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OPTIMAL COOPERATIVE BEAMFORMING DESIGN FOR MIMO USING MODIFIED AF RELAY CHANNELS

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Abstract*:*The paper proposes a transmit beamforming design for MIMO Modified AF half-duplex two-hop relay channels with a direct source destination link. Motivated by the rapid growth of wireless applications with multiple antenna terminals, Multiple Input Multiple Output (MIMO) relaying has gained much attention now a day due to its improved data rate, coverage extension and improved Signal to Noise Ratio (SNR). In this work, a transmit beam forming design for MIMO MODIFIED Amplify-and-Forward (AF) ,MIMO Decode-and-Forward (DF), MIMO Amplify-and-Forward (AF) and MIMO Compress-and-Forward (CF) half-duplex two-hop relay channels with a direct source–destination link is considered. Network model consist of source, relay and destination. Design includes four different cases in terms of the number of antennas deployed at source, relay and destination node which contains 2:2:1 scenario, , N_s:1:1 scenario and N_s: N_r:1 scenario. Optimal beam forming design to the scenario where all the three nodes are equipped with multiple antennas i.e., N_s: N_r: N_d is also considered. Here, beam forming design is based on exact capacity formulation and low-complexity explicit expressions are used. Effect of parameter such as number of antennas on the performance of MIMO relay channels is also investigated. Optimal beam forming design for MIMO MODIFIED Amplify-and-Forward (AF) relaying scheme achieves high performance gain and higher information rates than MIMO Decode-and-Forward (DF) and MIMO Compress-and-Forward (CF) relaying scheme.

Keywords: Beamforming and optimization,decode and forward, MIMO, relay, transmit.

I.INTRODUCTION

Relay is an important and effective technology in achieving coverage extension, energy saving and spectral efficiency improvement for wireless systems and therefore it has received a considerable concern in research interest. Several relaying schemes have been incorporated in standard proposals, such as 3GPP release 10 for next generation wireless systems. Generally there are two popular relay strategies i) Amplify-and-Forward(AF),where the relay decodes the received signals and then forwards them to the destination and ii) Decode-and-Forward(DF), where the relay decodes the received signals and then forwards the Re-encoded information to the destination. Compared with the AF strategy, the DF strategy demands relay

Nodes with greater signal processing capabilities, but it outperforms the AF strategy especially when the source-relay channel is statistically better than the source-destination and relay-destination channels. In this paper, we consider half-duplex DF relaying systems, where the relay is only allowed to transmit and receive using orthogonal time or frequency.

1.1. COOPERATIVE COMMUNICATIONS

The classic representation of a communication network is a graph with asset of nodes and edges. The nodes usually represent devices such as a router, a wireless access point, or a mobile telephone. The edges usually represent communication links or channels, for example, an optical fibre, a cable, or a wireless link. This work

deals mainly with Rayleigh at fading wireless channels. Both devices and the channels may have constraints on their operation, For example, a router might have limited processing power ,a wireless phone has limited battery resources, the maximum transmission distance of an optical fibre is limited by several types of dispersion, and a wireless link can have rapid time vibrations arising from mobility and multipath propagation of signals.

The purpose of a communication network is to enable the exchange of messages between its nodes. Due to the broadcast nature of wireless links, signal transmissions between two nodes may be received at the neighbour nodes. It has been understood in the information theory for over three decades that overhear the transmission, as these intermediate nodes may themselves generate transmissions based on processing of the overhead signals. Let us consider the system, where one system node (source) is sending a message to another system node (destination).due to the broadcast nature of the wireless link, this message is overhead by a third node of the network(relay).During the First phase of transmission, the source broadcasts the nitary message symbols to both relay and destination using the power Es. The second phase consists of relay transmitting a transformed version of its received signal to destination while source is silent. Note that the two phases indicate two independent transmissions. This may be achieved by using orthogonal coding; e.g. using different time slots or different frequency careers.

