InnoCube - Preparing the Fully Wireless Satellite Data Bus for Launch

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ABSTRACT

The Innovative CubeSat for Education (InnoCube) mission is a technology demonstrator cubesat mission relying on a fully wireless data-bus, set to launch in November 2024. This paper will discuss the mission objectives, design and implementation of the InnoCube mission with an emphasis on the wireless data bus. The mission is a collaborative project between the University of Wuerzburg and the Technische Universität Berlin in Germany. The mission objectives are to showcase the viability of a fully wireless data-bus for intra-satellite communication onboard cubesats and satellites in general, to provide a platform for testing and validating these new technologies, and to provide an opportunity for students to gain hands-on experience in the design and operation of a cubesat mission. The design of the InnoCube mission includes a 3U cubesat bus including the avionics, the wireless data-bus, and a suite of payloads provided by the TU Berlin. The wireless data-bus is based on a time-division multiple access protocol and will enable the cubesat's subsystems to communicate within the satellite, relying only on wireless means of communication. InnoCube will provide valuable insights and data concerning the feasibility of a wireless data bus for space applications, which can be especially beneficial to larger satellites and their associated large data harness. The mission will be operated from the Technische Universität Berlin and will be launched in 2024. Firstly, the paper will give an overview of the design of the satellite's subsystems including the additional payloads. Then, the technology used in the wireless bus will be described. Special emphasis will be given to the integration and testing of the wireless bus before launch. This paper will also discuss the challenges associated with the InnoCube mission, such as the need for robust communication protocols, the need for reliable power sources, and the need for reliable redundancy control schemes. Additionally, the paper will discuss the potential applications of the technology demonstrated by the InnoCube mission along with their advantages and disadvantages compared to a traditional data harness. Finally, the paper will discuss the potential benefits and open topics for future missions using wireless technology for intra-satellite communication as demonstrated by the InnoCube mission.

INTRODUCTION

By eliminating the need for cabling within a satellite, not only is the weight and complexity of the spacecraft reduced, it also paves the way for a more streamlined and adaptable system. The advent of a modular satellite design enables the seamless integration of components without the burdensome concern of large cabling arrangements for data exchange, a traditionally convoluted aspect of the design and integration process.

The significance of weight reduction in satellite design is exemplified by the Mars Express probe, which was launched in 2003. Among the probe's total dry mass of 640 kg, a substantial 64 kg was solely attributed to the cable harness.[1] The potential cost savings resulting from a 10% reduction of the mass range from 76,000 € to 204,800 € , considering the launch costs ranging from approximately 10,000 € to over 20,000 € per kilogram for Low Earth Orbit (LEO) or Sun-Synchronous Orbit (SSO) deployments.[2] The primary objective of the SKITH project is to systematically establish a comprehensive framework which allows the integration of wireless communication as a substantiated and universally applicable design within spacecraft in general.

In conventional spacecraft architecture, numerous sensors and actuators are directly linked to the on-board computer or their associated subsystems, resulting in the necessity for a considerable quantity of input-output interfaces (IO interfaces). Given the mission-dependent nature of the utilized components, the on-board computer must be tailored to the specific interfaces of each new mission.

In space technology, the significance of wireless communications technology within spacecraft has grown in the recent years, assuming an increasingly crucial role in fulfilling networking, modularity, and cable-free requirements, among other emerging demands.[3] This heightened attention to wireless communications technology has prompted the Consultative Committee for Space Data Systems (CCSDS) to intensify research efforts in this domain. Consequently, several wireless communications standards tailored for aerospace applications have been developed.[3,4] There have already been certain missions which tested single components that communicate with the main satellite bus using a wireless connection.[5] The Defli-C3 mission for example tested an autonomous wireless sun sensor, but only one of two units remained functional and the main satellite bus still used conventional data harness.[6] Another form of wireless intra-satellite communication is Optical Wireless Links for Intra-Satellite Communications (OWLS).[7] The OWLS technology gained in-orbit experience through the OPTOS satellite launched by INTA in November 2013, which employed optical wireless links, eliminating the need for data wires as all units communicated via a optical Wireless-CAN protocol.[8] Ratiu et al. used an ultra-wideband (UWB) wireless module for intra-satellite communication. The paper presents experimental results achieved through the implementation of a wireless spacecraft payload network using the ISA100 industrial wireless protocol over IEEE 802.15.4 UWB PHY specifications. The network is organized in a star topology. The conducted test scenarios involved sending tele-command image acquisition messages from the PC application to each sensor and receiving the images back. The obtained experimental results demonstrate the effectiveness of ISA100 over UWB transmissions for implementing intra-spacecraft communication.[9]

