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ASSESSMENT OF WIRELESS COMMUNICATION QUALITY BASED ON INDUSTRIAL NOISE

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ABSTRACT

Owing to noise in industrial environment, wireless signal is seriously interfered in industrial environment, and wireless communication quality will be affected seriously. Requirements of industrial wireless network and the wireless network standards are analyzed in this paper. The wireless communication quality model of IEEE 802.15.4 and IEEE802.11b is deduced. The simulation system based on this wireless communication quality model is established by Matlab. The simulation presents and compares communication quality of IEEE 802.15.4 and IEEE802.11b at the industrial noise range (typically between 20dB and 80 dB) and security level (IEC61508 defined standard- SIL1, SIL2 and SIL3).

Keywords: *Communication Quality, Wireless Communication, Industrial Noise, IEC61508*

1. INTRODUCTION

Wireless communication technology has become a hot spot in the study field of industrial network control system based on wireless (WNCS). Wireless technology can bring many benefits to industrial network control system. However, wireless technology have not gained widespread acceptance at the factory floor. One reason is the difficulty in achieving the real-time and successful transmission of packets by error-prone wireless channels [1, 2].

Wireless industrial networks have created interest in both academia and industry. The first publications date back to 1988. One of the earliest projects, the European Union OLCHFA project, started in June 1992 with the goal to provide wireless spread-spectrum transmission for the WorldFIP (formerly just FIP) fieldbus. Today, several companies and consortia are active, for example, the wireless industrial networking alliance (WINA). They are considering the use of standardized wireless technologies like IEEE 802.11, BT, or IEEE 802.15.4 in a fieldbus-controlled industrial network. But the communication quality of the existing wireless communication technologies will decline seriously in the worst industrial environments. So the wireless technology is not used widely in the industrial field.

For the purpose of improving the performance of wireless signal transmission, it is important that the wireless communication quality based on industrial noise is discussed. So, we summarize requirements of industrial wireless network, and establish communication quality model, and discuss wireless communication quality based on industrial noise by simulation in this paper, which will be useful to engineer and researchers.

2. REQUIREMENTS OF INDUSTRIAL WIRELESS NETWORK

The requirements of the industrial wireless network are included as follows:

(a)Reliability: Reliability includes real-time, deterministic, redundancy etc., it is far more important than others.

(b)Security: The wireless medium is an open medium. Attacker is easy to eavesdrop it, and to insert malicious packets, or to jam the medium. These ways will affect system operation.

(c)Robustness: it included housing protection level, temperature range, energy consumption, simple installation and operation etc. In addition, protocol scalability and energy efficiency is also required.

3. WIRELESS NETWORK STANDARDS

The existing standards of wireless network technology (defined by the IEEE) are divided by network coverage. A brief overview of the various standards is as follows [3, 4]:

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1) Wireless WAN (IEEE802.20): IEEE802.20 is a new mobile wireless standard for data communications, known as 4G challenger. The coverage of the standard is the same with the existing mobile phone systems. They are on a global scale. The transmission rate has reached at the level of Wi-Fi.

2) Wireless MAN (IEEE802.16): IEEE802.16 is establishing a wireless access path between the user region and the backbone network. The backbone network may be a public telephone network or Internet.

3) Wireless LAN (IEEE802.11): IEEE802.11 defined that wireless LAN can be operated in the 2.4GHz band, this band is defined the spread spectrum band by the global radio regulations entity. On August 1999, IEEE802.11 standard had been further improved and revised. A SNMP protocol based on MIB is used to replace the original OSI protocol based on MIB. It adds two elements. One is IEEE802.11a standard, which extends the physical layer standard. Its working frequency band is 5GHz, and QFSK modulation is used. The transmission rate is between 6Mb/s and 54Mb/s. The other is IEEE802.11b standard. It works at 2.4GHz frequency band, and uses compensation code keying (CCK) modulation. Its transmission rate is 11Mb/s.

