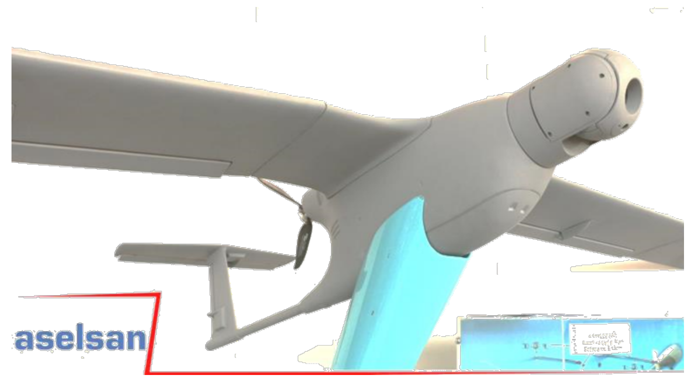
SIMULATION AND FLIGHT TESTING OF AN ALGORITHM THAT USES “RF DISTANCE” TO GUIDE UAVs TO HOME POSITION IN GNSS-DENIED ENVIRONMENT



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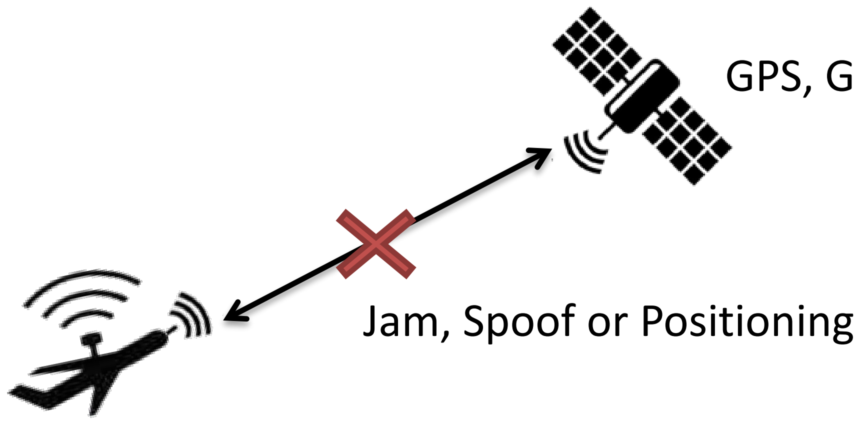
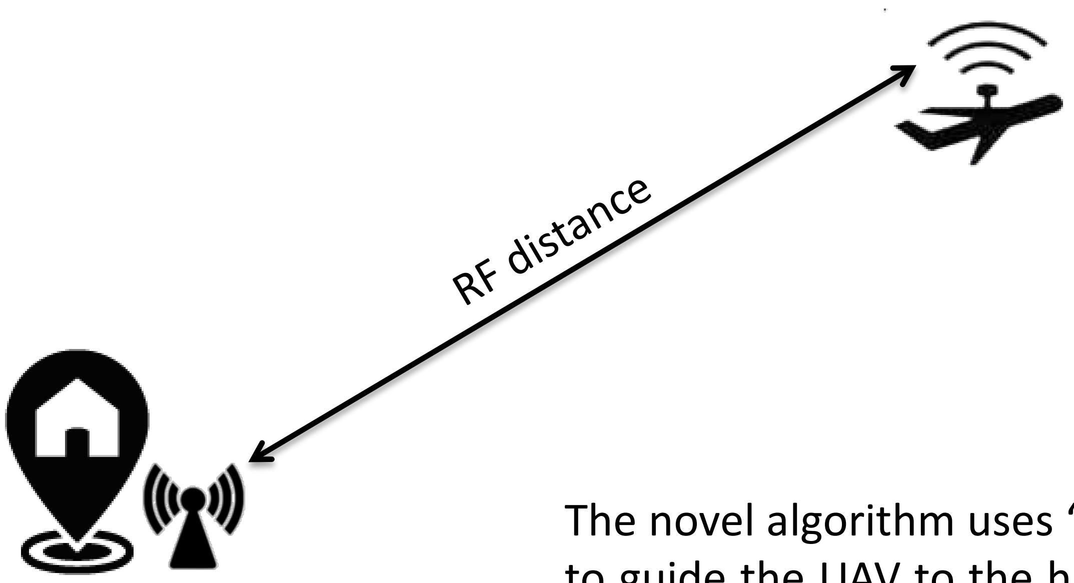
INTRODUCTION



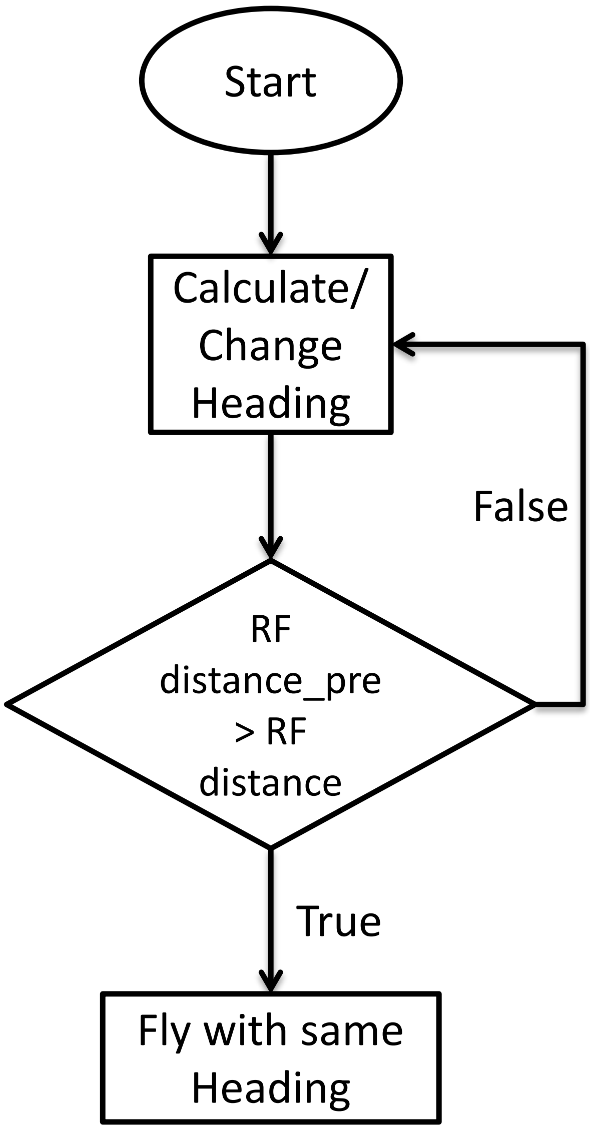
Several methods were found to counter UAS. One very popular method among the latter group is to jam the GPS/GNSS signals. By this method, the UAVs, which depend mostly, if not entirely on GNSS data for navigation, are unable to determine their position and velocity; therefore, they turn out to be random flying objects out in the blue. To solve this problem in some matters, a novel approach will be presented where a limited navigation is achieved by using “RF distance” in GNSS-denied environment.

