Techniques for Predicting Nonlinear Distortion Effects in Ka-band Uplink Gateways

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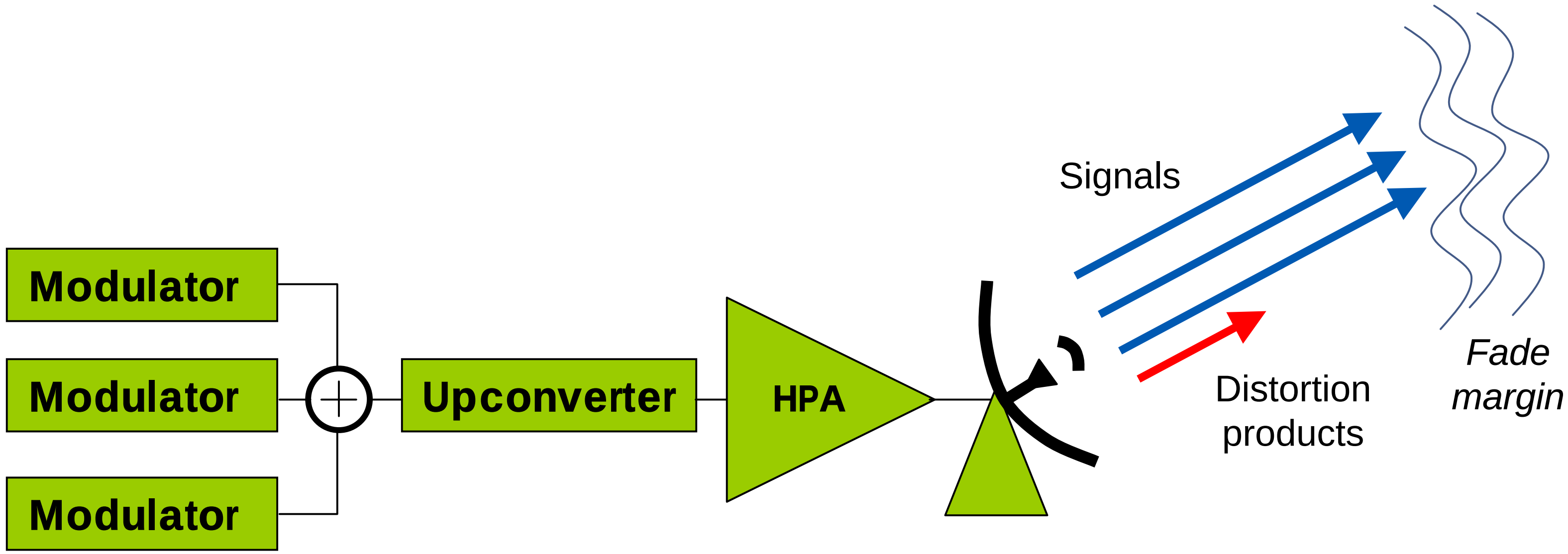
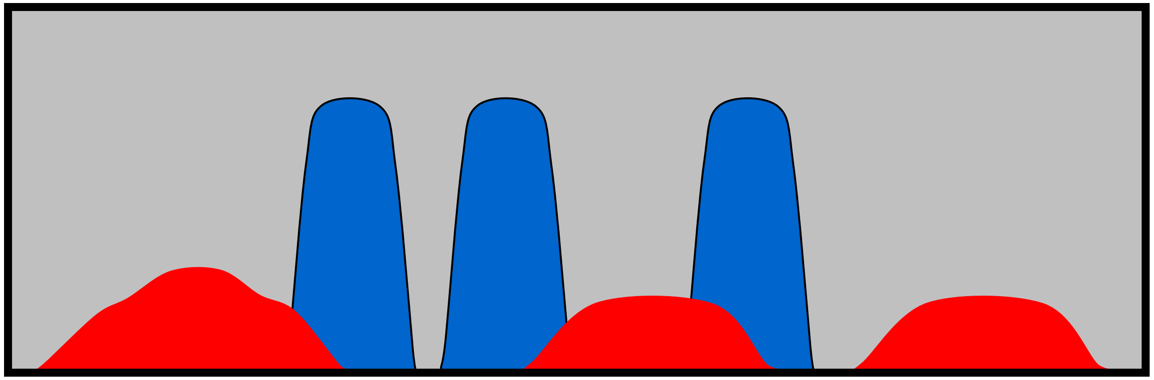
How to maximize per-signal EIRP?





