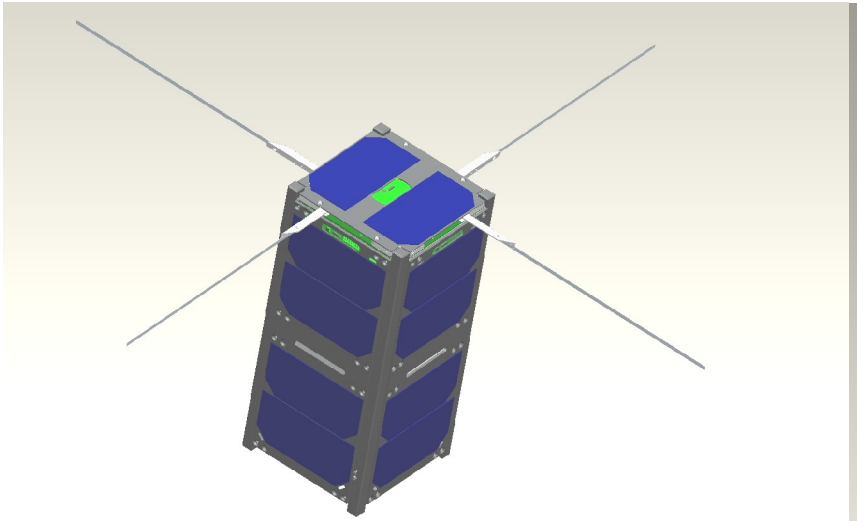
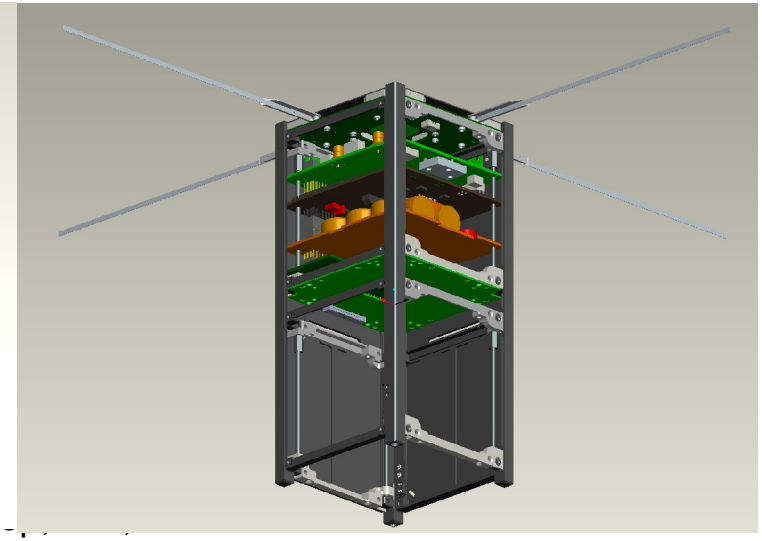
DISCLAIMER

- The contents of this presentation present the view presented at the 3rd QB50 Workshop, held at VKI, Brussels.
- The specifications have changed! Please check https://www.qb50.eu/ for all recent information, standards and the request for proposals

QB50 Challenges

- Small space platform
  - Not a lot of space available
  - Deployed from a cannister/dispenser/pod
  - 2-3 W orbit average power available for the whole satellite, COMMS needs to be efficient





Considering:

- from 200km orbits, contact time per day is less than 4 minutes on average, per ground station.
- 9600bps is considered the highest data rate that most CubeSat teams will be able to achieve with COTS technology
- Most CubeSats will use UHF frequencies in the Amateur Satellite Service for downlinking
- Most CubeSats will use VHF frequencies in the Amateur Satellite Service for uplinking
- The CubeSats are in one “cloud” when they are deployed.
- You are free to choose another comms system. However, you will have to convince us in your proposal and technical support will be limited

