20th ANNIVERSARY

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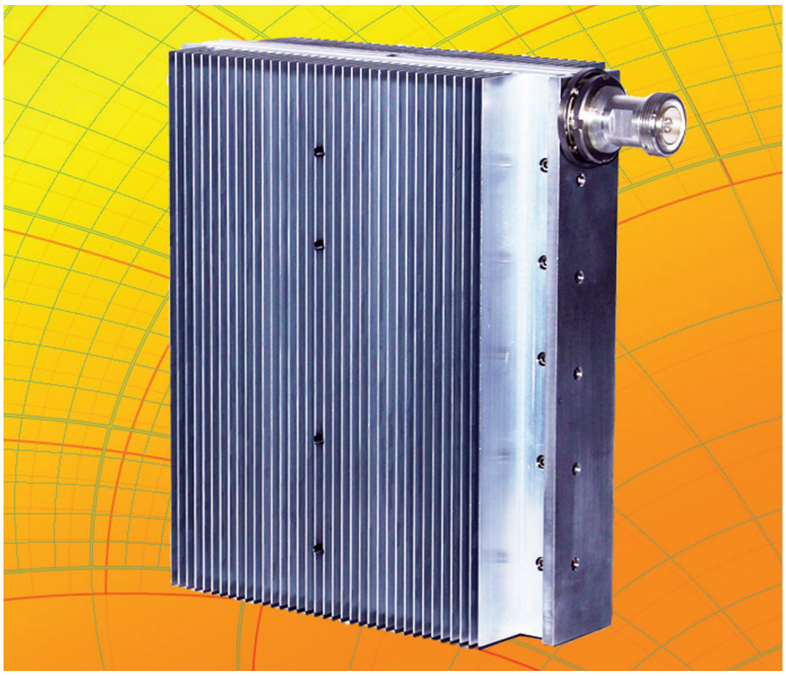

Termination for Broadband

This versatile high power termination, Model TA-A10, uses new design concepts to dissipate up to 1000W with an operating frequency range of 700 MHz to 8 GHz. The unit provides a unique combination of high power, broad frequency range, and low PIM, along with high temperature. The input VSWR is only 1.20 typical with a 7-16 DIN connector (optional type N will extend the frequency range with even lower VSWR).

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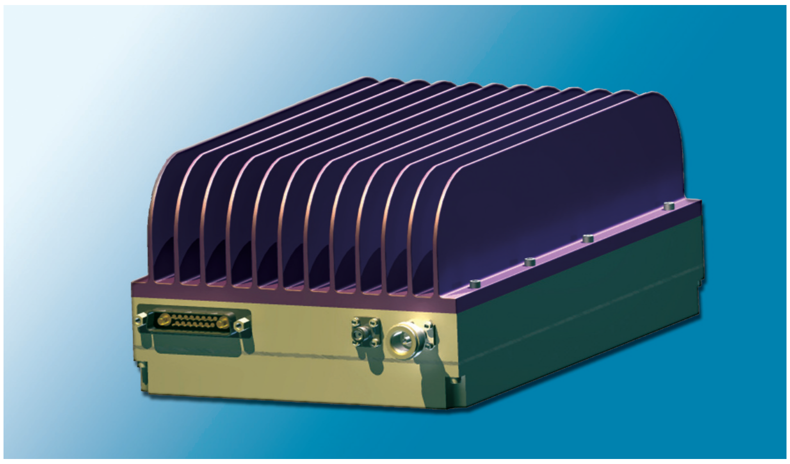
R&D MICROWAVES



Digital Pre-Distortion MCPA Product Line

A new line of single- and multi-carrier DPD power amplifiers for WiMAX, WCDMA, and LTE in a variety of operating frequencies and power levels has been launched. A 50 ohm RF input is standard and CPR1/OBSA1 interfaces are planned for TMA models. The DPD technology employed is modulation-agnostic and can automatically adapt to any mix of carrier types within its operating bandwidth.

