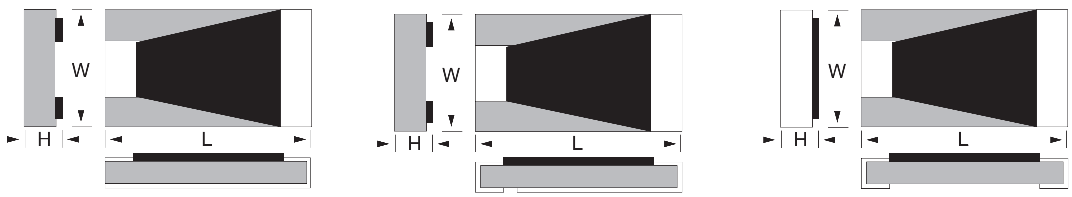
Z Power Resistors
High Power and High Frequency Without Compromise

The need for resistors with both high frequency performance and high power handling capability is growing. In most cases, the smaller the resistor, the better performance at high frequencies. At the same time, the larger the resistor, the better the thermal properties are. Many designers are making compromises when both power and performance matter. IMS has solved this dilemma with an innovative resistor that offers the best of both worlds called "Z Power resistors". The Z Power device is offered as a termination or as a feed through component. The terminal styles are available in SZG (Single Wrap to Ground) suitable for use as a traditional termination, EZW (Extended Wrap) used commonly as an SMT style termination and WZA (Wrap Around) used as a feed through load. The metallization and termination geometries are shown in figure 1 below:



SZG STYLE
Single Wrap to Ground with
"Z" Style Tapered Resistor

EZW STYLE
Extended Wrap with
"Z" Style Tapered Resistor

WZA STYLE
Full Wraparound with
"Z" Style Tapered Resistor

Figure 1 – Z Power terminal configuration geometries

Power

Thermal management is becoming much more important as the density of electronic components and the applied power increase. Both factors lead to higher temperatures produced by not only the individual components, but also the entire assembly. If this heat is not properly transferred out of the part, the heat build-up can cause the part to shift in value and eventually fail electrically and mechanically. Therefore heat dissipation in high power electronics creates challenges for integrating material selection together with thermal designs.

To make use of the extremely high power levels specified in advertisements and data sheets, there are certain criteria that the designer must control. Identifying a maximum surface temperature or maintaining a constant baseplate temperature are common examples (often listed in the "fine print") of the ways manufacturers manage the power ratings. The devices themselves are capable of running at these power ratings due to the higher thermal conductivity of the substrate and the ability to quickly and efficiently transfer the heat away from the device. The challenge is where that heat gets transferred. One common technique is to employ a thermal back plane as seen in figure 2.

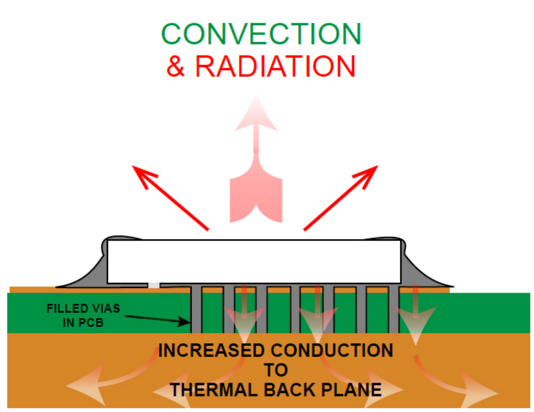


Figure 2 – Example of back plane and via conductive cooling

This technique uses a larger copper plate on the backside of the board to transfer the heat away from the circuit. This way the heat is spread over a large thermal mass, which will increase the area to transfer heat by convection, conduction and/or radiation. Note that if active thermal management is not employed, the board and surrounding environment may succumb to the heat and exceed safe operating temperatures.

To take the power handling one step further, IMS has implemented a “scrub-cut” rather than a traditional L-cut during the laser trimming process. The scrub-cut runs parallel with the tapered resistor meaning less current crowding or hot spots along the resistive element.

