UHF GAN SSPA FOR SPACE APPLICATIONS

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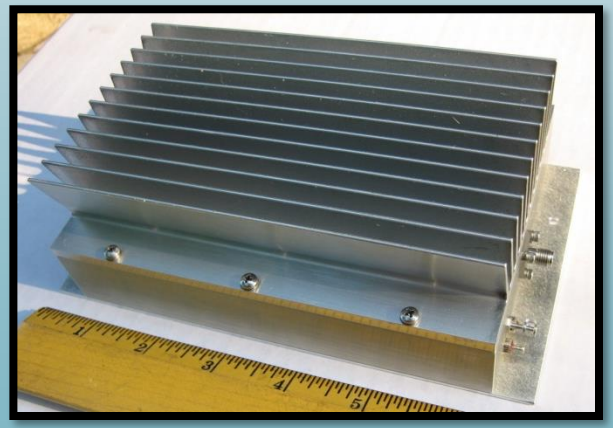
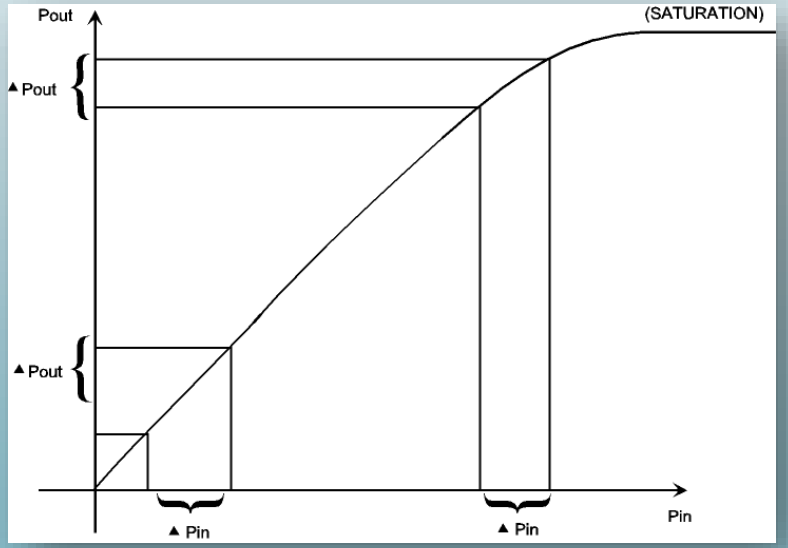


INTRODUCTION

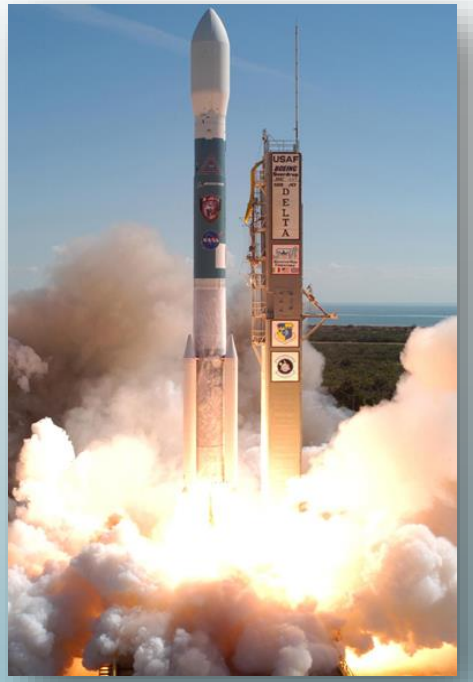
- OBJECTIVE: PRODUCE LINEAR UHF PA WITH HIGHEST POSSIBLE EFFICIENCY
- TARGET: **SPACE APPLICATIONS**

- NEED HIGHEST EFFICIENCY TO MINIMIZE DC POWER / BATTERY SIZE & WEIGHT
- FOR LINEAR OPERATION NEED TO BACKOFF
- THE HIGHER THE BACKOFF THE LOWER THE EFFICIENCY



GaN vs. GaAs AT UHF

- GaAs PAs
  - LONG HISTORY OF USE IN SPACE AT MICROWAVE
  - RECENTLY USED AT UHF FOR HIGH EFFICIENCY
  - PRIMARILY FOR SPACE (PAE > 60%)
  - LINEARIZATION USED FOR OPERATION CLOSER TO SATURATION
- GaN PAs
  - SHOW GaN FETS PROVIDES EVEN BETTER EFFICIENCY (PAE > 80%)
  - LINEARITY NOT AS WELL BEHAVED: LINEARIZATION EVEN MORE IMPORTANT



