# NASA TECH BRIEF



## Phase-Lock Loop Frequency Control and the Dropout Problem

In the tracking of space satellites, receivers featuring phase-lock loop circuitry have been used to advantage, but usually, manual frequency adjustment is required to maintain contact. Additionally, such systems frequently suffer loss of signal (dropout) to a degree that reduces such manual frequency adjustment techniques to futile and frustrating "hunting" exercises. An investigation has been made into these problems and concepts derived that should eliminate or greatly relieve them.

A technique has been conceived for automatically setting the frequency of narrow band phase-lock loops within automatic lock-in range. In the past, phase-lock loops have been constrained so as to provide an automatic lock-in bandwidth sufficiently wide to accommodate both the uncertainty factor of the incoming frequency and the drift or uncertainty characteristics of the phase-lock loop.

In many applications it is desirable to construct a phase-lock loop possessing narrowband filter characteristics, while being capable of tracking or locking to a signal varying in frequency by a factor large relative to the filter bandwidth of that phase-lock loop. Such is the case for spacecraft phase-lock tracking receivers operating with a large frequency uncertainty due to the high relative velocities and resulting doppler effects as well as equipment drifts.

This concept suggests a means of automatically presetting a phase-lock loop to a desired center frequency by use of a closed loop electronic frequency discriminator, and holding the phase-lock loop to that center frequency until lock is achieved. Specifically, it uses a two-state digital frequency discriminator and a reference signal in a "bang-bang" type nonlinear frequency lock loop. In this manner the phase-lock loop is preset to, and dithered slightly around, a desired center frequency until the phase-lock is achieved. The phase-lock transfer characteristics of the loop are modified only slightly by the additional frequency lock circuit, thus providing normal phase-lock of the signal to override the frequency preset.

In a typical operation, there is a very good chance that the signal will disappear or fade so badly that the received signal-to-noise ratio will be inadequate to permit tracking. Should the condition persist, normal tracking procedures will not be able to recover the signal when it reappears. There are several reasons for this: acceleration during the dropout period, noise, and imperfect components. The latter is a practical matter, but even in the absence of equipment limitations, the problem still cannot be solved by conventional means.

This concept considers the limitations of conventional tracking methods and suggests a method which shows promise of being able to allow the system to carry through a dropout period of up to 2.5 seconds.

Although there may be a wide variety of causes of received signal dropout, there are two that are apt to occur in many operational situations. The first may occur during injection into orbit, immediately after which accurate tracking is desired. This dropout could occur rapidly and exhibit a very large reduction in signal strength; however, the accelerations are not expected to be inordinate at that time. The second cause is multipath, which causes fading. The rate of signal decay is probably lower and only under very special conditions can the received signal strength approach zero. The "down" time is generally less than during orbital injection.

In order to simplify the analysis and to permit readier understanding, a simplified carrier loop is analyzed. The principles can be applied without modification in systems that have recently been developed.

(continued overleaf)

Whenever the signal is present, the phase-lock loop will track the phase of the received carrier. Depending upon the characteristics of the "tracking filter," the tracking capability is governed by the signal spectrum of the received phase. For example, if the received phase has constant rate, there will be a small phase tracking error with a Type I loop and none with a Type II loop. In general, one may assume that the loop response must be sufficient to track a fairly high acceleration for a period of seconds. As a result, under most conditions, the loop may be considered to have reached "equilibrium" in a short time before a dropout might occur.

When signal dropout occurs, the control signal out of the phase detector vanishes but the noise does not, but may even increase if the agc falls. The loop is now open.

When the signal strength recovers, the loop will relock if the accumulated frequency error is not too large. An alternate method of recovery is to sense the signal loss in the agc circuit, open the loop until the system indicates recovered signal strength, whereupon the loop is reclosed. Under poor conditions neither method is acceptable without appreciable loop sophistication.

**Note:**

Copies of these concepts may be requested from:
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No patent action is contemplated by NASA.

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