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***Application Note 46***

# Mechanical Vibrations of CCMT Tuners used in On-Wafer Load Pull Testing

## Introduction

The following are possible alternatives for automatic load pull (and partly noise) measurements: a) Electronic (pin diode) tuners [1], b) Active systems (load pull only) [2] and c) Electro-mechanical tuners [3], options a) and b), although not very popular because of system shortcomings and/or excessive cost, do not present the risk of mechanical vibrations when operating, because they, in general, include only electronic parts.
Electro-mechanical tuners on the other hand use stepper motors to help position the RF probes accurately and repeatedly in the "horizontal-vertical" space. These motors generate vibrations when moving, which can be a cause for concern when using these tuners for on-wafer testing.
The purpose of this note is to evaluate the vibrations created by Focus' tuners and to establish their compatibility with on-wafer testing in quantitative terms.

## Sources of mechanical vibration

The sources of vibrations in electro-mechanical tuners are in the stepper motors used. Different levels of vibration may be generated depending on the gear mechanism used to translate the motor movement to the horizontal and vertical axis.
Focus tuners use timing belts made of synthetic material to transfer the motor movement to both the horizontal and vertical axis. This attenuates the vibrations, compared to metal-on-metal contacts, as used in other tuners.
There is, sometimes, a false impression generated when acoustical operation noise is confused with mechanical vibration. We found, experimentally, that higher operation noise does not necessarily mean higher levels of vibrations.
Trying to reduce, or even eliminate tuner vibrations is not an easy task.
Some think that by affixing the tuners solidly with the probe station will eliminate the vibrations. Again, experiments have shown that this is not necessarily true. It depends a lot on the "eigen-axis" of vibration of the tuners.
We suggest letting the tuners vibrate by mounting them properly but not too tightly with the probe station. Tight fixation may generate undesired vibrations along unpredictable axes.
Beyond all experience and theoretical considerations the real test is measuring mechanical vibrations under "worst case" conditions, i.e.: when the tuners go back to zero position, horizontally and vertically, and reverse. In the following sections we will describe these tests.

# Tests of mechanical vibrations in tuners

We tested our tuners under two basic conditions:

1. In “on-the bench” operation
2. In “on-wafer” operation

Condition 1, “on-the bench”:

For this test the tuners are operated on a test marble on a laboratory table, without any attachment.

We operate them under continuous “initialization or zeroing” condition, which consists in sending both tuner axis 100 steps in the main direction and then returning to zero. Return to zero consists of moving the axis backwards (upwards) until the mechanical switch is detected, then over-run the switch in slow speed (=high torque) for 50 steps and return in the main direction, again in slow speed, until the switch goes “off”. This guarantees zero backlash operation and makes the maximum noise of movement (if this is an indication of higher vibration). In any case the axis reverse is the greatest vibration possible in these tuners.

These tests have been performed under two additional conditions: 1. The tuner lies on an insulating foam ½” thick and 2. The tuner is resting flat on the test marble, but without any attachments.

