Electron Technologies, Inc.

# Space Qualified 140-W Linearized L-band Helix TWTA

Jon R. Feicht, Keith N. Loi, William L. Menninger,
Jon G. Nicolello, Xiaoling Zhai

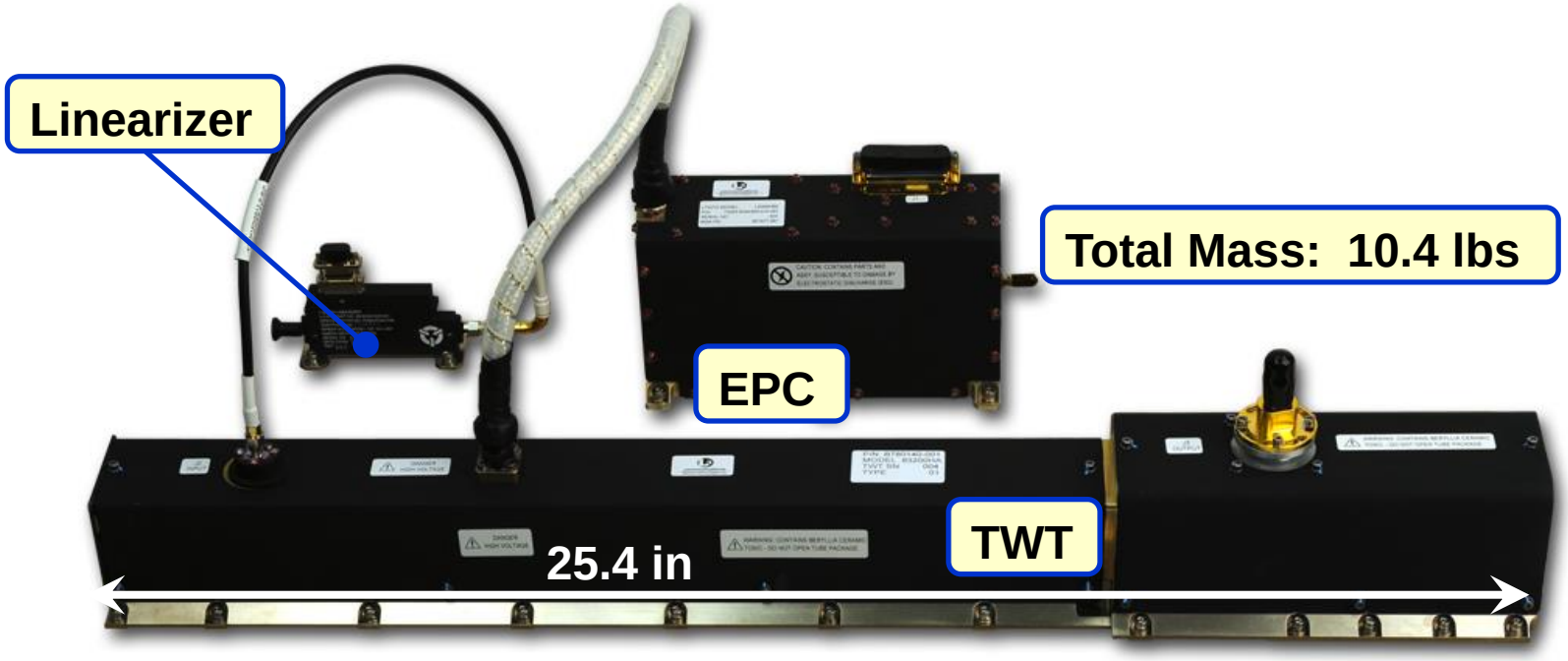
IVEC-IVESC 2012 Talk 16.4, April 26, 2012

# L-Band Satellite Applications

- **Higher RF output power demanded by emerging services.**
  - ***"SAT NAV" GPS, GALILEO, GPS Augmentation (QZSS), also GOES downlink***
  - ***200 W – 400 W requests common: Improved SNR, Anti-jam, NextGen ATC***
  - ***COMSAT Applications***
- **Satellites present a challenging environment for HPAs.**
  - ***Power budget is fixed and decreases with time***
  - ***Satellites are increasingly dissipation limited***
  - ***Background radiation levels are high. (LEO, MEO, EMP)***
  - ***Temperature, vibration, and shock levels are extreme***
  - ***Mission life 15 to 18 years***
- **TWTAs have excellent, demonstrated reliability**
  - **Weekley, IEEE T-ED 2005; Strauss, IEEE T-ED 1994**
- **L-band TWTAs are a good fit for GPS specifications**
  - **Ehret, IEEE T-ED 2005, IVEC 2007**

# L2000HBZ L-band LTWTA

- **Linearized Traveling-Wave Tube Amplifier**
- **140 W Saturated RF Output**
  - **At 1.57 GHz (GPS/Galileo L1) can provide 260 watt with +6 dB multipactor margin**
  - **8 MHz BW specification (unit can go much wider)**
  - **EPC DC input 100 volt (can operate at 28 to 100 Volts). Powers TWT and Linearizer**
  - **~ 65 % DC conversion efficiency**




**All equipment manufactured by L-3 Communications**

# Navigation LTWTA–HPA Comparison

| Specification | LTWTA | Nominal GPS Spec | Advantage vs. typical SSPA |
|---|---|---|---|
| **RF Power Out** | 180 watts | 180 watts | Similar |
| **AM-to-PM Conversion** | 1.5 deg/dB | 4.5 deg/dB | Similar |
| **Group Delay Variation w/Temp** | 0.05 nSec /100°C | 0.24 nSec /10°C | Similar |
| **Noise Figure** | 14 dB | 28 dB | Similar |
| **Gain Variation/Temp** | 0.25 dB/100°C | 1.0 db/86°C | Similar |
| **C3/IM (2 dB OBO)** | 20 dB | 14 dB | Similar |
| **Efficiency (%)** | ≥ 65% | 28% (typical SSPA) | 47 points |
| **DC Power (W)** | 278 | 645 (typical SSPA) | 367 Watts less |
| **Dissipated Power (W)** | 97 | 463 (typical SSPA) | 366 Watts less |
| **Mass** | 10.4 lb | 22 lb (typical SSPA) | 53% less |
| **Life (year)** | >18 | 15 | Similar |

