TUNER REPEATABILITY: FACT AND FICTION

Figure 1 — Maury automated tuners.

Introduction

Automated tuners are becoming increasingly important in a variety of automated test applications. Mechanical automated tuners, as shown in Figure 1, are the most popular because of their wide matching range, low loss, broad bandwidth, high power handling, and flexibility of application. For example, a single setup can be used to characterize the noise parameters of a low noise device, or the high power and intermodulation performance of a power device. Applications can also be combined, as with the case of measuring the noise parameters and intermodulation distortion of a receiver front end device.

Repeatability is a Key Specification

One of the key requirements of an automated tuner is its repeatability. Typically, tuners are pre-characterized over a range of impedance settings, producing a look up table of s-parameters versus tuner positions. This look up table will be used to set the tuners to known states during device measurement. This approach saves time because it eliminates the network analyzer measurement time. In most cases, it also eliminates the need for a dedicated network analyzer. Typical repeatability on a Maury tuner is shown in Figure 2.

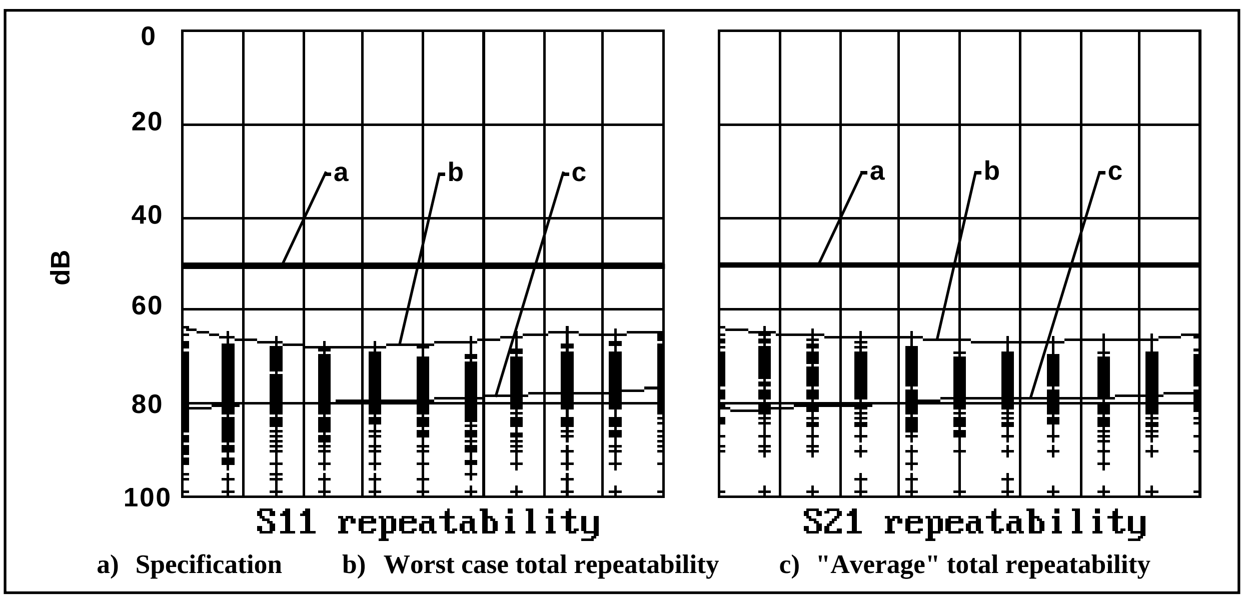

Figure 2 — Typical Maury total repeatability data.

