Application Note #72A
High-Power Solid State Pulsed Amplifiers

For years, when discussing high field-strength electromagnetic compatibility (EMC) radiated susceptibility testing, Traveling Wave Tube Amplifier (TWTA) technology has been the only available option for pulsed field generation. Now, there is a very attractive alternative to this technology. AR RF/Microwave Instrumentation is now offering high-power Solid State pulsed amplifiers. These SP-series amplifiers include various frequency ranges and output power levels to meet several standards. Additionally, designs can be tailored to suit your specific application. This application note will discuss some of the key features and benefits of AR's new line of Solid State pulsed amplifiers.

Characteristics

Inherent to the nature of TWTA technology, there are a number of characteristics that are undesirable for EMC applications, one of which is harmonic distortion. TWTAs are rich in harmonic content. While many consider this to be a benefit in the world of audio amplification, the opposite is true of RF amplifiers in EMC testing applications. When producing an electric field for EMC testing, harmonics lead to an inaccurate representation of the intended field. Many EMC specifications go as far as requiring that harmonics be below a certain threshold. Often times, TWTAs have difficulty meeting these requirements. This is not the case with solid state amplifier technology. AR's new SP-series are specified with typical harmonic content of -18 dBc or better at P1dB. Additionally, the SP-series has a much higher compression point than their TWTA counterparts, thus allowing for a wide range of linear gain.

Another extremely important feature of RF amplifiers is mismatch tolerance. In EMC applications, there are an abundance of available antennas for use in field generation. While this provides a lot of options for frequency range, gain, power handling and so on, this can lead to significant variances in the antennas' voltage standing wave ratio (VSWR), meaning that the impedance of the antenna can vary greatly from an ideal 50Ω, thus causing reflected RF power. While antennas most often used in the frequency range in question typically have a relatively stable VSWR, this, along with chamber loading and large EUTs (common for high field strength applications), can be a serious issue for TWTAs. Generally, TWTAs have a

poor mismatch tolerance and will begin to foldback or even shut off for a relatively small VSWR. Solid-state amps on the other hand, tend to have a much higher mismatch tolerance than TWTAs. For example, AR's SP series amps will not begin to foldback until the reflected power reaches half that of the rated output power. Better still, solid state technology does not exhibit the parasitic oscillations that occur in TWTAs.

Solid State amplifiers also have a much higher reliability than TWTAs. Tube technology suffers from numerous deficiencies in reliability, including repeatability in production, parts availability and the decreasing number of tube manufacturers throughout the world. Performance of the TWTAs can even dwindle when left in standby or sitting unpowered on the shelf. If a TWTA does not have any planned use, it is necessary that the user periodically run the amp to prevent degradation of the tube. These solid state pulsed amplifiers also have a much lower noise figure (NF) than their TWTA counterpart. In addition to the above advantages the warranty for these AR solid state amplifiers is 3 years and repairs are much easier to accomplish, and can be completed during a much shorter time frame.

Other characteristics of SP amplifiers include pulse widths up to 100+ µsec, duty cycles up to 10%, a front panel digital display providing forward and reflected power as well as system and transistor status, IEEE-488 and Ethernet interfaces and forced air and water cooling options.

Frequency and Power Levels

AR's new line of Solid State pulsed amplifiers are designed for a variety of frequency bands between 1 and 4 GHz. These bands primarily line up with automotive, aviation and military standards. Particularly, these frequency bands cover L and S band radar pulse testing as required by automotive standards, as well as various high-power offerings for specific octave frequencies from 1 – 2 GHz and 2 – 4 GHz as required by MIL-STD-464 and DO-160, as well as full vehicle automotive testing.

Within these frequency bands, a number of standard output power options from 1 kW to 20 kW are available. Paired with the appropriate antenna, these amps can generate a wide range of field strengths at a wide array of antenna distances. Additionally, AR has the capability to build custom amplifiers up to 150,000 watts depending upon frequency and pulse conditions.

Below is a table showing our standard product lines and their applicable applications.

Frequency Range	Power Level Offerings	General Applications
1 - 2 GHz	1 kW, 3 kW, 6 kW, 12 kW, 15 kW, 20 kW	EMC testing to MIL-STD-464 and DO-160 Standards, Radar Systems, Communications, TWT Replacement and Particle Accelerators
2 - 4 GHz	1 kW, 3 kW, 6 kW, 12 kW, 15 kW, 20 kW	EMC testing to MIL-STD-464 and DO-160 Standards, Radar Systems, Communications, TWT Replacement and Particle Accelerators
1.2 - 1.4 GHz	1 kW, 2 kW, 4 kW, 8 kW, 10 kW	EMC testing to Automotive Standards, Radar Systems, Communications, TWT Replacement and Particle Accelerators
2.7 - 3.1 GHz	1 kW, 2 kW, 4 kW, 8 kW, 10 kW	EMC testing to Automotive Standards, Radar Systems, Communications, TWT Replacement and Particle Accelerators

Example Applications

As previously described, the SP series amplifiers have been designed for a number of different applications. Pairing AR's new solid state pulsed amps can provide you with a wide range of field strengths. The following table gives example field strength levels when using various SP-series amplifiers and AR high-gain horn antennas. This table assumes reasonable losses.

