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SERIES K: PROTECTION AGAINST INTERFERENCE

Electromagnetic field (EMF) strength inside underground railway trains

ITU-T K-series Recommendations – Supplement 19

Supplement 19 to ITU-T K-series Recommendations

Electromagnetic field (EMF) strength inside underground railway trains

Summary

The electromagnetic field (EMF) environment surrounding underground railway trains is among those most frequently met by the general public in daily life. When an underground railway train passes through a tunnel, especially, passengers are exposed to the EMF radiated by several repeaters installed on the wall. EMF sources are close to passengers under these conditions. Supplement 19 to ITU-T K-series Recommendations reports evaluations of EMF exposure levels in underground railway trains from mobile communication base stations installed in tunnels.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T K Suppl. 19	2019-09-20	5	11.1002/1000/14078

Keywords

EMF strength, tunnel, underground railway train.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Electromagnetic field (EMF) strength inside underground railway trains

1 Scope

This Supplement reports evaluations of electromagnetic field (EMF) strength inside underground railway trains.

2 References

[ITU-T K.100] Recommendation ITU-T K.100 (2019), *Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service*.

[IEC 62232] IEC 62232:2017, *Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 electric field strength (*E*) [b-ITU-T K.83]: Magnitude of a field vector at a point that represents the force (F) on a small test charge (q) divided by the charge:

$$E = \frac{F}{q}$$

The electric field strength is expressed in units of volt per metre (V/m).

3.1.2 electromagnetic field (EMF) [b-ITU-T K.91]: A field determined by a set of four interrelated vector quantities that characterizes, together with the electric current density and the volumic electric charge, the electric and magnetic conditions of a material medium or of a vacuum.

3.1.3 exposure [b-ITU-T K.52]: Exposure occurs whenever a person is exposed to electric, magnetic or electromagnetic fields, or to contact currents other than those originating from physiological processes in the body or other natural phenomena.

3.1.4 exposure level [b-ITU-T K.70]: Value given in the appropriate quantity used when to express the degree of exposure of a person to electromagnetic fields or contact currents.

3.1.5 exposure limits [b-ITU-T K.70]: Values of the basic restrictions or reference levels acknowledged, according to obligatory regulations, as the limits for the permissible maximum level of the human exposure to the electromagnetic fields.

3.1.6 far-field region [b-ITU-T K.83]: Region of the field of an antenna where the radial field distribution is essentially dependent inversely on the distance from the antenna. In this region, the field has a predominantly plane-wave character, i.e., locally uniform distribution of electric field and magnetic field in planes transverse to the direction of propagation.

NOTE – In the far-field region, the vectors of the electric field E and the magnetic field H are perpendicular to each other, and the quotient between the value of the electric field strength E and the magnetic field strength H is constant and equals the impedance of free space Z_0.

3.2 Terms defined in this Supplement

This Supplement defines the following term:

3.2.1 reference levels: Reference levels are provided for the purpose of comparison with exposure quantities in air. The reference levels are expressed as electric field strength (*E*), magnetic field strength (*H*) and power density (*S*) values.

NOTE – In this Supplement the reference levels are used for the exposure assessment.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

EMF Electromagnetic Field

GPS Global Positioning System

LTE Long-Term Evolution

Wi-Fi Wireless Fidelity

5 Conventions

None.

6 Measurement position in the train

Measurement positions were selected equidistant from the left and right walls based on the travelling direction of the train. Then measurements were taken by positioning the probe at a height of 1.5 m from the bottom of the train. All measurement positions are located in the far-field region. See Figure 1.

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Figure 1 – Tunnel and underground railway train

7 Method and equipment for measuring the electric field strength

Equipment consisted mainly of an isotropic probe, receiver and shielding cable, which was longer than 1.5 m. The probe was supported by a tripod made by wood. The receiver is capable of frequency selection, allowing the independent monitoring of the various frequency bands. Because the measurements were performed in the far field region, only electric field strength, which is one of the reference levels, was measured. See [ITU-T K.100] and [IEC 62232] for detailed measurement methodologies. See Figure 2 and Table 1.

