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Application Note 49

Comparing Tuner Repeatability

An important parameter characterizing the performance of electromechanical microwave tuners is the repeatability of their RF characteristics.

In this note we present experimental repeatability results obtained on two production units, one from Focus, model CCMT-1808 (0.8-18GHz) and one from Maury, model MT982E (0.8-8GHz), both with APC-7 connectors.

The results show that there is no major difference between the performance of either tuners; the slightly better data obtained for the Focus unit might be due to the general state of the units, which could not be accounted for.

Both units have been tested using Focus Calibration and Test Software, the Maury unit was controlled by a Maury Controller, model MT986B, driven by Focus Software.

Test Methodology

Because Focus software allows interpolation and tuning to any point of the Smith Chart we distinguish between "RF Repeatability" and "Tuning Accuracy", the first resuming to a more or less purely mechanical repeatability whereas the latter also involves the precision of the computing algorithms for interpolation and tuning.

Maury Microwave and many users of Focus and Maury systems have been using the RF Repeatability as a main criterion for qualifying the tuners. So we will do the same in this note.

RF Repeatability is the difference, mostly in reflection factor, between two or more repeated settings of the tuner to the same motor positions, measured by a calibrated Vector Network Analyzer (VNA)

Figure 1: Maury and Focus tuners used in comparison test

This can be done either by setting the tuner to a number of positions around the Smith Chart and saving the coordinates in a local file for repetition, or driving the motors using a repetitive position-generating algorithm. In our test we used the normal tuner calibration routine, which has the advantage of generating impedances covering the whole Smith Chart uniformly, thus not favouring lower reflection factor points, twice: one time we measure and save the data in memory then we repeat the algorithm, retrieve the data from the VNA and compare with the memory data. The Error in repeatability is computed using the relation

$$S_{11}\ \text{Repeatability} = 20 \bullet \log | S_{11m} - S_{11c} | \qquad [1]$$

Where S_{11} are vectors and S_{11m} stands for "S_{11} measured" and S_{11c} for "S_{11} in memory".

Test Results

Even though the tests have been done immediately one after the other there still are a number of reasons for non-perfect repeatability, not all of them related to the tuners themselves:

1. Short term (10-15 minutes) Network Analyzer drift (for this test we used a well warmed up hp-8753D, calibrated using TRL)
2. Changes in tuner and cable temperature, due to operation heat-up
3. Mechanical tuner repeatability errors, including zero positioning inaccuracies
4. Errors in motor control continuity (losing steps)

Some of these errors can be identified from the data plots and others cannot. The short-term VNA drift can be identified from the error measured at the lowest reflection factors: in this case we in fact measure a quasi transmission line repeatedly (after a few minutes) and save the data difference. Initialization (zero positioning) errors and errors in motor control would appear as major repeatability errors due to a slippage in phase, which has not been detected. Changes in tuner and cable temperature should disappear after a few hours of operation and we could not detect a systematic drift over time.

Under these circumstances what is left is to compare the data and attribute the remaining error to tuner imperfections.

It is to be noted that the tests have not been carried through in a specially controlled environment. We believe that the data, to be of any practical guidance to the average test Engineer, have to be acquired under normal laboratory conditions, such as we have been using.

In the following pages we illustrate data measured under the same external conditions on the tuners of roughly the same size, airline and connector type (shown in figure 1), one from Focus and the other from Maury.