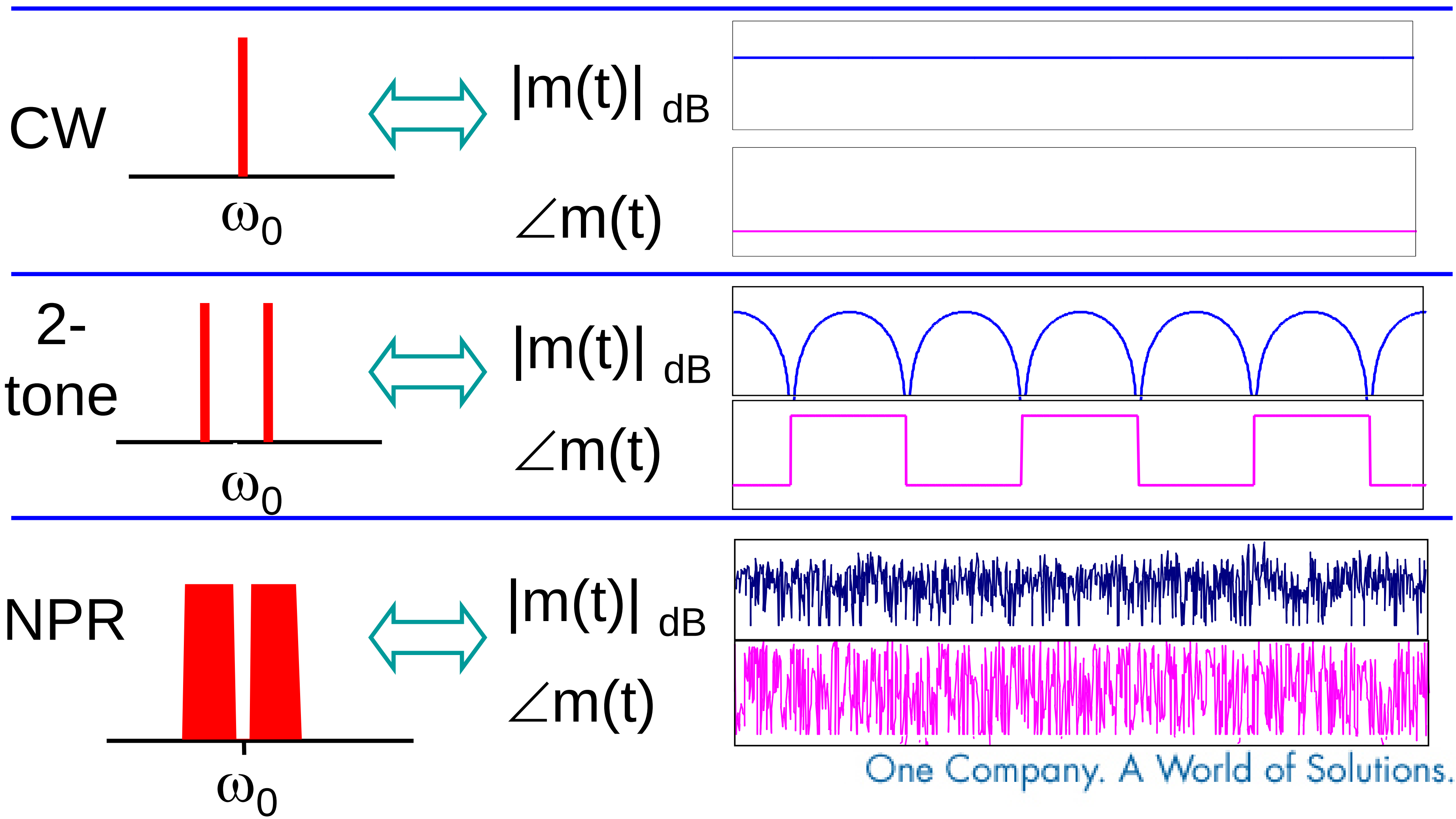
Objective:
1. **Characterize the HPA**
2. **Simulate the distortion**
3. **Optimize the output operating level**

