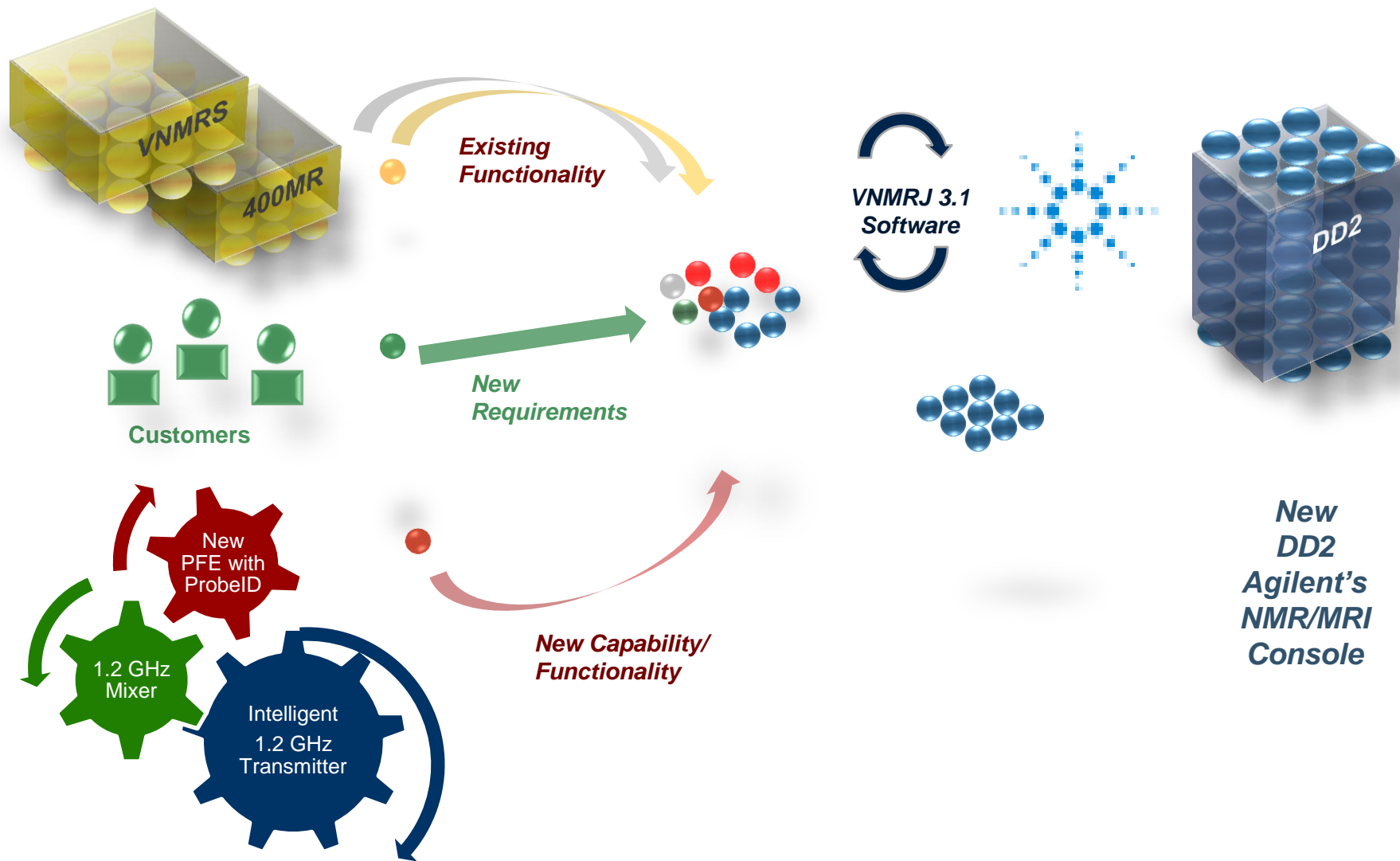


DD2 NMR/MRI Console



Agilent Technologies

DD2: Agilent's NMR/MRI Console



**New
DD2
Agilent's
NMR/MRI
Console**

DD2: Agilent's NMR/MRI Console

- ❖ **Enhancements to all Products**
 - ❖ **400MR DD2 & NMR/MRI DD2**
- ❖ Intelligence embedded in the RF transmit path
- ❖ Leveraging Agilent Expertise for Design and Manufacturing
- ❖ Synergy with the World's Premier Measurement Company



DD2: Agilent's NMR/MRI Console

- **DD2 is the second-generation DirectDrive Console**
- *Still a controller on every channel*
- *Still no hidden timing delays*
- *New intelligent Transmitter board*
- *New optimized Mixer/Receiver module*