4) Wireless PAN (IEEE802.15): IEEE802.15 commission has developed three different WPAN standards. IEEE802.15.1 standard is a wireless network technology of moderate rate, and it adapts to the short communication. Its QoS mechanisms are suitable for voice services. IEEE802.15.3 is a high-rate WPAN standard, and is suitable for multimedia applications. It has a higher QoS, and it uses UWB technology in physical layer. IEEE802.15.4 standard is a wireless network technology of low-power and low-cost, its target markets are industry, families, medical industry and others.

Basic parameters of the above standards [5]-[9] are shown as Table 1:

Table 1: The Basic Parameters Of Wireless Network Standard

1Protocol		Modulation/spread spectrum	Frequency	Transmission Rate	Range
802.11	802.11	DSSS,FHSS	2.4G	2M	100m
	802.11a	OFDM	5G	6-54M	100m
	802.11b	CCK/DSSS	2.4G	2-11M	100m
	802.11g	OFDM	2.4G	11M,54M	100m
802.15	802.15.1	FHSS	2.4G	1Mbps	10m
	802.15.3	Multiband OFDM and DS-CDMA	2.4G	100Mb/s	10m
	802.15.4	DSSS	868/915MHz 2.4GHz	20-250K/s	30-100m
802.16	802.11a	Single carrier and many carriers OFDM	2~11GHz	74Mb/s	50km
	802.16b	OFDM, TDMA and OFDMA	5－6GHz		50km
802.20		OFDM	3.5GHz below	1Mbps/user	

4. WIRELESS COMMUNICATION QUALITY MODEL

Assuming that the signal propagates in free space, the attenuation coefficient AFS in free space can be defined as below:

$$A_{FS}(f) = \frac{\alpha(4\pi)^2 D^2 f^2}{G_T G_R c^2} + \partial \quad (1)$$

In the formula, G_T is the gain of omnidirectional antenna; C is the speed of light: 3×10^8m/s; G_R is the effective area of the receiving antenna. α is correction parameter. ∂ is a parameter for different wireless network standard.

Now, we suppose that $P_S(f)$ is the power spectral density, therefore, the total transmits power P_S is equal to quadrature of $P_S(f)$ in the range of transmission frequency. If f_H and f_L are the upper and lower frequency in the range, the total transmits power P_S is:

$$P_s = 2\int_{f_L}^{f_H} P_s(f)df \quad (2)$$

When the given formula (1) is used for attenuation coefficient in free space, by the method of P.H. Sheng et al [10], signal power P_r received by receiver can be shown as follow:

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$$P_r = 2\int_{f_L}^{f_H} \frac{P_s(f)}{A_{FS}(f)} df = 2\int_{f_L}^{f_H} P_s(f) \frac{1}{a(4\pi)^2 D^2 f^e \Big/ G_T G_R c^2 + \partial} df \quad (3)$$

The system margin of the receiver is M_S. If the requirements of SNR_{spec} are met, the signal power P_r may be expressed:

$$P_r = M_s SNR_{spec} P_N \quad (4)$$

Receiver receives signals by receiving energy E in the limited interval time, E is mainly composed of two components: signal energy E_r and noise energy E_{noise}. Noise energy may come from a lot of noise sources. These noise sources are uncorrelated and independent, such as thermal noise, multi-user interference and external interference. So the expression of E is shown as Equation 5. [10]:

$$E = E_r + \sum_{i=1}^{N} E_i = E_r + E_{noise} \quad (5)$$

Where, $SNR_{spec}(i = 1,..., N)$ is corresponding to different noise sources.

$$SNR_i = E_r / E_i \quad (6)$$

According to channel model and parameters of IEEE 802.15.4 and IEEE 802.11b in physical layer, we can model and analysis by *Matlab*.

