

Performance Enhancement in SU and MU MIMO-OFDM Technique for Wireless Communication: A Review

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ABSTRACT

The consistent demand for higher data rates and need to send giant volumes of data while not compromising the quality of communication has led the development of a new generations of wireless systems. But range and data rate limitations are there in wireless devices. In an attempt to beat these limitations, Multi Input Multi Output (MIMO) systems will be used which also increase diversity and improve the bit error rate (BER) performance of wireless systems. They additionally increase the channel capacity, increase the transmitted data rate through spatial multiplexing, and/or reduce interference from other users. MIMO systems therefore create a promising communication system because of their high transmission rates without additional bandwidth or transmit power and robustness against multipath fading. This paper provides the overview of Multiuser MIMO system. A detailed review on how to increase performance of system and reduce the bit error rate (BER) in different fading environment e.g. Rayleigh fading, Rician fading, Nakagami fading, composite fading.

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1. INTRODUCTION

Maxwell has been predicted that existence of EM waves in 1867 and Marconi transmitted radio signals across Atlantic Ocean in the 1901. Since then there has been rapid advancements in the field of wireless communication. Wireless networks widely used today include: cellular networks, wireless mesh networks (WMNs), wireless Local Area Networks (WLANs), personal area networks (PANs), and wireless sensor networks (WSNs).

The first generation mobile communication systems were analog. The 2nd generation (2G) used digital multiple access technology. The 2G system (called GSM), furthermore its add-ons such as HSCSD and GPRS provided data rates of 22.8 Kbps to 172.2 Kbps[1,2]. EDGE systems supported on GSM, with two add-ons particularly increased circuit switched data (ECSD) and the increased general packet radio service (EGPRS) has become very hip. The maximum data rate of the EDGE system is 473.6 Kbps. The third generation (3G) provided data transfer rates greater than 2 Mbps. Universal Mobile Telephone System (UMTS) could be a leading technology for 3G systems. WCDMA is the air-interface technology for UMTS. The next generation is Internet Protocol (IP) based mostly and known as fourth generation (4G). LTE - advanced which is one of the system standards for 4G is expected to achieve data downloadrates of about 3 gigabits per second and upload rates as high as 1.5 Gbps [1,2]. With evolution in mobile communication standards, the demand for higher data rates has increased. In a single carrier transmission (SISO) to achieve higher data rates, larger bandwidth is required. But the available spectrums are limited and hence stringent constraints are imposed on its use. Thus it is necessary to pack more number of bits per Hz of bandwidth [3]. A MIMO (multiple-input multiple-output) system has multiple antennas at both transmitter and receiver sides

as shown in Figure 1. Each antenna element utilizes the similar time and frequency resources facultative capacity to be enhanced without increase in bandwidth or increased transmits power. MIMO systems provide a promising solution for further wireless communications systems. In the MIMO systems the sender and the receiver antennas communicate in such a way that the quality (the bit error rate (BER) or the data rate) for each user is improved [3-5]. The wireless communication systems also suffer from multipath fading which gives rise to higher noise and thus the high bit error rate. MIMO systems resort to spatial diversity to combat fading [4]. For this purpose Space Time Block Coding (STBC) is employed which exploits spatial domain along with time domain. STBC creates redundancy and thus reduces outage probability of the transmitted signal. It is thus possible to achieve high reliability, high spectral efficiency and high performance gain. The goal of STBC is to find code matrices that satisfy certain optimality criteria.

