Modeling, Simulation and Capacity Analysis of Spatially Correlated Channel in MIMO System

B.Praveen Chakravarthy,
M.Tech (2nd Year),
Dept. of E.C.E,
SISTAM,Ampolu ,
Sriakulam, AP-532404.

S.Venkata Swamy,
Professor& Head,
Dept. of E.C.E,
SISTAM,Ampolu,
Sriakulam, AP-532404.

P.Sirish Kumar
Assistant Professor,
Dept. of E.C.E,
AITAM,Tekkali,
Sriakulam, AP-532201.

Abstract:

Future wireless communication systems will utilize the spatial properties of the wireless channel to improve the spectral efficiency and thus increase capacity. Due to the unpredictable nature of the wireless channel, a common approach is to model its effects statistically. These models are partly based on some bulk parameters that describe the characteristics of the channel over larger areas of several wavelengths. Such parameters include shadow fading, angle spread, and delay spread, etc.

In the spatial channel model (SCM) these large-scale parameters are assumed independently between separate links, i.e., channel modeling, propagation between different mobile and base stations .This paper focus on investigation of MIMO system capacity using the Spatial Channel Model (SCM) and Channel Capacity, Spatial Autocorrelation for different channel environment.

***Keywords**: SCM, MIMO, shadow fading, angle spread, channel modeling.*

1. Introduction:

CDMA is also used in the third generation (3G) systems. In the 3rd generation (3G) and beyond-3G (B3G) wireless communication systems, higher data rate transmissions and better quality of services are demanded. By deploying spatially separated multiple antenna elements at both ends of the transmission link, multiple-input multiple-output (MIMO) technologies can improve the link reliability and provide a significant increase of the link capacity. To approach the promised theoretical MIMO channel capacity, practical signal processing schemes for MIMO systems have been proposed.

MIMO systems are designed in such a way to smooth out the delays and make the signals to arrive in some form of pattern. The challenge of the MIMO systems is then to provide a high-performance, reliable data link that can operate with restricted receiver power levels, severe channel fading due to multipath reflections and interfering energy from other devices nearby. The single input single output (SISO) channels dose not provides such data transfer reliability. This is one of the reasons why the use of MIMO systems has increased so rapidly in the recent years. The Spatial Channel Model (SCM) is a standardized model developed by 3rd Generation Partnership Project (3GPP-3GPP2) for evaluating MIMO system performance in outdoor environments.

2. Objectives:

For different channel environments, proposed by standardization bodies (3GPP3GPP2) for third generation system, the main objective of this thesis is

- To investigate MIMO system capacity using spatial channel model in Fast Fading
- To investigate channel capacity variation with time.
- To investigate variation in spatial autocorrelation with time.
- To generate its power delay profile

3. MIMO System Model:

The characteristics of wireless signal changes as it travels from the transmitter antenna to the receiver antenna. These characteristics depend upon the distance between the two antennas, the path(s) taken by the signal, and the environment (buildings and other objects) around the path. The profile of received signal can be obtained from that of the transmitted signal if we have a model of the medium between the two. This model of the medium is called channel model.