# Qualification Testing Summary

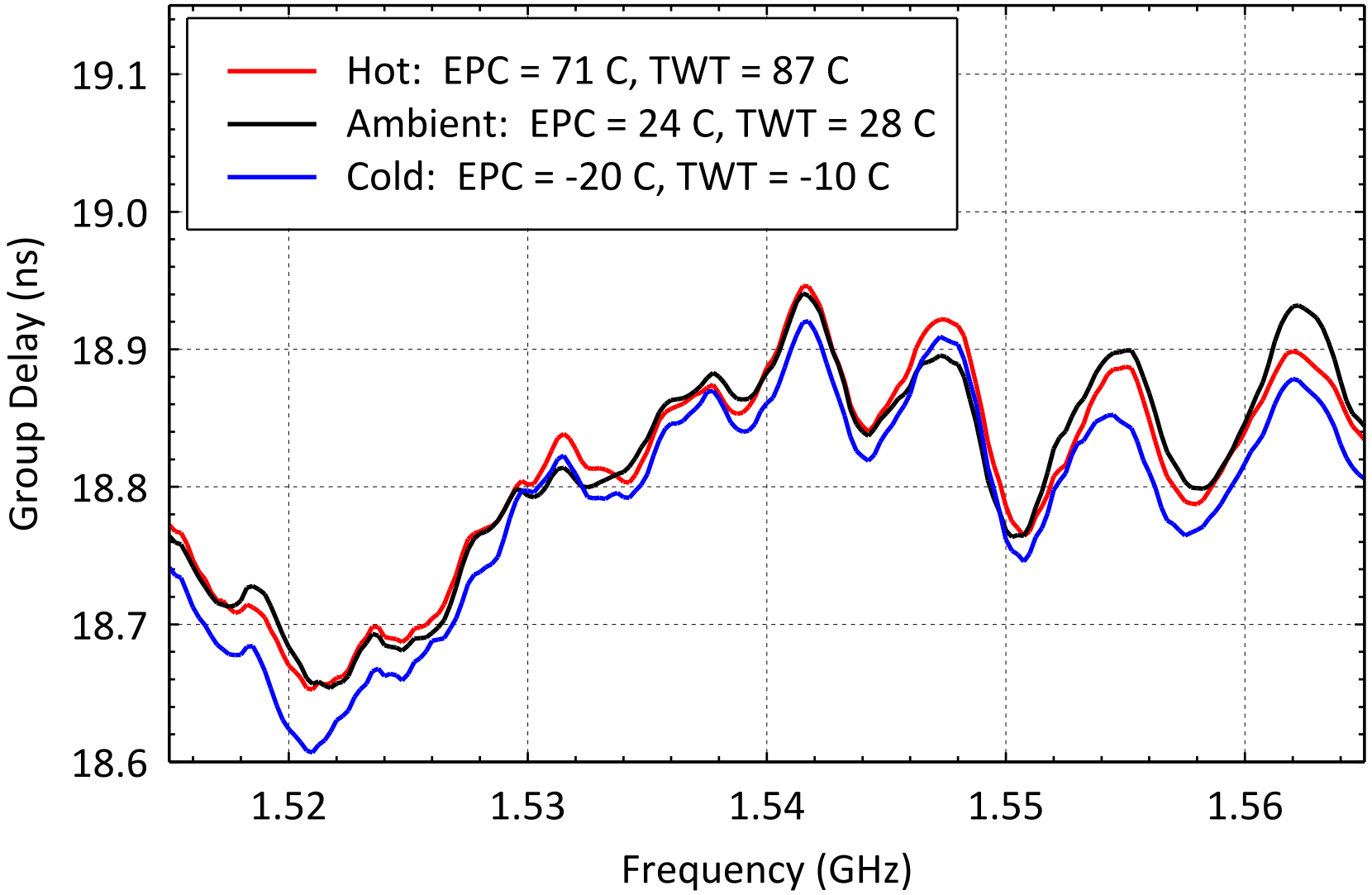
| Test (units) | Linearizer | EPC | TWT |
|---|---|---|---|
| Random Vibe (GRMS) 120 sec | 14.9 ⊥<br>9.4 // | 18.7 ⊥<br>17.4 // | 18.7 ⊥<br>13.0 // |
| Sine Vibe (G) 2 Oct/min | 5-13 ⊥<br>5-13 // | 4-20 ⊥<br>4-15 // | 4-20 ⊥<br>4-15 // |
| Shock (G) 3x | 3920 | 3300 | 1700 |
| Temperature (C) | -30/+75 | -35/+65 | -35/+95 |

