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Technical Note 1-2000

Brief Comparison of Harmonic Load Pull Solutions

Harmonic Load Pull is important for designers of PCS power and linear amplifiers; harmonic tuning improves transistor efficiency and linearity in this competitive field, where a large number of units must be manufactured at minimum cost and extracting the best performance of the costly power transistors is a crucial economic consideration.

This note compares the two first of the following harmonic load pull solutions:

- HLP with Di- or Triplexers (Maury)
- HLP with Harmonic Tuner (Focus)
- Active Harmonic Load Pull (Various)
- HLP with multistate PIN diode tuners (ATN)

a. HLP with Di- or Triplexers

The basic block diagram is given in figure 1; in order to perform Source and Load harmonic pulling a **total of two triplexers and four harmonic tuners are required.**

Advantages:

- Straightforward to understand
- Can be an extension to existing load pull setups
- Can use tuners with constant Γ (SWR≈50:1 at 2fo, 3fo) or variable Γ (SWR<15:1 at fo, 2fo, 3fo)
- Is relatively easy to calibrate (each tuner separately and the triplexers as four-ports).

Disadvantages: Most disadvantages come from the use of the triplexers; triplexers are filter combinations developed for telecommunication networks and not for load pull measurements, therefore:

- Lossy triplexers will reduce the SWR at DUT reference plane significantly. Typical triplexer loss at PCS frequencies is 0.5dB, much higher at higher frequencies. This reduces SWR by at least 1dB (example: SWR of 20:1 /Rmin=2.5Ω at tuner reference plane is reduced to 9.5:1 /Rmin=5.2Ω);
- Wideband and high frequency triplexers are not easy to procure
- Out-of-band reflections of waveguide (=low-loss) triplexers are high; this causes parasitic oscillations.
- Low out-of-band reflection triplexers are made from suspended stripline substrates and suffer severe power limitations (a few Watts Max).
- Availability of triplexers from external vendors is questionable and has typically long lead times.

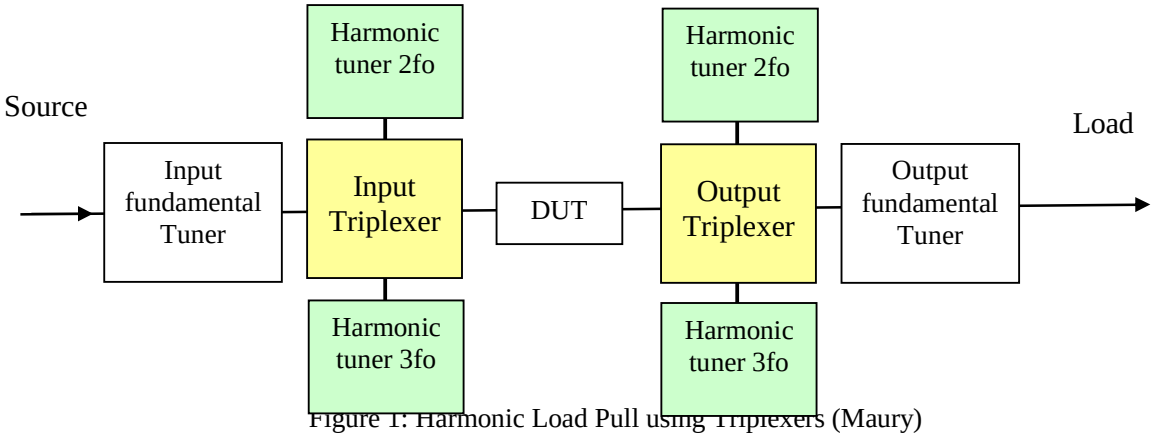

Figure 1: Harmonic Load Pull using Triplexers (Maury)

b. HLP with Focus PHT Harmonic Tuners

Programmable Harmonic Tuners, model series PHT[+], invented and first introduced by Focus in 1997, are meanwhile the technique of choice for harmonic load pull worldwide, for several practical reasons:

Advantages: Among others, PHT Harmonic Tuners

- Generate gamma up to 0.98 at both harmonic frequencies
- Eliminate diplexers and triplexers in the setup
- Have extremely low insertion loss at fo, therefore
- They do not require active modules to increase reduced reflection factors
- Have low reflection at fo (<-25dB) and lower frequencies, therefore
- They do not create risk of low frequency parasitic oscillations
- Handle high power (typically 5 to 10 times more than fundamental tuners at high SWR)
- Are compatible with existing Focus and Maury Load Pull systems
- Can be calibrated very fast (2-5 minutes per frequency point, depending on the VNA used)
- Switching between frequency bands and applications is easy and can be made "in-situ".

Disadvantages: we are aware of a single disadvantage

- PHT cannot change the amplitude of the reflection factor at 2fo and 3fo, only its phase [6]; where this is an absolute requirement a triplexer solution (offered also by Focus as a last resort alternative) or an active-harmonic load pull system must be acquired.

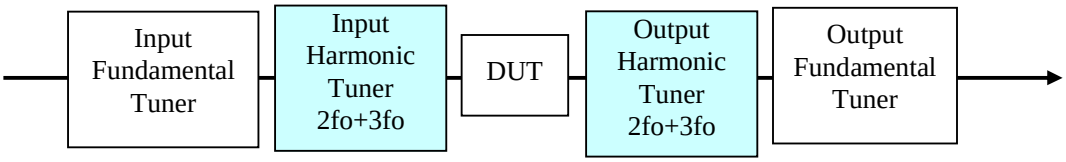

Figure 2: Harmonic Load Pull using Focus PHT harmonic tuners (Focus)

Item	Focus	Maury	ATN
Maximum $\Gamma(fo)\|_{DUT}$ [1]	0.89 [2]	0.805 [3]	0.8
Maximum $\Gamma(2fo)\|_{DUT}$	0.97	0.85	0.8
Maximum $\Gamma(3fo)\|_{DUT}$	0.95	0.85	0.8
Maximum Power (fo)	>100W	3-10W (Triplexer)	2-5W
Tune to other bands	Change Harmonic Resonator in-situ	Change Triplexer	Included as far as bandwidth OK
Source Harmonic Tuning	Yes	Yes	No
Parasitic Oscillations	No	Yes	Not enough data
Total Calibration Time	8-10 min	≈1-3 hours	> 5 hours
Harmonic Isolation	45dB	60dB	20dB
Need for Active Modules	No	Probably Yes	Yes [5]
Triplexers (≈12 wk deliv)	No	Yes	No
Tuning Points	5-10,000,000	1-2,000	≈1000 max
Approximate Price (US$)	≈125k	≈135k [4]	≈120k [4]

Table I: Comparison of key characteristics of the available Harmonic Load Pull Systems

Remarks:

(1) $|_{DUT}$ means at the test fixture port
(2) ≈0.96 with PMT (Prematching Tuners, SWR≈100:1)
(3) Assuming a "good" triplexer with 0.5dB insertion loss
(4) Use with precaution, prices and discounts may vary significantly
(5) Active Modules are though not offered by ATN
(6) PHT generates $|\Gamma(2fo,3fo)|\approx 1$, as required for almost all classes of operation: A, AB, C and F.

+ The company Maury Microwave also offers "harmonic tuners" model MT999, one tuner per harmonic frequency; however these harmonic tuners differ radically from Focus' PHT harmonic tuners as to they represent a wideband variable short to the DUT, instead of a frequency selective reflection as the PHT, and cannot be used without a triplexer in the setup.