Delta Tuners For 5G Applications

Product Note #93

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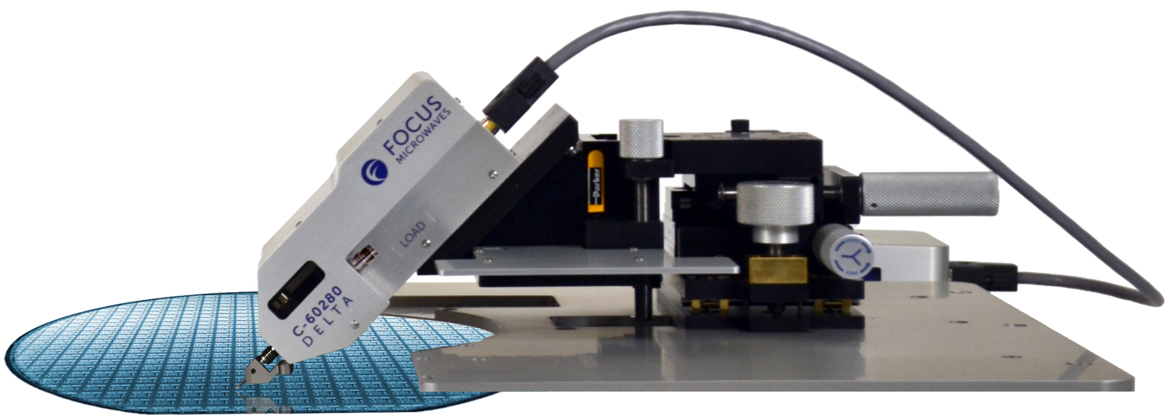


This Product Note is an introduction to Delta Tuners for 5G applications.

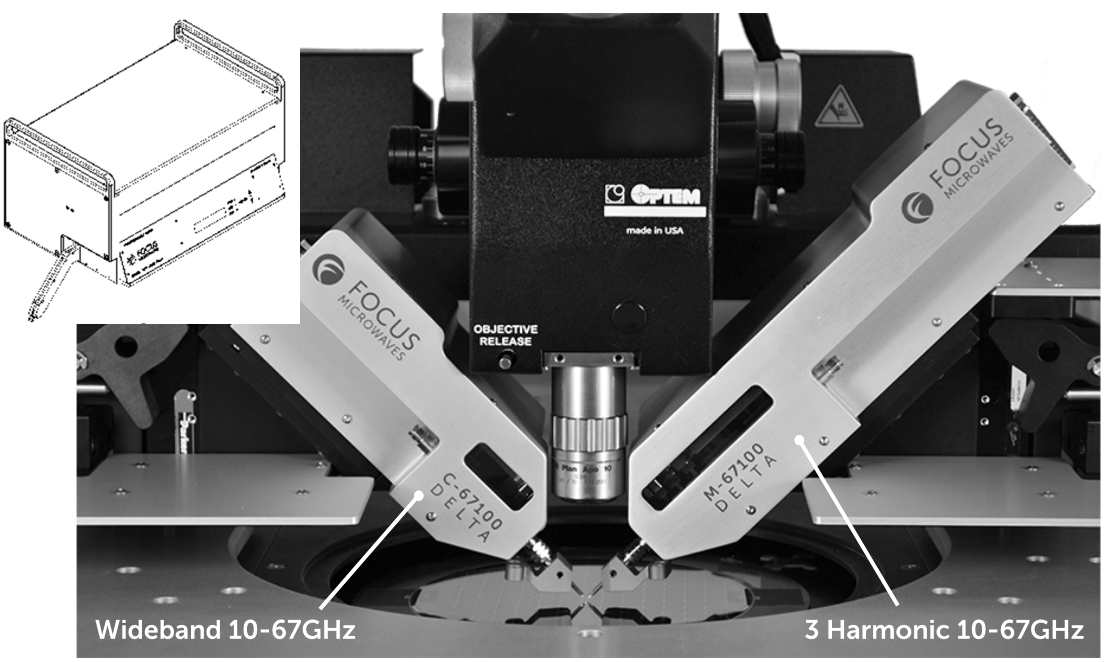
Summary

Except for limited tuning speed, electro-mechanical tuners have superior performance, such as high-power handling and multi-octave bandwidth compared to all other solutions, except for tuning range. Whereas tuning range of the tuners themselves is enough (VSWR $\geq$ 30:1), when integrated in wafer setups the loss of the cables and probes reduces the VSWR to values ≈ 6-7:1, which is often insufficient.

