Performance Test of LTE-R Railway Wireless Communication at High-Speed (350 km/h) Environments

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***Abstract*—** LTE-Railway (LTE-R) is a communication technology that enables immediate and effective response in case of emergencies by providing voice, data, and video services through LTE, a 4th-generation wireless communication technology, optimized for the railway environment. LTE-R, which is currently under development in South Korea, provides the capability to send and receive data for group calls and emergency calls, as well as internal control calls on trains linked to smartphones. However, infrastructure construction and technical services are required to ensure seamless services as well as the quality of service (QoS) in a high-speed moving environment. The Telecommunications Technology Association (TTA) has established the LTE-R wireless communication standard to support these requirements; however, verification of the established data standard is necessary in an actual high-speed rail environment to ensure its reliability. This study measures the QoS through a mobile terminal in the LTE-R infrastructure network constructed by the Korea Railroad Research Institute in a high-speed moving environment (300 km/h to 350 km/h). The measurement results will be used as reference materials for LTE-R construction and research.

Keywords—LTE-R, testing; quality of service

I. INTRODUCTION

A wireless communication network for rail is essential for enhancing the security and safety of railway travel given large-scale railway accidents and terrorism. In addition, it would improve railroad arrival punctuality and satisfy the demand for high-quality passenger services. Thus, domestically and overseas, major countries have established an integrated wireless network for railway, and further introduced a railway dedicated wireless communication network standard for the safety and efficient management of railway vehicles and facilities.

The European Telecommunications Standards Institute (ETSI) and European Integrated Railway Radio Enhanced Network (EIRENE) in Europe have established a GSM-R system using the Global System for Mobile (GSM) communication method to provide the related services. The Telecommunications Technology Association (TTA) in South Korea has established LTE-based railway communication system requirements [1] and user requirements for LTE-based railway communication systems [2] as a standard for the use of LTE-R systems. However, these LTE standards were established by analyzing the European railway system GSM-R speed standard (400 km/h), and the standards did not undergo a separate verification process in an LTE-based high-speed moving environment (~350 km/h). Thus, this study performed the performance verification in an environment where the actual LTE-R infrastructure is established based on the LTE-R standard values as defined in Tables [1] and [2].

TABLE I. REQUIREMENTS FOR LTE-BASED RAILWAY COMMUNICATION FUNCTIONS

Service type	Service in detail
Voice service	Individual voice calls, public emergency calls, broadcast voice calls, group voice calls, multi-party voice calls
Data service	Multimedia message service, general data service, train control service
Video service	Individual video calls, group video calls, video information transmission
Call related services	ID display of incoming/outgoing users, display restriction of incoming/outgoing users, priority and preemption right, closed user group, forwarding, call hold, call waiting, billing information, call restriction, automatic response system, all voice/video call recording
Railway-dedicated service	Function addressing, location-based addressing, railway emergency call, shunting mode, direct communication

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TABLE II. PERFORMANCE REQUIREMENTS FOR LTE-BASED RAILWAY COMMUNICATION SYSTEM

Items	Content
Coverage and performance	The coverage should be continuous in time and space. To ensure stability, the temporal and spatial range should be greater than 98% based on the vehicle in which the external antenna is installed. The network should be capable of accommodating a mobile terminal for railway communications. The system should provide communication when traveling at a lower speed than the railway speed limit or at 500 km/h.
Call setup time	· Railway emergency call <1 second (90%), <2 seconds (100%) · Broadcast and group call <1 second (90%), <2.5 second (100%) · All voice/video calls that are not covered by the above items <3.5 seconds (90%), <5 seconds (100%)
Handover Success Rate	The network should be capable of seamless data transmission, and the handover success rate should be at least 99%.
Connection admission success rate	The call admission rate should be at least 99%.
Long-term connection cut-off rate	It is necessary to guarantee a cut-off rate of 0.01 times or less per hour during a long phone call.
Train control data transmission	Networks should ensure a data reliability of at least 99% for data transmission for train control. Train control data should have the highest priority.
Network redundancy	Base station equipment, core equipment, and networks, including servers, should be redundant for stability and availability.
Broadcast and Group call area	A wireless device within a designated area may participate in broadcast and group calls, and wireless devices that are outside the broadcast and group call area during a call are excluded from the call.

