High Power Amplifier High Order Modulation Response

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Abstract

Worldwide demand for high power amplifiers for digital satellite communication at Ka-band frequencies between 27 and 31 GHz is steadily increasing. CPI has developed a family of high power amplifiers using different power devices, each tailored for various uplink applications. The Helix Traveling Wave Tube (TWT), Extended Interaction Klystron (EIK) and the Millitron Coupled Cavity TWT each have specific niches in the power/bandwidth continuum. Data will be presented to directly compare performance using three common methods: Intermodulation, Noise Power Ratio, and ACPR (Adjacent Channel Power Ratio). CPI's Satcom Division has integrated the devices into High Power Amplifiers (HPAs) suitable for antenna hub-mount applications. The amplifiers use pre-distortion networks to provide a high degree of linear response when operated in output power back-off mode.

High Power Device Design Overview

The three most common devices used for uplinks over 100 watts are the Helix Traveling Wave Tube, the Extended Interaction Klystron (EIK) and the Millitron Coupled Cavity TWT. Each has differences in design, which are summarized below. In general, the broadest band device is the Helix TWT and the highest power device is the EIK, with the Millitron taking the middle ground in both power and bandwidth. Other key differences are shown in Table 1:

Table 1: Typical Ka band device Operating Parameters

Parameter	Helix TWT	EIK	Millitron	Units
Beam Voltage	13.5	7.7	16.0 – 17.0	kV
Beam Current	0.135	0.40	0.390 – 0.440	A
Control voltage	Anode	Anode	Focus electrode	-
Peak power	250	850	500	W
Average power	125	850	500	W
Focusing Method	PPM	PM	PPM	-
Circuit Sections	3	2	2	-
Collector Stages	2	1	2	-
Collector Depression	38% / 18%	70%	30% / 20%	Stage1 / Stage 2
Saturated Gain	49	50	33 – 42	dB
Small Signal Gain	53	53	37 – 48	dB
Frequency	27.0 – 30.0	29.8 – 30.0	28.35 – 29.50	GHz
Instantaneous Bandwidth	3000	200	1100	MHz
Prime Power (typical)	460	2156	1700	Watts
Size (L×W×H)	15.8 × 2.2 × 2.7	15 × 7 × 7	12.9 × 3.6 × 3.4	Inches
Weight	7.5	25	13	Pounds

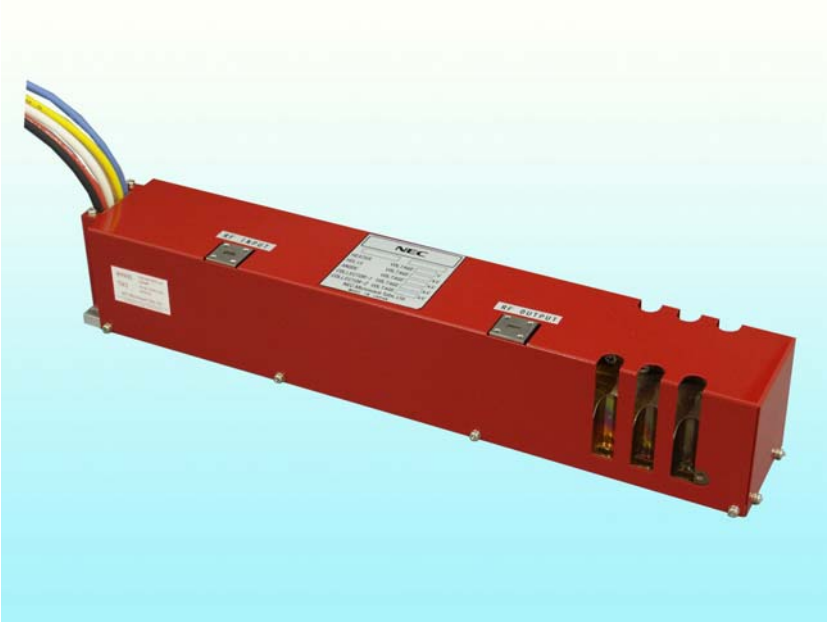


Figure 1. 250 W peak Helix TWT (courtesy NEC)