**Composite table: Values reflect component mass, program requirements, placement on satellite, launch vehicle, etc.**

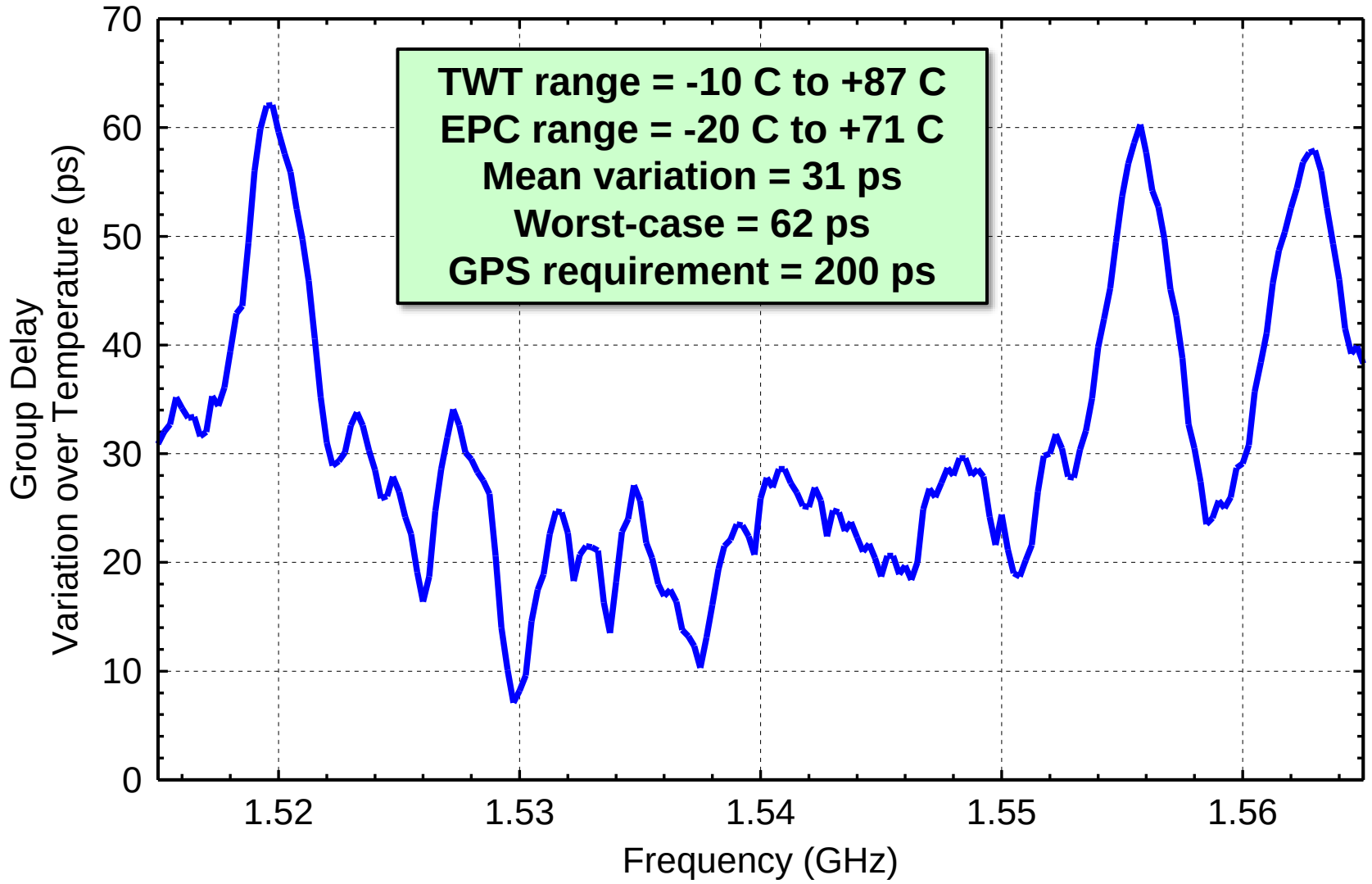
# LTWTA Flight Set Performance Summary

| LTWTA S/N | 421 | 422 | 423 | 424 | Mean |
|---|---|---|---|---|---|
| Pout (dBm) | 51.27 | 51.39 | 51.30 | 51.24 | **51.30** |
| Phase Shift (deg) | -1.8 | -2.1 | -2.9 | -3.4 | **-2.5** |
| 2-Tone C/3IM (dB) | 13.1 | 13.0 | 13.1 | 12.7 | **13.0** |
| DC Power (W) | 207.6 | 213.8 | 207.8 | 210.3 | **209.9** |
| Efficiency (%) | 64.5 | 64.4 | 64.9 | 63.2 | **64.3** |
| Dissipation (W) | 73.6 | 76.1 | 72.9 | 77.3 | **75.0** |

