

# EE-SE Trade-Off of the 2BS-DMIMO System

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**Abstract:** For high speed wireless communication, data are transmitted with high spectral efficiency, high data rate and reliability. But due to Rayleigh fading, the channels suffer from lot of attenuation resulting in the reduction of Energy Efficiency (EE) and Spectral Efficiency (SE). The proposed system consists of DMIMO system. It contains multiple of MIMO in a system. Here using Closed Form Approximation (CFA) method for trade-off of the EE-SE. Distributed Multiple Input Multiple Output (DMIMO) systems are form of spatial diversity in which we use multiple antennas at transmitter as well as receiver. Closed-form approximation of the Energy Efficiency vs. Spectral Efficiency (EE- SE) trade-off for the uplink/downlink of distributed multiple- input multiple-output (DMIMO) system with two cooperating base stations. This method shows tight match between closed-form approximations for EE- SE trade-off. For given a target SE requirement, there exists an optimal antenna setting that maximizes the EE. In addition, DMIMO scheme can offer significant improvement in terms of EE for both uplink and downlink configurations. While spectral efficiency increases the energy get reducing for various  $p \times q$  antenna configurations.

**Keywords:** Communication, Transmission, Wireless, MIMO, DMIMO, EE-SE, network

## 1. Introduction

All The traditional approach for designing wireless network focuses on the spectral efficiency (SE) metric for optimizing system performance. The current trend of increasing energy demand and increasing energy related operating cost is currently steering research towards the design of energy efficient networks. However, a conflict of interest does exist between maximizing SE, which is a ratio of the capacity in bits/s to the available spectrum, and maximizing energy efficiency (EE), which is a ratio of the capacity to the total consumed power  $P_T$  [11]. The SE is the spectrum utilization indicator while the EE is the energy consumption indicator; hence the relationship between both indicators needs to be carefully studied through their trade-off, i.e. the EE-SE trade-off. The EE-SE trade-off of the point-to-point additive white Gaussian noise (AWGN) can be easily computed [1]. However, closed-form approximations (CFAs) are required for explicitly expressing the EE-SE trade-off of more complex channel such as point-to-point multiple-input multiple-output (MIMO) Rayleigh fading channel [12], [13]. Furthermore, the CFA of the EE-SE trade-off for the uplink of the symmetric coordinated multi-point (CoMP) system is given in [5]. In this work, interested in obtaining a tight CFA for the EE- SE trade-off of the distributed MIMO system, which is a promising technique for meeting the high data rate requirement of the next generation mobile communication networks. The DMIMO scheme combines both the advantages of point-to- point MIMO and distributed antenna system (DAS), i.e. micro and macro diversity, respectively [14], [15]. In [14], [16]–[18], closed-form expressions of the channel capacity of DMIMO were presented. To the best of our knowledge, the CFA of the EE-SE trade-off of DMIMO is yet to be presented.

In this, present a framework to analyze the EE-SE trade-off of DMIMO system with two cooperating base stations (2BS-DMIMO) over the Rayleigh fading channel by following the same approach as in the pioneering works of [12] and [13] on the EE-SE trade-off CFA for the single-user MIMO scenario. In Section 3.1, introduce the system model for the

2BS-DMIMO. In Section 3.3, first derive the CFA of the EE-SE trade-off for the uplink of the 2BS-DMIMO by designing a parametric function and using a heuristic curve fitting method [12], [13], [19]. In section 3.4, derive the CFA of the EE-SE trade-off for the downlink of the 2BS-DMIMO by relying on a similar approach as in the uplink. Our results show that there exists an optimal number of BS antennas that maximizes EE and that 2BS-DMIMO can be far more energy efficient than MIMO system.

## 2. Literature Review

### 2.1 EE-SE trade-off concept and related works

Spectral efficiency, spectrum efficiency or bandwidth efficiency refers to the information rate that can be transmitted over a given bandwidth in a specific communication system. The efficiency of a communication system has traditionally been measured in terms of spectral efficiency (SE), which is directly related to the channel capacity in bit/s.

$$S = R/W \text{ (bit/s/Hz)} \quad (1)$$

The EE of a communication system is closely related to its power consumption. It is reduce the amount of energy required to transmit the data signal from transmitter to receiver. EE is expressed in terms of energy-per-bit ( $E_b$ ) or bit-per-joule capacity ( $C_j$ ) as  $E_b = P_\Sigma / R$  or  $C_j = R / P_\Sigma$  respectively and  $P_\Sigma$  is the total consumed power.

