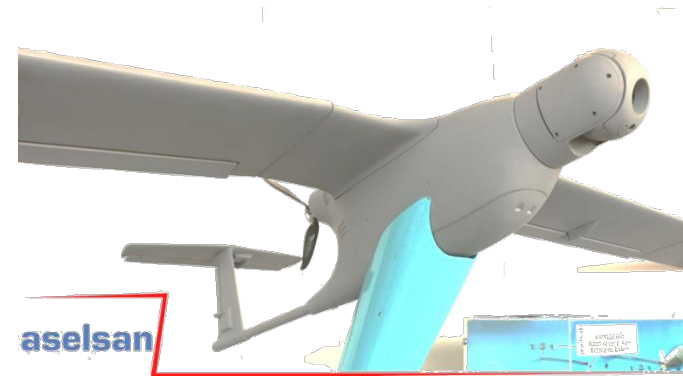


SIMULATION AND FLIGHT TESTING OF AN ALGORITHM THAT USES “RF DISTANCE” TO GUIDE UAVs TO HOME POSITION IN GNSS-DENIED ENVIRONMENT



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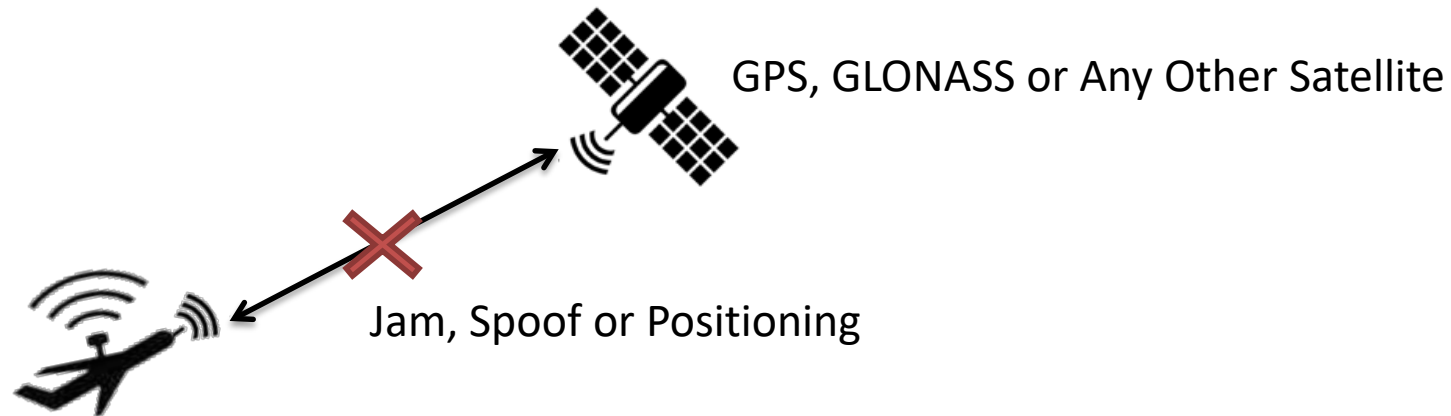
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Kubra DOĞAN

