Theoretical Analysis and Test of EMF in TDFI Bus

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Abstract— There are growing concerns of electromagnetic radiation, and we performed some tests and theoretical analysis to provide some insight for RF exposure assessment of TDFI equipment. The result of EMF testing in TDFI bus shows that the EMF level generated by TDFI equipment is much less than international standard and people can use it safely.

1. INTRODUCTION

The fourth generation of mobile communications is expected to deliver multimedia services anywhere, anytime, with global support and integrated wireless solutions. TDFI is equipment which transform TD-SCDMA/TD-LTE network signal into WIFI signal, Using TDFI solution, people riding in buses can experience rapid and stable LTE TDD data services using WIFI-enabled smart phones.

Meanwhile, the electromagnetic radiation generated by TDFI is drawing the public's increasing attention. Although the radiation power of TDFI is little, it has both TDS/TDL antenna and WIFI antenna; passengers and drivers are likely to locate in the strong electromagnetic radiation field when riding in buses. For the above reason, we performed some tests and theoretical analysis to provide some insight for RF exposure assessment of TDFI equipment.

In this paper, the bus, which has been installed the TDFI equipment, is named TDFI bus. The result of EMF testing in TDFI bus shows that the EMF level generated by TDFI equipment is less than 0.5 $\mu W/cm^2$, which is much less than international standard (20 $\mu W/cm^2$) [1].

2. BRIEF DESCRIPTIONS OF TDFI

TDFI is Mobile/WIFI Integration equipment. There are two modules in TDFI: one WLAN module is used for Wireless Access, the other TD-SCDMA/TD-LTE module is used for Wireless backhaul instead of a Wired Network. The TD-SCDMA/TD-LTE module receives signals from the Macro network and then relays them towards the end users using WIFI.

TDFI can be deployed in places without IP backhaul network, we use TDFI equipment to solve WLAN backhaul problems and increase usage of TD-SCDMA/TD-LTE networks. With TDFI, end users can access TD-SCDMA/TD-LTE networks with any WIFI-enabled devices to enjoy high-speed mobile data services.

Figure 1 shows the comparison of Traditional WLAN and TDFI, traditional WIFI networks utilize wired transmissions, which causes a lack of transmission resources and a lengthy deployment process. The TDFI solution adopts wireless backhaul instead of wired backhaul to solve the last-mile problem of WLAN deployment. Compared to traditional WIFI networks, the TDFI solution helps operators achieve rapid, low-cost deployment and supports WIFI user authentication and billing.

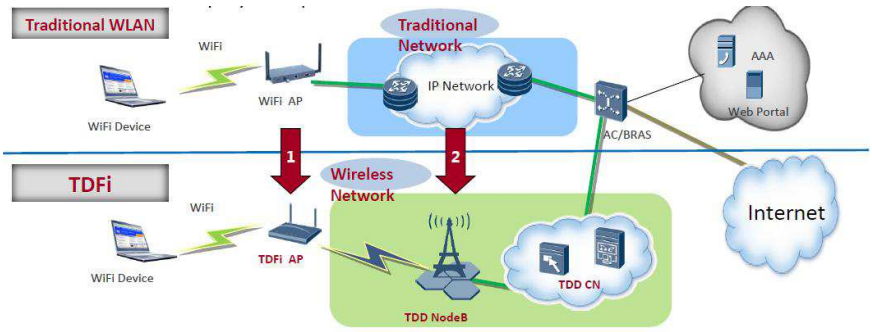


Figure 1: Traditional WLAN and TDFI.

TDFI are mainly deployed in buses, passengers can use the high speed service when the bus is moving. WIFI service on buses has been launched in 1,800 buses on 60 routes in Beijing by March

2013, including No. 1, 52, 57 and 300. It is expected more than 10,000 buses will install Wi-Fi by the end of the 2013.

3. THEORETICAL ANALYSIS AND TEST OF EMF IN TDFI BUS

3.1. Theoretical Analysis

TDFI has both TDS/TDL antenna and WIFI antenna, parameters of TDS/TDL antenna and WIFI antenna are shown in Table 1, TDS/TDL module has 2 elements, average output power of each element is 23 dBm (200 mW). Frame structure of Up/down collocation is DSUUDDSUUD, so the duty ratio is 0.4.

Table 1: Parameters of TDS/TDL antenna and WIFI antenna [2].