This study was aimed to test the performance of the LTE-R railway communication infrastructure network links with mobile terminals, and an analysis of the results is presented in the following Chapter.

II. RESULTS AND DISCUSSION

A. LTE-R Test Environment

The test environment in this study includes testing in the LTE (700 MHz)-based infrastructure of Iksan-Jeongup (open terrain 28 km) and Noryeong Tunnel (6.3 km long tunnel) as shown in Fig. 1.

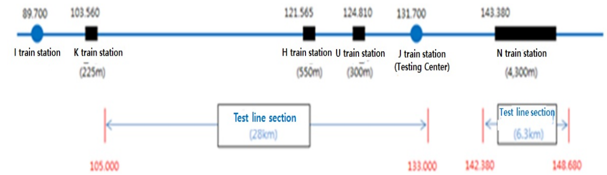


TABLE III. CONSTRUCTION OF LTE-R TEST NETWORK

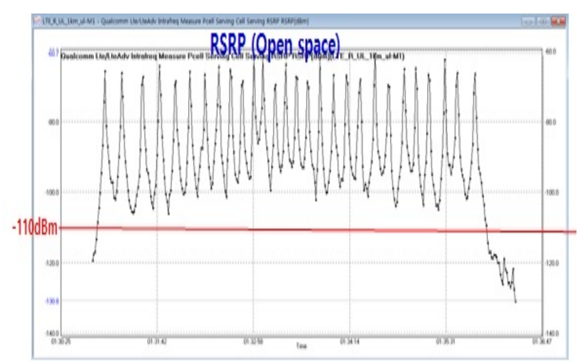
Division	Amount	Installation location
EPC	1	Jeongup Test Center
DU	4	Gamgok SP - 2, Jeongup Test Center - 1, Noryeong InEC - 1
RRU	4	Trackside power poles - 31 (1 km interval), Tunnel hoops- 9 (0.5 km interval)

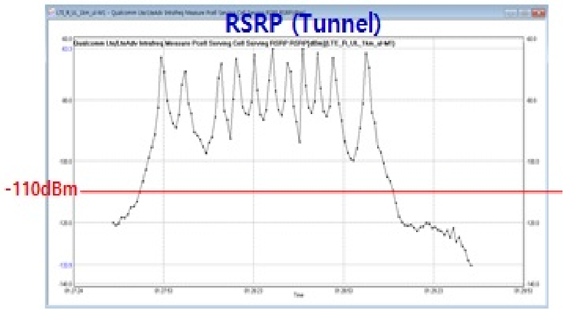
B. Test Scenario

By using mobile terminals for LTE-R under the high-speed moving environment of 300 km/h to 350 km/h, the QoS, such as overall reliability and stability, is measured. Regarding the LTE-R coverage and performance measurement (RSRP), call setup time, handover success rate, connection admission rate, long term connection cut-off rate, train control data transmission, and network redundancy are also measured.

C. Test Results

1) Coverage and performance





Test Items	Criteria	Measurements	
Guaranteed area percentage of reference RSRP	Within -110 dBm, 98% or more	First	100%
		Second	100%
		Third	100%
		Fourth	100%
		Fifth	100%

RSRP is a measure of wireless signal quality within the cell coverage, and all five test sessions showed good performance within the reference values.

2) Call setup time

Test items	Criteria	Measurements (number of normal operation/number of tests)
Emergency call success rate	99% or more	100%, (3/3)
PTT call success rat	99% or more	100%, (3/3)
emergency call setup time	Within 300 ms	32 ms
PTT call setup time	Within 300 ms	31 ms

The call setup time is a measure of the time required to connect the voice service (emergency call and group call PTT) in the train, and all the test sessions showed a good performance within the reference values of the call success rate (100%) and within 32 ms.

