



International Journal of Intelligent Systems Technologies and Applications

ISSN online: 1740-8873 - ISSN print: 1740-8865

<https://www.inderscience.com/ijista>

Analysis of interference cancellation under limited frequency band resources for B5G communication system application scenarios

Xin Wang, Na E, Ziyu Wang, Meng Wu

DOI: [10.1504/IJISTA.2025.10068592](https://doi.org/10.1504/IJISTA.2025.10068592)

Article History:

Received:	11 July 2024
Last revised:	26 September 2024
Accepted:	30 October 2024
Published online:	30 September 2025

Analysis of interference cancellation under limited frequency band resources for B5G communication system application scenarios

Xin Wang*

Network Center,
Hulunbuir University,
Hulunbuir, 021008, China
Email: xin_wang1990@outlook.com
*Corresponding author

Na E

School of Law and Economic Management,
Hulunbuir University,
Hulunbuir, 021008, China
Email: ena@hlbec.edu.cn

Ziyu Wang

Department of Key Accounts,
China Mobile Group Neimenggu Co., Ltd.,
Hulunbuir Branch,
Hulunbuir, 021008, China
Email: wangziyu@nm.chinamobile.com

Meng Wu

Network Center,
Hulunbuir University,
Hulunbuir, 021008, China
Email: 2008_huanhuan@163.com

Abstract: In a bandwidth-constrained setting, precise self-interference cancellation in communication systems poses challenges. This research extends optical self-interference cancellation to propose an adaptive interference mitigation strategy tailored for advanced mobile communication systems beyond the fifth generation. By considering delay gains in reference and self-interference channels, along with multipath temporal aspects, an unconstrained optimisation algorithm is introduced. Additionally, an adaptive mitigation strategy for multipath channels is devised using orthogonal frequency-division multiplexing technology. Simulation experiments demonstrate the optimised algorithm's 29.82–38.15% reduced sampling energy consumption compared to alternatives. The self-interference cancellation strategy saves energy, achieving –30.02 dB detection depth. Post-cancellation,

the signal spectrum's error vector magnitude is only 6.71%, a 71.72% decrease. The results highlight the effectiveness of this adaptive interference mitigation strategy in self-interference and multipath signal elimination in communication systems.

Keywords: band-limited resources; interference mitigation; unconstrained optimisation algorithm; delay gains; multipath signals.

Reference to this paper should be made as follows: Wang, X., E, Na, Wang, Z. and Wu, M. (2025) 'Analysis of interference cancellation under limited frequency band resources for B5G communication system application scenarios', *Int. J. Intelligent Systems Technologies and Applications*, Vol. 23, No. 3, pp.253–271.

Biographical notes: Xin Wang received his Master's degree in Computer Technology from Harbin University of Science and Technology (2011). Currently, he serves as the Deputy Director of the Network Center of Hulunbuir University. He has published a number of academic papers in the field of computer network and information security research, and chaired a number of scientific research projects at various levels. He has co-authored several textbooks and monographs, and holds a number of software copyrights. His research interests include computer networks, information security, satellite communications and communication transmission.

Na E received her Master's degree in Law from Dalian Maritime University (2015). Currently, she is working as a Full-Time Teacher in the School of Law and Economic Management of Hulunbuir University. She has presided over several scientific research projects and published many academic papers in the field of law. Her research interests include criminal law.

Ziyu Wang graduated from Inner Mongolia Agricultural University with a major in Computer Science and Technology. Currently, he serves as a Project Manager in the Government and Enterprise Customer Department of China Mobile Communications Group Inner Mongolia Co., Ltd., Hulunbuir Branch. He has participated in numerous conferences related to 5G fields and published multiple patents and papers. His areas of expertise include 5G communication technology, AI, cloud computing, software development, and more.

Meng Wu graduated from Information Management and Information System Major of Hulunbuir University in 2015. Currently, he is working as a Network Engineer at the Network Center of Hulunbuir University. He has presided over several scientific research projects. His research interests include computer networks, network security, and communication transmission.

1 Introduction

Beyond the 5th generation (B5G) mobile communication systems enable the localisation of three major application scenarios characterised by large bandwidth, extensive connectivity, and low latency, seamlessly integrating with vertical applications such as industrial IoT, smart healthcare, and intelligent agriculture (Gheisari et al., 2023; Vaezi et al., 2022). However, the substantial increase in the number of user nodes in communication systems, coupled with the inherent limitations of wireless channels due to

resource constraints, intensifies interference, leading to a drastic reduction in system performance and a severe issue of co-frequency interference. Current interference mitigation research predominantly includes self-interference cancellation and multi-user interference cancellation. Among them, self-interference cancellation can meet the requirements of full-duplex communication on the same frequency in the system and seamlessly integrate into the communication system architecture (Zheng et al., 2022). Self-interference cancellation technology (SIC) is mainly divided into three stages: analogue domain, transmission domain, and digital domain self-interference signal cancellation (Huang et al., 2021). In the analogue domain SIC, electronic SIC (ESIC), constrained by the fixed principles of radio frequency microwave components, has limited self-interference cancellation bandwidth, while optics-based SIC (OSIC) can reduce the working frequency band and bandwidth limitations of ESIC (Ahmed and Hashim, 2021; Xing et al., 2021). Furthermore, co-frequency transmission and reception signals result in B5G communication systems being constrained by loop self-interference, reducing the reception and transmission of useful signals and weakening the performance of communication systems. Therefore, this study proposes a high-frequency bandwidth B5G communication OSIC system adaptive delay gain feedback control and frequency domain equalisation interference mitigation strategy based on the coordination of delay amplitude and multipath from the perspectives of the reference channel and time-variant self-interference channel. The research focuses on the SIC problem in B5G communication systems with the aim of improving the performance of full-duplex communication and optimising the use of spectrum resources. With the increase in the number of users, the frequency band resources become tight, while multipath effects and hardware limitations pose challenges for interference cancellation. The study proposes an OSIC-based adaptive strategy to cope with these challenges by optimising models and algorithms to improve the efficiency and accuracy of interference cancellation.

An OSIC-based adaptive interference cancellation strategy is proposed to dynamically adjust the interference cancellation parameters through time-varying channel conditions, which provides a new solution to the SIC problem in B5G communication systems and improves the flexibility and adaptability of SIC. Meanwhile, a new unconstrained optimisation algorithm (UOA) is designed to provide an efficient computation method for adaptive SIC, which is important for fast interference cancellation in real-time systems. In addition, an adaptive interference cancellation technique for multipath self-interference is designed in the study by utilising orthogonal frequency division multiplexing (OFDM) signal adaptive frequency-domain pre-equalisation (FDPE) instead of conventional conventional frequency-domain pre-equalisation (FDPE). (FDPE) instead of the traditional conventional multiple optical path taps, which provides a new idea for self-interference cancellation in complex wireless environments and improves the effectiveness of interference cancellation, especially in scenarios with significant multipath effects.