TDS/TDL Antenna	Built-in omnidirectional antenna, 3 dBi
WIFI Antenna	8 dBi directional antenna
TDS/TDL Power	2*(23±2 dBm)
WIFI Power	IEEE 802.11b: 15±2 dBm; IEEE 802.11g: 13±2 dBm; IEEE 802.11n: 11±2 dBm
WLAN	2.4G 802.11b/g/n
Size	200 mm × 240 mm × 61 mm (3L)

For propagation distances d much larger than the antenna size, transmit antenna modeled as a point source, the power density S at distance d from a transmitter with power P and antenna gain G is:

$$S = \frac{P_t G_t}{4\pi d^2} \tag{1}$$

In the TDFI bus, the received power S is the sum of TDS/TDL antenna and WIFI antenna radiation energy. There are four parameters, P_1, P_2, G_1, G_2, which represent the TDS/TDL Power, WIFI Power, TDS/TDL Antenna Gain, WIFI Antenna Gain.

$$S = \frac{P_1 G_1 * 0.4}{4\pi d^2} + \frac{P_2 G_2}{4\pi d^2} \tag{2}$$

As the propagation distance increases, the radiated energy is spread over the surface of a sphere of radius d, the path loss PL between two antennas can be expressed as follows, where the loss is found in dB.

$$PL = 32.44 + 20\log d\ (\text{km}) + 20\log f_c(\text{MHz}) \tag{3}$$

The 307 bus, which has two coaches, is 18 meters long, 2.5 meters wide and 3.5 meters high, and the TDFI is installed behind the driver. We choose 8 points for EMF analysis and testing.

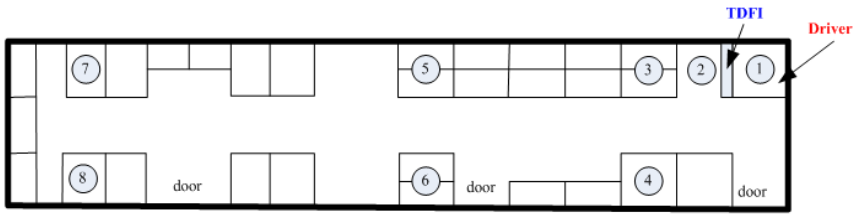


Figure 2: Sampling points of TDFI bus.

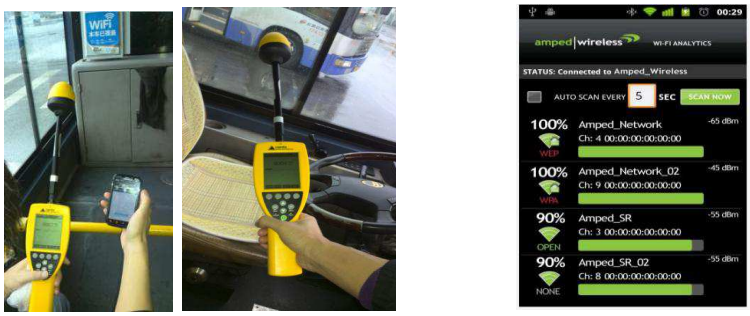
The WIFI works in 2400 MHz. Energy contribution of WIFI antenna in point 1 is ignored as it is 8 dBi directional antenna and front-to-back ratio of WIFI antenna is about 12 dB, using the average of TDS/TDL Power and WIFI Power, the theoretical calculation result is shown in Table 2.

Table 2: Theoretical calculation result.

Point	Distance (m)	Theoretical calculation result			
		S (V/m)	S (μW/cm^2)	PL (dB)	WIFI signal strength (dBm)
1	0.5 (driver position)	6.18	10.14	34.02	−33.02
2	0.5	7.30	14.15	34.02	−21.02
3	1.5	2.43	1.57	43.57	−30.57
4	2.5	1.46	0.57	48.00	−35.00
5	8	0.46	0.06	58.11	−45.11
6	8.5	0.43	0.05	58.63	−45.63
7	16	0.23	0.01	64.13	−51.13
8	16.5	0.22	0.01	64.39	−51.39

3.2. EMF Test in TDFI Bus

Two tools were used to test the EMF in the 307 TDFI bus, as shown in Figure 3, one is broadband field meter NBM 550, and anther is Wi-Fi Analytics app in mobile phone. The Amped Wireless Wi-Fi Analytics Tool analyzes the Wi-Fi networks. It provides advanced signal strength graphs of Wi-Fi network.



(a) (b)

Figure 3: Test tools ((a) NBM550, (b) Wi-Fi Analytics app).

Record the measured values three times and take the average, the test result is shown in Table 3.

Table 3: Testing result.

