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A study on wireless intra-satellite bus system using UWB technology

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ABSTRACT

To overcome the weakness of a complicated wired data bus system in satellites, much research on the implementation of wireless data bus system has been studying. To this end, optical communication and various RF communications are suggested as the alternatives. This paper proposes the wireless intra-satellite bus system using UWB (Ultra Wide Band) technology (IEEE802.15.4a) with advantages in terms of power consumption, data rate and channel characteristics. The proposed system which provides a communication link among the subsystems in a satellite consists of operation block, MAC level block and UWB block with RF transceiver. The functional operation was demonstrated and the PER (Packet error rate) performance of the system was measured in dummy satellite structure.

1. INTRODUCTION

Satellites transmit and receive command, telemetry and data between units, modules and payloads through various wired interface standards to carry out specific missions so that the development of an efficient harness system is necessary. The harness cable system of satellites consists of power transmission cable and data transmission cable and their weight occupies about 6 to 10 % of that of the whole satellite. This leads to various drawbacks in the aspect of satellite design such as the increase in the weight of satellite, the development period and cost of harness system and the establishment complexity of a test environment, etc.

To resolve these problems due to the wired harness system, many researches on applying the ground wireless communication systems to the data bus system in satellites have been carried out. However, to adopt a ground communication system to the satellite, the effect cause by the satellite's structural and physical environment and the operation environment in space need to be studied.

This paper proposes to utilize the IEEE 802.15.4a system, which is excellent in power consumption, transmission speed, channel characteristics and implementation complexity compared with other wireless communication systems, to do construct a wireless intra-satellite bus system. To do this, a conceptual design is proposed and verification was performed by measuring PER (Packet Error Rate) with a dummy model satellite.

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2. Wireless intra-satellite bus system

2.1 Comparison of short range wireless communication system

To implant a ground wireless communication system to the wireless intra-satellite bus system, the advantages and disadvantages of various wireless communication systems such as WiFi, Bluetooth and ZigBee, etc. are studied. Accordingly, the system architectures of each communication standard and the network topologies are intensively studied. Especially, CCSDS adopted the IEEE 802.15.4a (ZigBee) to implement an intra-satellite network for the purpose of surveillance and control of the subsystems in satellite. Also, it performed researches about the effects of EMI (Electro-Magnetic Interference) and EMC (Electro-Magnetic Capability) which are caused by using radio wave instead of wire line. We chose the IEEE 802.15.4a which uses IR-UWB (Impulse-Radio Ultra Wideband) as one of the physical layer technique to implement a wireless data bus system of satellite considering power emission and robustness in multipath fading environment.

2.2 IEEE802.15.4a

The IEEE 802.15.4a is a low-to-medium rate short range wireless communication system employing ultra wideband impulse. It became a standard technique in 2007 and its PHY standard using IR-UWB allows for high aggregate throughput (lots of throughput over time) communications with a precision ranging capability (within 1 meter accuracy) within the scope of the WPAN. Not only the characteristics mentioned above, IR-UWB communication system provides excellent penetrability through walls and non-metal partitions, etc. and low power consumption by employing low duty cycle impulse radio wave. Therefore, IR-UWB is expected to be proper for implementing a wireless intra-satellite communication system. The IEEE 802.15.4a consists of PHY (physical) and MAC (medium access) layer performing physical connection and wireless access control, individually. Table 1 depicts the detailed system specification.

Table 1. UWB system requirement

Frequency range	3.1~10GHz
Data rate	0.85Mbps(110kbps~27Mbps)
Communications range	about 30m
Channels bandwidth	499.2MHz
Modulation method	BPM & BPSK (burst position modulation & binary phase-shift keying)
Chip rate	499.2MHz
Channel coding	RS(Reed Solomon) + Convolutional code
Channel access system	Aloha + CSMA/CS (Carrier Sense Multiple Access/Collision Avoidance)

2.3 Conceptual design

The satellite system is divided into several subsystems according to their missions and each subsystem consists of several units as well. Fig. 1 shows the block diagram of the wireless intra-satellite bus system that we proposed. The power for operation of each unit in the subsystems is provided by harness cable, while data communication is achieved by the simplified UWB wireless communication system. In satellites, normally, a relatively small number of units are involved in communication that a medium access control (MAC) method based on contention allowing collision is inappropriate. Therefore, a simple MAC with which data is transferred during contention free period in order is devised for the purpose of complexity and performance as well.