An UWB wireless module was also used in the ESA founded WiSAT-3 technology assessment project, where they developed an engineering qualification model (EQM) of a spacewire to UWB module for intra-satellite communication.[10] Buta et al. focuses on the testing and validation of a wireless transmission system within a spacecraft network, replacing traditional wired intra-spacecraft communications. The system utilizes Ultra-Wideband (UWB) technology as a suitable wireless solution for intra-satellite data transfer. The study involves the implementation and testing of two Space-Wire(SpW)-to-UWB Wireless Interface Units (WIUs) that function as SpW routers and adhere to SpW standards. The devices successfully passed qualification tests. The results demonstrate the reliability and functionality of the proposed UWB wireless communication solution within the spacecraft environment, offering potential for future satellite missions. The adopted architecture, based on SpW, ISA100, and IEEE 802.15.4 UWB PHY, proves to be a viable option for both current and future spacecraft communications, supported by studies conducted by the CCSDS.

Zheng et al. discusses how intra-satellite communication can be integrated into the various satellites subsystems. The paper also highlights that wireless communication in spacecraft introduces challenges such as potential interference with other components, susceptibility to interference from both internal sources and the environment, and the additional space occupied by the transceiver. However, these drawbacks can be effectively mitigated through engineering and technology advancements. The utilization of wireless communication in spacecraft avionics architecture offers notable advantages, including reduced weight, enhanced flexibility, improved redundancy and fault protection, as well as decreased complexity.[11]

Comparison between conventional and wireless data bus

In the following we give a comparative overview of the advantages of the wireless system compared to the state-of-the-art cable harnesses:

Conventional data harness

- On-board computer must be adapted to the required interfaces for each mission
- Complex and error-prone integration of the cable harness
- Interfaces and cable harnesses must be provided for tests on the integrated satellite
- Approx. 10 % of the total weight of a satellite is accounted for by the cable harness
- Cables and connectors carry a risk of failure in the event of vibrations or harsh conditions

Wireless data bus

- On-board computer requires standardized radio interface
- Modules of the satellite can be easily plugged together
- Easy testing and monitoring from outside the satellite (multi monitor capabilities)

- Miniature radio modules weigh only a few grams for each connected module
- Transmission path unaffected by mechanical stress
- Redundant hardware does not affect each other: No power, no wireless signal
- Possible reduced bandwidth

SKITH

In the InnoCube mission, the primary satellite data bus will exclusively rely on wireless data connections. As such, the SKITH project represents a wireless infrastructure designed explicitly for satellites.

To address this challenge, the University of Wuerzburg has undertaken several research initiatives focusing on the development of programmable wireless modules capable of facilitating radio transmission while providing the customary interfaces required for IO connections in satellites.[12–14]

These front-end modules perform all the necessary protocol conversions accordingly and thus provide a uniform, wireless interface for all IO devices. In this way, the on-board computer becomes completely independent of the interfaces of the sensors and actuators used. Replacing one device with another within the satellite after integration has begun or has been completed is normally unthinkable. Due to the uniform radio standard, the system offers the necessary flexibility to make this possible without any problems.

A nice side effect of this effort is the ease of monitoring, even after final integration without having to provide interfaces for external devices or additional software. Sensor data can be easily recorded and analyzed via a receiver outside the satellite. Sensor data can also be fed into the avionics network from outside via a transmitter. Thus, even hardware or software in-the-loop tests are possible on the fully integrated satellite, which would only be feasible with great effort on external interfaces on conventional satellites.

Like in the mentioned projects in the introduction, these modules have also previously been based on a STM32F4 using the DecaWave DW1000 wireless transceiver.[15] These modules have been used in many of the university projects such as Space Maneuvering Simulators or drones with added extension boards. Because of power constraints, the InnoCube CubeSat will use different wireless hardware which will be described later in this paper.