1.2 COOPERATIVE STRATEGIES

The strategies are as follows:

1. Amplify-and-Forward (AF)
2. Classic Multi-hop
3. Compress-and-Forward (CF)
4. Decode-and-Forward (DF)
5. Multipath Decode-and-Forward (MDF)

The above strategies can be used for both wire line and wireless networks and they require progressively more coordination. For example, consider a RC, Amplify-and-Forward (AF) and classic multi-hop do not necessarily require changes at the source or destination nodes, e.g., for multi-hop the relay can behave as if it is the destination or the source. Compress-and-Forward (CF) does not necessarily require changes at the source but it does require some extra knowledge about the link capabilities. Decode-and-Forward(DF) requires changes at both the source and destination and Multipath Decode-and-Forward(MDF) requires additional changes at higher layers of the protocol stack. Decode-and-Forward (DF) or Multipath Decode-and-Forward (MDF) with network coding requires even more changes at higher layers.

1.3 MIMO

Deploying multiple antennas at wireless terminals can bring many desirable benefits into wireless communication systems, such as boosting the channel capacity via transmit spatial multiplexing and/or enhancing the transmission reliability through spatial modulation and diversity combining. The resulting so-called Multiple-Input-Multiple-Output(MIMO) technology has been widely investigated over the past decades. MIMO schemes have also been included in standard proposals for next generation mobile broadband communication systems, e.g.,3GPP LTE-Advanced and WiMAX. As such, there has been a growing interest in MIMO relay channels, where the source code, the relay node and/or the destination node may have multiple antennas. Multi-antenna MIMO (or single user MIMO) technology has been developed and implemented in some standards,e.g.,802.11n products.

II.OPTIMAL COOPERATIVE BEAMFORMING DESIGN

Consider a network model consisting of a source S, a relay R and a destination D, as shown in the figure3.1. It is assumed that the direct link between S and D exists in the system and the relay R helps the information transmission from S to D. Multiple antennas are deployed at

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both S and R, and only one antenna is equipped at D.

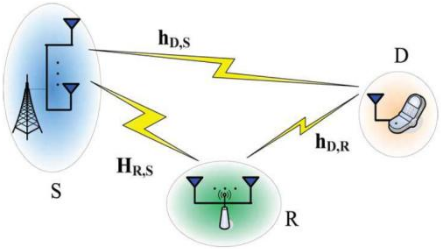


Fig.2.1.System model of MIMO relay channel

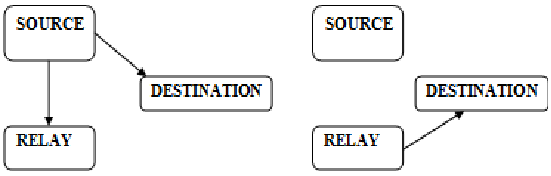


Fig.2.2. Phases of relay transmission.

Half duplex mode is adopted so that R cannot transmit and receive signals at the same time. Therefore, each round of information transmission from S to D can be divided into two phases. In the first source phase, S broadcasts its information to both R and D, while in the second relay phase R decodes the received information and then forwards the decoded information to D. Thus, D can obtain the desired information by decoding the combined signals received over the above mentioned two phases.

In the Source Phase, S transmits its information to both R and D, while in phase 2, R decodes the received information in the case of DF MIMO relay channel and then forwards the decoded information to D. At D, the received signals in aforementioned two phases are combined and decoded to obtain the desired information. In the case of MIMO AF relay channel R amplifies the received information and then forwarded to destination whereas in the case of MIMO CF relay channel R compresses the received information and forwards to destination.