This study is divided into six sections. Section 1 introduces the research background and purpose. Section 2 summarises research achievements and shortcomings of eliminating communication system interference at home and abroad. Section 3 focuses on research and design of adaptive interference cancellation strategy based on OSIC. In Section 4, the proposed interference cancellation strategy is tested and analysed. Section 5 discusses the experimental results. Section 6 summarises the experimental results and points out the future research direction.

2 Related works

With the rapid development of information technology, wireless communication systems are widely used in various aspects of people's daily lives and learning. Therefore, in-depth research on these systems has become a new trend. Khoshafa et al. (2021) addressed the dual attenuation problem introduced by the auxiliary link of reconfigurable intelligent surfaces in wireless communication systems. They designed an active element that can amplify the incoming signal's reflection, thereby achieving gain introduced by the link and significantly reducing the size of the reconfigurable intelligent surface. Ye et al. (2021) developed two end-to-end frameworks for frequency-selective channels and multiple-input-output channels, which provide improved performance in frequency-selective channels and multiple-input-multiple-output channels compared to conventional communications. In order to address the direct strong interference issue between transmitters and readers, Tao et al. (2021) proposed a novel interference elimination scheme with minimal hardware complexity, utilising the periodicity of sinusoidal radio frequency carriers. This approach resulted in an optimal detector with superior performance in the absence of interference signals. In order to evaluate the performance of an intelligent reflective surface-assisted evaluation of a bidirectional full-duplex communication system in a real-world scenario, a closed-form expression derivation for the traversal capacity and symbol error rate over a Rayleigh fading channel is carried out, taking into account self-interference cancellation and hardware impairments (Nguyen et al., 2021).

The implementation of wireless communication is constrained by various interference factors. When nodes transmit and receive signals on the same frequency, relay data can interfere with the communication network itself. Therefore, effectively eliminating self-interference has become a crucial research focus in the field of communication (Luo et al., 2021). Hong et al. (2022) proposed a frequency-domain RF self-interference cancellation framework with a novel filter weight optimisation algorithm to track the self-interference channel changes and automatically stop the transmission of backhaul signals in wireless in-band backhaul. Hu et al. (2022) proposed a photonics-based simultaneous adaptive RF self-interference cancellation and frequency down-conversion method to recover 16 quadrature amplitude modulation (QAM) signals with a symbol rate of 10 Msym/s in self-interference signals with 500 MHz and 1 GHz bandwidths. Kim et al. (2022) aimed to effectively eliminate self-interference in communication systems and proposed a SIC based on a full-duplex multiple-output system. They discovered that, in cases of imperfect channel estimation, the error rate performance of uplink spatial suppression is superior to that of subtracting self-interference channels.

In summary, scholars worldwide have explored various aspects of wireless communication systems and SIC research. However, current SIC technology faces challenges in meeting the requirements of high-frequency bands and practical applications. Further exploration is needed for research on wireless communication SIC. Therefore, a study is proposed that introduces an adaptive interference elimination strategy from the perspectives of coordinating delay magnitude between reference channels and time-varying self-interference channels, as well as coordinating multipaths. An innovative UOA is introduced, and the proposed self-interference elimination strategy is applied to the elimination of multipath self-interference signals.

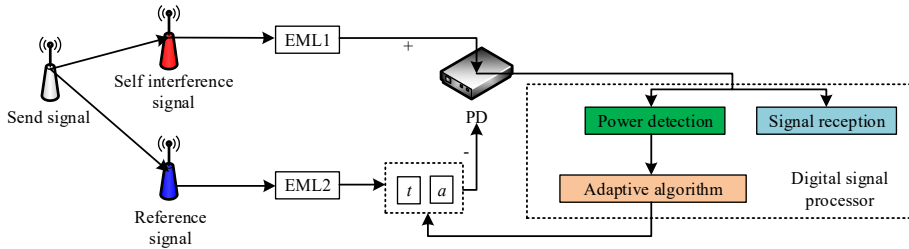
3 Adaptive interference elimination strategy based on OSIC

To address the issue of communication systems being limited by loop self-interference, a strategy for adaptive interference elimination based on OSIC has been proposed. Initially, by referencing the delay gains of the communication channel and self-interference channel, an optimisation problem model for the communication system was established. Furthermore, an adaptive feedback control technique based on OSIC was introduced. Based on this, an adaptive interference elimination technique on OSIC was designed according to the control scheme.

3.1 Adaptive control technology based on OSIC delay gain

In communication systems, the alignment magnitude of the delay gains of the reference channel and self-interference channel directly impacts the effectiveness of OSIC self-interference elimination. Moreover, the alignment of same-frequency transmission and reception signals causes the wireless channel's line-of-sight path to change over time, which is unfavorable for the transmission of communication signals (Xia et al., 2023; Björnson et al., 2022). Therefore, a control technique based on OSIC was proposed, specifically for a B5G communication system based on an electro-absorption modulated laser (EML), as illustrated in Figure 1.

Figure 1 Adaptive control method based on OSIC (see online version for colours)



In Figure 1, the self-interference signal and the reference signal are allocated to two separate EMLs. The lower path of the reference signal undergoes optical delay and attenuation, and it is subtracted from the upper path of the allocated self-interference and useful signal in the power delivery (PD). Simultaneously, the signal output from PD is split into two paths, one for signal reception and the other for power detection. The detected received signal power value is transmitted to the adaptive algorithm for feedback. The relationship between the power value after self-interference elimination and the difference in delay gain of the upper and lower optical signals is expressed by formula (1).

$$Q_r(a, t) = [1 + (a)^2 - 2a \cos(\partial t)] * Q \quad (1)$$

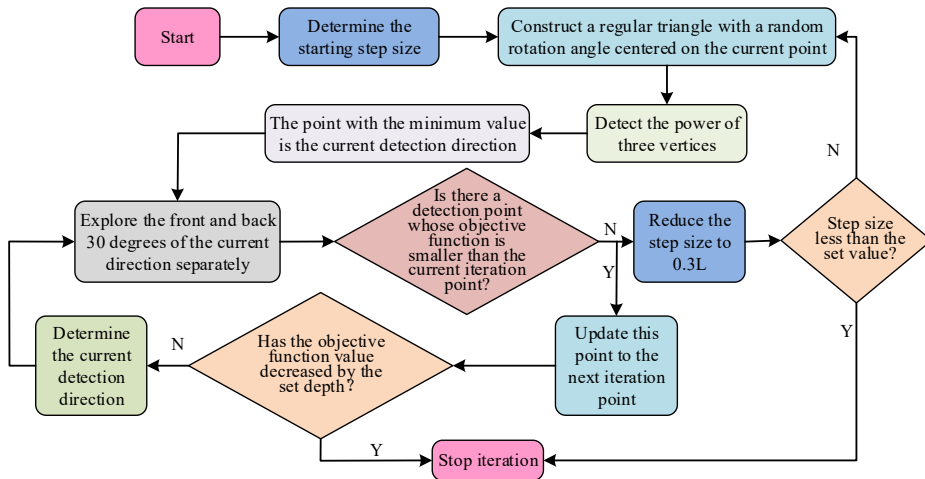
In formula (1), Q_r represents the power of the signal after self-interference elimination, a represents the gain difference of the optical signal in the self-interference elimination system, t represents the time difference of the optical signal in the self-interference elimination system, ∂ represents the weight parameter of the time difference, and Q represents the power before self-interference elimination. The relationship between the

power value after self-interference elimination and the two parameters satisfies a convex function, and the minimum power value matches the optimal self-interference elimination effect. Therefore, the feedback control method based on OSIC can be summarised as a convex programming problem, with the specific expression given by formula (2).

