National Aeronautics and Space Administration

Investigation into Increasing Data Return from Venus during Solar Superior Conjunctions

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Program: FY21 R&TD Innovative Spontaneous Concepts

Objectives

To increase reliable data return during Earth-Venus solar superior conjunctions: (1) developing channel models at X and Ka-band as a function of the SEP angle and tailored to the Earth-Venus geometry; (2) quantify the frame error rate (FER) of several modulation and coding schemes under the developed channel models; (3) quantify the FER; and (4) study the performance of MFSK tone detection to enable low rate critical data return from the spacecraft when operating at very small SEP angles (PSK breaks down).

Background

During upcoming decades, significant robotic exploration of Venus is expected. The direct link can easily be maintained during most of the 584-day synodic period. However, this link encounters increased intervening charged particles during superior solar conjunctions (SSCs) at small Sun-Earth-Probe (SEP) angles, corrupting the signals. Previous work focused on characterizing communications over conventional SSC geometries. We made use of channel models providing predictions of FER statistics versus SEP angle. Such models imply that data return should be reliable at SEP angles > 2.4 deg at X-band (8.4 GHz), and > 1 deg at Ka-band (32 GHz) for solar conjunction geometries already examined. The Earth-Venus solar conjunction geometry allows for higher data return for probes at Venus because the signal line-of-sight is shorter, reducing the total electron column and concomitant propagation effects. For Venus missions ~5 years, we will encounter ~3 SSCs where minimum SEP angles < 2 deg.

Significance/Benefits to JPL and NASA

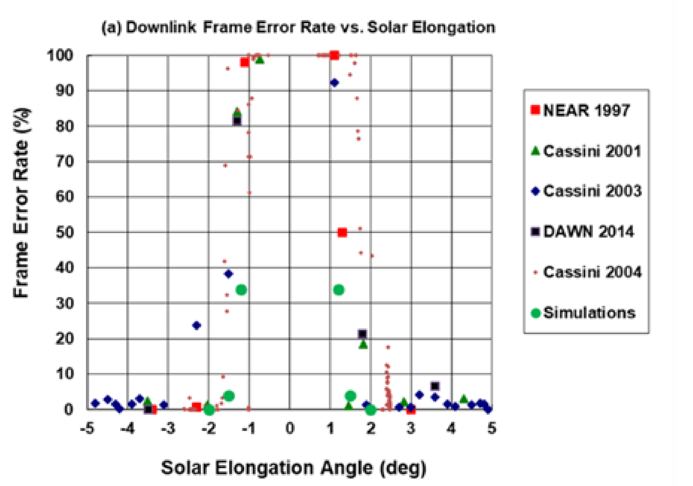
The results of the simulations can be used by flight projects to assess appropriate telemetry configurations for different regimes of SNR and SEP angle.. Small frame size/high data rate shows the best performance at low SNR's. Large frame size/high data rate tended to show worst performance at higher SNR's. This work will benefit forthcoming Venus missions as it has been demonstrated that at low SNRs, one can make use of shorter-temporal frame sizes to realize higher data return in the presence of strong scintillation. The results of the simulations also show that one can achieve good performance using Ka-band for SSCs with SEP angles ~1 deg. By strategically employing redundancy on selected frames of shorter duration and employing ARQ techniques, one can realize additional improved data return.

