Ka Band
Solid State Amplifier Products
Ka Band SSPA Products

- Paradise Datacom has a long history of providing solid state Ka Band products for Satellite Communications.
- 40W Ka Band SSPAs & SSPBs have been in production since 2008
- Hundreds of Ka Band SSPAs have been delivered on U.S. Army Trojan program and installed on JNN Trailers.
- Paradise Datacom has pioneered many design innovations that have enhanced Ka Band SSPA operation including:
  - Innovative low-loss waveguide & spatial power combining structures
  - Analog Predistortion circuit designs to increase Linear Output Power capability
  - RMS power detectors for true RF output power monitoring
- Paradise Datacom has been an early adopter of GaN technology and produced some of the first GaN based Ka Band Solid State Power Amplifiers.
Legacy 40W SSPB
Psat = 40W, Plinear=20W

Weight just under 40 lbs. Dimensions: 10 in. wide x 6.5 in. high x 19.5 in. long.

- Certified to MIL STD-461 EMC / EMI requirements
- Certified to MIL STD-810 Environmental requirements
- Carries CE Mark

Hundreds of 40W Ka Band SSPBs (30.0-31.0 GHz) have been delivered into stringent military programs.

Extremely Robust Outdoor Operation
- -40 C to +60 C Operating Range

Universal Input Power Supply
- 90-265 VAC input range, PFC

Variable Gain: 50 to 70 dB, 0.1dB steps

Output Power Detector

Output Power Sample Port, -40 dBC

Internal 1:1 Redundant Controller

Large status LED

Serial or Parallel Monitor and Control (RS232 / RS485)

Ethernet Interface Standard, UDP-SNMP-Web Browser

Auxiliary +15VDC power port for LNB or Fiber Optic module
Module design based on combining (8) Triquint GaAs MMIC’s using a planar waveguide combiner.

Analog Predistortion utilized to enable amplifier to achieve > 25W of Linear Output Power.
80W Ka Band Compact Outdoor SSPA

- 80W Psat (40W Plinear) Ka Band Compact Outdoor SSPA introduced in 2014.
- All the same features of the legacy 40W Psat Compact Outdoor SSPA.
- Using the latest millimeter wave GaN HEMT MMICs
Compact Outdoor Physical Design

Large passive AC Mains filter for immunity to AC Mains disturbances (lightning) as well as meeting compliance with EN and MIL EMI/EMC requirements.

Filter for suppression of Local Oscillator Feedthrough

L-Band to Ka Band Block Up Converter Module

SSPA Module planar waveguide power combiner

DC / DC Power Supply mounted on side heat sinks for excellent thermal management

TELEDYNE Paradise Datacom
A Teledyne Technologies Company
Compact Outdoor Physical Design

Gasketed Cover easily removable to access the internal ‘modular’ design

Output Circulator with High Power Load

Ka Band Pre Amplifier with Integral Predistortion Linearizer

AC / DC Power Supply mounted on side heat sinks for excellent thermal management
SSPA Module Design

Ka Band SSPA Module
Combining (16) 8W GaN MMICs

16 Way Spatial Waveguide Combiner designed using the latest 3D Electromagnetic design tools.
100W & 180W Compact Outdoor SSPA

Two new additions to the Compact Outdoor Ka Band Amplifier family for 2017.

100W and 180W Psat
50W and 90W Plinear

Weight just under 40 lbs. Dimensions: 10 in. wide x 6.5 in. high x 19.5 in. long.

• SSPBs typically have an I.F. Input Frequency Range of 1000 MHz to 2000 MHz
  • 28.0 – 29.0 GHz
  • 29.0 – 30.0 GHz
  • 30.0 – 31.0 GHz

• SSPA only: Broadband SSPAs can cover 2 to 3 GHz of Bandwidth
  • 27.0 -30.0 GHz
  • 28.0 – 31.0 GHz
Wideband 100W SSPA Gain

Typical RF Bandwidth of SSPA Module without BUC

27.5 GHz

32.0 GHz
Paradise Datacom and Quorvo have a collaborative effort in developing Ka Band SSPAs around the Spatium Module.

The Spatium Module is a spatially combined array of (16) high power MMICs that produce 100W of output power.

Paradise Datacom’s 100W Ka Band Compact Outdoor SSPA is based on a single Spatium module while the 180W unit is designed around two Spatium modules that are phase combined.

Single 100W Spatium Module in 100W Ka Band SSPA

Two Spatium modules phase combined in the 180W SSPA
Teledyne Paradise Datacom has designed a wide variety of custom physical designs such as this 80W Ka Band SSPA module on a liquid cold plate.

