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Simulation of Multiple Targets for Radar Testing

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Abstract

The project is to simulate the multiple targets for validating the functionality of the radar by integrating the future trajectory of the target and generating various scenarios using MATLAB and Simulink. Knowing the basic Parameters like speed, acceleration, bank angle and using various kinematics equations, in which the target can sustain along with eliminating the various problems like cross over targets and targets in formation which may arise in trajectory generation.

Key Words: *Cross over targets, Targets information, Parameters, Validating*

1. INTRODUCTION

As we know that, the aircrafts will not always move in the straight line. It will be generating various scenarios like cross over targets, targets taking turn, targets in formation, various forms of maneuvring etc. Also, predicting the trajectory of the targets is very important so as to determine its future path. So, we need to determine various solutions regarding these problems. Radar will detect both real target and clutters, but it is required to differentiate real targets and clutters, which is done based on Doppler speed of the various detected objects. These detections will be in the form of plots in range azimuth and elevation wise. Track generator can generate targets in fixed or random locations in order to test target.

The main function of the radar system is the generation of target trajectory. In the radar system various problems arise in different scenarios like cross over targets and targets in formation. In cross over targets two targets starting at same time simultaneously with same speed, elevation and acceleration in opposite direction, then there are chances that they may collide with each other on reaching at the final point or may deviate from their path, leading to the miss prediction of the target trajectory. Similarly, in Targets in formation various targets making the formation may be viewed as a single entity rather than identifying them individually. In a cluttered environment, the received measurements may not all arise from the real targets. Some of them may be from clutter or false alarm. As a result, there always exist ambiguities in the association between the previous known targets and measurements. Assigning wrong measurements to tracks often results in lost tracks and track breaks. Moreover, clutter can produce false tracks, and if the clutter density is sufficiently large, the resulting number of false tracks can overwhelm the available computational resources of the systems, as well as degrade the overall picture of the environment. These are the problems which need to be tackled in the radar system.

The calculations based on the initial values of the parameters i.e. speed, acceleration, bank angle using various kinematics equations can be used to solve the above problems.

2. MODELLING AND SIMULATION

Modeling and simulation techniques provide an appropriate avenue for exploring system performance in detecting and tracking airborne targets. The performance and dynamics of the radar and tracker under real world site-specific conditions, coupled with the generation of intruder targets, are simulated to evaluate the time required for the radar and tracking system to detect and initiate track on an airborne target.

The resulting simulation data will enable us to quantitatively map out safe airspace volumes for UAS operations at any given site within the NAS. The overall modeling and simulation approach is summarized in Fig1. The modeling of the different radar systems and an airspace traffic characterization in the concerned operational volume are completed as a pre-process. In the simulation environment, aircraft targets are generated from aircraft performance and operating characteristics distributions. We simulate track initiation and maintenance for each target by the tracking model, which receives target detection information from heterogeneous and asynchronous radar systems. As the signal from a given radar is reflected off the aircraft target, the likelihood of detecting the target is precisely the probability of detection (Pd) at that location for the given radar system, as determined by the radar performance model.

Results from the modeling and simulation environment include statistical distributions of target detection, track initiation, and track maintenance performance parameters

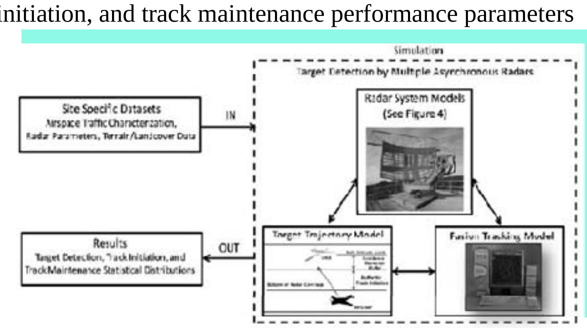

Fig1:- Aircraft detection and tracking modeling and simulation approach

The active diagram shows the proposed work. The azimuth, elevation And range of the system is predefined and based on the requirement user inputs the speed, acceleration and bank angle to generate the required target trajectory. Then the plots can be viewed in the form of graphs in MATLAB.

