Allen Katz HEPA (High Efficiency Power Amplifiers) SDC

IEEE_MTTS

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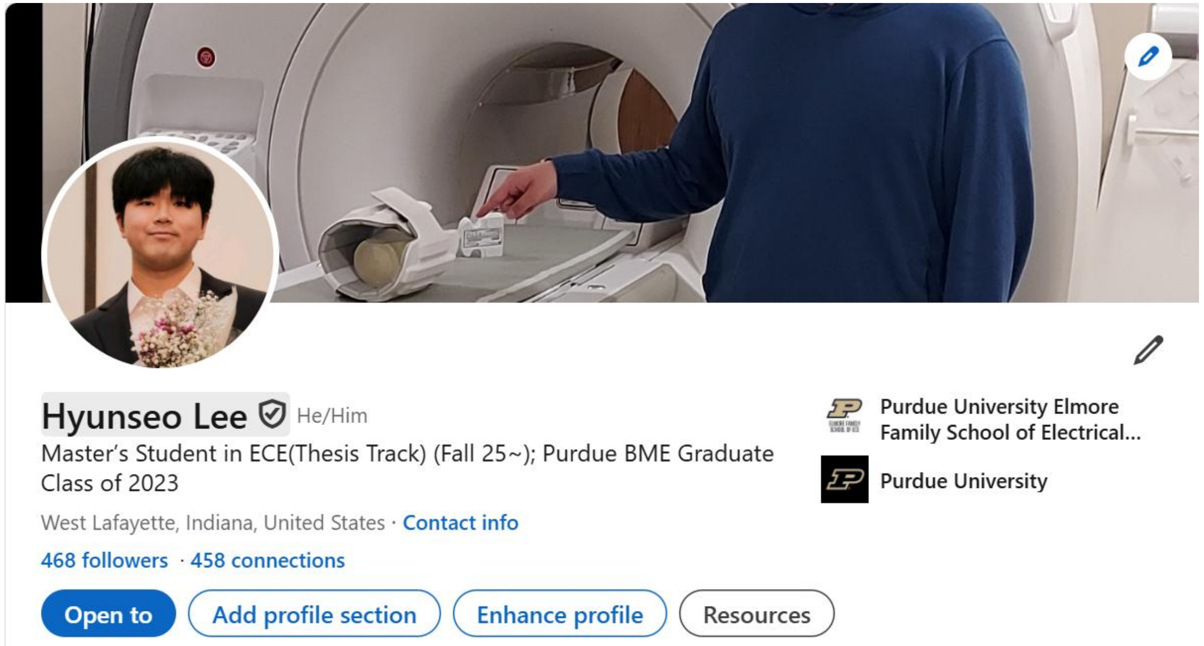
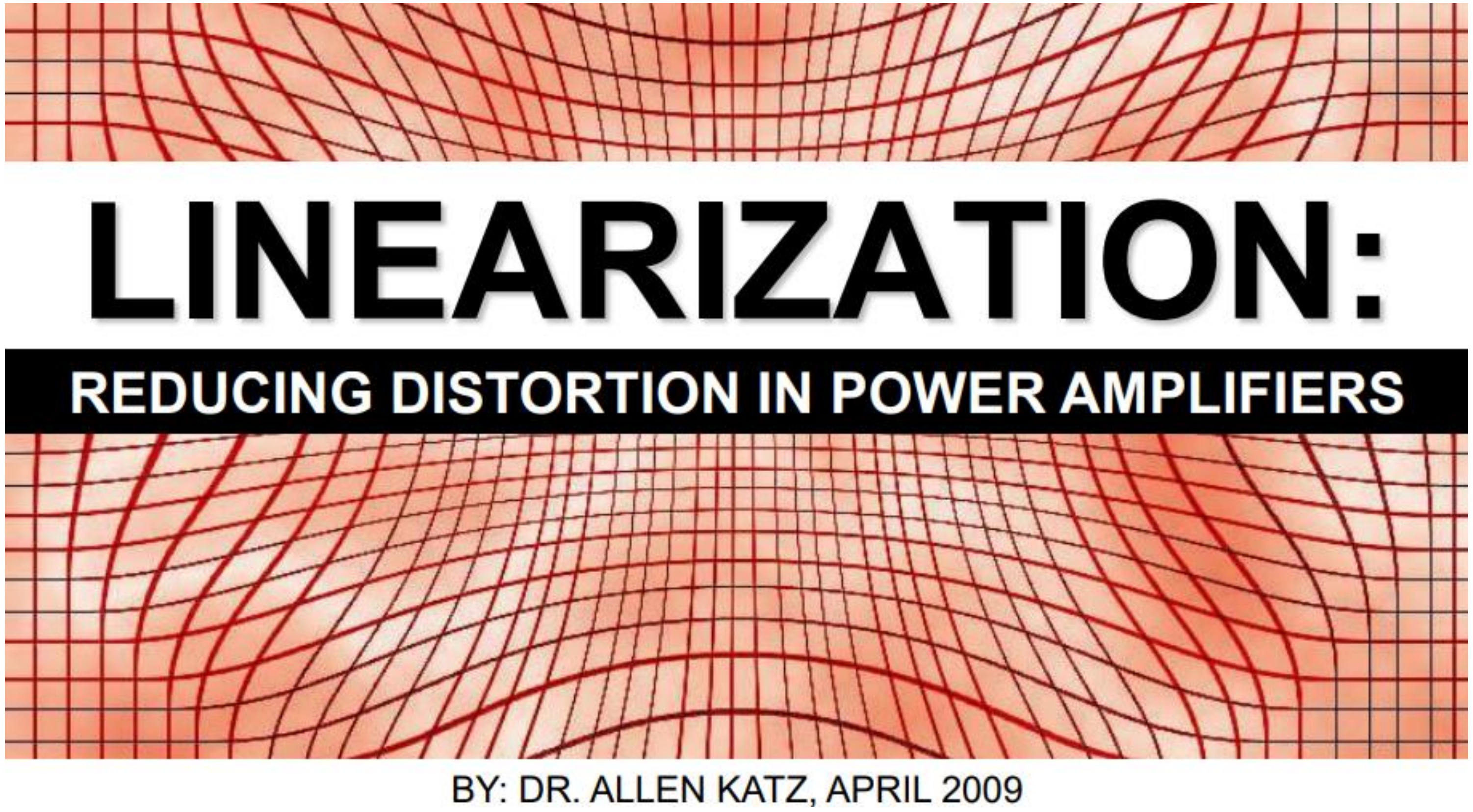
Who are you?

