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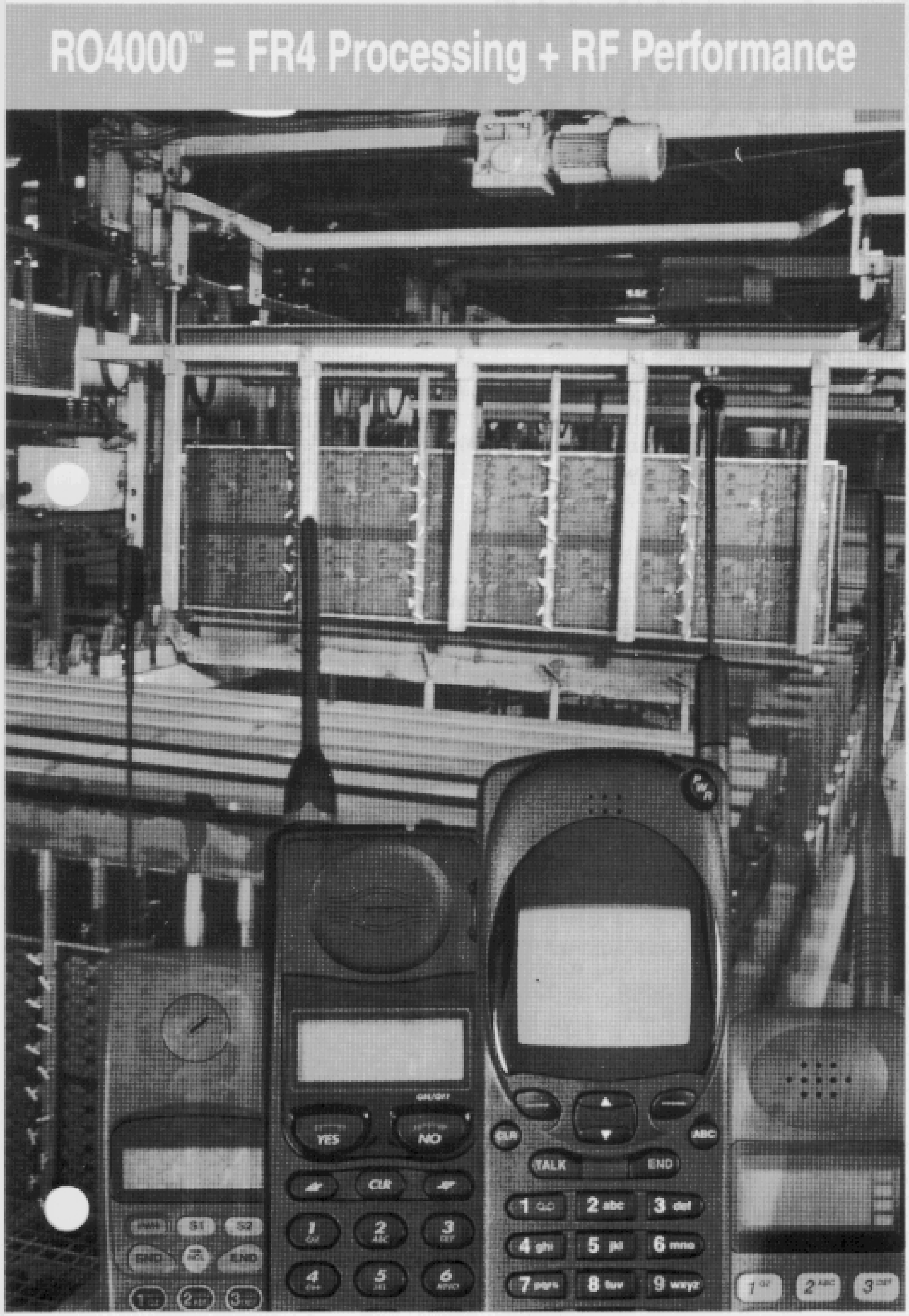