DD2: Agilent's NMR/MRI Console

- ❖ **New capabilities – 400MR DD2**
- ❖ *Intelligent* transmitter board
- ❖ Redesigned mixer assembly
- ❖ High performance lock filter
- ❖ Improved pneumatics with high / low temp option
- ❖ ProbeID link to physical probe hardware & stored data
- ❖ Integrated cryogen monitor

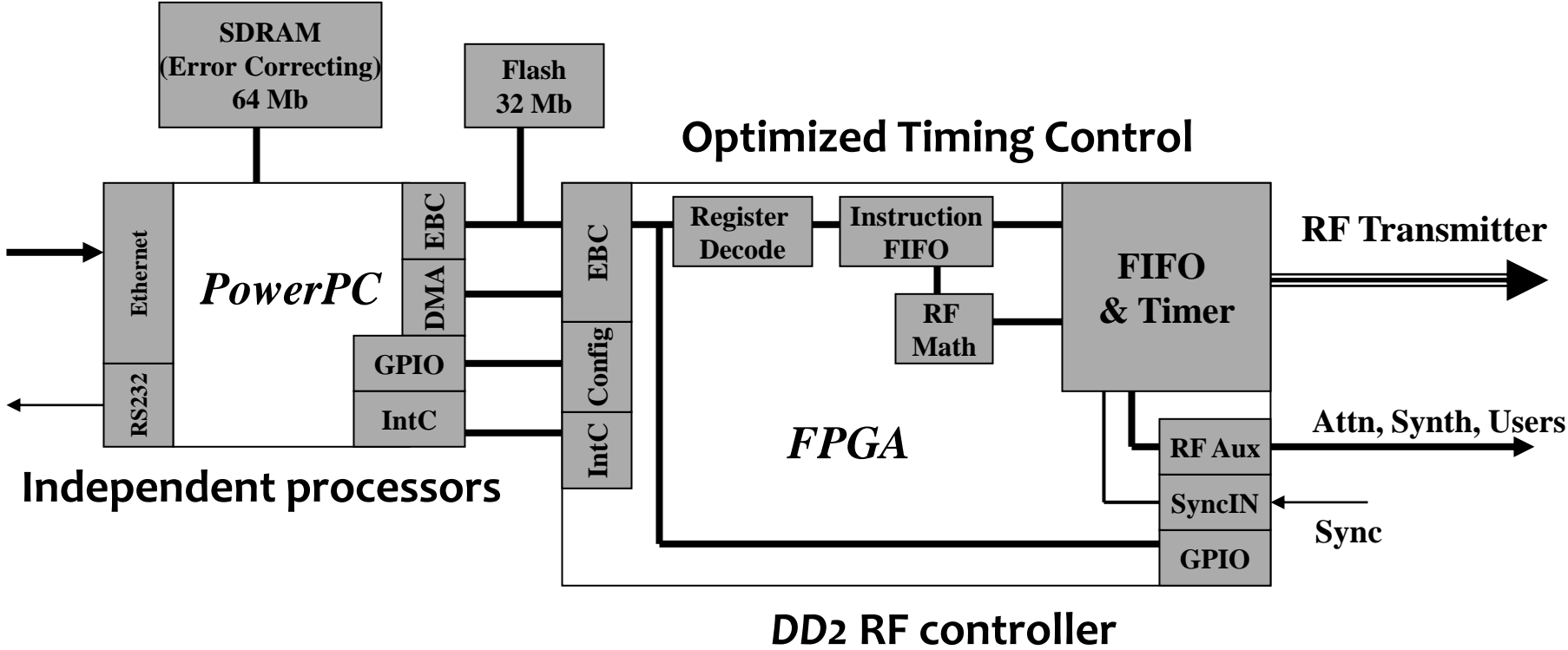


DD2: Agilent's NMR/MRI Console

- ❖ **New capabilities – DD2**
- ❖ *Intelligent* transmitter board
- ❖ Redesigned mixer assembly
- ❖ Digital phase shifter
- ❖ 16-bit phase
- ❖ 16-bit amplitude
- ❖ 25 ns event time
- ❖ 12.5 ns resolution



