

An EMC Study on Intentional Transmitter of Railway Train Base on Poynting Vector

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Abstract—Base on Poynting Vector to determine the field strength sensitive boundary between the intentional transmitter antenna and the equipment or apparatus installed on railway train. A detail calculation is made to analyse radiation field strength. This paper focuses on how to determine the far field of the rod antenna. By analyzing the radiation field strength of the antenna, it is beneficial to determine the layout design of the antenna on the vehicle at the beginning of the design.

Keywords—EMC; intentional Transmitter; poynting vector

I. INTRODUCTION

This paper presents a way to determine the boundary of intentional transmitter, which is sensitive to the equipment or apparatus installed on railway train.

Equipment or apparatus installed on railway train complies with the EN 50121-3-2 EMC Standard. The Standard applies to emission and immunity aspects of EMC for electrical and electronic apparatus, and it states the radiated emission requirement in this standard is not intended to be applicable to the intentional transmission from a radio-transmitter as defined by the ITU.

Intentional transmitter is a high field strength source. Near it, the field strength may exceed the equipment's resistance. Base on Poynting Vector, the boundary can be calculated.

The field strength in the near field is complex and not easy to calculate. The field strength in the far field is easy to calculate. This paper focuses on how to determine the far field of the rod antenna.

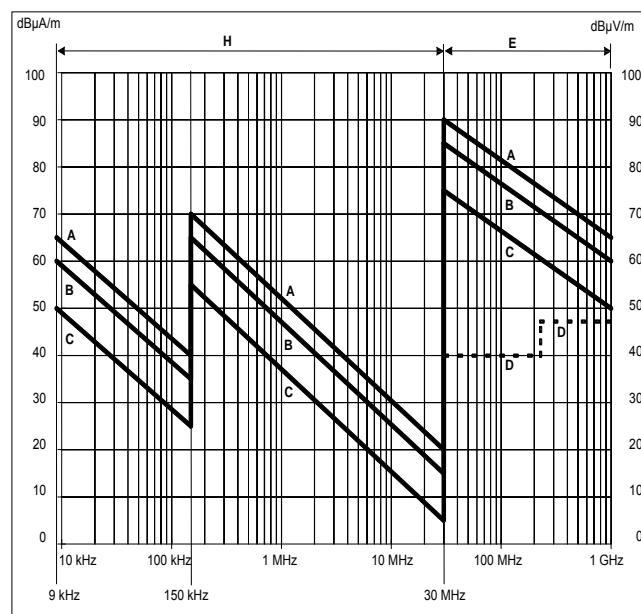
II. EN 50121 REQUIREMENTS

A. Train Unintentional Transmitters Emission Limit

The train has many electronic and power electronics switching devices which are capable of generating electromagnetic disturbances.

All of the systems on the train are designed and tested to satisfy the limits of EN50121-3-1 and EN50121-3-2:2006.

This limits the radiated emissions for the train and systems below 50kVA are shown in Figure 1.



NOTE 1 Emission limits
A = 25 kV a.c.
B = 15 kV a.c., 3 kV d.c. & 1.5 kV d.c.
C = 750 V & 600 V d.c., including trans/trolleybuses for use in city streets
Limits for slow moving test (Peak, 10m)
D = Equipment limits (QP, 10m)

FIGURE 1. UNINTENTIONAL RADIATED EMISSION LIMITS FOR EQUIPMENT AND TRAIN [1, 2]

B. Equipment or Apparatus Immunity Level

The Radiated Immunity Level of the equipment or apparatus installed on railway train refers to Table 1.