5. SIMULATION AND RESULT NALYSIS

5.1 Simulation

First, we calculate spectral density of Gaussian [10]. Secondly, we must obtain the *PSD* and *frequency* (limited range $[f_L, f_H]$) by the function (*n_Gaussian_PSD)* [11]. Finally, using the above results and formula (3), we obtain link budget under a certain noise and error rate. The realization is as follows:

```
function [f_vector, PSD_vector] =
threshold_fr_PSD_vectors(fr, PSD, threshold)
L = length(fr);
f = fr(length(fr))/length(fr);
[P_high,index] = max(PSD);
f_peak = index * f;
P_threshold = P_high*10^(threshold/10);
index_max = index;
P0h = PSD(index);
while (P0h>P_threshold )&(index_max<=L)
      index_max = index_max + 1;
      P0h = PSD(index_max);
end
f_high = (index_max-1) * f;
index_min = index;
P0l = PSD(index);
while (P0l>P_threshold)&(index_min>1)&(index>1)
      index_min = index_min - 1;
      P0l = PSD(index_min);
end
f_low = (min(index,index_min)-1) * f;
BW = f_high - f_low;
f_vector = f(index_min:index_max);
PSD_vector = PSD(index_min:index_max);
```

```
function [R_M_t, R_M_t] =
link_budget(link_M,F_noise, fr, PSD,Pre, x1, x2)
dist=zeros(3,19);
Rb=linspace(x1,x2,19); % rate range
M = 2;
F = 10^(F_noise/10);       % W to dBm conversion
l_M = 10^(link_M/10);
kt = 1.38e-23;
T0 = 300;
Gf=1;    % Gf said transmitter antenna gain
Gs=1;     % Gs that the receiver antenna gain
N0 = F*kt*T0;
Eb_N0 = logspace(0.5,2);
for i=1:3
      Pre_temp = 1;
         j=1;
      while Pre_temp > Pre
      Pre_temp =(1-1/M)*erfc(sqrt(Eb_N0(j) * 3 *
log2(M)/(M^2-1)));
            Eb_N0_t = Eb_N0(j);
            j=j+1;
      end
   for k=1:19
 D_Rb(i,k) = max_distance(Gf, Gs, fr,PSD,l_M,
1/Rb(k), N0, Eb_N0_t);
      end
end
```

Where, the parameter f_r is vector of frequency range. The parameter *PSD* is the power spectral density of transmitting wave. This function returns value f_vector, and it is the calculated frequency range of bandwidth. The parameter *PSD_vector* included the initial value of power spectral density in the scope of bandwidth. The parameter *link_M* is link margin. The parameter F_noise is noise exponent of the receiver. The parameter $x1$ and $x2$ is range of transmission rate.

5.2 Result Analysis

Using the above procedure, we have simulated. According to the defined industry standard [12] (security level SIL1, SIL1 and SIL3 in IEC61508,

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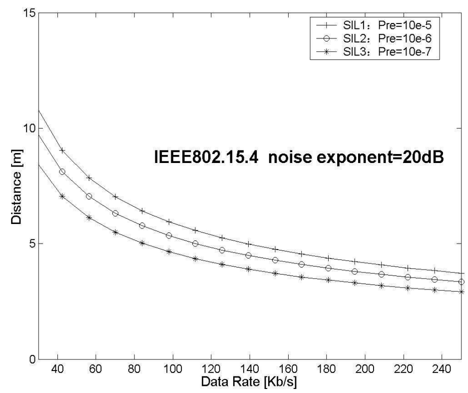
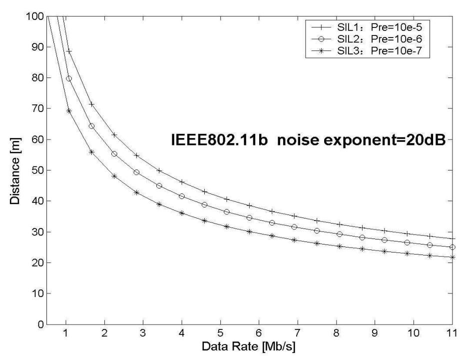
the data error rate is from 10^{-6} to 10^{-5} in SIL1, the data error rate is from 10^{-7} to 10^{-6} in SIL2, the data errors rate is from 10^{-8} to 10^{-7} in SIL3). We can calculate the relationship curves between the maximum transmission distance and data rate under the error rate P_{re} (10^{-5}, 10^{-6} and 10^{-7}) and the noise exponent (20dB, 40dB, 60 dB and 80dB) based on IEEE 802.15.4 and IEEE 802.11b. The curves are shown in Figure 1-4.