ELECTRONIC DEFENSE

THE OTHER SIGINT/ELINT

SUPPLEMENT — MICROWAVES IN EUROPE

A MMIC VARIABLE-GAIN AMPLIFIER FOR TX/RX APPLICATIONS

CONTENTS, P. 10

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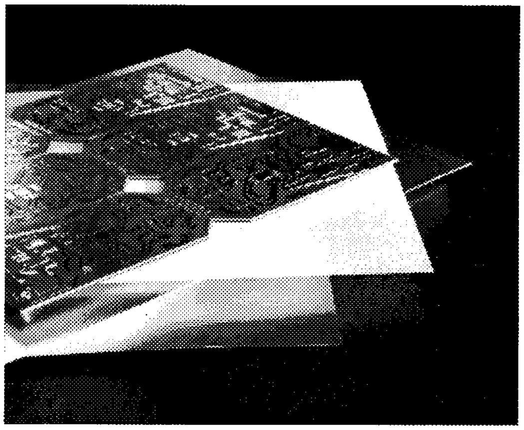

A LOW COST LAMINATE FOR WIRELESS APPLICATIONS

Wireless commercial applications require low cost substrate materials with tight dielectric constant control (±1 to 2 percent) and low electrical loss (dissipation factor less than 0.005). Applications requiring a high performance laminate are typically above 500 MHz, such as cellular and pager linear power amplifiers, cellular handset filters and direct-broadcast service low noise block downconverters.

Polytetraflouroethylene (PTFE)-based substrates have satisfied the electrical needs of these applications, but at a fabrication cost premium. The high costs are associated with special surface treatments for plated through-hole manufacturing, machining tools and conditions, and handling requirements. These special requirements restrict the number of printed board fabricators willing to process PTFE-based laminates.

TABLE I

TYPICAL PROPERTIES

	RO4003	RO4350	TFG	FR4[1,2]
Dielectric constant ε_r (±0.05) at 10 GHz	3.38	3.48	3.20	4.20
Dissipation factor at 10 GHz	0.00”	0.004	0.003	0.020
Water absorption (%)	0.06	0.06	< 0.2	< 0.1
Thermal coefficient of ε_r (ppm/°C)[3]	+40	+50	−100	not avail.
T_g (°C)	> 280	> 280	n/a	130
Flammability rating	–	94VO	94VO	94VO

[1] measured at 1 MHz using different test methods
[2] FR4 tolerance is not known
[3] measured from −100° to +250°C, except TFG (from −25° to +150°C)

The RO4000™ series high frequency circuit materials establish a new paradigm for high performance laminates. R04000 material was developed to combine the high frequency performance comparable to woven-glass PTFE substrates with the ease of fabrication associated with epoxy/glass.

RO4000 series laminates arc not based on PTFE but are a woven-glass-reinforced hydrocarbon and ceramic thernioset material with a high glass transition temperature (T_g greater than 280°C). Unlike PTFE-based microwave material, no special through-hole treatments are required. R04000 circuit processing costs are comparable to epoxy/glass laminates. Currently, there are two versions, including R04003 and RO4350. RO4350 materials have additives that make the product flame retardant. The company anticipates receiving a UL 94VO rating from Underwriters Laboratory Inc. for the RO4350 material.

The R04000 material family offers a good combination of electrical propertics, as listed in ***Table*** 1. The Institute for Interconnecting and Packaging Electronic Circuits (IPC) TM-650 Method 2.5.5.5 was used to obtain an accurate picture of the performance of the material. This method utilizes a two-wavelength-long, 10 GHz resonator etched onto one side of an eight-mil-thick piece of dielectric. The material under test is clamped on either side of the resonator at 500 psi. The resonator,

