. If the running speed of a train is larger than the speed given by signaling lamp, ATS will interrupt the train operation for safety. Where ATS is Automatic Train Stop system identical with trackside signaling.

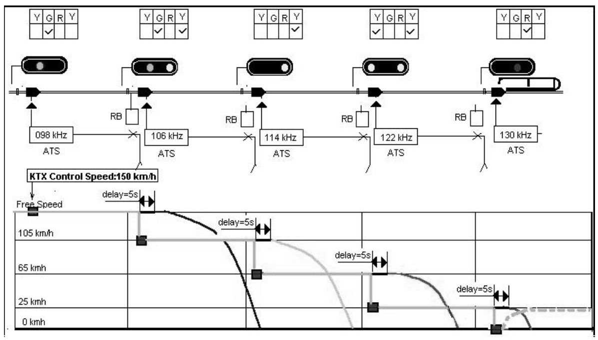

Fig. 1 Speed control curve on ATS

The main components of ATS trackside equipments are provided by beacon. The beacon transmit the operation information from track to train by the color of signaling lamps. It is installed on the right hand or left hand of track. The beacon installed on the right hand is used for the subway, while the one on the right is used for all the other trains.
If the running train exceeds the train speed given by a signaling lamp, the train driver has to run the braking system within 5 seconds. If he fails to do this requirement, the emergency braking system will be run automatically. For the lower price of this Trackside device, it is suitable for the shunting section into auxiliary lines or sections requiring lower speed.
But the speed deceleration is necessary for bad weather conditions such as snow, rain, and fog. ATS system does not guarantee the safety and reliability at the speed over 140km/h. The amount of data that can be sent though the ATS system is severely restricted [1].

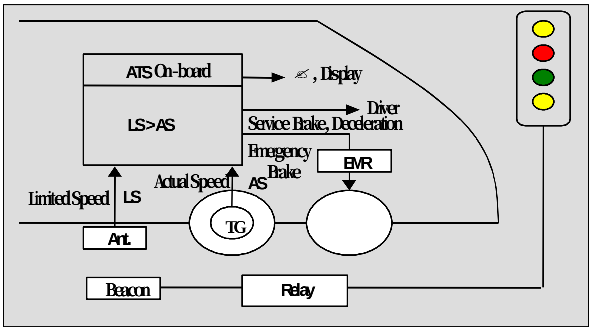

Fig. 2 ABS/ATC block diagram

In on-board signaling, the following train is systematically controlled to ensure the safe interval from the front train by calculating its own speed from the beacons in real time after receiving the trackside information such as the location and speed of preceding train, geographical features of scheduled track. This type would be designed in consideration of braking features for various types of trains, which are operated in railroads. Also it can prevent accidents regardless of weather conditions. Also it can provide more safety and reliability than ATS system and make it possible to improve train speed. And, it is much easier to reduce the headway than Trackside signaling and it is also possible to increase the train speed up to maximum 220km/h if the conditions of lines and vehicles are improved. However, this system requires higher costs for construction than Trackside signaling. One of the defects is that the effectiveness is low, considering the investment needed, in the sections that have low level of frequency and demand the lower speed. On-board system called a new generation ETCS (European Train Control System) in Europe is on the basis of on-board signal system and safety.
The system is standardized in accordance with the specifications required for the existing signal system and unified in Europe. After all, the companies that are engaged in the railroad industry have built up the integrated railroad signal market by sharing the standardized specifications. As the result, ETCS realization is divided into ETCS Level 1, Level 2 and Level 3 in consideration of technical limitations of now and available development status in the future ([3],[4]). For the fundamental features of each ETCS Levels are subscribed in Table 1.

Table 1 ETCS Level features

	Level 1	Level 2	Level 3
Block system	Fixed Block	Fixed Block	Moving Block
Information Transmission	Balise	Balise/Radio	Radio
Track circuit/ Axle counter	Use	Use	Out of use
Trackside Signaling	Use	Use/ Out of use	Out of use

ETCS Level 1 depends on the fixed block and Trackside signal lamp. This has the same features as the existing ATP(Automatic Train Protection) system. The applicable information is transmitted from track to train by balise or loop which delivers the intermittent information to control the speed of train.