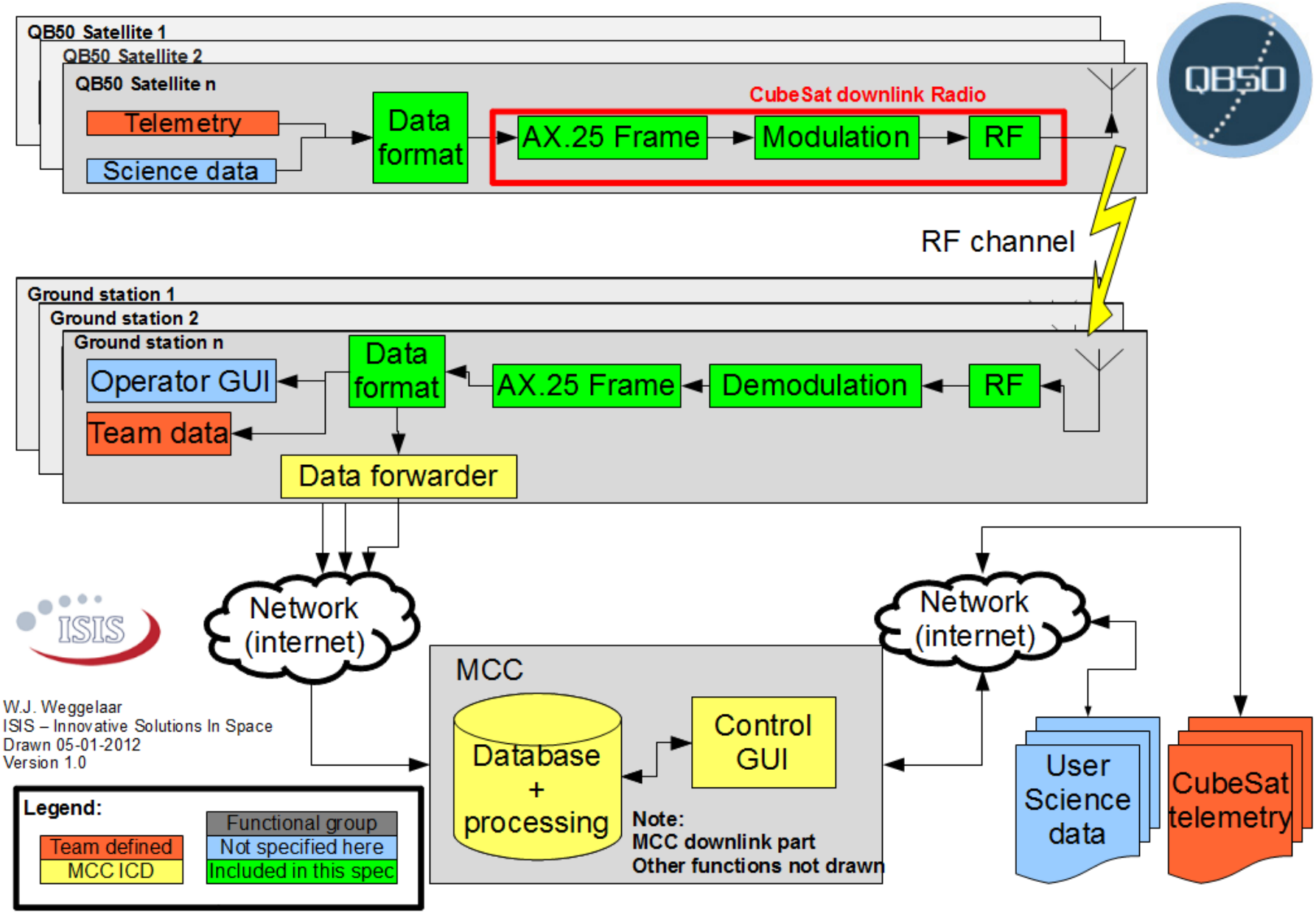
Frequency Bands Available

Band	Allocated bandwidth	Global allocation?	Purpose	notes
137-138MHz	1MHz	Yes, limited	Meteorological Satellites + research	
144-146MHz	2MHz (200kHz)	Yes	Amateur radio	IARU coordinates 200kHz of spectrum for satellite usage.
400-402MHz	2MHz	Yes	Various satellite service	Lengthy coordination process, lots of users
435-438MHz	3MHz	No	Amateur radio	IARU coordinates 3MHz of spectrum for satellite usage.
460-470MHz	10MHz	Yes	Meteorological Satellites	Power Spectral Density requirement, or file for allocation
1690-1710MHz	20MHz	Yes	Meteorological Satellites	Not researched extensively, needs new harware designs
2200MHZ	90MHz	No	Space downlink	Requires license
2400MHZ	80MHz	No	ISM (amateur 2400-2450)	No licenses required. Lots of interference

