Linearizer Technology, Inc.™

WIDEBAND ANALOG PREDISTORTION LINEARIZATION FOR HIGH POWER AMPLIFIERS

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Objective

TO DISCUSS THE STATE OF THE ART IN ACHIEVING WIDEBAND LINEARIZATION OF HIGH POWER AMPLIFIERS (HPAs)

USING ANALOG PREDISTORTION
NECESSARY FOR
MULTI GHz/MULTI OCTAVE OPERATION

CONSIDER SSPAs, TWTAs and KPAs

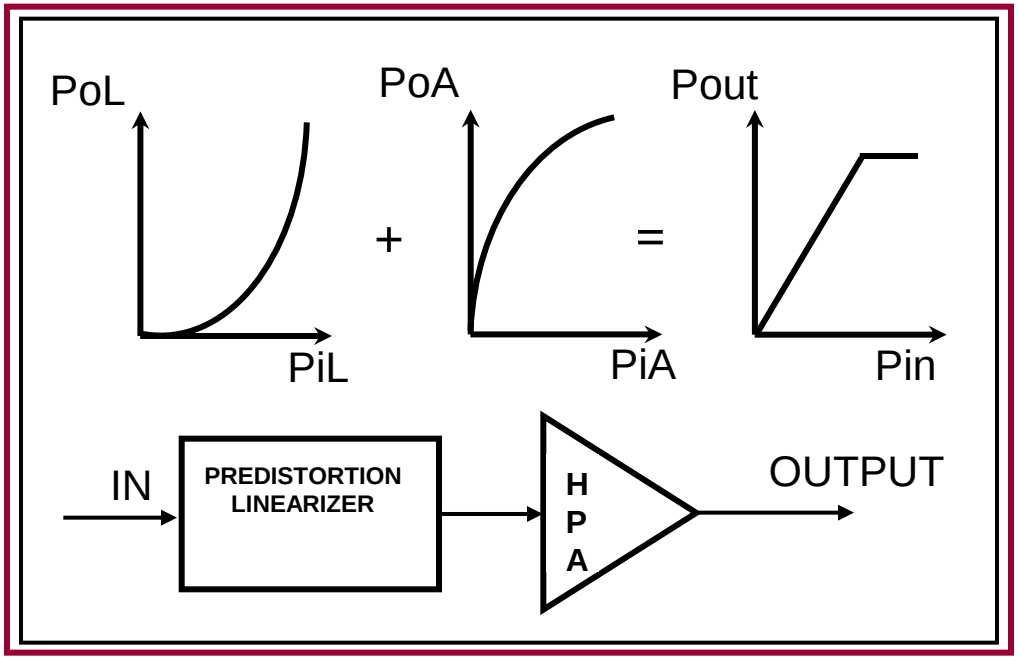
Outline

- REVIEW THE BASIC PD LINEARIZATION CONCEPT
- DISCUSS WAYS OF ACHIEVING WB PERFORMANCE

  - SINGLE WIDEBAND (WB) LINEARIZER

  - COMBINING MULTIPLE SINGLE BAND LINEARIZERS
- SHOW CHARACTERISTICS OF SOME WB LINEARIZERS
- DISCUSS MULTI-OCTAVE LINEARIZER PROBLEM
- PROVIDE DATA FOR A QUAD-BAND LINEARIZED HPA
- PRESENT CONCLUSIONS

PD Linearization Overview

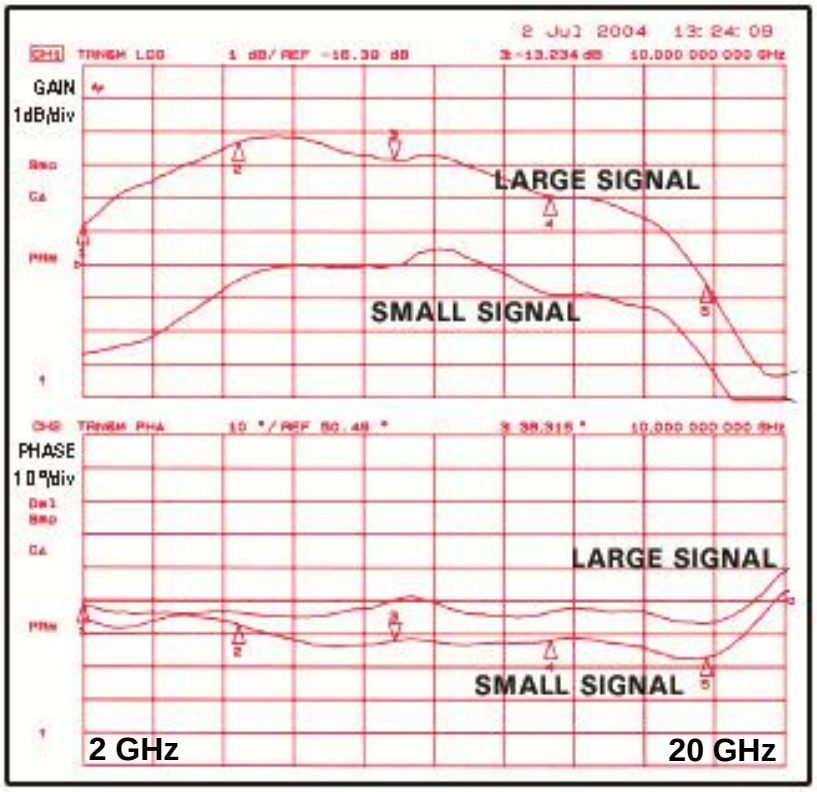


FOR WB PERFORMANCE OVER FREQUENCY:

- MUST CORRECT BOTH GAIN AND PHASE
- MUST EQUALIZE LINEAR GAIN AND PHASE (DELAY)
- MUST MATCH NON-LINEAR CHARACTERISTICS OVER FREQUENCY

Very Wideband Linearizer

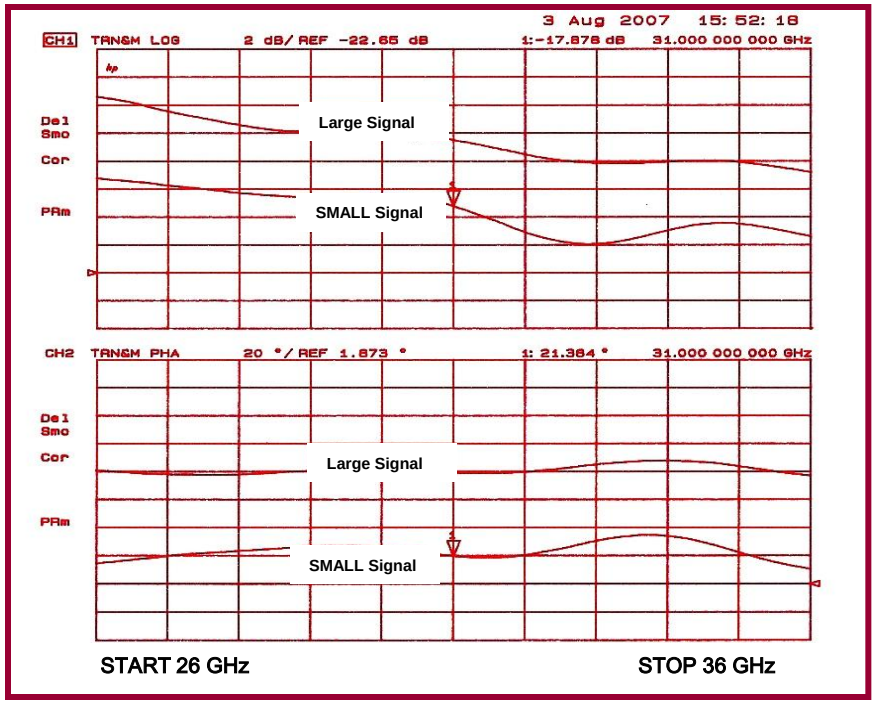
- THERE IS INTEREST IN VERY WB LINEARIZATION
- APPLICATIONS INCLUDE MULTI-FUNC COM, EW & RADAR
- LINEARIZERS CAN BE MADE WITH > 3 OCTAVES OF BANDWIDTH