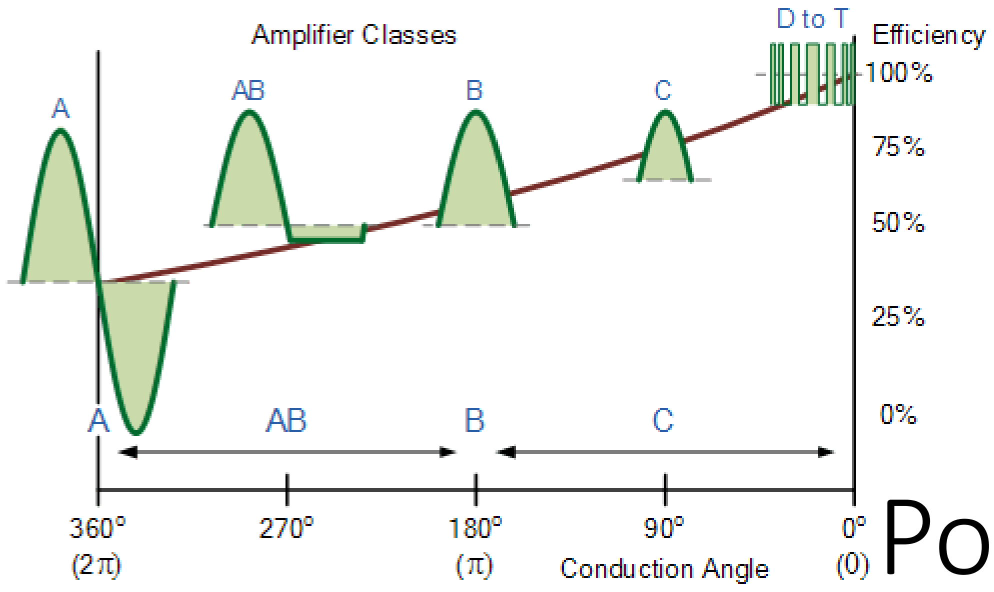


Background



Optimization of the tradeoff between Efficiency and Linearity in Power Amplifier is key in PA Design.