### 2.2 EE-SE Trade-off

In simple words, the concept of EE-SE trade-off can be described as how to express EE as a function of SE. Let  $R$  (bit/s) be the achievable rate of an encoder and  $P_\Sigma$  (Watt) be the total consumed power for transmitting data at this rate, then the EE can either be expressed in terms of energy-per-bit,  $E_b$ , or bit-per-Joule capacity,  $C_j$ , as  $E_b = P_\Sigma / R$  or  $C_j = R / P_\Sigma$ , respectively. Note that  $P_\Sigma = P$  in most of the theoretical works related to the EE-SE trade-off [2], [6]–[8], where  $P$  (Watt) is the transmit power. As far as the maximum achievable SE or

equivalently the channel capacity per unit bandwidth  $C$  (bit/s/Hz) is concerned, it can be expressed as,  $C = f(\gamma)$  (2) via the Shannon's capacity theorem[4], where  $\gamma = P/(N_0W)$  is the signal-to-noise ratio (SNR),  $W$  (Hz) is the bandwidth and  $N_0$ (Joule) is the noise spectral density. Here  $f(\gamma)$  is,

$$f(\gamma) = \log_2(1+\gamma) \quad (3)$$

Let  $S = R/W$  (bit/s/Hz) be the achievable SE, then  $\gamma$  can be re-expressed as a function of both the SE and EE such that

$$\gamma = \frac{P}{N_0W} = \frac{SE_b}{N_0} \quad (4)$$

Inserting (3) into (2), the EE-SE trade-off is simply expressed as follows

$$\frac{E_b}{N_0} = \frac{f^{-1}(C)}{S} \quad (5)$$

where  $f^{-1} : C \in [0, +\infty) \rightarrow \gamma \in [0, +\infty)$  is the inverse function of  $f$ . Equation (5) indicates that a straightforward solution for finding an explicit expression of the EE-SE trade-off boils down to obtaining an explicit expression for  $f^{-1}(C)$ . For instance in the AWGN channel case  $C = f(\gamma) = \log_2(1 + \gamma)$  and, hence,  $f^{-1}(C)$  is directly given by  $\gamma = f^{-1}(C) = 2^{2^C} - 1$  [1], [2]. However, in cases where  $f(\gamma)$  does not have a straightforward formulation, e.g. MIMO Rayleigh fading channel, approximating  $f^{-1}(C)$  can provide an acceptable solution. In [6], it has been stated that the EE of a communication system depends mainly on its SE in the low-power/low-SE regime such that the EE-SE trade-off can be approximated as (equation (28) of [2])

$$\frac{E_b}{N_0} \geq \frac{E_b}{N_{0 \min}} 2^{c/s_0} \quad (6) \quad \text{Where, } \frac{E_b}{N_{0 \min}} = \frac{\ln(2)}{f(0)} \text{ and } s_0 = \frac{2[f(0)]^2}{-f'(0)}$$

are the minimum energy-per-bit and the slope of the SE, respectively, and  $f'(0)$  and  $f''(0)$  are the first and second order derivatives of  $f(\gamma)$  when  $\gamma = 0$ . This method is in effect quite generic and, thus, it can be used to approximate the EE-SE trade-off of any communication channels or systems for which an explicit expression of its maximum achievable SE as a function of  $\gamma$ , i.e.  $f(\gamma)$ , exists and is twice differentiable. It has first been utilized in [2] for approximating the EE-SE trade-off over the AWGN and various fading channels, such as the MIMO Rayleigh and Rician channels. Because of its simplicity, this approach has gained popularity and it has been extended over the years to most of the communication scenarios of interest, as previously mentioned in the introduction. However, the main shortcoming of this approach is its rather limited range of SE values for which it is accurate. Indeed, it is by design limited to the low-SE regime and thus, it cannot be used for assessing the EE of future communication system such as LTE which are meant to operate in the mid-high SE region. So far, the two main approaches for obtaining explicit

expression of the EE-SE trade-off have been either to use the explicit expression of  $f(\gamma)$  for finding an explicit solution to  $f^{-1}(C)$  or to use the explicit expression of  $f(\gamma)$  for approximating  $f^{-1}(C)$ .