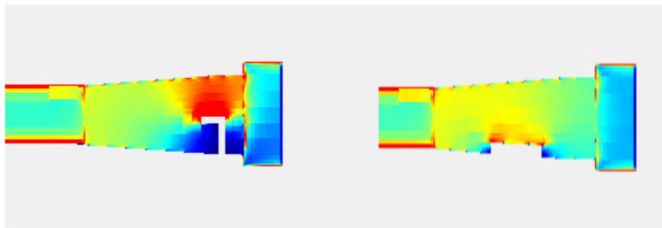


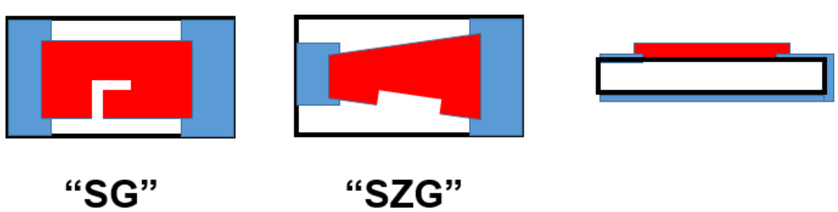
Figure 3 – Power density of L-cut (left) and scrub cut (right) resistor elements

You can see by the color mapping that there is much higher current density in the L- cut resulting in a hot spot while there is almost no current crowding in the scrub cut image.

Once the optimum configuration of resistor trimming and contact area has been achieved, the last design input to determine ideal thermal performance is the material thickness. For highly conductive ceramic materials to be optimized for thermal transfer through the substrate, thinner materials are best. This means that maximum power handling when employing conductive cooling to the component can be achieved with the thinnest substrate. In terms of components, .010” AlN material would prove to be ideal. IMS has the ability to use this material in many sizes (typically up to 1020 package) which allows for a number of designs to be offered in both the standard .015” thickness and the thinner, .010” size. The impact to power conduction is linear, meaning that a material that is 33% thinner has the ability to be 33% higher power while maintaining the same thermal properties.

Frequency Performance

The Z Power resistor uses a tapered resistor body with a smaller input pad. Fabricating a smaller input terminal improves the VSWR at elevated frequencies. The resistor body expands to a larger cross section to optimize heat dissipation and maintain VSWR matching. The actual impedance match is a combination of the customer input line width and the customer’s substrate materials and how they interact with the component. The wider output trace also lowers the high frequency impedance linearly due to the taper. The increased capacitance of the wider trace lowers the impedance as you move towards the back end of the part which is connected to ground (with the termination style) and therefore zero ohms. The taper takes the 50Ω input, and starts transitioning the impedance towards the output end of zero ohms.



Compared to the standard SG, the Z Power “SZG” resistor has a drafted resistor body to minimize input termination width differences from the trace. The Z Power resistors use a “scrub-cut” or edge-trim for tuning within a 2% tolerance. The combination of these 2 manufacturing characteristics maximizes the frequency performance of the Z Power design.

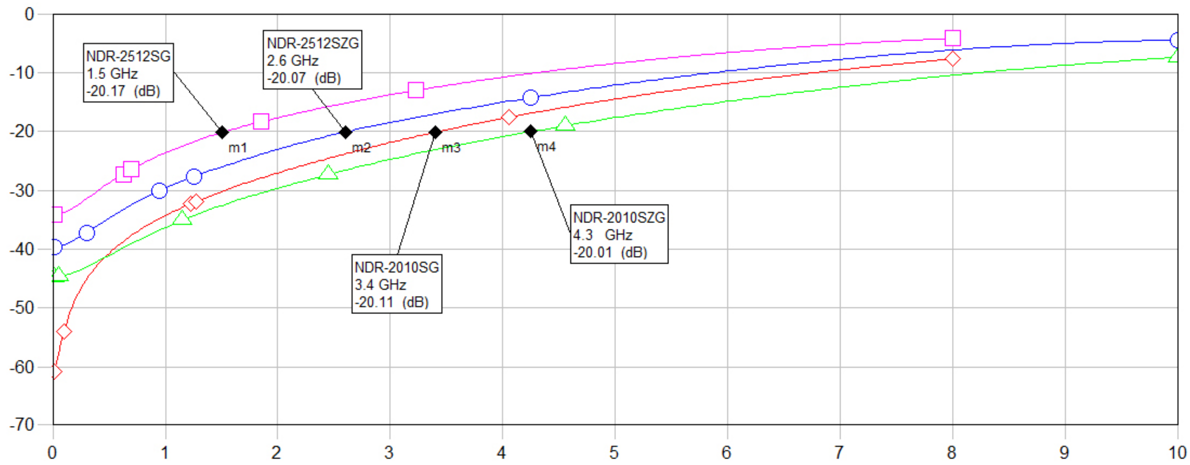
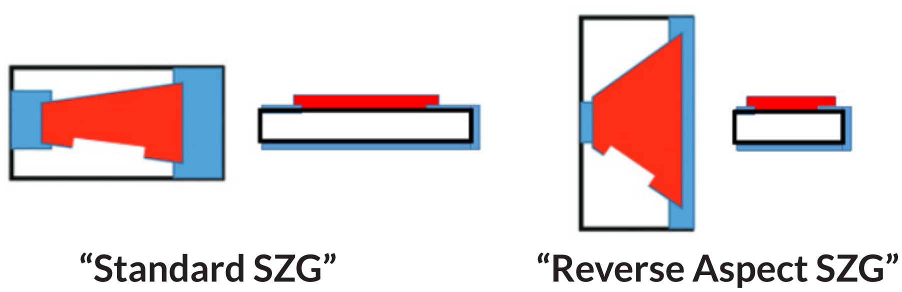