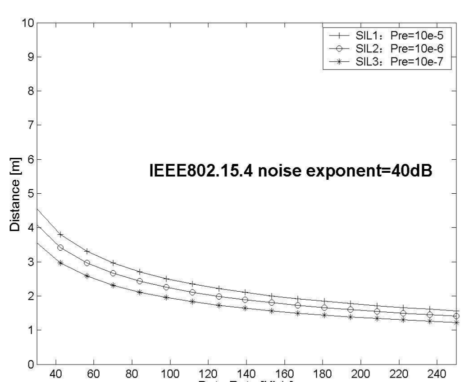


(a)

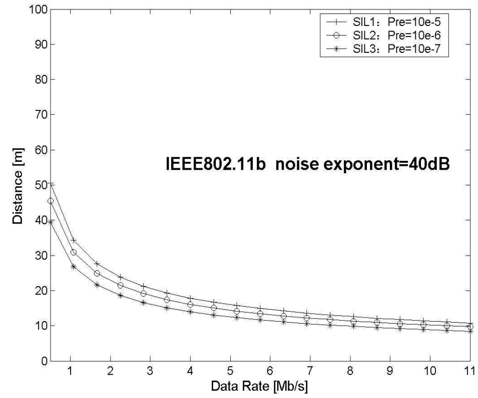


(b)

Figure 1: Relationship of data rate and distance in the noise exponent 20dB

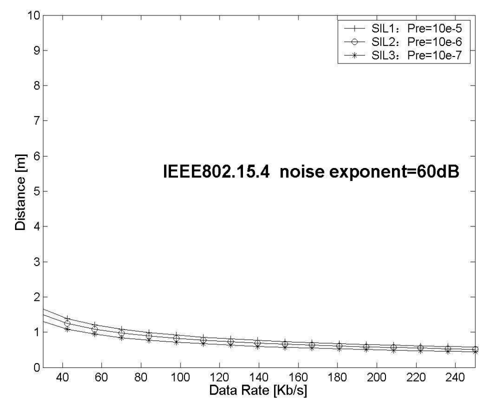


(a)

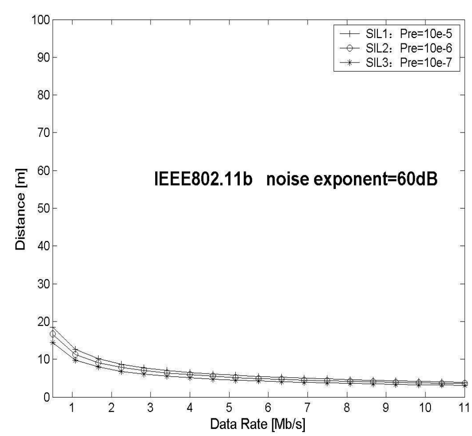


(b)

Figure 2: Relationship of data rate and distance in the noise exponent 40dB



(a)



(b)

Figure 3: Relationship of data rate and distance in the noise exponent 60dB

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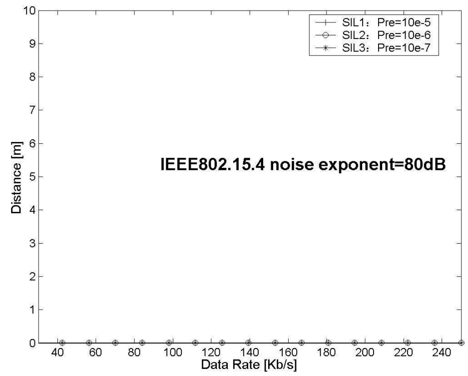
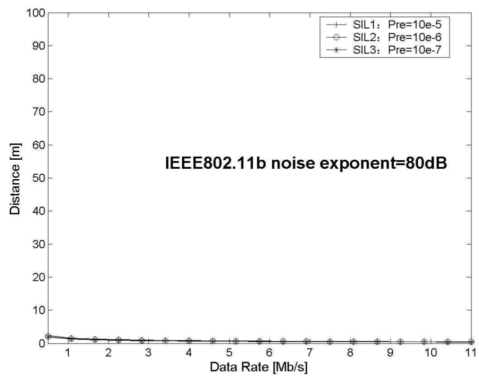


