Waveform Design for UAV Payload Communication in C-band

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Abstract— **Currently, LTE mobile communication technology is considered as the main communication link of UAV. However, an auxiliary communication link is indispensable for stable operation and mission execution of UAV even in areas where existing mobile communication networks can not cover. For stable operation of UAV, auxiliary communication link requires greater communication coverage and link availability than existing LTE mobile communication network. In that sense, it is difficult to use for the auxiliary communication link un-licensed band where there is the small power limitation and severe interference is suffered. Therefore, C-bands, which is allocated for UAV control and payload communication, could be good candidate. In this paper, we propose a new waveform for UAV payload communication in the C-band and show its performance results.**

***Keywords*— UAV, Payload Communication, Waveform.**

I. INTRODUCTION

The data link of the UAV system can be divided into control communication link and payload communication link. The payload data link is a data link related to UAV mission and generally needs broadband than the control communication link. On the other hand, the control communication link is defined as a link for conveying data related to UAV flight control, status monitoring, system management, etc. [1].

LTE mobile communication technology has advantages such as larger coverage and QoS management than existing unlicensed band low power communication technology such as WiFi which is widely used in UAV. However, LTE mobile communication technology also has a problem that communication is cut off outside coverage of existing mobile communication network such as mountain and sea. Considering that unmanned operation must be possible in any areas, an auxiliary communication link is required for stable control and mission execution of UAV in areas where LTE mobile communication of main communication link is not available.

For this purpose, unlicensed band communication technologies such as WiFi, which are widely used in UAV, can be considered, but it is difficult to guarantee coverage and secure communication link due to limited power and interferences. Accordingly, in order to stabilize the operation of UAV and to expand the operation of UAV, licensed frequency bands for UAV control and payload have been allocated in the C band frequency in Korea.

The C-band frequency for UAV control allocated in Korea is 5030-5091 MHz band, and is internationally allocated for UAV control by ITU-R for the purpose of integration of UAV into national airspace [2]. On the other hand, the C-band frequency for the UAV payload was allocated in the 5091-5150 MHz band for domestic use in Korea. In the licensed band, it is possible to secure a more stable communication link than the communication in the un-licensed band, and as the auxiliary communication link of the LTE main communication link of UAV. However, differently from UAV control communication in C-band, UAV payload communication technology in C-band has not been developed and standardized.

Therefore, in this paper, we propose candidate waveform technology for UAV payload communication in C-band.

II. UAV CONTROL COMMUNICATION TECHNOLOGY

The C-band control communication frequency is distributed globally at WRC-12 of ITU-R, and the international standardization process is being carried out by the Radio Technical Commission for Aeronautics (RTCA) and the International Civil Aviation Organization (ICAO). At present, the RTCA has completed the first stage of standardization for UAV control communication and developed the DO-362 MOPS standard [3]. In the ICAO, the details of the technical solutions for UAV operation were decided to be referred to the standards of RTCA and EUROCAE in Europe. Considering that EUROCAE in Europe is not proceeding standardization of terrestrial control communication technology, the RTCA DO-362 standard is likely to be adopted as an ICAO standard. The characteristics of the control communication technology of the RTCA are as followings.

- Operating bands: C-band (5030-5091 MHz)
- Target link availability: 99.8 %
- Duplexing: GPS based time division duplex (TDD) to avoid interference between adjacent TRx
- Frame duration: 50 ms
    - o Based on maximum repetition rate for manual operational mode of 20 Hz

- Modulation: GMSK with BT=0.2 (BT = Bandwidth x Symbol Rate)
- Forward error correcting: Punctured turbo coding
- Multiple Access
  - o Downlink (UA → GRS): FDMA
  - o Uplink (GRS → UA): FDMA (P2P), FDMA/TDM (P2MP)
- Symbol Rate/Transmission bandwidth
  - o Downlink (UA → GRS): 34.5-552 ksps / 30-480 kHz
  - o Uplink (GRS → UA): 34.5-103.5 ksps / 30-90 kHz (P2P), 103.5-828 ksps / 90-720 kHz

III. WAVEFROM DESIGN UAV PAYLOAD COMMUNICATION

In order to derive a new waveform technology, the following requirements is considered.

