2. Sum Rate Performance for Full-Duplex User in Co-operative NOMA Systems over Weibull Fading Channel

Rampravesh Kumar, Department of ECE, Birla Institute of Technology, Ranchi-835215, India
rampraveshkumar6@gmail.com
Sanjay Kumar, Department of ECE, Birla Institute of Technology, Ranchi-835215, India
skumar@bitmesra.ac.in

ABSTRACT

This work evaluates the sum rate performance for dual user with full duplex co-operative nonorthogonal multiple access (FD-CNOMA) over Weibull fading channel environment. For this, we derived closed form expressions for sum-rate in various scenario. One user always acts as decode and forward full duplex relay to help far users in each scenario. In the first scenario, no direct link exist between base station (BS) and far user. In second scenario, direct link exist between BS and far user. The main investigation is to study the effect of fading parameters in different channel condition on sumrate performance. Since, Weibull Distribution (WD) has an advantage to model different fading condition using varying parameter it is more suitable to study impact of fading condition on different wireless techniques for next generation mobile cellular communication. Therefore, WD is used in this study for sum rate performance evaluation . Finally simulations were conducted on MATLAB to evaluate the system performance under different fading parameters of Weibull fading channels.

Index Term- *NOMA; FD-NOMA; Weibull Distribution; Sum Rate Performance; DL*

INTRODUCTION

A lot of attention has been paid to achieve higher spectral efficiency of the fifth generation (5G) mobile communication network, NOMA [1] is one of them. NOMA's key features are to allow multiple users to share the same resource elements (i.e., time / fequency / code) across different power lev-els. The successive nterference cancellation (SIC) is done on the receiver side. In [2], the effect of user pairing with the NOMA system's fixed power allocation was analyzed in depth.

However, in deep fade case, cooperative communication is a powerful technique to either expand network coverage or improve the reliability of communication [3]. Recent contributions to NOMA research in the field of cooperative communication discussed in [4–8] are as follows.

In [4], the authors explored the probability of decoding-and-forward (DF) relaying for NOMA. In [5] Nakagami-m fading channels addressed the outage performance of a variable gain amplify-andforward (AF) relaying with NOMA. In addition, a cooperative NOMA definition was first suggested in [6], where near-users with better channel conditions were considered to be DF relaying to support the far-off users. As a further advancement with consideration of energy-related issues, simultaneous wireless information and power transfer (SWIPT) was used by close NOMA users, which was considered to be DF relays in [7]. While cooperative NOMA can improve performance gains for weaker users (not necessarily far-off users), it does bring additional slot costs to the systems. To avoid this problem, the implementation of full-duplex (FD) relay technology is a promising solution. FD relaying receives and transmits simultaneously in the same frequency band and time slot stimulated researchers ' interest in exploring more effective spectral systems [8]. FD relay technology has recently been suggested as a promising technique for 5G networks in [9]. The authors tested the efficiency of the cooperative NOMA based on FD device-to-device in [10]. Nonetheless, only the weaker user's outage performance was analyzed.

In [11], cooperative NOMA with FD relay has been used for finding the outage performance in closed form expressions, assuming Rayleigh fading channels. Note that the Rayleigh distribution is widely used to model the fading due to multi-paths in an urban environment, where radio waves are received via large number of paths. Therefore, the central limit theorem (CLT) is used to derive the Rayleigh model theoretically. Nevertheless, if the number of incoming radio paths is small, the Rayleigh distribution may not be a suitable fading model as the CLT's validity conditions may not hold. Some evidence suggests that Weibull distribution may explain the signal amplitude in this situation. Experimental evidence is published in [12] supporting the appropriateness of the Weibull model and [13] considered its use as a basis for indoor fading channels. The distribution of Weibull is useful for modeling the amplitude of multipath fading signals. Based on fading channel data from [14], in some cases the Weibull distribution can be used to model well outdoor multi-paths.

The Weibull distribution's probability density function (PDF) [17] is given as in equation *1,* where, B is called the Weibull fading parameter and A is a positive scaling parameter. The Weibull fading parameter B can take values between 0 and ∞. In the special case when B = 1, the Weibull distribution becomes an exponential distribution; when B = 2, the Weibull distribution specializes to a Rayleigh distribution.

$$f_x(x) = \mathrm{B}x^{B-1}e^{(-x^B/_A)}/\,\mathrm{A} \qquad \ldots\ldots.(1)$$

These all, inspires us to work on for the evaluation of various performance parameters for the next generation mobile cellular system in wireless environment. Sum rate performance, one of those parameters under NOMA with FD Relay over Weibull fading channels has been analysed in this paper. Sum-rate is the sum of individual user rate.