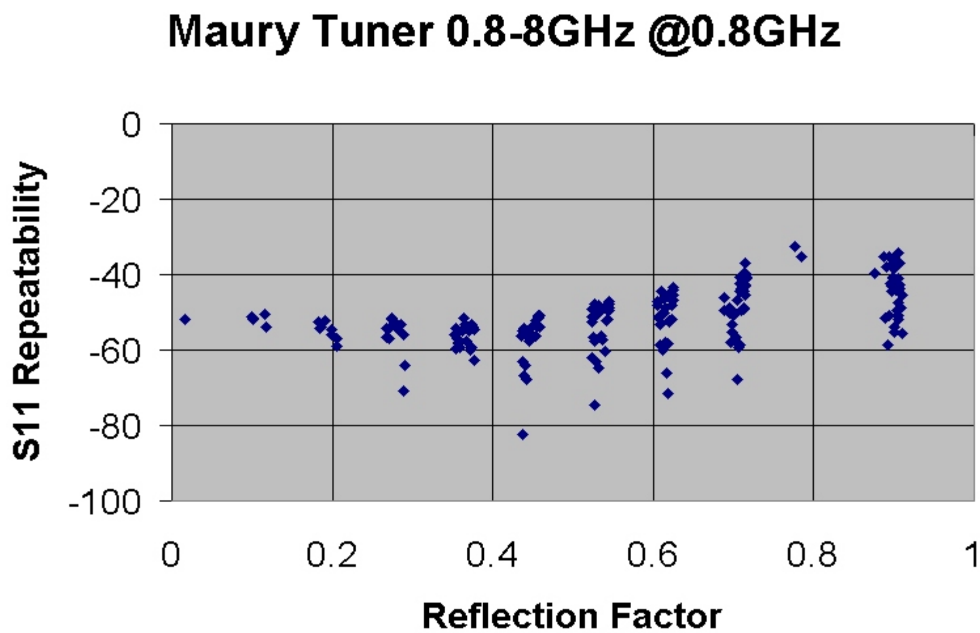

Figure 2

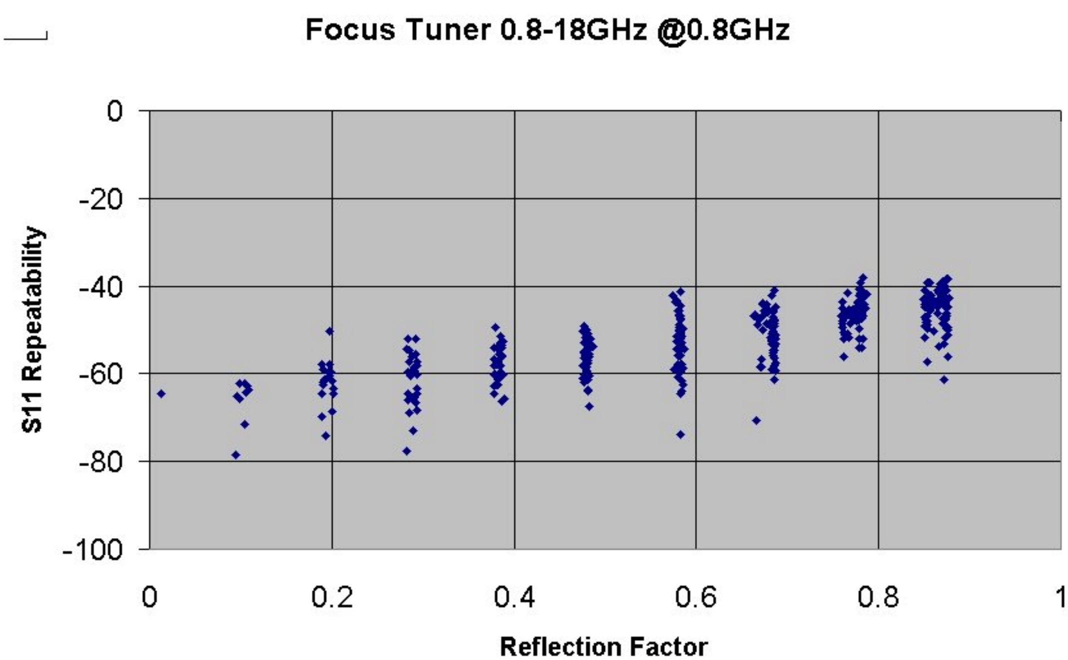

Figure 3

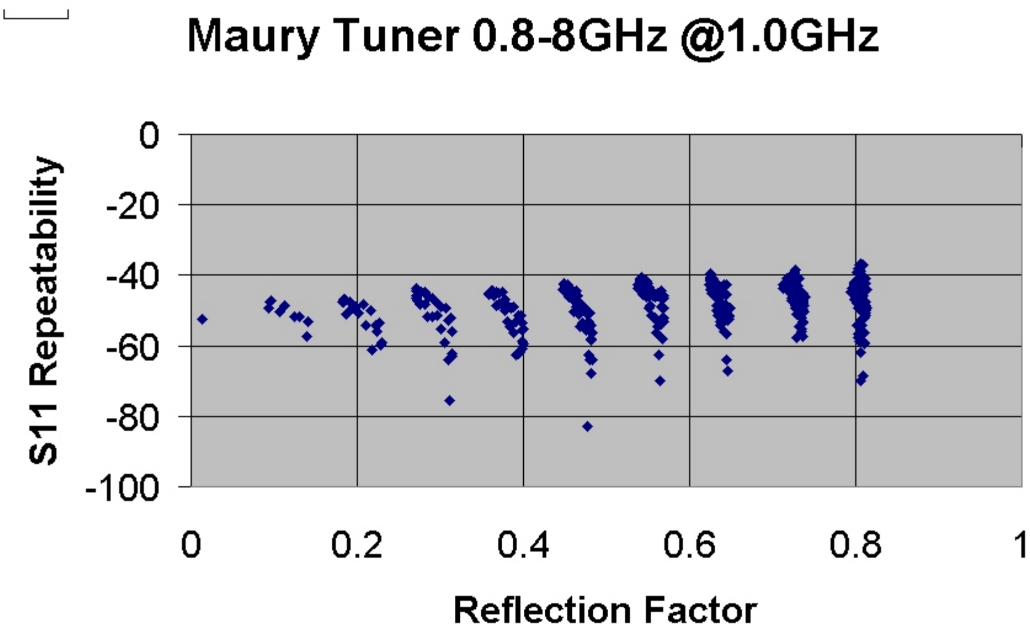

Figure 4

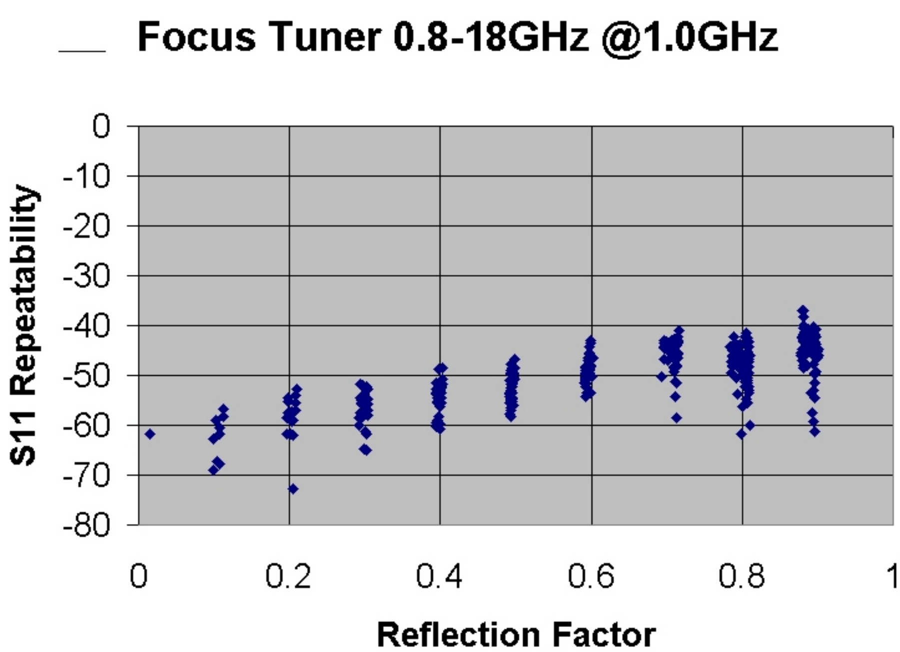

Figure 5

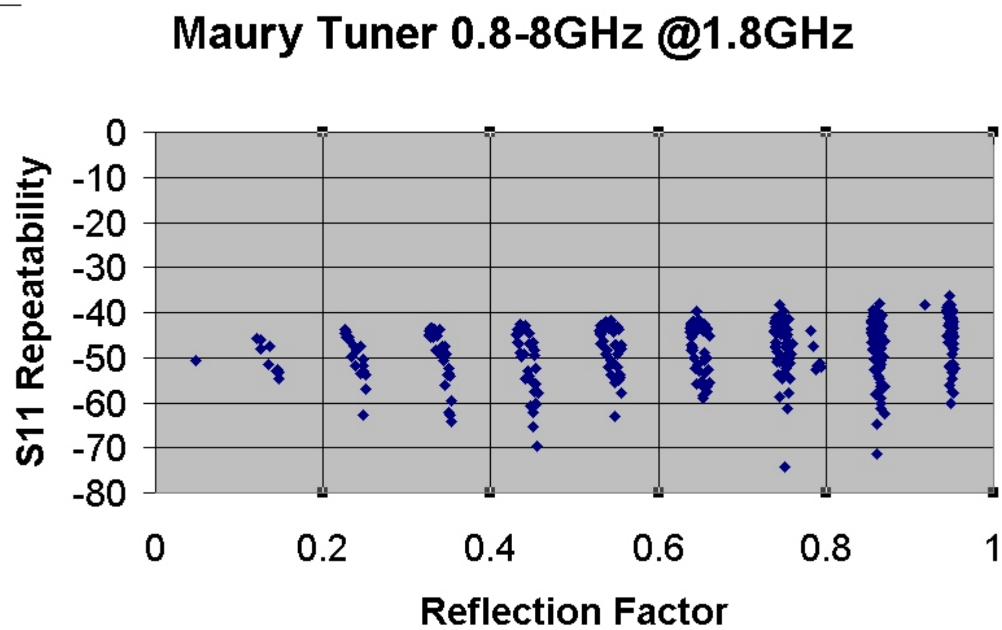

