COSMIC S4 Data

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At the First FORMOSAT-3/COSMIC Data Users Workshop (Oct 16-18, 2006) in Boulder, CO, representatives from the ionospheric community requested that the COSMIC GPS receivers provide scintillation data on all GPS satellite links (up to 16 GPS satellites every second). Due to receiver data format constraints and satellite downlink bandwidth limitations, UCAR in collaboration with JPL scientists had to develop an efficient on-board algorithm in the GPS RO receiver that minimized the data record size yet maximized the accuracy of the resulting scintillation data product. This algorithm was implemented into the GPS RO receiver software by JPL. The on-board algorithm does not measure the S4 index directly. It measures signal-to-noise intensity fluctuations from the raw 50-Hz L1 amplitude measurements and these intensity measurements are recorded (with a minimum number of bits) in the data stream at a 1-Hz rate. After these data are downloaded, the S4 indices are reconstructed in CDAAC ground processing. On January 2007, the software to measure the signal-to-noise intensity fluctuations was uploaded to one of the COSMIC GPS RO receivers (FM2) for initial testing.

The raw scintillation measurement from the receiver is the RMS of the intensity fluctuations:

$$\sigma_I = \sqrt{\left\langle \left(I - \langle I \rangle \right)^2 \right\rangle}\ , \tag{2}$$

where I is the square of the L1 CA SNR, and the brackets $\langle\ \rangle$ denote the average taken over one second (50 samples). From the one-second L1 CA SNR (denoted by $\langle A \rangle$ below) and σ_I, an approximate value of $\langle I \rangle$ can be calculated on the ground assuming Gaussian distribution of the scintillations (SNR fluctuations due to scintillations). Although scintillations may not be in a Gaussian distribution, this assumption seems adequate for the purpose and leads to:

$$\langle I \rangle \approx \sqrt{\tfrac{1}{2}\sigma_I^2 + \langle A \rangle^4}\ . \tag{3}$$

Having one-second values of $\langle I \rangle$, a low pass filter can be applied to a time series of these values to obtain a new average of the intensity at each second, i.e. $\overline{\langle I \rangle}$. This value is then considered as the more correct mean intensity against which the S4 index is calculated:

$$S_4 = \frac{\sqrt{\left\langle \left(I - \overline{\langle I \rangle} \right)^2 \right\rangle}}{\overline{\langle I \rangle}}, \tag{4}$$

where

$$\left\langle \left(I - \overline{\langle I \rangle} \right)^2 \right\rangle = \sigma_I^2 + \left(\langle I \rangle - \overline{\langle I \rangle} \right)^2. \tag{5}$$

Thus, from only two parameters provided by the GPS receiver every second, $\langle A \rangle$ and σ_I, we are able to reconstruct a long-term de-trended S4 scintillation index on the ground. This approach ignores de-trending within each second (over 50 samples), but preliminary tests show that such short-term de-trending is not strictly necessary. The long-term de-trending, which is what we do when estimating the intensity fluctuations relative to $\overline{\langle I \rangle}$ instead of $\langle I \rangle$, is more important. The approach also allows the user to estimate an S4 index over several seconds by calculating (5) over several seconds.