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ENHANCED COMBINING SCHEME FOR SINGLE RELAY COOPERATIVE COMMUNICATION SYSTEMS

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Abstract - *We consider a cooperative diversity system with a source, a relay and a destination. The relay adopts decode and forward protocol. In this work, we propose a enhanced diversity combining scheme based on the assigned threshold value. Furthermore, We derive the end-to-end symbol error probability of this scheme with M-ary phase shift keying for a slow, flat Rayleigh fading. Numerical results show that the Switched combining scheme performs better than the conventional selection combining*

***Key Words*: (Decode and forward (DF), M-ary phase-shift keying (MPSK), Rayleigh fading, Scaled Selection,, symbol error probability (SEP).**

1.INTRODUCTION

Diversity combining technique is one of the effective methods formulated against Fading in wireless Communication. In this cooperative diversity, users in this network will share their antennas or resources to provide diversity. Most commonly using diversity technique is spatial diversity which involves multiple antennas which be used with enough distance separation between them. So that the receiver can receive multiple independently fading signal paths. By focusing on this problem we came across with one alternative which involves the distributed space diversity named as Cooperative Communication. Cooperative diversity error analysis is carried out in [1],[2].In [5], paired error approach based error analysis of a single relay cooperative diversity system has been performed and [1]-[3] assume source-to-relay link (SR), relay-to-destination(RD),and source to destination (SD) channels to be statistically independent. In this paper, we propose a hybrid diversity combining scheme which is a combination of switched diversity and a scaled selection combining. At the destination, if the instantaneous SNR of Source to destination (SD) is above a certain threshold, then we choose the source to destination (SD) link. Otherwise, we switch over to the Relay to destination (RD) link. If the scaled version of instantaneous SNR of relay to destination (RD) link is higher than the SD link, then we choose Relay to Destination (RD) link else we revert to source to destination (SD) link.The values of assigned threshold value is obtained by trial and error approach which minimizes the end-to-end symbol error probability(SEP). We derive the end-to-end SEP of this scheme with help of paired error approach for MPSK Signaling. We assume slow, flat Rayleigh fading environment for this paper work.

2. SYSTEM MODEL

In this paper cooperative communication system with Single relay is considered. The binary information is modulated by M-ary PSK modulator and broadcasted to destination as well as to the relay over frequency non selective flat fading Rayleigh channel.

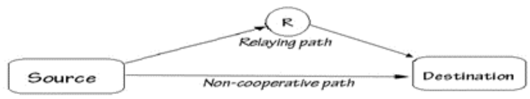

Fig -1: **Relaying communication**

The received signal is demodulated and detected using DF algorithm. Let the information carrying complex signal have energy $2E_s$ to the constellation S, which is refers to symbol and it is given by,

$$S_m=\sqrt{2E}_s\exp\left(\frac{j2\pi(m-1)}{M}\right), \quad m=1,2,3,\ldots M$$

Where, $j=\sqrt{-1}$. In this transmission system the transmission of symbol is done by two time slots. At first time slot, the source transmits the MPSK symbol to the destination as well as the relay. The complex baseband received signal at the destination and at the relay at the first time slot is represented as,

$$r_{sd} = h_{sd}.S + n_{sd} \qquad r_{sr} = h_{sr}.S + n_{sr}$$

Where h_{sd} and h_{sr} are the random complex fading gains of the source to destination (SD) link and source to relay (SR) link. Further, the additive white Gaussian noises of the source to destination and source relay links are n_{sd}, n_{sr} respectively. Whereas the fading gains are formed as symmetric Gaussian random variable with zero Mean and Variance Ωsd and Ω_{sr}

respectively. The noises are formed as zero mean complex Gaussian random variable with the variance $2N_0$.

