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LINEAR ANTI-INTERFERENCE ALGORITHM FOR DIGITAL SIGNAL TRANSMISSION IN FIBER OPTIC COMMUNICATION NETWORKS BASED ON LINK ANALYSIS

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Abstract. In order to achieve accurate transmission of protection signals in fiber optic communication networks, it is necessary to perform channel balancing configuration of fiber optic communication networks and adaptive forwarding control processing of relay protection signals, the author proposes an accurate transmission method for relay protection signals in fiber optic communication networks based on time-varying multipath fading suppression and adaptive beamforming. The system analyzes the sources of wireless long-distance pain signal interference signals, introduces anti-interference technologies such as two-dimensional joint processing (STAP), provides anti-interference algorithms and related gain analysis, and conducts signal processing gain simulation using MATLAB. Based on the analysis of comprehensive simulation results, at a given symbol length, the signal bandwidth increases, and the processing gain infinitely approaches the given theoretical limit value, rather than increasing nonlinearly. The reason is that the channel is affected by noise, and the channel estimation value and signal conjugate multiplication produce a noise quadratic term. At this point, the estimated value of the coherent region channel is reduced by the influence of noise, and the signal-to-noise ratio loss caused by the noise quadratic term is reduced, so the processing gain increases. During the process of infinite increase in signal bandwidth, the input signal-to-noise power ratio of the receiver tends to decrease towards an infinite value, limited by the size of the coherent region. The channel estimation value increases under the influence of noise, and the noise quadratic term is the main factor affecting the output noise power. When the symbol length is greater than the coherent time, the smaller the maximum Doppler frequency shift and the larger the coherent detection area, the greater the processing gain.

Key words: Wireless communication, Digital signal processing, Anti interference algorithm, Gain analysis, MATLAB simulation

1. Introduction. With the rapid development of wireless communication technology and fiber optic network communication technology, the use of fiber optic network communication to achieve large-scale data and signal transmission greatly facilitates people's production and work, and meets the needs of people for large bit sequence signal transmission and remote communication [6, 9, 3]. Fiber optic communication networks have the advantages of large transmission bandwidth and good real-time communication output. However, during the transmission of relay protection signals in fiber optic networks, multipath attenuation is prone to occur due to the influence of signal attenuation and transmission distance, moreover, the electromagnetic waves of relay protection signals are easily affected by environmental electric and magnetic fields, resulting in great ambiguity in the output of communication signals. Therefore, it is necessary to optimize the transmission design of relay protection signals in optical fiber communication networks, combining signal balance control and multipath attenuation suppression methods to improve the accurate transmission ability of relay protection signals in optical fiber communication networks, in traditional methods, there are mainly signal transmission control methods for relay protection signals in fiber optic communication networks, such as Baud interval equalization control, fractional interval equalization transmission control, beamforming method, and matched filter detection method. Frequency domain equalization method is used for inter symbol multipath suppression, and a fiber optic network communication channel equalization model is constructed to improve the accurate transmission ability of relay protection signals.Based on the above principles, Cao, Y. et al. proposed an energy internet data security transmission algorithm based on wireless opportunity network confidence to resist the impact of malicious behavior. The advantages of this algorithm in parameters such as success rate and data transmission delay were verified through simulation of real scenes [2]. Zhou, G. et al. proposed optical communication based on nonlinear Fourier transform (NFT) and digital coherent transceivers as a new theoretical framework for

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nonlinear fiber channel communication. For discrete eigenvalue transmission (or soliton transmission), people seek to encode as much information as possible in each degree of freedom and shorten the distance between adjacent pulses to improve the overall bit rate. However, this attempt can lead to nonlinear inter symbol interference (ISI) across multiple symbols and significantly reduce transmission performance [18].

