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# Asymmetric Distributed Space Frequency Coded Cooperative Network with Convolution Coding

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***Abstract—This paper proposes a novel algorithm for Asymmetric Distributed space frequency coding [DSFC] which utilizes convolution coding for error correction purpose. It is implemented at relay node for Decode and Forward [DAF] protocol. In asymmetric DSFC, the number of paths per fading channels is different. The asymmetric DSFC with direct link and without direct link with convolution coding is designed and analysed with the help of SER versus SNR performance and compares with existing system which had been implemented with CRC coding. The results obtained shows that the proposed system improves improved performance in terms of SER along with improvement in flexibility of new generation of cellular networks by providing additional paths and provide increased throughput in wireless communication.***

***Keywords— Decode and Forward, relay channels, space frequency coding, Cooperative communications, OFDM, Diversity.***

## I. INTRODUCTION

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In wireless communication system, the transmitted signal is affected by many channel impairments like shadowing, fading. This results into the degradation of the wireless system performance. To improve the system performance various diversities has been introduced. It has been proved that, spatial diversity improve the system performance by reducing the effect of channel impairments. Later cooperative diversity has been introduced [1] [2] [3], which uses cooperative node to forward the information to destination node to improve the diversity gain.

The performance of a wireless system also depends on the location of the mobile relay and the protocol used by the relay [4] [5]. Lately [4] [6], various relaying protocols and several combining methods has been introduced to achieve diversity, which include Decode and Forward [DAF] and Amplify and Forward protocol [AAF] [3]. In DAF protocol, relay node decodes the information and retransmit it to destination node. In case of AAF protocol, relay node simply amplifies the signal and retransmit it to destination node. Use of cooperative communication improves the capacity and increases the coverage of wireless network [6].

As the number of relay increases the data rate loss increases [7]. Due to this, Distributed space time code [DSTC] and Distributed Space Frequency Code [DSFC] is introduced to achieve the full diversity [1] [8] [9]. For the case of broadband multipath fading channels the design of DSFC is needed to exploit the frequency diversity of the channel. A General system of DSFC consists of only transmitter node to relay node link and relay node to destination node link [9]. It does not consist of direct transmitter node to destination node path, which can be used to recover the signal at the destination node.

In [10], Jinsong, Honggang and Uysal proposed Distributed space time frequency coding [DSTFC] for relay based Amplify and forward protocol [AAF]. The paper [10] shows comparison of DSFC and DSTFC for AAF protocol. In paper [11], Space frequency coding is applied at transmitter node and at relay node the circular shift is done. In paper [9] [11], the number of paths between transmitter node and relay node varies from number of paths between relay nodes to destination node. Maximum Likelihood [ML] combiner is used at destination to combine the received signal in paper [9] [10] [11].

In paper [12], Wang and Xia have proposed one way and two way Distributed Space Time Code [DSTC] and Distributed space Frequency code [DSFC] for problem of time asychronism and frequency asynchronism. In paper [13] considered that all relay decode the information correctly, which is not the practical scenario. Whereas in [9] [12], the proposed DSFC system uses Cyclic Redundancy Code [CRC] at relay node to check whether relay node have correctly decoded information or not. If relay node correctly decodes then only it will transmit the information to destination node.

In all above papers, the DSFC design is restricted to the use of CRC at relay node and ML combiner technique at destination. CRC is error detecting code, not error correcting code. Due to that, performance of DSFC with CRC coding at relay node has limitations. The direct link criteria is also not considered in these papers. To remove these limitations of above DSFC systems, the Asymmetric as well as symmetric DSFC is designed with Decode and Forward protocol [DAF], which gives more flexibility and improves the system performance.

 

In the proposed paper, Distributed Space Frequency Coding [DSFC] with direct link and without direct link is considered. Different number of paths between transmitter node and relay node and relay node and destination node are considered [9] [10]. When the number of paths between transmitter node and relay nodes are same with the number of paths between relay node and destination node, such scenario is named as Symmetric DSFC [S-DSFC]. Otherwise, when the number of paths between transmitter node and relay nodes are different from the number of paths between relay node and destination node, such scenario is named as Asymmetric DSFC [A-DSFC].

