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Atanasković, Aleksandar, Ilić, Nataša Maleš, Stošić, Biljana P., Đorić, Aleksandra and Budimir, Djuradj

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Doherty Amplifier Linearity Test for Fifth Generation Signals

Aleksandar Atanasković
Faculty of Electronic Engineering
University of Niš
Niš, Serbia
aleksandar.atanaskovic@elfak.ni.ac.rs

Nataša Maleš Ilić
Faculty of Electronic Engineering
University of Niš
Niš, Serbia
natasa.males.ilic@elfak.ni.ac.rs

Biljana P. Stošić
Faculty of Electronic Engineering
University of Niš
Niš, Serbia
biljana.stosic@elfak.ni.ac.rs

Aleksandra Đorić
Faculty of Electronic Engineering
University of Niš
Niš, Serbia
aleksandra.djoric@elfak.ni.ac.rs

Djuradj Budimir
Wireless Commun. Research Group
University of Westminster
London, UK
d.budimir@wmin.ac.uk

***Abstract*—In this paper, the linearity of a fabricated microstrip Doherty amplifier in asymmetrical topology (ADA) is experimentally tested for the fifth generation signals. The measurement set-up contains a Matlab programming platform, a signal generator, and a vector signal analyzer. The Matlab development platform and the signal generator are used for the generation of the 5G FBMC, UFMC, and FOFDM signals. The 5G signal spectra are measured by the vector signal analyzer at the input and output of the Doherty amplifier. The output spectra of the 5G signals for different input power levels gained in measurements are compared to the simulated results.**

Keywords—*Doherty amplifier, fifth generation signals, baseband signal, FBMC modulation, UFMC modulation, FOFDM modulation, experimental test*

I. Introduction

The rapid development of the fifth generation (5G) mobile communication systems imposes the utilization of new modulation formats, such as FBMC (Filter Bank Multi-Carrier), UFMC (Universal Filtered Multi-Carrier) and FOFDM (Filtered Orthogonal Frequency Division Multiplexing), which can satisfy the required 5G system characteristics such as high efficiency, high data rate, linearity, reliability, low latency etc. [1], [2].

Doherty amplifier (DA) is a very suitable topology for 5G systems applications considering its linearity and high efficiency.

In this paper, we represent the simulated and measured output spectra of the microstrip asymmetrical Doherty amplifier (ADA) for the FBMC, FOFDM, and UFMC 5G modulations for various values of the input power (Pin). The obtained measurement results presented in the graphs show the output spectra of the mentioned modulation forms at the input and the output of the Doherty amplifier. The simulated results are extracted from the ADS (Keysight Advanced Design System) simulator and relate to the signals at the ADA output.

Anteriorly developed linearization technique (DEB_LIN technique) within our research group, was tested in the ADS for the single PA that operates at 3.5 GHz for the FBMC, FOFDM, and UFMC signals with 50 MHz useful signal bandwidth [3], [4] and for the symmetrical two-way DA that operates at 3.5 GHz for the LTE signals with useful signal frequency bandwidth of 20 MHz, as well as for the FBMC signal with 50 MHz bandwidth [5], [6].

The DEB_LIN technique was experimentally approved on the ADA for the 16QAM signal with 1 MHz useful signal frequency bandwidth and also for the 64QAM signal with 2 MHz useful signal frequency bandwidth [5], [7], [8]. This linearization technique uses adequately processed baseband signals that modulate the carrier second harmonic, and a detailed explanation of the technique operation can be found in the mentioned literature [3]-[8].

In future work, experimental validation of the DEB_LIN technique is planned for the FBMC, UFMC, and FOFDM signals on the ADA. The experiments will include linearization signals insertion to the input and/or output of the carrier cell in the ADA topology and the results will be obtained for diverse Pin.

