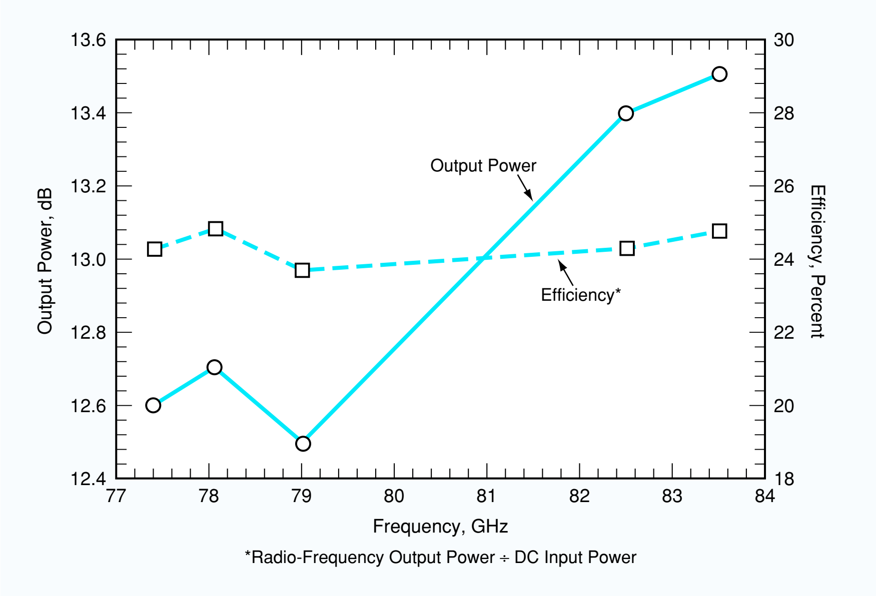


Figure 2. The **Output Power and Power Efficiency** of the frequency oscillator were measured as functions of frequency over its 6-GHz-wide tuning range.

motive radar applications, among others.

This oscillator (see Figure 1) includes two AlInAs/GaInAs/InP HEMTs. One HEMT serves mainly as an oscillator gain element. The other HEMT serves mainly as a varactor for controlling the frequency: the frequency-control element is its gate-to-source capacitance, which is varied by changing its gate supply voltage.

The gain HEMT is biased for class-A operation (meaning that current is conducted throughout the oscillation cycle). Grounded coplanar waveguides are used as impedance-matching transmission lines, the input and output matching being chosen to sustain oscillation and maximize output power. Air bridges are placed at discontinuities to suppress undesired slot electromagnetic modes. A high density of vias is necessary for suppressing a parallel-plate electromagnetic mode that is undesired because it can propagate energy into the MMIC substrate.

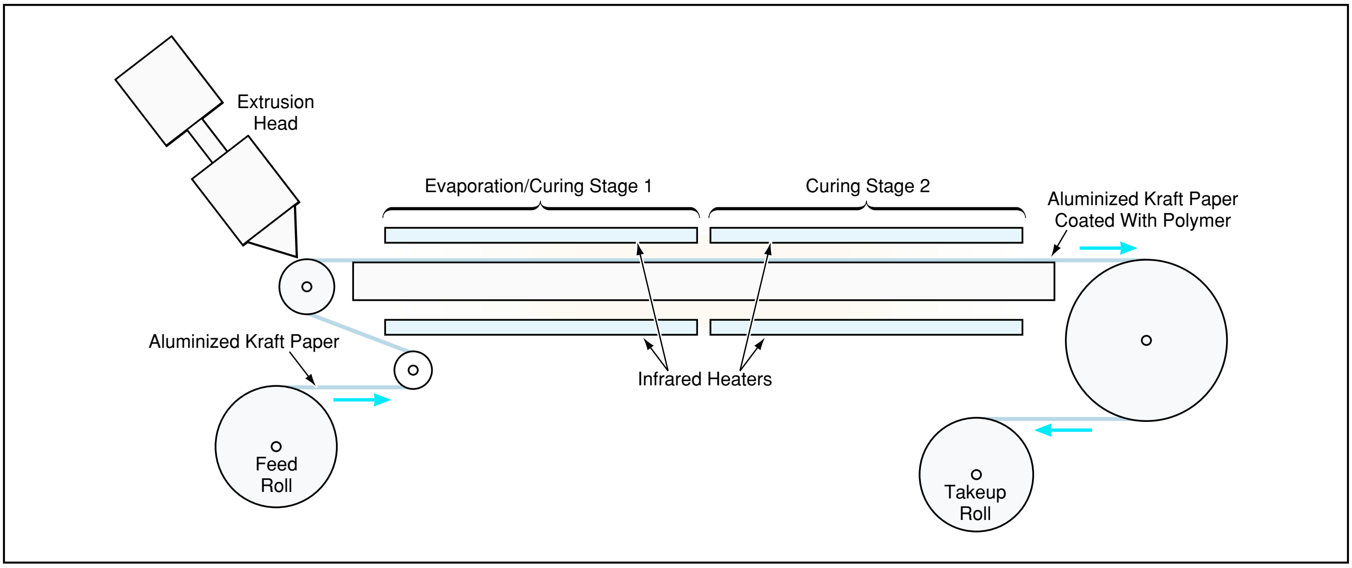
Previous attempts at constructing HEMT-based oscillators yielded circuits with relatively low levels of output power and narrow tuning ranges. For example, one HEMT VCO reported in the literature had an output power of 7 dBm (≈5 mW) and a tuning range 2-GHz wide centered approximately at a nominal frequency of 77 GHz. In contrast, as shown in Figure 2, the present MMIC HEMT VCO puts out a power of 12.5 dBm (≈18 mW) or more over the 6-GHz-wide frequency range from 77.5 to 83.5 GHz.

