MEASUREMENT CONSIDERATIONS

WHEN USING

THE 5390A OPTION 010

Application Note 225-1

HEWLETT hp PACKARD

AN 225-1

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Introduction

The "dual mixer time difference" (DMTD) method for characterizing the frequency stability of non-offsettable sources was proposed at the 29th Annual Symposium on Frequency Control in 1975 by David W. Allan of NBS (see proceedings of the 29th Annual Symposium on Frequency Control, 28-30 May 1975, Atlantic City, New Jersey, pp 404-411). The technique was incorporated into the 5390A Frequency Stability Analyzer as option 010. The measurement considerations discussed in this note apply to the 5390A option 010 when using the dual mixer time difference measurement technique.

Basic Configuration

Figure 1 shows the equipment set-up for the dual mixer time difference configurations. The Hewlett-Packard part number 0960-0496 power splitter is used to split the reference oscillator's signal between the two 10830A mixer inputs. For measuring quartz oscillators, additional isolation is necessary between channels and can be provided by adding isolation amplifiers following the 0960-0496 power splitter as shown in *Figure 1b*.

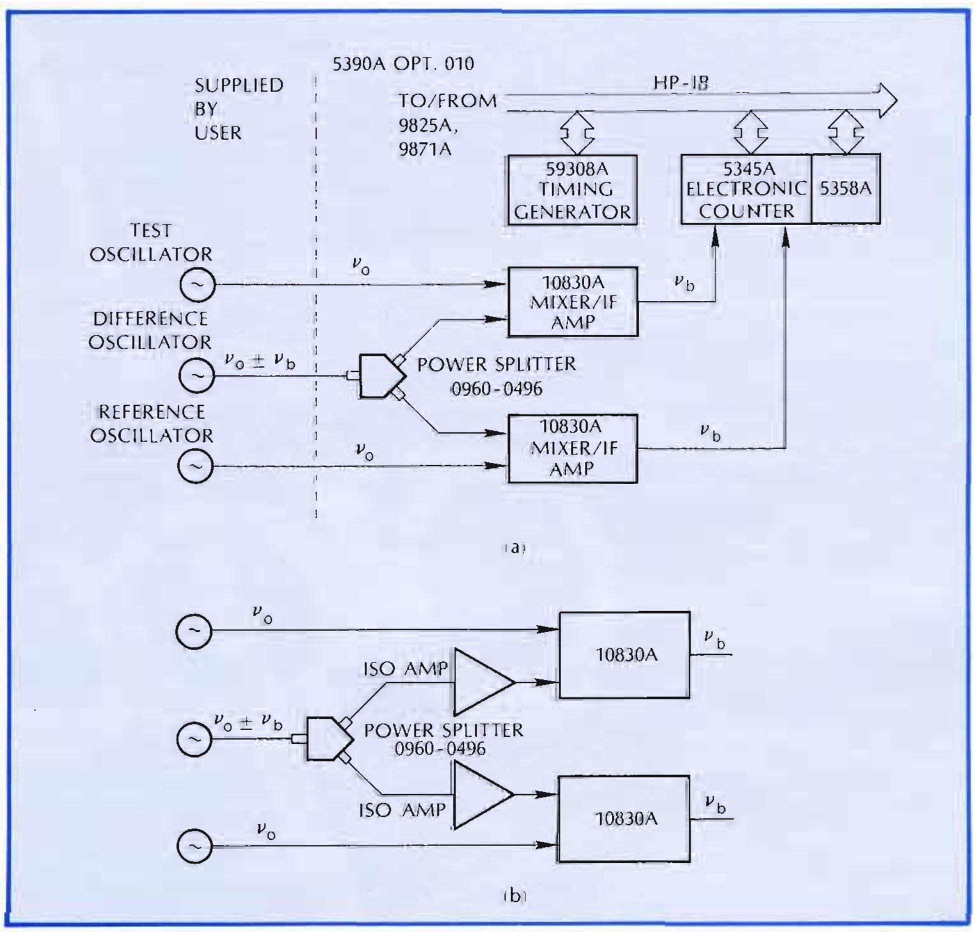

Figure 1. (a) 5390A Opt. 010 measurement configuration (b) additional isolation between channels may be obtained by adding isolation amplifiers following the power splitter.

Measurement Considerations

1. Frequency Pulling Caused By Insufficient Channel Isolation.

In *Figure 2*, an oscillator is shown followed by a buffer amplifier with forward gain G dB and reverse gain R dB so that the net reverse transfer isolation is (G - R)dB. If the amplitude of the output signal is V_o, and the amplitude of an incident signal (from another source or a reflected version of V_o) is V_i, the the amplitudes at the oscillator output will be

$$V_1 = \frac{V_o}{G} \text{ and } V_2 = V_i \times R.$$

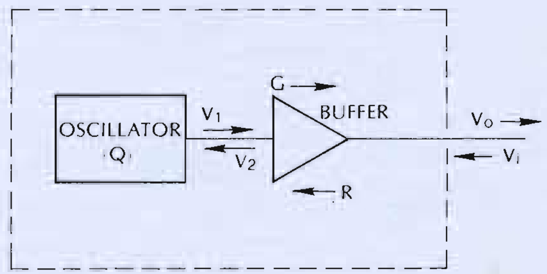

Figure 2. Oscillator Model

In the worst case (when V_1 and V_2 are orthogonal), V_2 will cause a shift in phase which, for small V_2, is approximately $\Delta\phi \cong \frac{V_2}{V_1}$.