Another approach would be to use an accurate CFA of  $f(\gamma)$ , i.e.  $f(\gamma) \approx \tilde{f}(\gamma)$  for finding an explicit solution to  $f^{-1}(C)$  as it is here presented for the MIMO Rayleigh fading scenario. Note that it has recently used the same approach for accurately and explicitly expressing the EE-SE trade-off in the uplink of cellular system [5].

### 2.3 EE-SE Trade-off for Realistic PCMs

In a practical setting,  $P$  is not equal to  $P_\Sigma$ . For instance in [6] and [7],  $P_\Sigma$  is expressed as,

$$P_\Sigma = N_{\text{Sector}} N_{\text{PApSec}} (P_{\text{Tx}}/\mu_{\text{PA}} + P_{\text{SP}})(1+C_C)(1+C_{\text{PSBB}}) \quad (7)$$

where  $N_{\text{Sector}}$  is the number of sector,  $N_{\text{PApSec}}$  is the number of power amplifier (PA) per sector,  $P_{\text{Tx}}$  is the transmit power per PA,  $\mu_{\text{PA}}$  is the PA efficiency,  $P_{\text{SP}}$  is the signal processing overhead,  $C_C$  is the cooling loss and  $C_{\text{PSBB}}$  is the battery backup and power supply loss.

In general, the number of PAs of a BS is equal to the number of transmit antennas such that  $N_{\text{Sector}} N_{\text{PApSec}} = t$ , and the linear

PCM is equivalent to  $P_\Sigma = t(\Delta_P P_{\text{Tx}} + \bar{P}_0)$ , where

$\Delta_P = (1+C_C)(1+C_{\text{PSBB}})/\mu_{\text{PA}}$  and  $\bar{P}_0 = P_{\text{SP}}(1+C_C)(1+C_{\text{PSBB}})$  are the slope and constant part of the PCM, respectively. This BS PCM has been refined in [9] such that the power consumption of extra BS components e.g. direct current (DC)-DC and analog current (AC)-DC converters, have also been included. Even though this model takes into account the non-linearity of the PA, it has been shown in [9] that the relation between relative radio frequency (RF) output power and BS power consumption is nearly-linear and, consequently, a linear abstraction of this model has been defined for the 2x2 antenna setting and different types of BS in [9]. Moreover, as it is explained in [9], it is anticipated that the power consumption of components like DC-DC/AC-DC converter and cooling unit will not grow linearly with the number of antennas and, thus, the PCM gives an upper bound on the power consumption of a BS with  $t$  transmit antennas. A more realistic double linear PCM, i.e. linear both in terms of  $P$  and  $t$ , would consider that only one part of the overhead power grows linearly with  $t$  and one part remains fixed such that

$$P_\Sigma = t(\Delta_P P_{\text{Tx}} + P_0) + P_1 \quad (8)$$

Which is consistent with the BS PCM recently proposed in [10]. Substituting  $P$  in (4) by  $P_\Sigma$  in (8), it can generalize the EE-SE trade-off in (4) as follows

$$\frac{E_b}{N_0} = \frac{1}{S} \left[ \Delta_P f^{-1}(C) + \frac{tP_0 + P_1}{N} \right] \quad (9)$$

Where,  $N = N_0W$  is the noise power. Note that (8) reverts to (4) when  $\Delta_P = 1$  and  $P_0 = P_1 = 0$ , i.e. in the theoretical case.

2.4 CFA of the EE-SE trade-off for MIMO Systems

Energy Efficiency (EE) can be seen as a mature field of research in communication, at least for power-limited applications such as battery-driven system, e.g. Mobile terminal, underwater acoustic telemetry, or wireless ad-hoc and sensor networks. However, in the current context of increasing energy demand and price, it can be considered as a new frontier for communication network. Indeed, network operators are currently driving the research agenda towards more energy efficient network as a whole in order to decrease their ever-growing operational costs. The first signs of this trend can already be seen in the development of future mobile systems such as long term evolution-advanced (LTE-A). The efficiency of a communication system has traditionally been measured in terms of spectral efficiency (SE), which is directly related to the channel capacity in bit/s. This metric indicates how efficiently a limited frequency spectrum is utilized; however, it fails to provide any insight on how efficiently the energy is consumed. Such an insight can be given by incorporating an EE metric in the performance evaluation framework. Apart from the widely used energy-per-bit to noise power spectral density ratio [1],[2]-[3] i.e.  $E_b/N_0$ , one can also use the bit-per-Joule capacity, the rate per energy or the Joule-per-bit as an EE metric.

