# 164-GHz MMIC HEMT Frequency Doubler

**Conversion loss is lower than that of other HEMT frequency doublers above 100 GHz.**

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A monolithic microwave integrated circuit (MMIC) that includes a high-electron-mobility transistor (HEMT) has been developed as a prototype of improved frequency doublers for generating signals at frequencies >100 GHz. Signal sources that operate in this frequency range are needed for a variety of applications, notably including general radiometry and, more specifically, radiometric remote sensing of the atmosphere.

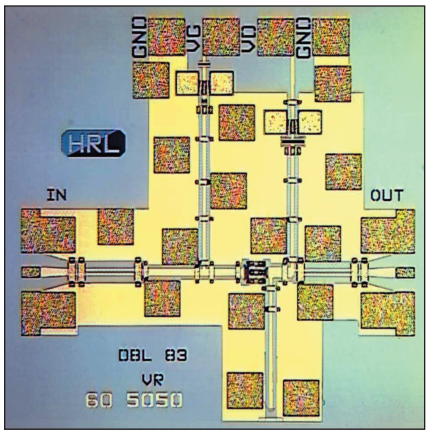


Figure 1. This **MMIC HEMT Frequency Doubler** occupies a chip with dimensions of 1.1 mm by 1.2 mm by 50 μm.

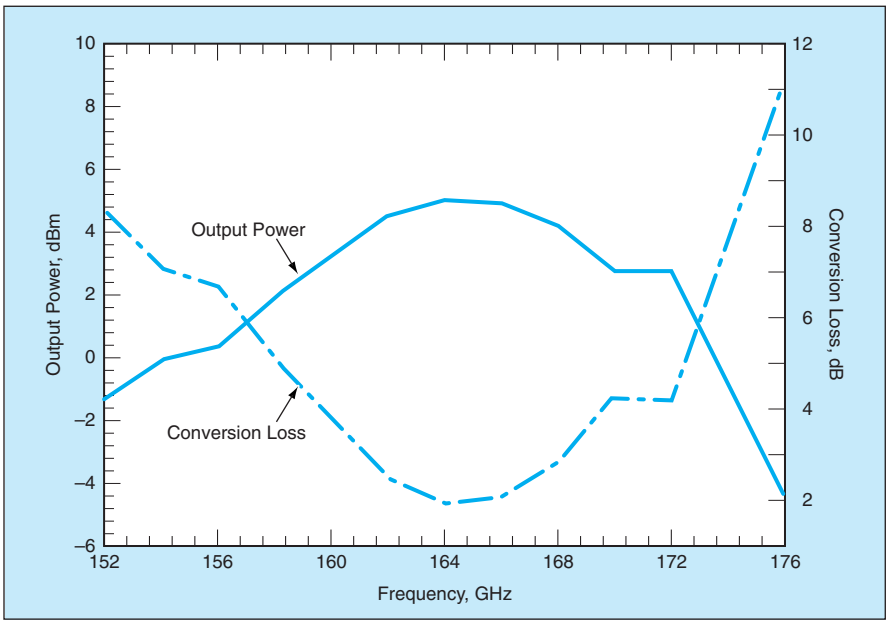


Figure 2. The **Output Power and Conversion Loss** of the frequency doubler were measured as functions of frequency.

Heretofore, it has been common practice to use passive (diode-based) frequency multipliers to obtain frequencies >100 GHz. Unfortunately, diode-based frequency multipliers are plagued by high DC power consumption and low conversion efficiency. Moreover, multiplier diodes are not easily integrated with such other multiplier-circuit components as amplifiers and oscillators. The goals of developing the present MMIC HEMT frequency doubler were (1) to utilize the HEMT as an amplifier to increase conversion efficiency (more precisely, to reduce conversion loss), thereby increasing the output power for a given DC power consumption or, equivalently, reducing the DC power consumption for a given output power; and (2) to provide for the integration of amplifier and oscillator components on the same chip.

The MMIC frequency doubler (see Figure 1) contains an AlInAs/GaInAs/InP HEMT biased at pinch-off to make it function as a class-B amplifier (meaning that it conducts in half-cycle pulses). Grounded coplanar waveguides (GCPWs) are used as impedance-matching transmission lines. Air bridges are placed at discontinuities to suppress undesired slot electromagnetic modes. Another combination of GCPWs also serves both as a low-pass filter to suppress undesired oscillations at frequencies below 60 GHz and as a DC blocker. Large decoupling capacitors and epitaxial resistors are added in the drain and gate lines to suppress bias oscillations. At the output terminal, the fundamental frequency is suppressed by a quarter-wave open stub, which presents a short circuit at the fundamental frequency and an open circuit at the second harmonic.

At an input power of 7 mW, the output power and conversion loss at an output frequency of 164 GHz were found to be 5 dBm (≈3.2 mW) and 2 dB, respectively, with a 3-dB output-power bandwidth of 14 GHz. This is the best performance reported to date for an MMIC HEMT frequency doubler above 100 GHz.

*This work was done by Lorene Samoska of* **NASA's Jet Propulsion Laboratory**, *Vesna Radisic, Miro Micovic, Ming Hu, Paul Janke, Catherine Ngo, and Loi Nguyen of HRL Laboratories, LLC, and Matthew Morgan of Caltech. Further information is contained in a TSP (see page 1).*

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# GPS Position and Heading Circuitry for Ships

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Circuit boards that contain radio-frequency (RF) and digital circuitry have been developed by NASA to satisfy a requirement of the Port of Houston Authority for relatively inexpensive Global Positioning System (GPS) receivers that indicate the azimuthal headings as well as the positions of ships. The receiver design utilizes the unique architecture of the Mitel commercial chip-set, which provides for an accurate GPS-based heading-determination device. The major components include two RF front ends (each connected to a separate antenna), a surface-acoustic-wave intermediate-frequency fil-

ter between second- and third-stage mixers, a correlator, and a reduced-instruction-set computer. One of the RF front ends operates as a master, the other as a slave. Both RF front ends share a 10-MHz sinusoidal clock oscillator, which provides for more accurate carrier phase measurements between the two antennas. The outputs of the RF front ends are subjected to conventional GPS processing. The commercial-based chip-set design approach provides an inexpensive "open architecture" GPS platform, which can be used in developing and implementing unique GPS-heading and attitude-determination algorithms for specific applications. The heading is estimated from the GPS position solutions of the two antennas by an algorithm developed specifically for this application. If a third (and preferably a fourth) antenna were added, it would be possible to estimate the attitude of the GPS receiver in three dimensions instead of only its heading in a horizontal plane.

*This work was done by Michael P. Cooke, Hester J. Yim, and Susan F. Gomez of* **Johnson Space Center.** *Further information is contained in a TSP (see page 1).*
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