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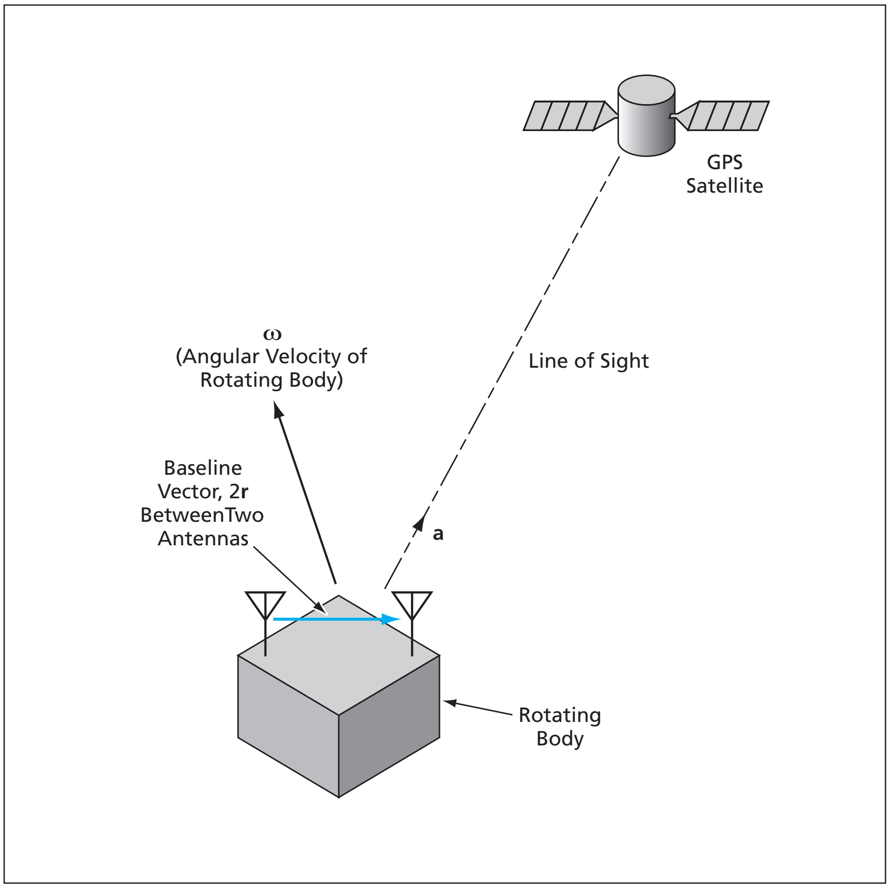

Two Antennas on a Rotating Body would have different components of velocity along the line of sight to a GPS satellite, giving rise to different Doppler shifts of the two received GPS signals.

It is assumed that the received f_{r1} and f_{r2} signals would be subjected to the usual GPS processing, including phase-shifting and cross-correlation with the applicable GPS pseudorandom-noise code for acquisition and tracking. To obtain the differential Doppler frequency $f_{r1} - f_{r2}$ for a given antenna pair and a given GPS satellite, the f_{r1} and f_{r2} signals would be fed to a multiplier. By virtue of the trigonometric identity for the product of sines of different arguments, the low-frequency multiplier output would be a sinusoidal waveform of frequency $f_{r1} - f_{r2}$. For high accuracy, the multiplier output could be fed to a subsystem containing a zero-crossing detector coupled with a counter driven by a quartz-crystal clock circuit. Such a subsystem could accumulate counts over times long enough to enable estimation of periods of rotation to within microseconds.

This work was done by Charles E. Campbell, Jr., of **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*

This invention has been patented by NASA (U.S. Patent No. 6,593,879). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center, (301) 286-7351. Refer to GSC-14087-1.

Monitoring Temperatures of Tires Using Luminescent Materials

Hot spots are detected and monitored as indications of local damage.

John H. Glenn Research Center, Cleveland, Ohio

A method of noncontact, optical monitoring of the surface temperature of a tire has been devised to enable the use of local temperature rise as an indication of potential or impending failures. The method involves the use of temperature-sensitive paint (or filler): Temperature-sensitive luminescent dye molecules or other luminescent particles are incorporated into a thin, flexible material coating the tire surface of interest. (Alternatively, in principle, the luminescent material could be incorporated directly into the tire rubber, though this approach has not yet been tested.) The coated surface is illuminated with shorter-wavelength light to excite longer-wavelength luminescence, which is observed by use of a charge-coupled-device camera or a photodetector (see Figure 1).

