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Adaptive Digital Corrector for Dual-Band Data Transmission System under Quadrature Distortions

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Abstract—The digital compensation process for nonlinearly inertial characteristic of the transmit path of dual-band communication system with concurrent data transmission in the presence of unbalance of modulator quadratures has been considered. Analytical relationships enabling us to identify adaptively or change the parameters of dual-band polynomial model of corrector with due regard for the modulator quadrature distortions caused by the LMS, RLS and conjugate gradient algorithms are derived. A model of corrector based on the neural network representing a multilayer perceptron was built for the system. Experimental comparative analysis of the linearization efficiency of link with 25 W power amplifier using correctors with polynomial and neural network architecture is carried out. A comparative analysis of convergence speed, computational complexity and the linearization efficiency of adaptive algorithms (LMS, RLS and conjugate gradient algorithm) based on the polynomial architecture has been performed. The signals using 16QAM modulation with bandwidth of 4 MHz and frequency tune-out of 16 MHz are used as test signals. The results of experimental analysis show the highest computational efficiency without any loss of linearization quality of polynomial compensator that is identified by the conjugate gradient algorithm.

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INTRODUCTION

Higher data transmission rates in conditions of limited frequency resources are achieved nowadays at the expense of employing an advanced and economically viable solution implying the use of multi-standard and multi-band systems of wireless communication. In case of concurrent data transmission, the hardware communication facilities are used effectively, since only one transmitter is employed simultaneously for several independent receivers, and the compatibility of systems employing different standards is ensured. In transmitting circuits of such systems, the signals at different closely spaced carrier frequencies are combined and amplified by one wideband power amplifier.

As is known, any radio link that operates in the power-efficient regime introduces different nonlinearly dynamic distortions into the transmitted signal. The digital predistortion method [1] is now in wide use for ensuring the linearization of transmitter. For the dual-band system under consideration, it has specific features. For compensating distortions occurring in transmission link, it makes sense to consider closely spaced signals at different carriers as one wideband signal. However, in such case the correct linearization requires such sampling frequency of ADC and DAC that enables us to cover 5–7 bands of the resultant wideband signal. As a rule, this makes the specified approach unrealizable in practice. Therefore, such systems involve the need of implementing digital predistortions separately in each channel.

In the case of dual-band data transmission, the nonlinearity of power amplifier leads to additional distortions of radiated signal due to the emergence of products of cross modulation between the frequency components of signals of different bands. Therefore, the traditional methods of digital predistortions based on inertial models, for example, on the Volterra model or polynomial model [2, 3] are unable to compensate completely distortions in such systems. In this case, the nonlinear transfer characteristic of amplifier must be a two-dimensional function of signals of both bands [4, 5].

Besides the signal distortions introduced by power amplifier, the transmission link in each channel can contain an analog quadrature modulator, imperfections of which lead to the quadrature unbalance and shift of heterodyne. The methods of linearization of power amplifier and quadrature modulator are proposed in

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

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REFERENCES

1. Q. Lu and C. Yu, "In-Band Digital Predistortion for Concurrent Dual-Broadband Phased Array Transmitters," *IEEE Microw. Wirel. Components Lett.* **29**, No. 4, 294 (Apr. 2019). DOI: 10.1109/LMWC.2019.2902725.
2. L. I. Averina, V. D. Shutov, R. A. Rybalkin, "Structureless modeling of power amplifiers accounting for inertial properties," *Radioelectron. Commun. Syst.* **56**, No. 1, 42 (2013). DOI: 10.3103/S0735272713010056.
3. L. I. Averina and S. S. Lavlinskii, "Two-block model of a digital corrector for linearization of an analog radio channel," *J. Commun. Technol. Electron.* **62**, No. 7, 794 (Jul. 2017). DOI: 10.1134/S1064226917070014.
4. C. Yu, C. Fan, X. Meng, J. Li, F. Liu, Y. Li, "A square-root-based memory polynomial model for concurrent dual-band digital predistortion," *IEEE Microw. Wirel. Components Lett.* **29**, No. 2, 152 (Feb. 2019). DOI: 10.1109/LMWC.2018.2886634.
5. S. A. Bassam, M. H. Helaoui, and F. M. Ghannouchi, "2-D digital predistortion (2-D-DPD) architecture for concurrent dual-band transmitters," *IEEE Trans. Microw. Theory Tech.* **59**, No. 10 PART 1, 2547 (2011). DOI: 10.1109/TMTT.2011.2163802.
6. S. Lajnef, N. Boulejfen, A. Abdelhafiz, and F. M. Ghannouchi, "Two-dimensional cartesian memory polynomial model for nonlinearity and I/Q imperfection compensation in concurrent dual-band transmitters," *IEEE Trans. Circuits Syst. II Express Briefs* **63**, No. 1, 14 (Jan. 2016). DOI: 10.1109/TCSII.2015.2482678.
7. L. Li, F. Liu, G. Yang, and H. Wang, "A pruning method of joint 2D digital predistortion model for nonlinearity and I/Q imperfections in concurrent dual-band transmitters," in *Proc. of 2014 IEEE/ACIS 13th Int. Conf. on Computer and Information Science*, ICIS 2014 (2014), pp. 71–74. DOI: 10.1109/ICIS.2014.6912110.
8. V. I. Djigan, *Adaptive Filtering of Signals: Theory and Algorithms* [in Russian] (Tekhnosfera, Moscow, 2013).
9. D. G. Luenberger and Y. Ye, *Linear and Nonlinear Programming*, 3rd ed. (Springer, 2008). DOI: 10.1007/978-0-387-74503-9.
10. L. I. Averina and O. V. Bugrov, "Digital predistorters based on neural networks for linearization of power amplifiers," *Vestnik VGU. Ser. Fizika, Matematika*, No. 1, 5 (2017). URI: https://elibrary.ru/item.asp?id=28989670.