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Versatile Linearized TWTAs for Phased Arrays in Space

Linear Products

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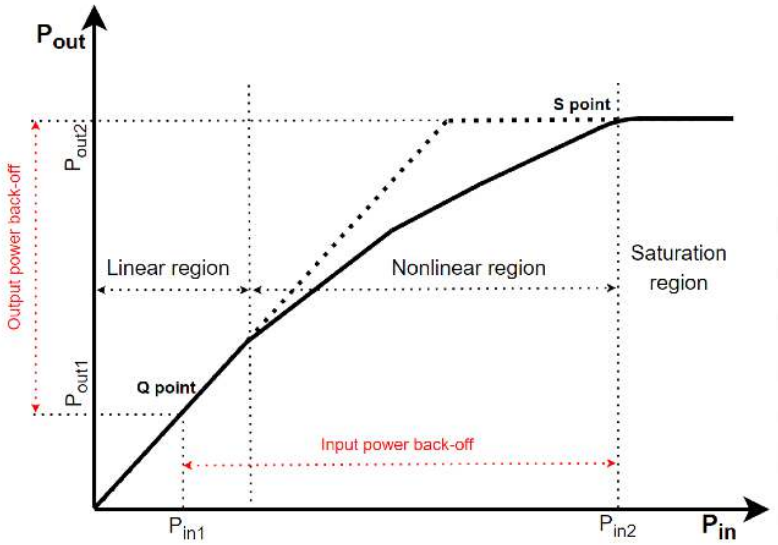
The Space Business in Transition

- New requirements for satellites carrying high-data rate traffic using bandwidth-efficient modulations.
  - Lower power
  - Wider bandwidth
  - Greater flexibility
- PAs must be operated efficiently at multiple power levels, that can be adjusted in real time.
  - *Highest efficiency means linearity is a must!*
- Highest linearity over the greatest possible bandwidth requires analog predistortion linearization (APDL).
  - Smaller size
  - Lower complexity
  - Superior performance

Linearization and Efficient PAs

- Communication system linearity is dominated by PA linearity.
- PA output power is reduced (i.e. “backed off”) to achieve satisfactory linearity – *however, backing off greatly reduces efficiency!*
- Linearization corrects nonlinearity and allows the PA to operate more efficiently at a given output power level.
- Linearizer characteristics must adapt as PA output power changes, in order to maintain maximum linearity and efficiency.

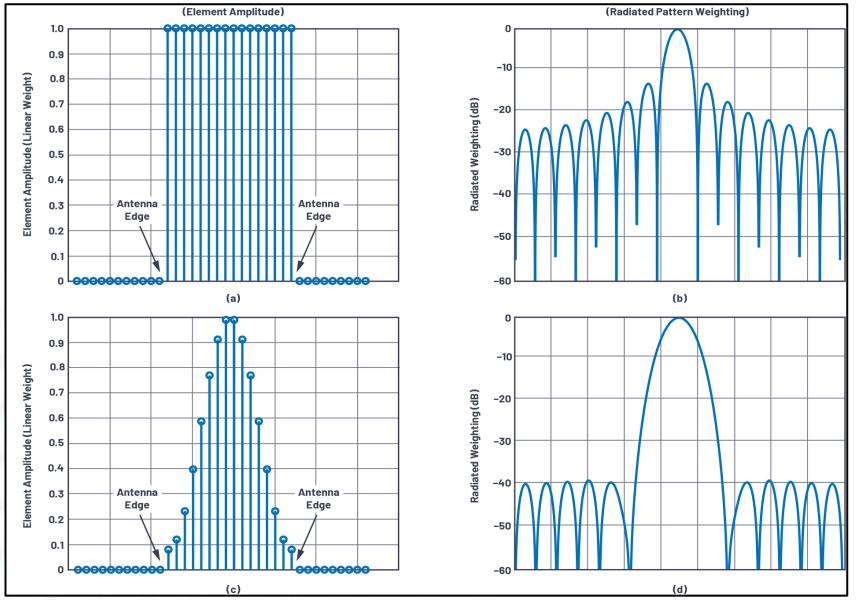


Linearizers and Microwave Power Modules (MPMs)

- Microwave power modules (MPMs) comprise complete, powered PA systems in a single package
  - Miniature traveling-wave tube (TWT)
  - Electronic power conditioner
  - Remarkably small and light-weight
  - Low power, high efficiency
- Linearization of MPMs provides the most advanced performance in SATCOM amplification by leveraging the best of solid-state and TWT vacuum technologies.
  - Solid-state linearizer front end gets the best performance out of the PA
  - MPM TWTAs offer power density and power conversion efficiency comparable or superior to those of SSPAs

