jected. If the hardware were accepted, the image would be saved, along with other information, as a quality record. If the hardware were rejected, the histogram and ancillary information would be recorded for analysis of trends. The software would perceive particles that are too large or too numerous to meet a specified particle-distribution profile. Anomalous particles or fibrous material would be flagged for inspection.

This work was done by James Rhodes of Lockheed Martin Corp. for **Johnson Space Center**. *For further information, contact the Johnson Technology Transfer Office at (281) 483-3809.*
MSC-23836

Phase Correction for GPS Antenna With Nonunique Phase Center

Position can be determined more accurately.

Lyndon B. Johnson Space Center, Houston, Texas

A method of determining the position and attitude of a body equipped with a Global Positioning System (GPS) receiver includes an accounting for the location of the nonunique phase center of a distributed or wraparound GPS antenna. The method applies, more specifically, to the case in which (1) the GPS receiver utilizes measurements of the phases of GPS carrier signals in its position and attitude computations and (2) the body is axisymmetric (e.g., spherical or round cylindrical) and wrapped at its equator with a single- or multiple-element antenna, the radiation pattern of which is also axisymmetric with the same axis of symmetry as that of the body.

The figure depicts the geometric relationships among the GPS-equipped object centered at position $\mathbf{r}_B$, the *i*th GPS satellite at position $\mathbf{r}_{si}$, and the phase center at position $\mathbf{r}_{pi}$ relative to the center of the body during observation of the *i*th satellite. The main GPS observable calculated from the phase measurement for the *i*th satellite is the pseudorange $\|\mathbf{v}_i\|$, which is nominally the distance from the phase center to the *i*th satellite. However, what is needed to determine the position of the center of the body is another pseudorange — that which one would obtain if the phase center were at the center of the body. That pseudorange would nominally equal $\|\mathbf{r}_{si} - \mathbf{r}_B\|$. In order to determine $\|\mathbf{r}_{si} - \mathbf{r}_B\|$ from phase measurements, it is necessary to account for the phase difference attributable to $\mathbf{r}_{pi}$.

A straightforward mathematical derivation that starts with the law of cosines for this geometry and that incorporates simplifying assumptions based on the axisymmetry and on the smallness of $\|\mathbf{r}_{pi}\|$ relative to $\|\mathbf{r}_{si} - \mathbf{r}_B\|$ leads to the following equations:

$$\|\mathbf{r}_{si} - \mathbf{r}_B\| = \|\mathbf{v}_i\| + \|\mathbf{r}_{pi}\| \cos(\beta_i) \quad (1)$$

and

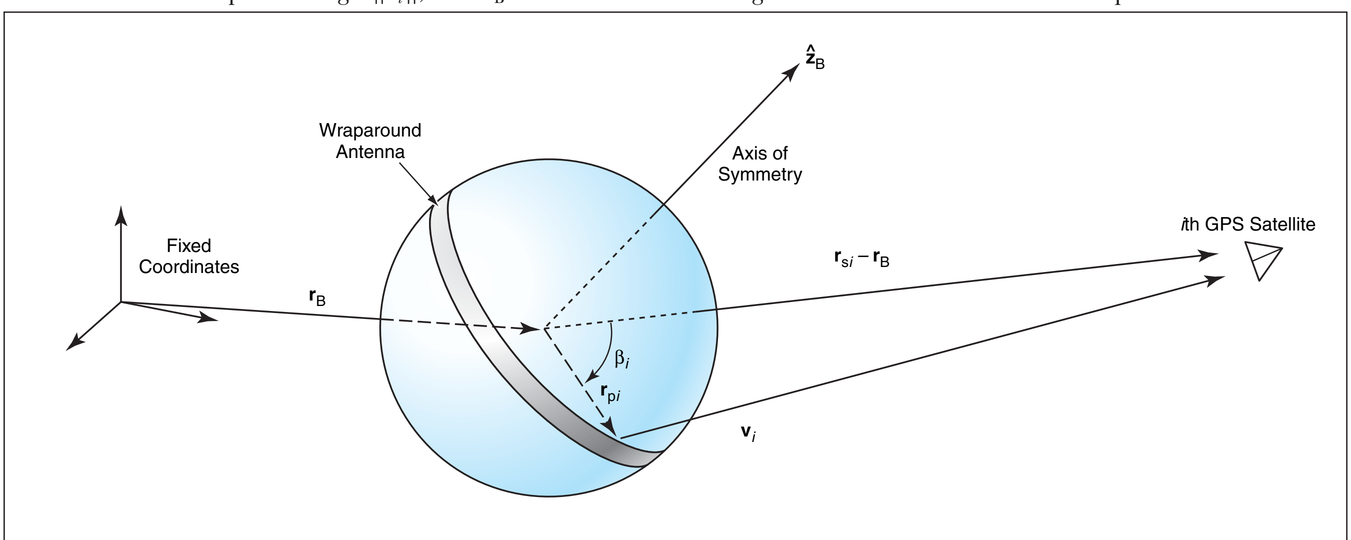
$$\cos(\beta_i) = \left[1 - \left(\hat{\mathbf{r}}_{sib} \cdot \hat{\mathbf{z}}_B\right)^2\right]^{1/2} \quad (2)$$