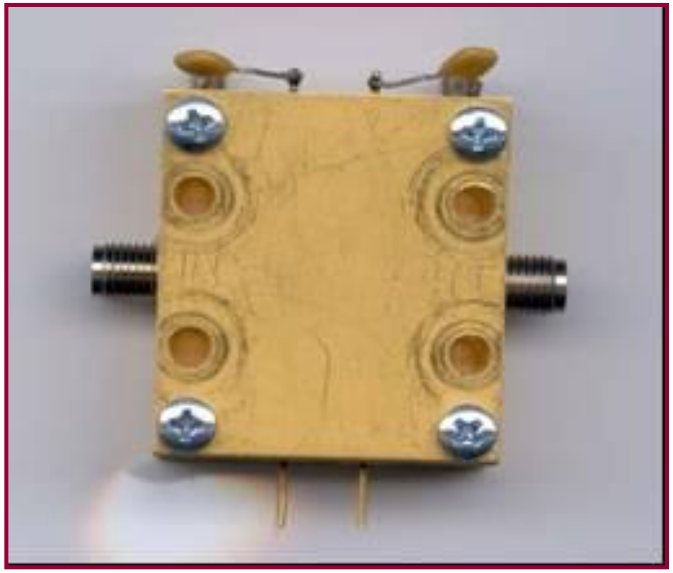


- USEFULL LINEARIZER CHARACTERISTICS < 3 GHz TO > 20 GHz.
- ~3 dB GAIN INCREASE FROM 6 TO 16 GHz.
- INCREASING PHASE CHANGE

Very Wideband Linearizer

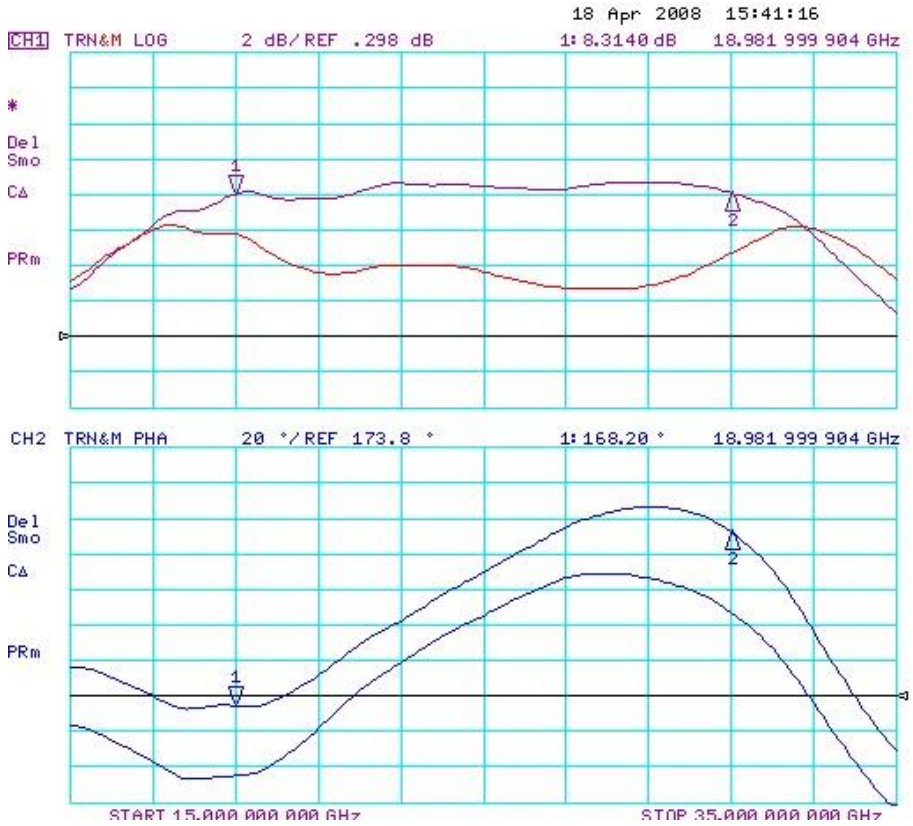
- BELOW IS SHOWN AN EXPERIMENTAL Ka-BAND WB LINEARIZER
- FOR TWTA (ΔG > 4 dB & ΔPHASE 50°) APPLICATION
- WITH BANDWIDTH > 10 GHz (26 TO 36 GHz)