Power Amplifier



5.1. Equipment for Power Amplifier Measurement

Various instruments and components are involved in the measuring process of PAs such as circulators, attenuators, as shown in Fig. 3.

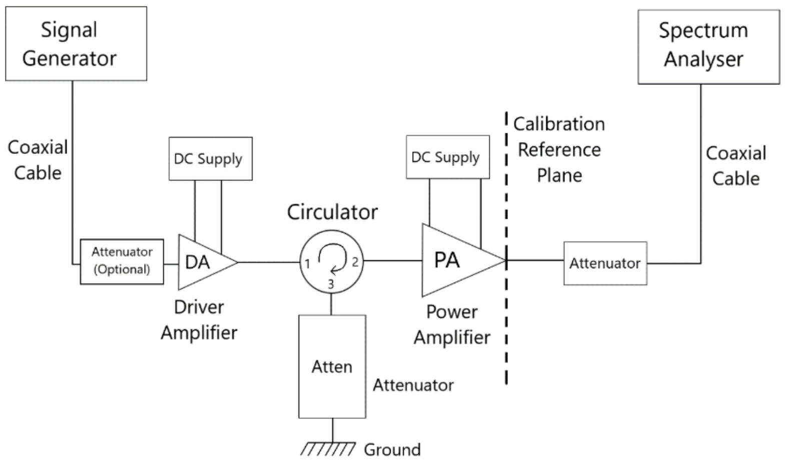


Fig. 3. Block diagram of power amplifier measurement setup at CSA Catapult. Source: Primary.

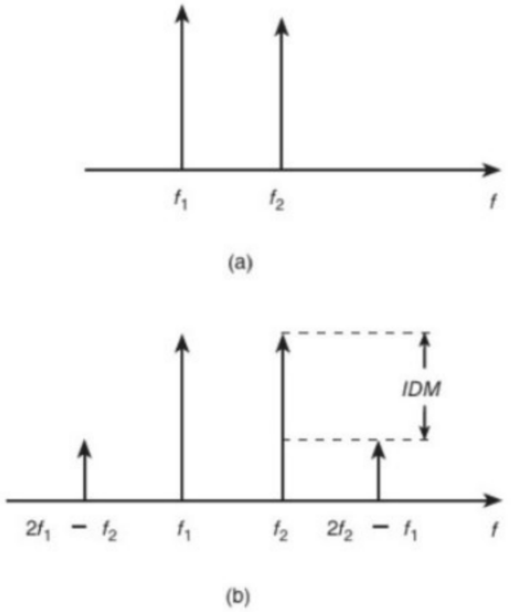


Fig. 2. (a) is two signals of different frequencies at the input port. (b) are the transmitted signals that consist of the original signals and intermodulation products. Source: [3].

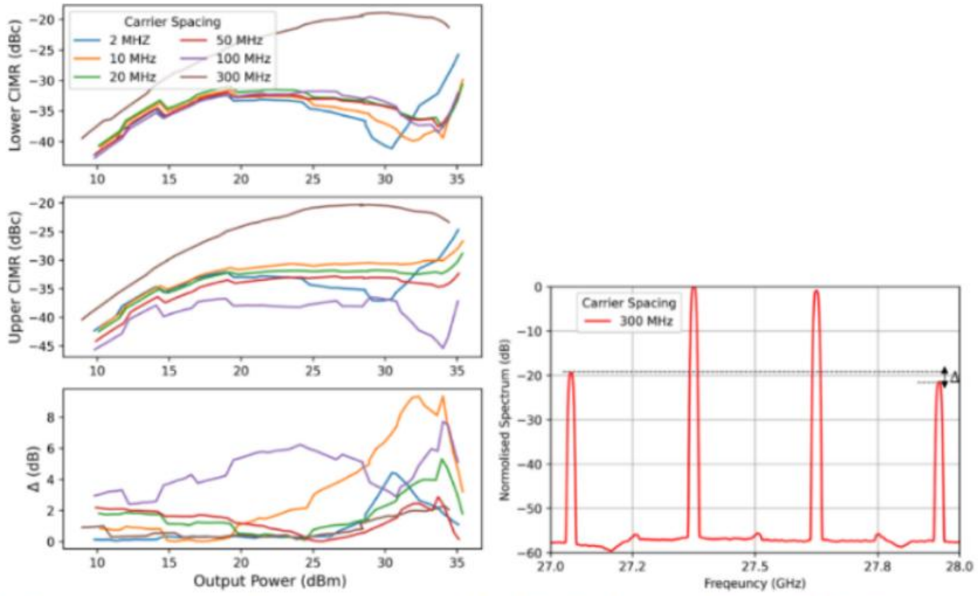
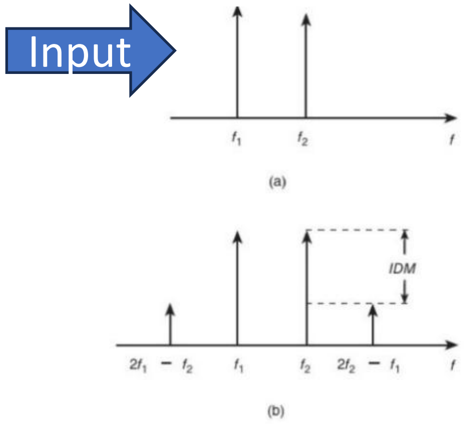