INNOCUBE MISSION OVERVIEW

InnoCube is a 3U-CubeSat mission currently under development as a collaboration of the University of Wuerzburg and TU Berlin. Two innovative technologies will be evaluated in orbit: Wall#E and SKITH. Figure 1 shows a structural ground model of the 3U CubeSat.

Figure 1: InnoCube structural ground model

Wall#E is an innovative technology concept which aims to develop a structural battery which servers as structure and energy storage at the same time. This structural battery uses fibre composites as well as solid-state battery materials.[16] In InnoCube, a prototype of this battery will be tested for its space suitability. Since Wall#E will be a first technology demonstration, the prototype will be integrated as a payload and not as the main power storage system of InnoCube.[17]

Furthermore, the EPISODE payload aims to assess the hardware and algorithms required for a software defined radio solution to enhance the accuracy of CubeSats' on-orbit positioning using global navigation satellite systems (GNSS). As part of this objective, InnoCube will be equipped with a laser-ranging reflector to validate the payload data.

This paper mainly discusses the wireless technology SKITH. Within SKITH, the conventional data bus using wires and harness will be replaced using wireless modules. It is important to note that InnoCube will exclusively utilize wireless connections for communication between its subsystems.

The InnoCube mission is a satellite project developed by a team of students and research assistants and will undergo all phases (A to F) of the mission cycle. This holistic approach ensures that the project team gains valuable experience throughout the entire process, starting from the initial preparation phase, followed by the conception and definition phase, progressing through the design and development phase, and finally reaching the operation and disposal phase. In phase E the Launch and Early Orbit Phase (LEOP) is a crucial stage that involves a meticulous check of all subsystems for optimal functionality. This is followed by the calibration and commissioning of the EPISODE and laser ranging payloads, which are expected to be completed within a period of three months. Subsequently, the payloads will enter nominal operational mode, generating valuable data aligned with the project's scientific objectives. The total mission duration is set to be one year in orbit.

In addition to the scientific goals, the project has the primary objective of educating students. This encompasses various aspects, including component development, technical and electrotechnical training, as well as hands-on satellite operation. The aim is to provide a comprehensive learning experience for the students.

The project spans a duration of five years and includes the design, manufacturing, launch, and operation of a small satellite, adhering to the following key boundary conditions:

- Fabrication, validation, and verification of a CubeSat flight model within 5 years
- Successful launch, followed by up to three months of LEOP and payload commissioning.
- Mission life expectancy of 12 months (in-orbit).
- Reliability of both the satellite and science payloads for operational use, expected to last 9-12 months until the mission's end (active phase) and until the end of life (passive laser ranging).
- Verification of science experiments and collection of relevant data.
- Achievement of science and engineering objectives.
- Comprehensive hardware and software testing.

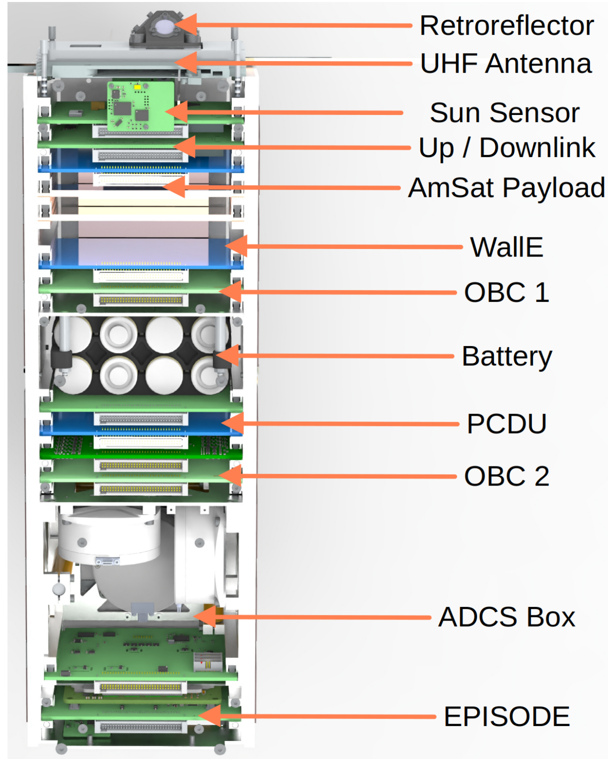

Figure 2: InnoCube Systems Overview

Figure 2 depicts the main systems of the InnoCube satellite. Communication will be established using an omnidirectional UHF antenna, in addition to two redundant uplink and downlink modules equipped with a transceiver operating within the 435 to 438 MHz frequency band. A VHF to UHF transponder will also be included as a payload, serving as a secondary redundant communication path.

