



## Two-Stage Variable Sample-Rate Conversion System

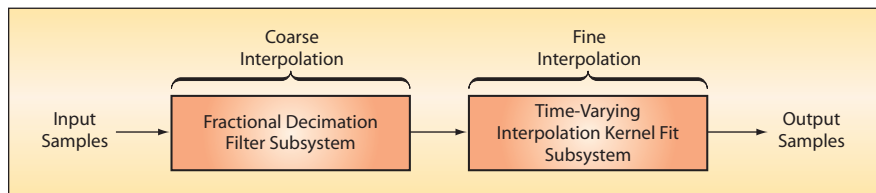
**A filtering/coarse-interpolation process would precede a fine-interpolation process.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A two-stage variable sample-rate conversion (SRC) system has been proposed as part of a digital signal-processing system in a digital communication radio receiver that utilizes a variety of data rates. The proposed system would be used as an interface between (1) an analog-to-digital converter used in the front end of the receiver to sample an intermediate-frequency signal at a fixed input rate and (2) digitally implemented tracking loops in subsequent stages that operate at various sample rates that are generally lower than the input sample rate.

Traditional SRC systems are constructed from multirate building blocks that typically include integer/fractional decimation filter subsystems. Traditional SRC systems work well when SRC factors are fixed at rational values, but not when SRC factors vary or are irrational.

The input to the proposed two-stage SRC system would be the input sampled signal,  $r[l] = r_d[l] + r_u[l]$ , where  $r_d[l]$  is the desired component (the signal of interest);  $r_u[l]$  is the undesired component, which may include noise plus out-of-desired-frequency-band artifacts of the sampling process (alias components); and  $l$  is an integer denoting the



This **Two-Stage System** would be capable of converting from an input sample rate to a desired lower output sample rate that could be variable and not necessarily a rational fraction of the input rate.

current sample time index. In the proposed system (see figure), the first stage would be a fractional decimation filter subsystem that would suppress the alias components and would effect a coarse interpolation in the sense that it would convert to a sample rate approximating the desired value. The second stage would effect a fine interpolation from the approximate to the desired sample rate by means of a fit to a temporally varying interpolation kernel.

Several approaches to implementation of both the coarse- and the fine-interpolation stages have been studied theoretically and their strengths and weaknesses have been examined by analyzing results of computational simulations. For the coarse-interpolation stage, single and cascaded sets of filters and

decimation filter subsystems were considered, with emphasis on the cascaded subsystems because of their modularity. For the fine-interpolation stage, the computationally efficient Farrow structure (a multirate, continuously-variable-delay filter structure, a description of which would exceed the space available for this article) was used in conjunction with a variety of piecewise-polynomial interpolation kernels, with emphasis on the cubic B-spline kernel on account of its commendable performance.

*This work was done by Andre Tkachenko of Caltech for NASA's Jet Propulsion Laboratory.*

*The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-44539.*

## Estimating Transmitted-Signal Phase Variations for Uplink Array Antennas

**Transmitted signals serve as their own phase references.**

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A method of estimating phase drifts of microwave signals distributed to, and transmitted by, antennas in an array involves the use of the signals themselves as phase references. The method was conceived as part of the solution of the problem of maintaining precise phase calibration required for proper operation of an array of Deep Space Network (DSN) antennas on Earth used for communicating with distant spacecraft at frequencies be-

tween 7 and 8 GHz. The method could also be applied to purely terrestrial phased-array radar and other radio antenna array systems.

In the DSN application, the electrical lengths (effective signal-propagation path lengths) of the various branches of the system for distributing the transmitted signals to the antennas are not precisely known, and they vary with time. The variations are attributable mostly to thermal expansion

and contraction of fiber-optic and electrical signal cables and to a variety of causes associated with aging of signal-handling components. The variations are large enough to introduce large phase drifts at the signal frequency. It is necessary to measure and correct for these phase drifts in order to maintain phase calibration of the antennas.

A prior method of measuring phase drifts involves the use of reference-frequency signals separate from the trans-