THEORY OF ALGORITHM



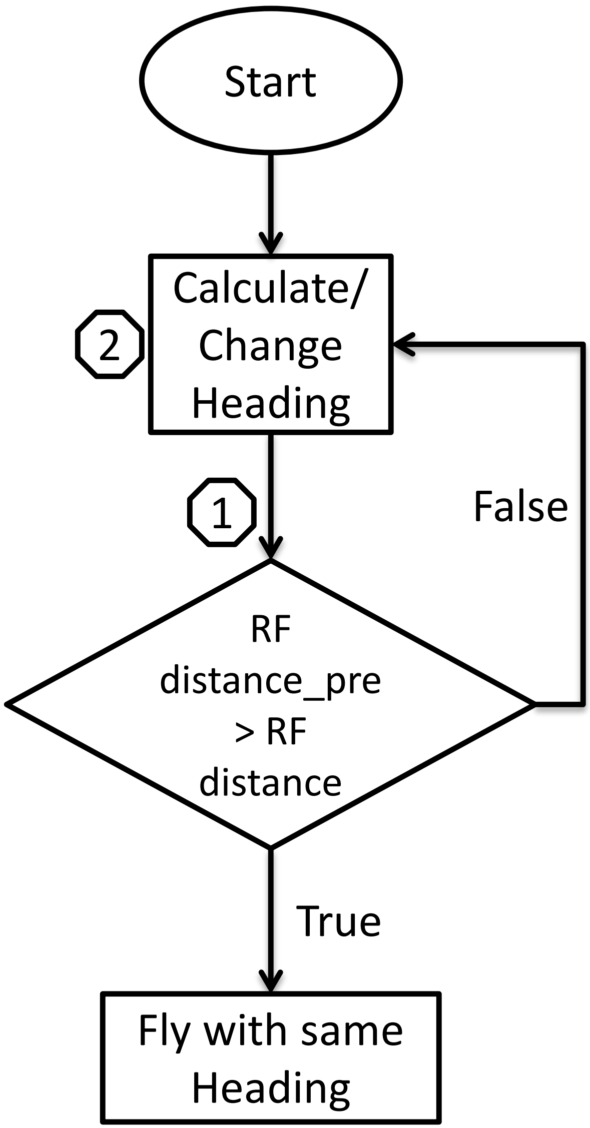
The novel algorithm uses 'RF distance' information to guide the UAV to the home position as close as possible, by keeping track of the decrease in the RF distance and changing the direction of the UAV by a certain amount whenever it starts increasing and this is repeated until RF distance starts decreasing back again.

THEORY OF ALGORITHM



- The aim is to reduce the distance.
- In control theory this is analogous to the pure P-controller.
- Two requirements need to be met:
  - UAV must be kept at the same altitude.
  - UAV must be flying at a constant speed. (This requirement can be easily met for the fixed wing UAV but a transformation of controls need to be made for the multi-rotor UAV.)

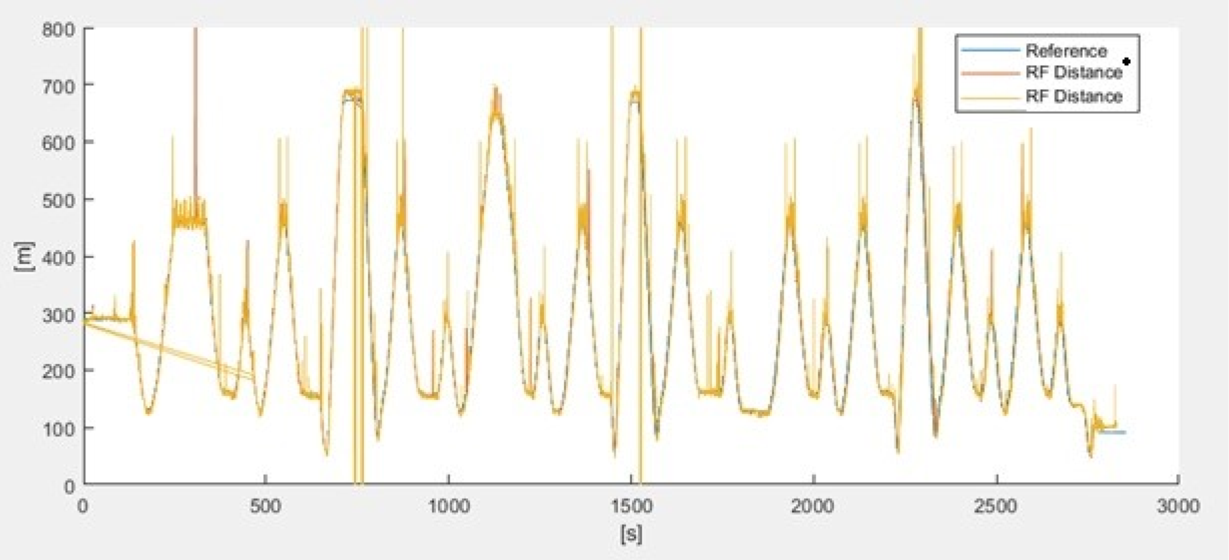
NUMERICAL IMPLAMANTATION



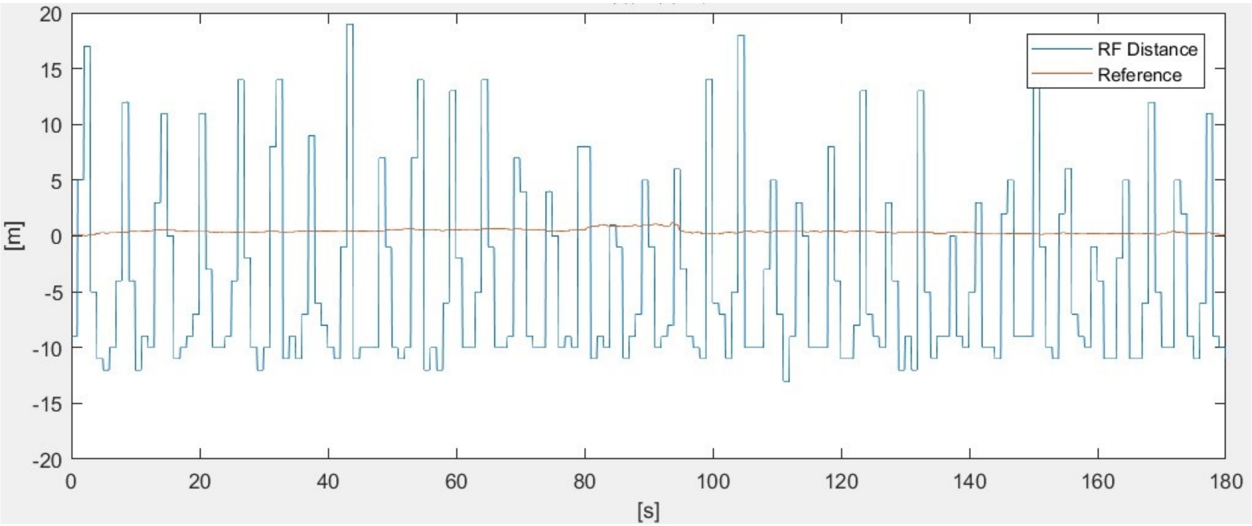
Two major parameters must be concern:

1. How often the RF distance need to be observed (To overcome the issues related with noise and obviously and affected by the flight speed),
2. How much correction need to be made on the UAV's heading (Due to the dynamics of the UAV, it can be found from the simulation studies).