Extended slablines (picture insert) have alleviated the problem, because they are less lossy than cables, but do not represent the best compromise, since the tuning probe (slug), which creates the reflection, is still inside the tuner body far away from the DUT. A new tuner type, the "DELTA" wideband and harmonic tuners solve this problem: in these tuners, designed mainly for 5G applications (10-67GHz), the slabline is short, in line and in direct contact with the wafer probe and the tuning probe is immediately adjacent to the tuner test port. This allows VSWR at DUT reference plane higher than 10:1 at 30GHz, which is enough for many 5G applications.

DELTA tuners:

1. Create higher Gamma on-wafer.
2. Reduce Impedance skewing**.
3. Reduce hybrid feedback power.

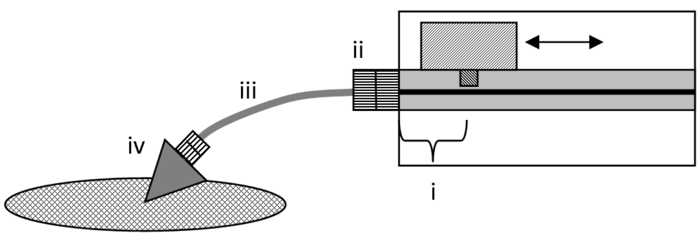


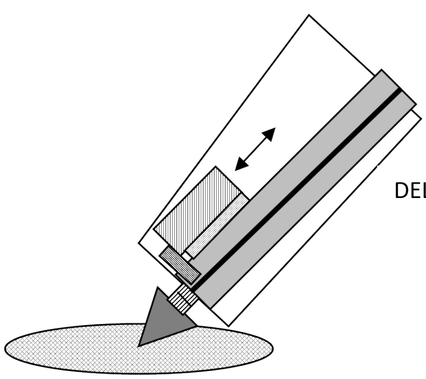
(*) patent pending; *(**) Spread of reflection factor angle for modulated signal*

Higher Gamma On-Wafer

The reflection factor Gamma.DUT presented to the DUT is the reflection factor Gamma.PROBE, created by the tuning probe inside the tuner, reduced (approximately) by the insertion loss of

(i) The transmission line section inside the tuner,
(ii) The test port adapter,
(iii) The cable or bendline between test port and wafer-probe,
(iv) The wafer-probe and its adapter.
DELTA tuners reduce item (i) and eliminate items (ii) and (iii).





(i) DELTA tuners are made using miniature carriages and brackets that allow the tuning probes to be placed immediately next to the test port.
(ii) There are no test port adapters.
(iii) There are no cables or bend-lines

(*) patent pending; *(**) Spread of reflection factor angle for modulated signal*

