Circular Polarization for Self-Interference Cancellation in Single Channel Full-Duplex

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Abstract—Self-interference occurred due to implementation of single channel full-duplex, where the transmit signal interfere the receive signal in the same node. The previous work [2] has been studied the passive cancellation, but those techniques only against the direct path. Then proposed a method using directional antenna with circular polarization to solve self-interference issue. The use of different circular polarization type on transmitter and receiver gives better quality against self-interference. In free space loss channel, using this method obtain polarization loss factor (PLF) as 0 means self-interference totally eliminated. However, AWGN channel gives effect that change polarization shape that results PLF not same as 0. The alpha - comparison between side lobe and main lobe power at directional antenna- makes impact on system performance. For obtaining bit error rate (BER) 10^{-3} needs SINR 17.04 dB, 16.29 dB, and 16.05 dB with alpha value $10^{-0.5}$, 10^{-1}, and $10^{-2.5}$.

Keywords—single channel full-duplex, self-interference cancellation, circular polarization.

I. INTRODUCTION

The existing condition of communication system is using half-duplex that transmit data with FDD (Frequency Division Duplex) or TDD (Time Division Duplex) scheme. FDD uses different frequency for sending and receiving data in the same time. TDD uses same frequency for sending and receiving data in different timeslot. In half-duplex method, the utility of timeslot (TDD) and frequency (FDD) are quite low that still found timeslot or frequency in idle mode when not in use.

Full-duplex wireless communication system is a radio communication system that use the same frequency and time to transmit and receive data simultaneously. However, it's very possible to make self-interference. Self-interference occured when transmit signal from one node interfere the receive signal in the node itself. Self-interference cancellation is a cancellation techniques to eliminate self-interference that occur in full-duplex communication. Self-Interference Cancellation should be able to improve link capacity in wireless communication.

Many of the full-duplex designs in the literature have employed passive and/or active cancellation method as the self-interfefence mitigation strategy. In paper [2], beam separation, directional absorber, and cross-polarization has been proposed as the passive cancellation technique to mitigate self-interference, but these technique effective only against the direct path. In paper [3] the only passive suppression mechanism utilized is physical separation of transmit and receive antenna, i.e., free-space path loss. The active cancellation use an analog method such as estimate transmission delay, amplitude error, and phase error in Rician fading channel was studied by [4], but it's complex mathematically.

This study using directional antenna with circular polarization. The method that will be proposed in this study use the different type of circular polarization, such as Right Hand Circular Polarization (RHCP) and Left Hand Circular Polarization (LHCP) in a node. Circularly polarized antennas can radiate electromagnetic waves that spin clockwise or counterclockwise depending on the structure. So, the same polarized antenna should be used to receive these signals.

The organization of the paper is as follows. In Section II, we describe the system model in detail. Then the simulation design is discussed in Section III. In Section IV we present the outcomes of the simulation and give the reason in each result. In Section V we conclude with some final discussions.

II. SYSTEM MODEL

This study use circular polarization in different type for transmit antenna and receive antenna in a node and obtain good performance of system and suppress the self-interference totally if the self-interference channel assumed free space loss channel. With the implementation of full-duplex system in future technology, there will increase spectrum efficiency to large the capacity in 5G technology.

A. *Self-Interference Cancellation*

Self-interference cancellation used in this study is the technique of passive cancellation. The system simulated by this study is the SISO-OFDM. Environmental testing of the system is the indoor WiFi through Rayleigh channel. The simulation use simulation software.

