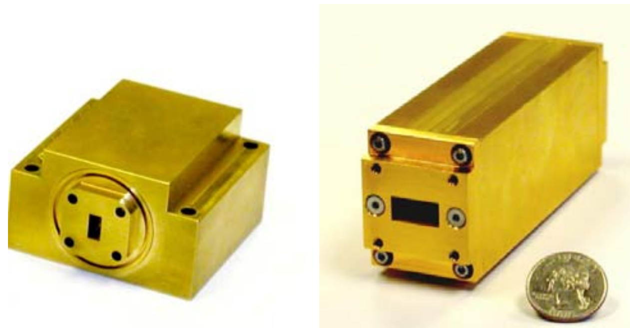
Via Satellite's

Tech Focus Report

Spatial Power Combining



16 Watt 30-31 GHz PowerStream Grid Amplifier (on left) and
50 Watt 14-14.5 GHz PowerStream Deck Amplifier (on right)

Demand for higher data rates and greater mobility in satellite communications is driving the need for smaller, lighter, more efficient and less costly power amplifiers. An innovative approach that power combines solid-state transistor outputs in free space inside a waveguide provides the high efficiencies and rugged, compact packages needed to meet these challenges.

Satellite service providers agree that providing the highest service level at the lowest cost is what customers want. For high data rate users, low power customer premise equipment doesn't meet their needs, but large antennas with bulky RF equipment isn't attractive. For users valuing mobility, there aren't many solutions. One answer is using smaller, lighter, solid-state power amplifiers (SSPAs) that provide high radio frequency (RF) power while drawing less DC power to reduce the size and cost of the entire terminal.

WAVESTREAM

545 West Terrace Drive, San Dimas, CA 91773
Tel: +1 (909) 599-9080
Email: sales@wavestream.com Web: www.wavestream.com

The Solid-State Dilemma

Use of solid-state transistors for power amplification has spread dramatically from cell phones to satellite terminals because of their high reliability, compact size, and low cost. Applications of SSPAs in satellite communications have been limited by the amount of power generated by individual transistors, and the ability to efficiently combine the output power of many transistors. The most common form of power combining, binary microstrip combining, efficiently combines only about 16 transistor outputs on a single chip. Binary combining efficiency deteriorates as the number of combined transistors increases, due to ohmic loss in the additional combining stages. Commercially available MMICs using this combining currently reach maximum power of around 8 W at Ku-band and 4 W at Ka-band.

Demand for higher power than individual MMICs provide has resulted in SSPA architectures that combine many MMIC outputs using microstrip and/or waveguide combining. These combining networks are lossy and bulky, and the resulting SSPAs are costly to manufacture, and too large and heavy for many portable applications.

The Spatial Power Combining Advantage

The spatially power combined amplifier employs a different technique for combining the transistor outputs. Rather than combining in multiple steps, increasing loss and size with each combining stage, all transistor outputs are combined in a single step. Many amplifying elements synchronously amplify the input signal, and their outputs are combined in free space for very high combining efficiency (Figure 1).

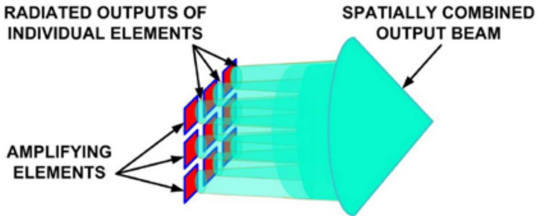


Figure 1.
Spatial Power Combining of Many Elements in a Single Combining Stage

Two spatial power combining approaches have been used to develop waveguide-based SSPAs. The Grid Amplifier, operating at millimeter-wave frequencies, uses a single output stage chip patterned with an array or grid of transistor pairs. The Deck Amplifier, operating at microwave frequencies, stacks up cards containing traditional MMIC amplifier chips for spatial combining of their outputs. Both achieve high power density and high efficiency.