II. Measurement Set-Up

Fig. 1 represents the measurement set-up formed to generate the FBMC, UFMC, and FOFDM signals and to capture their output spectra at the output of the ADA. Figure 1a) illustrates the block scheme of the used equipment during the measurements whereas the Fig. 1b) is the photo of a real laboratory setup for the 5G signals generation and analysis.

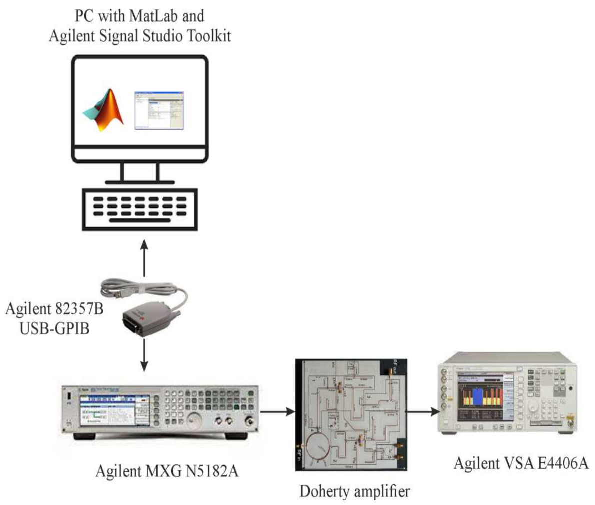
The measuring set-up consists of a signal generator (Agilent MXG N5182A) and a vector signal analyzer (Agilent VSA E4406A). The Matlab environment was used for the signal processing and preparation. The signal created in Matlab was downloaded to the signal generator via Agilent Signal Studio Toolkit utility software. The connection between the PC and the signal generator was established over the GPIB (General Purpose Interface Bus) interface. The RF output signal from the signal generator was fed to the input of the Doherty power amplifier, while the output of the ADA was measured and analyzed using the vector signal analyzer.

Fig. 2 depicts a layout of the microstrip ADA which operates at 900 MHz central frequency with 9 dB maximal transducer gain, 15 dBm output power at 1-dB compression point, and 18 dBm maximum output power [9]. The carrier and peaking PA in asymmetrical DA were designed based on AP602A-2 GaAs MESFET on Rogers 3010 substrate with

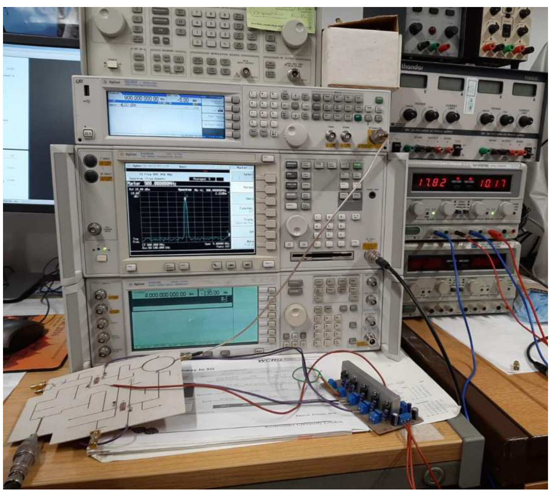
1.6 mm thickness and 17 μm metallization layer. The carrier amplifier operates in class AB and the peaking amplifier in class C. Table I represents the values of the components used for the fabrication of the ADA.

III. Results

The signals used for testing the ADA are the 5G FBMC, UFMC, and FOFDM signals at carrier frequency 900 MHz with a useful signal frequency bandwidth of 3.75 MHz. The output spectra of the 5G FBMC, UFMC, and FOFDM signals were measured by the vector signal analyzer and presented in Figs. 3 to 5. The simulation testing and measurements were performed for the three different 5G signal input power levels: -10 dBm, 0 dBm, and 10 dBm. The simulated results were gained in the ADS for the ADA circuit whose layout is shown in Fig. 2. The simulation was performed when the same 5G signals, as the ones used in the measurement set-up, were at the amplifier input. The first graphs on the left side demonstrate the spectra of the three mentioned types of signals measured at the input of the ADA, while the second and the third graphs represent the measured and simulated spectra at the output of the ADA, respectively.



a)



b)

Fig. 1. The measurement set-up: a) Block scheme, b) Photo.

