IEEE 802.3aq Task Force
Dynamic Channel Model Ad Hoc
Task 2 - Time variation & modal noise
10/13/2004 con-call

Time variance in MMF links – Further test results

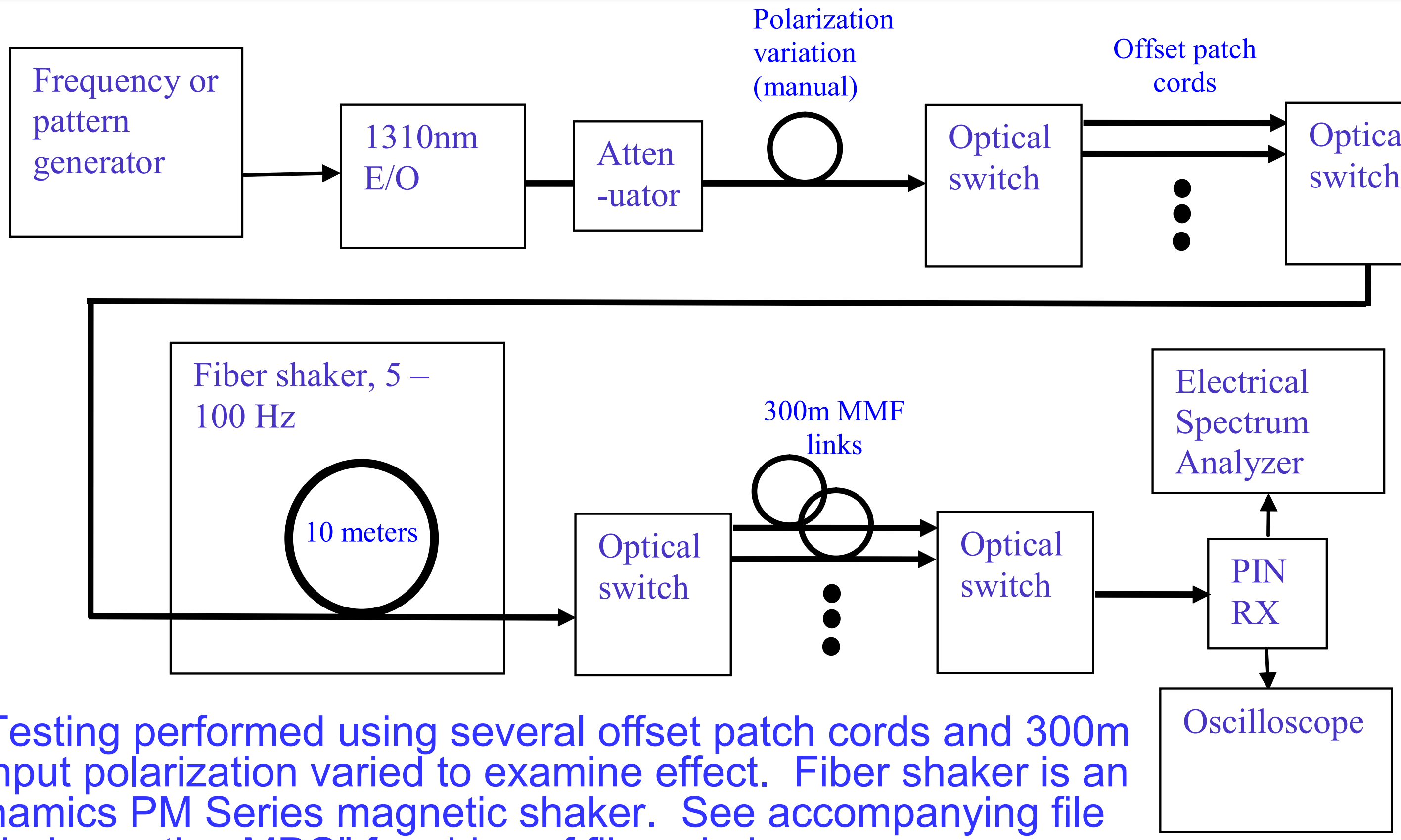
Rob Coenen

Overview

Based on the formulation presented at the August 18th 2004 con-call, measurements were made of the maximum dynamic channel variation rate in response to a vibration at a known frequency .