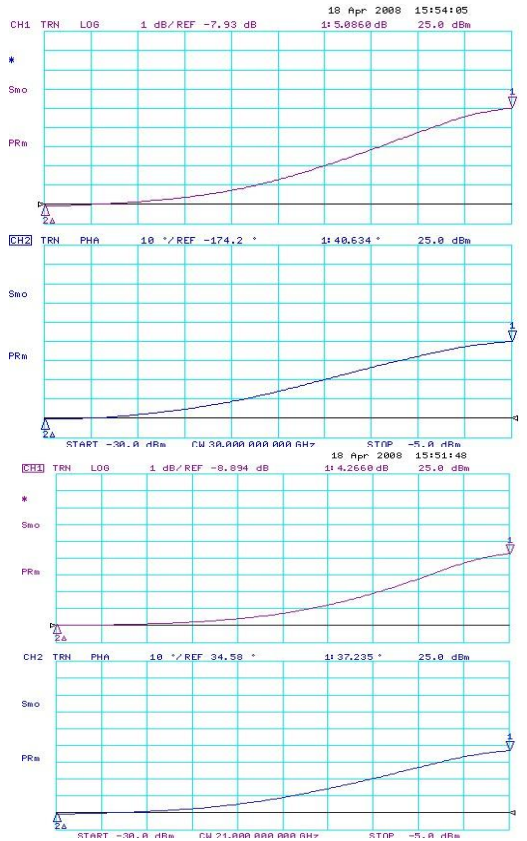




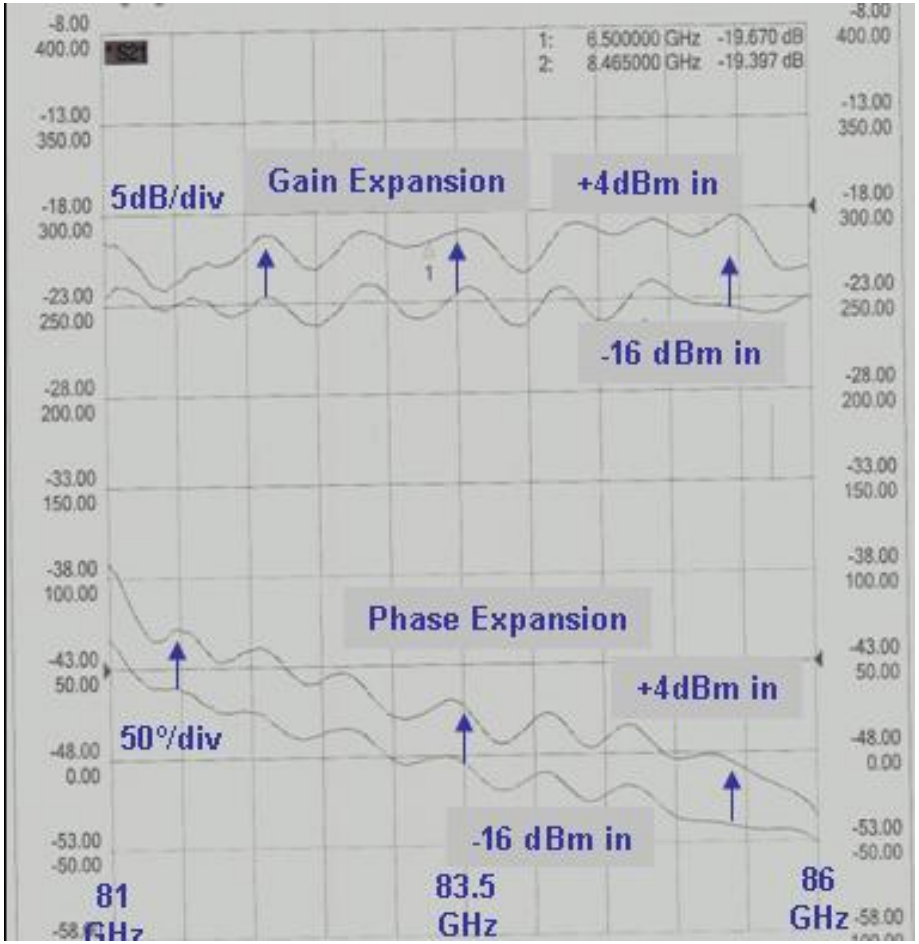
Very Wideband Linearizer

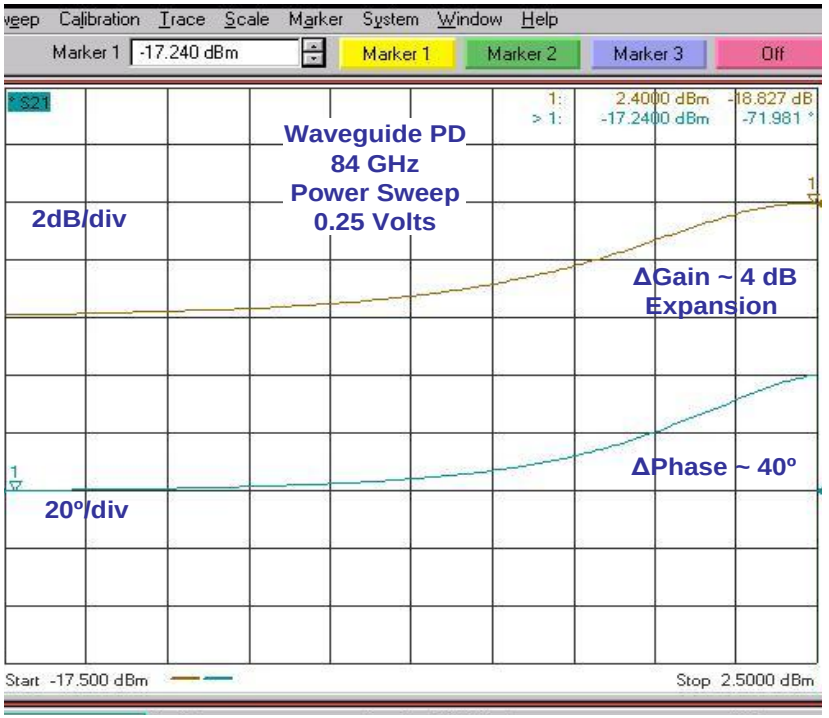
- BELOW IS SHOWN AN EXPERIMENTAL K-BAND WB LINEARIZER
- FOR TWTA APPLICATION (ΔG > 4 dB & ΔPHASE 40°)
- WITH BANDWIDTH > 10 GHz (<20 TO >30 GHz)