Classes of non-linear distortion

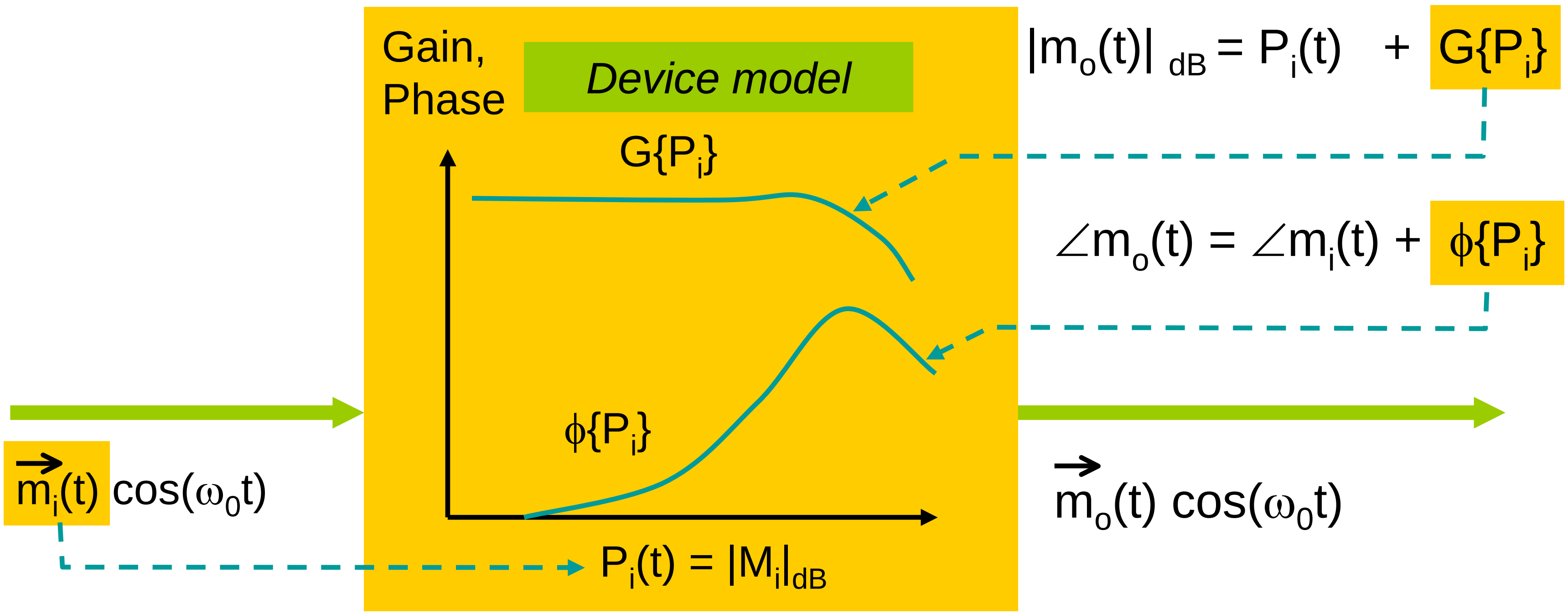
- **Static**
  - Voltage transfer curve; no phase shift
- **Quasi-static ("memoryless")**
  - Gain & phase shift are instantaneous functions of the input power ("transfer curves")
  - A surprisingly good approximation for Ka-band HPAs and many other devices
  - Easy to simulate using *complex modulation* theory
- **Dynamic ("non-memoryless")**
  - Memory effects are significant
  - Transfer function varies with time,
    - e.g. bias circuit settling, thermal effects
  - Extremely difficult to characterize and simulate

Complex modulation

Any set of signals = ***complex*** modulation $\vec{m}(t)$ x ***one arbitrary*** carrier