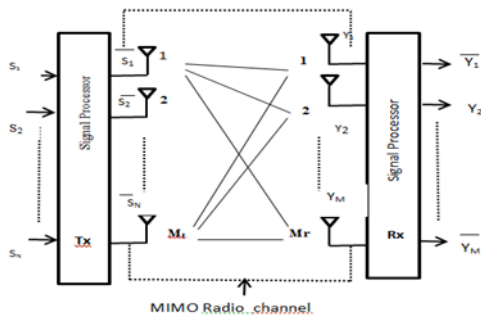


Figure 1. MIMO system representation

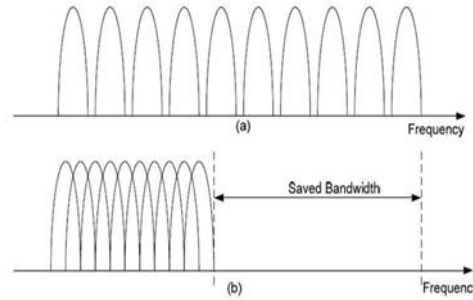


Figure 2. OFDM system representation

The MIMO idea becomes even a lot of attractive in multiuser scenarios wherever the network capability will be accumulated by simultaneously accommodating many users without the expense of valuable frequency resources. Multiuser access of MIMO system is that the actual demand in mobile communication. On the other hand, because of high spectral efficiency and resistance to multipath fading, the OFDMA (Orthogonal Frequency Division Multiple Access) could be a promising candidate for high speed wireless multiuser communication networks, such as 3GPP long term evolution advanced (LTE-A), IEEE 802.16 worldwide ability for microwave access (Wi-MAX), and IEEE 802.22 wireless regional area networks (WRAN). In Associate in Nursing OFDMA system as shown in Figure 2, the fading coefficients of various subcarriers are likely to be statistically freelance for various users. With channel state information at the transmitter (CSIT), the maximum system capacity can be achieved by selecting the best user for every subcarrier and adapting the respected transmits power. Recently, an increasing interest in multi-media services such as video conferencing and online high definition (HD) video streaming has tends to an incredible demand for high data rate communications with certain guaranteed quality of service (QoS) properties. The mix of MIMO and OFDMA is taken into account a viable solution for achieving these high data rates. In fact, the data rate improvement due to multiple antennas is unlimited if we allow the numbers of antennas employed at both the transmitter and also the receiver to grow. Yet, the benefits of MIMO and OFDMA do not come for free. They have significant financial implications for service providers due to the apace increasing price for energy consumption in circuitries that is usually overlooked in the literature.

2. RESEARCH METHOD

2.1 For single user MIMO system:

Antennas $T_{x_1}, \dots, T_{x_{N_T}}$ respectively send signals x_1, \dots, x_{N_T} to receive antennas $R_{x_1}, \dots, R_{x_{N_R}}$. Each receives antenna combines the incoming signals which coherently add up. The received signals at antennas, $R_{x_1}, \dots, R_{x_{N_R}}$ are respectively denoted by y_1, \dots, y_{N_R} . We express the received signal at antenna $T_{x_q}; q = 1, \dots, N_R$ as:

$$y_q = \sum_{p=1}^{N_T} h_{qp} \cdot x_p + b_q; q = 1, \dots, N_R \tag{1}$$

The flat fading MIMO channel model is described by the input-output relationship as:

$$y = H \cdot x + b$$

2.2 For Multiuser MIMO systems:

The received signal vector at user U_k ; $k = 1 \dots K$ is expressed as :

$$Y_k = H_k \cdot \text{Vt}_{BF}^{(k)} \cdot x_k + \sum_{j=1, k \neq j}^K H_k \cdot \text{Vt}_{BF}^{(j)} \cdot x_j + B_k; k = 1, \dots, K \quad (2)$$

Where:

- $H_k(M_k \times N)$ is the complex channel matrix between receiver U_k and the transmit base station.
- $B_k(M_k \times 1)$ is an additive noise signal vector.
- $\text{Vt}_{BF}^{(k)} (N \times 1)$ is the transmit beamforming vector of index k. The transmit beamforming matrix is :

$$\text{Vt}_{BF} = [\text{Vt}_{BF}^{(1)}, \dots, \text{Vt}_{BF}^{(k)}]$$

At the receive side, beamforming vectors are denoted by:

$$\begin{aligned} \text{Vr}_{BF}^{(k)} (M_k \times 1). \\ \text{Vr}_{BF}^{(k)} = [\text{vr}_{BF}^{(1)}, \dots, \text{vr}_{BF}^{(M_k)}]^T \end{aligned}$$

The resulting signal at user U_k is :

$$z_k = Y_k^* \cdot \text{Vr}_{BF}^{(k)}; k = 1, \dots, K. \quad (3)$$

OFDM (Orthogonal Frequency Division Multiplexing):

OFDM consists of many carriers. Thus the complex signals $S_s(t)$ is represented by:

$$S_s(t) = \frac{1}{N} \sum_{n=0}^{N-1} A_n(t) e^{j[\omega_n t + \varphi_n(t)]} \quad (4)$$