where

- β_i is the angle between $\mathbf{r}_{si} - \mathbf{r}_B$ and $\mathbf{r}_{pi}$ as shown in the figure,
- $\hat{\mathbf{z}}_B$ is the unit vector along the axis of symmetry as shown in the figure, and
- $\hat{\mathbf{r}}_{sib} \equiv \left(\dfrac{\mathbf{r}_{si} - \mathbf{r}_B}{\|\mathbf{r}_{si} - \mathbf{r}_B\|}\right)$ is the unit vector along $\mathbf{r}_{si} - \mathbf{r}_B$.

The computation of the desired pseudorange $\|\mathbf{r}_{si} - \mathbf{r}_B\|$ begins with a coarse estimate of $\mathbf{r}_B$ — for example, a previously computed value or a value computed anew without the phase correction. The coarse estimate of $\mathbf{r}_B$ is used to obtain an estimate of $\hat{\mathbf{r}}_{sib}$, which is used in iterations of equation 1 to obtain successively refined estimates of $\mathbf{r}_B$. Optionally, one can also obtain successively refined estimates of $\hat{\mathbf{r}}_{sib}$ from the iterations, though in most GPS applications, the error in the initial estimate of $\hat{\mathbf{r}}_{sib}$ should be negligible.

The iterations follow one of two courses, depending on whether or not $\|\mathbf{r}_{pi}\|$ and the attitude of the body are known *a priori*. If the attitude is known, then $\hat{\mathbf{z}}_B$ is known and can be inserted in equation 2, which yields $\cos(\beta_i)$ for use in equation 1. Then $\|\mathbf{r}_{pi}\|$ and $\cos(\beta_i)$ can be used in equation 1 without fur-



An **Axisymmetric Body With a Wraparound GPS Antenna** at its equator contains a GPS receiver that measures the phase of the signal from the *i*th GPS satellite at a nonunique phase center at position vector $\mathbf{r}_{pi}$ relative to the center of the body. For simplicity, $\|\mathbf{r}_{pi}\|$ is depicted as equal to the radius of the wraparound antenna, but it could differ.

ther ado. If $||\mathbf{r}_{pi}||$ and $\hat{\mathbf{z}}_B$ are not known *a priori*, then it is necessary to determine $||\mathbf{r}_{pi}||$, the attitude, and the phase-correction term $||\mathbf{r}_{pi}||\cos(\beta_i)$ from a least-squares or other fit of (a) an approximate geometric model of the amount by which the phase at $\mathbf{r}_{pi}$ leads the phase at $\mathbf{r}_B$ to (b) phase measurements for all of the GPS signals detected by the receiver.

This work was done by Patrick W. Fink and Justin Dobbins of **Johnson Space Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-23228.

Compact Infrasonic Windscreen

High values of infrasound-transmission and wind-noise-attenuation coefficients can be realized.

Langley Research Center, Hampton, Virginia

A compact windscreen has been conceived for a microphone of a type used outdoors to detect atmospheric infrasound from a variety of natural and manmade sources. Wind at the microphone site contaminates received infrasonic signals (defined here as sounds having frequencies <20 Hz), because a microphone cannot distinguish between infrasonic pressures (which propagate at the speed of sound) and convective pressure fluctuations generated by wind turbulence. Hence, success in measurement of outdoor infrasound depends on effective screening of the microphone from the wind.

