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CPI SuperLinear® HPAs

The Latest Advancement in High Power Amplifier Technology

CPI's SuperLinear® Traveling Wave Tube Amplifiers (TWTAs) are designed for optimal operation at backoff power levels that are required in order to meet traditional international intermodulation specifications. This has resulted in a line of HPAs that is smaller, lighter and runs cooler than competing products.

Most traditional high power amplifiers (HPAs) are designed to run from small signal to saturated power. In practice however, the true usable power in a typical uplink application is limited by linearity requirements set by Intelsat and other satellite organizations. Thus, while power backoff of 3 to 7 dB is all that is ever required, one still needs the top end peak power to avoid clipping of the transmitted signal. This clipping results in Intermodulation products, spectral regrowth, and other non-linearities. Operating power must be limited to a maximum –3 dB from the maximum peak power for low bit-error rates when transmitting QPSK, QAM, CDMA, and OFDM signals.

The TWT, linearizer and HPA can be optimized to work best at the 3 dB backoff point (half average power). This results in a more efficient amplifier at the true operating point. Internal TWT and amplifier temperatures are reduced, required amplifier prime power is minimized, and HPA size and weight are dramatically reduced.

A comparison of the specifications of CPI's SuperLinear® 2250 W HPA against those of traditional TWTAs (non-optimized and non-linearized) and SSPAs shows a 30% reduction in size, a 20% reduction in weight, and a 25-70% reduction in prime power. This is a rare case of 'win-win-win,' with no penalty for the extra performance. Predistortion linearizers are highly effective with the SuperLinear® HPA, and as with traditional HPAs are recommended for maximum carrier traffic.

Internal alarm and fault levels are set in the HPA to automatically avoid excessive helix current if driven past 3 dB backoff. The intermod and spectral regrowth specifications are the same as they are rated for a traditional, full-CW HPA, typically –24 dBc intermods or 6 dBc spectral regrowth. SuperLinear® TWTAs are now available in C- and X-, Ku-, Ka- and Tri-bands.

END USER BENEFITS OF SUPERLINEAR HPAs

The technology used in CPI SuperLinear® HPAs is based on the simple idea that most applications use the HPA up to a maximum 3 dB power backoff. By optimizing the design of the TWT, the design of the power supply and the TWT distortion correction with a linearizer, the SuperLinear® HPA transfer curve is shaped to maximize the performance level up to a "linear power" level. The "linear power" point is typically defined as the IM3 = -25 dBc (see Figure 1).