The EE of a communication system is closely related to its power consumption and the main power-hungry component of a traditional cellular network is the base station (BS). In most of the theoretical studies [1],[2]-[3], the total consumed power of a transmitting node such as a BS has been assumed to be equal to its transmit power, whereas in reality, it accounts for various power elements such as cooling, processing or amplifying power. Thus, in order to get a full picture of the total consumed power in a system and evaluate fairly its EE, a more realistic power consumption model (PCM) must be defined for each node, such as the ones recently proposed for the BS of various communication systems, e.g. GSM, UMTS and LTE. The PCMs are linear, whereas the one is nearly-linear.

Minimizing the consumed energy, or equivalently maximizing the EE, while maximizing the SE are conflicting objectives and, consequently, they can be linked together through their trade-off. The concept of EE-SE trade-off has first been introduced in [2] where an approximation of this trade-off has been derived for the white and colored noises, as well as multi-input multi-output (MIMO) fading channels based on the first and second derivatives of the channel capacity. This linear approximation is accurate in the low-SE regime but largely inaccurate otherwise. This work has inspired numerous other works where the same analytical method was used to approximate the EE-SE trade-off of correlated multi antenna, multi-user, multi-hop, or cooperative communication system in the low-SE regime. In general, the problem of defining a closed-form expression for the EE-SE trade-off is equivalent to obtaining an explicit expression for the inverse function of the channel capacity per unit bandwidth. This has so far been proved feasible only for the additive white Gaussian noise (AWGN) channel and deterministic channel with colored noise in [1] and [2] respectively, and it explains why the various works

previously cited have resorted to approximation instead of explicit expression.

In this comparing method, that is closed-form approximation and explicit expression methods for various antenna configurations by using given below theory. Despite being less accurate than  $f(\gamma)$ , the main advantage of  $\tilde{f}(\gamma)$  over  $f(\gamma)$  is the fact that the inverse function of  $\tilde{f}(\gamma)$ , i.e.  $\tilde{f}^{-1}(C)$ , can be expressed into a closed-form. Consequently, an accurate CFA of the EE-SE trade-off can be formulated as  $\gamma \approx \tilde{f}^{-1}(C) = \frac{1}{2(1+\beta)} \{-1 + (1 + [w_0(g_r(C))]^{-1}) \times (1 + [w_0(g_r(C))]^{-1})\}$  (10) in the MIMO Rayleigh fading case, where  $W_0(x)$  denotes the real branch of the Lambert function [5].

3. Proposed System

3.1 System Model

Here consider a standard DMIMO communication system where two base stations (BSs) equipped with  $p$  antennas each cooperate to transmit/receive data to/from a user terminal (UT) equipped with  $q$  antennas, as illustrated in Fig.3.1. In this consider only one active user in the system due to the use of an orthogonal access scheme. Here, assume as in [14], [17] that all  $2p$  antennas have a separate feeder to the central unit where all signal processing is done. Also assume that  $p \geq q$ , which is a practical and reasonable assumption [15]. The matrices  $\Omega_i$  and  $H_i$  represent the deterministic distance dependent pathloss/shadowing

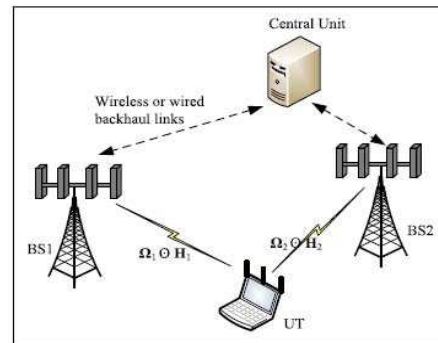


Figure 3.1: Distributed MIMO system model (2BS-DMIMO)

and the MIMO Rayleigh fading channel, respectively, between the  $i^{th}$  BS and the UT,  $i \in \{1, 2\}$ . And  $\alpha_i$  represents the average channel gain between the UT and the  $i^{th}$  BS. Furthermore, the total number of transmit and receive antennas of the 2BS-DMIMO Fig.3.1. Distributed MIMO system model (2BS-DMIMO) system is defined as  $N_t$  and  $N_r$ , respectively. In the uplink case  $N_t = n = q$  and  $N_r = 2p$ , whereas in the downlink case  $N_t = 2p, N_r = q$  and  $n = p$ , where  $n$  is the number of transmit antenna per node.