- Maximum data rate: above 7 Mbps
  - o To support HD video transmission
- Maximum communication rate: 30 km
- Maximum UAV velocity: 150 km/h in NLOS, 1500km/h in LOS
- Maximum delay spread: 1~2us
- Low PAPR
- Support of variable rate
- Low spectrum leakage: out-of-band emission below -60dBc from peak
- Coexistence with control communication in C-band

Considering the above requirements, the characteristics in Table I are applied in the proposed waveform design.

A. Frame Structure

Each radio frame has a length of $T_f = 50$ ms, and consists of subframe # 0 with a length $T_{sf0} = 24.3$ ms and frame # 1 with a length $T_{sf1} = 25.7$ ms. The first subframe (0, # 0) is used by the indication of the upper layer. When the first subframe is not used, subframe # 0 is not transmitted. The radio frame number corresponding to an integer multiple of 20 starts at an integer multiple of 1 second in UTC time.

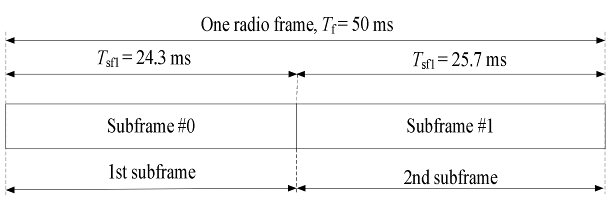
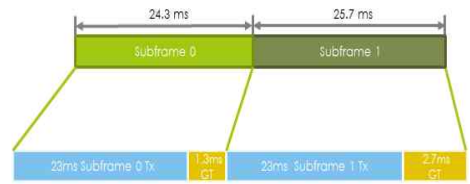


Figure 1. Frame structure

The 0th subframe and 1st subframe have a length of T_{sf0} = 24.3 ms and a length of T_{sf1} = 25.7 ms, respectively, and consist of front guard symbols, one preamble block, 34 slots (pilot+data), tail guard symbols and guard time as followings.

TABLE I. MAIN CHARACTERISTICS OF WAVEFORM FOR UAV PAYLOAD COMMUNICATION

	Characteristics
Frame structure	• GPS-based 50ms frame structure identical to the frame structure of the C-band control communication standard to reduce interference from C-band control communication. 
waveform	• Single carrier based waveform considering characteristics of amplifier nonlinearity from SWaP point of view of small UAV (PAPR characteristic is better than multi-carrier system such as WiFi) • Applied SC-FDE (Single Carrier-Frequency Domain Equalization) scheme for low-complexity operation in multi-fading channels
Pilot placement	• Considering UAV velocity of 150km/h • Considering 1~2us delay spread
Modulation	• QPSK, 16QAM to support variable rates and HD video transmission
Preamble	• Zadoff-Chu sequence with low PAPR
Coding	• Puncture turbo code to support variable rates
MCS mode	• Support of variable modulations and coding rates
Low spectrum leakage	• To apply Tx RRC filtering

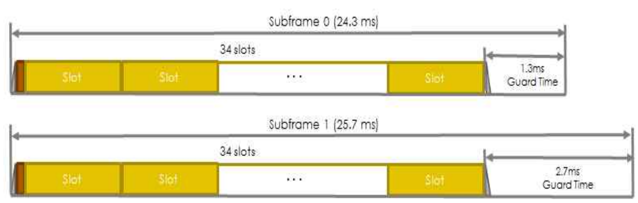


Figure 2. Subframe structure

Each slots has 3 pilot blocks and 15 data blocks. Both pilot blocks and data blocks consist of CP of 24 symbol length and useful block of 256 symbol length. The useful block of pilot and preamble blocks are based on zadoff-chu sequence for low PA

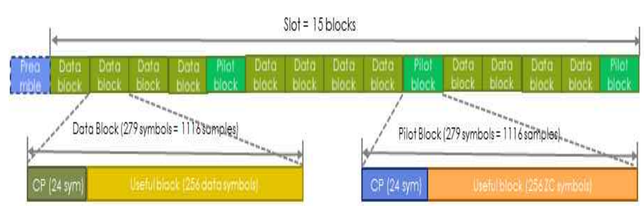


Figure 3. Slot structure

B. Channel coding

In order to support variable MCS modes, punctured turbo code is proposed similar to LTE but here additional channel interleaving is considered after rate matching in order to overcome multipath fading mobile channel environment.