This paper is organized as follows. Section II presents the proposed system model with related works done so far of our interest. This section highlights the processes involved at the transmitting and receiving ends in the FD-CNOMA System. Section III derives the generalized expressions for sum rate performance under the defined system model in various scenario where as section IV describes the simulation parameters taken according to formulated sum rate expressions on MATLAB over Weibull fading channel conditions. Section V interprets the obtained simulation results and finally, section VI concludes the sum rate performance of FD-CNOMA over conventional NOMA.in various scenario.

THE SYSTEM MODEL

Under this section, the system model in downlink (DL) channel with dual users in single cell along with relevant equations for different scenarios are discussed.

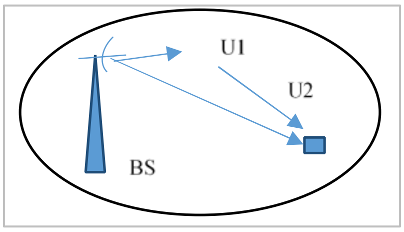

Figure 2-1 Single cell two users FD-CNOMA in DL channel

We consider a FD cooperative NOMA system composed of one source (i.e. the base station (BS)) that intends to communication with the far user U2 under the assistance of the near user U1. Both no direct link and direct link scenarios between the BS and U2 are considered. U1 is regarded as user relaying and DF protocol is employed to decode and forward the information to U2 .

To enable FD communication, U1 is equipped with one transmit antenna and one receive antenna, while the BS and U2 are single-antenna device. All wireless links in the network are assumed to be independent non-selective block Weibull fading and are disturbed by additive white Gaussian noise with mean power . h , h , and h are denoted as the complex channel coefficient of BS →U1, U1 → U2, and BS →U2 links, respectively. The channel power gains $|h_1|^2$, $|h_2|^2$ and $|h_0|^2$ are subjected to Weibull random variables (RVs) with the parameter B_i, A_i, $i \in \{1, 2, 3, 4\}$, respectively. The residual loop self-interference (LI) is modelled as a Weibull fading feedback channel with coefficient h , B and A is the corresponding fading parameters.

According to [15], U1 receives the superposed signal and loop interference signal simultaneously. The observation at U1 can be given by

$$y_{U1} = \mathrm{h}_1\left(\sqrt{a_1 P_s} x_1 + \sqrt{a_2 P_s} x_2\right) + \mathrm{h}_{LI}\left(\sqrt{\overline{w} P_r} x_{L1}\right) + N_0 \qquad \text{…….(2)}$$

where $\overline{w}$ is the switching operation factor between HD mode and FD mode. In this work, $\overline{w}$=1. P_s and P_r are the normalized transmission powers at the BS and U1 respectively; a_1 and a_2 are the power allocation coefficient and x_1 and x_2 are the signal of U1 and U2, respectively; denotes loop interference signal. Without loss of generality, we assume that $a_2 > a_1$ with $a_1 + a_2 = 1$.

Applying NOMA principle, successive interference cancellation (SIC) [16] is employed at U1. Therefore, the received signal to interference and noise ratio (SINR) at U1 to detect the U2's message x_2 is given by

$$\gamma_{U1+U2} = \frac{|h_1|^2 a_2 \rho_s}{|h_1|^2 a_1 \rho_s + \overline{w}|h_{LI}|^2 \rho_s + 1} \qquad \text{..(3)}$$

where $\rho_s = P_s / N_0$ is transmit signal to noise ratio (SNR). Note that x_1 and x_2 are supposed to be normalized unity power signals, i.e. $\mathrm{E}\{{x_1}^2\} = \mathrm{E}\{{x_2}^2\}$. Where E { ▪ } denotes expectation operation. After SIC, the received SNR at U1 to detect its own message x1 is given by

$$\gamma_{U2} = \frac{|h_1|^2 a_1 \rho_s}{\overline{w}|h_{LI}|^2 \rho_s + 1} \qquad \text{…..(4)}$$

In the FD mode, the received signal at U2 can be written as;

$$y_{U2} = \mathrm{h}_0\left(\sqrt{a_1 P_s} x_1 + \sqrt{a_2 P_s} x_2\right) + \mathrm{h}_{LI}\left(\sqrt{P_r} x_2 \right) + N_0 \qquad \text{……(5)}$$

