Electronics/Computers

Multiple Differential-Amplifier MMICs Embedded in Waveguides
Amplifiers are separated by no more than fractional-wavelength distances.

NASA's Jet Propulsion Laboratory, Pasadena, California

Compact amplifier assemblies of a type now being developed for operation at frequencies of hundreds of gigahertz comprise multiple amplifier units in parallel arrangements to increase power and/or cascade arrangements to increase gains. Each amplifier unit is a monolithic microwave integrated circuit (MMIC) implementation of a pair of amplifiers in differential (in contradistinction to single-ended) configuration.

Heretofore, in cascading amplifiers to increase gain, it has been common practice to interconnect the amplifiers by use of wires and/or thin films on substrates. This practice has not yielded satisfactory results at frequencies >200 Hz, in each case, for either or both of two reasons:
• Wire bonds introduce large discontinuities.
• Because the interconnections are typically tens of wavelengths long, any impedance mismatches give rise to ripples in the gain-vs.-frequency response, which degrade the performance of the cascade.

Heretofore, it has been very difficult to achieve net increases in power by combining the outputs of amplifiers at frequencies >100 GHz. The only successful approach that has been even marginally successful has involved the use of waveguide combiners designed and fabricated as components separate from the amplifiers. At these frequencies, even waveguides exhibit high losses that can easily dissipate any power gained by combining outputs.

In the present development, neither thin-film nor wire interconnections are used for cascading, and separate component waveguide combiners are not used for combining power. Instead, the amplifier units are designed integrally with the waveguides and designed to be embedded in the waveguides. The underlying concept of differential-amplifier MMICs designed integrally with and embedded in waveguides and the advantages of the differential over the single-ended configuration were reported in "Differential InP HEMT MMIC Amplifiers Embedded in Waveguides" (NPO-42857) *NASA Tech Briefs*, Vol. 33, No. 9 (September 2009), page 35. The novel aspect of the present development lies in combining the integration and embedment concepts with the cascading and parallel-combining concepts to obtain superior performance. In an amplifier assembly of the present type,

there is no need for interconnecting wires or thin-film conductors nor for separate waveguide power combiners because the waveguide in which the MMICs are embedded is the connecting medium. Because the distance between successive MMICs in a cascade is only a fraction of a wavelength, cascading can be highly efficient and ripple in gain versus frequency is reduced to a minimum. Moreover, power combining can be highly efficient because it is accomplished simply by placing MMICs side by side within the waveguide.

Rapid Corner Detection Using FPGAs
This algorithm can be used in automotive, navigation, and industrial factory applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

In order to perform precision landings for space missions, a control system must be accurate to within ten meters. Feature detection applied against images taken during descent and correlated against the provided base image is computationally expensive and requires tens of seconds of processing time to do just one image while the goal is to process multiple images per second.

To solve this problem, this algorithm takes that processing load from the central processing unit (CPU) and gives it to a reconfigurable field pro-

grammable gate array (FPGA), which is able to compute data in parallel at very high clock speeds. The workload of the processor then becomes simpler; to read an image from a camera, it is transferred into the FPGA, and the results are read back from the FPGA.

The Harris Corner Detector uses the determinant and trace to find a "corner score," with each step of the computation occurring on independent clock cycles. Essentially, the image is converted into an x and y derivative

map. Once three lines of pixel information have been queued up, valid pixel derivatives are clocked into the product and averaging phase of the pipeline. Each x and y derivative is squared against itself, as well as the product of the i_x and i_y derivative, and each value is stored in a W×N size buffer, where W represents the size of the integration window and N is the width of the image. In this particular case, a window size of 5 was chosen, and the image is 640×480.

Over a W×N size window, an equidis-

tance Gaussian is applied (to bring out the stronger corners), and then each value in the entire window is summed and stored. The required components of the equation are in place, and it is just a matter of taking the determinant and trace. It should be noted that the trace is being weighted by a constant κ, a value that is found empirically to be within 0.04 to 0.15 (and in this implementation is 0.05). The constant κ determines the number of corners available to be compared against a threshold σ to mark a "valid corner."

After a fixed delay from when the first pixel is clocked in (to fill the pipeline), a score is achieved after each successive clock. This score corresponds with an (x, y) location within the image. If the score is higher than the predetermined threshold σ, then a flag is set high and the location is recorded.

Special Component Designs for Differential-Amplifier MMICs
Transistors and transmission lines are optimized for differential operation.
NASA's Jet Propulsion Laboratory, Pasadena, California

Special designs of two types of electronic components — transistors and transmission lines — have been conceived to optimize the performances of these components as parts of waveguide-embedded differential-amplifier monolithic microwave integrated circuits (MMICs) of the type described in the immediately preceding article. These designs address the following two issues, the combination of which is unique to these particular MMICs:

- Each MMIC includes a differential double-strip transmission line that typically has an impedance between 60 and 100 W. However, for purposes of matching of impedances, transmission lines having lower impedances are also needed.
- The transistors in each MMIC are, more specifically, one or more pair(s) of InP-based high-electron-mobility transistors (HEMTs). Heretofore, it has been common practice to fabricate each such pair as a single device configured in the side-to-side electrode sequence source/gate/drain/gate/source. This configuration enables low-inductance source grounding from the sides of

the device. However, this configuration is not suitable for differential operation, in which it is necessary to drive the gates differentially and to feed the output from the drain electrodes differentially.

The special transmission-line design provides for three conductors, instead of two, in places where lower impedance is needed. The third conductor is a metal strip placed underneath the differential double-strip transmission line. The third conductor increases the capacitance per unit length of the transmission line by such an amount as to reduce the impedance to between 5 and 15 W.

In the special HEMT-pair design, the side-to-side electrode sequence is changed to drain/gate/source/gate/drain. In addition, the size of the source is reduced significantly, relative to corresponding sizes in prior designs. This reduction is justified by the fact that, by virtue of the differential configuration, the device has an internal virtual ground, and therefore there is no need for a low-resistance contact between the source and the radio-frequency circuitry.

The source contact is needed only for DC biasing.

These designs were implemented in a single-stage-amplifier MMIC. In a test at a frequency of 305 GHz, the amplifier embedded in a waveguide exhibited a gain of 0 dB; after correcting for the loss in the waveguide, the amplifier was found to afford a gain of 0.9 dB. In a test at 220 GHz, the overall gain of the amplifier-and-waveguide assembly was found to be 3.5 dB.

Multi-Stage System for Automatic Target Recognition
This system is capable of identifying hazards to avoid in robotic vehicle and automobile navigation.
NASA's Jet Propulsion Laboratory, Pasadena, California

A multi-stage automated target recognition (ATR) system has been designed to perform computer vision tasks with adequate proficiency in mimicking human vision. The system is able to detect, identify, and track targets of interest. Potential regions of interest (ROIs) are first identi-

fied by the detection stage using an Optimum Trade-off Maximum Average Correlation Height (OT-MACH) filter combined with a wavelet transform. False positives are then eliminated by the verification stage using feature extraction methods in conjunction with neural net-

works. Feature extraction transforms the ROIs using filtering and binning algorithms to create feature vectors. A feedforward back-propagation neural network (NN) is then trained to classify each feature vector and to remove false positives. The system parameter optimiza-