Figure 2. CPI VTA-2400 850 W EIK

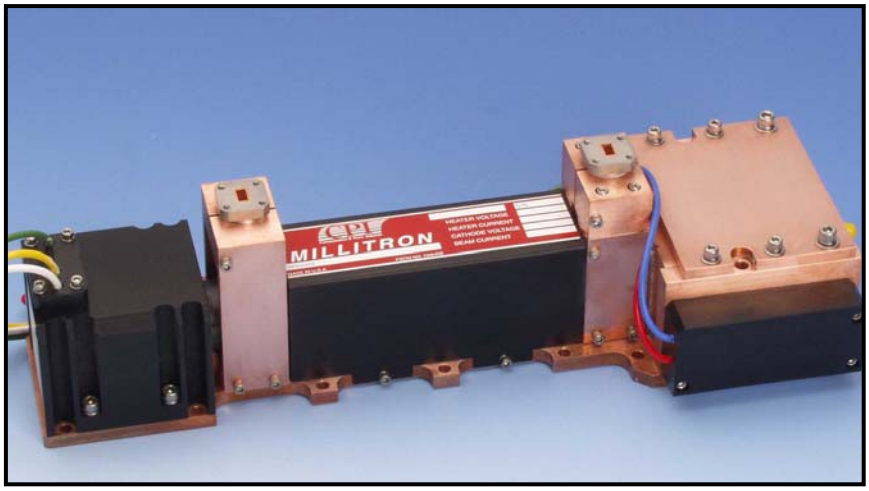


Figure 3. VTA-6430A2 Millitron Coupled-Cavity Traveling Wave Tube

Ka-Band 500 Watt Outdoor Packaged Amplifier

CPI's Satcom Division has incorporated the VTA-6430A2 TWT into a packaged amplifier suitable for wideband, single- and multi-carrier satellite service. The amplifier is compact and weatherproof for outdoor and antenna hub-mount applications. Bandwidth of the Millitron is up to 1650 MHz, more than adequate for most modern systems. Figure 4 shows the conduction-cooled HPA enclosure that houses the TWT and lists typical operating specifications.

Frequency: 28.35 to 30.0 GHz
Output Power: 400Watts
Bandwidth: 1650 MHz
Gain: 70 dB at Rated Power
75 dB Small Signal

Size: 13.1"W x 14.5"H x 24"L
Weight: 91 Pounds
Environmentally Sealed
Power Consumption: 1.7 kVA

Figure 4. HPA Enclosure VZA-6905C5

The output waveguide line, consisting of a high power isolator and directional couplers, reduces the rated power of the system to 400 watts. Internal solid-state amplifiers provide minimum 70 dB gain at rated power levels. The amplifier is fitted with a pre-distortion network (linearizer) that compensates for the amplitude and phase distortion of the TWT and reduces intermodulation products.

Similarly, the Helix TWT and EIK devices have also been packaged with integral power supplies and cooling into a self-sufficient HPA suitable for outdoor use.

Linearity measurements

The key metric used in evaluating HPA performance is the maximum power available with acceptable impairment of a multi-carrier signal. 2-tone Intermod is easy to measure, using the generally accepted spec level of –24 dBc. Beyond the simple two-carrier intermodulation test, modern system designers use two other ratios. The first test is the Noise Power Ratio (NPR) of an amplifier, defined as the difference between a theoretical infinite carrier source with a notch input, and the notch noise after amplification. An NPR value of between 18 and 20 dB has been used for typical systems. NPR is basically a self-interference measurement. The second test is Adjacent Channel Power Ratio (ACPR), again using a theoretical infinite carrier input, and measuring the intersymbol intermodulation power at a distance of 0.5 data rate from the main carrier. ACPR is a measurement of spectrum re-growth associated with modern modulation methods such as QPSK, 8PSK, and QAM. ACPR values of 26 to 30 dB are typical for system design. Intermodulation, NPR, and ACPR are all highly correlated with each other, although the pushing factors with backoff differ slightly.

