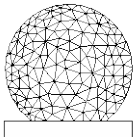


RDBE Setup and Operations

Chet Ruszczyk
IVS 9th TOW 2017



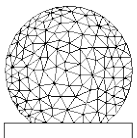
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Agenda

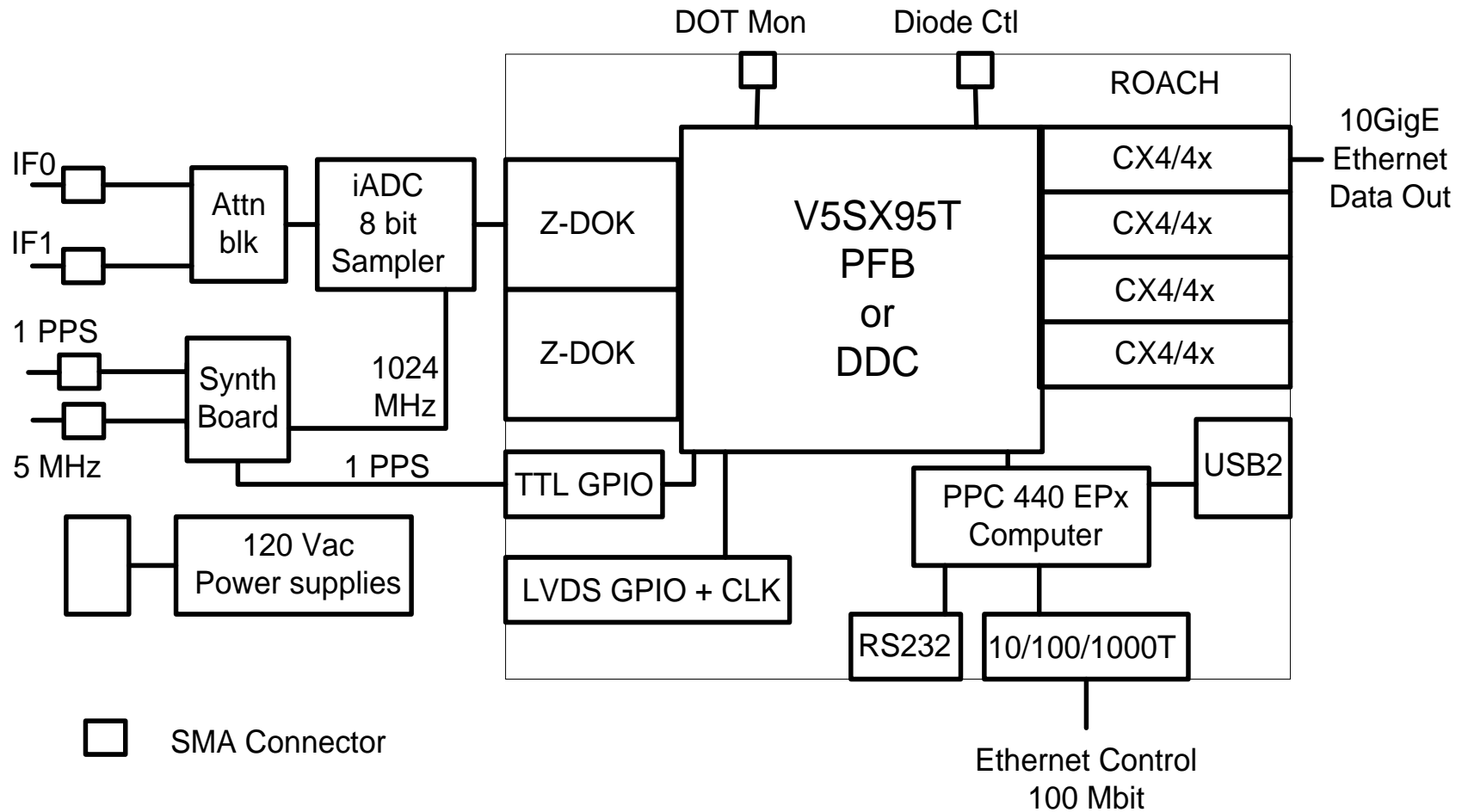
- System overview
 - Hardware components
 - Firmware components
 - Software components
- Features
- Command set
- Basic operation
- Next Generation
- Demonstration (time permitting)

System Overview

- **RDBE – ROACH Digital Backend System**
 - Originally a joint collaboration between NRAO and Haystack
 - Name is assigned to a specific base system
 - Specific hardware components
 - Was available from Digicom (ROACH reached EOL)
 - Variations are expected
 - Represented by hyphenating the name **RDBE-X**
 - **X** represents the hardware components of the RDBE
 - Presently there are RDBE-H, RDBE-S, RDBE-G
 - This overview covers the new RDBE-G

