Performance of Dual Polarized MIMO System using Six-Port Receiver for Cognitive Radio

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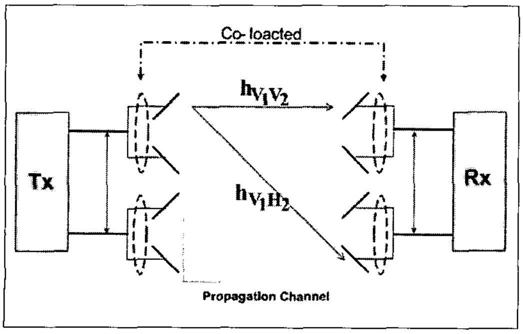
Abstract

Cognitive radio is a paradigm for wireless communication in which either network of wireless node itself changes particular transmission or reception parameters to execute its tasks efficiently without interfering with the licensed users. This paper represents a performance of the cognitive radio technology on dual polarized MIMO system using six-port receiver. Six-port technology is well known direct conversion receiver. In this paper, a six-port phase discriminator based polarization signal separation is shown. That is, the SER (Symbol Error Rate) performance is improved using polarization separator and simple receiver architecture is proposed applying six-port receiver. The six-port technology has priority to adapt changeable frequency system and variable environments for cognitive radio. In general, dual polarized MIMO system has good capacity and quality using polarization separator [1].

I. INTRODUCTION

Cognitive Radio is a transmission technology currently being investigated as a good means for wireless communication. But conventional wideband receivers require filters at the RF and IF, which can usually only be implemented by bulky surface acoustic wave (SAW) or crystal filters. Hence, integration on a single chip, small size and low cost cannot be achieved. For that reason, direct conversion receivers are needed. Promising architecture is the six-port. Advantage of six-port devices is that no mixer components are needed. Particularly, the six-port based on dual polarized MIMO system became an important method for changeable frequency and high capacity fixed device for cognitive radio. The polarization separator structure was applied to improve the system performance. Through SCM dual polarized MIMO channel model, it is represented exact channel characteristics. Especially, the proposed channel model for dual polarized antennas is taken into account cross-polarization discrimination, Ricean K-factor, and fading signal correlation. The figure 1 shows dual polarized MIMO system and channel. And the figure 4 is shown that a six port receiver [2] with signal separator using polarization canceller. Also, table 1 for the directly detection method selected low voltage level is represented finding correct symbols which are matched signal constellations observing only the minimized power strength with one of the four ports for QPSK communication. This paper is organized as follows. In section Ⅱ, it is shown that dual polarized MIMO channel applying SCM. We



⟨Fig. 1⟩ Dual polarized MIMO system

proposed receiver architecture based on six-port receiver and the separators of polarizations in section Ⅲ. In section Ⅳ, the simulation results are analyzed about simple IQ-regeneration procedure for QPSK communication using six-port phase discriminator (SPD). Section Ⅴ concludes the paper.

Ⅱ. CHANNEL MODEL

1. Polarized channel model using SCM

For the equations of channel coefficients add on polarization are described as

Vertical polarization

$$S_V = S\cos(\alpha_{S_i})$$

Horizontal polarization

$$S_H = S\sin(\alpha_{S_j})$$

Orthogonal-Vertical-polarization

$$S_{V\perp} = S\cos(\alpha_{S_j} - \pi/2)$$

Orthogonal-Horizontal-polarization

$$S_{H\perp} = S\sin(\alpha_{S_j} - \pi/2) \qquad (1)$$

$$\begin{aligned} S_{Total} &= (S_V + S_{V\perp})\cos(\alpha_{U_k}) + (S_V + S_{V\perp})\sin(\alpha_{U_k})\cos(\theta_{AoA})\sqrt{r_1} \\ &+ (S_H + S_{H\perp})\sin(\alpha_{U_k})\cos(\theta_{AoD})\cos(\theta_{AoA}) \\ &+ (S_H + S_{H\perp})\cos(\alpha_{U_k})\cos(\theta_{AoD})\sqrt{r_2} \end{aligned} \qquad (2)$$