$$\begin{cases} \min Q_r = G(a, t) \\ \text{s.t. } a_0 \leq a \leq a_1 \\ t_0 \leq t \leq t_1 \end{cases} \quad (2)$$

In formula (2), $G(a, t)$ represents the optimal state of self-interference elimination for the corresponding Q_r . By solving this convex optimisation problem, the optimal delay and gain can be determined, achieving the optimal self-interference suppression ratio in the OSIC system. However, the convergence speed of the OSIC system is directly influenced by the feedback control algorithm, requiring further optimisation of its algorithm. Assuming the optimal solution exists within the modulation range of adjustable delay lines and attenuators, the optimal values are obtained using an unconstrained optimisation direct method. Considering that the device adjustment time and sampling time during each detection far exceed the iteration operation time, an UOA sensitive to sampling energy consumption is proposed to reduce sampling energy consumption, and its main calculation steps are shown in Figure 2.

Figure 2 UOA algorithm process (see online version for colours)



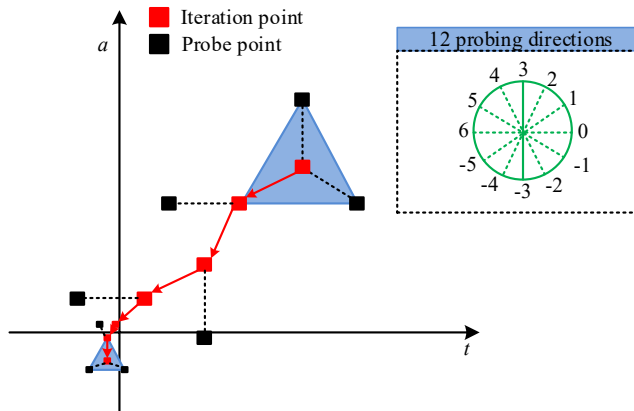
Firstly, in the detection of an equilateral triangle, the system explores in the directions of the three vertices of the equilateral triangle centred on the current iteration point. The distance from the iteration point to the three vertices is the current iteration step size. After determining a vertex as the next iteration point, a detection is carried out in the directions facing and opposing 30° to the direction connecting the two consecutive iteration points, maintaining the step size unchanged. Based on this, the point with a smaller objective function value and less than the current iteration point is chosen as the next iteration point and continues moving forward until the average value of the objective function for the two detection points is less than the objective function value of the current iteration point. Otherwise, the step size is reduced by 0.3 times, and the

calculation is restarted from the first step. When iterating to a certain point, the algorithm stops when the reduction amplitude of the objective function value is greater than or equal to the set range or the reduction amplitude of the step size is less than or equal to the set range. The objective function formula is shown in formula (3).

$$Aim = \frac{1}{H} \prod_{h=1}^{H=10} Q_r \left(f_0 + \frac{hB}{H} \right) \quad (3)$$

In formula (3), Aim represents the objective function. H represents the number of samples used for geometric mean calculation. B represents the bandwidth. f_0 represents the boundary of low frequencies in the frequency band. The UOA algorithm employs an equidistant detection of forward and backward 30° , which is calculated by the number of degrees of the angle with the positive direction of the transverse coordinates, and all the directions involved belong to integer multiples of 30° , which are divided into a total of 12 directions in the two-dimensional plane, and the specific detection and convergence paths are shown in Figure 3.

Figure 3 UOA algorithm detection and convergence path (see online version for colours)



In Figure 3, the origin of the coordinate system is assumed to be the optimal value point, and the points further away from the origin have larger objective function values. The relative position of the starting point to the origin is unknown, and the algorithm tries the objective function values of the three vertices by constructing a square triangle with random rotations in 12 directions. After finding the minimum value, it proceeds in the direction of the red line. Red points indicate successful iteration points and black points indicate failed points. When the trial fails in both directions at the fifth iteration point, the algorithm reduces the step size and reconstructs the square triangle. The seventh iteration point satisfies the stopping condition and the algorithm uses this point as the optimal estimate.

3.2 Adaptive interference elimination technology based on OSIC time-varying multipath self-interference

In practical B5G environments, wireless interference channels predominantly consider the line-of-sight path as the primary route, leading to the emergence of multipath effects in time-varying channels. Consequently, further research has been conducted to design adaptive interference elimination technology. The multipath effects of self-interference signals are illustrated in Figure 4.

Figure 4 Multipath effects of self-interfering signals (see online version for colours)

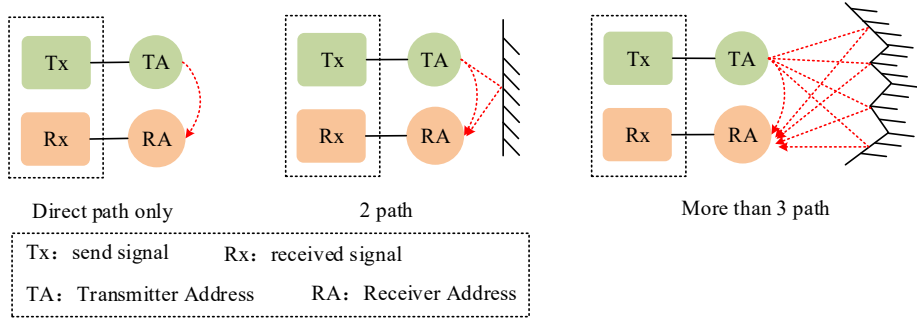
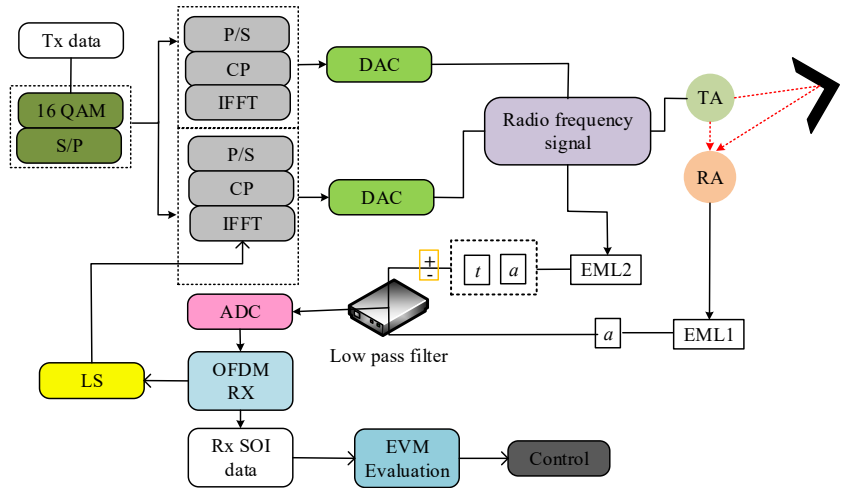