In second time slot, the relay regenerate the symbol $\hat{s}$ and transmit to the destination. The destination receives the relay signal as,

$$r_{rd} = h_{rd}.\hat{s} + n_{rd}$$

where hrd and nrd are fading gains and additive white Gaussian noise of the Relay Destination link respectively. We assume that the destination have knowledge about the channel state information (CSI) of all links including relay to destination and source to destination, Meanwhile relay has the CSI of SR link.
Now we indicate the instantaneous SNRs of the SD, SR, and the RD links, respectively as

$$\Upsilon sd = \frac{Es}{No}|h_{sd}^2|,\ \Upsilon sr = \frac{Es}{No}|h_{sr}^2|,$$
$$\Upsilon rd = \frac{Es}{No}|h_{rd}^2|$$

The corresponding average SNRs are given by,

$$\Gamma_{sd} = E[\Upsilon_{sd}] = \frac{E_S\ \Omega_{sd}}{N_0},$$
$$\Gamma_{sr} = E[\Upsilon_{sr}] = \frac{E_S\ \Omega_{sr}}{N_0},$$
$$\Gamma_{rd} = E[\Upsilon_{rd}] = \frac{E_S\ \Omega_{rd}}{N_0}.$$

Where, rth is known as assigned average SNR threshold value and E [.] is known as expectation operator. The destination detects received signal $\check{S}$ and finally detected symbol is obtained from the proposed decision rule is,

$$\check{S} = \begin{Bmatrix} \arg\left\{\begin{matrix}\max \\ s \in S\end{matrix} Re(S^* h_{SD}^* \Upsilon_{SD})\right\} \\ \arg\left\{\begin{matrix}\max \\ s \in S\end{matrix} Re(S^* h_{SR}^* \Upsilon_{SR})\right\} \\ \arg\left\{\begin{matrix}\max \\ s \in S\end{matrix} Re(S^* h_{RD}^* \Upsilon_{RD})\right\} \end{Bmatrix}$$

$\check{S}$ partial to the following conditions,

$$\begin{cases} if\ \Upsilon_{SD} < \Gamma_{th}, \\ if\ \Upsilon_{SD} < \Gamma_{th}\ \text{and}\ \Upsilon_{SD} < \Upsilon_{RD}, \\ if\ \Upsilon_{SD} < \Gamma_{th}\ \text{and}\ \Upsilon_{SD} > \Upsilon_{RD}. \end{cases}$$

3. PERFORMANCE ANALYSIS

We represent the instantaneous SNR as,

$$\Upsilon = \frac{Es}{No}|h|^2,$$

In this section, we use the mathematical probability model for DF relaying proposed in [4] to derive a closed-form expression for the outage probability of the SC system.
The conditional error probability for MPSK is given by,

$$P_e(\Upsilon) = \frac{1}{\pi}\int_0^{\frac{\pi(M-1)}{M}} \exp\left(-\frac{\Upsilon \sin^2\frac{\pi}{M}}{\sin^2\emptyset}\right)$$

3.1 SEP for Source-Destination link

The probability of error in SD link is derived in the form under the condition $\Upsilon_{SD} > \Upsilon_{Th}$ or $\Upsilon_{SD} > \Upsilon_{RD}$ is given by,

$$P_{eSD1} = \int_{\Gamma_{th}}^{\infty}\frac{1}{\pi}\int_0^{\frac{\pi(M-1)}{M}} exp\left(-\frac{\Upsilon \sin^2\frac{\pi}{M}}{\sin^2\emptyset}\right)\times \left(\frac{1}{\Gamma_{SD}}\right) exp\left(-\frac{x}{\Gamma_{SD}}\right) dx d\emptyset$$

Simplify error probability equation by applying integral over x,

$$P_{eSD1} = \frac{1}{\pi\Gamma_{SD}}\int_0^{\frac{\pi(M-1)}{M}} \frac{1}{\left(\frac{\sin^2\frac{\pi}{M}}{\sin^2\emptyset}+\frac{1}{\Gamma_{SD}}\right)}\times exp\left(-\left(\frac{\sin^2\frac{\pi}{M}}{\sin^2\emptyset}+\frac{1}{\Gamma_{SD}}\right)\right)\Gamma_{th} d\emptyset$$

