Generalized Reconfigurable mm-Wave Tx Architecture and Antenna Interface with Active Impedance Synthesis

Chandrakanth R Chappidi , *Student Member, IEEE* and Kaushik Sengupta, *Senior Member, IEEE*

***Abstract*—With the expected proliferation of devices and technology in the mm-Wave frequency region (28-86 GHz), future mm-Wave wireless architectures need to move from custom-designed and fixed frequency operation to dynamically programmable and frequency-reconfigurable operation, with high spectral and energy efficiency, while simultaneously being operable in an electromagnetically changing environment with antenna load mismatches and process variations. This report presents a generalized multi-port network synthesis approach that enables programmable, frequency-agile, waveform-agile power amplifier (PA) / transmitter architectures in mm-Wave spectrum for high efficiency operation.**

***Index Terms*—Power Amplifier, 5G, Broadband, backoff, DAC**

I. Introduction

The growth of potential 5G communication in the 28-40GHz band, exploiting higher bandwidth, have propelled the application areas of integrated mm-Wave systems on chip. One of the most challenging blocks in the transmitter is the design of Power Amplifier (PA) with high-efficiency, high-power generation and high linearity in silicon. As can be understood, there is a trade-off between the amount of power-generation, efficiency and bandwidth of any PA. Typical broadband PA designs attempt to create the optimal loadpull impedances at the PA output *for peak power operation* across the spectrum through high-order complex matching networks which are typically very inefficient, particularly for high output power generation with low-Q passives (*frequency reconfigurability*). The efficiency further degrades when operated at other power levels. On the other hand, to enable high back-off efficiency *at a given frequency*, techniques such as Doherty attempts to create the optimal impedance conditions at peak and single or multiple back-off power levels *back-off reconfigurability*. Similar to the previous case, the efficiency deteriorates significantly at other frequencies and worse when the finite-Q passives are considered.

This research project stems from a broader objective of designing a single unified transmitter system which can be efficiently reconfigured to address vast applications over a larger mm-Wave spectrum across wider PBO range, breaking the aforementioned trade-offs.

II. Proposed Architecture

The proposed architecture is shown in Fig.1 which exploits the interaction of mm-Wave DAC cells in a multi-port combiner network switched asymmetrically to synthesize the optimal impedances through active impedance synthesis across the 2D space of reconfiguration: frequency and back-off [1],[2]. With all the DAC cells ON, the frequency reconfigurability could be achieved by adjusting the phases while

The authors are with the Department of Electrical Engineering, Princeton University, Princeton, NJ 08544. (chappidi@princeton.edu)

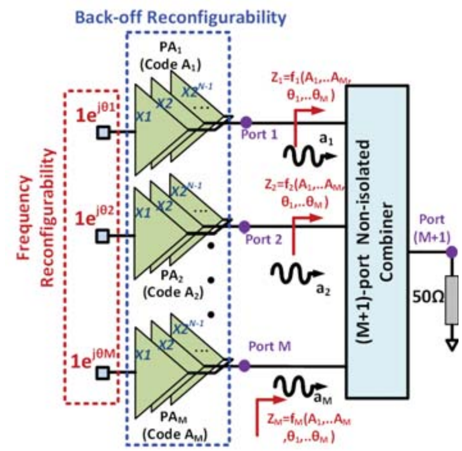

Fig. 1. Proposed Architecture: The impedances seen by PAs could be actively synthesized for optimal performance attaining dual frequency-PBO reconfigurability

the PBO reconfigurability could be attained by controlling the codes of individual DACs. For operating across different frequencies, different sets of optimum asymmetric switching codes can exist for the same PBO level. If this is guaranteed for all PBO levels at all frequencies, the PA efficiency remains constant. An example is shown in Fig.2 which presents a 2-way asymmetrical combiner following the simple 2^{nd} order Γ-conjugated topology with optimized parameter values [2]. As illustrated in the 3D plot of efficiency against the dual axes of frequency (30-80 GHz) and backoff (up to -10 dB PBO) in Fig.2(e), the combiner achieves nearly more than 90% efficiency with a static phase control in one branch with high efficiency upto 50% at 10 dB back-off across the entire range.

The frequency-dependent switching codes are illustrated in Fig.2(a)-(d). At the lower portion of the frequency range (40GHz), for efficiency enhancement at deep PBO levels, PA_1 shuts off completely and PA_2 acts like a main PA. However, at the higher frequency end (70GHz), the roles of these PAs switch and PA_1 now acts like a main PA for efficiency enhancement at deep PBO levels , while PA_2 shuts off. This role reversal maintains a PBO performance almost similar to Doherty across the extremely broad frequency range. Functionally, this emulates an array of mm-Wave switchable narrowband Doherty-like PAs across wide spectrum. In this topology, this functionality is achieved through a generalized treatment of mutual controlled interactions in an asymmetrical, compact and low-loss combiner to enable optimal operation across frequency and back-off simultaneously.