Figure 5 An OSIC architecture for adaptive OFDM frequency domain equalisation (see online version for colours)



When obstacles are present in the wireless environment, the radio frequency signals emitted by the transmitting antenna undergo reflection from obstacles, returning to the receiving antenna. This reflection overlaps with the original line-of-sight path signal, resulting in the formation of multipath effects. The number of paths changes randomly based on the specific conditions of obstacles in the wireless environment (Alexandropoulos et al., 2021; Liu et al., 2021). To address this, a method for broadband multipath interference elimination using OSIC has been designed. This involves utilising FDPE instead of traditional multiple optical paths taps through the use of OFDM signal.

Additionally, the regenerated OFDM is employed to replace the reference signal, enabling the complete elimination of reference and multipath signals through their coordinated combination. Therefore, the adaptive OFDM frequency-domain equalisation based OSIC architecture is depicted in Figure 5.

Considering that multipath interference elimination requires inverse fast Fourier transform (IFFT) and fast Fourier transform (FFT) transformations and that OFDM signals undergo frequency-domain processing during modulation and demodulation, research employs the least squares (LS) algorithm for estimating multipath interference channel responses (He et al., 2022; Dovelos et al., 2021). For the B5G communication transceiver, the expression for the broadband signal received under multipath channel conditions is given by formula (4).

$$P_r(\tau) = P_{SOI}(\tau) + g_1 * \sum_{i=1}^N a_i P_{SI}(\tau - t_i) - g_2 * P_{ref}(\tau) \quad (4)$$

In formula (4), $P_r(\tau)$ represents the baseband signal received under multipath channel conditions. $P_{SOI}(\tau)$ denotes signals received from other transceivers. g_1 signifies the impulse response of the OSIC system's branch. N indicates the number of variables. P_{SI} represents signals transmitted to other transceivers, perceived as self-interference signals by the local receiver. g_2 represents the impulse response of the branch under the OSIC system. $*$ denotes convolution operation. τ is a time parameter. $P_{ref}(\tau)$ represents the reference signal generated by the transmitter. To fully suppress P_{SI} and acquire $P_{SOI}(\tau)$, a conditional formula for the function of receiving baseband signals is set, as detailed in formula (5).

$$g_1 * \sum_{i=1}^N a_i P_{SI}(\tau - t_i) - g_2 * P_{ref}(\tau) = 0 \quad (5)$$

The conditional formula is further transformed into an equivalent frequency domain expression, as shown specifically in formula (6).

$$G_2(f)P_{ref}(f) = G_1(f)P_{SI}(f)G_{MC}(f) \quad (6)$$

In formula (6), G_{MC} represents the frequency response generated by the multipath channel. To eliminate multipath signals in the frequency domain expression, a filter is introduced to enhance the paths' signals in the frequency domain. Therefore, the expression for the reference signal is updated as shown in formula (7).

$$P_{ref}(f) = P_{SI}(f)G_{PE}(f) \quad (7)$$

In formula (7), G_{PE} represents the added filter, also indicating the frequency response of the pre-equaliser. Based on the equivalent frequency domain expression and the reference signal function, its mathematical expression can be further derived, specifically as shown in formula (8).

$$G_{PE}(f) = \frac{G_{MC}(f)G_1(f)}{G_2(f)} \quad (8)$$

To calculate the parameters of G_{PE} , the LS estimation algorithm is used to solve the frequency response of the base station's broadband self-interference and the reference

channel between the transmitter's digital-to-analogue converter (DAC) and the receiver's analogue-to-digital converter (ADC). The expression for the frequency domain received symbols using the LS algorithm is shown in formula (9).

$$R(k) = X(k)G(k) + Y(k) \quad (9)$$

In formula (9), $R(k)$ represents the received symbols in the OFDM frequency domain. $X(k)$ represents the transmitted symbols. $G(k)$ represents the response of the frequency domain node channel. $Y(k)$ represents Gaussian white noise. According to the basic principles of the LS algorithm, its cost function formula is shown in formula (10).

$$C(\hat{G}) = \|R - \hat{R}\|^2 \quad (10)$$

In formula (10), represents the cost function. $\hat{R}$ represents the vector of the estimated pilot sequence. Since Gaussian white noise has a negligible effect in the LS algorithm, the cost function update formula is shown in formula (11).

$$C(\hat{G}) = \|R - \hat{R}\|^2 = R^G R - R^G X \hat{G} - \hat{G}^G X^G R + \hat{G}^G X^G X \hat{G} \quad (11)$$

In formula (11), $\hat{G}$ represents the estimated channel response. According to the principle of minimising the average, the numerical value of the cost function should be minimised. Therefore, investigating the use of partial derivative formulas to make the cost function zero. The partial derivative formula is shown in formula (12).

$$\delta C(\hat{G}) / \delta \hat{G} = 0 \quad (12)$$

In formula (12), δ represents the partial derivative parameter, taking the value of 0. According to the partial derivative formula, the updated cost function formula is shown in formula (13).

$$\frac{\delta C(\hat{G})}{\delta \hat{G}} = -2(X^G R)^* + 2(X^G X \hat{G})^* = 0 \quad (13)$$

Based on the above formulas, further obtain the estimated value of the channel response, with the specific expression formula as shown in formula (14).

$$\hat{G}(k) = X^{-1}(k)R(k) \quad (14)$$

In formula (14), $\hat{G}(k)$ represents the channel response at a certain subcarrier of the OFDM symbol. Based on the estimated channel response, a smoothing calculation is performed between adjacent 6 frequency points to obtain the average frequency response curve. The specific calculation formula is shown in formula (15).

$$S_\tau = \alpha V_\tau + (1 - \alpha)S_{\tau-1} \quad (15)$$

In formula (15), S_τ represents the predicted value. α represents the smoothing coefficient. V_τ represents the actual value. $S_{\tau-1}$ represents the predicted value from the previous stage.