Probability of error in source to destination link $\Upsilon_{SD} > \Upsilon_{RD}$ is obtained by applying integral over x and further substitution we get total symbol error probability of S-D link is given as,

$$\boldsymbol{P_{eSD}} = \frac{\mathbf{1}}{\Gamma_{SD}}\boldsymbol{\rho}_{2(\Gamma_{SD},\emptyset_0)} - \boldsymbol{\rho}_{1(\Gamma_{SD},\emptyset_0,\Gamma_{th})} - \boldsymbol{\rho}_{4(\Gamma_{SD},\Gamma_{RD},\emptyset_0)} + \boldsymbol{\rho}_{3(\Gamma_{SD},\Gamma_{RD},\emptyset_0,\Gamma_{th})}$$

3.2 SEP for Source-Relay-Destination Link

The probability of error in R-D (Relay-Destination) link, under the condition of $\Upsilon_{sd} < \Upsilon_{rd}$ is given by ,

$$P_{eRD} = \int_z^{\infty}\int_0^{\Gamma_{th}}\int_0^{\infty} p_e(y,z)\frac{1}{\Gamma_{SD}} exp\left(-\frac{x}{\Gamma_{SD}}\right)\times \left(\frac{1}{\Gamma_{RD}}\right) exp\left(-\frac{y}{\Gamma_{RD}}\right)\frac{1}{\Gamma_{SD}} exp\left(-\frac{z}{\Gamma_{SD}}\right) dz dx dy$$

Lets define $P_{eRD1}, P_{eRD2}, P_{eRD3}$

$$P_{eRD1} = \left(\frac{1}{\Gamma_{SR}}\right)\rho_2(\Gamma_{SR},\emptyset_0)\int_x^{\infty}(1\ (y))\times \left(\frac{1}{\Gamma_{RD}}\right) exp\left(-\frac{y}{\Gamma_{RD}}\right) dy$$

$$P_{eRD2} = \int_0^{\infty} P_e\ (y)\frac{1}{\Gamma_{SR}} exp\left(-\frac{z}{\Gamma_{SR}}\right) dz$$

$$P_{eRD3} = \sum P_{l,k}\ (y)\int_0^{\infty} P_{k,l}\ (z)\frac{1}{\Gamma_{SR}} exp\left(-\frac{z}{\Gamma_{SR}}\right) dz$$

$P_{l,k^{(z)}}$ is probability of error in S-R link when S_k is transmitted in S-R link and it is detected as S_l at the relay node. $P_{k,l^{(y)}}$ is probability of error in R-D link when S_l is transmitted from relay to destination and it is detected as Sk at the destination node.

By solving above equations we get,

$$P_{eRD1} = \left(1 - P_e(y)\right)\frac{1}{\pi}\int_0^{\frac{\pi(M-1)}{M}}\int_0^{\infty}\frac{1}{\Gamma_{SR}} \times exp\left(-\left(\frac{\sin^2\frac{\pi}{M}}{sin^2 Ø} + \frac{1}{\Gamma_{SR}}\right) - \right) zdzdØ$$

Now applying integral over y in as,
By Substituting $P_{e^{(y)}}$ we get,

$$P_{eRD1} = \left(\frac{1}{\Gamma_{SR}}\right)\rho_2(\Gamma_{SR}, Ø_0) \times \left(\frac{1}{\Gamma_{RD}}\right) \times exp\left(-\frac{x}{\Gamma_{RD}}\right)\int_0^{\frac{\pi(M-1)}{M}}\frac{1}{\left(\frac{\sin^2\frac{\pi}{M}}{sin^2 Ø}+\frac{1}{\Gamma_{RD}}\right)} exp\left(-\left(\frac{\sin^2\frac{\pi}{M}}{sin^2 Ø} + \frac{1}{\Gamma_{RD}}\right)\right) xdØ$$

By applying integral over x and by further substitution, we get total symbol error probability of R-D link is given as

$$\boldsymbol{P_{eRD}} = \sum_{l=1, l\neq k}^{M}\frac{1}{4\pi\Gamma_{SD}\Gamma_{SR}}\left[\rho_2(\Gamma_{SR}, Ø_1) - \rho_2(\Gamma_{SR}, Ø_2)\right] \times \boldsymbol{(P1 - P2)}$$