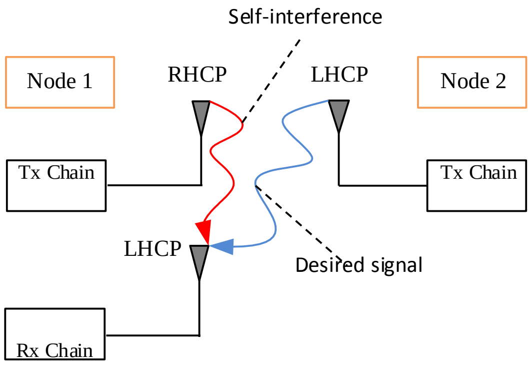

Fig. 1. Proposed Self-Interference Cancellation Model

B. *Polarization Technique*

To make the data can be transmitted like the RHCP, in simulation software this study use 1+j1 as a wave equation (1ax+j1ay) that transmit from tx-1 and the wave equation of rx-1 is 1-j1 (1ax-j1ay). If the channel is FSL (Free Space Loss), PLF (Polarization Loss Factor) value is 0. And if the channel is AWGN, so the PLF value is in range between 0 and 1. The picture of this model is shown below :

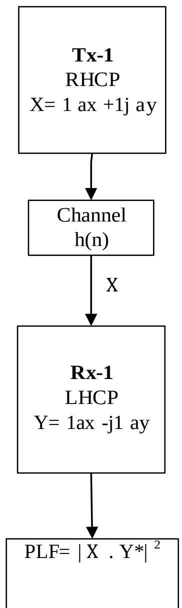

Fig. 2. PLF Calculation for Proposed Method in Self-Interference Channel

Based on the Fig.2 , the noise from the AWGN channel is assume as (a+jb), so X' value is (1+j1)+(a+jb). The AWGN noise is random and make X' value will different with the X value because of the behaviour of AWGN noise. It means that the polarization has change from X to X' and the PLF value is in range between 0 and 1 (0 < PLF< 1).

The desired signal from tx-2 will through the AWGN and Rayleigh channel because the distance between tx-2 to rx-1 was assumed far so it's obtain the reflected signal. Signal from tx-2 use LHCP and the antenna type of rx-1 is LHCP antenna, so the PLF value will toward to 1. The model of desired signal channel is shown in the picture below :

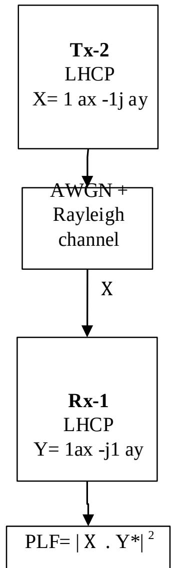

Fig. 3. PLF Calculation for Proposed Method in Desired Signal Channel

Based on Fig. 3, the channel is not FSL, so the PLF value is in range between 0 and 1, but the PLF value in this model is higher than the PLF value in Fig.3 if the channel is AWGN, it because of using the different polarization

III. SIMULATION DESIGN

The performance of the simulation is determined by BER to SINR. Hopefully, as small as self-interference cancellation occur, as lower as BER will be achieved.

A. *Specification of System*

In this part will be simulated full duplex systems use proposed method (different type of circular polarization) with PLF value 0.2. The specification of the system is shown in the table below :

TABLE I. SPECIFICATION OF SYSTEM

Parameter	Specification
Number of bits	1536
Modulation	OFDM
Mapper	64-QAM
Channel coding	LDPC
Coderate	1/2
Number of subcarriers	128
Iteration	50
Self-interference channel	AWGN
PLF	0.2
Alpha	$10^{-0.5}$; $10^{-0.6}$; $10^{-0.8}$; 10^{-1}; $10^{-1.5}$; 10^{-2}; $10^{-2.5}$

Alpha is assumed as the parameter that is defined as comparison between sidelobe power and mainlobe power. This scenario will be simulated the system using omnidirectional antenna. Then the alpha will be 1, means that has a non-directional pattern (circular pattern) in a given plane with a directional pattern in any orthogonal plane.

