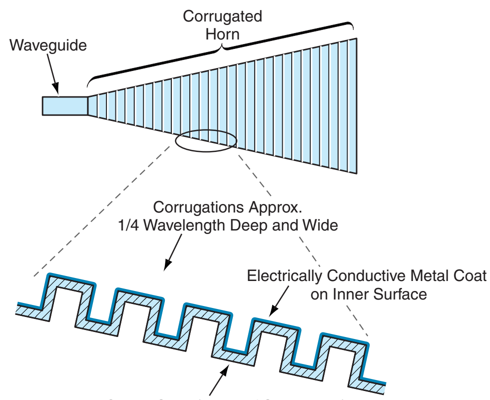
Lightweight, Self-Deploying Foam Antenna Structures

Advantages would include lightness, simplicity, reliability, compactness in stowage, and low cost.

NASA's Jet Propulsion Laboratory, Pasadena, California

Lightweight, deployable antennas for a variety of outer-space and terrestrial applications would be designed and fabricated according to the concept of cold hibernated elastic memory (CHEM) structures, according to a proposal. Mechanically deployable antennas now in use are heavy, complex, and unreliable, and they utilize packaging volume inefficiently. The proposed CHEM antenna structures would be simple and would deploy themselves without need for any mechanisms and, therefore, would be more reliable. The proposed CHEM antenna structures would also weigh less, could be packaged in smaller volumes, and would cost less, relative to mechanically deployable antennas.



A **CHEM Corrugated Horn Antenna** would consist of a lightweight CHEM shell coated with metal on its inner surface.

The CHEM concept was described in two prior *NASA Tech Briefs* articles: "Cold Hibernated Elastic Memory (CHEM) Expandable Structures" (NPO-20394), Vol. 23, No. 2 (February 1999), page 56; and "Solar Heating for Deployment of Foam Structures" (NPO-20961), Vol. 25, No. 10 (October 2001), page 36. To recapitulate from the cited prior articles: The CHEM concept is one of utilizing open-cell foams of shape-memory polymers (SMPs) to make lightweight, reliable, simple, and inexpensive structures that can be alternately (1) compressed and stowed compactly or (2) expanded, then rigidified for use. A CHEM structure is fabricated at full size from a block of SMP foam in its glassy state [at a temperature below the glass-transition temperature (Tg) of the SMP]. The structure is heated to the rubbery state of the SMP (that is, to a temperature above Tg) and compacted to a small volume. After compaction, the structure is cooled to the glassy state of the SMP. The compacting force can then be released and the structure remains compact as long as the temperature is kept below Tg. Upon subsequent heating of the structure above Tg, the simultaneous elastic recovery of the foam and its shape-memory effect cause the structure to expand to its original size and shape. Once thus deployed, the structure can be rigidified by cooling below Tg. Once deployed and rigidified, the structure could be heated and recompacted. In principle, there should be no limit on the achievable number of compaction/deployment/rigidification cycles.

Thus far, several different designs of a 3.5-m-long CHEM conical corrugated horn antenna have been analyzed (see figure). A small CHEM structural antenna model was fabricated and a thin, electrically conductive layer of aluminum was deposited on the inner surface of the model. This structural model was then subjected to the compaction and deployment treatments described above to demonstrate the feasibility of a CHEM corrugated horn antenna.

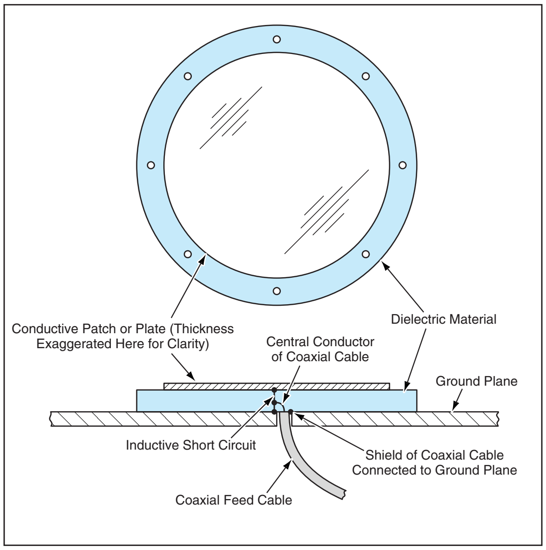
This work was done by Witold Sokolowski, Steven Levin, and Peter Rand of Innovative Technology for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-30272

Electrically Small Microstrip Quarter-Wave Monopole Antennas

Inductive/resonant feeds make it possible to reduce sizes.