Where

$$\omega_n = \omega_0 + n\Delta\omega$$

This is of course a continuous signal. If we consider the waveforms of each component of the signal over one symbol period, then the variables $A_c(t)$ and $f_c(t)$ take on fixed values, which depend on the frequency of that particular carrier, and so can be rewritten:

$$\varphi_n(t) \rightarrow \varphi_n$$

$$A_n(t) \rightarrow A_n$$

If the signal is sampled using a sampling frequency of $1/T$, then the resulting signal is represented by:

$$S_s(kT) = \frac{1}{N} \sum_{n=0}^{N-1} A_n e^{j[(\omega_0 + n\Delta\omega)kT + \varphi_n]} \quad (5)$$

At this point, we have restricted the time over which we analyse the signal to N samples. It is convenient to sample over the period of one data symbol. Thus we have a relationship:

$$t = NT$$

If we now simplify Eq. (5), without a loss of generality by letting $\omega_0 = 0$, then the signal becomes:

$$S_s(kT) = \frac{1}{N} \sum_{n=0}^{N-1} A_n e^{j\varphi_n} e^{j(n\Delta\omega)kT} \quad (6)$$

Now Eq.(6) can be compared with the general form of the inverse Fourier transform:

$$g(kT) = \frac{1}{N} \sum_{n=0}^{N-1} G\left(\frac{n}{NT}\right) e^{j2\omega k/N} \quad (7)$$

In Eq.(6), the function $A_n e^{j\varphi_n}$ is no more than a definition of the signal in the sampled frequency domain, and $s(kT)$ is the time domain representation. Eqns.(6) and (7) are equivalent if:

$$\Delta f = \frac{\Delta\omega}{2\pi} = \frac{1}{NT} = \frac{1}{r} \quad (8)$$

This is the same condition that was required for orthogonality (see *Importance of orthogonality*). Thus, one consequence of maintaining orthogonality is that the OFDM signal can be defined by using Fourier transform procedures.

3. LITERATURE SURVEY

The author Narendra M.R. in [1] present the study of transmission characteristics of MIMO system for different modulation techniques, and evaluated the Performance evaluation of Alamouti, ZF and MLD decoder done for 2x2 system and conclude that Alamouti gives better performance. For a MIMO system, the STBC multiplexing techniques and ZF and MLD receivers promotes achieving better SNR performances for digital transmission. Researcher considers only BPSK and QPSK, other systems of digital modulation gives better performance so the problem of co-channel interference is present. Komi E. Dawui, Dirk T. M. Slock in [2] has presented an approach based on full CSI known at transmitter and the SVD method but they have assumed perfect channel state information at transmitter which is not always possible in practical situation. In [3], there published that, the compare absolute SNR-based scheduling and normalized SNR-based scheduling for heterogeneous and homogeneous wireless networks but that system did it for only Nakagami-m fading channel because Practically there are many more fading channels.

Further Gurpreet Singh, Priyanka Mishra, Rahul Vij has done work of comparing BER for ML-VBLAST [4] for two different modulation schemes BPSK and QPSK with different antenna configuration in ricean and Rayleigh fading in this scheme the Maximum likelihood decoding scheme suffers from complexity issue. Uma Singh Raghu wanshi, Prof. Pushpraj Tanwar has have been studied and analysed [5] that ZF-VBLAST,MMSE-VBLAST,QR-VBLAST wrt their SNR and BER. But detailed information about V-Blast is not provided. Noise or interference conditions are not clearly mentioned.

