FOCUS MICROWAVES GROUP

Delta Tuners Inherently Offer Better Accuracy On-Wafer

Product Note #94

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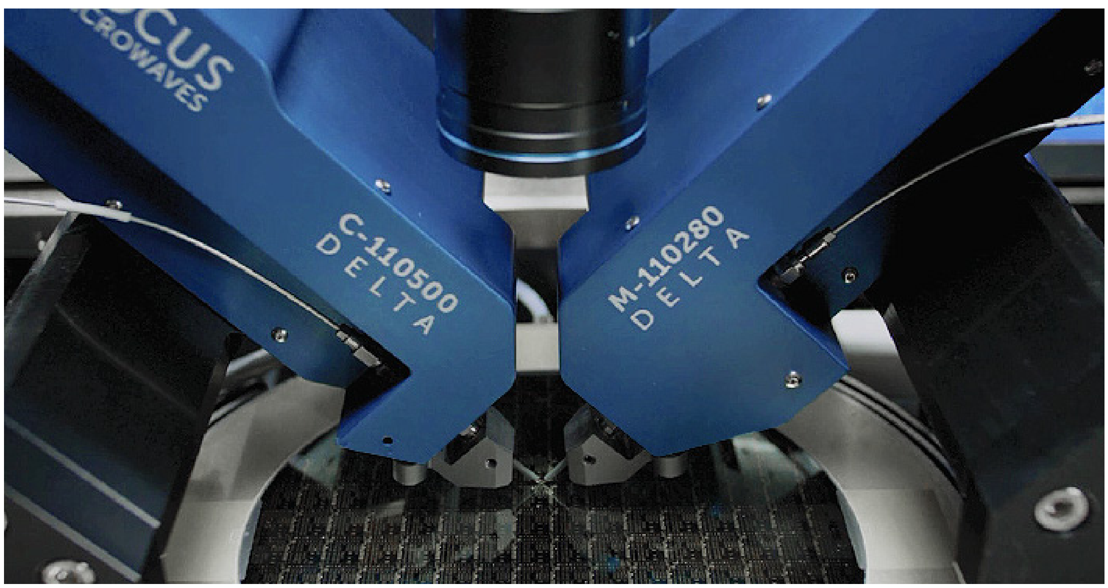


This Product Note explains and proves how Delta Tuners offer inherently better accuracy for On Wafer Load Pull

Summary

The DELTA tuner technology has been introduced in 2019 (Focus US patent 11,002,762) to achieve:

- Higher GAMMA on-wafer
- Lower phase dispersion (skewing) for modulated signal.
- Best integrability on-wafer probe stations
- Reduced injected power requirement in hybrid systems.

All this has been documented in Focus' Product Note 93 (March 2019).

However, a less known, but critical, benefit, characteristic to the DELTA concept, is higher operational tuning accuracy, particularly under very high GAMMA (Γ).

All things being equal, the fact that DELTA eliminates the adapters and transmission cables between the tuner itself and the wafer probe allows operating the tuner itself at lower internal reflection factor S_{11} for the same Γ_{DUT} and this also reduces unavoidable tuning errors.

Facts

Slide screw Impedance tuners have been, historically, bulky sturdy boxes, dictated by the extreme mechanical precision required for reliable and accurate repositioning of one or more metallic tuning probes (slugs) in a perfectly straight aluminum slabline. Typical vector tuning accuracy data reached between 0.01 and 1% for GAMMA up to 0.95. In many cases the tuner accuracy is in par with the VNA accuracy, especially when the VNA is not expertly calibrated. This includes all VNAs (Keysight, R&S, Anritsu).

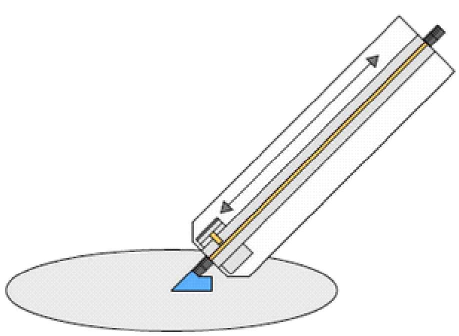
The only objective and most sensitive accuracy test for tuners is therefore the back-to-back verification, because in this case all possible errors amplify. In a perfectly calibrated environment, we have observed on-wafer back-to-back transducer gain GT errors of harmonic tuners with 3 slugs of less than 0.05dB up to GAMMA=0.95.

This to say that measurement is a search for an elusive truth and tuners are not necessarily the main source of error, the calibration and stability of the test environment are also crucial. When measuring non-50 Ohm on wafer we swim in deep waters. Anything can go wrong, starting with the reliability of the contacts on the chips.

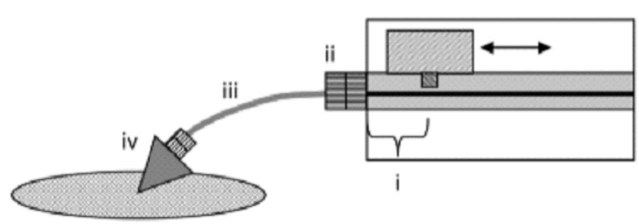
On-wafer testing requires using long cables between the probes and the tuner itself: items I, II, III, IV in the picture below. This increases the insertion loss between the probe tip and the tuner slug. Since we cannot manipulate the wafer probes, we at least need to look for the ones with the best S_{21}.