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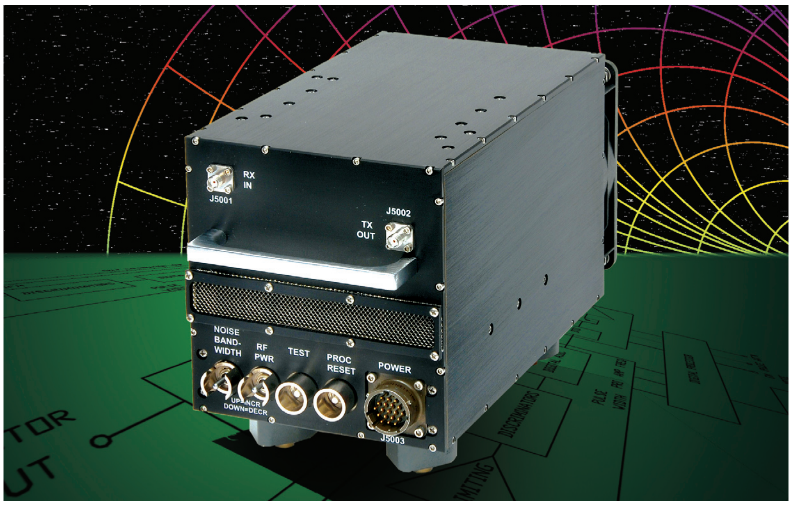
STEALTH MICROWAVE, DIVISION OF MICRONETICS



Set-On-Receiver (SOR)

This new SOR provides wideband, fast frequency set-on for EW Radar jamming. It consists of an IFM receiver, digitally tuned oscillator (DTO) and a microprocessor controller. The threat radar signal frequency is measured within 80ns of its transmission. The noise modulated DTO is then tuned to the same frequency within a total time of 250ns. The SOR is very effective at jamming frequency hopping radars. Frequency jamming priority, jam time, look through, power output and noise spot width can be programmed and stored in the SOR.

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TELEDYNE COUGAR

In This Issue

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Volume 20, Issue 3

New Developments in High Frequency Printed Circuit Board Materials

by John Coonrod, Market Development Engineer, Rogers Corporation

Understanding the many different properties of circuit materials can have a major impact on circuit fabrication costs, assembly concerns, reliability issues and end-use performance. This article will discuss how modifications to a high frequency printed circuit board (PCB) material improved registration of the material through multi-layer board (MLB) processing, and tightened significantly the tolerance realized on subtractively processed planar resistors. The two attributes, registration and resistor tolerances, are very different from each other but benefited from the same product modifications. There are several benefits of this material for the end-user, and replacing discrete resistors with in-plane resistors will eliminate the assembly and reliability issues of the component– not to mention the potential to simplify the circuit construction. The material discussed will be a polytetrafluoroethylene (PTFE) based material.

Figure 1: Cross-sectional view of a circuit material substrate using a copper in-plane resistive layer.

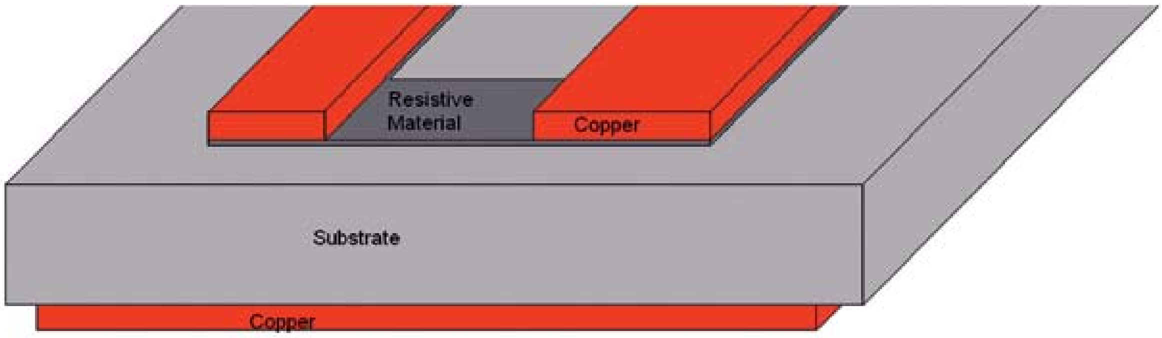

Figure 2: Simple double-sided circuit showing resistive material between two conductors