Researcher in [6], have studied the performance of cooperative OFDMA system under realistic condition and propose transceiver structure to reduce interference between subcarriers and they assumed that there is no channel power allocation difference between the users. D. A. Basnayaka, P. J. Smith, and P. A. Martin in [7] try to solve macrodiversity problem using MMSE and ZF in terms of SNR with arbitrary number of transmit and receive antennas. And the analysis did [7] is only for three base stations because they have considered only Rayleigh fading channel. M Jung, Y Kim, J Lee, and S Choi has been [8] evaluated that, the ergodic sum throughputs based on the optimal number of users using Monte Carlo simulations and spatially uncorrelated MIMO channels considered. It was never mention in [8] anything about channel or fading environment which was taken under consideration while performing this analysis. S Sun, Chih-Wei C, Shin-Wei C, Hsiao-Hwa Chen and W Meng in [9] introduced a new type of complementary code named 3DCC which integrate STC and CDMA for MIMO system but that code did it only for two transmitting antennas so transmit diversity is very less in this scenario. Yi Hong, E Viterbo and J C Belfiore has used TAST block codes and perfect STBCs for such systems in order to achieve the highest possible transmission rate and full diversity gain in [10] considered only 4 transmitting antennas, in [10] never mentioned as no. of antennas increases what is overall effect on system. Ashu Tuli, Narender Kumar & Kanchan Sharma has been combining 16- QAM& OFDM [11] to reduce peak to average ratio of the OFDM signal with K Fading channel coefficient. The system is implemented for only for single user. In real they multiple users, to solve total fading problem MIMO required with OFDM.

The MIMO scheme in [12] has been demonstrated by the researchers for the next generation WLANs over multipath fading channel with AWGN channels. In this paper a novel hybrid space-time block coding (HSTBC)scheme is proposed for mitigating signal fading as well as enhancing the performance of MIMO-OFDM based WLANs in which signal to be transmitted is first pre-coded and the resulting output is then coded using space-time block code to form a HSTBC.

Wei Ni, R P Liu, J Biswas, Xin W, I. B. Collings, and Sanjay Jha has proposed new scheduling algorithm for multiuser [13] depends on priorities. Authors prove that with this algorithm video quality goes on increasing. In this work researcher consider only urban area the proposed mathematical limitations shows

that there is upper bound to the number of selected users. Further in [14] derived mathematical model of average BER and SE for MU-MIMO and shown that variable ST gives better results as compared to fixed ST but the authors has considered only quasi-static Rayleigh fading channel and never consider inter symbol interference and co-channel interference.

In [15], A Chahal, A Kaur R Singh introduce an orthogonal spatial division multiplexing in that divides the central signal streams into time and frequency. Also to increase the spatial diversity we are going to introduce spatial modulation along with STBC for our new MIMO-OSDM by considering the only Rayleigh fading channel. Further in [16], X Wang and D Yue, Bin Lin & Yu Gong provided the study of performance evaluation results of several codes of OSTBC with the closed-form expressions; additionally, Monte Carlo simulation results are presented, it is demonstrate the accuracy of closed-form solutions and checked performance of space time block code over nakagami-m channel in MIMO system.

In [17], M R. Bhatnagar, Are H and L Song have proposed that by co-ordinated transmission of single user STBCs we can completely eliminate co-channel interference in a multiple cell scenario. A 4×4 both user STBC code design is presented which provides decoupled decoding of the data of each user. The proposed multiuser STBC performs better than the existing multiuser STBCs and also provides lower value of peak-to-average power ratio (PAPR) as compared to a trivial TDMA based STBC. In [18], the researchers did evaluation of Alamouti, MRC decoder done with BPSK and conclude that Alamouti gives better performance with 2×2 MIMO system Alamouti gives better results with BPSK but lot of other digital modulation schemes are present which gives less BER. Also number of detection systems is present which gives better result.

In "Multiuser Detection of Alamouti Signals" [19], Chee W T and A. R Calderbank presented solutions to the multiuser detection problem for Alamouti signals over an i.i.d. Rayleigh fading multiple access channels by A-BLAST algorithm for decoding signal and QOSTBC for modulation. To improve performance 1 or 2 bit feedback is used to instruct the transmitter but this system provides diversity at transmitter end not receiver end therefore BER possibility is more. Further, in [20], Researcher proposes that if no. of transmitting antennas is 4 per user for k user with no. of receiving antennas k/2. MMSE detection scheme gives better results than ZF. In this study the researcher never considers intersymbolinterference, co-channel interference. Further the enhancement has done to improve the coverage of communication system researcher derived new analytical expression in multirelay environment of MIMO system [21]. It calculates only diversity order and coding gain problem but lot of issues related to MIMO system need to be solved. In [22] is has been shown how MIMO-STBC using multiple transmit and receive antennas increases the diversity, which results in high signal to noise ratio (SNR). It is observed that by using multiple transmit and receive antennas SNR increases for single as well as for multiple users. Researcher increased number of antenna at Tx-Rx side; diversity goes on increasing, fading decreases, SNR increases by this enhancement MIMO solve the problem of fading but still intersymbol interference & co-channel interference is the major issue.