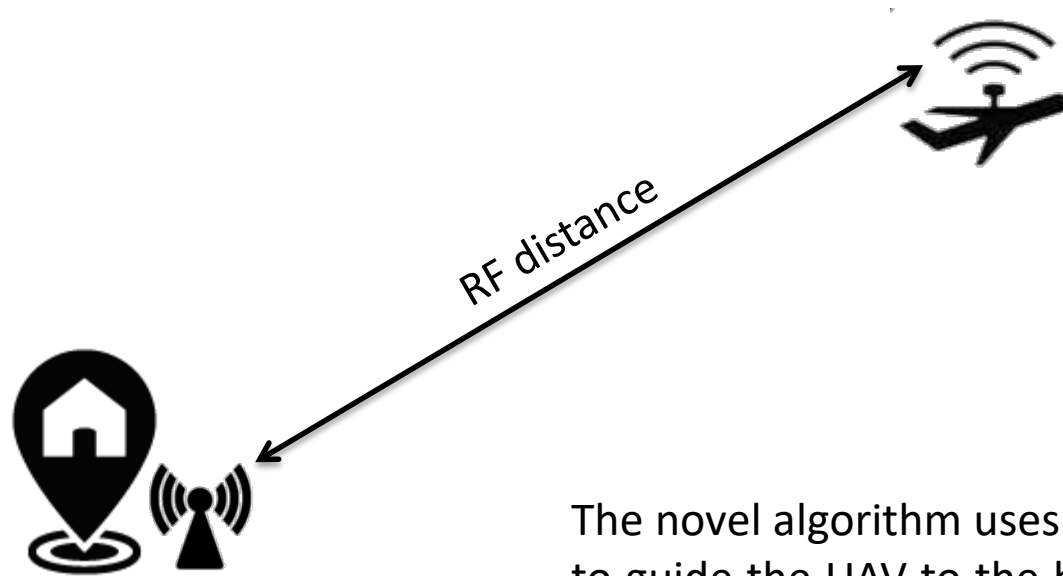
Specialist in Aselsan Inc., Turkey

INTRODUCTION



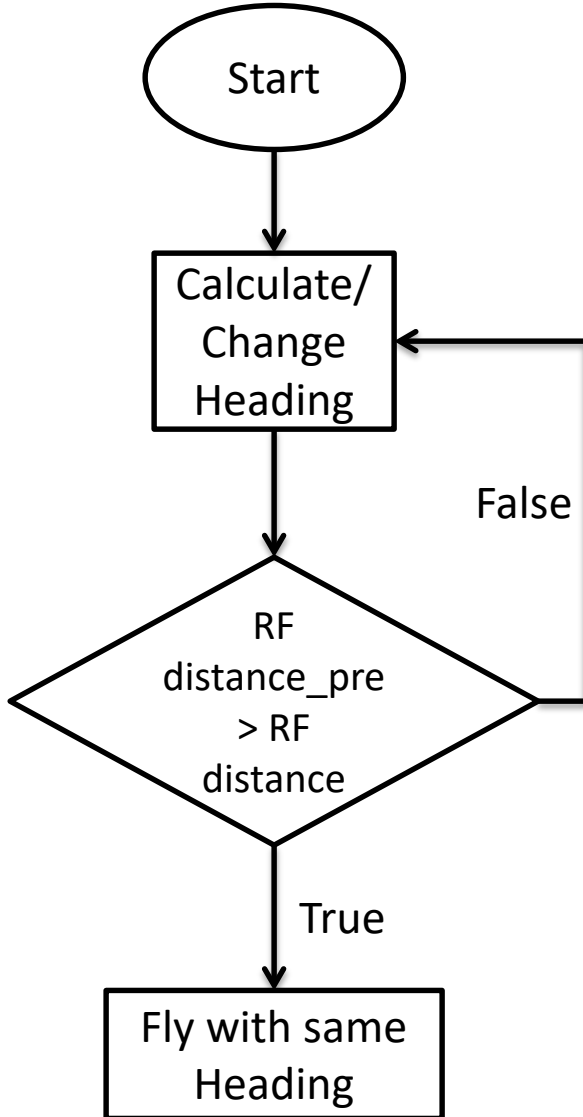
Several methods were found to counter UAS. One very popular method among the latter group is to jam the GPS/GNSS signals. By this method, the UAVs, which depend mostly, if not entirely on GNSS data for navigation, are unable to determine their position and velocity; therefore, they turn out to be random 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



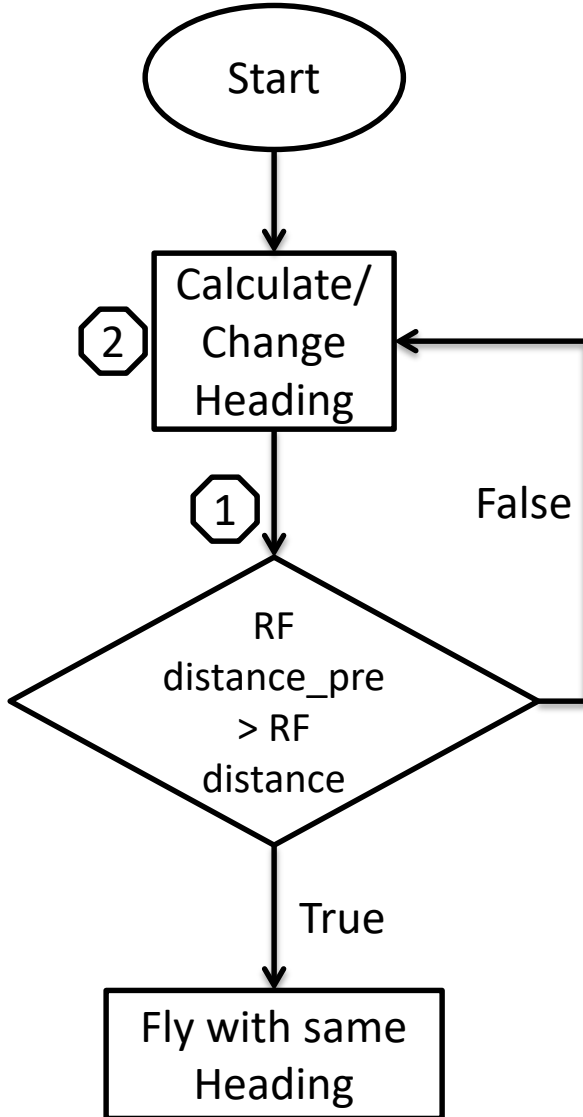
The novel algorithm uses 'RF distance' information to guide the UAV to the home position as close as possible, by keeping track of the decrease in the RF distance and changing the direction of the UAV by a certain amount whenever it starts increasing and this is repeated until RF distance starts decreasing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

