

## *Product Note 46*

# Programmable “Combo” Load Pull Tuners For Fundamental and Harmonic Tuning

**Fundamental and Harmonic Load Pull Tuners model CCMT-option H2/H3 perform independent selective tuning at the fundamental and one or both harmonic frequencies  $2f_0$  and  $3f_0$  in a wide frequency range, reaching from below 1 GHz and**

**up to 60 GHz in different models. These tuners can be used at the source and load side of transistors in order to determine simultaneously the optimum impedances at  $f_0$ ,  $2f_0$  and  $3f_0$  for Power, Gain, Efficiency etc...**

## **Description**

The new electromechanical tuners combine the distinct advantages of Programmable Harmonic Tuners PHT [1] and Computer Controlled Microwave Tuners CCMT [2]. They include in the same box a harmonic tuning section for  $2f_0$  (and/or  $3f_0$ ) followed by the fundamental tuning section, each being controlled and acting independently. The new tuners use the same proven mechanical components of over 350 already built and operating CCMT (December 1997). They are compatible with all existing FOCUS load pull systems and can be controlled by an upgraded CCMT tuner controller, model CC-4. They may replace existing load pull tuners and provide very high reflection factors at the harmonic frequencies  $2f_0$  and  $3f_0$ , up to 0.98 (VSWR  $\approx 100:1$ ), and 360 degrees of continuous automatic phase control.

Their tuning capability at the fundamental frequencies is practically equivalent to existing high VSWR tuners of FOCUS. The harmonic section of the CCMT-H2/H3 tuners has very low insertion loss at the fundamental frequency  $f_0$  ( $< 0.2$  dB) and therefore negligible effect on the CCMT's tuning range at the fundamental frequency.



Figure 1: Programmable “Combo” Tuner for  $f_0=1.6-18$  GHz,  $2f_0=3.2-18$  GHz.

Programmable Harmonic Tuners (PHT [1]) as well as “Combo” tuners CCMT-H2/H3, have the following advantages compared to other Harmonic Tuning techniques, especially those using cumbersome, lossy and oscillation prone Diplexers and Triplexers and associate Active Modules:

**CCMT-H2/H3**

- Generate  $\Gamma_{max}$  up to  $\approx 0.98$  at one or both harmonic frequencies
- Generate  $\Gamma_{max} \approx 0.9$  at the fundamental frequencies
- Eliminate "diplexers" and "triplexers"
- Eliminate parasitic oscillation-prone "active modules"
- Reduce the risk of low frequency spurious oscillations of the DUT, because of their low-pass characteristics.
- Can handle high power
- Are fully compatible with existing Focus L/P systems
- Are available up to 60 GHz
- Are configurable either for 2fo and 3fo (-H2/H3) or for only 2fo (-H2)

The harmonic tuning range of CCMT-2H/3H is nearly 8% (150-200 MHz in the PCS bands) around the fundamental center frequency. Harmonic frequencies can be changed by replacing the harmonic resonators following a very simple procedure and recalibrating only the harmonic section. Resonators can be purchased at a later time for new frequencies within the operation bandwidth.

Power handling is limited only by the connectors used (50 Watt min with APC-7). For higher power CCMT-2H/3H with N or 7/16 connectors can be used.

Harmonic Tuner Calibration provides for data required in an automatic synthesis of harmonic impedances at 2fo and 3fo (in addition to impedance synthesis at the fundamental frequency fo, which is inherent part of existing CCMT Load Pull systems).

Available “Combo” Tuners

Fo	2Fo/3Fo	Connectors
0.8 -18 GHz	1.6 – 18 GHz	APC-7
4 – 26 GHz	8 – 33 GHz	3.5 mm
6 – 40 GHz	12 – 44 GHz	2.9 (K)
6 – 50 GHz	12 – 50 GHz	2.4 mm
10 – 50 GHz	20 – 60 GHz	1.9 (V)
2 – 40 GHz	4 – 44 GHz	2.9 (K)

Table I: Typical “Combo” Tuners. Other combinations of frequencies and connectors possible on “custom” base.

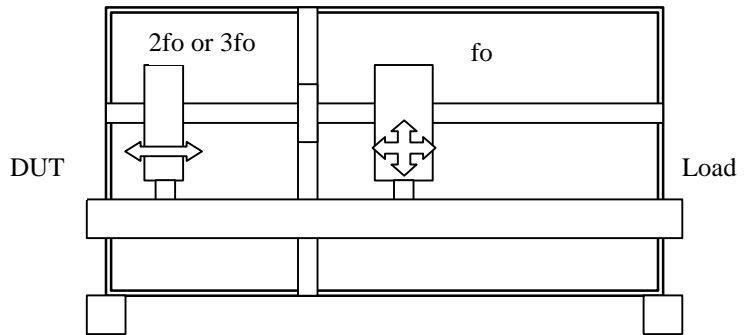


Figure 2: Design of output “Combo” Tuner, model CCMT-2H/3H

Depending on the frequency range and test requirements the “Combo” tuner’s harmonic section can be fitted with a double resonator layout for high tuning isolation between fundamental and harmonic impedances. Typical “uncorrected” isolation of 15-20 dB can

his way be increased to over 30dB. In real operation effective isolation is always improved by the “tuning back” capability of the measurement software [3].



Figure 3: Ultra wideband “Combo” tuner, model 3003-2H with 3.5 mm connectors,  $f_0=3-30$  GHz,  $2f_0=6-33$  GHz.

