XBOX Operation and Performance

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on behalf of Xbox Team

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SINAP, Shanghai, China
Outline

- Test stands specifications
- XBOX1
  - Challenges during last year
  - New Pulse Compressor tuning software
- Bunker optimization
- XBOX2
  - Performance
  - Future upgrade
- XBOX3
  - Components conditioning
  - Structure conditioning
  - Pulse Compressor conditioning
  - Frequency shift tool
- Conclusions
- Future plans
Test Stands specifications

- The required input power to commission CLIC structures is typically 40-60MW and a 250ns flat pulse.
- The speed of conditioning depends on the number of pulses, therefore, high pulse repetition rates are preferred.
- XBOX 1 and XBOX2 use a single 50MW klystron and pulse compressor to test one structure, although up to two structures could be tested.
- Scandinova modulator, CPI klystron, pulse compressor factor ≈3.

450kV, 350A, 1.5µs, 50Hz

50MW
- XBOX3 combines the power of two smaller klystrons with a higher rep. rate ≤400Hz to test two structures.
- Scandinavian modulator, 6MW Toshiba klystron and pulse compression with a compression factor ~4
1. Pulse length and LLRF frequency are set:
2. Fast → pulse to pulse
   • PID loop on the incident power to the structure
3. Medium → seconds-minutes
   • increase power by 10kW every few minutes (cycle loop) if no BD
   • reduce power by 10kW if successive BDs too close in time
4. Slow → hours
   • BDR measurement performed across a moving window of approx. 1M pulses.
   • BDR measurement and stop power increase if it is too high
June 2017

TD26CCN2
Feedback control of the incident power was modified to use the diode detector instead of the log detector.

The power output is now much more stable.
June 2017

Installation of diode detectors

Stopped pulsing due to a problem in the klystron
Installation of diode detectors

June 2017

Installation new klystron and tests performed

September 2017

Stopped pulsing due to a problem in the klystron

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Installation new klystron and tests performed

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Installation of the spectrometer from XBOX2
XBOX1 @ CTF2

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Restart of XBOX1 after a year maintenance

June 2017

September 2017

January 2018

February 2018

TD26CCN2
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February 2018
Restart of XBOX1 after a year maintenance

Summer 2018
Reconnection to CLEAR
XBOX1 @ Pulse Compressor Tuning

- New software for tuning pulse compressor by changing automatically the temperature of the chillers connected to each cavity of the pulse compressor.
The Bunker

- Installation of a new waveguide cooling system for both XBOX2 and XBOX3
The Bunker

- Installation of a new waveguide cooling system for both XBOX2 and XBOX3
- New high power chillers in XBOX3 to maintain tuning temperature of the pulse compressor stable at a repetition rate of 400HZ (200Hz/line)
Radiation

- Exceeding the radiation limits interlocked the system
Radiation

- Exceeding the radiation limits interlocked the system
- We solved the problem by removing the spectrometer from XBOX2 and shielding the downstream faraday cups with 500Kg of lead
New Control room

- Since summer 2017, located in front of the testing facilities
- All XBOXes can be operated from the control room, including XBOX1@CTF2
- Meeting room
XBOX2

- Three different structures since last year
- Most robust test stand
Three different structures since last year
Most robust test stand
4M pulses per day
80% availability
- Three different structures since last year
- Most robust test stand
- 4M pulses per day
- 80% availability

- XBOX2 upgrade with the goal to split the line after the pulse compressor to feed two structures (Superstructure)
XBOX2 upgrade

- XBOX2 can provide a nominal power of about 130MW which is enough to feed two structures, though right now only one is installed
XBOX2 upgrade

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Variable power splitter
XBOX2 can provide a nominal power of about 130MW which is enough to feed two structures, though right now only one is installed.
XBOX2 upgrade

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- Variable power splitter and phase shifter are being tested at high power in line 1 and 2 of XBOX3.

Phase change after power splitter, thus it needs a phase shifter.
Variable power splitter.
Two 3D printed loads, phase shifter and power splitter were tested last year in lines 1 and 2 of XBOX3.
XBOX3 – Components conditioning

- Conditioning with an algorithm based on vacuum pressure calculations instead of BDR.
  - Set a pressure limit
Conditioning with an algorithm based on vacuum pressure calculations instead of BDR.
- Set a pressure limit
- Power increase based on the difference between actual pressure and limit pressure
XBOX3 – Components conditioning

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  - Pressure limit has to be set close to baseline pressure to avoid a fast increase on the power that will lead to vacuum spikes
XBOX3 – Components conditioning

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  - Set a pressure limit
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  - At low power leakage between lines is critical, needs manual adjustment of the phase between lines and keeping a similar power in both lines
XBOX3 – Components conditioning

- Conditioning with an algorithm based on vacuum pressure calculations instead of BDR.
  - Set a pressure limit
  - Power increase based on the difference between actual pressure and limit pressure
  - Pressure limit has to be set close to baseline pressure to avoid a fast increase on the power that will lead to vacuum spikes
  - At low power leakage between lines is critical, thus keep similar power level in both lines
  - Requires a lot of human monitoring
  - Set to constant power during unattended periods

Compact load
Compact Load

- Only vacuum conditioned as there was not significant reflected power to be measured
- Not limited exclusively by peak power or average power but by a combination of both
- Reached 17MW@50ns and 1E-8mbar pressure
- Pressure in the load will not improve with further conditioning at constant power