Figure 6

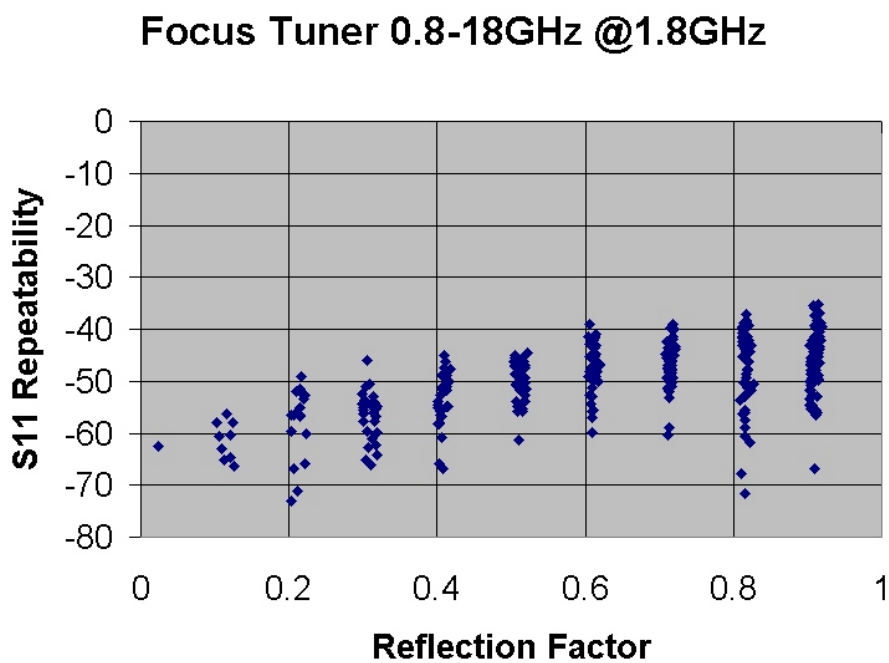

Figure 7

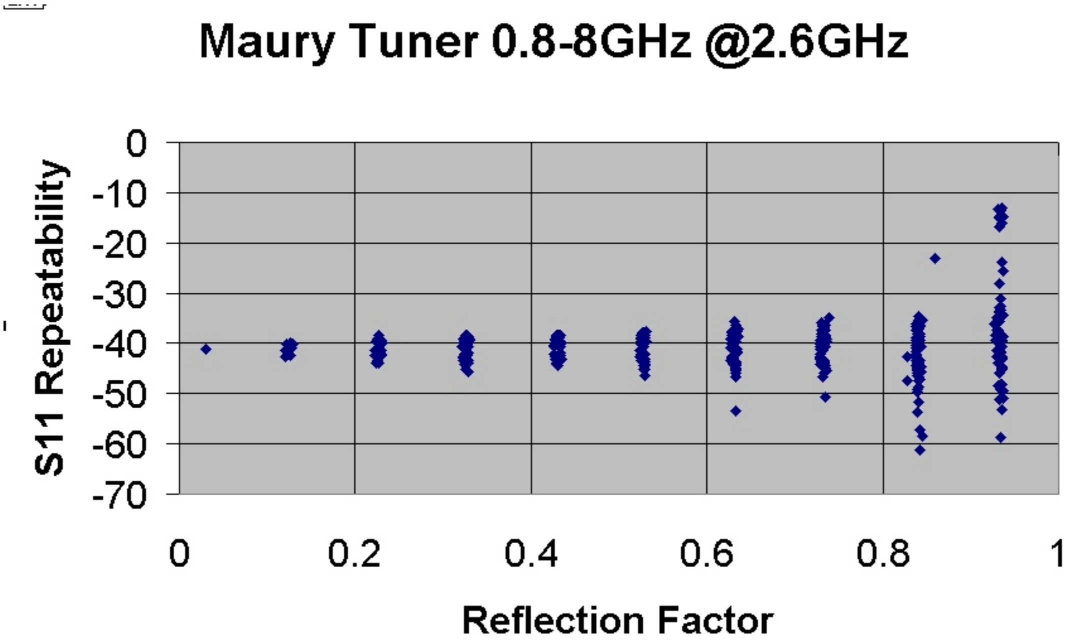

Figure 8

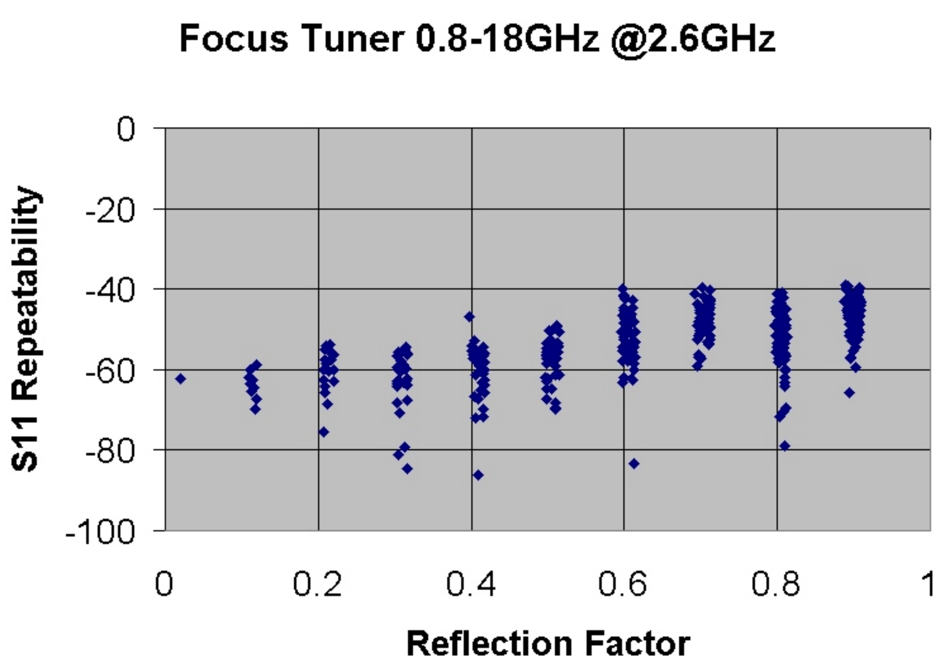

Figure 9

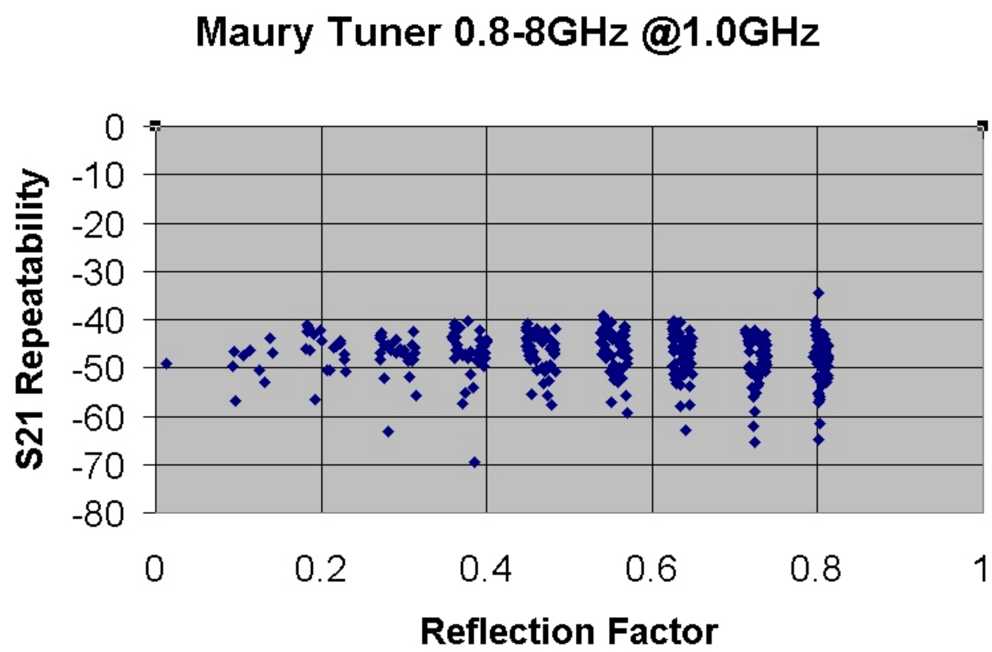

Figure 10