In the Source phase, the information symbol x_1 is first multiplied with a beam forming vectorws before being transmitted from the transmit N_s antennas

Of source S . Received SNR at D during phase 1 is given by

$$\gamma_{D,1} = |h^T_{D,1} w_s|^2 P_s$$

Where hD, 1 denotes the channel gain vector from S to D. Applying singular value decomposition (SVD)

$$H_{R,1} = U \Lambda V^H$$

WhereHR_1 denotes the channel gain matrix from source S to relay R. Effective received SNR at R is

$$\gamma_{R,1} = || H_{R,1} w_s ||$$

In Relay phase, R forwards its processed symbol to D using beam forming transmission over its N_r antennas. Received SNR at D in phase 2 is given by

$$\gamma_{D,2} = |h^T_{D,2} w_r|^2 P_r$$

where $h_{D,2}$ denotes the channel gain vector from R to D .Total achievable information rate at D from S over the MIMO relay channel can be given by

$$C_{IF} = \frac{1}{2} min\{log_2(1+\gamma_{R,1}), log_2(1+\gamma_{D,1}+\gamma_{D,2})\}$$

2.1. OPTIMAL SOLUTION DISCUSSION:

Solves the optimal beam forming design problem for different cases. The beam forming vectors are optimized both at S and R to maximize the achievable rate for MIMO relay channels. Optimization problem is given by

$$\max min\ (\gamma_{R,1}, \gamma_{D,1}+\gamma_{D,2})$$

$$\text{s.t., } ||W_s||^2 = 1$$

$$|W_r||^2 = 1$$

Where the optimal beamforming vector for the transmission from R to D in the relay phase is given by

$$w_r^* = \frac{h_{D,2}}{||h_{D,2}||}$$

Then obtain the maximum of $\gamma_{D,2}$ as

$$\gamma^*_{D,2} = \|h_{D,2}\|^2 P_r$$

Then the optimization problem can be transformed into

$$\max min\ (\gamma_{R,1}\ ,\gamma_{D,1}+\gamma^*_{D,2}\ )$$
$$\text{s.t.,} \|W_s\|^2 = 1$$

Such a max-min problem is in general difficult to solve by using conventional methods. Properties of optimal solution are used to get better insights into the beamforming design for MIMO relay channels. Since the matrix *V* in (2) is a unitary matrix of full rank, for an arbitrary beamforming vector W_s with $\|W_s\|^2 = 1$,there exists a unique complex vector W satisfying

$$W_s = Vw$$

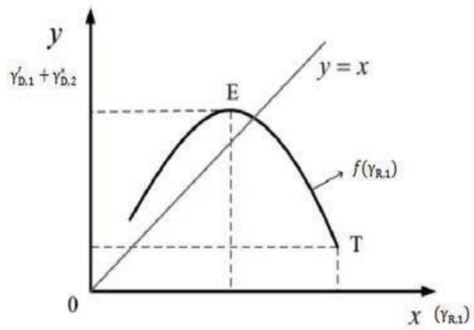
By substituting this into (1) and (3), $\gamma_{R,1}$,$\gamma_{D,1}$ becomes,

$$\gamma_{D,1} = \left(\sum_{i=1}^{N_s} \left|h_{D,1}^T v_i w_i\right|^2 P_s\right)$$

And

$$\gamma_{R,1} = \sum_{i=1}^{N_s} \lambda_i^2 |w_i|^2 P_s$$

Thus transformed optimization problem from (6) to (12).This max-min problem is difficult to solve. Here, take the mapping relation from $\gamma_{R,1}$ to $\gamma_{D,1}$ and use some key features of optimal solution of optimization. Thus, arrive at an efficient algorithm to calculate the optimal beamforming vector.



2.2. OPTIMAL BEAMFORMING DESIGN:

Solves the optimal beam forming design problem in different cases based on number of antennas deployed at source, relay and destination. It includes 2:2:1 scenario, N_s: 1:1 scenario and N_s: N_r: 1 scenario.

2.2*.1. Optimal Beam forming Design for 2:2:1 Scenario*

The optimal beam forming (α1+ α2) satisfies following system of equation

A1+ α2=1

Where

$$\begin{cases} \alpha_1 = \dfrac{1-2AB \pm \sqrt{1-4AB\,P_s - 4B^2}}{2+2P_s^2} \\ \alpha_2 = 1-\alpha_1, \alpha_1, \alpha_2 \geq 0 \end{cases}$$

2.2.2.Optimal Beam forming Design for N_s:1:1 Scenario

Optimal beam forming vector is given by

$$W^*_s = \mu_1 e_1 + \mu_2 e_2$$

Here, μ_1 and μ_2 are optimal solutions.