NUMERICAL IMPLAMANTATION

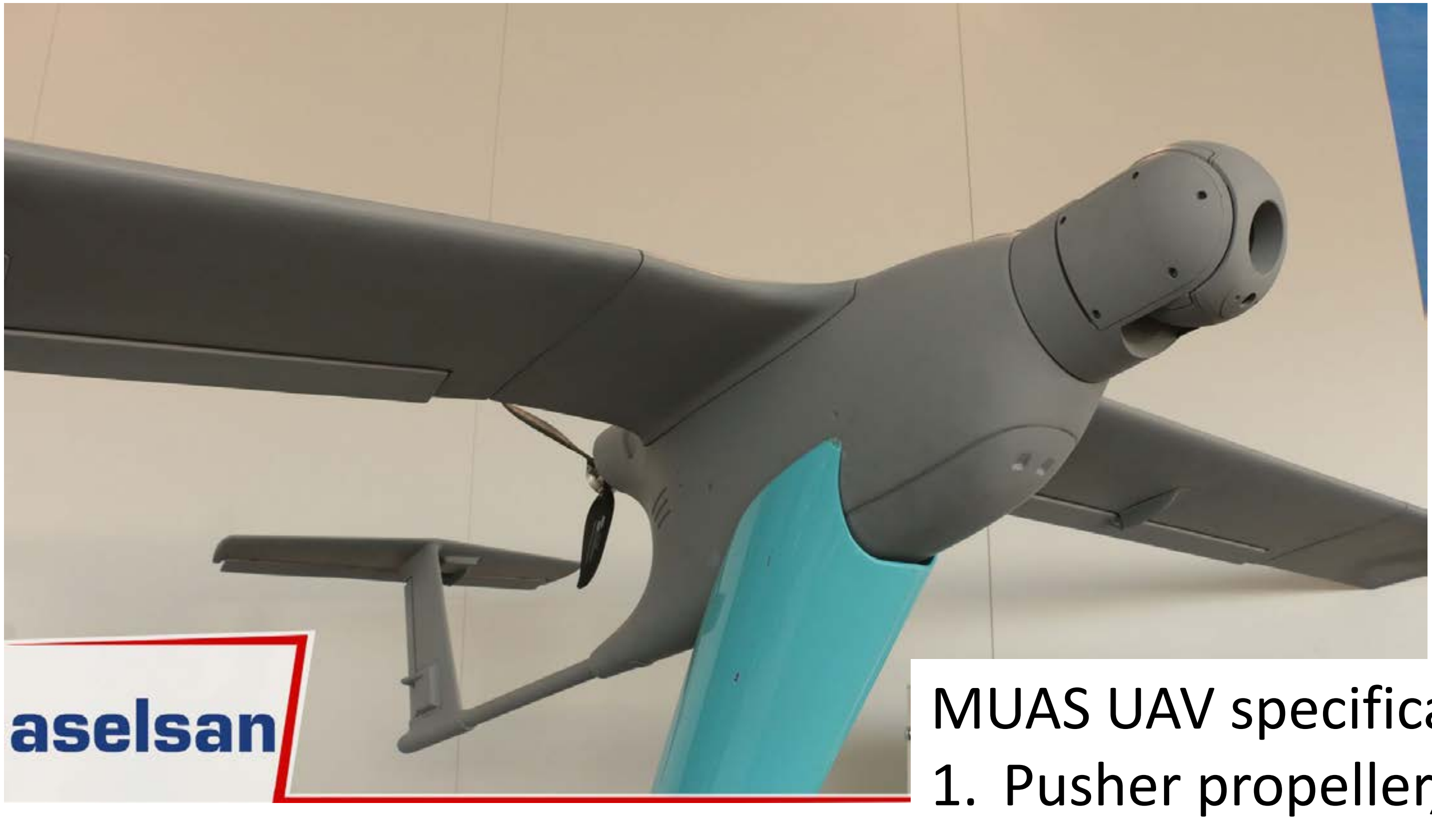


Moving Ground Test



Stationary Ground Test
(Pre-flight test)

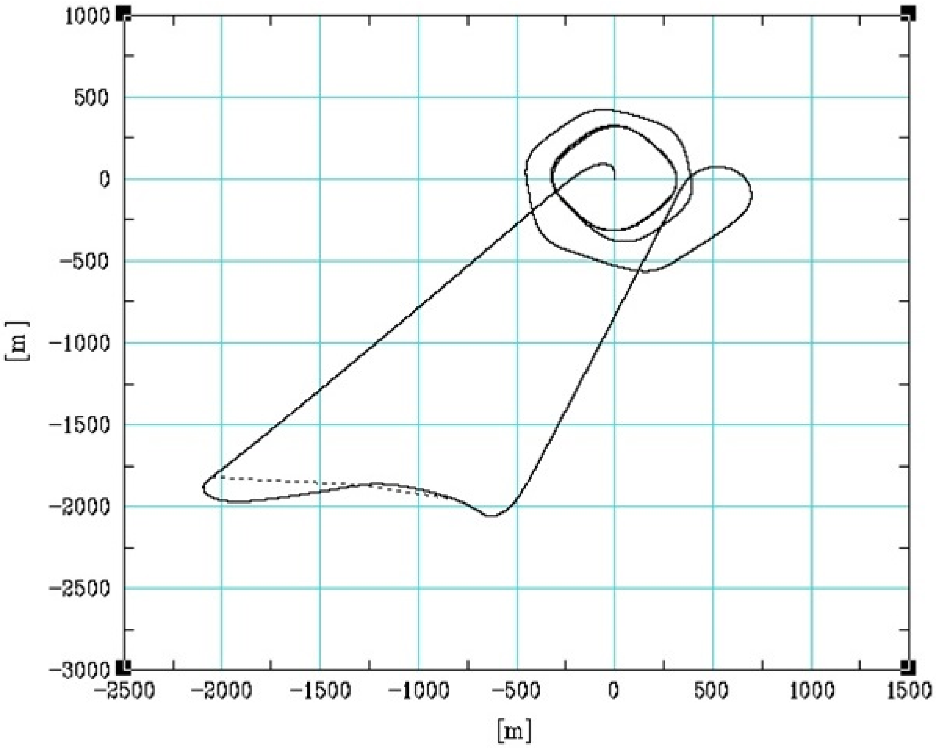
SIMULATION MODELS



MUAS UAV specifications:
1. Pusher propeller,
2. T-shape tail,
3. Hand-launched.