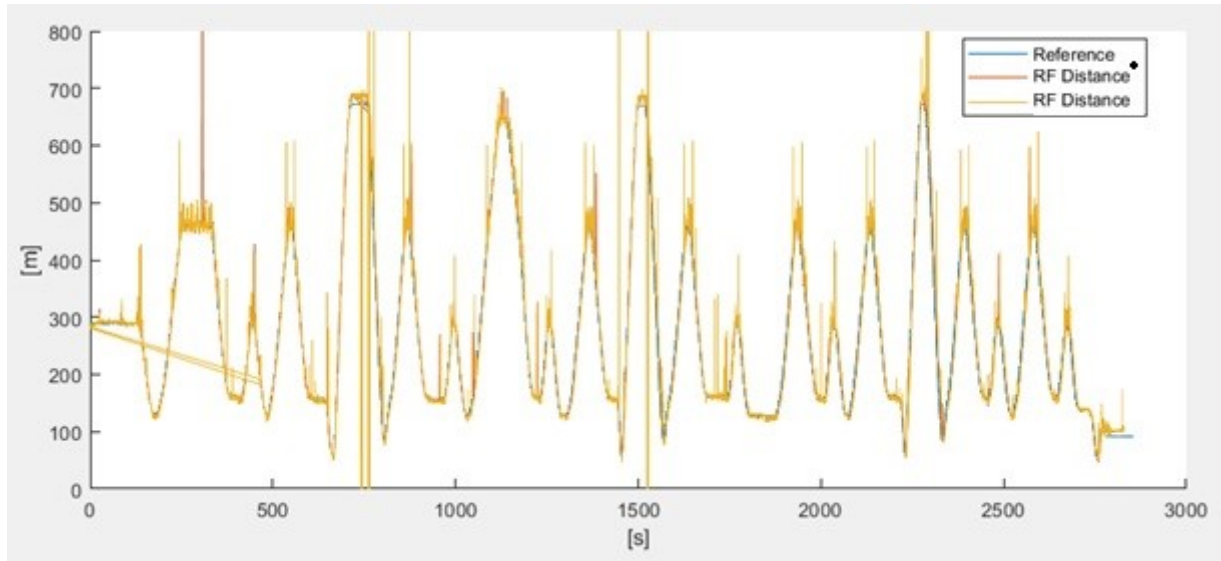
NUMERICAL IMPLEMENTATION



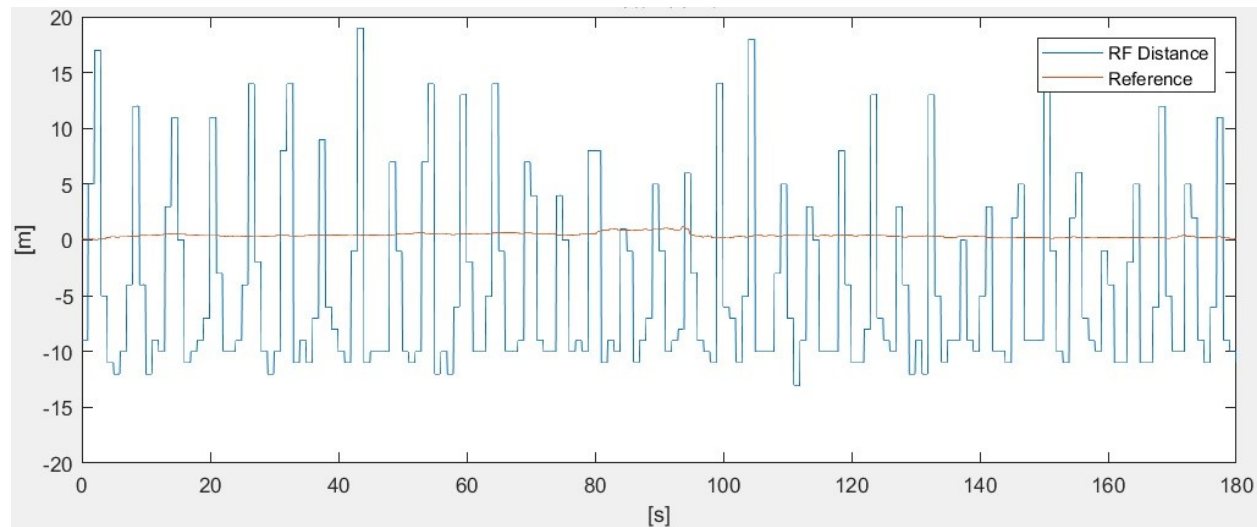
Two major parameters must be concern:

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 IMPLEMENTATION



Moving Ground Test



Stationary Ground Test
(Pre-flight test)

SIMULATION MODELS

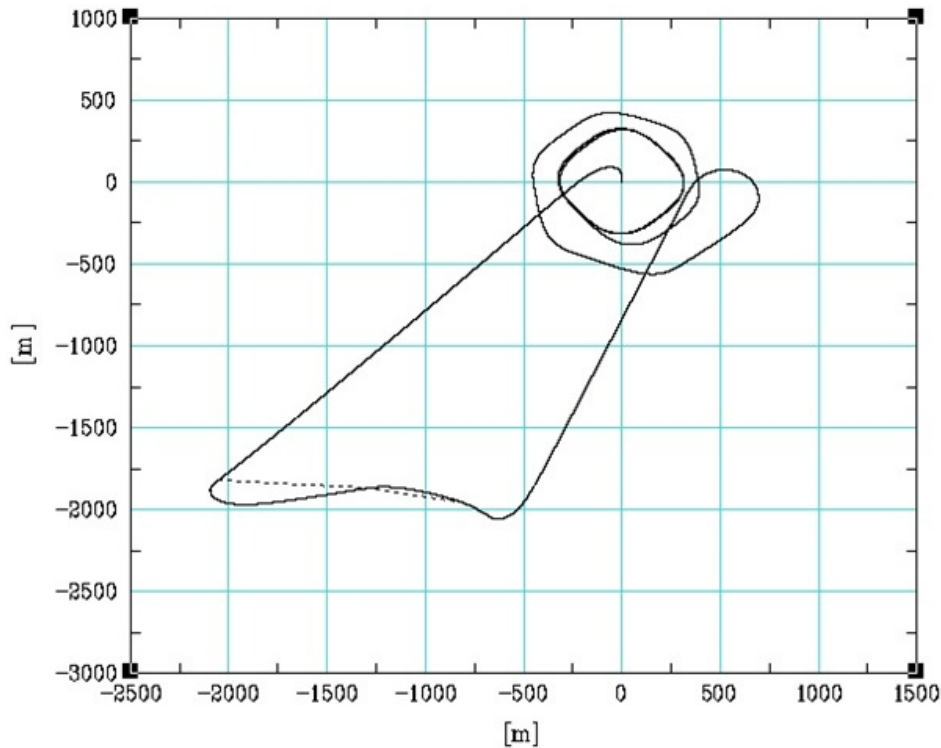


MUAS UAV specifications:

1. Pusher propeller,
2. T-shape tail,
3. Hand-launched.

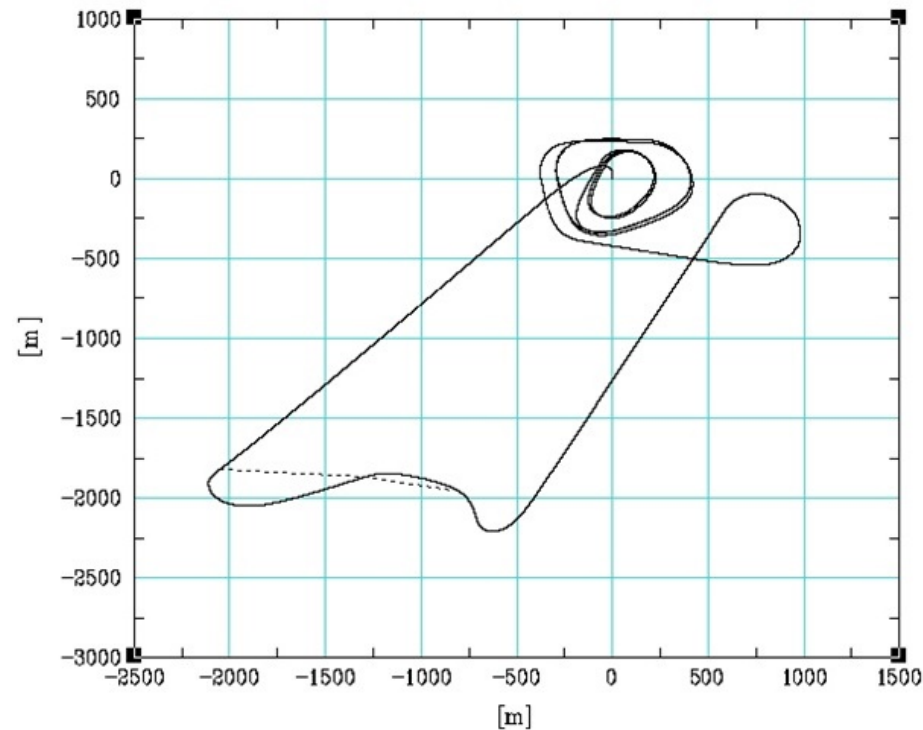
SIMULATION and RESULTS

Handling the noise in the measurement system:

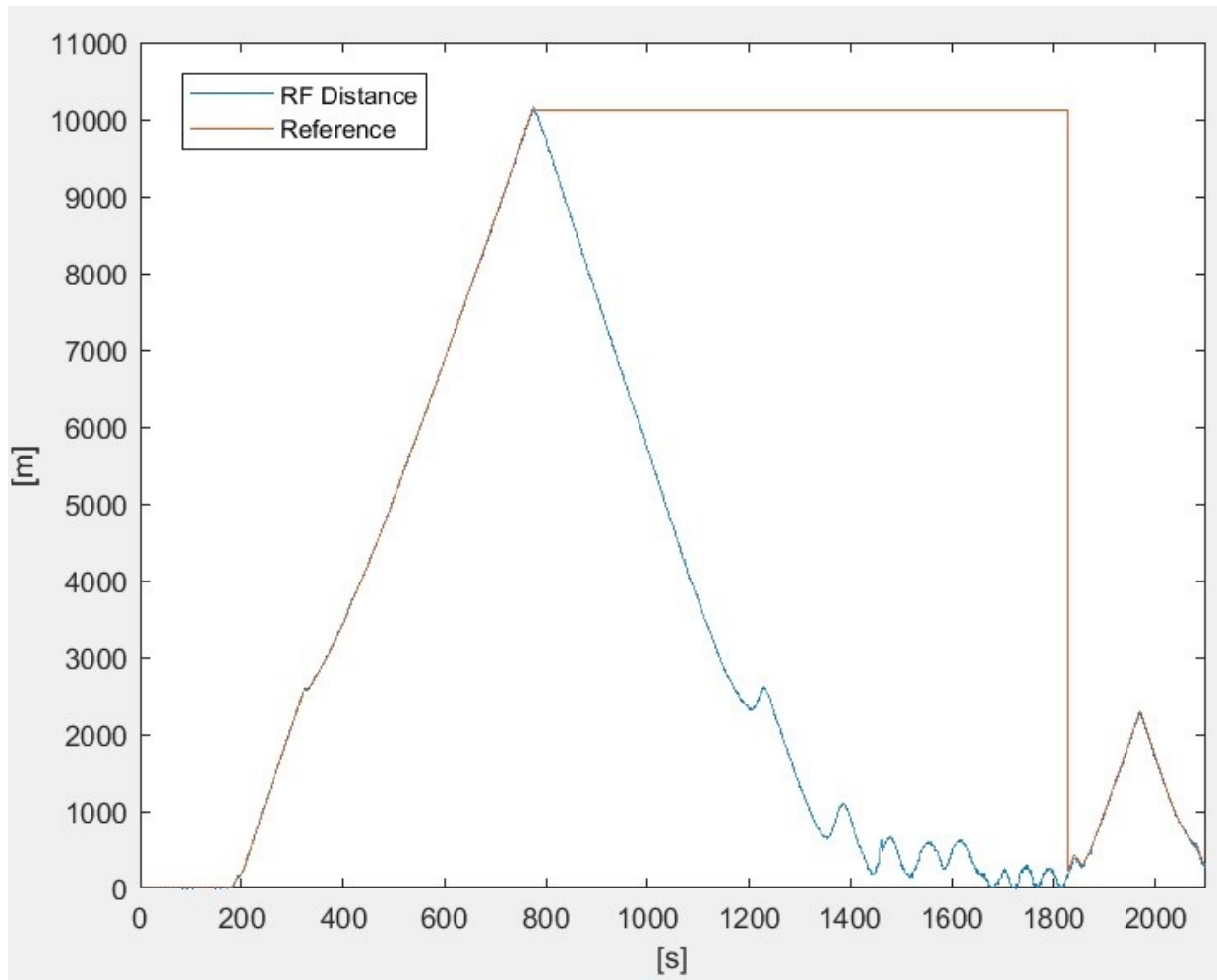


Fixed Wing Simulation; No Wind Condition

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



FLIGHT TEST RESULTS FOR FIXED WING UAV



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.