The power system of InnoCube relies on a single NanoPower BPX Battery pack, utilizing lithium-ion batteries in a 2S-4P configuration.[18] EnduroSat solar panels are employed on all four main CubeSat sides.[19] Charging, power conditioning, and distribution will be handled by two PCDU modules developed at DLR Bremen. A backplane will be utilized for distributing power lines to the satellite systems. Since wireless connections are employed across all modules, the backplane will not carry any data signals.

On-board data handling will be accomplished by four cold-redundant on-board computer modules. The on-board software will be based on RODOS, a real-time operating system developed for satellite applications.[20] The software framework CORFU will be utilized to create the on-board software, employing easy-to-use configuration files that allow for the auto-generation of general software capabilities, such as telemetry and telecommand functionalities.[21,22]

The attitude determination and control system (ADCS) will be integrated into the main satellite structure using a dedicated sub-structure, facilitating easy testing and integration processes. Six wireless sun sensors will be placed on all sides of the CubeSat, along with a magnetometer and a rate-gyro, enabling attitude determination through the use of an extended Kalman filter algorithm. Three magnettorquers and reaction wheels will be employed to control the satellite's attitude. The ADCS system will play a crucial role in maintaining the alignment of the laser ranging reflector during laser ranging experiments and ensuring accurate antenna pointing for the EPISODE antenna.

SKITH WIRELESS BUS

In InnoCube, the main satellite data-bus will rely solely on wireless data connections. Figure 3 depicts the wireless node network of InnoCube. The communication between these modules uses the wireless system, there are no traditional data connections available. The technology used in SKITH will be described in the following sections.

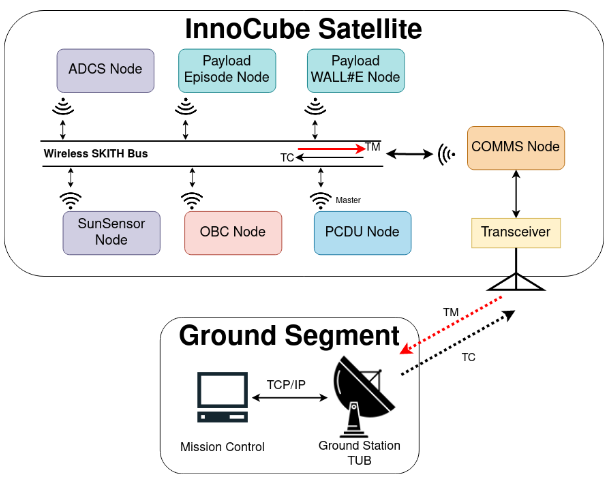

Figure 3: InnoCube wireless system

Hardware

The hardware of InnoCube utilizes the Silicon Labs Gecko EFR32FG12 40 MHz microcontroller, which features an integrated 2.4 GHz radio interface. This interface enables transmission and reception of data in the 2.4 GHz band, offering a transmission power of up to 19 dBm, a data rate of 2 Mbit/s and support for various modulations.[23] The microcontroller handles essential tasks such as preamble generation, sync word detection for frame start, frame length management, and CRC-16 checking. However, the user is responsible for managing collision avoidance and other aspects on this interface.

To establish communication, we have developed our SKITH protocol on top of this interface. The protocol employs a Gaussian Frequency Shift Keying (GFSK) modulation with a frequency deviation of +/- 1 MHz and a data rate of 1 Mbit/s. The chosen bandwidth of 2 MHz is twice the required bandwidth for the data rate, providing increased stability for data transmission. We define a set of 40 channels with 2 MHz spacing within the frequency range of 2402-2482 MHz, utilizing a transmission power of 9 dBm. For InnoCube's operations, only one fixed channel is utilized, while the remaining channels are available for development purposes.

