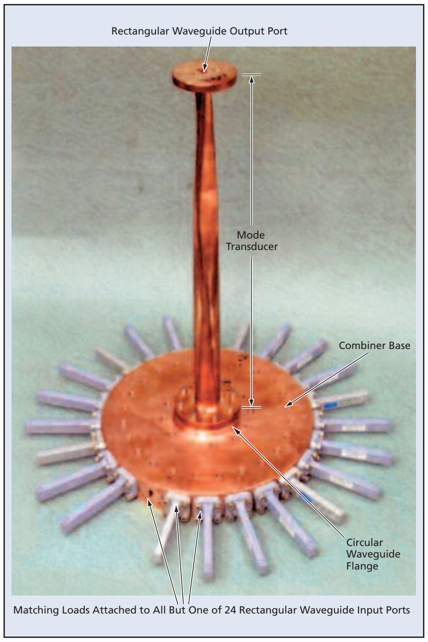
24-Way Radial Power Combiner/Divider for 31 to 36 GHz

A unique design affords high bandwidth with high order of combining.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure shows a prototype radial power-combining waveguide structure, capable of operation at frequencies from 31 to 36 GHz, that features an unusually large number ($N = 24$) of combining (input) ports. The combination of wide-band operation and large N is achieved by incorporating several enhancements over a basic radial power-combiner design. In addition, the structure can be operated as a power divider by reversing the roles of the input and output ports.



This **Power Combiner** contains 24 internal reduced-height radial waveguides with impedance-transforming height and width steps, plus an internal central matching post.

In this structure, full-height waveguides at the combining ports are matched in impedance to reduced-height radial waveguides inside the combiner base. This match is effected by impedance-transforming stepped waveguide sections. This matching scheme is essential to achievement of large N because N is limited by the height of the waveguides in the base.

Power is coupled from the 24 reduced-height radial waveguides into the TE_{01} mode of a circular waveguide in the base with the help of a matching post at the bottom of the base. ("TE" signifies "transverse electric," the first subscript is the azimuthal mode number, and the second subscript is the radial mode number.) More specifically, the matching post matches the reflections from the walls of the 24 reduced-height waveguides and enables the base design to exceed the bandwidth requirement.

After propagating along the circular waveguide, the combined power is coupled, via a mode transducer, to a rectangular waveguide output port. The mode transducer is divided into three sections, each sized and shaped as part of an overall design to satisfy the mode-conversion and output-coupling requirements while enabling the circular waveguide to be wide enough for combining the 24 inputs over the frequency range of 31 to 36 GHz. During the design process, it was found that two different rectangular waveguide outputs could be accommodated through modification of only the first section of the mode converter, thereby enabling operation in multiple frequency ranges.

This work was done by Larry Epp, Daniel Hoppe, Abdur Khan, and Daniel Kelley of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Three-Stage InP Submillimeter-Wave MMIC Amplifier

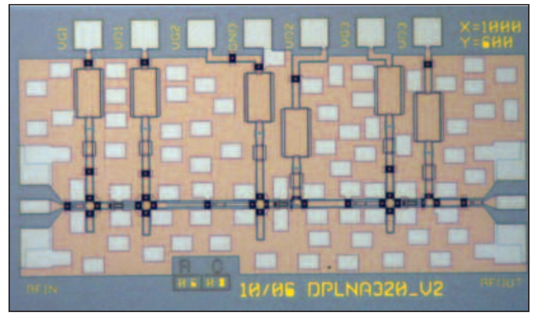
Submillimeter-wave amplifiers can enable more sensitive receivers for earth science, planetary remote sensing, and astrophysics telescopes.

NASA's Jet Propulsion Laboratory, Pasadena, California

A submillimeter-wave monolithic integrated-circuit (S-MMIC) amplifier has been designed and fabricated using an indium phosphide (InP) 35-nm gate-length high electron mobility transistor (HEMT) device, developed at Northrop Grumman Corporation. The HEMT device employs two fingers each 15 micrometers wide. The HEMT wafers are grown by molecular beam epitaxy (MBE) and make use of a pseudomorphic $In_{0.75}Ga_{0.25}As$ channel, a silicon delta-doping layer as the electron supply, an $In_{0.52}Al_{0.48}As$ buffer layer, and an InP substrate. The three-stage design uses coplanar waveguide topology with a very narrow ground-to-ground spacing of 14 micrometers. Quarter-wave matching transmission lines, on-chip metal-insulator-metal shunt capacitors, series thin-film resistors, and matching stubs were used in the design. Series resistors in the shunt branch arm provide the basic circuit stabilization. The S-MMIC amplifier was measured for S-parameters and found to be centered at 320 GHz with 13–15-dB gain from 300–345 GHz.

This chip was developed as part of the DARPA Submillimeter Wave Imaging Focal Plane Technology (SWIFT) program (see figure). Submillimeter-wave amplifiers could enable more sensitive receivers for earth science, planetary remote sensing, and astrophysics telescopes, particularly in radio astronomy, both from the ground and in space. A small atmospheric window at 340 GHz exists and could enable ground-based observations. However, the submillimeter-wave regime (above 300 GHz) is best used for space telescopes as Earth's atmosphere attenuates most of the signal through water and oxygen absorption. Future radio telescopes could make use of S-MMIC amplifiers for wideband, low noise, instantaneous frequency coverage, particularly in the case of heterodyne array receivers.