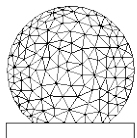
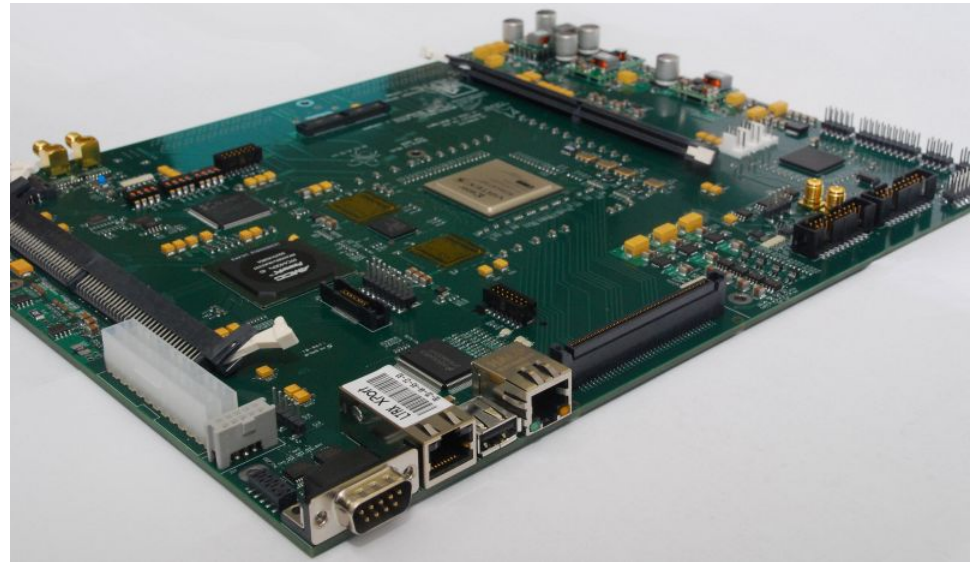


RDBE-X Block Diagram



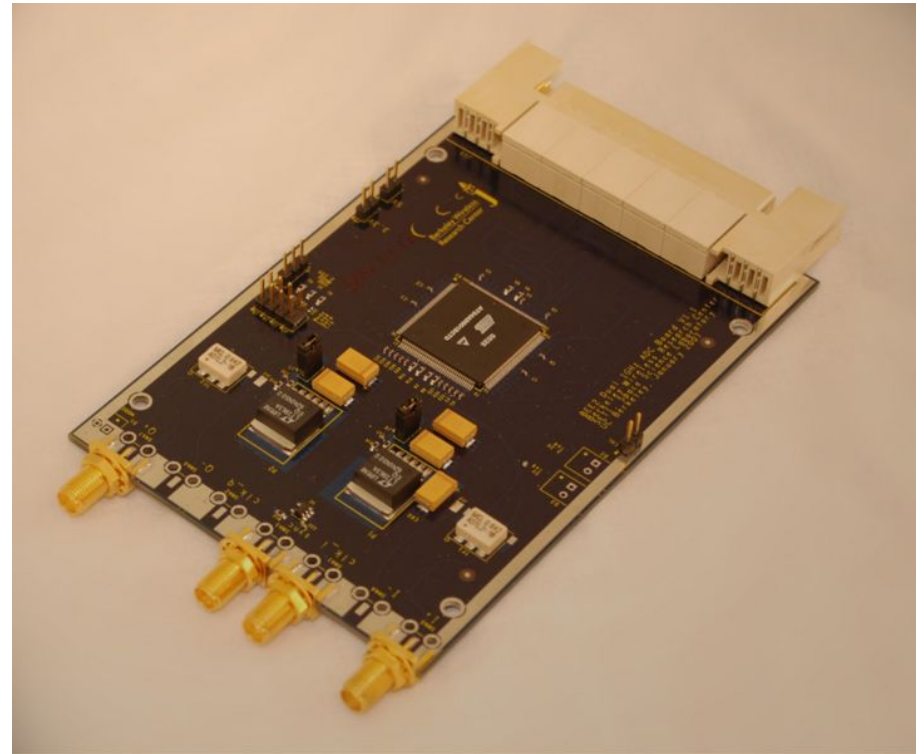
RDBE Hardware Components

- ROACH Board
 - **R**econfigurable **O**pen **A**rchitecture **C**omputing **H**ardware
 - Developed by the CASPER group at Berkeley / NRAO / KAT
- Virtex 5 FPGA
- 440 PPC processor
- 2G RAM
- 2 ZDOK connectors
 - iADC
- RS232 interface
- 1G / 100M Ethernet
- 4 CX4 10G Ethernet ports
- 1 XPORT interface



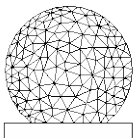
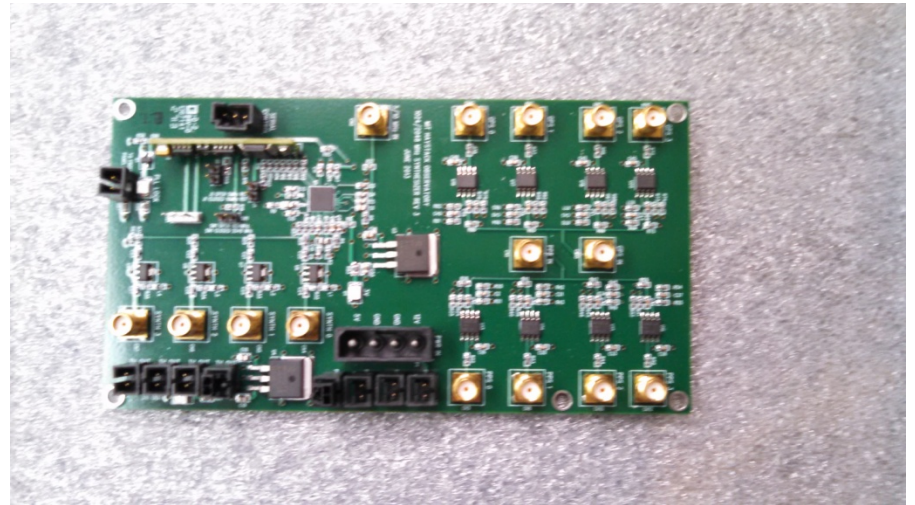
RDBE Hardware Components