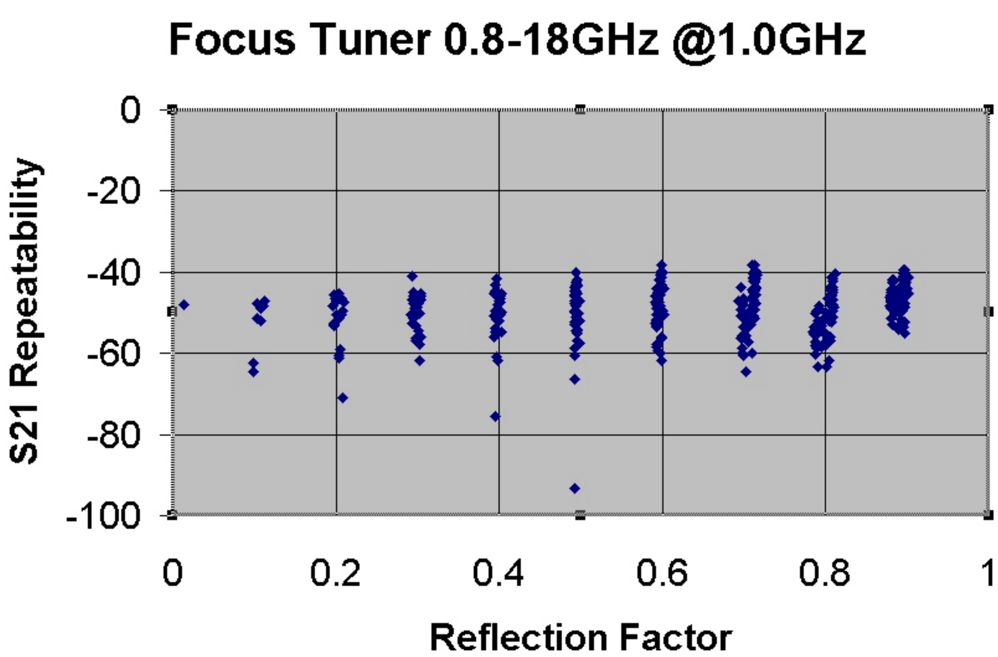

Figure 11

Repeatability Versus Tuning Accuracy

As stated in the introduction we define "Tuning Accuracy" as the difference between S-parameters measured and "tuned-to". "Tuned-to" meaning that the user or the tuning routine, requests the software to send the tuners to such motor positions as to synthesize any required and non-calibrated impedance within the tuning range of the tuner. In order to complete the picture of tuner performance on this subject, we ran this test on one a Focus tuner, based on a calibration file and a pattern file both of approximately 400 points. The following figures explain the principle and show the measured data.