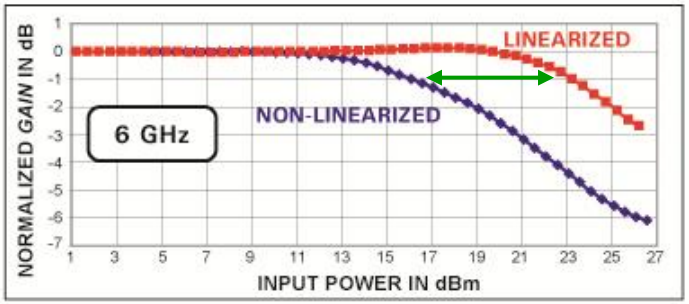


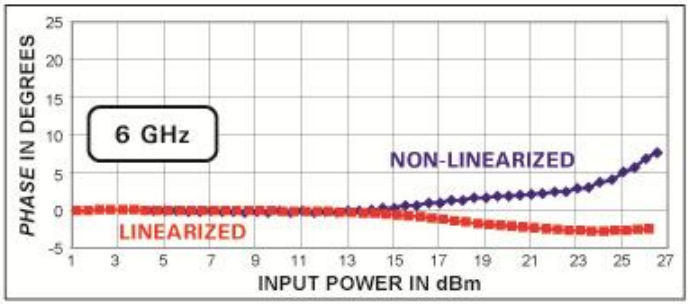
E-band Linearizer

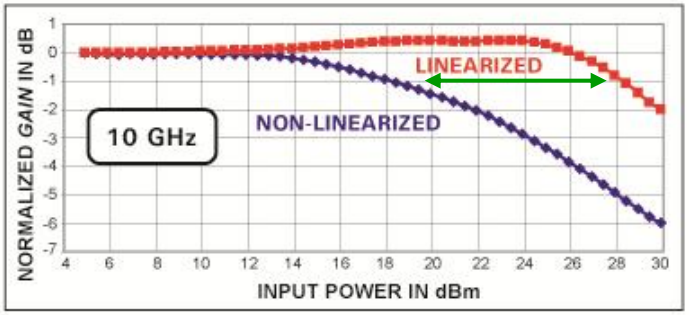


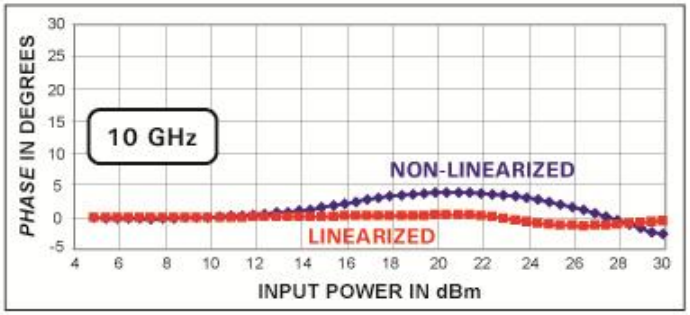


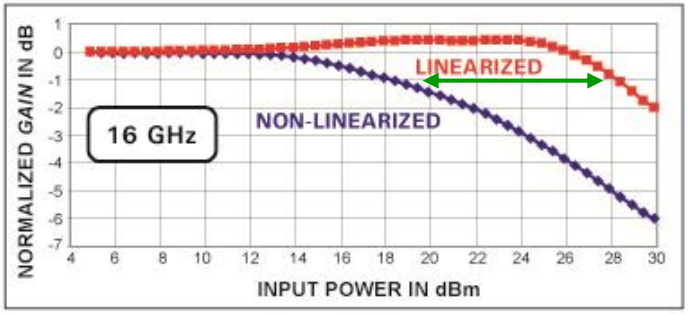
Very Wideband Results with GaN SSPA

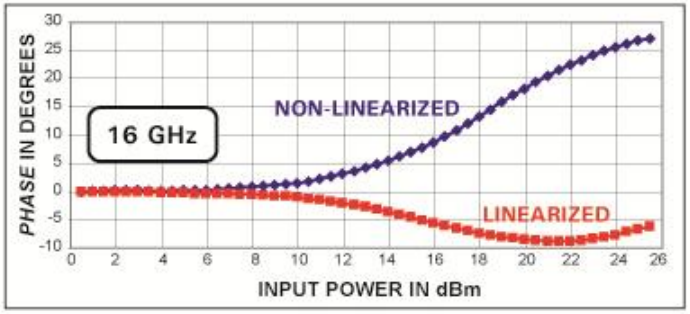








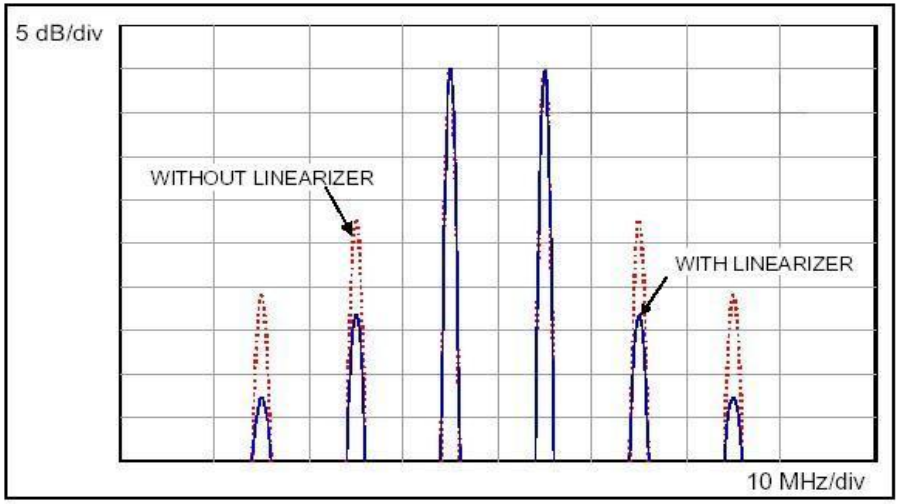


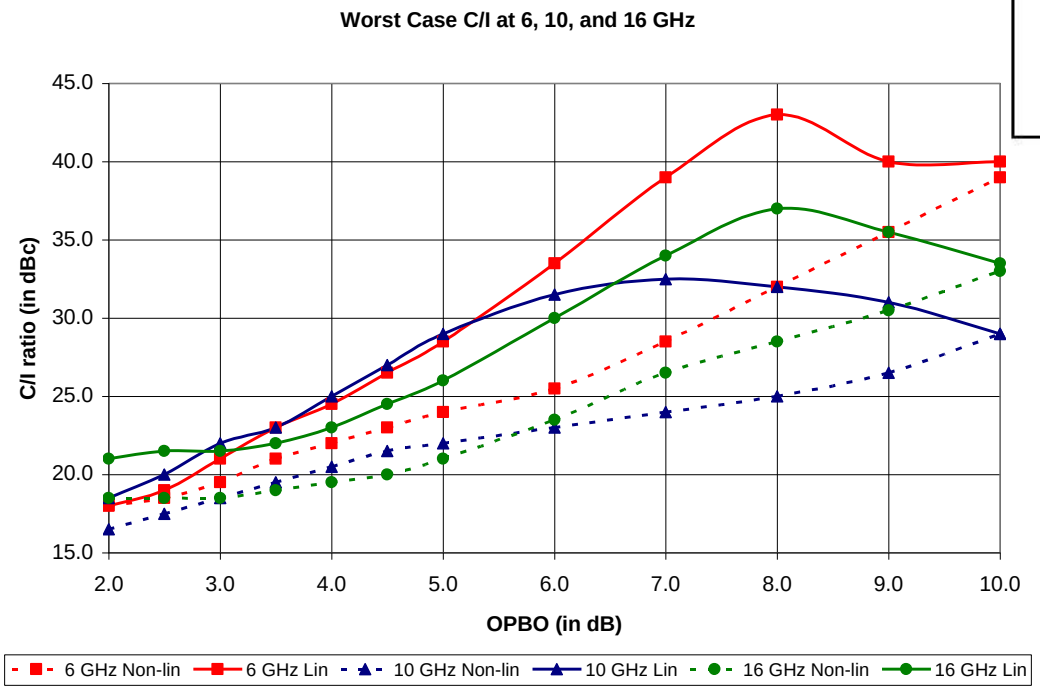


1 dB CP IS MOVED > 6 dB CLOSER TO SAT FROM 6 TO 16 GHz
PHASE SHIFT IS REDUCED FROM > 30° TO < 10 ° OVER THIS BAND

Very Wideband Results with GaN SSPA

2-TONE CARRIER TO INTERMOD (C/I) IS A COMMON MEASURE OF DISTORTION REDUCTION.



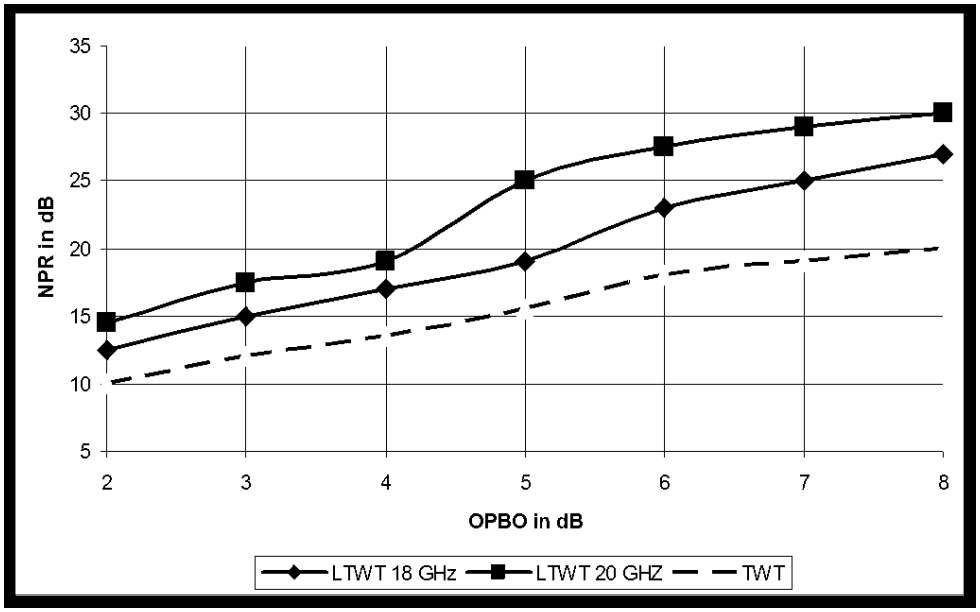


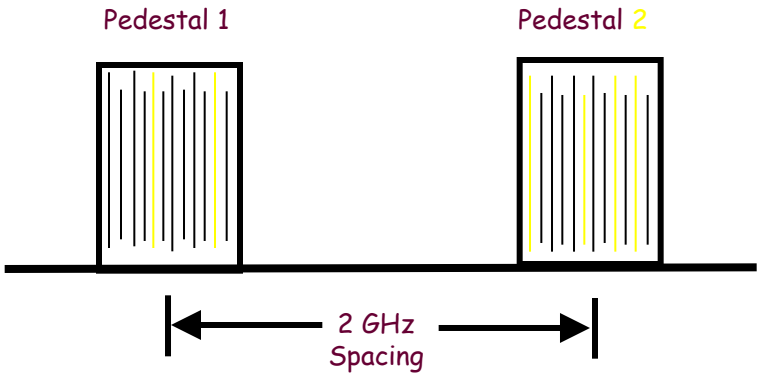
AT 6, 10 & 16 GHz:

C/I INCREASE OF 5-11 dB FOR OPBOs OF 5–8 dB

Very Wide Dynamic Bandwidth

- DYNAMIC BANDWIDTH IS A CONCERN AT MW.
- HPA's CAN HAVE A WIDE OPERATIONAL BANDWIDTH (corrects the distortion of a narrow, fractional, bandwidth signal across the full band.)
- BUT ALSO NEED TO WORK WELL WITH A VERY WIDE BAND SIGNAL, OR MULTIPLE WIDELY SPACED SIGNALS.