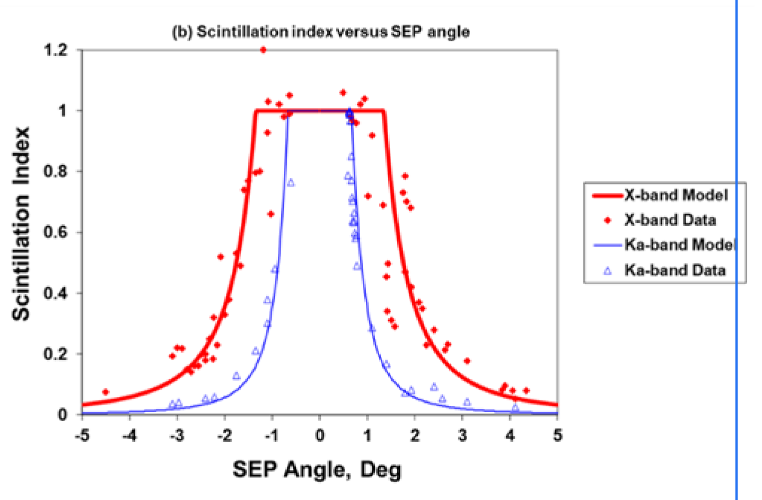
Publications

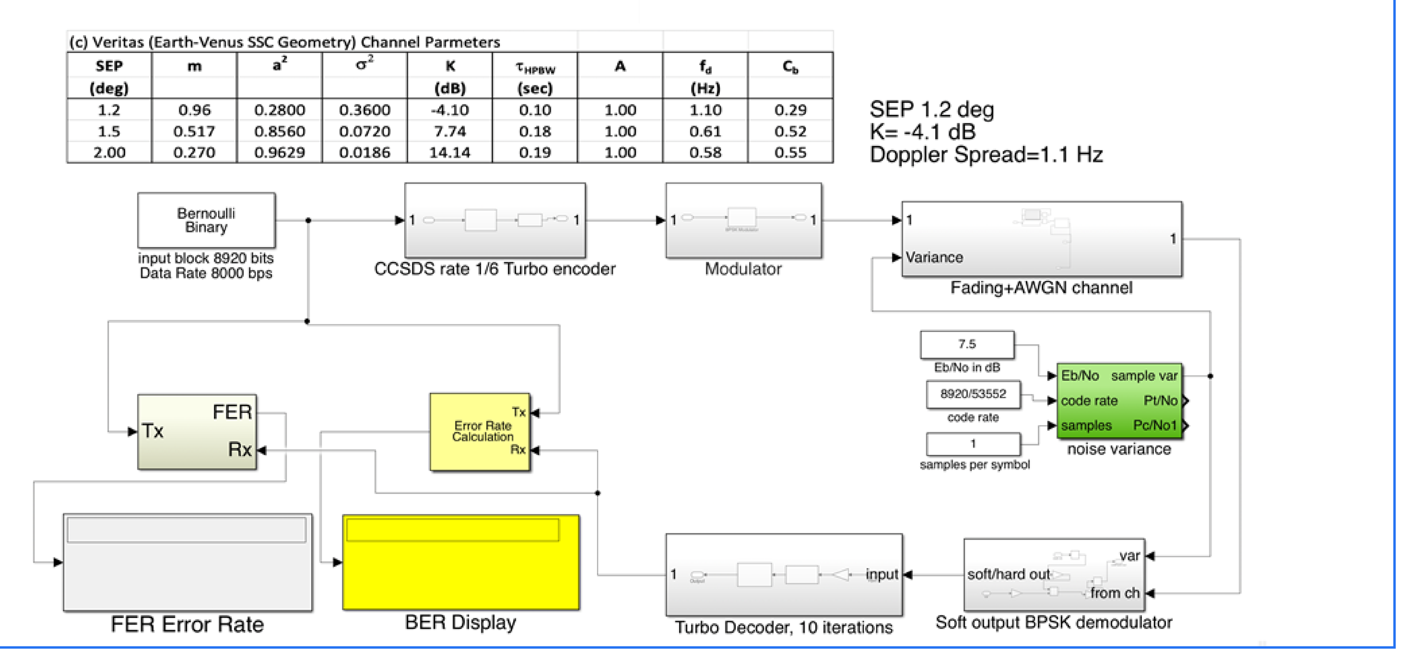
Morabito, D. D., D. Divsalar, M. Sanchez Net and A. Babuscia "Realizing higher data return for Venus-Earth Solar Superior Conjunction Communications," In preparation.

Approach

We developed channel models of solar plasma signal propagation for simulations involving conventional and Earth-Venus SSC geometries. Using computer simulations of Rician fading models of signal amplitude, we estimate FERs involving different modulation/coding techniques, frame sizes and data rates. We investigated strategies to reduce error statistics by varying telemetry parameters at small SEP. We validate the technique using measured FER's available from the Cassini 2003 SSC. Top-left figure displays X-band FERs from measurements and simulations. Top right figure displays measured X-band scintillation indices (m's) versus SEP (red points) and model (solid red curve). DSN downlink FERs start to degrade at SEP ~ 2.3 deg for X-band. We performed simulations at selected SEP angles to compare against the trends seen in top-left figure where the results of these simulations are shown in green circles, whose trend with SEP is as expected and consistent with measured FER's. At the low SNRs, the short frames perform better than the long frames for the same E_b/N_0 SNR, and become similar at higher SNRs. For the Turbo 1/6 code, small frame size/high data rate shows the best performance at low SNR.