On the basis of current research, the author proposes an accurate transmission method for relay protection signals in fiber optic communication networks based on time-varying multipath fading suppression and adaptive beamforming. The system analyzes the sources of wireless long-distance pain signal interference signals, introduces anti-interference technologies such as two-dimensional joint processing (STAP), provides anti-interference algorithms and related gain analysis, and conducts signal processing gain simulation using MATLAB [12]. Based on the analysis of comprehensive simulation results, at a given symbol length, the signal bandwidth increases, and the processing gain infinitely approaches the given theoretical limit value, rather than increasing nonlinearly.The reason is that the channel is affected by noise, and the channel estimation value and signal conjugate multiplication produce a noise quadratic term. At this point, the estimated value of the coherent region channel is reduced by the influence of noise, and the signal-to-noise ratio loss caused by the noise quadratic term is reduced, so the processing gain increases. During the process of infinite increase in signal bandwidth, the input signal-to-noise power ratio of the receiver tends to decrease towards an infinite value, limited by the size of the coherent region. The channel estimation value increases under the influence of noise, and the noise quadratic term is the main factor affecting the output noise power.

2. Methods.

2.1. Communication Channel Model and Relay Protection Signal Analysis.

(1) Construction of communication channel model. In order to achieve accurate transmission of relay protection signals in fiber optic network communication under strong interference, a fiber optic network communication channel model is first constructed. Fading channels are used for signal transmission link allocation and autocorrelation matched filtering design of the fiber optic network communication channel. It is assumed that the fiber optic network communication channel is a wide and stable channel with limited time domain bandwidth.The amplitude of the relay protection real signal $x(t)$ received at the receiving end of the multipath fading channel between the received pulses is proportional to α_k/N_k (α_k is the amplitude attenuation of the k-th fading channel, N_k is the noise power spectral density), and the variance of channel transmission (variance ance) is defined as:

$$\sigma_x^2 = E\left[x^2(t)\right] \tag{2.1}$$

Among the n_R feedforward filters, the inter code interference intensity of the fiber optic network communication channel is $s_i(t), i = 1, 2$. Due to the varying path lengths of fiber optic network communication channels, the gain of the diversity equalizer branch satisfies the maximum likelihood sequence estimation (MLSE), and a feedback equalization model for fiber optic network communication channels is constructed, based on the maximum likelihood sequence estimation results, multipath propagation attenuation suppression of the communication channel is performed, and the calculation amount of each received symbol is proportional to M_s^N. The symbol transfer rate and measurement error of the fiber optic network communication channel are:

$$\begin{aligned} S_x &= E\left[x^3(t)\right] + \sqrt{s} bu\left[s\left(t-\tau_0\right)\right] \\ K_x &= E\left[x^4(t)\right] - 3E^2\left[x^2(t)\right] b \end{aligned} \tag{2.2}$$

Among them, $E[x^3(t)]$ is the attenuation feature of the relay protection signal symbols in each reception, b is the tap delay line, and the tap interval sampling method is used for sampling the transmission bit sequence, from this, the relay protection signal model outputted by the fiber optic network communication channel is obtained, and the instantaneous frequency estimation is performed based on the time-frequency distribution of the relay protection signal, thereby accurately simulating the pulse response of fiber optic network communication and wireless sensor network communication [7, 20]. The pulse response of the relay protection signal $S(t)$ received by the fiber optic network communication system is:

$$S(t) = a_0 \sum_{i=1}^{N} a_i \delta\left(t-\tau_i\right) e^{j w_c t} \tag{2.3}$$

In the formula, N represents the number of communication channel paths in the fiber optic network, τ_i and a_i respectively represent the time delay and frequency attenuation of the i-th fiber optic network communication channel, and ω_c represents the output modulation carrier frequency of the relay protection signal in the fiber optic network communication, based on the time-varying multipath fading loss of the channel, the optimal baud interval sampling of the relay protection signal is carried out, and channel blind equalization technology is used to estimate the delay and amplitude of the communication channel. Establish a tap delay model for channel multipath component suppression, and set each node bi for fiber optic network communication, the pulse frame number of the channel's impact response is N_f. frames, and the output time delay in the phase offset direction is T_f. The pulse broadening of the relay protection signal in the fiber optic communication network is:

$$T_s = N_f T_f \tag{2.4}$$

In the transmission of relay protection signals in optical fiber communication networks, the multipath arrival time delay is T_d, and the relevant beam modulation method is used, divide the relay protection signal in the fiber optic communication channel of the fiber optic network into N_c chips, with a tap time interval of $R_b < 1/\Delta$, and obtain the time extension of the relay protection signal output that meets the following requirements:

$$T_c = \operatorname{ent}\left(T_f / N_c\right) \tag{2.5}$$

It can be seen that there is a spectral zero in the frequency response of the channel at the communication output end. Through channel equalization allocation, a phase shift is generated in the received signal, improving the accurate transmission performance of relay protection signals in fiber optic network communication, and thus improving communication quality [14, 5].