Point	Distance (m)	Measured value (average)	
		NBM 550 (μW/cm^2)	Wi-Fi Analytics (dBm)
1	0.5 (driver position)	0.4	−39
2	0.5	0.7	−35
3	1.5	0.3	−37
4	2.5	0.2	−43
5	8	0.1	−45
6	8.5	0.1	−47
7	16	0.1	−50
8	16.5	0.1	−51

Take no account of point 1, theoretical analysis result and testing result of electromagnetic radiation (EMR) intensity in TDFI bus is compared in Figure 6, and theoretical analysis result and testing result of WIFI signal intensity in TDFI bus is compared in Figure 7.

Figure 4: The appearance and inside of 307 TDFI bus.

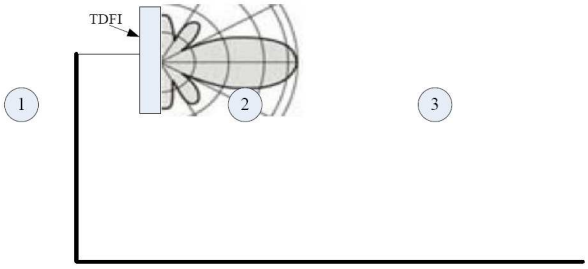


Figure 5: Side view of test point.

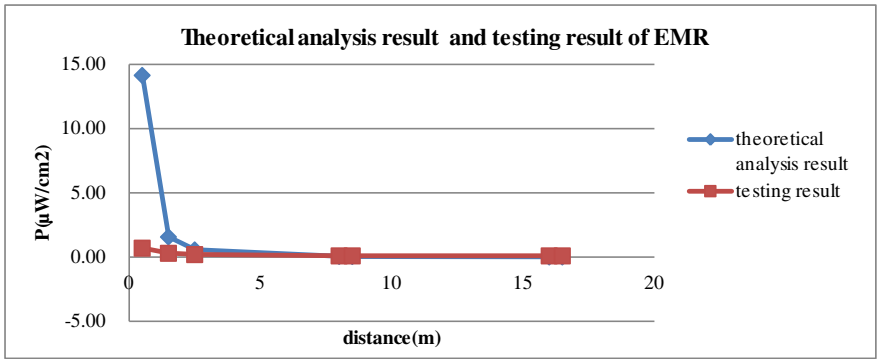


Figure 6: Theoretical analysis result and testing result of EMR in TDFI bus.

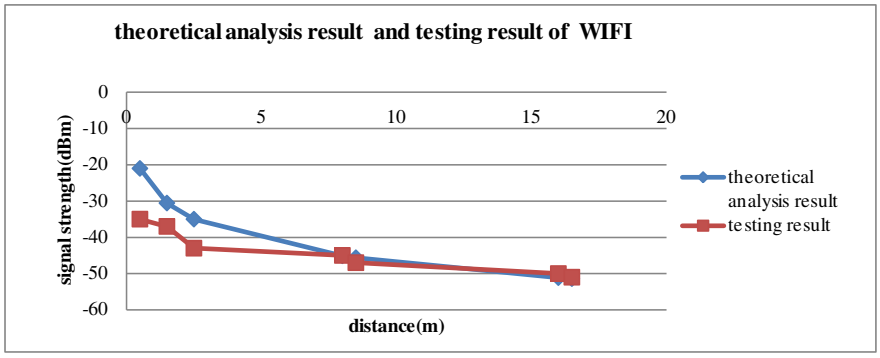


Figure 7: Theoretical analysis result and testing result of WIFI in TDFI bus.

Measured value is identical with the theoretical value while the distance is about 8 m. When the distance is below 8 m, the measured point is not at the main beam direction of the antenna, so the measured value is less than the theoretical value. When the distance is above 8 m, the measured point is affected by the reflection wave, so the measured value is not identical with the theoretical value.

4. CONCLUSIONS

Although passengers and driver is likely to locate in the strong electromagnetic radiation field when riding in buses, theoretical analysis and test of EMR in TDFI bus showed that the EMF level generated by TDFI equipment is less than $0.5\,\mu W/cm^2$, which is much less than international standard ($20\,\mu W/cm^2$).

TDFI can realize hotspot coverage on buses, which will enable further green transportation development. In the near future, the TDFI solution will enable LTE TDD to enrich people's mobile communications in medical care, information sharing, mobile video and community management among others.

REFERENCES

1. GB 8702-88, "Regulations for electromagnetic radiation protection,".
2. TDFi700 product overview v1.0, Huawei Technology Co., Ltd.