This work is aimed at pushing the MMIC and transistor technologies toward higher frequencies and, at these higher frequencies (>300 GHz), a wealth of spectral lines of molecular species exist and could be studied with more sensitive receivers. There are potential applications for future millimeter-wave Earth observational instruments such as the Scanning Microwave Limb Sounder, GeoSTAR, and other planetary instrument concepts being proposed, such as the Microwave Sounding Unit for Mars. These future instruments and missions need high-gain, low-noise amplifiers at or above 180 GHz. Implementation of high-gain, low-noise amplifiers would greatly improve the signal-to-noise ratio of future heterodyne receivers.



A **Chip Photograph** of the 320-GHz three-stage S-MMIC amplifier.

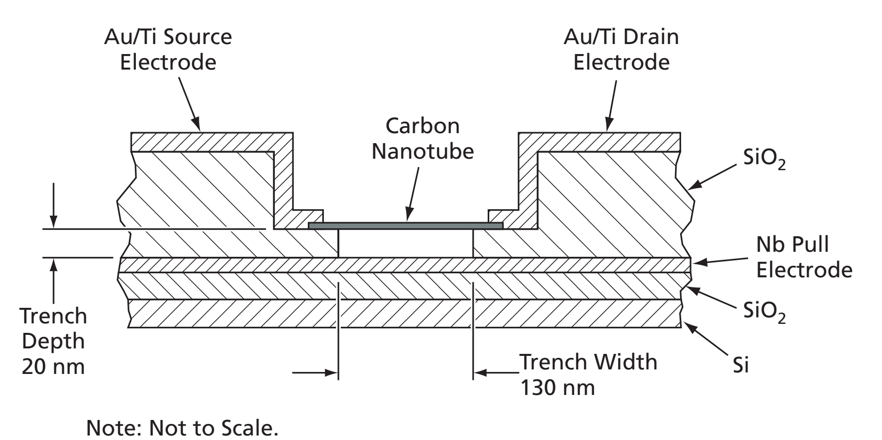
This work was done by David Pukala, Lorene Samoska, King Man Fung, and Todd Gaier of Caltech and William Deal, Richard Lai, Gerry Mei, and Stella Makishi of Northrop Grumman Corporation for NASA's Jet Propulsion Laboratory. The contributors would like to acknowledge the support of Dr. Mark Rosker and the Army Research Laboratory. This work was supported by the DARPA SWIFT Program and Army Research Laboratory under the DARPA MIPR no.06-U037 and ARL Contract no. W911QX-06-C-0050. Further information is contained in a TSP (see page 1). *NPO-45046*

Fast Electromechanical Switches Based on Carbon Nanotubes

Potential applications include computer memory, cell phones, and scientific instruments.

NASA's Jet Propulsion Laboratory, Pasadena, California

Electrostatically actuated nanoelectromechanical switches based on carbon nanotubes have been fabricated and tested in a continuing effort to develop high-speed switches for a variety of stationary and portable electronic equipment. As explained below, these devices offer advantages over electrostatically actuated microelectromechanical switches, which, heretofore, have represented the state of the art of rapid, highly miniaturized electromechanical switches. Potential applications for these devices include computer memories, cellular telephones, communication networks, scientific instrumentation, and general radiation-hard electronic equipment.



A **Carbon Nanotube Is Suspended** between source and drain electrodes over a pull electrode. By application of a suitable potential (typically a few volts), the nanotube is drawn into contact with the pull electrode.

A representative device of the present type includes a single-wall carbon nanotube suspended over a trench about 130 nm wide and 20 nm deep in an electrically insulating material. The ends of the carbon nanotube are connected to metal electrodes, denoted the source and drain electrodes. At bottom of the trench is another metal electrode, denoted the pull electrode (see figure). In the "off" or "open" switch state, no voltage is applied, and the nanotube remains out of contact with the pull electrode. When a sufficiently large electric potential (switching potential) is applied between the pull electrode and either or both of the source and drain electrodes, the resulting electrostatic attraction bends and stretches the nanotube into contact with the pull electrode, thereby putting the switch into the "on" or "closed" state, in which substantial current (typically as much as hundreds of nanoamperes) is conducted.

Devices of this type for use in initial experiments were fabricated on a thermally oxidized Si wafer, onto which Nb was sputter-deposited for use as the pull-electrode layer. Nb was chosen because its refractory nature would enable it to withstand the chemical and thermal conditions to be subsequently imposed for growing carbon nanotubes. A 200-nm-thick layer of SiO_2 was formed on top of the Nb layer by plasma-enhanced chemical vapor deposition. In the device regions, the SiO_2 layer was patterned to thin it to the 20-nm trench depth. The trenches were then patterned by electron-beam lithography and formed by reactive-ion etching of the pattern through the 20-nm-thick SiO_2 to the Nb layer.