For both S-DSFC and A-DSFC case, the Symbol Error Rate [SER] performance is compared by taking two types of error correcting/detecting codes at relay node, Cyclic Redundancy Code [CRC] and Convolution code. The performance comparison shows convolution coding outperforms CRC coding in terms of BER. Lastly at destination node, Maximum ratio combining [MRC] technique is used. The Proposed System is designed to achieve diversity for any number of relay nodes. It is assumed that all relay nodes are in synchronization.

The rest of the paper is organized by considering Decode and Forward [DAF] protocol. In Section II shows the Proposed system model of Distributed Space Frequency Coding [S-DSFC]. The algorithm of Asymmetric DSFC [A-DSFC] without direct link is explained. In section III, the simulation results of proposed system in comparison of existing system are presented. Finally, Section IV concludes the paper.

## II. PROPOSED SYSTEM

### *A. System Model: DSFC with Direct Link*

The general system model of Distributed Space Frequency Coding [DSFC] consist of one transmitter node, L relay Node [1, 2, 3,…L] and one destination node. All the channels in the system are multipath fading channels. OFDM modulation is used throughout the system with K subcarriers. Figure 1, shows the system model of DSFC with direct link [9] [14].

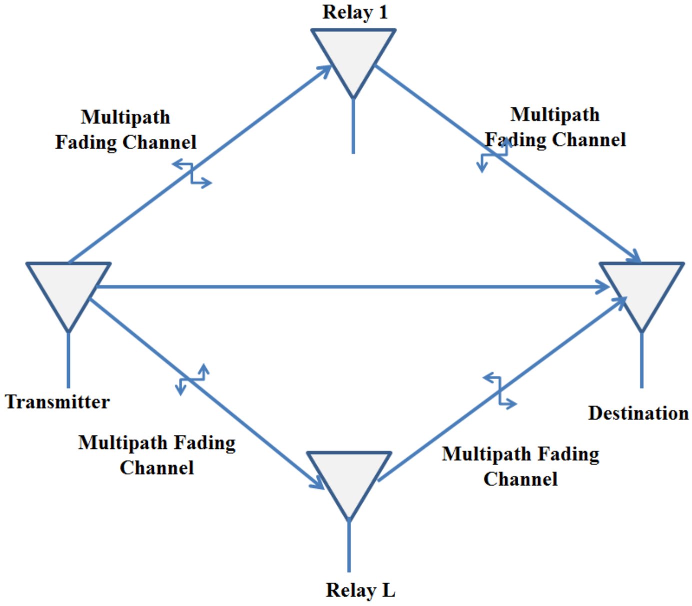


Fig. 1 System Model: DSFC with direct link

In phase 1, transmitter node broadcast the message to relay nodes as well as destination node over M paths.At l-th relay, the received signal in frequency domain over k-th subcarrier is given as [9].

$$y_{t,r_l}(k)=\sqrt{p_t}h_{t,r_l}(k)t(k)+\eta_{t,r_l}(k), k=1,......K \quad [1]$$

$$H_{t,r_l}(k)=\sum_{m=1}^{M}\alpha_{t,r_l}(m)\exp^{-j2\Pi(k-1)\Delta\tau_m}, k=1,......K \quad [2]$$

Where the channel coefficient between transmitter node to the l-th relay node on the k-th subcarrier is modeled as $h_{t,r_l}(k)$ .The transmitted symbol and the power is given as t(k) and Pt, respectively. $\eta_{t,r_l}(k)$ is additive white Gaussian noise of l-th relay node on the k-th subcarrier that is expressed as zero mean circularly symmetric complex Gaussian random variable with variance $\frac{N_0}{2}$ per dimension.

