independent interleavers, and the 15 groups of 372 Hamming symbols would be permuted by 15 independent interleavers before being fed to the 15 accumulators. This code structure at the transmitter would enable the use, in the receiver, of a high-speed iterative decoder that could include 372 soft-input, soft-output (SISO) modules to decode the 372 constituent Hamming codes in parallel and 15 SISO modules to decode the 15 constituent accumulator codes in parallel. Hence, the overall decoder could have a parallel architecture.

This work was done by Dariush Divsalar and Samuel Dolinar of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov.
NPO-40678

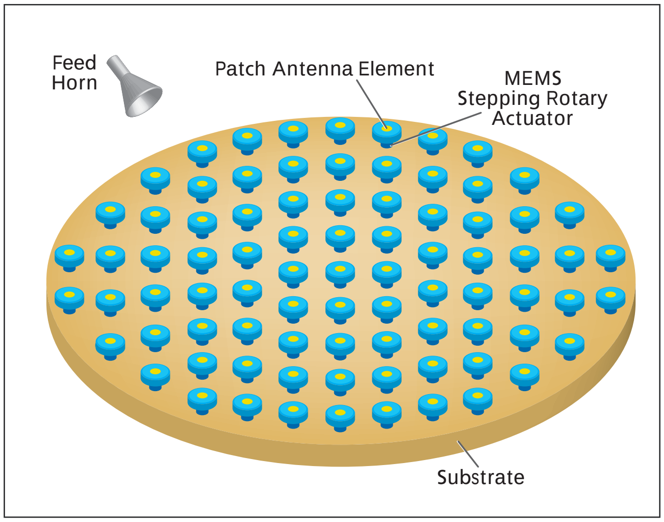
Wide-Angle-Scanning Reflectarray Antennas Actuated by MEMS

These could be simpler, cheaper alternatives to electronically scanned phased-array antennas.

NASA's Jet Propulsion Laboratory, Pasadena, California

An effort to develop large-aperture, wide-angle-scanning reflectarray antennas for microwave radar and communication systems is underway. In an antenna of this type as envisioned, scanning of the radiated or incident microwave beam would be effected through mechanical rotation of the passive (reflective) patch antenna elements, using microelectromechanical systems (MEMS) stepping rotary actuators typified by piezoelectric micromotors. It is anticipated that the cost, mass, and complexity of such an antenna would be less than, and the reliability greater than, those of an electronically scanned phased-array antenna of comparable beam-scanning capability and angular resolution.

In the design and operation of a reflectarray, one seeks to position and orient an array of passive patch elements in a geometric pattern such that, through constructive interference of the reflections from them, they collectively act as an efficient single reflector of radio waves within a desired frequency band. Typically, the patches lie in a common plane and radiation is incident upon them from a feed horn. Certain phase-sensitive types of such elements can be clocked to predetermined angles, relative to those of their neighbors, to modify the phase of the radiation incident from the feed horn and reflected from the elements so as to, for example, make the a flat array of patches act as though it were a parabolic reflector.



Passive Patch Antenna Elements in an array would be mounted on shafts of MEMS stepping rotary actuators that, in turn, would be mounted on a common substrate. The patch elements would be circularly polarized, and would be phase-sensitive in the sense that each would alter the phase difference between incident and reflected radiation by an amount that would depend on the actuator shaft angle.

Another reflectarray characteristic, essential to the present development, is that if the patch elements are rotated in unison, then the beam radiated by the antenna can be steered in elevation and azimuth through angular displacements of as much as ±50°. In an antenna of the type under development, the patch elements would be phase-sensitive in the sense mentioned above, would be circularly polarized, and would be mounted on the shafts of MEMS stepping rotary actuators (see figure). The maximum range of element rotation needed for wide-angle beam scanning would be only about ±180°, and scanning could be effected by use of relatively coarse rotational steps.

This work was done by Houfei Fang, John Huang, and Mark W. Thomson of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). ***NPO-45971***

Biasable Subharmonic Membrane Mixer for 520 to 600 GHz

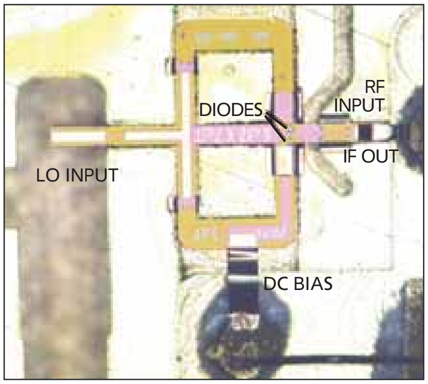
This is a prototype of mixers for future submillimeter-wavelength spectrometers.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure shows a biasable subharmonic mixer designed to operate in the frequency range from 520 to 600 GHz. This mixer is a prototype of low-power mixers needed for development of wide-band, high-resolution spectrometers for measuring spectra of molecules in the atmospheres of Earth, other planets, and comets in the frequency range of 400 to 700 GHz.

Three considerations dictated the main features of the design:

- It is highly desirable to operate the spectrometers at or slightly below room temperature. This consideration is addressed by choosing Schottky diodes as the frequency-mixing circuit elements because of all mixer diodes, Schottky diodes are the best candidates for affording sufficient sensitivity at or slightly below room-temperature range.