The peak frequency pulling, y, is $y = \frac{\Delta\phi}{2G}$, where Q is the quality factor of the resonant circuit in the oscillator. *Figure 3* is a plot of peak frequency pulling versus Net Reverse Transfer Isolation and oscillator Q for the case where $V_i = V_o$.

In the 5390A Option 010, lack of adequate net reverse transfer isolation can give incorrect results. For cesium standards and rubidium standards, high Q and large reverse transfer isolation internal to the instrument reduce frequency pulling below noticeable limits. *Figure 4* shows 5390A Option 010 plots for the HP 5065A rubidium standard versus data taken using manual methods. The agreement is excellent.

For quartz oscillators, the reverse transfer isolation and Q may be poor enough that significant errors are introduced by frequency pulling. *Figure 5* shows a plot of data taken on 10544B quartz oscillators without additional isolation compared with the same measurements made with isolation amplifiers in place. The measurements made without the isolation amplifiers are in error by a large amount. The isolation amplifiers used in the measurement were constructed after a design reported in the proceedings of the 30th Annual Symposium on Frequency Control 1976 (Walls, Stein, Gray, Glaze "Design Considerations in State-of-The-Art Signal Processing and Phase Noise Measurement Systems", pp 269-272). Amplifiers such as these or commercially available amplifiers with isolation in excess of 70dB are therefore recommended when measuring quartz oscillators with DMTD.

2. Maximum Allowable Frequency Offset Between the "Non-Offsettable" Sources

The algorithm for computing $\sigma^2 y\ (\tau)$ cannot tolerate greater than 2π radians of phase shift during a measurement cycle. Therefore, Δf must be less than the reciprocal of the largest measurement gate time requested. For example, if measurements are to be made at 0.01, 0.1, 1, 10, and 100 seconds, the maximum allowable frequency offset between the two sources is 100^{-1} = 0.01 Hz.

3. Reference Oscillator Stability Requirements

The main criteria for selecting a common reference oscillator is that its white phase noise be lower than the oscillators under test if τ <1 second data is desired.