The test set-up is shown on the following slide.

Time variance test set-up. (Note: offset loss per optical switch is approx 0.5 dB)



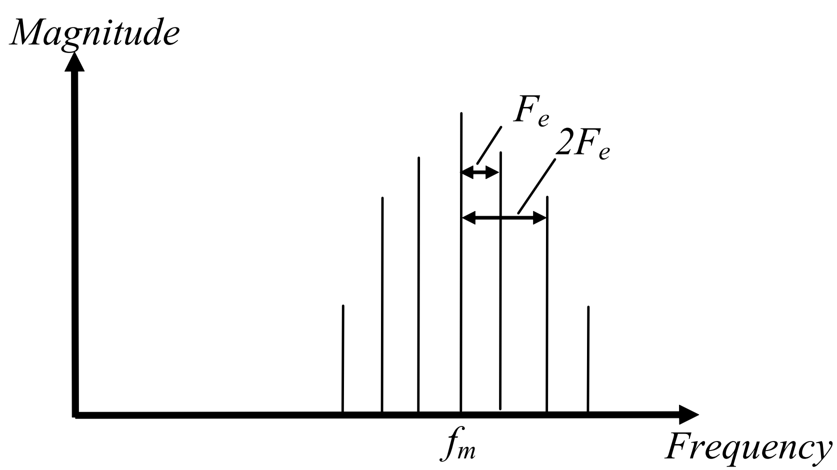
Note: Testing performed using several offset patch cords and 300m links. Input polarization varied to examine effect. Fiber shaker is an MB Dynamics PM Series magnetic shaker. See accompanying file "Fiber shaker action.MPG" for video of fiber shaker.

Review of conclusions of contribution *"Measuring channel variation in MMF"*

- The contribution states that the equation for the channel time variation due to mechanical vibration will take on the form:

$$P_{out}(t) = [P_o + P_m \cos(\omega_m t)] \left\{ \begin{array}{l} (I_{11}a_1)^2 + (I_{21}a_2)^2 + (I_{31}a_3)^2 + (I_{12}a_1)^2 + (I_{22}a_2)^2 + \ldots \\ 2(I_{11}a_1 I_{21}a_2)\cos((\theta_1 + \sigma_1) - (\theta_2 + \sigma_1)) + \\ 2(I_{11}a_1 I_{31}a_3)\cos((\theta_1 + \sigma_1) - (\theta_3 + \sigma_1)) + \\ 2(I_{21}a_2 I_{31}a_3)\cos((\theta_2 + \sigma_1) - (\theta_3 + \sigma_1)) + \\ 2(I_{11}a_1 I_{12}a_1)\cos((\theta_1 + \sigma_1) - (\theta_1 + \sigma_2)) + \\ 2(I_{11}a_1 I_{13}a_1)\cos((\theta_1 + \sigma_1) - (\theta_1 + \sigma_3)) + \ldots \end{array} \right\}$$

- For the case of a sinusoidal input to the E/O, the channel variations due to mechanical vibration will result in sidebands upon the resulting received signal spectrum at multiples of the mechanical vibration frequency.