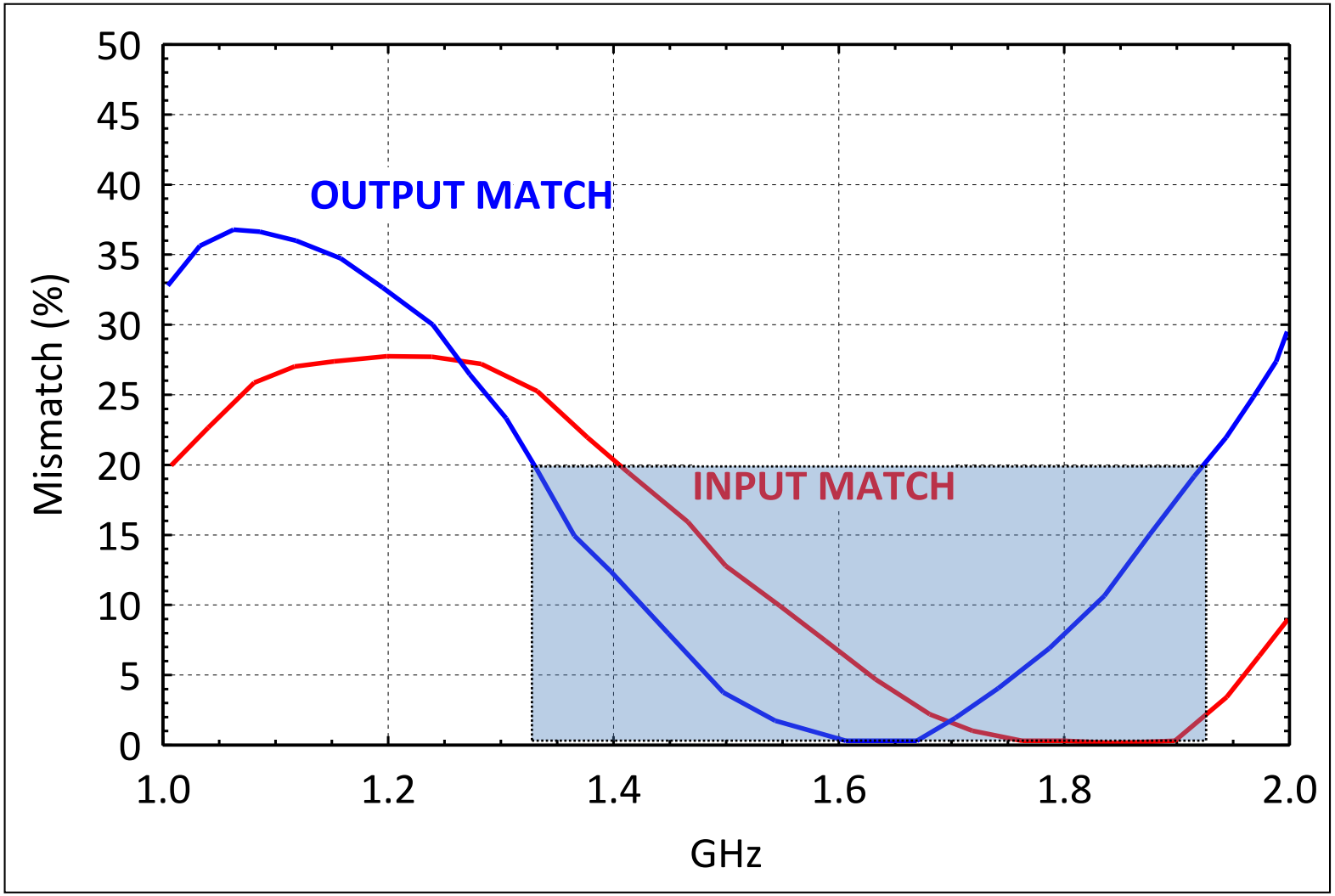
# S/N 424 Group Delay over L1 Band



# LTWTA Group Delay Variation over ~100 ºC
## S/N 0424

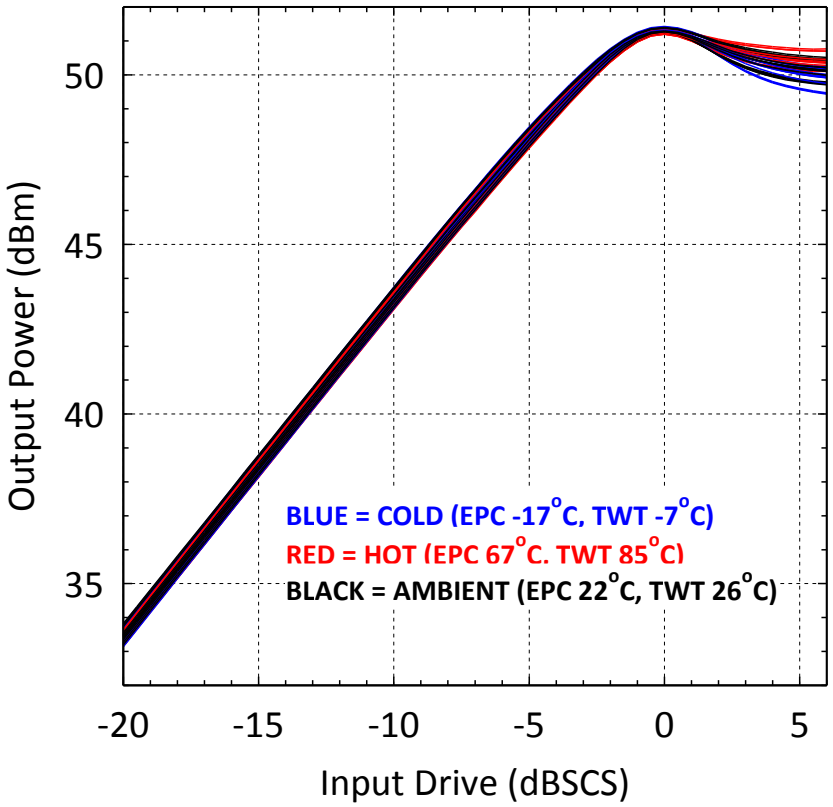


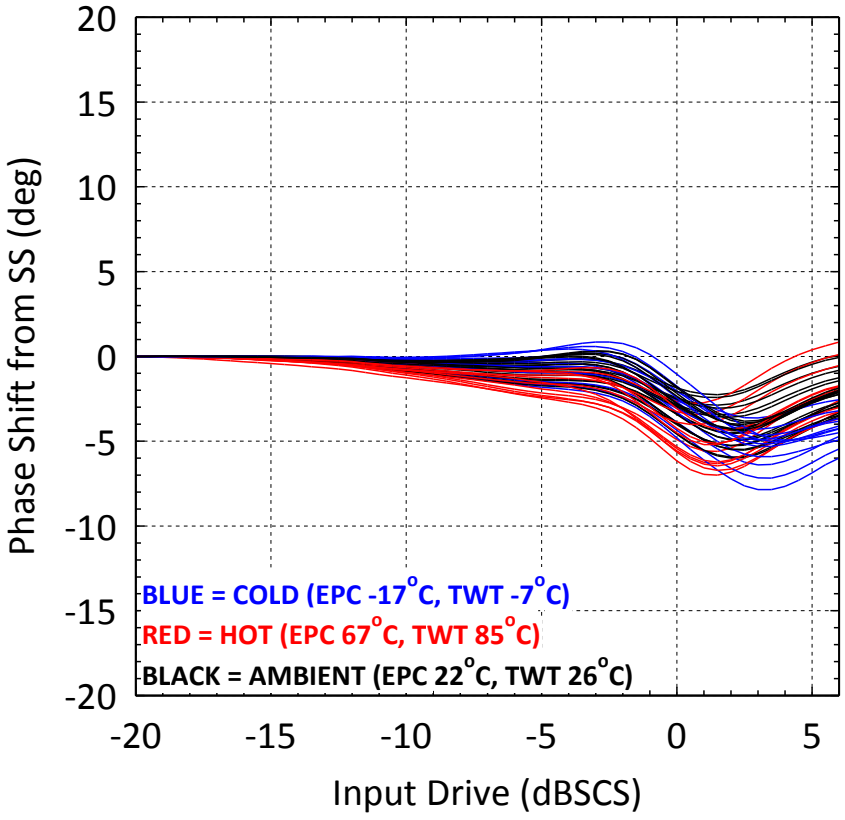
# TWT circuit match (cold match)



