

# Flexible Printed Antennas Span 100 kHz To 40 GHz

Modern flexible substrate materials enable the design of compact, light-weight, and cost-effective antennas for a wide variety of wireless applications.

**f**lexible circuit technologies have enabled antenna designers to speed the evolution of versatile and cost-effective solutions for a wide range of wireless applications. From contactless access cards, smart passports, RF-identification (RFID) tags through Bluetooth devices, mobile telephone and pager antennas to point-to-point base-station antennas, designers have seized on flexible circuit

technology to solve the problems of weight, shape, reproducibility, and cost. Antennas typically designed with a view to using a printed-circuit solution include flat coils, patches, microstrip antennas, stripline antennas, and dipoles with operating frequencies spanning the range from 100 kHz to 40 GHz. An example is illustrated in **the figure**. At the lower frequencies, smart cards and RFID tags

predominate, while at the higher end, mobile radios (including telephones) and flat point-to-point antennas also use this approach.

Microstrip or patch antennas are widely used for microwave applications, as they are small and easily fabricated. Almost any shape of conductor can be excited on the surface of a dielectric substrate having a reference groundplane. Excitation can be through microstrip transmission line, from either the front or the back through an aperture in the groundplane. When microstrip

antennas are produced on flexible circuit materials, including polyimide and polyester substrates (Table 1), dielectric constants from approximately 3 to past 5 at low frequencies typically characterize these materials (Table 2). This results in more energy being stored in the reactive near-field region, so the antennas are high quality factor (Q), narrowband compared to other types. However, the term “narrowband” in the gigahertz range still means a useful operating

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This is an example of a typical flexible printed antenna for wireless applications.

bandwidth.

Narrower beamwidths, higher gain, and greater power handling can be achieved by combining multiple elements into arrays. Printed arrays will generally be of the “active”

variety, where each element is individually driven by its own feed. Altering the phase shift between elements allows the antenna to be electronically steered without physically moving. Recent enhancements to this technology have lead to the development of spectrum- and power-efficient smart antennas which self-configure to direct the RF energy only where required. Similar to their thicker and heavier rigid counterparts, flexible circuits are available in a number of configurations, depending on the complexity of the conductor pattern to be implemented.

Single-sided antennas consist of a base-insulator film onto which one cop-

**Table 1: Summarizing antenna materials**

MATERIAL	USED FOR	THICKNESSES COMMONLY AVAILABLE
Copper	conductors	18, 35, 70, 105 $\mu\text{m}$
Polyimide	substrate	12, 25, 40, 50, 75, 100, 125 $\mu\text{m}$
Polyester	substrate	25, 50, 75, 125 $\mu\text{m}$
Epoxy glass	substrate	110 $\mu\text{m}$

per (Cu) conducting layer is bonded. The printed and etched pattern may be subsequently encapsulated with a further insulating film (coverlay) or printed mask (covercoat). Double-sided antennas consist of two Cu layers on either side of a central insulating film, allowing two layer-transmission lines to be easily implemented. If required by the design, the two layers can be interconnected by printing conductive silver (Ag)-loaded polymer ink through suitably positioned bleed holes. This construction lends itself to microstrip-antenna configurations.

Multilayer antennas consist of three or more Cu layers interconnected through

plated-through-holes. Stripline transmission lines can also be included in the design. Sculptured antennas are a special variant of single-sided circuits, using a heavier-gauge Cu for the implementation of robust un-

supported Cu termination features. Flex-Rigid designs combine standard multilayer hardboards with one or more of the flexible constructions outlined earlier. Typically, antenna designs are configured as single-sided circuits to support high volume reel-to-reel processing.

A number of materials are available depending on the antenna performance required and the nature of the assembly process. This selection deliberately excludes special high frequency/low-loss materials, which, in general, do not lend themselves to cost-effective volume manufacture. Table 1 shows readily available thicknesses, while the remainder of this section describes the

**Table 2: Summarizing dielectric properties**

PROPERTY	POLYESTER	POLYIMIDE	EPOXY-GLASS
Dielectric constant, $\epsilon_r$ (1 kHz)	3.1	3.0	4.2 to 5.3
Dielectric constant, $\epsilon_r$ (1 MHz)	3.0	3.4	2.0 to 2.1
Dielectric constant, $\epsilon_r$ (1 GHz)	2.8	3.0	2.0 to 2.05
Loss factor, $\tan \delta$ (1 MHz)	0.02	0.01	0.03
Dielectric strength, (V/mil)	3400	3600	240
Volume resistivity, ( $\Omega$ -cm)	$10^{18}$	$10^{18}$	$10^{15}$

materials in more detail. Polyimide (standard and adhesiveless) is a high-temperature plastic which combines good dielectric properties with the ability to withstand all conventional assembly techniques. It is available with conventional Cu cladding where the metallization is bonded to the substrate with a separate acrylic or epoxy adhesive layer and in an adhesiveless form which provides superior dielectric performance at higher frequencies.

Polyethylene terephthalate (Polyester) is a low-cost thermoplastic suitable for applications where pressure or other mechanical contact can be employed or where low-temperature assembly techniques are available. This material is widely used in mobile-telephone antennas, contactless smart cards, and RFID tags. Epoxy glass is not normally considered a flexible material, but thin gauges of epoxy glass are now available which are cost effective and may offer advantages where wire bonding is the proposed component-assembly method.

Reel-to-reel production of circuit patterns in continuous roll form results in consistent quality, while maintaining high-volume throughput. Some designs have added features such as local rigidizing, self-adhesive backing, or other added materials or components. Print-through Ag is an alternative technique to plated through-holes in high-volume double-sided circuits offering low-cost and rapid processing. Punching, drilling location holes, component attach holes and final profiling can be achieved by a variety of tooling or machining processes.

Surface insulation, when required, can be achieved by over bonding an additional layer of the chosen substrate material or by printing a flexible solder mask. The former approach reduces the calculated impedance of a microstrip by up to 20 percent, while the effect of the latter process is about 5 percent. The layout of the flexible circuit need not be limited to the antenna element itself. The technology supports a wide variety of assembly methods from mechanical crimping through wave, reflow, and hot-bar soldering. **MRF**