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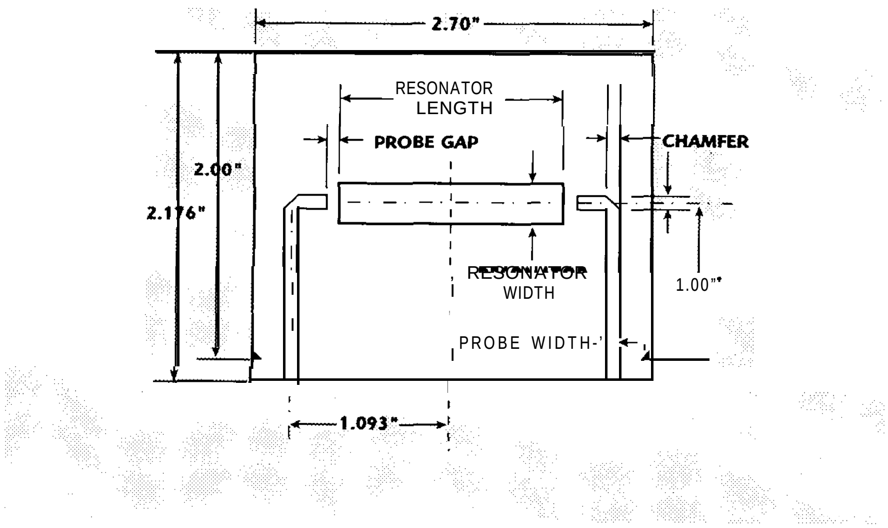
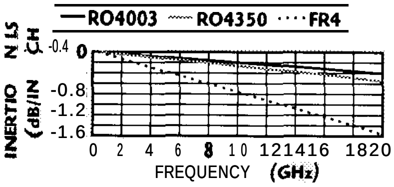


▲ *Fig. 1 The stripline resonator.*



▲ *Fig. 4 The insertion loss vs. frequency.*

Fig. 5 Typical RF/digital multilayer construction. ▼

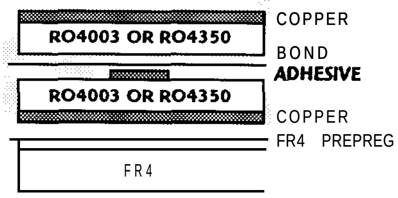


Fig. 2 The dielectric constant's change vs. frequency. ▼

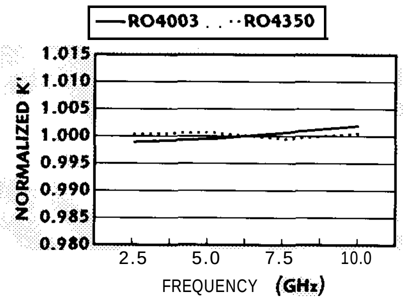
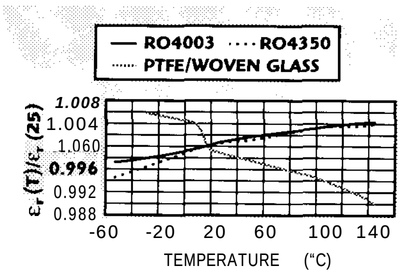


Fig. 3 The dielectric constant's change vs. temperature. ▼



shown in **Figure I,** is coupled loosely so as to measure the material properties and not the circuit Q.

Resonance exists at four nodes, which occur approximately at 2.5, 5, 7.5 and 10 GHz. These frequencies cover the majority of modern wireless applications. The frequency of each resonant node is measured using a scalar network analyzer. Dielectric constant is derived using the standard equation for wavelength, adjusted for fringing effects.

The Q of the material is calculated by dividing the resonant frequency by the 3 dB bandwidth and correcting for copper losses. The IPC test methods manual contains specific information on conducting the test. The dielectric constant change vs. frequency can be determined by comparing the measurements at the four nodes and is essentially equal to zero, as shown in **Figure 2.**

The thermal coefficient of dielectric constant for both the R04003 and RO4350 laminates exceeds the stability of PTFE/woven-glass laminates, providing the needed temperature performance for critical components such as filters and oscillators. This material attribute was determined using the IPC test fixture in a thermostatically controlled oven. The temperature coefficient of ε_r is shown in **Figure 3.**