SSPA DETAILS

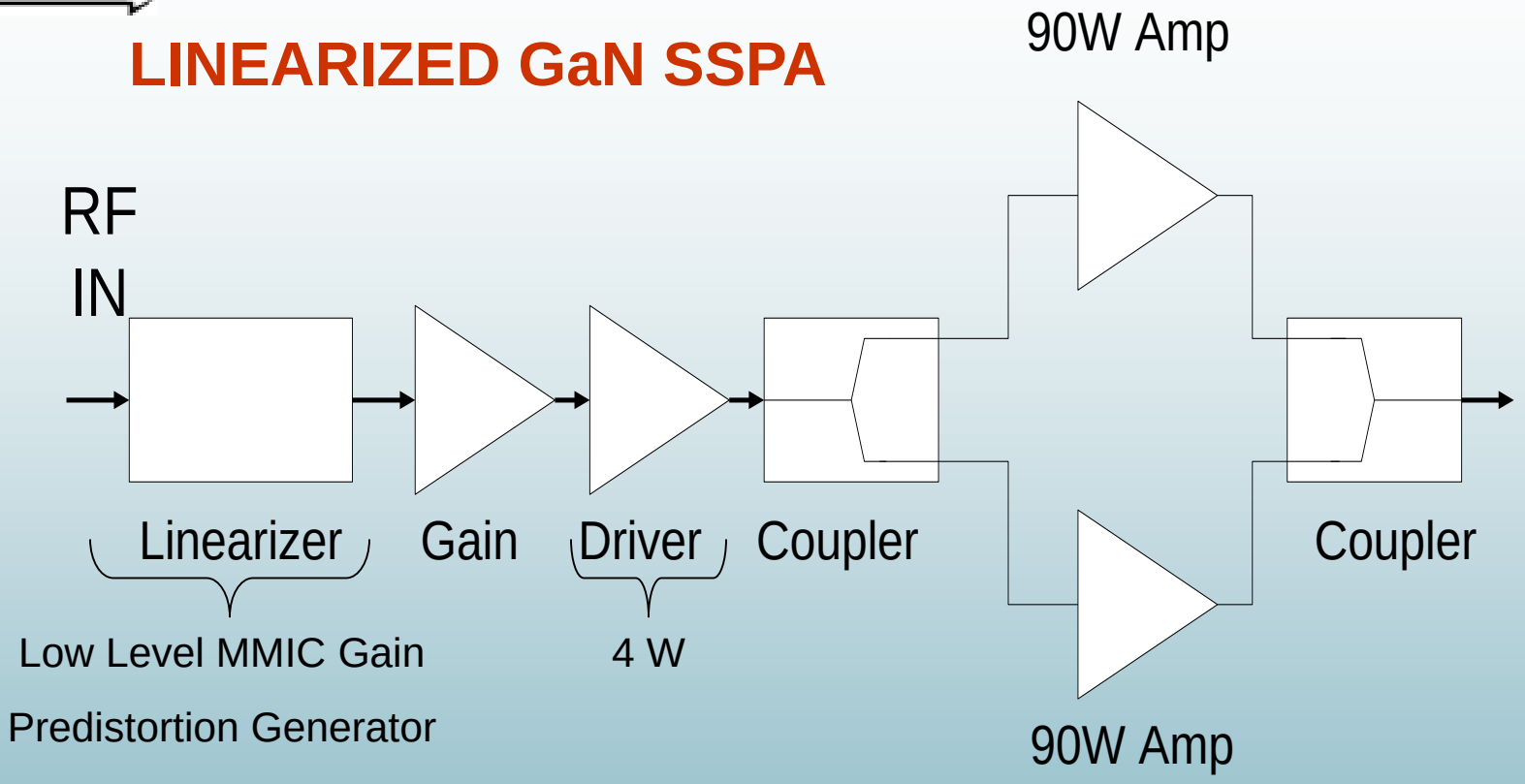
- OPERATES AT UHF (290-320 MHz & 360-380 MHz)
- POWER OUTPUT OVER 60 W
  - SELECTED EUDYNA EGN90MK GaN POWER FETS
- SATISFIES LINEARITY TYPICALLY REQUIRED FOR WCDMA SATELLITE LINK TRANSMISSION
- EMPHASIS ON ACHIEVING PEAK EFFICIENCY
  - USED ADVANCED ANALOG LINEARIZATION
- HIGH GAIN WITH EXCELLENT FLATNESS
- COMPACT AND LIGHT WEIGHT
- ELECTRONIC POWER CONVERTER

SSPA GOALS

Specification	Min	Max	Units	Conditions/Achieved	√
Linear Power	60	-	Watts	At linear oper. point	√
Efficiency (PAE)	80	-	%	At maximum power	√
Efficiency (PAE)	60	-	%	At linear oper. point	√
Operating band	291	318.3	MHz	360-380 MHz	√
VSWR		1.5:1		Z_o = 50 Ohms	√
Gain	30	-	dB	Small signal	√
Gain Flatness	-	+/- 0.5	dB	Over operating band	√
Spurious Signals	-	-60	dBc		√
ACLR		-25	dBc	WCDMA	√
EVM		17	%	WCDMA	√
PCDE		-34	dBc	WCDMA	√