Where, P1 and P2 is given as,

$$P1 = \int_0^{\pi - Ø_3}\frac{1}{\left(\frac{\sin^2 Ø_4}{sin^2 Ø}+\frac{1}{\Gamma_{RD}}\right)}\frac{1}{\left(\frac{\sin^2 Ø_3}{sin^2 Ø}+\frac{1}{\Gamma_{RD}}+\frac{1}{\Gamma_{SD}}\right)} \times \left(1 - exp\left(-\left(\frac{\sin^2 Ø_3}{sin^2 Ø} + \frac{1}{\Gamma_{RD}} + \frac{1}{\Gamma_{SD}}\right)\right)\Gamma_{th}\right) dØ$$

$$P2 = \int_0^{\pi - Ø_4}\frac{1}{\left(\frac{\sin^2 Ø_4}{sin^2 Ø}+\frac{1}{\Gamma_{RD}}\right)}\frac{1}{\left(\frac{\sin^2 Ø_4}{sin^2 Ø}+\frac{1}{\Gamma_{RD}}+\frac{1}{\Gamma_{SD}}\right)} \times \left(1 - exp\left(-\left(\frac{\sin^2 Ø_4}{sin^2 Ø} + \frac{1}{\Gamma_{RD}} + \frac{1}{\Gamma_{SD}}\right)\right)\Gamma_{th}\right) dØ$$

4. NUMERICAL RESULTS

In this section, we discuss about the error analysis for DF relaying protocol and Symbol error probability (SEP) measure is carried out . Plots are done for received signal SEP with varying average SNR the decision rule.Fig.2 shows the results for Non cooperation, conventional Scaled selection combining and Threshold switching selection combining.

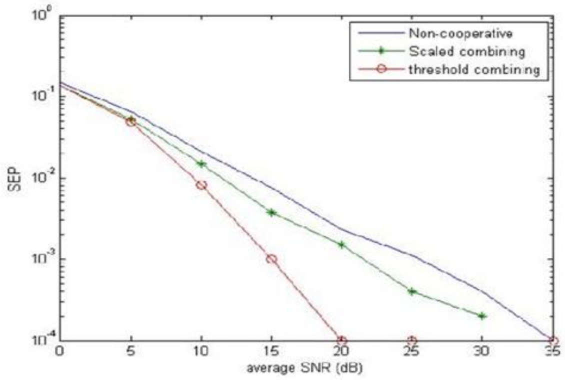

Fig -2: **BER Comparison for Non cooperative, Scaled Selection combining and Threshold (switched) combining.**

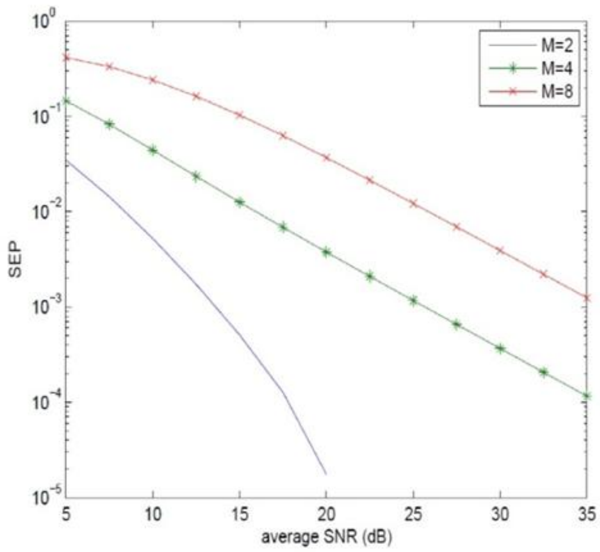

Fig -3: **Shows that the result of BPSK, QPSK and 8-PSK performance for threshold switched selection scheme.**

The plots shows that the BER performance of proposed scheme is improved compared to the conventional selection combining.Fig.3 shows the results of Symbol error probability for various instantaneous SNR values of MPSK.In this evaluated result we use switched threshold decision rule for performance analysis.

5. CONCLUSIONS

In this paper, we proposed the threshold switching technique which incorporates the effect of source to relay link to reduce the probability of error. The end to end symbol error probability is derived for M-PSK signalling with DF relaying in flat Rayleigh fading. We have proved that the BER of proposed scheme is reduced than conventional non cooperation and scaled selection combining schemes.

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