IAN 43 CHOPPER JITTER MEASUREMENT AND EFFECTS

1.0 CHOPPER JITTER

Typically the chopped beam illuminates an optical system under test. A detector senses its pulsed light output, producing an ac signal accompanied by random and/or discrete frequency interference. This signal, along with a coherent reference frequency derived from the chopper head, is fed to a signal recovery device such as a Lock-In Amplifier. The Lock-In Amplifier acts as a very selective ac voltmeter, responding to the frequency of interest and rejecting the noise.

1.1 Blade Jitter

Blade phase jitter manifests itself in the frequency domain as coherent fractional components of the reference frequency. These will be spaced at intervals equal to the rotational frequency of the motor (i.e., chopping rate divided by number of slots in the blade). For example, a 10-slot blade operating at full speed (6000 rpm = 100 cps) will chop at 1 kHz. It would exhibit small components at 100, 200, 300, ..., 900, 1100, ... Hz, in addition to the dominant ideal square wave component at 1000 Hz and its odd harmonic overtones at 3000, 5000, ... Hz. In the time domain, the blade jitter will appear on an oscilloscope (expanded, delayed sweep) as a constant-width edge uncertainty pattern. See Figure 1.

1.2 MOTOR JITTER

Motor speed jitter manifests itself as random frequency shifting of the entire blade jitter spectrum. The frequency hunting will occur at roughly a 1 Hz "rate" for ITHACO choppers. In the time domain, motor speed jitter will appear on a scope as a random shifting left and right of the entire blade jitter pattern as shown in Figure 1.

2.0 MEASURING JITTER

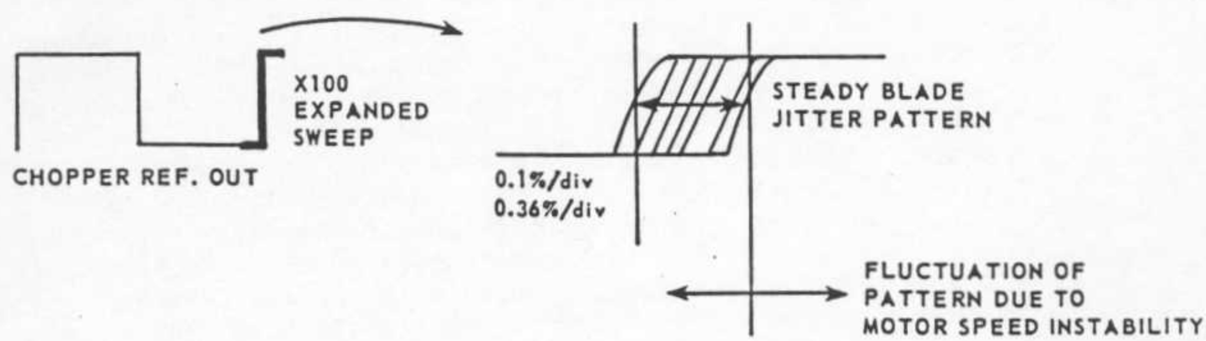

FIGURE 1 CHOPPER BLADE JITTER DISPLAY

The test method illustrated above is the standard technique for evaluation of chopper quality. It should be used to check the claimed specifications of competitive equipment which is being compared to ITHACO Choppers. Beware! Other manufacturers may indulge in specmanship practices such as "typical" jitter expressed in rms units. The rms units make the chopper look 3 times better than if the jitter were expressed realistically as peak deviation from the mean. ITHACO tests its Model 220 and Model 230 choppers using the peak method and guarantees that they will meet or exceed specifications for blade and motor.

3.0 JITTER EFFECTS ON LOCK-IN AMPLIFIERS

3.1 BLADE EFFECTS

Blade phase jitter will be innocuous in most applications. For the types of Lock-Ins that would be used with a chopper, the instrument must be designed to reject harmonic and subharmonic interference (must respond only to the rms sinewave fundamental of the input). In addition, the jitter components are quite small compared to the signal.

Another way to view this is to consider the LIA as a narrowband filter centered on (locked to) the chopping frequency. The beat frequencies lying nearest the modulation frequency (e.g., 900 Hz and 1100 Hz on either side of 1 KHz) will be outside the bandwidth of the LIA as set by its Time Constant control, and therefore will be suppressed to the point of negligibility.

Blade effects <u>will</u> be important in some types of measurements. For example, in luminescence decay experiments one might mount two blades on the motor to provide narrow duty cycle excitation pulses. Aperature irregularity would be greatly magnified in this case, leading to a subharmonic secondary modulation which would appear as a large discrete frequency interference.

3.2 MOTOR EFFECTS

Motor speed jitter can cause serious problems for certain types of Lock-Ins. Those employing narrowband (e.g., Q=100) tuned amplifier front ends to suppress odd harmonic responses will encounter large amplitude and phase error fluctuations as the signal frequency varies back and forth over the passband of the input preamplifier. Also a steady error will develop if the chopper exhibits long term speed drift. Although this type of Lock-In Amplifier is not the best choice for any chopper application, it can be made to work if the chopper has short term and long term stability commensurate with the tuned amplifier fractional bandwidth. The superior stability of ITHACO choppers leads to accurate results with what would have been an unworkable setup had a poorer quality chopper been used with such a lock-in.

ITHACO DYNATRAC Heterodyning Lock-In Amplifiers provide the best solution to chopper optical measurement problems since they are insensitive to short term frequency fluctuations and automatically track a drifting reference frequency. ITHACO/NF Model 3921 likewise gives excellent results, owing to its novel sinewave approximation detector. The ITHACO/NF Model 3961 is also insensitive to chopper motor fluctuations, due to its low Q peaked lowpass signal conditioning capability (BPL1 or BPL5 modes).

