

# CuFLON® Microwave Substrate Primer

POLYFLON's CuFLON Microwave Substrates are unique because the copper conductors are plated directly onto virgin Teflon® dielectric substrate without any adhesive or binder.

When used in microstrip and stripline circuits, POLYFLON's electroplated TFE has many advantages over other laminated substrates.

- **Ultra-Low Loss** – Teflon dielectric losses are one order of magnitude below conventional board materials. (Loss tangent about .0003 from DC to Ku Band).
- **Stable Dielectric Constant** – Over wide Temperature and wide Frequency ranges.
- **High Operating Temperature** – Circuits can be operated up to 200°C continuously without degradation of dielectric to metal bond.
- **High Solderability** – The high permissible operating temperature allows repeated soldering and un-soldering without affecting metal dielectric bond strength. This also allows mechanical installation by soldering.
- **Ultra-Thin Dielectric** – Tight coupling and high ca-

pacitance are achieved with thicknesses as small as one quarter of one mil. The absence of an adhesive means no addition conductor separation other than the dielectric is present.

- **Long Flexural Life** – the electro-depositing process results in fully annealed copper with no work-hardening as compared to laminated boards where both the basic rolling and the laminating process do work-harden the copper, reducing its eventual flexural life. The Teflon substrate itself will not break even if fully bent back upon itself.
- **Plated-Thru Holes** – Holes incorporated into the substrate before plating are automatically plated thru. Holes added after plating can be thru plated by electroless deposition.
- **High Voltage Capability** – The dielectric strength of the dielectric is very high, over 1000v/mil.

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®CuFlon is the registered trademark of POLYFLON Company

## What are the most ideal uses of CuFLON?

Because of its low loss properties, CuFLON is most commonly used for:

- Band Pass Filters:** The narrower the bandwidth of a device, the more the loss increases for a given Qu (loss factor).
- Components with Long Line Lengths** such as Phase Shifters, Phased Array Antenna Networks and Delay Lines. In devices of this nature, the loss/inch of the transmission line can make a big difference.
- Super Low Loss Components** in high power applications or in super low noise applications where every .1dB is important.

## How to take the most advantage of the low properties of Teflon.

Since Teflon is a very low loss material used extensively as the base material in most other common substrate materials and given that the copper plating is equal to that used on other materials, the best way to minimize losses is to use as

thick a substrate as possible. In other words, if a thick substrate such as 31,61 or 125 mil is contemplated, then priority should be given to CuFLON.

This does not mean that thin CuFlon substrates are not useful in minimizing losses. Thin CuFlon substrates are very handy when microstrip circuits with long line lengths are being designed. For instance, if .05 dB/inch can be saved on a 20 inch long line, there is a 1 dB savings in power. In a high power application, every .1 dB saved means 2% of the incoming power saved. If the designer is not worried about what the power loss does to the system performance, he should be concerned about what it does to component temperature rise and the subsequent effects on component reliability.

## Loss tradeoffs in the design of microwave circuits.

The total loss of a device is described by the formula:

$$\text{Loss Total} = \text{Loss Conductor} + \text{Loss Dielectric} + \text{Loss Radiation} + \text{Loss VSWR}$$

The task of the designer is to address each of the four problem areas that result in loss and try to minimize them in judicious compromise with other important design parameters. The VSWR losses do not have much to do with material selection except to the extent that the mechanical dimensions of a certain transmission line may be troublesome to match out over broad bandwidths. But this problem is not much different for materials of similar dielectric constant used in the same geometry.

Figure 1 shows some trends for the three material related loss components for a particular material in microstrip configuration. There are some important points to be noted when one examines this graph.

