



## Program Merges SAR Data on Terrain and Vegetation Heights

NASA's Jet Propulsion Laboratory, Pasadena, California

X/P Merge is a computer program that estimates ground-surface elevations and vegetation heights from multiple sets of data acquired by the GeoSAR instrument [a terrain-mapping synthetic-aperture radar (SAR) system that operates in the X and P bands]. X/P Merge software combines data from X- and P-band digital elevation models, SAR backscatter magnitudes, and interferometric correlation magnitudes into a simplified

set of output topographical maps of ground-surface elevation and tree height.

For computational efficiency, inversions are performed by use of lookup tables. The program performs calibrations to remove biases from output estimates, calibrates interferometric correlation magnitudes by accounting for geometric and radiometric errors, differentiates between surface and vegetated

areas, and, on a pixel-by-pixel basis, selects the lookup table corresponding to the best user-specified inversion approach.

*This program was written by Paul Siqueira, Scott Hensley, Ernesto Rodriguez, and Marc Simard of Caltech for NASA's Jet Propulsion Laboratory.*

*This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-40268.*

## Using G<sup>4</sup>FETs as a Data Router for In-Plane Crossing of Signal Paths

Cross-talk is low enough that integrity of signals could be preserved.

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Theoretical analysis and some experiments have demonstrated that silicon-on-insulator (SOI) 4-gate transistors of the type known as G<sup>4</sup>FETs could be efficiently used for in-plane crossing of signal paths. Much of the effort of designing very-large-scale integrated (VLSI) circuits is focused on area-efficient routing of signals. The main source of difficulty in VLSI signal routing is the requirement to prevent crossing, in the same plane, of wires that are meant to be kept electrically insulated from each other. Consequently, it often becomes necessary to design and build VLSI circuits in multiple layers with vias (connections between conductors in different layers at selected locations). Suitable devices that would prevent, or at least sufficiently suppress, undesired electrical coupling (cross-talk) between wires crossing in the same plane would enable compact, simpler implementation of complex interconnection networks with in-plane crossings that, heretofore, have not been possible in VLSI circuitry. The use of G<sup>4</sup>FETs as in-plane signal-crossing devices or routers, in combination with the use of G<sup>4</sup>FETs as universal programmable logic gates, would create opportunities for reducing complexity in VLSI design.

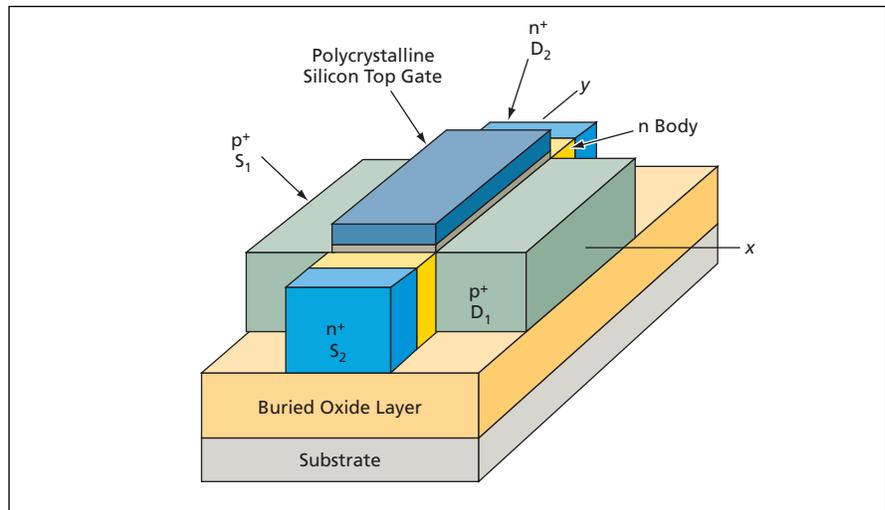


Figure 1. The G<sup>4</sup>FET consists of a p-channel inversion-mode MOSFET (including source S1 and drain D1) for current flowing in the x direction and an accumulation-mode n-channel MOSFET (including source S2 and drain D2) for current flowing in the y direction. The gate, body and substrate are common to both transistors.

A G<sup>4</sup>FET, depicted in simplified form in Figure 1, has the same basic structure as does a prior SOI cross-MOSFET (metal oxide/semiconductor field-effect transistor), though the cross-MOSFET is somewhat wider. The cross-MOSFET consists essentially of an inversion-mode and an accumulation-mode MOSFET that share gate and substrate terminals

and are oriented perpendicularly to each other. The prior use of the cross-MOSFET involved sequential operation of the inversion-mode and accumulation-mode MOSFETs. In contrast, the use of the G<sup>4</sup>FET as an in-plane router involves the simultaneous operation of the inversion-mode MOSFET in one in-plane direction and the accumulation-

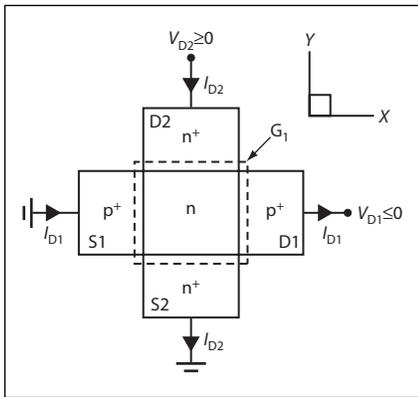


Figure 2. The DC Configuration of the G<sup>4</sup>FET of Figure 1 is helpful in understanding the ability of the device to function as a router.

mode MOSFET in the orthogonal in-plane direction.