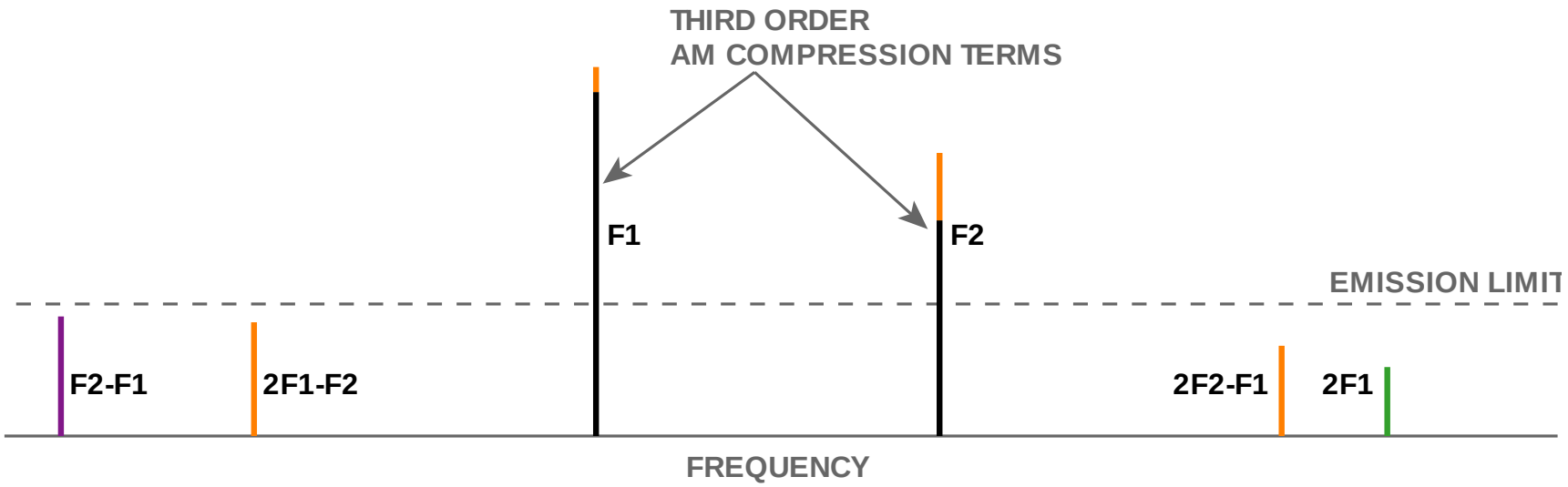




NPR of two noise pedestals linearized simultaneously

Multi-Octave Linearizer

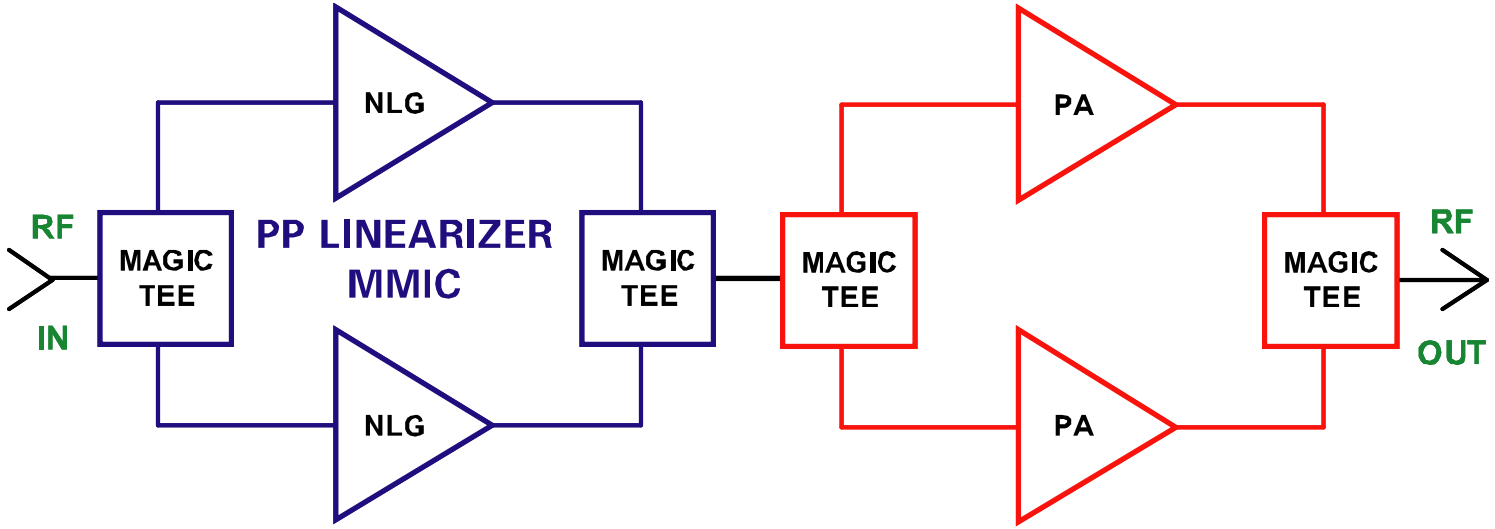
FOR WB AMPLIFIERS (> OCTAVE BW) - EVEN AND ODD ORDER DISTORTION MUST BE CONSIDERED



- IM AND HARMONIC DISTORTION A PROBLEM
- 2F1, F2-F1, 2F2-F1 AND 2F1-F2 PRODUCTS OF MOST CONCERN
- MOST PREDISTORTERS CORRECT ONLY ODD ORDER DISTORTION

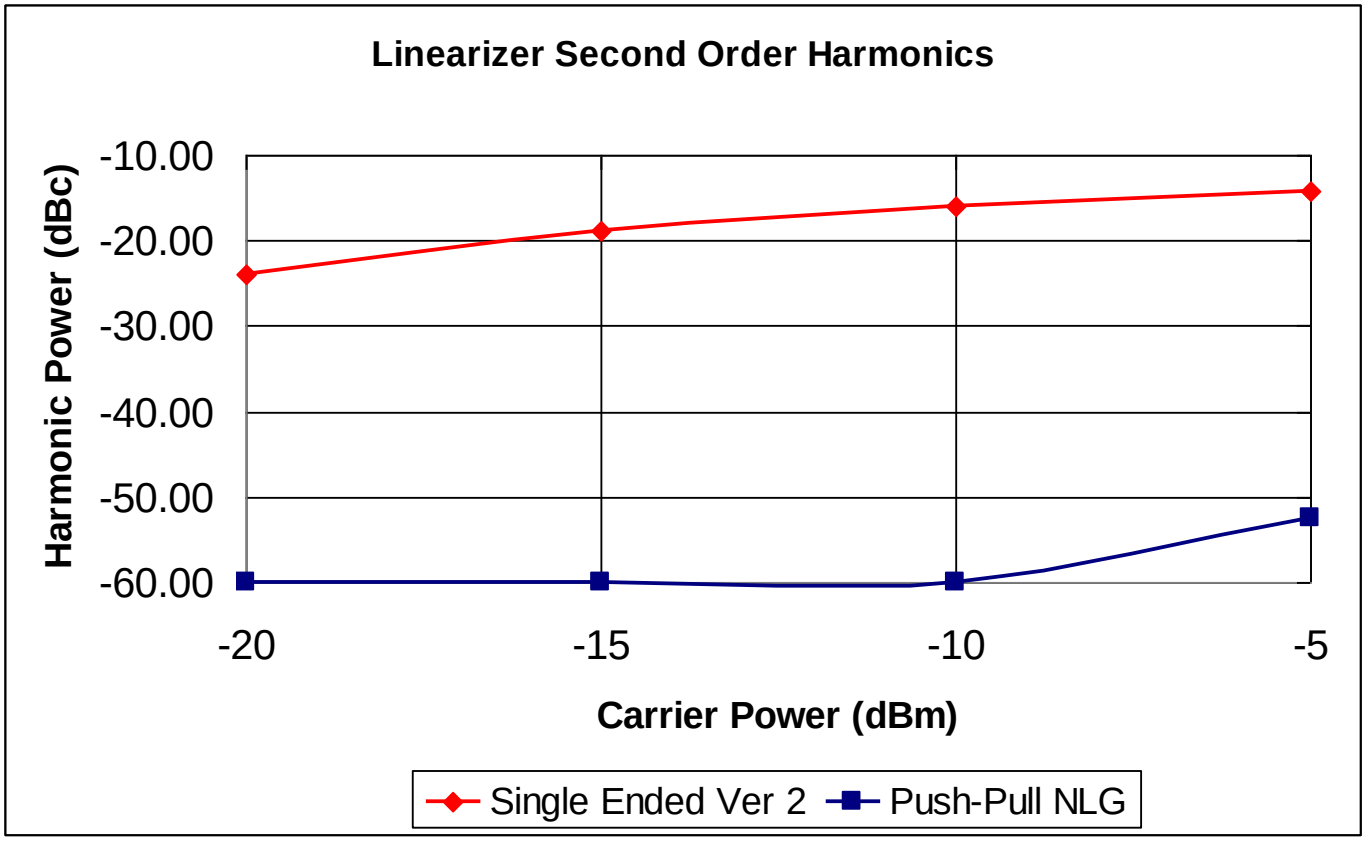
Multi-Octave Linearizer

UTILIZE PUSH-PULL PA/LINEARIZER DESIGN TO MINIMIZE EVEN ORDER DISTORTION



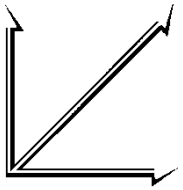
- USE *PRE-DISTORTION LINEARIZER* TO MINIMIZE ODD ORDER INTERMODULATION DISTORTION
- USE PUSH-PULL TO MINIMIZE 2^{ND} HARMONIC & F2-F1 PRODUCTS
- PUSH-PULL PROVIDES > 25 dB OF SUPPRESSION

Multi-Octave Linearizer



PUSH-PULL EVEN HARMONIC SUPPRESSION

- PA SHOWED SIMILAR RESULTS



Very Wideband Linearizers

+ ALLOWS OPERATION OVER A LARGE, CONTINUOUS AND UNRESTRICTED FREQUENCY BAND
+ ALLOWS USE OF VERY WIDEBAND MODULATIONS AND SPECTRAL SPREADING TECHNIQUES
+ CAN CORRECT FOR IN BAND HARMONIC (BOTH EVEN AND ODD ORDER) & F2-F1 PRODUCTS
+ MAY PROVIDE ENHANSED POWER BY CONTROL OF HARMONICS

