

Doherty PA Linearization by Injection of the 2nd order Digitally Processed Signals for 5G FBMC modulation

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Abstract – In this paper, the analysis of the linearization effects of the 2nd order digitally processed signal for the linearization that modulates the 2nd harmonic of the fundamental carrier has been performed on the Doherty power amplifier for FBMC 5G modulation form. In the first method, linearization signals are injected at the input and output of the main Doherty amplifier, whereas in the second method, they are inserted at the outputs of the Doherty main and auxiliary amplifiers.

Keywords – 5G, FBMC, Doherty power amplifier, baseband signal, second harmonic, linearization.

I. INTRODUCTION

Fifth generation (5G) mobile communication systems represent one of the most important segments of the overall digital transformation of society based on the concept of Industry 4.0. The importance of 5G systems for the global development of the economy and society has been widely recognized, so that the coordinated introduction of 5G mobile networks in many countries has become part of the strategy of complete social and economic development. New technologies such as artificial intelligence (AI) and machine learning, cloud computing, augmented and virtual reality (AR / VR), IoE (Internet of Everything) and IoT (Internet of Things) and billions of connected devices are pushing boundaries and setting new demands on connectivity and mobile communication network performance. 5G mobile networks are expected to provide ultra-fast connectivity with low latency, not only to individual users, but also to a large number of connected facilities, as well as to create an ambient for expansion of technological and business innovations in different industrial sectors (agriculture, energy, trade, health, education, public safety, tourism, media, etc.). The frequency bands provided for 5G systems can be divided into three groups: High band (frequencies from 24 GHz to 60 GHz and above), mid band (which can be divided into two parts, from 1 GHz to 2.6 GHz and from 3.5 GHz to 6 GHz), and low band (below 1 GHz). Each of these bands has comparable advantages and disadvantages. The 5G systems operating in the low band will provide large cells but with a slight improvement in performance compared to 4G systems. In the high band range, all the advantages of the 5G systems in terms of performance compared to 4G systems will be expressed, with transfer speeds from 1 to 3 Gbps and even higher. The

disadvantage of high band is shown in the fact that due to the large attenuation of the signal as a result of millimeter wave propagation and potential interference from various obstacles (such as vegetation and buildings) it is necessary to provide very small cells. Mid band spectrum is considered ideal for 5G because it can carry plenty of data while also traveling significant distances.

The most important limitations that existed in previous generations of communication systems with OFDM modulation schemes are loss of spectral efficiency due to the use of cyclic prefix (CP) and needs for fine time and frequency synchronization to ensure the orthogonality of the carriers. To overcome these limitations, several alternative modulation schemes for 5G systems, known as 5G candidates, have been introduced over the past few years, such as filter bank multicarrier (FBMC), universal filtered multi carrier (UFMC), generalized frequency division multiplexing (GFDM) and filtered orthogonal frequency division multiplexing (FOFDM).

The results of Doherty power amplifier (DPA) linearization in simulation by applying a method that uses second-order digital signals processed in the baseband are presented in this paper. After adjusting for the amplitude and phase in the baseband, the second order digital signals modulate the second harmonic of the fundamental carrier and then are injected into the gate and drain (input and output) of the PA transistor [1]. The results obtained by applying this linearization method in simulation or experiments have already been published in [2-4] for single-stage PA and two-way DPA, which operate at a frequency of about 1 GHz and tested for QAM and OFDM modulation schemes. In this paper, we analyzed the behavior of the DPA when source signal is 5G FBMC signal.

The paper is organized in the following manner: after introduction, the second section is devoted to the 5G FBMC signal, and the results of the linearization are illustrated in the third section. Conclusion and list of used literature are given at the end of paper.

II. 5G FBMC SIGNAL

FBMC is a type of multi carrier modulation scheme based on OFDM. It represents an improvement of OFDM with the aim of eliminating certain shortcomings at the cost of increasing the complexity of signal processing. It consists of a set of data that are broadcast through a bank of modulation filters that filter each subcarrier. The prototype of the used filter can be chosen in a suitable way, so that there is very little leakage into the adjacent channels. FBMC has significantly better utilization of channel capacity and can offer higher data throughput in a given bandwidth, which

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means it provides better spectral efficiency. Also, the FBMC has eliminated one of the main disadvantages of OFDM, which is the use of the cyclic prefix (CP) [5]. The cyclic prefix is essentially a copy of part of a transmitted symbol in OFDM that is appended at the beginning of the next symbol. This leads to a reduction in signal speed as well as unnecessary loss of transmitted power.

create the appropriate FBMC signal. This software was chosen because it provides a simple interface in which parameters related to the FBMC signal can be easily adjusted, and the impact of changing the appropriate parameters on the FBMC signal itself can be monitored, either in time or in the spectral domain. Figure 1 shows the interface for creating FBMC signals in the SystemVue environment, as well as a set of parameters that control the signal characteristics and signal appearance in the frequency domain.