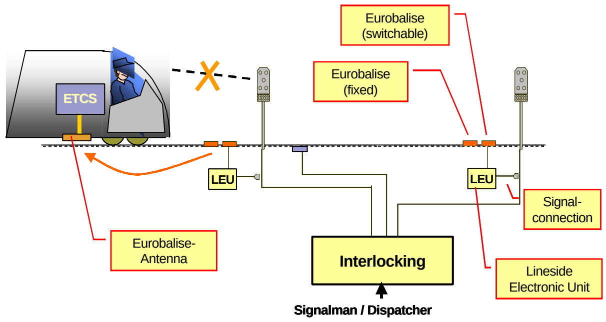

Fig. 3 ETCS Level 1 block diagram

However, ETCS Level 2 performs the successive speed control of trains by using the intermittent information transmission for the continuous bi-direction wireless communication between track and train. But, Trackside signal lamp is needed when combined with the existing signal system. Trackside signal lamp is not needed if we only use Level 2.

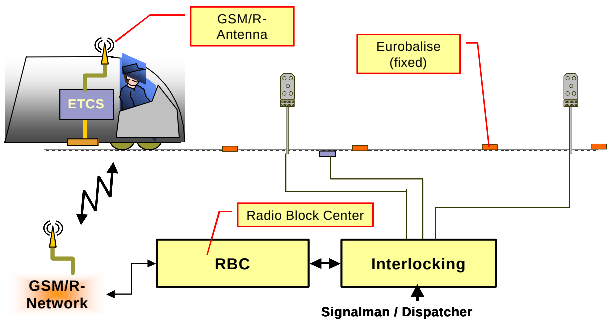

Fig. 4 ETCS Level 2 block diagram

ETCS Level 3 performs the perfect successive information transmission by the wireless method in function. To check the train position and the train interval between the preceding train and following train, a fixed block system is used in Level 1 and Level 2, while MBS(Moving Block system) is used in Level 3.

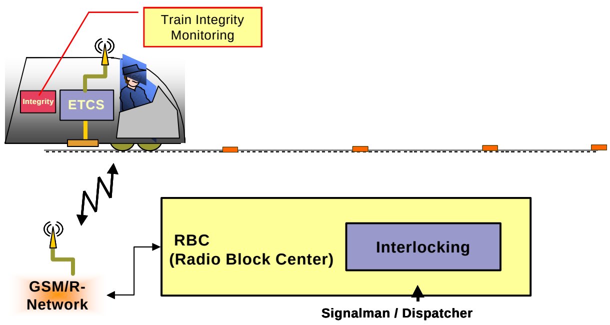

Fig. 5 ETCS Level 3 block diagram

Along with the developmental direction of this TCS(Train Control System), the train network of existing lines and high-speed trains can provide the optimized performance and safety for operation of trains. We also expect to obtain interoperability with the existing system, compatibility for TCS between countries, build up of the borderless trail system, capacity increment of line and operation, and maintenance at lower costs as well. In particular, as ETCS is upgraded from lower Level to higher Level, most of materials on lines are replaced by the new wireless system, and operation or maintenance for materials on lines are decreased.