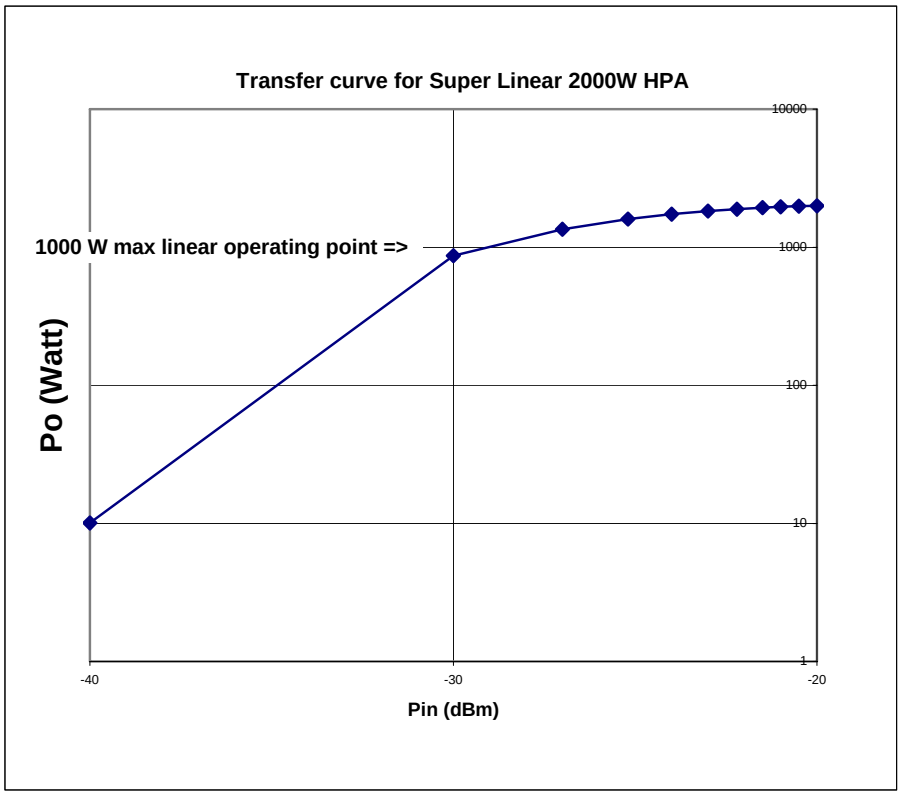


Figure 1. Transfer Curve for SuperLinear 2.25 kW C-Band TWTA

Benefits of TWT Optimization

Satellite uplink operators usually wish to determine the minimum operational output backoff they can obtain from their uplink amplifiers, whether they are SSPAs or linearized TWTAs. The number of carriers per HPA can vary from two to a higher number of modulated carriers, depending on the application. Therefore the cumulative power (sum of all carrier powers) determines a factor of merit for the HPA linearity.

If the uplink amplifier is an SSPA, the output backoff is calculated from P1dB (1 dB compression point) at the output flange. If the uplink amplifier is a linearized TWTA, the output backoff is calculated from Psat (saturated power of the TWT). Typically, the

output flange power is 0.6 dB below the TWT output power. Since saturated power varies from TWT to TWT, the guaranteed rated power is used in the calculations (2.25 kW).

A typical goal for the Intermodulation Product for two carriers (IM3) is –25 dBc. Beyond two carriers, an estimate of the Intermodulation Product (IMD) is provided by the de-rating factor formulas below:

For three or four carriers:

OBO = 0.5 x (IMD(dB) – 18 dB)

For five to N carriers:

OBO = 0.5 x (IMD(dB) – 16 dB)

For example, to obtain -25 dBc IMD with three carriers, the approximate Output Backoff would be: OBO = 3.5 dB. The OBO for two carriers is typically 3 dB (from P1dB for the SSPA and from Psat for the TWTA).

A comparison between a 1.5 kW (61.4 dBm P1dB) C-Band SSPA, a traditional CPI 2.25 kW C-Band TWTA, and a SuperLinear 2.25 kW C-Band TWTA is provided below:

Table 1. Intermodulation Products Performance – Two Carriers

	SuperLinear TWTA	**Traditional TWTA**	**1.5 kW SSPA**
Rated Power	2.25 kW	2.25 kW	1.5 kW
P1dB at output flange (dBm)	NA	NA	61.4 dBm
P1dB at output flange (W)	NA	NA	1384 W
Psat at output flange (dBm)	63.0 dBm on TWT, operable up to 60.0 dBm	63.0 dBm	NA
Psat at output flange (W)	2000 W on TWT, operable up to 1000 W	2000 W	NA
-25 dBc IM3 Aggregate Output Power (W)	**997.6 W**	500 W	693 W

A similar comparison can be done for a higher number of carriers. For example, to calculate the Aggregate Output Power for five to ten-carrier operation, the above formula can be used, which leads to the following conclusions in Table 2:

Table 2. Intermodulation Products Performance – Five to Ten Carriers

	SuperLinear TWTA	Traditional TWTA	1.5 kW SSPA
Rated Power	2.25 kW	2.25 kW	1.5 kW
P1dB at output flange (dBm)	NA	NA	61.4 dBm
P1dB at output flange (W)	NA	NA	1384 W
Psat at output flange (dBm)	63.0 dBm on TWT, operated up to 60.0 dBm	63.0 dBm	NA
Psat at output flange (W)	2000 W on TWT, operated up to 1000 W	2000 W	NA
-25 dBc IM3 Aggregate Output Power (W) – Three Carriers	**707.9 W**	354.8 W	489.8 W

In practice, a SuperLinear® TWTA can be optimized around a particular backoff value and particular frequency within the available bandwidth of the amplifier. Figure 2 illustrates an example optimized around 7 to 8 dB backoff.