− MORE DIFFICULT TO ALIGN
− REQUIRES EQUALIZING TWTA GAIN AND PHASE DELAY OVER FREQUENCY RANGE OF INTEREST
− GENERALLY, THE NARROWER THE BANDWIDTH THE BETTER THE PERFORMANCE THAT CAN BE ACHIEVED

Multi-band Linearizers

SWITCHING BETWEEN MULTIPLE SINGLE BAND LINEARIZERS IS ANOTHER WAY TO OBTAIN WB PERFORMANCE

DAUL & TRI BAND LINEARIZERS HAVE BEEN IN PRODUCTION FOR SEVERAL YEARS

Quad-BAND Linearized HPA Performance

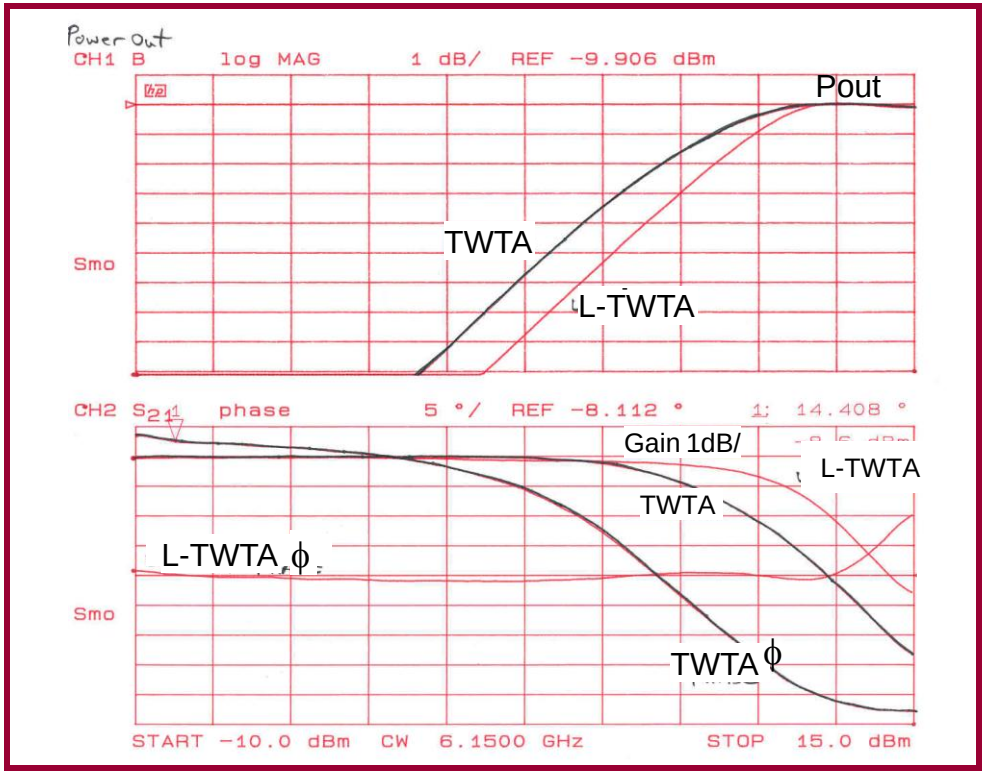
- A 6 TO 18 GHz TWTA WAS CORRECTED FOR DISTORTION OVER THE FULL C, X, KU, AND DBS SATELLITE BANDS WITH A QUAD-BAND LINEARIZER.

- THE L-TWTAs WERE FIRST POWER SWEPT USING A NETWORK ANALYZER AND ADJUSTED FOR ***FLAT* GAIN AND PHASE** VERSUS RF INPUT DRIVE.

- TESTING WAS THEN CONDUCTED WITH DIFFERENT SIGNAL SOURCES ON EACH BAND.

Quad-Band L-TWTA @ C-Band

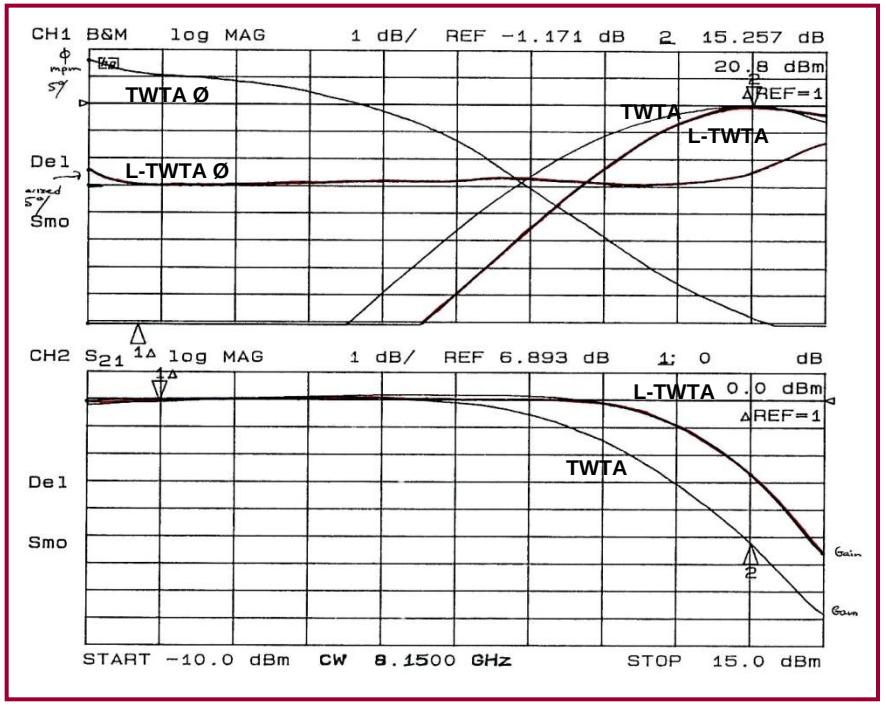
MAGNITUDE & PHASE ARE IMPORTANT INDICATORS OF PERFORMANCE



- 1 dB COMPRESSION POINT MOVED FROM ~ 5 dB FROM SAT TO < 2 dB
- ΔPHASE from SMALL SIGNAL TO SAT REDUCED FROM > 45° TO < 1°

Quad-Band L-TWTA @ X-Band

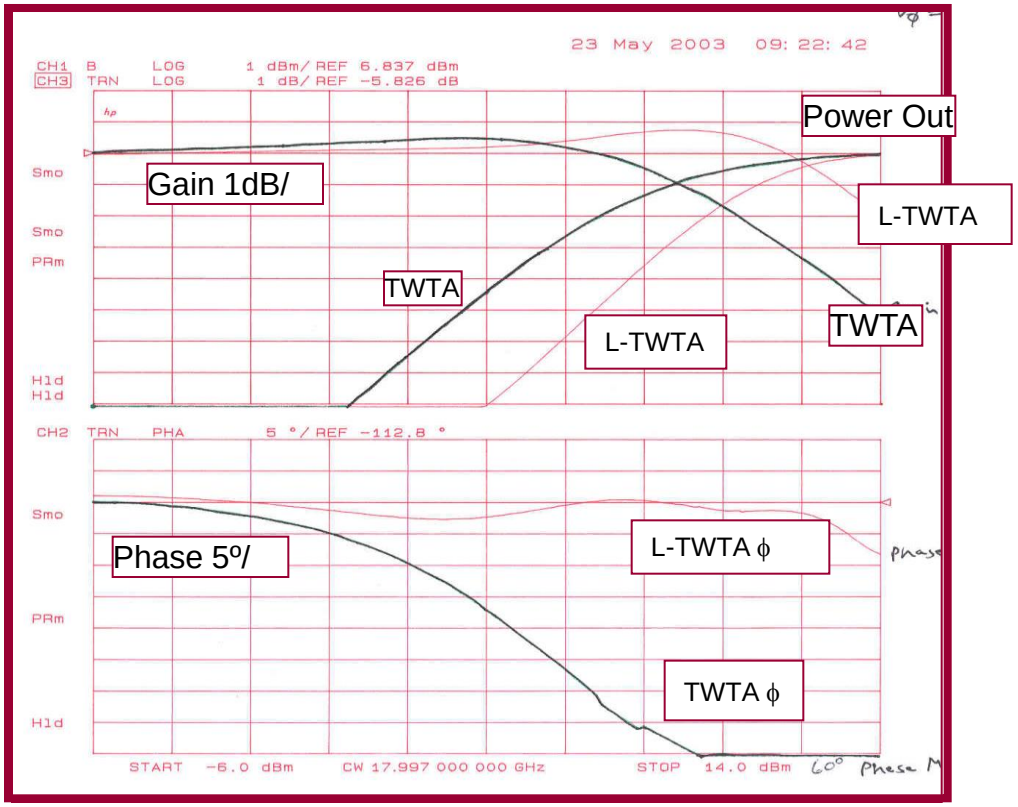
MAGNITUDE & PHASE ARE IMPORTANT INDICATORS OF PERFORMANCE



- 1 dB COMPRESSION POINT MOVED FROM ~ 6.5 dB FROM SAT TO < 2.5 dB
- ΔPHASE FROM SMALL SIGNAL TO SAT REDUCED FROM > 45° TO < 2°