However, the observation at U2 for the direct link can be written as;

$$y_{U2Direct} = \mathrm{h}_0\left(\sqrt{a_1 P_s} x_1 + \sqrt{a_2 P_s} x_2\right) + N_0 \qquad \text{……(6)}$$

The received SINR at U2 to detect is given by

$$\gamma_{U2} = |h_2|^2 \rho_s \qquad \text{…..(7)}$$

As in [17, 18], the relaying link from U1 to U2 corresponding to the direct link from BS to U2 has small time delay for any transmitted signals. Therefore, we assume that the signals from the relaying link and direct link can be combined by maximal ratio combining (MRC) at U2. The received SINR after MRC at U2 can be given by

$$\gamma_{U2DR} = \frac{|h_0|^2 a_2 \rho_s}{|h_0|^2 a_1 \rho_s + 1} + |h_2|^2 \rho_s \qquad \text{…..(8)}$$

SUM RATE PERFORMANCE EXPRESSIONS

In this work, generalized sum-rate performance expressions for two users in NOMA and FD-NOMA have been derived using the above set of equations.

A. USER RELAYING IN NON-DIRECT LINK

$$sumrate = \log_2(1 + \gamma_{U1}) + \log_2(1 + \gamma_{U2}) = \log_2\left(1 + \frac{|h_1|^2 a_1 \rho_s}{\overline{w}|h_{LI}|^2 \rho_s + 1}\right) + \log_2(1 + |h_2|^2 \rho_s) \quad (9)$$

B. USER RELAYING IN DIRECT LINK

$$sumrate = \log_2(1+\gamma_{U1}) + \log_2(1+\gamma_{U2DR}) = \log_2\left(1+\frac{|h_1|^2 a_1 \rho_s}{\overline{w}|h_{LI}|^2\rho_s+1}\right) + \log_2(1+\frac{|h_0|^2 a_2 \rho_s}{|h_0|^2\rho_s+1} + |h_2|^2\rho_s) \quad (10)$$

C. USER WITHOUT RELAYING (NOMA)

SINR at U1, U2 can be written as

$$\gamma_{U1N} = |h_1|^2 a_1 \rho_s \qquad \text{.....(11)}$$

$$\gamma_{U2N} = \frac{|h_0|^2 a_2 \rho_s}{|h_0|^2 a_1 \rho_s+1} \qquad \text{.....(12)}$$

$$sumrate = \log_2(1+\gamma_{U1N}) + \log_2(1+\gamma_{U2N}) \quad (13)$$

SIMULATION SETUP

This study compares the sum-rate performance of NOMA and co-operative NOMA for direct and nondirect relay scenario for different channel fading condition derived from Weibull distribution. Initially, experiments were carried on to study Weibull distribution curve for different scaling and shape parameter A and B respectively.

