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This is a copy of the author's accepted version of a paper subsequently published in the proceedings of the 12th Mediterranean Conference on Embedded Computing (MECO), Budva, Montenegro, 06 - 10 Jun 2023.

The final published version will be available online at:

https://doi.org/10.1109/meco58584.2023.10155074

Contribution to Evaluation of Nonlinear Distortion in 5G IoT Subsystems

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***Abstract*— An evaluation of nonlinear distortion in mmWave 5G IoT wireless transmitters is investigated in this paper. A Filter Bank Multi-Carrier (FBMC) waveform for mmWave 5G IoT wireless transmitters is used. Simulated output power spectra of the MMIC power amplifier (HMMC 5026) for 5G FBMC 5 MHz waveform and different input power levels such as -10 dBm, 0 dBm and 10 dBm are presented. Simulated output power spectra of the power amplifier for 5 MHz 5G FBMC signals at different input power levels are illustrated.**

Index Terms— 5G IoT, FBMC waveform; power spectra; MMIC power amplifiers.

I. Introduction

There has been a proliferation of wireless services and devices, followed by increasing demands for higher data rates in the past decade. Over a limited frequency spectrum more information needs to be transmitted. 5G is almost here, and like 3G, and 4G before it, it will change the way we send and receive information.

What's even more exciting is that 5G will enable countless automated wireless applications for the rapidly growing Internet of Things (IoT) market. It is predicted that global mobile data traffic is doubling every year and within the next ten years, trillions of devices will connect to mobile wireless networks [1]-[5]. They will cause a frequency spectrum shortage and generate a thousand-fold increase in total mobile traffic. By 2025, more than 75 billion devices will be connected to the Internet of Things, from disposable tracking devices used in shipping pharmaceuticals and perishables to smart city lighting and utilities. Alternative waveforms for various input power levels, channel bandwidths and new technologies in higher parts of the frequency spectrum are needed to enable low cost, better spectral efficiency and efficient mobile wireless data services.

Mobile wireless networks have occupied lower frequency bands, below 5 GHz, where carrier signals can pass easily around obstacles and through the air. But this sought-after frequency spectrum has already been heavily used, making it difficult for operators to acquire more of it. There a variety of physical layer enhancements have been proposed to increase the network capacity. However, since the current technologies have already approached the information theory capacity limits, there is growing interest in wireless transmission over mmWave 5G frequencies, above 24 GHz, as a potential solution to the frequency spectrum shortage. In particular, the mmWave above 24 GHz (FR2) 5G frequency bands (e.g. 5G TDD frequency range FR2: 24.25 – 52. 60 GHz: n257: 26.50 – 29.50 GHz; n258: 24.25 – 27.50 GHz; n260: 37.00 – 40.00 GHz; n261: 27.50 – 28.35 GHz; 40.5 - 42.5 GHz, 42.5 - 43.5 GHz, 43.5 - 47 GHz, 47 - 47.2 GHz, 47.2 - 50.2 GHz, 50.4 - 52.6 GHz, 66 -71 GHz, 71-75 GHz and 81-86 GHz), have been released by the International Telecommunication Union (ITU) to provide broadband wireless services.

There are several 5G waveform candidates such as Filter Bank multi-Carrier (FBMC) which implements subcarrier filtering to achieve better spectral efficiency and overcomes the strict synchronization specifications of OFDM, Universal Filter multi-Carrier (UFMC), Generalised Frequency Division Multiplexing GFDM, etc [2]-[4]. This paper represents evaluation of the nonlinear behaviour of a nonlinear power amplifier using 5G FBMC and UFMC signals. The two leading 5G waveform candidates were evaluated and compared for bandwidths up to 50 MHz at different input power levels. Experiments were also carried out to evaluate the spectral efficiency performance for the 5G waveform candidates (FBMC, UFMC) at different input power levels for different bandwidths.

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II. Filter Bank Multi-Carrier (FBMC)

Filter Bank Multi-Carrier (FBMC) transmits data by filtering each sub-carrier individually rather than the whole sub-band. The frequency domain localization and time domain localization are controlled by using prototype filters, which results in low side lobe levels in contrast to CP-OFDM. FBMC signal can achieve better spectral efficiency as it does not use cyclic prefix and respects Nyquist rate. In contrast to CP-OFDM, the low side-lobes, steep slope at the edges of the signal band and the use of larger number of subcarriers during transmission all help to improve spectral efficiency at the output of the wireless transmitter [6]. One major advantage of FBMC over other waveform candidates (such as CP-OFDM, GFDM and UFMC) is that it enables fundamental spectral efficiency at low signal processing complexity.

Better performance can be achieved comparable to CP-OFDM with the help of multiple prototype filters between spectrum confinement and orthogonality among adjacent sub-carriers [6]. This waveform provides better performance in frequency selective channel with long delay spread and low Out-of-Band emissions and it's a potential candidate for the 5G wireless transmitters and has the capability to maintain system performance over a wide bandwidth.