- **iADC**
 - Analog to Digital Converter (sampler board)
 - Developed by the CASPER group
 - 2GHz bandwidth
 - 1 Giga sample / sec
 - 8 bits / sample
- 2 iADC cards supported per ROACH



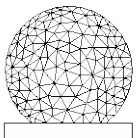
RDBE Hardware Components

- Synthesizer / timing board
 - Developed AEER
 - Inputs
 - 10 or 5 MHz
 - Jumper configurable
 - 1pps
 - Outputs
 - 1pps
 - four SMA's
 - 1024 MHz
 - four SMA's



RDBE Hardware Components

- Attenuators
 - Analog level control (ALCs)
 - Off the shelf
 - Mini-circuits
 - 1 IFs in / 1IFs out
 - Two boards per system
 - 0-31.5 dB attenuator
 - 0.5dB steps
 - No 20dB solar attenuation



RDBE Hardware Components

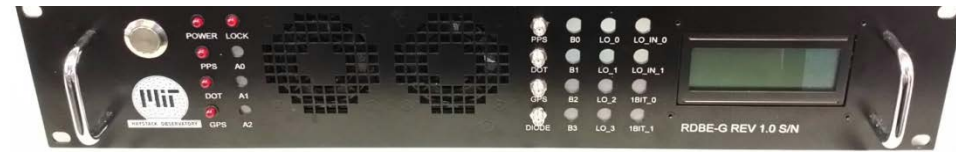
- GPIO Board
 - Mated to high speed differential connector on ROACH Board
- Developed to support interfaces to:
 - LCD front panel
 - Diode control (calibration)
 - Attenuator control communication
 - etc.



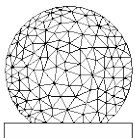
RDBE Hardware Components

- Miscellaneous
 - Power supply
 - 90 ~ 132 VAC or 180 ~ 264 VAC auto sensing
 - 1pps LED
 - Indicates 1pps internal to FPGA code (DOT Clock)
 - 5MHz lock LED
 - Power LED
 - 4 SMA connectors front
 - Output
 - 8 SMA connectors back
 - Inputs + Diode control out + pps

RDBE-G Front Panel



RDBE-G Back Panel



RDBE Firmware

- 4 Personality types (FPGA code)
 - Polyphase filter bank-geodesy (PFBG) Ver. 3.0
 - Input is two 512MHz IFs
 - Standard output is sixteen of 32 possible 32-MHz channels (2Gbps)
 - Mode of all thirty-two 32 MHz channels available (4Gbps)
 - Output is a 8224 byte VDIF data format (next slide)
 - **Complex Data**
 - Standard 32 byte header
 - eVLBI VTP protocol available



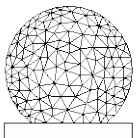
RDBE Firmware

- **Original Polyphase filter bank-geodesy (PFBG) Ver. 1.4**
 - Input is two 512MHz IFs
 - Output is sixteen of 32 possible 32-MHz channels
 - Output is a 5008 byte Mark5B data format
- **Polyphase filter bank-astronomy (PFBA) Ver. 1.5**
 - Input is four 512 MHz IFs
 - Output uses two of the four 10Gbps CX4 interfaces
 - 2-bit quantized
 - 4Gbps / interface
 - 8224 byte packets using the VDIF format.