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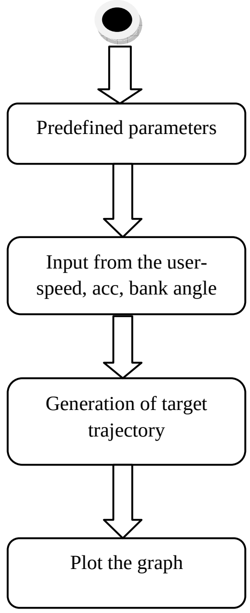

Fig2:- Activity diagram

The power ‘Pr’ returning to the receiving antenna is given by the equation.

$$P_r = \frac{P_t G_t A_r \sigma F^4}{(4\pi)^2 R_t^2 R_r^2}$$

Where,
Pt = Transmitter power.
Gt = Gain of the transmitting antenna.
Ar = Effective aperture of the receiving antenna.
σ = Radar cross section.
F = Pattern propagation factor.
Rt = Distance from the transmitter to target.
Rr = Distance from the target to the receiver.

The Doppler frequency shift for active radar is as follows, where F_D is Doppler frequency, F_T is transmitting frequency, V_R is radial velocity, and C is the speed of light.
.

$$F_D = 2 \times F_T \times \left(\frac{V_R}{C}\right)$$

Passive radar is applicable to electronic countermeasures and radio astronomy as follows

$$F_D = F_T \times \left(\frac{V_R}{C}\right)$$

3. GENERATION OF TARGET TRAJECTORY

3.1 Predicting the Target Trajectory

A trajectory is the path that a moving object follows through space as a function of time. The object might be a projectile or a satellite, for example. It thus includes the meaning of orbit—the path of a planet, an asteroid or a comet as it travels around a central mass. A trajectory can be described mathematically either by the geometry of the path, or as the position of the object over time. All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.
In control theory a trajectory is a time-ordered set of states of a dynamical system (see e.g. Poincaré map). In discrete mathematics, a trajectory is a sequence $(f^k(x))_{k \in N}$ of values calculated by the iterated application of a mapping *f* to an element *x* of its source.

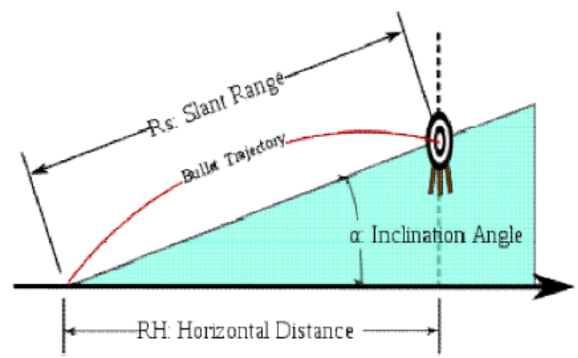

Fig 3: - Radar systems provide surveillance information for air traffic Management (ATM)

Radar wave propagation is affected by atmospheric and environmental conditions, terrain, and land coverage. Performance analysis of primary surveillance radar systems is critical for enabling routine Unmanned Aircraft System (UAS) access to the National Airspace System (NAS). The safe operation of UAS in the NAS necessitates a capability to sense and avoid other airborne objects. One solution is a Ground Based Sense and Avoid (GBSAA) concept, which fuses radar data in a specially tuned tracking system and provides traffic information to a ground observer and pilot. In this paper, we will present a modeling and simulation approach for assessing site-specific radar detection performance and apply the results to the GBSAA application. High fidelity primary surveillance radar performance and tracking system models enable simulation studies with the objective of determining target probability of detection and distributions of expected track initiation times across the surveillance volume. These models take into account target characteristics, site-specific radar performance, and tracking system filtering and initiation logic. This information will help in the development of a

GBSAA concept of operation, mission planning, and will ultimately define where UAS can operate with sufficient surveillance coverage to meet sense and avoid functional requirements. The target trajectory for the target is generated based on the prior information of speed, acceleration, banking angle etc. Then the future trajectory is estimated.