Figure 4 – Comparison of "SG" and SZG" resistor performance

Figure 4 shows the frequency response (return loss) between the SG and the SZG in 2 different package sizes. The NDR-2010SG has a RL of -20dB at 3.4GHz while the NDR-2010SZG has a RL of -20dB at 4.3GHz, yet both have a power rating of 150 Watts. All of the Aluminum Nitride (N-series) are available with IMS' Ultra Leach Resistant Termination (ULR) metallization. (For more information on the ULR termination metallization please see the white paper *Advantages of multi-metal terminations for non-magnetic, high temperature solder applications* on the ims-resistors.com website.)

Reverse Aspect Resistors

For applications where footprint can be customized and both power and frequency performance must be optimal, changing the resistor to be wider than the distance between the terminals can offer a benefit. This configuration is called "reverse aspect" due to the fact the overall component is very wide and very short in similar proportions to traditional case sizes, but in reverse. A 2512 case size may appear as a "1225" in this configuration.



By changing the aspect ratio on the resistor the "term to term" distance is shortened giving the component a better frequency response at higher frequencies. In most cases the surface area of the resistor body does not vary. This preserves the potential heat dissipation of the design so that the power handling is not altered by a large degree, while taking advantage of the frequency performance enhancement. For example, the N-series 1020 SZG has 92% of the resistive element surface area of the N-series 2010 SZG component. This translates to nearly identical thermal heat transfer performance which ensures the power ratings are very close. The reverse aspect ratio style of resistor also features more metallized terminal surface area and resistor-termination interface area. This only helps to normalize the heat transfer across the entire resistor substrate body to the heat sinking of the circuit board. These conditions improve frequency response and thermal performance, enabling a better performing component with equivalent power capabilities in the same footprint.

In Figures 6 and 7 below you can see the NDR-2010SZG has a 1.2:1 VSWR (RL of -20dB) at 4.25GHz while the NDR-1020SZG has a 1.2:1 VSWR (RL of -19.8dB) at 5.45GHz with similar power ratings of 100W – 200W depending on the level of thermal management involved.

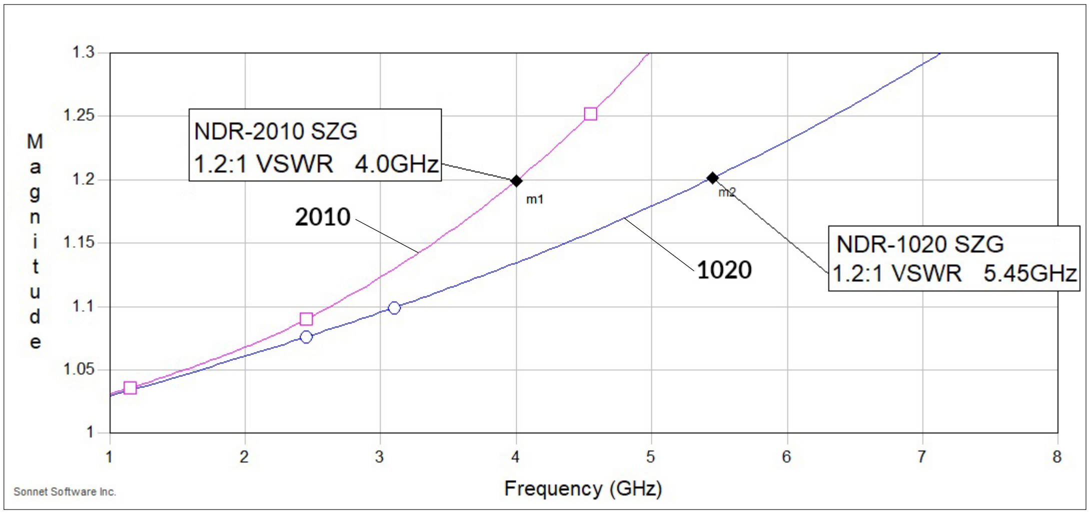


Figure 6 – VSWR comparison of 2010 (violet) and 1020 (blue)