3.3 MOTOR EFFECTS ON LIA NOISE MEASUREMENT

When using the Lock-In Amplifier to measure low level random noise superimposed on a large coherent signal, chopper motor quality is paramount, regardless of Lock-In Amplifier type. The motor phase jitter can easily obscure the source noise. See ITHACO IAN 36, "Digital Techniques for Random Noise Measurement using Lock-In Amplifiers", Sections 4.6.3, 4.7.4 and 5.2. Section 5.2, in particular, contains experimental results of making simultaneous signal and noise measurements against a chopper motor jitter background. Some tricky considerations such as the tracking speed of the reference input phase locked loop become important.

In noise measurement application, one should use the Model 220 in preference to the Model 230 chopper. The larger blade diameter yields a better flywheel effect, making the speed fluctuations both slower and lower in amplitude. The Lock-In of choice for making simultaneous signal and noise measurements in chopper systems is the Model 3990 if the noise levels are 50dB or more below the signal (1 Hz bandwidth basis). It possesses both the best signal recovery characteristics and the best analysis capabilities, due to its phased dual channel features, due to tracking optimization by means of plug-in cardsets, and due to digital computation of noise.

4.0 ERROR CAUSED BY TUNED AMPLIFIER LIA'S

The tables below show the reading error in Lock-In Amplifiers that use a high Q tuned amplifier in the signal channel to avoid harmonic responses as a function of both 'Q' and of tuning error 'F/FO', where 'F' is the actual signal (or reference) frequency, and 'FO' is the frequency the amplifier is tuned to.

TABLE 1 -- SINGLE PHASE LIA

F/FO	1.0	.999	.998	.997	.996	.995	.994	.993	.992	.991	.99
Q 5	1.00	.999	.999	.999	.998	.997	.996	.995	.993	.991	.99
10	1.00	.999	.998	.996	.993	.99	.985	.98	.974	.968	.961
15	1.00	.999	.996	.991	.985	.977	.968	.957	.945	.931	.916
20	1.00	.998	.993	.985	.974	.961	.945	.926	.906	.884	.86
25	1.00	.997	.99	.977	.961	.94	.916	.89	.861	.83	.798
30	1.00	.996	.985	.968	.945	.917	.884	.849	.811	.772	.733
35	1.00	.995	.98	.957	.927	.89	.849	.805	.759	.714	.668
40	1.00	.993	.974	.945	.906	.861	.811	.759	.707	.656	.607
45	1.00	.991	.968	.931	.884	.83	.773	.714	.656	.601	.55
50	1.00	.99	.961	.917	.861	.799	.734	.669	.607	.55	.497
55	1.00	.988	.953	.901	.837	.766	.695	.626	.561	.502	.45
60	1.00	.985	.945	.884	.812	.734	.657	.584	.518	.459	.407
65	1.00	.983	.936	.867	.786	.701	.62	.545	.478	.419	.369
70	1.00	.98	.927	.849	.76	.67	.584	.508	.441	.384	.335
75	1.00	.977	.917	.831	.734	.638	.551	.473	.407	.352	.305
80	1.00	.975	.906	.812	.708	.608	.518	.441	.377	.323	.278
85	1.00	.971	.896	.793	.682	.579	.488	.412	.349	.297	.255
90	1.00	.968	.885	.773	.657	.551	.46	.384	.323	.274	.234
95	1.00	.965	.873	.754	.632	.524	.433	.359	.3	.253	.215
100	1.00	.961	.861	.734	.608	.498	.408	.336	.279	.234	.198

TABLE 2 -- VECTOR SUM LIA

F/FO	1.0	.999	.998	.997	.996	.995	.994	.993	.992	.991	.99
Q 5	1.00	.999	.999	.999	.999	.998	.998	.997	.996	.995	.994
10	1.00	.999	.999	.998	.996	.995	.992	.99	.987	.984	.98
15	1.00	.999	.998	.995	.992	.988	.984	.978	.972	.965	.957
20	1.00	.999	.996	.992	.987	.98	.972	.962	.952	.94	.927
25	1.00	.998	.995	.988	.98	.969	.957	.943	.927	.911	.893
30	1.00	.998	.992	.984	.972	.957	.94	.921	.9	.879	.856
35	1.00	.997	.99	.978	.962	.943	.921	.897	.871	.845	.817
40	1.00	.996	.987	.972	.952	.928	.901	.871	.841	.81	.779
45	1.00	.995	.984	.965	.94	.911	.879	.845	.81	.775	.741
50	1.00	.995	.98	.957	.928	.893	.856	.818	.779	.741	.705
55	1.00	.993	.976	.949	.915	.875	.833	.791	.749	.709	.67
60	1.00	.992	.972	.94	.901	.856	.81	.764	.719	.677	.638
65	1.00	.991	.967	.931	.886	.837	.787	.738	.691	.648	.607
70	1.00	.99	.962	.921	.872	.818	.764	.712	.664	.619	.579
75	1.00	.988	.957	.911	.857	.799	.742	.688	.638	.593	.552
80	1.00	.987	.952	.901	.841	.78	.72	.664	.614	.568	.528
85	1.00	.985	.946	.89	.826	.761	.699	.642	.59	.545	.505
90	1.00	.984	.94	.879	.81	.742	.678	.62	.568	.523	.483
95	1.00	.982	.934	.868	.795	.724	.658	.599	.548	.503	.463
100	1.00	.98	.928	.857	.78	.706	.639	.579	.528	.483	.445