In second phase, each relay node take part into the process of transmission and transmitter node will stop broadcasting the message. In decode and forward [DAF] protocol, relay node decodes the information and it is checked with the help of error detecting code before forwarding the message to destination node. Convolution coding is used at relay node to check whether relay have correctly decoded the information or not [12] [9]. If the information is correctly decoded then only it will be forwarded to the destination node. If the information is not correctly decoded then that relay will remain idle and will not transmit the information to destination node.

 

In phase 2, Space frequency code is constructed in matrix form. K x L space -frequency (SF) code word transmitted from the relay nodes is given by

$$S_r = \begin{pmatrix} S_r(1,1) & S_r(1,2)\ldots\ldots & S_r(1,L) \\ S_r(2,1) & S_r(2,2)\ldots\ldots & S_r(2,L) \\ S_r(K,1) & S_r(K,2)\ldots\ldots & S_r(K,L) \end{pmatrix}$$

In phase 2, at destination node, information from relay node as well as transmitter node is combined with the help of Maximum Likelihood [ML] combiner. The received signal at destination over M paths is given as,

$$y_d(k) = \sqrt{p_t}\sqrt{p_r}h_{t,d}(k)b(k)\sum_{l=1}^{L} H_{r_l,d}(k)S_r(k,l)I_l + \eta_{t,d}(k) + \eta_{r_l,d}(k), k = 1,\ldots\ldots K$$

$$h_{b,d}(\tau) = \sum_{m=1}^{M} \alpha_{b,d}(m)\delta(\tau - \tau_m) \qquad [3]$$

Where the channel coefficients between transmitter node to the destination node on the k-th subcarrier is modeled as ht;d(k). _t;d(k) is additive white Gaussian noise on the k-th subcarrier for destination node. The channel coefficients are known at destination, not at transmitter. The block diagram of DSFC with direct link is given in figure 2.

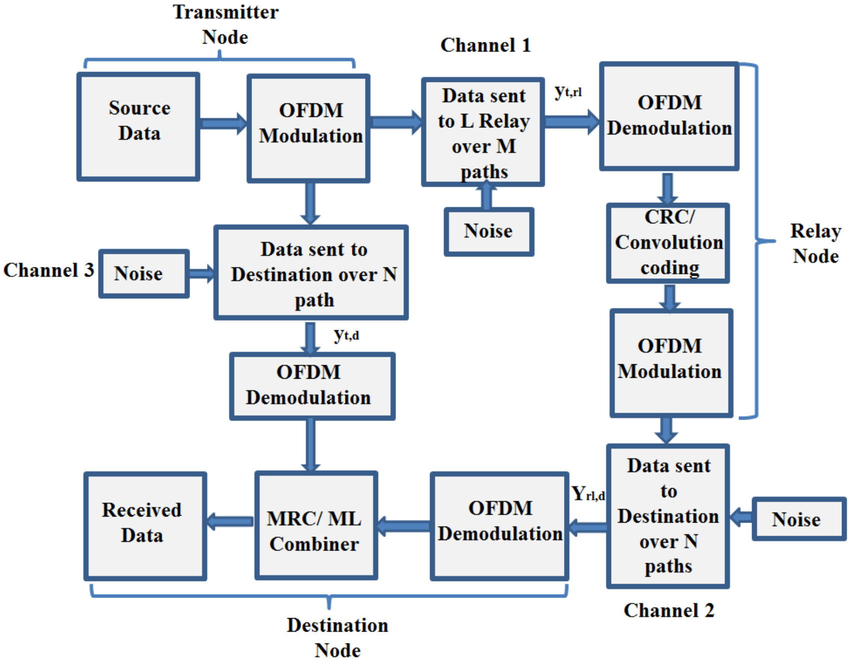


Fig. 1 Block Diagram: DSFC with direct link

DSFC with direct path is designed to achieve the diversity of order [M+1] L. This diversity is achieved due to two stage coding [9]. First one is transmitter node coding, which gives diversity of order [M+1], as the number of paths between transmitter node to l-th relay node is M and there is one direct path from transmitter node to destination node. Secondly, the relay node coding gives the diversity of order [M+1] L, as the number of relay nodes are L. Thus DSFC with direct link has diversity of order [M+1] L [9].