Results for the TWT, EIK, and Millitron are presented below using the same test equipment to measure. While the exact value may differ depending on system bandwidth, etc., the following data can be used as a relative comparison of the three HPA technologies.

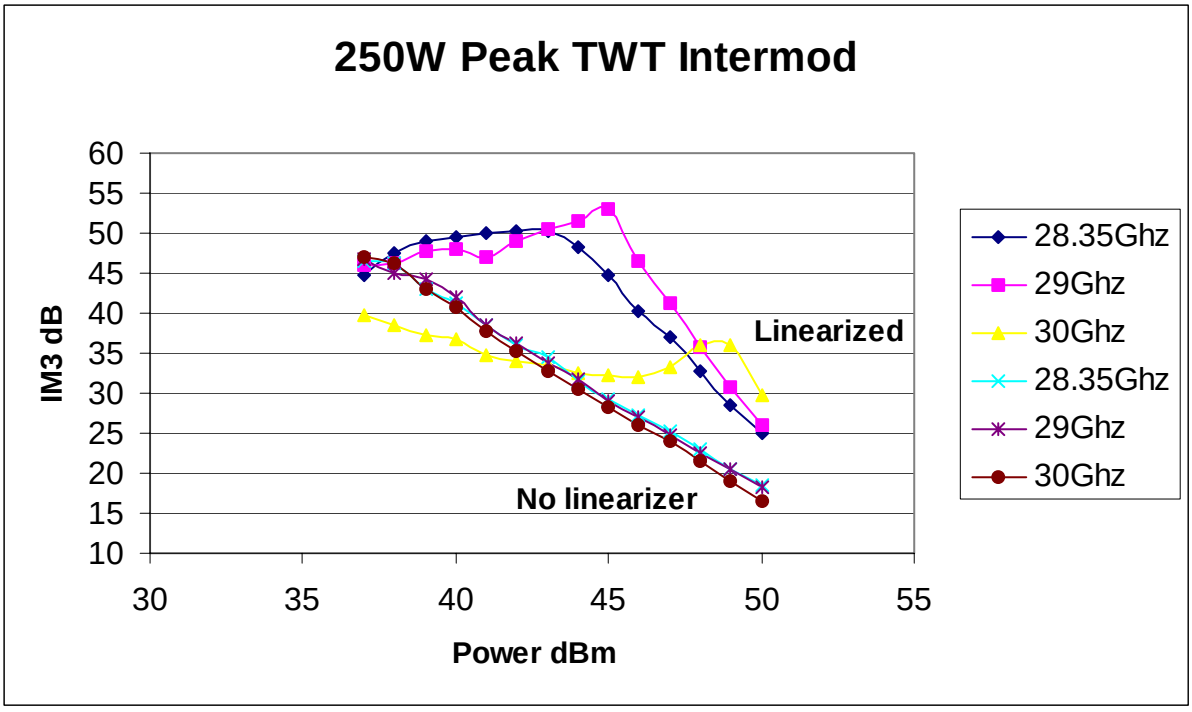
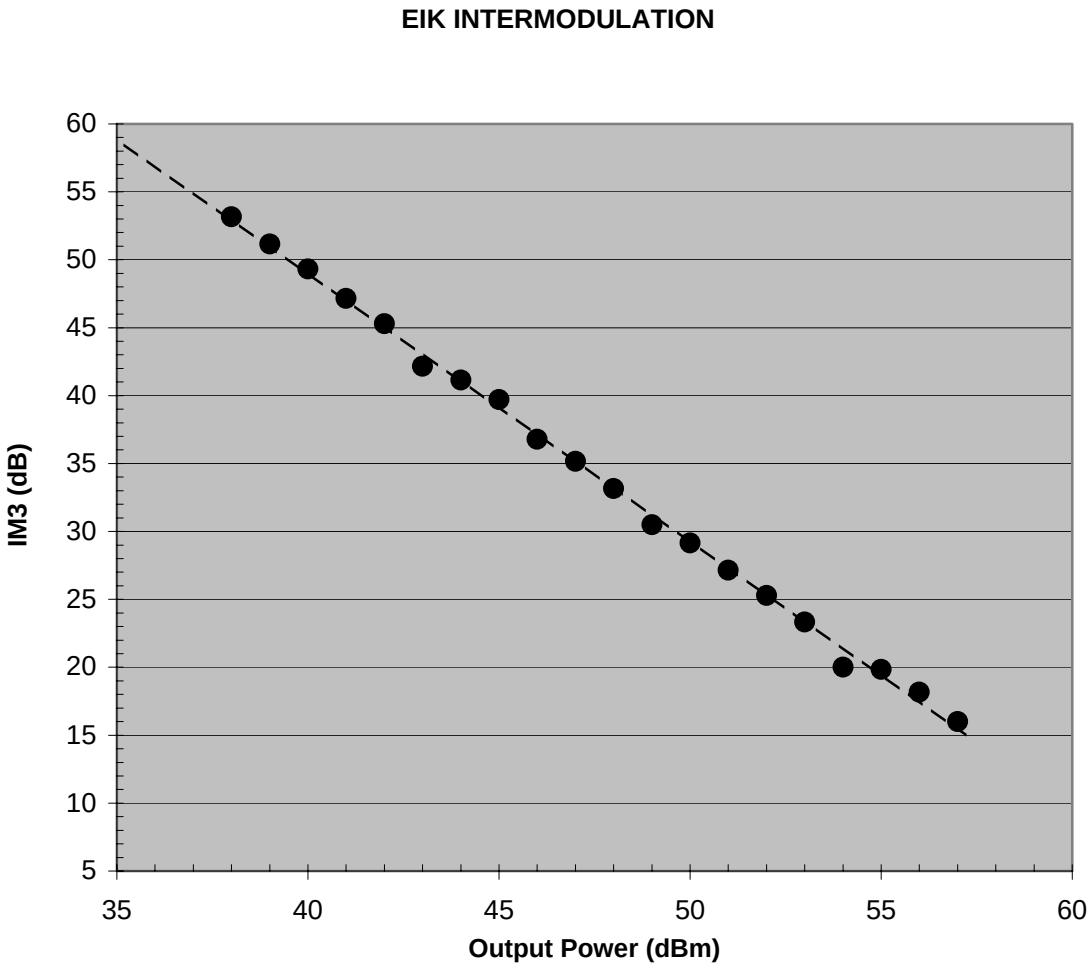