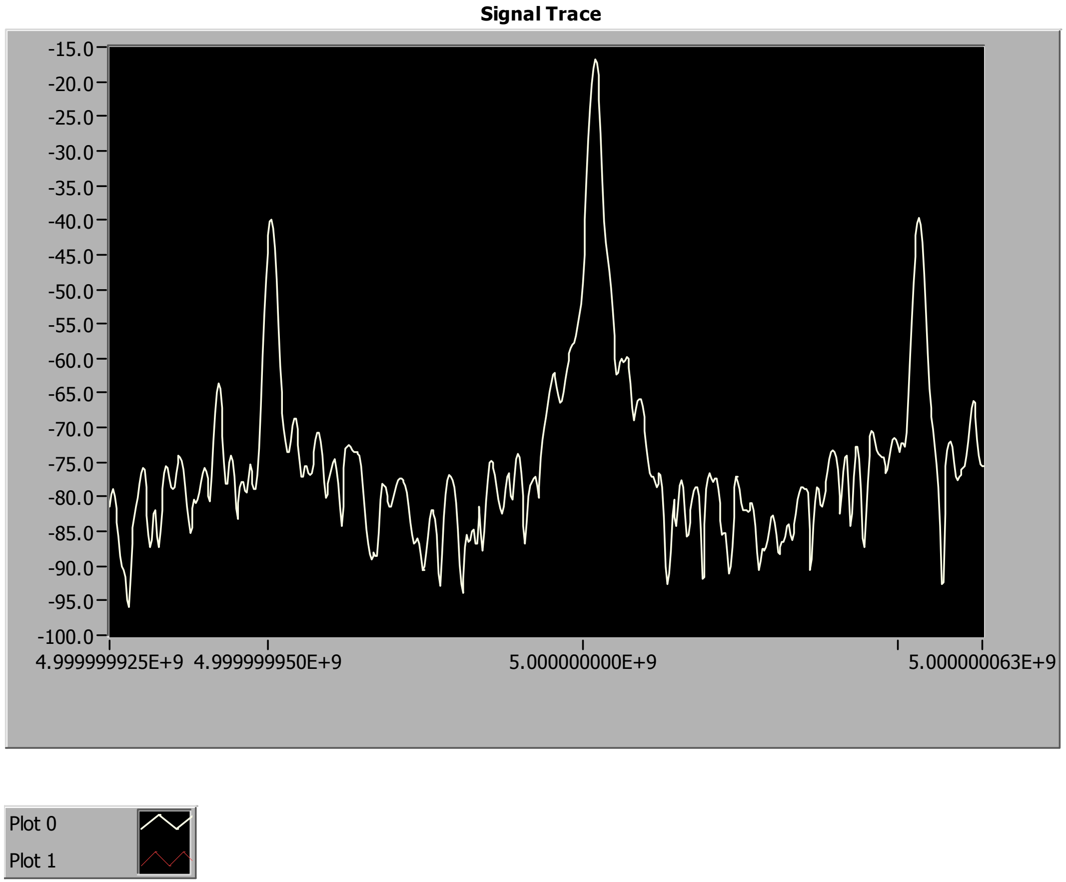
Test set-up

- Using the test set-up shown, the 10m fiber coil was mechanically shaken on two axis (suspended horizontally and hanging upright). Various frequencies between 6 and 30 Hz were examined with a shaker deflection of up to 7mm.
- Test measurements were taken using time-domain oscilloscope observations and narrow-bandwidth spectral analysis.

Test observations.

- Testing performed with a 5 GHz tone. Testing with a 900 MHz tone yielded similar results. As expected, the magnitude of envelope distortion on the scope is noticeably smaller for a lower frequency carrier.
- Changing the input polarization changes the channel response, varying the magnitude of the channel variations (and thus the magnitude of the visible envelope and sidebands) but it does not appear to vary the maximum channel variation frequency or the ratio of the sideband peaks to each other in any deterministic way.
- Vibrations with the coil hanging upright appear to produce the same amount of variations as suspended horizontally.

RX signal spectrum. 5GHz carrier. No vibration. Sidebands at 52Hz from carrier at –23 dB due to sinusoidal signal source.