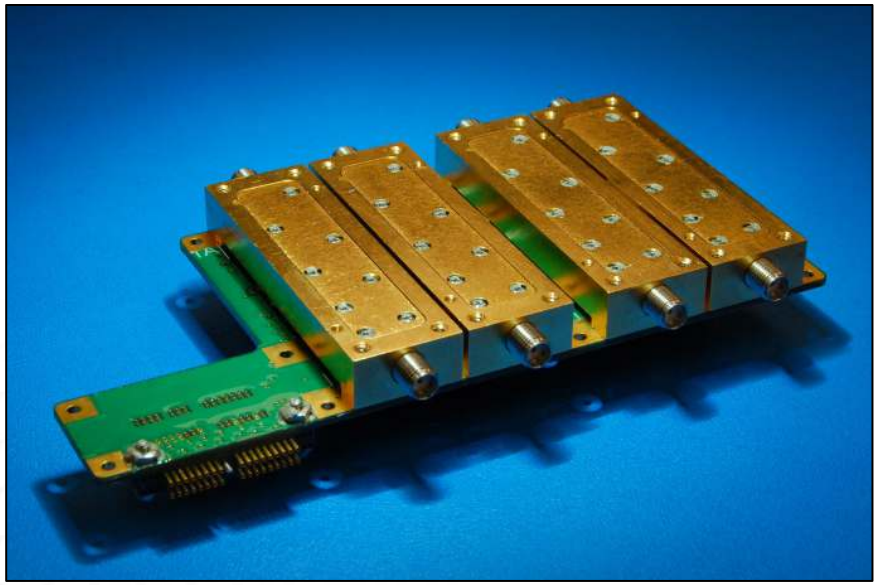
Linearized MPMs for Phased Arrays

- Phased array antenna systems are composed of multiple antenna elements, each driven by a PA.
- Since efficiency is usually highest near P_{SAT}, PAs must be designed or tuned for P_{SAT} corresponding to their position in the array taper.
- Sufficiently versatile linearization allows for the use of a *single PA design* for every array position, and *optimal performance at each!*
  - MPM anode voltage may be adjusted for appropriate P_{SAT}, and linearizer maximizes efficiency



Versatile Linearizer Front-End (VLFE) for Space Communications

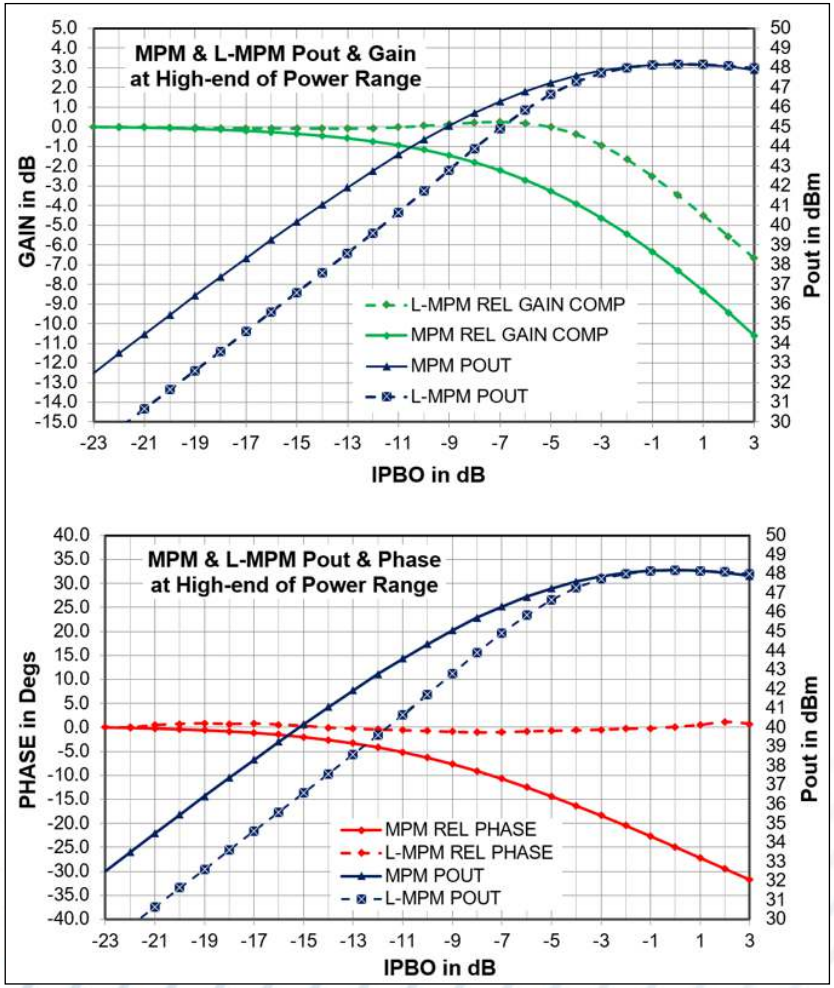
- New, highly versatile linearizer front-ends (VLFEs) are an engineer's best bet for use in cutting-edge space communications systems.
  - >5 GHz instantaneous bandwidth
  - AM/AM and AM/PM correction
  - Ability to correct for variances in PA characteristics in real time
    - Manufacturing variances
    - Beamforming
  - Multiple channel configurations
  - Less complex than feedforward or digital predistortion
- Correct both magnitude and phase over frequency and power level.