It's worth noting that InnoCube does not integrate any other 2.4 GHz radio systems on board, minimizing concerns related to electromagnetic interference (EMI). The German Federal Network Agency has recommended using the frequency band between 2446 and 2454 MHz, making channels 23 to 25 suitable for space applications, with a 2 MHz margin to the band limits. This frequency band selection takes into account considerations of other space-used bands and potential interference from terrestrial signals.

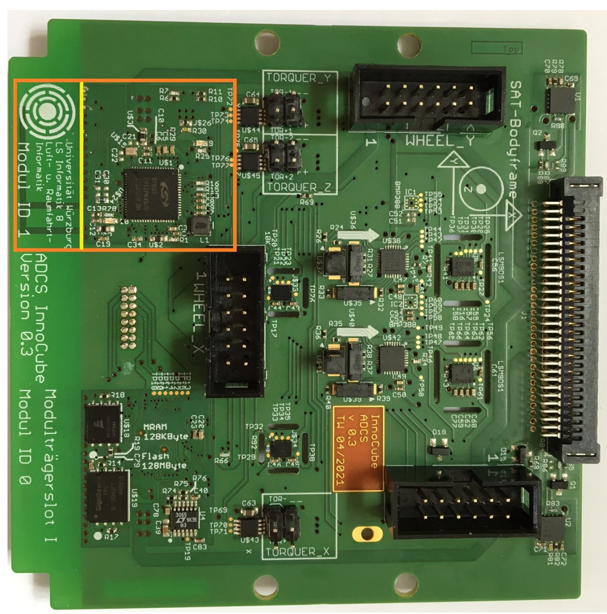

Figure 4: ADCS Board (SKITH marked orange)

The minimal footprint using the pcb-antenna currently is approx. 21mm x 31mm and can be seen as used by ADCS mainboard design in figure 4. Only very few external components are required for the operation of the internal radio interface. The antenna is integrated into the PCB and occupies approx. one-third of the total footprint. The used micro controller provides a wide range of IO sufficient for most on-board data handling operations and can therefore be used on all satellites subsystems, all sharing the same minimal SKITH PCB layout.

Power Consumption

SKITH on InnoCube uses the radio-interface of the EFR32FG12 micro-controller, which is designed to be used in low-power application. The power-draw is summarized in table 1. It should be noted, that the power measurements were taken during maximum transmission power of 80mW. The actual power used on the satellite will be much lower, thus the power consumption will be lowered additionally. It can be seen, that for lower data-rates (such as 56kpbs in InnoCube), a very low power draw can be achieved, which is comparable to the consumption by other micro controllers such as the STM32F4, also used in CubeSat missions.[24] The power draw of one of these modules is also lower than the power used by the UWB DecaWave DW1000 wireless transceiver modules and is therefore more suitable for the cubesat.[15]

Table 1: Power consumption in different modes using 80mW transmission power

Mode	Power (@3.3V)
Idle	79 mW
Continuous Random Sending	323 mW
SKITH (13 Nodes, 54 kbps)	98 mW

Environmental tests

An important step in developing new hardware for spaceflight application using commercial off the shelf (COTS) components is the qualification process. Therefore, environmental tests have been conducted. For the SKITH hardware, thermal vacuum (TV) and total dose radiation (TID) tests are from particular interest. Mechanical testing will be conducted at a later stage of the project but since there are no external interfaces such as antenna-connectors or other mechanical parts involved, we do not expect any degrading effects.

TV-Tests took place at the vacuum chamber at the University of Wuerzburg. Three PCBs have been subject to the testing procedure: The ADCS board, the OBC and one sun-sensor. All PCBs share the same SKITH hardware, but differ in peripherals. Test-data has already been collected using the SKITH wireless interface, with an external SKITH transceiver placed outside of the chamber (see figure 5). Signal-strength showed to be sufficient up to a few meters away from the chamber by using maximum transmission power. Frame-loss could therefore be measured directly from the received test data. During testing, no wireless dropouts or change in frame-loss occurred. Currently, we measure a frame loss of less than 0.02%. We expect this loss to be caused by interference with other terrestrial signals at the same frequency, but this effect has to be evaluated further. Test-parameters can be found in table 2. It should be noted, that the receiving SKITH node outside of the chamber was kept at room temperature, resulting in a temperature difference of approx. 50 °C. Still, transmission and receiving operated normally.