3.2 Closed-Form Approximation of the EE-SE Trade-off

The capacity per unit bandwidth of the Rayleigh fading DMIMO channel is given such that  $C=f(\gamma)$  (11).

The EE,  $C_j$  is the bit-per-Joule capacity and is equivalent to  $R/P_T$ , where  $R$  is the achievable rate and  $P_T$  is the total consumed power. Note that when considering the idealistic model,  $P_T = P$  and  $P_T = 2P$  in the uplink and downlink cases, respectively. Using the inverse function of  $f$ ,  $f^{-1}$  (i.e.  $f_u^{-1}$  and  $f_d^{-1}$  for the uplink and downlink case, respectively), for expressing  $\gamma$  as a function of  $C$ , obtain that

$$C_{ju} = S / (N_0 * \int_u^{-1}(C)) \quad (12)$$

$$C_{jd} = S / (2 * N_0 * \int_d^{-1}(C)) \quad (13)$$

For the uplink and the downlink of the 2BS-DMIMO system, respectively, where  $S = R/W$ . Equations (12) and (13) indicate that the EE-SE trade-off can be formulated by finding an explicit expression for  $f^{-1}(C)$ . For example,  $f^{-1}(C)$  can easily be obtained for point-to-point AWGN channel as in [1], however, this is not as straightforward for more complex channel scenarios such as DMIMO.

Instead, approximating  $f^{-1}(C)$  as in [12]–[5] is an effective solution for formulating a closed-form expression of the DMIMO EE-SE trade-off.

### 3.3 EE-SE Trade-off CFA for the Uplink of 2BS-DMIMO

The closed-form expression for the ergodic capacity per unit bandwidth in the uplink of the 2BS-DMIMO system can be expressed from [16] as

$$C \approx \frac{1}{\ln(2)} [q \ln(1 + k\alpha_1^2 P u_1 + k\alpha_2^2 P u_2) + p \ln(1 + \alpha_1^2 P w) + p \ln(1 + \alpha_2^2 P w) - p(\alpha_1^2 P u_1 + \alpha_2^2 P u_2) w] \quad (14)$$

In bits/s/Hz, where  $k = p/q$ ,  $u_i, i \in \{1, 2\}$  and  $w$  are the unique solution to the following equations:

$$u_i = (1 + \alpha_i^2 P w)^{-1}, i = 1, 2$$

$$w = (1 + k\alpha_1^2 P u_1 + k\alpha_2^2 P u_2)^{-1}$$

Let us define  $g = k\alpha_2^2 P u_2 (\Delta x + 1)$ ,  $d_1 = \Delta \alpha_2^2 P w$  and  $d_2 = \alpha_2^2 P w$ , where  $\Delta$  is the SNR offset between the two links i.e.  $\Delta = \alpha_1^2 / \alpha_2^2$ ,  $\alpha_2$  is the link with the lowest gain and  $x = u_1 / u_2$  in addition, let  $\bar{g} = 2g + 1$ ,  $d_1 = 2d_1 + 1$  and  $d_2 = 2d_2 + 1$ . then, equation (29) can be re-expressed as

$$C \approx \int_u^{-1}(\gamma) = \frac{1}{\ln(2)} (S_q + S_{p1} + S_{p2}) \quad (15)$$