Figure 2 schematically shows the DC configuration of the G<sup>4</sup>FET relevant to its use as a signal router. The drain (D1) of the inversion-mode p-channel MOSFET is biased to  $V_{D1}$ , the drain (D2) of the accumulation-mode n-channel MOSFET is biased to  $V_{D2}$ , and the source terminals (S1 and S2) of both transistors are grounded.

The two drain currents,  $I_{D1}$  and  $I_{D2}$ , are perpendicular to each other and can flow at the same time.  $I_{D1}$  depends on minority charge carriers and flows at the surface in the  $x$  direction, while  $I_{D2}$  depends on majority carriers and flows at the mid-depth of the silicon film in the  $y$  direction. Surface holes and bulk electrons do not recombine because front-gate-induced depletion region isolates them. The top gate can modulate both drain currents —  $I_{D1}$  through regular MOS action and  $I_{D2}$  through vertical-depletion-width modulation.  $I_{D1}$  and  $I_{D2}$  can also weakly modulate each other — an undesirable effect in that it results in some cross-talk. In operation of the G<sup>4</sup>FET as a router, S1 and S2 would be disconnected from ground and signals would be applied to D1 and D2 for the purpose of coupling them to S1 and S2, respectively. In experiments on a G<sup>4</sup>FET that had not been optimized for use as a router, square-wave signals of various frequencies from 1 kHz to 1 MHz were applied to D1 and D2 simultaneously and were shown to be coupled to S1 and S2, respectively, as desired. Cross-talk was ob-

served, but was found to be within conventional noise margins. This result supports the expectation that the integrity of digital signals could be preserved when using G<sup>4</sup>FETs as routers.

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## Two Algorithms for Processing Electronic Nose Data

Vapors are identified and their concentrations are estimated.

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Two algorithms for processing the digitized readings of electronic noses, and computer programs to implement the algorithms, have been devised in a continuing effort to increase the utility of electronic noses as means of identifying airborne compounds and measuring their concentrations. One algorithm identifies the two vapors in a two-vapor mixture and estimates the concentration of each vapor (in principle, this algorithm could be extended to more than two vapors). The other algorithm identifies a single vapor and estimates its concentration.

An electronic nose consists of an array of sensors, all of which respond to a variety of chemicals. By design, each sensor is unique in its responses to these chemicals: some or all of the sensitivities of a given sensor to the various vapors differ from the corresponding sensitivities of another sensor. The two algorithms exploit these sensitivities and the differences among them.

The validity of the two-vapor algorithm depends on the validity of the assumption that, of all the vapors of inter-

est, no more than two of them are present at the time of measurement. This algorithm utilizes the following mathematical model of the response of a given sensor to a given pair of vapors:

$$z = A + (Bx^C + Dy^E)^F,$$

where  $z$  is the sensor response,  $x$  and  $y$  are the concentrations of the two vapors, and parameters  $A$  through  $F$  are obtained by least-squares best fit of sensor responses to known concentrations of the individual vapors and to known concentrations of mixtures of the two vapors. The reason for choosing this model is that this research has shown it to be the best for mixtures of vapors. The model equation defines a response surface of the given sensor for the given pair of vapors.

Given the responses of an electronic nose to an unknown single vapor or two-vapor mixture, the first step of this algorithm is to calculate the difference between (1) the actual response of each sensor and (2) the model response of the sensor for an assumed

pair of vapors. This calculation yields an error surface for the given sensor for the given two vapors. Next, the error surfaces thus calculated for all the sensors in the array are combined to obtain an error surface for the electronic nose with respect for the assumed two vapors. Next, the process as described thus far is performed for a different pair of vapors. The process is repeated until error surfaces for all possible pairs of vapors have been calculated.

It is necessary to find the minimum point on the electronic-nose error surface for each pair of vapors. In the present version of the algorithm, this is done by sampling values on a grid and selecting the sample that has the minimum value. In a subsequent enhanced version of the algorithm, a more sophisticated technique (e.g., gradient descent) might be used to find the minimum. The pair of vapors for which the electronic-nose error surface has the lowest minimum value is deemed to be identified as the vapor pair sensed by the electronic nose. Provided that this identification is cor-