(2) Time-varying multipath attenuation suppression. Based on the above construction of the fiber optic network communication channel model, the optimal baud interval sampling of the relay protection signal is carried out based on the time-varying multipath fading loss of the channel. The EEE802.15.SG3a communication protocol is used to construct the shortest routing algorithm for the relay protection signal transmission channel of fiber optic communication.The node distribution model of the fiber optic communication data link layer is constructed, and the output sampled relay protection signal model is obtained as follows:

$$s(t) = \sum_i b_j \sum_{j=0}^{N_f - 1} p\left(t - iT_s - jT_f - c_j T_c\right) \tag{2.6}$$

Assuming that the impulse response of the relay protection signal in the fiber optic network communication channel is $h(n)$, the nonlinear equilibrium parameter of the relay protection signal transmission channel is $n(n)$, and the time-varying multipath fading loss in the frequency domain is $y(n)$, the symbol of each feedforward branch is $\tilde{x}(n)$. Under a limited symbol rate, the optimal baud interval sampling of the relay protection signal is performed based on the time-varying multipath fading loss of the channel. The spectrum characteristics of the relay protection signal in the output fiber optic network are:

$$\text{Computition}\left(n_j\right) = \left[\left(E_{\text{elec}} + E_{\text{DF}}\right)\delta + E_{\text{elec}} + \varepsilon_{fs} d_j^2\right] l \tag{2.7}$$

Adjust the tap coefficient of the fiber optic network communication system, use blind equalization method for multipath suppression, and improve the output fidelity of the signal [4, 11].

2.2. Analysis of Interference Signals and Anti interference Techniques. Interference signals often come from potential interference and adversarial interference sources such as natural and human interference sources. The sources of natural environmental interference are the astronomical noise generated by charges in the atmosphere, the cosmic noise in outer space of the Earth, and the background noise of the natural environment [13]. Human interference sources mainly come from various electromagnetic interferences that humans believe to be generated, including signal noise interference generated by active radiation devices such as broadcasting, television, radar signals, and mobile communication; At the same time, there are various high-voltage transmission lines and engineering equipment that emit electromagnetic interference. Interference with signal reception is extremely common. In response to communication conditions in harsh environments, spread spectrum technology serves as an effective anti-interference technology in wireless signal transmission communication. Spread spectrum can reduce interception probability and increase communication distance. The pseudo random sequence signal used for spread spectrum has white noise statistical characteristics, and the spread spectrum signal can effectively combat multipath fading characteristics. With the development of technology, two-dimensional spread spectrum technology has been adopted, that is, synchronous spread spectrum in the time and frequency domains, fully utilizing the signal's correlation gain in the time and frequency domains to improve its anti-interference ability. Due to the surge in wireless communication traffic and the increasing complexity of long-distance communication transmission environments, as well as the need for high frequency spectrum utilization in multi-system communication requirements. We have started to adopt multi antenna multi interface technology (MIMO), which has array gain and coding characteristics, which can effectively suppress transmission channel interference, significantly increase data transmission rate, and expand communication capacity [16, 8].

In recent years, technicians from various countries have adopted technologies such as Orthogonal Frequency Division Multiplexing (OFDM), Orthogonal Frequency Division Multiplexing Multiple Access (OFDMA), and Single Carrier Frequency Division Multiplexing (SC-FDMA). It effectively solves the problem of spectrum resources. With the improvement of broadband wireless data services such as wireless local area networks and wide area networks, the Wireless Ethernet Compatibility Alliance (WECA) has proposed WiFi technology, Bluetooth technology, and Zigbee technology applied to multi-sensor networks such as the Internet of Things, creating a more complex wireless communication environment today.