Flight Test Results of Fixed Wing UAV

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)

LINK: SAĞLANDI RSSI: %100 SÜRE: 20 dk İRTİFA: 59 m MOD: GNSS YOK Flight Mode: GNSS LOST

YERİZİN ÜSTÜNE: 390 DAKİKA UÇUŞ SÜRESİ: 00:17:42 EME USZAKLIK: 272,7636m RÜZGAR SİRKETİ: 0 m/s YATAY HIZ: 2 m/s DİKEY HIZ: 0,2 m/s E3 İRTİFA: 10 m ID: 2022 E4 İRTİFA: 59,7 m #17

CONFIG PARAMS CTRL PARAMS ERU PARAMS UÇUŞ DATALARI GRAFİK OLUSTUR SENSÖRLER GİHBALL ARAC ID YAZ YER PROHİT

PARAMS	VALUE	PARAMS	VALUE	PARAMS	VALUE
gnss_saman_mn_u32	1649760869	ruşgar_yen_1_hk_2_u8	134	gnss_hata_sync_u8	0
system_zaman_mn_u32	1309351	PDB_m0_current_ma_u16	3905	IMU_hata_sync_u8	0
p_roll_deg_u16	8,9	PDB_m1_current_ma_u16	6061	PDB_hata_sync_u8	0
p_pitch_deg_u16	-4,7	PDB_m2_current_ma_u16	1933	p_mag_hata_sync_u8	0
p_yaw_deg_u16	-191,6	PDB_m3_current_ma_u16	9268	s_mag_hata_sync_u8	0
kmv_roll_deg_u16	11	PDB_voltage_mv_u16	21298	leder_hata_sync_u8	0
kmv_pitch_deg_u16	-3,4	ort_harcama_wt_u16	749	p_pitch_u8	0
kmv_yaw_deg_u16	-191,1			p_roll_u8	0
s_roll_deg_u16	13,0	p_bmw_sesallk_id_u16	32,7		
		x_bmw_sesallk_id_u16	30,9		
		m0_pwm_u8	1492		
p_roll_deg_u16	8,9	m1_pwm_u8	1565		
p_pitch_deg_u16	-3,7	m2_pwm_u8	1628		
p_yaw_deg_u16	0	m3_pwm_u8	1624		
s_roll_deg_u16	2,8	max_thk_zaman_min_u8	56		
s_pitch_deg_u16	-18,9	max_din_ykl_dm_u16	1000		
s_yaw_deg_u16	-2,4	yeniss_ucus_dms_u8	0		
p_arm_x_cm02_u16	0,4	gnss_saman_u8	90		
p_arm_y_cm02_u16	1,4	gnss_saman_flag_u8	13		
p_arm_z_cm02_u16	0	task_bayraklar_u32	21207400		
s_arm_x_cm02_u16	2,4	act_drm_bayraklar_1_u32	10		
s_arm_y_cm02_u16	-6,1	uyari_drm_bayraklar_2_u32	0		
s_arm_z_cm02_u16	-1,1	system_bayraklar_1_u32	4277853		
uavm_mode_u8	10	system_bayraklar_2_u32	11500975		
gnss_hata_u16	101	system_bayraklar_3_u32	2		

Command for Roll and Pitch

1,026

RF Distance

TEMİZLE

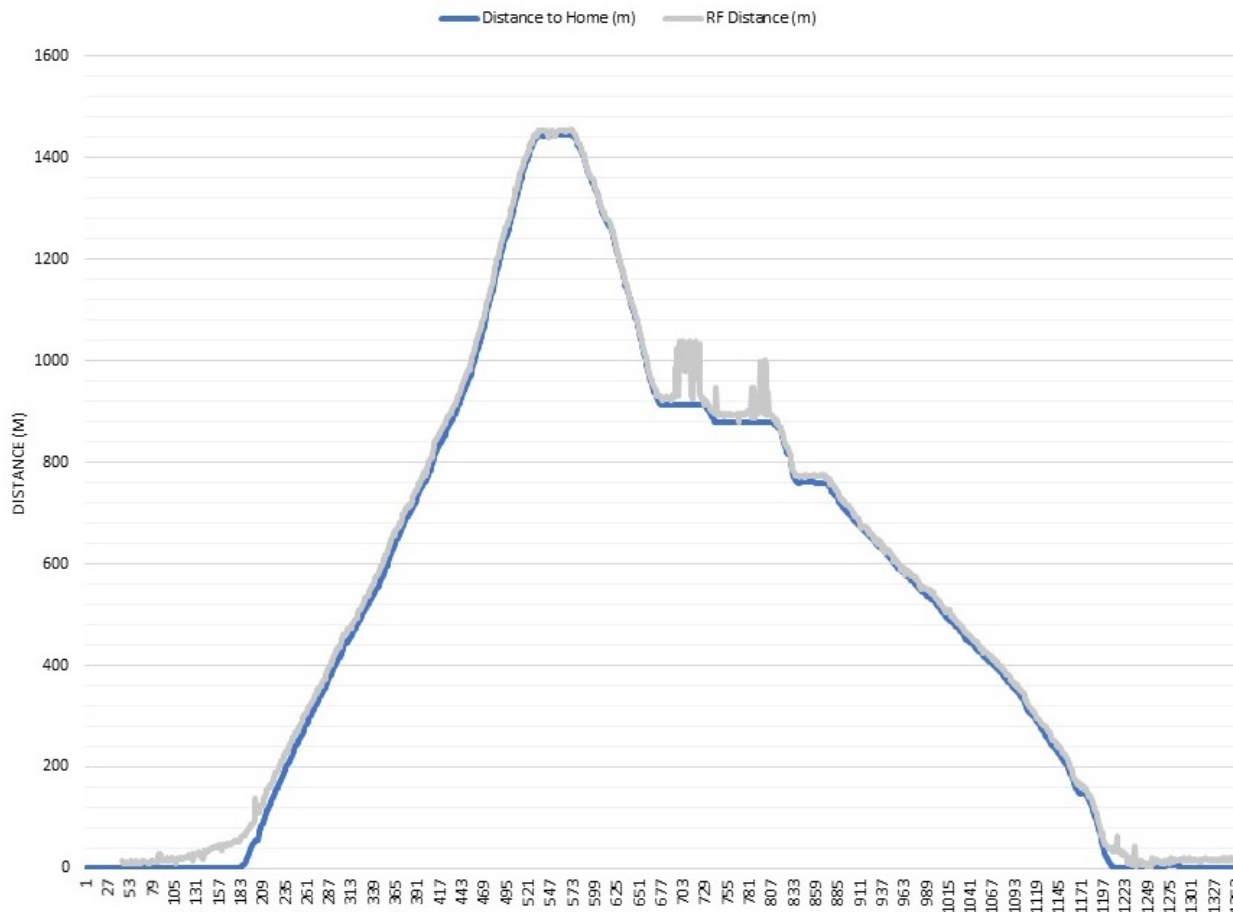
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FLIGHT TEST RESULTS FOR MULTIROTOR UAV