We can observe from the figures that very similar results of the FBMC, UFMC, and FOFDM signals were obtained in the measurements as in the simulations for all considered Pin. The measured output spectra of the 5G signals at the output of the ADA detains the same spectrum shape as the simulated one for the in-band signal part, while out-of-band parts have a similar shape but slightly different values, which is more visible with the increased power.

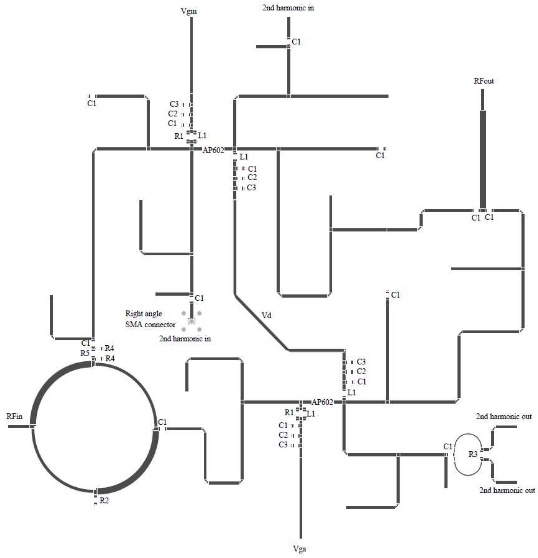


Fig. 2. Layout of the asymmetrical Doherty amplifier.

TABLE I. Lumped Elements and Components Value on the Layout Scheme

Component	Value	
C1	100 pF	0805 package
C2	100 nF	
C3	2.2 uF	
R1	620 Ω	
R2	50 Ω	
R3	100 Ω	
R4	430 Ω	
R5	12 Ω	
L1	27 nH	
IC1	AP602 FET	

IV. Conclusion

The linearity test was experimentally performed on a two-way microstrip Doherty amplifier with asymmetrical configuration when the source signals are the 5G FBMC, UFMC, and FOFDM modulation forms. The useful 5G signals were generated by the Matlab programming platform. The Agilent Signal Studio Toolkit utility software was exploited to download signals from Matlab to the signal generator Agilent MXG N5182A. The signal generator output signals were led to the input of the amplifier. The Agilent VSA E4406A vector signal analyzer was utilized for the measurement and analysis of the signals at the input and the output of the ADA. The acquired measurement results were compared with the simulated one from the ADS for the same conditions at the output of the ADA. The measured results show that all considered 5G signals retain the same spectrum shape and similar values as in the simulations.