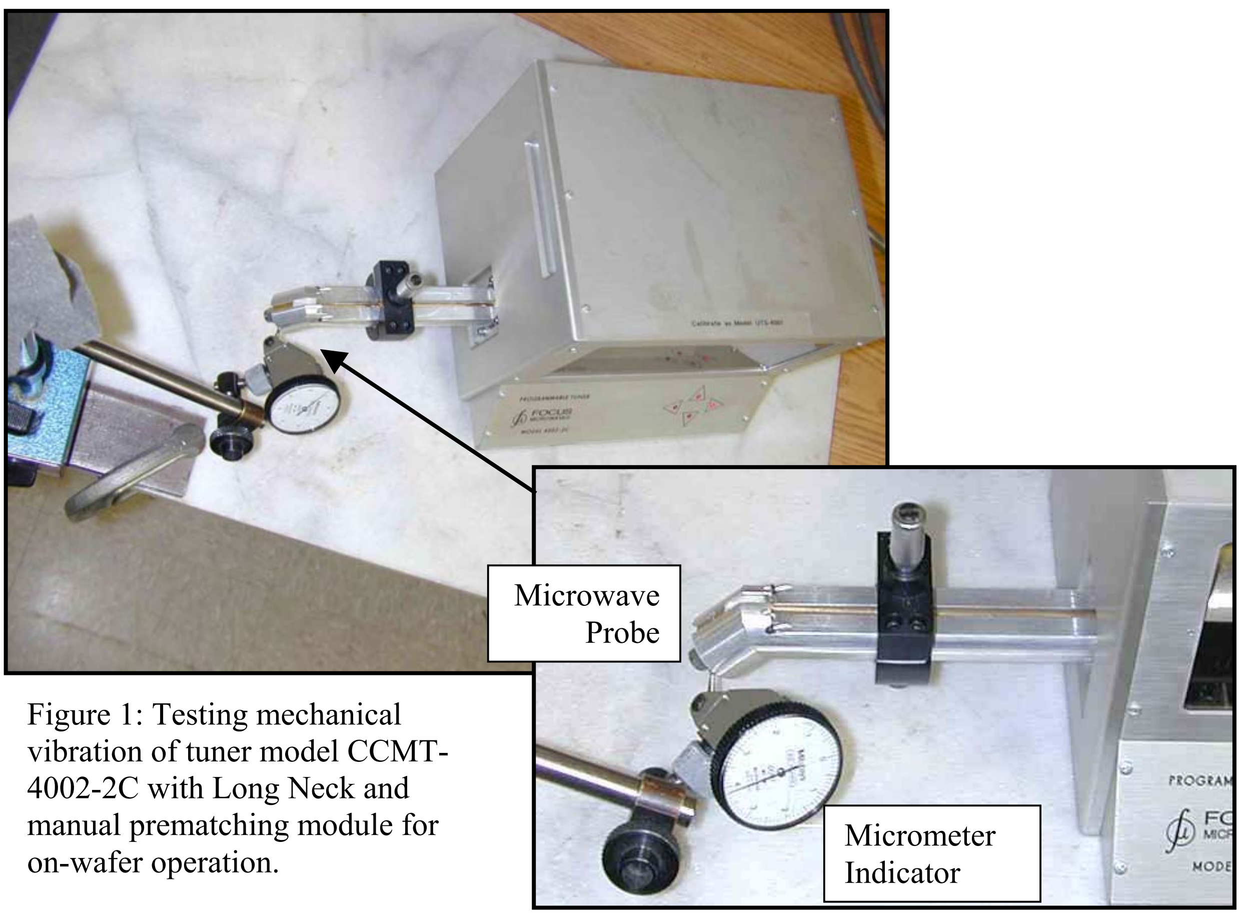


Figure 1: Testing mechanical vibration of tuner model CCMT-4002-2C with Long Neck and manual prematching module for on-wafer operation.

Results of “on-the bench” tests during continuous tuner initialization:

| Tuner setup | Tuner on a foam ½” thick (Real suspended operation) | Tuner rests on test marble (No extra attachments) |
|---|---|---|
| Indicator Deflection | ±10µm | Less than ±1µm |

Table I: Measurement of mechanical vibration using micrometric indicator.

These results confirm our experience over several hundreds of tuners tested, that laying the tuners on a solid flat surface is enough to minimize their vibrations.

Condition 2, “on-wafer”:

For this test the tuners are mounted on a manual probe station in our laboratory and fastened using a simple adjustable bracket (vise). The basic setup using Focus tuners is shown in figure 2 whereas an actual test setup for vibration purposes is shown in figure 3. Then a microwave probe is attached to the tuner and a sample wafer with a test pattern is used to establish contact with the probe (figures 4 and following...).

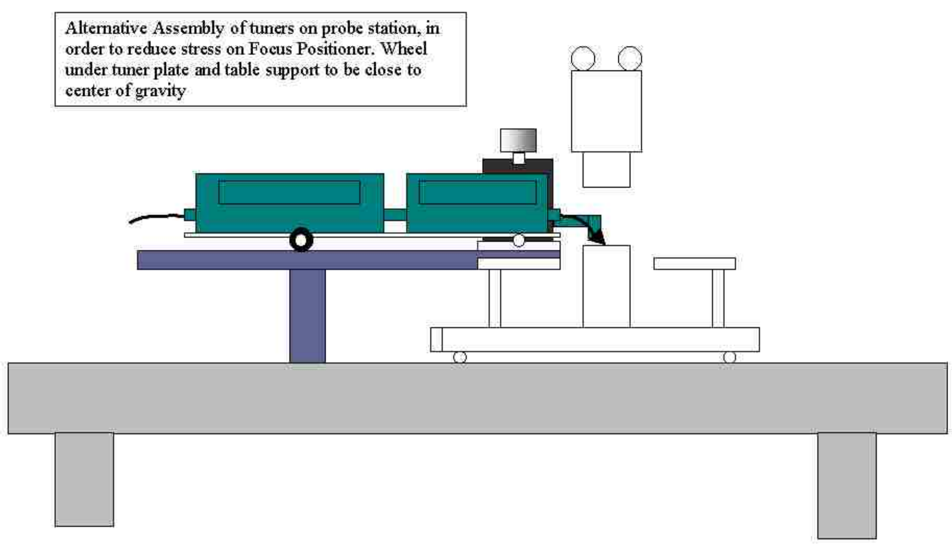


Figure 2: Schematic drawing of wafer setup using Focus tuners and micrometric positioners

