

## Multiplexed Energy Coupler for Rotating Equipment

*John H. Glenn Research Center, Cleveland, Ohio*

A multiplexing antenna assembly can efficiently couple AC signal/energy into, or out of, rotating equipment. The unit only passes AC energy while blocking DC energy. Concentric tubes that are sliced into multiple pieces are assembled together so that, when a piece from an outer tube aligns well with an inner tube piece, efficient energy coupling is achieved through a capacitive scheme.

With  $N$  outer pieces and  $M$  inner pieces, an effective  $N \times M$  combination can be achieved in a multiplexed manner. The energy coupler is non-contact, which is useful if isolation from rotating and stationary parts is required. Additionally, the innovation can operate in high temperatures. Applications include rotating structure sensing, non-contact energy transmission, etc.

*This work was done by Xiaoliang Zhao of Intelligent Automation, Inc. for Glenn Research Center.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18467-1*

## Attitude Estimation in Fractionated Spacecraft Cluster Systems

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

An attitude estimation was examined in fractionated free-flying spacecraft. Instead of a single, monolithic spacecraft, a fractionated free-flying spacecraft uses multiple spacecraft modules. These modules are connected only through wireless communication links and, potentially, wireless power links. The key advantage of this concept is the ability to respond to uncertainty. For example, if a single spacecraft module in the cluster fails, a new one can be launched at a lower cost and risk than would be incurred with on-orbit servicing or replacement of the monolithic spacecraft.

In order to create such a system, however, it is essential to know what the navigation capabilities of the fractionated system are as a function of the capabilities of the individual modules, and to have an algorithm that can perform estimation of the attitudes and relative positions of the modules with fractionated sensing capabilities.

Looking specifically at fractionated attitude estimation with startrackers and optical relative attitude sensors, a set of mathematical tools has been developed that specify the set of sensors necessary to ensure that the attitude of the entire cluster ("cluster attitude") can be ob-

served. Also developed was a navigation filter that can estimate the cluster attitude if these conditions are satisfied.

Each module in the cluster may have either a startracker, a relative attitude sensor, or both. An extended Kalman filter can be used to estimate the attitude of all modules. A range of estimation performances can be achieved depending on the sensors used and the topology of the sensing network.

*This work was done by Fred Y. Hadaegh and Lars James C. Blackmore of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-46962*

## Full Piezoelectric Multilayer-Stacked Hybrid Actuation/Transduction Systems

**Applications range from dynamic control and underwater detection to health monitoring and use in acoustic structures.**

*Langley Research Center, Hampton, Virginia*

The Stacked HYBATS (Hybrid Actuation/Transduction system) demonstrates significantly enhanced electromechanical performance by using the cooperative contributions of the electromechanical responses of multilayer, stacked negative strain components and positive strain components. Both experimental and theoretical studies indicate that, for Stacked HYBATS, the displacement is over three times that of a same-sized conventional flexensional actuator/transducer. The coupled resonance mode between positive strain and negative strain components of Stacked HY-

BATS is much stronger than the resonance of a single element actuation only when the effective lengths of the two kinds of elements match each other. Compared with the previously invented hybrid actuation system (HYBAS), the multilayer Stacked HYBATS can be designed to provide high mechanical load capability, low voltage driving, and a highly effective piezoelectric constant.

The negative strain component will contract, and the positive strain component will expand in the length directions when an electric field is applied on the device. The interaction between the two

elements makes an enhanced motion along the Z direction for Stacked-HYBATS. In order to dominate the dynamic length of Stacked-HYBATS by the negative strain component, the area of the cross-section for the negative strain component will be much larger than the total cross-section areas of the two positive strain components. The transverse strain is negative and longitudinal strain positive in inorganic materials, such as ceramics/single crystals. Different piezoelectric multilayer stack configurations can make a piezoelectric ceramic/single-crystal multilayer stack exhibit negative strain or