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# The Improved Amplify-and-Forward (IAF) Three Time Periods TDMA Fashioned Protocol with Inter-Relay Communication

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## Abstract

The TDMA constructed protocols have been planned (i.e., proposed) by various researchers. These protocols are generally two time periods or three time periods based, and have shown significant reduction in Bit Error Rates (BER), because of low diversity order. Consequently, the Improved Amplify-and-Forward (IAF) protocol has been proposed. The IAF protocol uses three time periods, to transmit data from transmitter to receiver. Moreover, the transmitter is stimulated during the second as well as third time periods, to broadcast to receiver, and the diversity order is improved. It is shown from results that IAF demonstrated significant reduction in BER and rise in BER-Gain, over the previous proposed two time periods as well as three time periods protocols. The IAF protocol demonstrated substantial improvement in Global-Percentage-Error-Decrease (GPED) and Local-Percentage-Error (LPED) values, both at severe as well as at low fading conditions, over to previous proposed TDMA constructed protocols (i.e., two time periods as well as three time periods based).

**Keywords:** BER, BER Gain, GPED, IAF, LPED, TDMA

## 1. Introduction

Because of the fading effects, the wireless signals weaken during travelling from transmitter to receiver.

Diversity communication has been used to solve the issue of fading effects. Different diversity techniques have been used to acquire diversity communication[1].

However, due to too many users the issue of interference and complexity arise. Moreover, the total power consumed by the wireless equipment's also increase, which indicates the inefficiency of the diversity protocols.

Cooperative diversity communication protocols have been introduced to solve the described issues. The users or relays cooperate among each other, to achieve cooperative diversity communication[2–6].

The cooperative phenomenon of cooperative diversity protocols reduces the size of the wireless equipment's (hardware), their cost and interference among the users as well[7]. Moreover, due to the decrease in multipath fading, by using multiple access techniques and cooperative diversity phenomenon, the wireless channel capacity of cooperative wireless channel also increases, in terms of high data rates[8–11].

Different TDMA based cooperative diversity protocols (i.e., three times slots protocols) have been presented by researchers, in the literature[12,13]. However, these protocols have various limitations, by demonstrating of low diversity at receiver (destination) and low broadcasting (source) at transmitter.

The BER and outage probability have been effectively improved, by using Hybrid TDMA-FDMA approach and Nakagami-m multipath fading[14].

In[14,16] also proposed TDMA formed protocols (i.e., three time slots). However, the proposed protocol had shown low BER, because the transmitter was not stimulated in second and third time slots (periods). It is observed that low diversity order and low broadcasting degree has been the issue in the previous described work

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and limits the performance of TDMA based protocols[12,17]. Moreover, the transmitter has been disabled, during transition from transmitter to receiver in the second and third time periods. This also affects the output of TDMA constructed protocols, in demonstrating ineffective diversity transmission (i.e., low diversity).

In this research work, the Improved Amplify-and-Forward (IAF) TDMA constructed protocol is proposed. The communication model for the proposed protocol is inter-relay communication based. The key impact is that the transmitter transmits in the second and third time periods, and diversity has been upgraded at the receiver. The upgraded diversity has shown improved BER and BER-Gain data values. The results shown significant improvement in reduction of BER as well as rise in BER gain, by the IAF TDMA fashioned protocol, over the protocols in[12] (i.e., two time periods based), and in[15] (i.e., three time periods based).

# 2. The Improved Amplify-and-Forward (IAF) TDMA Fashioned Protocol with Inter-Relay Communication based Approach

The IAF protocol summary is described in Table 1. The IAF protocol is TDMA fashioned, using three time periods. The transmitter broadcasts to receiver, relay 1 as well as relays 2, in first time period. The second time period is used to broadcast data by relays as well as transmitter, to the receiver. Moreover, the relays also broadcast their data to each other, in the second time period. The third time period is used to transmit the previous data exchanged by both relays, and transmitter as well, to receiver.