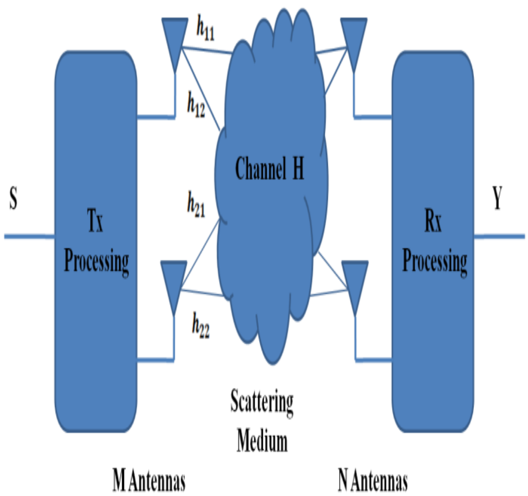

Fig.1: Basic MIMO channel model

3.1. MIMO System Capacity:

MIMO system capacity has been the subject of intense research in the past decade. Both Foschini and Telatar have shown that for i.i.d. channels MIMO system capacity increases linearly with the number transmit antennas and receive antennas rather than logarithmically. This result can be intuited as: MIMO systems exploit the spatial diversity benefits of the channel by transmitting data over a matrix rather a vector channel. A good overview of MIMO systems. The work in has been done under the assumption that only the receiver has perfect channel information. Therefore the equal power allocation scheme was used to calculated capacity. There are many techniques that can be used to achieve channel knowledge at the transmitter, such as feedback from the receiver or through the reciprocity principle in a duplex system. In this thesis, the channel knowledge is assumed. This document suggests a user's guide to a MATLAB application which simulates a Spatial Channel Model (SCM) based on reference with some minor adjustments. It focuses on how to use the Graphical User Interfaces (GUIs) and the functions of the application and avoids going into specifics about the nature of the parameters as this is done analytically in the reference document. The user should at any point consult for additional information. The MIMO spatial channel model simulates a wireless propagation channel in various cases and applies the concept of diversity (spatial and polarization) assuming multiple antennas at both the transmitter and receiver, thus forming a Multiple Input Multiple Output antenna system d to be available at transmitter.

3.2. Spatial Channel Model

The spatial channel model (SCM) is a standardized model established by combining the 3GPP-3GPP2 spatial channel model (SCM) with the adhoc group (AHG). Its scope is to develop and specify parameters and methods under spatial channel modeling for system and link level evaluations. SCM is a 2-D parameter channel model, which considers N clusters of scatterers. Each cluster corresponds to a path. There are M un-resolvable sub paths with in a path (M = 20 for SCM)

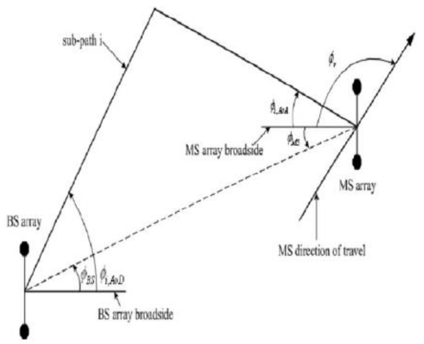

Fig 2: A simplified diagram of SCM for a 2 × 2 MIMO system

3.3. Angular parameter of a simplified SCM Model:

Φ_{BS}	LOS AOD direction between the BS and MS, with respect to the broadside of the BS array.
Φ_{MS}	Angle between the BS-MS LOS and the MS broadside.
$\Phi_{i,AOD}$	Absolute AOD for the i^{th} (i=1………..M) sub-path at the BS, with respect to the BS broadside.
$\Phi_{i,AOA}$	Absolute AOA for the i^{th} (i=1………..M) sub-path at the MS, with respect to the BS broadside.
Φ_{v}	Angle of the velocity vector, with respect to the MS broadside.

Table 1: Angular parameter of a simplified SCM Model:

3.4. Capacity analysis of various Systems:

C.Shannon first derived the channel capacity for additive white Gaussian noise (AWGN) channels in 1948 . Compared with the scalar AWGN channels, a MIMO system can offer significant improvement to either communication quality (bit-error rate or BER) or transmission date rate (bits/sec) by exploiting spatial diversity. We summarize absolute capacity bounds, which compare SISO, single-input-multiple-output (SIMO) and multiple-input-single-output (MISO) capacities. Since feedback is an important consideration of communication system designs. Before discussing capacity, some assumptions need to be stated:

In all these cases, i focus on the single user form of capacity, so that the received signal is corrupted by additive white Gaussian noise only. Capacity analysis is based on a “quasi-static” situation which means that the channel is assumed fixed within a period of time (a burst), and the burst is assumed to be a long enough duration in which sufficient bits are transmitted to make information theory be meaningful. The channels are assumed to be memory less channels which mean that each channel realization is independent of the others.

