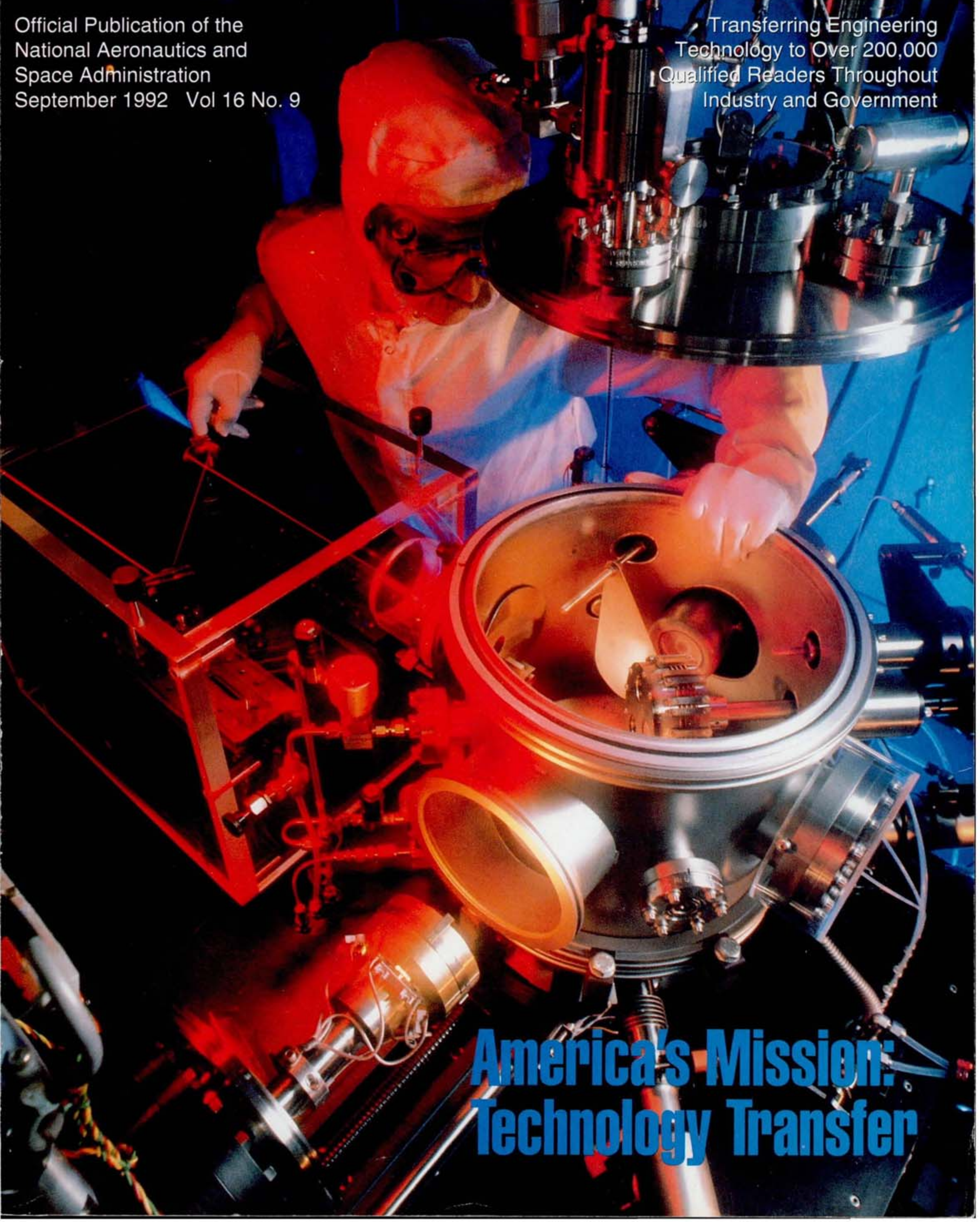
NASA Tech Briefs

Official Publication of the
National Aeronautics and
Space Administration
September 1992 Vol 16 No. 9

Transferring Engineering
Technology to Over 200,000
Qualified Readers Throughout
Industry and Government



America's Mission: Technology Transfer

electron beam is divided into a series of disks, each of which is divided further into four concentric rings. The trajectories of the rings and the amplitude and phase of the microwave field are determined from the calculated axial and radial electrical and magnetic forces arising from the distributions and motions of charge in the rings and the interactions between these charges and circuitry as the rings pass along the sequence of cavities. The magnitudes and the phases of the bunches in the electron beam are taken to be those of the calculated fundamental Fourier components of current.

Solutions are obtained by iteratively making integration passes of the equations of motion along the sequence of cavities until convergence of the microwave phase and amplitude is obtained. Typically, this requires about as many iterations as there are cavities.

A ground-station satellite communications coupled-cavity traveling-wave tube, operating in the uplink frequency band of the NASA Advanced Communications Technology Satellite (ACTS) and built according to the phase-adjusted taper design of Figure 2, achieved more than twice the peak-power conversion efficiency of a baseline tube with a conventional piecewise-linear taper. The efficiency increased from 9.6 percent to 22.6 percent, a record value for a traveling-wave tube at a frequency above 20 GHz. The corresponding peak output power increased from 420 to 1,000 W.

