SPATIAL MULTIPLEXING WITH SUCCESSIVE INTERFERENCE CANCELLATION

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ABSTRACT

This research paper is about Multiple Input Multiple Output (MIMO) spatial diversity. The goal is to improve the quality of wireless transmission with spatial mutltiplexing by use nonlinear detection for reliable performance. In wireless transmission, at the receiver, linear detection processing can be combined with successive interference cancellation to produce better performance.

Keyword: *diversity, ZF, SIC, SNR, detection*

1. INTRODUCTION

In In wireless transmission, to improve the quality of transmission, the technology of diversity technology is used. It refers to transmitting replicas of the transmitted signal over different channels. Diversity may be obtained through frequency, spatial, polarisation or time. For spatial diversity, the use of multiple antennas both in the transmission and reception results in a so-called multiple input-multiple output (MIMO) radio channel. .

2. MIMO TRANSMISSION

The mathematical modelling of MIMO channel with N_T transmitter antenna and N_R receiver antenna is defined by matrix H expressed as :

$$\boldsymbol{H} = \begin{pmatrix} h_{11} & h_{12} & \cdots & h_{1N_T} \\ h_{21} & h_{22} & h_{23} & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_R 1} & h_{N_R 2} & \cdots & h_{N_R N_T} \end{pmatrix} \quad (1)$$

Where h_{kl} with $1 \leq k \leq N_R; 1 \leq l \leq N_T$ represents the complex gain of the link between the i^{-th} transmitting antenna to the k $^{-th}$ receiving antenna. The number of channels involved in transmission is related to the number of singular values of channel H. Multiple receive antennas can be used to achieve performance and capacity.

The capacity of MIMO channel as expressed as [1]:

$$C_{MIMO} = \sum_{i=1}^{r} log_2(1 + \lambda_i \gamma / N_T) \quad (2)$$

Where, λ_i is the eigenvalue or the power gain of the i[th] independent channel, r is the number of nonzero singular values of H and γ the signal to noise ratio.

2.1 Transmitter antenna technology

At the transmitter, spatial multiplexing and space time coding are technology for use with multiple antenna.

- Spatial multiplexing

It is a multiplexing technique where several independent data streams are simultaneously multiplexed on each antenna. Compared to a SISO or Single Input Single Output channel which uses a single antenna, spatial multiplexing offers many advantages.

This techniques improves channel capacity significantly because more data is sent. In the case of two transmitting antennas, the first bit can be transmitted on the first antenna while the second is on the second.

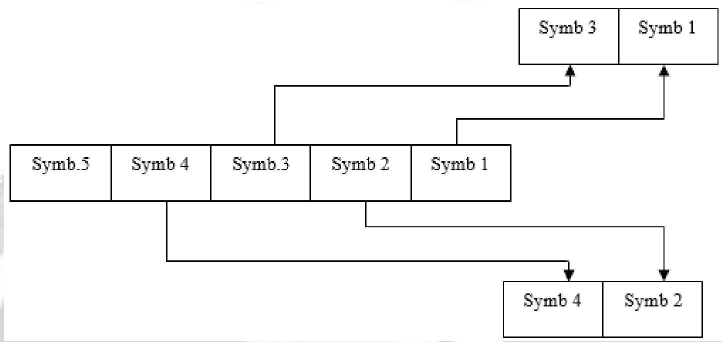

Fig. 1. Spatial multiplexing

Each spatial stream must then have its own pair of transmission/reception antennas at each end of the radio link. The number of simultaneous transmissions shall be limited by the minimum number of reception antennas or transmitters.

- Space times coding

This is a technique for exploiting multiple antennas on the transmitter side to introduce redundant information over time between the antennas.

The same information is sent via multiple antennas several times in time. The aim is to increase the signal-to-noise ratio at reception through redundancy.

Space-time codes fall into one of two primary classes: space-time block codes (STBC) and space-time trellis codes (STTC). In general, STTCs achieve better performance than STBCs, at the expense of more complexity.

2.2 Receiver antenna technology

For spatial multiplexing, the receiver can use linear or nonlinear methods detection. For linear receiver, each of the transmitted multiplexed data streams are estimated at the receiver as a linear combination of the received signals.

Zero Forcing (ZF) and the Linear Minimum Mean Square Error or (LMMSE) are based on linear technology. Zero, Forcing suppress the interference among the spatial layers completely by filtering the received signal with W an inverse of the channel, but also cause noise enhancement [2].

$$W_{ZF} = (H^H H)^{-1} H^H \tag{3}$$

For ZF, the estimated symbol is expressed as:

$$\hat{s} = Wy = (H^H H)^{-1} H^H y \tag{4}$$

For LMMSE, criterion based detectors also take the noise into account and minimize the total expected error.

$$W_{MMSE} = \left(H^H H + \frac{\sigma_N^2}{\sigma_S^2} I_{N_T}\right)^{-1} H^H \tag{5}$$

$$\hat{s} = \left(H^H H + \frac{\sigma_N^2}{\sigma_S^2} I_{N_T}\right)^{-1} H^H y \tag{6}$$

About nonlinear detection, Maximum Likelihood and Successive Interference Cancellation, are technology.

