Microstrip Antenna Arrays on Multilayer LCP Substrates

Antennas, feedlines, and switches are embedded in and on flexible sheets.

John H. Glenn Research Center, Cleveland, Ohio

A research and development effort now underway is directed toward satisfying requirements for a new type of relatively inexpensive, lightweight, microwave antenna array and associated circuitry packaged in a thin, flexible sheet that can readily be mounted on a curved or flat rigid or semi-rigid surface. A representative package of this type consists of microwave antenna circuitry embedded in and/or on a multilayer liquid-crystal polymer (LCP) substrate. The circuitry typically includes an array of printed metal microstrip patch antenna elements and their feedlines on one or more of the LCP layer(s). The circuitry can also include such components as electrostatically actuated microelectromechanical systems (MEMS) switches for connecting and disconnecting antenna elements and feedlines. In addition, the circuitry can include switchable phase shifters described below.

LCPs were chosen over other flexible substrate materials because they have properties that are especially attractive for high-performance microwave applications. These properties include low permittivity, low loss tangent, low water-absorption coefficient, and low cost. By means of heat treatments, their coefficients of thermal expansion can be tailored to make them more amenable to integration into packages that include other materials. The nature of the flexibility of LCPs is such that large LCP sheets containing antenna arrays can be rolled up, then later easily unrolled and deployed.

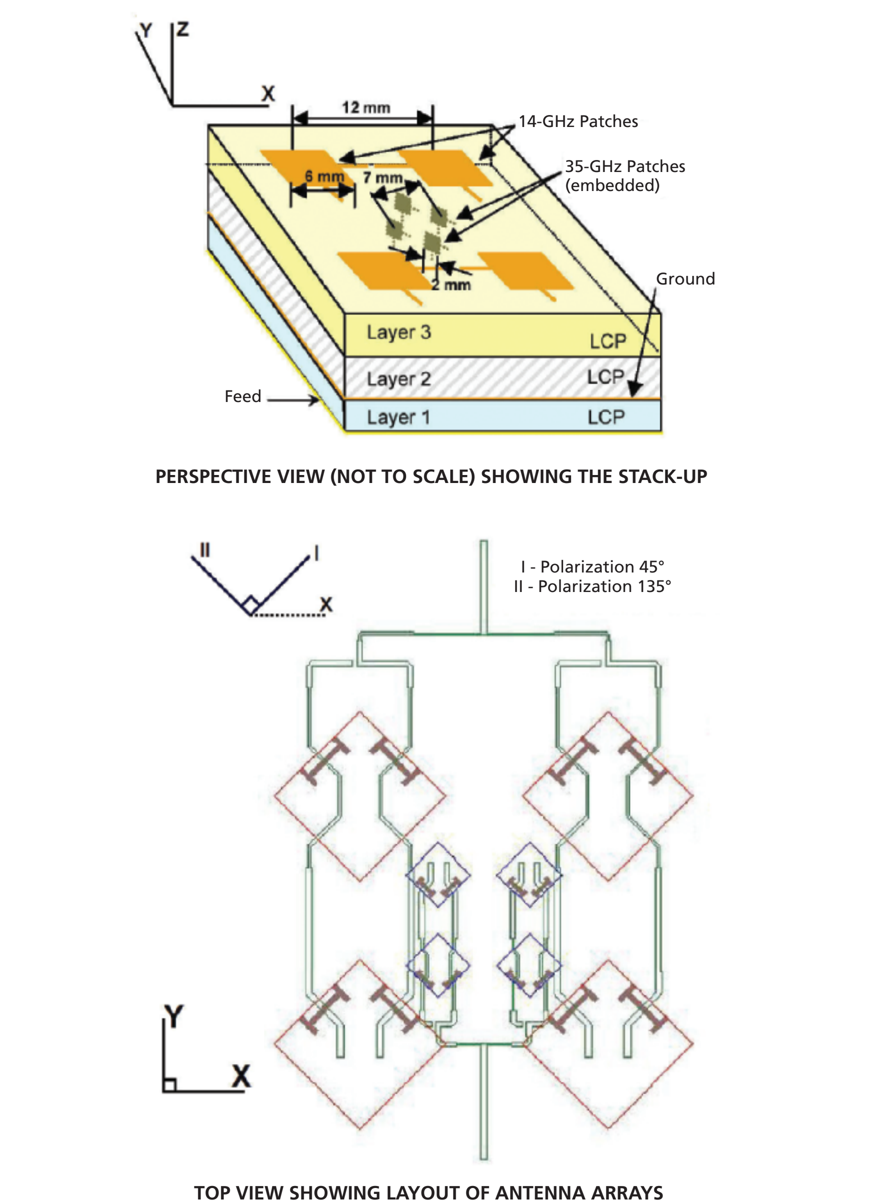

Figure 1. A **Dual-Frequency, Dual-Polarization Array** of microstrip patch antenna elements is packaged with three layers of LCP.

Figure 1 depicts a prototype three-LCP-layer package containing two four-element, dual-polarization microstrip-patch arrays: one for a frequency of 14 GHz, the other for a frequency of 35 GHz. The 35-GHz patches are embedded on top surface of the middle [15-mil (≈0.13-mm)-thick] LCP layer; the 14-GHz patches are placed on the top surface of the upper [9-mil (≈0.23-mm)-thick] LCP layer. The particular choice of LCP layer thicknesses was made on the basis of extensive analysis of the effects of the thicknesses on cross-polarization levels, bandwidth, and efficiency at each frequency.