2.3. Optimal Beam forming Design for MIMO relaying protocols

Based on the equations given above optimal beamforming design for different scenarios can be obtained. For the scenario where two antennas are deployed at both the source and the relay nodes and single antenna is deployed at the destination node, i.e., 2:2:1 scenario explicit expressions are used for optimal solution. For the scenario where N_s>1, antennas are deployed at the source and only one antenna is used at the relay and the destination nodes, i.e., N_s: 1:1scenario, a non-iterative numerical method is used to calculate the optimal solution. Here, also considered the beamforming design problem for all the nodes equipped with multiple antennas. Extensive simulation results show that the optimal beam forming design can be achieved for MIMO MODIFIED AF, MIMO DF, MIMO AF and MIMO CF relay channel with low complexity.

V.SYSTEM MODEL OF MODIFIED AMPLIFY-AND-FORWARD

In this proposed model, two nodes such as node 1 and node 2 has been considered as source nodes to transmit the information from source nodes to destination node of node 0. These source and destination nodes have access to full Channel State Information (CSI). Here, an orthogonal half-duplex amplify-and-forward cooperation scheme has been implemented to facilitate simple implementation.

In this work, the Modified Amplify-And-Forward (MAF) relaying strategy has been considered because it is the simplest in conditions of the hardware necessities of the cooperating nodes. Generally, the orthogonal AF scheme has been separates the channel resource equally among the users. In our modification scheme, the resource allocation has been enabling and it's shown in fig 4.1. In fig 4.1, in order to at each point on the boundary activate at each point on the boundary of the achievable rate region, the jointly optimal power and channel resource allocation has been required and it obtained by CSI. The joint power and resource allocation has the problem like its nor convex and its difficult to solve. But, we considered as target rate of one node and it written as a convex function of the transmission powers and the maximum achievable rate of the other node can be written as quasi-convex function of the resource allocation parameter. In addition, for a given resource allocation, a closed-form solution has been derived for the optimal power allocation.

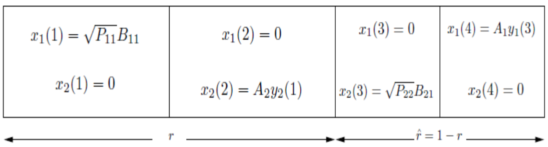
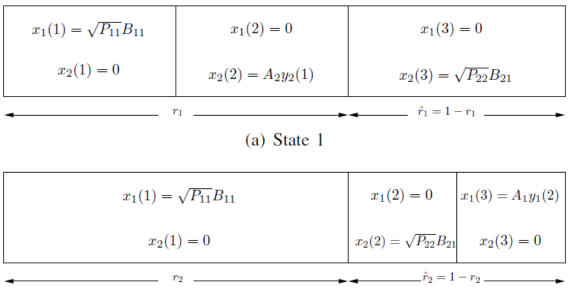


Fig. 4.1 .A frame of an orthogonal half-duplex AF cooperation scheme that enables resource allocation through the parameter r.



(b) State 2

Fig.4. 2. One frame of each state of the proposed modified orthogonal amplify-and- forward (AF) cooperation scheme.

The presented scheme has been worked based on time sharing among two states and is shown fig4.2. In first state, the node 1 message has been transmitter in a fraction r1 of the frame using AF relaying, and the node 2 acting as the relay and assigning a power P21 to the relaying of the message of Node 1. Quite the reverse, the node 2 utilizes direct transmission to broadcast its message to the destination node in a fraction $\hat{r}_1 = 1 - r_1$ of the frame using power P22. Then, in second state, the nodes (1 and 2) are exchange their roles and they are symmetric.