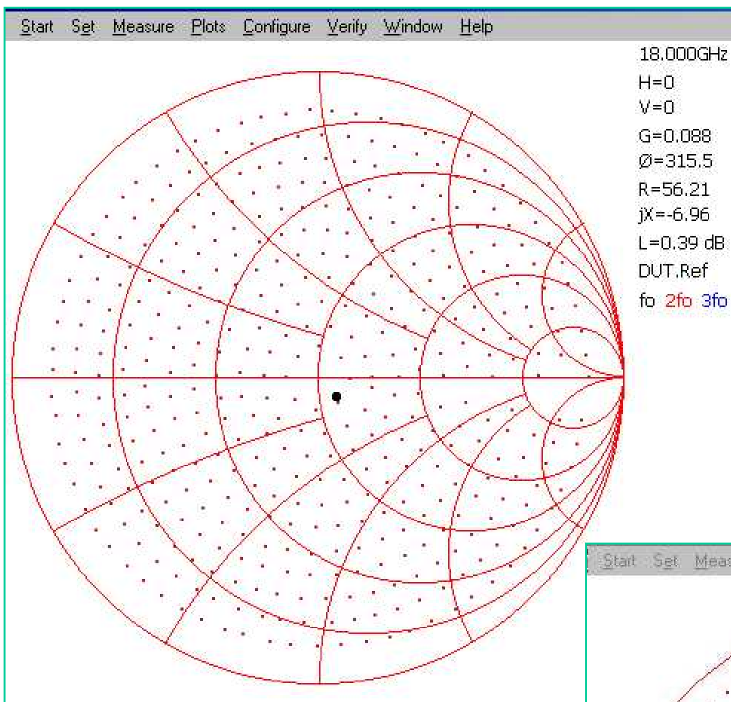

Figure 12: Pattern of a Focus tuner calibration points at 18GHz. It consists of 411 points. The motor positions are saved in the calibration file and repeated during the test.

Used for Repeatability test

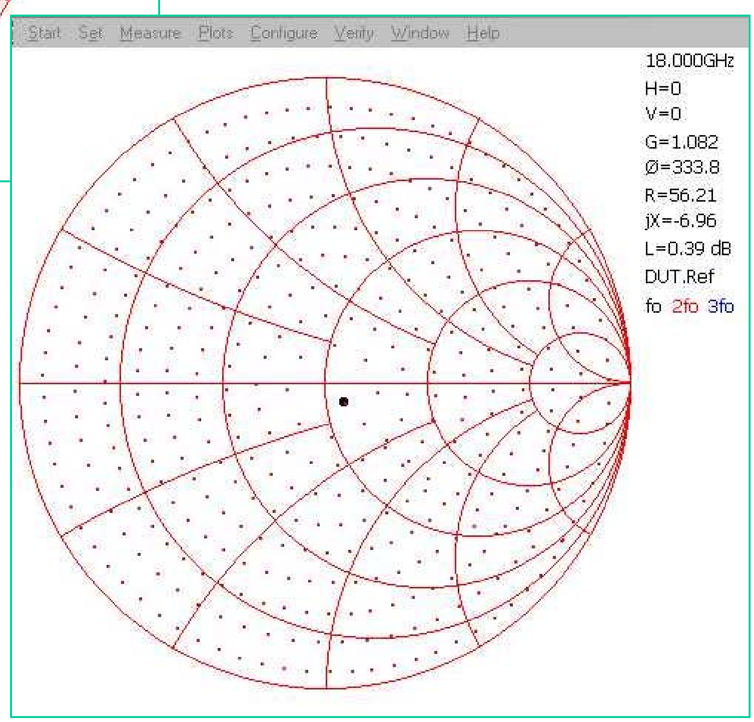

Figure 13: Pattern of tuned points at 18GHz using Focus software. It consists of 421 points. The motor positions are calculated to synthesize impedances and the S-parameter data is interpolated.