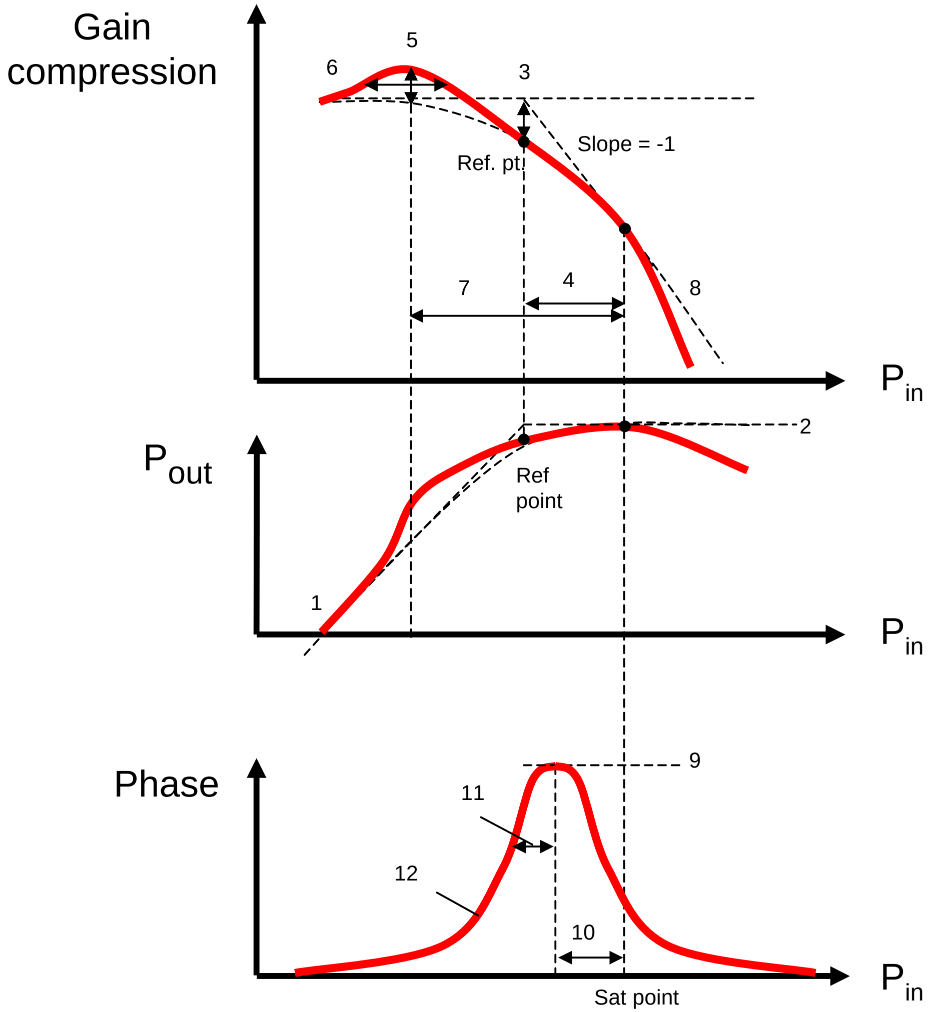
Quasi-Static Distortion Model



Transfer curves:

- Map input modulation to output modulation at each time instant.
- Fully characterize the distortion