The diagonal orientation of the microstrip patches in Figure 1 is not inherent in the LCP implementation: instead, it is part of an example design for a typical intended application in radar measurement of precipitation, in which there would be a requirement that both the 14- and the 35-GHz arrays exhibit

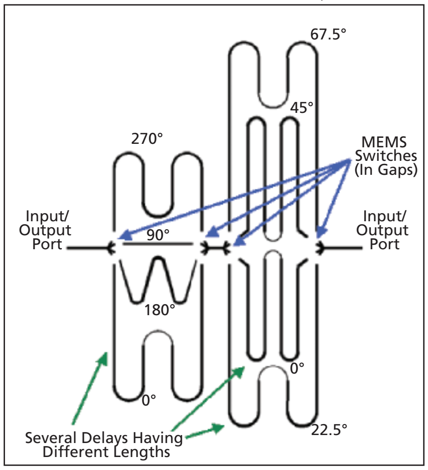

Figure 2. **MEMS Switches** are used to connect the input/output ports to one of the two delay lines to obtain one or the other of two different amounts of phase shift.

similar orthogonal-polarization characteristics, including high degrees of polarization purity. The diagonal orientation helps in realizing a symmetrical feed network for both polarizations with similar impedance characteristics and radiation patterns. RF MEMS switches would be included in a production model but are not included in the prototype: Instead, to simplify computational simulation and testing, switching of polarizations is represented by the presence of hard-wired open and short circuits at switch locations.

Figure 2 is a plan view of a switchable phase shifter — in this case, one that can be switched between two different phase shifts. The device includes electrostatically actuated RF MEMS switches that are used to make and break connections to eight microstrip delay lines having different lengths (e.g., 1 wavelength versus 3/4 wavelength). Necessarily omitting details for the sake of brevity, each MEMS switch includes a microscopic flexible electrically conductive member that, through application of a suitably large DC bias voltage, can be pulled into proximity with microstrip conductors on opposite sides of the gap. The flexible member is covered to prevent direct electrical contact with the microstrip conductors, but the effect of the proximity is such as to enable substantial capacitive coupling of the microwave signal across the gap. The measured loss of the four-bit packaged phase shifter is only 0.24 dB per bit with a phase error less than 4° at 14 GHz. At the time of this reporting, this is the first package flexible organic RF MEMS multibit phase shifter ever documented.

This work was done by Dane Thompson, Ramanan Bairavasubramanian, Guoan Wang, Nickolas D. Kingsley, Ioannis Papapolymerou, Emmanouil M. Tenteris, Gerald DeJean, and RongLin Li of Georgia Institute of Technology for **Glenn Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17980-1.

Applications for Subvocal Speech

Ames Research Center, Moffett Field, California

A research and development effort now underway is directed toward the use of subvocal speech for communication in settings in which (1) acoustic noise could interfere excessively with ordinary vocal communication and/or (2) acoustic silence or secrecy of communication is required. By "subvocal speech" is meant sub-audible electromyographic (EMG) signals, associated with speech, that are acquired from the surface of the larynx and lingual areas of the throat. Topics addressed in this effort include recognition of the sub-vocal EMG signals that represent specific original words or phrases; transformation (including encoding and/or enciphering) of the signals into forms that are less vulnerable to distortion, degradation, and/or interception; and reconstruction of the original words or phrases at the receiving end of a communication link. Potential applications include ordinary verbal communications among hazardous-material-cleanup workers in protective suits, workers in noisy environments, divers, and firefighters, and secret communications among law-enforcement officers and military personnel in combat and other confrontational situations.

This work was done by Charles Jorgensen of **Ames Research Center** *and Bradley Betts of Computer Sciences Corporation.*

This invention is owned by NASA and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Technology Partnerships Division at (650) 604-2954. Refer to ARC-15519-1.

Multiloop Rapid-Rise/Rapid Fall High-Voltage Power Supply

Marshall Space Flight Center, Alabama

A proposed multiloop power supply would generate a potential as high as 1.25 kV with rise and fall times <100 μs. This power supply would, moreover, be programmable to generate output potentials from 20 to 1,250 V and would be capable of supplying a current of at least 300 μA at 1,250 V. This power supply is intended to be a means of electronic shuttering of a microchannel plate that would be used to intensify the output of a charge-coupled-device imager to obtain exposure times as short as 1 ms. The basic design of this power supply could also be adapted to other applications in which high voltages and high slew rates are needed. At the time of reporting the information for this article, there was no commercially available power supply capable of satisfying the stated combination of voltage, rise-time, and fall-time requirements.

The power supply would include a preregulator that would be used to program a voltage 1/30 of the desired output voltage. By means of a circuit that would include a pulse-width modulator (PWM), two voltage doublers, and a transformer having two primary and two secondary windings, the preregulator output voltage would be amplified by a factor of 30. A resistor would limit the current by controlling a drive voltage applied to field-effect transistors (FETs) during turn-on of the PWM. Two feedback loops would be used to regulate the high output voltage. A pulse transformer would be used to turn on four FETs to short-circuit output capacitors when the outputs of the PWM were disabled. Application of a 0-to-5-V square to a PWM shut-down pin would cause a 20-to-1,250-V square wave to appear at the output.

This work was done by Douglas Bearden of **Marshall Space Flight Center**.

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32137-1.