This work was done by Lorene Samoska of ***NASA's Jet Propulsion Laboratory*** *and Vesna Radisic, Miro Micovic, Ming Hu, Paul Janke, Catherine Ngo, and Loi Nguyen of HRL Laboratories, LLC. Further information is contained in a TSP [see page 1].*
NPO-21214

High-Energy-Density Capacitors

Maximum sustainable energy density is more than twice that of polypropylene-film capacitors.

John H. Glenn Research Center, Cleveland, Ohio



A **Film of Dielectric Polymer Is Cast** on a continuous strip of aluminized kraft paper. High dielectric performance is obtained through selection of the materials and design of the process and machinery.

Capacitors capable of storing energy at high densities are being developed for use in pulse-power circuits in such diverse systems as defibrillators, particle-beam accelerators, microwave sources, and weapons. Like typical previously developed energy-storage capacitors, these capacitors are made from pairs of metal/solid-dielectric laminated sheets that are wound and pressed into compact shapes to fit into cans, which are then filled with dielectric fluids. Indeed, these capacitors can be fabricated largely by conventional fabrication techniques. The main features that distinguish these capacitors from previously developed ones are improvements in (1) the selection of laminate materials, (2) the fabrication of the laminated sheets from these materials, and (3) the selection of dielectric fluids.

In simplest terms, a high-performance laminated sheet of the type used in these capacitors is made by casting a dielectric polymer onto a sheet of aluminized kraft paper. The dielectric polymer is a siloxane polymer that has been modified with polar pendant groups to increase its permittivity and dielectric strength.

Potentially, this polymer is capable of withstanding an energy density of 7.5 J/cm^3, which is four times that of the previous state-of-the-art-capacitor dielectric film material. However, the full potential of this polymer cannot be realized at present because (1) at thicknesses needed for optimum performance ($\leq$8.0 µm), the mechanical strength of a film of this polymer is insufficient for incorporation into a wound capacitor and (2) at greater thickness, the achievable energy density decreases because of a logarithmic decrease in dielectric strength with increasing thickness. The aluminized kraft paper provides the mechanical strength needed for processing of the laminate and fabrication of the capacitor, and the aluminum film serves as an electrode layer. Because part of the thickness of the dielectric is not occupied by the modified siloxane polymer, the achievable energy density must be somewhat less than the maximum value.

The laminate is produced by a continuous film-casting process, using the machinery depicted schematically in the figure. The designs of the process and machinery are dictated partly by the fact that during the processing step prior to casting the polymer, the aluminized kraft paper becomes wet with water. Because the polymer resin to be cast is hydrophobic, the paper must be dried to make it possible to coat the paper uniformly, leaving no pinholes. Accordingly, an infrared heater is placed next to the paper feed roll to dry the paper prior to casting.

The polymer is cast onto the aluminized paper by an extrusion head. To ensure uniform thickness of the cast film, the designs of the extrusion head and the apparatus that feeds the resin to the head incorporate several refinements. To prevent undesired increases in viscosity, blockages, and other undesired effects of premature polymerization, the resin and the extrusion head are cooled to 0 °C to retard polymerization until the moment of casting. Downstream of the extrusion head, the resin-coated aluminized paper is heated to cure the polymer.

A total of ten dielectric fluids were evaluated with regard to their properties, compatibility with the polymer-coated kraft paper, and effect on the dielectric strength of the polymer. This evaluation led to the selection of castor oil as the dielectric fluid (with mineral oil and fluorinated siloxane as alternates for situations in which the use of castor oil would be problematic).

Experimental capacitors made from windings of the polymer-coated aluminized kraft paper with castor-oil and mineral-oil impregnation exhibited state-of-the-art performance. Notable among the performance characteristics was the ability to withstand energy densities up to 2.5 J/cm^3; although this is less than the theoretical maximum, it is more than double the maximum energy density of polypropylene-film capacitors now in use.

This work was done by Kirk Slenes of TPL, Inc., for **Glenn Research Center**. *Further information is contained in a TSP [see page 1].*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16921.