12-parameter HPA model

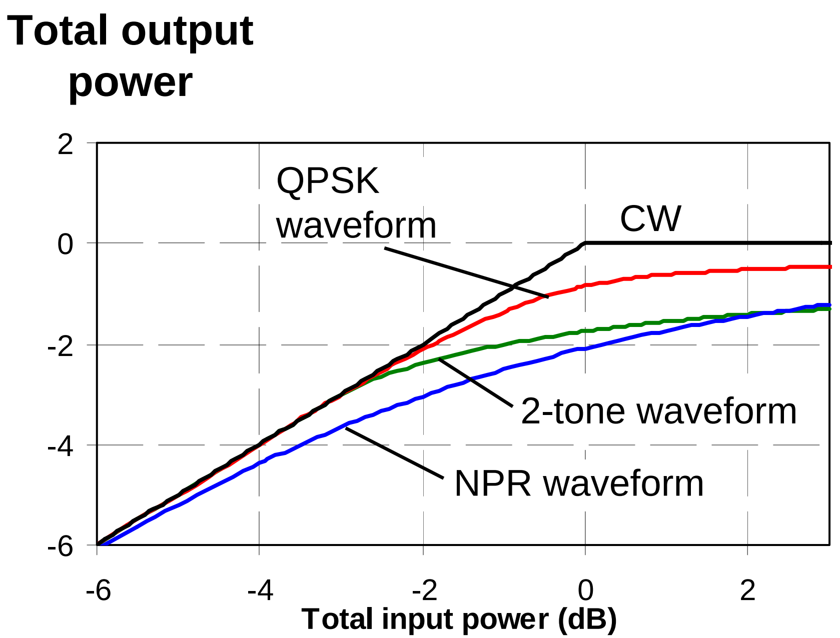


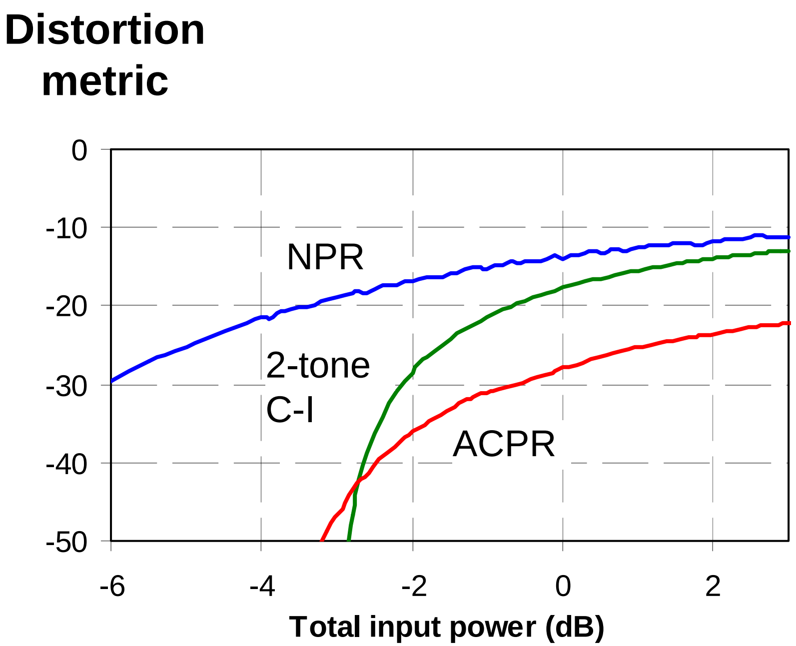
<u>Parameters</u>

Magnitude:
1. Small-signal gain
2. Psat
3. Softness factor
4. IBO of corner
5. Bump height
6. Bump width
7. IBO of gain bump
8. Foldover factor (=1 for constant Psat)

Phase:
9. Phase maximum
10. IBO of phase peak
11. Phase width
12. Shape factor (squareness)