Fig. 5. Two-Tone measurement results at centre frequency 27.5 GHz. The Lower and Upper CIMR (dBc) were measured at different power levels with carrier spacing ranging from 2 MHz to 300 MHz (left). Normalised output spectrum recorded from device with a signal that has carrier spacing of 300 MHz and at peak output power (right). The 'Δ' parameter is the difference between the Upper and Lower CIMR (dB). Source: [10].

How to Win

What exactly do we have to test?

$$PAE(\%) = \left(\frac{P_{out} - P_{in}}{P_{DC}}\right) \times 100$$



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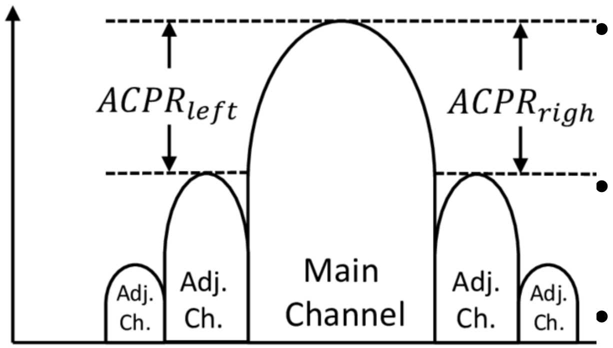

- Two-Tone Linearity Measurement
- Highest PAE(Power Added Efficiency) when producing a C/I of 30dB
- C/I = Carrier to Intermodulation Ratio
- Carrier : Desired Signal; I : Interfering signal received by Receiver
- ACPR = Power in adjacent channel / RMS Power in Main Channel
- ACPR was added this year
- Input Signal details are in the PDF online [PAPR = 9.8 dB]
- Soucre : https://www.everythingrf.com/community/what-is-acpr
- https://www.linkedin.com/pulse/microwave-communication-basics-part-2-david-ramirez-coatc/

Evaluation Process

More Details in PDF

9. The winner will be based on the amplifier's PAE measured during official testing at the lowest power level for which the C/I ratio* equals 30 dB. If the C/I ratio is better than 30 dB over the entire testing range, the measurement at 21 dBm input power per tone will be used. The figure of merit for scoring will be the PAE multiplied by a frequency weighting factor having the form (GHz)*0.25.
10. For demonstration purposes, modulated ACPR linearity (dB) and drain efficiency measurements will be conducted at the same lowest output power level for which the C/I ratio* equals 30 dB, 6dB lower, and 10dB lower. This measurement will not impact the scoring for the competition.

Basic Inspection

- Are RF Ports SMA Female Connectors?
- Are Bias connections banana plugs?
- ETC…
- Maximum of 2V DC for operation
- Should not requirement more input power than necessary

- Linearity Measurements
- Continuous wave Two-tone operation
- Max 21 dBM *Input power* per tone used
- Tone Power Sweep 0 ~ 21 dBm -> C/I Ratio Measured(Remember higher Ratio is better)
- At lowest power level where C/I Ratio = 30dB -> PAE Measured
- Remember Minimum Requirement for C/I is 30dB with 0dBM per tone input

In Summary,

10 minutes to Set Up
PAE is measured at the point where Carrier to Intermodulation Ratio meets the expected value.
Should be able to demonstrate ACPR Linearity and Drain Efficiency

Figure of Merit : PAE * Freq Weighting Factor(Ghz^0.25)

PAE during official testing at lowest power level for which the C/I ratio equals 30dB.
PAE measured at first output power with increasing Pin from 0 dBm where this ratio falls below 30 dB.