The high diversity order and low bit error rate at receiver, has been obtained by the proposed IAF protocol. The proposed IAF protocol is assessed with the protocols proposed in[15] (i.e., three time periods based), and in[12] (i.e., two time periods based). The IAF protocol revealed significant reduction in BER and rise in BER-Gain data values, over the protocols in[12,15].

**Table 1.** The IAF proposed protocol

| Time Period 1 | Time Period 2 | Time Period 3 |
|---|---|---|
| $t \to r1, t \to r2$ | $r1 \to r, r2 \to r$ | $r1 \to r, r2 \to r$ |
| $t \to r$ | $r1 \to r2, r2 \to r1$ | $t \to r$ |
| | $t \to r$ | |

## 2.1 The IAF protocol system model

The IAF protocol model is presented in Figure 1. It consists of transmitter (source), two relays and receiver (destination), mutually cooperate each other, to broadcast from transmitter to receiver. The transmitter, two relays i.e., $r_1$ and $r_2$ and receiver, are functioned by using only one antenna. The $h_{tr1}$, $h_{tr2}$, $h_{r1r}$, $h_{r2r}$, $h_{r1r2}$ and $h_{r2r1}$ are the multipath Rician fading channels for the transmitter to relay, transmitter towards relay2, relay1 towards receiver, relay2 towards receiver, relay1 towards relay2 and relay2 towards relay1 paths, respectively. However, both the relays are operated using Amplify-and-Forward (AF) communication.

## 2.2 Signal models of the IAF protocol

The signal models consist of information signal with Rician multipath fading and noise. The following Equations (1), (2) and (3), indicate the received signals by relay1, relay2 and receiver, respectively, in the first time period:

$$y_{tr1} = E_t h_{tr1} s + n_{tr1} \tag{1}$$

$$y_{tr2} = E_t h_{tr2} s + n_{tr2} \tag{2}$$

$$y_{tr,1} = E_t h_{tr} + n_{tr} \tag{3}$$

The transmitter is operated with transmit average energy $E_t$ of each symbol. The fading channels transmitter towards relay1 ($h_{tr1}$), transmitter towards relay2 ($h_{tr2}$), and transmitter towards receiver ($h_{tr}$) designates the Rician multipath fading of the respective links. Moreover, the transmitter to relay1, transmitter to relay2 and transmitter to receiver links are affected by the Additive White Gaussian Noises (AWGN's) $n_{tr1}$, $n_{tr2}$ and $n_{tr}$ respectively. Normalization of the signals is carried out at relay1 as well as relay2 after reception, and broadcasted to receiver in the second time period. The Equations (4), (5) and (6) demonstrate the receipted signals

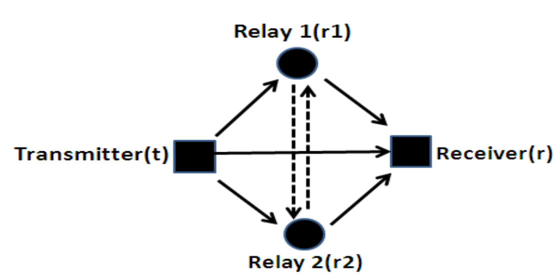


**Figure 1.** System model for IAF protocol.

at receiver from relay1, relay2 and transmitter, respectively. The receipted signals are in second time period, and are shown below as:

$$y_{r1r} = E_1 h_{r1r} \frac{y_{tr1}}{w_1} + n_{r1r} \tag{4}$$

$$y_{r2r} = E_2 h_{r2r} \frac{y_{tr2}}{w_2} + n_{r2r} \tag{5}$$

$$y_{tr,2} = E_t h_{tr} + n_{tr} \tag{6}$$

Where $w_1$ and $w_2$ are the normalization factors used for the normalization of received signals at relay 1 and relay2 respectively, and are given by the following equations:

$$w_1 = \sqrt{E_t \,|h_{tr1}|^2 + 1} \tag{7}$$

$$w_2 = \sqrt{E_t \,|h_{tr2}|^2 + 1} \tag{8}$$

The relay1 in addition to relay2 are operated with average transmit energies of $E_1$ and $E_2$ per symbol, respectively. The Multipath channels (i.e., Rician fading paths) relay1 to receiver ($h_{r1r}$) and relay2 to receiver ($h_{r2r}$) designates the Rician multipath fading of the respective links. Moreover, the relay1 to receiver and relay2 to receiver links are affected by the Additive White Gaussian Noises (AWGN's) $n_{r1r}$, and $n_{r2r}$ respectively. In addition, data exchange between the two relays (relay1 as well as relay2) takes place, after normalization of the received data in the second time period, from receiver.