How Grid Amplifiers Work

The PowerStream™ Grid Amplifier contains Grid Amplifier chips packaged directly in waveguide. A Grid Amplifier chip integrates hundreds of millimeter-wave transistors and combines their outputs in a single stage *in air*. The chip is mounted on an RF-transparent ceramic carrier in a specially designed waveguide housing (Figure 2), and receives its input directly from a beam incident on the back of the chip.

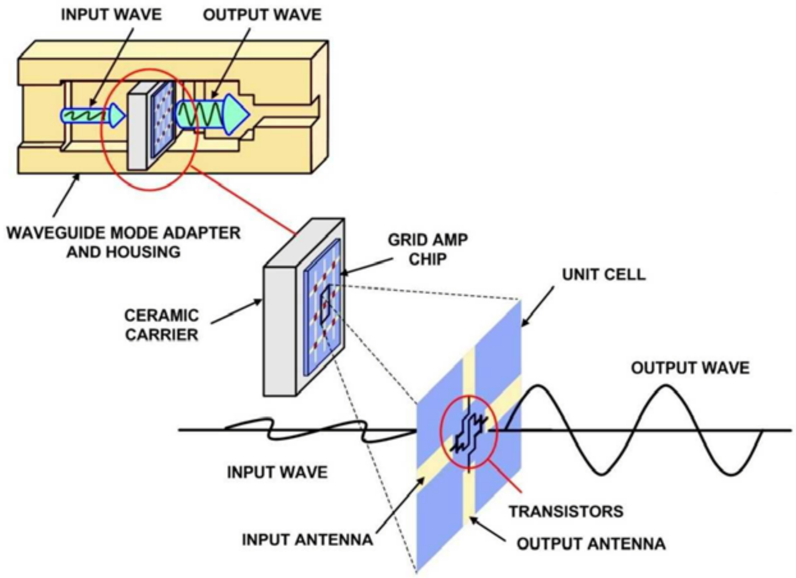


Figure 2.
PowerStream Grid Amplifier spatially combines outputs of hundreds of transistors on a single chip

The Grid Amplifier chip contains a dense grid pattern of “unit cells,” each with a pair of amplifying transistors connected to perpendicularly-oriented input and output “antenna” leads. These leads couple a portion of the RF input wave into each unit cell and radiate the amplified outputs of each transistor pair from the chip. These outputs coherently combine in a free-space beam, eliminating lossy microstrip combining used in traditional MMICs. The chip and carrier are mounted in a waveguide housing designed to ensure that the input and output waves efficiently couple to the chip. A “waveguide mode adapter” accepts standard single-mode waveguide input and distributes the RF input power uniformly across the back of the chip, and collects the output beam back into standard waveguide output. Mechanically, this housing also provides heat removal and a very compact, rugged package.

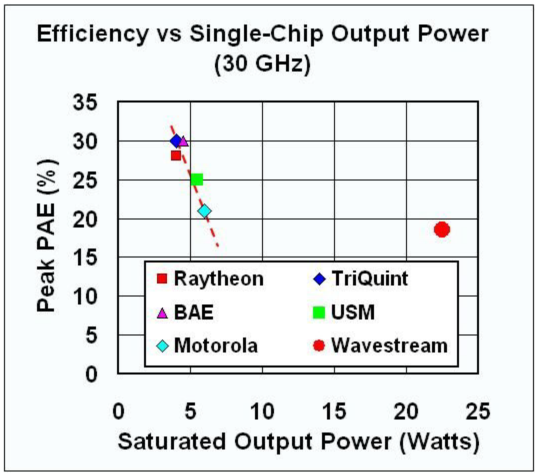


Figure 3.
PowerStream Grid Amplifier has demonstrated
over 20W single-chip RF output power with 19% efficiency at 30 GHz

Grid Amplifiers are also highly linear, especially when concerned with spectral regrowth in multi-channel systems, meeting single carrier requirements well into saturation. PowerStream Grid Amplifiers are robust with respect to adverse load conditions, very reproducible for volume production without hand tuning of individual units, and have high reliability with very graceful degradation. A summary comparison of PowerStream Grid Amplifiers and traditional SSPAs in the 15 to 50 W power level range (Figure 4) shows that the size, weight, and power draw are all reduced by 40 to 60%.