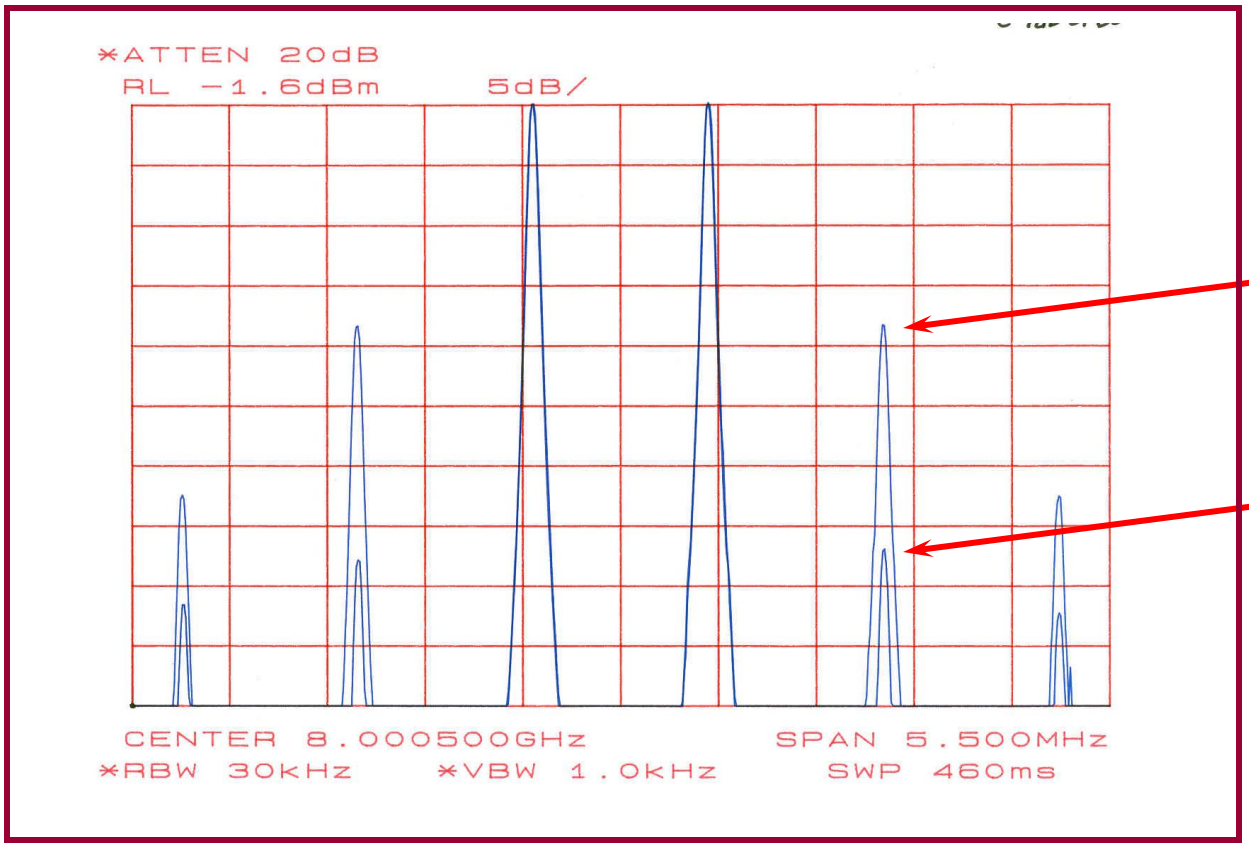
Quad-Band L-TWTA @ K-Band (DBS)

MAGNITUDE & PHASE ARE IMPORTANT INDICATORS OF PERFORMANCE



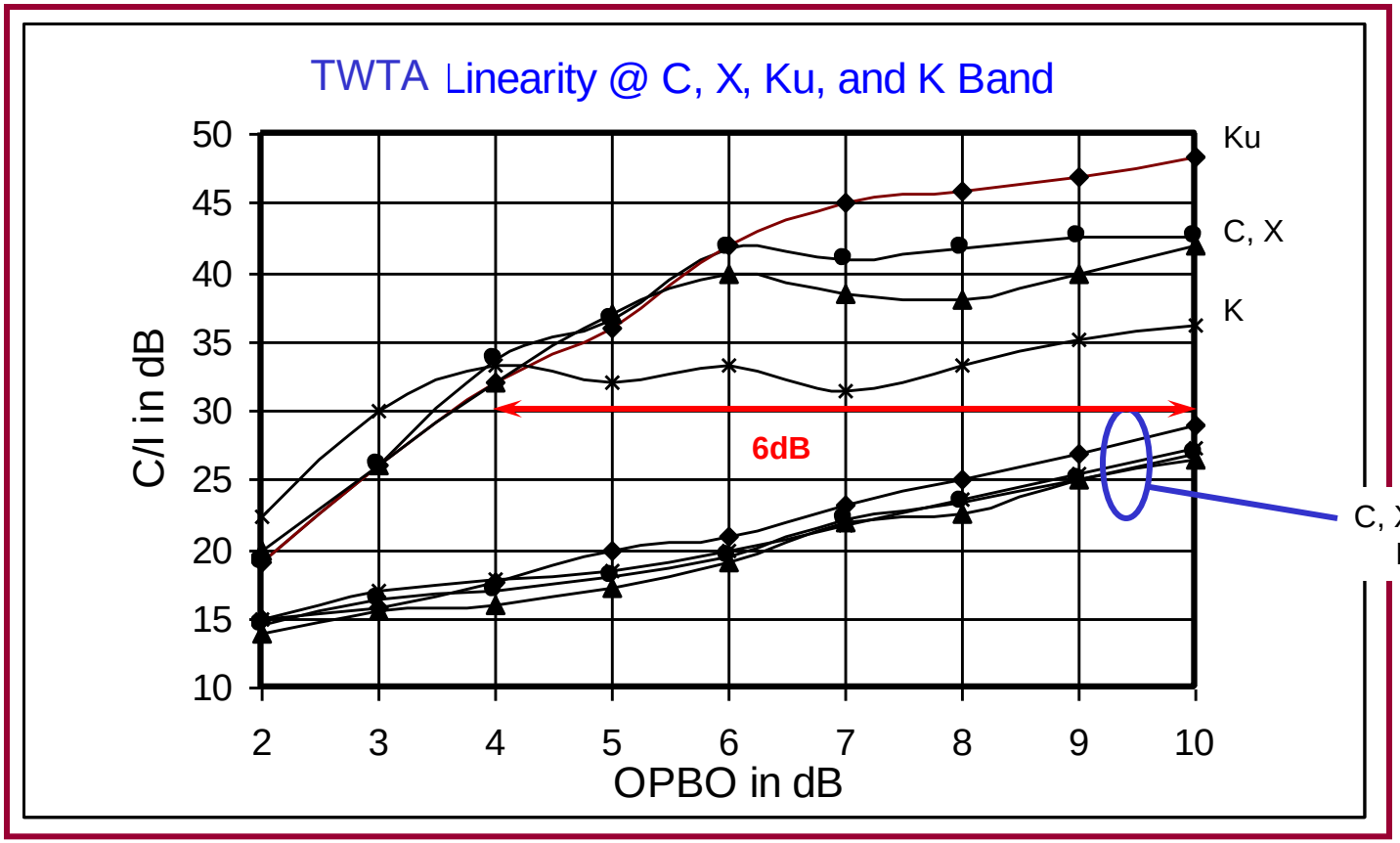
- 1 dB COMPRESSION POINT MOVED FROM ~ 4 dB FROM SAT TO < 0.5 dB
- ΔPHASE FROM SMALL SIGNAL TO SAT REDUCED FROM > 60° TO < 5°

