

A Thin Nb Bridge having  $T_c = 6$  K lies between thicker Nb contacts having  $T_c = 8.6$  K that, in turn, are connected to an antenna that couples submillimeter-wavelength radiation into the device.

the approach followed in developing the present device.

In the present device, the superconducting bridge having the  $T_c$  of 6 K is a thin film of niobium on a silicon substrate (see figure). This film is  $\approx 1 \mu\text{m}$  wide,  $\approx 1 \mu\text{m}$  long, and between 10 and 25 nm thick. A detector so small could lose some sensitivity if thermal energy were allowed to diffuse rapidly from the bridge into the contacts at the ends of the bridge. To minimize such diffusion, the contacts at the ends of the bridge are made from a 150-nm-thick niobium film that has a higher  $T_c$  (8.6 K). The interfaces between the bridge and the contacts constitute an energy barrier of sorts where Andreev reflection occurs. As a result, the sensitivity of the device depends primarily on thermal coupling between electrons and the crystal lattice in the Nb bridge. For this device,  $(\text{NEP}) = 2 \times 10^{-14} \text{ W/Hz}^{1/2}$  and the response time is about 0.5 ns.

In order to obtain high quantum efficiency, a planar spiral gold antenna is connected to the niobium contacts. The antenna enables detection of radiation throughout the frequency range from about 100 GHz to several terahertz. In operation, radiation is incident from the underside of the silicon substrate, and an antireflection-coated silicon lens (not shown in the figure) glued to the underside of the substrate focuses the radiation on the bridge (this arrangement is appropriate because silicon is transparent at submillimeter wavelengths).

*This work was done by Boris Karasik, William McGrath, and Henry Leduc of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).NPO-43619*

## Large-Aperture Membrane Active Phased-Array Antennas

Large arrays are constructed as mosaics of smaller ones.

NASA's Jet Propulsion Laboratory, Pasadena, California

Large-aperture phased-array microwave antennas supported by membranes are being developed for use in spaceborne interferometric synthetic-aperture radar systems. There may also be terrestrial uses for such antennas supported on stationary membranes, large balloons, and blimps. These antennas are expected to have areal mass densities of about  $2 \text{ kg/m}^2$ , satisfying a need for lightweight alternatives to conventional rigid phased-array antennas, which have typical areal mass densities between 8 and  $15 \text{ kg/m}^2$ . The differences in areal mass densities translate to substantial differences in total mass in contem-

plated applications involving aperture areas as large as  $400 \text{ m}^2$ .

A membrane phased-array antenna includes patch antenna elements in a repeating pattern. All previously reported membrane antennas were passive antennas; this is the first active membrane antenna that includes transmitting/receiving (T/R) electronic circuits as integral parts. Other integral parts of the antenna include a network of radio-frequency (RF) feed lines (more specifically, a corporate feed network) and of bias and control lines, all in the form of flexible copper strip conductors on flexible polymeric membranes.

Each unit cell of a prototype antenna (see Figure 1) contains a patch antenna element and a compact T/R module that is compatible with flexible membrane circuitry. There are two membrane layers separated by a 12.7-mm air gap. Each membrane layer is made from a commercially available flexible circuit material that, as supplied, comprises a 127- $\mu\text{m}$ -thick polyimide dielectric layer clad on both sides with 17.5- $\mu\text{m}$ -thick copper layers. The copper layers are patterned into RF, bias, and control conductors. The T/R module is located on the back side of the ground plane

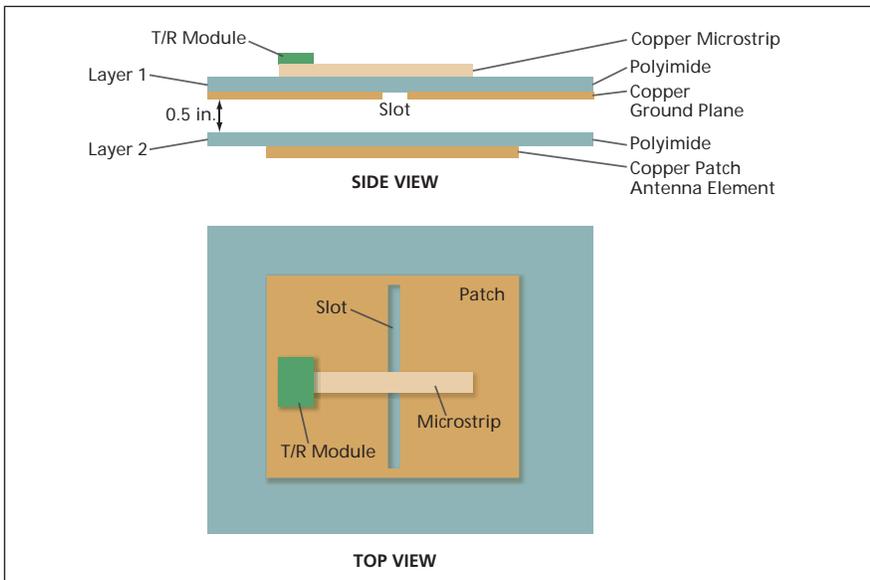


Figure 1. A Unit Cell of a phased-array antenna contains active and passive circuitry supported on two polyimide membrane layers.