DD2: Agilent's NMR/MRI Console



DD2: Agilent's NMR/MRI Console

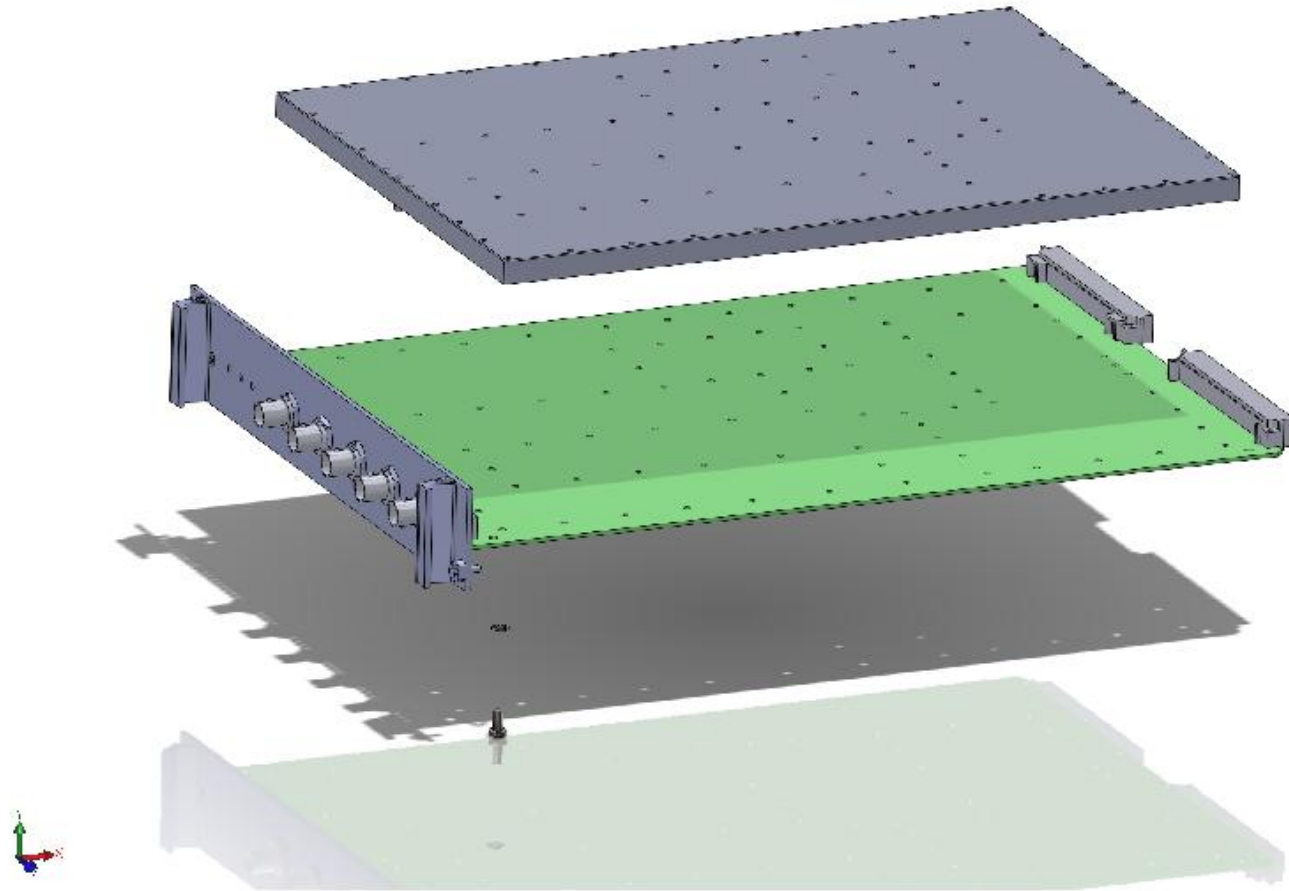
Intelligent combined attenuator and transmitter board

- ❖ FPGA technology extended to the RF transmitter
- ❖ Processing power applied to the transmit path
- ❖ Automatic hardware discovery and identification
- ❖ Automatic hardware/firmware configuration & update
- ❖ Unique ID to retain manufacturing history
- ❖ Field deployable software updates
- ❖ Front panel diagnostics
- ❖ Correction Tables resident on transmitter board
- ❖ Temperature monitoring resident on transmitter board