In this scenario, system will be simulated using directional antenna that has sidelobe power lower than main lobe. The alpha will set variant, which power transmit of sidelobe from tx-1 to rx-1 lower than mainlobe power. In this scenario, system will be simulated with alpha $10^{-0.5}$; $10^{-0.6}$; $10^{-0.8}$; 10^{-1}; $10^{-1.5}$; 10^{-2}; $10^{-2.5}$

Alpha value $10^{-0.5}$ means sidelobe power lower than mainlobe by 5 dB. Alpha value $10^{-0.6}$ means sidelobe power lower than mainlobe by 6 dB. Alpha value $10^{-0.8}$ means sidelobe power lower than mainlobe by 8 dB. Alpha value 10^{-1} means sidelobe power lower than mainlobe by 10 dB. Alpha value $10^{-1.5}$ means sidelobe power lower than mainlobe by 15 dB. Alpha value 10^{-2} means sidelobe power lower than mainlobe by 20 dB. Alpha value $10^{-2.5}$ means sidelobe power lower than mainlobe by 25 dB.

Purpose of this simulation is to know the impact of sidelobe power transmit that interference system. And to know the influence of alpha value to the perfromance system. PLF value of this scenario is 0.2, means some interference signal still received by receiver antenna.

B. Model of Testing System

The scenario model will be shown as picture below:

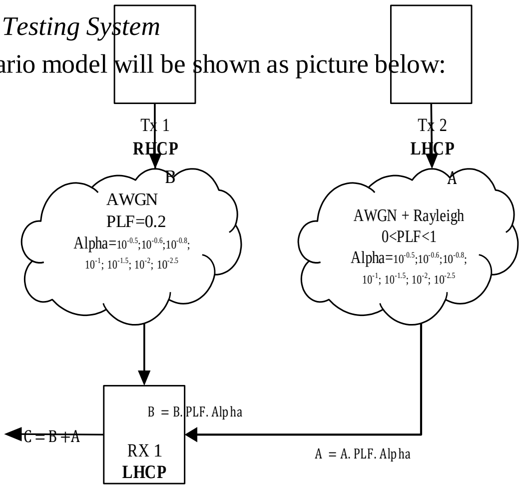

Fig. 4. Figure Model of Scenario System with Variant Alpha

From Fig.4, the signal with LHCP in Tx-2 (A value) will different with A' value because of the behaviour both of the Rayleigh and AWGN channel such as reflecting, scattering, etc. that can change the polarization. Although Rx-1 antenna has the same polarization type with Tx-2, but the PLF is not 1 anymore, it will be decrease by the AWGN channel, and in this testing system, the PLF value was set by 0.2.

IV. RESULT

A. PLF vs SNR in Desired Signal Channel

The picture below is the simulation result of the PLF calculation for the link of Tx-2 to Rx-1that through AWGN and Rayleigh channel :

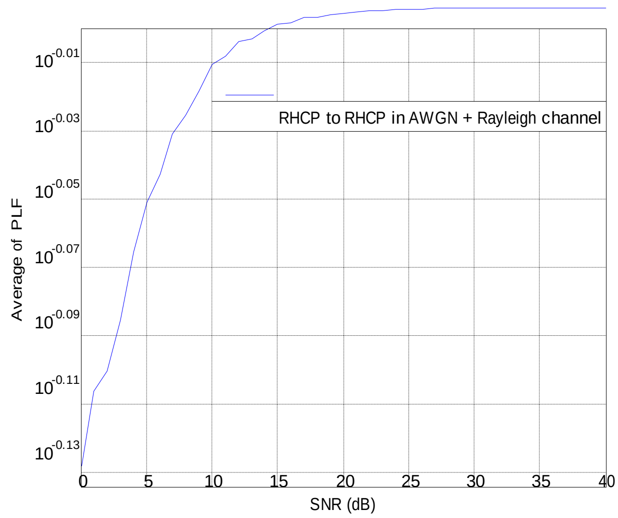

Fig. 5. PLF vs SNR For The Same Type of polarization in AWGN and Rayleigh Channel

In Fig. 5, the average of PLF value is obtained by 500 iteration of simulation. PLF value toward 1 with the higher SNR value. In the FSL channel, with the same polarization, the PLF value should be 1, but in this scenario the channel is influenced by AWGN and Rayleigh channel. In Rayleigh channel the probabilty of reflecting and scattering to occur is high, so the polarization will change. And the PLF will not be 1 anymore. But as high as SNR, the PLF will toward to 1.