The PAE Formula

The standard formula for PAE, expressed as a percentage, is:

$$\mathrm{PAE}(\%) = 100 \times \frac{P_{\mathrm{out}} - P_{\mathrm{in}}}{P_{\mathrm{DC}}}$$

Where:

- P_{out}: RF Output Power (Watts)
- P_{in}: RF Input Power (Watts)
- P_{DC}: DC Supply Power ($V_{\mathrm{DC}} \times I_{\mathrm{DC}}$)

ExampleExampleExampleExampleExamplExampleExample

When the instruction says, To qualify for the two tone linearity measurement, with 0 dBm per tone input, carrier-to-intermodulation ratio (C/I) must be greater than 30 dB*

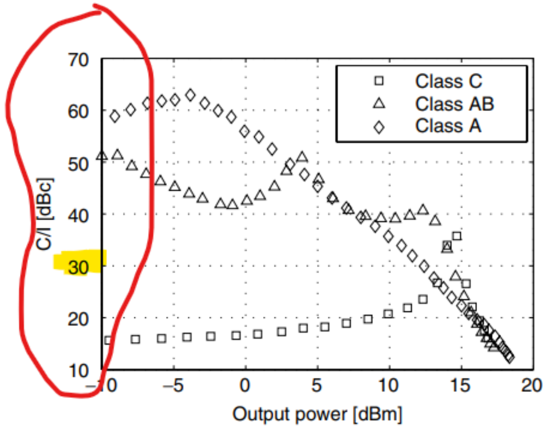

Fig. 15. Measured carrier-to-intermodulation ratio (C/I) versus output power for different classes of operation.

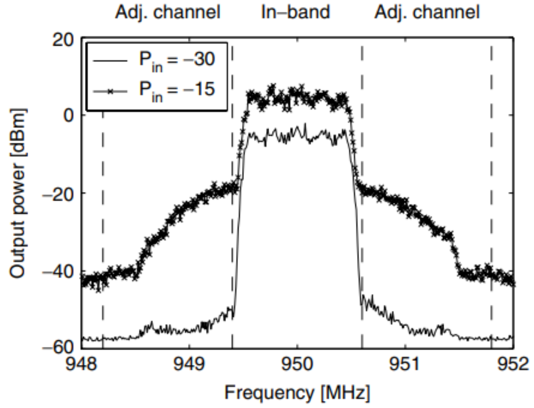

Fig. 17. Output spectrum for −30 and −15 dBm input power with a 1.2-MHz-wide CDMA input signal.

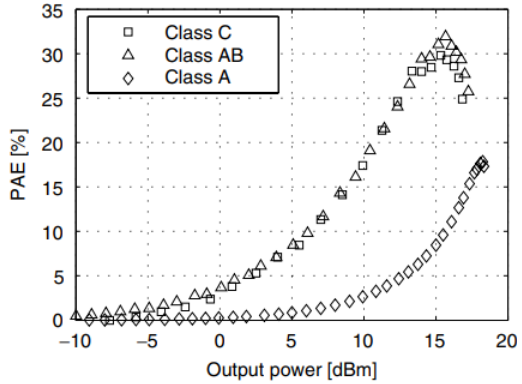

Fig. 16. Measured PAE versus output power for different classes of operation.

5) *Efficiency and Linearity Comparison:* The different

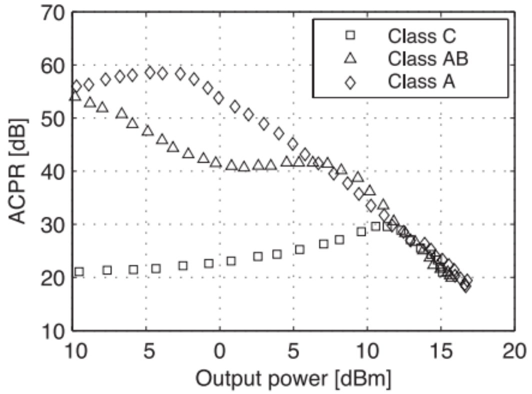

Fig. 18. Measured adjacent channel power ratio versus input power P_{in}.