To be effective, an infrasonic windscreen must fulfill four basic requirements: (1) it must attenuate noise generated by ambient wind, (2) it must transmit infrasound propagating across the microphone, (3) it must be useable in all weather, and (4) it must not be susceptible to generation of infrasound through shedding of vortices.

Past methods of wind screening include the use of cloth or open-cell foam, and the use of an array of pipes. A windscreen made of cloth or open-cell foam is thought to break up incident airflow into very small turbulent eddies that dissipate wind energy in the form of heat. Such a windscreen is effective at audio frequencies (>20 Hz) but not at infrasonic frequencies (<20 Hz).

An array of pipes used as a windscreen consists, more specifically, of several perforated pipes, called a "spider," fanning out radially from a microphone situated in an enclosed housing. The array is vast — covering an area comparable to that of an athletic field — and its performance as a windscreen is degraded by resonances that depend on the lengths of the pipes.

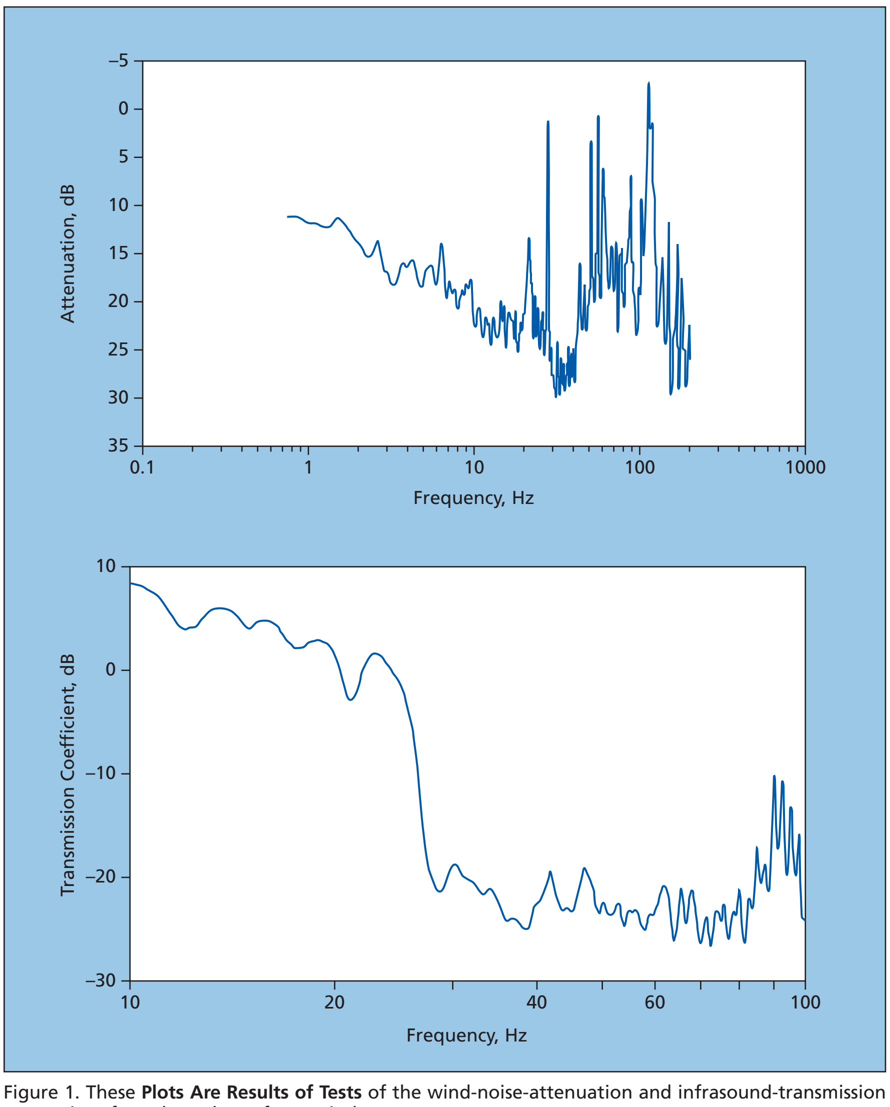


Figure 1. These **Plots Are Results of Tests** of the wind-noise-attenuation and infrasound-transmission properties of a polyurethane-foam windscreen.

Figure 2. A **Cylindrical Windscreen Covers a Microphone** mounted on a pole outdoors.