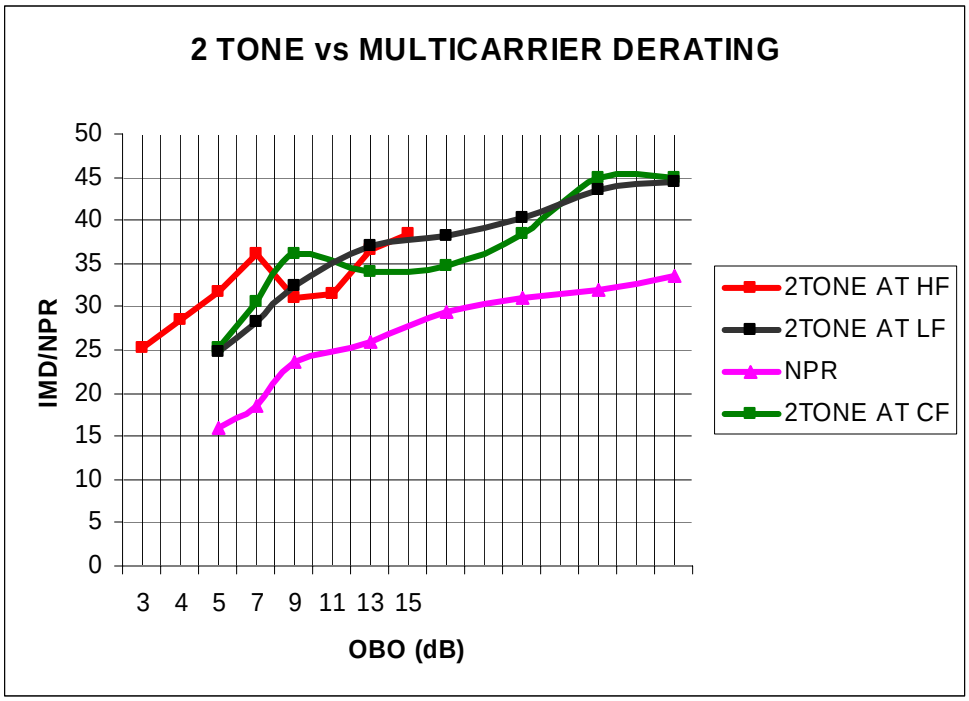


Figure 2. Intermodular Performance Optimization With The SuperLinear® TWTA

Efficiency Benefit – SUPER EFFICIENT

Contrary to SSPAs, the power consumption of TWTAs depends upon the RF output power. As the output power backoff increases, the power consumption decreases due to the split of voltage and current in the different TWT collectors. This translates into huge power savings. With the SuperLinear design, CPI has optimized the collector voltages and power supply to push the power consumption even lower, as illustrated by Figure 3 below:

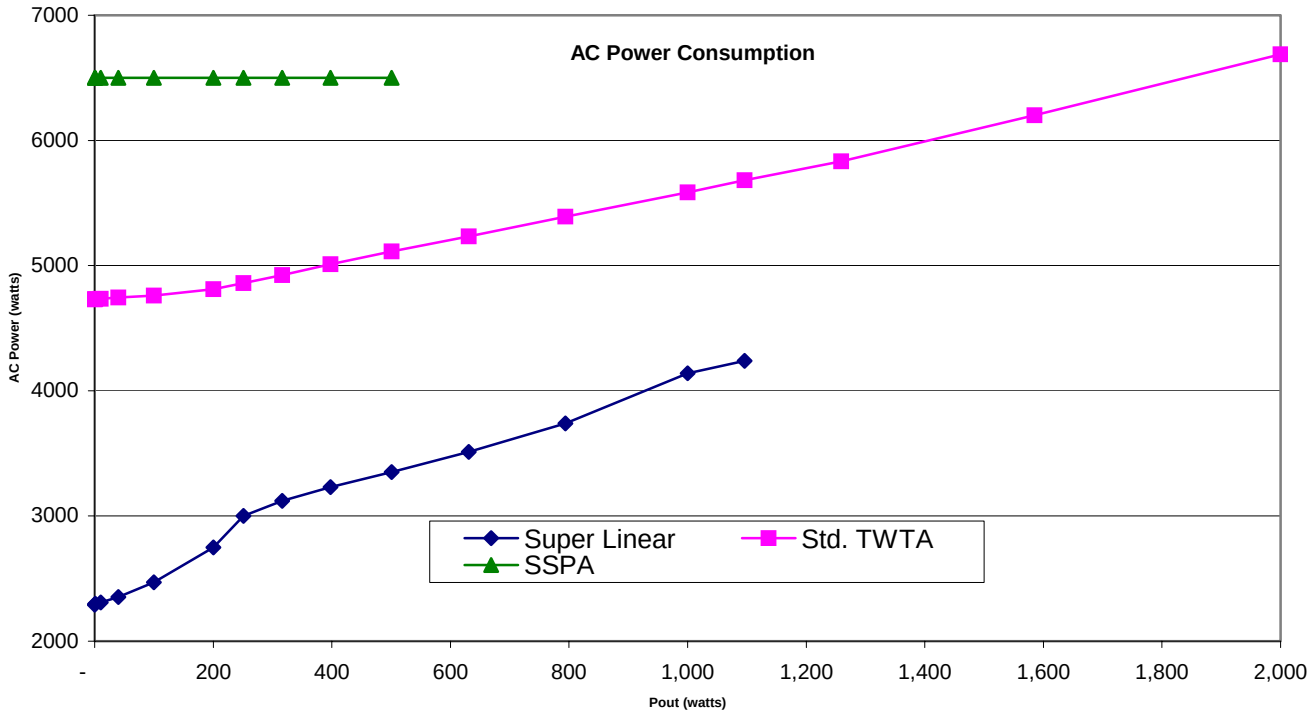
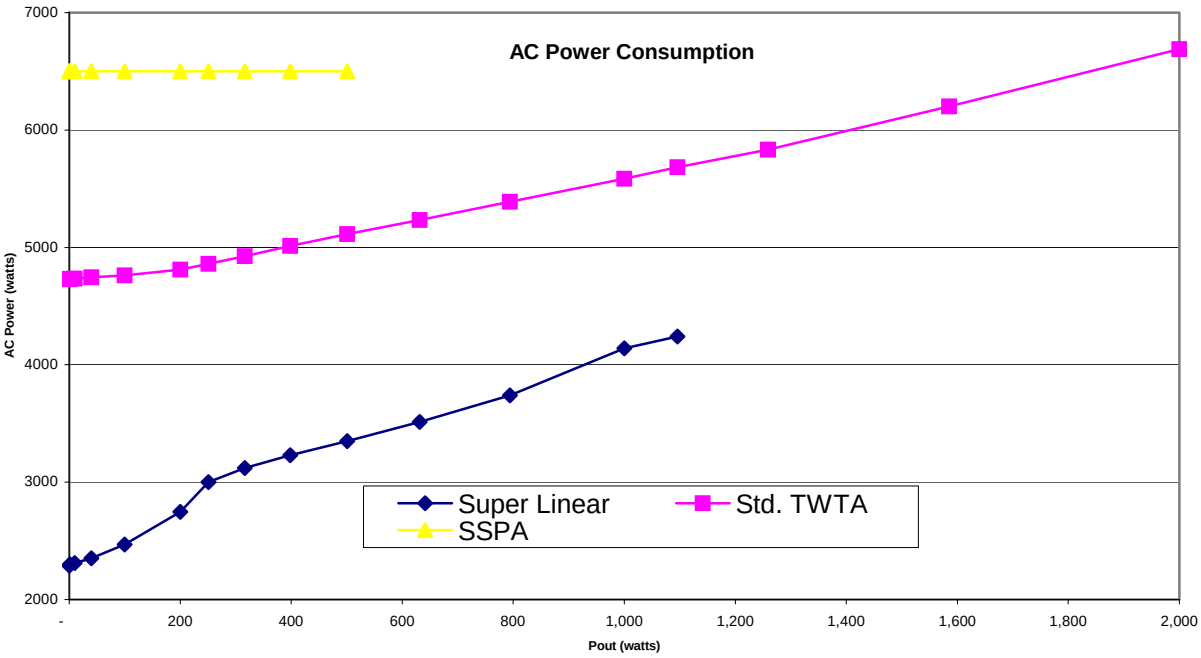