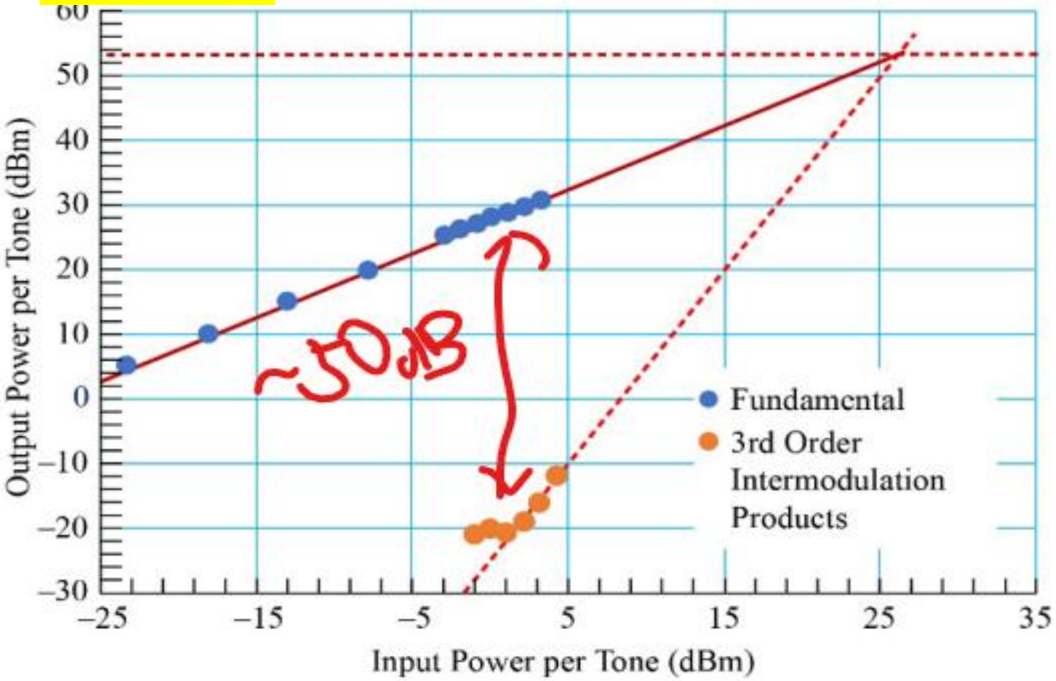

Figure 16.—Measured 3rd order intermodulation distortion (IMD) vs. input power per tone at sub-band f_0 = 29.5 GHz. Tone spacing is 5 MHz.

$$C/I(P_{in}) = P_{fund}(P_{in}) - P_{IMD3}(P_{in})$$

Source : Fager - A Comprehensive Analysis of IMD Behavior in RF CMOS Power Amplifiers
NASA - Demonstration of a Switched Wideband GaN High-Power Amplifi er for Future Space Missions

Details from the Document

More to be filled with our own design components..

Components / Criteria	Requirements	Check box	Cost
RF Ports	SMA Female Connector		
Bias Connections	Banana Plugs		
Power Amplifier(PA)	< 2 DC for operation		
PA Op Range	1 ~ 10 GHz		
Output Power Level	4 < excited by single carrier < 40 Watts		
Input Power	< 24 dBm to reach 4Watts(output)		
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…			
…			
…	.		
…			

*Excited with a single carrier

TOOLS

RF PA Design + Two Tone, harmonic balance simulation

- ADS Keysight [Crucial]
- AWR Microwave

EM Simulations for MN(Matching Networks) / Parasitics

- Ansys HFSS
- CST Microwave Studio

Circuit Board Implementation

- KiCad / Altium / Cadence Allegro
- Cadence Virtuoso [RFIC-Style Power Amplifier Core]

Pre-Testing

- Signal Gen + Spectrum Analyzer with MATLAB, Python, LTSpice

Timeline

ASAP	Feb ~ March	4/1/2026	4/15/2026	6/9/2026
Contact Organizors, get sample test data. *encouraged to contact the coordinators of the competition of your interest as early as possible to ensure a full understanding of the design specifications and judging criteria before your submission.	Begin design by at least 10 Feb. Q&A Sessions on ACPR	Hopefully, finish testing. Start final draft of the paper submission.	You must submit a competition application form no later than Wednesday, **15 April 2026**, or as indicated in the rules of the competition of interest.	At least one team member must register for IMS2026 and attend the student design competitions in person on Tuesday, **9 June 2026** in order to assist with measurements (where applicable) and answer questions.