The following Equations (9) and (10) indicate the receipted signals at relay2 as well as relay1, from relay1 as well as relay2, respectively, and are shown below as:

$$y_{r1r2} = E_1 h_{r1r2} \frac{y_{tr1}}{w_1} + n_{r1r2} \tag{9}$$

$$y_{r2r1} = E_2 h_{r2r1} \frac{y_{tr2}}{w_2} + n_{r2r1} \tag{10}$$

The fading channels relay1 towards relay2 ($h_{r1r2}$) and relay2 towards relay1 ($h_{r2r1}$) designate the Rician multipath fading of the respective links. Moreover, the relay1 towards relay2 as well as relay2 towards relay1 links are affected by the Additive White Gaussian Noises (AWGN's) $n_{r1r2}$ and $n_{r2r1}$ respectively.

The normalization of the previous exchanged data during the second time slot is carried by relay1 as well as relay2 in the third time period, and broadcasts towards receiver. The Equations (11), (12) and (13) indicate the receipted signals at receiver after relay1, relay2 and transmitter broadcast respectively, and is shown below as:

$$y_{r1t} = E_1 h_{r1r2} \frac{y_{r1r2}}{w_3} + n_{r1t} \tag{11}$$

$$y_{r2t} = E_2 h_{r2r1} \frac{y_{r2r1}}{w_4} + n_{r2t} \tag{12}$$

$$y_{tr,3} = E_t h_{tr} + n_{tr} \tag{13}$$

Where $w_3$ and $w_4$ are the normalization factors used for the normalization of received signals after the data exchange in the second time period, at relay 2 as well as relay1 respectively, and are given by the following equations:

$$w_3 = \sqrt{E_1 \,|h_{r1r2}|^2 + 1} \tag{14}$$

$$w_4 = \sqrt{E_2 \,|\mathrm{h}_{r2r1}|^2 + 1} \tag{15}$$

To get the information signal at receiver, the Maximum Ratio Combining (MRC) technique is implemented. The following Equation (16) indicates the required information signal at destination:

$$\begin{aligned} y_r = {} & y_{r1r} h^*_{r1r} h^*_{tr1} + y_{r2r} h^*_{r2r} h^*_{tr2} + y_{tr} h^*_{tr} + \\ & y_{r2r} h^*_{r2r} h^*_{r1r2} h^*_{tr1} + y_{r1r} h^*_{r1r} h^*_{r2r1} h^*_{tr2} + y_{tr} h^*_{tr} \\ & + y_{tr} h^*_{tr} \end{aligned} \tag{16}$$

The conjugates $h^*_{tr1}$, $h^*_{tr2}$, $h^*_{r1r}$, $h^*_{r2r}$, $h^*_{tr}$, $h^*_{r1r2}$ and $h^*_{r2r1}$ are used to for normalization, due to MRC at destination. The IAF protocol performance is improved due to channel conjugates, in term of reduction in BER and rise in BER-Gain.