2.3. Space Time Adaptive Anti-interference Technology.

(1) Two dimensional joint processing (STAP) anti-interference technology . At present, space-time adaptive anti-interference technology is the best technology to effectively ensure anti-interference reception of satellite signals in complex electromagnetic environments. This technology has extremely high dynamic characteristics and can quickly change the spatial response based on changes in the electromagnetic environment, ensuring stable reception of satellite navigation signals [17]. The main principle is to use the antenna array and time-domain delay to utilize the spatial and energy characteristics of the interference signal, and achieve spatial interference to zero, thereby achieving interference signal cancellation and suppression. Space time adaptive anti-interference technology has the characteristics of small size, modular design, and strong expansion compatibility. Space time adaptive anti-interference mainly includes time domain adaptive anti-interference and spatial domain adaptive anti-interference. Time domain adaptation is based on FIR filters, which achieve frequency domain filtering through time domain delay to filter out non operating frequency signals, and achieve maximum suppression of interference signals through spatial and temporal synchronization cooperation. The spatial adaptive anti-interference mainly relies on the spatial characteristics of the interference signal to achieve zero adjustment function for the interference direction in the spatial directional map.Through the combination of time-domain filtering, frequency-domain filtering, and spatial filtering, a spatiotemporal two-dimensional joint processing (STAP) anti-interference technology is formed. STAP technology extends one-dimensional time-domain, frequency-domain, and spatial filtering to the two-dimensional domains of time and space, forming a spatiotemporal two-dimensional processing structure. The combination of digital signal processing and array technology completes the adaptive processing function of the system. The spatiotemporal two-dimensional joint adaptive processing structure is derived using statistical likelihood ratio detection theory under the model of overlaying deterministic signals in the background of Gaussian noise, it uses a multi tap FIR filter in each element structure to achieve anti-interference processing. In the channels of each array element, various levels of delay constitute FIR filters to filter out interference in the time domain; Different time delay nodes of array elements form adaptive filtering in the spatial domain, which distinguishes spatial interference sources and forms spatial nulls in the spatial domain to suppress interference. Space time processing can also achieve the function of eliminating interference in the two-dimensional space time domain. Figure 2.1 shows a spatiotemporal frequency domain adaptive anti-interference loop.

(2) STAP anti-interference algorithm. The spatiotemporal two-dimensional joint processing technology lies in how to implement the spatial weight vector solving method. The time and space weight vectors are con-

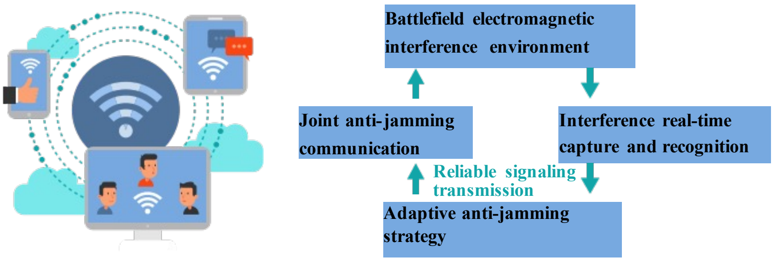

Fig. 2.1: Space time frequency domain adaptive anti-interference loop

strained by various criteria such as the minimum mean square error criterion, the maximum signal-to-noise ratio criterion, the linearly constrained minimum variance criterion, and the maximum likelihood criterion. In practical engineering applications, appropriate constraint criteria are selected based on different environments [15, 19]. The Linear Constrained Minimum Variance (LCMV) criterion is widely used. It utilizes the characteristics of navigation signal power being much lower than noise and interference power to weaken interference energy and avoid the impact of navigation signals. When it is difficult to separate signals from interference signals, the optimal processor of LCMV ensures that the signal is lossless by constraining both the spatial and temporal domains under the condition of spatiotemporal joint processing, adjusting the weights to minimize the variance of the output signal (power). The mathematical algorithm formula for the LCMV criterion is:

$$\min_{W}\left\{W^{H} R_{X} Y\right\} s \cdot t W^{H} C_{X}=g \tag{2.8}$$

In the above equation, R_x represents the covariance matrix of the received signal, $R_X = E\left(XX''\right)$. C_x represents the constraint matrix; G represents the constraint response vector. The spatial weight vector is solved using the Lagrangian equation:

$$W_{\text{opt}}=R_{X}^{-1} C_{X}\left(C_{X}^{H} R_{X}^{-1} C_{X}\right)^{-1} g^{H} \tag{2.9}$$

The linear constraint minimum variance criterion is limited by C_x, and its application conditions depend on the changes in the constraint matrix [1].