The main importance of the development of the phase-adjusted taper is that it very significantly increases the power capability of microwave transmission, thus enabling satellite-communication systems to have much higher data-transmission rates. This is especially important for the new high-frequency communications systems because of the rapid increase of atmospheric attenuation with increasing frequency. The efficiency enhancement capability of the phase-adjusted taper will be especially valuable for communications coupled-cavity traveling-wave tubes used in satellites where power can cost up to $1,000,000 per watt.

This work was done by Jeffrey D. Wilson of **Lewis Research Center**. *For further information, Circle 33 on the TSP Request Card.*

Further information may also be found in NASA TP-2675 [N87-22923], "Revised NASA Axially Symmetric Ring Model for Coupled-Cavity Traveling-Wave Tubes."

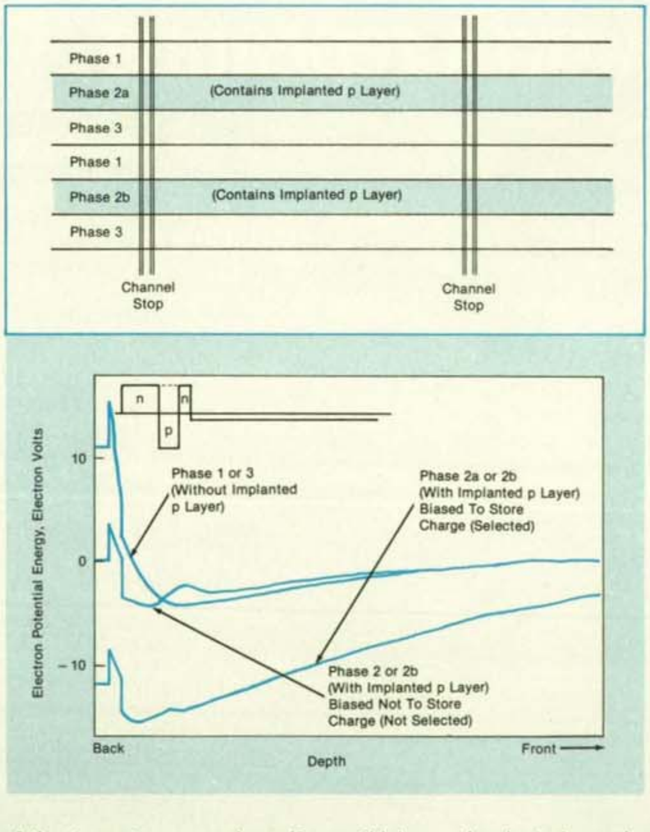
Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14989

CCD With Back-Side Illumination and Charge Steering

Multiple frames could be recorded in rapid succession, without sacrifice of efficiency.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed charge-coupled device (CCD) imaging array of photodetectors would have features of both a back-side-illuminated CCD and an interline-transfer CCD. The photoelectrons generated in each picture element of the array could be steered, by use of electrical control signals, to one of several nearby storage regions, without reduction of the part of the back-surface area available for collection of charge. Thus, by suitable timing of the control signals, charges from multiple image frames could be stored in rapid succession. Such a CCD could be particularly useful in imaging such rapid transient phenomena as chemically reacting flows, with interframe intervals of the order of microseconds.



The **Implantation of an Additional p Layer** in phase 2, combined with appropriate biasing, would enable the application of electric fields that would steer electrons to storage sites in phase 2a or 2b.

As in a conventional back-side-illuminated CCD, the photoelectrons would be generated near the back surface and swept by electric fields toward the front surface into collecting potential wells, which would constitute the storage regions. As in a conventional interline-transfer CCD and unlike in a conventional back-side-illuminated CCD, the electric fields would include components parallel to the surfaces, so that the photoelectrons from each back-side location could be directed alternately to nearby storage regions that would not be directly opposite that location.

The figure illustrates a three-phase version of the proposed CCD of the buried-n-channel type, in which the ability to steer electrons to two different storage regions in phase 2 would be imparted by the addition of an internal p layer. The control signals would be bias voltages applied to overlying gate electrodes; by appropriate choice of these voltages, one could select either of the two storage regions (2a or 2b) in phase 2. The sites without p layers in phases 1 and 3 would act as isolation regions that would prevent the flow of charge from selected storage regions (e.g., 2a) to the nearest nonselected storage regions (in this case, 2b).

In the first frame of a typical operating cycle, phase 2a would be selected as the storage region, while phase 2b would be deselected, causing photoelectrons generated under six adjacent electrodes in phases 1, 2, and 3 to be collected in phase 2a. In the second frame, the biases on phases 2a and 2b would be interchanged, so that all subsequent photoelectrons would be collected in phase 2b. After integration of the second frame, the CCD would be operated normally, albeit with shifted biases, to transfer out the two frames of image charges, which would appear in adjacent picture elements. In this way, two images, separated in time by a few microseconds, could be collected without loss of collection efficiency.