Further Tanvir A, Md. Ali and Shaikh E U in [23] have compare results of different detection methods for secured multiuser MIMO-OFDM with 2 transmitting antennas and 2 receiving antennas. With this method, authors got Pre MMSE gives less BER for 2×2 MIMO-OFDM system but still the problem of fading is present because diversity order is less. A Boudaa, M Bouziani has said in [24] that before SFBC encoding, designed and implemented eigenbeamforming with pre-processing multiplexing after that the data send on the channel with known CSI using Zero Forcing (ZF) method. Zero forcing scheme gives good results when channel is noiseless but when channel is noisy it amplify the noise.

In [25], S K Borra has compared performance of OFDM system with 16-QAM and BPSK done and concluded that 16-QAM gives best result over different fading environment. OFDM with 16-QAM increases spectral efficiency but still fading is the major issue. Further Uma Raj and Vidhyacharan Bhaskar [26] has studied the performance analysis of scheduling schemes for multiuser MIMO-OFDM systems employing Orthogonal Space-Frequency Block Coding in η - μ fading scenario over frequency selective fading channels and On basis of this ASE and BER are compared and presented advantages of SNR based scheduling in MIMO-OFDM system employing OSFBC and adaptive modulation and discussed but they never checked system for real application which is main disadvantage. Introduced a linear technique [27] that performs successive MMSE prefiltering in order to reduce the performance loss due to the zero MUI constraint and the cancellation of the interference between the antennas located at the same terminal. Further this paper offers two techniques, one with combining linear pre-coding technique called successive optimization and a non-linear technique called Tomlinson-Harashimaprecoding. Second introduced a linear technique that performs successive MMSE prefiltering in order to reduce performance loss. But the problem with such system is that it is implemented only for flat fading.

Ramoni Adeogun in [28], analyzed the capacity and BER of different multiple satellite scenarios using different models. The reseracher investigated the capacity and bit error rate (BER)performance of

Multiple Input Multiple Output (MIMO) satellite systems with single and multiple dual polarized satellites in geostationary orbit and a mobile ground receiving station with multiple antennas. Further C. Manikandan [29] investigates the effect of many antennas at the sender i.e. transmitter and receiver end of SU-MIMO and MU-MIMO, using a SVD based single and multiple beamforming technique, for various Modulation schemes namely ASK, BPSK, QPSK, 8-PSK and 8-QAM. But they never consider intersymbol and co-channel interference considered only 3×3 system. This paper also states that with the increase in number of antennas in the transmitter side and receive sides, there is a decrease in BER and thus increase in reliability. With single beamforming, there is a further substantial decrease in the BER as compared to multiple beamforming. There is one more investigation done by Chabalala S. Chabalala and Lebajoa Mphatsi for MIMO performance for wireless communication systems [30] in a multiuser environment. The user information is given by a data matrix formed by the observed input-output data of the system, from which subspace identification method is developed using LQ-decomposition of the matrix, also the ergodic channel capacity model has been presented and evaluated for different configurations for a MIMO system with varying number of transmit and receive antennas but in this design also the researcher never consider intersymbol and co-channel interference.

In [32] analyzed investigate the performance of multi user decode and forward network with a full MIMO design in the presence of CCI and AWGN. With some scenarios, investigators applied SNR-based selection criterion to select the Nth-best user. Furthermore, they have also presented three main remarks to differentiate the effect of key system parameters on the diversity order and the array gain of the system which is based on asymptotic SER expression but the investigators never consider the losses in decode and forward network. The researcher in [31] has compared the performance of Space Time Block Coding with code rate $\frac{1}{2}$ and $\frac{3}{4}$ for a Turbo Coded Multiple Input Multiple Output (MIMO) system and uncoded MIMO system. The turbo encoder encodes the input information bits and sends to a QPSK or 16 QAM or 64 QAM modulator. The Rayleigh fading effected received signal at receiver is a linear superposition of the transmitted signals. It is demonstrated that there is around 7- 11 db coding gain for using code rate $\frac{1}{2}$ compared to code rate $\frac{3}{4}$ of a TC coded MIMO system and there is around 8-10 db coding gain for using code rate $\frac{1}{2}$ compared to code rate $\frac{3}{4}$ of an uncoded MIMO system.