3. NONLINEAR DETECTION

During MIMO transmission, all symbols are subjected to the adverse effects of the propagation channel and the additive noise at the receiver. If the linear equalizers detect the symbols of the different streams in parallel, non-Linear Equalizer like Successive Interference Cancellation detects the symbols sequentially.

3.1 Maximum Likelihood Receiver

Maximum Likelihood Receiver decoding compares the received vector y with all possible transmit vectors s and finds the most likely one. The statistical estimation problem leads to the geometrical task of solving [2] :

$$y = \arg\min\|r - sH\|^2 \quad (7)$$

The ML receiver searches through all possible transmit symbol vectors. The complexity increases exponentially with the number of transmit antenna use.

3.2 Successive Interference Cancellation Receiver

The SIC receiver is an iterative receiver, and is the most popular use and outperforms ZF or LMMSE. The successive interference cancellation (SIC) algorithm detects the symbols sequentially: With this non-linear detection, each input packet is encoded independently. In first linear receiver is used.

- SIC algorithms detect the parallel streams sequentially, make a decision.
- Remodulate the signal, and subtract it from the received vector before detecting the next stream. The next packet is decoded in the same way but with one less interferer.

When a ZF receiver is used, the receiver is called ZF-SIC. When an unbiased MMSE receiver is used, it is called MMSE-SIC [3].

4. BEAMFORMING

Beamforming also referred as spatial filtering, is a technique used by sensor arrays for a directional signal transmission or reception.

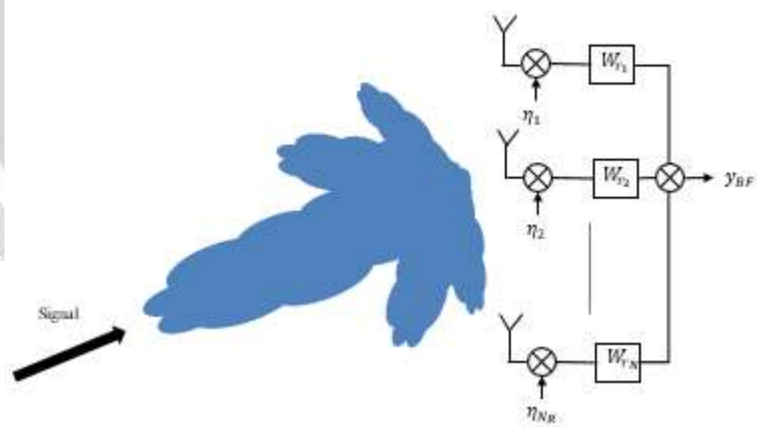

Fig. 2. Beamforming

Beamforming is used to point an antenna at the signal source to reduce interference and improve communication quality [4].

This is achieved by combining elements in an antenna array such that signals at specific angles are subject to constructive interference while others are subject to destructive interference. If $N_T = 1$ then the weights of Beamformer are just the Maximal Ratio Combining weights.

For beamforming with M sensor, array gain is equals as [3] [5]:

$$G = SNR_{array}/SNR_{sensor} = M \quad (8)$$

Beamforming with successive interference cancellation improves performance of wireless transmission.