### *B. Symmetric and Asymmetric DSFC*

In DSFC, the individual copies of message is transmitted over M paths to each relay node. Suppose the message is transmitted over 2 paths to first relay, as shown in figure 3. Then the paths between relay node and destination node depends on the relay decoding accuracy. If relay node correctly decode the message over path M1, then it will be forwarded to the destination. But as shown in figure 3[b], the message over path M2 is not forwarded to the destination, because the relay node fails to decode the message correctly. As a result, message is transmitted to destination node from first relay node over one path. This is Asymmetric DSFC case [A-DSFC].

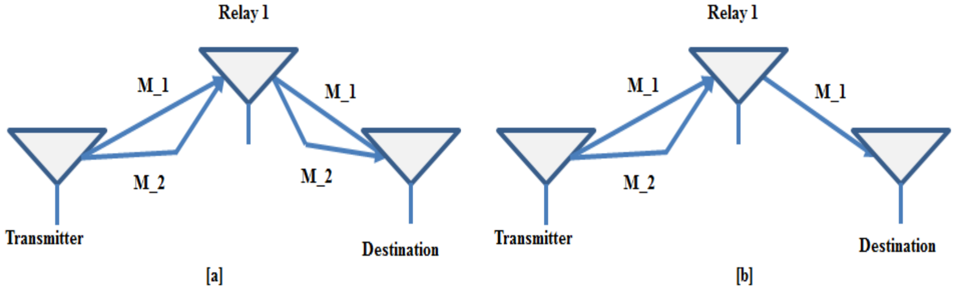


Fig. 3 S-DSFC and A-DSFC

 

As shown in figure 3[a], relay 1 correctly decodes the messages over path M1 and M2. As a result, two copies of processed message is received at destination node from relay 1.

## III. SIMULATION RESULTS

All The proposed system is simulated with the help of MATLAB software. For all simulation, Four relay and delay of 10 microseconds is considered. For this, the two ray model is taken with M paths, where two ray have equal variances. The modulation is OFDM modulation with k subcarriers, where k = 128.The system bandwidth is taken as 1MHz. The relaying protocol used at relay is Decode and forward protocol [DAF] The relay is considered at center location from base and destination. The power from source is equal to power from relay.i.e. pb = pr

### *A. DSFC without direct link*

Figure 4 and 5 shows the simulation of symmetric DSFC and Asymmetric DSFC without direct link. Figure 5, 6 represents for S-DSFC and A-DSFC with CRC coding and convolution coding at relay node, respectively. For symmetric DSFC number of paths are, M = 4 with delay of[0, 5, 10, 15 microseconds]. In Asymmetric DSFC, number of paths between transmitter node and relay node M = 4 with delay of [0, 5, 10, 15 microsecond], whereas number of paths between relay node and destination node are M = 4 with delay of [0, 5, 10 microsecond]. The signals received at destination are combined with the help of MRC combiner, which ensures smaller SER.