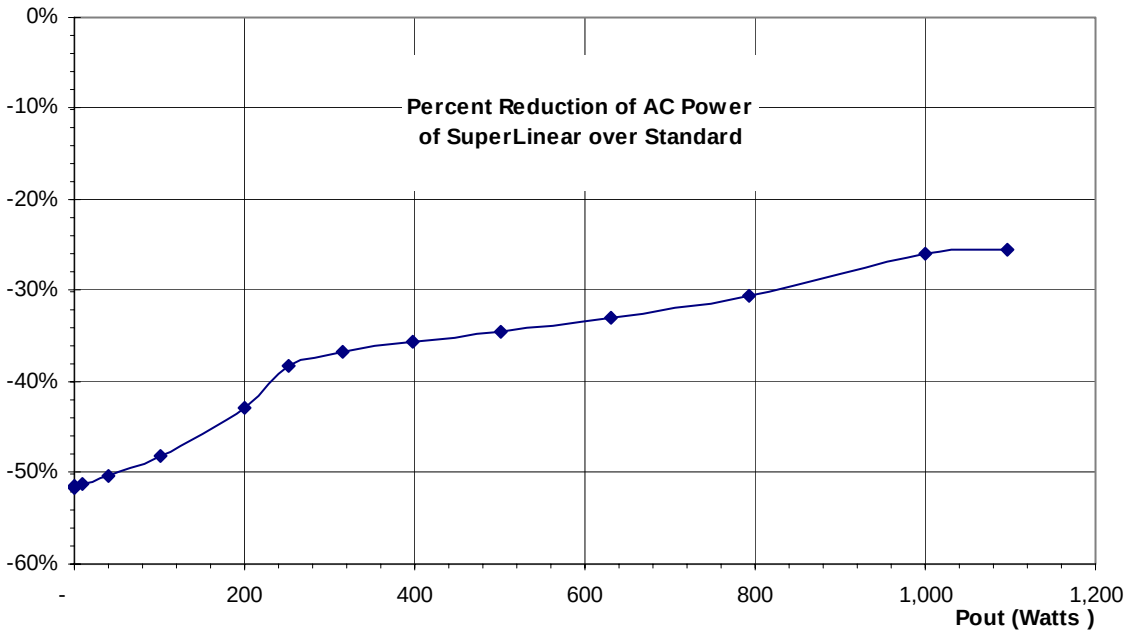
Figure 3. Super Efficiency Benefit

As an example, the power costs for a 1:1 SuperLinear TWTA system (2 HPAs), operating all year long at $0.11 per kWh, would be approximately $4,731. A SINGLE SSPA by contrast, would cost approximately $6,257 per year. Given that the SuperLinear TWTA can handle more carriers per HPA --- or alternatively, that the SuperLinear TWTA does not have to back off as far to achieve 25 dBc linearity --- the actual cost benefit only magnifies.

Reliability Benefit – SUPER COOL

By decreasing the power consumption requirement, the power supply dissipates less heat. Therefore, the HVAC dimensioning is reduced. Lower temperatures in the collectors also enhance the life expectancy of the HPA. A 1.5 kW SSPA dissipates over 3200 watts, while a 1:1 SuperLinear TWTA system dissipates only 750 watts.


AC Power Consumption
AC Power (watts)
7000
6000
5000
4000
3000
2000
-
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Pout (watts)
Super Linear
Std. TWTA
SSPA


Percent Reduction of AC Power
of SuperLinear over Standard
0%
-10%
-20%
-30%
-40%
-50%
-60%
-
200
400
600
800
1,000
1,200
Pout (Watts)