UHF Microstrip Antenna Array for Synthetic-Aperture Radar

This antenna performs well over an unusually broad range of frequencies.

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An ultra-high-frequency microstrip-patch antenna has been built for use in airborne synthetic-aperture radar (SAR). The antenna design satisfies requirements specific to the GeoSAR program, which is dedicated to the development of a terrain-mapping SAR system that can provide information on geology, seismicity, vegetation, and other terrain-related topics. One of the requirements is for ultra-wide-band performance: the antenna must be capable of operating with dual linear polarization in the frequency range of 350 ± 80 MHz, with a peak gain of 10 dB at the middle frequency of 350 MHz and a gain of at least 8 dB at the upper and lower ends (270 and 430 MHz) of the band. Another requirement is compactness: the antenna must fit in the wing-tip pod of a Gulfstream II airplane.

The antenna includes a linear array of microstrip-patch radiating elements supported over square cavities. Each patch is square (except for small corner cuts) and has a small square hole at its center. Figure 1 shows the layout and principal dimensions of the cavities and microstrip patches. Wide-band performance is made possible by the relatively large cavity depth.

Each patch is fed by four identical probes positioned symmetrically on the orthogonal patch axes. To obtain either or both of two orthogonal polarizations, the antenna is fed through either or both of two orthogonal ports. A high degree of isolation between the ports is achieved in the following way: the two probes on opposite sides of the center on same axis are fed 180° out of phase with each other. The electromagnetic fields from these probes travel to the orthogonal probes, but they result in little or no coupling to the orthogonal probes because they cancel each other by virtue of the 180° phase relationship.

As is usual for microstrip devices with thick dielectric substrates (in this case, the cavities are the dielectric substrates) each microstrip patch in this antenna presents undesired inductance at its feed points. With the help of empirical tuning, the feed probes (see Figure 2) are uniquely designed to provide enough capacitance to cancel this inductance. Each feed probe includes an outer metal cylinder plus an inner metal cylinder with a cone at one end. The upper end of the feed probe is separated from the microstrip patch by a 2-mm-thick polytetrafluoroethylene disk. The polytetrafluoroethylene-filled gaps and the cone at one end of the inner
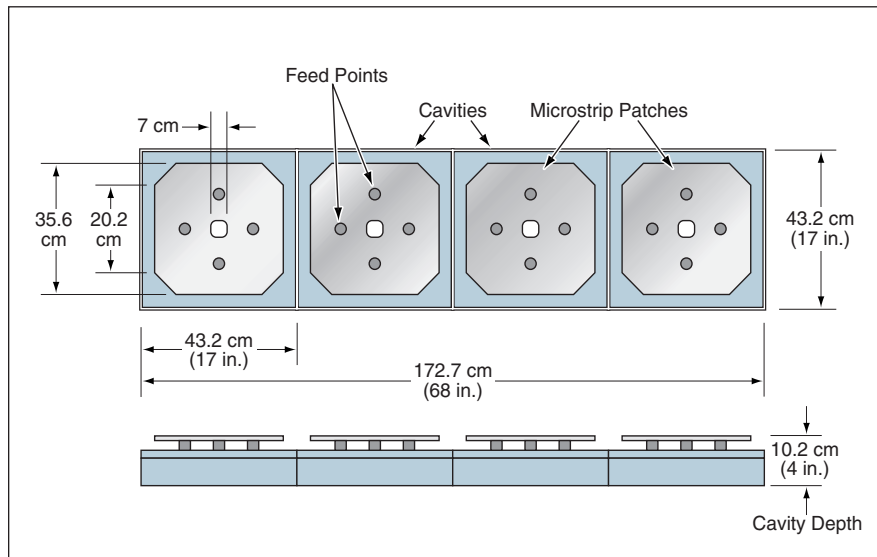

Complete Antenna

Four Feed Probes in a Cavity

Components of a Feed Probe

Figure 2. The **Feed Probes** provide capacitance that counteracts the inductance associated with the depth of the cavity. In addition, the combination of position and phase relationships among the probes is such as to minimize undesired coupling between orthogonal pairs of the probes.