Quad-Band: Reduction of 2-Tone IMD



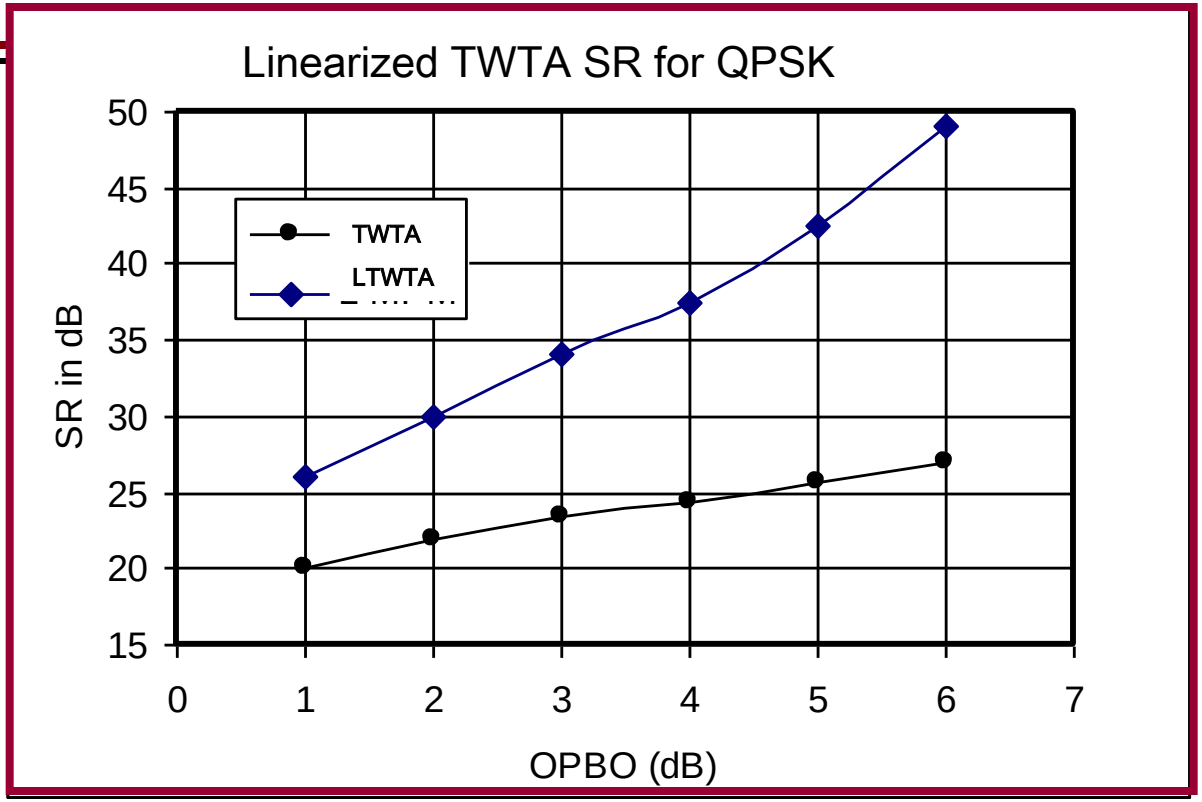
AT X-BAND THE LINEARIZER PROVIDES A 15 dB IMPROVEMENT
AT 4 dB OPBO WHEN OPTIMIZED

Quad-Band: Reduction of 2-Tone IMD



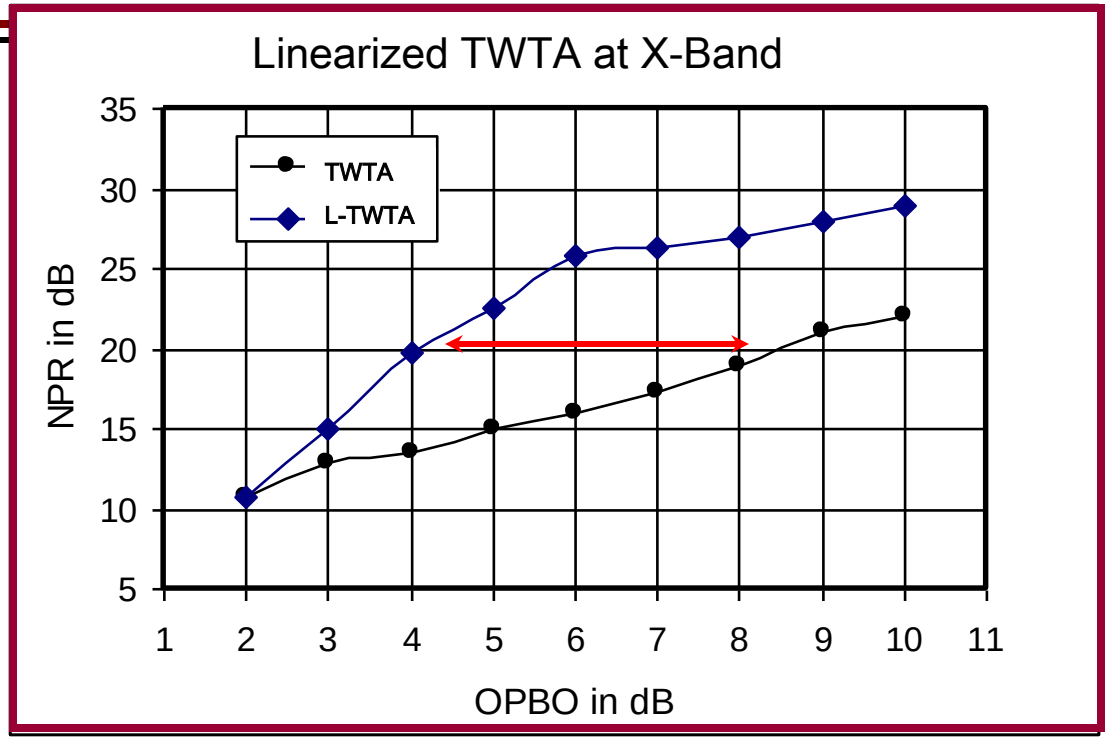
- >15 dB IMPROVEMENT IN C/I OBTAINED @ 5 dB OPBO BY LINEARIZING
- ALSO A >6 dB POWER INCREASE FOR C/IS > 30 dB

L-TWTA Spectral Regrowth



- SPECTRAL REGROWTH IS REDUCED BY > 20 dB AT 6 dB OPBO
- BPSK SHOULD YIELD ~ 1 dB POORER PERFORMANCE
- 8-PSK SHOULD YIELD ~ 1 dB BETTER PERFORMANCE

L-TWTA NPR/WCDMA Performance



- A 40 MHz NOISE PEDESTAL AT X-BAND WAS USED FOR THE NPR MEASUREMENT
- THIS IS A TYPICAL BW OF MOST SATELLITE TRANSPONDER CHANNELS
- THE RESULT: FOR AN NPR OF 20 dB, THE LINEARIZER ACHIEVES A 4.5 dB INCREASE IN EFFECTIVE OUTPUT POWER

Conclusions

- ✓ THE ABILITY TO LINEARIZE HPAs OVER VERY WIDE BANDWIDTH (> 10 GHz) IS CLEARLY ILLUSTRATED.
- ✓ THE ABILITY TO PRODUCE LINEARIZERS WITH DESIRED NON-LINEAR CHARACTERISTICS OVER A CONTINUIOUS MULTI-OCTAVE BANDWIDTH IS SHOWN.
- ✓ IMPROVEMENT OF BOTH IMD AND HARMONIC DISTORTION CAN BE OBTAINED.
- ✓ GREAT IMPROVEMENT OF C/I, SR AND NPR CAN BE ACHIEVED AT SELECT BANDS OVER A VERY LARGE BANDWIDTH (C TO K) BY COMBINING MULTIPLE LINEARIZERS.
- ✓ IN GENERAL THE NARROWER THE BANDWIDTH THE HIGHER THE IMPROVEMENT, BUT SUBSTANCIAL IMPROVEMENT OVER LARGE CONTINUOUS BANDWIDTHS OF MORE THAN AN OCTAVE CAN BE ACHIEVED.