4 Simulation analysis of adaptive interference elimination strategy based on OSIC

To validate the effectiveness of the adaptive interference elimination strategy proposed in the research based on OSIC, a simulation analysis was conducted using MATLAB software. First, the effectiveness of the UOA algorithm was analysed, followed by the verification of the effectiveness of the adaptive control technology based on OSIC time delay gain in the line-of-sight path. Finally, the performance of the adaptive interference elimination technology based on OSIC time-varying multipath self-interference was verified.

4.1 Experimental setup

The study constructs an experimental environment for adaptive interference cancellation strategies for B5G communication systems, which simulates B5G application scenarios. OFDM signals and EML are used as the basis of the B5G communication system in the experiment. The adaptive control techniques and interference cancellation techniques involved in the experiment are based on optics-based self-interference cancellation (OSIC) system. Meanwhile, in order to simulate the multipath effect, the direct path is considered as the main path in the experiment, and the 0.8–1.2 GHz OFDM signals generated by arrayed waveguide grating (AWG) are used as the self-interference signal and the reference signal, which are transmitted to the upper and lower arms of the OSIC system respectively, and are modulated by the two EMLs into the optical domain respectively, and the residual self-interference after phase cancellation of the two signals is obtained by the BPD and sampled with an oscilloscope. The whole is equipped with a computer for running the MATLAB software, which is connected to and controls each device in real time via an Ethernet switch, so that both the transmitter and the receiver are under MATLAB control, thus guaranteeing a real-time adaptive demonstration. Among them, the variable optical attenuator with 0.01 dB adjustment accuracy and the dimmable delay line with 0.08 ps adjustment accuracy are controlled by MATLAB through the serial port. The baseband DSP operations are also realised by MATLAB. Two arbitrary waveform generators are used as DACs, while an oscilloscope is used to implement the ADC. In addition, the simulation experiment system is assembled with two waveform generators to undertake the DAC function, which is responsible for generating the baseband signals, and one oscilloscope to undertake the ADC function, which is used to receive the baseband signals, and the relevant parameters are set, as shown in Table 1.

Table 1 Relevant parameter settings in the experiment

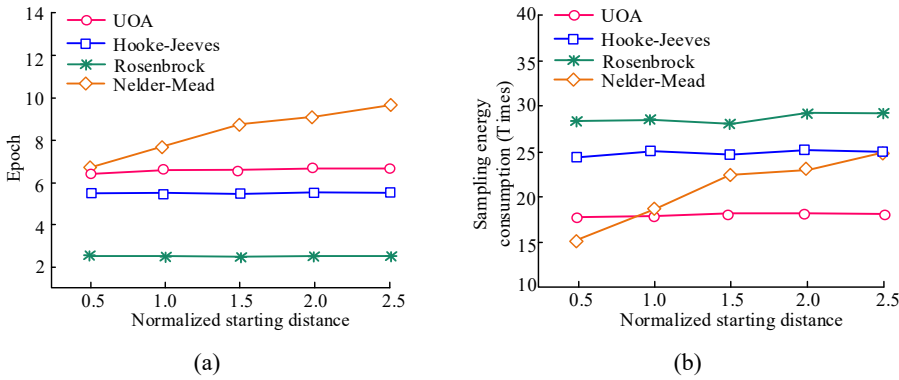
	<i>Symbolic</i>				
	N	N_s	B	f_s	f_c
Representation	FFT/IFFT points	Number of subcarriers used	Effective baseband bandwidth	Arbitrary waveform generator and oscilloscope sample rate	Radio frequency carrier
Value	4,096.00	1,000.00	1.22 GHz	5.00 GHz	12.33 GHz

Based on the parameters set in Table 1, the study tests the parameters in simulation experiments by simulating different channel conditions to test their effects on SIC effectiveness. The effectiveness of the proposed optimisation algorithm as well as the OSIC elimination strategy is verified by comparing the system performance under different delay gain and multipath time configurations.

4.2 Simulation of adaptive control technology based on OSIC time delay gain

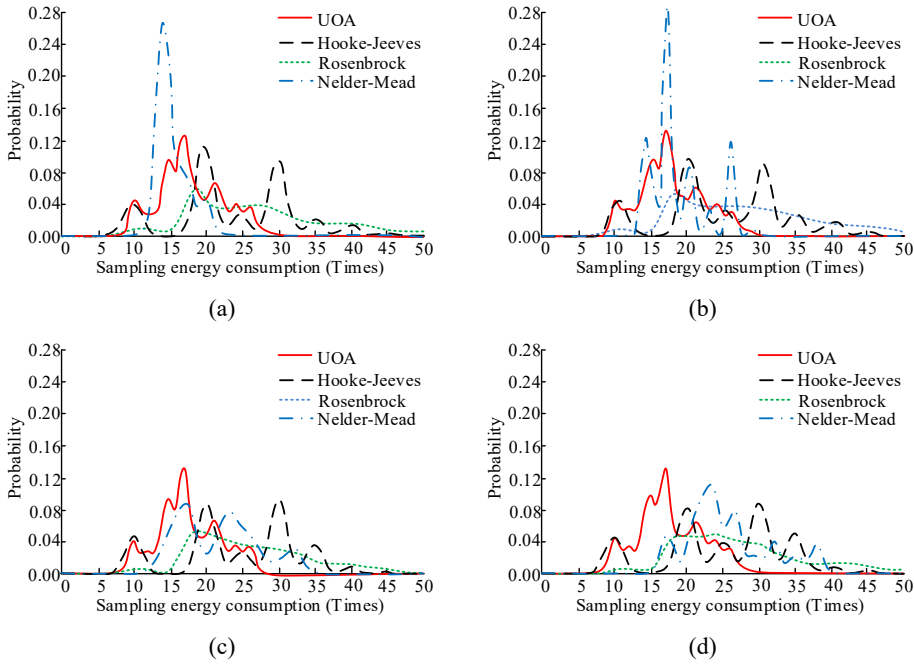
Based on the proposed adaptive control technology with OSIC time delay gain, the research compared the effectiveness of the UOA algorithm with pattern search methods (Hooke-Jeeves), rotational axis methods (Rosenbrock), and simplex search methods (Nelder-Mead). The parameters for the four algorithms were set as follows: initial step size, 0.3; decay factor, 0.38; gain factor, 1.34; reflection coefficient, 0.62; allowable error, $e-6$. With these parameters, the iteration times and sampling energy consumption of the four algorithms were compared, as shown in Figure 6.