## 3. Results and Discussion

The IAF protocol is implemented, using the simulation model shown in Figure 2. The $10^5$ symbols, using Bipolar Phase Shift Keying (BPSK) modulation are generated at receiver. The $h_{tr1}$, $h_{tr2}$ and $h_{tr}$ Rician multipath channels are generated for the transmitter towards relay1, transmitter towards relay2 and transmitter towards receiver links, respectively. The signal using BPSK modulation is mixed to each Rician channel, with average energy of each symbol. Each multipath channel is made multipath noisy channel, due to the addition of AWGN's. The noise added signals, having multipath effect as well, are received at relay1, relay 2 and receiver, in first time period. The receipted signals at relays are stabilized (i.e., normalized), using the normalization factors. The $h_{r1r}$, $h_{r2r}$, $h_{r1r2}$ and $h_{r2r1}$

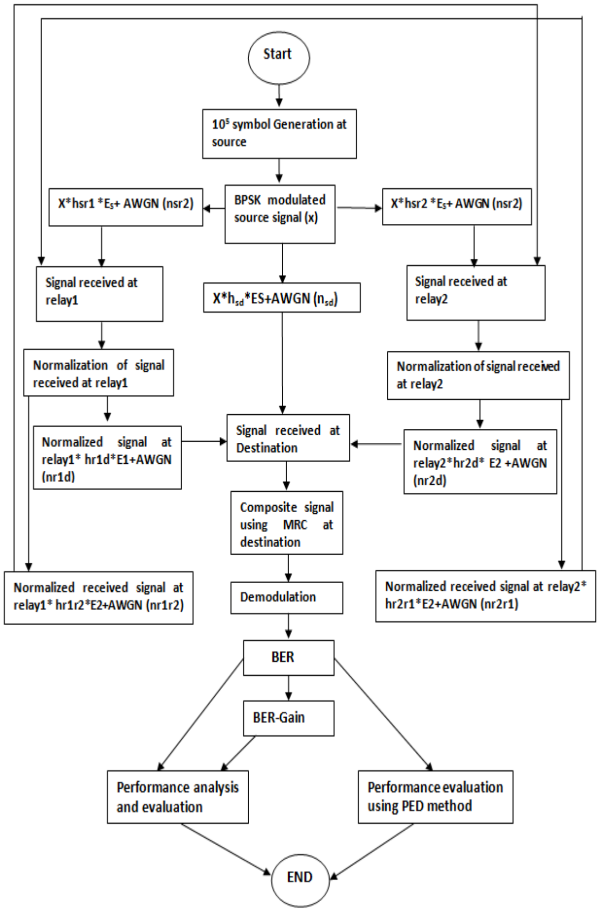


**Figure 2.** The IAF protocol simulation model.

multipath Rician channels are established, in the second time period, for relay1 towards receiver, relay2 towards receiver, relay1 towards relay2 and relay2 towards relay2 links, respectively. The stabilized wireless signals with average energy of each symbol are mixed to each multipath Rician channel. Each multipath channel is made multipath noisy channel, due to the addition of AWGN's. The receiver receives the noisy wireless signals having multipath influence, from relay1 as well as relay2, and transmitter, in the second time period. The stabilized wireless signals at the relays, with average energy of each symbol are mixed to the Rician multipath fading wireless channels $h_{r1r2}$ and $h_{r2r1}$, for the relay1 towards relay2 as well as relay2 towards relay1 links, respectively. The relay1 as well as relay2 gets wireless fading multipath signals from relay2 in addition to relay1, in second time period, respectively. The receipted signals at relay1 as well as relay2 are again stabilized using normalization factor, to broadcast the signal to receiver, in third time period. The stabilized signals at relay1 as well as relay2 are mixed to Rician wireless multipath channels $h_{r1t}$ in addition to $h_{r2t}$ respectively. The receiver takes the multipath noisy wireless signals (i.e., because of the addition of AWGN noises) from relay1 as well as relay2, in third time period. Moreover, the receiver also takes a copy of multipath noisy wireless signal from transmitter, in third time period. The composite wireless signal at receiver is obtained by using MRC. The performance study and assessment are carried out, with the protocols proposed in[12,15].

The performance analytical study of IAF protocol is carried out with variable increase in SNR, and constant K values. The BER as well as BER-Gain are observed, with the increase in SNR. However, the K values are kept constant and low. The purpose of taking low fading was to examine the performance of IAF protocol, at high fading environment. Figures 3 as well as 4 demonstrate reduction in BER values, with rise in SNR, and K data values are retained constant. Similarly, rise in BER-gain data values are indicated, with the variable rise in SNR. The BER as well as BER-Gain data values are also observed, with rise in K data values. However, the SNR values are retained constant. The reduction in BER as well as BER-Gain data values are demonstrated, with rise in K parameter values, while, SNR values are retained constant, as indicated in Figures 5 and 6.