Gain analysis. The time-frequency two-dimensional spread spectrum in multipath fading and fully scattering channels is a BPSK modulated signal, for the joint coherent and incoherent detection algorithm, the spread spectrum signal processing gain adopts the ratio of the output signal-to-noise ratio of the signal receiver to the input signal-to-noise ratio.

$$G=\frac{p_{so}/p_{no}}{p_{si}/p_{ni}} \tag{2.10}$$

In the above equation, P_{so} represents the output signal power and P_{no} represents the output noise power. Considering the influence of channel fading factor, which is a complex Gaussian random variable, the output signal-to-noise ratio of the signal after joint coherent and incoherent detection is:

$$\frac{P_{so}}{p_{no}}=\frac{1}{4} \frac{B^{2} T^{2}\left(1+N_{B} N_{T}\right)\left(P_{si}/P_{ni}\right)^{2}}{BTP_{si}/P_{ni}+1} \tag{2.11}$$

Based on the above formula calculation and analysis, the more coherent regions participate in non coherent detection, the higher the output signal-to-noise ratio. Considering the time-frequency twodimensional spread spectrum signals in multipath fading channels, for joint coherent and incoherent detection algorithms, the independence of coherent regions and the corresponding increase in reception diversity are beneficial for increasing

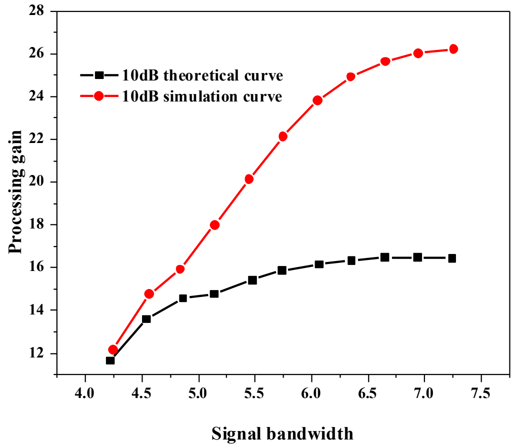

Fig. 3.1: Comparison of 10dB theory and simulation

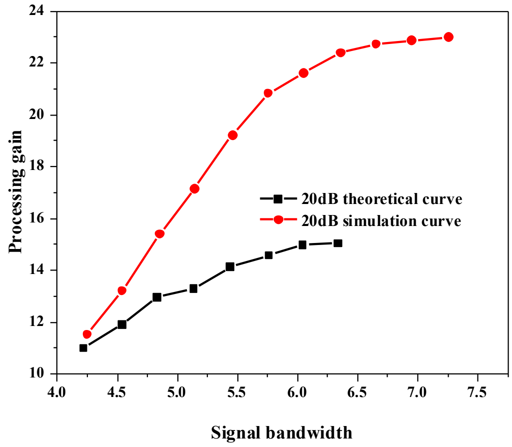

Fig. 3.2: Comparison of 20dB theory and simulation

the signal-to-noise ratio of the output signal in the detection algorithm. Simplifying the above equation, the spread spectrum signal processing gain is:

$$G = \frac{1}{4}\frac{B^2T^2\left(1+N_BN_T\right)P_{si}/P_{ni}}{BTP_{si}/P_{ni}+1} \tag{2.12}$$

The above analysis shows that when the input signal-to-noise ratio is large enough, the processing gain is directly proportional to the size and number of coherent regions. When the input signal-to-noise ratio is small enough, the output signal-to-noise decreases rapidly, and the processing gain is directly proportional to the size and number of coherent regions, as well as the input signal-to-noise ratio.

