Impact Analysis of Interference Sources on Data Communication System for CBTC application

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Abstract. We study the anti-interference performance of the 802.11 system when it works as Data Communication System (DCS) in Communication Based Train Control (CBTC). We first conduct extensive experiments on a 802.11b network to assess the ability on a lab test bed, then the outdoor experiments are also conducted. In the presence of jammer, we find that in each case of interference model, there exists a C/I threshold which determine the DCS-Access Point (DCS-AP) and DCS-Station Adapter (DCS-STA) communication performance. In the outdoor environment, different interference sources are adopted to investigate the data throughput value and other parameters of the DCS system under the critical state.

Introduction

Nowadays, most of the CBTC systems in China use WLAN technology as its Data Communication System which setting wireless link between train and railway side [1-2]. DCS contains DCS-Access Points (DCS-AP) which on the railway side and DCS-Station Adapters (DCS-STA) which on the locomotives. Because WLAN is working in the 2.4 GHz ISM band which is unlicensed, the variety of devices operates in this band and the rising RF interference disturbs CBTC somehow.[3-4] The technologies applied in DCS for CBTC application to counteract interference contain modulation, directive antennas, channel access scheme as well as carrier sense and collision avoidance. The two carrier frequencies are often used to realize frequency diversity to enhance the DCS system performance. Some papers evaluate the effectiveness of such devices in vehicle environments [5]. In this paper we consider 802.11b as a DCS system which using DSSS. When DCS and interference source are using the same spreading method at the same band, for example both systems are WiFi, the DCS performance is dramatically degraded. In this case carrier to Interference ratio (C/I) will be critical. On the other hand, if DCS and Interference source are using different modulation schemes. For example, the DCS is 802.11b using DSSS and the interference source is Bluetooth using FHSS, the impact will be less. The designers often make radio coverage to calculate carrier over interference [6]. They should consider following factors: the transmit output power, connector and cable losses, splitter and combiner losses, transmit antenna gain, path loss, receive antenna gain and receiver sensitivity. To evaluate the interference effect accurately, we conduct extensive experiments on a 802.11b network to assess the system ability on a lab test bed, and also in the outdoor environment to simulate practical electromagnetic case. And we focus on the DCS and interference systems are both using DSSS technology. The paper is organized as followings: Part 1 we illuminate the experiments in lad test bed. Part 2 the DCS-STA performance under interference on the ground is presented. Part 3 shows DCS-AP performance under interference on the ground. Part 4 is the conclusion.

Test arrangement in lab

To test the anti-interference performance of DCS, the architecture was set up as in Fig 1 in which the AP and STA are tested, the Agilent E4437B vector generator and WiFi-AP are set as interference sources. The vector generator is used to transmit AWGN with 10M bandwidth and adjustable power. The test system contains Agilent 11667A splitter and Agilent 8496B adjustable attenuator. DEMO software is applied to present measurement data.
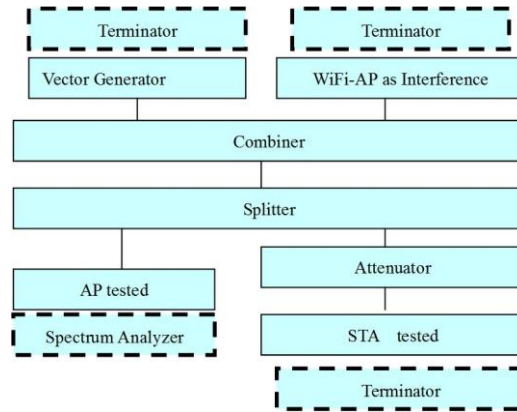

Fig. 1 Carrier to interference ratio testing scheme

In cases of testing received power, some devices should be replaced by terminators or spectrum analyzer shown as dashed blocks in Fig. 1. First the DCS under the interference of AWGN is tested, while WiFi-AP is switched off and the AWGN is transmitted from the generator. The DCS carrier central frequency is 2458MHz. When AWGN power is -40dBm, the spectrum analyzer indicates -65dBm/10MHz or -75dBm/1MHz for interference. The DCS power is -72.36dBm/1MHz. The test results are presented as in table 1.