III. RESULTS

Symmetrical two-way DPA that operates at 5G mid band was designed according to the instructions given in [6]. The DPA was designed by using CGH40010F GAN HEMT transistor. The drain voltage is 28 V, whereas the gate voltage of the main and auxiliary amplifier is -2.8 V, and -5.7 V, respectively. Main characteristics of DPA in simulation at 3.5 GHz are: 12.6 dB gain and 1-dB compression point at 31 dBm output power.

The designed DPA was linearized in ADS simulation using two linearization methods: 1) the first - standard method that leads linearization signals at the gate and drain of the transistor in the main cell of the DPA and 2) the second - modified method, where the linearization signals are put at the drain of the main and auxiliary amplifier transistors in the DPA [7]. The signal used for testing DPA was 5G FBMC signal at carrier frequency 3.5 GHz with useful signal frequency bandwidth of 50 MHz and two output power levels: around 30 dBm (1 dB below 1-dB compression point) and near 24 dBm (roughly 7 dB below 1-dB compression point).

The Figs. 2 and 3 show the output spectrum before and after application of the proposed linearization technique. Summarized results for ACP (Adjacent Channel Power) at ± 50 MHz offset over 5 MHz band are presented in Tables I and II. We can observe for 24 dBm output power, that the ACP is improved about 15 dB for both linearization methods, whereas for 30 dBm output power they become better by 5 dB for the 1st method and almost 8 dB for the 2nd method. A slight asymmetry can be noted in results for linearization between lower and upper adjacent channel.

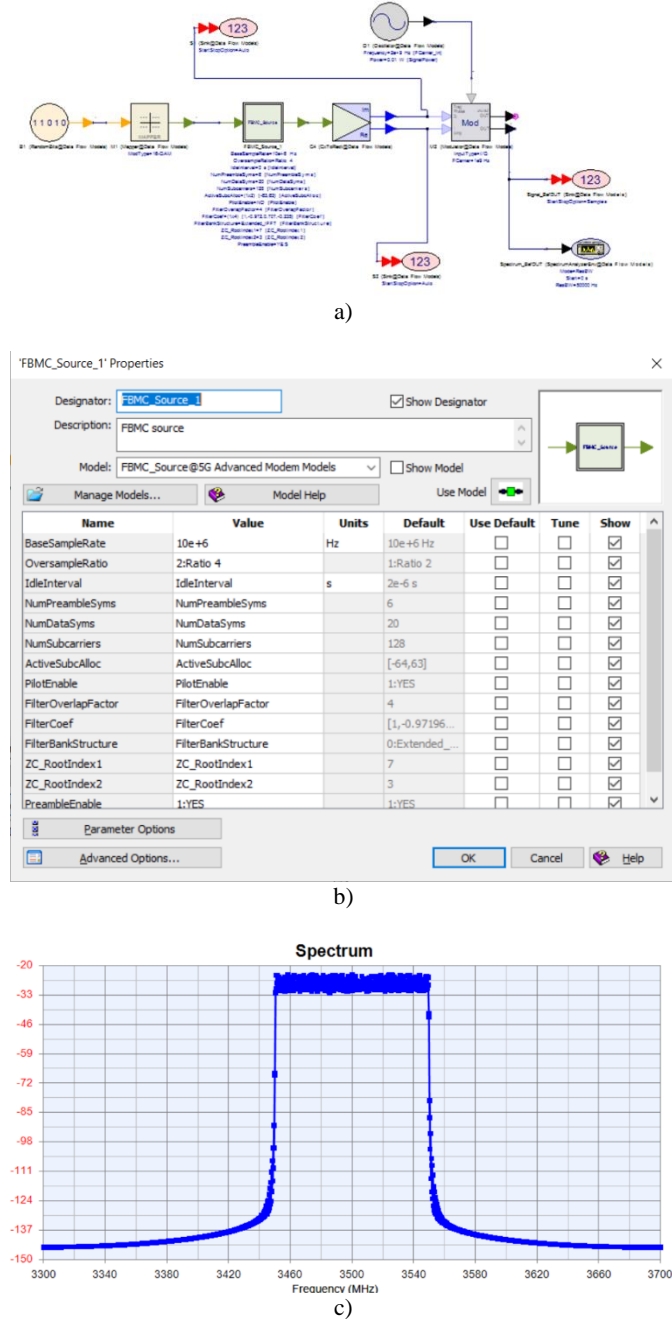


Fig 1. FBMC signal generation in Keysight SystemVue: a) FBMC transmitter; b) FBMC signal parameters; c) FBMC signal spectrum