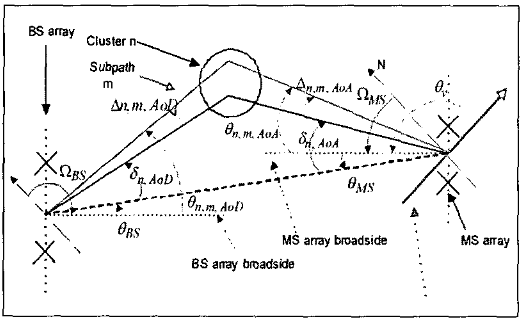
where S represent transmitted signal, r_1 and r_2

are related with the cross polarization discrimination (XPD). S and U are represented transmit (BS) and receiving (MS). J and k denote the number of selected antenna. (1) and (2) are considered effect of depolarization in wave propagation channel. Thus, the following equation forms are described in spatial channel model with dual polarization

$$\begin{aligned} A &= -\sqrt{2}\cos(-45^\circ)\cos(\theta_{AoD})\sqrt{r_{n2}}\,e^{j\Phi^{(v,h)}} + \\ &\quad -\sqrt{2}\sin(-45^\circ)\cos(\theta_{AoD})\cos(\theta_{AoA})e^{j\Phi^{(h,h)}} \\ B &= \sqrt{2}\cos(-45^\circ)e^{j\Phi^{(v,v)}} + \sqrt{2}\sin(-45^\circ)\cos(\theta_{AoA})\sqrt{r_{n1}}\,e^{j\Phi^{(h,v)}} \\ C &= -\sqrt{2}\cos(+45^\circ)\cos(\theta_{AoD})\sqrt{r_{n2}}\,e^{j\Phi^{(v,h)}} + \\ &\quad -\sqrt{2}\sin(+45^\circ)\cos(\theta_{AoD})\cos(\theta_{AoA})e^{j\Phi^{(h,h)}} \\ D &= \sqrt{2}\cos(+45^\circ)e^{j\Phi^{(v,v)}} + \sqrt{2}\sin(+45^\circ)\cos(\theta_{AoA})\sqrt{r_{n1}}\,e^{j\Phi^{(h,v)}} \end{aligned} \tag{3}$$

$$\begin{aligned} h_{vv\_r_1t_1} &= A \\ h_{vv\_r_1t_2} &= A \times e^{jkD_s\sin(\theta_{AoD})} \times e^{jk\|v\|\cos(\theta_{AoA}-\theta_v)t} \\ h_{vv\_r_2t_1} &= A \times e^{jkD_u\sin(\theta_{AoA})} \times e^{jk\|v\|\cos(\theta_{AoA}-\theta_v)t} \\ h_{vv\_r_2t_2} &= A \times e^{jkD_s\sin(\theta_{AoD})} \times e^{jkD_u\sin(\theta_{AoA})} \\ &\quad \times e^{jk\|v\|\cos(\theta_{AoA}-\theta_v)t} \end{aligned} \tag{4}$$

$r_M t_N$ M:rx antenna position and N: tx antenna position are expressed spatial channel coefficient with



<Fig. 2> Dual polarized Spatial Channel Model

referenced position. AoA and AoD denote the angle parameter in Figure 2. Each parameter of A, B, C and D is described by channel amplitude coefficients. Ds: distance between the transmit antennas and Du: distance between the received antennas. $\|v\|$: The low velocity almost fixed devices.