DD2: Agilent's NMR/MRI Console

Transmitter assembly



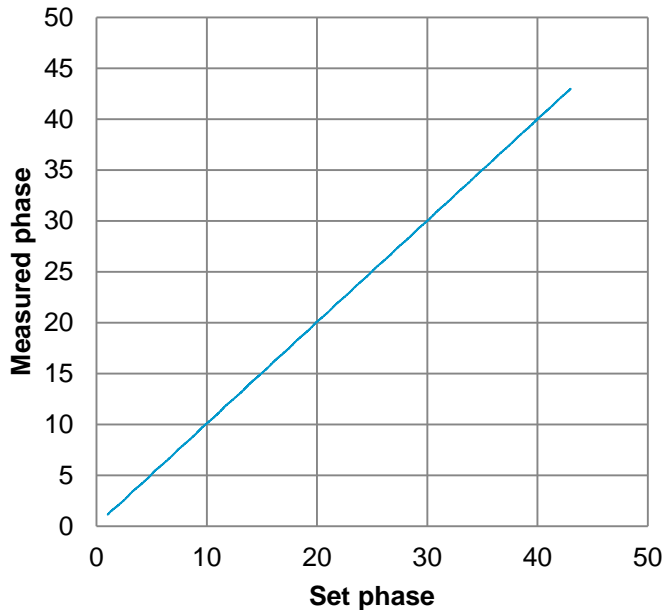
DD2: Agilent's NMR/MRI Console

Quality NMR requires fast and accurate RF waveforms

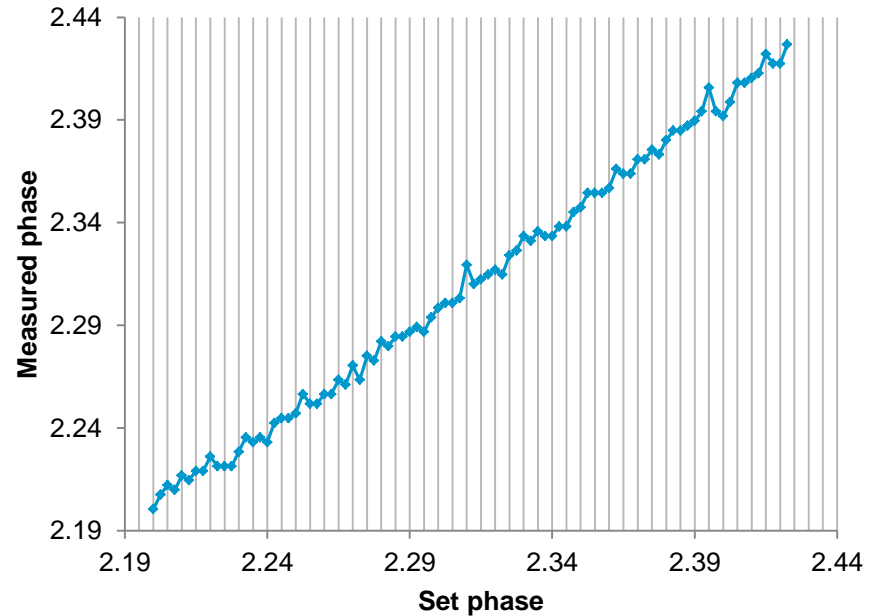
- ❖ Decreased step size to 25 ns
- ❖ Precise 12.5 ns resolution
- ❖ Digital Phase Shifter
- ❖ 16 bit phase with $\sim 0.0055^\circ$ resolution
- ❖ 16 bit fine amplitude control
- ❖ 100 dB attenuation range with 0.5 dB steps
- ❖ Waveforms have improved event time with sustained rates
- ❖ Full Transmit Chain Linearization

DD2: Agilent's NMR/MRI Console

The **digital phase shifter** provides phase-shifts with the **16-bit $\sim 0.0055^\circ$** precision and replaces the quadrature hybrid of VnmrS.



0°-42° in 1° steps

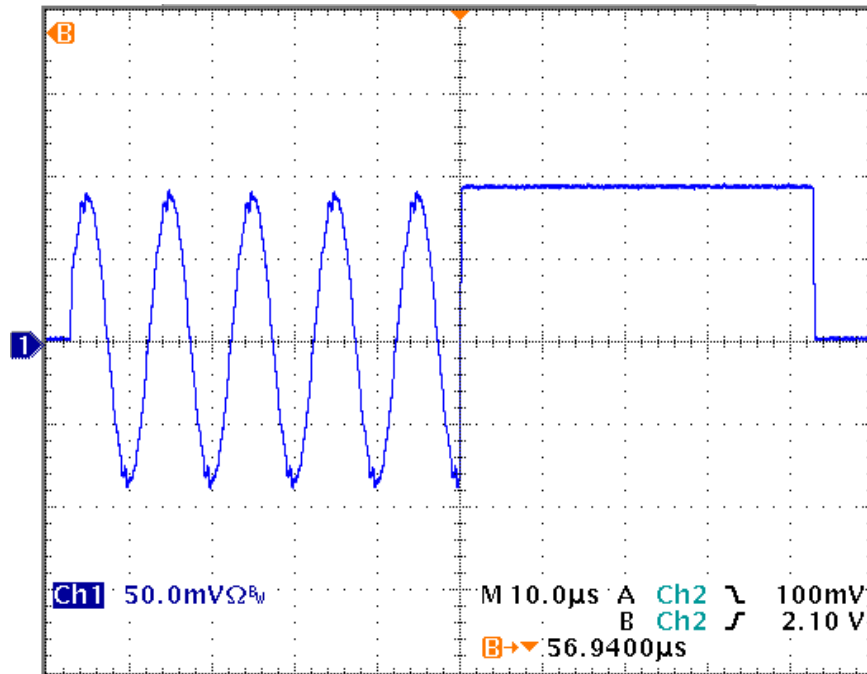


2.2000-2.4200° 1-bit steps

The NMR test HS90, a looped 8-pulse $[XYYXXYYX-acq]_n$ windowed multi-pulse sequence is used to evaluate phase shift accuracy. The signal offset of HS90 (vertical) is plotted against (phase setting) over a 42° and a 0.22° range. The plot is linear with uncertainty at the 1-bit level.