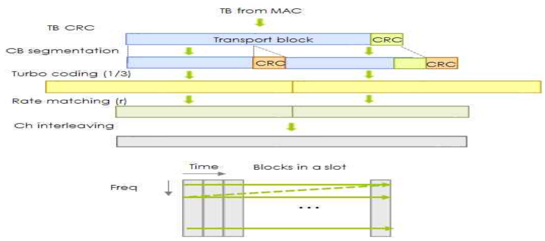


Figure 4. Channel coding

C. Detail waveform parameter design

Detail waveform parameters for UAV payload communication are designed as followings.

TABLE II. DETAIL WAVEFORM PARAMETERS

Parameters	Values
FFT size	256
CP duration (symbols)	32
Preamble duration (symbols)	384 (including 128 CP symbols)
Subcarrier spacing (kHz)	30
Effective symbol duration (us)	33.3333
Symbol rate (MHz)	7.68
Oversampling	4
Sampling rate (MHz)	30.72
RRC roll-off	0.3
Bandwidth	9.984
Number of slots per subframe	34
Number of preamble per subframe	1
Number of data blocks per slot	15
Number of pilot blocks per slot	3
Number of front symbols	5
Number of tail symbols	5
Subframe 0 duration (ms)	24.3
Subframe 1 duration (ms)	25.7
Frame duration (ms)	50

I. SIMULATION RESULTS

For performance evaluation, MCS modes in table III are considered.

TABLE III. MCS MODES

Mod	Modulation	TB size	Data Rate (Mbps)	Remarks
Mod 0	QPSK	616	0.419	Only subframe 0
Mode 1	QPSK	6072	4.129	Only subframe 0
Mode 2	QPSK	6072	8.260	Subframe 0 and 1
Mode 3	16QAM	10376	7.056	Only subframe 0
Mode 4	16QAM	10376	14.110	Subframe 0 and 1

First, figure 5 shows packet error rate according to SNR in AWGN channel similar to strong LOS channel environment of UAV operating at high altitude. In this simulation, MMSE equalizer is applied. From the simulation, when UAV is

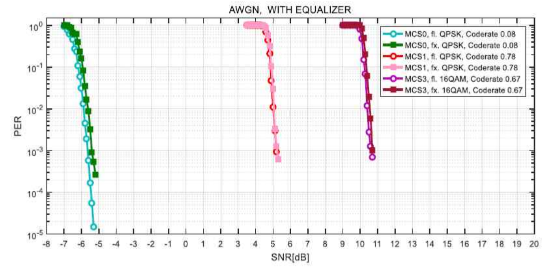


Figure 5. PER performance in AWGN

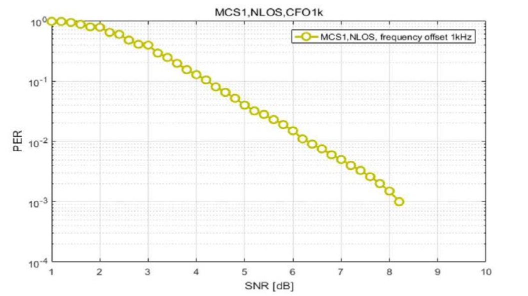


Figure 6. PER performance in NLOS

operated at high altitude and only subframe 0 is used, it is known that HD video transmission (above 4Mbps) is possible through the proposed waveform below SNR of 4dB and about 7Mbps data rate can be supported below SNR of 11dB.

Next, figure 6 shows packet error rate for MCS mode 1 according to SNR in HIPERLAN-C NLOS channel. From the figure, when UAV is operate at low altitude and only subframe 0 is used, performance is significantly degraded.

IV. CONCLUSION

In this paper, we propose a candidate waveform technology for UAV payload communication in C-band considering UAV SWAP-C and coexistence with C-band control communication technology. The proposed waveform technology can support variable data rates including HD video transmission in both LOS and NLOS channel environments with low PAPR and no interference to C-band control communication.

ACKNOWLEDGMENT

This work was supported by a project of the unmanned aerial vehicle safety support technology development called “Flight Safety Regulation Development and Integrated Operation Demonstration for Civil RPAS” (No. 19ATRP-C108186-05) funded by the Ministry of Land, Infrastructure and Transport (MOLIT), Republic of Korea government.

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