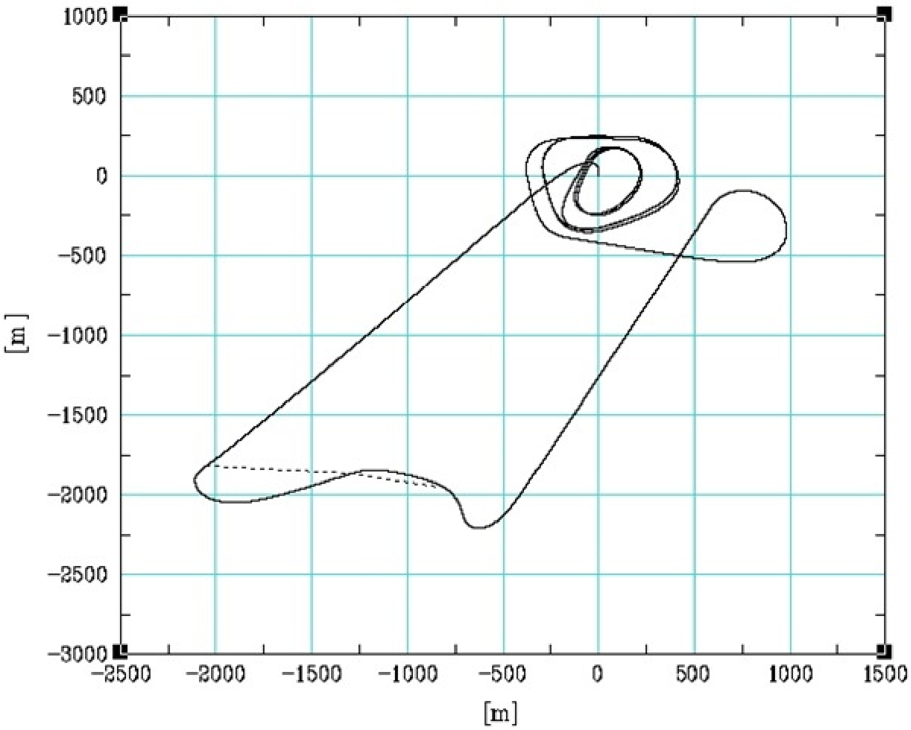
SIMULATION and RESULTS

Handling the noise in the measurement system:

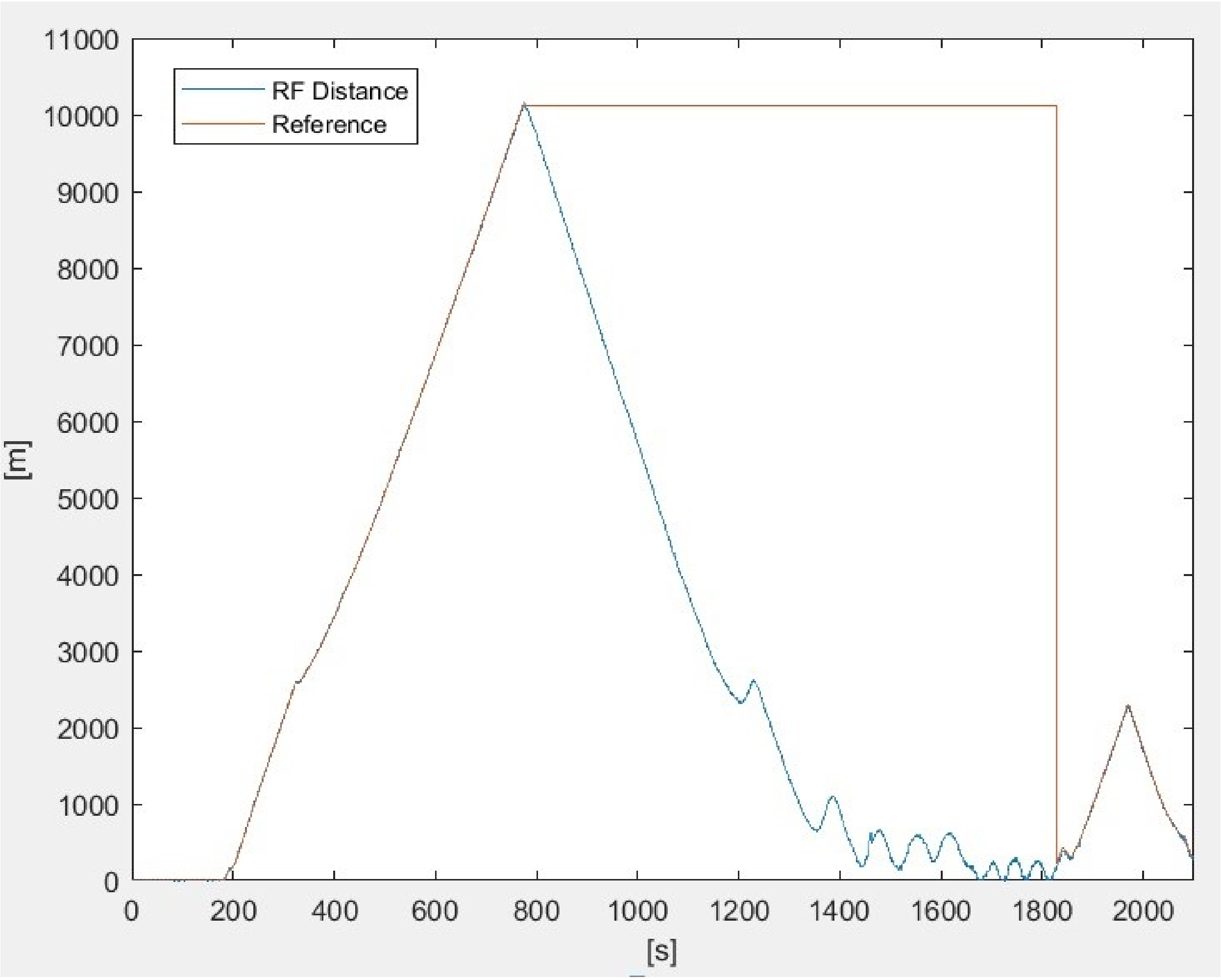


Fixed Wing Simulation; No Wind Condition

Fixed Wing Simulation with 5 m/s North-Wind Condition and Delta Heading Command Update Near Home