Reasons for VHF / UHF

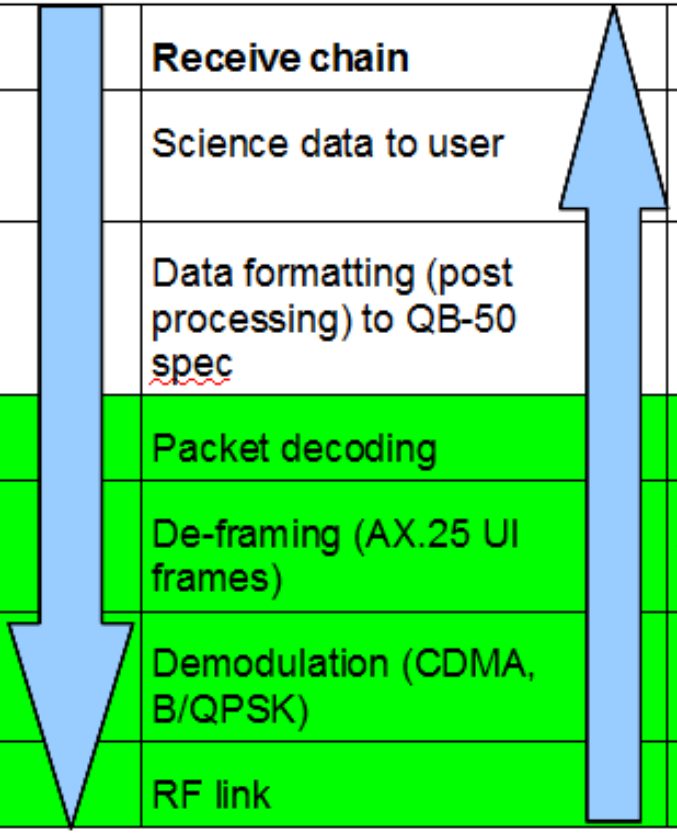
- Omnidirectional antennas on satellite
  - No attitude control required for COMMS
  - Quick commissioning
- “Low” data rate channels
  - Lower power consumption
- Frequency coordination (IARU)
- Reduced cost ITU Notification process
- Satellite tracking may not be necessary
  - Omni-directional ground station
  - Simultaneous reception of multiple satellites

QB50 communications architecture



The COMMS chain

Transmit chain	Receive chain	Remarks
Science data from instruments	Science data to user	
Data formatting (pre-processing) to QB-50 spec	Data formatting (post processing) to QB-50 spec	Formatting science data according to QB50 spec
Packet encoding	Packet decoding	TBD protocol, if needed
Framing (AX.25 UI frames)	De-framing (AX.25 UI frames)	AX.25 is used
Modulation (CDMA, B/QPSK)	Demodulation (CDMA, B/QPSK)	TBD which one
RF link	RF link	UHF downlink channel



Green parts are covered by this specification

DATA budget

- Is not fixed yet
- Baseline is 2Mbit per day for the science package data
- Data from the science package does not include satellite telemetry and auxiliary payloads
- Calls for minimum 9600bps data rate

9600 bps with 1MHz spectrum

Spectrum usage size	1000 kHz
Downlink data rate	9.6 kbps
Number of downlinks	50
FM deviation	3 +/- kHz

	Modulation type			
	BPSK	**QPSK**	**FSK (G3RUH)**	**GMSK**
Bits per symbol	1	2	1	1
Symbol rate	9.6 kbaud	4.8 kbaud	9.6 kbaud	9.6 kbaud
Spectral efficiency factor	1.5 times	1.5 times	1.625 times	1.6 times
Channel size	14.4 kHz	7.2 kHz	15.6 kHz	15.36 kHz
Doppler spacing	10 kHz	10 kHz	10 kHz	10 kHz
Total occupied spectrum	1230	870	1290	1278
Margin	**-230** kHz	**130** kHz	**-290** kHz	**-278** kHz

Spectral efficiency based on reference designs

9600 bps with 1.5MHz spectrum

Spectrum usage size	1500 kHz
Downlink data rate	9.6 kbps
Number of downlinks	50
FM deviation	3 +/- kHz

	Modulation type			
	BPSK	**QPSK**	**FSK (G3RUH)**	**GMSK**
Bits per symbol	1	2	1	1
Symbol rate	9.6 kbaud	4.8 kbaud	9.6 kbaud	9.6 kbaud
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Channel size	14.4 kHz	7.2 kHz	15.6 kHz	15.36 kHz
Doppler spacing	10 kHz	10 kHz	10 kHz	10 kHz
Total occupied spectrum	1230	870	1290	1278
Margin	**270** kHz	**630** kHz	**210** kHz	**222** kHz