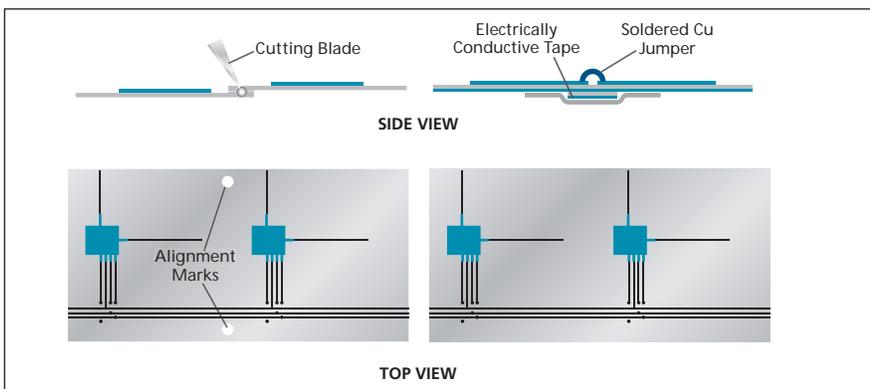


Figure 2. Aligned Adjacent Panels containing small (in this case, 1x2) membrane phased arrays are cut, then seamed together at the common cut line.

and is RF-coupled to the patch element via a slot. The T/R module is a hybrid multilayer module assembled and packaged independently and attached to the membrane array. At the time of reporting the information for this article, an 8x16 passive array (not including T/R modules) and a 2x4 active array (including T/R modules) had been demonstrated, and it was planned to fabricate and test larger arrays.

Because of limitations of available materials and equipment, the largest array that can be constructed as a single unit of the prototype design is a 2x8 array, which has dimensions of 0.28 m by 1.14 m. To construct a larger array, it is necessary to seam together 2x8 or smaller arrays. Figure 2 depicts selected aspects of the seaming process. Adjacent panels containing arrays to be seamed together are aligned using alignment marks on the panels and temporary tape. After the entire array has been aligned with temporary tape, the seams are match cut using an electric cutter. Finally, the cut panels are aligned, mechanically joined using a permanent adhesive and electrically joined using a combination of electrically conductive tape and soldered copper foil jumpers for the aforementioned conductive traces.

*This work was done by Alina Moussessian, Mark Zawadzki, Ubaldo Quijano, Linda Del Castillo, and Etai Weininger of Caltech for NASA's Jet Propulsion Laboratory.*

*For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-45152*

## Optical Injection Locking of a VCSEL in an OEO

**Compact, low-power atomic clocks could be developed.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Optical injection locking has been demonstrated to be effective as a means of stabilizing the wavelength of light emitted by a vertical-cavity surface-emitting laser (VCSEL) that is an active element in the frequency-control loop of an opto-electronic oscillator (OEO) designed to implement an atomic clock based on an electromagnetically-induced-transparency resonance. This particular optical-injection-locking scheme is expected to enable the development of small, low-power, high-stability atomic clocks that would be suitable for use in applica-

tions involving precise navigation and/or communication.

In one essential aspect of operation of an OEO of the type described above, a microwave modulation signal is coupled into the VCSEL. Heretofore, it has been well known that the wavelength of light emitted by a VCSEL depends on its temperature and drive current, necessitating thorough stabilization of these operational parameters. Recently, it was discovered that the wavelength also depends on the microwave power coupled into the VCSEL. Inasmuch as the microwave power circulating in the frequency-con-

trol loop is a dynamic frequency-control variable (and, hence, cannot be stabilized), there arises a need for another means of stabilizing the wavelength.

The present optical-injection-locking scheme satisfies the need for a means to stabilize the wavelength against microwave-power fluctuations. It is also expected to afford stabilization against temperature and current fluctuations. In an experiment performed to demonstrate this scheme, wavelength locking was observed when about 200  $\mu$ W of the output power of a commercial tunable diode laser was injected into a commercial