DESIGN APPROACH

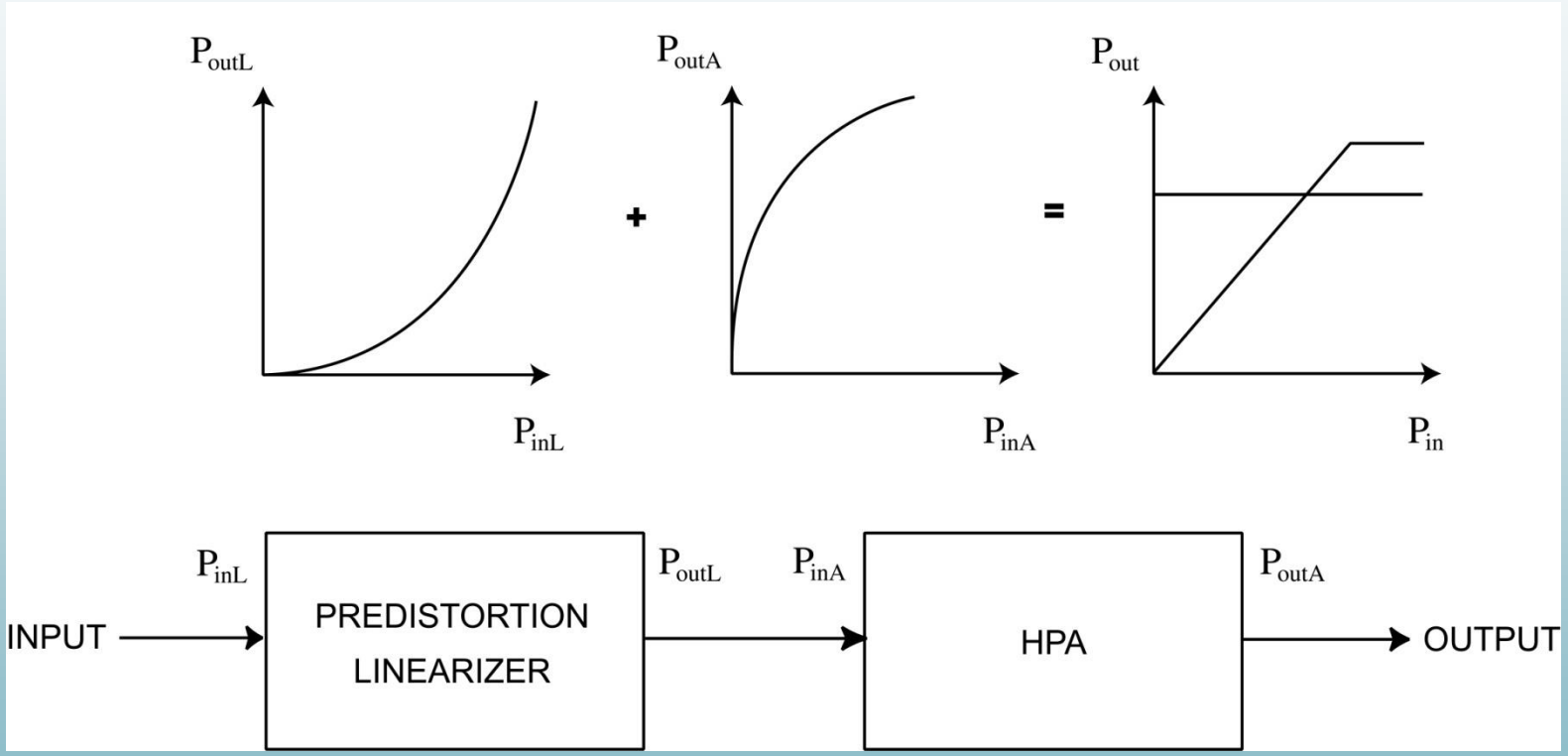
LINEARIZED GaN SSPA



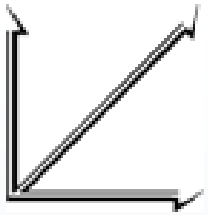
- USES 90 W GAN FET POWER STAGES BETWEEN COUPLERS
- OPTIMIZED FOR HIGH EFFICIENCY FROM 290 – 320 MHz

THE LINEARIZER

PREDISTORTION LINEARIZER – GENERATES FUNCTION WITH INVERSE MAG AND PHASE TO TRANSFER FUNCTION OF PA



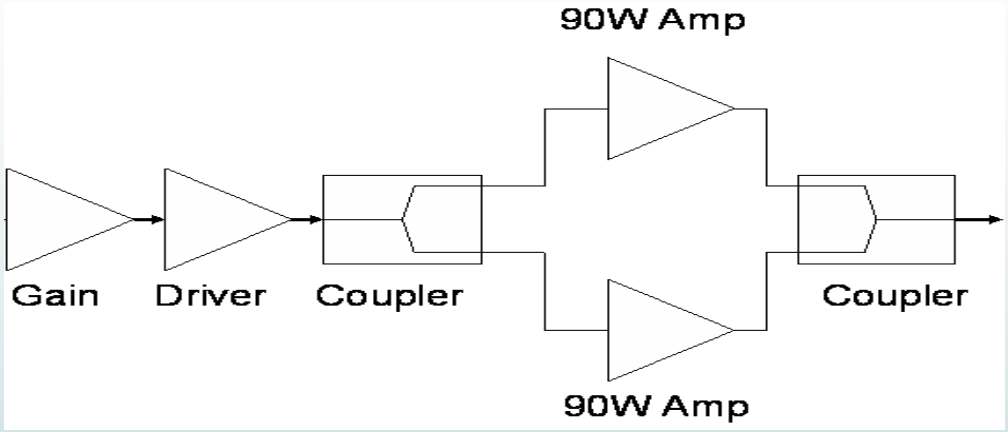
PREDISTORTS RF SIGNAL TO COMPENSATE FOR KNOWN NON-LINEARITIES IN PA FROM HIGHLY LINEAR OUTPUT



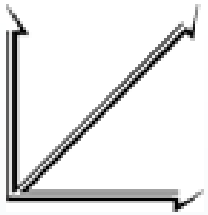
THE LINEARIZER

- GOAL OF SSPA: AMPLIFY AS EFFICIENTLY AND LINEARLY AS POSSIBLE – CONFLICTING
- INCREASE EFFICIENCY: DRIVE FET CLOSER TO SATURATION → SAME DISTORTION
- TWO CONTROLS
  - PHASE CONTROL: SETS PHASE CHANGE TO GAIN CHANGE RATIO FOR INCREASED INPUT
  - MAG CONTROL: SETS AMOUNT OF GAIN/PHASE INCREASE FOR GIVEN INPUT
- MOVED 1 dB COMPRESSION POINT OF SSPA 3 dB CLOSER TO SATURATION