If temporally constant illumination is used, then the temperature can be deduced from the known temperature dependence of the intensity response of the luminescence. If pulsed illumination is used, then the temperature can be deduced from the known temperature dependence of the time or frequency response of the luminescence. If sinusoidally varying illumination is used, then the temperature can be deduced from the known temperature dependence of the phase response of the luminescence.

Unlike a prior method of monitoring the temperature at a fixed spot on a tire by use of a thermocouple, this method is not restricted to one spot and can, therefore, yield information on the spatial distribution of temperature: in particular, it enables the discovery of newly forming hot spots where damage may be starting. Also unlike in the thermocouple method, the measurements in this method are not vulnerable to breakage of wires in repeated flexing of the tire. Moreover, unlike in another method in which infrared radiation is monitored as an indication of surface temperature, the luminescence measurements in this method are not significantly affected by changes in infrared emissivity.

This method has been demonstrated in application to the outside surface of

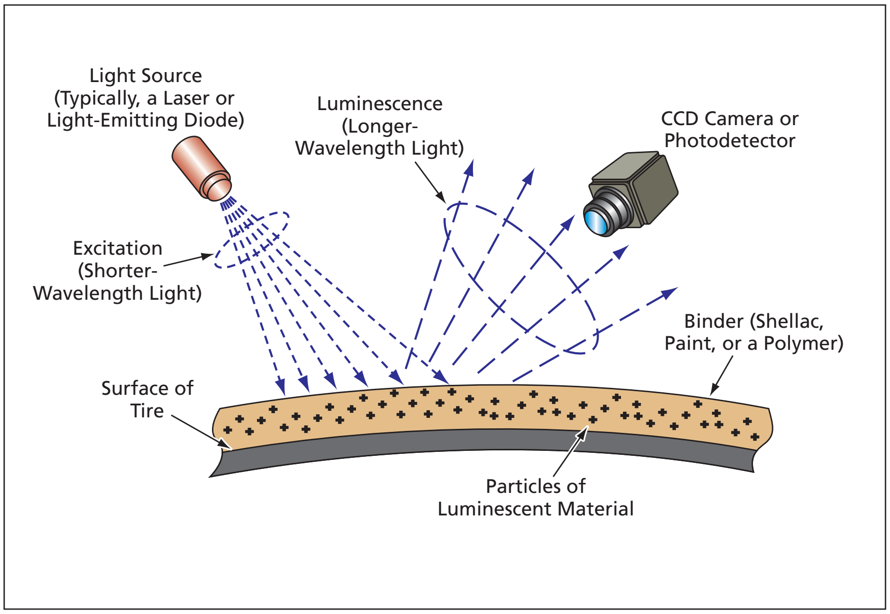

Figure 1. **Luminescent Dye Molecules or Other Particles** in a flexible binder on the surface of a tire are illuminated. The longer-wavelength luminescence is observed as an indication of temperature.

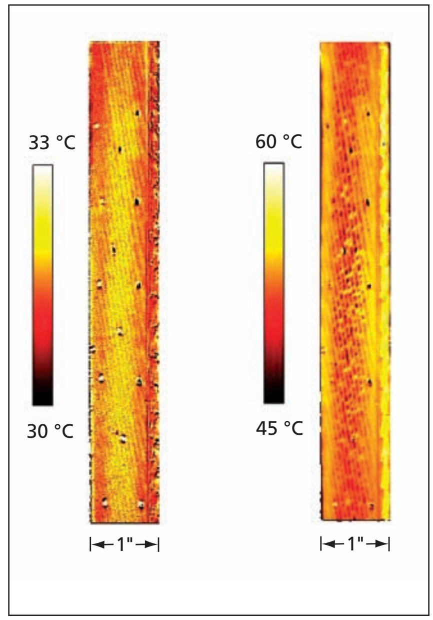

Figure 2. An ***In-Situ* Thermal Map** shows a tire sample during cyclic tensile-tensile loading. The temperature increases with increased loading.

a tire (see Figure 2), using both constant and pulsed light sources for illumination and cooled, slow-scan, gated CCD cameras for detection. For observing the temperature of the inside surface of a tire (this has not yet been done), it would probably be necessary to use fiber optics and/or windows for coupling excitation light into, and coupling luminescence out of, the interior volume.

This work was done by Timothy J. Bencic of **Glenn Research Center**. *Further information is contained in a TSP (see page 1).*

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-17417-1.