This **Biasable Subharmonic Mixer** for the RF range of 520 to 600 GHz consists of a monolithic integrated circuit on a GaAs membrane held in a precision-machined waveguide block.

- The short wavelengths in the intended operating-frequency range translate to stringent requirements for precision of fabrication and assembly of the circuits; these requirements are even more stringent for wide-bandwidth circuits. This consideration is addressed in two ways: (1) As much as possible of the mixer circuitry is fabricated in the form of a monolithic integrated circuit on a GaAs membrane, employing a modified version of a process used previously to fabricate a non-subharmonic mixer for a frequency of 2.5 THz and frequency multipliers for frequencies up to 2 THz. (2) The remainder of the circuitry is precision machined into a waveguide block that holds the GaAs integrated circuit.
- Generation of a local-oscillator (LO) signal having sufficient power to pump a mixer requires more DC power as the LO frequency increases; this is because the only wide-band LO sources available in this frequency range are Schottky-diode frequency multipliers, and their efficiencies decrease with frequency. This consideration is addressed in two ways: (1) Unlike the prior 2.5-THz GaAs-membrane mixer, this mixer is subharmonically driven, meaning that the LO operates at half the frequency of the incoming signal to be measured [denoted the radio frequency (RF) in traditional frequency mixer parlance]. (2) The diodes are arranged so that they can be biased to operate closer to their switching voltage so that less LO power is needed to switch the diodes between the conducting and nonconducting states. This switching is what makes the diodes act as a frequency mixer.

The Schottky diodes are fabricated in an antiparallel configuration, using beam leads, such that one electrode of each diode is grounded. One diode is AC grounded through a capacitor to allow the diodes to be biased. A simple probe picks up the LO signal from a waveguide shown on the left side of the figure. The LO signal bypasses an RF filter comprised of two vertical stubs and is coupled into the mixer diodes. Similarly, another probe picks up the RF signal from a waveguide shown on the right side of the figure and the RF signal flows leftward to the diodes.

The on-chip circuitry also conveys the lower-frequency mixer output signal [also denoted, variously, as the intermediate-frequency (IF) signal or the down-converted version of the RF signal in traditional frequency-mixer parlance] to an off-chip circuit board on the right side. The stub filter to the left of the diodes prevents the leakage of the RF signal past the diodes to the LO waveguide. Leakage of the LO signal into the RF waveguide is inherently blocked as it is below the cutoff frequency of the RF waveguide. There is also a filter in the output channel, implemented as shunt capacitors (not shown here), to prevent leakage of RF and LO signals to the off-chip circuitry that processes the IF signal.

This work was done by Erich Schlecht, Peter Siegel, Imran Mehdi, John Gill, James Velebir, Alejandro Peralta, Raymond Tsang, John Oswald, and Robert Dengler of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). *NPO-43594*

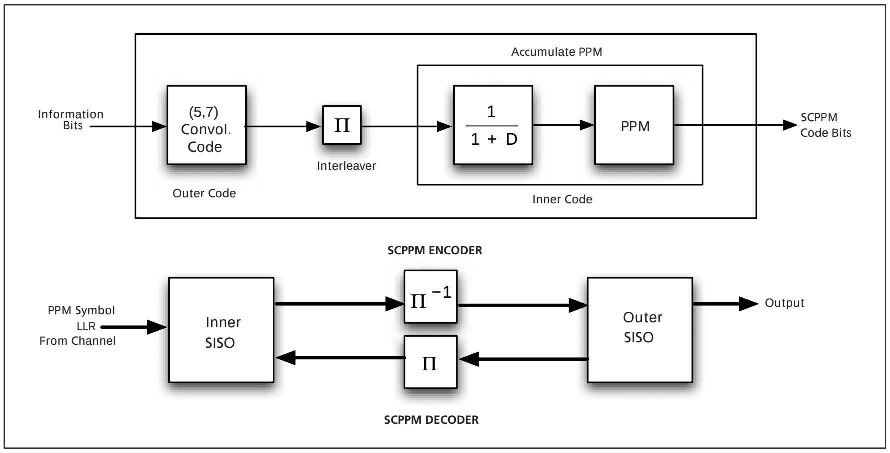
Hardware Implementation of Serially Concatenated PPM Decoder

Error-rate performance approaches channel capacity.

NASA's Jet Propulsion Laboratory, Pasadena, California

A prototype decoder for a serially concatenated pulse position modulation (SCPPM) code has been implemented in a field-programmable gate array (FPGA). At the time of this reporting, this is the first known hardware SCPPM decoder. The SCPPM coding scheme, conceived for free-space optical communications with both deep-space and terrestrial applications in mind, is an improvement of several dB over the conventional Reed-Solomon PPM scheme. The design of the FPGA SCPPM decoder is based on a turbo decoding algorithm that requires relatively low computational complexity while delivering error-rate performance within approximately 1 dB of channel capacity.

The SCPPM encoder consists of an outer convolutional encoder, an interleaver, an accumulator, and an inner modulation encoder (more precisely, a mapping of bits to PPM symbols). Each code is describable by a trellis (a finite directed graph). The SCPPM decoder consists of an inner soft-in-soft-out (SISO) module, a de-interleaver, an outer SISO



The **SCPPM Decoder** is designed according to a decoding algorithm that includes interleaving and de-interleaving algorithms in conjunction with SISO subalgorithms for decoding inner and outer codes.