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A 2GHz GaN Class-J Power Amplifier for Base Station Applications

K Mimis, K.A. Morris and J.P. McGeehan
University of Bristol, UK

1. INTRODUCTION

Need for reduction of base station power consumption while increasing QoS

- Power Amplifier is a major power consumer
- High order constellations are necessary
- Channel bandwidths keep increasing

Efficient
Linear
Wideband

2. CLASS-J THEORY

Class-J

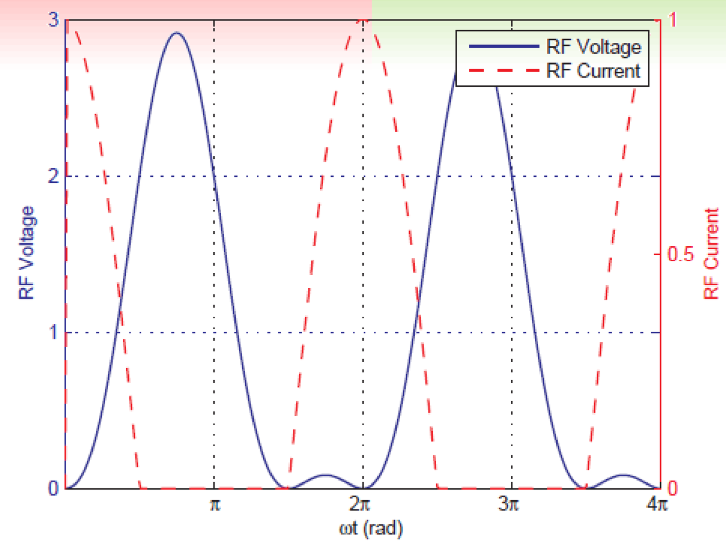
- Recently introduced (2006)
- Complex fundamental impedance
- Reactive 2nd harmonic

Continuous "design space"

- Multiple impedance pairs (Z_{fo}, Z_{2fo})
- Class-B-like output power and efficiency
- Class-B / J / J* are specific sub-cases

$Z_{fo} = 1.4142\angle 45°$

$Z_{2fo} = 1.1781\angle -90°$



$$Z_{fo} = \frac{\pi\sqrt{1+d^2}\left(1-\cos\frac{\alpha}{2}\right)}{a-\sin\alpha}\angle \operatorname{atan}\left(-\frac{1}{d}\right)+\varphi$$

$$\varphi = \begin{cases} \frac{\pi}{2}, & d \geq 0 \\ -\frac{\pi}{2}, & d < 0 \end{cases}$$

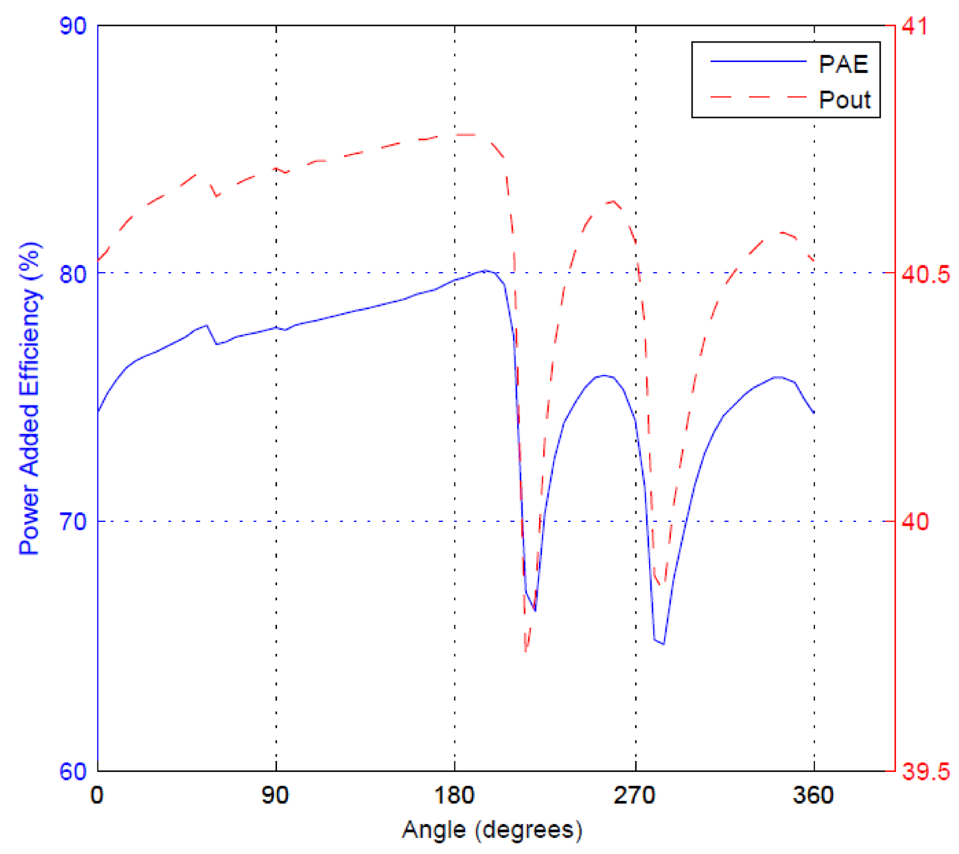
$$Z_{2fo} = \frac{d}{2}\frac{\pi\left(1-\cos\frac{\alpha}{2}\right)}{\sin\frac{\alpha}{2}-\frac{1}{3}\sin\frac{3a}{2}}\angle -\frac{\pi}{2}$$