Figure 6 Comparison of (a) the number of iterations and (b) sampling overhead of the four algorithms (see online version for colours)



From Figure 6(a), it can be observed that among the four algorithms, only the Nelder-Mead algorithm's iteration times increase with the increase in the initial distance, while the other three algorithms remain relatively stable overall. This indicates that the proposed UOA algorithm has a certain level of rationality. The Rosenbrock algorithm has the lowest iteration times among all algorithms, possibly due to its unique rotational axis characteristics, leading to fewer required iterations. From Figure 6(b), it can be seen that the sampling energy consumption of the proposed UOA algorithm is the lowest among all algorithms. Although the Nelder-Mead algorithm has the lowest sampling energy consumption when the initial distance is 0.5, it increases with the increase in the initial distance. When the initial distance is 0.25, the UOA algorithm reduces sampling energy consumption by 29.82–38.15% compared to the other three algorithms. This indicates that the proposed UOA algorithm reduces the time and energy required for sampling, greatly improving the effectiveness of UOA. Additionally, the research further compared the sampling energy consumption probability distribution of the four algorithms at initial sampling distances of 0.5, 1.0, 1.5, and 2.5, as shown in Figure 7.

Figure 7 Probability distribution of sampling energy consumption for four algorithms at different normalised starting distances, (a) starting distance 0.5 (b) starting distance 1.0 (c) starting distance 1.5 (d) starting distance 2.5 (see online version for colours)

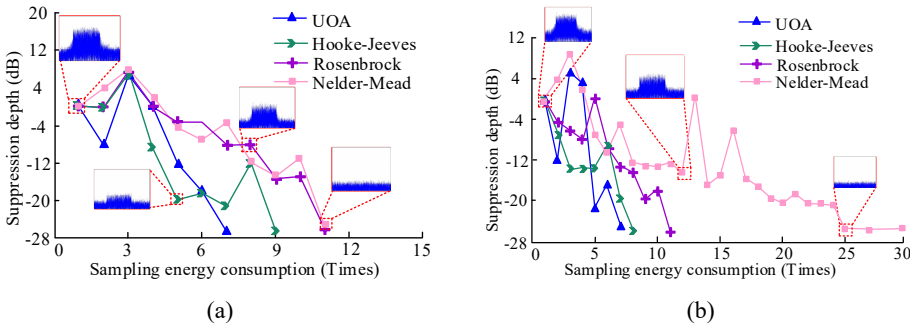


From Figures 7(a) and 7(b), it can be seen that when the sampling energy consumption is in the range of 10–20, all four algorithms exhibit peaks in the probability distribution. Among them, the Nelder-Mead algorithm shows significant fluctuations in probability changes under different sampling energy levels. As shown in Figures 7(c) and 7(d), when the initial distances are 1.5 and 2.5 respectively, the optimal points are distant from the starting points. The sampling energy of all four algorithms continues to increase, but the overall fluctuation of the probability distribution remains stable. Comparing the probability distributions under the four initial distances, it can be observed that the probability change trend of the proposed UOA algorithm is more stable than the other three algorithms, indicating superior performance. Furthermore, the study further analyses the effectiveness of the adaptive control technology based on the proposed OSIC delay gain. The impact of the varying number of samples on the suppression ratio in simulation experiments is shown in Figure 8.

Figure 8 shows the self-interference elimination process under different initial distances. From Figure 8(a), it can be seen that when the initial distance is close, the sampling energy consumption of all four algorithms is similar, but the UOA algorithm has the lowest energy consumption. Combining the power spectrum of the OFDM self-interference signal, it is observed that with the operation of the four algorithms, the signal power gradually decreases until it reaches the noise range and stops iteration. Figure 8(b) shows a comparison of the sampling energy consumption for 30 sampling cycles. It can be observed that, except for the Nelder-Mead algorithm, the sampling energy consumption of the other three algorithms remains stable as the initial distance increases, with the UOA algorithm still maintaining the lowest consumption. These

results indicate that the proposed UOA algorithm can effectively reduce sampling energy consumption in the adaptive interference elimination process of the OSIC system, and the adaptive control technology based on the OSIC delay gain can effectively achieve the elimination of direct-path self-interference in B5G communication systems. The UOA algorithm demonstrates superior performance under different channel conditions as well as sampling distances, which suggests that it is still advantageous and ideally robust under different communication environments.

Figure 8 Suppression ratio variation curve under different sampling times, (a) suppression ration variation curve of energy consumption for 15 samples (b) suppression ration variation curve of energy consumption for 30 samples (see online version for colours)



4.3 Simulation of adaptive interference suppression technology based on OSIC time-varying multipath interference

To achieve effective elimination of multipath self-interference in communication systems and validate the effectiveness of the proposed SIC, the study conducted experimental simulations in the MATLAB software. Considering that the parameter calculation of the pre-equaliser is mainly based on the LS algorithm for estimating the frequency response in the reference signal and multipath interference, the study utilised a vector network analyser (VNA) to test the S21 curve of the reference and self-interference channels as a comparison. The S21 curve, representing the most representative data in the OSIC system, can be used to calculate the power ratio between the OSIC input and output, determining the depth of suppression. The parameters such as the number of samples and subcarrier range set in the VNA are the same as those for the OFDM signal, with ports 1 and 2 connected to DAC and ADC, respectively. The pre-equaliser coefficients obtained by both methods are shown in Figure 9.

From Figure 9(a), it can be observed that the amplitude trend of the pre-equaliser obtained by the LS algorithm is generally similar to that calculated by the VNA. As the number of subcarriers increases, the response variations of the asynchronous mapping procedure (AMP) in both methods coincide. In Figure 9(b), the phase response of the pre-equaliser within 500 subcarriers is slightly higher for the LS algorithm than for the VNA, but the overall trend remains consistent. This indicates the reliability and rationality of the LS algorithm in estimating calculations for self-interference elimination and adaptive FDPE. Therefore, the study further utilised the LS algorithm to assess the baseband interference elimination effects under different multipath channels with or without FDPE, and the comparative results are shown in Figure 10.

Figure 9 Comparison of pre-equaliser coefficients, (a) pre-equaliser amplitude (b) pre-equaliser phase response (see online version for colours)

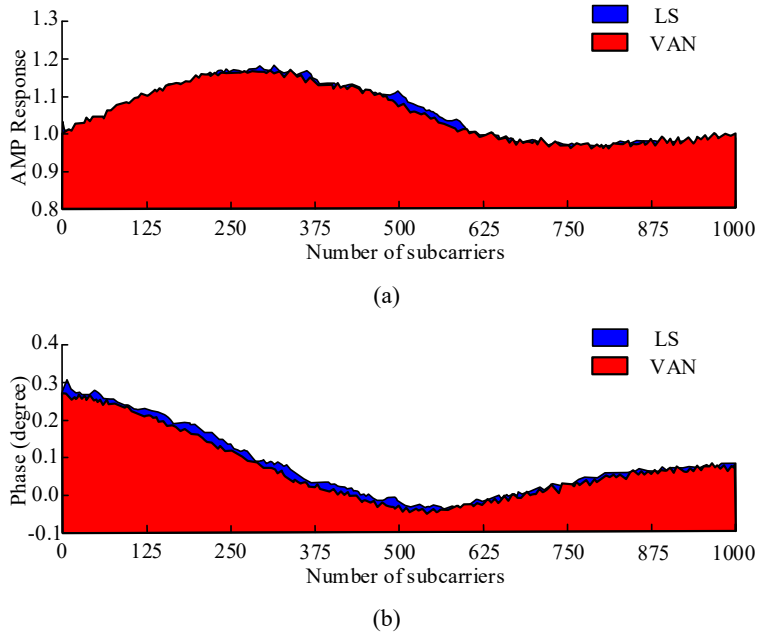


Figure 10 Depth of baseband self interference cancellation under different multipath channels with and without FDPE conditions (see online version for colours)