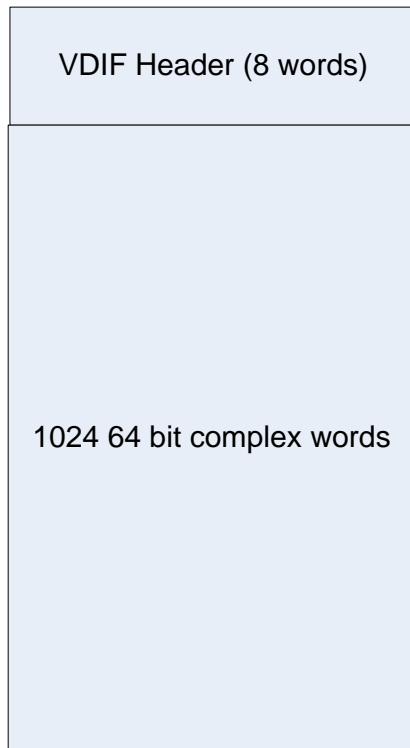


RDBE Firmware

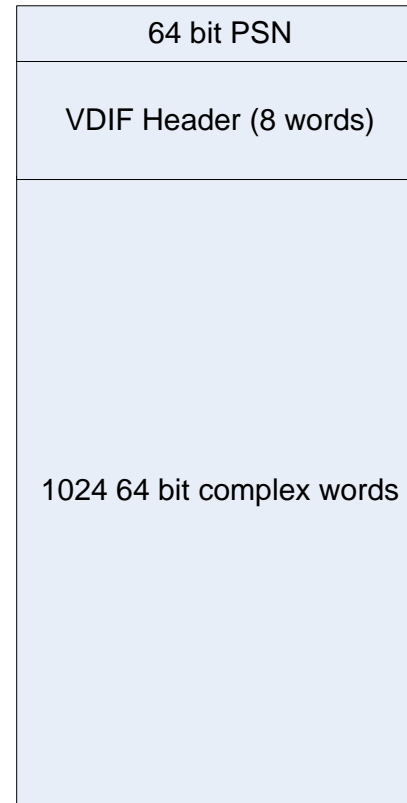
- **Digital down converter (DDC)**
 - Input is two 512MHz IFs
 - Output is four tunable channels
 - Bandwidths 128 / 64 / 32 / 16 / 8 / 4 / 2 / 1 MHz (same for all 4 channels)
 - Data rate proportional to bandwidth
 - Tunable in 15.625 kHz quanta (testing incomplete)
 - Output is in 5008 byte Mark5B format 2 bits / sample
 - 250-kHz common quantum with 10-kHz on legacy systems



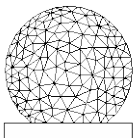
VDIF Payload Options



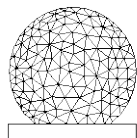
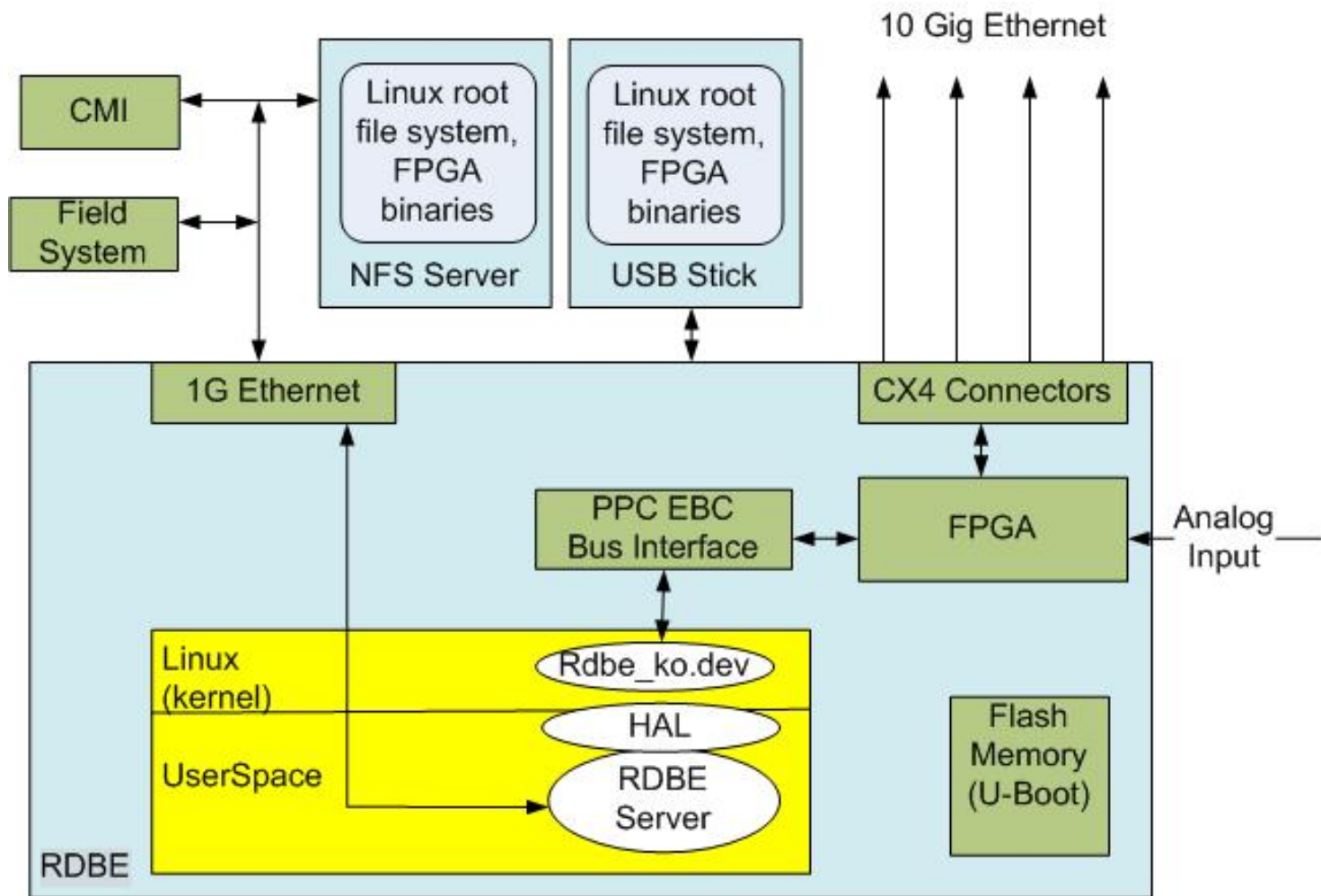
Standard VDIF Payload