Interested?

Two more spots left to join the current team with me but feel free to form a team of your own and collaborate with us.

You can show your display of knowledge in

RF Theory, Nonlinear Circuits, and obviously power amplifiers.

1) It Signals Deep RF Power Design Expertise

Most student projects stop at LNAs, mixers, or PLLs.

Power amplifiers are harder and more valuable.

A Katz HEPA project demonstrates:

- Load-pull theory
- Nonlinear transistor modeling
- Large-signal RF behavior (P1dB, AM-AM, AM-PM)
- Harmonic impedance engineering
- Drain efficiency vs PAE optimization
- Bias class trade-offs (Class AB, Class F, inverse-F, Doherty, Outphasing)

➡️ Hiring managers know only serious RF designers attempt this.

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2) It Shows You Understand Modern RF System Constraints

Allen Katz's work is famous because it connects **academic PA theory to real wireless system requirements**:

- High efficiency at backed-off power (critical for 5G/6G, radar, satellites)
- Linearity vs efficiency trade-offs
- Envelope tracking and digital predistortion compatibility
- Wideband operation constraints

➡️ This bridges **circuit design + communication systems**, which companies desperately want.

Thank You

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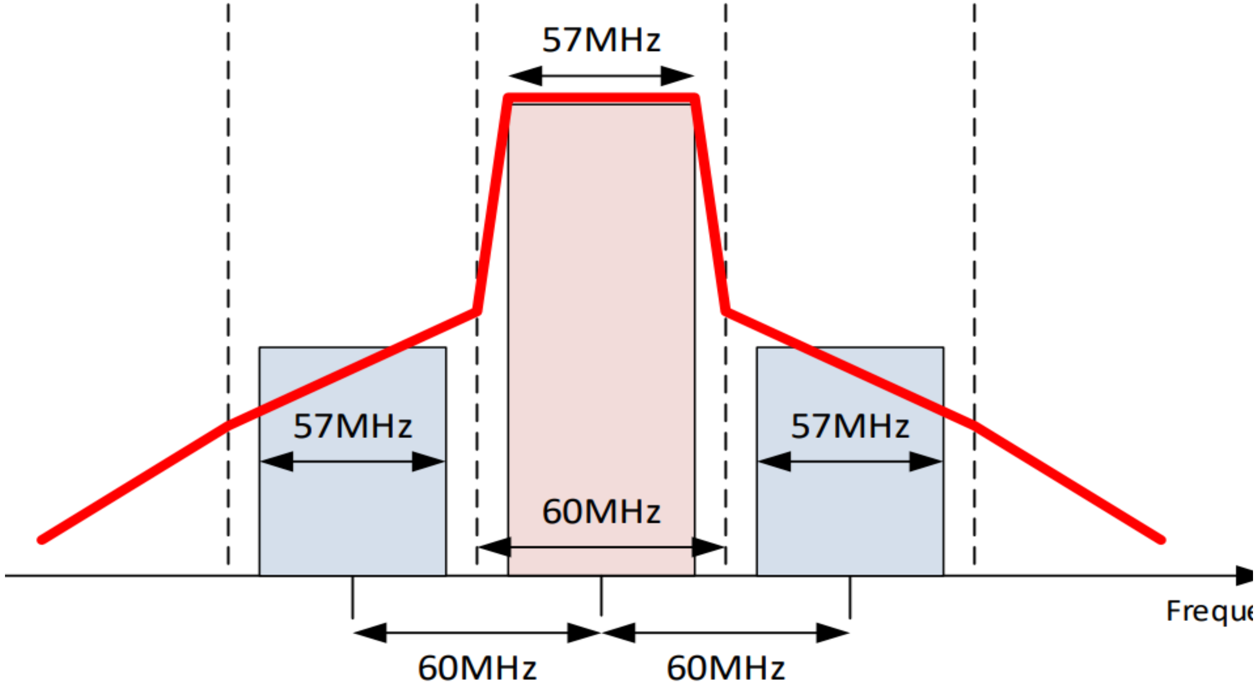
Terminology Explained(Very Briefly)

PA, PAE, C/I, Single Carrier, Two-tone carrier, ACPR

Demonstration - ACPR

Not measured; Performance in 5G and beyond.



ectrum showing ACPR Measurement with a 60MHz Channe