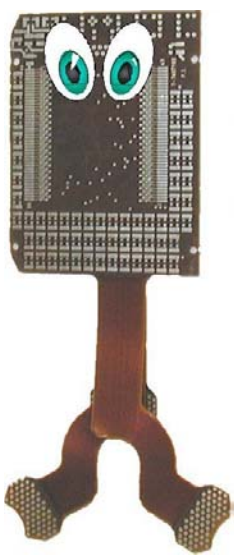
Arlon

Application Notes

Materials Selection for Wireless Cellular Infrastructure -- by Chet Guiles



Despite the sustained downturn in the telecommunications industry, it remains one of the areas in which substantial growth remains "right around the corner" because, frankly, it is no longer economical to build out hard-wired infrastructures for new systems in countries without existing copper wire legacies. For those who are designing circuitry for telecom infrastructure it will be no surprise that what we call "soft substrates" -- copper clad products based on PTFE (polytetrafluoroethylene) and other low loss polymeric materials, are some of the backbones of the electronic modules comprising the infrastructure on which that soon-to-resume burgeoning industry is anchored.

The impact on materials requirements within the rapidly changing electronics industry is not relegated to the microwave and high frequency RF areas. The evolution of hand-held portable electronics (multifunctional 3G phones, PDA's, sub-notebook computers) and the convergence of cellular communications and the provision of internet service and access have had an impact of the type of materials required. High volume digital transmissions at data rates of 10 Gb/s require materials capable of handling high speed data as well as providing systems that go back and forth between fiber backhaul and opto-electronic in the local distribution network. High frequency signal integrity issues are endemic, and higher frequency allocations such as "smart cars" with frequency usage from 75 to 100 GHz also require materials with unique properties. Not only do materials have to operate at higher frequencies, but must withstand rigorous environmental testing in preparation for use in harsh environments such as jet engine controls and automotive under-the-hood applications.

At the same time design and packaging trends are pushing for miniaturization and more miniaturization (you can put all the functionality you want into it, but you have to be able to hold it comfortably in one small hand) -- smaller, lighter and of course cheaper! Embedded component technology (resistors, capacitors) is being used more and more as a part of PWB design. Laser microvia formation has permitted the use of thinner, lighter boards with higher interconnect density. Smaller and higher density of course means narrower lines and smaller capture pads and therefore less tolerance for misregistration. As a matter of fact I have been told that through holes without pads behave better electronically. (Hole diameter = line width? There's a registration challenge for you.)

In microwave and RF the challenges focus around dielectric constant and loss -- and the ability of materials to provide these critical properties while still retaining their ability to be fabricated into printed wiring boards. This isn't an insubstantial challenge and we certainly have not yet come up with the "ideal material" that provides a tailorable dielectric constant, extremely low loss and the processability of FR-4 in a product that sells for under a buck a square foot FOB your manufacturing floor. How close have we come? And what options are available?

While all the properties are important, most of the time there will be a "gotta have" situation in which one or another of the characteristics of the material must be "just right" in order for the design to work -- or to be salable. Soft substrates are already widely used in microwave and RF circuitry and the reason for that is their proven ability to provide a wide variety of cost-performance effective products. For instance:

The use of PTFE, which is essentially non-polar, results in materials with low loss (as low as 0.0009) and low dielectric constant (as low as 2.17).