Table 2: Thermal vacuum test parameters

Parameter	Specification
Temperature Range	-30 - +70 °C
Dwell Time	2 hours at peaks
Slope	<5K/min
Cycles	8
Pressure	10^{-5} bar

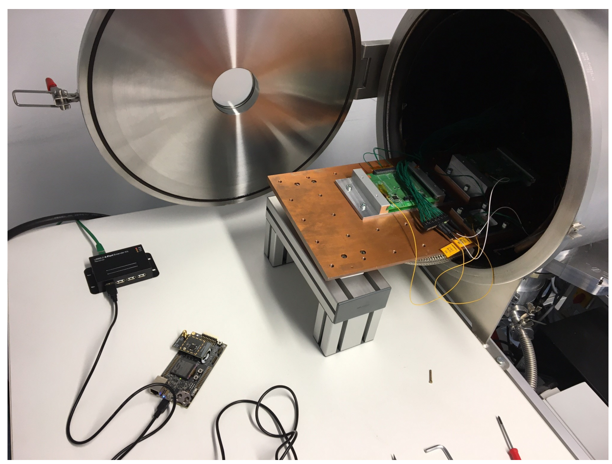

Figure 5: TV Test Setup

Total Dose Radiation suitability has been tested twice at the Helmholtz-Zentrum Berlin using a Cobalt-60 source. In the first test, the micro controller have been tested for general suitability Cobalt-60 source with a mission dose of 0.64 krad/h and a total ionisation dose of 10.8 krad over 20 hours. Test parameters of the second test can be found in table 3, which also include the expected mission dose of 10.8 krad in LEO. The wireless connection remained stable during the whole test duration and showed no effect of degradation. Even a high dose test with a TID of 37.5 krad did not alter this behaviour.

Table 3: Second radiation test parameters for dedicated flight hardware

Test	TID	Rate	Time
Mission Dose	10.8 krad	0.64 krad/h	17 h
High Dose	37.5 krad	7.22 krad/h	5.2 h

Software and Protocol

The radio protocol coordinates the communication between the modules in order to prevent transmission interference caused by simultaneous transmission of several modules. A central, defined coordinator (SKITH master node) is used, who regularly assigns time windows to each module during which they are allowed to transmit. This ensures a low complexity of the system and a fixed known system state. To prevent this central master node from becoming a single point of failure, redundant modules are available. A mechanism independent of the radio system ensures that exactly one of the two master nodes is always switched on. The active master node is always monitored for the function of the complete radio link. The complete redundancy concept is described in section

The radio hardware integrated in the EFR32FG12 Gecko micro controller takes care of the channel encoding, framing and securing the transmitted data with a checksum. The addressing of the data is already taken over by the RODOS middleware in the system, the SKITH radio system always sends all data as broadcast to all modules. The protocol then only has to take care of collision avoidance. For this purpose, the master node sends out so-called sync frames at periodic intervals. These contain a list that defines a time slot for each module contained in the satellite in which it may transmit. These time slots are always relative to the time of reception of the sync frame, which allows a high accuracy of the slots without time consuming synchronization. A Sync-frame with all corresponding data frames of the modules is called a SKITH cycle (figure 6). For InnoCube, the slot length has been set to 6ms with a resulting cycle length of 78ms. Each slot can contain up to 520 Bytes of payload data, resulting in a bandwidth of approx. 54 kbps per node.

Slot-management

The SKITH protocol uses a time division multiple access (TDMA) protocol, which is implemented by the use of so called slots. Normally, the master node assigns a transmit slot to each switched-on module in each cycle. Only switched-on (active) modules are assigned slots, which means that only about half of the available modules are assigned slots per cycle due to module redundancies. Figure 6 shows an example of a complete SKITH cycle.