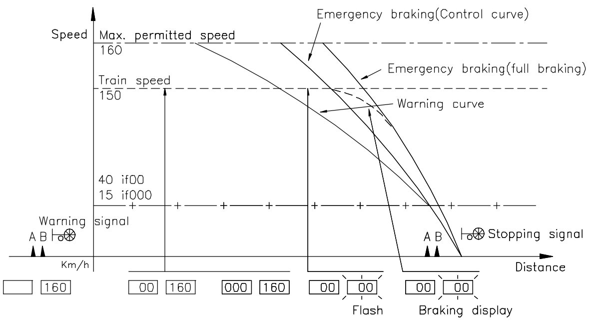

Fig. 6 Speed control on ATP System

3. BOTTLENECK SECTION OF SOUTH SEOUL

The block section is the system that allows only one train to be located in a section, after dividing the line into fixed sections in accordance with condition of line to prevent a head-on collision between trains. Specially, an interval between the preceding train and the following train, which is defined as headway, is calculated on the basis of the block section. The braking distance, which is defined as distance needed for a train with maximum speed to stop, is determined by the quantities of this block section[1]. In the section between Seoul and Siheung, about 17 km long, many commuters' trains are in operation. This section is going to be operated by both the existing trains and KTX from 2004.
Accordingly, it is predicted that the section would be the worst traffic jam zone from 2004[2]. Because the headway of Korean National Railroad is given from 6 to 10 minutes depending on the lines, the established plan to introduce the on-board signal of ETCS will shorten the headway over 4 minutes. The section between Seoul and Siheung, as the neck of bottle through which KTX, Kyoungbu, Honam, Janghang, Jeonra lines have been operated, is predicted to exhibit higer increasement ratio than other sections. The headway of the section between Seoul and Siheung according to ERTMS/ETCS installation level is analyzed in this article. The basic data under analysis are exhibited in the following tables([5],[6],[7]) :

Table 2 The location of signaling lamp

Up line		Down line	
Location (m)	Location (m)	Location (m)	Location (m)
50	9596	50	9494
505	10099	855	10185
1010	10405	1548	10728
1730	10904	1860	11443
2280	11581	2280	12000
2819	12299	2946	12900
3430	12880	3411	13755
4042	13450	4042	14400
4583	14020	4570	15070
5238	14610	5351	15700
5760	15210	5980	16380
6010	15830	6525	16950
6760	16350	6880	17410
7396	16930	7396	17775
7927	17400	7887	
8300	17840	8180	
8992		8700	

Table 3 Radius of curve

Up direction		Down direction	
Location (m)	Radius (m)	Location (m)	Radius (m)
2149	0	0	0
2892	500	2149	500
5505	0	2892	0
5744	500	5507	500
6356	0	5746	0
6447	400	6356	400
6708	0	6447	0
6871	400	6708	500
7341	0	6871	0
7781	500	7341	500
8183	0	7781	0
8412	600	8131	600
9046	600	8413	0
10927	0	8883	600
10991	800	9046	0
11706	0	10927	800
11768	600	10991	0
12135	0	11706	600
12471	800	11768	0
13622	0	12135	800
13794	600	12465	0
-		13655	600
-		13732	0

Table 4 Gradient data

Up direction		Down direction	
Location (m)	Gradient (‰)	Location (m)	Gradient (‰)
0	0	0	0
1006	0	1006	-10
1381	10	1381	-7.7
1975	7.7	1975	-10
2449	10	2449	0
3524	0	3524	10
4035	-10	4035	2
4335	-2	4073	0
5320	0	5058	-5.5
5640	5.5	5378	0
6340	0	6078	8
6960	-8	6698	0
7220	0	6958	-8
7740	8	7478	-3
8240	3	7978	-6
8580	6	8318	0
9933	0	9671	6.5
10220	-6.5	9958	-6.5
10560	6.5	10289	0
11653	0	11474	-5
11763	5	11693	10
12093	-22	11904	18.5
12408	24	12334	-15
13099	0	12989	0
13499	-1	15810	5
13800	1	16230	0
16120	0	17320	3
16540	-5	-	-
17680	0	-	-

Table 5 calculates the braking time and distance from maximum speed depending on train type. Table 6 provides acceleration time and distance depending on train type. In here train-running time depends on maximum running speed considered speed restriction (basically supposed to 12%) that provided with margin (maximum permission speed 7km/h) in accordance with drivers habit, permanent speed restriction, and temporary speed restriction[8].

