Cubesat data transmitter operating in the X-band

A proposal

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Already available similar modules

A few comercially available X-band modules exist, but the price is quite high. These are usually paired with a patch antenna, which is not inexpensive either.

Already available similar modules

Figure: Endurosat X-band transmitter; a comercially available solution; price: 20500 €

What we aim to improve

- Power consumtion
- System interface

Current modules draw a lot of power (usually around 10 W) and would require designing the cubesat around the existing interface.

The learning curve

- High frequency PCB design
- The harsh conditions in space
- Optimising the power consumtion

The last two play a vital role for all cubesat modules

Power consumption

- Low power digital interface to the system bus
- Power dissipation and cooling
- Optimising the RF stage

Since we transmit only when the satellite is overhead, the local storage may be filled slowly, thus reducing the microcontroler unit (MCU) power consumption.
Protocols to be considered are: CAN, LIN or RS-485. I^2C would also work, but CAN, LIN and RS-485 have robustness in mind.

Cooling and thermal radiation

More power consumption $\implies$ more heat $\implies$ higher junction temperatures.
In addition to this, ambient temperature varies greatly. All ICs have to be rated for aerospace/military temperature range.

RF design

- Desired carrier frequency: 10.45 GHz
- Allowed carrier drift: TBD
- RF output bandwidth: TBD
- Desired downlink bitrate: 1 Mbps

The output bandwidth is determined by the amount of filtering applied to the I and Q signals. These signals can be taken directly from the MCU, but filtering then reduces the final RF output bandwidth.

Maximum carrier drift Δf_0 would not be an issue were it not for regulatory bodies. So upon recieveing the frequency licence and determining the frequecy bandwidth, we will be able to determine the maxumum Δf_0.

RF design

$$BR = 1\,\text{Mbps}$$

$$D_{image} = 2.1\,\text{MP}$$

for 24 bits per pixel:

$$D_{image} \approx 48\,\text{Mbit}$$

adding FEC and preambles:

$$D_{total} = 50\,\text{Mbit}$$

This would mean that transmitting a single image would take 50 s. Bitrate could be raised and this is still subject to change.

The MCU

The MCU should be radiation hardened.
It preforms simple tasks, but may be employed to serve other cubesat modules (a redundant watchdog, for example).

Data acquisition and some considerations

The onboard memory needs to be radiation hardened as well. While the satellite is not visible from the ground station the local transmitter memory is slowly filled with raw images. These images are then sent out in bursts while the satellite is overhead.

Transmitter block diagram

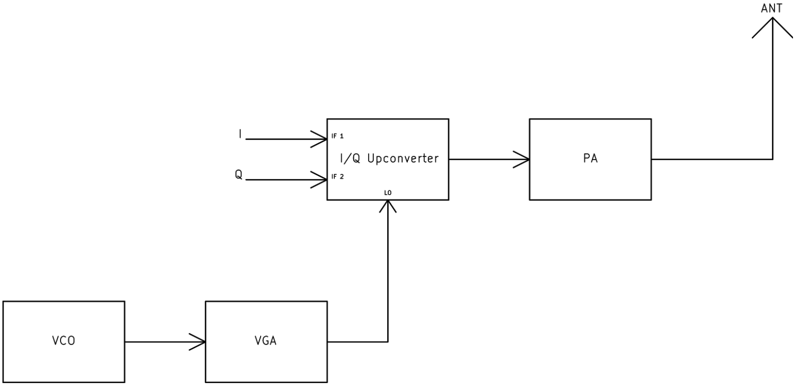
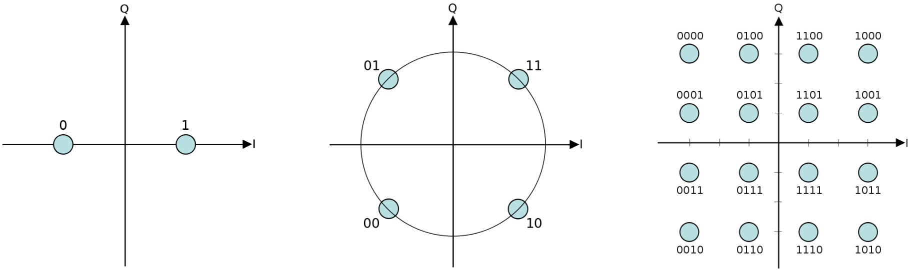


Figure: The transmitter block diagram

Modulation schemes considered



(a) BPSK (b) QPSK (c) 16-QAM

Figure: Constellation diagrams of the considered modulation schemes

The cubesat

The X-band payload sits in between the camera and sensor modules. The antenna array will have a hole cut in the middle of the array for the camera.

Conclusion

The high datarate downlink module is vital to this mission since other means of communication are very slow in comparison.

Questions?