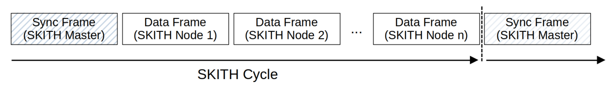

Figure 6: SKITH frame cycle

For modules with lower data rate requirements, such as the sun sensors, it is not necessary to reserve a slot in each cycle. Also, the slot length can be shortened for certain modules if they have a smaller maximum topic size. Therefore, more bandwidth can be allocated to data heavy nodes. However, this functionality will not be used in the commissioning phase of InnoCube and will only be tested when the bus proves to be reliable and the main objectives of the mission have been achieved.

Frame format

In order to provide the slot information and to encapsulate the data into the wireless packages, the following frame format has been implemented:

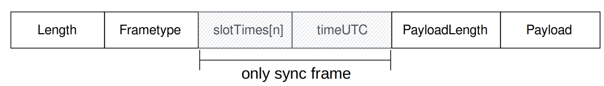

Figure 7: SKITH frame structure

Table 4: SKITH frame structure

Name	Type	Description
Length	uint 16	Length of complete frame
Frametype	uint 8	0=Data-Frame, 1=Sync-Frame
slotTimes[n]	*uint 32*	Start of the slot of node n, relative to the sync frame [μ s]
timeUTC	*uint 64*	UTC-time of SKITH master
Payload Length	uint 16	Length of RODOS middleware frame
Payload[n]	uint 8	RODOS middleware frame payload

Figure 7 shows the frame format, table 4 gives a detailed description of the fields. The frames used by the master and the normal modules use the same structure. The coordinator frames (master frames), which are sync frames, also contain the slot list and the current UTC time of the master node. These fields are listed in italics. The payload of the frames then contains one or more RODOS middleware frames, each containing a published topic with its payload. Always as many RODOS middelware frames are transmitted in a SKITH frame as are currently available in the output buffer, or until the slot is full.

A slot must therefore always be at least as large as the largest topic published by the module, so that a transfer is always possible. The length of a slot always results from the beginning of the next slot. If no slot is assigned to a module, its slot time is set to 0.

Time Sync

The master node distributes its current UTC time with each sync frame. Because the sync frame is received by modules always at exactly the same time using interrupts, an exact time synchronization can be achieved by very simple means. In addition, a "One Pulse Per Second" flag is set in the sync frame approximately every second. This can be used to trigger processes that have to run regularly at exactly the same time on several modules. (e.g. sun sensor measurements). Since one second is not necessarily an integer multiple of the cycle time and the cycle time can also change, this flag cannot be used for operations that must run exactly every second. A specific analysis of the achieved timing accuracy will be evaluated in another work.

Redundancy Concept

To ensure the reliable functioning of the entire system, it is crucial that only one master node is activated at any given time. If both nodes were switched on simultaneously, they would send out unsynchronized sync frames, leading to uncertainty regarding which node the other modules should follow. Additionally, it is essential to detect any potential failures in the active master node to enable a smooth transition to the backup node. This detection encompasses verifying the proper operation of both the software and the radio hardware's transmitting and receiving units.

To facilitate secure switching between redundant modules in the PCDU (which function as the radio master node) a specialized power switching mechanism is implemented. Both modules are connected to keep-off switches, which remain in the off position as long as regular pulses are applied to the control input at intervals of one second or less. When these pulses are absent, the switches activate. Each master node controls the switch of the other, establishing bidirectional control. By continuously sending Keep-Off pulses to the switch off the inactive master node, the active module ensures that only one module is powered on simultaneously, guaranteeing proper functionality. The PCDU was chosen as the radio master node because it has information and control of all the other node power states and only one of the redundant PCDU controllers can be active at any given time.

The keep-off pulses are generated when all critical threads of the PCDU node regularly transmit "I am alive" messages and receive radio messages from the other modules. Thus, the master node's sending and receiving capabilities are assured since other modules can only respond if they have received a sync frame from the master node beforehand . Consequently, at least one other module must always remain powered on. The system design guarantees that at least one of the COMS modules fulfills this requirement. In the event of any malfunction, the keep-off pulses cease, and the other master node module takes over. It then generates keep-off pulses itself, switching off the first module. When the power supply is activated (such as after separation or because of a system reboot) both master node modules start simultaneously. However, the first keep-off pulse is deliberately delayed by a few milliseconds, introducing a random element to determine which module becomes active. This approach ensures a fair and unbiased selection between the two modules.

