Back Propagation Artificial Neural Network for Improving the Performance of STBC-based OFDM with Subcarrier Power Modulation

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ABSTRACT

Orthogonal Frequency Division Multiplexing with Subcarrier-Power Modulation (OFDM-SPM) has recently been proposed as a promising, potential transmission technique for future wireless communications (i.e., 6G and beyond) due to its multiple beneficial characteristics, including higher spectral efficiency, low latency with good reliability while maintaining low complexity. In this paper, Orthogonal Frequency Division Multiplexing with Subcarrier-Power Modulation and Space-Time Block Coding (OFDM-SPM-STBC) technique is compounded with Back Propagation Artificial Neural Network (BPANN) in a multiple-input-single-output (MISO) setup to study, investigate and quantify the wireless system's performance of their combination over a multi-path Rayleigh fading channel. Particularly, we analyze two main performance metrics: bit-error-rate (BER) and throughput of the newly designed technique called OFDM-SPM-STBC-BPANN, and then quantify the amount of resulting gains in both BER and throughput due to using the proposed system. We also consider two scenarios for OFDM-SPM-STBC-BPANN transmission. The first one is the power re-assignment policy (PRP), and the second one is the power saving policy (PSP). It is found that the sub-carrier optimized power-reassignment scheme provides the best BER performance for the proposed transmission scheme. In contrast, the PSP for SPM is seen to provide an intermediate improvement in the average BER. The performance of the system in terms of BER and Throughput is improved furthermore by implementing Feed-Forward Back-Propagation Artificial Neural Network (BPANN) at the receiver side. It is observed an average SNR gain of about 7 dB in the BER by implementing BPANN with OFDM-SPM-STBC. It is also found that the optimized power-reassignment scheme provides the best BER performance for the proposed OFDM-SPM-STBC transmission scheme with BPANN at the receiver.

INDEX TERMS: Alamouti STBC, BER, OFDM, OFDM-SPM, Throughput, Subcarrier Power Modulation, Back Propagation, Neural Network.

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References

- [1] C. Chung, "Spectral precoding for constant-envelope OFDM", IEEE Transaction on Communications, Vol. 58, No. 6, pp. 555 – 567, Feb. 2010, doi: 10.1109/TCOMM.2010.02.080682.
- [2] J.M.Hamamreh, and A.Hajar, "The Generalization of Orthogonal Frequency Division Multiplexing with Subcarrier Power Modulation to Quadrature Signal Constellations", RS Open Journal on Innovative Communication Technologies, 2020, <https://doi.org/10.21428/03d8ffbd.4948e89e>.
- [3] S. M. Alamouti, "A simple transmit diversity technique for wireless communications," in IEEE Journal on Selected Areas in Communications, vol. 16, no. 8, pp. 1451-1458, Oct. 1998, doi: 10.1109/49.730453
- [4] J. M. Hamamreh, A. Hajar, and M. Abewa, "Orthogonal Frequency Division Multiplexing With Subcarrier Power Modulation for Dou-bling the Spectral Efficiency of 6G and Beyond Networks." in Transactions on Emerging Telecommunications Technologies, 2020. doi:<https://doi.org/10.1002/ett.3921>.
- [5] M. Abewa and J. M. Hamamreh, "Non-coherent OFDM-Subcarrier Power Modulation for Low Complexity and High Throughput IoT Applications, "RS Open Journal on Innovative Communication Technologies, vol. 1, no.1, July 2020.
- [6] Y. Belallou, J. M. Hamamreh and A. Hajar, "OFDM-Subcarrier Power Modulation with two dimensional Signal Constellations," 2019 Innovations in Intelligent Systems and Applications Conference (ASYU), Izmir, Turkey, 2019, pp. 1-6.
- [7] A. Hajar, J. M. Hamamreh, M. Abewa and Y. Belallou, "A Spectrally Efficient OFDM-Based Modulation Scheme for Future Wireless Systems,"2019 Scientific Meeting on

Electrical-Electronics and Biomedical Engineering and Computer Science (EBBT), Istanbul, Turkey, 2019, pp. 1-4, doi: 10.1109/EBBT.2019.8742049.