The IAF protocol performance is evaluated with the previous proposed protocol (TDMA based two time period) in[12]. The IAF protocol performed better over the protocol in[12], and showed reduction in BER as well as rise in BER-Gain, as shown in Figures 3 and 4, respectively. Owing to the fact that the IAF protocol has improved diversity order, and is operated with one extra time slot (i.e., reception of two additional copies of transmitter signal at receiver), in comparison with the protocol in[12].

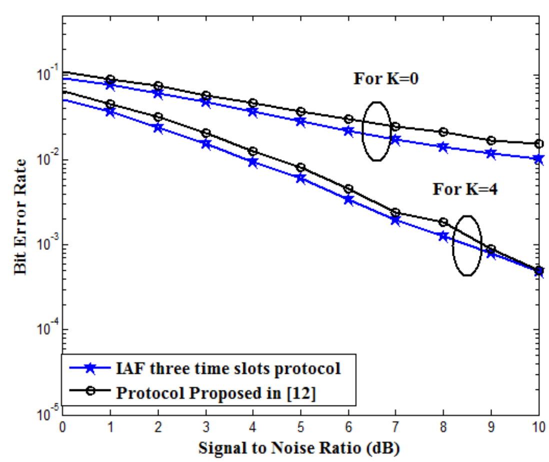


**Figure 3.** BER comparison of IAF protocol with protocol in[12] using variable SNR and different persistent K data values.

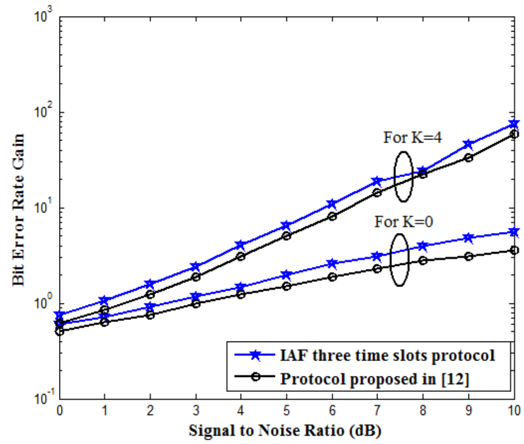


**Figure 4.** BER-Gain assessment of IAF protocol with protocol in[12] using variable SNR and persistent K data values.

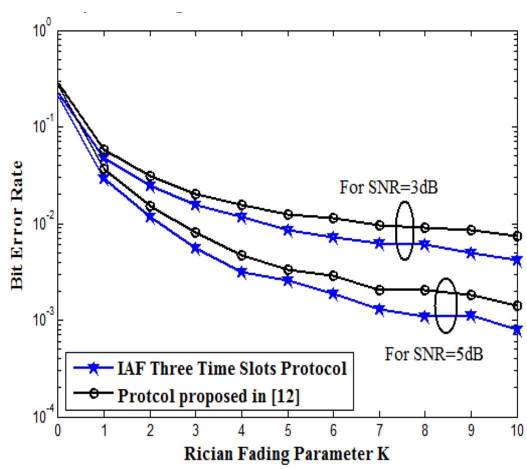


**Figure 5.** BER comparison of IAF protocol with previous protocol in[12] using variable K values and persistent SNR.

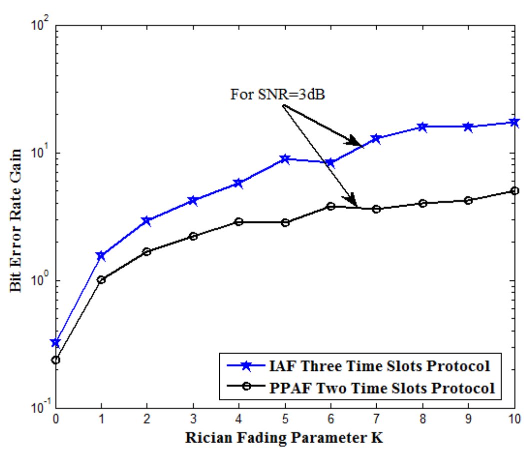


**Figure 6.** BER-Gain assessment of IAF protocol with protocol proposed in[12] using variable K data values and persistent SNR.