TABLE I. RADIATED IMMUNITY LEVEL OF THE EQUIPMENT OR APPARATUS [1]

	Environmental Phenomena	Test specification		Basic Standard	Test set-up	Applicability note	Remarks	Performance criteria
1	Radio-frequency electromagnetic field. Amplitude modulated	80 MHz to 800 MHz 20 V/m (rms) 80 % AM, 1 kHz	Unmodulated carrier	EN 61000–4–3	EN 61000–4–3	See a and b	The test level specified is the rms value of the unmodulated carrier	A
2	Radio-frequency electromagnetic field, from digital communication devices	800 MHz to 1000 MHz 20 V/m (rms) 80 % AM, 1 kHz	Unmodulated carrier	EN 61000–4–3	EN 61000–4–3	See b	The test level specified is the rms value of the unmodulated carrier	A
		1400 MHz to 2000 MHz 10 V/m (rms) 80 % AM, 1 kHz						
		2000 MHz to 2700 MHz 5 V/m (rms) 80 % AM, 1 kHz						
		5100 MHz to 6000 MHz 3 V/m (rms) 80 % AM, 1 kHz						
a This limit applies to equipment mounted in the passenger compartments, drivers cab or external to the rolling stock (roof, underframe). For equipment mounted in all other areas a severity level of 10 V/m may be used. b For large apparatus (e.g. traction drives, auxiliary converters) it is often not practical to perform the immunity test to radiated electromagnetic fields on the complete unit. In such cases the manufacturer should test susceptible sub-systems (e.g. control electronics). The test report should justify the selection or not of sub-systems and any assumptions made (e.g. reduction of field due to case shielding).								

The key characteristics are detail in Table 2 and Table 3.

III. INTENTIONAL TRANSMITTER

The Intentional Transmitter is called Train Radio, it is a Tetra system, which is Terrestrial Enhanced Trunked Radio [4].

TABLE II. TRAIN COMMUNICATION SYSTEM

System	Operating Characteristics		Additional Information
Train Radio System	Frequency bands	380 – 430 MHz, 407 – 473 MHz	Tetra system Located in Cab. Use of screened coax cable to antenna.
	Duplex spacing	5, 7, 8, and 10 MHz programmable	
	Channel	25 kHz	
	Time multiplexing	TDMA, 4 slots per port	
	Digital Modulation	$\pi/4$ DQPSK	
	RF Output Power	1 W	
	Output impedance	50 Ohms	
	Receiver class	Class A and B	
	Static Sensitivity	-112 dBm	
	Dynamic Sensitivity	-103 dBm	

TABLE III. TRAIN RADIO ANTENNA

System	Operating Characteristics		Additional Information
Train Radio Antenna	Frequency range	410 – 430 MHz	Located on Roof of Cab.
	Operational bands	S2	
	Bandwidth @ 2:1 VSWR	5%	
	Gain: Isotropic	2dBi	
	Compare with 1/4 wave	0dB	
	Polarisation	Vertical	
	Groundplane	Integrated baseplate Groundplane	
	Height	42mm	
	Diameter	160mm	
	Material	Engineering Plastic	

IV. TRAIN RADIO ANALYSIS

$$c = 2.997 \times 10^8 \text{ m/s} \quad \text{Speed of light in a vacuum}$$

$$f_1 = 410 \times 10^6 \text{ Hz} \quad f_2 = 430 \times 10^6 \text{ Hz} \quad \text{Upper and lower bounds antenna frequency Tetra range}$$

$$f = 410 \times 10^6 \text{ Hz} \quad \text{Lower bound of frequency in use antenna by Tetra system}$$

$$\lambda = c / f \quad \text{Calculation of wavelength}$$

$$\lambda = 0.731 \text{ m} \quad \text{and} \quad \lambda / 4 = 0.183 \text{ m}$$

The Transition Boundary between Reactive/Radiating Field is calculated from solution of the Raleigh function for practical antennas (ones with finite length) it is found to be $\lambda / 4$.

$$\lambda / 4 = 0.183 \text{ m} \quad \lambda / 2\pi = 0.116 \text{ m} \quad [3, 5]$$

$$\text{The diameter of antenna shroud: diameter} = 160 \text{ mm} \\ \text{radius} = \text{diameter} / 2 = 0.08 \text{ m}$$

