Terminations designed to dissipate significant amounts of power at RF frequencies have traditionally been fabricated on beryllium oxide (BeO) substrates. The high thermal conductivity and moderate dielectric constant make BeO an ideal choice for this application. Increased regulation regarding the use of BeO, though, has necessitated the search for alternative materials that do not have the toxicity associated with beryllia. Aluminum Nitride (AlN) has emerged as the best current candidate to replace BeO in these applications. This paper delineates the issues involved and provides two examples of terminations designed to the same specification, one utilizing BeO, and the other AlN.

Material	Thermal Conductivity (25 degrees C)	Dielectric Constant
Beryllium Oxide	270 W/mK	6.7
Aluminum Nitride	170 W/mK	8.8

TABLE1

Table 1 summarizes the material characteristics of typical commercially available BeO and AlN. A cursory examination quickly reveals the central issue; AlN exhibits lower thermal conductivity and higher dielectric constant than BeO. A resistor designed using BeO, therefore, cannot simply be fabricated using AlN and achieve the same level of performance in all critical specifications. For this discussion, the critical specifications are:

Thermal Impedance
Return Loss (over the desired frequency range)

For the most common type of termination design having a single rectangular resistive element, it is necessary to increase the film area on the AlN termination to maintain the same film temperature as that of the BeO termination. The film temperature must not exceed the design value (in this case 250 degrees C) when the maximum rated power is dissipated. Mounting the termination to a heat sink and maintaining the heatsink temperature within the constraints of the derating curve (Figure 1) ensures this. Since some of the resistive film is usually ablated to trim the resistor to the desired value (50 ohms), the most significant attribute is the remaining area after trimming.

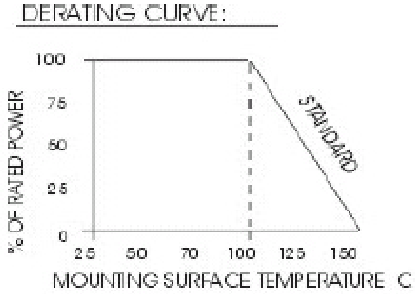

FIGURE 1

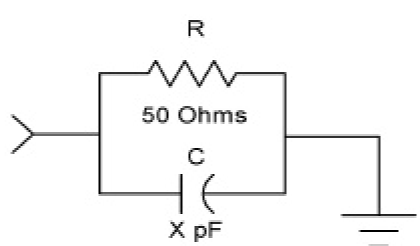

FIGURE 2

Figure 2 shows the schematic representation of the simplified equivalent circuit for this device. Since the capacitance of the film is proportional to the area and also to the dielectric constant, the increase in film area required to maintain the power rating combined with the increase in dielectric constant leads to a significant increase in capacitance. For the return loss to be maintained over the desired frequency range, the matching circuitry also needs to be adjusted accordingly.

To illustrate the points stated above, two termination designs will be compared, T50R0-150-25Q and TA50R0-150-25Q. Table 2 lists the pertinent specifications for this analysis.

Part Number	Power Rating	Frequency Range	VSWR (MAX)
T50R0-150-25Q	150 Watts	DC-4 GHz	1.30:1
TA50R0-150-25Q	150 Watts	DC-3 GHz	1.15:1

TABLE 2

Figure 3 and Figure 4 show the circuit patterns of the terminations.

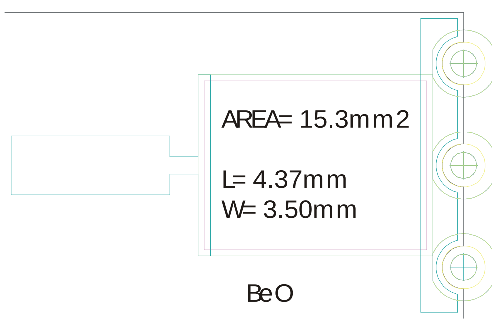

FIGURE 3

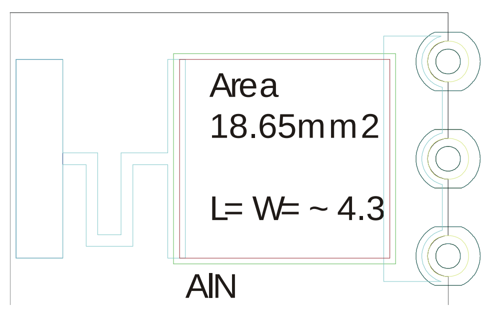

FIGURE 4

It is clear that the nominal area of the resistive film in figure 4 has been enlarged to maintain the thermal impedance as discussed above. In addition, less material is allowed to be ablated in the manufacture of the AlN design. The success of this approach is evident in Figure 5 and Figure 6, where the infrared measurement data for each of the devices under full power operation is shown.

