Review on MIMO System and MIMO Channel Characteristic

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1.0 Introduction

Because of broadband wireless systems benefit from accurate channel characterization, there is growing interest in broadband wireless multiple-input multiple-output (MIMO) channel models. While coding and signal processing are key elements to successful implementation of a MIMO system, the communication channel representing a major component that determines system performance. This paper will focus on MIMO channel characterization and channel modeling.

2.0 MIMO System

Wireless communication system has a bright future to improve because transmission signal over multiple inputs multiple outputs (MIMO) system promise high capacity by limited bandwidth and transmit power. MIMO system used multiple transmit and multiple received antenna to improve the communication performance.[1]

Figure 1: MIMO system

Figure 1 describes a general model of MIMO wireless communication system. MIMO communication system has two parts. The first part is signal processing and coding while the second part is channel. The radio frequency (RF) component is included in the MIMO channel since they influence the end-to-end transfer function. Input data stream are encoded into discrete-time complex baseband at the transmitter. Then the input will distribute the signal over the Nₜ output (space) and/or over samples (time). Then the pulse shaping converts the discrete-time samples into continuous time baseband wave form and feed them into Nₜ channel inputs (Beamforming network and antennas). The channel H combines the input signals to obtain the NR element output (receive) waveform vector y. Then the signal will convert to discrete-time baseband and the space/time decoder generates estimates of the transmitted signal stream.[2]
3.0 MIMO Channel

MIMO channel is referring to the medium used to convey the information from transmitter to receiver. Characterization of MIMO channel is important for the analysis behavior of system. Non-MIMO systems are linked over multiple channels by several frequencies. While MIMO channel has multiple links and operates on the same frequency [3]. The important parameter to provide a description of MIMO channel are phases, delays, Doppler frequency, angle of departure (AOD), angle of arrival (AOA), bit error rate (BER) and angle spread.

![Figure 2: MIMO Channel](image)

Figures 2 shows a MIMO channel model with M transmit element and N receive signal. For the MIMO propagation model, the input-output relationship can be express as:

\[ Y = Hs + n \] (1)

Where H is narrow band MIMO channel matrix, n is the receiver noise vector and s and y is the signal vector for transmits and receive signals. The MIMO channel has to be describing for all transmit and receive antenna pairs. An N and M is considered as the number of transmits and receive antenna respectively. The narrow band channel transferred matrix H is constitute by N*M complex coefficients \( [s_1, s_2, \ldots, s_m] \). The channel model includes the matrix H with the direct and indirect channel components, \( h_{11} \) is the direct component represent the channel flatness whereas the indirect component is \( h_{21} \) stand for channel isolation. The knowledge of H is essential for decoding and is estimated through a known training-sequence. If the receiver sends the channel approximation to the transmitter it can be used for pre-coding.

4.0 MIMO channel modeling.

Modeling of MIMO radio channel has attracted much attention to the researcher even recent study has prove by employing multiple antenna at the both end can increase the channel capacity [3][8]. In wireless communications, the radio propagation is modeled by the impulse response of the propagation channel between the locations of the transmitter and receiver. MIMO channel model is divided into physical and non physical model [9][10][11].

4.1 Physical model

Physical model characterize an environment on the basic electromagnetic wave propagation by describing the double directional multipath propagation between locations transmit and receiver front end. Physical model can classified as deterministic, geometry- based stochastic and non-geometry stochastic model. Physical model can be easily converted to analytical. One of the physical models is Saleh-Valenzuela with angle (SVA) model. Author from [12] shows the model parameter for a single cluster and characterize amplitude of each arrival, arrival time,
angle of arrival and angle of departure for the indoor channel. Zwick’s model introduced a stochastic indoor MIMO model that allows a time-variant, polarization-dependent broadband description of the multipath channel. In [2], the dependent location of the transmit and receive arrays, the frequency response between the centre an element of these arrays is express as:

$$H(t,f,\Omega_{Rx}) = \sum_{l=1}^{N(t)} \Gamma_l(t) e^{-j2\pi f l(t)} \delta(\Omega_{Tx} - \Omega_{Tx,l}(t)) \delta(\Omega_{Rx} - \Omega_{Rx,l}(t))$$

$$\tau l(t) = \text{delay}$$
$$\Omega_{Tx,l}(t) = \text{direction of departure}$$
$$\Omega_{Rx,l}(t) = \text{direction of arrival}$$
$$\Gamma_l(t) = \text{full polarimetric (2x2) transfer matrix}$$

Each MPC is characterize by it delay, direction of departure, direction of arrival and the full polimetric (2x2) transfer mtrix. Author used recent deterministic ray tracing result to produce the data sets required for the statistical evaluation of the parameters of the proposed model.

### 4.2 Analytical model.

Analytical or non-physical model can describe the impulse response or equivalently the transfer function of the channel between transmits and receive antenna array. Then the data will be combining in channel matrix as an analytical mathematical expression [9]. Recent analytical model are Kronecker, Independent and Identically Distribution (i.i.d), Weichselberger and Virtual channel representation model.

To model MIMO channels in a realistic way, model has been created to incorporate channel correlation. A very popular model doing this is Kronecker model where transmitter and receiver correlation properties are assumed to be independent and are modeled separately [13]. This model enforces all DoD to be linked to all DoA. The joint DoD-DoA spectrum of a synthesized Krocker channel is the product of the average DoD and the average DoA spectra. This means that all DoD are linked to all DoA with the same pattern, only the total power of the DoA depends on the chosen DoD, analogously only the total power of the DoD depends on the chosen DOA.

**Independent and Identically Distribution (i.i.d)** model is the most simple model for MIMO channel. This idealized model assumes a random channel matrix with i.i.d zero mean complex circularly symmetric Gaussian elements. Also used for analytical assessments in information theory. Only one real valued parameter needs to be specified.

The **Weichselberger** model is one of the analytical models. The idea of Weichselberger was to continue the Kronecker model. A crucial point in the derivation of this model is to understand the coupling between the transmit and receives eigenmodes for the Kronecker model. The Weichselberger model parameters are the eigenbases of the transmit and receive correlation matrices, $U_{Tx}$ and $U_{Rx}$ and the coupling matrix, $\Omega_{weichsel}$. [14][15]

The **virtual channel representation (VCR)** model is the MIMO channel in the beamspace instead of the eigenspace. The VCR can be easily interpreted. Its angular resolution and accuracy depend on the actual antenna configuration. Its accuracy increases with the number of antennas, as angular bins become smaller. The model is fully specified by coupling matrix [15].
From [16], the validation shows that, Weishelberger model can cope with system up to 4 x 4, whereas the Kronecker model should be limited to 2 x 2. Author from [17] illustrate through experimental results that Kronecker model might provide large underestimations of the mutual information. Then [14] pointed out that the mathematical and propagations conditions must be fulfill for the Kronecker model to be regiously valid for any antenna spacing and array configurations.

5.0 References


[3] Introduction to MIMO systems


[8] Antenna spacing effect on Indoor MIMO Channel Capacity


[14] E. Bonek Ove "Experimental validation of analytical MIMO channel Models, original arbeiten, Jun 2005