In state 1, each frame has been consists of three blocks, in this, first two blocks having fractional length $r_1/2$ and third block having fractional length of $\hat{r}_1$. State 1, in the first block, the node 1 has been transmitted message with power P11, which satisfies$\frac{r_1}{2}\mathrm{P11} = \overline{\mathrm{P}_1}$, where $\overline{\mathrm{P}_1}$ represents the maximum average power for Node 1 whilst Node 2 listens. State 1, in second block, re-transmits that signal with a power P21 to the target node. Then, in block three, Node 2 broadcasts its message straight to the target node with power P22. In that process, at optimality the power components of Node 2 should satisfy$\frac{r_1}{2}P_{21} + \hat{r}_1 P_{22} = \bar{P}_2$.

In State 2, the nodes (1 and 2) are reverse their roles and it has been denoted as$\frac{\hat{r}_2}{2}\mathrm{P22} = \overline{\mathrm{P}_2}$, where $\overline{\mathrm{P}_2}$ denoted as the maximum average power for Node 2 and$r_2 P_{11} + \frac{\hat{r}_2}{2}\mathrm{P12} = \overline{\mathrm{P}_1}$. In Fig. 4.2, in the time domain, resource allocation has been implemented. Generally, it can be implemented in both time and frequency.During blockℓ, K_{mn} , $\mathbf{y}_i(\ell)$ has been defined to be the signal block received via Node ito be the complex channel gain among Nodes m ∈ {1,2} and n ∈ {0,1,2}, and $z_n(\ell)$ has been defined to be the zero-mean additive white circular complex Gaussian noise with variance σn2 at Node n.

The received signal blocks in the first state can be expressed as

$$y_2(l) = \begin{cases} K_{12}x_1(l) + z_2(l) & l \bmod 3 = 1 \\ 0 & l \bmod 3 \neq 1, \end{cases}$$

$$y_o(l) = \begin{cases} K_{10}x_1(l) + z_0(l) l \bmod 3 = 1, \\ K_{20}A_2 y_2(l-1) + z_o(l) l \bmod 3 = 2, \\ K_{20}x_2(l) + z_0(l) l \bmod 3 = 0, \end{cases}$$

Where $A_2 = \sqrt{\frac{P_{21}}{|K_{12}|^2 P_{11} + \sigma_2^2}}$. In the second state, they are

$$y_1(l) = \begin{cases} K_{12}x_2(l) + z_1(l) & l \bmod 3 = 2 \\ 0 & l \bmod 3 \neq 2, \end{cases}$$

$$y_o(l) = \begin{cases} K_{10}x_1(l) + z_0(l) & l \bmod 3 = 1, \\ K_{20}x_2(l) + z_0(l) & l \bmod 3 = 2, \\ K_{10}A_1 y_1(l-1) + z_o(l) & l \bmod 3 = 0, \end{cases}$$

Where $A_1 = \sqrt{\frac{P_{12}}{|K_{21}|^2 P_{22}+\sigma_1^2}}$. For notational simplicity, we will define γmn = |Kmn|2/σn2.

For a given allocation for the power components, P = (P11, P12, P21, P22), and a given value for r1, if our model has been defined $\overline{P_{11}} = r_1 P_{11}$, $\overline{P_{21}} = r_1 P_{21}$ and $\overline{P_{22}} = \hat{r}_1 P_{22}$, then the attainable rate region in State 1 of the system has been described above is the set of all rate pairs (R1, R2) that satisfy

$$\check{P}_{22} = \frac{\hat{r}_2}{2}\log\left(1+\frac{2\gamma_{20}\bar{P}_2}{\hat{r}_2}+\frac{2\gamma_{10}\gamma_{21}(2\bar{P}_1-\check{P}_{11})\bar{P}_2}{\hat{r}_2(\hat{r}_2+2\gamma_{21}\bar{P}_2+\gamma_{10}(2\bar{P}_1-\check{P}_{11}))}\right)$$

$$R_1 \leqslant \bar{R}_1(\mathcal{P}, r_1)$$
$$= \frac{r_1}{2}\log\left(1+\frac{2\gamma_{10}\bar{P}_1}{r_1}+\frac{2\gamma_{20}\gamma_{12}\bar{P}_1\tilde{P}_{21}}{r_1(r_1+\gamma_{20}\tilde{P}_{21}+2\gamma_{12}\bar{P}_1)}\right),$$
$$R_2 \leqslant \bar{R}_2(\mathcal{P}, r_1) = \hat{r}_1\log\left(1+\frac{\gamma_{20}\tilde{P}_{22}}{2\hat{r}_1}\right).$$