B. PLF vs SNR in Self-Interference Channel

The simulation result of PLF calculation for AWGN channel in the different type of polarization is shown in the picture below :

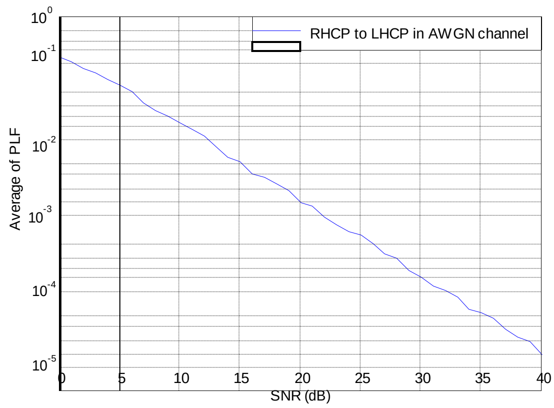

Fig. 6. PLF vs SNR For Different Type Of Polarization In AWGN Channel

Based on Fig. 6, with the different type of polarization (example from RHCP antenna to LHCP antenna) through AWGN channel, the PLF value is not 0 anymore like the condition if through the FSL channel. But as high as SNR, the PLF value will toward to 0. The average of PLF value is obtained by 500 iteration of simulation.

C. The Result of Testing System

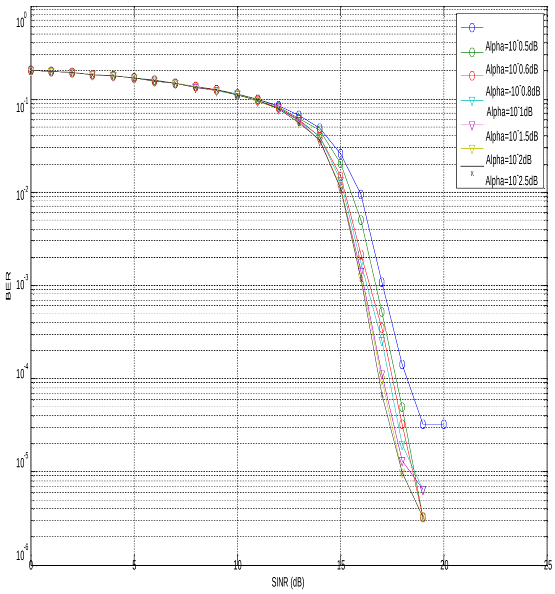

Fig. 7. Impact of Alpha Value to The Performance System at PLF=0.2

From Fig. 7, alpha value give impact to the system. Lower alpha value will make good performance. And higher alpha make worst performance due to interference level will be increase. Below is SINR value that need to achieve BER 10-3.

TABLE II. THE SINR REQUIREMENT TO GET BER 10^{-3} IN DIFFERENT ALPHA VALUE

Alpha	SINR (dB)
$10^{-0.5}$	17.04
$10^{-0.6}$	16.71
$10^{-0.8}$	16.40
10^{-1}	16.29
$10^{-1.5}$	16.13
10^{-2}	16.09
$10^{-2.5}$	16.05

As small as alpha value, as good as the performance of the system. It means that as high as the sidelobe power, as possible as the self-interference occure. But, with using of circular polarization with two type, i.e., RHCP and LHCP in a node, the self-interference is lower than use the same polarization.

V. CONCLUSIONS

The impact of using directional antenna has been discussed in this study. Lower alpha value will make system performance better. Means lower comparison between sidelobe power and mainlobe power. Thus self interference will be supressed. Using directional antenna take some benefit than omnidirectional because just give little impact of self- interference. It because the radiation pattern of directional antenna just focus on spesific area.

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