Table 5 Braking time and distance

Train type	Deceleration	Time	Target distance	Max. Speed
	γ_a (m/s²)	t (s)	t_d (m)	km/h
KTX (150)	0.5	77	1726	150
KTX (135)	0.5	69	1397	135
Saemaul	0.5	66	1203	125
Mugunghwa	0.5	68	1111	120
Freight train	0.4	56	773	90

Table 6 Acceleration time and distance

Train type	Acceleration	Time	Target distance	Max. Speed
	γ_a (m/s²)	t (s)	t_d (m)	km/h
KTX (150)	0.4	104	2163	150
KTX (135)	0.4	94	1767	135
Saemaul	0.37	94	1635	125
Mugunghwa	0.36	96	1579	120
Freight train	0.3	88	1033	90

4. HEADWAY SIMULATION

The present headway on KNR lines varies from 6 to 10 minutes depending on the lines as stated in the KNR document describing Seoul CTC. KNR asks for a 4 minutes headway when using ETCS. In fact, the only line sections where a very good headway is necessary are the Seoul-Siheung section and the Hoedeok- Daejeon section which will be the common routes for all trains when the Kyoungbu HSL(High Speed Line) will be in operation.

In order to enlighten the choice concerning the most suitable level of ETCS, a headway comparison has been carried out on these two sections between the current ABS/ATS operation, ETCS level 1 operation and ETCS level 2 operation.

A number of hypotheses have been taken into account as in the following:

- The 5 aspects ABS is currently in operation on both line sections;
- As for the signal visibility for ABS, we assume 600 meters everywhere. But, where necessary, it is restricted to the length of the previous block section;
- We have used actual signal positions and we assume that, with the introduction of ETCS, signal positions and block sections length will not change;
- We only take passenger trains with the assumption that Saemaeul-type trains and KTX-type trains have similar braking performance;
- As the actual line speed was not at our disposal, we have estimated it by using curves radius;
- The practical headway (the one which is used to schedule trains) is deduced from the technical headway (i.e. the minimum time between two successive trains) by using a 25 % sturdiness margin as recommended by 405-R UIC leaflet. Furthermore, we assume that the margin is evenly allocated to each train;
- As for ETCS (both levels), the braking deceleration used for signaling on-board curves has been estimated on the basis of a similar study that is carried out on French Railways' behalf; this value (0,62 m/s^2) is, of course, less than the one which is used for the ATP function (0,83 m/s^2);
- As for ETCS (both levels), we assume that the driver drives using only ETCS cab orders and that he ignores lineside signals aspects other than the stop (red) one which corresponds to an end of authority.

With the assumptions above, the headway was analyzed after the following procedures by using the headway analyzing program used in Systra in France:

① ABS operation :
For each signal, we calculate the necessary time before it returns to the Green aspect, taking into account the actual length of each block section, the visibility length of the signal, the trains length and the permitted speed.

② ETCS Level 1 operation :
We calculate first the distance from which the engine could be disturbed in advance of the end of authority, taking into account the line gradient, the train characteristics and the driving ergonomics times. Then, we establish the position of the in-fill balise which is to be set at a main signal. Finally the minimum time between two successive trains is calculated in the same manner as for ABS operation but, of course, without any visibility matter.

③ ETCS Level 2 operation :
As for Level 1, we calculate first the distance from which the engine could be disturbed in advance of the end of authority. Taking into account the length of the detection block section and the line speed, we obtain directly the minimum time between two successive trains.