Where  $S_q, S_{p1}$  and  $S_{p2}$  are given by

$$S_q = q \left( -\frac{1}{2} \ln(2) + (1/1 + \bar{g}) + \ln(1 + \bar{g}) \right),$$

$$S_{p1} = p \left( -\frac{1}{2} \ln(2) + (1/1 + \bar{d1}) + \ln(1 + \bar{d1}) \right), \text{ and}$$

$$S_{p2} = p \left( -\frac{1}{2} \ln(2) + (1/1 + \bar{d2}) + \ln(1 + \bar{d2}) \right), \quad (16)$$

respectively. It can re-express the first equation in (16) as  $g_q(S_q) = -1 / (1 + \bar{g}) \exp(-1/1 + \bar{g})$  (17)

where,  $g_q(S_q) = -\exp(-((S_q/q) + 0.5 + \ln(2)))$ . It can reformulate as that

$$\frac{-1}{1 + \bar{g}} = W_0(g_q(S_q))$$

$$\bar{g} = -[1 + 1/W_0(g_q(S_q))] \quad (18)$$

This results in the following approximation for  $f_u^{-1}(C)$  in,

$$\int_u^{-1}(C) \approx -2 + [1 + (-1 - \bar{g})] [(1 + (-1 - \bar{d1})) + (1/\Delta) (2 + (-1 - \bar{d2}) - 1)] / 4 * \alpha_2^2 (k\Delta x + k + 1) \quad (19)$$

Note that,  $u_1 = 2 / (1 + \bar{d1})$  and  $u_2 = 2 / (1 + \bar{d2})$  are such that

$$X = u_1 / u_2 = W_0(g_p(S_{p1})) / W_0(g_p(S_{p2})) \quad (20)$$

Thus, obtaining the closed-form expression of the EE-SE trade-off for the uplink of the 2BS-DMIMO system is equivalent to expressing  $S_q, S_{p1}$  and  $S_{p2}$  as a function of  $C$  in

(19). Moreover, since  $\bar{C} = C \ln(2) \approx S_q + S_{p1} + S_{p2}$  in (15), can define parametric functions  $\Psi_{p,q}(C) \approx S_{p2} / S_{p1}$  and  $\Phi_{p,q}(C) \approx S_q - (S_{p1} + S_{p2})$ , such that obtain  $S_q, S_{p1}$  and  $S_{p2}$  as a function of  $C, p$  and  $q$  by solving a set of linear equations. In tightly approximate  $S_q - (S_{p1} + S_{p2})$  as a function of  $C$  when  $\kappa \geq 2$  and  $1 \leq \kappa < 2$  respectively.

### 3.4 EE-SE Trade-off CFA for the Downlink of 2BS-DMIMO

The closed-form expression for the ergodic capacity per unit bandwidth in the downlink of DMIMO can be expressed as

$$C \approx \int_d^{-1}(\gamma) = \frac{1}{\ln(2)} [q \ln(1 + \alpha_2^2 P (\Delta u_1 + u_2)) + p \ln(1 + \bar{k} \alpha$$

$$^2 \Delta P w) + p \ln(1 + \bar{k} \alpha_2^2 P w) - q \alpha^2 P w (\Delta u_1 + u_2)] \quad (21)$$

in bits/s/Hz, where  $\bar{k} = q/p$ ,  $u_i, i \in \{1, 2\}$  and  $w$  are the unique solution to the following equations:

$$u_i = (1 + \bar{k} \alpha_i^2 P w)^{-1}, i = 1, 2$$

$$w = (1 + \alpha_1^2 P u_1 + \alpha_2^2 P u_2)^{-1} \quad (22)$$

Similar to the uplink scenario, define  $g = \alpha_2^2 P u_2 (\Delta x + 1)$ ,  $d_1 = \bar{k} \Delta \alpha_2^2 P w$  and  $d_2 = \bar{k} \Delta \alpha_2^2 P w$ . Moreover, define  $\bar{g} = 2g + 1$ ,  $\bar{d1} = 2d_1 + 1$  and  $\bar{d2} = 2d_2 + 1$ . Which results in the following approximation for  $f_d^{-1}(C)$  in

$$\int_d^{-1}(C) \approx 2 + [1 + (-1 - \bar{g})] [(1 + \bar{d1}) + (1/\Delta) (2 + (-1 - \bar{d2}) - 1)] / 4 * \alpha_2^2 (\Delta x + \bar{k} + 1) \quad (23)$$

Using a similar approach as in the uplink case, the closed-form expression for the downlink of 2BS-DMIMO can be obtained by expressing  $S_q, S_{p1}$  and  $S_{p2}$  as a function of  $C, p$  and  $q$ . CFA for the EE-SE trade-off of the downlink of the 2BS-DMIMO system is then obtained by inserting  $\int_d^{-1}(C) \approx \int_d^{-1}(C)$  in (28). In Fig.4.6, demonstrate graphically the accuracy of the EE-SE CFA in the downlink of 2BS-DMIMO system for various  $q \times p$  antenna configurations.

