Construction of power loss equation for intelligent car based on maximum likelihood estimation

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Abstracts: Aiming at the integrated control system of intelligent car and shore control center, revolving around high frequency wireless transmission control, this paper introduces the concept of maximum likelihood estimation (MLE), and proposes a power loss equation construction method of the intelligent car based on frequency domain transformation. Proceeding from frequency domain model, the influence of the corresponding parameters on path loss performance of received power which reaches the intelligent car is simulated and analysed in this paper. From simulation results of the frequency domain model, when the incident angle, α, is 0.4π, the corresponding received power path loss to the intelligent car is minimized. The result reflects the smallest received power path loss to the intelligent car and the impact on the system performance.

1. Introduction

In the design of intelligent car control system, the design and analysis are usually carried out on the ground, and the performance analysis is mainly based on the time-domain model of the system. But sometimes it is difficult to get good system performance characteristics in time-domain model, so we can analysis the system performance from the transform-domain model proceeding from the signal processing method. Fourier transform and Laplace transform are used in the control system to transform the signal for frequency domain, complex frequency domain and S domain respectively. In this paper, according to the characteristics of intelligent car control system in offshore operation, proceeding from the perspective of Fourier transform, the performance parameters of frequency domain characteristics related parameters are processed to study the effect on system performance.

Fourier transform involves continuous Fourier transform and discrete Fourier transform. Considering the characteristics of wireless signal, this paper deals with the parameters of discrete system based on fast Fourier transform (FFT).

2. Received power loss model for intelligent car

Intelligent car works on offshore ships, in order to realize the operation control on intelligent car, the shore control center can establish communication connection with intelligent car by using 3-30MHz high frequency transmitting signal, to form an integrated control system of the offshore ship, intelligent car and shore control center [¹, ²]. For high-frequency signals of 3-30MHz, information can be transmitted between the atmospheric ionosphere and the earth through multiple reflections from the atmospheric ionosphere and sea surface. Fig. 1 shows the power loss model of the system in a calm
sea level environment, among which $P_t$ is the signal transmitting power, and its frequency is $f(n)$; $P_r$ is the signal received power; $h$ is the atmospheric ionosphere height; and $\alpha$ is the incident angle of the high frequency carrier signal.

2.1 Mathematical model of received power path loss

According to the system model of Fig. 1, after primary reflection between ionosphere and surface the total power loss of HF signals transmitted by shore control center can be expressed as follows [7]:

$$ZL_{dB}(n) = (2 + \beta)(1 + k)L_{dB1}(n)$$

In formula (1), $K$ is the reflection coefficient of the high frequency electromagnetic wave on the calm sea surface [8]; $\beta$ is the coefficient in the ionosphere [3], and where $0.2 < \beta_{day} = 0.10, \beta_{night} = 0.25$; $L_{dB1}(n)$ is the propagation path loss of the signal between the earth and the atmosphere. It is expressed as follows:

$$L_{dB1}(n) = 20\log f(n) + 20\log h - 20\log \sin \alpha + 32.44dB$$

2.2 Simulation results of path loss and $f(n)$ in time domain environment

The formula (2) reflects the relationship between $L_{dB1}(n)$ and frequency $f(n)$, and the result of simulation according to formula (2) is shown in Figure 2. As can be seen from Fig. 2, when $\alpha$, the incident angle of the high frequency carrier signal, is determined, the propagation path loss $L_{dB1}(n)$ between the ground and the atmosphere increases with the increase of the frequency; and when $\alpha$ changes, the $L_{dB1}(n)$ decreases with the increase of $\alpha$.

The formula (1) reflects the relationship between $ZL_{dB}(n)$ and frequency $f(n)$, and the result of simulation according to formula (1) is shown in Figure 3. As can be seen from Fig. 3, when $\alpha$, the incident angle of the high frequency carrier signal, is determined, the total power loss of system $ZL_{dB}(n)$ increases with the increase of the frequency; and when $\alpha$ changes, the $ZL_{dB}(n)$ decreases with the increase of $\alpha$. 
3. Received power loss of intelligent car in frequency domain

For the integrated control system performance of intelligent car and shore control center in time domain system, in order to reflect the parameter characteristics of related indexes in frequency domain, the performance of the integrated control system is simulated in frequency domain environment. In order to achieve this goal, fast Fourier transform (FFT) to time-domain correlation parameters is used to simulate and analyze correlation characteristics when the relevant parameters are kept unchanged.