FLIGHT TEST RESULTS FOR FIXED WING UAV



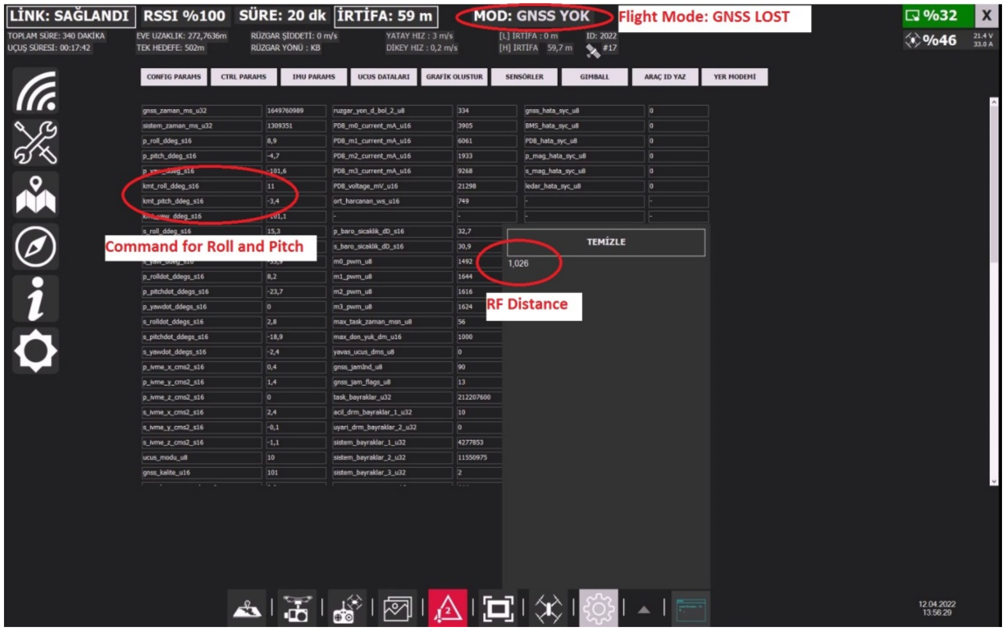
Flight Test Results of Fixed Wing UAV

Time between 800 s and 1850s is the stage where the algorithm presented here is tested. This stage can be seen in four substages;

- Initial stage,
- Corrections to approach home,
- Circling around home,
- Narrowing the circle around home.

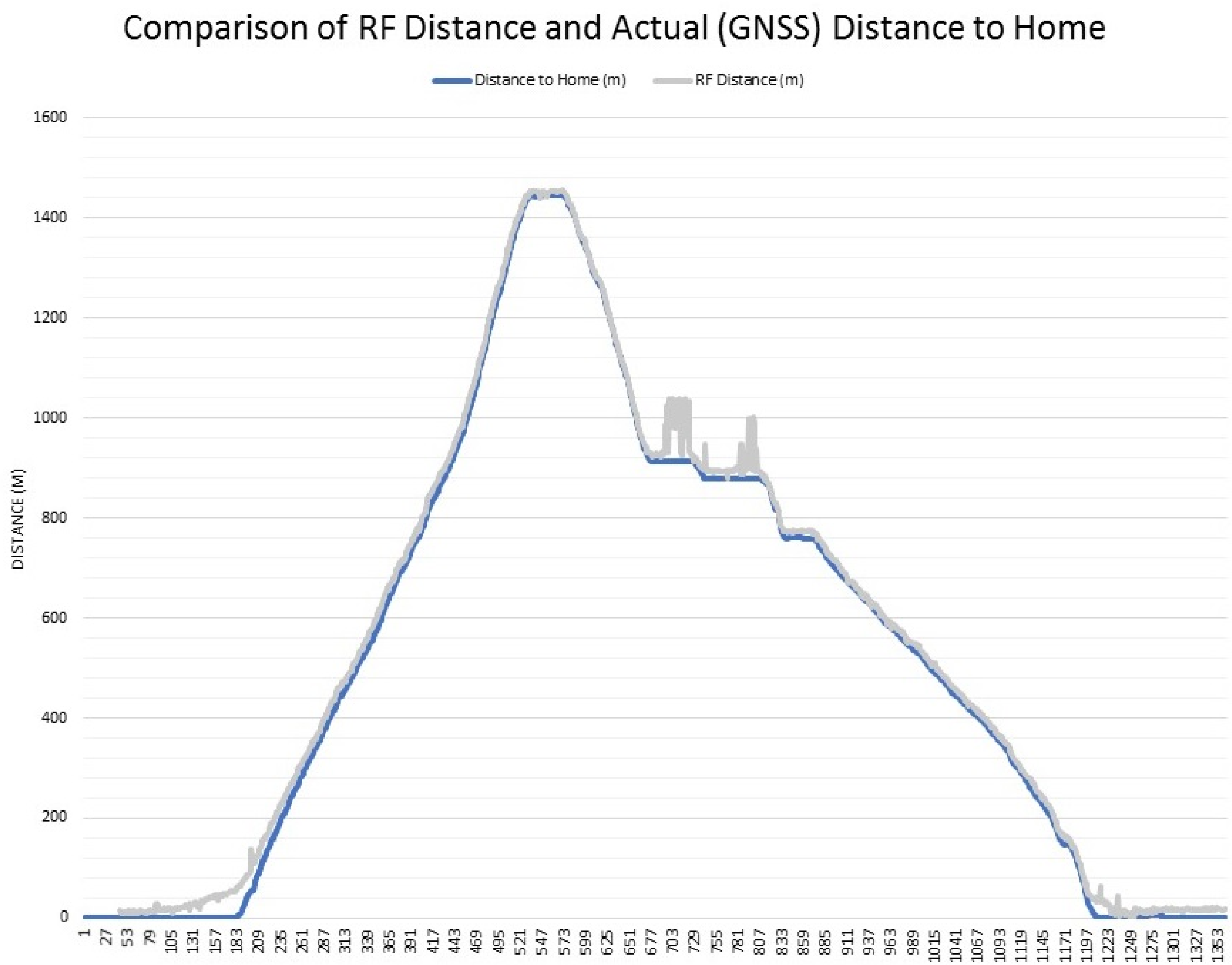
SERCE MULTIROTOR UAV and TEST SCREEN

Specification	Value
No. Rotors and Their Combination	4 Rotors (X Configuration)
Endurance	50 min.
MTOW	7.2 kg
Payload	1 kg (EO+LRF)
Maximum Speed	12 m/s
Mission Radius	10 km
Wind Resistance	10 m/s
Ceiling	4000 m (MSL)