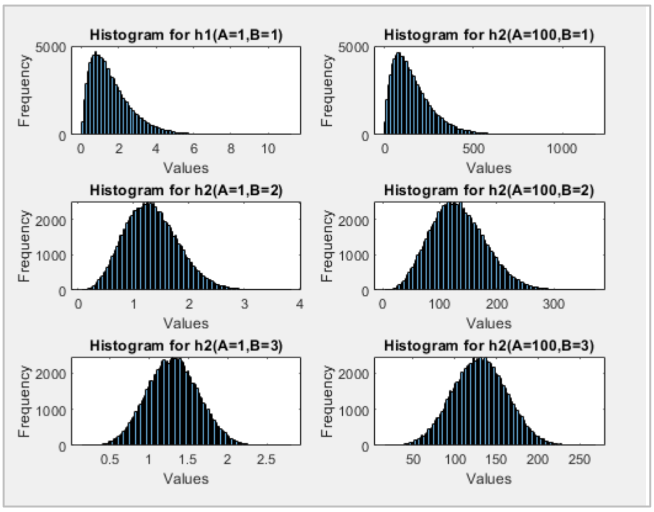

Figure 2-2 Histogram plot (Weibull distribution) for different A and B

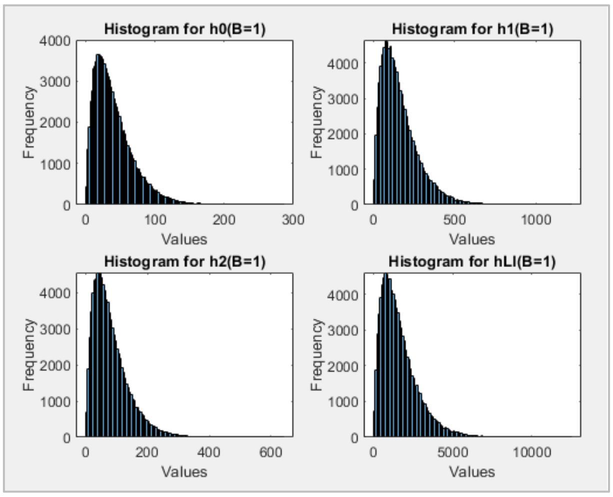

Figure 2-3 Histogram plot for different channel condition

Fig. 2-2 plots histogram for random variable x generated for different values of A and B. As clearly evident from the Fig.2-2, as value of A is increased from 1 to 100 keeping B constant, the magnitude of the data points increases by 100 times. Simultaneously, when value of B is changed from 1 to 3, shape changes from Exponential to Gaussian.

To simulate the experiment, four channels with different strength in every fading scenario have been simulated The order of strength for the four channel conditions are: $|h| < |h| < |h| < |h|$. Fig.2-3 plots the histogram for random vector generated for different channel condition satisfying the above stated strength condition. Power allocation factor a_1 and a_2 is selected to be of values 0.1 and 0.9 respectively. SNR is varied from -20db to 20db.

SIMULATION RESULTS & INTERPRETATION

Under this section sum rate performance for various conditions are discussed. Initially, sum rate performance for different values of B are observed individually for both NOMA and Full Duplex relay Co-operative NOMA (FD-CNOMA). Further sumrate comparative performance is observed.

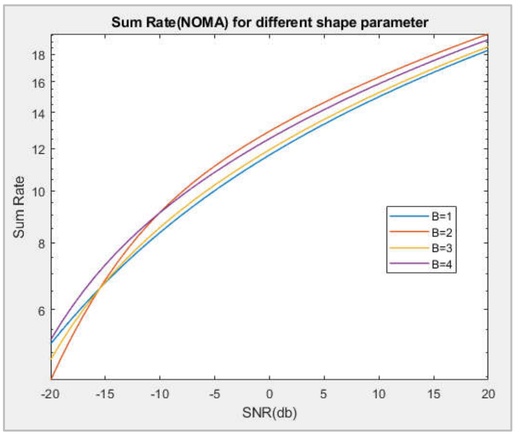

Figure 2-4 Sum Rate for NOMA

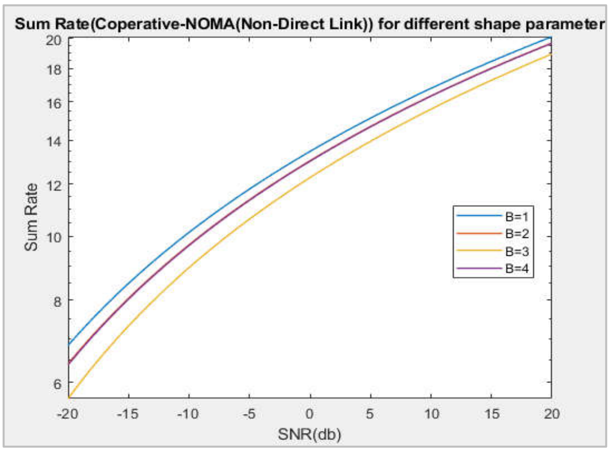

Figure 2-5 Sum Rate for Co-operative-NOMA (Non-Direct)

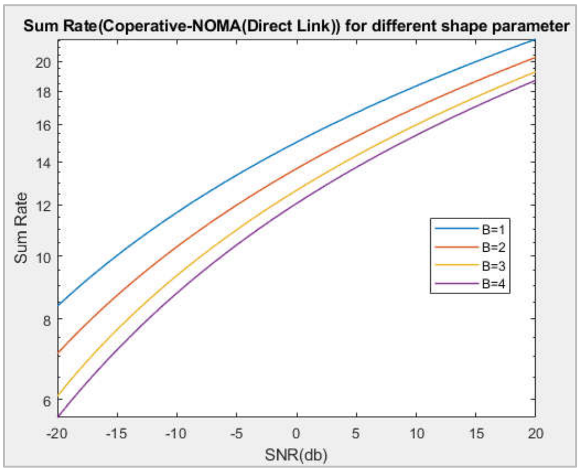

Figure 2-6 Sum Rate for Co-operative-NOMA (Direct)

Fig. 2-4, 2-5 and 2-6 plots the experimental results of sumrate obtained on varying SNR from -20db to +20db for different shape parameter for NOMA, C- NOMA (Non-Direct Link) and FD-CNOMA (Direct Link). In Fig. 2-4, the sum-rate performance for B=2 is comparatively superior to others. However, for noisy data (i.e. SNR < -10 dB), sum rate performance of B=4 is found to be best. However, for FD-CNOMA, the sum-rate performance for B=1 is comparatively superior to others for all SNR condition for both direct and non-direct relay.