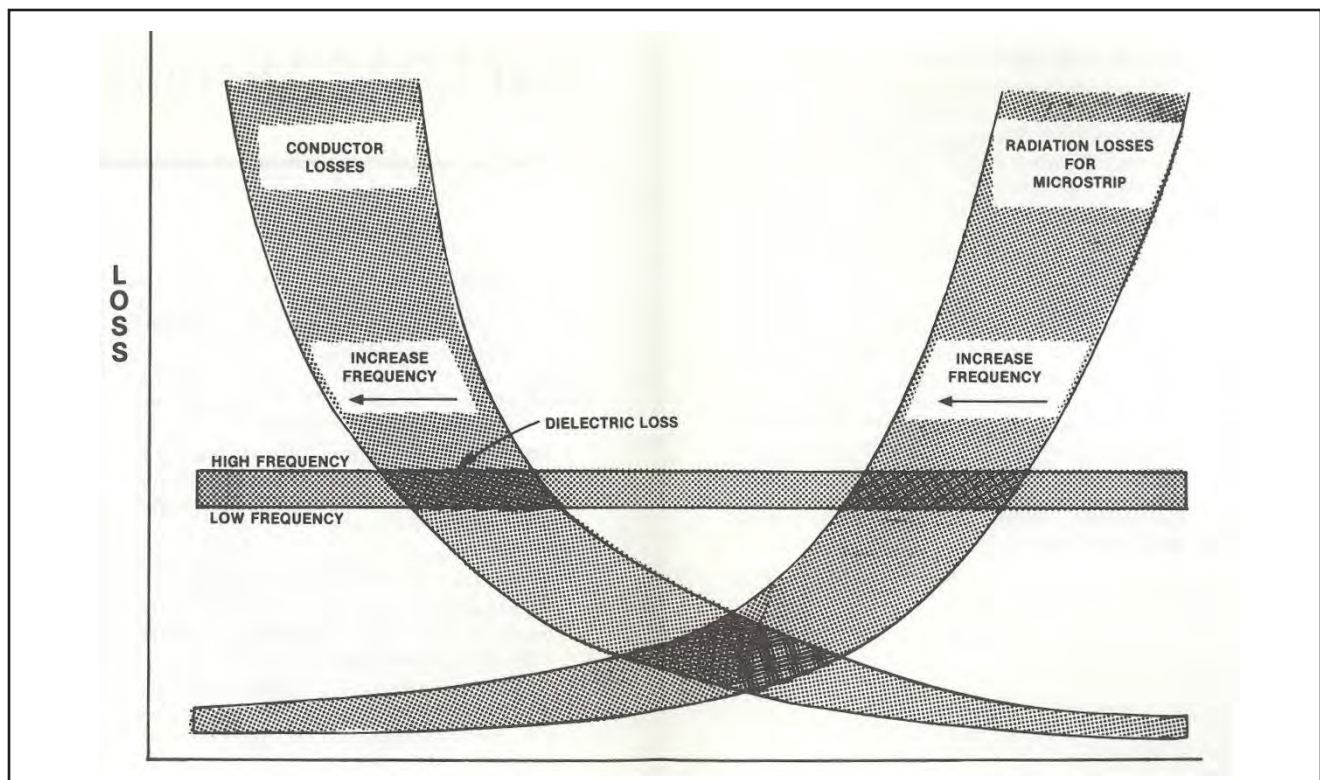
1. Conductor losses decrease dramatically, radiation losses increase dramatically but dielectric losses are nearly constant as the substrate thickness is increased.
2. The same thing is true as frequency is increased in the 1-40 GHz range.
3. Since conductor loss and radiation loss vary sharply, controlling them by skilled design is most important. Dielectric loss is very simply controlled by choosing the proper dielectric. Therefore, choosing the dielectric with the lowest possible dielectric loss offers no disadvantages and should therefore be considered immediately.

**Control of Conductor Losses** is done by choosing a high conductivity metal such as copper of a minimum thickness of

.35 mil (1/4 oz.) above 1 GHz and .70 mil (1/2 oz.) above 200 MHz. Any more metal does not help losses but is useful in controlling fractures in the copper traces due to temperature stresses. Another factor in controlling copper losses is surface roughness. Pure Teflon has a very smooth surface and when ED plated, results in lower loss metallization than glass filled materials. Another important factor in achieving low conductor loss is doing a good job in etching. It is important to obtain good straight lines with minimum of undercutting and no feathered edges since there is a high concentration of current near the edges of striplines.

