

cylinder provide the needed capacitance.

In a test, the antenna exhibited gains of 8, 10, and 11 dB at 270, 350, and 430 MHz, respectively. The 10-dB gain at the middle frequency is associated with an aperture efficiency of 80 percent. This

high aperture efficiency is expected because in the 270-to-430-MHz frequency band, one expects low insertion losses in a power divider, cables, and hybrids that are parts of the antenna feed. Also determined in the tests was the level of isolation between orthogonal ports; this

level was found to be 37 dB across the frequency band.

*This work was done by Robert F. Thomas and John Huang of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-20524*

## Multimode Broad-Band Patch Antennas

Tuning ranges could be octaves wide.

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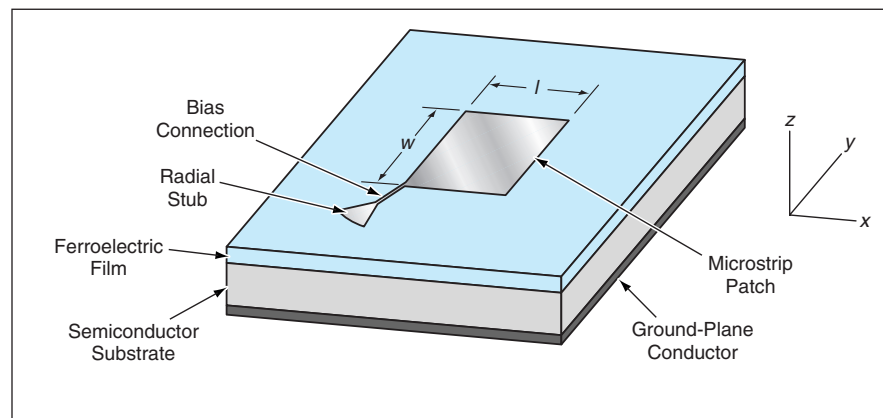
Microstrip patch antennas of a proposed type would be tunable over broad wavelength ranges. These antennas would be attractive for use in a variety of microwave communication systems in which there are requirements for transmission and/or reception at multiple, widely separated frequencies.

Prior efforts to construct tunable microstrip patch antennas have involved integration of microstrip circuitry with, variously, ferrite films with magnetic-field tuning, solid-state electronic tuning devices, or piezoelectric tuning actuators. Those efforts have been somewhat successful, but have yielded tuning ranges of 20 percent and smaller — much smaller than needed in typical practical cases.

Like prior microstrip patch antennas (both tunable and non-tunable), the proposed antennas would have instantaneous bandwidths of about 1 percent of their nominal or resonance frequencies. However, these would be tunable over much broader frequency ranges — as much as several octaves, depending on specific designs. They could be fabricated relatively simply and inexpensively by use of conventional photolithography, and without need for integration with solid-state electronic or piezoelectric control devices.

An antenna as proposed (see figure) would include a microstrip patch radiating element on a thin ferroelectric film on a semiconductor substrate with a ground-plane conductor on the underside of the substrate. The ferroelectric film could be, for example, SrTiO<sub>3</sub> with a thickness of the order of 1 or 2 μm.

To enable operation at multiple desired frequencies, the antenna would be designed to resonate in a fundamental TM<sub>01</sub> mode that lies at an odd common denominator of the desired frequencies. (In an odd mode, the an-



A Multimode Patch Antenna would be designed to resonate at an odd submultiple of possibly widely separated desired operating frequencies. By use of a combination of (1) varying the DC bias voltage to vary the permittivity of the ferroelectric film and (2) selection of the desired harmonic frequency, one could effectively achieve tuning over an unprecedentedly wide frequency range.

tenna would radiate strongly in a direction perpendicular to the antenna plane, while an even mode would place a null of the radiation pattern in the perpendicular direction.)

A simple cavity mathematical model yields the following equation for the resonance frequency of the  $m, n$  mode: 
$$f_{mn} = (c/2\pi\epsilon_r^{1/2})[(m/w)^2 + (n/l)^2]^{1/2}$$
, where  $m$  and  $n$  are integers,  $c$  is the speed of light in vacuum,  $\epsilon_r$  is the effective relative permittivity of the combination of the ferroelectric film and dielectric substrate, and  $w$  and  $l$  are the width and length of the patch, respectively. In practice, resonance frequencies tend to be somewhat lower than predicted by this simple formula, because of fringing fields.

The value of  $\epsilon_r$ , and hence the resonance frequency, could be controlled by applying an electric field across the ferroelectric film. For this purpose, a controllable DC bias potential would be applied between the microstrip patch and the ground plane. A virtual ground plane can also be manipulated in this manner by controlling the carrier population in the semiconductor.

Positive bias on the patch forms a sea of electrons near the ferroelectric interface, whereas a reverse bias forms a depletion layer. For isolation of the DC bias source from the radio-frequency signal, the DC bias would be fed in via a high-impedance microstrip transmission line with one end connected to a corner of the patch and the other end terminated in a quarter-wave radial stub (the quarter-wavelength radius would be chosen for a frequency near the middle of the desired radiation-frequency range). A wire would deliver the bias voltage to a radio-frequency virtual-short-circuit location on the transmission line so that the impedance would not be perturbed.

*This work was done by Robert R. Romanofsky of 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, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16792.*