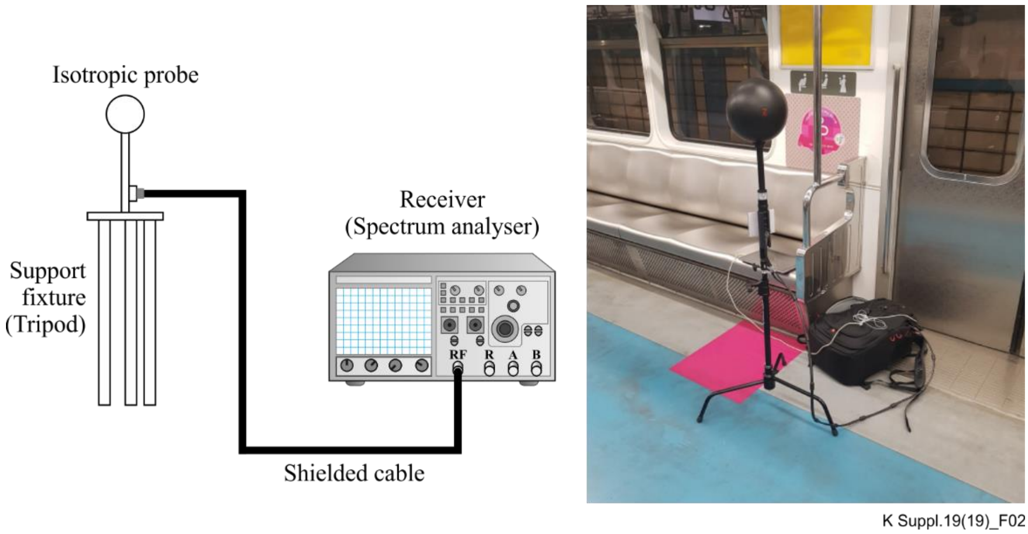

Figure 2 – Set-up and measurement scene

Table 1 – Main equipment

Isotropic probe	Frequency range: At least 30 MHz to 3 GHz or higher At least 0.05 V/m or less, up to 100 V/m or higher Isotropic properties: Within ±2.5 dB
Receiver	Frequency range: At least 30.0 MHz to 3.0 GHz or higher Sweep time:10 ms to 1 000 s
Support	1.1 m, 1.5 m, 1.7 m height adjustment function Material and mass: Wood, 2.2 kg or less

8 Synchronization with real-time context-aware system

The entry into and exit from the underground railway tunnel section by the train is detected in real time by analysing acoustic patterns and wireless fidelity (Wi-Fi) signals, because in the underground railway environment, reception of global positioning system (GPS) signals is impossible. Measurement data are transmitted in real time to the cloud server via long-term evolution (LTE) communication through synchronization with measurement equipment and through mapping changes in position. See Figure 3.