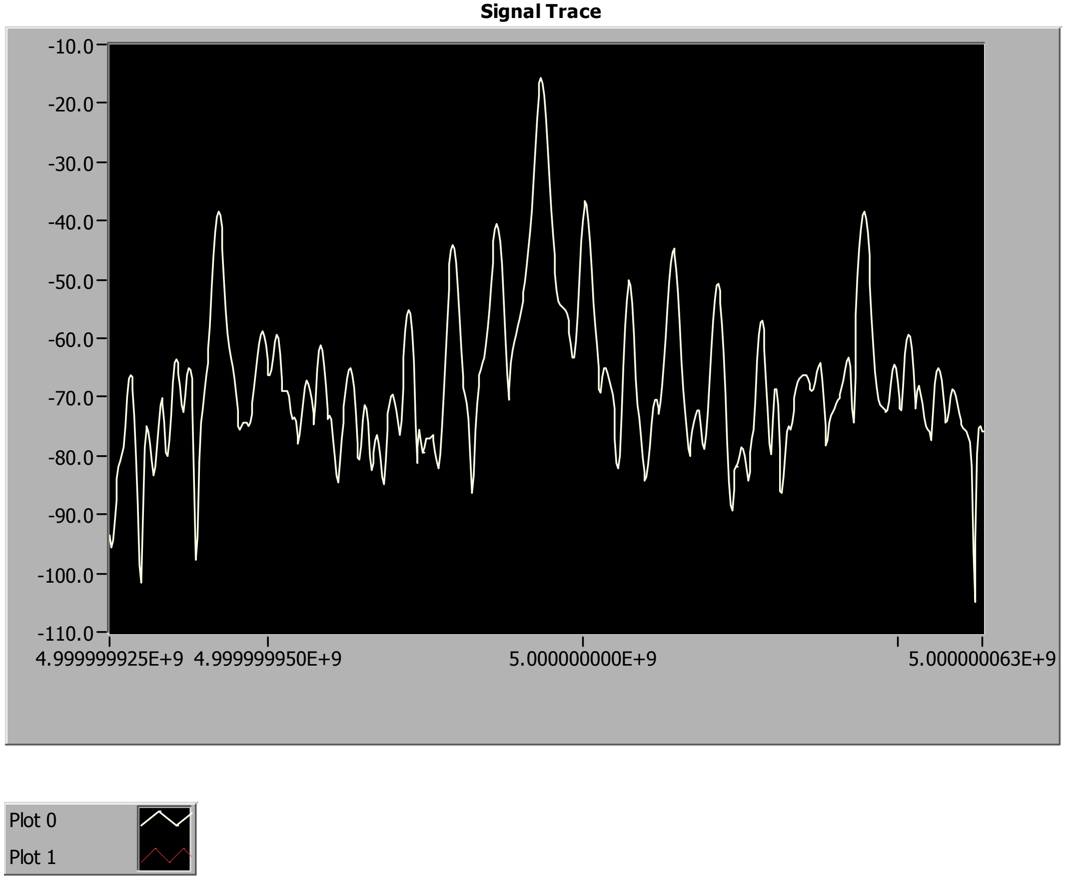


Baseline results

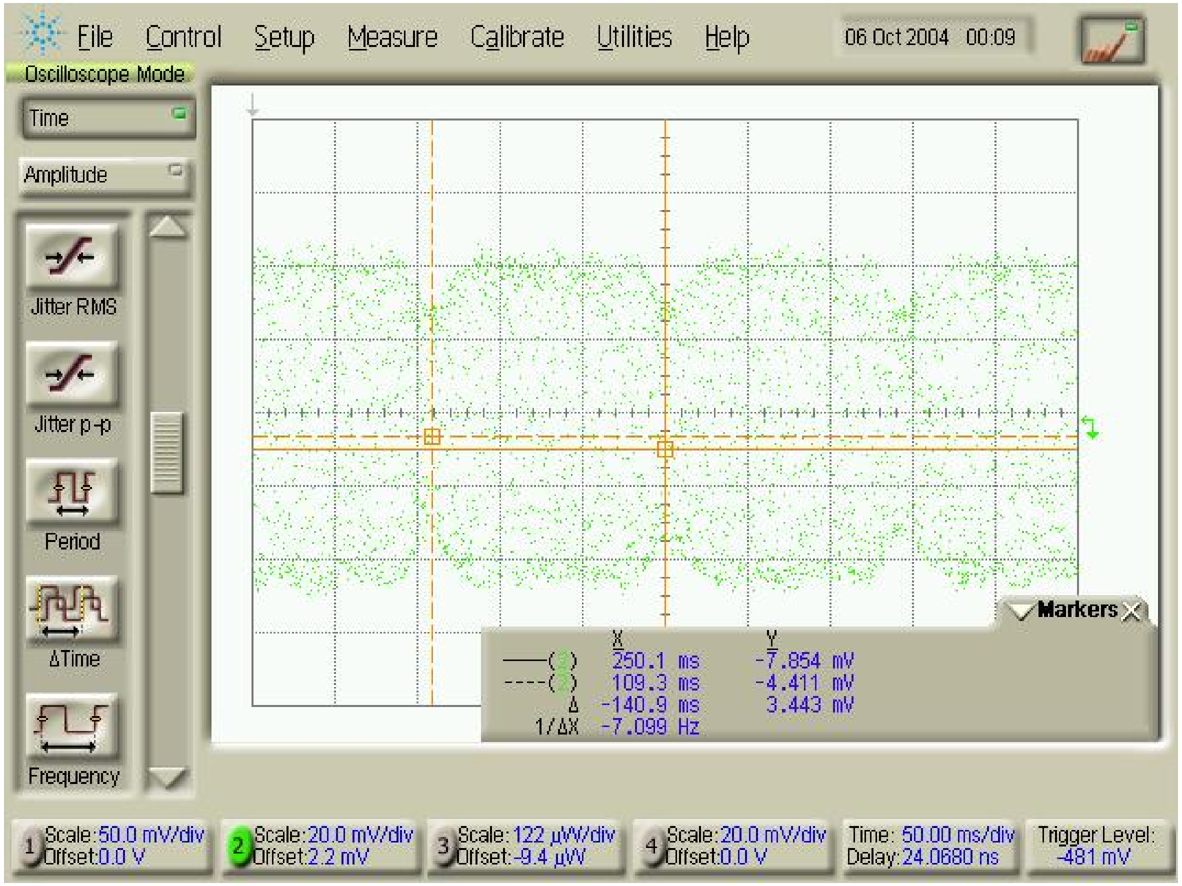
- Without vibration, the only sidebands visible are due to phase jitter from the signal source.
- Received time domain signal is constant and stable.

- Now vibration is applied.