3. Results and Analysis. Using MATLAB simulation software, simulate the gain of time-frequency two-dimensional spread spectrum signal processing. The simulation results are shown in Figures 3.1, 3.2, 3.3, and 3.4. During the simulation process, the channel response in the coherent region is not completely correlated, with a time domain correlation coefficient not greater than 0.5 and a frequency correlation coefficient not greater than 0.9. The simulated output signal-to-noise and processing gain values are lower than the theoretical values [10].

Based on the analysis of comprehensive simulation results, at a given symbol length, the signal bandwidth increases, and the processing gain infinitely approaches the given theoretical limit value, rather than increasing nonlinearly. The reason is that the channel is affected by noise, and the channel estimation value and signal conjugate multiplication produce a noise quadratic term. At this point, the estimated value of the coherent region channel is reduced by the influence of noise, and the signal-to-noise ratio loss caused by the noise quadratic term is reduced, so the processing gain increases. When $\frac{E_b}{N_0}$ is constant, the signal bandwidth increases infinitely, and the input signal-to-noise power ratio of the receiver decreases towards an infinite value. Limited by the size of the coherent region, the channel estimation value increases under the influence of noise, and the noise quadratic term is the main factor affecting the output noise power. When the symbol length is greater than the coherent time, the smaller the maximum Doppler frequency shift and the larger the coherent detection area, the greater the processing gain.

4. Conclusion. Optimize the transmission design of relay protection signals in fiber optic communication networks, combining signal balance control and multipath attenuation suppression methods, to improve the accurate transmission ability of relay protection signals in fiber optic communication networks, the author proposes an accurate transmission method for relay protection signals in fiber optic communication networks based on time-varying multipath fading suppression and adaptive beamforming. The wireless communication system has limited transmission power, long-distance signal propagation, harsh and complex channel environments,

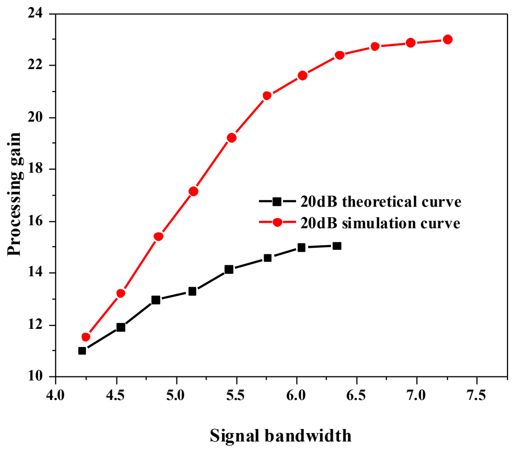

Fig. 3.3: Comparison of 10Hz theory and simulation

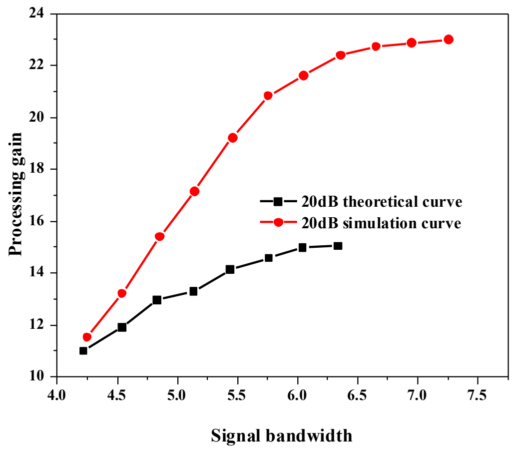

Fig. 3.4: Comparison of 00Hz theory and simulation

extremely low signal-to-noise ratio, increasingly complex wireless communication network structure, and severe interference from physical and system environments on the receiving end signal. The author proposed a two-dimensional joint processing (STAP) anti-interference technology to analyze and simulate the gain of the joint coherent and incoherent detection algorithm for time-frequency two-dimensional spread spectrum modulated signals in multipath fading and fully scattered channels using MATLAB. The results showed that the simulated output signal-to-noise and processing gain values were lower than the theoretical values.

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