Phase 2 Specification

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Equipment

- 4 HackRF SDRs
- 3 coax antenna mounts
- 4 telescoping whip antennas
- 1 Raspberry PI (for ground side)
- 1 STM32F4 (for 'drone' side)
- Assembled Drone

Objective

RF

The primary RF objective for Phase 2 is to transition from a unidirectional proof-of-concept link to a bi-directional TDMA wireless system between:

- Three synchronized ground station nodes
- One airborne drone node

The system shall support command uplink and telemetry downlink in a packet format representative of autonomous flight operation.

Key goals:

- Implement two-way packet exchange within a fixed TDMA frame
- Improve ground station clock synchronization

- Improve triangulation accuracy using synchronized TOA measurements
- Maintain robustness under Doppler, multipath, and drone motion
- Integrate STM32 and HackRF, use PI clock for ground HackRFs
- ToF handshake protocol, on top of TOA (reach)

The MAC layer shall remain TDMA-based. The PHY layer will remain as BFSK.

Drone

The primary drone objective is to:

- Fully assemble the drone platform
- Validate power, propulsion, and structural integrity
- Achieve stable manual flight
- Ensure safe integration of SDR payload

The drone shall support:

- Onboard SDR payload operation during flight
- Communication with STM32 flight controller
- Emergency manual override via RC transmitter

Control

- Design and validate the outer-loop control algorithm for autonomous flight
- Define RF packet interface for control inputs
- Implement firmware interface between RF subsystem and STM32

The control system shall:

- Accept command packets from the RF subsystem
- Produce firmware control outputs (outer loop commands)
- Support safe mode transitions (manual → autonomous → failsafe)

Systems Overview

RF System

Architecture

Ground Segment

- Three HackRF nodes positioned in a known geometry
- Connected to Raspberry Pi processors
- Capable of synchronized timestamping

Airborne Segment

- Test flight with one HackRF mounted to the drone
- Interface to STM32 flight controller
- Optional Raspberry Pi for onboard processing

Multiple Access Scheme

The MAC layer remains TDMA.

Each TDMA frame consists of:

- Ground-to-drone command slots
- Drone-to-ground telemetry slots
- Guard intervals
- Preamble and payload per packet

PHY Layer Options

Baseline PHY

- BFSK modulation

- Matched filtering for preamble detection
- Symbol timing recovery

Drone System

The drone consists of:

- Mechanical airframe
- Propulsion system (motors + ESCs)
- Power distribution system
- Flight controller (STM32)
- SDR payload

The SDR shall interface with flight control firmware via defined packet structures.

Control System

The control architecture includes:

- Inner-loop stabilization (STM32)
- Outer-loop position/velocity controller
- RF interface layer

The outer loop produces desired attitude and thrust commands based on RF setpoints.

Requirements

RF Requirements

Bi-Directional Communication

- The system shall implement bi-directional communication between three ground SDR nodes and one airborne SDR node.
- The system shall maintain a fixed TDMA frame structure for the lifetime of the link.
- Each packet shall contain a preamble and payload.
- Each packet shall include a packet identifier and checksum or CRC.

Frequency and Modulation

- The RF channel shall operate within the 902–928 MHz ISM band.
- The center frequency shall remain within 905–925 MHz.
- The occupied bandwidth shall not exceed 10 MHz.
- The PHY layer shall support BFSK modulation at minimum.

Synchronization

- The three ground nodes shall implement relative clock synchronization.
- The synchronization method shall reduce inter-node timing offset relative to Phase 1.
- Each ground node shall timestamp received packets.
- The system shall produce consistent TOA measurements across ground nodes.

Localization

- The system shall compute relative transmitter position using synchronized TOA measurements.
- The system shall demonstrate improved triangulation consistency compared to Phase 1.
- The system shall provide telemetry including localization estimates to at least one ground node.
- Reach - ToF estimation

Robustness

- The link shall maintain packet decoding while the drone is in motion.
- The link shall tolerate indoor multipath conditions.
- The system shall detect packet loss.

- The system shall measure round-trip latency.

Drone Requirements

Mechanical and Electrical

- The drone shall be fully assembled prior to integration testing.
- The drone shall provide sufficient lift for SDR payload and battery.
- The drone shall supply regulated power to the SDR subsystem.
- The SDR mounting shall not interfere with propulsion or structural integrity.

Flight Performance

- The drone shall demonstrate stable manual hover.
- The drone shall demonstrate controlled translation in manual mode.
- The drone shall sustain powered flight for the duration of the live demonstration.
- The drone shall support safe landing under manual control.

Control Requirements

Outer-Loop Controller

- The outer-loop controller shall accept RF command packets as input.
- The outer-loop controller shall output desired roll, pitch, yaw rate, and thrust commands.
- The controller shall be validated in simulation prior to flight testing.
- The controller shall be testable independently of the RF subsystem.

RF Interface

- Control packets shall include timestamp, command mode, and desired state.
- Telemetry packets shall include estimated state and battery level.
- The system shall detect loss of link within a defined timeout interval.
- The system shall enter a failsafe mode upon link loss.

- Manual override shall always take priority over autonomous commands.

Deliverables

Phase 2 shall demonstrate:

- Live bi-directional TDMA communication
- Successful command uplink to the drone
- Successful telemetry downlink
- Ground station synchronization improvement
- Demonstration of improved triangulation consistency
- Stable manual flight of assembled drone
- Independent validation of outer-loop controller

Next Steps

Phase 3 will focus on:

- Full integration of RF, Drone, and Control subsystems
- Closed-loop autonomous flight
- Improved localization filtering
- Optimization of latency and reliability