FBMC signals for simulation purposes can be created using various software packages (Matlab, Keysight SystemVue, ...) or using general purpose programming languages (Python, C/C++, ...). In this paper, we used Keysight SystemVue to

TABLE I

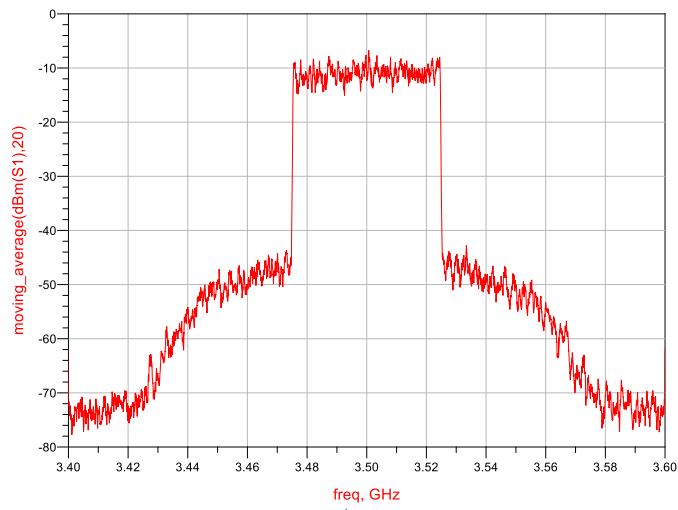
RESULTS OF LINEARIZATION FOR 24 DBM OUTPUT POWER

	Pout [dB]	ACP lower [dB]	ACP upper [dB]
Before lin.	24.1	-25.6	-26.5
Lin. by method 1	24.5	-41.0	-38.8
Lin. by method 2	24.4	-40.9	-39.1

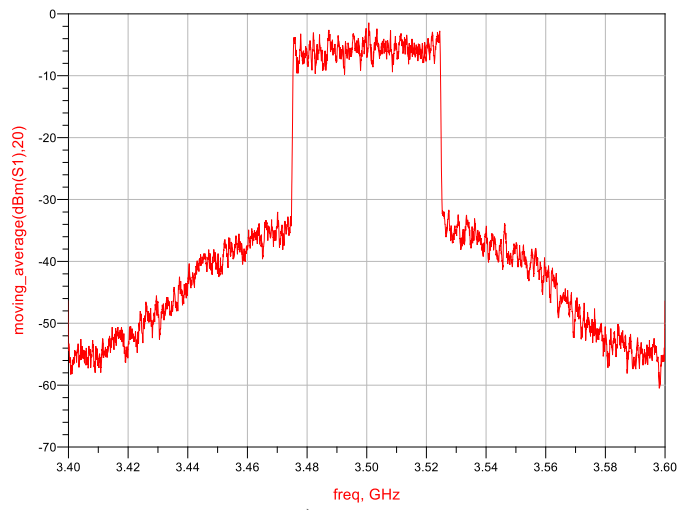
TABLE II

RESULTS OF LINEARIZATION FOR 30 DBM OUTPUT POWER

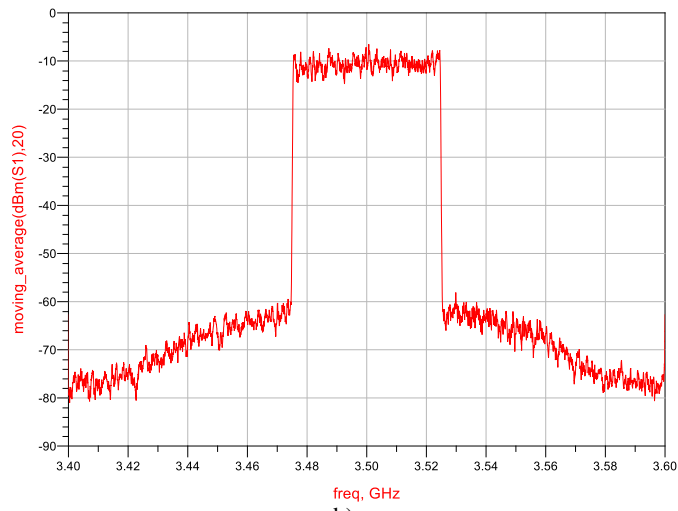
	Pout [dB]	ACP lower [dB]	ACP upper [dB]
Before lin.	29.4	-14.6	-14.5
Lin. by method 1	30.1	-19.2	-18.8
Lin. by method 2	30.2	-22.2	-20.7