4. Channel Generation Procedure:

- Select N rays and their relative powers
- Generate a correlated set of Gaussian random variables and map to DS, AS and LN values.
- Obtain Standard Deviation of AoDs
- The AoDs are sorted in order of increasing absolute deviation from MS angle
- Generate N excess delays for each of the rays
- Choose 20 sub-rays at the BS to replace each of the rays in step 1
- Choose N AoAs at the MS

5. SCM Parameter Assumptions:

SCM offers three simulation environments: suburban macro-cell, urban macro-cell and urban micro-cell.

5.1. Suburban Macro: The suburban macro cell scenario describes a rural/suburban area with generally residential buildings and structures.. The BS antenna position is high, well above local clutter. As a result, the AS and DS are relatively small. In addition, the base-to-base distance is approximately 3 km.

5.2. Urban Macro: The urban macro cellular environment describes large cells in areas with urban buildings of moderate heights in the vicinity and significant scattering. The BS antennas are placed at high elevations, well above the rooftops of any buildings in the immediate vicinity. The distance between BSs is again about 3km.

5.3. Urban Micro: The urban micro cell scenario describes small urban cells with inter base distances of approximately 1km. Base antennas are located at roof top level and therefore large ASs are expected at the BS, even though the DS is only moderate.

6. General parameters & assumptions:

The received signal at the MS consists of N time-delayed multipath replicas of the transmitted signal. These N paths are defined by powers and delays and are chosen randomly according to the channel generation procedure. Each path consists of M sub paths.

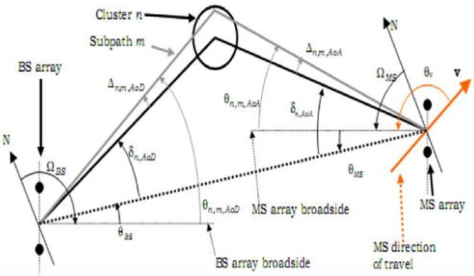

Fig 3: Angular variable definitions

6.1. BS &MS Angle Parameters:

Ω_{BS}	BS antenna array orientation, defined as the difference between the broadside of the BS array and the absolute North (N) reference direction.
θ_{BS}	LOS AOD direction between the BS and MS, with respect to the broadside of the BS array.
$\delta_{n,\ AOD}$	AOD for the nth (n = 1 … N) path with respect to the LOS AOD $\theta 0.$
$\Delta_{n,m,AOD}$	Offset for the m^{th} (m = 1 … M) subpath of the nth path with respect to $\delta n,\ AoD$
$\theta_{n,m,AOD}$	Absolute AOD for the m^{th} (m = 1 … M) subpath of the nth path at the BS with respect to the BS broadside.
Ω_{MS}	MS antenna array orientation, defined as the difference between the broadside of the MS array and the absolute North reference direction
θ_{MS}	Angle between the BS-MS LOS and the MS broadside.
$\delta_{n,\ AOA}$	AOA for the n^{th} (n = 1 … N) path with respect to the LOS AoA $\theta 0,MS$
$\Delta_{n,m,AOA}$	Offset for the m^{th} (m = 1 … M) subpath of the nth path with respect to $\delta^{n,AoA}$.
$\theta_{n,m,AOA}$	Absolute AOA for the mth (m = 1 … M) sub path of the nth path at the MS with respect to the BS broadside.
V	MS velocity vector
θ_V	Angle of the velocity vector with respect to the MS broadside: θ_V = arg(v).

Table 5.1: BS &MS Angle Parameters

7. Results:

In this section, we analyze the MIMO channel capacity and Spatial Autocorrelation using the SCM channel model. The channel model is based on the 3GPP Spatial Channel Model (SCM) [15] which generates the channel coefficients according to a set of selected parameters (e.g., AS, AOD, AOA, etc.). We consider three cases of suburban macro-cell, urban macro-cell and urban micro scenarios here.