[8] A. A. Kamil and M A Hadi, "STBC-OFDM System under Rayleigh Fading Channel with Known and Unknown CSI at the Transmitter", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 7, No. 5, pp. 5377-5384, 2018, doi:10.15680/IJIRSET.2018.0705113.

[9] J. Yang and K. Cheun, "Low complexity implementation of Alamouti space-time coded OFDM transmitters," in IEEE Communications Letters, vol. 8, no. 4, pp. 229-231, April 2004, doi:10.1109/LCOMM.2004.827443

[10] F. A. P. de Figueiredo, N. F. T. Aniceto, J. Seki, I. Moerman and G. Fraidenraich, "Comparing f-OFDM and OFDM Performance for MIMO Systems Considering a 5G Scenario," 2019 IEEE 2nd 5G World Forum (5GWF), Dresden, Germany, 2019, pp. 532-535, doi:10.1109/5GWF.2019.8911702

[11] Y. J. Moon et al., "OFDM-based 25Gbps Wireless Backhaul System for 5G Convergence Service," 2020 International Conference on Information Networking (ICOIN), Barcelona, Spain, 2020, pp. 814-817, doi:10.1109/ICOIN48656.2020.9016621.

[12] S. J. Saikia, K. K. Sarma, "ANN based STBC-MIMO set-up for Wireless Communication", International Journal of Smart Sensor and Ad-hoc Net-work, Vol. 1, No. 4, April 2012, pp. 289-292.

[13] C. H. Cheng, Y. P. Cheng, W. C. Li and Y. H. Huang, "Using Back Propagation Neural Network for Channel Estimation and Compensation in OFDM Systems," 2013 Seventh International Conference on Complex, Intelligent, and Software Intensive Systems, Taichung, Taiwan, 2013, pp.340-345.

[14] N. Taşpınar and M. N. Seyman, "Back propagation neural net-work approach for channel estimation in OFDM system," 2010 IEEE International Conference on Wireless Communications, Networking and Information Security, Beijing, China, 2010, pp. 265-268, doi:10.1109/WCINS.2010.5541934.

[15] K. Hiray and K. V. Babu, "A neural network-based channel estimation scheme for OFDM system," 2016 International Conference on Communication and Signal Processing (ICCSP), Melmaruvathur, India, 2016, pp.0438-0441, doi: 10.1109/ICCSP.2016.7754174.

- [16] M. Zhang, M. Fan and M. Chen, "Joint Estimation and Detection for MIMO-STBC System Based on Deep Neural Network," 2019 2nd IEEE Middle East and North Africa Communications Conference (MENA-COMM), Manama, Bahrain, 2019, pp. 1-5.
- [17] H. Wang and J. Li, "An intelligent receiver for space time block coded OFDM system," 2016 First IEEE International Conference on Computer Communication and the Internet (ICCCI), Wuhan, China, 2016, pp. 535-538, doi: 10.1109/CCCI.2016.7778981.
- [18] A. Sarwar, S. M. Shah and I. Zafar, "Channel Estimation in Space Time Block Coded MIMO-OFDM System using Genetically Evolved Artificial Neural Network," 2020 17th International Bhurban Conference on Applied Sciences and Technology (IBCAST), Islamabad, Pakistan, 2020, pp. 703-709.
- [19] E. Chen, R. Tao and X. Zhao, "Channel Equalization for OFDM System Based on the BP Neural Network," 2006 8th international Conference on Signal Processing, Guilin, China, 2006, pp. 1-4, doi:10.1109/ICOSP.2006.345910.
- [20] F. Bouguerra and L. Saidi, "Simplified ANN for 256 QAM Symbol Equalization Over OFDM Rayleigh Channel," 2018 International Conference on Smart Communications in Network Technologies (SaCoNeT), El Oued, 2018, pp. 19-24, doi: 10.1109/SaCoNeT.2018.8585641.
- [21] M. Mathew, A. Francis, K. Vijayakumar and G. V. Titus, "Semi blindneural network based channel estimation technique for OFDM receivers," 2013 Annual International Conference on Emerging Research Areas and 2013 International Conference on Microelectronics, Communications and Renewable Energy, Kanjirapally, India, 2013, pp. 1-5, doi:10.1109/AICERA-ICMiCR.2013.6576037.
- [22] L. S. Chen, W. H. Chung, I. Y. Chen and S. Y. Kuo, "AMC with a BP-ANN Scheme for 5G Enhanced Mobile Broadband," in IEEE Access, 2021, doi:10.1109/ACCESS.2020.3024726.
- [23] W. Jiang and H. D. Schotten, "Neural Network-Based Fading Channel Prediction: A Comprehensive Overview," in IEEE Access, vol. 7, pp.118112-118124, 2019, doi: 10.1109/ACCESS.2019.2937588.
- [24] P. Pathak, R. Pandey, "A Novel Alamouti STBC Technique for MIMO System Using 16-QAM Modulation and Moving Average Filter", Int. Journal of Engineering Research and Applications, Vol. 4, No. 8, August 2014, pp.49-55.

