

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.**

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A compact windscreen has been conceived for a microphone of a type used outdoors to detect atmospheric infrasound from a variety of natural and man-made 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 require-

ments: (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.

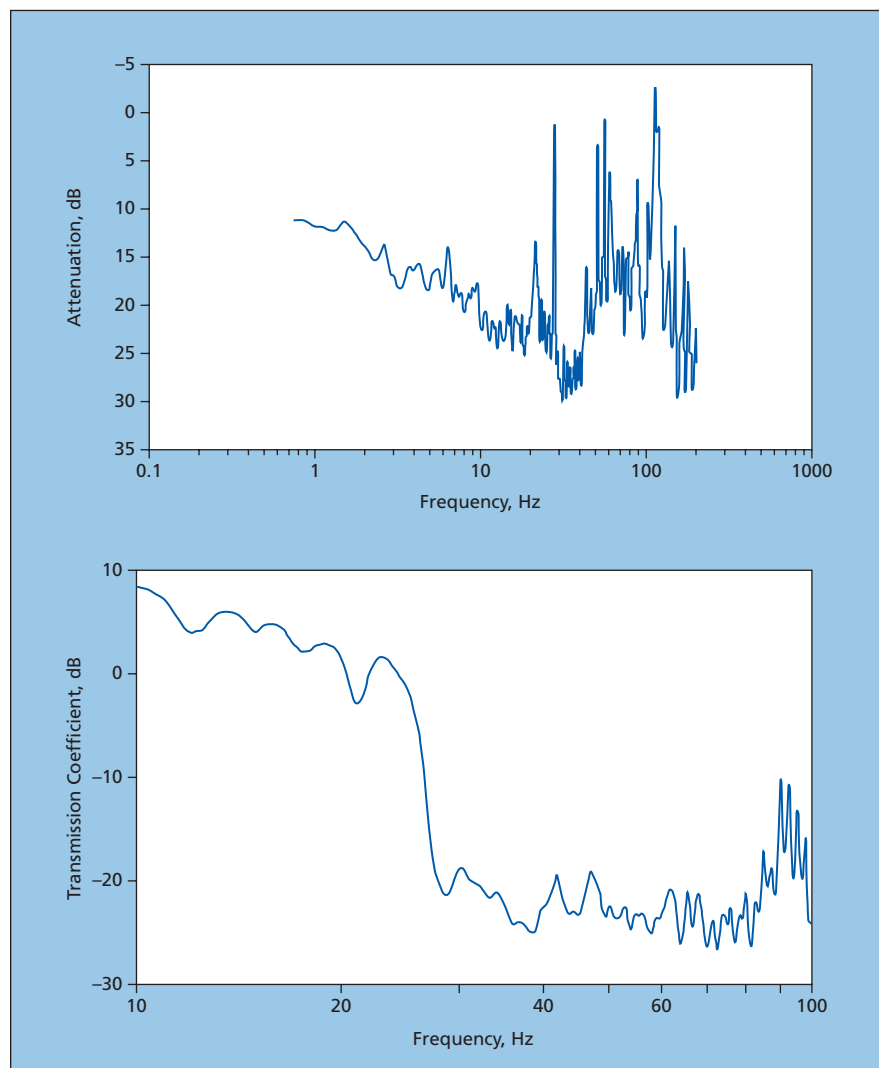


Figure 1. These Plots Are Results of Tests of the wind-noise-attenuation and infrasound-transmission properties of a polyurethane-foam windscreen.



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

The present compact windscreen is based on an entirely different principle: that infrasound at sufficiently large wavelength can penetrate any barrier of practical thickness. Thus, a windscreen having solid, non-porous walls can block connected pressure fluctuations from the wind while transmitting infrasonic acoustic waves. The transmission coefficient depends strongly upon the ratio between the acoustic impedance of the windscreen and that of air. Several materials have been found to have impedance ratios that render them suitable for use in constructing walls that have practical thicknesses and are capable of high transmission of infrasound. These materials (with their impedance ratios in parentheses) are polyurethane foam (222), space-shuttle tile material (332), balsa (323), cedar (3,151), and pine (4,713).

A small wind tunnel was built to test the acoustical properties of a variety of windscreen materials. A fan generated wind at speeds up to 21 mph (9.4 m/s) across an infrasonic microphone. Tests were conducted with and without the windscreen; the difference in the noises detected in

the presence and absence of the windscreen was used as a measure of the attenuation of wind noise by the windscreen.