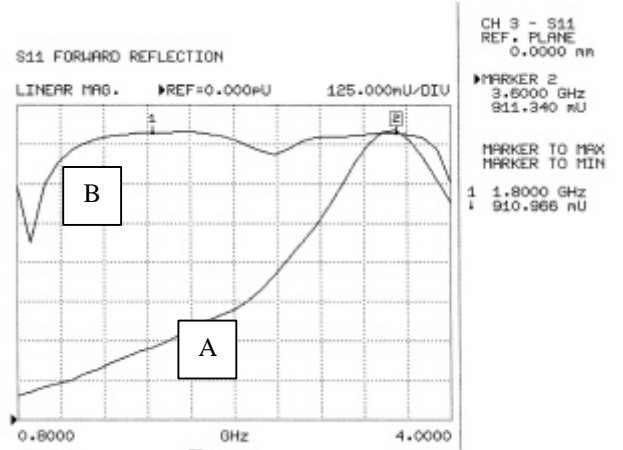


Figure 5: Tuning using “Combo” tuner model 1816-2H; trace A: fundamental probe extracted; trace B: fundamental probe at maximum depth; marker 2 ( $=\Gamma(2f_0)$ ) is unaffected by fundamental tuning.



Figure 4: Wideband “Combo” tuner, model 5010-2H with 1.9 mm (V) connectors,  $f_0=10-50$  GHz,  $2f_0=20-60$  GHz designed for “on-wafer” load pull.

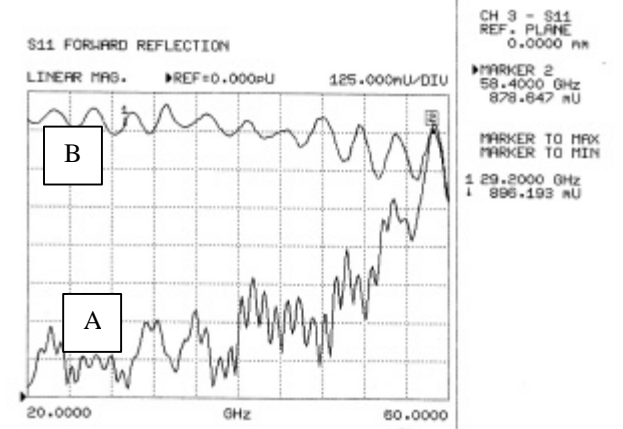


Figure 6: Tuning using “Combo” tuner model 5010-2H; trace A: fundamental probe extracted; trace B: fundamental probe at maximum depth; marker 2 ( $=\Gamma(2f_0)$ ) is unaffected by fundamental tuning.

## Harmonic Load Pull Setup using CCMT-2H Tuners

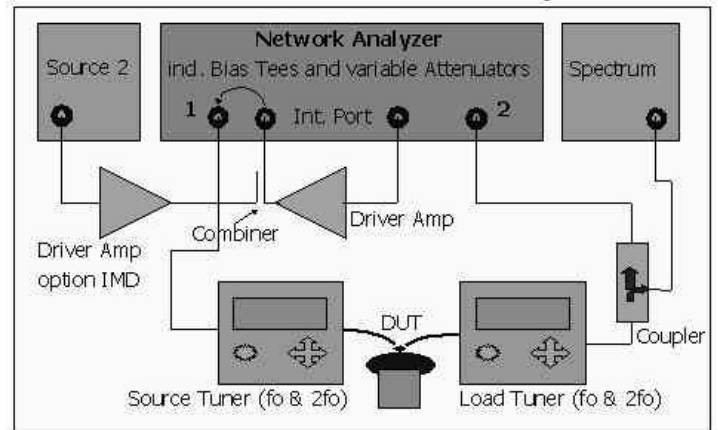
The harmonic load pull setup proposed here (figures 7, 8) is built using a network analyzer with an auxiliary port, a test fixture (or probe station) and two programmable harmonic “combo” tuners models 1816-2H, 3003-2H or 4006-2H. These tuners include fundamental heads from 1.6 to 18 GHz, and 3 to 30 GHz and 6 to 40 GHz and harmonic heads from 3.2 to 18, 6 to 33 GHz and 12 to 44 GHz correspondingly (figures 1, 3, 4).

The network analyzer serves as signal source and fast receiver and includes internal bias tees for DC biasing the DUT. For Intermod tests a second synthesizer is required and the two signals are combined at port 1 of the analyzer and injected into a spectrum analyzer via an output directional coupler.

The setup is calibrated using a power meter connected to port 1 of the analyzer for absolute power reference.

The system is controlled by an IBM-PC<sup>®</sup> equipped with a GPIB interface and a CC-3 tuner controller, who can position and initialize the two “combo” tuners with three axes each.

The tuners can be calibrated “in-situ” at  $f_0$  but must be replaced by a Through line for harmonic calibrations at  $2f_0$  (or  $3f_0$ ).



Figures 7,8: Integrated harmonic load pull system (picture shown with test fixture and 1.6 to 18 GHz tuners). Operational up to 44 GHz with 4006-2H tuners.

### Literature

- [1] Product Note 44: “Programmable Harmonic Tuner – PHT”, Focus Microwaves, December 1997
- [2] Product Note 41: “Computer Controlled Microwave Tuner – CCMT”, Focus Microwaves, January 1998
- [3] Application Note 33: “Harmonic Tuning Isolation in Load Pull Setups using PHT”, Focus Microwaves, May 1999