First Step: Verifying RF Distance

Comparison of RF Distance and Actual (GNSS) Distance to Home

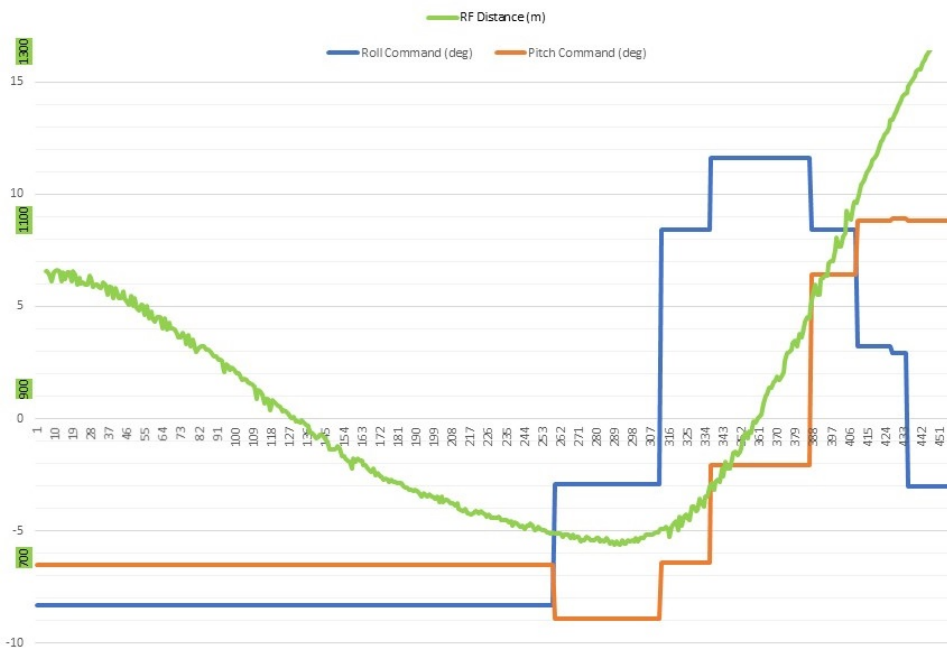


In between 700 and 800 time interval, there is a distortion effect. In this interval RSSI value of modem was decreased, which means the link quality was decreased.