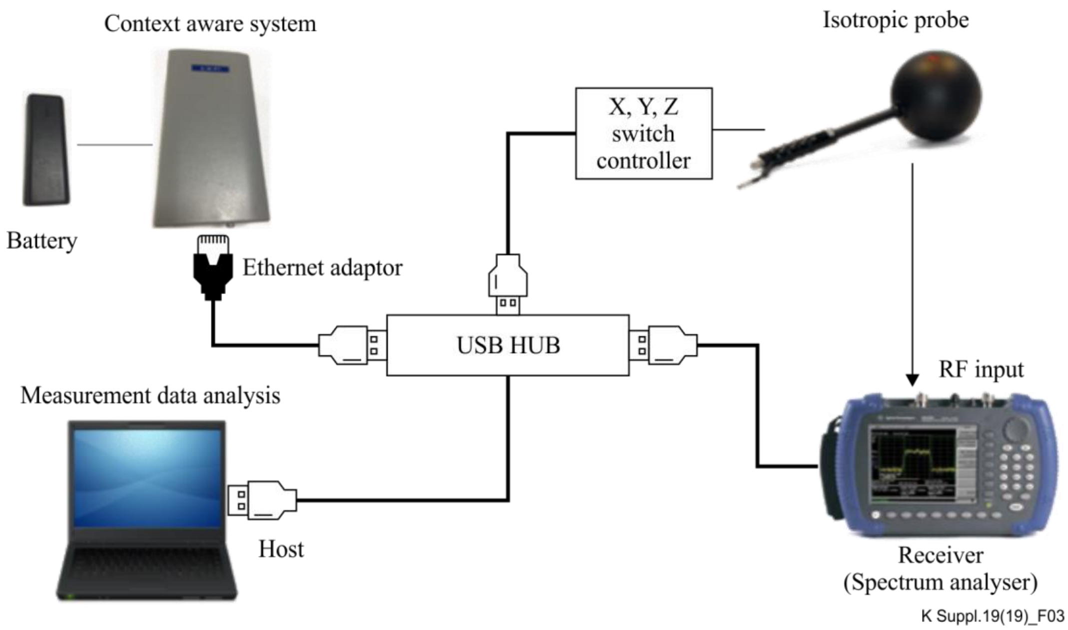

Figure 3 – Synchronization system

9 Target signal

Target signals are 10 bands of LTE signals of three mobile telecommunication service companies. The frequency band is in the 800 ~ 2 100 MHz range. These bands contain both the down-link and up-link signals. See Table 2.

Table 2 – Frequency band for measurement of EMF strength

Service companies	LTE base station frequency band (MHz)			
	LTE low	LTE mid	LTE high1	LTE high2
S	874~884	1 810~1 830	2 130~2 140	2 620~2 640, 2 660~2 670
K	949.3~959.3	1 830~1 860	2 150~2 160	–
L	884~894	–	2 110~2 130	2 640~2 660

10 Measurement locations

Measurements were performed on the 10 underground railway lines in Seoul, South Korea, avoiding rush hours in the morning and evening (10:00~17:00).The detailed operating information is summarized in Table 3 and Figure 4.

Table 3 – Measurement locations

Type	Departure station	Arrival station	Travel Time (one-way) (min)
Line 1	Incheon Station	Dobongsan	110
Line 2	City Hall Station	City Hall Station	90
Line 3	Daehwa Station	Ogeum	96
Line 4	Oido Station	Danggogae	115

Table 3 – Measurement locations

Type	Departure station	Arrival station	Travel Time (one-way) (min)
Line 5	Banghwa Station	Macheon	90
Line 6	Bulgwang Station	Bonghwasan	65
Line 7	Bupyeong-gu Office Station	Jangam	105
Line 8	Moran Station	Amsa	30
Line 9	Gaehwa Station	Sports Complex Station	75
Bundang Line	Moran Station	Wangsipri Station	35

Figure 4 –Underground railway map, Seoul, South Korea

11 Tunnel section where values were measured

Three round-trip measurements were performed from the departure to the arrival station for each line. Six measurements were carried out for every single trip. The peak-values were saved with the sweep time depending on the frequency range of the target signals and the average values (six measurements) of electric field strength derived from every tunnel.

12 Tunnel section values

The highest measurement value or exposure level was observed as 2.09 V/m in line 7. This value corresponds to 4.95% of that of the [b-ICNIRP] guidelines. The minimum value was 1.00 V/m (2.36% of that in [b-ICNIRP]). See Table 4.

Table 4 – Measurement results

	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Line 7	Line 8	Line 9	Bundang Line
Average values (V/m)	1.35	1.5	1.35	1.19	1.73	1.30	2.09	1.26	1.00	1.03
Ratio to guidelines (%)	3.20	0.67	3.19	2.83	4.10	3.08	4.95	3.00	2.36	2.44

13 Conclusion

The EMFs generated from mobile communication base stations in underground railways were investigated and analysed for the first time. The results provide accurate information and a useful basis for resolving the concern about health effects where a mobile communication network is indispensable for expeditious response to emergency arising from the surge in the use of smartphones.

A survey of the current status of EMF strength was performed efficiently, using an equipment capable of detecting the entry into and exit from a tunnel section by a train. The train position was tracked in real time based on the acoustics and unique identification number of Wi-Fi for each underground railway station in conjunction with the EMF measurement equipment in an underground railway environment subject to interference with reception of GPS signals. The maximum value of EMF strength was observed to be 2.09 V/m (4.95% of exposure limits).

Bibliography

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