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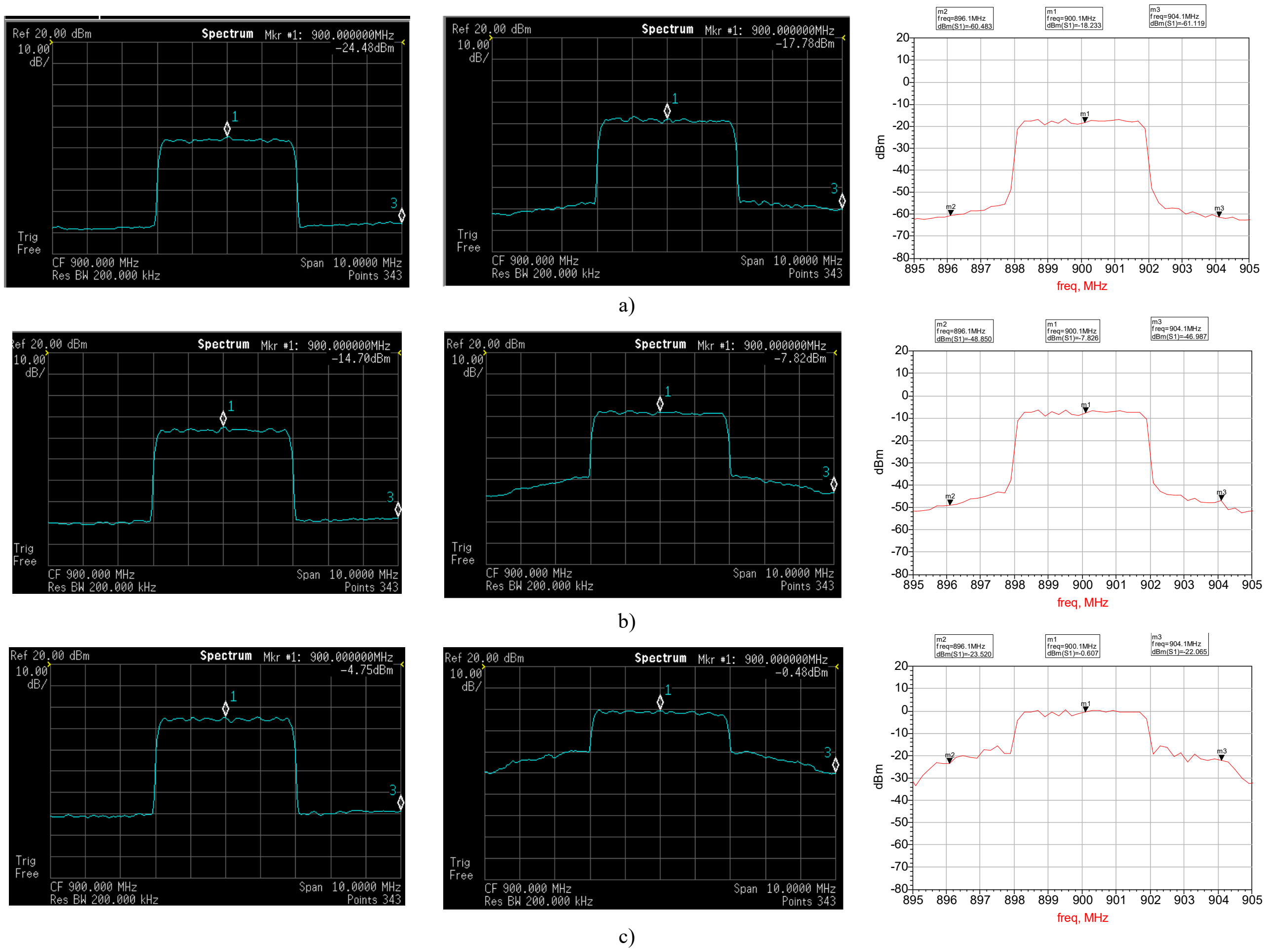
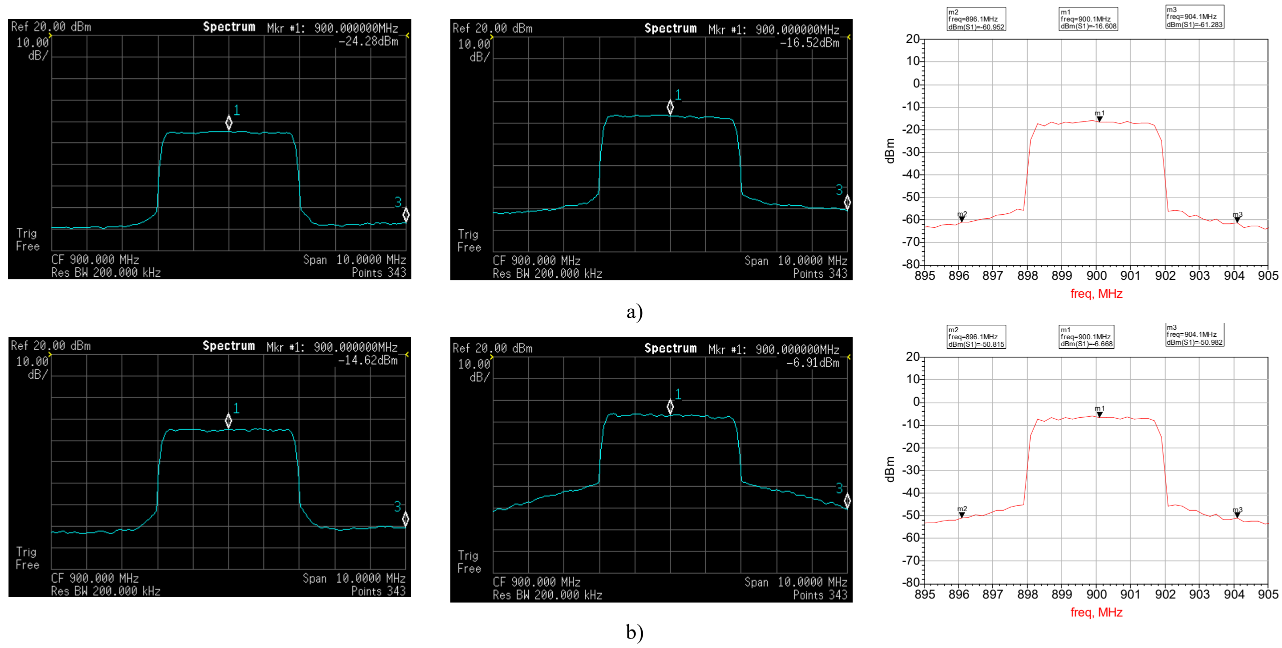
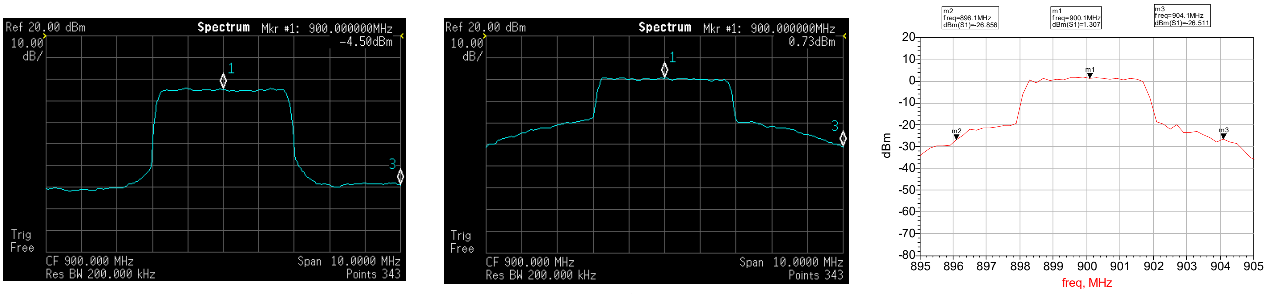