FLIGHT TEST RESULTS FOR MULTIROTOR UAV

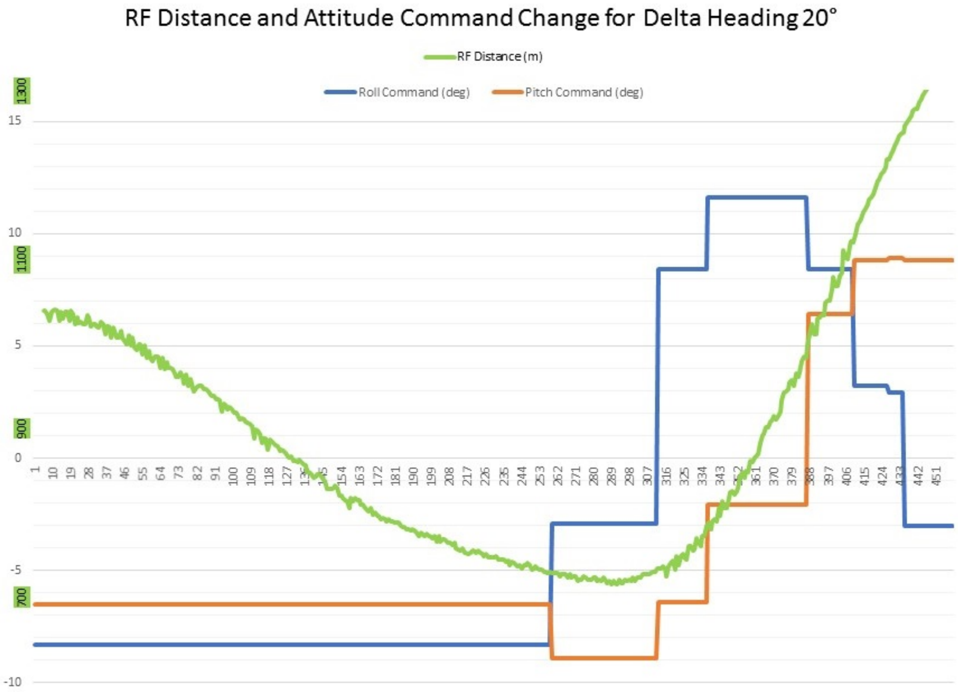
First Step: Verifying RF Distance

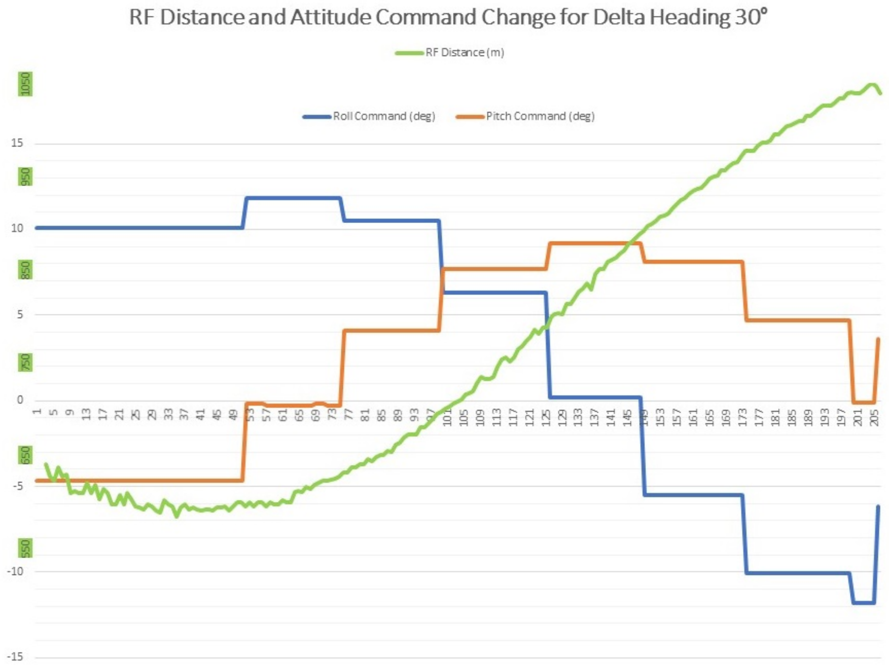


In between 700 and 800 time interval, there is a distortion effect. In this interval RSSI value of modem was decreased, which means the link quality was decreased.

FLIGHT TEST RESULTS FOR MULTIROTOR UAV

Second Step: Returning Home in a GNSS-Denied Flight by using different delta heading commands in the algorithm





