

App Note 010 -

SSPA vs TWT & Tube Technology: Which is Best?

Short Answer:

- The best choice depends on the application, frequency range, and power requirements.

Summary:

Tube Technology Overview-

- Includes Traveling Wave Tubes (TWTs), Klystrons, Magnetrons, and other vacuum tube amplifiers.
- Historically dominant in high-power applications but has been gradually replaced due to reliability concerns.
- Uses high-voltage power supplies, which are prone to failure and require frequent maintenance.
- Although perceived as "old technology," tubes still offer advantages in ultra-high-power applications.

Solid-State Power Amplifier (SSPA) Overview-

- Utilizes semiconductor devices like GaAs, LDMOS, and GaN for RF amplification.
- Compact, efficient, and operates at lower voltages, leading to improved reliability.
- Technological advancements have enabled broadband, high-power performance previously only achievable with tube-based solutions.
- Offers significant advantages in size, reliability, and manufacturability.

Key Advancements in SSPAs-

- **Broadband Performance:** Modern SSPAs can operate across wide frequency ranges with high efficiency.
- **GaN Technology:** High power-to-size density ratio and broadband capabilities surpass older semiconductor technologies.
- **RF & Microwave Combining Technology:** Advanced power combining techniques allow SSPAs to replace high-power tube amplifiers.

Achievements in SSPA Technology-

Frequency Range	Power Output	Notes
700MHz - 6.0GHz	>150W	Achieves wideband, high-power operation not accomplished with TWT designs, power combined too multi-KW power levels
6.0GHz - 18.0GHz	>80W	Effective alternative to tube-based amplifiers, power combined too multi-KW power levels
>18GHz	>40W	Replaces legacy millimeter-wave tube amplifiers, power combined to 400W power levels
>40GHz	>20W	Replaces legacy millimeter-wave tube amplifiers, power combined too >120W power levels

Advantages of SSPAs Over Tube-Based Amplifiers-

<u>Features</u>	<u>SSPA</u>	<u>TWT/Tube Technology</u>
Reliability	High	Lower due to high-voltage failures
Performance	Low harmonics, no warm-up time	High harmonics, long warm-up time, extended repair times, cost of ownership high
Power Supply	9-50VDC	Requires high-voltage power sources
Size & Weight	Compact	Bulky; requires additional shielding
Maintenance	Minimal	Requires periodic servicing
Warranty	Typically, 3 years	Shorter lifespan & maintenance requirements
Availability	Readily available	Long lead times for manufacturing & repairs
Cost	More economical	Higher due to complex power supply and maintenance

Application-Specific Considerations-

TWTs and Tubes Are Still Preferred For:

- Space and ground-based SATCOM applications - where ultra-high power (>10KW) is required.
- Some UAV and airborne EW/ECM systems - due to robustness in extreme environments.
- Legacy systems requiring tube technology - where infrastructure is already designed around tube-based solutions.

SSPAs Are Ideal For:

- General high-power CW applications up to KW levels below 18.0GHz.
- Hundred-watt CW levels below 40.0GHz.
- KW Pulse power levels for applications up to 18.0GHz.
- Pulse Radar applications.
- EMC/EMI testing applications.
- EW/ECM Military applications.
- Commercial & scientific applications requiring compact, reliable solutions.

Technological Evolution and Future Outlook:

- **TWTs and Tubes:** Limited advancements due to declining demand and challenges in high-voltage power supply reliability.
- **SSPAs:** Continuous improvements in GaN, Super-GaN, and RF combining technologies continue closing the power gap with tubes.

Conclusion:

The best choice between SSPA and tube technology depends on the specific power and frequency requirements of the application. Tubes remain relevant in ultra-high-power applications such as space and ground-based Sat-com, UAVs, and certain EW and ECM applications that require power levels exceeding 10KW or even 100KW. However, SSPAs are increasingly preferred in many modern applications due to their reliability, efficiency, compact size, and quicker delivery times. With continuous advancements in solid-state technology, SSPAs now offer competitive performance, making them the superior choice for most RF and microwave systems.