DD2: Agilent's NMR/MRI Console

Waveform frequency switching using a phase ramp

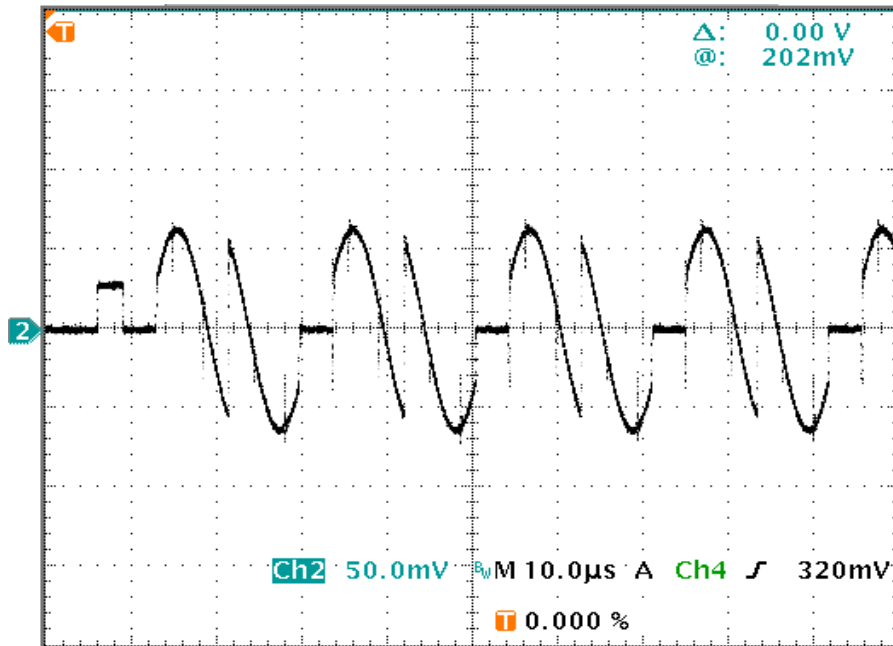
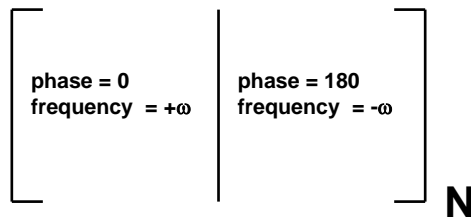


A scope picture of a deconvoluted 100 kHz frequency jump with **a simultaneous 180° phase shift**. The frequency and phase-shift times can be (<25 ns) using DD2.