FLIGHT TEST RESULTS FOR MULTIROTOR UAV

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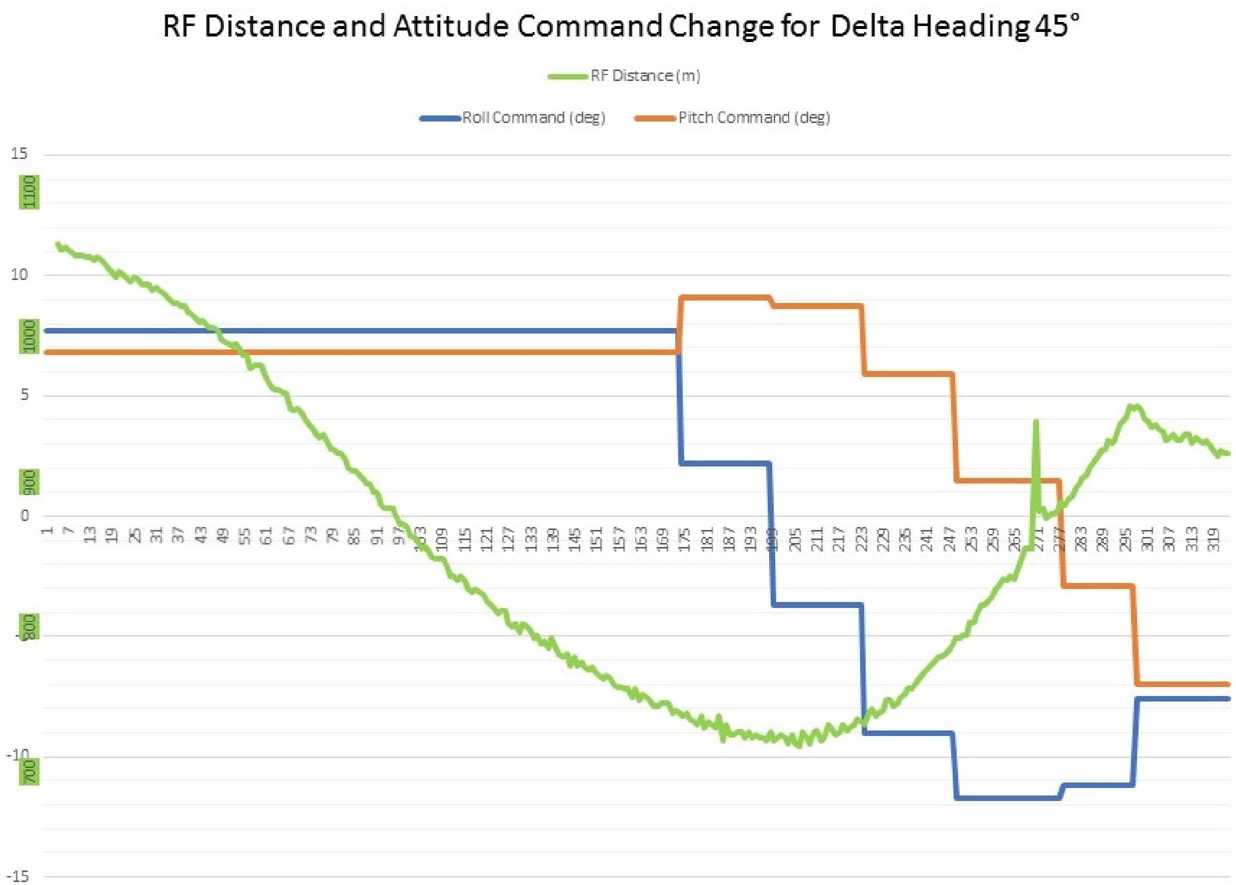
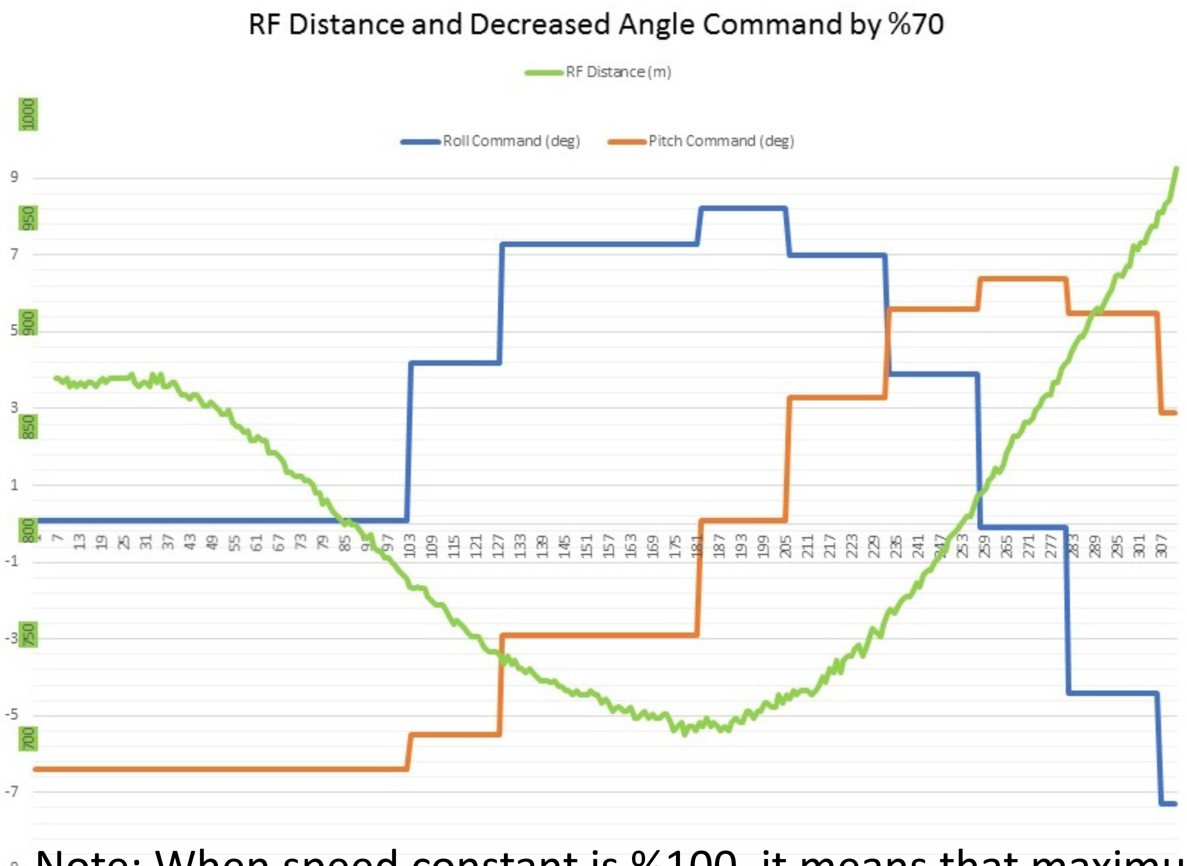


UAV could not come closer to home position easily if it was turned by 20° and 30°. On the other hand, if it was turned by 45°, it was seen that UAV starts to converge to home position more easily.

FLIGHT TEST RESULTS FOR MULTIROTOR UAV

Third Step: Returning Home in a GNSS-Denied Flight by using different magnitudes of the roll and pitch commands in the algorithm.