POWER AMPLIFIER



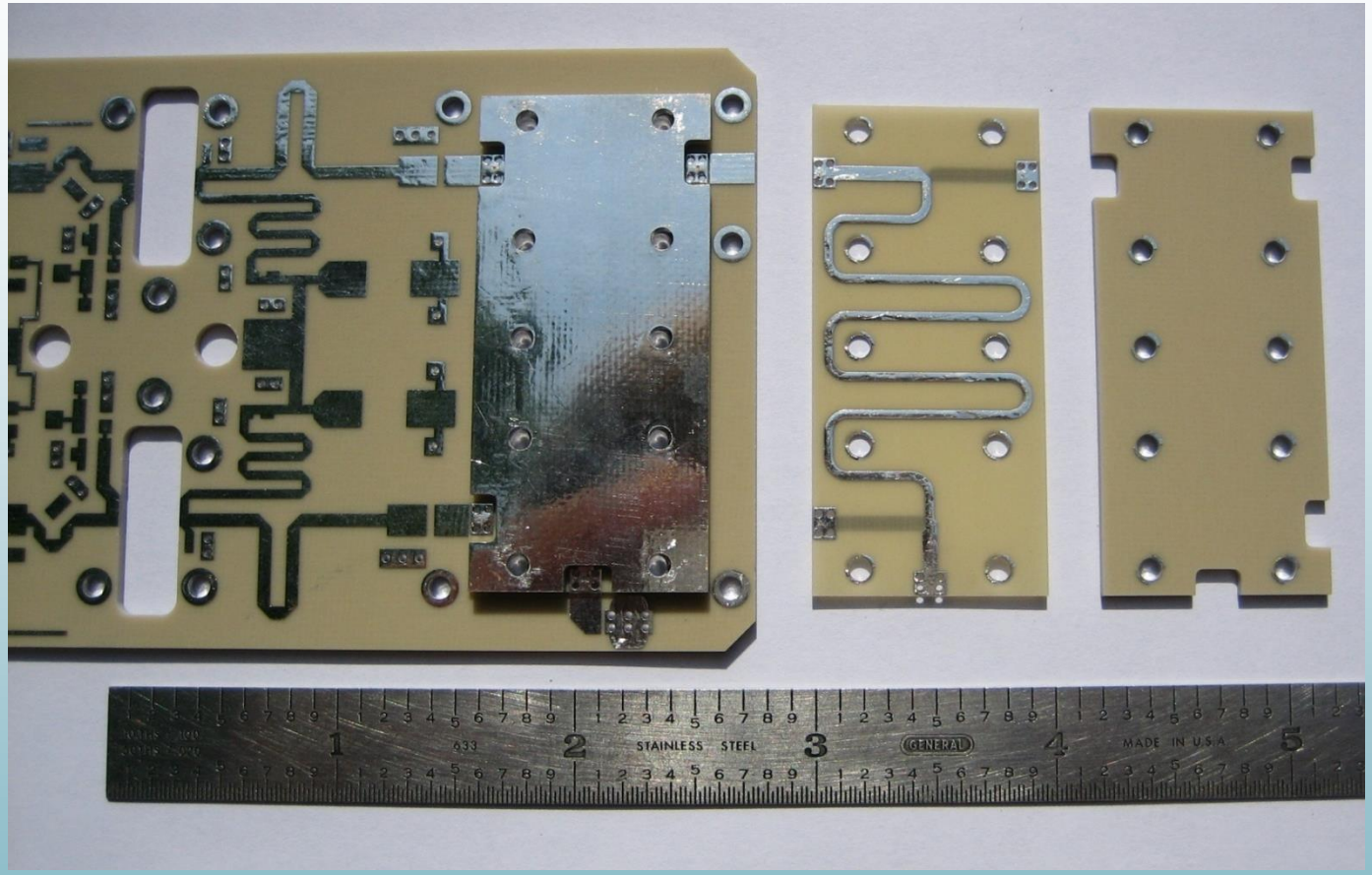
- GAIN AND DRIVER STAGES USED TO:
  1. OFFSET LOSSES FROM PREDISTORTER (10 dB)
  2. RAISE RF SIGNAL TO LEVEL REQUIRED TO DRIVE DUAL 90 W AMPLIFIERS
- CONSISTS OF:
  - ONE EUDYNA EGN004MK GaN FET (4 W)
  - TWO EUDYMA EGN090MK GaN FETS (90 W)
  - BROADSIDE COUPLERS (LOW INSERTION LOSS)



POWER AMPLIFIER

- USES MICROSTRIP INTERCONNECTIONS ON ROGERS 4003 LOW DIELECTRIC 32 MIL MATERIAL
- WITH MULTIPLE VIA HOLES FOR A GOOD GROUND RETURN
- PROPER DESIGN OF DRAIN AND GATE DECOUPLING IS IMPORTANT *(MEMORY EFFECTS*).
  - GaNs' RELATIVE LOWER CURRENTS MAKE LESS CRITICAL
  - GaAs DEVICES' LARGE CURRENTS CAUSE MEMORY EFFECTS
- THE IMPEDANCE OF THE MATCHING NETWORKS AND BIAS CIRCUITS AT THE SECOND HARMONIC FREQUENCY IS AN IMPORTANT CONTRIBUTOR TO PA EFFICIENCY

BROADSIDE COUPLER



- MULTI-LAYER STRIPLINE DESIGN
- LOW INSERTION LOSS

TEST RESULTS

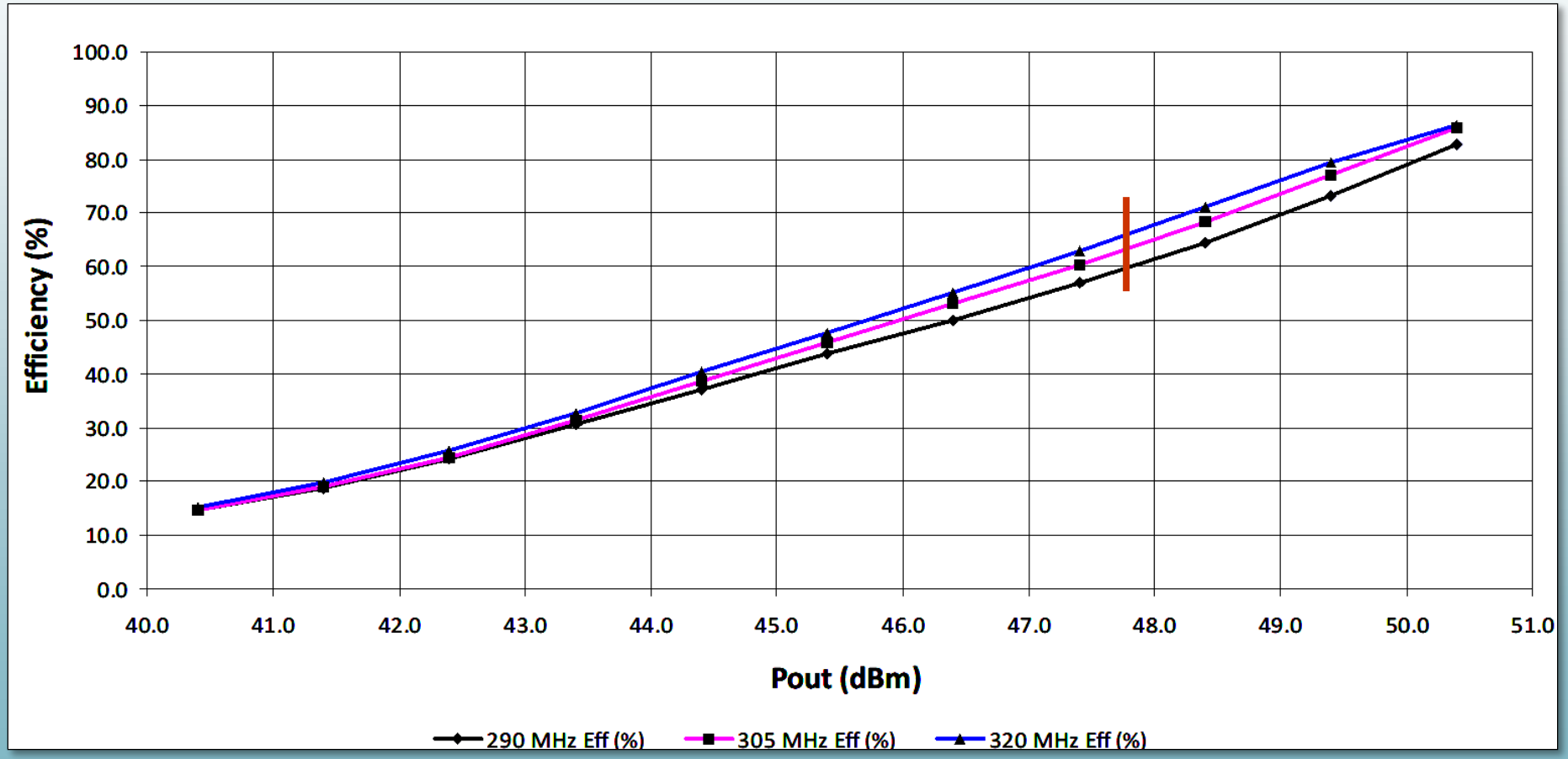
DATA AT CENTER BAND (305 MHz):