The actual setup includes the following components:

- Summit 9000 probe station
- Tuner CCMT-1808, normal version (= no special low vibration features)
- 45° prematching section
- Focus Positioner
- 40 GHz Picoprobes GSG 150µm pitch 45°
- No special mounting effort to eliminate vibrations

Pictures were taken through the probe microscope under several conditions:

1. Before touching the probes,
2. After touching the stationary tuner probes
3. After touching the tuner probes and running the tuner to the zeroing-operation 500 times continuously.

Results before and after the test are shown in pictures 4 to 7.

* Initialization or "zeroing" condition, again, means sending both tuner axes 100 steps in the main direction and then returning to zero. Return to zero consists of moving the axis backwards (upwards) until the mechanical switch is detected, then over-run the switch in slow speed (=high torque) for 50 steps and return in the main direction, again in slow speed, until the switch goes "off".

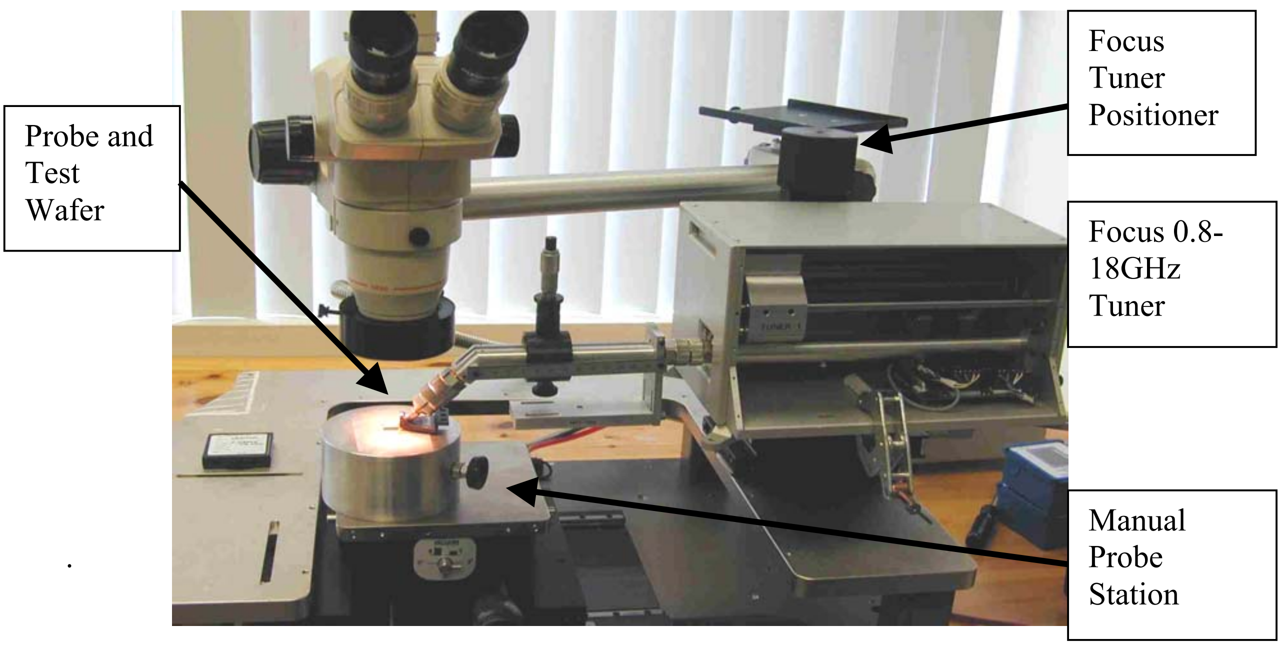


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Figure 3: Actual test setup for vibration measurements on-wafer, using a CCMT-1808 tuner and a manual prematching module, representing practical a "worst case" configuration

The following photographs show the effect of mechanical vibrations on a test pattern through the microscope lens, before and after the tuner operation.