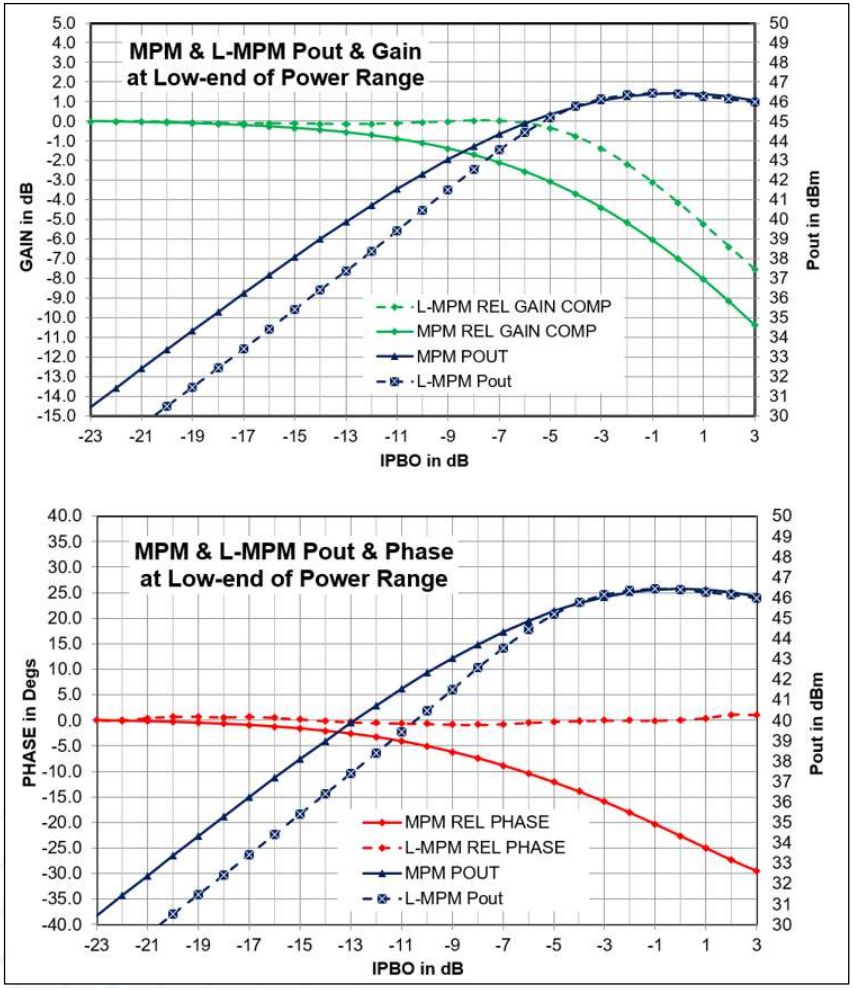


Linearizer Results

- Ka downlink band.
- 1-dB compression point moved within 1.5 dB of P_{SAT}.
- Phase advance reduced to less than one degree.
- Instantaneous bandwidth of 3 GHz.
- Dynamic range of adjustment of >6 dB.
- Multiple RF output power levels.
- At a noise power ratio (NPR) of 16 dB the linearizer provided:
  - 2-dB increase in output power
  - Nearly 40% increase in efficiency

Linearizer Results, continued





Conclusion

- Modern satellite systems have unique and more stringent requirements.
- Linearized MPMs offer the best combination of power, efficiency, bandwidth, size, linearity, and manufacturability for a wide variety of applications.
- Analog predistortion linearization allow for the optimal use of MPMs in phased array applications:
  - Wide instantaneous bandwidth for high-data rate traffic
  - Versatility sufficient for single MPM design for all array elements.
- Linearizers are in production that meet the demands of cutting-edge SATCOM systems passing high-data rate traffic using modern modulation techniques.