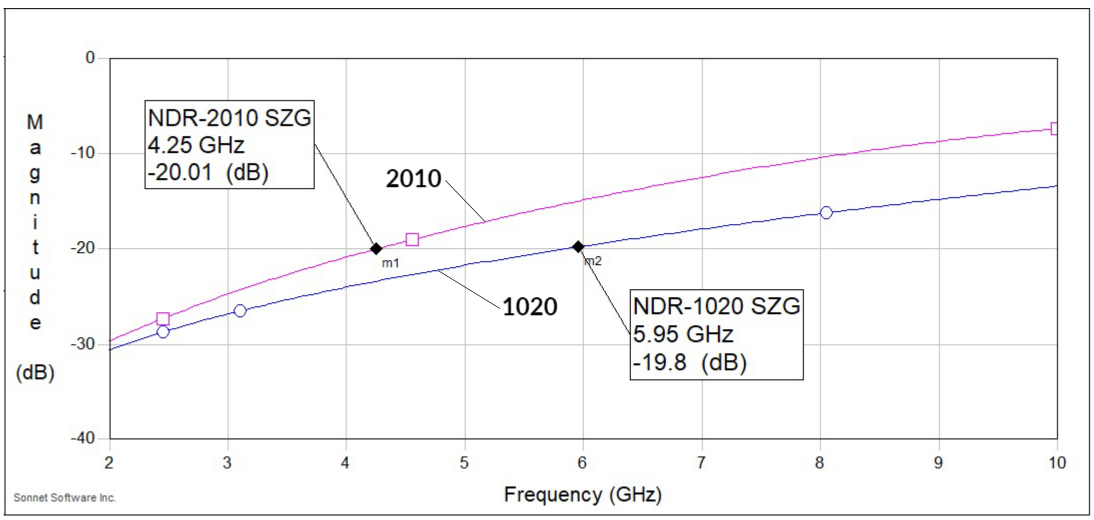


Figure 7 – Return loss comparison of 2010 (violet) versus 1020 (blue)

Conclusion

The Z Power style resistor gives a better frequency response than components with the same footprint, with thermal properties equivalent to the same size package. Figure 8 below illustrates the advantage to both RF performance and power handling associated with various Z Power configuration products. Using this technology, designers have novel and exciting combinations available by selecting the ideal thickness, package, aspect ratio and terminal geometry. When looking for a high power, high frequency resistor without compromise, N-series Z Power resistor is recommended. Please contact the experts at IMS to discuss how this technology can help achieve your next generation designs.

Substrate Thickness D=0.015"

Size	SUB	Terms	f @ -20dB RL	f Range	Power Rating ΔT = 100	ΔT = 85	ΔT = 50
0306	D	SZG	18.76GHz	26.3GHz	20W	15W	10W
0510	D	SZG	17.2GHz	23GHz	60W	45W	30W
0512	D	SZG	14.14GHz	18.9GHz	80W	60W	40W
0612	D	SZG	12GHz	15GHz	105W	85W	50W
1005	D	SZG	5.5GHz	8GHz	60W	50W	30W
1206	D	SZG	4.8GHz	6.6GHz	95W	80W	50W
2010	D	SZG	3GHz	4.3GHz	220W	180W	110W
2512	D	SZG	1.9GHz	3.3GHz	310W	250W	155W
2525	D	SZG	0.5GHz	1GHz	480W	385W	240W
3725	D	SZG	0.4GHz	0.7GHz	875W	680W	390W
1020	D	SZG	6GHz	9GHz	195W	140W	100W
1225	D	SZG	3.6GHz	6GHz	370W	260W	185W
2537	D	SZG	0.9GHz	1.65GHz	765W	535W	380W

Substrate Thickness C=0.010"

Size	SUB	Terms	f @ -20dB RL	f Range	Power Rating ΔT = 100	ΔT = 85	ΔT = 50
0306	C	SZG	24.35GHz	32GHz	30W	20W	15W
0510	C	SZG	16.5GHz	22GHz	85W	70W	40W
0512	C	SZG	16.6GHz	22GHz	115W	90W	60W
0612	C	SZG	13.5GHz	18GHz	165W	130W	80W
1005	C	SZG	6.5GHz	8.6GHz	90W	70W	45W
1206	C	SZG	6GHz	7.5GHz	95W	75W	50W
1020	C	SZG	2.5GHz	5.3GHz	290W	210W	150W

Figure 8 – Z Power product package sizes and associated performance data

Input terminal width can be matched to customer trace width.