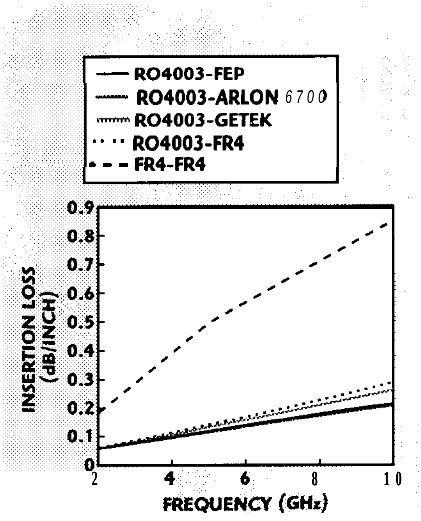
The R04000 laminate family is better suited for temperature-sensitive applications, like patch antennas and VCOs, than for PTFE/woven-glass materials. Insertion loss was determined by measuring the electrical loss of a 50 Ω line. The insertion loss of the R04000 laminate is clearly superior to epoxy/glass substrates, as shown in **Figure 4.** This low loss performance extends the useful range of these materials well above 20 GHz.

The success of a modern wireless high volume application hinges on the repeatability of the components used to effect the design. Key properties such as dielectric constant and material thickness must be controlled statistic& iii an effort to reduce tuning and t'est time. The tighter the control on key laminate properties, the larger the process window afforded the designer. An extensive computer database is maintained on key laminate properties.

The mechanical properties of the RO4000 series laminates facilitate a wide variety of construction and assembly practices. The combination of a thermoset resin system and a woven glass reinforcement provides for a rigid laminate with low X and Y coefficients of expansion. The rigidity of the RO4000 laminate provides a firm platform suitable for pick-and-place or other forms of high volume manufacturing processes.

Applications requiring high interconnect densities or miniaturization usually resort to multilayer PCBs. These PCBs are often made entirely of the high performance material to ensure mechanical compatibility. The X and Y expansion characteristics of R04000 provide a suitable physical match to epoxy/glass laminates. Hybrid constructions or combinations of high performance laminates and epoxy/glass substrates are increasingly utilized to reduce overall costs. The DC, control and digital signal paths are designed onto the lower cost epoxy/glass, and the RF or microwave sign&are carried on the RO4000 dielectric layer.

The R04000 dielectric surface does not require special surface



▲ *Fig. 6 RO4003 50 Ω stripline insertion loss.*

preparation to promote wrtability for plating solutions. Standard FR4 prepreg can he used to bond R04000 laminates to epoxy/glass. A hybrid multilayer board, shown in ***Figure 5***, can be manufactured without requiring exotic processes such as sodium or plasma etching. The result is a high performance, low loss material that can be fabricated using standard epoxy/glass processes offered at competitive prices.

Careful consideration must be given when selecting an appropriate bonding film. Because many applications have limited loss budgets, many designers may be overly conservative when selecting adhesive bonding film. Films such as fluorethylene propylene (FEP) can provide low loss, but also add significant fabrication costs. In reality, thin, higher loss adhesive films, such as FR4 prepreg, have minimal impact on loss performance in most applications. Design analysis is encouraged on a case-by-case basis.

Figure 6 shows all of the FR4 construction layers (prepreg and laminate), plotted on the same graph. Insertion loss is shown as a function of frequencv for stripline constructions using various adhesive bonding films and 0.03" dielectric. The adhesive films examined include FR4, GETEK, Arlon 6700 and FEP. It is evident from this graph that the various adhesives have a negligible impact on insertion loss for these constructions.

RO4000 laminates deliver the performance of PTFE but fabricate like FR4. Currently, designs using woven-glass PTFE can lower overall cost by using R04000 materials. Wireless manufacturers who are struggling with the impact of dielectric constant and thickness variations can benefit from high performance laminates without paying a significant premium.

CONCLUSION

R04000 laminates are a non-PTFE-based material family, which provide tight dielectric constant and thickness control, electrical loss performance similar to PTFE and low thermal coefficient of dielectric constant. In addition, the materials arc mechanically compatible with FR4, use standard FR4 processing techniques and offer fabrication costs similar to FR4. A flame-retardant version is also available.

This new type of circuit material can change the way that certain high frequencv circuits arc made, cutting circuit fabrication costs associated with microwave circuits. R04000 materials break the long-standing tradition of using PTFE to design and fabricate high -frequency and high performance circuits.

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