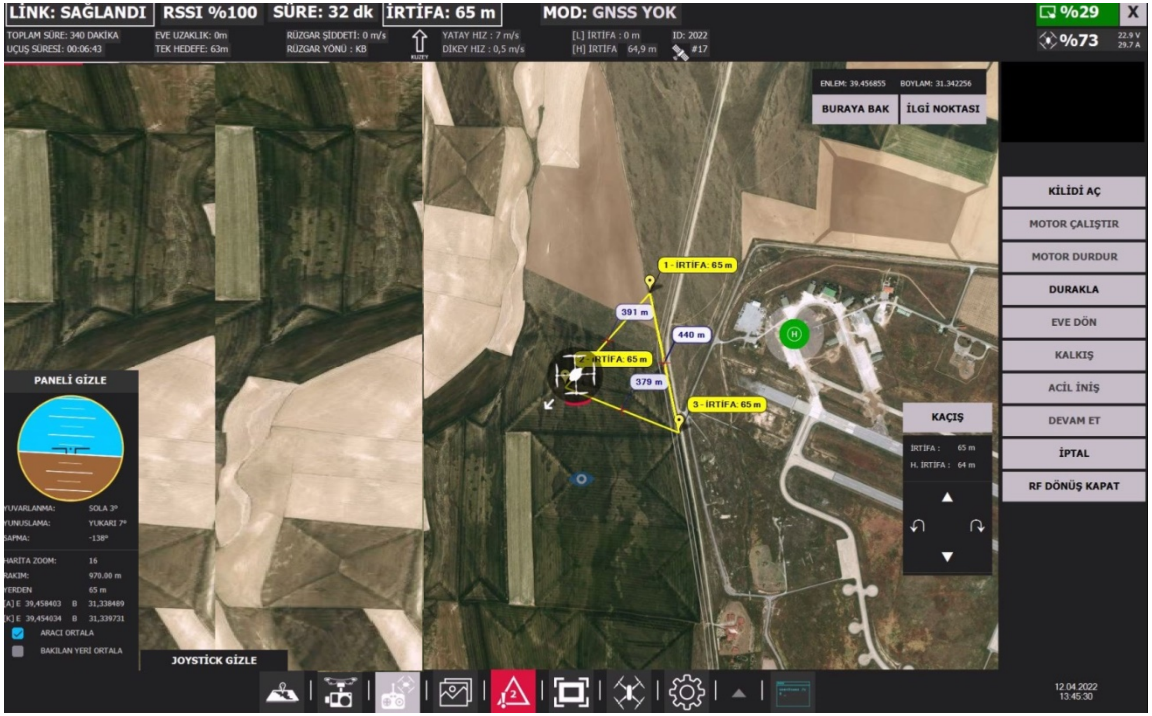


Speed constant is decreased to %70 (resultant angle command for roll and pitch 8.4°), while delta heading value is kept at 45°. Due to the windy weather, the pitch and roll angles generated were not enough to produce the speed that can overcome this wind speed. This caused the UAV to drift in the wind direction.

Note: When speed constant is %100, it means that maximum angle command can be 12 degrees.

FLIGHT TEST RESULTS FOR MULTIROTOR UAV

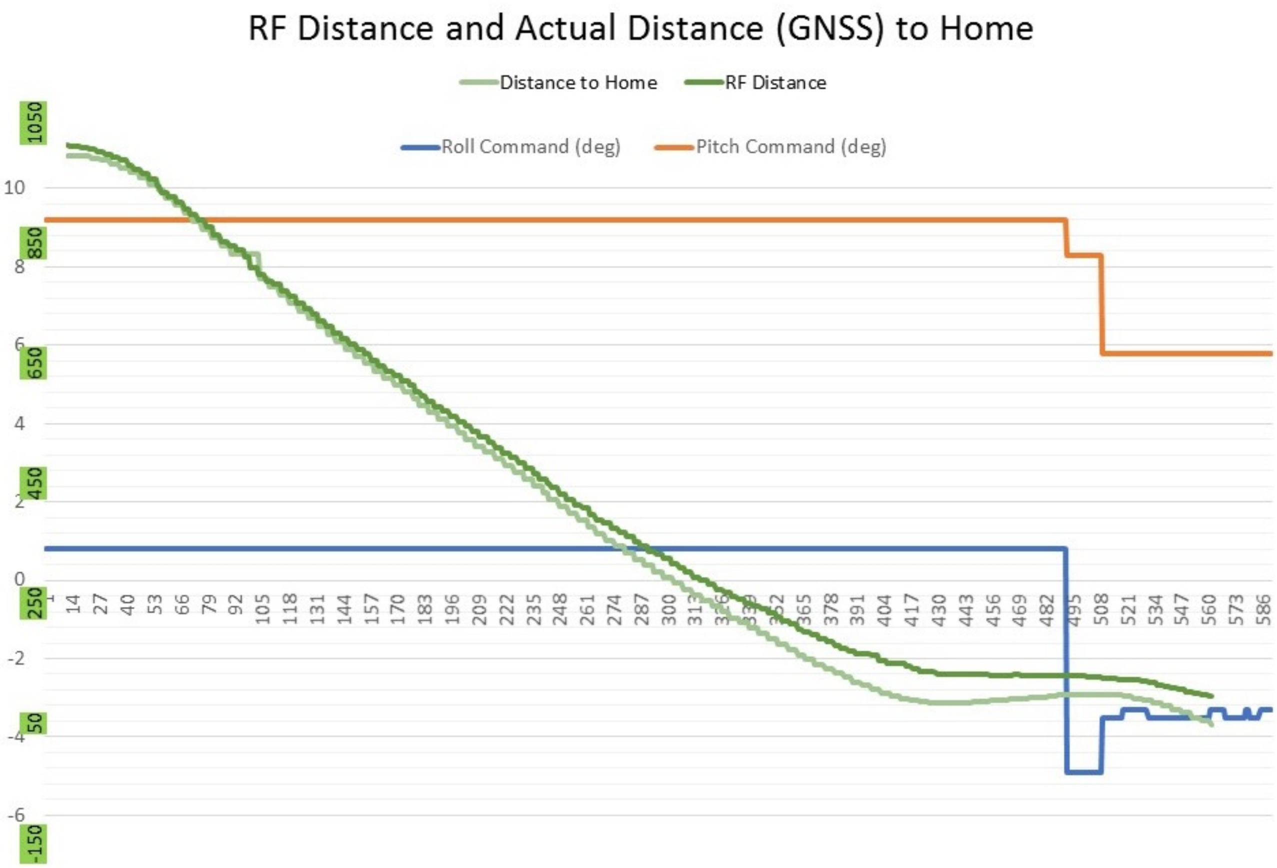
Fourth Step: Returning Home in a GNSS-Denied Flight by starting to use algorithm when UAV is in cruise.



GNSS Loss in Waypoint Navigation

The first thing UAV did was to try to stop and hover and generate the real angle commands. This caused it to slip from the point where it obtained the last GNSS coordinate before losing GNSS. As a result, this created an error in calculation of returning to home from the beginning. Especially when the weather is windy, the UAV could not return to home directly.

FLIGHT TEST RESULTS FOR MULTIROTOR UAV



Successful Return Home in GNSS Denied Environment

For Serce multirotor UAV, according to the flight test results, to utilize from the algorithm, values used in the algorithm and weather conditions are summarized below:

- Initial mode (just before the GNSS loss) is hover,
- Delta heading angle is 45 degrees,
- Speed constant is %100,
- Wind speed was less than 4 m/s.

CONCLUSION AND FUTURE WORK

The importance of the novel method presented here suggests no additional hardware or any other addons, neither on ground or in the air therefore it should be applicable for any type UAV without additional cost. In the future this baseline study and method can be modified to keep the aforementioned RF distance constant to create a fence control over a base.

For the multirotor UAVs, the algorithm can be improved by following future works:

- Speed constant can be adaptive; if RF distance can not be reduced for a certain time or for a certain number of heading command change, speed constant can be increased,
- Another improvement can be done in the UAV controller itself; speed constant can be stationary, but its corresponding angle can be increased,
- Similar comparison tests can be done for other parameters such as RF distance checking period (it is normally 5 sec), the distance that the algorithm is ended,
- The conditions that the heading command is changed; the comparison of RF distance for each period can be done between the actual RF distance and not the just previous data but the data from the previous checking period.

THANK YOU FOR LISTENING
QUESTIONS?