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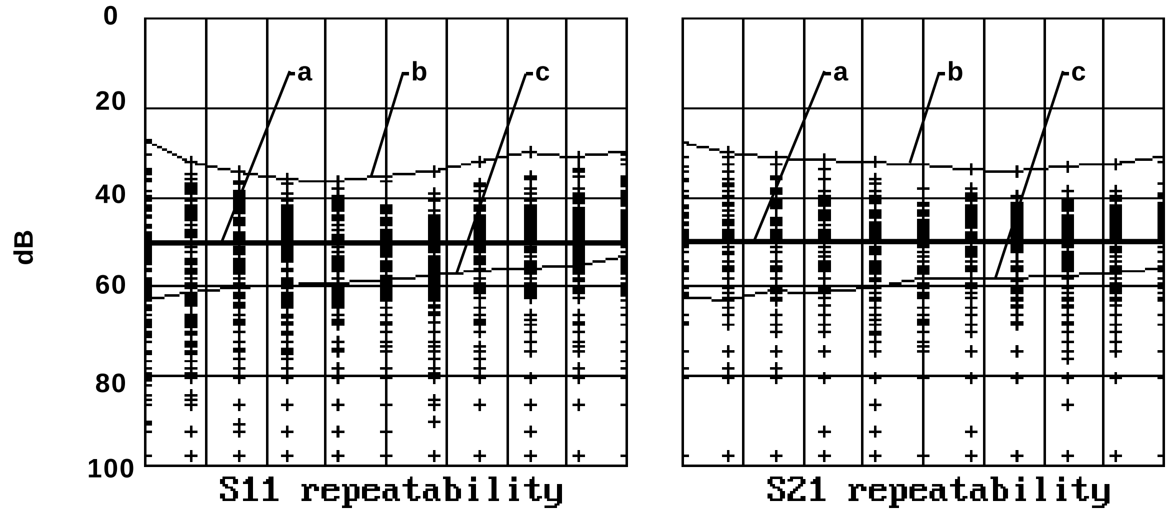

Figure 3 — The poor performance of this tuner is masked by the misleading "average" specification.

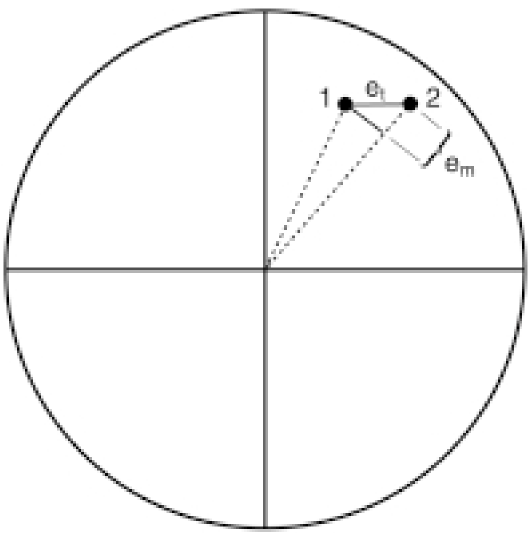

Figure 4 — Repeatability error vectors. Magnitude repeatability e_m is always smaller than total repeatability e_t.

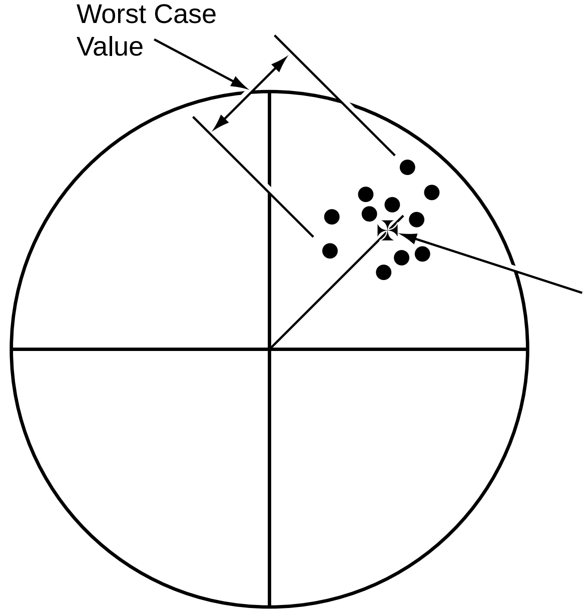

Figure 5 — If the average of several measurements is used to determine repeatability, then repeatability can be made to look better than the worst case.

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Definition of Repeatability

The definition of repeatability is illustrated in **Figure 4**. Point 1 represents one of the s-parameters measured with the tuner set to a specified position. This could be S11, S12, S21, or S22. Point 2 represents the same s-parameter after the tuner has been moved to another position and then returned. The arrow drawn between the two points represents the repeatability error vector e_t. The length of that error vector can be expressed in dB as given by equation 1. In this equation, small errors equate to large negative dB values.

$$\textbf{Repeatability} = 20 \log_{10}(|e_t|) \text{ dB} \quad (1)$$

In general, Point 2 could be anywhere on a circle surrounding Point 1, producing magnitude and phase components. The magnitude error e_m will vary between zero and e_t. The average will be about half of the total repeatability error, making the data look 6 dB better.