III. Results

In this section, FBMC waveform is evaluated at different saturation input levels of the nonlinear MMIC power amplifier (HMMC 5026) at 25 GHz shown in Fig. 1. with the following features:
Frequency range: 2 to 26.5 GHz

Gain (S21): 9.5 dB

Input reflection coefficient S11: 14 dB,

Output reflection coefficient S22: 13 dB

Power at 20 GHz:

P–1 dB : 18 dBm

Psat : 20 dBm

Power at 26.5 GHz:

P–1 dB : 15 dBm

Psat : 17 dBm

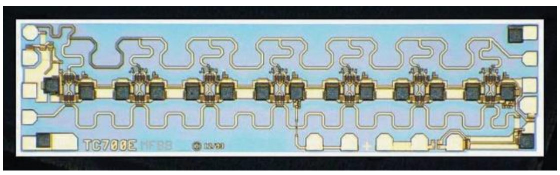

Fig. 1. Layout of MMIC power amplifier.

In Fig. 2 the simulated setup is shown. Simulated output power spectra of the mmWave 5G MMIC power amplifier (HMMC 5026) for FBMC waveform with 5 MHz channel bandwidth and input power levels of -10 dBm, 0 dBm, 10 dBm and 30 dBm are shown in Fig. 3, Fig. 4, Fig. 5 and Fig. 6, respectively. The simulated nonlinear distortion is about 40 dBc. A maximum of 20 MHz channel bandwidth can be supported by 4G LTE whilst mmWave 5G is expected to use a minimum cannel bandwidth of 400 MHz.

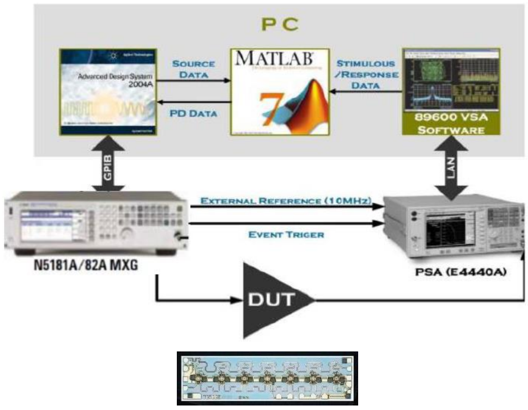

Fig. 2. Simulation setup

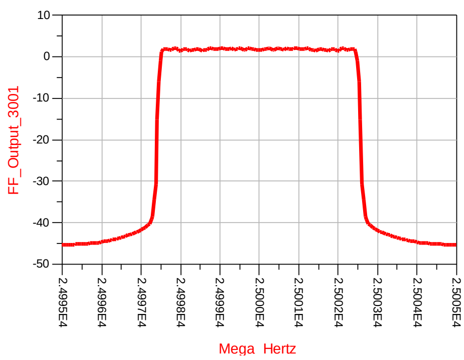

Fig. 3. Power spectra of the power amplifier for FBMC 5 MHz waveform and input power of -10 dBm.

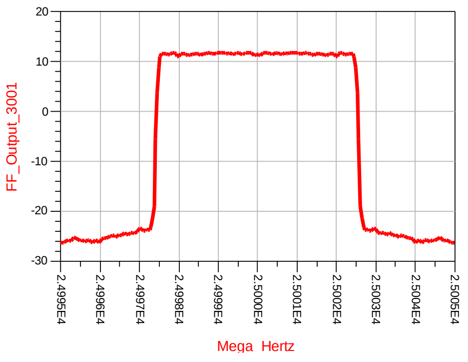

Fig. 4. Simulated output power spectrum of the PA for 5G FBMC 5 MHz waveform and input power of 0 dBm.

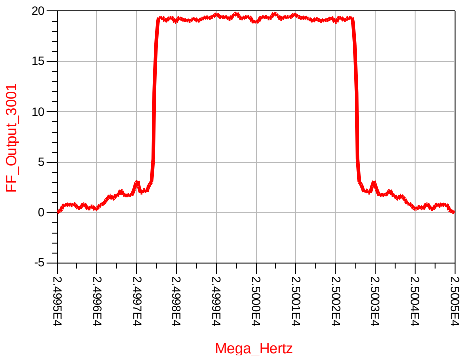

Fig. 5. Power spectra of the power amplifier for 5G FBMC 5 MHz waveform and input power of 10 dBm.

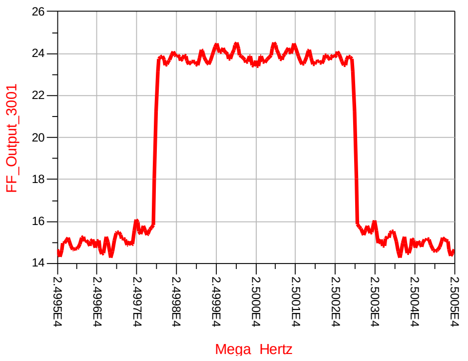

Fig. 6. Power spectra of the power amplifier for 5G FBMC 5 MHz waveform and input power of 30 dBm.

IV. Conclusion

Illustration of nonlinear distortion effects on 5G waveform ca ndidate in mmWave wireless transmitters for 5G Internet of Things applications has been described in this paper. 5G waveform candidate such as Filter Bank Multi-Carrier (FBMC) was evaluated at channel bandwidth of 5 MHz and different power levels for nonlinear distortions at the 25 GHz 5G frequency bands respectively. Simulated output power spectra of the mmWave power amplifier for 5 MHz FBMC waveforms and input power of -10 dBm, 0 dBm, 10 dBm and 30 dBm at 25 GH GHz have been presented. The nonlinear distortion of about 40 dBc has been achieved for 25 GHz case. A

Acknowledgment

This work was supported by UK India Education Research Initiative University Grants Commission under grant IND/CONT/G/16-17/63

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