Figure 5. 250W Peak TWT Intermods, with and without linearizer



Note: linear output power improves 2 to 3 dB with linearizer

Figure 6. 850W EIK Intermods

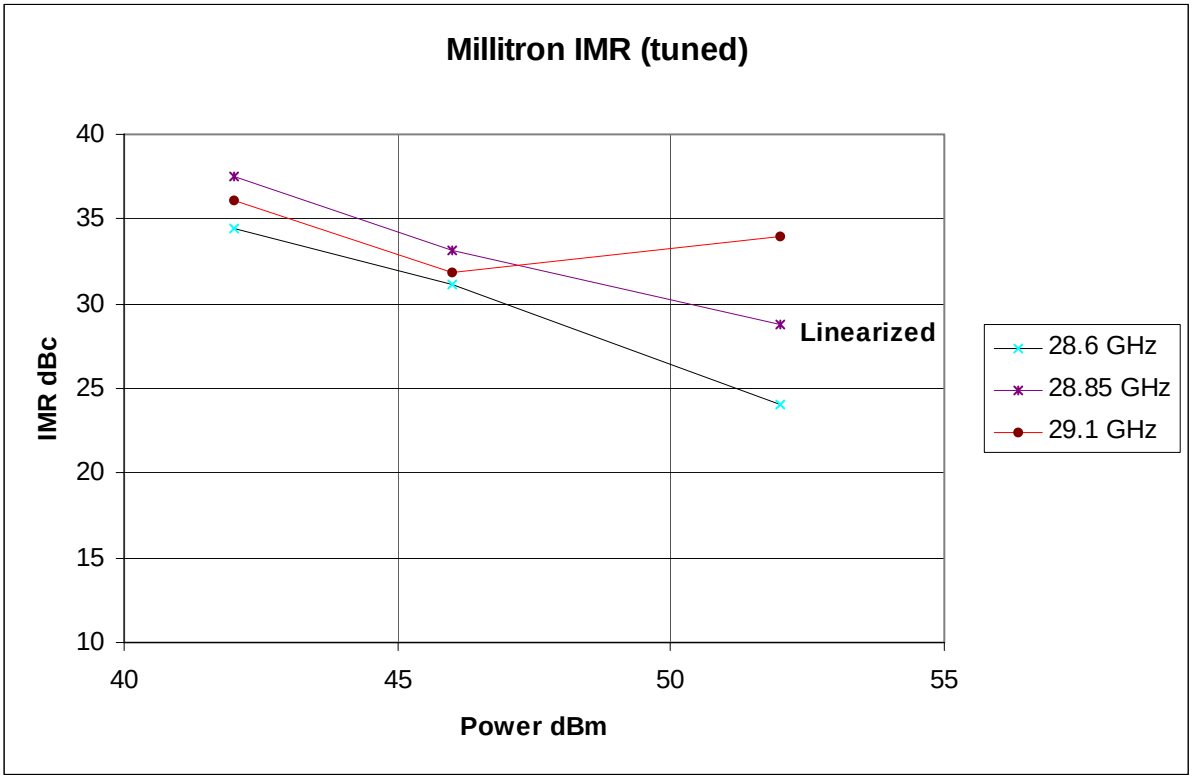


Figure 7. 500W Millitron HPA Intermods