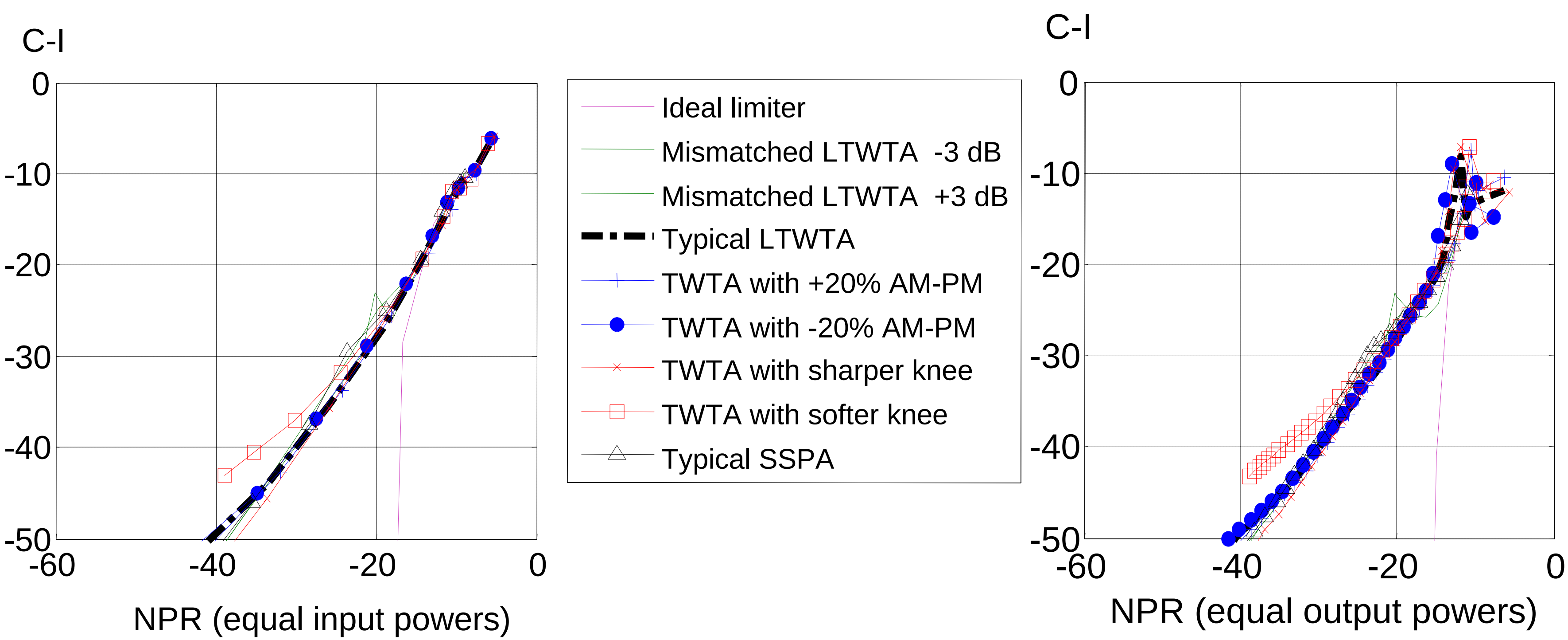
Example simulation: an ideal limiter





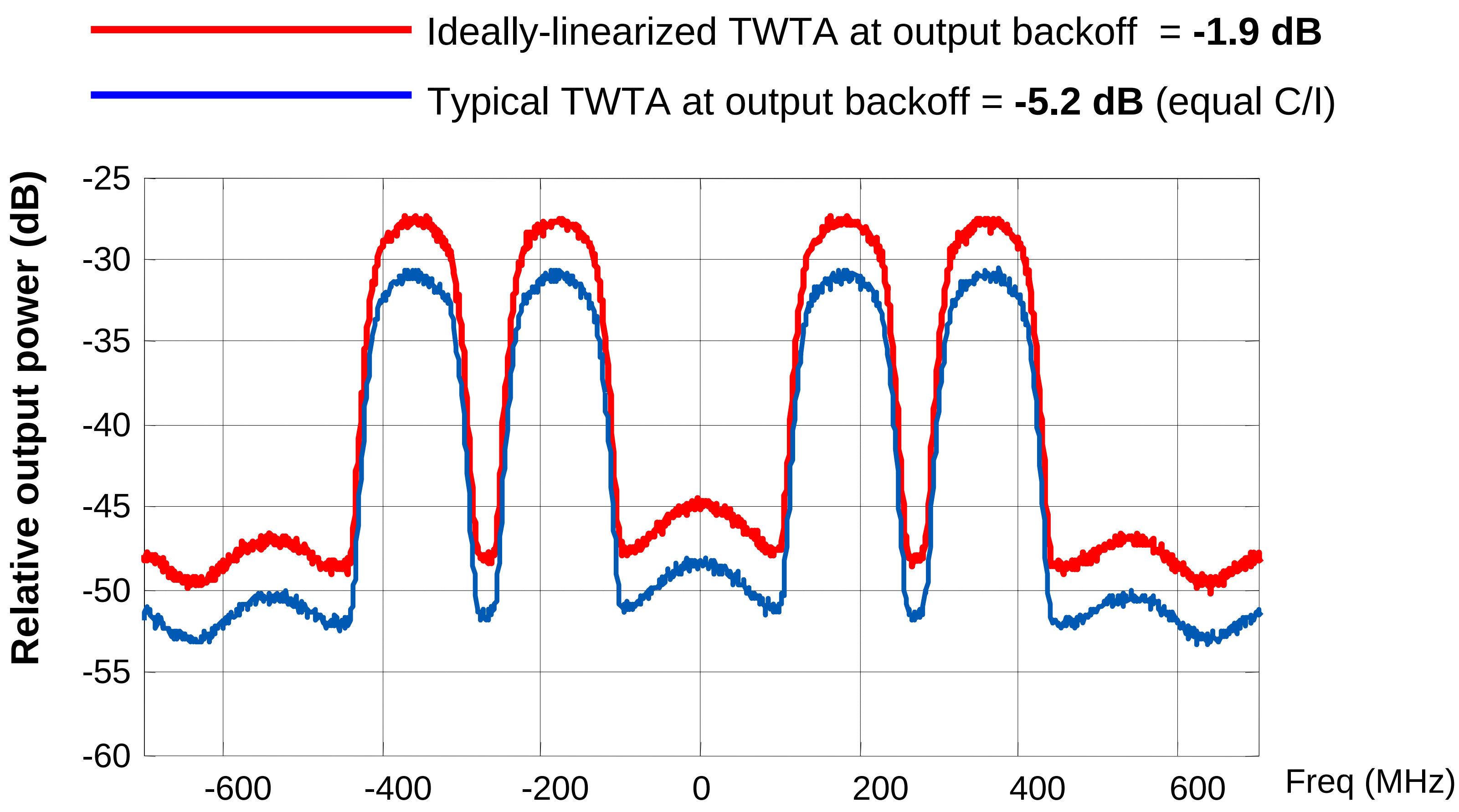
- Saturated power depends on the modulation
- 2-tone intermodulation does not follow the 3:1 rule... because the distortion is very badly approximated by a third-order polynomial