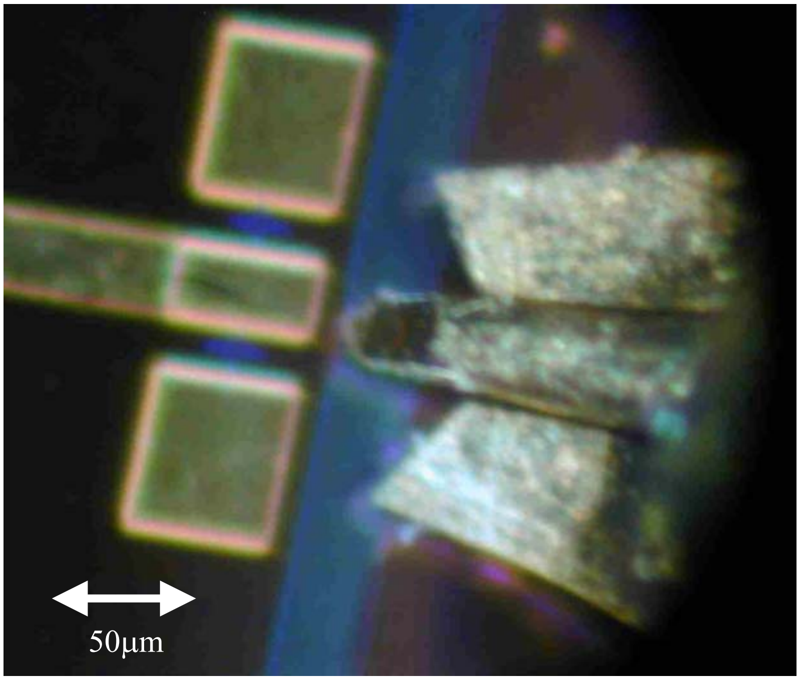


Figure 4: Test pattern and Probe before touching with the tuner.

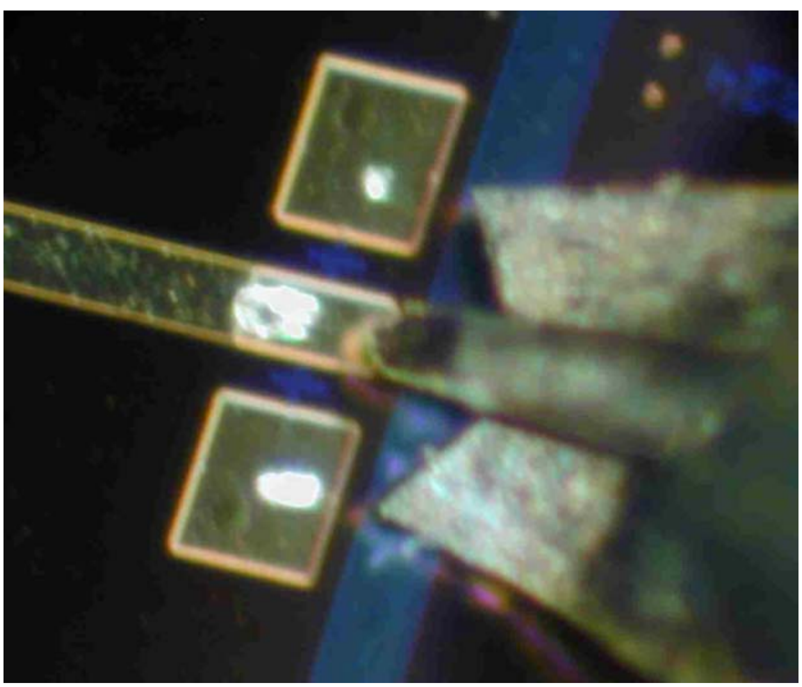

Figure 5: Test pattern and Probe after touching and lifting the tuner without any tuner movement. The “resting” patch is about 20µm in diameter on the center conductor.