To overcome the multiuser interference problem Yuan O [33] and his team propose an analytical model and closed form BER performance equation of the MB- OFDM UWB systems with multiuser interference for LOS and NLOS multipath fading channels even though they have considered the multiuser interference problem but they ignored the interband interference and assumed static during the symbol interval. In [34], authors investigated the reduce of the average BER for multiuser MIMO-OFDM systems with different suboptimal detectors. For the ZF and SIC detectors, the optimal and suboptimal algorithms are presented by applying the exhaustive search and Lagrange multiplier method and to minimize the computational complexity. Subcarriers are allocated to users under the assumption that the transmit power is identical over all antennas for each subcarrier. The proposed suboptimal algorithm achieves an improvement over conventional algorithms for each detector. In [35], Jing M, C Chen, L Bai, H Xiang, and Jinho Choi stated that optimal algorithms have a prohibitive high complexity, so introduced the low-complexity suboptimal algorithms that separately allocate the subcarriers and power. Also considered few detectors, ML, linear and SIC, and derived the optimal subcarrier and power allocation algorithms that are based on the exhaustive search and numerical methods. The performance achieved by the suboptimal algorithms can be close to that with the corresponding optimal algorithms.

The paper [36] states the investigation about MIMO-OFDM for VLC systems which assumes the phase differences of channel matrices in the FD induced by the distance differences of the multiple transmitter-receiver links. Different from state-of-the-art MU-MIMO VLC schemes, zero forcing and MMSE precoding techniques are performed on the complex channel matrices for each subcarrier, which are less correlated when the phase differences are considered. It is also stated that the subcarrier with higher index achieves more spectral efficiency, especially when the users are highly correlated. MMSE precoding outperforms that with zero forcing when the optical power is low and when more performance gain is achieved when the users are closer. In [37], MU-MIMO-OFDM is studied for indoor VLC systems. In these investigators considers the distance differences of the multiple transmitter receiver links, which causes phase differences in the FD. The zero forcing and MMSE precoding techniques are applied on the complex channel matrices for each subcarrier, which are less correlated when the phase differences are considered. The paper also introduces the two DC bias and scaling schemes for different sceneries. It has been observed that the subcarrier with higher index achieves more spectral efficiency, especially when the users are highly correlated. MMSE is feasible for zero forcing when the optical power is low and more performance gain is achieved when the users are closer.

In [38], introduces a nullspace combining BD technique and SIC technique for a multiuser MIMO-OFDM system uplink with the same subcarrier shared by multiple users named low complexity multiuser

detection algorithm (RSZF-SIC), whose aim was to eliminate the CCI by recursively successive zero-forcing process and successive interference cancellation process at the base station. The paper also proposed algorithm reduced the computational complexity effectively because the total number of SVD operations and the dimension of the SVD matrix were reduced greatly by recursively eliminating the interference based on the nullspace orthogonal theorem. In [39], the problem of CFO estimation in the context of a single and multi-user MIMO-OFDM systems communicating over a frequency selective wireless channel has been addressed using the MEP criterion. This method poses the CFO estimation problem as a detection problem, which is achieved by discretizing the continuous CFO parameter space into a finite number of discretized bins. We have theoretically derived the statistics of the CFO estimation error and the BER degradation due to this error using the MEP method. The performance of the proposed method is shown to be better than that of the classic MAP and ML based methods both in the MSE and BER sense.

4. CONCLUSION

As discussed by the researchers in the various papers it is found that they have used different technologies in wireless communication systems for analyzing performance of SU and MU MIMO system which are used to reduce the bit error rate and to increase the quality of signal. As mentioned in the literature of this paper each research work has its merits and demerits. Now a days requirement of data rate is high and also improvement in signal quality by removing fading effect is required MIMO system is used in the higher data rate where fading problems are occurred. To remove the interference the OFDM is used. Hence to resolve such issues in wireless communication where high data rate is required we need to concatenate both MIMO and OFDM system. This MIMO-OFDM system not only increases the data rate but also overcomes the problem of fading in wireless communication.

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