According to formula (1) and (2), power loss $Z_{LdB}(n)$ can be summarized as:

$$Z_{LdB}(n) = f(f(n))$$

FFT is applied to formula (3), and then:

$$ZL_{dB}(k) = FF T[L_{dB}(n)] = \sum_{n=0}^{N-1} ZL_{dB}(n) W_N^{nk} \quad 0 \leq k \leq N-1$$

### 3.1 Simulation results of $ZL_{dB}(k)$ and $f(k)$ in frequency domain

Formula (4) is the FFT transform expression of received power path loss, $ZL_{dB}(n)$, of intelligent car. It reflects the relationship between $ZL_{dB}(k)$ and frequency $f(k)$. The simulation results in frequency domain are shown in Figure 4 after fitting processing.

As can be seen from Figure 4, when analyzing the received power path loss $ZL_{dB}(k)$ of the intelligent car, the received power path loss $ZL_{dB}(k)$ of the intelligent car varies with the frequency $f(k)$ given the incident angle of the high frequency carrier signal. In order to analyze the parameter performance in the frequency domain model, the value of $ZL_{dB}(k)$ is the result of FFT transformation. It only shows the changing trend, but does not represent its actual physical significance. However, through the maximum value shown in Fig. 4, it shows that the smaller the angle of incident angle is, the larger the loss is. The result reflects the corresponding relationship between $f(k)$ and $ZL_{dB}(k)$ and the influence on system performance. It also can be seen from Figure 4 that the values of $ZL_{dB}(k)$ mainly overlap around 0 at four angles of incidence. To further demonstrate the specific performance, the figure is enlarged and Figure 5 is get.

![Fig. 2 relationship between $L_{dB}(n)$ and $f(n)$](image1)

![Fig. 3 relationship between $Z_{LdB}(n)$ and $f(n)$](image2)
As can be seen from Fig. 5, the values of $Z_{LdB}(k)$ vary from -30 to -20 at four angles of incidence, most of which focus on -24 to -22. The trend of the change is relatively gentle. The result reflects the corresponding relationship between $f(n)$ and $Z_{LdB}(n)$ in frequency domain model, and also reflects the corresponding system performance in time domain and frequency domain model.

3.2 Simulation results of amplitude spectrum of $Z_{LdB}(k)$ in frequency domain

Based on above system performance analysis of the received power path loss of intelligent car, the simulation results of the amplitude spectrum of formula (4) are given according to the frequency domain transformation expression. The graph is shown in Figure 6 and the value of independent variable $f(n)$ is in the range of $[-15, 15]$. From the amplitude spectrum simulation, it can be seen that the received power path loss $Z_{LdB}(k)$ of the intelligent car varies as a sampling function. The energy mainly concentrates on the main lobe, and the waveforms of the left and right half axes are symmetrical.

As also can be seen from Fig. 6, the amplitude spectrum of $Z_{LdB}(k)$ varies relatively centrally and overlaps basically in the side lobe at four angles of incidence. The smaller the angle of incidence $\alpha$ is, the larger the maximum value of the amplitude spectrum of $Z_{LdB}(k)$ in the main lobe is, and the maximum value of the amplitude spectrum in the main lobe is about 100. The fitting curves of $Z_{LdB}(k)$ amplitude spectra in the side lobe overlap basically, and the maximum value of the main lobe is about 60.
4. Maximum likelihood estimation

In order to further analyze the performance of received power path loss $ZL_{dB}(n)$ of intelligent car, the maximum likelihood estimation is carried out. Since the loss is a decibel representation of the ratio of the received power to transmitting power, and the received power is less than transmitting power, the ratio should be less than 1, which can be interpreted as a probability density function. Representation is below according to likelihood function:

$$Q_{ZL} = \prod_{k=1}^{n} f(x_k, \theta_1, \theta_2, \theta_3, \ldots, \theta_r)$$

In formula (5), $x_k$ is sample and $\theta_i$ is parameter.