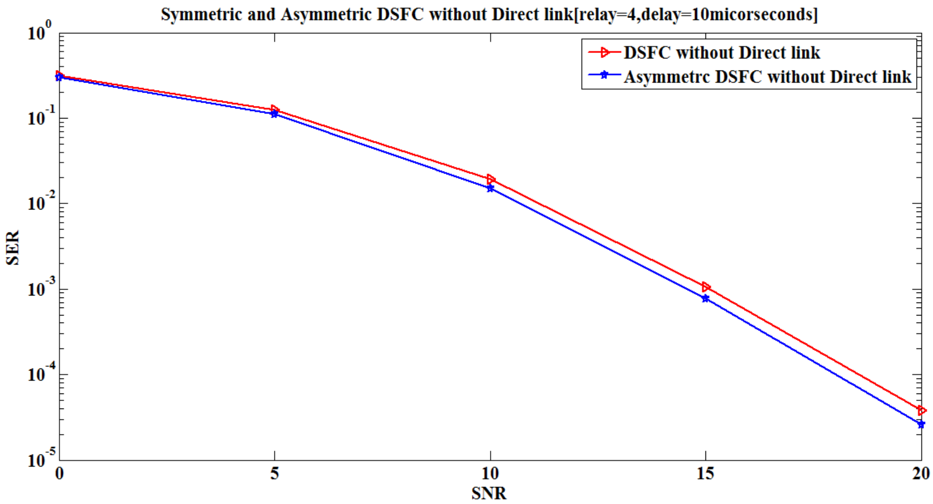


Fig.4 S-DSFC and A-DSFC without direct link, L=4, M=4, N=3, CRC

In case of figure 4, CRC error correcting code is used at the relay, where the code rate is Rc = 1/3 . As CRC is only error detecting code, so it gives poor performance than Convolution coding. From Figure 4, it is observed that the asymmetric DSFC without direct link is showing better performance than symmetric DSFC.

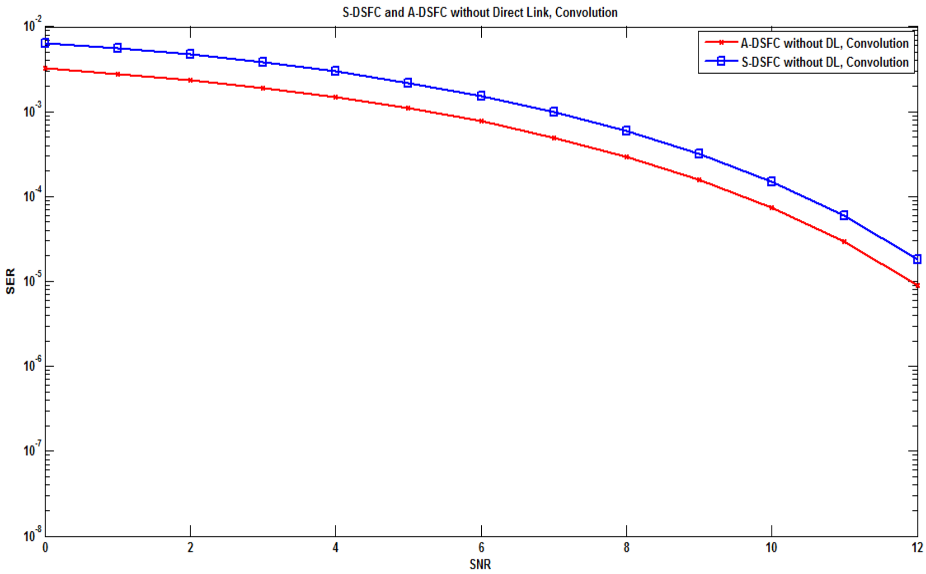


Fig.5 S-DSFC and A-DSFC L=4, M=4, N=3, Convolution

The proposed system is mainely designed for A-DSFC with convolution coding at relay. While using error correcting code i.e. convolution code, the symbol error rate decreases because the convolution code detects and corrects the data at relay node. This results into increase in probability of data getting correctly decoded at relay node.

 

### *B. DSFC with Direct Link*

Figure 6 shows the performance of Symmetric DSFC and Asymmetric DSFC with direct link. In figure 6, the cyclic redundancy coding is used in both cases. The effect of convolution coding on S-DSFC and A-DSFC is shown in figure 7. DSFC with direct link gives better result than DSFC without direct link because the base to destination path is added to recover the information, which increases the performance of the system.