At Saturation →

OPBO (dB)	P_{in} (dBm)	P_o (dBm)	VDC	IDC	P_o (W)	PAE: (%)
0	**-26.9**	**50.4**	**40.03**	**3.19**	**109.65**	**85.87**
1	-31.8	49.4	40.07	2.82	87.10	77.08
2	-34	48.4	40.11	2.53	69.18	68.18
3	**-35.5**	**47.4**	**40.14**	**2.27**	**54.95**	**60.31**
4	-36.8	46.4	40.17	2.05	43.65	53.01
5	-37.7	45.4	40.19	1.88	34.67	45.89
6	-38.5	44.4	40.20	1.77	27.54	38.71
7	-39.5	43.4	40.21	1.73	21.88	31.45
8	-40.5	42.4	40.20	1.76	17.38	24.56
9	-41.5	41.4	40.20	1.80	13.80	19.08
10	-42.6	40.4	40.19	1.85	10.96	14.75

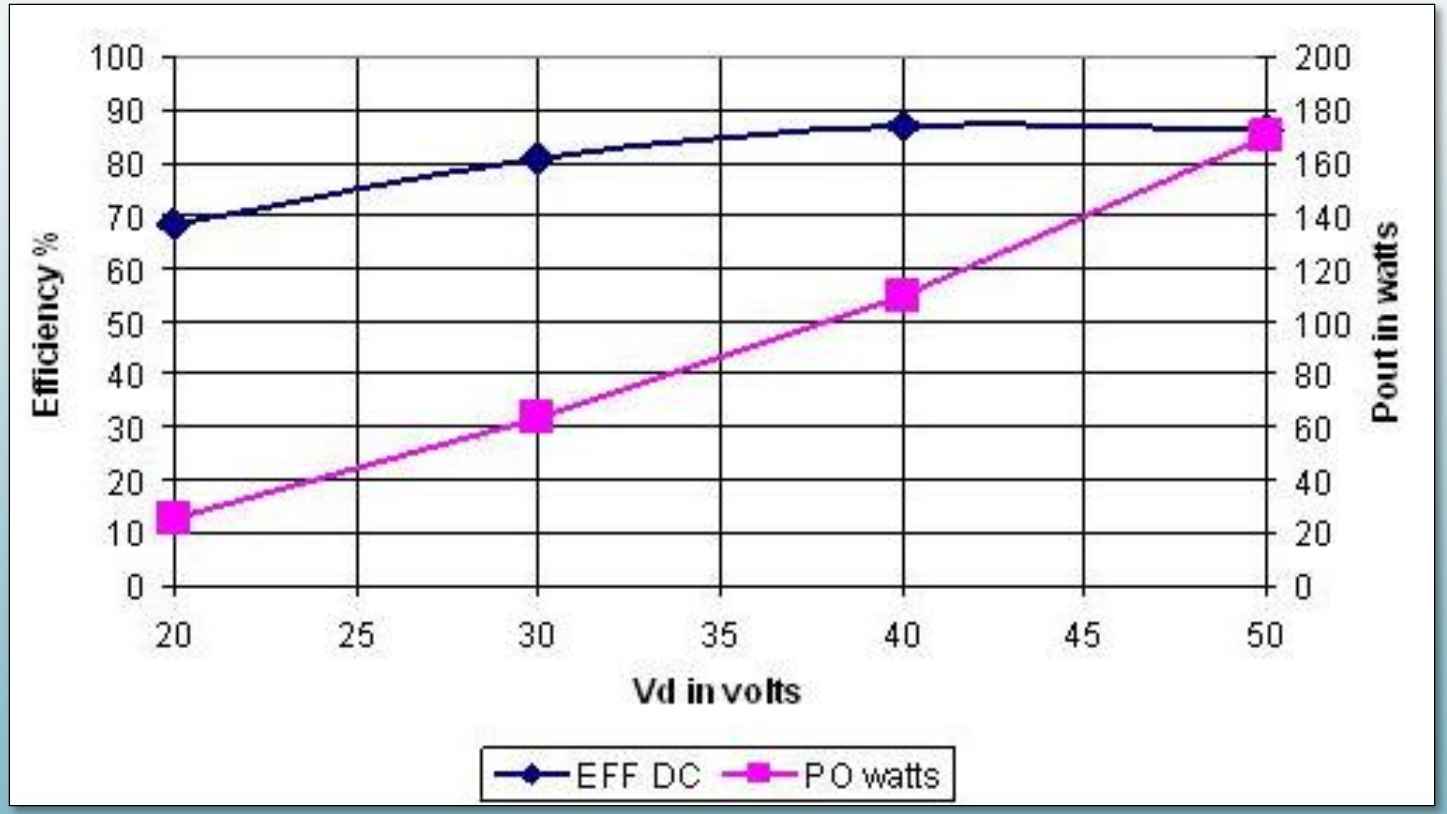
POWER ADDED EFFICIENCY

PAE over band vs. output power in dBm (40 V, 2.5 A):



