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The reliability of Phase Locked Loops during superior solar conjunctions

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When a spacecraft is near superior solar conjunction, the solar plasma content in the telemetry, tracking and command (TT&C) link increases as the Sun-Earth-Probe (SEP) angle gets smaller, resulting in an increased degradation of the radio signal due to amplitude and phase scintillation. Standard deep space TT&C links typically exploit phase modulation techniques and are not designed for periods of solar conjunction. As a consequence, link interruptions or complete disruptions at very low SEP angles (e.g. 1°–2° for systems operating in the X-band) may be experienced for days or even weeks.

In this poster, we will present the results from an empirical model that and determines the likely performance of a phase locked loop (PLL). This model takes into account the effects of the deep amplitude fades as well as the phase scintillation, encountered at small SEP. The empirical model consists of two parts, a basic model which does not include the effects of amplitude fading where the contributions to the overall phase variance of the solar plasma and the thermal noise are accounted for and a fading model. The probability distribution of the amplitude fading is considered to be Nakagami in form with the shape and spread parameters being derived from a fit to experimental observations obtained at a range of SEP angles. Since the phase variance resulting from the thermal noise depends on the depth of the fade, then the probability that various levels of thermal phase noise occur can be calculated and hence the probability of the PLL being unable to track the signal (this is considered to occur when the total phase variance>0.1 rad^2) can also be found.