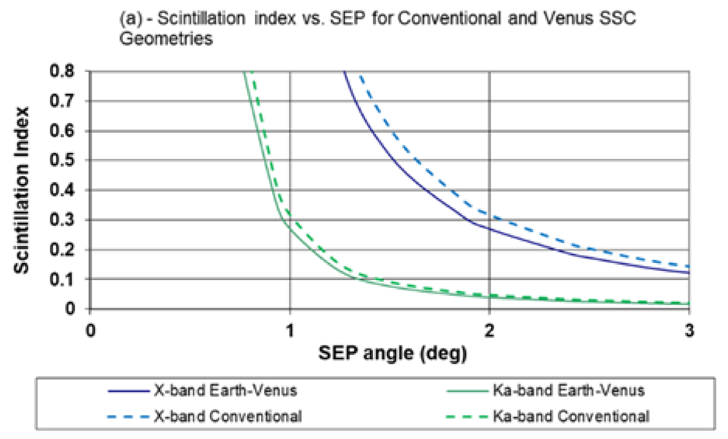


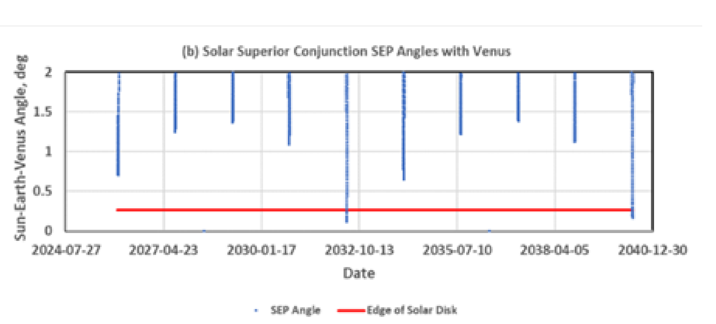


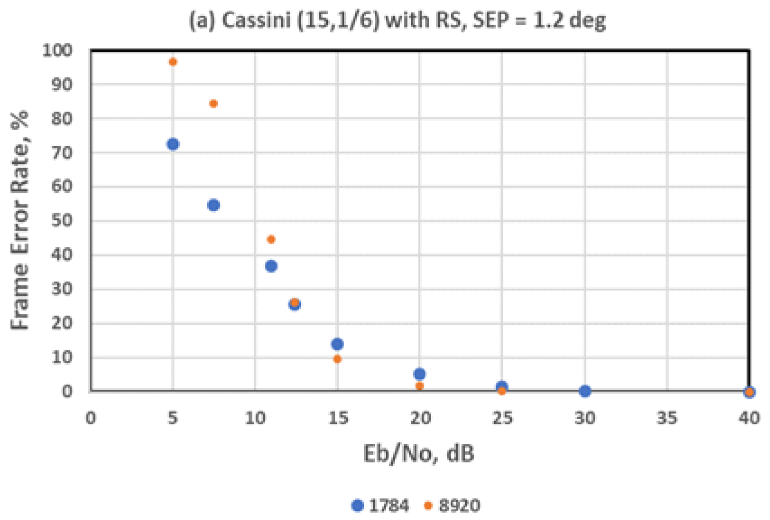
Results

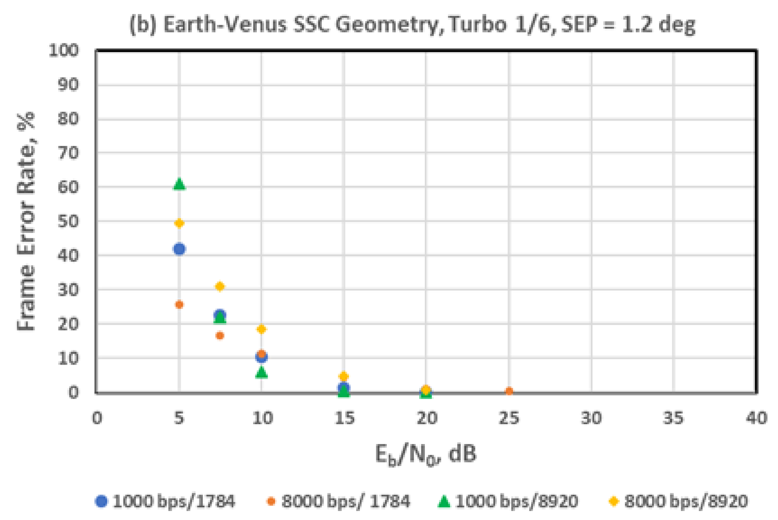
We studied the results for the Earth-Venus SSC geometry. The top-left figure presents a comparison of the model m's, showing less degradation for this geometry. One expects better performance as evidenced by the larger Rician factors for VERITAS. The top-right figure displays minimum SEP angles for upcoming Earth-Venus SSCs (blue). During normal operations, VERITAS will have SSCs on 2029-03-23 (~1.4 deg), 2030-10-20 (~1.1 deg) and 2032-06-02 (~0.11 deg). The results of the simulations for VERITAS X-band at SEP = 1.2 deg with Turbo 1/6 are shown in the bottom-right figure showing improved performance at the same low SNR relative to Cassini's conventional SSC geometry in the bottom-left figure.

Ka-band telemetry starts degrading ~ 1 deg SEP at the same m as X-band at ~2.3 deg SEP. The channel parameters for m ~ 0.3 at 0.94 deg SEP (Earth-Venus) are very similar to those of Cassini X-band at ~2 deg. Thus, one expects near zero frame errors for Ka-band at ~1 deg, which means good Ka-band data return for the first two VERITAS conjunctions. During the third VERITAS SSC, one needs to consider MFSK.









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