3.2 Generation of target trajectory

Tracks are generated by specifying the range (in meters), azimuth (in degree), elevation (in degree) and heading of the track. A trajectory is the path that a moving object follows through space as a function of time. The object might be a projectile or a satellite, for example. It thus includes the meaning of orbit—the path of a planet, an asteroid or a comet as it travels around a central mass. A trajectory can be described mathematically either by the geometry of the path, or as the position of the object over time. The object moves only under the influence of a uniform gravitational force field. Generally, when determining trajectories it may be necessary to account for non uniform gravitational forces, air resistance (drag and aerodynamics). This is the focus of the discipline of ballistics. A trajectory is the path followed by a projectile.

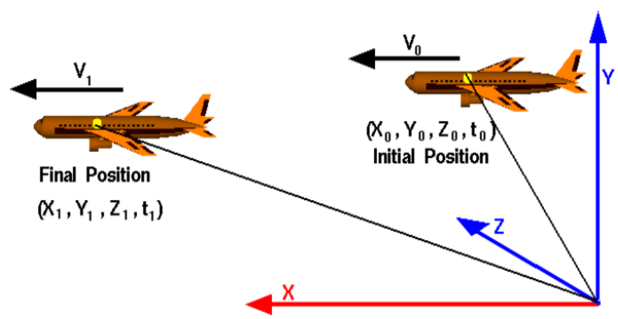

Fig 4: - Aircraft Translation

The kinematic equations for the motion of a target object travelling with constant speed.

Vx=Speed * Sin(azimuth Heading)*Cos(elevation Heading)

Vy=Speed * Cos(azimuth Heading)*Cos(elevation Heading)

Vz=Speed * Sin(elevation Heading)

X_0=Range * Sin(azimuth)*Cos(elevation)

Y_0=Range * Cos(azimuth)*Cos(elevation)

Z_0=Range * Sin(Elevation)

X_1=X_0+Vx * Time

Y_1=Y_0+Vy * Time

Z_1=Z_0+Vz * Time

4. GENERATION OF SCENARIOS

The various scenarios for the targets can be generated which are:

- cross over targets
- targets in formation
- banking
- maneuvers

4.1 Cross over targets

One of the scenarios can be generated for cross over targets. It can be achieved for multiple targets but generally two targets are considered for cross over. When two targets with same parameters i.e. azimuth, elevation, range, speed, acceleration start simultaneously at same time in opposite direction, there are chances that the targets may collide on reaching the common point or deviate from the path. This leads to the miss prediction of target trajectory. So, scenario is generated in such a way so as to avoid this.

4.2 Targets in formation

The other scenario can be achieved for many targets making a formation. it is implemented for many targets moving in a group. The formation made by such moving targets give the illusion that a single entity exists rather than a number of targets in the group. So, the individual targets cannot be uniquely identified. Thus, the problem arises in determining the future trajectories of the targets. so, scenario is generated so as to determine the individual targets properly in the group.

4.3 Banking

This scenario depicts about an aircraft or target taking a turn. A target doesn't always move in a single straight line. It needs to take a turn along its path. It can take turn in either direction. This turn taken is based on the bank angle. Banking can be achieved using the following equations.

Formulas for banking of trajectory

$V^2=V_x^2+V_y^2+V_z^2$

$V= \sqrt{(V_x^2+V_y^2+V_z^2)}$

Radius = V^2/ (9.8*tan (bank angle))

Angular velocity = v /Radius

4.4 Maneuvers

Maneuvring is making a controlled series of changes in movement or direction of a moving vehicle towards an objective as in flight path. Aircrafts will perform different forms of maneuvring to avoid detection by RADAR.

Some types of manoeuvring are like

- Aerobatic maneuvring
- Air Combat maneuvring.