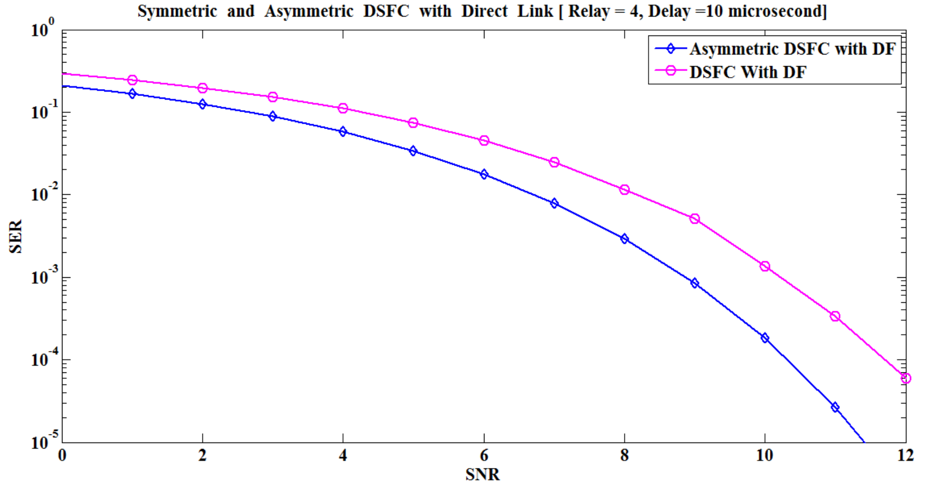


Fig.6 S-DSFC and A-DSFC with direct link

DSFC with direct link uses same parameters as DSFC without direct link. Again in CRC and convolution coding, Asymmetric DSFC has fewer symbols in error compared to symmetric DSFC. Whereas CRC have large number of symbols in error as compared convolution coding.

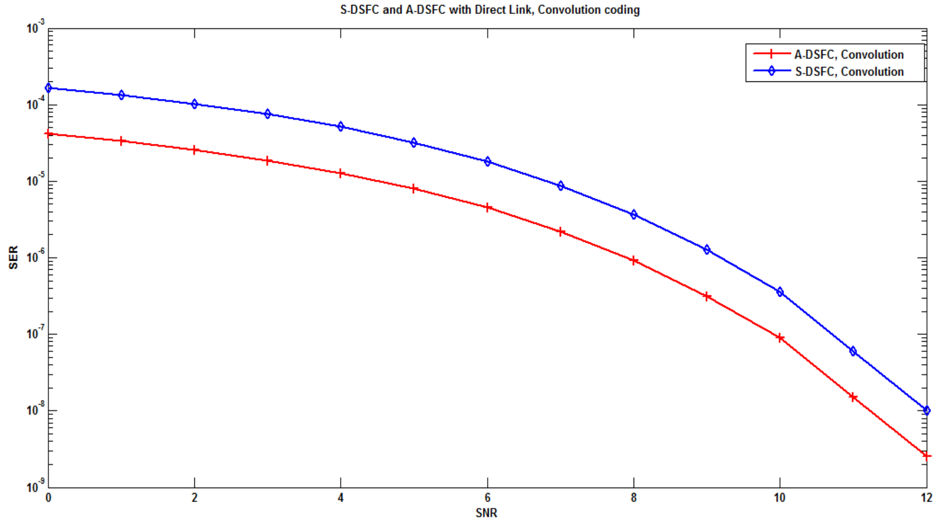


Fig.7 S-DSFC and A-DSFC with direct link, L=4, M=4, N=3, Convolution

The above simulations are obtained if all relay to destination link have same quality. If suppose one relay to destination link quality is better than second relay to destination link quality, then first relay will give lower SER compared to second relay.

## IV. CONCLUSIONS

The Asymmetric DSFC without Direct link is giving flexibility to the system, but in practice the number of paths are different between base to relay and relay to destination. The addition of direct link from base to destination node helps to recover the information from base node and can be used to compare it with the received information from relay. This results into the significant increase in the performance as well as improved diversity order of the cellular network, which is the maximum achievable diversity of the system. The combination of Asymmetric DSFC with direct link gives both flexibility and diversity to the system. For poor base to relay links, the combination of Asymmetric DSFC with direct link and DAF protocol with convolution coding is the best choice for SER, BER and spectral efficiency performances, which gives better flexibility to the cellular network.

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