50µm

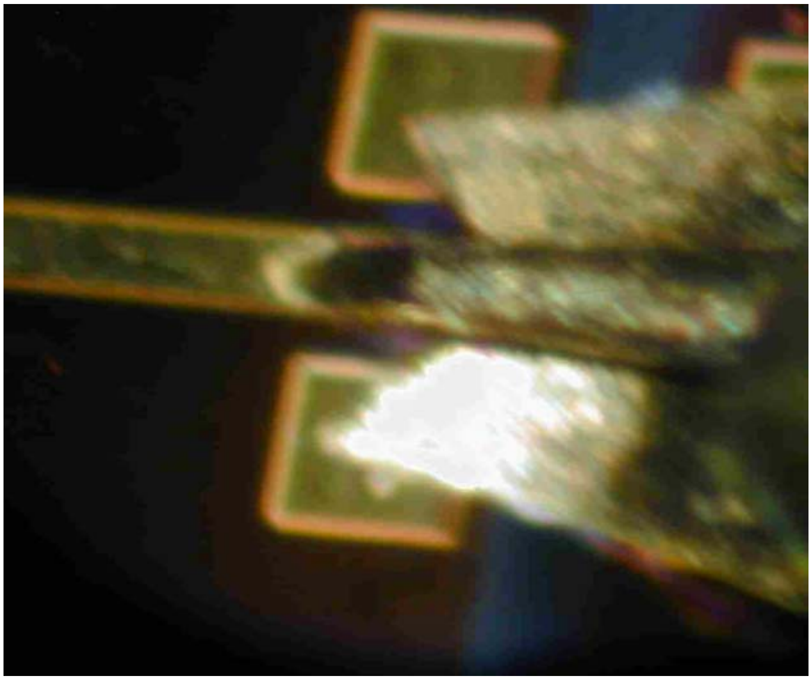

Figure 6: Probes on test pattern and tuner initializing. The photo is taken during actual tuner movement.

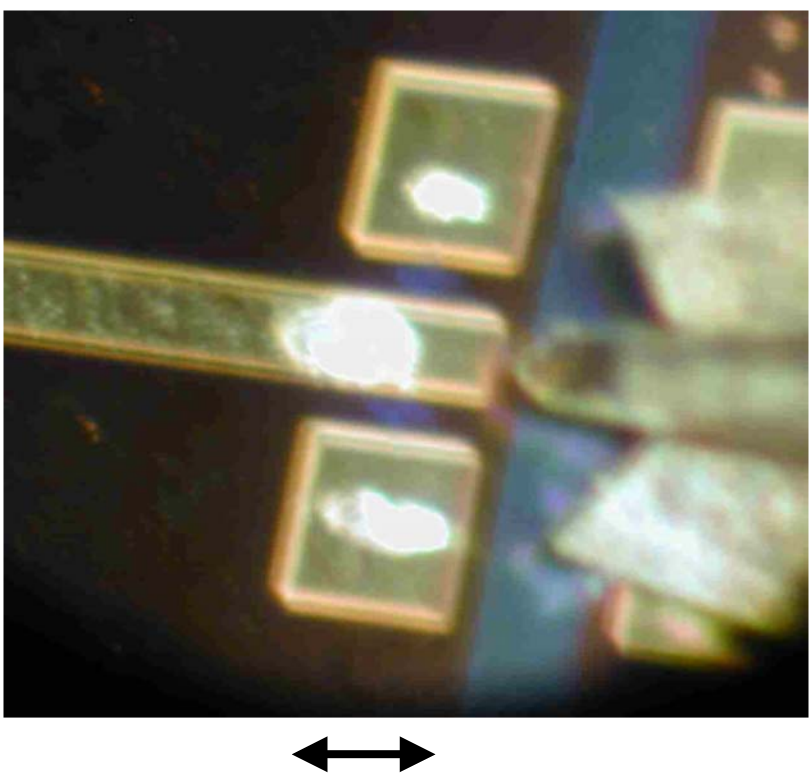


Figure 7: Test pattern after 500 tuner initializations. The observable patch "smearing" due to tuner vibrations is ≈ 30µm.

Comparing with the "resting" patch of figure 5 we realize that the tuner movement has smeared the touching pad by about 10µm, fitting to the numbers in table I for mounting conditions between "suspended" and "lying flat on the marble".

## Conclusions

The tests we performed on the mechanical vibration of our electromechanical tuners confirm experiences from various test laboratories, which use the tuners in sensitive setups for wafer load pulling without vibration problems worth reporting.

“On the bench” tests show total mechanical vibration amplitude between 2µm and 20µm, depending on the layout and the mounting.

“On wafer” tests are supported by microscope pictures and show a maximum vibration amplitude of 30µm (figure 7), of which around 20µm are due to the initial contact of the resting probes themselves (figure 5).

It is therefore certain, that Focus’ electromechanical tuners can be safely used for on-wafer load pull testing from the mechanical vibrations point of view, even without any particular stabilizing procedures and accessories.

## Literature

[1] “A load Pull System for Digital Mobile Radio Power Amplifiers”, Microwave Journal, March 1995, page 116-118, ATN Microwave Inc.

[2] “ALPS, Active Load Pull System for PCN Applications”, Product Note 33, Focus Microwaves, 1966.

[3] “Computer Controlled Microwave Tuner System, CCMT”, Product Note 41, Focus Microwaves, January 1998.