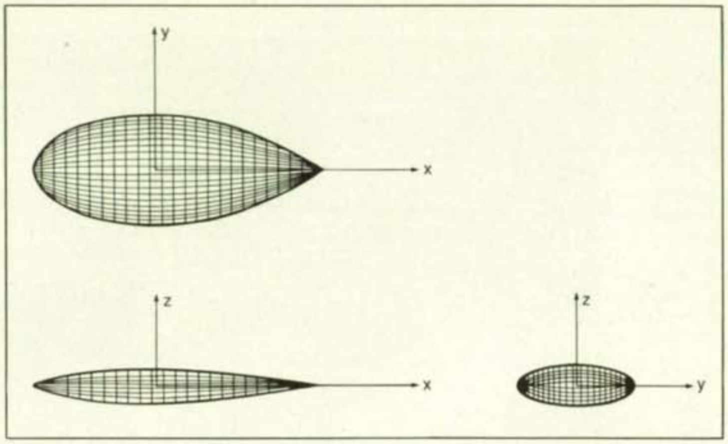
This work was done by Eric R. Fossum of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 43 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 24]. Refer to NPO-18387.

Almond-Shaped Test Body

A unique shape results in a low radar cross section.

Langley Research Center, Hampton, Virginia



The **Almond-Shaped Test Body** has a radar cross section that varies with angle over a large dynamic range.

A test body has been developed for use in an electromagnetic anechoic chamber for purposes of evaluation of range and measurement of components. A microwave anechoic chamber should have the capability to measure the electromagnetic fields scattered from an object over a very large dynamic range — especially fields of very low amplitude. The chamber should be evaluated before any measurements can be trusted.

In the past, a sphere, which has good bistatic scattering characteristics, has been used, but the return is very large and some other means are required to test the performance for low-level signals. Another canonical shape has been the ogive, which has a very low backscattered return for very-near-axial incidence. However, there is a desire for another canonical shape that has a very low return over a very broad angular region to verify the performance of the chamber. The almond-shaped test body (see figure) was designed to have all the desirable characteristics for producing a scattered field of large dynamic range over large angular regions (see figure).

The almond-shaped test body provides a low radar cross section. The surface of the body is a composite formed by joining properly scaled ellipsoidal surfaces together. The scattering performance of the body is controlled by three main factors. First, the low backscatter return (< -55 dB/m^2 above 6 GHz) is obtained by having a sharp tip with a small cone angle to eliminate any specular return over a large angular region. The only returns are due to tip and creeping-wave diffractions, which are low-level returns. Secondly, the end opposite the tip is a smoothly curved termination that gently sheds energy. Shedding the energy in this manner, unlike in the manner of an ogive surface, which has sharp tips at both ends and from which energy scatters strongly off the rear tip, gives the desired performance. Thirdly, up to second derivative, the surface is continuous and smooth over the whole body, except at the tip. This factor eliminates any large diffraction centers that would raise the whole-body return.

The almond-shaped test body can also be used to mount components, the radar cross sections of which are to be measured. The advantage is that the almond-shaped test body has a very low return that does not perturb the measurement of the desired response significantly. This test body can also simulate backscatter characteristics of the component as though the component were over an infinite ground plane. The basic almond design has been improved through the addition of a planar surface, which was blended into the existing surface for mounting of components. In addition, a rigid metal mount has been incorporated in the almond-shaped test body to facilitate measurements.

Therefore, there are two applications for this design. One is as a test body to examine the measurement performance of a microwave anechoic chamber. The other is to support components so their radar cross sections can be measured in a microwave anechoic chamber. This development should be of considerable interest to a sizable group of people — in industry, universities, and research agencies — who make scattering measurements in anechoic chambers.

This work was done by Allen Dominek of Ohio State University and Richard Wood and Mel Gilreath of **Langley Research Center**. *For further information, Circle 23 on the TSP Request Card.*
LAR-13747

Faraday Cage Protects Against Lightning

High transient currents are diverted from equipment inside.

John F. Kennedy Space Center, Florida

A Faraday cage has been designed to protect electronic and electronically actuated equipment inside it from direct and nearby strikes by lightning. The specific design is intended to prevent accidental detonation of, or damage to, explosive devices about to be tested. However, the general concept is applicable to the protection of other equipment; for example, scientific instruments, computers, radio transmitters and receivers, and power-switching equipment.

The design follows standard lightning-protection principles, so that whether lightning strikes the cage or the cables running to equipment in the cage, the lightning current is canceled or minimized in the equipment and is discharged safely into the ground. In principle, a completely closed metal surface surrounding the equipment could provide nearly complete protection; in practice, it is necessary to make holes to admit the cables (see figure), and this unavoidably makes paths along which transient currents and electromagnetic fields can enter.

The problem is to minimize penetration by the lightning transients. One protective measure is to use only coaxial and shielded multiconductor cables, and to terminate the shields of these cables with 360° backshell connectors that mate with feedthrough connectors mounted on the cage.