Table. 1 DCS single carrier under interference

Carrier power		Interference power		C/I（dB）	Throughout loss（%）	performance
Read by software（dBm）	Read by analyzer (dBm/MHz)	Set in generator（dBm）	Read at test point (dBm/MHz)	C_2/I_2	F2	F2
-73	-72.36	-40	-75	2.64	94.35	failure
-71					91.79	failure
-73	-72.36	-42	-77	4.64	56.2	failure
-73					59.51	failure
-73	-72.36	-45	-80	7.64	4.72	pass
-73					7.53	pass

The results shows according to the DCS requirements, the below two rows are satisfied, while the top four rows are failure. Secondly, DCS works at two carriers which transmitting the same data for frequency diversity. The central frequencies are 2408MHz and 2458MHz. The interference source WiFi-AP is switched on and the transmitting frequency is 2412MHz which interferes with the carrier 1. WiFi-AP is set as test mode and interference I1 is 10dB higher than carrier C2. At the test point, the spectrum analyzer shows that I1 is -29.7dBm/22MHz or -43.1dBm/1MHz. The DCS power for C1 and C2 is -72.3dBm/1MHz. Thus

C1/I1＝(-72.3)－(-43.1)＝-29.2dB

The test results are shown in table 2.

Table.2 DCS double carrier under interferences

Carrier (dBm/MHz)		Interference (dBm/MHz)		C/I（dB）		Throughout loss（%）		Response time(s)	FER （%）	Performance		DCS performance
F1: C1	F2: C2	WiFi:I1	Generator:I2	C1/I1	C2/I2	F1	F2	F2	F2	F1	F2	
-72.3	-72.4	-43.1	-75	-29.2	2.64	100	92.19	21.71	83.87	failure	failure	failure
						99.7	86.89	31.03	75.3	failure	failure	failure
-72.3	-72.4	-43.1	-77	-29.2	4.64	99.61	46.06	1.89	19.25	failure	failure	failure
						100	43.6	1.42	20.16	failure	failure	failure
-72.3	-72.4	-43.1	-80	-29.2	7.64	100	1.18	0	0	failure	pass	pass
						100	2.21	0	0	failure	pass	pass

When DCS two carriers both under the AWGN interference，and C/I≤4.64dB, the throughout loss is higher than 10％ and carrier is considered as failure. When C/I≤2.64dB, the throughout loss is very high and the response time is 26.37s which greater than standard 3s, the FER is 79.85％ which greater than standard 30％. Then the DCS system is considered as failure. At the bottom row, because carrier 2 is not interfered and transmit the same information, then the DCS system fit the requirement. The test data read from DEMO software and that from spectrum analyzer is very close and the difference is less than 1dB.

2. DCS-STA under interference on the ground

The more tests are conducted in cases of DCS-STA under the interferences of some systems working in the ISM band, such as WiFi, PTP (P-com AUFSD-2G1). The tests are carried out on the ground as shown in Fig. 2. The AP is at the right side position D(0m, 0m) of the street and the SA is placed at the left side, positions of A1(340m, 0m), A2(320m, 0m), A3(300m, 0m), A4(280m, 0m), A5(260m, 0m), while the interference is placed at position of I1(283m, 11m).
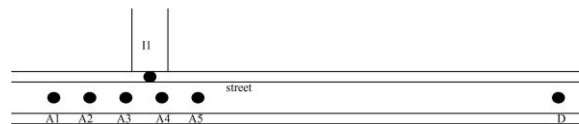