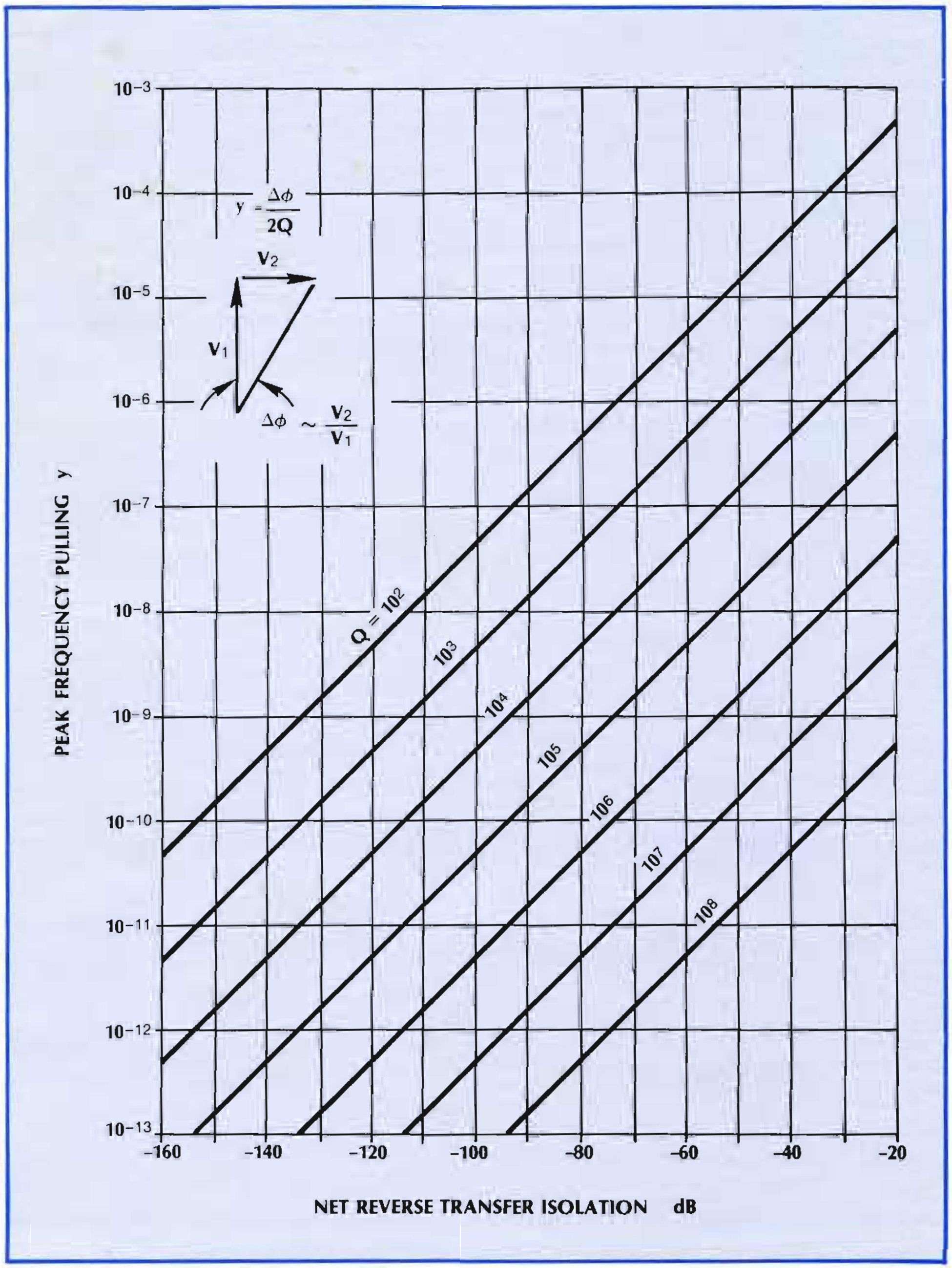

Figure 3. Frequency pulling as a function of net reverse transfer isolation.

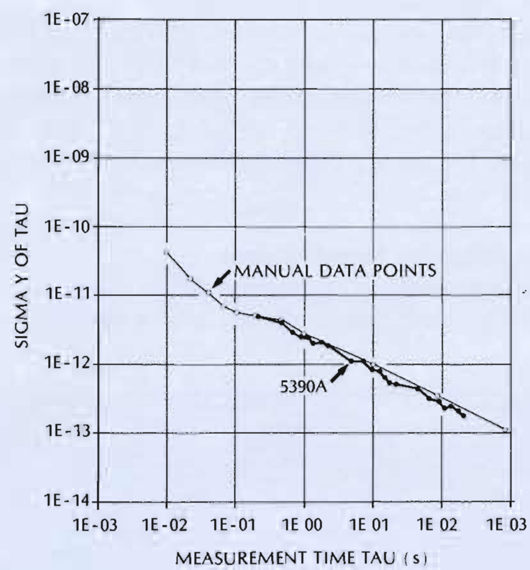

Figure 4. 5390A Opt. 010 Measurements on 5065A Rubidium Standard Compared with Manual Data Points show Excellent Agreement. Measurements were made without additional isolation beyond that provided by the 0960-0496 Power Splitter.

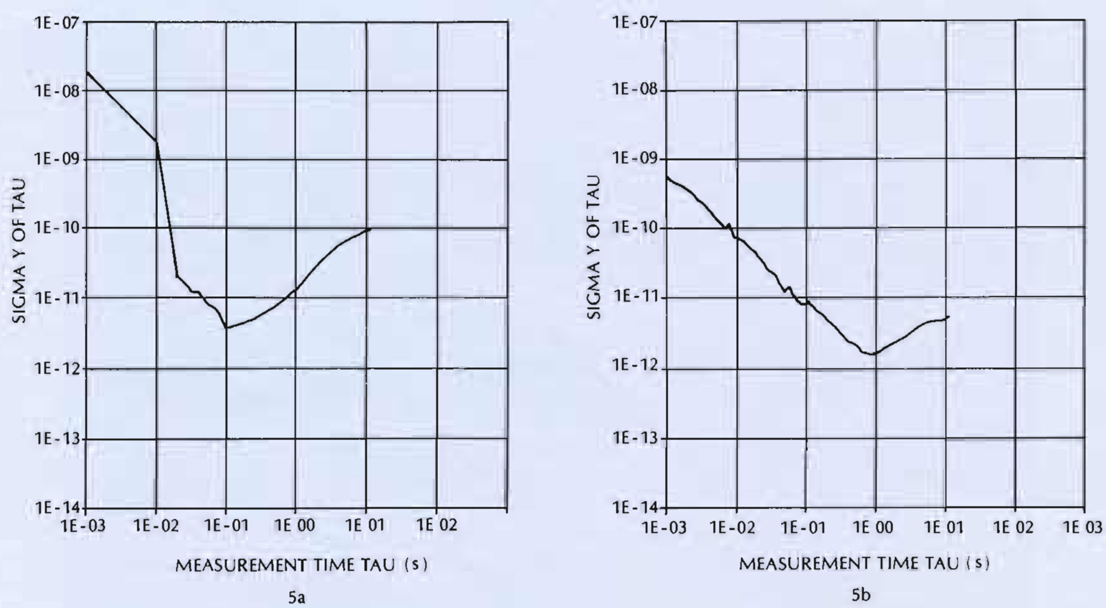

Figure 5. (a) Measurement of 10544B without additional isolation is in error (b) Measurements repeated with isolation amplifiers as in figure 1(a) give expected results.

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