❖ Suburban macro cell:

In this section we present some stimulate results for Channel capacity and Spatial Autocorrelation in Suburban macro-cell environment.

❖ Channel Capacity:

The Fig.4 gives the channel capacity for 3 sector and 6 sector antennas at base station in Suburban macro-cell environment and how the channel capacity varies with time.

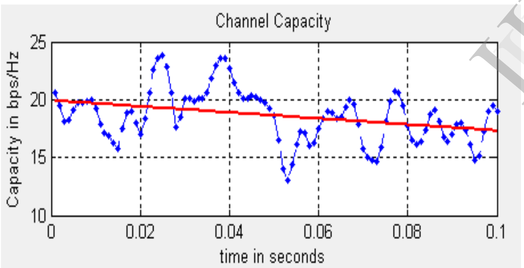

Fig 4a: Channel capacity for 3 sector antenna

The channel capacity is dramatically increased when 6 sector antennas is used as shown in Fig.4b. When we are using 3sector antenna the capacity is reducing manner as shown in Fig.4a.

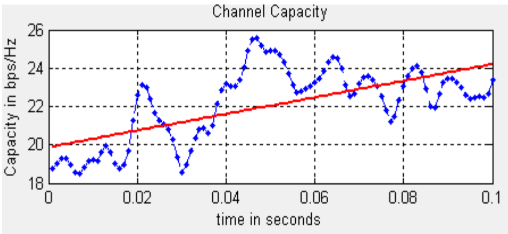

Fig 4b: Channel capacity for 6 sector anteena

As the sectors of an antenna is increasing the capacity of the channel is increased, that what we required in channel modeling to increase the throughput of the system.

❖ Spatial Autocorrelation:

The Spatial Autocorrelation for Suburban macro cell environment i.e. 3 sector and 6 sector antenna at the base station is show in Fig.5a & Fig.5b respectively.

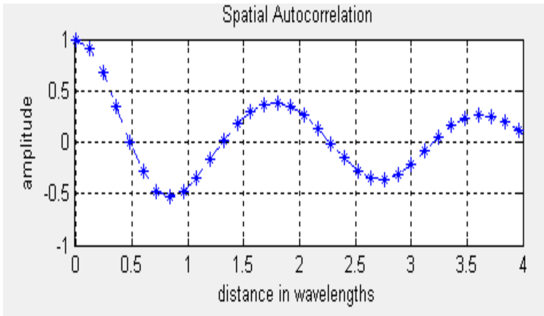

Fig.5a Spatial Autocorrelation for 3 sector antenna

As the distance is increasing the amplitude of the system is in decreasing manner i.e. the correlation between the antennas is less this gives the best transmission.

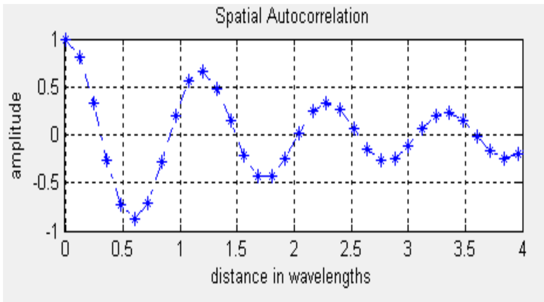

Fig.5b Spatial Autocorrelation for 6 sector antenna

The sectors of an antenna is increasing the correlation is decreasing as shown in Fig 5b.

❖ Urban macro cell:

In this section we present some stimulate results for Channel capacity and Spatial Autocorrelation in Urban macro-cell environment

❖ Channel capacity:

The channel capacity is increased when 3 sector antenna is used as shown in Fig.6a. When we are using 6 sector antenna the capacity is less as shown in Fig.6b.