DRAIN VOLTAGE VARIATION

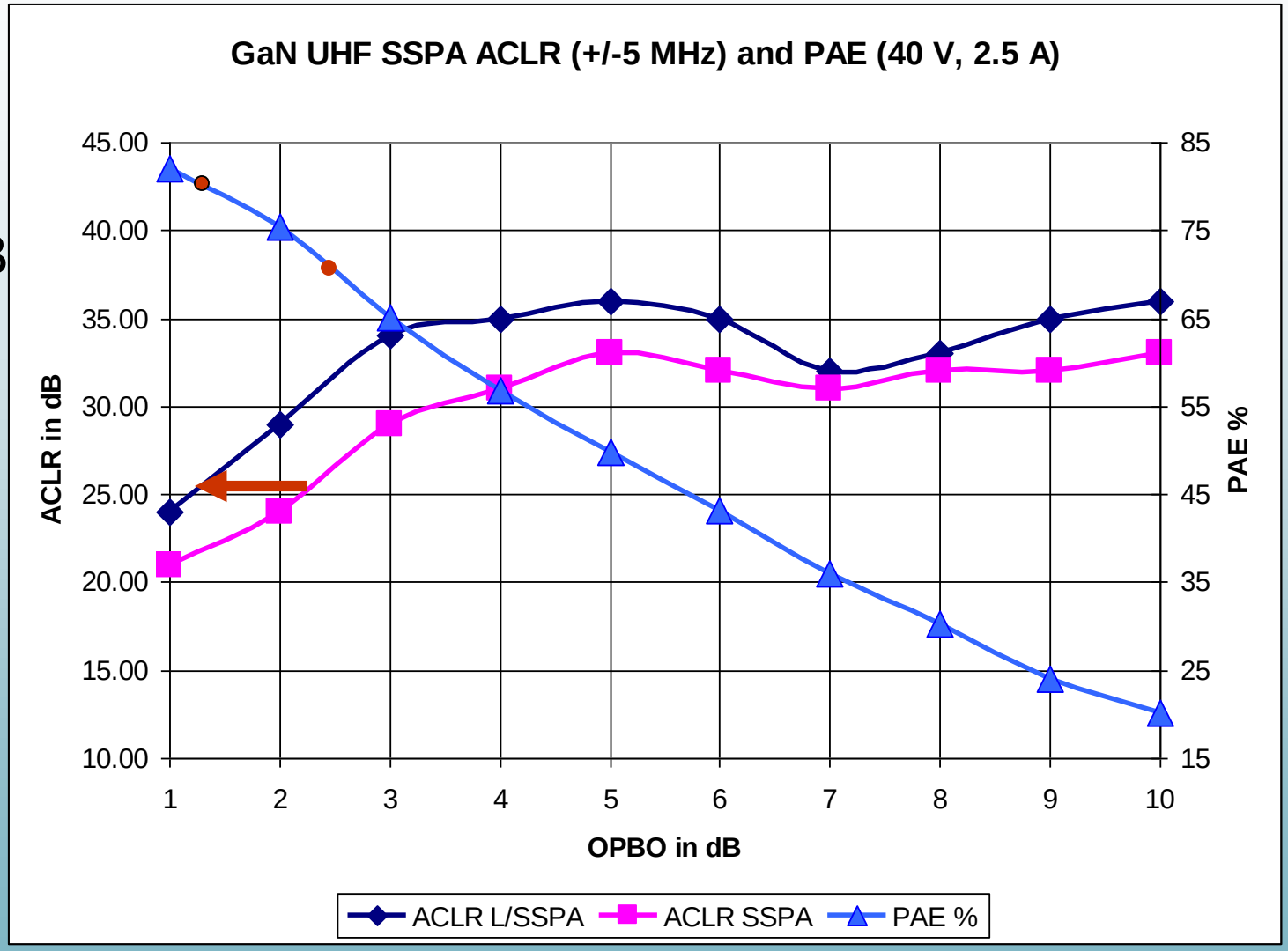
DC EFFICIENCY AND POWER VS. DRAIN VOLTAGE:



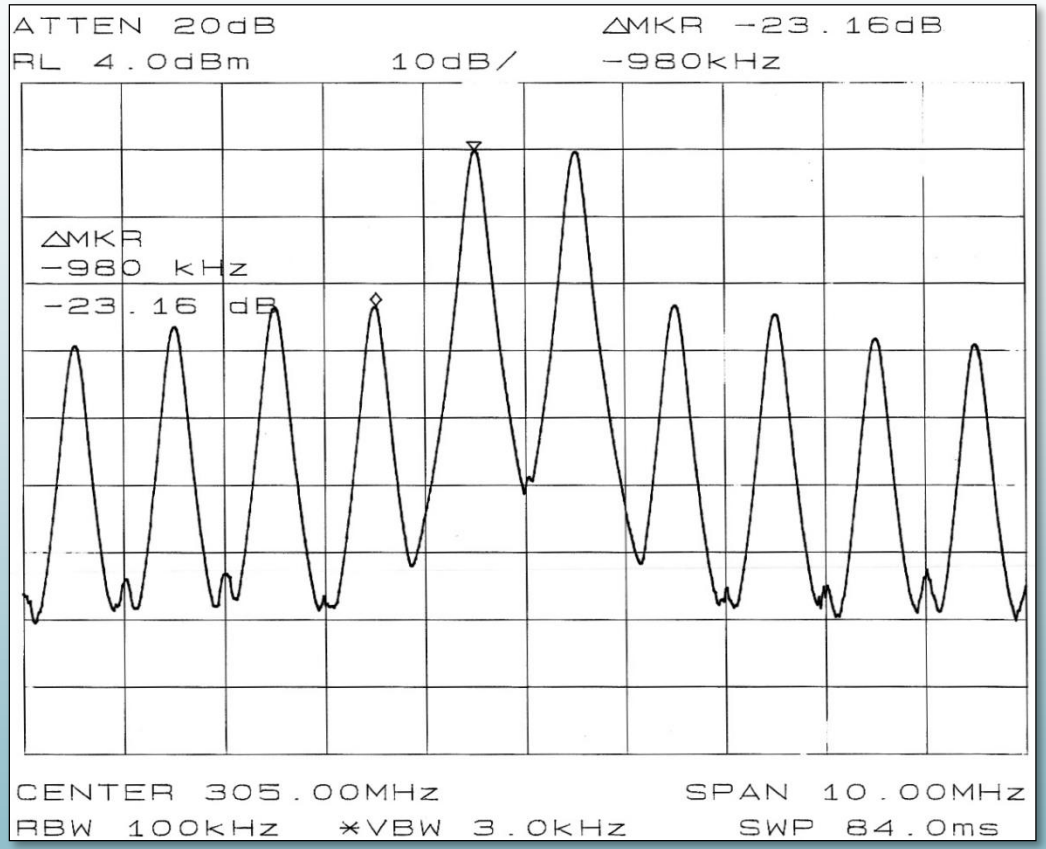
EFFICIENCY > ~70% FROM 20 TO 50 V

WCDMA ACLR & PAE

- ACLR -25 dB
- OPBO 1.2 dB
- PAE ~80%

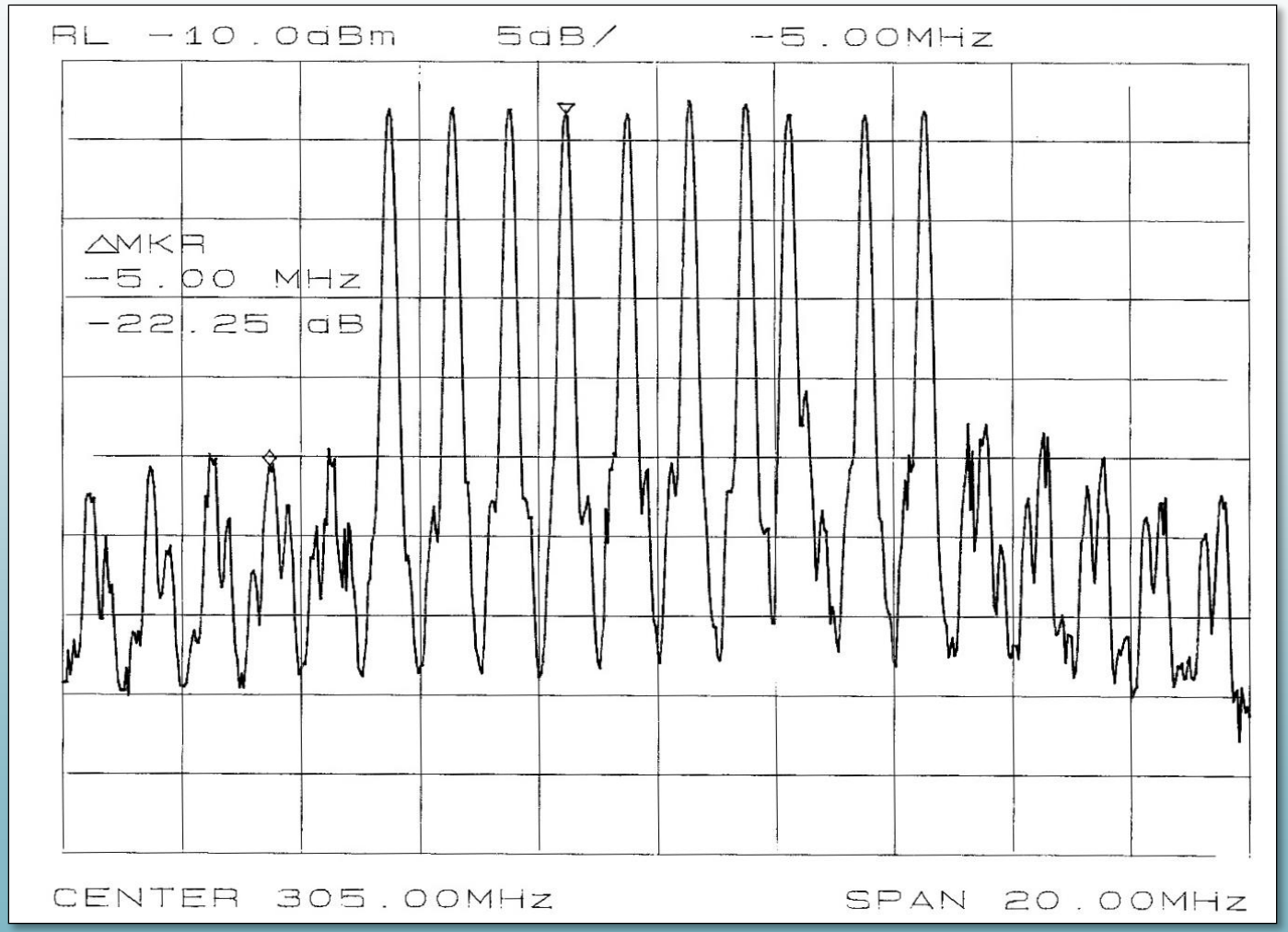


MULTI-TONE C/I PERFORMANCE

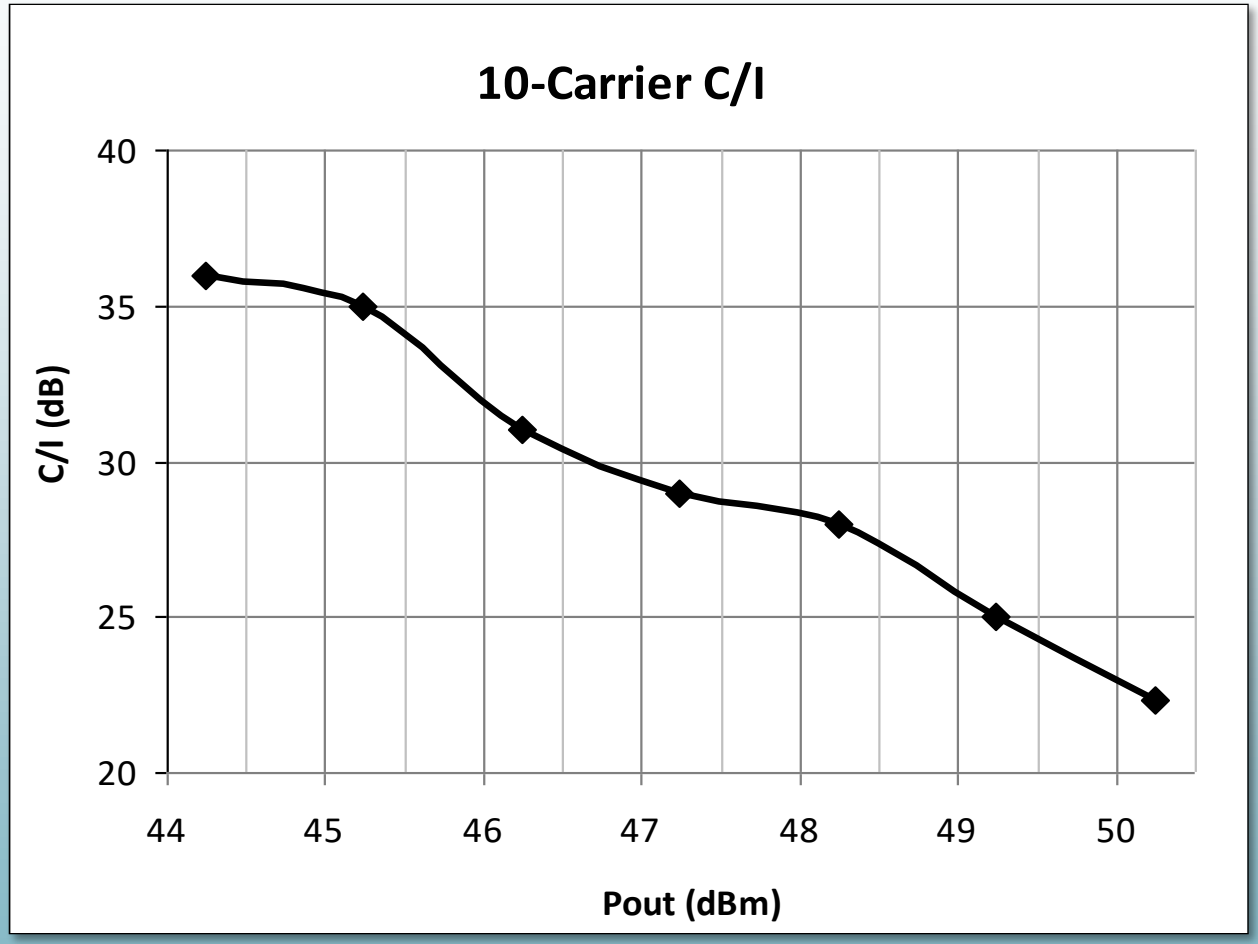


ACHIEVED C/I OF 25 dB AT SLIGHTLY > 2 dB OPBO WITH LINEARIZATION

TEN CARRIER C/I AT 2 dB OPBO

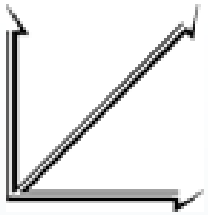


10-CARRIER C/I PERFORMANCE



- BIASED 50 V AND Iq 2.5 A
- OPBO 2 TO 8 dB
- CENTERED 305 MHz

10-TONE C/I > 25 dB ACHIEVED AT 3 dB OPBO



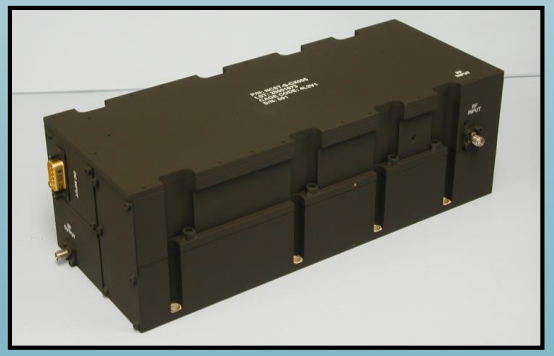
ACHIEVED

- EMPHASIS ON EFFICIENCY
  - PEAK EFFICIENCY APPROACHES 90%
  - > 84% EFFICIENCY ACROSS 290 TO 320 MHZ BAND
  - MAINTAINS EFFICIENCY OVER WIDE POWER RANGE (~20 TO > 110 W)
- ADVANCED ANALOG LINEARIZATION