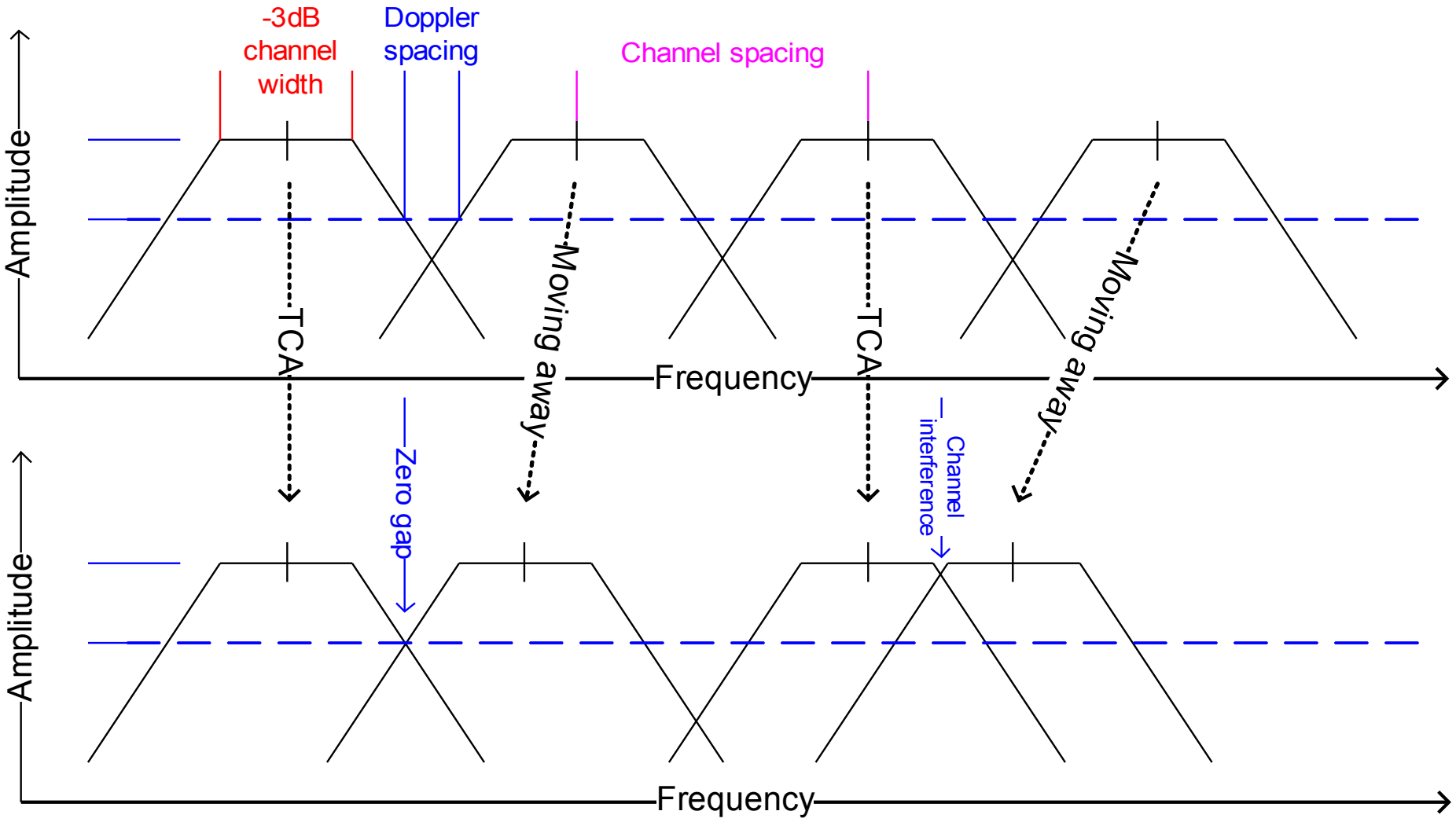
Spectral efficiency based on reference designs

FDMA(narrow band)

Frequency Division Multiple Access

- No hopping!
- Requirement for 50 satellite channels to be coordinated
- Doppler shifts them around
- All satellites a different channel, because orbital dynamics cause the satellites to move
- Large allocation / coordination problem
- Efficient modulation scheme necessary
- Easy KISS approach
- Proven technology

FDMA


-3dB
channel
width
Doppler
spacing
Channel spacing
Amplitude
TCA
Moving away
Frequency
TCA
Moving away
Zero gap
Channel
interference
Amplitude
Frequency

CDMA

Code Division Multiple Access

- Re-use of the same B/W (spectrum) by all 50 sats
- Code Division used to distinguish satellites (orthogonal code)
  - As in 3G telephones, WiFi and GPS
- Less sensitive to narrow band interference
- Causes less interference on existing narrow band channels
- Enables reception of multiple cubes simultaneously
- Cons:
  - Complex compared to ordinary BPSK
  - Requires close cooperation between the CubeSat teams

Ground Segment

- Each team is required to have access to at least one ground station with uplink capability (by law!)
- CubeSat teams may organize their own downlink network
- GENSO is raising the scientific return of the cubesats
- Science package data has to be delivered to the QB50 MCC (Mission Control Center) / MDC (Mission Data Center)
  - Interface to MCC is TBD
  - Terminology is still mixed (apologies, we will fix that..)

Conclusions

- Most parameters are TBC
- 9600 bits per second communications
- AX.25 UI frames
- QPSK is highly advantageous for spectral efficiency
- BPSK is the next runner up, closely followed by GMSK and G3RUH FSK
- CDMA is optional
- FEC not specified yet

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