The next study is to observe the comparative variation in sum-rate performance for NOMA and FD-CNOMA with changing SNR for different values of B.

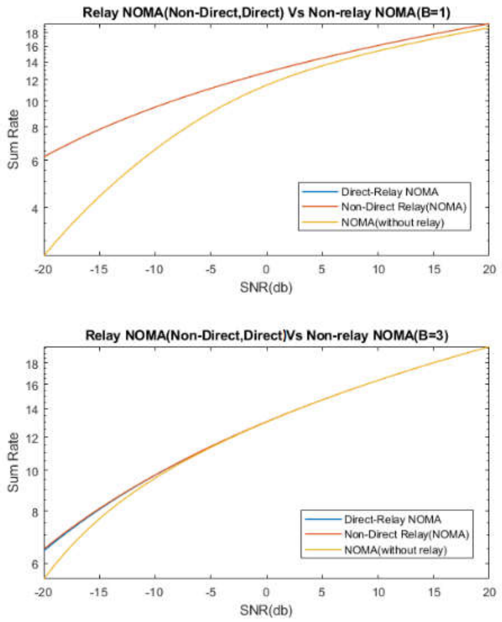

Figure 2-7 Sum Rate for B=1, B=3

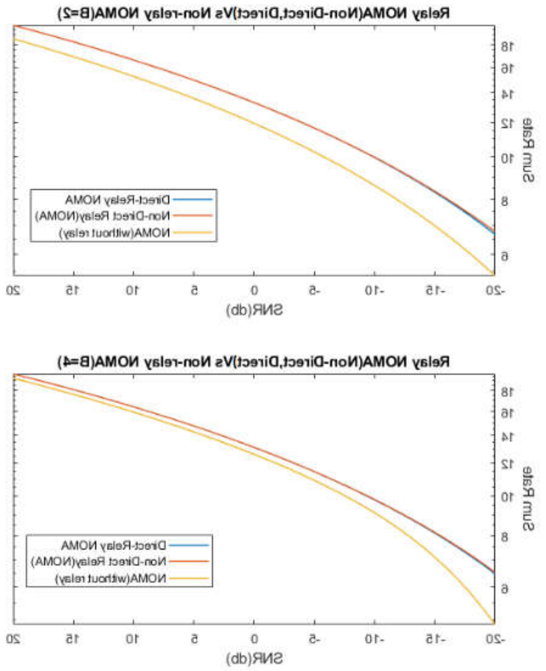

Figure 2-8 Sum Rate for B=2, B=4

Fig. 2-7 and 2-8 plots the results for the same for nondirect and direct FD-CNOMA. From both Fig. 2-7 and 2-8, it is observed that the sum-rate performance of both direct and non-direct relay FD-CNOMA is identical for different values of B for higher SNR. As SNR is decreased to -20db, performance of nondirect relay FD-CNOMA is slightly better than direct relay FD-CNOMA. Moreover, sum-rate performance of both direct and non-direct relay NOMA is superior to conventional NOMA for all values of B. However, for higher SNR, the sum-rate performance values for both NOMAs converges for all values of B.

CONCLUSION

This paper has investigated Weibull fading channel condition for varying scaling and shaping parameter for NOMA and FD-CNOMA. It is observed that the sum-rate performance of FD-CNOMA is superior to NOMA for all fading conditions obtained by varying B. For NOMA, best sum-rate performance is observed for B=2 for higher SNR. However, the performance for same degrades for lower SNR. In comparison of direct and non-direct relaying, best sum-rate performance is observed for B=1. In terms of magnitude of sum-rate performance at -20db, best performance of 8.25 bps/Hz is observed for direct relaying, followed by 6.5 bps/Hz for non-direct relaying for FD-CNOMA and 5.75 bps/Hz for conventional NOMA.