From inspection of the antenna the maximum linear dimension of the antenna is the length $D = 42 \text{ mm} = 0.042 \text{ m}$

The transition between near field and far field for a practical (finite) antenna is found by $2D^2 / \lambda = 0.004826 \text{ m}$ Ref 3.4.5

$$\text{As } 2D^2 / \lambda < \lambda / 4, \text{ for the antenna, the far Field will use } \lambda / 2\pi = 0.116 \text{ m} \quad [3, 5]$$

In order to calculate the Electric Field Strength versus distance a variable for distance must be defined.

$$n = 1 : 1000 \quad \text{Index for array variables}$$

$$r_n = (n / 100 + 0.1) \text{ m} \quad \text{Distance variable } r_n \text{ for } 0.1 \text{ m to } 10 \text{ m in } 10 \text{ mm step}$$

$$Pwr = 1 \text{ W} \quad \text{Train Radio System RF Output Power}$$

The Poynting Vector can be used to find the radiated Power Density S of an infinitesimal isotropic antenna. It also holds true for any antenna when the distance is large compared to the antenna dimensions (in wavelength terms) and providing the directive/gain is taking into account.

A. The Poynting Vector

$S = \text{Power} / \text{Area}$ In the case of an isotropic antenna it radiates equally in all directions hence the area is the surface of a sphere $4 * \pi * \text{radius}^2$

$$\text{Gain} = 10^{(2/20)} \quad \text{Convert Gain from dB}$$

$$\text{EIRP} = Pwr * \text{Duty} * \text{Gain} \quad \text{Radiated Power}$$

$$S_n = \text{EIRP} / (4 * \pi * r_n^2) \quad \text{Radiated Power Density}$$

$$\text{For far Field, The Poynting Vector } S = E \wedge H = E^2 / \eta$$

$$\text{In Free Space, the characteristic impedance } \eta_0 = 120 * \pi \Omega$$

$$E_n = \sqrt{S_n * \eta_0} \quad \text{Electric Field Strength}$$

A SCILAB program is used to implement the above calculation.

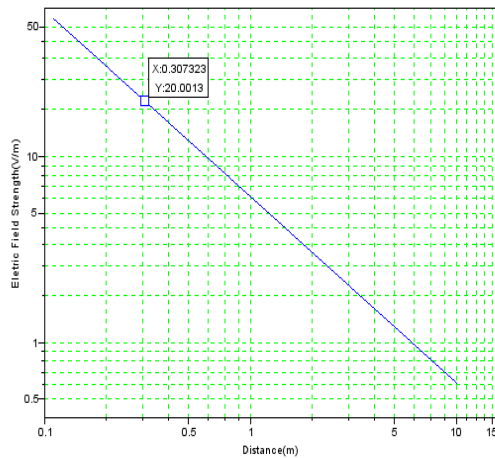


FIGURE II. ELECTRIC FIELD STRENGTH VERSUS DISTANCE FOR TRAIN RADIO ANTENNA

As the frequency is 410MHz, refer to Table 1, the Radiated Immunity Level of the equipment or apparatus is 20V/m.

Finding the Boundary at which 20V/m is exceeded using the Poynting vector from Figure 2.

$$r = 0.30732m = 307.32mm$$

An analysis of the trainborne radio installation shows that the 20V/m field strength threshold is reached at a distance of 0.307m from the centre of the antenna on the top surface of the train. Below top surface of the train radio antenna the field strength will be significant lower due to the antenna polarization. The electrical and electronic equipments on the train have been designed against 20V/m (146dBμV/m) field strength in the train radio frequency range according to EN 50121-3-2, and it should also be noted that the peak field strength in EN50121-3-2 is actually 36V/m due to the 80% Amplitude Modulation. And the location of antenna is away from any emissive equipment on top surface of the train.

V. SUMMARY

By analyzing the radiation field strength of the antenna, it is beneficial to determine the layout design of the antenna on the vehicle at the beginning of the design.

REFERENCES

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