The results are shown in the following figures and tables :

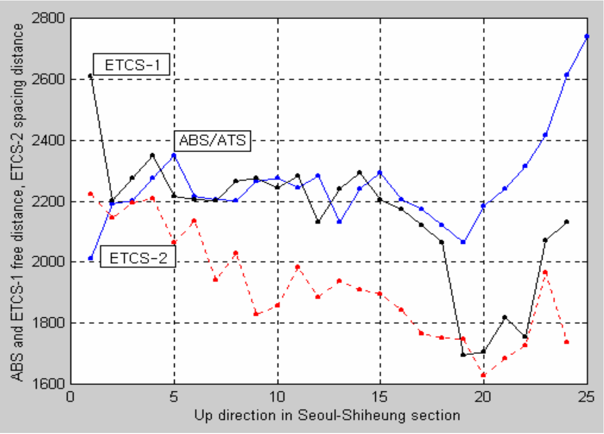

Fig. 7 Free distance on Up direction

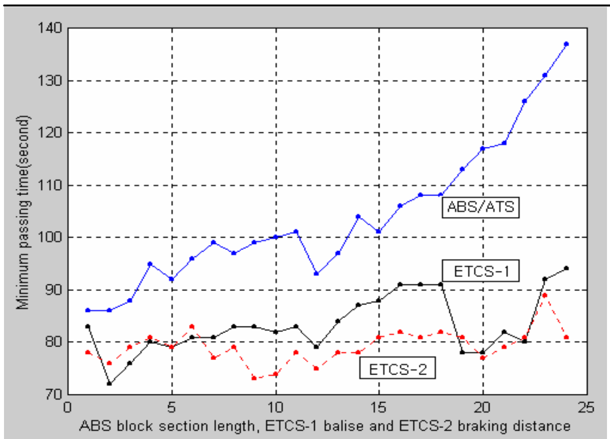

Fig. 8 Minimum time between trains on Up direction

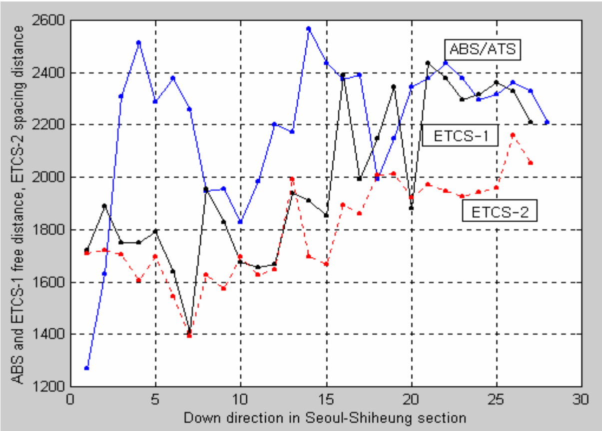

Fig. 9 Free distance on Down direction

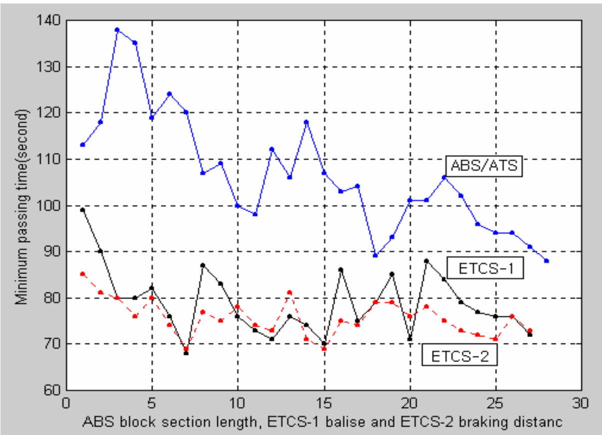

Fig. 10 Minimum time between trains on Down direction

Table 7 Result of the headway analysis

Line Direction	Minimum time between trains (sec)		
	ABS	Level 1	Level 2
Up	138	99	85
Down	137	94	89
	Practical headway (min)		
Up	4.0	3.0	2.5
Down	4.0	3.0	2.5

5. CONCLUSION

If the trackside signaling would be optimized, the headway should be 4 minutes. But the headway in ETCS level 1 should be 3 minutes and level 2 will provide 2 minutes 30 seconds as the headway. Therefore, the on-board signaling can reduce the headway compared with trackside signaling. So it can make it easier to predict increment of track capacity on the bottleneck section. Especially if the speed of conventional trains increases, the headway of related sections will decrease more.

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