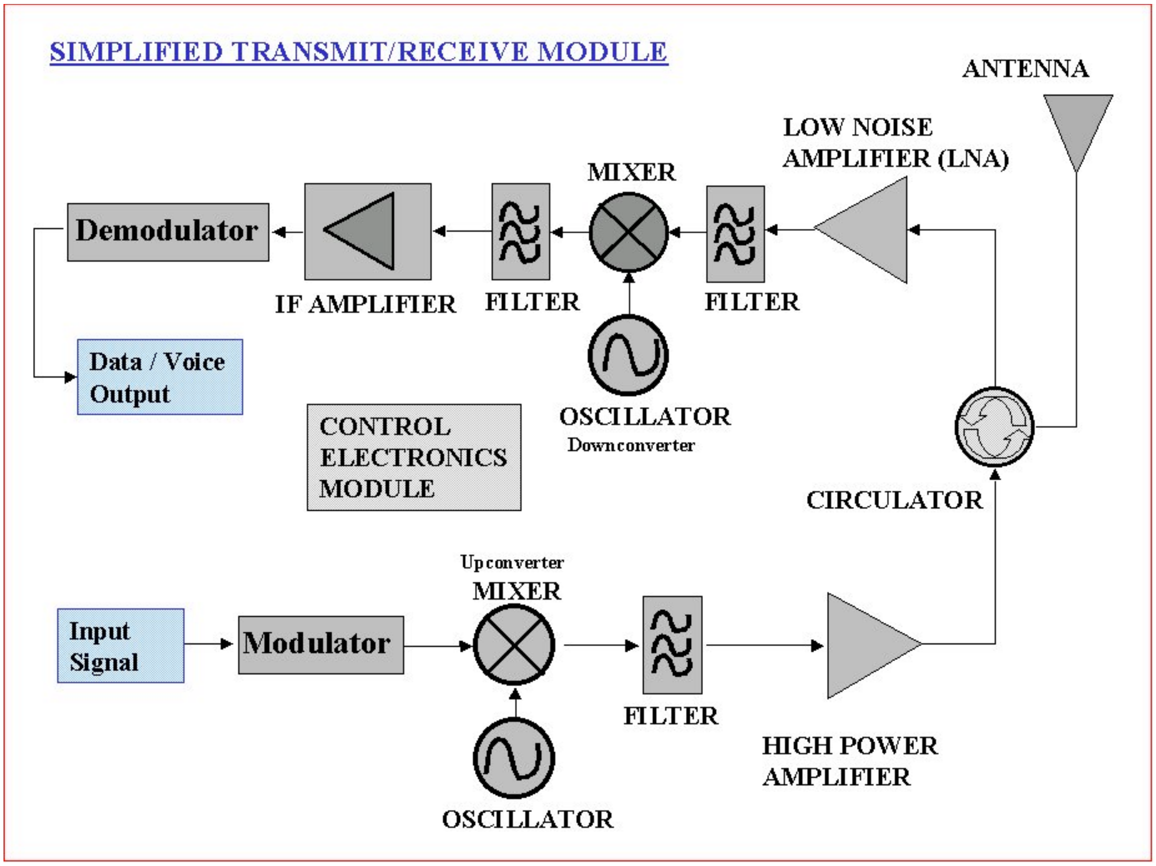
By the addition of various ceramic fillers and by the variation of the ratios and types of glass reinforcement, PTFE and filler, we can achieve a variety of “standard” and specialty products that permit operation over various environmental conditions, offer higher dielectrics for circuit miniaturization and higher heat transfer characteristics:

We offer materials with low CTEr, and we have materials with dielectric constants of 4.5, 6 or 10 in addition to standard lower Er products.

By using either PTFE or non-PTFE resins with ceramic fillers and/or standard FR-4 type glass reinforcements and constructions we can achieve a variety of low cost/low loss options.

There are a variety of subcomponents represented in a typical transceiver, and each of those subcomponents could be fabricated using any of a variety of circuit materials. This article will focus on how to make the obvious choices of Arlon MED materials for some of these critical components.

The most critical elements of a transceiver for a cellular base station are the antenna, the LNA and filters on the receive side of the system. Here the signal strength is typically orders of magnitude less than on the transmit side, since a cellular phone may transmit at



under 0.5 watt while the transmitter in a base station operates at 50 watts or more. Materials with very low loss are always preferable for these receive elements, and Arlon's PTFE based DiClad 880 (Er 2.17 and loss 0.0009 measured at at 10 GHz) is often used in base station antennas as well as in the first stage amplifiers and filters before the signal is downconverted to intermediate frequency.

In an antenna the issue of passive intermodulation distortion also arises, especially when talking about 3rd Generation phones that will be handling high levels of digital data. 3rd and 5th order PIM products from the transmit side of a system can interfere with low powered receive signals at adjacent frequency. Specialty materials with reduced tendency to exhibit PIM Distortion are available, and Arlon's tech service people can also advise concerning our experience with some of the printed circuit process-related issues that can also result in degradation of PIM performance in etched antennas.

