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
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
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 (\(\Delta G > 4\) dB & \(\Delta\)PHASE 50°) APPLICATION
- WITH BANDWIDTH > 10 GHz (26 TO 36 GHz)
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
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
• 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

FOR WB AMPLIFIERS (> OCTAVE BW) - EVEN AND ODD ORDER DISTORTION MUST BE CONSIDERED
• USE PRE-DISTORTION LINEARIZER TO MINIMIZE ODD ORDER INTERMODULATION DISTORTION

• USE PUSH-PULL TO MINIMIZE 2\textsuperscript{ND} HARMONIC & F2-F1 PRODUCTS

• PUSH-PULL PROVIDES > 25 dB OF SUPPRESSION
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 ENHANCED 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.

Dual & Tri band linearizers have been in production for several years.
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

- 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

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°

MAGNITUDE & PHASE ARE IMPORTANT INDICATORS OF PERFORMANCE
Quad-Band L-TWTA @ K-Band (DBS)

MASSITUDE & 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
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
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
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 CONTINUOUS 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.