Dielectric Liquid Cooled (PAO) 80W, 30-31 GHz module for avionics application.
SSPBs, Solid State Power BUC

- **SSPBs:**
  - SSPBs typically have an I.F. Input Frequency Range of 1000 MHz to 2000 MHz
    - 28.0 – 29.0 GHz
    - 29.0 – 30.0 GHz
    - 30.0 – 31.0 GHz

Units have a high stability internal 50 MHz Reference Oscillator but can detect and phase lock to an externally applied 10 or 50 MHz reference.
Typical SSPB Phase Noise
Compact Outdoor EMI/EMC Compliance

**Commercial – CE Compliance**
EN 55022, 2007 : Conducted Emissions
EN 55022: 2007 : Radiated Emissions
EN 61000-3-2: 2001 : Harmonic Current Emissions
EN 61000-3-3: 1995: Voltage Fluctuations & Flicker
EN 61000-4-2: 1999: Electrostatic Discharge
EN 61000-4-3 : Radiated Immunity
EN 61000-4-4: 1995: Electrical Fast Transient / Burst
EN 61000-4-5: 1995: Surge
EN 61000-4-6: 2003: Conducted Immunity
EN 61000-4-8: 1994: Magnetic Field Immunity
EN 61000-4-11: 1994: Voltage Dips & Interruptions

**Military Spec**
MIL-STD-461F, CE102 : Conducted Emissions, Power Leads 10 KHz to 10 MHz
MIL-STD-461F, CS101 : Conducted Susceptibility, Power Leads, 30 Hz to 150 KHz
MIL-STD-461F, CS114 : Conducted Susceptibility, Bulk Cable Injection 10 KHz to 200 MHz
MIL-STD-461F, CS115 : Conducted Susceptibility, Bulk Cable Injection Impulse Excitation
MIL-STD-461F, CS116 : Conducted Susceptibility, Damped Sinusoidal Transients 10 KHz to 100 MHz
MIL-STD-461F, RE102 : Radiated Emissions, Electric Field 10 KHz to 18 GHz
MIL-STD-461F, RE103 : Radiated Susceptability, Electric Field 30 MHz to 18 GHz
MIL-STD-1686C, HESD: 16 kV, HESD level 3
Compact Outdoor Environmental Compliance

*Military Spec*

MIL-STD-810F, Method 501.4: High Temperature
MIL-STD-810F, Method 503.3: Temperature Shock
MIL-STD-810F, Method 505.3: Solar Radiation
MIL-STD-810F, Method 507.4: Damp Heat, Humidity
MIL-STD-810F, Method 502.4: Low Temperature
MIL-STD-810F, Method 506.4: Blowing Rain
MIL-STD-810F, Method 510.3: Blowing Dust
MIL-STD-810F, Method 510.3: Blowing Sand
MIL-STD-810F, Method 508.5: Mould Growth
MIL-STD-810F, Method 509.4: Salt Fog
MIL-STD-344A, : Random Vibration, 20-50Hz : 0.02 g·Mz, then rolling up to 0.001g/Hz at 500 Hz
: Shock, 25g for 4000 Bumps, 10g 6 msec, 1-2 Bumps/second
300W - 400W Ka Band SSPA/SSPB

High Power Outdoor SSPA Package

Size slightly larger than the Compact Outdoor SSPA
Weight just under 90 lbs. Dimensions: 16.5 in. wide x 27.5 in. high x 9.3 in. deep.

Psat = 300W, 400W
Plinear = 150W, 200W

Coming Q4, 2017: Psat = 400W
Plinear = 200W

Extremely Robust Outdoor Operation
- -40 C to +60 C Operating Range

Universal Input Power Supply
- 90-265 VAC input range, PFC

Variable Gain: 50 to 70 dB, 0.1dB steps

Output Power Detector

Output Power Sample Port, -40 dBc

Internal 1:1 Redundant Controller

Large status LED

Serial or Parallel Monitor and Control (RS232 / RS485)

Ethernet Interface Standard, UDP-SNMP-Web Browser

Auxiliary +15VDC power port for LNB or Fiber Optic module
Supporting Products and Systems

• Hand Held Interface Controller
• Remote Control Panel
• M&C Software Options
• Redundant Systems
• Phase Combined Systems
Controllers for Outdoor SSPAs

Convenient Local Interface that works with both Compact Outdoor and High Power Outdoor Amplifiers

Emulates Indoor SSPA Chassis front panel operation

1 RU chassis
Can remotely control SSPA up to 4000 ft. (1000 m)
mimics actual SSPA chassis front panel
Can be used with Indoor or Outdoor SSPAs
Ethernet and Serial Ports
All Paradise Datacom SSPA Products have built-in Web Browser Capability.
Universal M&C Windows Program
Amplifier Linearity

- CW Power Transfer
- AM/PM Distortion
- Single Carrier
- Two-Tone
- Multi-Carrier
- Noise Power Ratio
Psat, the saturated output power of an amplifier is the maximum, CW, output power that an amplifier can produce.