In the IF stages of the system a lot has to do with the number of multiplexed signals and the degree to which power must first be split to separate signals and then reamplified. If signals must be reamplified through several stages, it is often desirable to use a multilayerable low cost, low loss thermoset system such as Arlon's 25N or 25FR to produce IF splitters, amps and filters. With a dielectric constant or 3.38 and a nominal loss of 0.003 at 1-2 GHz, 25N represents a good compromise between lossy FR-4 or PPO/epoxy blends and the more expensive PTFE based products.

Less costly materials such as FR-4 or PPO/epoxy blends can be used in many of the elements of the system such as MUX/DEMUX (multiplex/demultiplex) modules and control electronics that supply voltage and control without having to enter into the direct signal processing stream.

On the other side of the system the critical elements are the outgoing filters and high powered amplifier. A variety of materials have been used in these areas, but the most popular seem to be products with dielectric constants in the 3.0 to 3.5 range with loss values around 0.003 and a thermal conductivity of 0.4 W/m-^{o}K. Obviously there are many options to choose from, but as a start I would suggest considering a PTFE product such as AD-350 (Er 3.5, loss 0.003) if the board or component is to be two-sided, or a multilayerable product like 25N or 25FR if a multilayer structure is needed.

Some designers have elected to use a high dielectric constant product such as Arlon's AR-1000 in high powered amplifiers, which confers the joint benefit of circuit miniaturization due to the higher Er and, with a thermal conductivity of 0.65 w/m-^{o}K, the diffusion and dissipation of heat is more manageable.

In certain applications where antennas are going to be used outdoors in an environment where there will be wide temperature fluctuations either intraday (such as in the desert) or over a longer period of time (Summer to Winter) and where frequency stability over temperature is very critical, materials are available that exhibit a very flat dielectric constant response over temperature. An example of such a material is Arlon's CLTE and to a lesser but still significant degree, 25N and 25FR.

Clearly there will be some applications where the cost factor will make the decision between two materials both of whose performance is "acceptable" and where a slightly degraded performance will be offset by a lower price. It is important first of all to establish performance requirements and select materials that will provide acceptable performance -- then make the price cut. Often a lot of time and effort goes into trying to qualify materials that in the end won't work because they are marginal to begin with, or because they have excessive variation in properties. Selection of the right materials for the required system performance will minimize this costly and potentially embarrassing approach to material selection.

	Low Cost Low Loss Thermoset	High Er Ceramic-Filled PTFE	Low Er Low Loss PTFE	Stable Er -40C to +140C	Low Cost PTFE Grades
Arlon Example	25N / 25FR	AR-1000	DiClad 880	CLTE	AD-350/AD-250
Dielectric Constant (10 GHz)	3.38/3.58	10	2.17	2.98	2.5 / 3.5
Loss Tangent (10 GHz)	.0025/.003	0.003	0.0009	0.0025	0.0018 / 0.003
CTE (ppm/degree C)	15 to 18	14 to 16	25 to 35	17-18	9 to 12
Heat Transfer W/m-K	0.4	0.65	0.3	0.5	0.3
Thermal Coefficient of Er	-25	-233	-160	Nil	-100
Typical Applications	IF Amps	Power Amps	Antennas	Antennas	Antennas
in Cellular	Combiners	Miniaturization	Lo Noise Amps	Filters	Hi Power Amps
Infrastructure	Splitters	Replace Ceramic	Filters	Space Apps	Filters

In this chart we summarize the typical materials options that exist. In addition to these basic varieties of product, we also can offer a wide range of product thicknesses, cut panel sizes, copper cladding options and dielectric properties. Many PTFE laminates are available in sheets up to 72" in length, suitable for high gain directional antenna applications.

If you are a designer of circuit boards or antennas for cellular infrastructure we would like to talk to you about how you design and how you select materials for your PWB's. We have a "wish list" that of course includes your selecting only Arlon materials for your microwave and RF designs, but beyond that that addresses the areas in which we only have partial information. That wish list:

• That we better understand how shifts in the industry affect materials requirements – qualitatively and quantitatively – for instance between 2g and 3g;

• That the properties trade-offs between various materials somehow could be tied more explicitly to the cost-performance of the final assembled product; and

• That we better understand what materials technology will be required to meet future wireless infrastructure requirements.