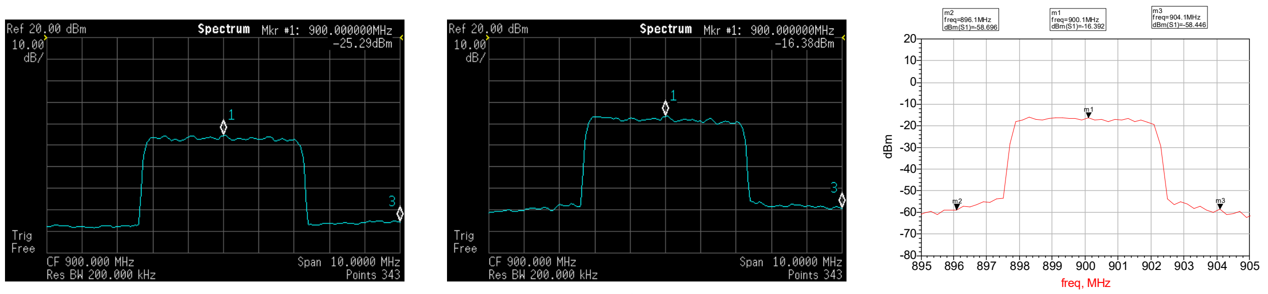
Fig. 3. FBMC signal spectra measured at the input and output of ADA (left and middle, respectively) and simulated at the output of ADA in ADS software (right) for input power: a) -10 dBm; b) 0 dBm; c) 10 dBm.