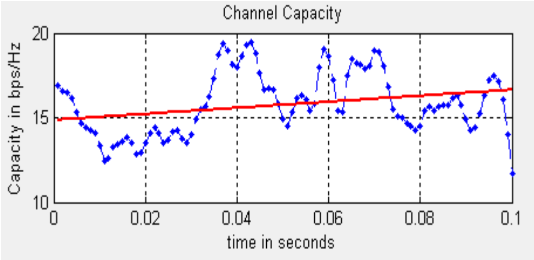

Fig.6a :Channel capacity for 3 sector antenna

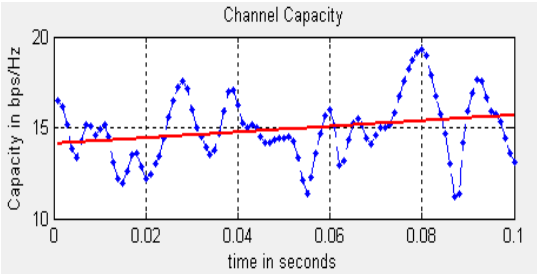

Fig 6b: Channel capacity for 6 sector antenna

❖ Spatial Autocorrelation:

The Spatial Autocorrelation for Urban macro cell environment is shown in Fig.7a & Fig.7b respectively for 3 sector and 6 sector antennas.

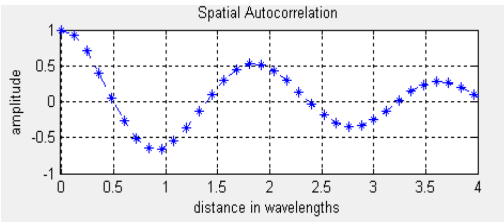

Fig 7a: Spatial Autocorrelation for 3 sector antenna

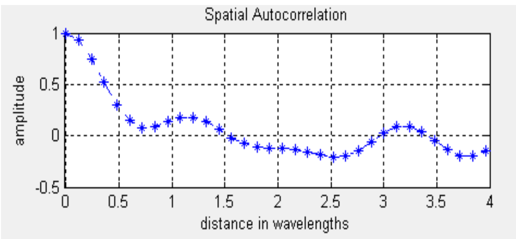

Fig 7b: Spatial Autocorrelation for 6 sector antenna

❖ Urban micro cell:

In this section we present some stimulate results for Channel capacity and Spatial Autocorrelation in Urban macro-cell environment

❖ Channel capacity:

The channel capacity is increased when 3 sector antennas is used as shown in Fig.8a. When we are using 6 sector antennas the capacity is less as shown in Fig 8b.

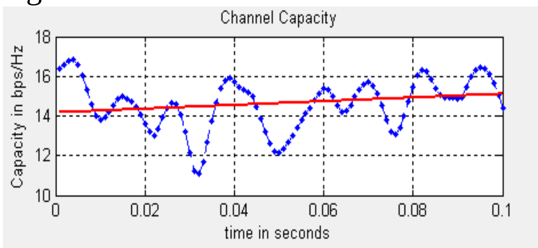

Fig.8a Channel capacity for 3 sector antenna

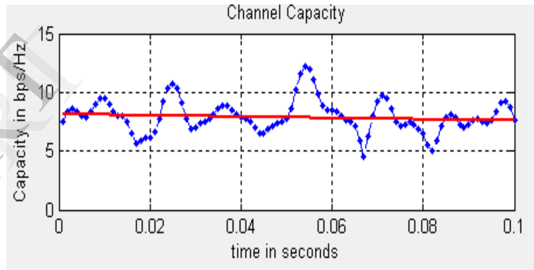

Fig 8b: Channel capacity for 6 sector antenna

In this section as we increase antenna sectors the channel capacity is decreasing as shown in Fig.8a & Fig.8b

❖ Spatial Autocorrelation:

The Spatial Autocorrelation for Urban micro cell environment are shown in Fig.9a & Fig.9b respectively for 3 sector and 6 sector antennas.