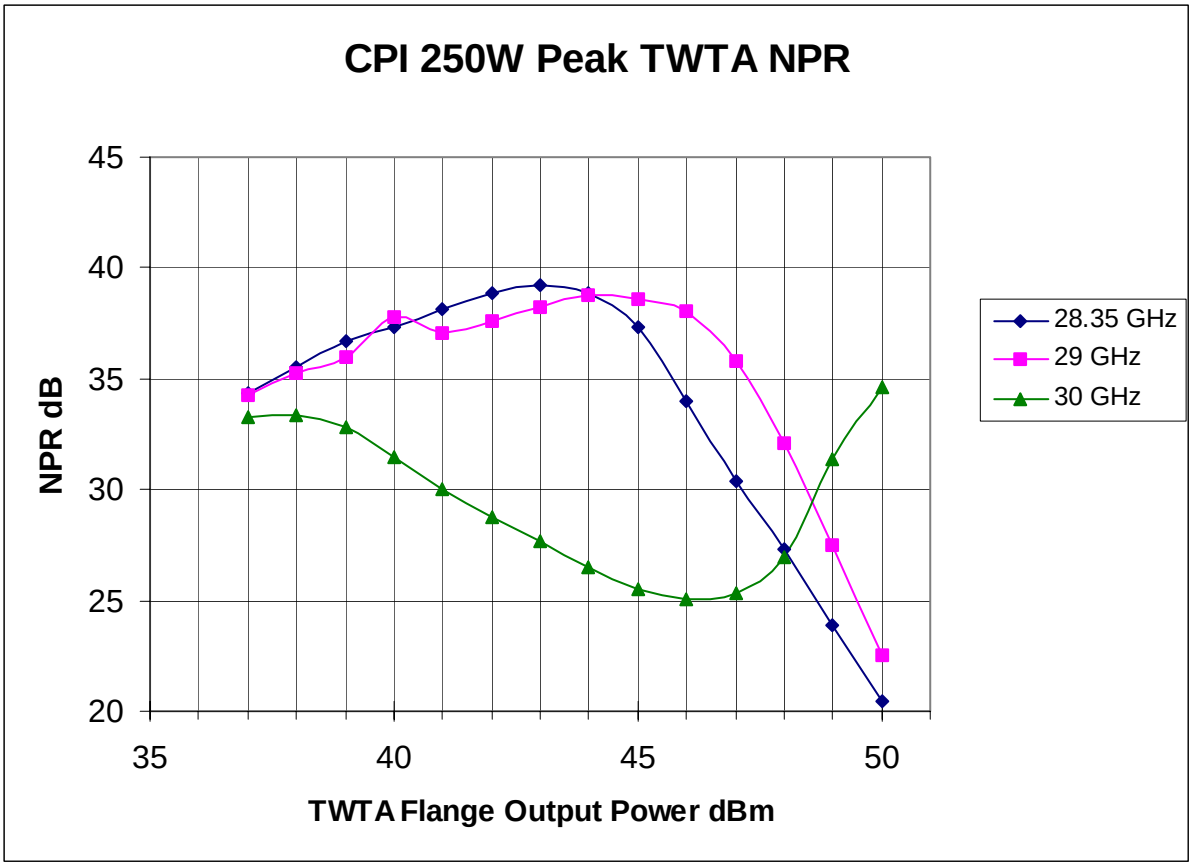


Figure 8. 250W Peak Helix TWT Noise Power Ratio (NPR) Linearized

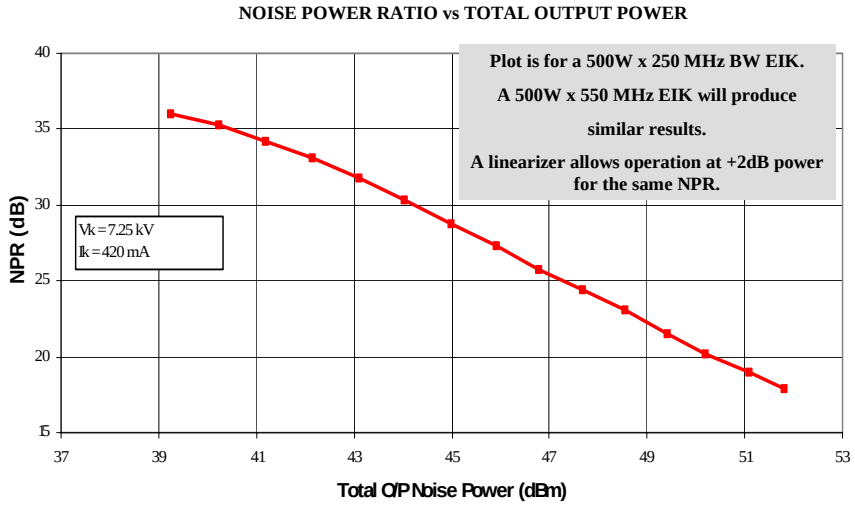


Figure 9. Extended Interaction Klystron (EIK) NPR (no linearizer)