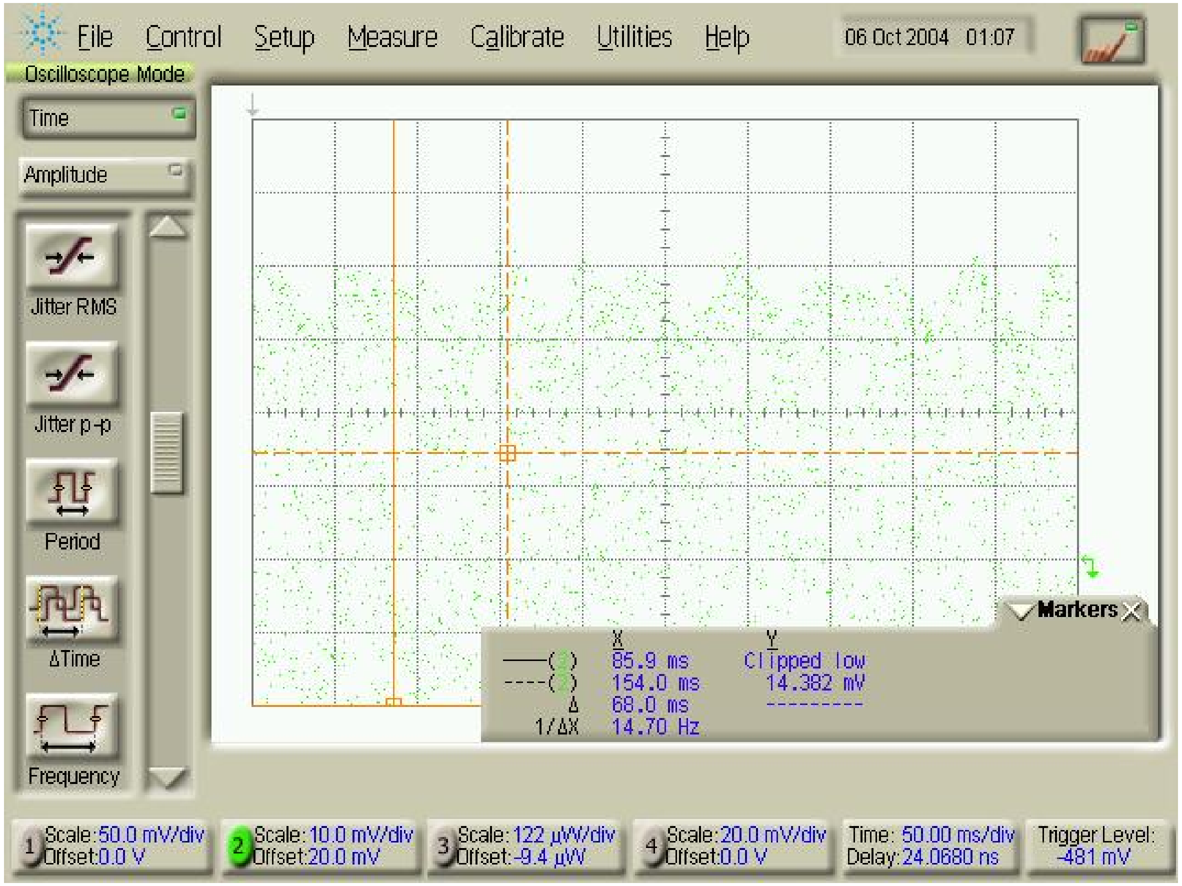
RX signal spectrum. 7Hz vibration, 1G acceleration (5mm deflection). Sidebands at 7, 14, 21 and 28Hz from signal tone. Sideband ratios are -21, -28, -30 and -35 dB.



