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PHASE TRANSIENTS IN DIGITAL RADIO LOCAL OSCILLATORS

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ABSTRACT

Phase transients that occur in microwave local oscillators are discussed. The harmful effects of these transients on coherent digital transmission are evaluated, with emphasis placed on complex modulation schemes such as 64 QAM or 256 QAM. The sources of phase transients are identified, and the methods that quantify these transients are presented along with procedures that ensure phase transient free operation of local oscillators.

INTRODUCTION

Bandwidth efficient digital radio transmission demands complex modulation schemes. 64 QAM with 4.55 bits/sec/Hz bandwidth efficiency is now widely used in long haul, high capacity microwave transmission systems. More complex modulation schemes such as 256 QAM are currently at the developement stage.

As the number of states increase and more information is transmitted, it is increasingly difficult to distinguish between states in the presence of noise which corrupts the received signal. One of the sources of degradation of the received signal is the local oscillator (LO) phase noise. LO phase noise is usually specified in terms of long and short term frequency stabilities. These parameters are well known, predictable, easily specified measured and met.

There is, however, another abnormal type of LO phase instability, that being Phase Transients (PT). A PT may be defined as a temporary LO phase instability which is not tracked by the carrier recovery loop of the receiver demodulator. A PT is an unpredictable, rare, and short lived event. The causes of these events are many and varied their measurement and diagnosis is difficult. PT's may originate externally or internally to the LO. This paper discusses the sources of PT's and their detrimental effects, particularly in digital systems with data traffic. It is shown that digitized voice transmission is quite immune to rare PT's. Test methods that quantify PT's are presented along with methods of provoking them in LO's by thermal and mechanical shocks, and power supply transients.

EFFECTS OF PHASE TRANSIENTS

The effects of LO phase transients on the Bit Error Rate (BER) of a digital transmission can be evaluated by rotating the constellation of signal states as shown in Figure 1 for 64 QAM. The extend of the degradation of the BER depends on the following factors:

a) Phase Transient Amplitude and Duration

A PT will cause errors when its peak value exceeds a certain threshold $\emptyset e$, which brings at least some of the signal states within the boundary of adjacent ones. The value of $\emptyset e$ for several high order modulation schemes are given in Table 1.

b) Modulation Scheme

As the angular spacing between states decreases in higher modulation schemes, the error transient amplitude necessary to cause errors decreases also. In the case of M-ary PSK, the angular spacing is equal for all states, and if a PT exceeds $\emptyset e$, all states will be in error. In QAM systems, the corner states are the most sensitive. From Table 1, it is apparent that QAM systems are less sensitive than PSK systems and that the sensitivity increases with the complexity of modulation.

c) Presence of Noise

A noisy received signal results in higher system sensitivity to PT's. Terrestrial microwave radio under no fade conditions operates virtually error free. BER's of 10-20 are common. Since deep fade and LO phase transients are independent events of very low probability, the case of PT's in the presence of noise may be neglected.

d) Type of Transmitted Information

In a 135 Mb/s transmission system, a PT of 100 usec duration and sufficient amplitude results in a block of 13,500 errors. This has a serious effect on data transmission. Framing bits are lost and necessary reframing causes still more errors. Digitised voice transmission is much more tolerant. The sampling interval is 125 usec and the previously mentioned PT would cause the loss of roughly one sampling interval with little effect, since there are 8000 samples in a second.
A PT of sufficient amplitude and duration may interfere with clock and carrier recovery circuits, thus disrupting the demodulation process entirely. PT's must be kept well below leves causing errors (Table 1) or better yet, the sources of PT's must be eliminated completely.

SOURCES OF PHASE TRANSIENTS

A PT is a phase tracking error $\emptyset e(t)$ of the carrier recovery PLL most commonly caused by the step change Δf of the LO frequency. The phase error of the second order loop with an active filter is shown in Figure 2. The peak value is proportional to the frequency step and is a function of the loop parameters. Due to other considerations such as phase noise and acquisition time, the loop cannot be optimized to minimize frequency steps.