ACKNOWLEDGEMENT

We thank Dr.S.S.Sahu, Prof. Sanjeet kumar & Prof. Janardan Sahay, from ECE Department, BIT Mesra, for providing valuable suggestions and resources as well as UGC-NET JRF for providing the fellowship.

REFERENCES

[1] Z. Ding, Y. Liu, J. Choi, Q. Sun, M. Elkashlan, C. L. I, and H. V. Poor,“ Application of non-Orthogonal multiple access in LTE and 5G networks,” IEEE Commun. Mag., vol. 55, no. 2, pp. 185– 191, Feb. 2017.

[2] Z. Ding, P. Fan, and H. V. Poor, “Impact of user pairing on 5G non-orthogonal multiple access downlink transmissions,” IEEE Trans. Veh Technol., vol. 65, no. 8, pp. 6010–6023, Aug. 2016.

[3] F. Gao, T. Cui, and A. Nallanathan, “On channel estimation and optimal training design for amplify and forward relay networks,” IEEE Trans. Wireless Commun., vol. 7, no. 5, pp. 1907–1916, May 2008.

[4] J. B. Kim and I. H. Lee, “Non-orthogonal multiple access in coordinated direct and relay transmission,” IEEE Commun. Lett., vol. 19, no. 11, pp. 2037–2040, 2015.

[5] J. Men, J. Ge, and C. Zhang, “Performance analysis of nonorthogonal multiple access for relaying networks over nakagami-m fading channels,” IEEE Trans. Veh. Technol., vol. PP, no. 99, pp. 1–1, 2016.

[6] Z. Ding, M. Peng, and V. Poor, H, “Cooperative nonorthogonal multiple access in 5G systems,” IEEE Commun. Lett., vol. 19, no. 8, pp. 1462–1465, 2014.

[7] Y. Liu, Z. Ding, M. Elkashlan, and H. V. Poor, “Cooperative nonorthogonal multiple access with simultaneous wireless information and power transfer,” IEEE J. Sel. Areas Commun., vol. 34, no. 4, pp. 938–953, April 2016.

[8] H. Ju, E. Oh, and D. Hong, “Improving efficiency of resource usage in two-hop full duplex relay systems based on resource sharing and interference cancellation,” IEEE Trans. Wireless Commun., vol. 8, no. 8,pp. 3933–3938, August 2009.

[9] J. Men and J. Ge, “Full deplex techniques for 5G networks: self-interference cancellation, protocol design, and relay selection,” IEEE Commun. Mag., vol. 53, no. 5, pp. 128–137, 2015.

[10] Z. Zhang, Z. Ma, M. Xiao, Z. Ding, and P. Fan, “Full-duplex device-to-device aided cooperative non-orthogonal multiple access,” IEEE Trans. Veh. Technol., vol. PP, no. 99, pp. 1–1, 2016.

[11] Yue, Xinwei, Yuanwei Liu, Shaoli Kang, Arumugam Nallanathan, and Zhiguo Ding. "Outage performance of full/halfduplex user relaying in NOMA systems." In 2017 IEEE International Conference on Communications (ICC), pp. 1-6. IEEE, 2017.

[12] N. H. Shepherd, “Radio wave loss deviation and shadow loss at 900 MHz,” IEEE Trans. Veh. Technol., vol. 26, pp. 309–313, Nov.1977.

[13] H. Hashemi, “The indoor radio propagation channel,” Proceedings of the IEEE, vol. 81, pp. 943–968, July 1993.

[14] G. Tzeremes and C. G. Christodoulou, “Use of Weibull distribution for describing outdoor multipath fading,” Antennas and Propagation Society International Symposium, vol. 1, pp. 232–235, 2002.

[15] T. M. Cover and J. A. Thomas, Elements of information theory, 6th ed., Wiley and Sons, New York, 1991.

[16] T. Riihonen, S. Werner, and R. Wichman, “Hybrid fullduplex/half-duplex relaying with transmit power adaptation,” IEEE Trans. Wireless Commun., vol. 10, no. 9, pp. 3074–3085, September 2011.

[17] D. P. M. Osorio, E. E. B. Olivo, H. Alves, J. C. S. S. Filho, and M. Latva-aho, “Exploiting the direct link in full-duplex amplify-and forward relaying networks,” IEEE Signal Process. Lett., vol. 22, no. 10, pp. 1766–1770, Oct 2015.

[18] I. S. Gradshteyn and I. M. Ryzhik, Table of Integrals, Series and Products, 6th ed. New York, NY, USA: Academic Press, 2000.