P1, is the CW output power at the point in which the gain decreases by 1 dB.

It became a common convention to name or benchmark GaAs amplifiers by the P1.

In a GaAs amplifier the Psat is typically only 0.5 dB to 1 dB greater than P1.

In a GaN amplifier the Psat can be several dB higher than the P1.

Amplifiers with softer compression characteristics such as GaN HEMTs, TWTAs, and Klystrons are typically named by their Psat.

The Plin, maximum linear output power, is often referenced by an amount of dB’s backed off from the Psat or P1.
100W SSPA CW Power Sweep

Input Power vs. Output Power Sweep at 30.0 GHz

Note the extremely well behaved AM/PM characteristic of the GaN SSPA. AM/PM Distortion is <1 degree / dB well into saturation.
Linear Output Power, $P_{\text{linear}}$

The most important output power parameter is the linear output power, $P_{\text{linear}}$. The $P_{\text{linear}}$ rating of an amplifier is the maximum output power at which:

-25 dBc intermod can still be achieved with a two-tone intermod test
-30 dBc spectral regrowth on a single carrier digitally modulated signal
80W SSPA with Single OQPSK Signal

1.5 dB Back Off
Higher Crest Factor Single Carrier

Use 2.0 to 2.5 dB Back Off for 16APSK or 16QAM Single Carrier
Typical two-tone intermod performance of 100W Ka Band SSPA.

Intermod levels achieving -25 dBc at 47.5 dBm or 56 W.

Note IMD levels flatten out at lower power levels. This is characteristic of Class AB amplifier.
100W Ka Band 3-Tone Intermod Test
8-Carrier Intermod on 100W Ka Band SSPA

Eight Carriers at 3 dB Back Off, Worst case IMD product is -22 dBc

Eight Carriers at 4 dB Back Off, Worst Case IMD is -27.5 dBc

Eight Carriers at 5 dB Back Off, Worst Case IMD is -33 dBc
An Ideal Amplifier would have -20 dB Noise Power Ratio at 4 dB Backoff
SSPA Back-Off for Linear Power

- Single Carrier – (Low Crest Factor such as QPSK or OPSK)
  - GaN Amplifier: Psat -1.5dB

- Single Carrier – (High Crest Factor such as 16 QAM or OFDM)
  - GaN Amplifier: Psat -2.5dB

- Two-Tone CW – Popular Benchmark Rating
  - GaN Amplifier: Psat-3dB

- Multi-Carrier – 3 or more tones
  - GaN Amplifier: Psat-4dB

- NPR
  - GaN Amplifier: Psat – 4 dB for 19 dB NPR
Ka Band Products in Development

- Wideband Block Up Converters
- Modular Redundant Products
Band Switchable Converters

Converter Architectures that allow the full utilization of the wide band Ka band amplifier

Dual Superheterodyne Block Up Converter will allow ‘Real-Time’ Band Switching among the:
- 27.0 – 28.0 GHz
- 28.0 – 29.0 GHz
- 29.0 – 30.0 GHz
- 30.0 – 31.0 GHz Bands in one SSPB.

This will allow a single SSPB of any output power level operate over all three Ka sub bands. Presently have to buy three separate SSPBs to accomplish all three bands of operation.
Multiple IF Input Converters

Converter Architectures that allow the full utilization of the wide band Ka band amplifier

Multiple IF Inputs allow the full Ka band bandwidth usage instantaneously; without the need for band switching.
Modular Hot-Swap Architectures

An (8) 100W Module SSPA to achieve 53.5 dBm out Linear Output Power in the event of a module failure.

Using (8) modules, the SSPA can achieve a Psat of nearly 600W. With (7) modules active, the SSPA can achieve a Psat of 56.5 dBm.

Using a 3 dB back off to guarantee the linear output power, a Plinear of 53.5 dBm (225W) is achievable with (7) modules operational.

<table>
<thead>
<tr>
<th>Output Power</th>
<th>8 of 8 Modules</th>
<th>7 of 8 Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psat</td>
<td>57.7 dBm</td>
<td>56.5 dBm</td>
</tr>
<tr>
<td>Plinear</td>
<td>54.7 dBm</td>
<td>53.5 dBm</td>
</tr>
</tbody>
</table>

With 8 of 8 modules operational, the maximum available linear output power is 54.7 dBm (300W).
Single Chassis 8-Module System

Sealed Enclosure, Front
Removable Panels for access to modules

Outdoor Enclosure Rear Panel Vents
Ka Band Redundant Systems

Traditional 1:1 and 1:2 Redundant Systems and Phase Combined Systems can be configured with the Ka Band Compact Outdoor SSPA.