We must also bring the tuning probe (slug) as close to the wafer probe as physically possible, and this is what DELTA does. We will show here how and why the reduction in the insertion loss in the DELTA enhances the measurement accuracy.

DELTA TUNER



TRADITIONAL TUNER



Proof

The available gain of a transmission line section with insertion loss $|S_{21}|$ terminated by a reflection $|S_{11}|$ is:

$$G = \frac{|S_{21}|^2}{1-|S_{11}|^2}$$

S_{11} and S_{21} are measured with a certain systematic error, or uncertainty, ΔS_{11} and ΔS_{21}, which is normal to every observation, $S_{21}=S_{21o}\pm\Delta S_{21}$, $S_{11}=S_{11o}\pm\Delta S_{11}$.

The uncertainty (error) in the available gain is either analyzed by deriving $G\pm\Delta G$ or $\Delta G/G$.

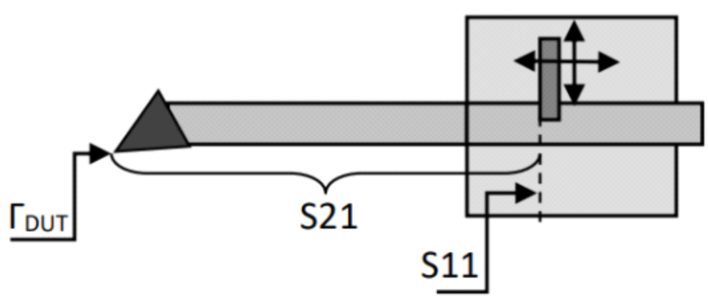
The available gain error equation is:

$$dG = \frac{\partial G}{\partial S_{11}}dS_{11} + \frac{\partial G}{\partial S_{21}}dS_{21}$$

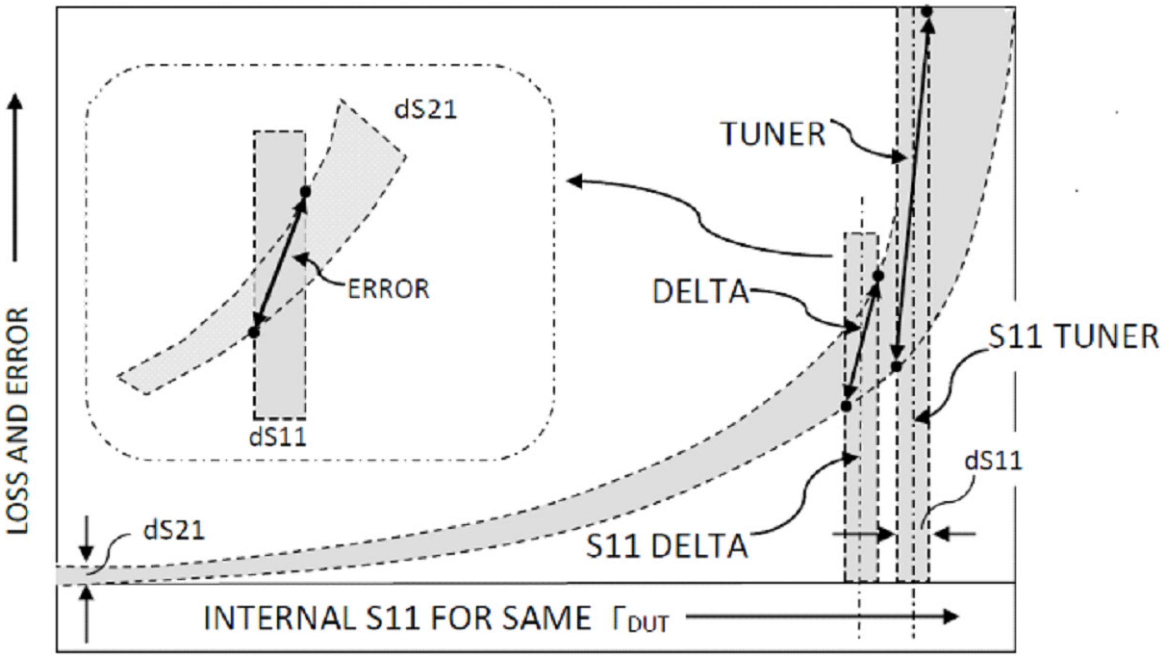
Consequently:

$$|\Delta G| = \frac{2}{1-|S_{11}|^2}\left[G|S_{11}||\Delta S_{11}| + |S_{21}||\Delta S_{21}|\right]$$

Under high VSWR, when S_{11} gets closer to 1, and S_{21} approaches 0, the expression of G becomes indefinite ≈0/0, however both G and ΔG converge to zero and it is more convenient to analyze ΔG/G to evaluate the total measurement error. It is obvious that in an indefinite critically balanced situation close to 0/0 any minor disturbance will lead to unacceptable uncertainty.



Proof



The graph above depicts ΔG/G as a function of the required Γ_{DUT} and clearly shows the multiplying effects of any errors in both S_{11} and S_{21} under high Gamma. It also demonstrates that by reducing the insertion loss in the tuner DELTA, the errors in the measurements are drastically improved.

IN SHORT:

DELTA tuners can measure under
higher Γ_{DUT} with smaller error, as the shorter interface lowers the internal S_{11} required to obtain same Γ_{DUT}. This improvement of Γ_{DUT} is equivalent to twice the losses removed by shortening the long access path.