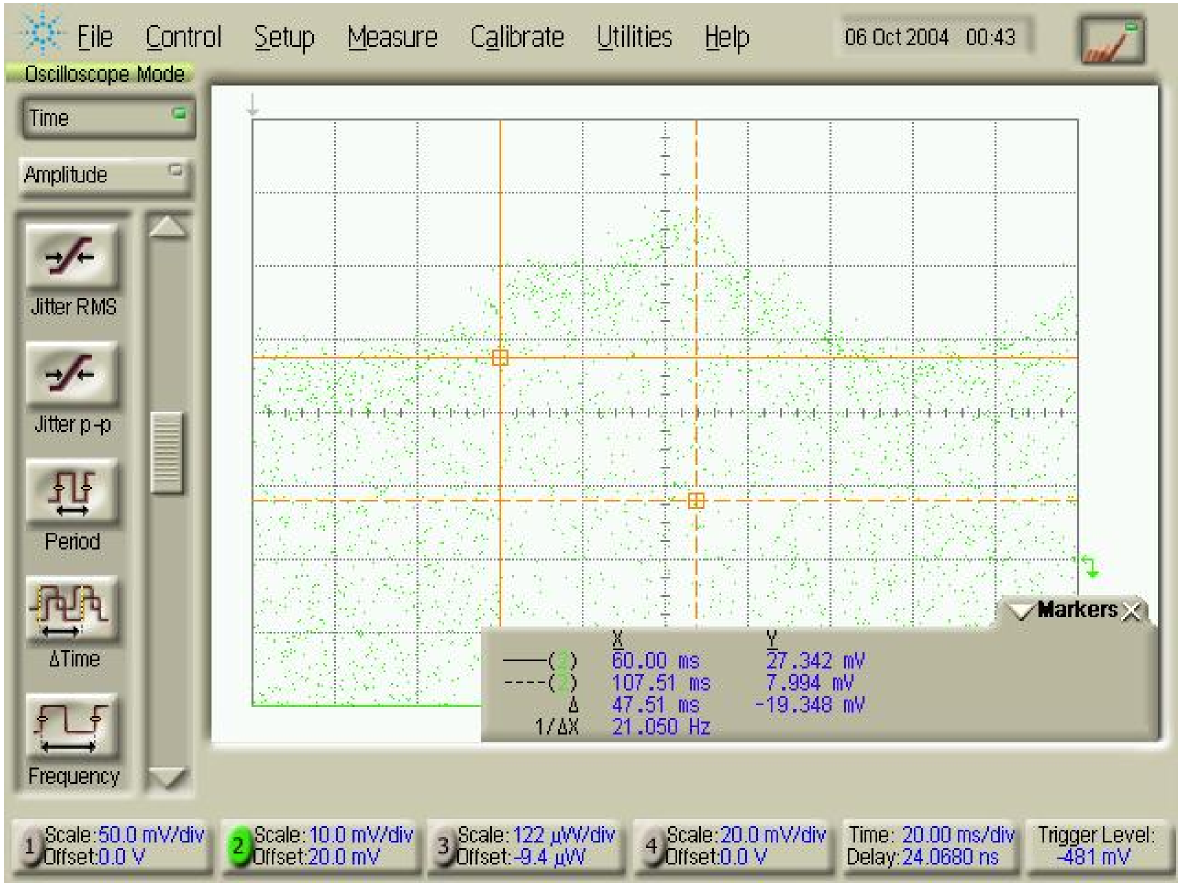
RX Time-domain signal. Expanded time-base. 7Hz, 1G acceleration (5mm deflection). Prominent channel variation at 7Hz.