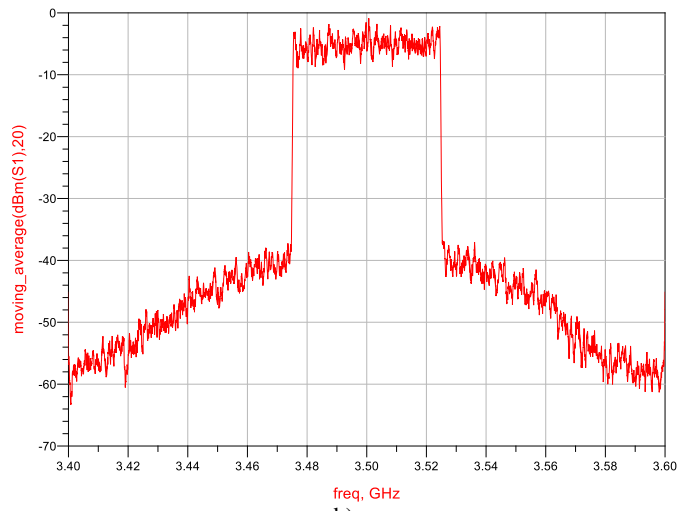
a)



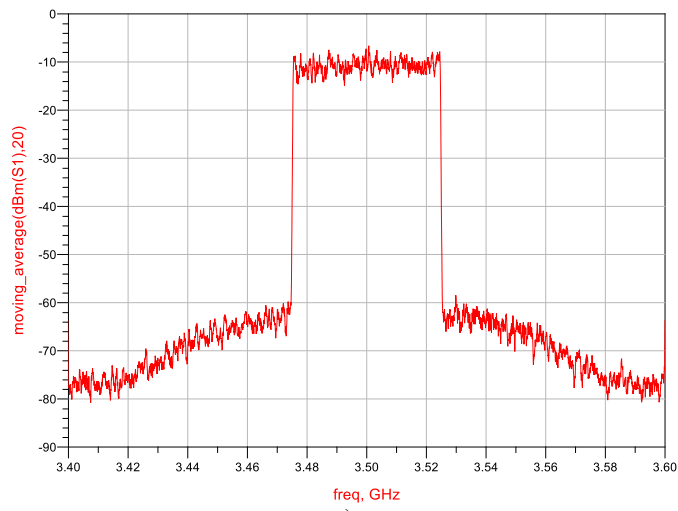
a)



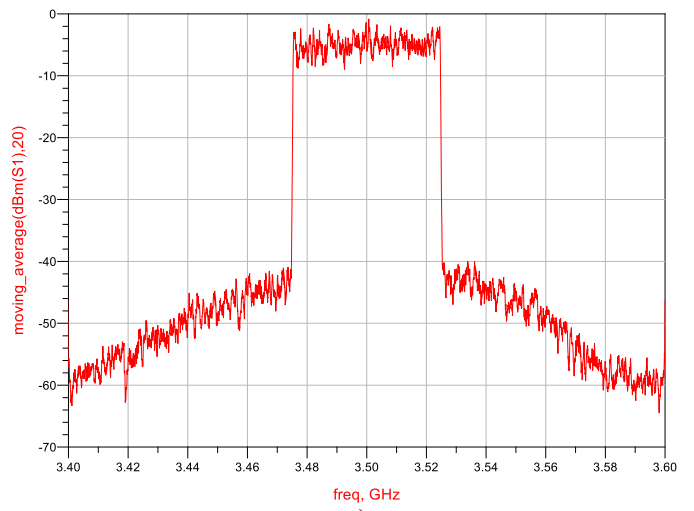
b)



b)



c)



c)

Fig. 2. Output spectrum for FBMC signal of 50 MHz useful signal frequency bandwidth for output signal power 24 dBm: a) before linearization; b) after linearization by method 1; c) after linearization by method 2

Fig. 3. Output spectrum for FBMC signal of 50 MHz useful signal frequency bandwidth for output signal power 30 dBm: a) before linearization; b) after linearization by method 1; c) after linearization by method 2

IV. CONCLUSION

We analyzed the effect of the linearization technique that uses baseband signals of the 2nd order nonlinearity adequately shaped and processed in magnitude and phase in baseband and then modulate the 2nd harmonic of the fundamental useful signal carrier. The linearization signals formed in this way are then inserted at the input and output of the main amplifier of DPA (linearization method 1) as well as at the output of the main and auxiliary amplifier of DPA (linearization method 2). The linearization was performed for the 5G FBMC signal.

It can be concluded that very acceptable improvement in adjacent channels power was achieved by applying the proposed linearization technique. On the bases of the obtained results, it can be noticed that the 2nd method provides slightly better results for higher power than the application of the 1st method.

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