Frequency Range	AR's Pulsed Amplifier	Power Output	Antenna	Distance	Achievable Field Strength	Spot Size (meters)	Standard & Cat	Application	Description
1-2 GHz	1000SP1G2	1 kW	ATH800M6G	1 meter	650 V/m	0.45	DO-160G (Cat B, Cat D), MIL-STD-464C (Table 1, 3)	Avionics and Military	Ø For cat B, distance can be increased up to 3 meters to achieve 250 V/m Ø Covers Section 20(RS/CS) of DO-160
	2000SP1G2	2 kW	ATH800M6G	2 meter	650 V/m	0.89	DO-160G (Cat B, Cat D), MIL-STD-464C (Table 1, 3)	Avionics and Military	Ø For cat B, distance can be increased up to 3 meters to achieve 250 V/m Ø Covers Section 20(RS/CS) of DO-160
	3000SP1G2	3 kW	ATH800M6G	1 meter	1100 V/m	0.45	DO-160G (Cat F)	Avionics	Ø Covers Section 20(RS/CS) of DO-160
	4000SP1G2	4 kW	ATH800M6G	1 meter	1350 V/m	0.45	DO-160G (Cat F)	Avionics	Ø Covers Section 20(RS/CS) of DO-160
	18000SP1G2	12 kW	ATH800M6G	1 meter	3000 V/m	0.45	DO-160G (Cat G), MIL-STD-464C (Table 2 and Table 4)	Avionics and Military	Ø Covers Section 20(RS/CS) of DO-160
	18000SP1G2	18 kW	ATH800M6G	1 meter	3500 V/m	0.45	MIL-STD-464C (Table 6)	Avionics and Military	
2 - 4 GHz	3000SP2G4	3 kW	ATH800M6G	1 meter	1400 V/m	0.45	DO-160G (Cat B, Cat D), MIL-STD-464C (Table 3)	Avionics and Military	Ø For cat B, distance can be increased up to 2 meters to achieve 375 V/m
	6000SP2G4	6 kW	ATH800M5G	1 meter	1800 V/m	0.3	DO-160G (Cat D ,Cat F)	Avionics	Ø For cat D, distance can be increased up to 2 meters to achieve 750 V/m
	6000SP2G4	6 kW	ATH800M5G	2 meter	900 V/m	0.6	DO-160G (Cat D)	Avionics	

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Frequency Range	AR's Pulsed Amplifier	Power Output	Antenna	Distance	Achievable Field Strength	Spot Size (meters)	Standard & Cat	Application	Description
1.2 - 1.4 GHz	1000SP1z2G1z4	1 kW	ATH800M6G	1 meter	600 V/m	0.45	Automotive L-Band Radar Pulse Testing at 1 meter	Automotive	Ø Based on the Automobile manufacturer's test chamber and EUT surface area Field levels may vary
	2000SP1z2G1z4	2 kW	ATH800M6G	2 meter	350 V/m	0.89	Automotive L-Band Radar Pulse Testing at 2 meter	Automotive	Ø Based on the Automobile manufacturer's test chamber and EUT surface area Field levels may vary
	8000SP1z2G1z4	8 kW	ATH800M5G	1 meter	1200 V/m	0.3	Automotive L-Band Radar Pulse Testing at 1 meter	Automotive	Ø Based on the Automobile manufacturer's test chamber and EUT surface area Field levels may vary
	8000SP1z2G1z4	8 kW	ATH800M5G	2 meter	600 V/m	0.6	Automotive L-Band Radar Pulse Testing at 2 meter	Automotive	Ø Based on the Automobile manufacturer's test chamber and EUT surface area Field levels may vary
2.7 - 3.1 GHz	2000SP2z7G3z1	2 kW	ATH2G4	1 meter	1500 V/m	0.28	Automotive S-Band Radar Pulse Testing at 1 meter	Automotive	Ø Based on the Automobile manufacturer's test chamber and EUT surface area Field levels may vary
	4000SP2z7G3z1	4 kW	ATH2G4	2 meter	1000 V/m	0.56	Automotive S-Band Radar Pulse Testing at 2 meter	Automotive	Ø Based on the Automobile manufacturer's test chamber and EUT surface area Field levels may vary
	8000SP2z7G3z1	8 kW	ATH2G4	3 meter	1000 V/m	0.84	Automotive S-Band Radar Pulse Testing at 3 meter	Automotive	Ø Based on the Automobile manufacturer's test chamber and EUT surface area Field levels may vary

Conclusion

To date, pulsed high-power RF amplifier performance from 1 – 4 GHz has been dominated by low Mean Time Between Failure (MTBF) and low warranty TWTAs, but AR's new solid state pulse amplifier designs offer better performance and reliability, and backed by the AR brand with a 3-year warranty. These amplifiers provide an attractive alternative to TWTA solutions. If you would like to learn more, feel free to contact one of our applications engineers at 800-933-8181 or visit our website at www.arworld.us.