Langley Research Center, Hampton, Virginia

Microstrip-patch-style antennas that generate monopole radiation patterns similar to those of quarter-wave whip antennas can be designed to have dimensions smaller than those needed heretofore for this purpose, by taking advantage of a feed configuration different from the conventional one. The large sizes necessitated by the conventional feed configuration have, until now, made such antennas impractical for frequencies below about 800 MHz: for example, at 200 MHz, the conventional feed configuration necessitates a patch diameter of about 8 ft (≈2.4 m) — too large, for example, for mounting on the roof of an automobile or on a small or medium-size aircraft. By making it possible to reduce diameters to between



The **Inductive-Short-Circuit Feed Configuration** of this microstrip-style antenna makes it possible for the antenna to have a smaller diameter and still radiate efficiently.

a tenth and a third of that necessitated by the conventional feed configuration, the modified configuration makes it possible to install such antennas in places where they could not previously be installed and thereby helps to realize the potential advantages (concealment and/or reduction of aerodynamic drag) of microstrip versus whip antennas.

In both the conventional approach and the innovative approach, a microstrip-patch (or microstrip-patch-style) antenna for generating a monopole radiation pattern includes an electrically conductive patch or plate separated from an electrically conductive ground plane by a layer of electrically insulating material. In the conventional approach, the electrically insulating layer is typically a printed-circuit board about 1/16 in. (≈1.6 mm) thick. Ordinarily, a coaxial cable from a transmitter, receiver, or transceiver is attached at the center on the ground-plane side, the shield of the cable being electrically connected to the ground plane. In the conventional approach, the coaxial cable is mated with a connector mounted on the ground plane. The center pin of this connector connects to the center of the coaxial cable and passes through a hole in the ground plane and a small hole in the insulating layer and then connects with the patch above one-third of the radial distance from the center.

The modified feed configuration of the innovative approach is an inductive-short-circuit configuration that provides impedance matching and that has been used for many years on other antennas but not on microstrip-style monopole antennas. In this configuration, the pin is connected to both the conductive patch and the ground plane. As before, the shield of the coaxial cable is connected to the ground plane, but now the central conductor is connected to a point on the pin between the ground plane and the conductive plate (see figure). The location of the connection point on the pin is chosen so that together, the inductive short circuit and the conductive plate or patch act as components of a lumped-element resonant circuit that radiates efficiently at the resonance frequency and, at the resonance frequency, has an impedance that matches that of the coaxial cable.

It should be noted that the innovative design entails two significant disadvantages. One disadvantage is that the frequency bandwidth for efficient operation is only about 1/20 to 1/15 that of a whip antenna designed for the same nominal frequency. The other disadvantage is that the estimated gain is between 3-1/2 and 4-1/2 dB below that of the whip antenna. However, if an affected radio-communication system used only a few adjacent frequency channels and the design of the components of the system other than the antenna provided adequate power or gain margin, then these disadvantages could be overcome.

This work was done by W. Robert Young of **Langley Research Center**. *Further information is contained in a TSP (see page 1).*
LAR-16330

A 2-to-48-MHz Phase-Locked Loop

Noisy and degraded reference clock signals are taken as input and phase-locked clock signals of the same frequency are output with a corrected wave shape.

Lyndon B. Johnson Space Center, Houston, Texas

A 2-to-48-MHz phase-locked loop (PLL), developed for the U.S. space program, meets or exceeds all space shuttle clock electrical interface requirements by taking as its reference a 2-to-48-MHz clock signal and outputting a phase-locked clock signal set at the same frequency as the reference clock with transistor-transistor logic (TTL) voltage levels. Because it is more adaptable than other PLLs, the new PLL can be used in industries that employ signaling devices and as a tool in future space missions.

A conventional PLL consists of a phase/frequency detector, loop filter, and voltage-controlled oscillator in which each component exists individually and is integrated into a single device. PLL components phase-lock to a single frequency or to a narrow bandwidth of frequencies. It is this design, however, that prohibits them from maintaining phase lock to a dynamically changing reference clock when a large bandwidth is required — a deficiency the new PLL overcomes. Since most PLL components require their voltage-controlled oscillators to operate at greater than 2-MHz frequencies, conventional PLLs often cannot achieve the low-frequency phase lock allowed by the new PLL.

The 2-to-48-MHz PLL is built on a wire-wrap board with pins wired to three position jumpers; this makes changing configurations easy. It responds to variations in voltage-controlled oscillator (VCO) ranges, duty cycle, signal-to-noise ratio (SNR), amplitude, and jitter, exceeding design specifications. A consensus state machine, implemented in a VCO range detector which assures the PLL continues to operate in the correct range, is the primary control state machine for the 2-to-48-MHz PLL circuit. By using seven overlapping frequency ranges with hysteresis, the PLL output sets the resulting phase-locked clock signal at a frequency that agrees with the reference clock with TTL voltage levels.

As a space-shuttle tool, the new PLL circuit takes the noisy, degraded reference clock signals as input and outputs phase-locked clock signals of the same