Figure 1. A **Linear Array of Microstrip Patches** supported over square cavities is shaped and dimensioned to provide the desired gain and broad-band frequency response with dual linear polarization.
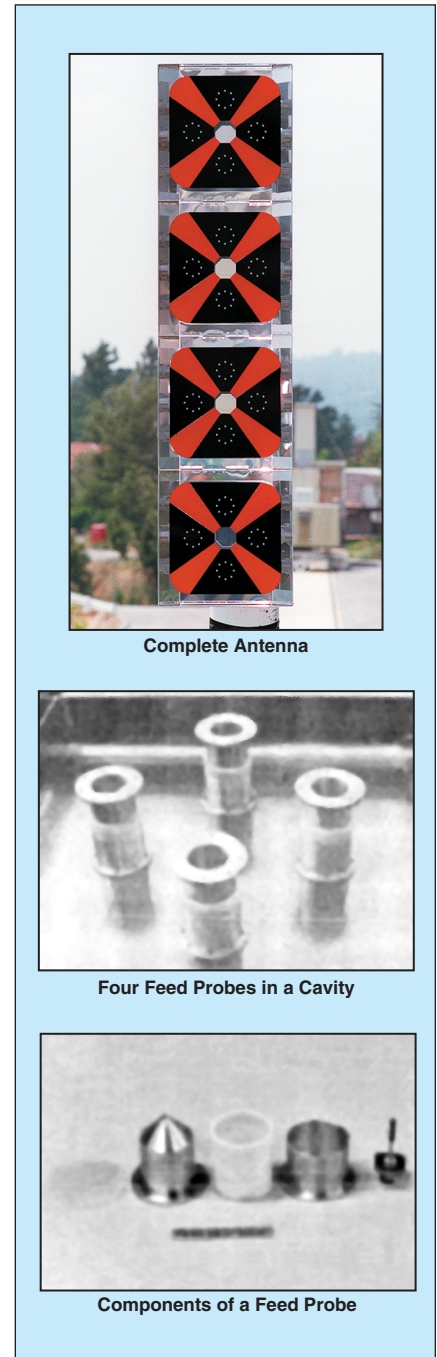
cylinder provide the needed capacitance.

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.

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.
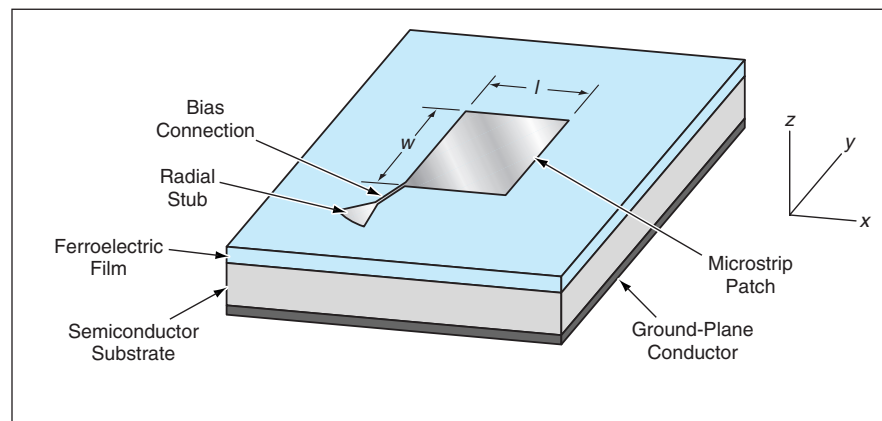
An antenna as proposed (see figure) would include a microstrip patch radiating element on a thin ferroelectric film on a semiconductor substrate with a ground-plane conductor on the underside of the substrate. The ferroelectric film could be, for example, $SrTiO_3$ with a thickness of the order of 1 or 2 μm.

To enable operation at multiple desired frequencies, the antenna would be designed to resonate in a fundamental TM01 mode that lies at an odd common denominator of the desired frequencies. (In an odd mode, the antenna 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:

$$f_{mn} = (c/2\pi\varepsilon_r^{1/2})[(m/w)^2+(n/l)^2]^{1/2},$$

where m and n are integers, c is the speed of light in vacuum, ε_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 ε_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.

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.