VTP Compliant Payload



RDBE Software

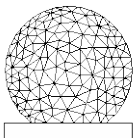


RDBE Software

- **rdbe_dev.ko**
 - Linux kernel device driver
 - Allows the application to read / write to the FPGA personality
- **rdbe_server**
 - Version 3.0 will be required for operation with FS
 - Accepts VSI-S commands
 - Verifies and takes actions on valid commands
 - Specified in the RDBE command set version 3.0
 - Not backward compatible with 1.4/1.5/DDC

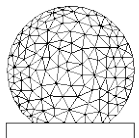
Ver. 3.0 RDBE Command Set – (VSI-S)

dbe_1pps_mon	Set the 1pps monitoring broadcast state
dbe_atten	Set / get the attenuator setting for INPUT 0/1
dbe_bstate?	Quantizer state counts in percent for all channels
dbe_chsel	Set / get the input to output channel assignments
dbe_chsel_en	Set / get the data rate (2/4Gbps), chsel enabled/disabled, psn enabled / disabled
dbe_arp	Set / get the IP to MAC address resolution
dbe_data_connect	Set / get the destination IP the data is being sent
dbe_data_send	Transmit a data stream out of the DBE 10G interface
dbe_diode	Set ./ get diode control frequency and blank time in micro-seconds
dbe_dot	Set / get the Data Observable Time (DOT) clock information
dbe_dot_inc	Increment the DOT clock, default is 1 second
dbe_gps_offset?	Get the GPS offset in micro-seconds to 1pps DOT clock
dbe_hw_version?	Get the hardware version information from the DBE
dbe_ifconfig	Set / get DBE 10G network interface configuration
dbe_init	Resets FPGA sampler, clocks and enables PPS interrupt
dbe_mac	Set / get the 10 CX4 port MAC address
dbe_ntpdate	Set / get the NTP server's IP address to synchronize to
dbe_option	Set / get formatting options (spaces, long time format - fractional seconds)
dbe_pcal	Set / get phase cal frequency in hertz (default is 0 Hz)
dbe_personality	Set / get the RDBE FPGA bit code personality
dbe_pps_mon	Set / get the once per second multicast data IP address and port.
dbe_pps_offset?	Get the pps offset to the incoming MASER pps signal
dbe_quantize	Set / get present channel quantization data
dbe_raw?	Get 100 raw samples for an interface from the DBE
dbe_reboot	Set the number of seconds before the DBE reboots
dbe_status?	Get system status (query only)
dbe_sw_version?	Get the software version information from the DBE
dbe_tsys?	Get 16 Tsys on values followed by 16 off values normalized to 1000000

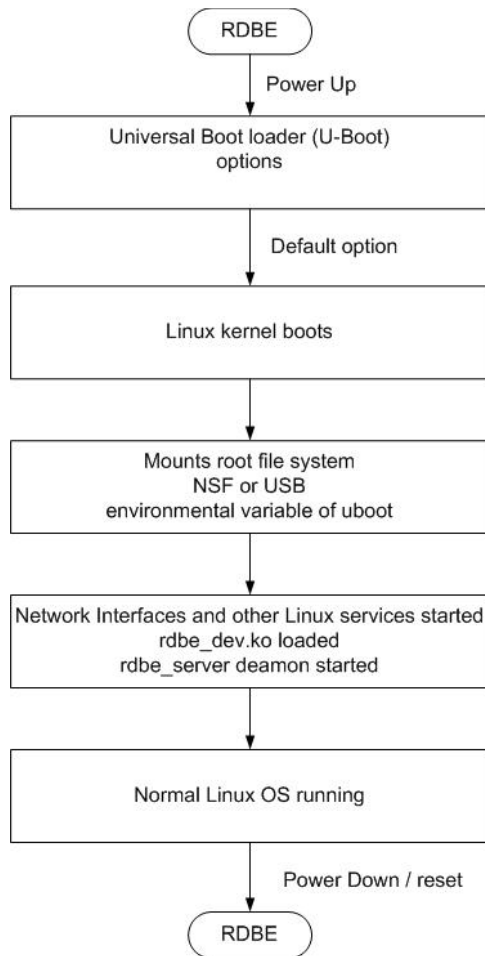


Basic Operations

- Topics addressed on the following slides
 - Boot Up
 - `rdbe_server` daemon communication
 - `dbe_data_send` operational modes
 - Monitoring capabilities
 - `lpps`
 - `tsys`
 - `pcal`
 - raw capture mode
 - PPS / GPS offsets
 - Software utilities