#### 4. Results and Discussion

##### 4.1 Accuracy of $S_{p2}/S_{p1}$

In fig 4.1 shows that the graph between Spectral Efficiency (SE) and approximation error. When the value of spectral efficiency increases the green color indicates that capacity varying randomly for  $p \times q$  antenna configurations for ten antenna settings. And red color indicates that ratio of the spectral efficiency for base station antennas ( $p_2$  and  $p_1$ ). The above result shows that while maximizing the antenna settings the approximation error gets minimized.

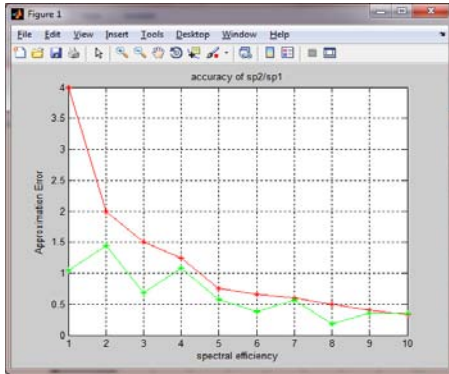


Figure 4.1: Snapshot of accuracy of  $S_{p2}/S_{p1}$

##### 4.2 EE-SE Trade-off of the uplink of 2BS-DMIMO

Figure 4.2 shows that EE-SE for uplink channel. Here, user terminal consists of  $q$  antennas and two base stations consist of  $p_1$  and  $p_2$  antennas while the signal is transmitting from  $q$  to  $p_1$  and  $p_2$ . From that energy efficiency gets reduced while increasing the spectral efficiency. And the number of transmitting antenna and receiving antenna configuration increases the energy efficiency get reduced.

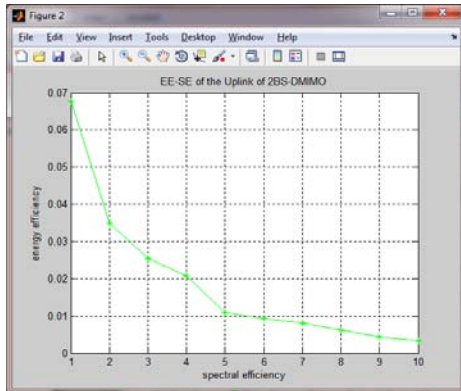


Figure 4.3: EE-SE Trade-off of the uplink of 2BS-DMIMO

##### 4.3 EE-SE Trade-off of the downlink of 2BS-DMIMO

Figure 4.3 shows that EE-SE for downlink channel. Here, user terminal consists of  $q$  antennas and two base stations consist of  $p_1$  and  $p_2$  antennas while the signal is transmitting from  $p_1$  and  $p_2$  to  $q$  antennas.

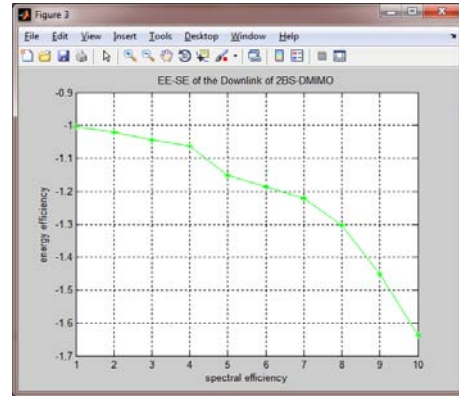


Figure 4.3: EE-SE Trade-off of the downlink of 2BS-DMIMO

From that energy efficiency gets reduced while increasing the spectral efficiency. And the number of transmitting antenna and receiving antenna configuration increases the energy efficiency get reduced.

#### 5. Conclusion

For high speed wireless communication, data are transmitted with high spectral efficiency, high data rate and reliability. But due to Rayleigh fading, the channels suffer from lot of attenuation resulting in the reduction of Energy Efficiency (EE) and Spectral Efficiency (SE). The proposed system consists of DMIMO system. This system gives high spectral efficiency and energy efficiency respectively.

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