4.4.1 Aerobatic maneuvring

Aerobatic maneuvers are flight paths putting aircraft in unusual attitudes, in air shows, dog fights or competition aerobatics. Aerobatics can be performed by a single aircraft or information with several others. Nearly all aircraft are capable of performing aerobatics maneuvers of some kind, although it may not be legal or safe to do so in certain aircraft. Aerobatics consist of five basic maneuvers: Lines (both horizontal and vertical loops, rolls, spins, and hammerheads. Most aerobatic figures are composites of these basic maneuvers with rolls superimposed. A loop is when the pilot pulls the plane up into the vertical, continues around until he is heading back in the same direction, like making a 360 degree turn, except it is in the vertical plane instead of the horizontal. The pilot will be inverted (upside down) at the top of the loop. A loop can also be performed by going inverted and making the same maneuver but diving towards the ground.

It can be visualized as making a loop of ribbon, hence the name it is given. A roll is simply rotating the plane about its roll axis, using the ailerons. It can be done in increments of 360 degrees (i.e. four short 90 degree rolls will bring the aircraft back to its upright position). A Spin is more complex, involving intentionally stalling a single wing, causing the plane to descend spiralling around its yaw axis in a corkscrew motion. A Hammerhead (also known as a Stall turn) is performed by pulling the aircraft up until its pointing straight up (much like the beginning of a loop), but he continues to fly straight up until his airspeed has dropped to a certain critical point. He then uses the rudder to rotate the aircraft around its yaw axis until it has turned 180deg and is pointing straight down, facing the direction he came from. The aircraft gains speed, and he continues back exactly the way he came. It is also known as a "tailslide", from the yawing turn, which is different from the typical method of turning an aircraft in the pitch axis.

4.4.2 Air Combat maneuvring

Air combat maneuvering is the art of maneuvering a combat aircraft in order to attain a position from which an attack can be made on another aircraft. It relies on offensive and defensive basic fighter maneuvering (BFM) in order to gain an advantage over an aerial opponent. The main idea for the aircrafts to perform various sorts of maneuvers is to avoid their detection by the radar. Thus, it‘s very useful in military purpose so that their aircrafts could not be easily detected by the enemy‘s country.

5 CONCLUSION

Generating the target trajectory is very important aspect of the radar system. Although existing methods allow us to do some prediction of the target trajectory, it cannot avoid the risk of cross over targets or targets in formation. Aircraft trajectory forms the basis for validating the functionalities of the RADAR. Simulation of aircraft trajectory helps in overcoming the various problems which may arise in actual target trajectory of the helicopter. It is very challenging to predict the trajectory of the aircraft precisely.

6 RESULTS

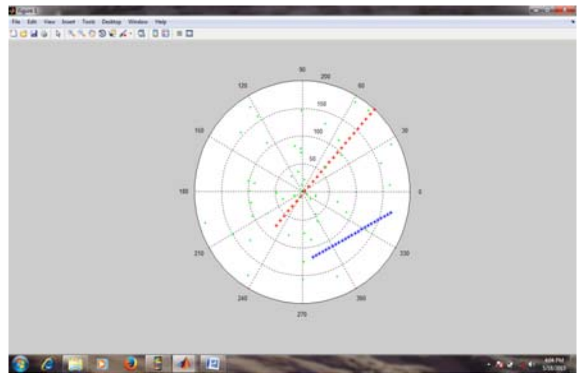

Fig 5:- Two targets making Formation

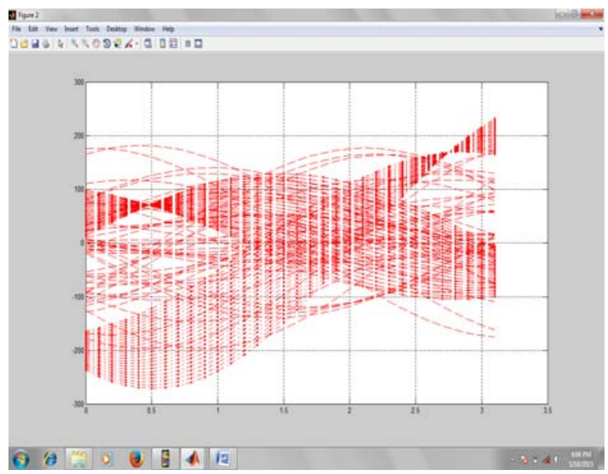

Fig 6:- Recevied signal of two targets crossing over each other.

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BIOGRAPHIES

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