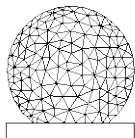


Boot Up

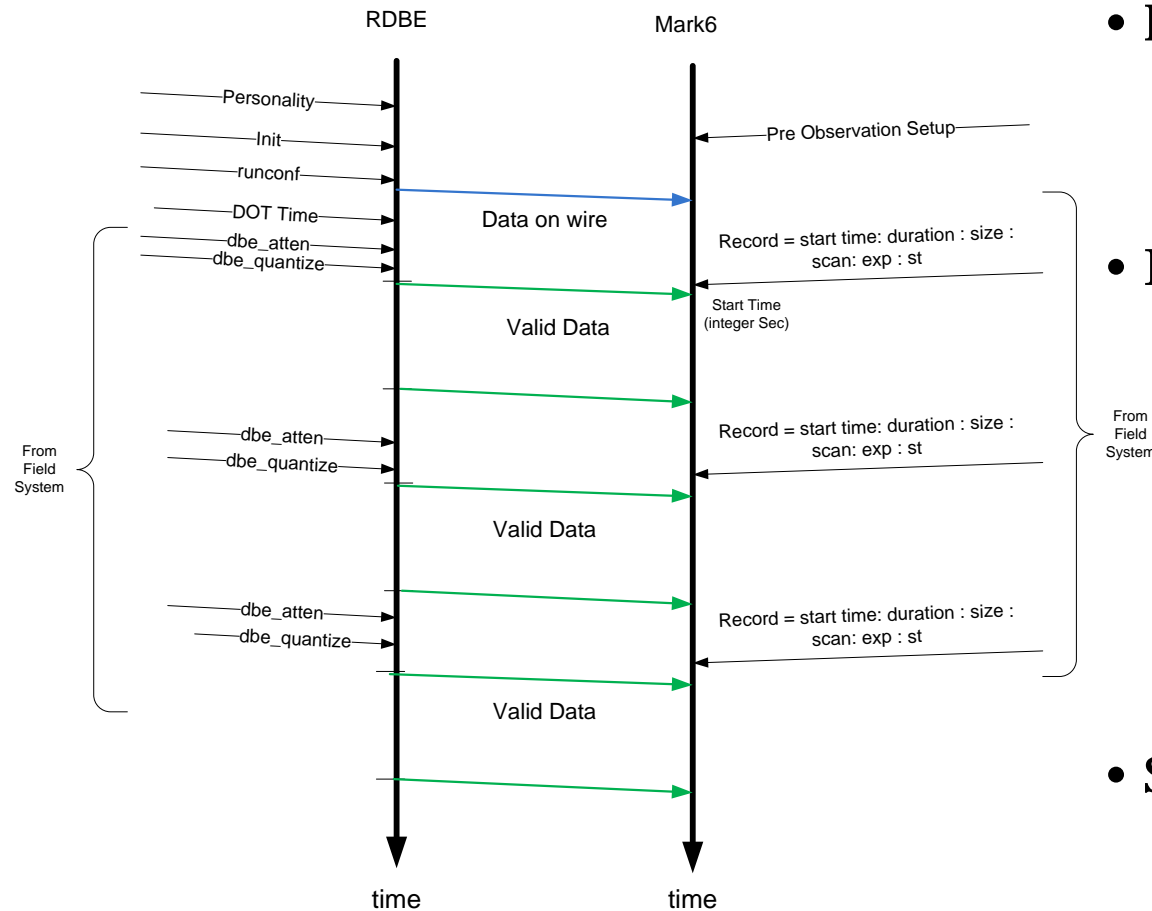


• U-Boot options

- Environment variables defining what the boot loader will execute
 - location of the kernel in flash (address)
 - location of the root file system
 - USB
 - NFS
 - SDRAM
 - bootp
 - Network configuration
 - Static
 - Dynamic
- Details are beyond the scope of this talk
 - Detail documentation available if needed



rdbe_server



- Loading the FPGA personality

- Located where the root file system is mounted
- /home/roach/personalities

- Initialization

- Setting the FPGA registers
- Setting the DOT time

- system time
- manually

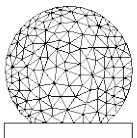
- Quantization

- Formats the filter bank channels at 2 bits / sample

- Monitoring capabilities

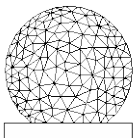
- Set for normal operations

- Transmitting data out CX4 interface
- Status / etc.



I/O Channel Selection

- Capability to set the input output channel assignment for the VLBI Payload
 - Feature for PFBG personality only
 - Input is two 512MHz IFs
 - Output is 8 out of 16 per IF possible 32-MHz channels
 - Version 1.4/1.5 has any possible combination
 - Version 3.0 does not
 - The command
 - `dbe_chsel = <input>:<channel(s)>;`
 - `input`
 - 0 or 1 for IF0 or IF1
 - `channel(s)`
 - individual channels



Configuration

- Initialization of static information
 - e.g. 10G IP, MAC, ARP entry, etc.
 - Handled with command
 - `run_conf=/path/filename`
 - `/home/roach/personalities/conf/filename`
 - See next page for example / explanation
 - New version of `rdbe_server` automates this process
- The channel ordering
 - The present geodetic personality
 - The default `dbe_chsel? {0,1}` returns
 - `dbe_chsel ? 0: 0 : 1 : 3 : 5 : 7 : 9 : 11 : 13: 15 ;`
 - `dbe_chsel ? 0: 1 : 1 : 3 : 5 : 7 : 9 : 11 : 13: 15 ;`