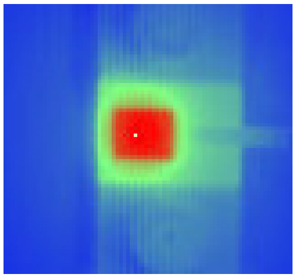

FIGURE 5

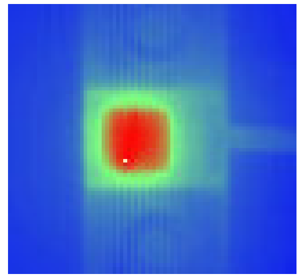

FIGURE 6

Finally, the difference in the matching structures employed in the devices is apparent from inspection of Figure 3 and Figure 4. The RF test data in Figure 7 and Figure 8 show that the more complex matching structure used in the AlN design was adequate to maintain the required return loss.

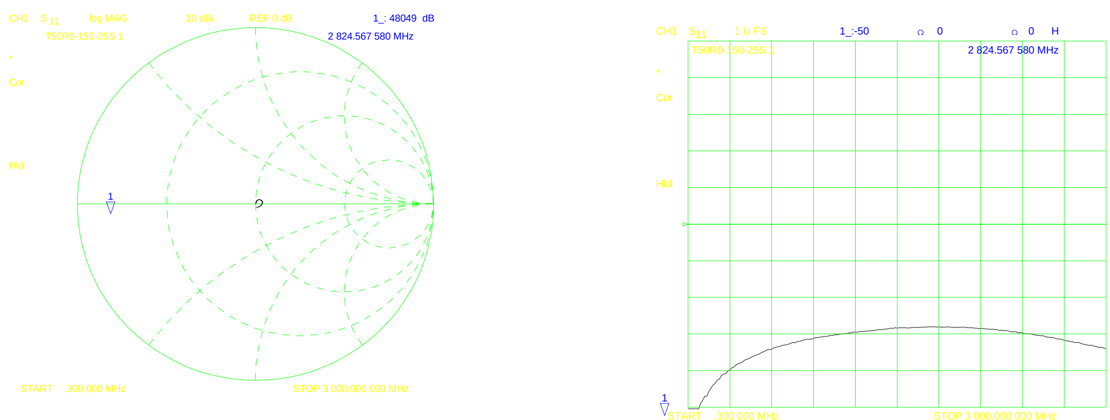

FIGURE 7 T50R0-150-25 (BeO)

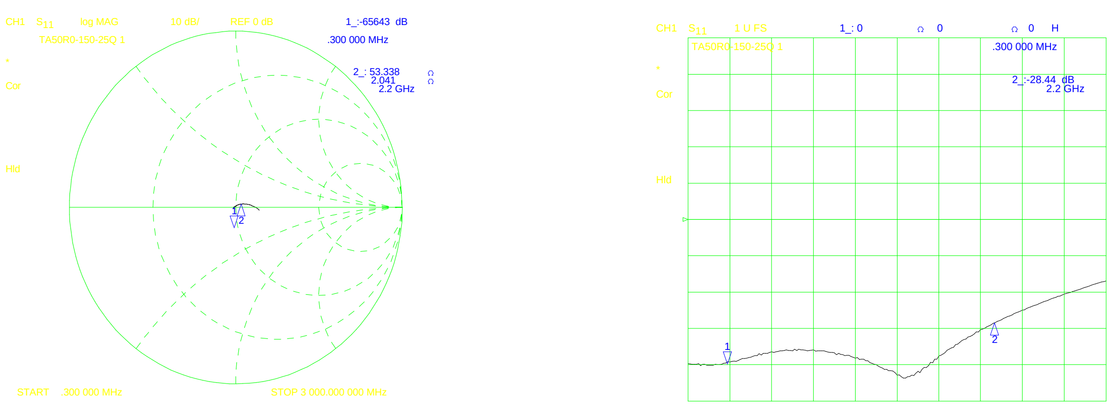

FIGURE 8 TA50R0-150-25 (AlN)