Using Model and Flight Check Results to Identify Sources of False Targets on a Precision Approach Radar

Simbo A. Odunaiya, Ph.D.
Ohio University
Athens, Ohio 45701
Tel: (740) 593-1531
Fax: (740) 593-1604
Email: odunaiya@ohio.edu

Michael Mowry
Ohio University
Athens, Ohio 45701
Tel: (740) 593-1520
Fax: (740) 593-1604
Email: mowry@bobcat.ent.ohiou.edu

ABSTRACT

The issue of false targets is very common with radars especially radars that are situated within the airport. This phenomenon affects both terminal radars and precision approach radars. While terminal radars are mostly affected by buildings and other structures near the radar, false targets in precision approach radars (PAR) can be caused by both structures and the terrain. False targets in the azimuth section of the PAR are due to structures while false targets in the elevation section are mostly due to terrain effects. Mathematical modeling of the scenario can be a very good tool in identifying the cause of false targets, especially when they are used in conjunction with results from flight checks. A case in point is the false targets observed on the FPN-63 Precision Approach Radar serving runway 19R at the Meridian Naval Air Station (NAS). A mathematical computer model was used to analyze the site and the results were compared with flight check results. This analysis shows that while terrain up-slopes can cause false targets in the operation of a PAR, it is not necessarily the only cause. In such situation where the terrain is not the problem, modeling also offers a way of ruling out the terrain. This paper will show how the computer model was applied. Results from flight check and comparisons with model results will also be shown.

BACKGROUND

A precision approach radar (PAR) is used to provide guidance to aircraft for final approach and landings. Azimuth, Elevation, and range information is displayed on the operator's console which is used to direct the pilot to a precision landing. This is accomplished through the use of the azimuth and elevation portions of the system (Figure 1). In an uncooperative environment, a PAR can provide false target returns continually that can confuse an annoy the ground controller. For the elevation or vertical part of the PAR, the false target returns can usually be attributed to irregular terrain in front of the system. In such situations the false target will track along with the aircraft movement (actual target). Sometimes this false target will track at angles and distances where the Air Traffic Controller can easily assume this to be a false target, however, this is still very annoying to the controller.

In the case of the azimuth part of the PAR, the sources of the false targets are usually buildings, power lines, or trees in the vicinity of the system. Ohio university already has a model that can be used to predict false targets and false replies due to buildings, power lines or trees near a radar system[1]. This paper is therefore restricted to the vertical portion of the PAR.

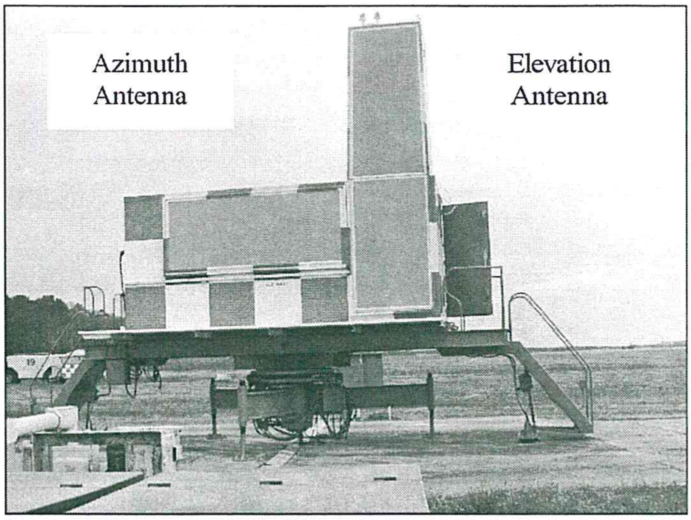

Figure 1: Picture showing the Azimuth and Elevation antennas of a PAR.

OBSERVATIONS

One example of a PAR with false replies is the FPN-63 PAR serving runway 19R at the McCain field, Meridian Naval Air Station (NAS), Meridian, Mississippi.

The topography in front of the radar antenna, figure 2, suggests the possibility that when the elevation beam of the FPN-63 scans down to -1 degree, the ground, which can serve as a reasonably good reflector, is illuminated.

The reflected signal and the subsequent return signal now pass through unobstructed airspace. This hypothesis is supported by the evidence obtained from the radar performance and visual inspection of the site.

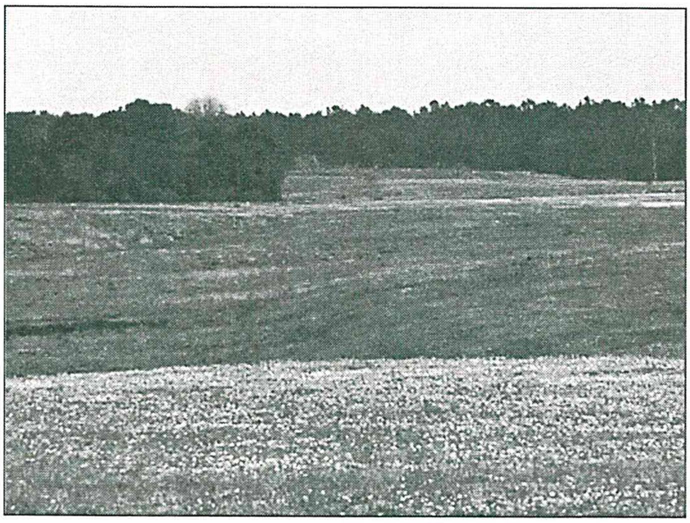

Figure 2: Terrain in front of PAR at Meridian NAS.