Similarly, if we define $\overline{P_{11}} = r_1 P_{11}$, $\overline{P_{21}} = r_1 P_{21}$ and $\overline{P_{22}} = \hat{r}_1 P_{22}$, then the attainable rate region in State 2 of the system in Fig. 2 is the set of all rate pairs (R1,R2) that assure

$$R_1 \leq \bar{R}_1(\mathrm{P}, r_2) = r_2 log\left(1+\frac{\gamma_{10}\bar{P}_{11}}{2r_2}\right)$$
$$R_2 \leq \bar{R}_2(\mathrm{P}, r_2) = \frac{\hat{r}_2}{2}\log(1+\frac{2\gamma_{20}\bar{P}_2}{\hat{r}_2} + \frac{2\gamma_{10}\gamma_{21}\bar{P}_{12}\bar{P}_2}{\hat{r}_2(\hat{r}_2+2\gamma_{21}\bar{P}_2+\gamma_{10}\bar{P}_{12})}$$

while the presented system has been considering scenarios, where full CSI is available, the channel resource allocation and power has been needed to move towards a particular point on the boundary of the attainable rate region for State k can be found by maximizing $\overline{R_i}$ for a given target value of $\overline{R_j}$, subject to the bound on the transmitted powers; i.e.,

$$\max_{P_{ij}\geqslant 0,\, r_k\in[0,1]} \overline{R_1}(\mathrm{P}, \mathrm{rk})$$

subject to
$$\bar{R}_2(\mathcal{P}, r_k) \geqslant R_{2,\mathrm{tar}},$$
$$\frac{r_k}{2}P_{i1} + \frac{\hat{r}_k}{2}P_{i2} \leqslant \bar{P}_i \qquad i = 1, 2.$$

Furthermore, a closed-form solution derived for the optimal power allocation for a given resource allocation rk, and we will show that this allows the solution of above equations using an easy competent search over the resource allocation parameter, rk. By combining those solutions, a simple efficient algorithm has been attained for the joint optimization of the transmission powers and channel resource allocation for each state of the proposed cooperation scheme.

V.RESULTS AND DISCUSSION

MATLAB is a high-performance language for technical computing. It integrates computation, visualization and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. In this project, MATLAB 2017 version is used to get the efficient simulation results.

5.1.SIMULATED ACHIEVABLE TRANSMISSION RATE V.S. SNRGRAPH FOR 2:1:1 SCENARIO:

Fig 5.1.shows the achievable information rate v.s. SNR graph for the second case i.e., Ns: 1:1 where number of antennas at source is varied according to which arrive at the conclusion that almost the same results are obtained in this case also as that of case 1. The MODIFIED AMPLIFY-AND-FORWARD based beam forming design for 2:1:1 scenario achieves the maximum achievable information rates.