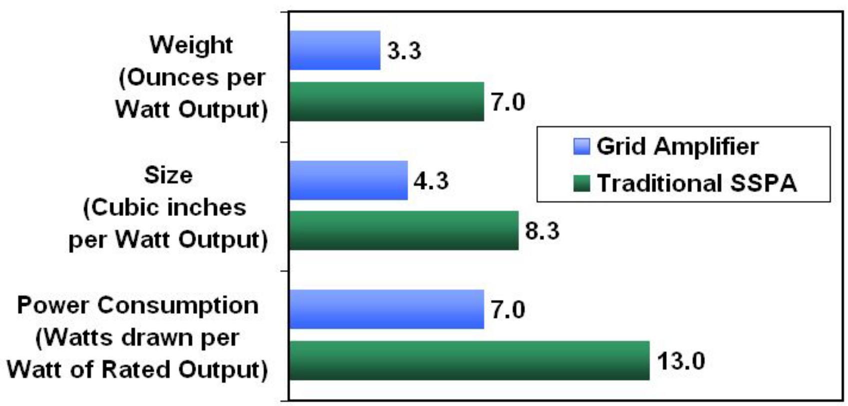


Figure 4.
Comparison of PowerStream Grid Amplifier and traditional SSPAs

System Benefits

The high power capability and reduced size and power draw of these amplifiers provide system-level benefits over other solid-state approaches including:

- Ability to reach higher output powers without complex or costly combining – keeps size, weight, cost down
- Reduced DC power load for given output power – minimizes power supply size and cost
- Reduced thermal load–dramatically reducing system size and weight
- Lower component cost *plus* significant reductions in other system costs

Benefits to satellite communications systems developers over traveling wave tube approaches include:

- Longer life times – reduce life cycle costs through fewer replacements
- Enhanced physical design flexibility from compact size and low weight
- Simple, low-voltage power supply
- Lower component cost *plus* significant reductions in other system costs

PowerStream Grid Amplifiers can be used for a range of communications and imaging applications, and are wellsuited for today's satellite communications systems. Its high output power at low cost strengthens service providers' business cases by driving revenue through increased data rates and availability while lowering life cycle costs through improved system reliability and lower terminal cost.

How Deck Amplifiers Work

The PowerStream™ Deck Amplifier contains an array of solid-state MMIC amplifier chips mounted on cards stacked in a waveguide enclosure (Figure 5). Each card is imprinted with input antennas that receive a portion of the input signal and output antennas that radiate a portion of the amplified output. These coherently combine within the waveguide, creating the high power output.

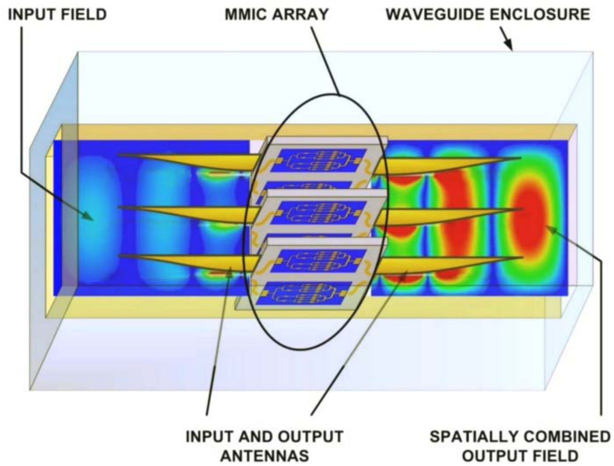


Figure 5.
PowerStream Deck Amplifier spatially combines outputs of cards stacked in waveguide

Two unique aspects of Deck Amplifier architecture provide significant advantages over traditional SSPAs which use microstrip or waveguide combining. The first is the single stage of combining in air, making it highly efficient. The Deck Amplifier has demonstrated 90%combining efficiency, independent of the number of devices combined, while traditional SSPA binary combiner efficiency degrades as the number of elements increases.