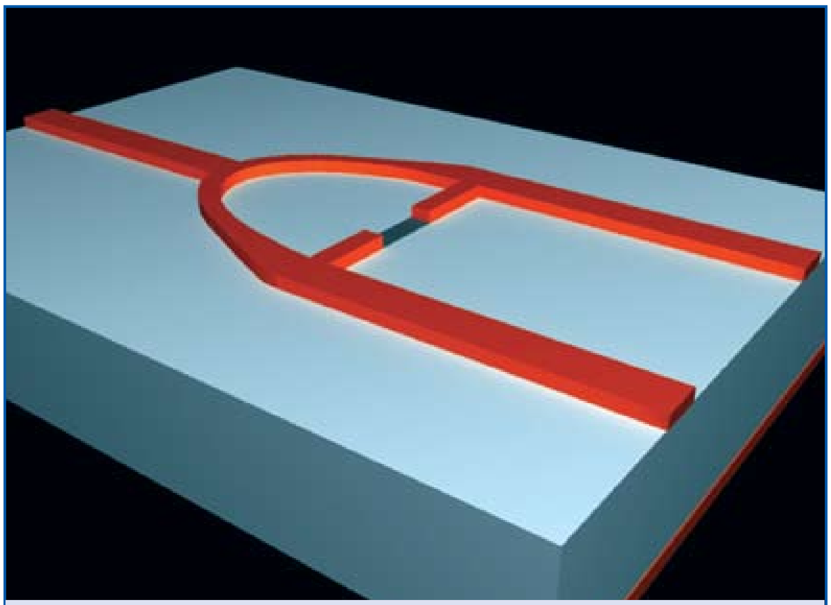

Figure 3: Equal-split microstrip Wilkinson power divider with resistive layer in the PCB

Traditionally, the nearly pure PTFE laminates were well known to have the best electrical performance for high frequency applications. However, some of these laminates had very difficult circuit fabrication limitations. Some time ago it was discovered that if special ceramic filler was used with the PTFE many of the circuit fabrication issues could be minimized or eliminated. This was done with the Rogers' RT/duroid® 6002 material. The additional filler helped minimize CTE (coefficient of thermal expansion), which was good for PCB fabrication, end-use performance and reliability. Of course with a change to any system there are always pros and cons, and in this case the ceramic filler somewhat increased the dissipation factor. The dissipation factor for this material is still considered quite low at a value of 0.0016.

Matching the expansion characteristics of laminate to copper improved intrinsic dimensional stability. However, as denser circuitry became more prevalent, poor registration due to mechanical distortion of cores during inner-layer processing had to be overcome. Issues of misalignment due to handling were resolved by adding layers of woven glass reinforcement to the ceramic filled PTFE substrates. The right combination of PTFE resin, ceramic powders, and woven glass layers were used to create a material capable of meeting the electrical performance and processing needs of the industry, and the resulting material is the Rogers' RT/duroid 6202 laminate.

There have been many demands to form planar resistors on inner-layer circuit patterns that are subsequently buried within multi-layer constructions. To have the ability to form resistors on the same plane as the copper would require screening of polymer ink resistors or, preferably, cladding cores with subtractively processing resistive foils. With the resistive foil approach, there would be an extremely thin layer of a resistive material just between the copper and substrate as shown in a cross-sectional view in Figure 1.

Rogers Corporation has worked for many years with these suppliers. As a recent addition to the Rogers' RT/duroid product line, the RT/duroid 6202PR substrate uses resistive foils supplied by Ohmega Technologies Incorporated. Many attributes that made RT/duroid 6202PR laminate an attractive material option for designers and fab houses also improved the manufacturing yield of in-plane resistors. One such enhancement was adding the woven glass layers to improve how the material handled through resistor formation process.

A quick description of how a circuit can be made with planar resistors as part of the PCB circuit pattern follows. The basic circuit fabrication process will be:

1. Image and etch the circuit pattern as normal. In areas where the copper was etched away, there is exposed resistive material at the surface.
2. Chemically remove the exposed resistive material.
3. Apply photoresist to protect the circuit pattern and have selective openings imaged in the photoresist that will define the resistors.
4. Etch the copper in the selectively open areas down to the resistive material.
5. Remove the protective layer. A simple drawing of this technology with a resistor in the middle of two copper conductors is shown in Figure 2.