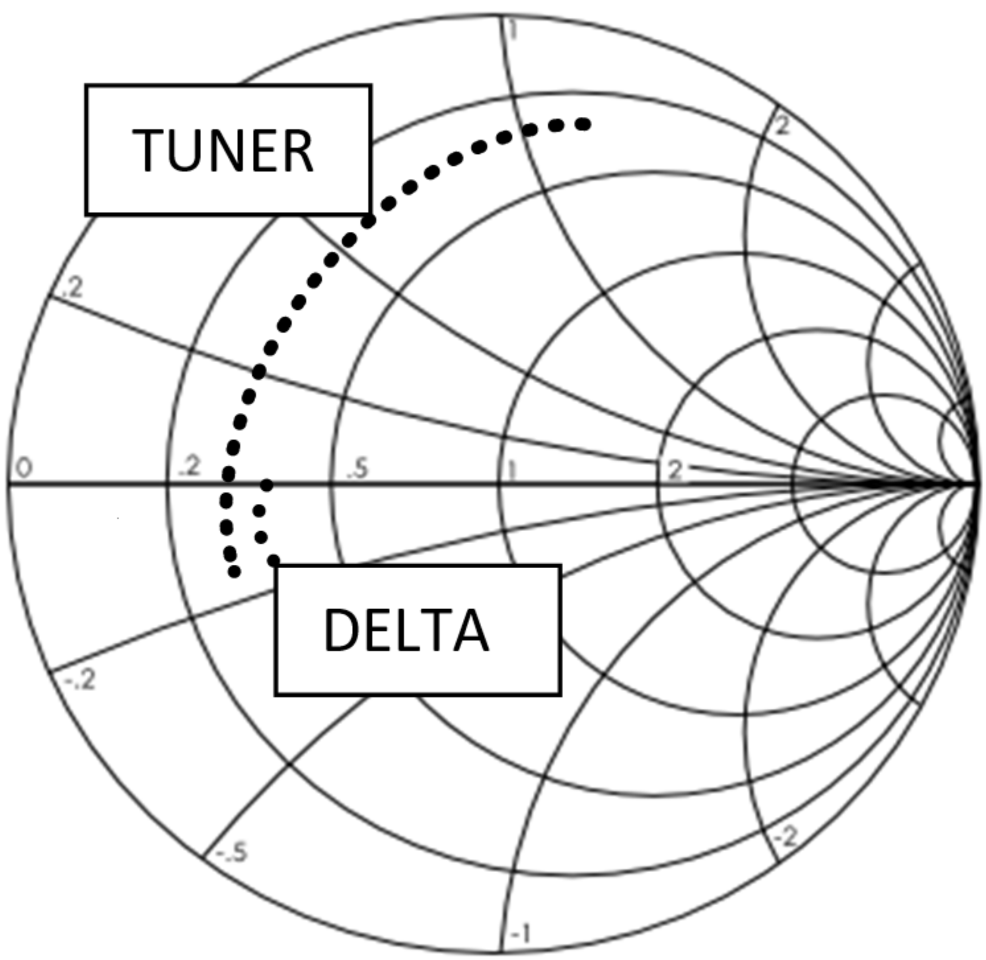
Reduced Impedance Skewing

Impedance skewing or spread comes from the fact that the phase of the reflection factor changes with frequency. The phase of a passive reflection is $\Phi=-4*\pi*L_{el}/\lambda$

whereby L_{el} is the electrical length of the section between the test plane (DUT reference) and the reflective element (in our case the tuning probe). Converted in degrees this gives: $\Delta\Phi[^{o}]=-0.024*L_{el}[cm]*\Delta F[MHz]$.

It is to notice that $\Delta\Phi$ does not depend on the frequency **F** itself, only of the modulation frequency ΔF. Therefore, the shorter L_{el} the smaller $\Delta\Phi$. Or, the skewing due to the tuner assembly in DELTA tuners, is approximately 10 to 20 times smaller than in tuners with cable or bendline (L_{el}.DELTA~1-2cm, L_{el}.TUNER~10-20cm [items (i), (ii) and (iii) above]).

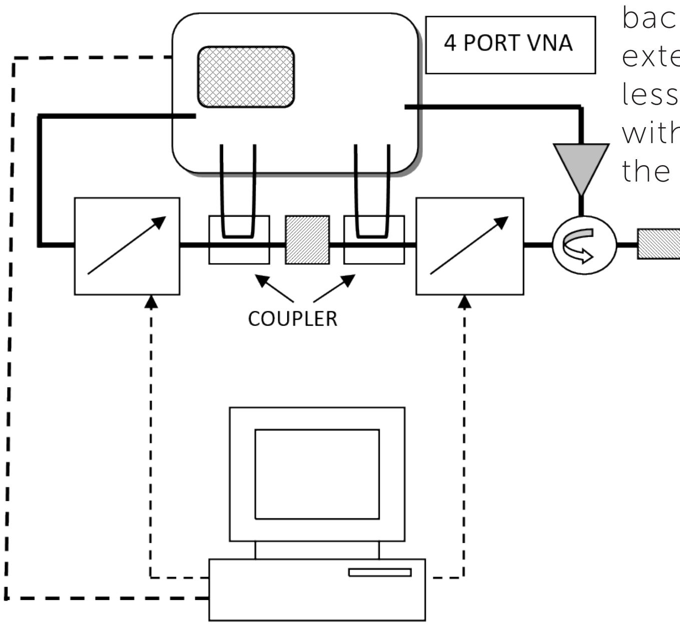
This enables and of course simplifies Intermod and multi-tone testing using passive tuners only.