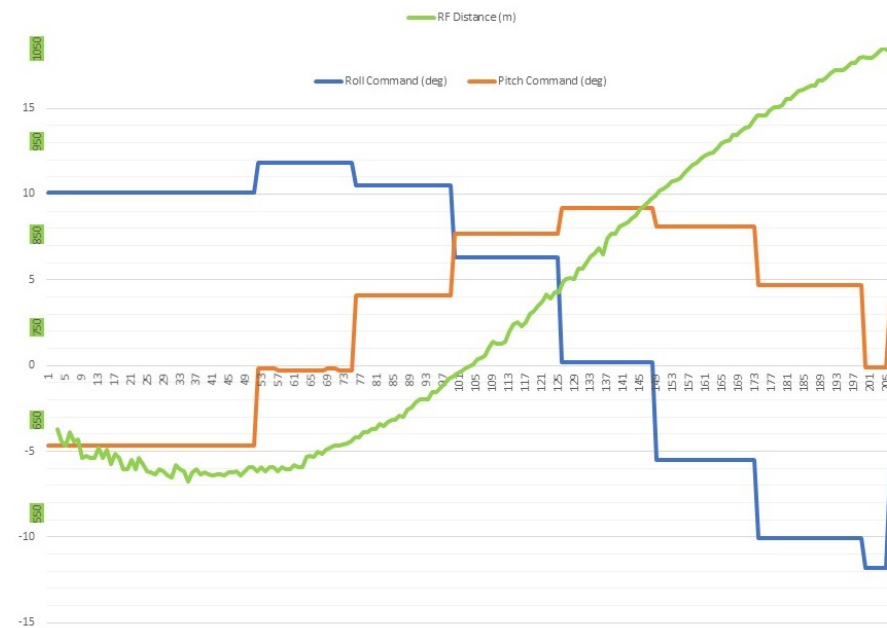
FLIGHT TEST RESULTS FOR MULTIROTOR UAV

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

RF Distance and Attitude Command Change for Delta Heading 20°



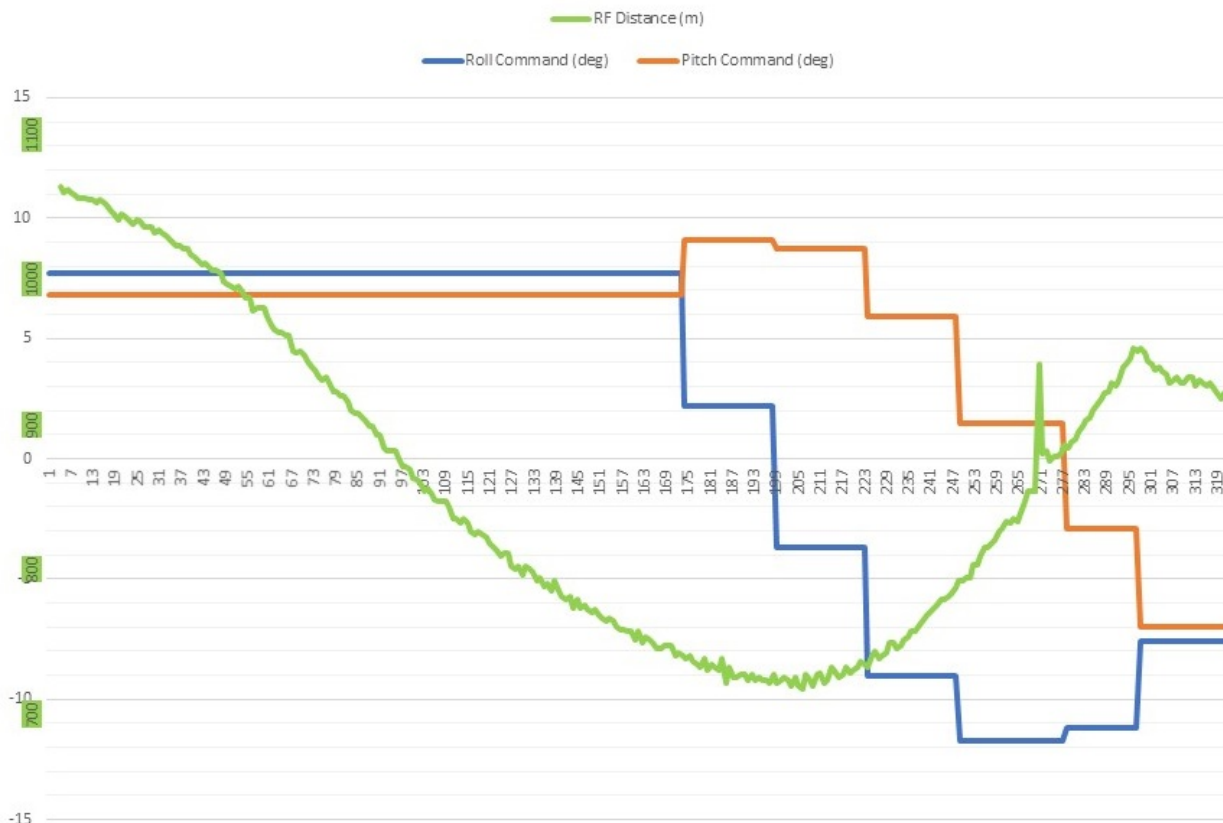
RF Distance and Attitude Command Change for Delta Heading 30°



FLIGHT TEST RESULTS FOR MULTIROTOR UAV

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

RF Distance and Attitude Command Change for Delta Heading 45°

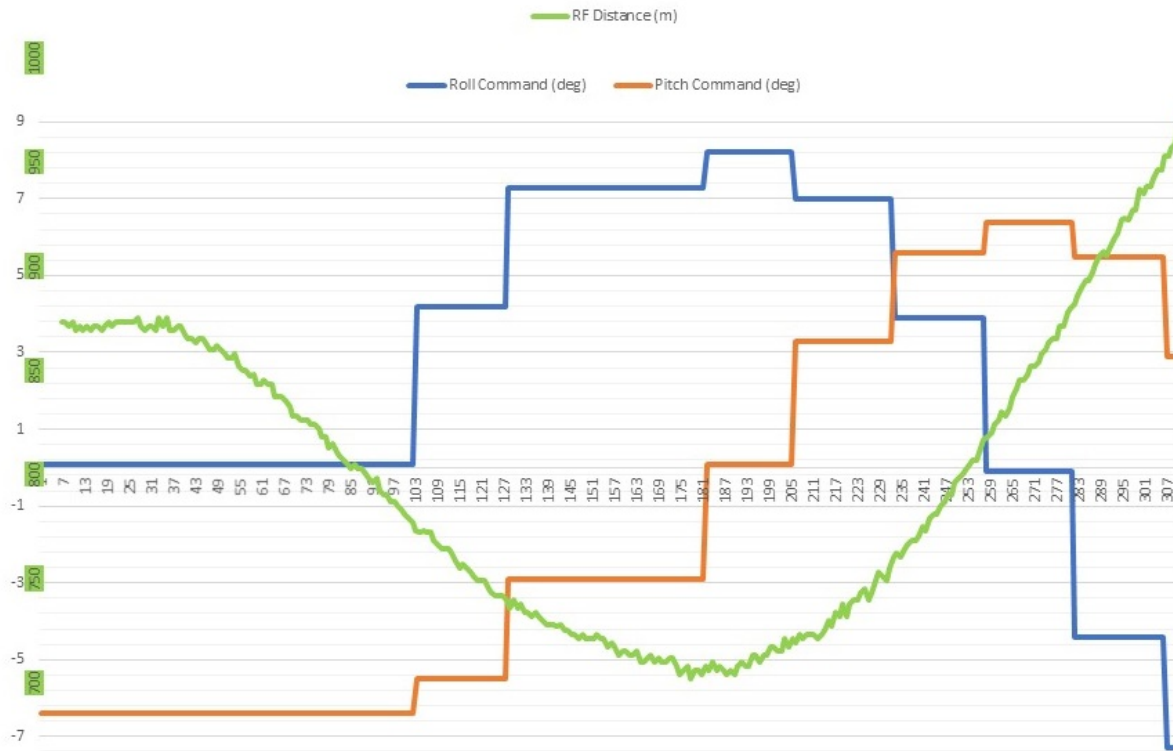


UAV could not come closer to home position easily if it was turned by 20° and 30°. On the other hand, if it was turned by 45°, it was seen that UAV starts to converge to home position more easily.

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.