5. RESULTS

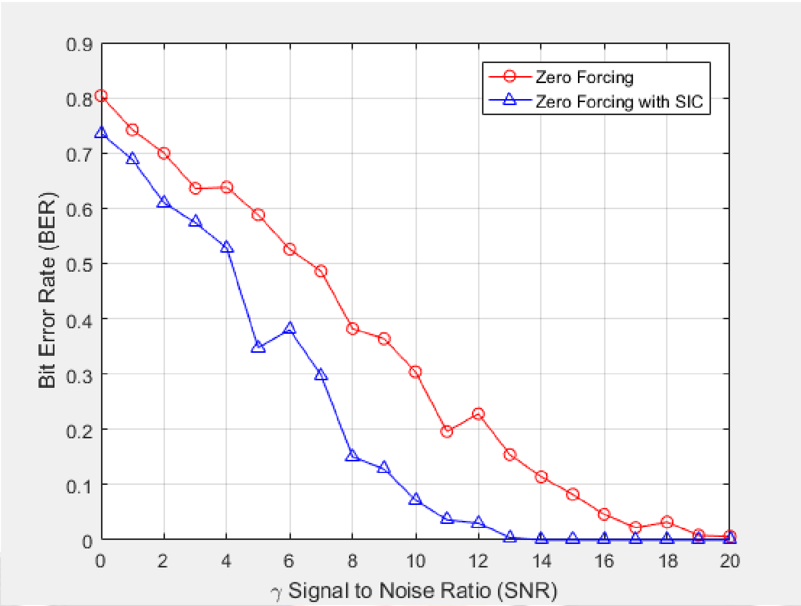

Fig. 3. Zero Forcing and Zero Forcing with SIC

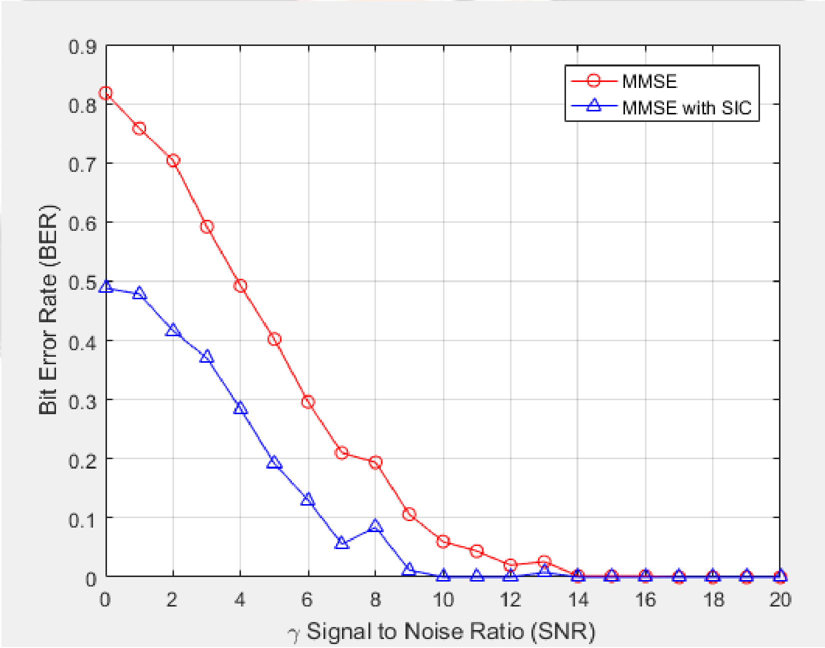

Fig. 4. MMSE and MMSE with SIC

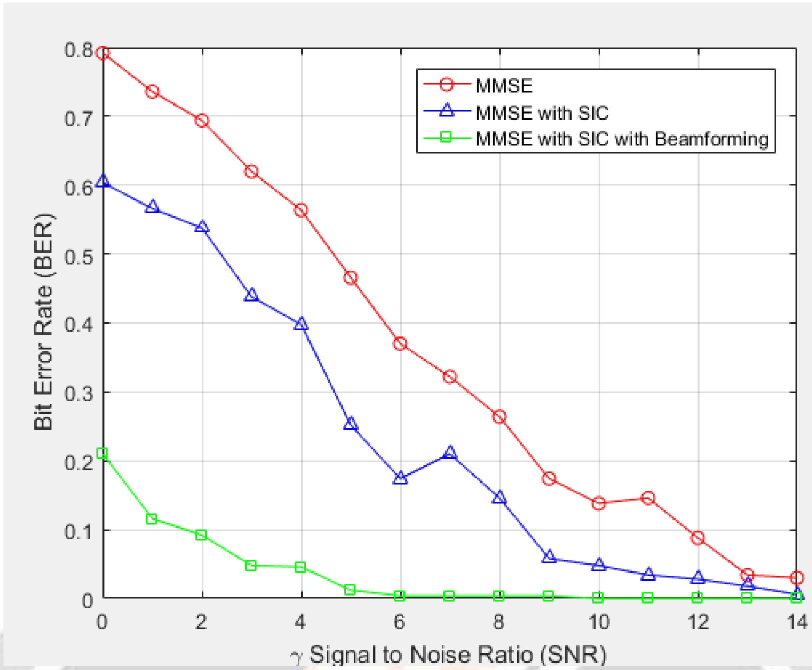

Fig. 5. MMSE with SIC and beamforming

From **Fig-3** and **Fig-4**, with successive interference cancellation the quality of ZF and MMSE receivers increases. From **Fig-3**, **Fig-4** and **Fig-5**, with beamforming, MMSE and SIC receiver improve more than MMSE and SIC combined.

6. CONCLUSION

Nonlinear detection, outperform linear method for spatial multiplexing. Successive Interference cancellation is more performant than Zero forcing and Minimum Mean Square Error. This provides improved performance at the cost of increased computational complexity because of sequential detection. With beamforming, when interference is present, the received signals can be combined to maximize the output signal-to-interference-plus-noise ratio, rather than just the signal to noise ratio.

7. REFERENCES

[1]. J. R. Hampton, “Introduction to MIMO Communications”, Cambridge University Press 2014.
[2]. L. T. Berger, A. Schwager, P. Pagani, D. M. Schneider, “MIMO Power Line Communications”, CRC Press, 2014.
[3]. H. Bolcskei, D. Gesbert, C. B. Papadias, A. J. Van Der Veen, “Space-Time Wireless Systems from Array Processing to Mimo Communications”, Cambridge University Press 2006.
[4]. A. N. Andriamanalina, A.A. Randriamitantsoa, P. A. Randriamitantsoa, “Performance of fixed Beamforming”, IJARIIE, 2022.
[5]. J. Grythe, N. AS, Oslo, Norway, “Array gain and reduction of self-noise”, Technical note, Norsonic, 2015.