3) Handover success rate

Test items	Criteria	Measurements (number of normal operation/number of tests)	
Handover	In normal operation	First	6/6
		Second	6/6
		Third	6/6
		Fourth	6/6
		Fifth	6/6
Handover success rate	99% or more	First	100%
		Second	100%
		Third	100%
		Fourth	100%
		Fifth	100%
Handover switching time	Within 300 ms	First	20 ms
		Second	21 ms
		Third	15 ms
		Fourth	33 ms
		Fifth	22 ms

The handover success rate test determined whether there was a service interruption due to the high-speed movement of the terminal in the train car. All five of the test sessions showed a good performance within the reference values.

4) Connection admission success rate

Test items	Criteria	Measurements (number of normal operation/number of tests)
Connection admission operation	In normal operation	115/115
Connection admission success rate	99% or more	100%

The connection admission success rate test determined whether the terminal in the train car could normally accept a voice service request, and 115 test sessions showed a 100% success rate.

5) Long-term connection cut-off rate

Test Items	Criteria	Measurem

		ents
Connection operation	In normal operation	In normal operation (149 h)
Cut-off rate during long-term connection	0.01 times per hour	0

The long-term connection admission success rate was a test to determine whether long-term (5 or more days) service within the coverage of the terminal and LTE-R network were possible in a static environment. The results showed that normal seamless services were possible.

6) Train control data transmission

Test items	**Criteria**	**Measurements (number of normal operation/number of tests)**	
Data transmission operation	In normal operation	First	339/339
		Second	268/268
		Third	302/302
		Fourth	307/307
		Fifth	352/352
Data transmission success rate	99% or more	First	100%
		Second	100%
		Third	100%
		Fourth	100%
		Fifth	100%

The train control data transmission test determined whether ping data can be normally transmitted to the railway center as the terminal moves in the train car at high speed; all five test sessions showed a 100% success rate.

7) Network redundancy

Test Items	**Criteria**	**Measurements**
EPC board switching	In normal operation	In normal operation
EPC board switching time	Within one second	Within one second

The test also determined whether the service continued normally without interruption of the connection at the terminal in service when a forced failure of the EPC system occurred. From the test results, it can be confirmed that the board redundancy can be normally connected.

III. Conclusion

This study conducted tests in an actual LTE-R infrastructure environment to determine whether the mobile terminal for LTE-R satisfies the LTE User Requirements for an LTE-based Railway Communication System, established by the TTA, in trains (300–350 km) moving at a high speed in the LTE-R infrastructure (RRU interval open terrain 1 km, tunnel 0.5 km) environment, which is the 4G railway wireless communications technology. The test results showed that the infrastructure configuration was suitable for all the tested parameters, such as coverage and performance, handover, and data transmission, which proved that the infrastructure configuration was suitable for a high-speed train. The results of this study could be used as important reference material for future LTE-R expansion and research.

Acknowledgment

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References

[1] Telecommunications Technology Association(TTA), TTAK.KO-06.0369, "Railway Wireless Network Construction - Domestic and Overseas Status, Implications, Functional Requirements," 2014.

[2] Telecommunications Technology Association(TTA), TTAK.KO-06.0370, "LTE User Requirements for LTE based Railway Communication System"), 2014.

[3] Telecommunications Technology Association(TTA), TTAK.KO-06.0407, "LTE based Railway Communication System Requirements, 2015.

[4] B.S. Yoon, J.S. Kim, S.K. Lee, K.H. Kim, Y.K. Kim, D.K. Park, "Technologies and standards of future railway mobile telecommunication", Journal of the Korean Society for Railway, Vol.16, No.6, 2013, pp. 519-527.

[5] K.H. Kim, Y.K. Kim, D.K. Park, "A study on the problem analysis and improvement plan for the korean railways communication networks", Journal of the Korean Society for Railway, Vol.16, No. 6, 2013, pp. 534-539.

[6] N.H. Park, S.K. Lee, K.C. Lee, D.J. Kim, D.S. Kwon, "Technical mode for national safety disaster communication network", Information and Communication Magazine, Vol. 31, No. 10, 2014, pp. 12-18.

[7] Y.S. Song, J.Y. Kim, S.W. Choi, Y.K. Kim, "Long term evolution for wireless railway communications : Testbad deployment and performance evaluation," IEEE Communications magazine, Vol. 54. No. 2, February. 2016, pp 138-145.