DD2: Agilent's NMR/MRI Console

FSLG uses the continuous 25 ns steps of the DD2 transmitter

The FSLG Pattern



A scope shot of a deconvoluted FSLG waveform

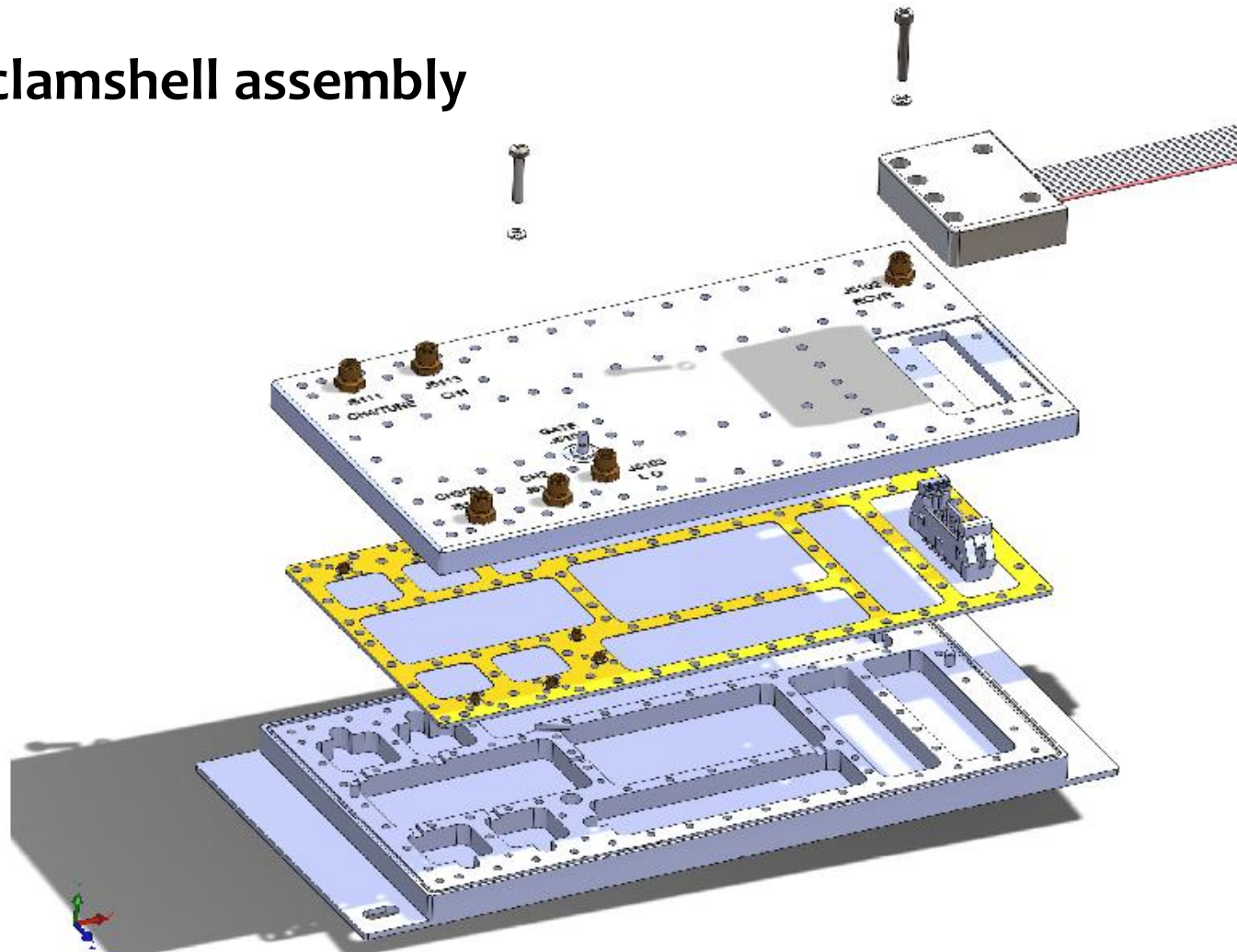
DD2: Agilent's NMR/MRI Console

Quality NMR requires stable, low noise mixer & receiver

- ❖ New Mixer Receiver Module
- ❖ Latest generation low loss cabling
- ❖ Improved RF Immunity
- ❖ Specifications optimized to 1.2 GHz

DD2: Agilent's NMR/MRI Console

Mixer clamshell assembly



DD2: Agilent's NMR/MRI Console

- ❖ Intelligence embedded in the RF transmit path
- ❖ Transmitter and Mixer/Receiver have optimized specifications to 1.2 GHz
- ❖ Finer Phase and Amplitude control produce better waveforms
- ❖ **Transmit channel linearization**



DD2: Agilent's NMR/MRI Console

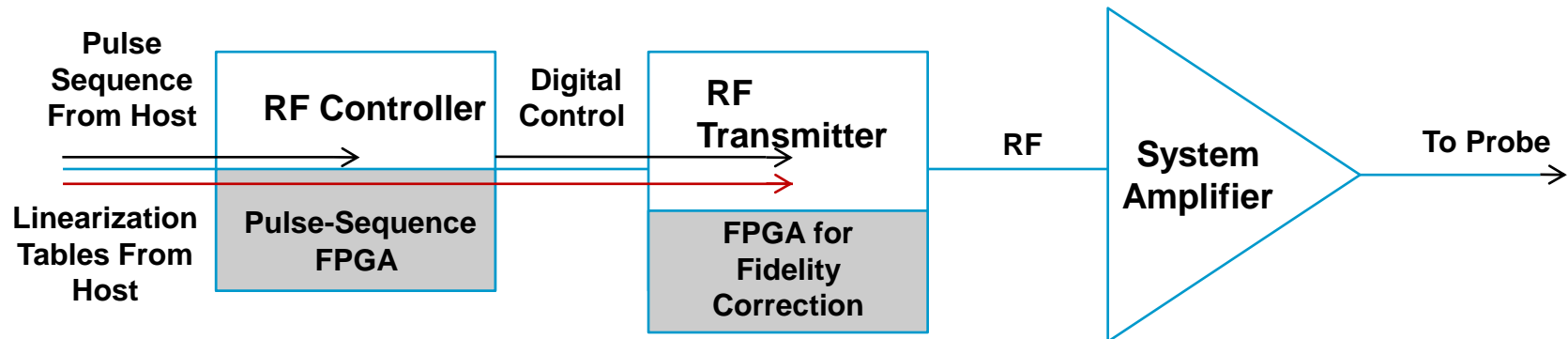
Full Transmit Channel Corrections Amplitude and Phase Linearization with *Fidelity*

- ❖ The *Fidelity* module of VnmrJ3.1 sets up tables to produce a linear relationship between input and output power and phase of the full transmit chain including the system amplifiers.
- ❖ *Fidelity* corrects digital input of the transmitter – both coarse and fine power - so that amplifier RF output is proportional to the expected – linear - value.
- ❖ All pulses, shaped pulses and waveforms are corrected, independent of the source. Software compression factors for *Pbox*, *BioPack* etc are no longer needed when *Fidelity* is used.
- ❖ *Fidelity* corrections are fast and built into the transmitter, so they have no effect on pulse-sequence timing.