In most microwave applications this technology is often used for termination resistors of transmission lines. Also used in power dividers, this planar resistor technology is often used as the matching resistors. And in other applications this technology has been used for minimizing or eliminating the inductive reactance of a SMT device. A simple example of an equal-split microstrip Wilkinson power divider is shown in Figure 3 with the planar resistor between the power branches.

As with all technologies there are several considerations for the electrical and PCB design aspects. The planar resistor has a simple relationship for determining the design resistor value. It is merely the length divided by the width and then multiplied by the surface resistance of the resistive material, where the length and width would be the dimensions of the

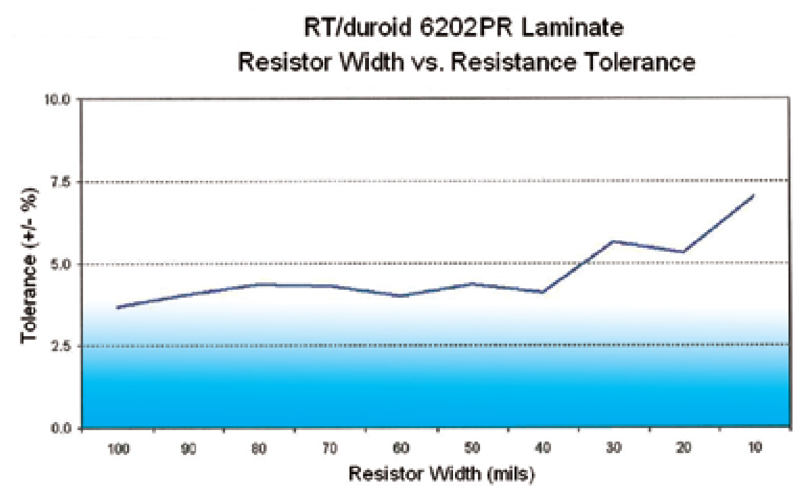

Figure 4: Resistor width vs. resistance tolerance [1] of the RT/duroid 6202PR laminate