3. METHODOLOGY – REALIZATION OF THE POWER AMPLIFIER

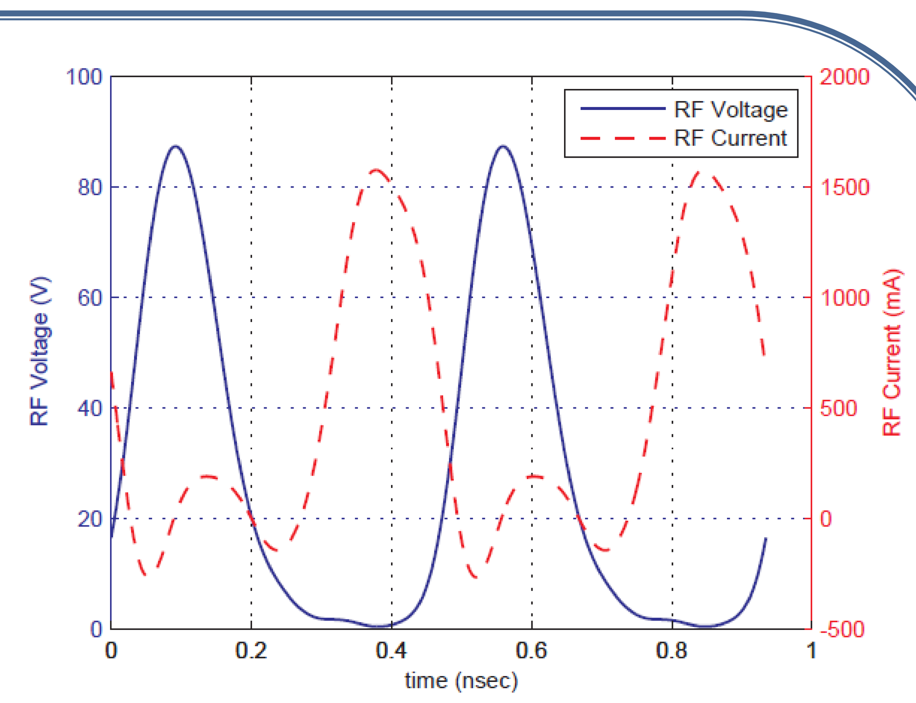
- Large signal transistor model
- Extrinsic parasitics and package model
- Intrinsic drain impedances given from theory
- **No** active harmonic load-pull
- **No** RF waveform probing

1. Deep Class - AB biasing
2. Determine appropriate load-line
3. Intrinsic drain impedances based on theory
4. **3rd output harmonic impedance**
5. **Source-pull for efficiency/gain**
6. **Observe intrinsic drain waveforms**
7. **Design matching networks**