# Power and Phase vs. Drive

## FL, FC, FH, All Temperatures

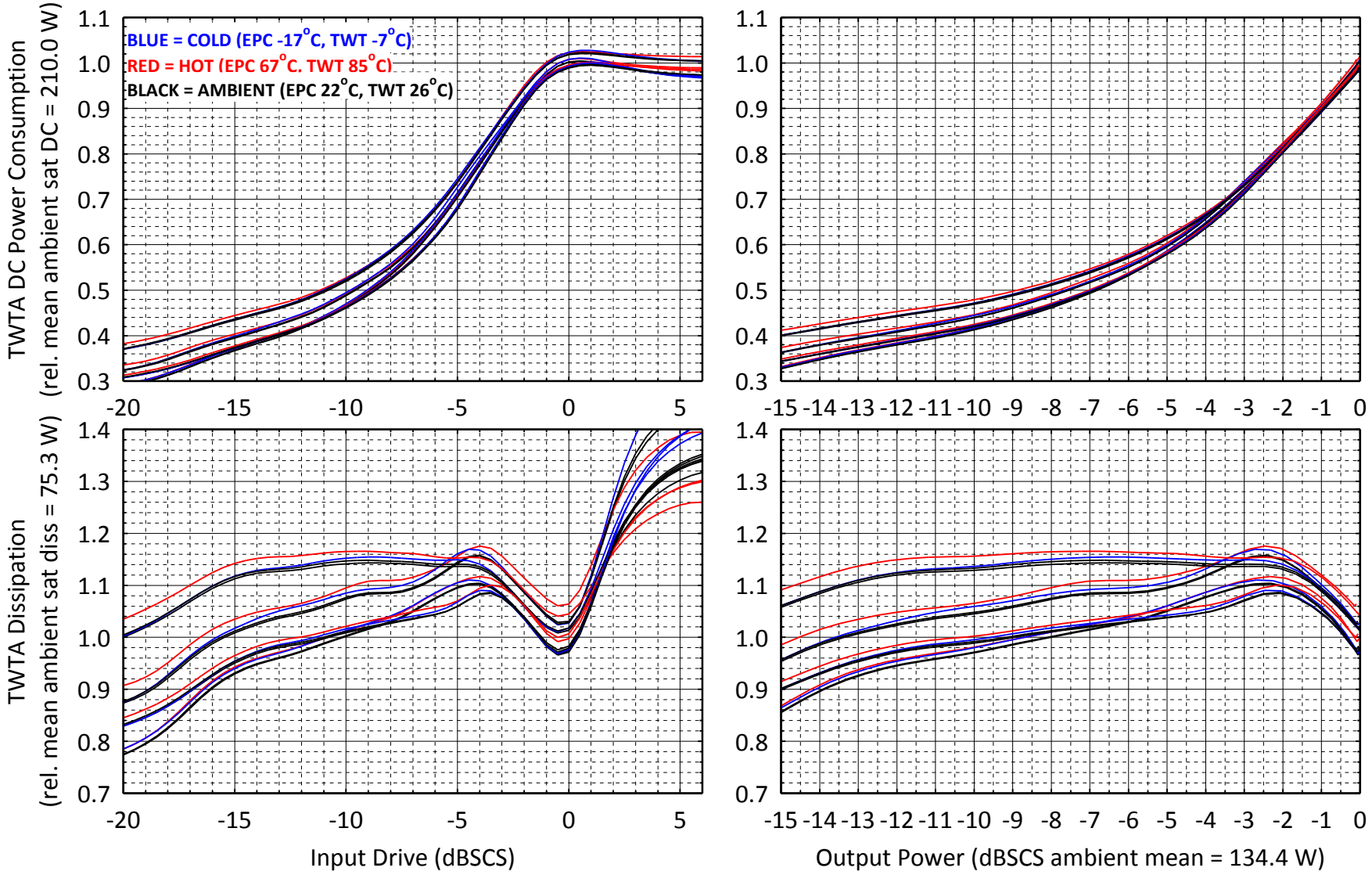



**Note: Single transfer curve predistortion linearization. No pre-selection/tuning. Linearizers can be interchanged without affecting performance.**

