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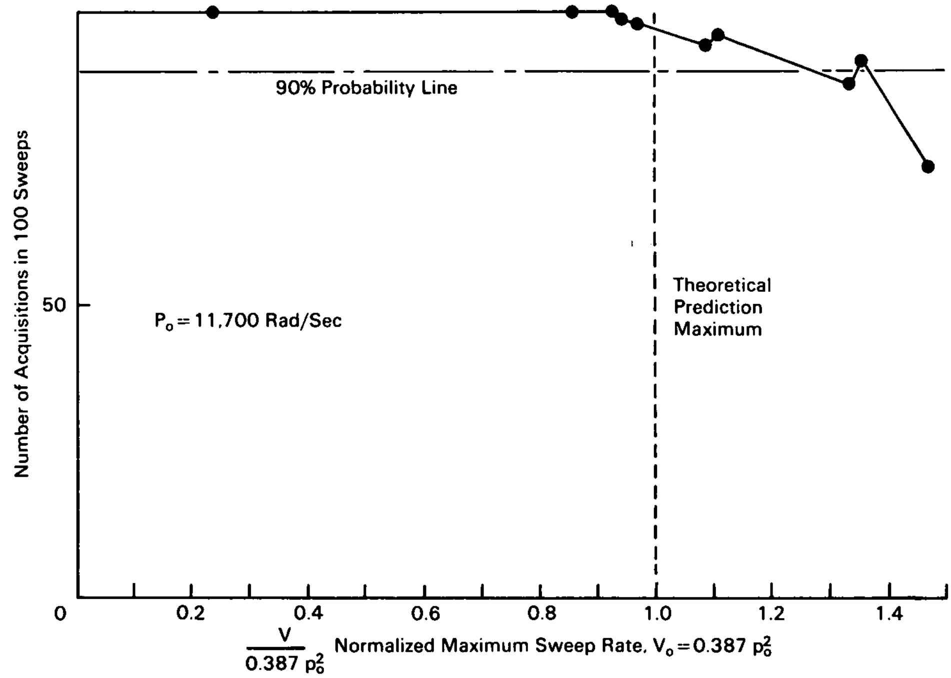
NASA TECH BRIEF

An Investigation of Phase-Lock Loop Swept-Frequency Synchronization



Rapid synchronization of phase-locked oscillators is essential in many aerospace tracking and communication systems. The need arises, for example, when one ground station attempts to communicate with many satellite vehicles and must resynchronize when addressing a new vehicle or when doppler velocity uncertainty requires that a receiver search over large frequency shifts. It is the purpose of this investigation to examine the synchronization phenomena and determine the manner in which minimum acquisition time is achieved.

Essentially, the synchronization problem resolves itself into a determination of how rapidly the unknown frequency band may be searched for with certainty of acquisition as a measure of performance. The swept-frequency acquisition technique, wherein the voltage-controlled oscillator (VCO) is linearly swept through the uncertainty band, is chosen as a result of the following reasoning:

Although theory shows that unaided acquisition middle of the uncertainty band and allowing natural (setting the VCO free-run frequency initially in the feedback action to cause synchronism) occurs within

(continued overleaf)

one cycle of the initial difference frequency for a filterless phase-lock loop, it also follows that this type of loop will have a noise bandwidth approximately equal to the doppler uncertainty bandwidth. Inasmuch as additive noise is usually present in the environment of intended use (otherwise use of a phase-lock loop would not be necessary), even a small amount of input noise will reach the VCO and interfere with the synchronizing process. When a filter is inserted in the loop, the harmful noise effects are reduced, but in return the capture range (maximum difference frequencies at which the unaided loop will just synchronize) is reduced. As a consequence, the noise performance and the flexibility of having more control over the process dictate the use of the more positive swept-frequency approach.

The nonlinear, time-variant phase-lock loop differential equation is formulated for arbitrary loop voltage-controlled oscillator sweep voltages. The choice of the linear form of sweep voltage and the proportional plus integral loop filter permits a computer solution to obtain synchronization information. Bounds upon the permissible sweep-rates with associated acquisition probabilities are established after several simplifying assumptions allow utilization of the phase-plane trajectory to yield the solution. The smallest sweep-rate above which lock-on is never possible is found to be equal to the square of the loop natural frequency, P_o^2. The largest sweep-rate below which lock-on always occurs is found to be 0.387 P_o^2 (Rad/sec). Knowledge of these sweep-rate values allows the phase-lock loop parameters to be selected for acquisition within a given time interval.

Notes:

1. An experimental, linearly swept, phase-lock loop test circuit was employed to verify the results. The agreement between theoretically predicted maximum sweep rates and the observed experimental results were found to differ by less than seven percent.
2. Inquiries concerning this investigation may be directed to:

   Technology Utilization Officer
   Marshall Space Flight Center
   Huntsville, Alabama 35812
   Reference: B66-10423

Patent status:

No patent action is contemplated by NASA.

Source: Richard A. Dye
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