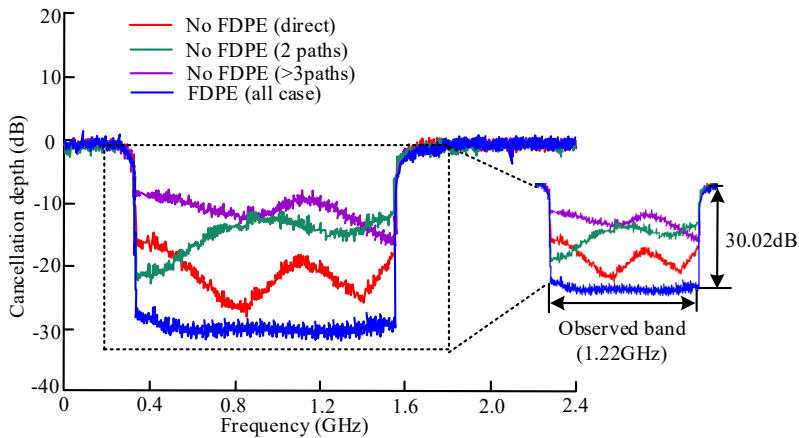
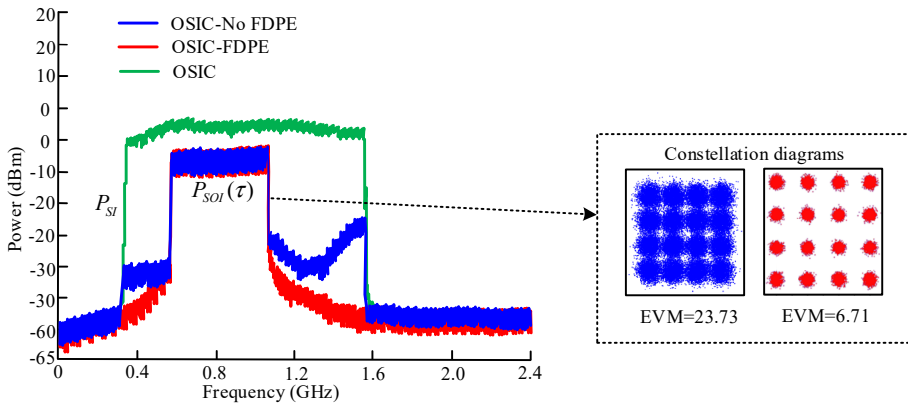


Figure 10 illustrates that the baseband fluctuations in the three-path channels without FDPE are significant, and the depth of self-interference suppression is low, adversely affected by band noise. After FDPE, the curve is suppressed to the baseline level, achieving a flat depth of approximately -30.02 dB within the observed frequency band of 1.22 GHz. The depth of band elimination without FDPE fluctuates from -6 dB to -27 dB, indicating poor performance in self-interference suppression without FDPE and confirming the superiority of the proposed interference suppression strategy. Finally, the

study further analysed the recovery of the useful signal after interference elimination. To better observe the elimination of P_{SI} and the restoration of $P_{SOI}(\tau)$ effects, the bandwidth ratio of P_{SI} to $P_{SOI}(\tau)$ was set wider. The spectrum of the received baseband signal before and after self-interference elimination is shown in Figure 11.

Figure 11 The spectrum of the received baseband signal before and after self interference cancellation (see online version for colours)



From Figure 11, it can be seen that in the OSIC system without self-interference elimination (green), the received useful signal is completely masked by strong power. After self-interference elimination but without FDPE (blue) processing, part of the useful signal spectrum appears, but is still disturbed by residual strong power. The probability of a flat spectrum for the useful signal after self-interference elimination and FDPE (red) processing is significantly higher than the other two untreated conditions. Comparing the constellation diagrams of self-interference without FDPE and self-interference elimination with FDPE, it is evident that the error vector magnitude (EVM) of the signal spectrum after FDPE is only 6.71%, while the EVM value of the signal spectrum with only self-interference elimination is as high as 23.73%. This indicates that the proposed adaptive interference suppression technology based on OSIC time-varying multipath interference can eliminate deeper self-interference and confirms the effectiveness of the proposed interference suppression strategy.

5 Discussion

The proposed OSIC-based adaptive interference cancellation strategy of the study shows significant performance enhancement for the application in B5G communication systems. To further illustrate the superiority of the proposed method, the study will analyse the experimental results in depth, explore the performance under different conditions, and make a comprehensive comparison with existing techniques. The experimental results show that the UOA algorithm proposed by the study outperforms the existing algorithms in terms of the number of iterations and sampling energy consumption, demonstrating higher computational efficiency. The proposed strategy excels in reducing the sampling energy consumption and increasing the detection depth, which can effectively improve

the overall performance of the communication system. The strategy is able to adapt to different channel conditions and interference environments with better robustness.

The study assumes a Rayleigh fading channel model to simulate the wireless communication environment during the design and evaluation of the OSIC adaptive interference cancellation strategy. This assumption helps the algorithm performance itself to be independent of the complex channel conditions. At the same time, the study takes into account the delay gains of the self-interfering channel and the reference channel and assumes that the UOA algorithm is able to converge to an optimal or near-optimal solution within a limited number of iterations, which may affect the convergence of the algorithm. However, the comparison results with other algorithms show the advantage of the UOA algorithm in converging iterations.

It is worth mentioning that the performance of adaptive interference cancellation strategies may vary in different communication modes. In high dynamic environments, the channel conditions change faster, placing higher demands on the real-time and predictive capabilities of the algorithm. On the contrary, in low dynamic environments, the algorithms have more time to adjust and optimise the parameters and may achieve better performance. While the channel configuration as well as the interference level will have an impact on the performance of the proposed strategy, the UOA algorithm proposed in the study takes into account the changes in the actual interference environment during the design process, and adapts to different interference levels by dynamically adjusting the algorithm parameters.