Used for Tuning Accuracy test

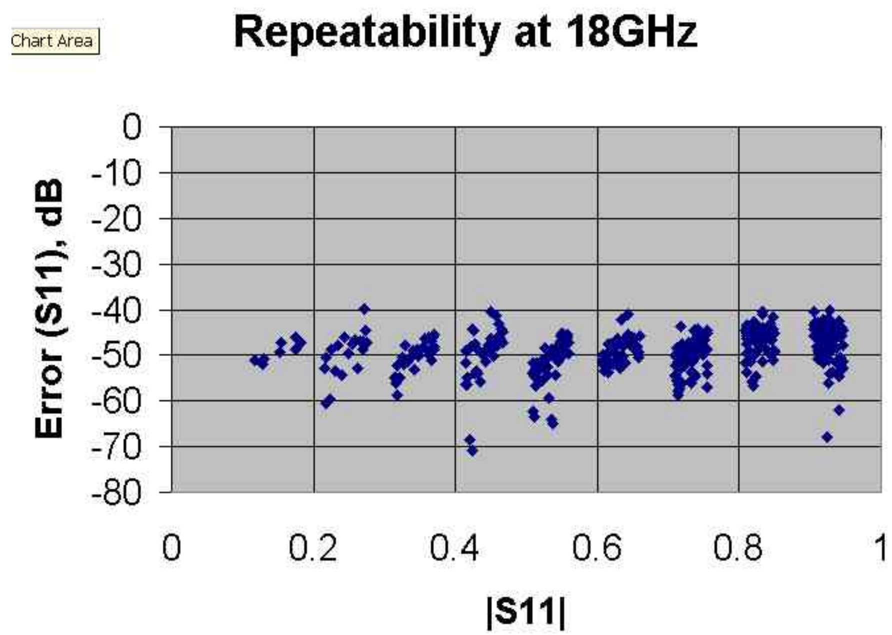

Figure 12

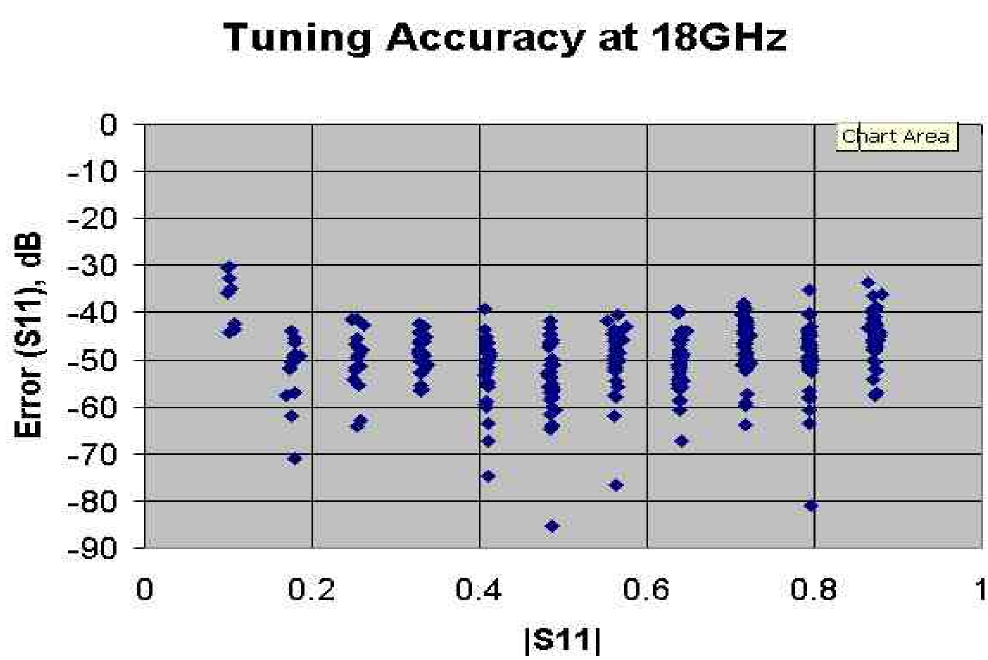

Figure 13

Conclusions

Comparative experimental data on S-parameter repeatability of electromechanical tuners of Focus Microwaves and Maury Microwave are presented in this note and let us summarize as follows:

1. The tests have been carried out on arbitrary production tuners, which have been used in a lab or demos for more than 1 year, ranging from 0.8 to 8 resp 18 GHz, using the same connector type (APC-7), same size central conductors, airlines and similar overall size.
2. The tests have been carried out using the same test setup (TRL calibrated hp-8753D) connected with the tuners using long semi-rigid cables.
3. The tests have been carried out alternatively; such as to eliminate long term setup drifts.
4. The test routine has been run twice for each tuner at various frequencies between 0.8 and 2.6 GHz.
5. The test routine consists in calibrating the tuner at roughly 400 points, re-measure these points immediately after and save the data as a vector difference.
6. The data is displayed using Excel plots of Error over Reflection Factor

Summary of findings

1. Both tuners have similar S_{11} repeatability errors in the order of 40dB or better for reflection factors up to approximately 0.9
2. Focus tuner perform slightly better in most tests, this being possibly due to the overall better condition of the specific tuner
3. The same is valid for the transmission S_{21}.

In conclusion it can be said that both tuners using similar technology, step motor size and airline structures, are subject to similar types of errors and performance regarding repeatability.

General Remark:

Maury Microwave has been reporting much better repeatability data than found in this test. New Focus tuners also perform better by about 10dB on average. However we chose to limit our comparative tests on available used equipment, which are typically employed by the average user of a load pull system, making the results more representative. This being said we would like to emphasize that 40dB or better of tuning accuracy is normally fully adequate for load pull or noise testing, in view of other possible errors due to associated instruments (VNA, power meters, etc.) and setup components (adapters, cables, test fixtures) and their calibrations.