Static Configuration File

Command Executed	Comments
ifconfig= up : 9000 : 4 : 192.168.1.102 : 1	10G Network setup = State : payload size : TCP : Source IP : Network Interface Source IP Address
mac=00.00.11.22.33.42	MAC Address of the 10G, made up unique for each RDBE
chsel_en=2 : chsel_enable : psn_enable	# 2 Gbps data rate, with Channel select and PSN enabled
arp= 192.168.1.3 : 00.60.dd.44.9f.81	ARP entry for destination Mark6 IP address and MAC Address
data_connect=192.168.1.3 : 9002 : 0xBdC : 1	# Set the configuration for IP / UDP / VDIF header. destination IP address : UDP port : Station / RDBE Identifier : Thread ID
pps_mon=disable	Disable previous initialized multicast transmission
pps_mon=enable : 239.0.5.50 : 20055	Multicast enabled : Unique Multicast IP, unique Port. Set these to RDBE IP address
pcal=1.4e6	Set pcal for UDC fractional portion
data_send=on	Start transmitting data over 10G interface
option=time_long	Use fractional time long format when replying to requests



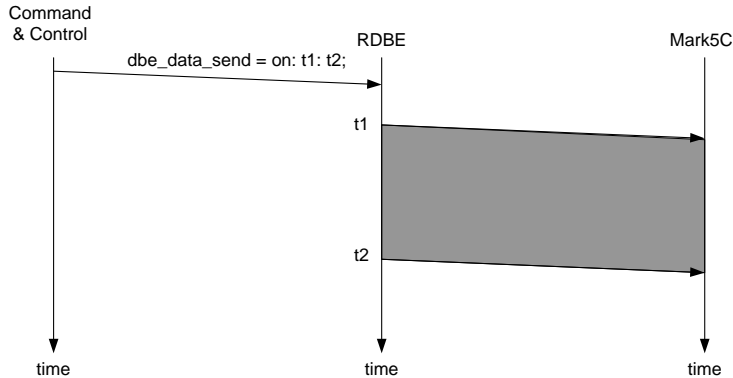
Data Transmission

- In the past data were always available and the gating function was performed on the recording device
 - Record = on / off commands
 - Supported with `dbe_data_send=on`
- One can also gate at the source and destination for transmission over WANs:
 - To gate at the RDBE
 - Since the start and end time are known a priori
 - use the `dbe_data_send` to gate the output on the 10G

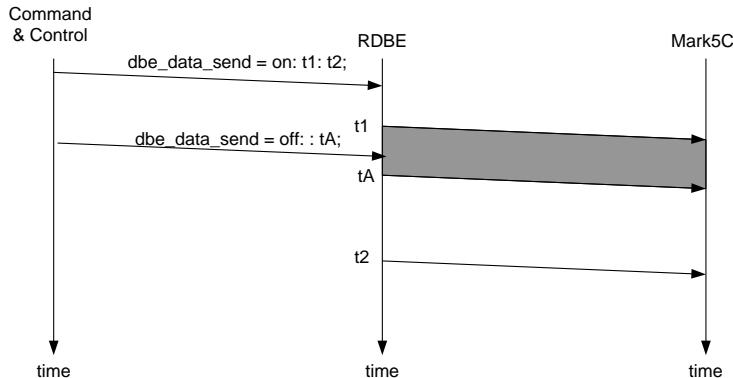
Design Philosophy

- start time \leq present DOT time $<$ end time
 - Personality will transmit valid packets
 - Times are specified as integer seconds
- Start and end times are programmed into the FPGA using the command:
 - `dbe_data_send`
 - command format
 - `dbe_data_send = < state > : [< ts >] : [<te>] : [<delta>];`
 - state - either “on” or “off”
 - start and end times (ts, te) are of the format YYYYDDDDHHMMSS
 - delta - specified in integer seconds.

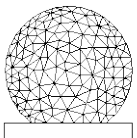
dbe_data_send options



- Specify start / end time
 - YYYYDDHMMSS
- Or specify start and delta time
 - t2 is generated as t1 + delta
 - delta is integer seconds



- Ability to abort an active transmission
 - send the off state with
 - a specified time
 - no time - meaning next integer second