III. Measurement Results

The chips are designed in 130nm SiGe process. The measured performance for the first prototype chip designed for

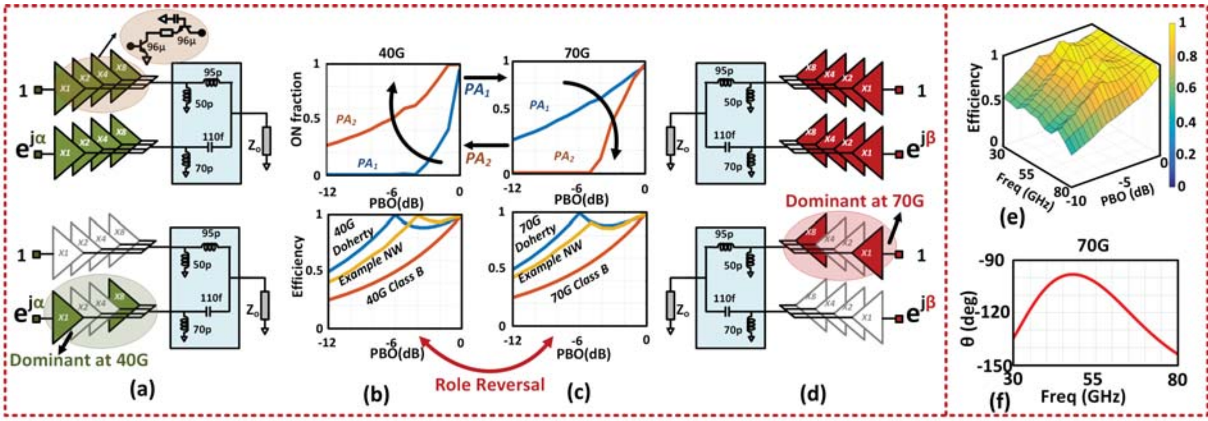

Fig. 2. Simultaneous frequency-PBO reconfigurability: Example (a)-(d)Operation across PBO levels at 40GHz and 70GHz. (e) 3D Efficiency plot across frequency-PBO axes. (f) Optimal phase drive across the frequency.

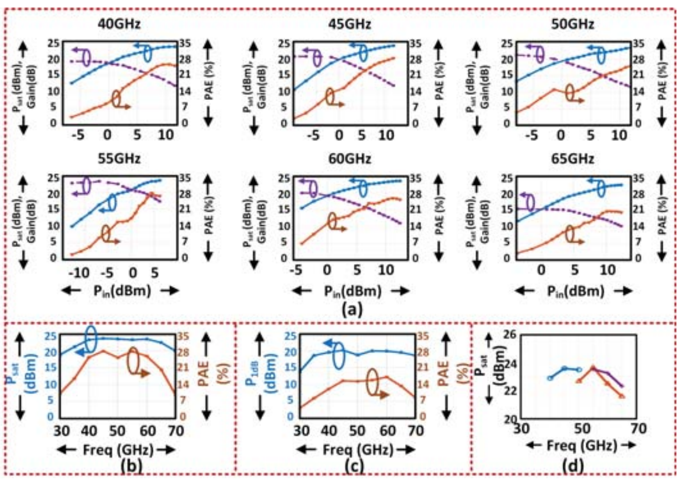

Fig. 3. Initial prototype chip demonstrating frequency reconfigurability: (a)-(c) Measured large signal performance across 30-70GHz through active configuration. (d) Performance across frequencies for a given configuration

frequency reconfigurable operation across 40-65GHz, is shown in Fig.3 [1]. It achieves a P_{sat} of 23.6dBm with PAE of 27.7% at 55GHz with $P_{sat,1dB}$ bandwidth spanning across 40-65GHz while PAE_{1dB} bandwidth spans across 40-60GHz. The performance of the second prototype chip is shown in Fig.4 [2]. This chip is designed for spectral efficient operation across 30-55 GHz showing dual frequency-PBO reconfigurability. The modulated 16-QAM constellations are measured at carrier frequencies of 30 and 50GHz with average measured power of $16.4dBm$ and $16.9dBm$, with η_{out} of 19.9% and 24.6% respectively at data rate of 4Gbps.

IV. Career Plan

I would like to thank the IEEE MTTS for granting me the Graduate Fellowship Award for the year 2017. This has really motivated me to pursue my career in wireless industry and think out-of-the-box for any research problem I encounter with. I am planning to work in research lab associated with industry which will allow me to work closely and solve the highly impactful problems in the real-world. I would like to

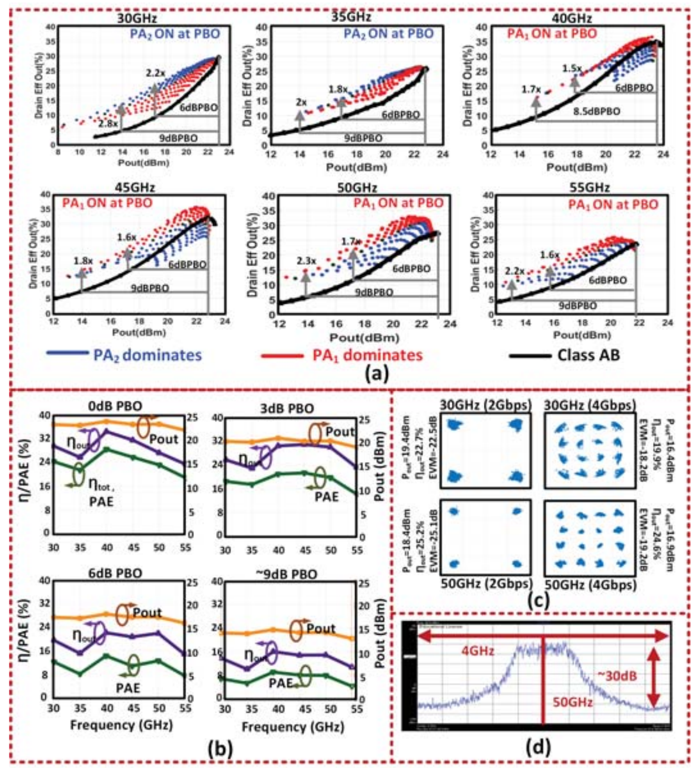

Fig. 4. Second prototype chip showing dual frequency-PBO reconfigurability: (a),(b) Measured continuous-wave performance across 30-55GHz. (c) QPSK and 16-QAM constellations at 30 and 50GHz (d) Spectrum of 16-QAM at 50 GHz with datarate of 4Gbps

make positive impact on our society that could last more than my lifetime.

References

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