

In the proposed method, a compensator would be inserted into each optical train, upstream of the location where the output beam from the two telescopes are combined. Each compensator would be an optical subsystem that would control the amplitude and phase of the electric field of the spatial mode that couples into the detector, and would do so independently at each wavelength for each of the two polarization states of the beam. The compensator would correct for the imperfections in the optical train and in the beam combiner, making it possible to obtain a deep null from an imperfect instrument.

In one conceptual compensator (see figure), the uncompensated beam from

the telescope would be split by a birefringent optical element into vertically and horizontally polarized components, which would be dispersed into wavelength components. The light of the various wavelength components would be focused by a paraboloidal mirror onto a deformable mirror, forming two bright lines, each corresponding to the dispersed spectrum for each polarization state. That is to say, each combination of polarization and wavelength would be focused to a different point on the mirror. The local piston displacement and local slope of the deformable mirror would be controlled to control the phase and amplitude, respectively. Then the light would be re-collimated by the paraboloidal mirror, the wavelength

components would be recombined by another dispersive optical element, and then the horizontal and vertical polarization components would be recombined by another birefringent element to produce a single, corrected output beam. The sensing of the amplitude and phase errors and the control of the deformable mirror would be effected by use of a combination of previously developed nulling and wavefront-sensing-and-control techniques. This approach has been successfully demonstrated in the laboratory, both at near-infrared and mid-infrared wavelengths.

*This work was done by Oliver P. Lay and Robert D. Peters of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-40152*

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## Reducing the Volume of NASA Earth-Science Data

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

A computer program reduces data generated by NASA Earth-science missions into representative clusters characterized by centroids and membership information, thereby reducing the large volume of data to a level more amenable to analysis. The program effects an autonomous data-reduction/clustering process to produce a representative distribution and joint relationships of the data, without assuming a specific type of distribution and relationship and without resorting to domain-specific knowledge about the data.

The program implements a combination of a data-reduction algorithm known as the entropy-constrained vector quantization (ECVQ) and an optimization algorithm known as the differential evolution (DE). The combination of algorithms generates the Pareto front of clustering solutions that presents the compromise between the quality of the reduced data and the degree of reduction.

Similar prior data-reduction computer programs utilize only a clustering algorithm, the parameters of which are tuned manually by users. In the present

program, autonomous optimization of the parameters by means of the DE supplants the manual tuning of the parameters. Thus, the program determines the best set of clustering solutions without human intervention.

*This program was written by Seungwon Lee, Amy J. Braverman, and Alexandre Guillaume of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-45583.*

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## Reception of Multiple Telemetry Signals via One Dish Antenna

**Telemetry signals coming from slightly different directions can be separated.**

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

A microwave aeronautical-telemetry receiver system includes an antenna comprising a seven-element planar array of receiving feed horns centered at the focal point of a paraboloidal dish reflector that is nominally aimed at a single aircraft or at multiple aircraft flying in formation. Through digital processing of the signals received by the seven feed horns, the system implements a method of enhanced cancellation of interference, such that it becomes possible to receive telemetry signals in the same frequency channel

simultaneously from either or both of two aircraft at slightly different angular positions within the field of view of the antenna, even in the presence of multipath propagation.

The present system is an advanced version of the system described in "Spatio-Temporal Equalizer for a Receiving-Antenna Feed Array" NPO-43077, *NASA Tech Briefs*, Vol. 34, No. 2 (February 2010), page 32. To recapitulate: The radio-frequency telemetry signals received by the seven elements of the array are digitized, converted to complex

baseband form, and sent to a spatio-temporal equalizer that consists mostly of a bank of seven adaptive finite-impulse-response (FIR) filters (one for each element in the array) plus a unit that sums the outputs of the filters. The combination of the spatial diversity of the feed-horn array and the temporal diversity of the filter bank affords better multipath-suppression performance than is achievable by means of temporal equalization alone. The FIR filter bank adapts itself in real time to enable reception of telemetry at a low bit error rate, even in the

presence of frequency-selective multipath propagation like that commonly found at flight-test ranges.

The combination of the array and the filter bank makes it possible to constructively add multipath incoming signals to the corresponding directly arriving signals, thereby enabling reductions in telemetry bit-error rates. The combination of the array and the filter bank also makes it possible to extract, in real time, pointing information that can be used to identify both the main beam(s) traveling directly from the target aircraft and the beam(s) that reach the antenna after reflection from the ground. Information on the relative amplitudes and phases of the incoming signals, which is indicative of the difference between the antenna pointing direction and the actual directions of the direct and reflected beams, is contained in the adaptive FIR weights. This information is fed to an angle estimator, which generates instantaneous estimates of the difference between the antenna-pointing and target directions. The time series of these estimates is sent to a set of Kalman filters, which perform smoothing and prediction of the time

series and extract velocity and acceleration estimates from the time series. The outputs of the Kalman filters are sent to a unit that controls the pointing of the antenna.

For the purposes of the present system, each telemetry signal is assumed to be conveyed by a constant-envelope phase modulation, known among specialists as SOQPSK-TG, that is commonly used on flight-test telemetry ranges. The main distinction between the present and previously reported versions of this system lies in the algorithm governing the adaptation of the FIR filters. In the previously reported version of this system, the filter weights would be adapted by an algorithm, known in the art as the constant-modulus algorithm (CMA), which tends to lock onto the strongest constant-envelope signal while suppressing others.

The algorithm used in present system, denoted the interference-canceling constant-modulus algorithm (IC-MA), is an extended version of the CMA. The IC-CMA goes beyond the CMA by incorporating adaptive interference-canceling and multiple-beam-forming subalgo-

rithms. Unlike the CMA, the IC-CMA does not lock onto a single signal: instead, utilizing adaptive estimates of cross-correlations between signals, it separates two interfering telemetry signals, making it possible to utilize both of them or, if desired, to ignore one of them. In addition, if multiple signals are present and the stronger ones are deliberately suppressed in early stages of IC-CMA processing, then weaker signals can sometimes be recovered.

*This work was done by Ryan Mukai and Victor Vilmrotter of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

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