III. RECEIVER ARCHITECTURE

1. Signal separator

Bootstrap adaptive algorithm which does not require training sequence employs an optimization criterion that based on minimization of output signal correlations. The learning process of this bootstrap algorithm is compared with that of the least mean square (LMS) algorithm. There are three configurations of bootstrapped structures; power-power, correlation-correlation and power-correlation were analyzed in detail [3]. Each configuration consists of two cross coupled interference separation loops. In this paper, the boot-strapped algorithm is applied power-correlation scheme. From the figure 3 shown the optimum weights calculation, it can be easily shown that the output is given by:

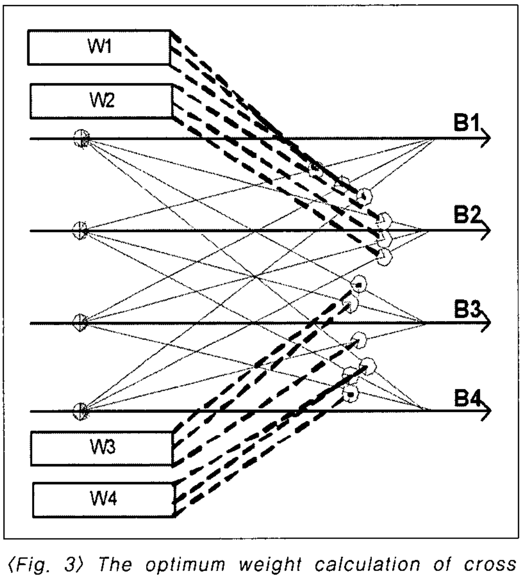
$$\mathbf{B}(t) = \mathbf{W}_B^{-1}\mathbf{y}(t) = \mathbf{W}_B^{-1}[\mathbf{H}\mathbf{x}(t) + \mathbf{n}(t)]$$

The solution to get the optimum weight we used the following recursive equations [4].

$$\mathbf{W}_B = \begin{bmatrix} 1 & -w_{12} & -w_{13} & -w_{14} \\ -w_{21} & 1 & -w_{23} & -w_{24} \\ -w_{31} & -w_{32} & 1 & -w_{34} \\ -w_{41} & -w_{42} & -w_{43} & 1 \end{bmatrix} \quad (6)$$

$$w_{i,j}(n+1) = w_{i,j}(n) - \mu e_{i,j}(n) b_j(n), n: sample\ time$$
$$i, j = 1,2,\dots,M \ i \neq j \ Branch: M$$
$$e_i = b_i(n) - S_i(n)$$

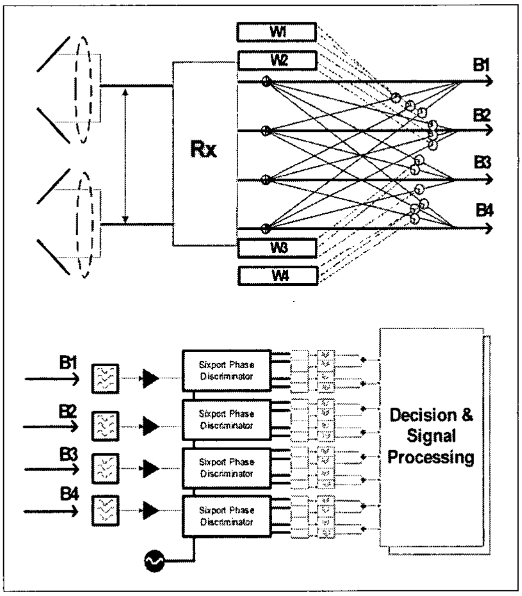
$S_i(n)$ is the constellation mapping signal for transmitted symbols. w(n) and w(n+1) are recursive weights updated. b(n) is the bootstrapped value. e(n) denotes relative error between the bootstrapped value and transmitted symbol.



〈Fig. 3〉 The optimum weight calculation of cross polarization cancellation

2. Six-port technique

The figure 4 shows the proposed six-port receiver structure with dual polarized MIMO



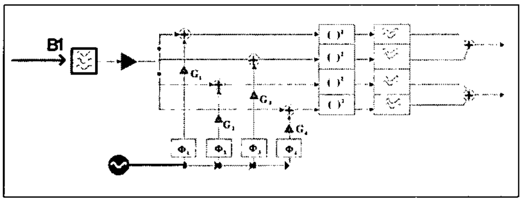
〈Fig. 4〉 The propoesed six-port receiver

system based on cross polarization separators.

