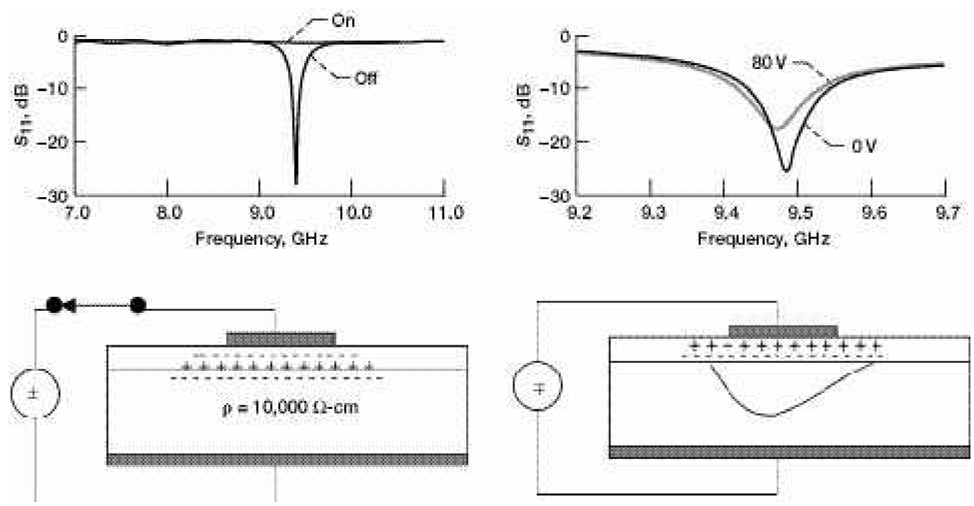
Ferroelectric/Semiconductor Tunable Microstrip Patch Antenna Developed

A lithographically printed microwave antenna that can be switched and tuned has been developed. The structure consists of a rectangular metallic "patch" radiator patterned on a thin ferroelectric film that was grown on high-resistivity silicon. Such an antenna may one day enable a single-phased array aperture to transmit and receive signals at different frequencies, or it may provide a simple way to reconfigure fractal arrays for communications and radar applications.

Modern aircraft are riddled with antennas to accommodate such needs as communications, navigation, and weather radar. For economic and safety reasons, there is a strong desire to bundle as many functions as possible into a single aperture. This is especially true in the case of small commercial and fighter aircraft. The problem will become more severe as consumers demand more access to information en route and as improved safety features such as microwave landing systems proliferate. The designs for spacecraft antennas are even more stringent because of mass and volume constraints. Phased-array antennas--antennas that steer a beam electronically rather than mechanically--are desirable for spacecraft because they are vibration free. But conventional arrays operate only over a single narrow band of frequencies.

The NASA Glenn Research Center has devised a prototype frequency agile antenna based on thin ferroelectric films and semiconductor substrates. The 350-nm $Ba_{0.5}Sr_{0.5}TiO_3$ film was grown by pulsed laser ablation on 10,000-Ω-cm 300-μm-thick silicon using a 50-nm $Bi_4Ti_3O_{12}$/50 nm yttria-stabilized zirconia buffer layer. The antenna corresponding to the figure measured 0.675 by 0.45 cm and resonated at about 9.5 GHz in the TM_{01} mode. The left side shows the antenna behavior when the radiator has a positive bias with respect to the ground plane. When the switch is closed, electrons are swept from the silicon to the ferroelectric/semiconductor interface. This sea of electrons, or plasma, forms a virtual ground resonance plane near the interface. An electron density of about $10^{19}/cm^3$ extinguishes the antenna. When the switch is opened, the radiator behaves more or less as a conventional patch antenna. The measured far-field E- and H-plane radiation patterns were normal. By reversing the polarity, as in the right side of the figure, electrons were swept to the natural ground plane and a depletion region formed under the patch in the silicon. In this configuration, the antenna was tuned about 25 MHz with 80 V applied. Operating the antenna in a higher order odd mode produced a second useful frequency of operation, and the ferroelectric effect was used for vernier tuning. The tuning range is ultimately limited by the formation of an inversion layer, or generation of higher order modes because of the electrical thickness of the stratified device.



Reflection coefficient of the antenna. Left: Forward-biased radiator. Right: Reverse-biased radiator.

Most startling is the current/voltage (I/V) relationship of the device. The structure exhibits discontinuities in the I/V curves, and at certain temperatures regions of negative differential resistance are encountered. This phenomenon is believed to be due to a tunneling process that may be enhanced by the polarization of the ferroelectric layer. Future work includes the redesign of the antenna to permit broader tuning and investigation of the I/V characteristics for alternative device applications. The antenna design and testing were conducted by Glenn, and the ferroelectric films were grown by the University of Maryland.

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