The second aspect is the flexibility of the stacked card approach, directly impacting amplifier cost and efficiency. With this architecture, the number of cards and number of chips per card can be varied to achieve optimum operating power with the fewest MMICs. Available chip-level power directly determines the number of chips to reach the desired output level, while in binary power combining the number of chips must be a power of two. This keeps Deck Amplifier efficiency high and recurring cost low.

Deck Amplifier Capability

The Deck Amplifier's flexible architecture makes addressing a wide range of output power levels possible. Limitations on set by available single-chip output power and space to stack cards in the waveguide. At Ku-band, PowerStream Deck Amplifiers can provide as much as 150 W in a 12 in3 package.

The Deck Amplifier's compactness is enhanced by reducing thermal management needed to cool it, due to its high efficiency. Typical 14 to 14.5 GHz 30 W SSPA units consume over 300 W DC. Power consumption of an SSPA using the Deck Amplifier is about 180 W. This 40% reduction in power consumption reduces the heat sink and cooling system size and weight dramatically.

Wavestream has demonstrated 30 and 50 W Deck Amplifiers in the package 12 in3 size, with >25% PAE for a 30 W output. A summary comparing PowerStream Deck Amplifier with traditional SSPAs shows 40 to 80% reductions in size, weight, and DC power (Figure 6).

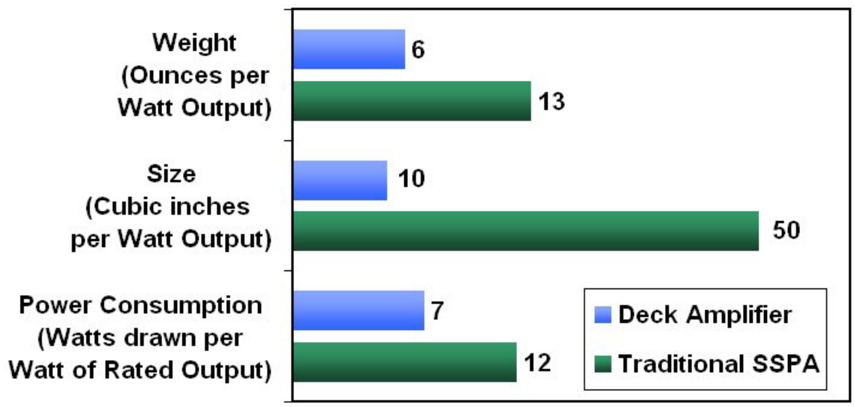


Figure 6.
Comparison of PowerStream Deck Amplifier with traditional SSPAs

System Benefits

The reduced size and power draw of the PowerStream Deck Amplifiers provide system-level benefits over other solidstate approaches including:

- Reduced DC power load for given output power – minimizes power supply size and cost
- Reduced thermal load– can dramatically reduce system size and weight , including location of SSPA at or near feed
- Lower component cost *plus* significant reductions in other system costs.

Demand for greater mobility at higher data rates can be better addressed with the Deck Amplifier when it enables SSPA placement directly at the feed. For example, a 25 W Deck Amplifier is comparable in size to an 8 W SSPA, making feed-mount amplifiers possible at 25 W power levels. Eliminating coaxial cable and waveguide losses from SSPAs located on a pedestal below the antenna can enable use of lower output power SSPAs. The result is less expensive, smaller, lighter terminals that meet the user's mobility needs.