We expect the following failure scenarios:

- SKITH transmitter/receiver fails
- Spontaneous error e.g. due to radiation induced bit flip
- Software error

Keep-Off pulses are generated only when frames are received from other modules. This ensures the functionality of radio communication because other modules rely on receiving a sync frame from the master node before transmitting. Any failure in radio communication caused by the aforementioned errors or others is thus detected and addressed.

To safeguard against the scenario where the coordinator maintains radio communication despite being unable to receive commands, the keep-off pulses are also interrupted if no commands are processed within a defined time period. An issue arises if the master node consistently restarts due to an error after the first keep-off pulse has been generated. In such cases, there is insufficient time for the redundant module to activate. To prevent this, the reason for the restart is examined before sending the first Keep-Off pulse. If the reason is something other than a "Power-On" event, indicating that the module was turned off for a different reason than activating the power switch, it remains idle and waits until the redundant module initiates its own activation and subsequently switches off due to the keep-off signal.

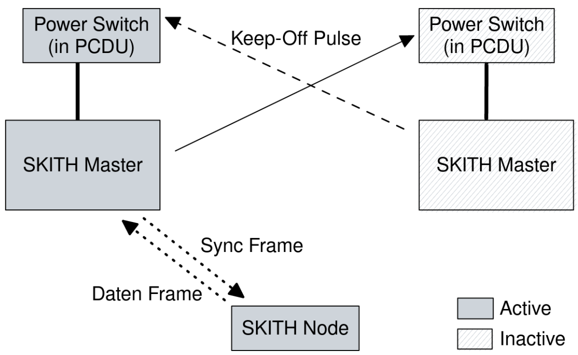

Figure 8: SKITH master redundancy concept

DISCUSSION AND CONCLUSIONS

The SKITH project as it will be launched in the InnoCube mission aims to demonstrate the feasibility and benefits of using wireless communication as a primary data bus within satellites. By eliminating the need for cabling, the weight and complexity of spacecraft can be significantly reduced, leading to cost savings and increased adaptability. The SKITH project builds upon previous research and utilizes programmable wireless modules based on the EFR32 microcontroller capable of facilitating radio transmission while providing standard interfaces for IO connections.

The significance of wireless communication in spacecraft has been recognized in recent years, leading to the beginning of the development of wireless communication standards tailored for aerospace applications. Several missions have already tested wireless components for intra-satellite communication, such as autonomous wireless sun sensors and optical wireless links. InnoCube will be one of the first satellites to rely only on a wireless data bus.

The comparison between conventional data harnesses and wireless data buses highlights the advantages of wireless systems, including easy integration, simplified testing and monitoring, reduced weight, and improved resilience to mechanical stress and failure. The SKITH project will demonstrate the practicality and benefits of wireless communication in the InnoCube CubeSat mission, contributing to the advancement of wireless technology in space applications.

The InnoCube mission will try to evaluate some of the open topics in using a wireless data bus for satellites. While working on the InnoCube project, we identified some open topics in the field:

- Performance and reliability of wireless communication in space: Further research and testing are needed to assess the performance and reliability of wireless communication systems in the harsh space environment, including factors such as signal interference, environmental effects, and long-term durability.

- Standardization and interoperability: As wireless communication becomes more prevalent in spacecraft, the need for standardization and interoperability between different wireless systems and protocols arises. Further work is required to establish common standards and ensure seamless integration of wireless modules from different manufacturers.

- Security and robustness: Wireless communication introduces potential vulnerabilities and risks, such as unauthorized access and signal jamming. Developing secure and robust wireless communication systems for space applications is an ongoing challenge that requires continuous research and advancements in encryption and protection mechanisms.

- Scalability and compatibility with existing systems: Integrating wireless communication into existing satellite architectures and systems can be complex. Exploring methods for scalability and compatibility with legacy systems will be essential for the widespread adoption of wireless communication in future space missions.

ACKNOWLEDGEMENTS

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