Digitally Calibrated TR Modules Enabling Real-Time Beamforming SweepSAR Architectures

Civilian and military remote sensing instruments could benefit from this work, as well as military intelligence applications.

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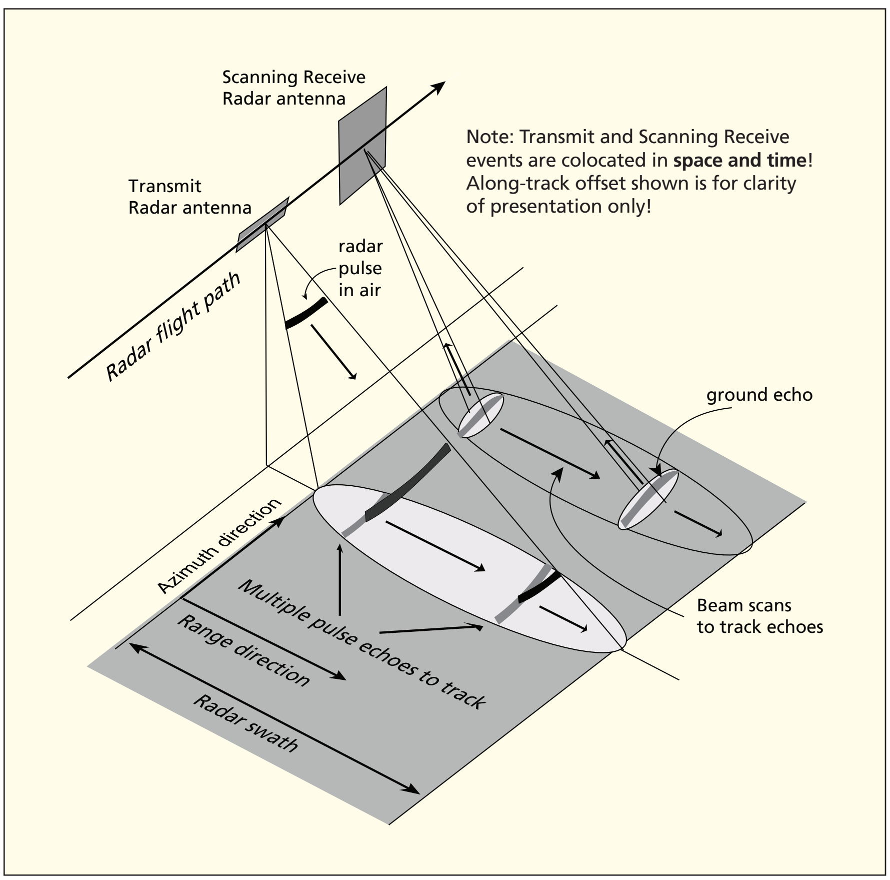
SweepSAR, a novel radar architecture that depends on a DBF (digital beamforming) array, requires calibration accuracies that are order(s) of magnitude greater than is possible with traditional techniques, such as *a priori* characterization of TR (transmit/receive) modules in thermal vacuum chambers, or simple loop-back of the calibration signal. The advantages of a SweepSAR architecture are so great that it is worth applying significant resources to calibration efforts.

Due to the nature of the DBF, each channel contains a digitizer and very powerful digital processor. Each channel can independently digitize (with the digitizer) and analyze (with the processor) its channel's unique calibration signal, and extract the relevant calibration parameters, namely channel gain and channel phase delay commonly referred to as the gain (or amplitude) and phase of the channel. Using the processor, each channel's gain and phase can theoretically be estimated with arbitrary precision through averaging a sufficiently large number of samples. Systematic errors and the changing gain and phase of the channels, typically due to temperature drifts, limits how long the averaging can occur, which limits the precision of the calibration estimate. However, results indicate that calibration knowledge of both the transmit and receive chains of each TR module can be improved by one or two orders of magnitude. Due to the digital nature of the receiver data, the channel's gain and phase may be corrected by a similar amount, while the transmit chain can only be corrected in a traditional manner. To implement SweepSAR, the order of magnitude improvement in the knowledge of the channel's gain and phase is needed, and the control of the receiver to a similar level is required.



The **SweepSAR Transmit and Receive** swaths. Transmit requires illumination of a large swath (small aperture), while Receive requires multiple small swaths (large apertures).

Inherent to the DBF array is the individual digitization of each of the array's receiver channels. Current systems typically combine all of the analog signals in the array into one or two analog channels, which are then digitized and processed. All signal conditioning performed prior to digitization is done using analog hardware (which is less precise than digital signal conditioning and dependent on temperature). The DBF digitizes every signal prior to combining, and can therefore analyze and correct received signals, as well as analyze signals that are being transmitted through analog hardware (by sampling a copy and digitizing). Each channel of a DBF also has a powerful processor. With this combination, one is able to digitize, analyze, and correct each channel prior to its being combined.

A unique factor is the ability to digitize and analyze (in real time) each of the array's channels independently, allowing one to achieve unprecedented knowledge of each channel's performance (gain and phase), and since the combining is done digitally, each receive channel can be corrected prior to combining. This enables an unprecedented level of accuracy and control through onboard processing.

SweepSAR promises significant increases in instrument capability for solid earth and biomass remote sensing, while reducing mission mass and cost. This new instrument concept requires new methods for calibrating the multiple channels, which must be combined onboard, in real time. New methods are being developed for digitally calibrating digital beam-forming arrays to reduce development time, risk, and cost of precision calibrated TR modules for array architectures by accurately tracking modules' characteristics through closed-loop digital calibration, thus tracking systematic changes regardless of temperature.

This work was done by James P. Hoffman, Louise A. Veilleux, Eva Peral, Chung-Lun Chuang, and Scott J. Shaffer of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48310