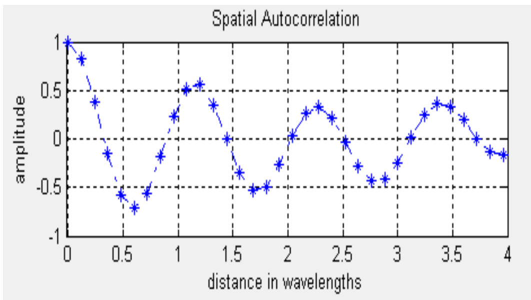

Fig 9a: Spatial Autocorrelation for 3 sector antenna

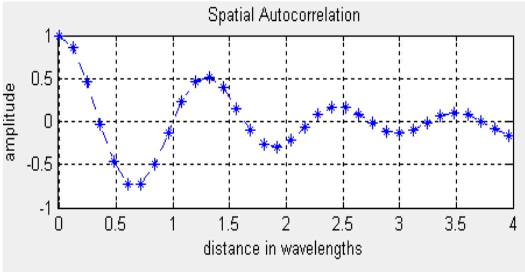

Fig.9b Spatial Autocorrelation for 6 sector antenna

As we are goon moving form environments capacity and Spatial Correlation is seen from this above results, we clearly observe that in Suburban macro- cell environment Channel capacity is more.

8. Conclusion:

In this paper, the spatial channel model proposed by the Third Generation Partnership Project (3GPP) has been studied by numerical simulations. It was found out that the 3GPP SCM model tends to estimate the MIMO outage channel capacity in three environments. This is due to the static nature of the 3GPP SCM in which each signal path is modeled by 20 sub paths having fixed azimuth directions and fixed power levels. Thus, the model is characterized by relatively small spatial correlation between MIMO antennas.

9. REFERENCES :

[1] J.Winters, "On the capacity of radio communication systems with diversity in a Rayleigh fading environment," IEEE Journal on Selected Areas in Communications, Vol. 5, pp. 871-878, June 1987.

[2] G. J. Foschini, M.J.Gans, "On limits of wireless communications in a fading environment when using multiple antennas," Wireless Personal Communications, Vol. 6, Issue 3, pp. 311-335, March 1998.

[3] I.E.Telatar, "Capacity of Multi-antenna Gaussian channels," AT&T Bell Laboratories, BL0 112 170-950 615-07TM, 1995.

[4] Emiliano Dall'Anese, Antonio Assalini and Silvano Pupolin, On the Effect of Imperfect Channel Estimation upon the Capacity of Correlated MIMO Fading Channels. 2009 IEEE.

[5] 3rd Generation Partnership Project (3GPP), "Spatial channel model for multiple input multiple output (MIMO) simulations (3GPP TR 25.996 version 6.1.0 release 6)," ETSI, Tech. Rep., 2003.

[6] J.Salo, G. Del Galdo, J.Salmi, P.Kyosti, M.Milojevic, D.Laselva, and C.Schneider, "MATLAB implementation of the 3GPP Spatial Channel Model (3GPP TR 25.996)," On-line, Jan. 2005, http://www.tkk.fi/Units/Radio/scm/.

[7] E.Telatar, Capacity of multi antenna Gaussian channels, AT&T Bell Laboratories, Tech. Memo., June 1995.

[8] G.J. Foschini and M.J. Gans, On limits of wireless communications in a fading environment when using multiple antennas, Wireless Pers. Commun., vol. 6, pp. 331-335, Mar.1998.

[9] X. Li and Z.P. Nie, "Mutual coupling effects on the performance of MIMO wireless channels," IEEE Antennas Wireless Propagate. LETT. vol. 3, pp. 344–347, Aug. 2004.

[10] Wang Jun, Yu Xiaochuan, Yan Qi, Deng ShaopingNat, "Channel Capacity of MIMO Systems under Correlate Fading Environment "IEEE conference on Wireless Communications Networking and Mobile Computing (WiCOM), 2010 .