Simulated Two-tone IMD vs. NPR



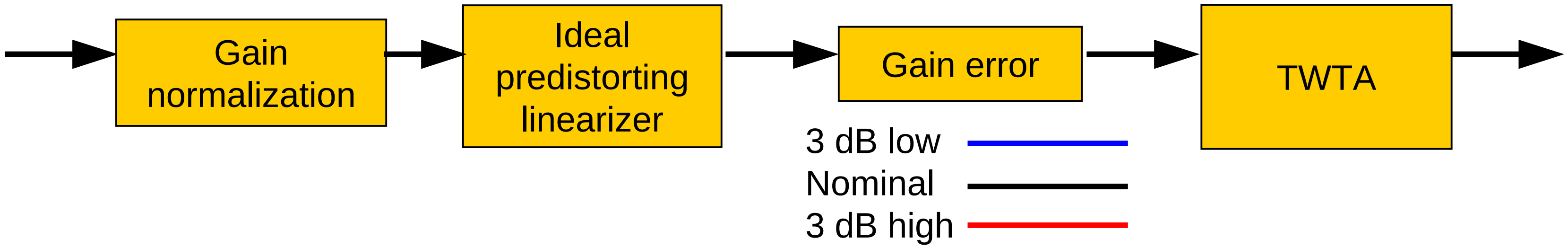
- There is no general solution relating NPR and two-tone IMD, but...
- Real-world HPA transfer curves do show approximate trends

How much does a predistorting linearizer help?