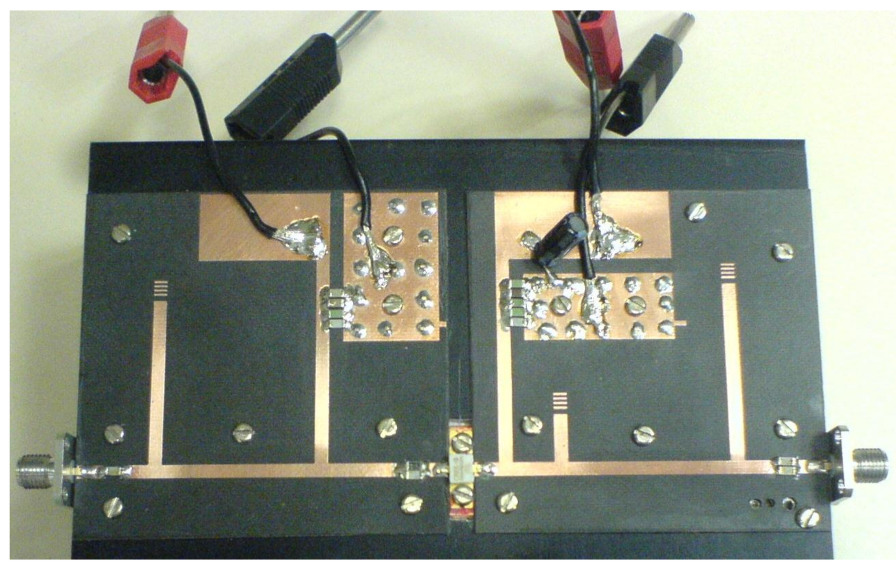
- 3rd harmonic not defined by theory
- 3rd harmonic reflection coefficient angle swept
- Affects efficiency / output power
- Chose an insensitive/efficient case



- Intrinsic drain waveforms
- De-embedded in simulations to prove Class of operation
- No "zero" voltage crossing
- Similar to expected waveforms
- Some 3rd harmonic present
- Current "hump"