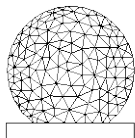


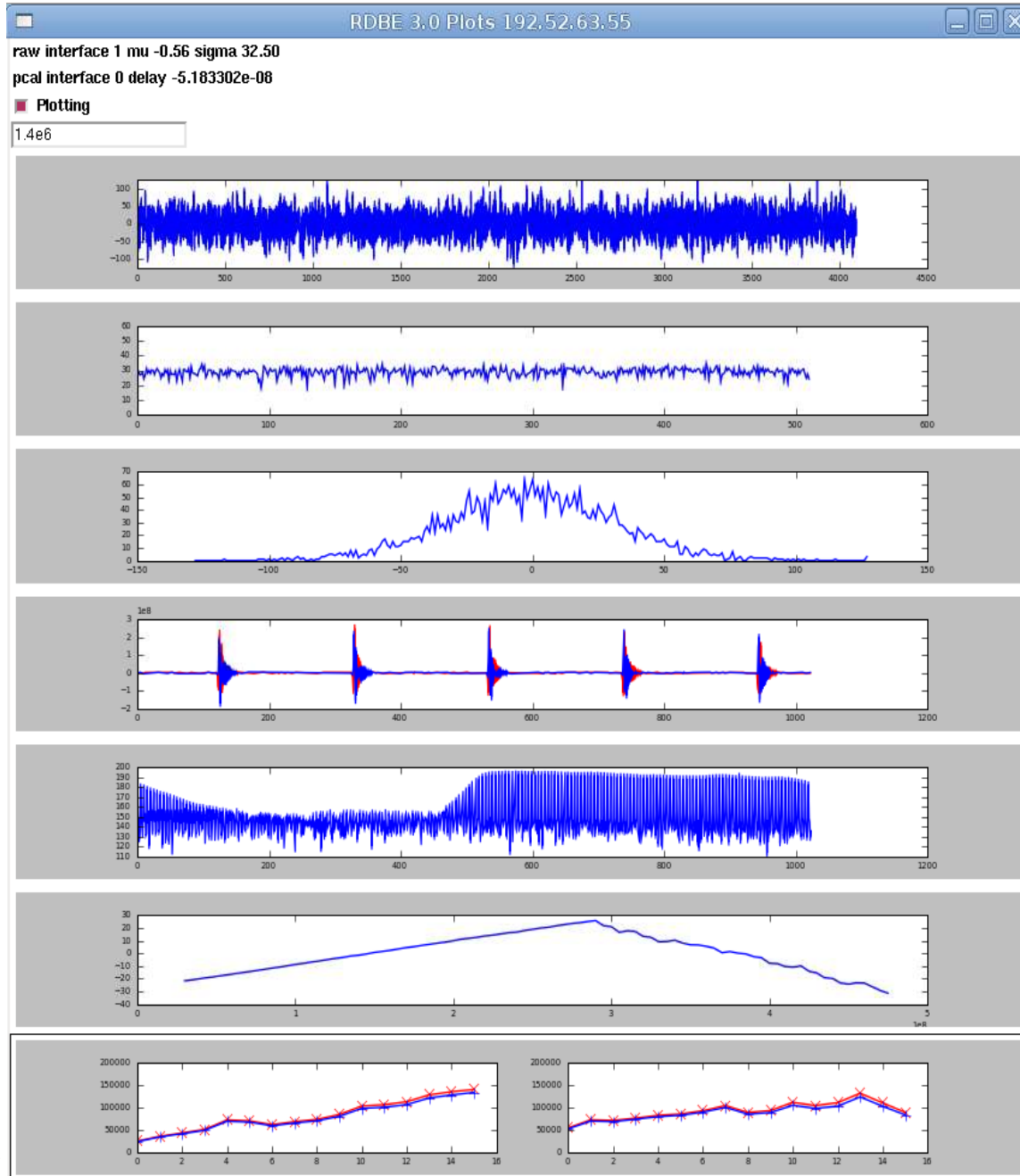


Monitoring Capabilities

- **1pps monitoring**

- Multicast monitoring data broadcast 1 per second (1pps)
- `dbe_1pps_mon = <enable> : <multicast IP address> : <port>;`
- Use `rdbe_mon.py` on a system attached to same network to receive multicast data
- **Tsys monitoring**
 - System temperature measurement
 - On power / off power of the receive chain
 - tsys data is summed every second
- **Raw Capture Mode**
 - Provides ability to see the incoming signal from the iADC before it is processed by the FPGA personality
 - 32000 samples are captured





Input signal

FFT of input signal

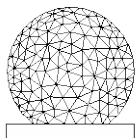
Histogram

Pulse cal extraction

FFT of pulse cal

phase of pulse cal tones

Power of IFX channels (on / off)



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Software Utilities

- *rbde_client -h <machine>*

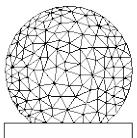
- Command line interface to RDBE
- *-h <machine>* is the target RDBE systems IP address (defaults to localhost).
- *rdbe_server* must be running on *<machine>*

- *rdbe30_mon.py -h <multicast addr> -p <port> -H <RDBE addr> -P <rdbe_server port>*

- *Graphical command and monitoring application*
- *Sends commands / displays multicast output graphically*
- *Very CPU intensive, to be used only for snap shot of RDBE*

RDBE Next Generation Development

- **R2DBE-G :**
 - **ROACH 2 board**
 - Vertex 6
 - 4 SFP+ Connectors
 - Fiber or Copper
 - Leveraged ADC FPGA code from Event Horizon Telescope
 - Code must be ported, extended for Geodetic filter bank features
 - Existing server code must be ported to new platform
 - **2 ADC**
 - 2G Samples
 - **New GPIO interface board**



RDBE Next Generation Development (cont)

- Same form factor as RDBE-G
- Order from Digi-com
- Undergoing zero base-line testing
- Expected by Sept. 2017

Demonstration

time permitting



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