(a)



(b)

Figure 4: Relationship of data rate and distance in the noise exponent 80dB

6. CONCLUSION

The wireless channel can influence the design of industrial network control system. With the success of wireless technologies in consumer electronics, wireless network technologies are envisioned for the deployment in industrial environments as well. Wireless network is, beyond all questions, an appropriate approach to obtain flexibility and mobility in the factory. Nevertheless, industrial wireless network often has stringent requirements on reliability, robustness, security and so on. In wired environments, industrial network system can satisfy requirements, such as reliability, real-time, robustness and security. For example, fieldbus is a mature technology, and it is designed to accomplish communication between digital controllers and sensors. When wireless network technologies are included, due to the adverse properties of the radio channels, the requirements of reliability, robustness and security are significantly more difficult to be met. So we discuss wireless communication quality based on industrial noise, Simulation data will be reference to research on industrial wireless network, and it will be helpful to researcher.

REFRENCES:

[1] S. Yoo et al., “Guaranteeing Real-Time Services for Industrial Wireless Sensor Networks with IEEE 802.15.4”, *IEEE Transactions on Industrial Electronics*, Vol. 57, No. 11, 2010, pp.3868-3876.

[2] V. Sipal et al., “Frequency-selective fading of ultrawideband wireless channels in confined environments”, *IET Microwaves, Antennas & Propagation*, Vol.5, No. 11, 2011, pp. 1328-1335.

[3] Dick Caro, “Wireless Networks for Industrial Automation”, *ISA-The Instrumentation Systems and Automation Society*, Vol.3, No.1, 2005, pp. 15-18.

[4] E. Kwon et al., “A Performance Model for Admission Control in IEEE 802.16”, *LNCS*, Vol.3510, No. 4, 2005, pp. 159-168.

[5] R. P. Anand, R. P. Neeli, “Performance Evaluation System Design and Network Deployment of IEEE 802.11”, *Wireless Personal Communications*, Vol.19, No. 1, 2009, pp. 57-79.

[6] K.S. Low et al., “Real options and technology management: Assessing technology migration options in wireless industry”, *Telematics and Informatics*, Vol.26, No. 2, 2009, pp 180-192.

[7] M. Dirani et al., “Cross-layer modeling of capacity in wireless networks: Application to UMTS/HSDPA, IEEE802.11 WLAN and IEEE802.16 WiMAX”, *Computer Communications*, Vol. 30, No. 17, 2007, pp. 3384-3391.

[8] A. Kalis, T. Antonakopoulos, “Direction finding in IEEE802.11 wireless networks”, *IEEE Transactions on Instrumentation and Measurement*, Vol.51, No. 5, 2002, pp. 940-948.

[9] L. Angrisani et al., “An IEEE802.15.4-based system for locating children on their school commutes”, *Transactions on Fundamentals of Electronics*, Vol. E93-A, No.5, 2010,pp. 950-957.

[10] J. L. Wang, C.G. Wang, “UWB communication principle and application”. Beijng: The People's Posts and Telecommunications Press, 2005.

[11] R. Cardinali et al., “UWB ranging accuracy in high-and low-data-rate applications”, *Microwave Theory and Techniques*, Vol. 54, No. 4, 2006, pp. 1865 - 1875.

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[12] W.M. Goble, J.V. Bukowski, "Extending IEC61508 reliability evaluation techniques to include common circuit designs used in industrial safety systems", *Proceedings of the Annual Reliability and Maintainability Symposium*, Vol.20, No. 12, 2001, pp. 339-343.