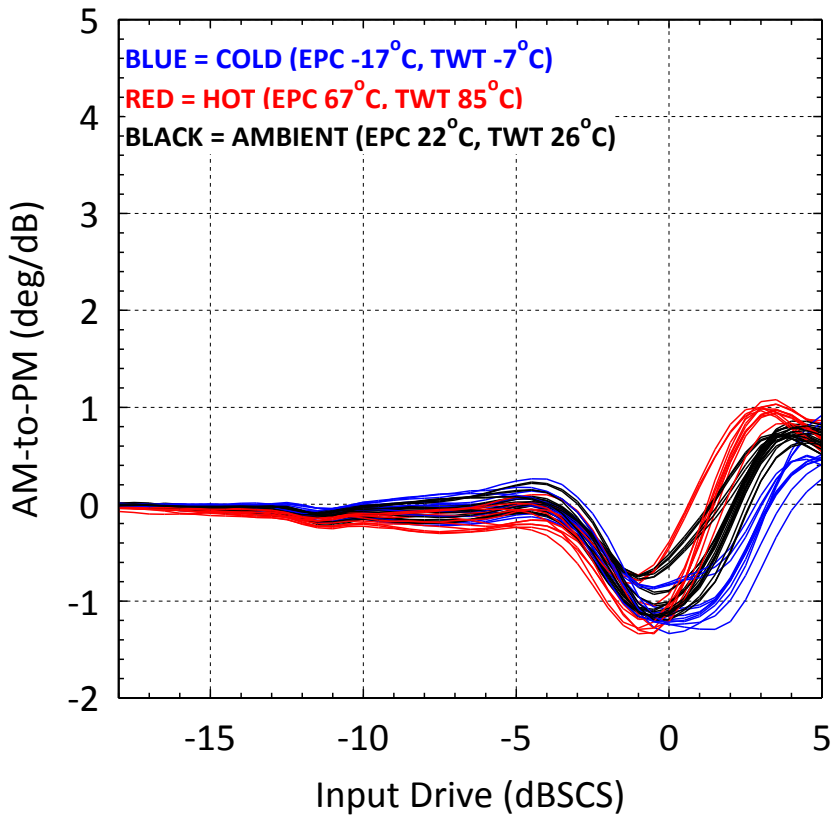
# DC Power and Dissipation vs. Drive

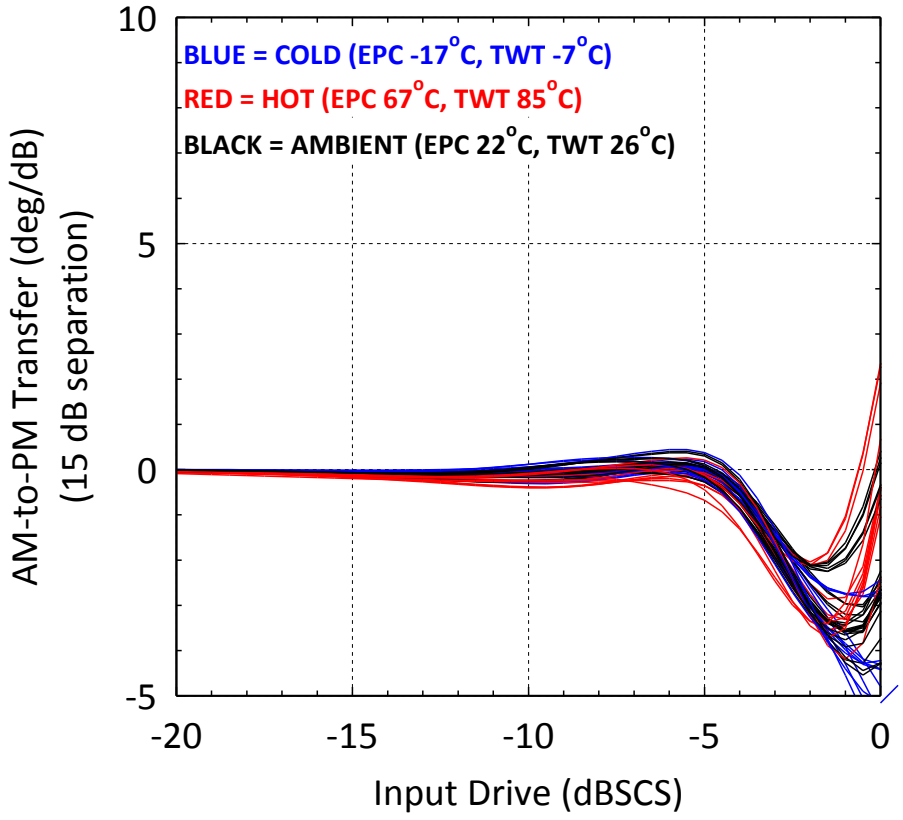
## FL, FC, FH, All Temperatures



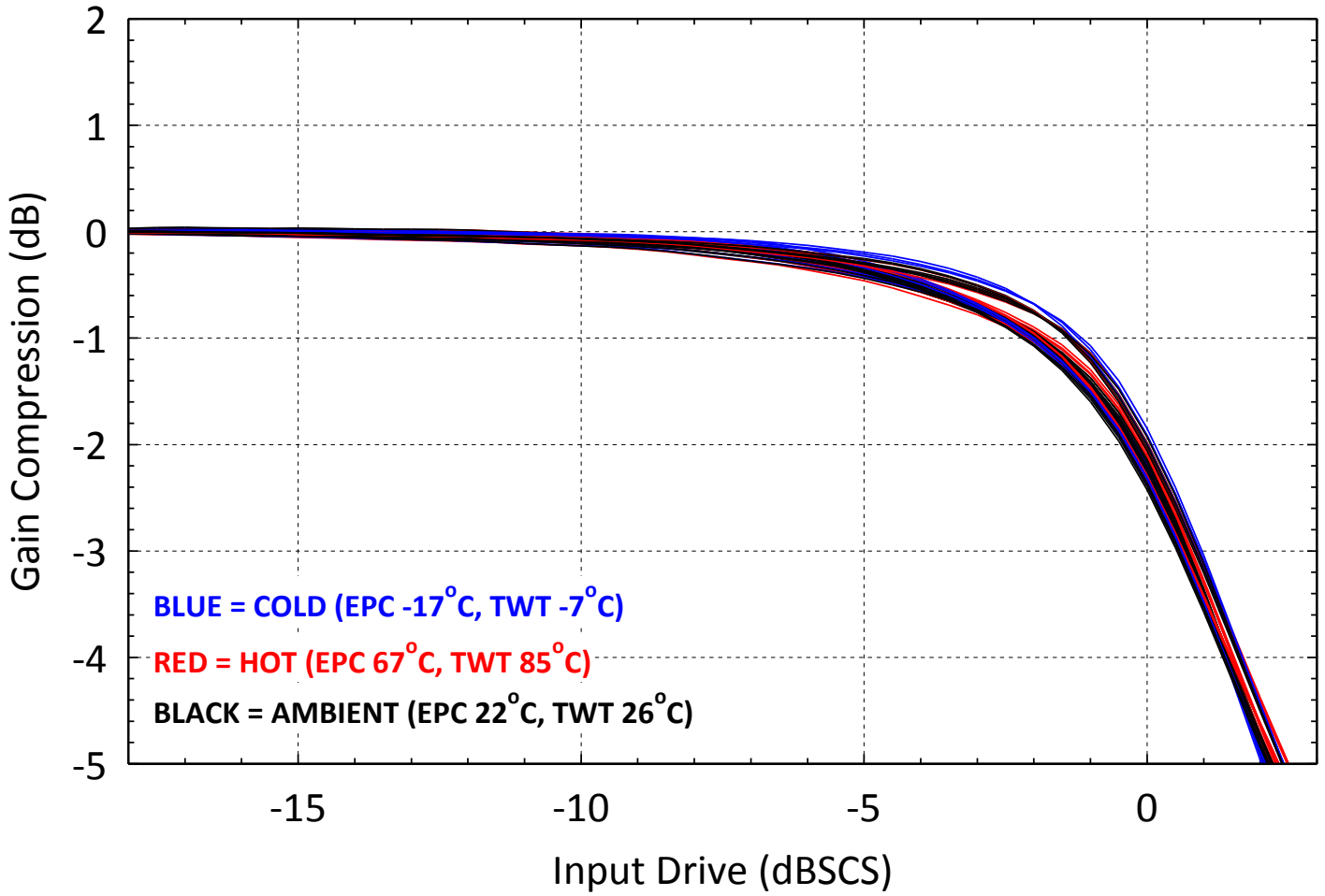
# AM-to-PM and AM-to-PM Xfr vs. Drive

## FL, FC, FH, All Temperatures



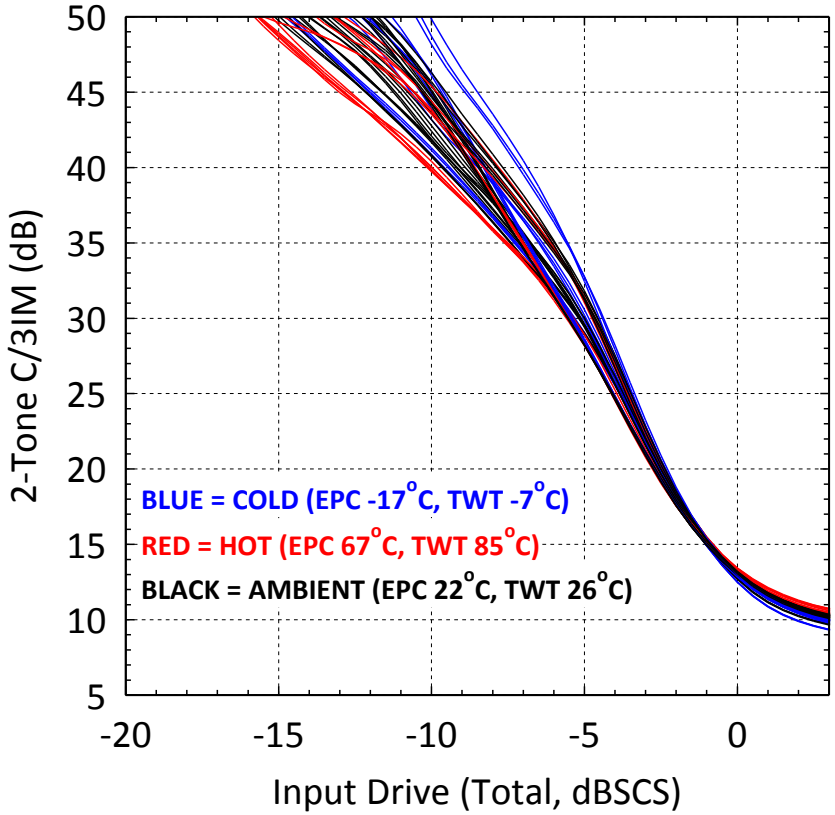



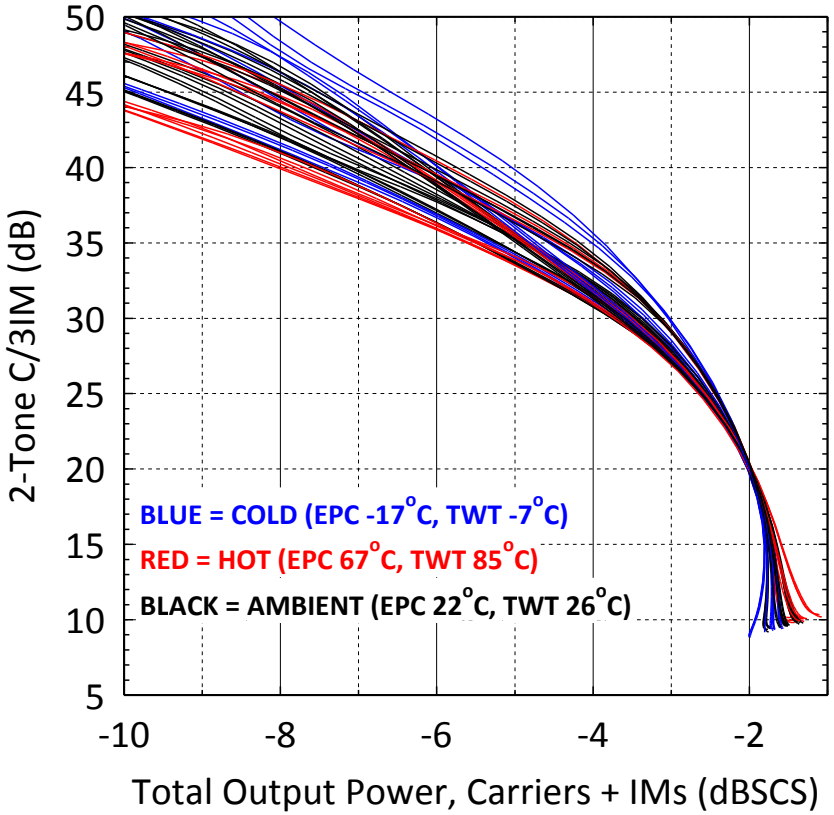
# Gain Compression
## FL, FC, FH, All Temperatures



# 2-Tone C/3IM vs. IBO and OBO

## FL, FC, FH, All Temperatures



# LTWTA Stability over Temperature

## ( > 90 °C Temperature Change)

| | |
|---|---|
| SS Gain (dB) | -0.27 |
| Sat Gain (dB) | -0.24 |
| Group Delay (ns) | -0.014 |
| Noise Figure (dB) | -1.10 |
| Sat Pout (dB) | -0.07 |
| DC Power (W) | 0.10 |
| Phase Shift SS to Sat (deg) | -1.60 |
| AM-to-PM @ Sat (deg/dB) | 0.39 |
| Gain Compression (dB) | -0.03 |