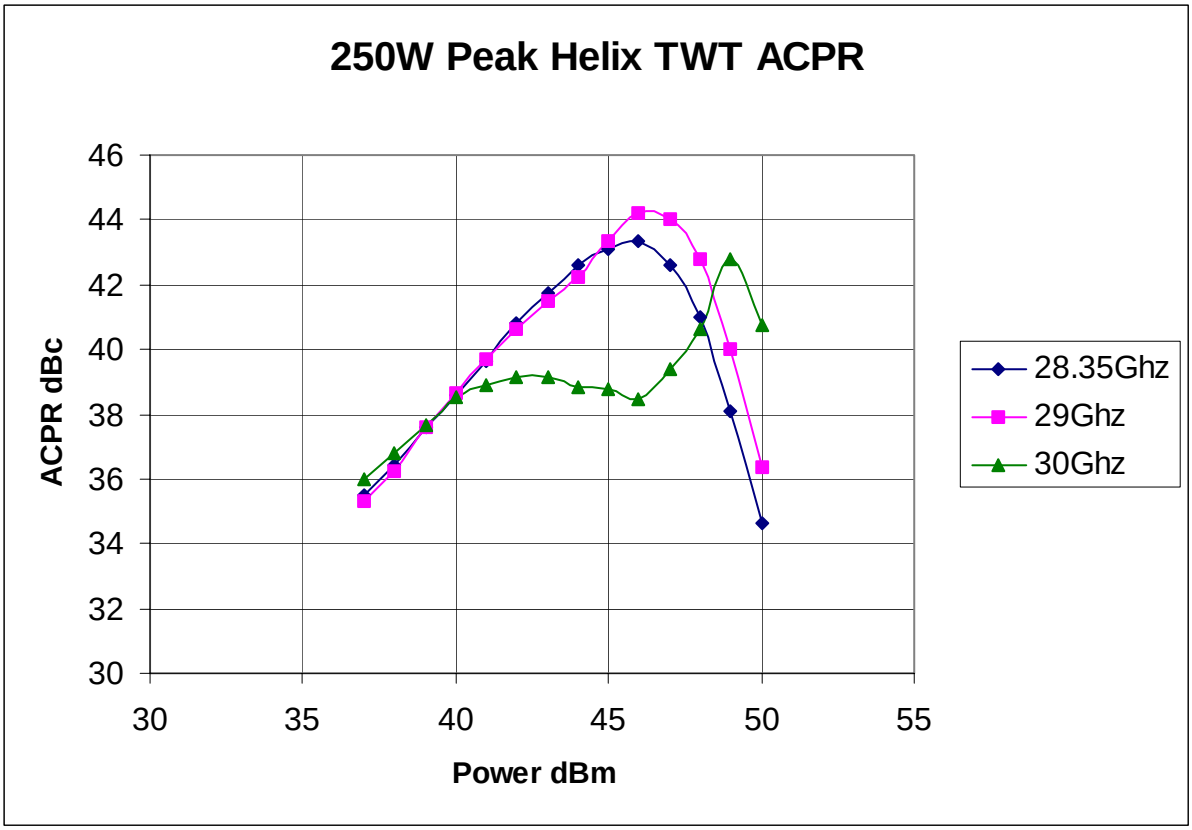


Figure 10. 250W Peak helix TWT Adjacent Channel Power Ratio (ACPR) linearized

Conclusion

Data taken on the three types of Ka-band HPAs produced by CPI have confirmed that all are suitable for linear uplink applications. The TWT is best used for lower power, broadband Gateway applications up to 100 W. The EIK is ideal for less bandwidth, high power TT&C and medium bandwidth uplinks up to 200 W without linearizer (or 400 W with linearizer). The Millitron is tailored to meet the bandwidth and power levels required for In Orbit Test (IOT) and Gateway operations up to 160 W. Multi-carrier transmissions are possible with any of these three choices. Selection of the particular type is determined by other constraints such as antenna hub size.

CPI has been at the forefront of Ka-band technology for years, and has taken advantage of three types of tube technologies to produce the broadest range of millimeter wave HPAs in the industry. The company has fielded nearly 20,000 HPAs in all frequency bands since 1971, and has the most extensive customer support network in the business.