DD2: Agilent's NMR/MRI Console

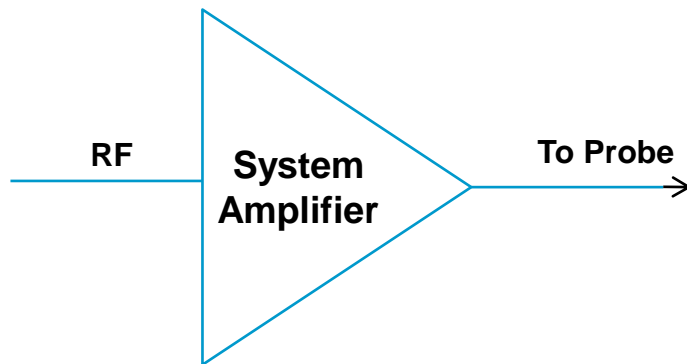
Amplitude and Phase Linearization with *Fidelity*

Fidelity takes advantage of the intelligence and processing capability of the new DD2 transmitter board

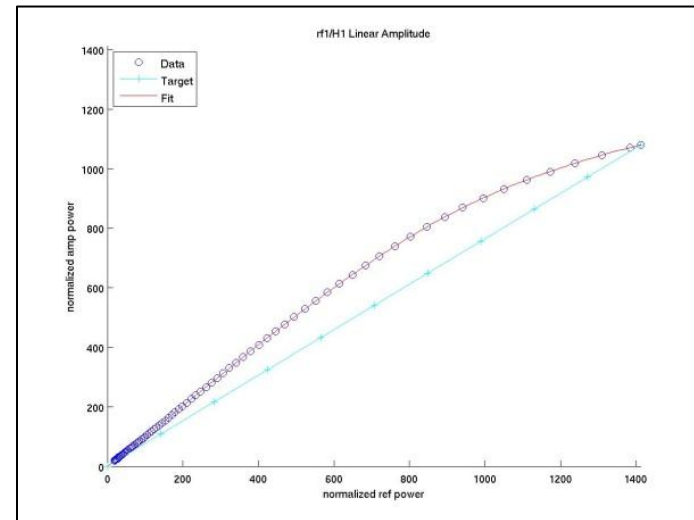


DD2: Agilent's NMR/MRI Console

Even the best linear amplifiers have compression at high power



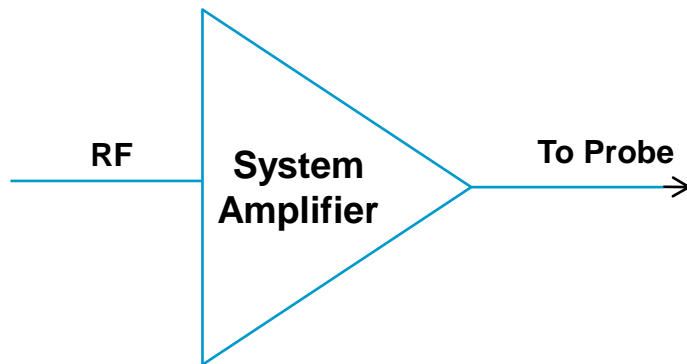
Uncorrected*



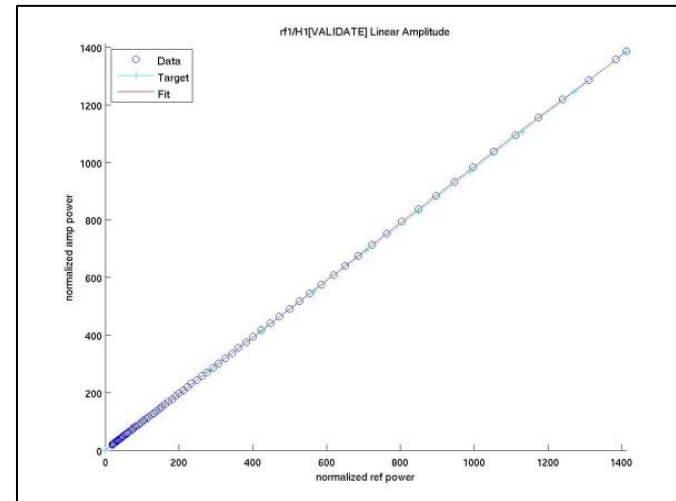
*Uncorrected output of a standard 100-Watt 1H amplifier at 600 MHz.