  - QPSK SPEC. REGROWTH > 20 dB AT 0.5 dB OPBO (~ 85% EFF)
  - WCDMA ACLR 25 dB AT 1.2 dB OPBO (~80% EFF)
  - 2-TONE C/I of 23 dB AT 2.5 dB OPBO (~ 65% EFF)
- COMPACT & LIGHT WEIGHT
  - 6” X 4” X 1” (TEST PA WITHOUT EPC)
- HIGH GAIN WITH EXCELLENT FLATNESS
  - > 30 dB SMALL SIGNAL GAIN WITH ±0.5 dB FLATNESS

CONCLUSION

- PROVIDED > 60 W OF LINEAR OUTPUT POWER FROM 290 – 320 MHz (& 360-380 MHz)
- WCDMA ACLR ~25 dB, PAE ~80% at P_0 of 80 W, SATURATED PAE ~85%
- SHOWS THAT PREDISTORTION LINEARIZATION COMBINED WITH HIGH VOLTAGE GaN DEVICES CAN PROVIDE LINEARITY AND HIGH EFFICIENCY
- READY FOR SPACE APPLICATIONS AT UHF

OUR THANKS TO ONR NSWC DAHLGREN FOR SUPPORTING THIS WORK UNDER CONTRACT NUMBER N00178-08-C-3010.



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