- [25] P. Zetterberg, M. L. Nordenvaad and B. Nilsson, "Synchronization of OFDM with null subcarriers in channels with significant ICI," OCEANS 2017 - Aberdeen, Aberdeen, 2017, pp. 1-5, doi:10.1109/OCEANSE.2017.8084727.
- [26] J. M. Hamamreh, E. Basar, and H. Arslan, "OFDM-subcarrier index selection for enhancing security and reliability of 5G URLLC services," IEEE Access, vol. 5, pp. 25 863-25 875, 2017.
- [27] Fiorina, Jocelyn. (2012). A New Family of Low-Complexity Decodable STBCs for 4 Transmit Antennas. IEEE Transactions on Wireless Communications. 12. 10.1109/TWC.2013.011513.120517.
- [28] Y. Belallou, J. M. Hamamreh and A. Hajar, "OFDM-Subcarrier Power Modulation with two-dimensional signal constellations," 2019 Innovations in Intelligent Systems and Applications Conference (ASYU), Izmir, Turkey, 2019, pp. 1-6, doi: 10.1109/ASYU48272.2019.8946346
- [29] R. Abu-alhiga and H. Haas, "Subcarrier-index modulation OFDM," in 2009 IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, Sep. 2009, pp. 177-181.
- [30] Abewa, M., Hamamreh, J. M. (2021). NC-OFDM-SPM: A Two-Dimensional Non-Coherent Modulation Scheme for Achieving the Coherent Performance of OFDM along with Sending an Additional Data-stream. RS Open Journal on Innovative Communication Technologies, 2(3). <https://doi.org/10.46470/03d8ffbd.a97a5236>.
- [31] Hajar, A., Hamamreh, J. M. (2020). The Generalization of Orthogonal Frequency Division Multiplexing With Subcarrier Power Modulation to Quadrature Signal Constellations. RS Open Journal on Innovative Communication Technologies, 1(1). <https://doi.org/10.21428/03d8ffbd.4948e89e>.
- [32] M. F. Zia and J. M. Hamamreh, "An Advanced NOMA Security Technique for Future Wireless Communication," Workshop on Information and Communications Technologies, International Conference on Software, Telecommunications and Computer Networks (SoftCOM), Sep. (2020), pp. 38-43.
- [33] Lemayian, J. P., Hamamreh, J. M. (2020). A Novel Small-Scale Nonorthogonal Communication Technique Using Auxiliary Signal Superposition with Enhanced Security for Future Wireless Networks. RS Open Journal on Innovative Communication Technologies, 1(2). <https://doi.org/10.46470/03d8ffbd.86b0d106>.

[34] Hamamreh, J. M., Abewa, M., Lemayian, J. P. (2020). New Non-Orthogonal Transmission Schemes for Achieving Highly Efficient, Reliable, and Secure Multi-User Communications. RS Open Journal on Innovative Communication Technologies, 1(2). <https://doi.org/10.46470/03d8ffbd.324cc0fb>