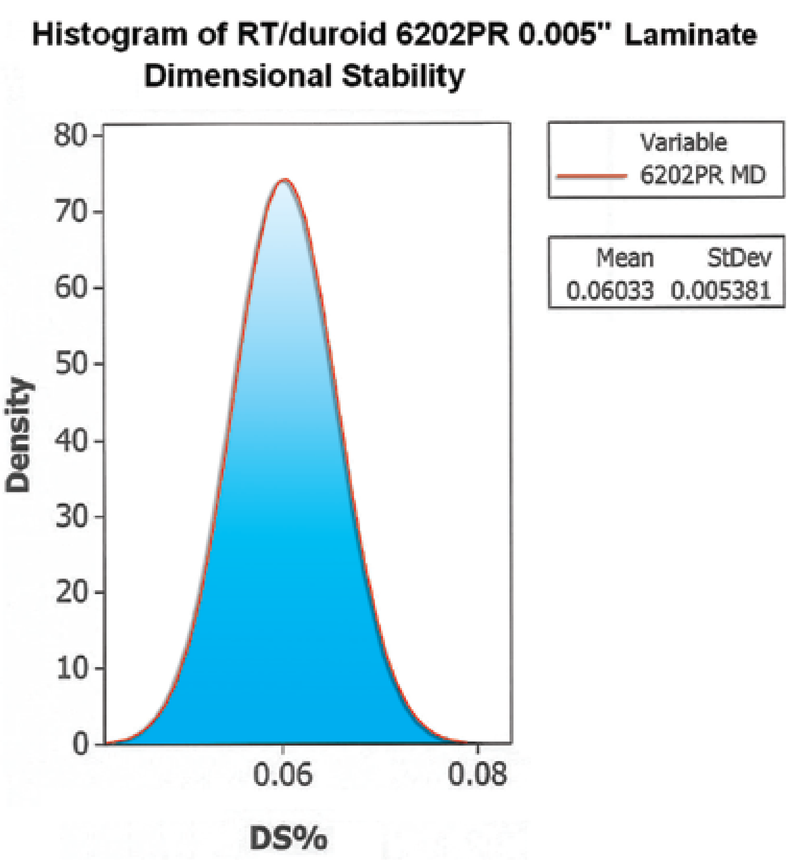

Figure 5: Dimensional stability of RT/duroid 6202PR laminate

planar resistor. There are other details of which the designer should be aware, and visiting the website for the supplier of the resistive foil at: http://www.ohmega.com is recommended.

The more common nominal surface resistance (RS) values of the resistive materials are 25, 50 and 100 ohm/square. There are also 10 and 250 ohm/square values available as well. Planar resistor technology has been around for many years and more recently it is becoming more widely adapted. There are several reasons for this trend. One reason is there are more applications now that can benefit from this technology. Another good reason is that the technology has been fine-tuned to achieve very accurate resistor values.

The resistive materials can have their nominal resistance value and their resistor tolerance changed by how the materials are made into a PCB laminate. Also, these values can be altered in the circuit fabrication process as well. There are many different types of laminates and each of them has different processing needs when making the laminate. High temperature exposure can affect the resistance values and tolerance. The higher performance microwave laminates are typically PTFE based and the temperature needed to make these laminates is very high. These laminates have always had very good microwave performance; however, the planar resistance tolerance was wider than desired with OEM's often tolerating a ± 20% range.

Lately multiple technology breakthroughs have led to a laminate that has excellent microwave performance and planar resistors with tight tolerances. That material is the RT/duroid 6202PR laminate and it uses the Ohmega resistive foil, OhmegaPly®, with nominal values of 25, 50 and 100 ohm/square. After the laminate is made, the nominal resistive values shift some and are stable. The typical resistive values for the RT/duroid 6202PR laminate are 27, 60 and 157 ohm/square. The tolerance can be very well controlled. However, there are several dependencies. One is the physical size of the resistor. A larger resistor will typically have much better resistance tolerance control. In recent studies there have been extremely good results with medium to large resistors and good results with relatively small resistors. A curve is shown in Figure 4, which illustrates some typical resistor widths and the tolerances associated with them.

There are other issues in the circuit fabrication and/or assembly process that can alter the resistor tolerance, so a careful study should be made for the particular application of interest.

There are other benefits to this laminate as well. When a PCB becomes more complex, dimensional stability of the laminate will play a major role in how the various circuit layers can be aligned. As part of optimizing the RT/duroid 6202PR substrate for planar resistor applications, many resources were applied to ensure that the dimensional stability of this laminate was very stable. It can be seen in Figure 5 that the dimensional stability mean is 0.06%, which is extremely good and the variation can be seen to be very good as well. The thickness of the material should also be noted. In **Figure 5** the materials tested were multiple lots of a 5mil thick substrate. Thinner substrates are always more difficult to control dimensional stability, and it can be seen that this thin substrate is very well controlled.

There are other benefits of replacing discrete resistors with the planar resistor technology. With the elimination of the discrete resistors, the reliability issues associated with assembly, soldering and rework are minimized or eliminated. The resistive material is lead-free compatible and can aid in board densification and size reduction. And with the capability of the planar resistors being used on internal layers of a PCB, plated via's could be eliminated.

In summary, RT/duroid 6202PR laminate has demonstrated excellent microwave capabilities as well as very well controlled planar resistance tolerances. This material is PTFE ceramic filled so the electrical performance is excellent and the fabrication issues are minimized.

There are many complexities to how a circuit material may perform in a circuit fabrication environment as well as the end-use performance, and there may be some possible interactions. Therefore the user will need to determine the fitness for use of the selected materials by conducting appropriate short-term and long-term reliability testing as dictated by the needs of the application.

References

[1] Internal Rogers Corporation study on the RT/duroid 6202PR - Mike Kuszaj. The study used a large matrix of resistor widths at different angles on multiple panels and multiple lot numbers of material.

ROGERS CORPORATION