However, the BER in addition to BER-Gain parameter values, are obtained due to rise in SNR, whereas, retaining persistent fading conditions.

The IAF protocol is also evaluated with the protocol in[12], using changing fading conditions, whereas, the SNR values are retained constant, as indicated in Figures 5 and 6. The IAF protocol revealed reduction in BER and rise in BER-Gain values, over the Previous Proposed Amplify-and-Forward (PPAF) Protocol in[12]. The SNR values are retained constant, whereas, the fading conditions are retained variable, as shown in Figures 5 and 6. Because of high diversity order, the reduction in BER and rise in BER-Gain have been shown by the IAF protocol.

The performance IAF protocol is also assessed with the protocol in[15]. The IAF protocol demonstrated better performance over the protocol in[15]. The IAF protocol revealed reduction in BER and rise in BER-Gain, using variable SNR, as indicated in Figures 7 and 8, respectively. It is due to the fact that the IAF protocol transmitter continuously broadcasts to receiver, in second as well as in third time periods, and does not remain silent. Due to this phenomenon, the high diversity order has been observed, which results in reduction in BER and rise in BER-Gain, at receiver.

The IAF protocol revealed reduction in BER values over the protocol in[15], using variable K values, whereas, SNR values are retained constant, as shown in Figure 9. Moreover, rise in BER-Gain is demonstrated, over the protocol in[15], using variable K values, as shown in Figure 10.

The IAF protocol is assessed statistically with Percentage Error Decrease Method (PED). This method demonstrates the magnitude error of two measured