In communication receivers, the six-port is a device with the RF signal and the local oscillator signal as two inputs and four outputs of power signals consisting of a mixture of IQ components. After low pass filtering, the I-channel, the Q-channel remains as well as static and dynamic DC component in common six-port receiver [5]. The following equation is represented out-port power

$$\begin{aligned} \tilde{P}_i(t) &= LP(\tilde{b}_i(t)) \\ &= \frac{K_i}{4}\left(x_I^2(t) + x_Q^2(t) + G_i^2\right) \\ &+ \frac{K_i}{2}\begin{pmatrix} x_I(t) G_i \cos(2\pi(f_0 - f_c)t + \varphi_i) \\ + x_Q(t) G_i \sin(2\pi(f_0 - f_c)t + \varphi_i) \end{pmatrix} \quad (7) \\ i &: 1, \dots, 4 \end{aligned}$$

$p(t)$ is the power strength of signal and $B(t)$ is signal which is applied low pass filter. The I-component and the Q-component are defined as $x_I(t)$ and $x_Q(t)$, respectively. Hence, assuming ideal direct down conversion i.e., the signal frequencies are $f_0=f_c$ where G_i describes the certain gain/attenuation and φ_i the unfixed phase shift of the paths from the figure 5. In the condition of $f_0=f_c$ it is possible tract the carrier frequency directly.



〈Fig. 5〉 The six-port receiver

3. The six-port phase discriminator (SPD)

The RF signals are connected at the two six-port inputs. Usually one of these signals is a reference signal and another is the unknown signal. The phase difference between the RF input signal and the reference signal can be obtained using power measurement at six-port outputs. If the two input signals have the same amplitude, the general equation for six-port output signal will be detected only power strength i.e., voltage at output port.

$$v_{iB1} = \frac{a}{2} e^{j\theta_{RF\_input}} \left\{ 1 - e^{j\left(\theta_{ref} - \theta_{RF\_input} - (i-1)\frac{\pi}{2}\right)} \right\} \quad (8)$$

$i = 1 \ldots 4$

Each output power is proportional with $|V_{iB1}|^2$ and has a minimum value corresponding to a certain phase difference $\Delta\theta = \theta_{ref} - \theta_{RF\_input}$ to equations (8). Therefore, the parameters can be directly used to demodulate a QPSK signal. For QPSK signal detection when the voltage output of one port is minimized, the received signal constellation can be determined. The smallest value of the voltage is matched QPSK demodulated constellation. Table Ⅰ. shows demodulation results for the QPSK modulation. Two bit sequences describe I and Q signal.

〈Table 1〉 DETECTION RESULTS FOR THE QPSK MODULATION

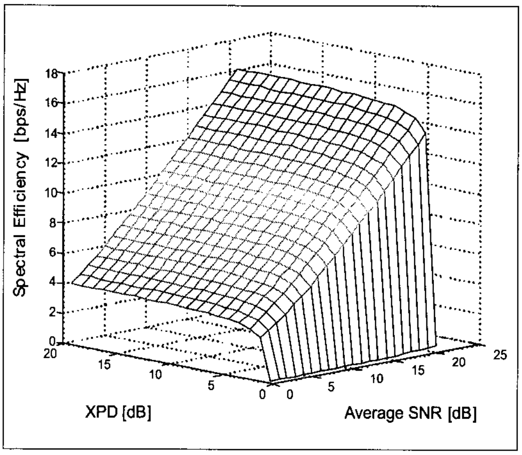
Tx	v1	v2	v3	v4	Rx
11	Min.	–	–	–	11
01	–	Min.	–	–	01
00	–	–	Min.	–	00
10	–	–	–	Min.	10

Ⅳ. SIMULATION RESULTS

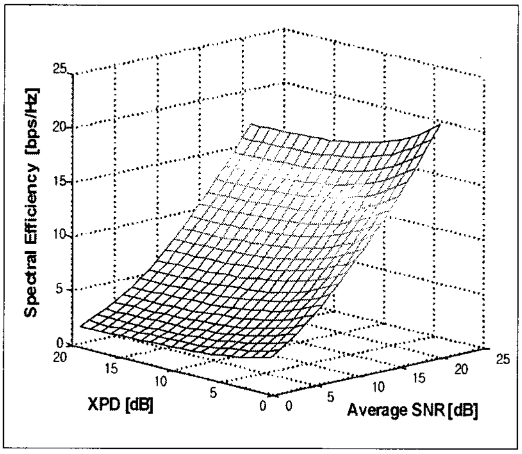
The simulation conditions are following as The trial number of Monte-carlo simulation is 100000 and carrier frequency is 1GHz and 2GHz. The QPSK modulation and demodulation schemes are applied.