RX Time-domain signal. Expanded time-base. 7Hz, 1G acceleration (5mm deflection). Higher harmonic channel variations much smaller in magnitude as indicated in spectral analysis, Eg 14Hz.



RX Time-domain signal. Expanded time-base. 7Hz, 1G acceleration (5mm deflection). Higher harmonic channel variations much smaller in magnitude as indicated in spectral analysis, Eg 21Hz.



Test results.

- As predicted in “Measuring channel variation in MMF”, sidebands at multiples of the vibration frequency are visible on either side of the carrier tone.
- These sidebands correspond to the low frequency channel variations visible in the time domain as a low-frequency envelope on the carrier wave, as first demonstrated in “Time variance in MMF links-initial test results.pdf”.
- The magnitude of the channel time variations are directly proportional to the magnitude of the spectral sidebands.

Test results con't.

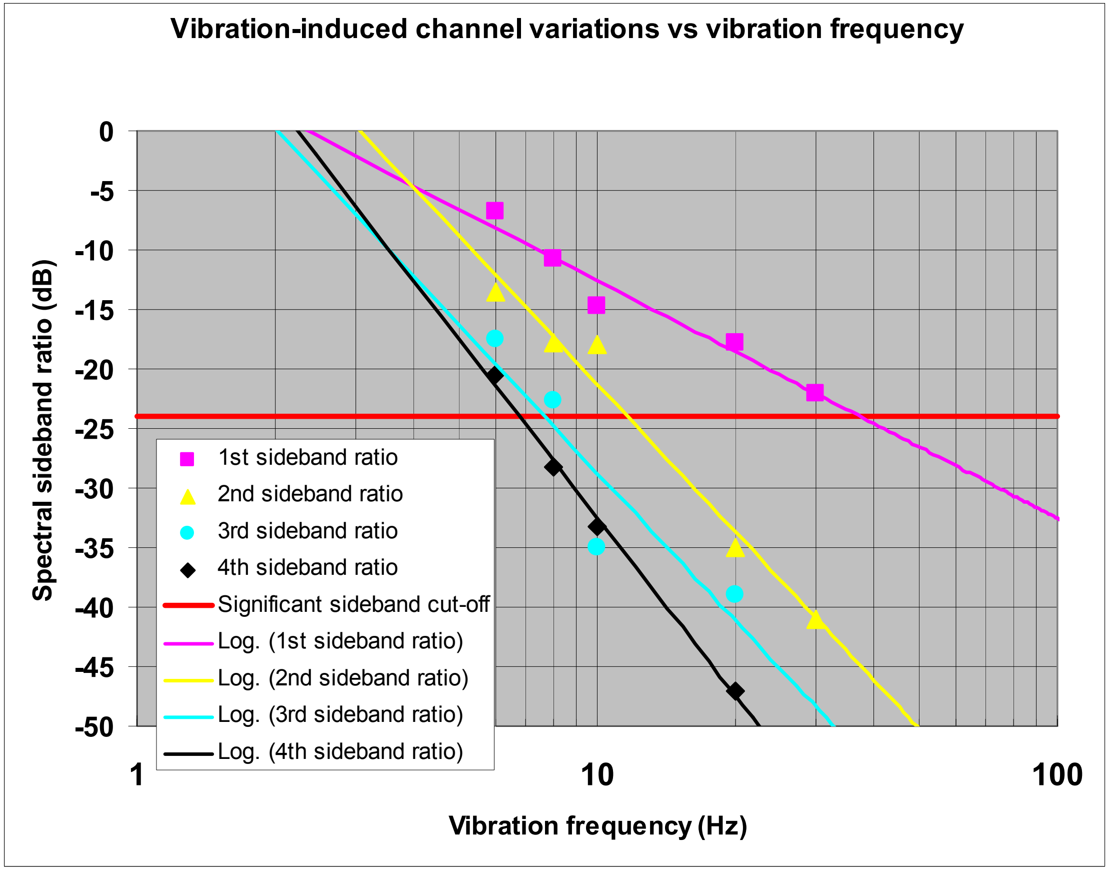
- Using this relationship, the maximum frequency of channel variations can be derived based on the relevant vibration standard, and the measured sideband magnitudes.
- To determine the maximum frequency of channel variations in an office environment, the fiber is vibrated at various frequencies at 1G acceleration and the resulting sideband magnitudes measured.

Data collection

- These deflection magnitudes were taken from Jonathan King's contribution, "Amplitude vs frequency for LRM vibration tests based on GR-63-CORE"
- Multiple measurements are taken for each vibration frequency to capture the worst case spectrum in terms of sideband magnitude.
- The resulting maximum sideband magnitude is then measured and plotted.
- Testing was performed with a 5 GHz tone.

Frequency (Hz)	Deflection (mm)	1st sideband ratio (dB)
6	7	-6.8
8	4	-10.8
10	2.5	-14.7
20	0.7	-17.8
30	0.3	-22

Ratio of transmitted signal to vibration induced side-band as a function of frequency.



Conclusions from vibration experiment.

- We can see from the graph of sideband magnitude vs vibration frequency, that the magnitude of channel variation drops rapidly with frequency. This is due to the exponential decrease in vibration deflection for a constant acceleration.
- It is total amount of physical movement of the fiber, not the rate at which it is moved, which dictates the magnitude of the channel variations.
- Thusly, the lower frequency vibrations produce the largest amount of channel variations. Overall, the maximum magnitude of the first harmonic dominates over the higher order harmonics.
- Choosing -24 dB as the absolute minimum sideband ratio that will produce noticeable channel variations, the maximum channel variation frequency is **< 40 Hz** which is due to the 1st harmonic. The max channel variation frequency due to the 2nd harmonic is ~24Hz.

Conclusions from vibration experiment con't.

- The value 40 Hz is the estimated maximum rate at which **any** significant channel variations may occur under the office vibration conditions given in GR-63-CORE.
- For larger channel variations which would more seriously exercise the channel adaptation of an EDC device, the maximum frequency is lower, the absolute amount depending upon the channel in question.

Conclusions from vibration experiment con't.

- The value -24 dB was chosen based on rough observations of the resulting channel envelope modulation during spectral measurements. More careful measurements of simultaneous envelope modulation and spectral sideband magnitude may adjust this value slightly upward or downward.
- Detailed testing was performed by hand for a single fiber. Tests of a second fiber yielded similar results in terms of the rate of fall-off of the sideband magnitude.