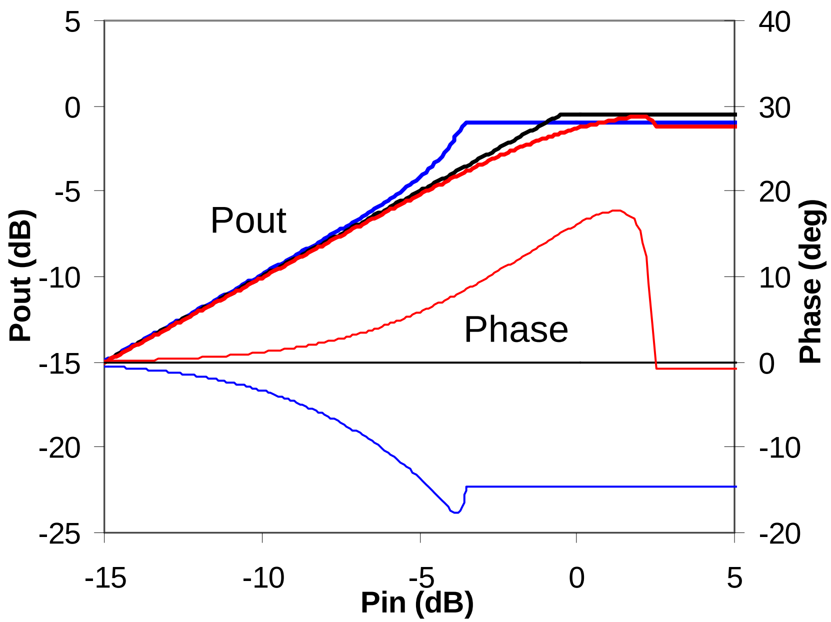


Signals: 64 Msps, QPSK, alpha = 0.35, raised cosine, randomized symbol delays

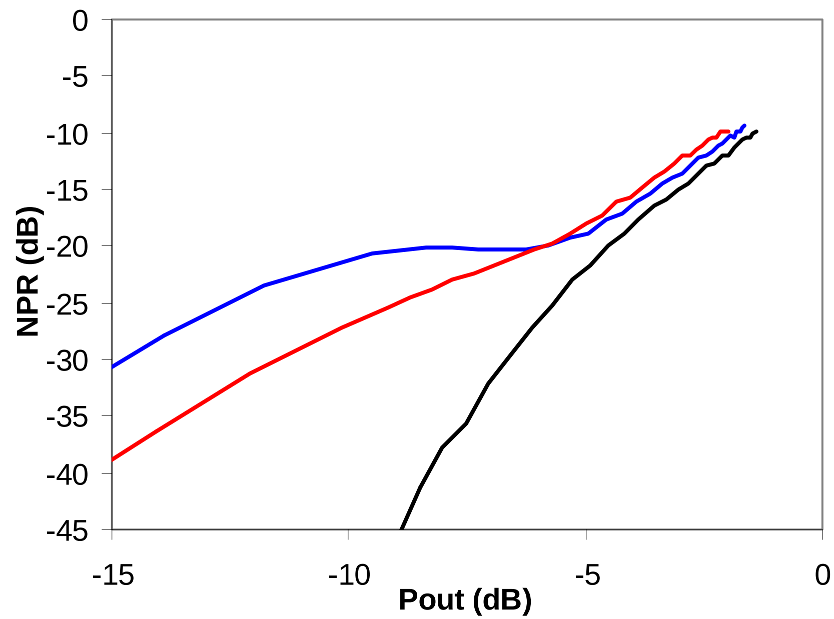
How well must a linearizer match its HPA?



Composite transfer curves

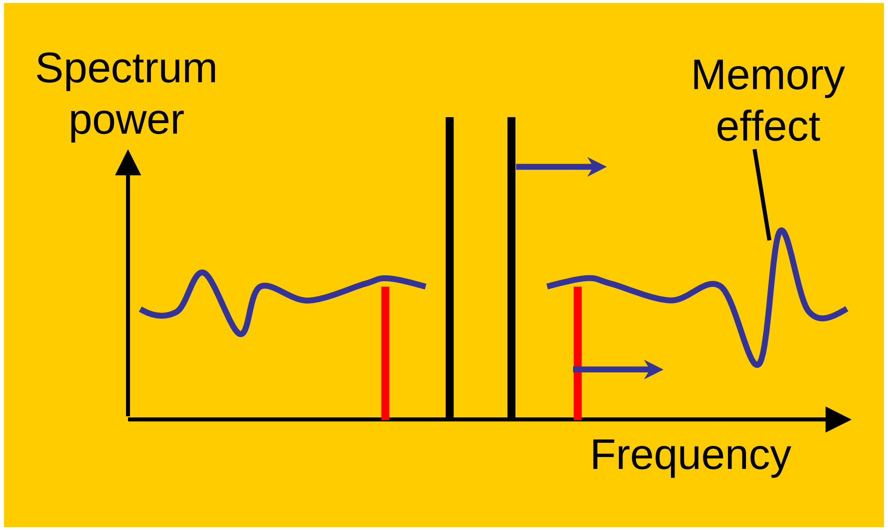


Net NPR distortion performance



Characterizing and validating the model

- Characterization
  = measuring AM-AM/AM-PM over wide dynamic range
  - Conventional or pulsed VNA
  - Spectral null pulse
- Validating the memoryless model
  = ruling out time-dependent distortion
  - Envelope transient reproduction
  - Swept two-tone



Conclusions

- Generalizations based on 3rd-order approximations are inaccurate at high levels
- The quasi-static approximation, while not exact, is a simple and powerful basis for insight into the distortion of high-power amplifiers
- 12-parameter model allows rapid study of distortion performance and tolerances
- Generalized metrics (NPR, 2-tone) or case-specific distortion can be quickly predicted and inter-related