If several measurements are taken at the same horizontal and vertical tuner position and the repeatability is calculated based upon the average of those several measurements, then the repeatability will appear much better than if the worse case magnitude between any two measurement points were used; see **Figure 5**. An honest repeatability specification must be the worst case error between any two measurement points as measured over the entire available position range and frequency range for each probe under test. **Maury Microwave measures the worse case repeatability between any two measurements at the same impedance position for over 13,000 impedance positions for each tuner. These measurements are done over the entire frequency range and matching range of the tuner.**

Measuring Tuner Repeatability

Repeatability is a measure of how well the tuner s-parameters repeat each time the tuner returns to a pre-determined position or state. Since a tuner is specified to operate over a wide range of impedances, the repeatability test needs to be done at many positions to find the worst case. The test must also be done over the full specified frequency range of the tuner.

Repeatability at one impedance setting is measured using the following procedure:

1. Calibrate a vector network analyzer for a 2-port measurement over the desired frequency range.
2. Connect both ports of the tuner to be tested to the network analyzer.
3. Move the tuner to a particular test position setting.
4. Take a sweep with the network analyzer over the specified frequency range of the probe being tested. Read the 2-port s-parameters and save them for later use.
5. Move the tuner (both the carriage and probe) away from the test position. Then move the tuner back to the test position.
6. Take another sweep with the network analyzer, and read the 2-port s-parameters.
7. Compare the second set of s-parameters to the first set. The preferred method is to take the complex (vector) difference of all four parameters at each frequency. The magnitude of this complex difference is the repeatability and can be expressed in dB, as in equations 2 through 5.

$$\textbf{S11Repeatability} = 20 \log_{10}(|S11ref - S11repeat|) \text{ dB} \quad (2)$$

$$\textbf{S21Repeatability} = 20 \log_{10}(|S21ref - S21repeat|) \text{ dB} \quad (3)$$

$$\textbf{S12Repeatability} = 20 \log_{10}(|S12ref - S12repeat|) \text{ dB} \quad (4)$$

$$\textbf{S22Repeatability} = 20 \log_{10}(|S22ref - S22repeat|) \text{ dB} \quad (5)$$

If the tuners and the measurement system were perfect, the repeatability magnitude would be zero. However, the noise and drift of the network analyzer will limit this.

A complete tuner repeatability test must execute this procedure for a large number of positions, representing the full range of tuner setability. **Figure 2** is a typical display of S11 and S21 repeatability versus frequency. The worst case repeatability of all the positions is seen as an envelope, tracing the worst case of the overlaid plots at each frequency. **Figure 3** illustrates how poor performance can be masked by using misleading specifications.

Maury Repeatability Specifications

All Maury tuners have repeatability specifications which refer to the worst case of total repeatability. In final test, this is measured at many positions over the specified frequency range. **Table 1** summarizes the specifications of a few Maury tuners.

Model	Frequency Range (GHz)	Minimum VSWR Range	Repeatability	
			Minimum dB	Typical dB
MT981A	0.25 — 2.5	10:1	40	50
MT981B	0.4 — 4.0	10:1	40	50
MT982B	0.8 — 18.0	10:1	40	50
MT982A	1.8 — 18.0	10:1	40	50
MT982A02	1.8 — 18.0	15:1	40	50
MT982A11	1.8 — 4.2	20:1	40	50
MT982A12	3.7 — 8.2	20:1	40	50
MT982A13	8.2 — 18.0	20:1	40	50
MT983A	4.0 — 26.5	10:1	37	50

Table 1 — Specification summary of some selected Maury tuners.

Conclusions

Automated mechanical tuners are the best solution to many measurement applications, but the repeatability specification is very important. When evaluating automated tuners, insist on a worst case total repeatability spec for all available positions over the full frequency range. Avoid poor quality tuners that have misleading specifications. Maury produces high quality tuners that have specifications that can be relied upon!

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