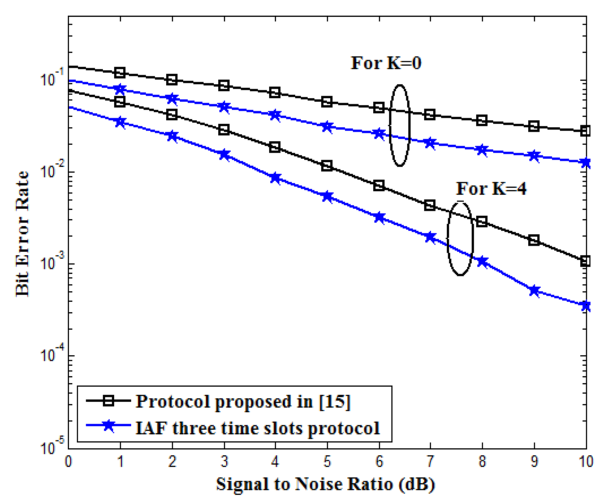


**Figure 7.** BER assessment of IAF protocol with protocol in[15] using variable SNR and persistent K values.

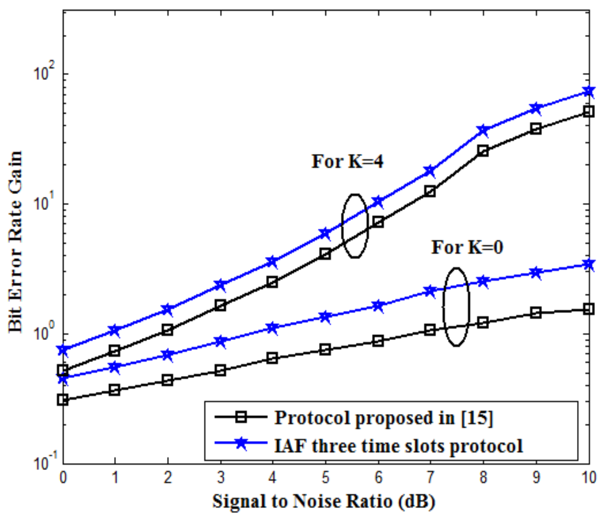


**Figure 8.** BER-Gain assessment of IAF protocol with protocol in[15] using variable SNR and persistent K values.

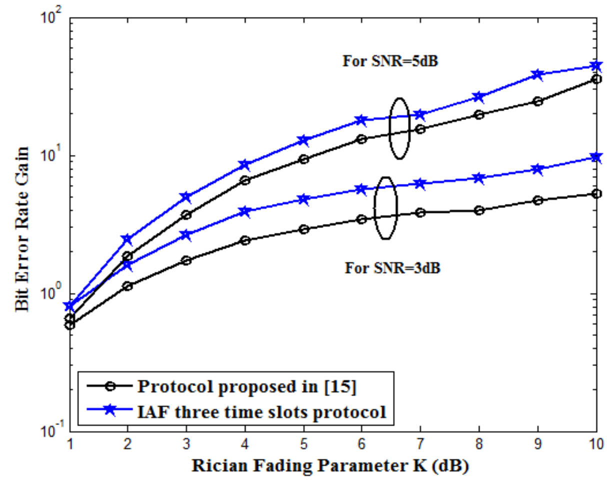


**Figure 10.** BER-Gain assessment of IAF protocol and protocol in[15], using variable K values and persistent SNR.

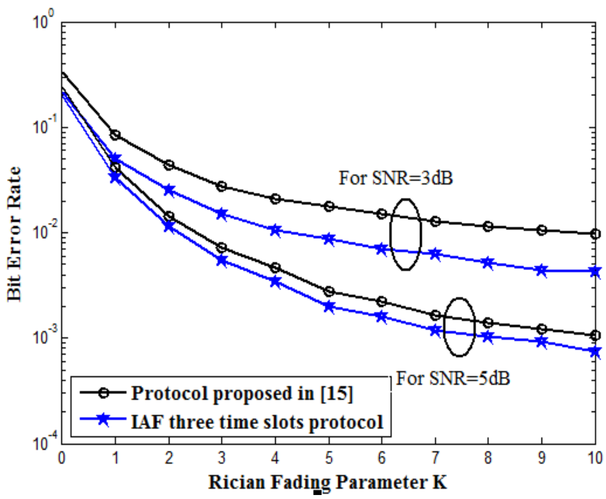


**Figure 9.** BER assessment of IAF protocol and protocol in[15] using variable K values and persistent SNR values.

quantities, and is used by scientists, to find the correctness of the proposed protocol. The PED method demonstrates the magnitude error, in terms of LPED as well as GPED. The IAF protocol showed rise in LPED as well as LPED values, over the protocols proposed in[12,15].

The LPED and GPED statistical values are obtained using the following Equations (17) and (18), respectively.

$$LPED = \left| \frac{\bar{V}_0 - \bar{V}_1}{\bar{V}_0} \right| \times 100 \tag{17}$$

$$GPED = \frac{\sum \left| \frac{\bar{V}_0 - \bar{V}_1}{\bar{V}_0} \right| \times 100}{L} \tag{18}$$

Where $\bar{V}_0$ indicates the BER average of IAF protocol, and $\bar{V}_1$ is the BER average of protocol in[12] or[15], and L is the overall SNR values in use.

The low to medium SNR values (i.e., 0-14dB) and constant fading conditions (i.e., K = 1, 3 and 5), are taken to obtained GPED and LPED values, as shown in Figure 11. The IAF protocol outperforms over protocol in[12], with 41.4% GPED at K equal to 1, 36.58% at K equal to 3, and 32.27% at K equal to 5. The GPED values indicate that the IAF protocol forms better over protocol in[12], in terms of high GPED at severe fading conditions, as compared to GPED values at low fading conditions. It is due to the rise in diversity order as well as broadcasting, as compared to protocol in[12].

It is also shown from Figure 11, that IAF protocol revealed LPED of 26.50%, 20.50%, 18.20% at K equal to 1, 3 and 5, respectively, over the protocol in[12]. Moreover, the performance of the IAF protocol is further improved with LPED of 51.40% at K equal to 1, 51.50% at K equal to 3 and 43.50% at K equal to 5, at SNR value of 14dB, over the protocol in[12].