The windscreen that performed best in the wind-tunnel tests was a cylinder made of polyurethane foam of a type known in the industry as “eight-pounder,” having an inside diameter of 3 in. (7.62 cm), a wall thickness of 0.5 in. (1.27 cm), and a length of 12 in. (30.48 cm). The attenuation of wind-generated noise was quantified as the ratio between the wind noises measured without and with this windscreen. The results, plotted in the upper part of Figure 1, show that this windscreen attenuated wind noise by amounts ranging from 12 to 20 dB at frequencies ranging from 0.7 to 20 Hz. The large spikes in the spectrum represent aeolian tones generated by the wind passing over the windscreen, but these lie above the infrasonic range.

For measurements of the infrasonic-transmission coefficient of this windscreen, a subwoofer was placed at an end of the wind tunnel and used to generate a tone that was swept over the frequency band from 10 to 200 Hz. In this case, the

ratio between detected sounds, with and without the windscreen, was taken as a measure of the transmission through the windscreen. The results for the portion of the spectrum from 10 to 100 Hz, plotted in the lower part of Figure 1, show that this windscreen had a large transmission coefficient at frequencies below 25 Hz, even exhibiting a gain as high as 8 dB at 10 Hz, but then attenuated sound at higher frequencies. Finally, a soak test revealed that the water absorbed by the polyurethane windscreen material amounted to only 2.1 percent by weight.

Figure 2 shows a windscreen installed over a microphone mounted on a pole in the field. The windscreen has proved robust in weather conditions of all seasons and it survived Hurricane Isabel with wind gusts up to 67 mph (30 m/s).

*This work was done by Allan J. Zuckerwar, Qamar A. Shams, Bradley S. Sealey, and Toby Comeaux of Langley Research Center. For further information, contact the Langley Innovative Partnerships Office at (757) 864-3521. LAR-16833-1*

## Broadband External-Cavity Diode Laser

**This relatively simple, inexpensive device is suitable for use in survey spectroscopy.**

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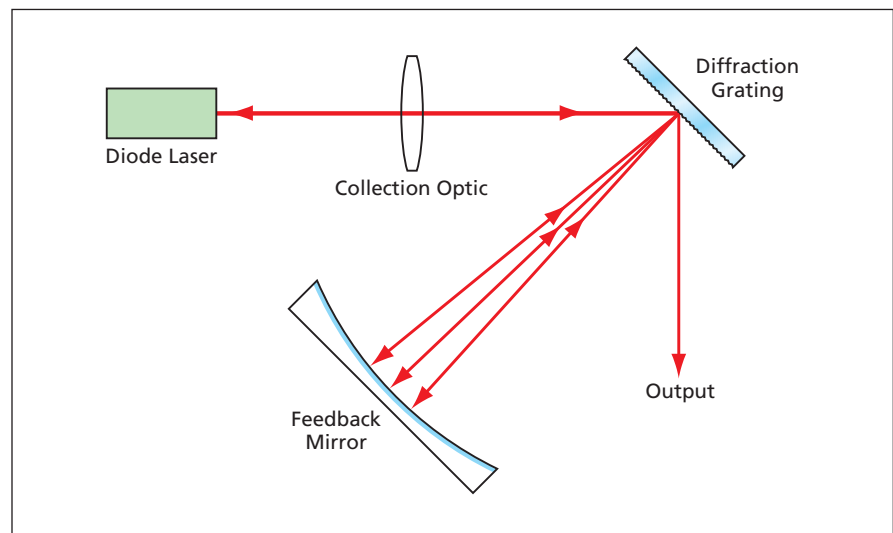
A broadband external-cavity diode laser (ECDL) has been invented for use in spectroscopic surveys preparatory to optical detection of gases. Heretofore, commercially available ECDLs have been designed, in conjunction with sophisticated tuning assemblies, for narrow-band (and, typically, single-frequency) operation, as needed for high sensitivity and high spectral resolution in some gas-detection applications. However, for preparatory spectroscopic surveys, high sensitivity and narrow-band operation are not needed; in such cases, the present broadband ECDL offers a simpler, less-expensive, more-compact alternative to a commercial narrowband ECDL.

To be precise, the output of the tunable, broadband ECDL consists of many narrow spectral peaks spaced at narrow wavelength intervals that, taken together, span a broad wavelength band. The broadband ECDL can, therefore, be likened to a light-emitting diode except that the spectrum incorporates the external-cavity mode structure. Unlike

light-emitting diodes, the ECDL offers the greater brightness, simpler fiber coupling, and superior spatial propagation properties of a laser. For example, the broadband ECDL is easily coupled into multiple-pass optical-path-length-

enhancement cells. A tunable filter — preferably, a monochromator or a spectrometer — is used to select a portion of the output spectrum.

The optical configuration of the broadband ECDL (see figure) is based



The **Feedback Mirror Is Made Curved** (in contradistinction to flat) to make it select a range of wavelengths (in contradistinction to a single wavelength).