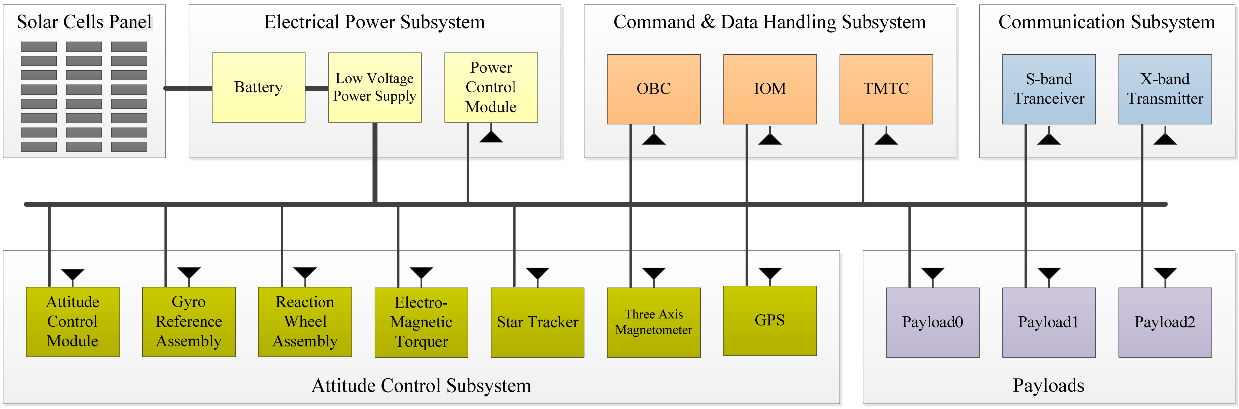


Fig. 1 Block diagram of wireless bus system

The units of the proposed wireless intra-satellite bus system is composed of operation block conducting data processing, sensing and actuating and MAC level block for network and UWB block for the PHY layer operation. Fig. 2 shows the block diagram of each unit.

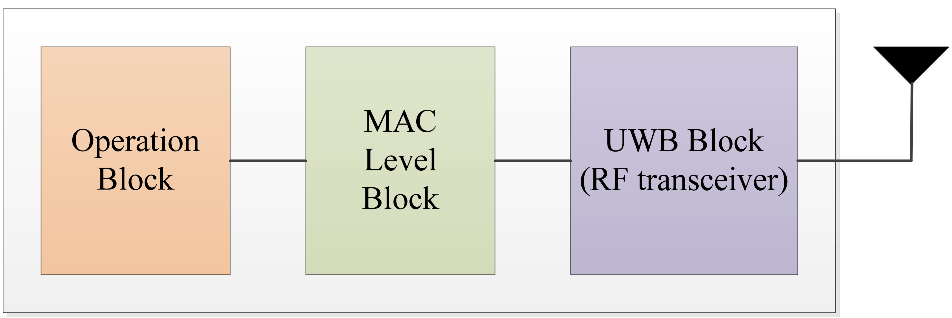


Fig. 2 Block diagram of a unit for wireless bus system

3. Experimental results

To verify the operation of UWB technology and apprehend the channel characteristic inside satellite, a test was carried out. To this end, a dummy satellite model made of aluminum with dimension of 1m x 1m x 1m was used and to replace the obstacles in satellite, aluminum panels were places inside the satellite model. The employed UWB communication available module is the IEEE 802.15.4a compatible one (EVB1000 made by Decawave).

The test was carried out in free air and inside the dummy satellite frame and which is also divided into two states of obstacle state and no-obstacle state. The communication test was performed set at channel 2 of the standard with 1024 preamble length, 16MHz Pulse Repetition Frequency and 110kbits/s. Fig. 3 shows the composition for the bench test to verify the operation of UWB wireless communication system.

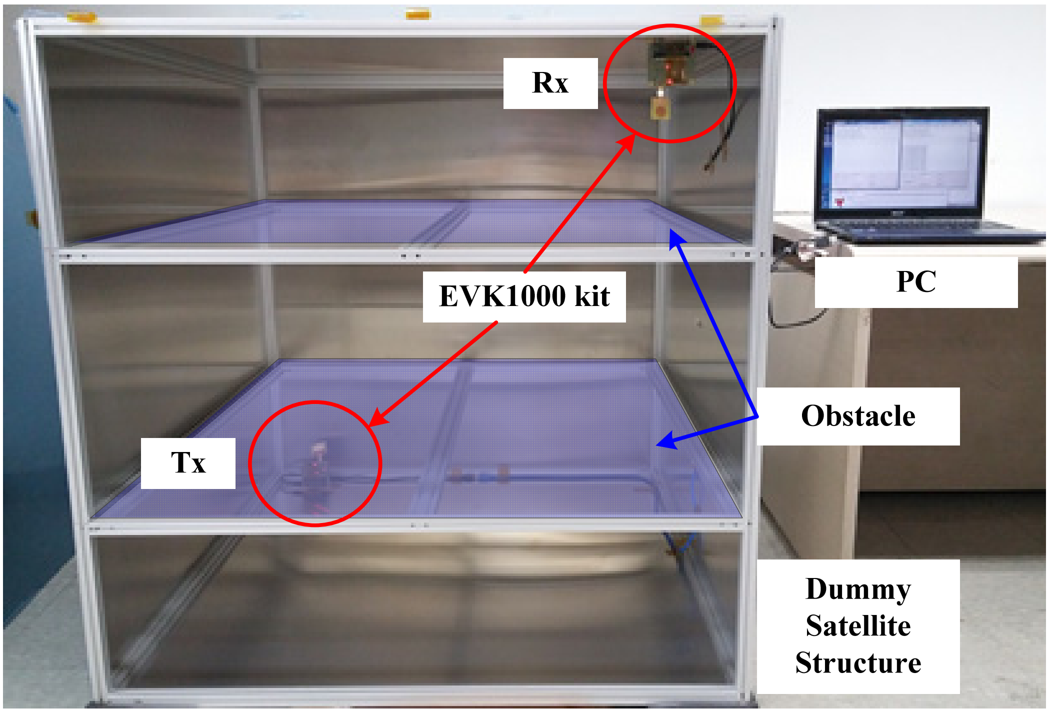
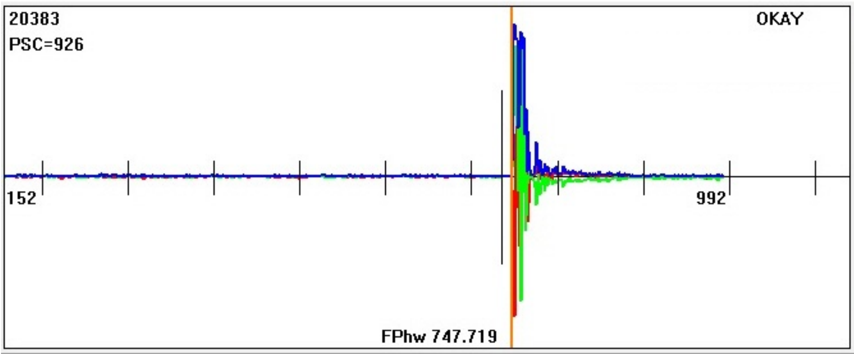