**Values are <Hot Value> minus <Cold Value>**

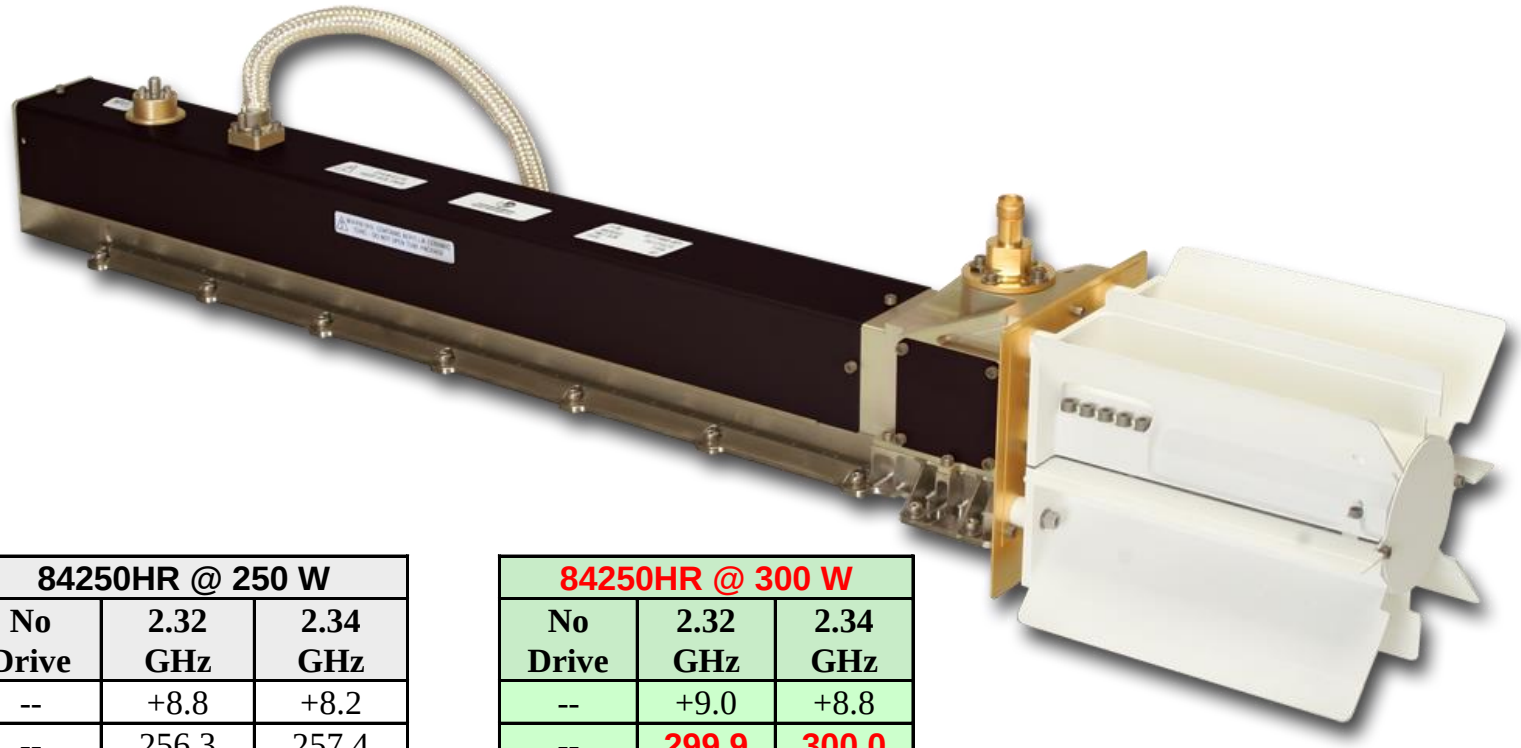
**Flight-Set Average**

**HOT: TWT = 85 C, EPC = 67 C**

**COLD: TWT = -7 C, EPC = -17 C**

# Direct Radiation Cooling Packaging option

**(TWT can be tuned to S-Band with minor changes. 250-300 Watt Pout at 72-74% efficiency)***



| PARAMETER | 84250HR @ 250 W | | |
|---|---|---|---|
| | No Drive | 2.32 GHz | 2.34 GHz |
| Pin (dBm) | -- | +8.8 | +8.2 |
| Pout (W) | -- | 256.3 | 257.4 |
| Gain (dB) | -- | 45.3 | 45.9 |
| Basic Eff (%) | -- | 37.5 | 37.7 |
| Overall Eff (%) | -- | 72.4 | 72.8 |
| Total DC (W) | 110.2 | 354.1 | 353.7 |
| Thermal Diss (W) | 110.2 | 97.8 | 96.3 |
| Iw (%) | 0.05 | 0.33 | 0.33 |

| 84250HR @ 300 W | | |
|---|---|---|
| No Drive | 2.32 GHz | 2.34 GHz |
| -- | +9.0 | +8.8 |
| -- | **299.9** | **300.0** |
| -- | 45.8 | 45.9 |
| -- | 39.1 | 39.1 |
| -- | **73.9** | **73.9** |
| 129.1 | 405.8 | 405.9 |
| 129.1 | 105.9 | 106.0 |
| 0.07 | 0.69 | 0.70 |

*** WR340 waveguide output is also available**

# Conclusion

- Flight Qualified L-Band LTWTA
- All Components built by L-3 Communications
- Two flight sets delivered
- Suitable for Navigation and SATCOM payloads
- Meets all NAV stability and performance requirements
- Can provide > 250 Watts at GPS/Galileo L1
- Radiation or Conduction Cooling Options
- Covers S-Band with minor changes (to 300 Watts)
- Much higher efficiency than competing SSPAs (lower mass too)