HIGH POWER CONDITIONING OF X-BAND RF COMPONENTS,
N. Catalan-Lasheras et al., IPAC2018
The load does not seem to have an intrinsic limitation

- Tested up to the maximum available power in the line which was 35.5 MW peak power for 50 ns and 25 MW for 200 ns pulses always at 200 Hz/line.
- The maximum average power put into the load was 2.1 kW
Phase Shifter

- VNA measurements done to variable phase shifter

- Completely retracted: 50mm
- Gap: 30mm

1mm insertion ~ 21° phase shift
17mm insertion ~ 360° phase shift
Power Splitter

- VNA measurements done to variable power splitter

Phase changes when moving the piston
High power conditioning

- Tested in XBOX3
- Power splitter conditioned one output port at a time
- Phase shifter conditioned with the piston at the middle of the shifting-range
High power conditioning

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- Power splitter conditioned one output port at a time
- Phase shifter conditioned with the piston at the middle of the shifting-range
- Power splitter conditioned faster than phase shifter in line 1 and we had to lower the power due to line-to-line leakage

Power Splitter

<table>
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<tr>
<th>Port1</th>
<th>Port2</th>
</tr>
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<tbody>
<tr>
<td>Port3</td>
<td>Power Splitter</td>
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</table>

3D printed spiral load (35MW)
High power conditioning

- Tested in XBOX3
- Power splitter conditioned one output port at a time
- Phase shifter conditioned with the piston at the middle of the shifting-range
- Power splitter conditioned faster than phase shifter in line 1 and we had to lower the power due to line-to-line leakage
- Both have reached 42MW@50ns
Two TD24SiC and two T24PSI structures were tested last year in lines 3 and 4 of XBOX3

~ 1400M pulses in each line
XBOX3 – Structures conditioning

- Many operational lessons learned.
- First SiC structure lost due to a hot-cell which developed and drove down the power as a consequence of a bug in the code when running a high rep. rate that switched the power between the two lines.

Structure lost

See J. Paszkiewicz talk
XBOX3 – Structures conditioning

- Many operational lessons learned.
- First SiC structure lost due to a hot-cell which developed and drove down the power as a consequence of a bug in the code when running a high rep. rate that switched the power between the two lines.
- Second SiC structure suffered from a BDs cluster that lasted ~30min due to a bug in the software that didn’t reduce the power.

Example of how it should work...but didn’t
XBOX3 – Structures conditioning

- Many operational lessons learned.
- First SiC structure lost due to a hot-cell which developed and drove down the power as a consequence of a bug in the code when running a high rep. rate that switched the power between the two lines.
- Second SiC structure suffered from a BDs cluster that lasted ~30min due to a bug in the software that didn’t reduce the power.
- Pulse compressor in line 3 wouldn’t condition any further and had to be changed for a new one.
PC in line 3 of XBOX3 wasn’t conditioned before installing the structures
First SiC structure got lost after 35MW and the second one couldn’t go more than 40MW because the PC wouldn’t stop breaking-down
Pulse Compressor line 3

- PC in line 3 of XBOX3 wasn’t conditioned before installing the structures
- First SiC structure got lost after 35MW and the second one couldn’t go more than 40MW because the PC wouldn’t stop breaking-down
- PC changed in the last installation and have since then being conditioned up to 40MW with a high power load
- PC in line 3 of XBOX3 wasn’t conditioned before installing the structures
- First SiC structure got lost after 35MW and the second one couldn’t go more than 40MW because the PC wouldn’t stop breaking-down
- PC changed in the last installation and have since then being conditioned up to 40MW with a high power load
- Next structure conditioning will not be limited by conditioning of the PC or the load
Frequency shift tool

- New frequency shift tool for rapid tuning of the pulse compressor after a power lost (BD).
  - Before the tuning frequency was achieved by changing the temperature on the chillers connected to the cavities of the PC, which is slower.
  - Calculates the correct transmitted phase and corrects the frequency.
  - Up to 1MHz shift.

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Calculates the correct transmitted phase and corrects the frequency.

Up to 1MHz shift.
Conclusions

- **Six** operational lines, 24h operation
- XBOX3 pulsing at 200Hz/line
  - New high power chillers
  - More radiation protection
- First time we do conditioning based on vacuum level not BDR
  - Suitable for components where there is not enough reflected power
  - Needs constant human monitoring
- PC automatic tuning
  - XBOX1: based on temperature change, slow
  - XBOX3: based on frequency shift, fast
- Software bugs fixed
- PC line 3 conditioned and ready for testing new structures
## Future plans

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<th>Xbox 1</th>
<th>Ongoing test</th>
<th>Next tests</th>
</tr>
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<tbody>
<tr>
<td>Xbox 2</td>
<td>T24 PSI N2</td>
<td>TD26_SiC superstructure</td>
</tr>
<tr>
<td>Xbox 3 Line 1</td>
<td>Power Splitter</td>
<td></td>
</tr>
<tr>
<td>Line 2</td>
<td>Phase Shifter</td>
<td>Both lines will be moved to Melbourne University</td>
</tr>
<tr>
<td>Line 3</td>
<td>New pulse compressor</td>
<td></td>
</tr>
<tr>
<td>Line 4</td>
<td>TD24 R05 SiC N2</td>
<td>Unbaked/Baked TD24</td>
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See N. Catalan Lasheras talk
Credits

Thanks to everyone in the XBOX Team...

... and thanks for your attention