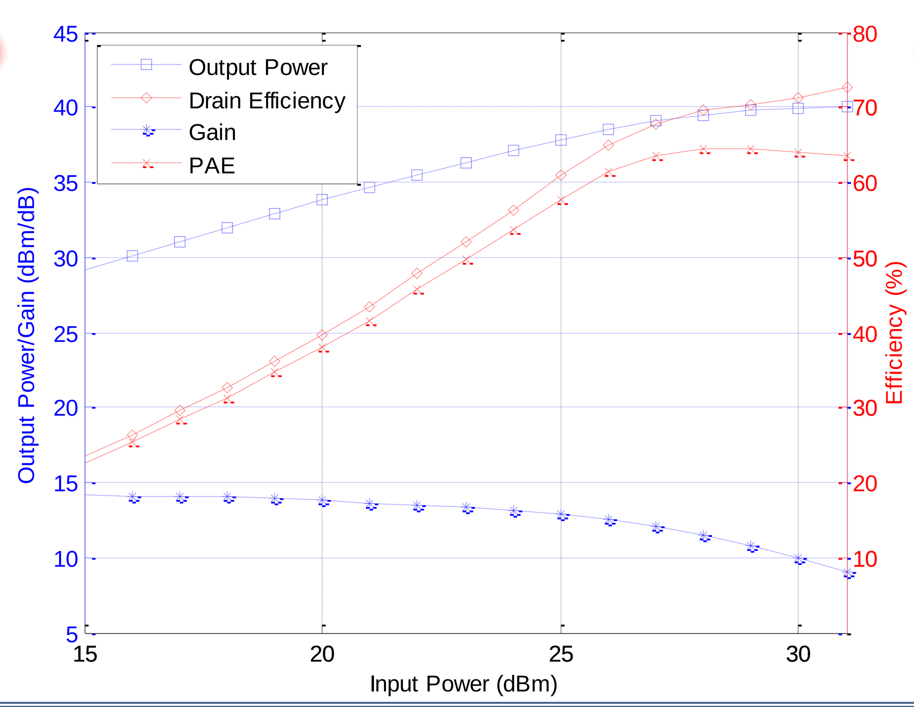


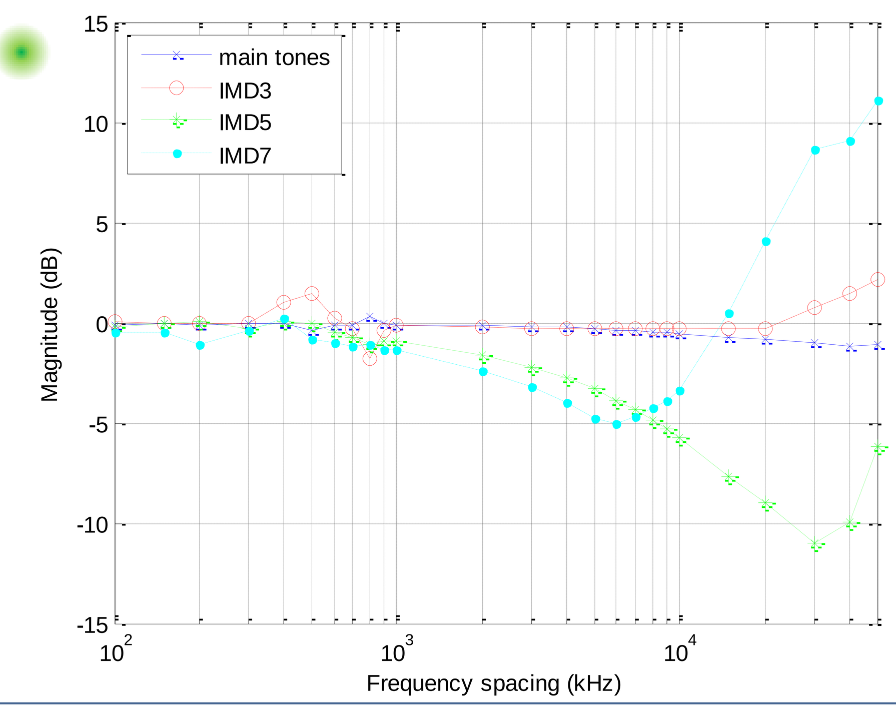
- Distributed matching networks
- 2 harmonics controlled at the input, 3 at the output
- RT/Duroid 8550 substrate
- E_r = 2.2, T = 787mm
- Size : 13.5 x 6.5 cm
- Higher E_r will reduce size

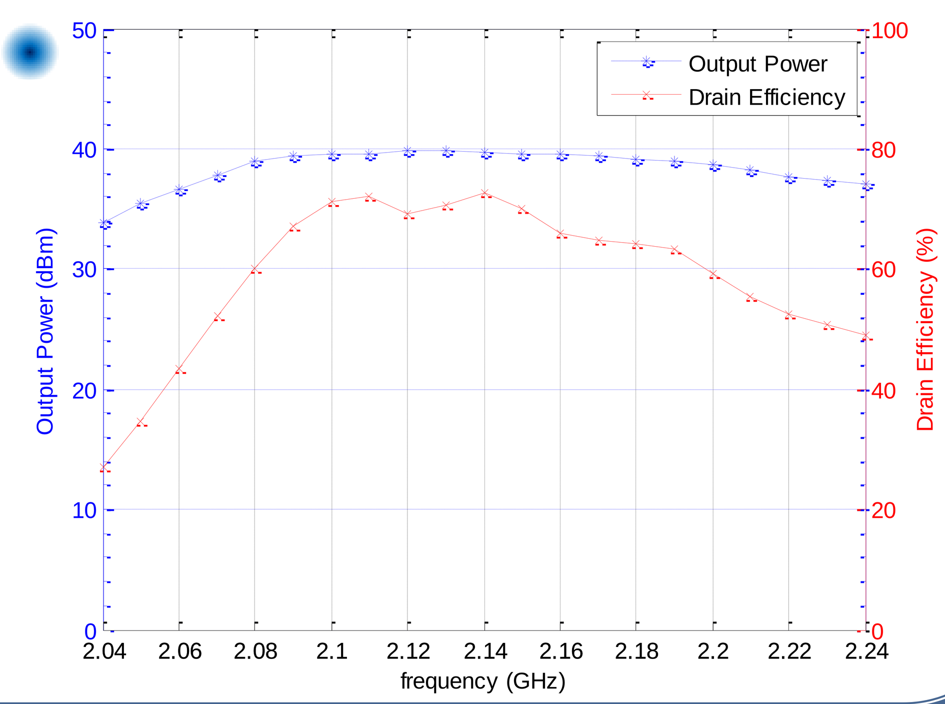


4. PERFORMANCE

- 65% maximum PAE
- 40dBm output power
- Good back-off performance
- Low asymmetry up to 20MHz
- Low memory effects
- Facilitates linearization
- 60%+ efficiency over 140MHz
- 39-40dBm output power over band
- LTE and LTE-Advanced







5. CONCLUSIONS

- **More freedom in PA design / No need for specific impedances**
- **Theory and extrinsic parasitic model is sufficient**
- **3rd output harmonic impedance is important**
- **65% PAE, over 70% drain efficiency, 40dBm output power**
- **Low memory effects**
- **Promising under ET/EER implementations**

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