(*) patent pending; (**) Spread of reflection factor angle for modulated signal

Lower Feedback Power

At frequencies above 28GHz the interconnections of the multiple parallel cells of power transistors create parasitic capacitors and leading inductors that increase the internal output impedance, or the optimum reflection factor to be matched. Wherein at 2GHz Zout≈1-2Ω (VSWR≈25-50:1) at 30GHz it is rather ≈5Ω (VSWR≈10:1). If a passive tuner can reach such VSWR at the transistor reference plane on wafer, then the overall setup simplifies radically. This is what makes Focus' new DELTA tuners so attractive. Hybrid (active+passive) tuning is often not necessary.



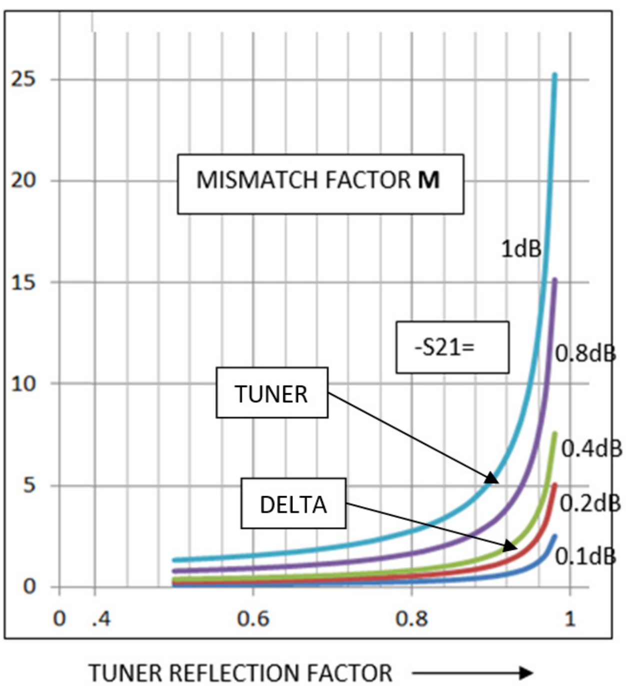
Hybrid tuning is not a panacea. Whereas it allows high VSWR at DUT reference plane, it still remains a rather complex test system with feedback power amplifiers and, often, a second, synchronized, signal source, plus the requirement for in-situ vector power wave measurement, possible through directional couplers inserted between the DUT and the tuner; this on the other hand reduces the tuning range and increases the need for even higher power amplifiers.

Passive pre-matching tuning in hybrid systems reduces the requirement for high power from the feedback amplifiers, but only to some extent: passive tuners are not lossless. Tuner loss increases rapidly with reflection factor and so does the power requirement.

(*) patent pending; *(**) Spread of reflection factor angle for modulated signal*

Lower Feedback Power

The critical quantity in tuner loss calculations is "mismatch loss". Mismatch loss is $S21^2/(1-S11^2)$
For high S11 values, as needed to pre-match for enhancing the passive reflection factor with active injection in a hybrid configuration, it happens that any increase in insertion loss S21 (due to cables, adapters etc. between tuner and DUT) is multiplied by a factor **$M=1/(1-S11^2)$**.
Typical values of the multiplication factor:
S11=0.9 (VSWR=19:1) -> **M=5.3;**
S11=0.96 (VSWR=50:1) -> **M=13.**



To increase the reflection factor at the probe tip (DUT) and minimize the power loss we must **maximize S21** and **minimize S11**. Any mismatch loss must be compensated by additional injected power in a hybrid (active/passive) tuner.

The DELTA tuners do just that. In most cases they even allow creating the required VSWR at the probe tips using passive tuning only. But even in hybrid configurations the higher S21 and the lower S11 required to pre-match reduce the injected power.

Or, if the additional insertion loss of the cable, or the bendline, necessary without DELTA tuner, is 0.3dB at 30GHz, then the required feedback power at S11=0.9 is 1.5dB (x1.4) resp. 4dB (x2.5) higher at S11=0.96. Whereas a DELTA tuner can operate with a
10W amplifier, a normal tuner requires at least 25W.

Example:
|S21|=1dB;|S11|=0.95 of a normal tuner versus |S21|=0.2dB;|S11|=0.75 of a DELTA tuner saves ~9.8dB=9.6, a 5W versus a 48W amplifier.

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