DD2: Agilent's NMR/MRI Console

Fidelity corrects for amplifier compression



Corrected*

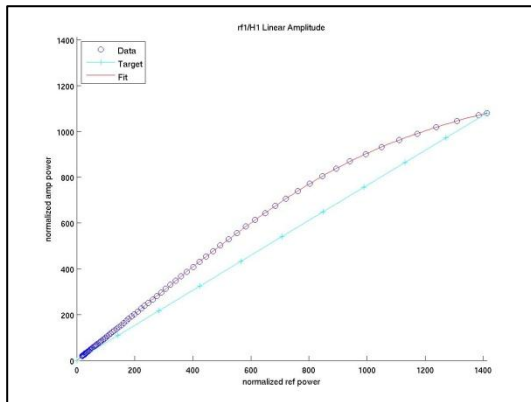


***Corrected output of a standard 100-Watt 1H amplifier at 600 MHz using Fidelity input linearization tables.**

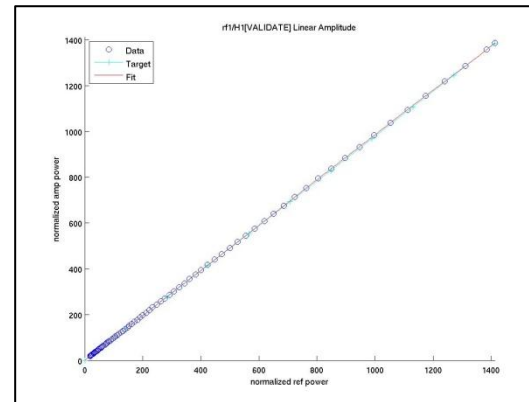
DD2: Agilent's NMR/MRI Console

Full Transmit Channel Linearization with *Fidelity*

uncorrected



corrected

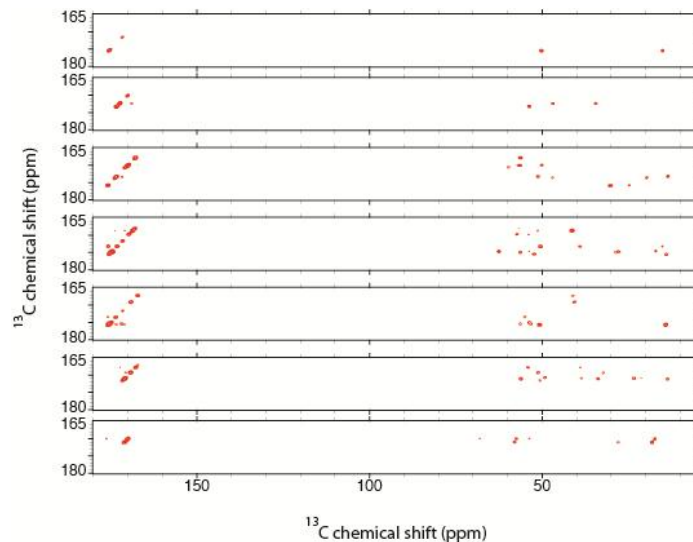
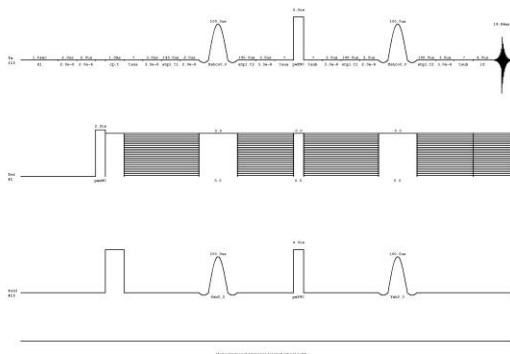


The new DD2 transmitter has an onboard FPGA with processor and memory for correction tasks. The *Fidelity* module of VnmrJ3.1 sets up tables to produce a strictly linear relationship between input and output power and phase of the full transmit chain including the system amplifiers.

Fidelity is used here in order to correct for the compression of a typical highband 100-Watt amplifier on a BioSolids 600. This “low-power” system runs a BioMAS probe with 100+ kHz linear decoupling, avoiding the need for the more expensive 800 Watt CMA.

DD2: Agilent's NMR/MRI Console

Linearization is significant for shaped pulses in J-based BioSolids experiments.



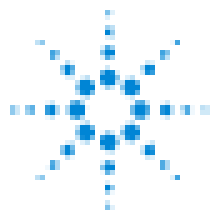
Many of the newest BioSolids experiments make use of selective, shaped inversion and refocusing pulses – just as for BioLiquids, linearization means more accurate shapes.

This J-based CTUC COSY of GB1 was courtesy Chad Rienstra, University of Illinois, Urbana-Champaign.

Summary

- ❖ Enhancement for all products
- ❖ Intelligence embedded in the RF transmit path
- ❖ Leveraging Agilent Expertise for Design and Manufacturing
- ❖ Synergy with the World's Premier Measurement Company





DD2 NMR/MRI Console

Extra Special Thanks to Dave Rice and Vadim Zorin for the excellent slides !

Paul Keifer

Judit Losonczi

Cameron Barnard

Console Engineering Group !!!

Software Group !!

Applications Group !!!



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