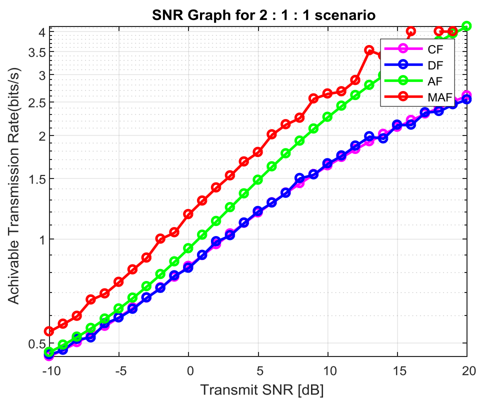


Fig.5.1. Simulated achievable transmission rate v.s. SNRGraph for 2:1:1 scenario

5.2. SIMULATED ACHIEVABLE TRANSMISSION RATE V.S. SNRGRAPH FOR 2:2:1 SCENARIO:

Fig. 5.2 gives the achievable information rate v.s. SNR graph for 2:2:1 scenario over MODIFIED AF, AF, DF and CF relaying scheme deploying MIMO technique. In this case two antennas are deployed at both source and relay and one antenna at destination. It is noticeable that achievable rate for modified AF relaying scheme is higher than AF,DF and CF relaying scheme as shown in Fig.5.2. Even though the deployment of modified AF increases the achievable information rate compared to AF,DF and CF, it amplifies the noise in the channel. So BER is higher for modified AF.. The MODIFIED AMPLIFY-AND-FORWARD based beam forming design for 2:2:1 scenario achieves the maximum achievable information rates.

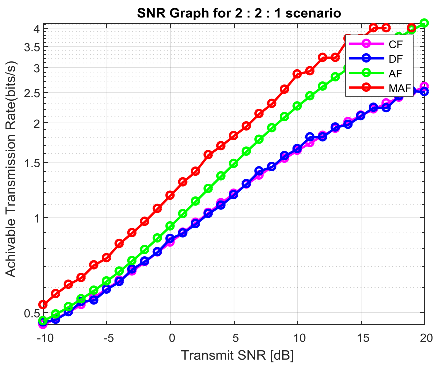


Fig.5.2. Simulated achievable transmission rate v.s. SNRGraph for 2:2:1 scenario

5.3. SIMULATED ACHIEVABLE TRANSMISSION RATE V.S. SNRGRAPH FOR 2:4:1 SCENARIO:

The MODIFIED AMPLIFY-AND-FORWARD based beam forming design for 2:4:1 scenario achieves the maximum achievable information rates. In this case, achievable information rate improved by more than 1.2 bit/s when all relaying schemes are considered. Thus, arrive at an observation that as the number of antennas at relay increases, achievable information rate also improves.

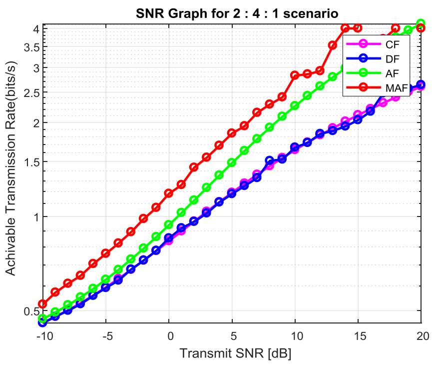


Fig.5.3. Simulated achievable transmission rate v.s. SNRGraph for 2:4:1 scenario

VI.CONCLUSION& FUTURE WORKS

In this work,the beam forming design for MIMO Modified Amplitude-and-Forward Relay channels were investigated, where both the source node and relay node are equipped with multiple antennas, an efficient scheme is developed to solve the optimization problem. Here, solves the optimal beam forming design problem in different cases. These cases in terms of the number of antennas deployed at source and relay nodes includes 2:2:1 scenario, N_s: 1:1 scenario and N_s: N_r:1 scenario. Optimal beam forming design to the scenario where all the three nodes are equipped with multiple antennas i.e., N_s: N_r: N_d is also considered. Optimal beam forming design achieves high performance gain, higher information rates with low complexity. From the simulations, it is noticeable that achievable rate for Modified AF relaying scheme is higher than DF,AF and CF relaying scheme. It is also noticeable that as the number of antennas at source, relay and destination is increased, achievable transmission rate is improved for MIMO AF, DF and CF relaying schemes. Unlike previous work on beam forming design of MIMO DF and AF channels, this beam forming design was based on the exact capacity formulation, which can achieve high accuracy.

FUTURE SCOPE:

In Future, we can extend to the beam forming design to the scenario where can implement this MIMO concept using some other pre-coder designs and also we can implement the different scenarios practically in future work.

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