Fig. 3 Bench test of UWB technology in dummy satellite structure

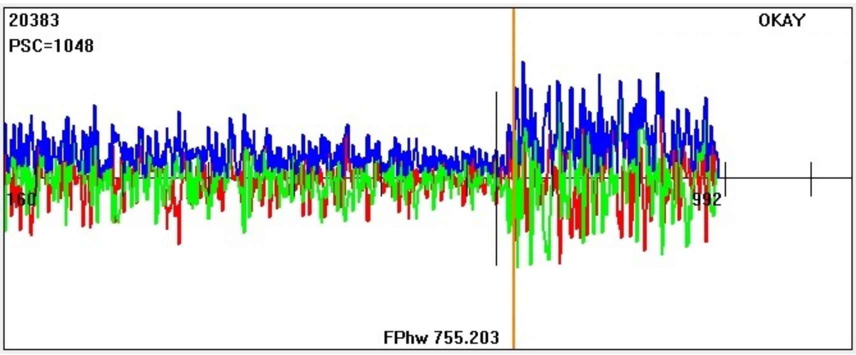
Table 2 shows the PER performance, received signal level (RSL) and signal-to-noise ratio in each condition mentioned above. The test results in the average PER of being 0 in indoor free air channel and 4.0E-04 in no-obstacle condition and 7.9E-04 in with-obstacle condition, individually. The results depict that the performance becomes worse as obstacles increase and accordingly RSL and SNR are reduced. Fig. 3.is the measured channel delay profile in each condition. The figure depicts that the more obstacles are placed, the more multipath signals influence in the channel, and that leads to reduced SNR and PER performance.

Table 2. Measurement results

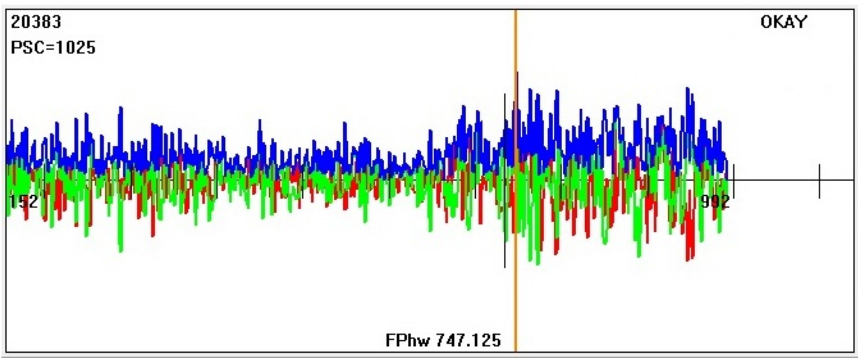
Condition		Average of received		
		PER	RSL(dB)	SNR(dB)
Free air		0.0E+00	-80.3	-0.8
In dummy satellite structure	Non-obstacle	4.0E-04	-82.9	-3.4
	Obstacle	7.9E-04	-84.5	-5.0



a. Free air



b. Non-obstacle in dummy structure



c. Obstacle in dummy structure
Fig. 3 UWB channel response view

4. CONCLUSIONS

We chose the IEEE 802.15.4a employing IR-UWB signal to construct a wireless data bus system in satellite. A conceptual design is proposed and the test results are shown. In point-to-point condition, the IR-UWB technique provides a performance good enough to construct a wireless data bus system in satellite. As the furthermore work, we need to devise a simple MAC structure and test the operation integrated with PHY.

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