**Control of Radiation** is done exclusively through microwave circuit design. Stripline (tri-plate) circuits do not suffer from this problem, however, they have become less popular because of their associated mechanical complexity. Stripline is still the only medium that can handle very high peak powers (above 2KW) and low loss CuFLON has been used successfully in such applications. Similarly, the need of high directivity, low loss couplers makes stripline hard to beat.

The avoidance of radiation in open structures, such as microstrip and slotline, has been the subject of many technical articles but can be summed up as an effort to cancel fields by meandering of lines and resonators, shielding of the circuit by a properly channelized housing and the design of very low reflection bends. Using such techniques, Qu measurements of nearly 1000 have been measured at X Band on 62 mil CuFLON.



**SUBSTRATE THICKNESS (H)**

Figure 1: Typical Loss Curves vs. Substrate Thickness for a Particular Material.

**What are some of the unique handling characteristics of CuFLON and how are they avoided?**

**Characteristic No. 1:**

Pure Teflon is soft and is subject to cold flow if put under constant mechanical stress.

**Solution No. 1:**

Do not put it under mechanical stress. When soldered or bonded to aluminum housings and used in microstrip form, there is no stress on the Teflon after assembly.

**Solution No. 2:**

If you use it in stripline and compress two boards together, make sure the boards fit snugly in the housing so that lateral movement is impossible. In this way, there is nowhere for the Teflon to flow.

**Characteristic No. 2:**

The copper may crack because of temperature changes. This problem has also been seen with glass filled Teflon boards.

**Solution:**

There is correlation between the copper thickness/line width and the amount of thermal stress to which a circuit can be subjected. From many years of experience, the following rules of thumb have been developed for safe operation:

Temperature Range	Copper Thickness	Min Lin Width
0-55 degrees C	1/2 oz.	7 mil
	1.0 oz.	3mil
-55 degrees to +85 degrees C	1.0 oz.	10 mil
slow change	2.0 oz.	5 mil
-55 degrees to +85 degrees C	1.0 oz.	20 mil
Temperature Shock	2.0 oz.	10 mil

The above numbers are very safe. If smaller conductors are contemplated, we suggest very thorough testing.

**Characteristic No. 3:**

Bonding with the use of Thermal Compression Bonding is a problem with all soft substrates.

**Solution:**

Experimentation is needed to learn how to work with the materials. Quite a few companies have had success bonding to these materials using ultrasonic bonding.

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**Tips on how to process CuFLON circuits**

**Etching** of CuFLON circuits is done the same way as on other soft boards. There is some tendency for the boards to bend in the etching process. The boards return to a flat shape after baking at 75 degrees C, just before the photoresist is stripped.

**Gold Plating** on top of copper has been done routinely. Please call the factory to get names of qualified platers.

**Cutting and Trimming** of CuFLON is relatively easy since the material is soft and has no glass fibers. High speed steel tools are generally used to cut and drill the material to any shape. The choice of tools is generally a function of the volume on any particular job.

**Cleaning:** Use normal cleaning after cutting to remove contamination due to handling. The etching process normally leaves the Teflon stained yellowish brown. In order to remove the stain and return the full white color to the Teflon, use a 50% bleach solution. Use a biodegradable copper cleanser to clean the copper, rinse with hot tap water, air or hand dry.

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**Soldering of the CuFLON circuit to a housing**

Pre-tin board side to be attached to the housing. Housing is placed on preheated hotplate set at 450-500 degrees F. Size will determine the time needed to bring assembly to temperature in order to pre-tin the cavity. Use Kester INDUSTRIAL 1544 Flux and 60/40 solder. Care must be exercised in how much solder is used. Not enough solder results in poor soldering. Too much solder results in uneven leveling of the board and solder overflow around the board. The board is placed under pressure to avoid board curling and soldering voids. Pressure is developed by placing templates, pre-cut to the same dimension as the PC board and cavity, extending above the housing surface and secured to the housing with the use of covers and screws. Allow the solder to solidify prior to removal for subsequent cleaning in a commercial product known as "Flux Off". Some hand scrubbing may be required to remove crystallized flux on boards and housings. Additional cleaning will be required with "freon" vapors.



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