1. The characteristics of dual polarized channel

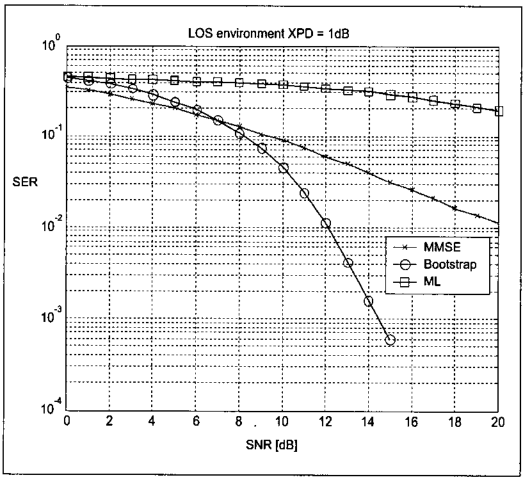
The Figure 6 describes the performance of dual



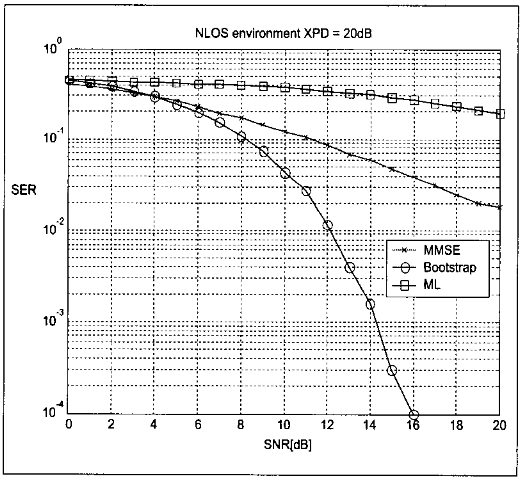
⟨Fig. 6⟩ Channel capacity in the urban micro LOS environment



⟨Fig. 7⟩ Channel capacity in the urban micro NLOS environment



⟨Fig. 8⟩ SER performance of LOS Environment , XPD=1dB



⟨Fig. 9⟩ SER performance of NLOS Environment , XPD=20dB

polarized channel capacities in the urban micro LOS environments. For the LOS case, channel capacity settled as a XPD increases. [1]. But the NLOS case is channel capacity decrease as a XPD increases. Fig. 6. and Fig. 7. are represented channel characteristics.

2. The performace of Symbol error rate

Through the proposed receiver structures, it is shown that Fig. 8. and Fig. 9. have improvement of SER performance. The Bootstrap curve has more 8dB gain at SER 0.01 in Fig. 8. and Fig. 9. NLOS cases show same improvements of performance. Therefore, the six-port receiver based on cross polarization canceller can be obtained high quality data.

V. CONCLUSION

This paper presents a new trial and structures in dual polarized MIMO system using six-port receiver. Dual polarized MIMO system has advantage of getting higher capacity in slow movable device. And six-port receiver can be used direct conversion receiver on Cognitive Radio system. Especially, the polarization canceller obtained lower symbol error. Thus, the proposed receiver structures can be adapted target system with good capacity and quality. It is able to obtain high capacity through the dual polarized MIMO system in low movable cognitive radio, to apply direct conversion using six-port network with simple detection in certain environment and to improve SER performance with polarization canceller.

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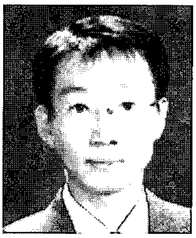

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