The GPED and LPED analysis of IAF protocol in comparison with the protocol in[15], is also carried. It is demonstrated that the IAF protocol outperform, with GPED of 28.57% at K equal to 1, 29.36% at K equal to 3 and 29.57% at K equal to 5, as shown in Figure 12. It was

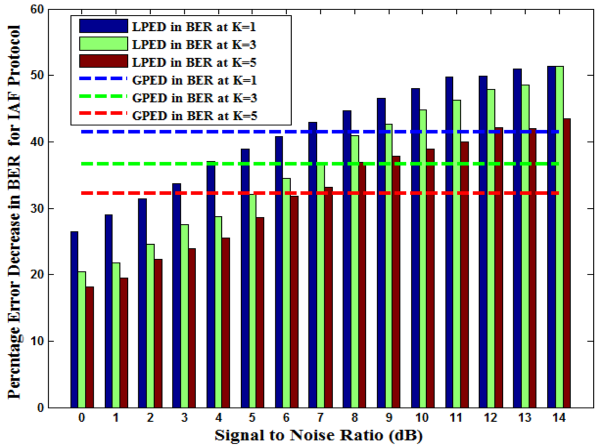


**Figure 11.** The LPED and GPED of IAF protocol compared to protocol in[12], using persistent K values and variable SNR.

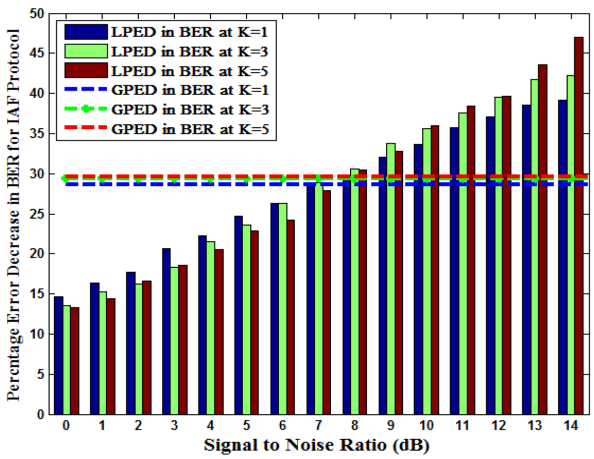


**Figure 12.** The GPED and LPED of IAF protocol compared to protocol in[15], at persistent K values and variable SNR.

shown from Figure 12 that the IAF protocol performed well over the protocol in[15], both at severe and low fading conditions. It is because the IAF protocol does not have much effect when the conditions changes from NLOS to LOS.

It was also shown increase in LPED values, by the IAF protocol, over protocol in[15], with the SNR increase. For instance, at 0dB, the IAF protocol showed LPED of 14.70% at K equal to 1, 13.40% at K equal to 3 and 13.30% at K equal to 5, as shown in Figure 12. However, using 14 dB SNR, the performance is further increased with LPED of 40.10% at K equal to 1, 45.60% at K equal to 3 and 47% at K equal to 5, as compared to the protocol in[15]. The LPED values indicated that the IAF protocol outperformed both at severe and low fading conditions. However, the IAF protocol marginally performed over the protocol in[15], with the change of low to medium SNR values.

## 6. Conclusions and Future Work

The IAF protocol is proposed in this work. It is shown that IAF demonstrated reduction in BER and rise in BER-Gain, over the protocols proposed in[12] (two time period protocol) and[15] (three time period protocol). The IAF protocol demonstrated improved GPED and LPED, both at severe as well as low fading conditions, as compared to previous proposed TDMA based protocols in[12,15].

In this work, the cooperative network with two relays is used as a system model. Nevertheless, the performance of the IAF protocol could be tested by taking multiple relays. Also the delays and throughputs at receiver could be demonstrated, to study the correctness of IAF protocol further.

## 7. Acknowledgement

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