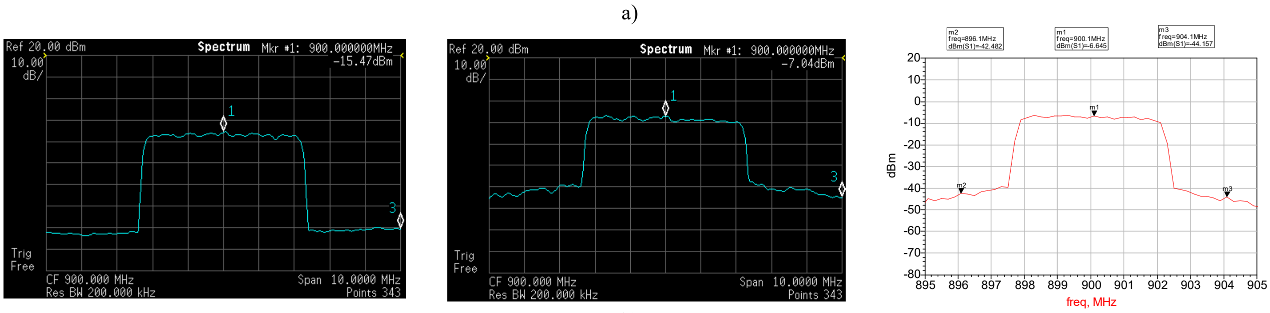


c)

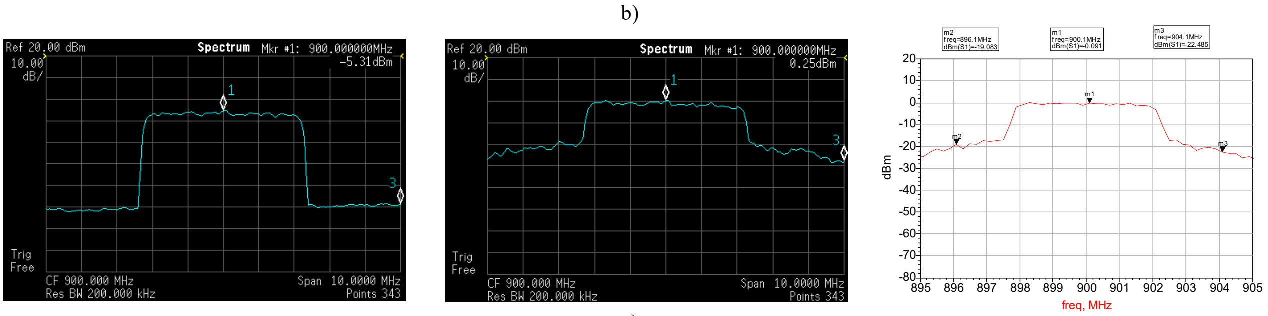
Fig. 4. UFMC signal spectra measured at the input and output of ADA (left and middle, respectively) and simulated at the output of ADA in ADS software (right) for input power: a) -10 dBm; b) 0 dBm; c) 10 dBm.



a)



b)



c)

Fig. 5. FOFDM signal spectra measured at the input and output of ADA (left and middle, respectively) and simulated at the output of ADA in ADS software (right) for input power: a) -10dBm; b) 0 dBm; c) 10 dBm.

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