Fig.2   Test arrangement on the ground

The tested system works in frequency diversity state which two working frequency channels are used to transmit the same data apart. There are two interference models: The first one is that only one working frequency is under the interference while the other working frequency works without any interference. The second model is that two working frequency work under interferences. The carrier power is adjusted by changing the attenuations. Figure 3 shows DCS-STA performance under the interferences of WiFi. Figure 4 shows DCS-STA performance under the interferences of PTP.
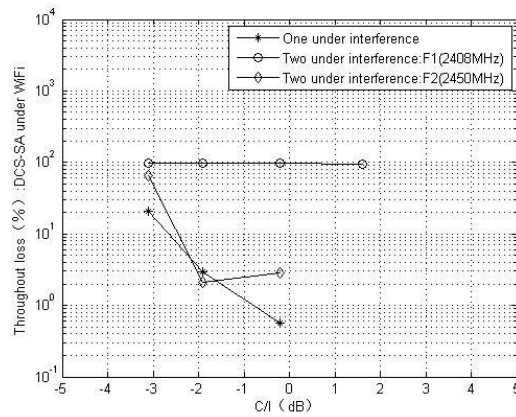
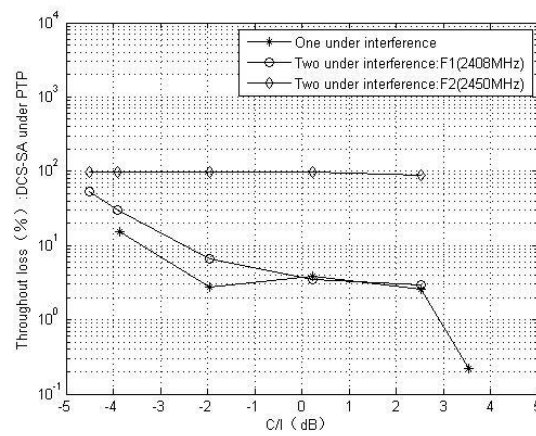Fig.3   DCS-STA under the interferences of WiFi.

Fig.4 DCS-STA under the interferences of PTP

DCS-AP under interference on the ground

The more tests are carried out in cases of DCS-AP under the interferences of some systems working in the ISM band, such as Wi-Fi, PTP. Figure 5 shows DCS-AP performance under the interferences of Wi-Fi. Figure 6 shows DCS-AP performance under the interferences of PTP.
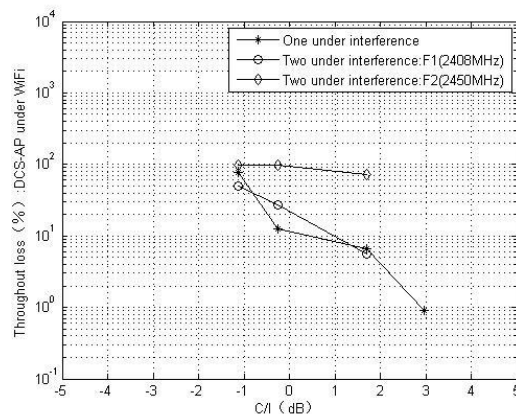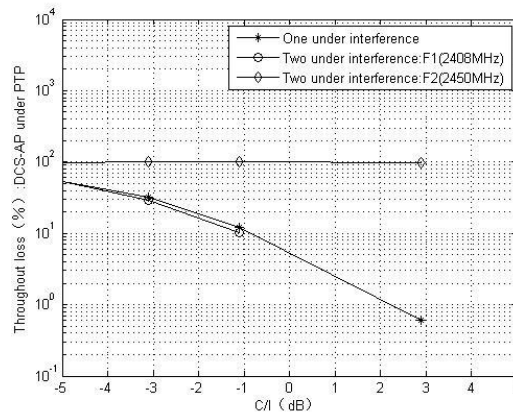

Fig.5   DCS-AP under the interferences of WiFi.

Fig.6   DCS-AP under the interferences of PTP

Conclusion

In case of DCS uses DSSS technology and the interference sources are also use the same modulation, the C/I and the throughput is investigated. As far as single frequency is considered, when C/I is less than or equal to 4.64dB, the channel does not reach the standard for the throughput loss. Outdoor tests show that the DCS throughput loss is worse due to interference of WiFi than that duo to PTP. The results will help designers to avoid DCS system degradation duo to potential interferences.

Aknowledgement

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