6 Conclusions

In addressing the performance challenges faced by B5G communication systems due to self-interference in the context of limited frequency band resources, this study proposed an adaptive interference elimination strategy based on OSIC. The research established an optimisation model and introduced a UOA algorithm to address the uneven delay magnitudes between self-interference channels and reference channels in B5G communication systems. Simulation experiments demonstrated that when the initial distance was set to 0.25, the UOA algorithm reduced sampling energy consumption by 29.82% to 38.15% compared to other algorithms, effectively decreasing the number of algorithm detection attempts. The proposed interference elimination strategy exhibited excellent performance in feedback computation, achieving a carrier bandwidth of 12.34 GHz, a baseband bandwidth of 1.22 GHz, and a suppression depth of -30.02 dB. Furthermore, the signal's recovered EVM value after self-interference elimination was only 6.71%. The results indicated that the proposed interference elimination strategy could reduce the detection attempts of search algorithms, lower system sampling energy consumption, enhance the processing speed of self-interference channels and reference channels, and improve the efficiency of interference elimination in communication systems. It enabled rapid recovery of useful signals in the presence of multipath self-interference.

However, while the study verified the effectiveness of the proposed strategy in a simulation environment, actual hardware implementation and testing is an important direction for future work. This includes testing the performance of the OSIC system in different physical environments, as well as addressing possible hardware limitations such

as the response speed and modulation accuracy of the optical devices. Future research could explore ways to apply OSIC strategies in multi-user and multi-antenna systems. This would involve more complex signal processing algorithms and network coding techniques to manage a larger number of users and data streams. In addition, B5G communication systems are expected to coexist with multiple wireless technologies. Investigating how to integrate OSIC strategies with other wireless technologies for wider applications and better performance is an area worth exploring.

References

- Ahmed, H. and Hashim, A. (2021) 'Geometry optimization, optical and electronic characteristics of novel PVA/PEO/SiC structure for electronics applications', *Silicon*, Vol. 13, No. 8, pp.2639–2644.
- Alexandropoulos, G.C., Shlezinger, N. and Del Hougne, P. (2021) 'Reconfigurable intelligent surfaces for rich scattering wireless communications: recent experiments, challenges, and opportunities', *IEEE Communications Magazine*, Vol. 59, No. 6, pp.28–34.
- Björnson, E., Wymeersch, H., Matthiesen, B., Popovski, P., Sanguinetti, L. and de Carvalho, E. (2022) 'Reconfigurable intelligent surfaces: a signal processing perspective with wireless applications', *IEEE Signal Processing Magazine*, Vol. 39, No. 2, pp.135–158.
- Dovelos, K., Matthaiou, M., Ngo, H.Q. and Bellalta, B. (2021) 'Channel estimation and hybrid combining for wideband terahertz massive MIMO systems', *IEEE Journal on Selected Areas in Communications*, Vol. 39, No. 6, pp.1604–1620.
- Gheisari, M., Hamidpour, H., Liu, Y., Saedi, P., Raza, A., Jalili, A., Rokhsati, H. and Amin, R. (2023) 'Data mining techniques for web mining: a survey', *Artificial Intelligence and Applications*, Vol. 1, No. 1, pp.3–10.
- He, Y., Zhao, H., Guo, W., Shao, S. and Tang, Y. (2022) 'Frequency-domain successive cancellation of nonlinear self-interference with reduced complexity for full-duplex radios', *IEEE Transactions on Communications*, Vol. 70, No. 4, pp.2678–2690.
- Hong, Z.H., Zhang, L., Li, W., Wu, Y., Zhu, Z., Park, S.I. and Angueira, P. (2022) 'Frequency-domain RF self-interference cancellation for in-band full-duplex communications', *IEEE Transactions on Wireless Communications*, Vol. 22, No. 4, pp.2352–2363.
- Hu, X., Zhu, D., Li, L. and Pan, S. (2022) 'Photonics-based adaptive RF self-interference cancellation and frequency downconversion', *Journal of Lightwave Technology*, Vol. 40, No. 7, pp.1989–1999.
- Huang, X., Le, A.T. and Guo, Y.J. (2021) 'Transmit beamforming for communication and self-interference cancellation in full duplex MIMO systems: a trade-off analysis', *IEEE Transactions on Wireless Communications*, Vol. 20, No. 6, pp.3760–3769.
- Khoshafa, M.H., Ngatched, T.M., Ahmed, M.H. and Ndjiongue, A.R. (2021) 'Active reconfigurable intelligent surfaces-aided wireless communication system', *IEEE Communications Letters*, Vol. 25, No. 11, pp.3699–3703.
- Kim, S M., Lim, Y.G., Dai, L. and Chae, C.B. (2022) 'Performance analysis of self-interference cancellation in full-duplex massive MIMO systems: subtraction versus spatial suppression', *IEEE Transactions on Wireless Communications*, Vol. 22, No. 1, pp.642–657.
- Liu, Y., Mu, X., Xu, J., Schober, R., Hao, Y., Poor, H.V. and Hanzo, L. (2021) 'STAR: simultaneous transmission and reflection for 360° coverage by intelligent surfaces', *IEEE Wireless Communications*, Vol. 28, No. 6, pp.102–109.
- Luo, H., Holm, M. and Ratnarajah, T. (2021) 'On the performance of active analog self-interference cancellation techniques for beyond 5G systems', *China Communications*, Vol. 18, No. 10, pp.158–168.

- Nguyen, T.N., Thang, N.N., Nguyen, B.C., Hoang, T.M. and Tran, P.T. (2021) 'Intelligent-reflecting-surface-aided bidirectional full-duplex communication system with imperfect self-interference cancellation and hardware impairments', *IEEE Systems Journal*, Vol. 17, No. 1, pp.1352–1362.
- Tao, Q., Li, Y., Zhong, C., Shao, S. and Zhang, Z. (2021) 'A novel interference cancellation scheme for bistatic backscatter communication systems', *IEEE Communications Letters*, Vol. 25, No. 6, pp.2014–2018.
- Vaezi, M., Azari, A., Khosravirad, S.R., Shirvanimoghaddam, M., Azari, M.M., Chasaki, D. and Popovski, P. (2022) 'Cellular, wide-area, and non-terrestrial IoT: a survey on 5G advances and the road toward 6G', *IEEE Communications Surveys & Tutorials*, Vol. 24, No. 2, pp.1117–1174.
- Xia, X., Hou, N., Zheng, Y. and Gu, T. (2023) 'PCube: scaling LoRa concurrent transmissions with reception diversities', *ACM Transactions on Sensor Networks*, Vol. 18, No. 4, pp.1–25.
- Xing, Y., Li, S., Xue, X. and Zheng, X. (2021) 'Photonic-assisted RF self-interference cancellation based on optical spectrum processing', *Journal of Lightwave Technology*, Vol. 40, No. 7, pp.2015–2022.
- Ye, H., Li, G.Y. and Juang, B.H. (2021) 'Deep learning based end-to-end wireless communication systems without pilots', *IEEE Transactions on Cognitive Communications and Networking*, Vol. 7, No. 3, pp.702–714.
- Zheng, B., You, C., Mei, W. and Zhang, R. (2022) 'A survey on channel estimation and practical passive beamforming design for intelligent reflecting surface aided wireless communications', *IEEE Communications Surveys & Tutorials*, Vol. 24, No. 2, pp.1035–1071.