According to formula (5), the maximum likelihood estimation of $ZL_{dB}(n)$ for intelligent car received power path loss can be solved. In this paper, the maximum likelihood estimation is simulated for the high frequency electromagnetic wave signal with the daytime ionosphere reflection. When the incident angle $\alpha$ is $0.4\pi$, the corresponding received power path loss to the intelligent car reaches the minimum value of 213.7dB. Thus, when the receiver sensitivity is in the range of -110 dBm ~ -160 dBm, the intelligent car can be effectively controlled.

5. Conclusions

In this paper, a method of constructing power loss equation of intelligent car based on frequency domain transformation is presented, and its performance is analyzed quantitatively and simulated. From the analysis results, it can be seen that the reasonable choice of the incident angle $\alpha$ can reduce the received power path loss of the integrated control system of intelligent car and shore control center, further improving the overall performance of the integrated control system and communication quality of wireless signal transmission. The analysis results are useful for power control and performance optimization of intelligent car in wireless communication system and mobile communication system.

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References

[1] William Stallings. *Wireless Communications and Networks* [M]. Tsinghua University Press.2004.6;
[2] Zhang Yu. *Electromagnetic Wave Propagation in Space* [M] (Xidian University Press) 2010.9
[3] Pan Weiyan, He Guangquan. *A Method for Obtaining Equivalent Height and the Reflection Coefficient of Lower Ionosphere by Measuring Loran-C Signal Waveforms* [J] (Chinese Journal of Radio Science) 1986, 1(1) pp 28-40
[4] You Yang. *Short-ware Communications Network Coverage Analysis Based on Computer Simulations* [J]. Radio Communications Technology.2012, 38(5): pp 19-25
[5] Sinmyong Park, Yisok Oh. *Accuracies of Theoretical and Communication Models For Estimating Reflection Coefficients of Rough Sea Surfaces* [C] IGARSS 2016 pp 3699-3701
[6] Zuo Xianglai, Yue Rong. *Concise Course on Probability Theory (Third Edition)* [M] (China University of Petroleum Press)2012.8
[7] Li Zhiqiang, Xu Feng, Li Jieying, et al. *The Calculation Method and Simulation of Characteristic of High Frequency Wave Wireless Channel* [J] (Fire Control & Command Control) 2014, 39 (4) pp 55-58
[8] Huang Fang, Du Wencai and Bai Yong *Maritime Radio Propagation Characteristics of Television White Space Spectrum with Impact of Ship Motions*[J] (Chinese Journal of Video Engineering) 2015,39(13) pp 140-44.
[9] Sun Jianghong, Li Gang, Yu Mei and Du Hongchen *Design of intelligent car control system based on new energy* [C] 2017 IEEE 13th International Conference on Electronic
Measurement and Instruments, ICEMI 2017 pp 136-41

[10] Ma Danping, Li Yong and Liang Qin'ou Motion Simulation and Trajectory Drawing of the Intelligent Vehicle with Wireless Remote Control [J] Chinese Journal of Zhejiang Normal University (Natural Science Edition) 2015,38 (1) pp 116-20

[11] Yin Qun, Zhang Jianbo, Wang Xinkai, et al The Video Intelligent Car Based on Wireless Sensor [J] Cluster Computing,DOI 10.1007/s10586-017-1100-4,2017(8) pp 1-16

[12] Chen Ping, Ni Zhen and Ma Wei The path following control analysis for 4-wheel differential omnidirectional mobile robot[J] (Journal of Chongqing University)2013,36(03) pp 20-24

[13] Dai Genling and Wang Penghao Design of Intelligent Car Based on WiFi Video Capture and OpenCV Gesture Control [C] 2017 Chinese Automation Congress (CAC) pp 4103-07

[14] Shen Zhongyu, Zhen Qiwen, Wang Chuan, et al Multi-smart car control system based on wireless communication network [J] Chinese Journal of Southeast University (Natural Science Edition),2013, 43(6) pp 18-21

[15] Javier Rodriguez-Fernández,Nuria González-Prelcic, Robert W. Heath A compressive sensing-maximum likelihood approach for off-grid wideband channel estimation at mmWave [C] (2017 IEEE 7th International Workshop on Computational Advances in Multi-Sensor Adaptive Processing) CAMSAP 2017 pp 1-5

[16] Yan Jun, Yu Kegen and Wu Lenan Fuzzy modeling, maximum likelihood estimation,and Kalman filtering for target tracking in NLOS scenarios [J] Journal on Advances in Signal Processing, 2014(105) pp 1-16