RF Distance and Decreased Angle Command by %70

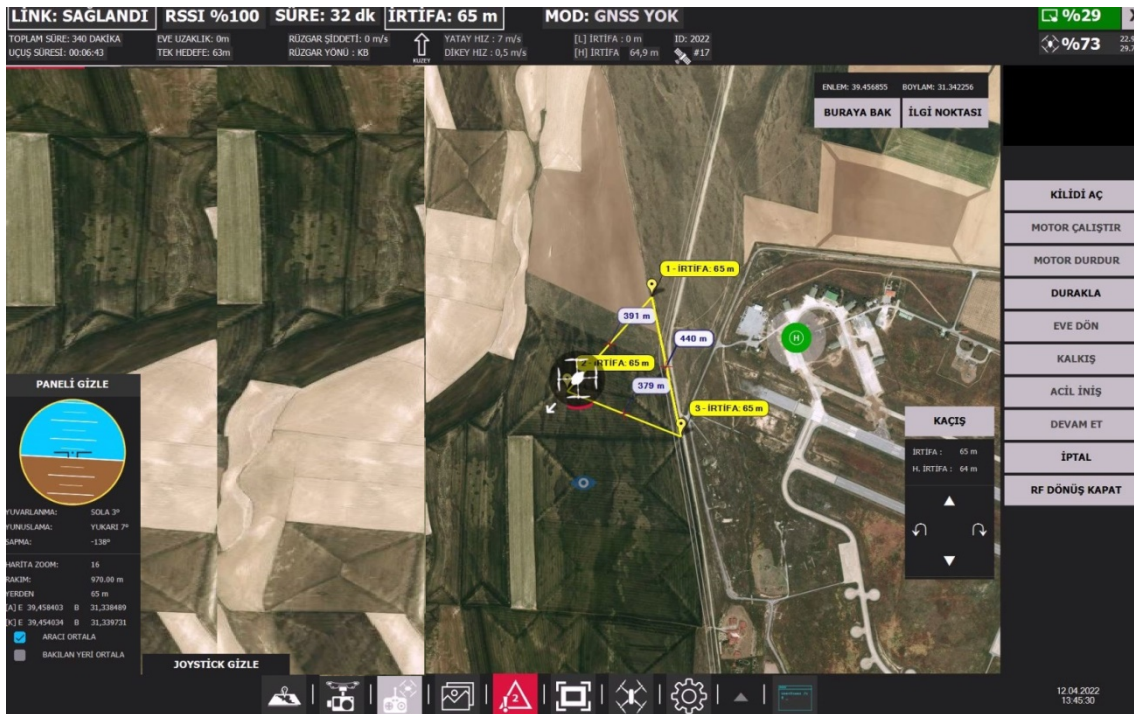


Speed constant is decreased to %70 (resultant angle command for roll and pitch 8.4°), while delta heading value is kept at 45° . Due to the windy weather, the pitch and roll angles generated were not enough to produce the speed that can overcome this wind speed. This caused the UAV to drift in the wind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

9 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.

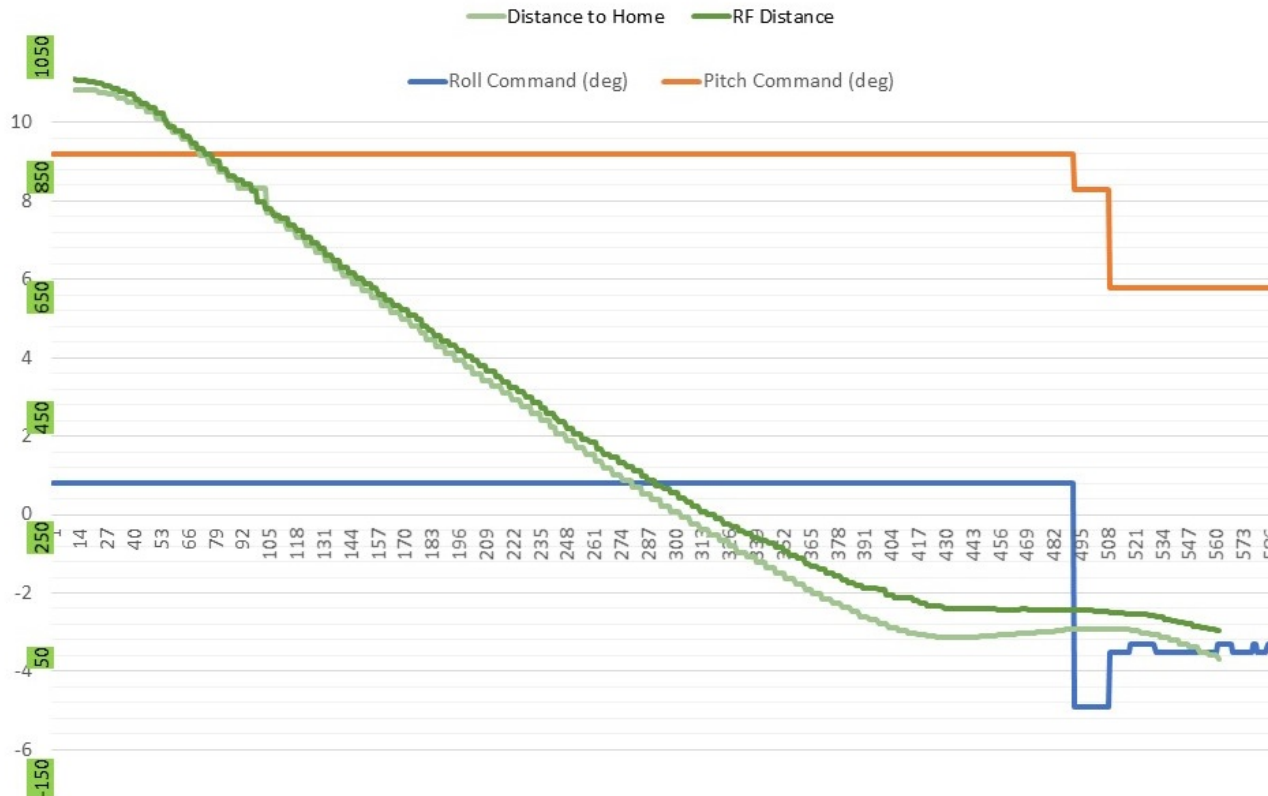


GNSS Loss in Waypoint Navigation

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

RF Distance and Actual Distance (GNSS) to Home



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?