The phenomenon reported was physically observed on the Plan Position Indicator (PPI) during a visit to the site. During test flights, a false target was clearly observed, essentially below the real target. The false target was located around 1-degree in elevation. Figure 3 is a photograph of the PPI during the test flight that shows both the real target and the false target. Line-of-sight and specular reflection analyses strongly suggest that this false target is created when the elevation antenna scans in a manner that illuminates the terrain in front of the radar and along the approach path. The fact that the false target essentially tracks along with the real target also suggests that the reflecting plane contributing to this phenomenon includes areas of ground in front of the radar antenna both before and after the touch-down zone.

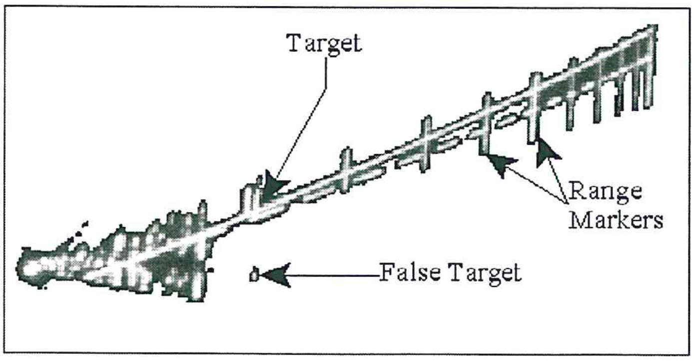

Figure 3: Observed false target at Meridian NAS PAR.

ANALYSIS

Radar modeling can be used to determine if the false targets which appear on the Runway 19R PAR are due to secondary source multipath. The onset of the false targets appears to coincide with the removal of trees along the approach path. This is a strong suggestion that the trees were hitherto serving as screens to reflected signals. In view of this one possible solution is to construct an RF screening fence (signal blocker) at some point along the radar signal path to minimize the multipath which gives rise to the false targets. Prior to constructing such a fence, it is economically prudent to mathematically examine the physical scene to determine whether deliberate blocking and harmless scattering of the radar signal (the purpose of the fence) will remove the false targets due to illumination of the ground in front of the PAR. The latter occurs as the radar scans through low-to-negative grazing angles

Methods of minimizing the effect of the ground can also be explored through the use of the scattering model. To perform the mathematical modeling of the radar, it is necessary to acquire a data set to characterize the radar itself, along topographic charts which describe the physical environment in which the radar operates. Once the area in front of the radar which gives rise to the multipath is identified using the radar model, different options for minimizing its effect can be studied, including the modeling of the PAR system response after a signal screen is installed. Such results will determine the efficacy of an RF screening fence as well as aid in its design and construction.

OHIO UNIVERSITY PRECISION APPROACH RADAR FALSE REPLIES IDENTIFICATION AND MINIMIZATION MODEL

Theory and Assumptions

In a PAR elevation system, a RADAR signal is typically swept between an elevation of around -1° relative to the horizon to about +7°. A target illuminated by the beam will reflect energy back to the receiver which then determines the elevation and distance of the target. The system is designed for single-aircraft use, so any reflection not originating from the target being tracked is identified as a false target. A false target generally occurs when energy from the PAR is reflected forward by the surrounding terrain towards the approaching aircraft and is in turn reflected

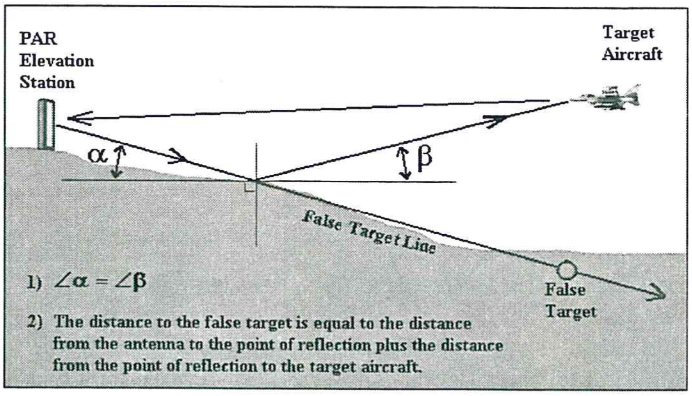

Figure 4: Determination of False-Target Location

back to the PAR receiving antenna. The elevation angle of the antenna and the extra travel time of the reflected energy are then interpreted as a second target (See Figure 4).

The developed model makes use of the Geometrical optics (GO) techniques to determine the characteristics of signal reflections from the surrounding terrain. The GO technique is a high frequency technique used to compute approximations to the fields reflected from surfaces, with the directions of the fields determined by Snell's law of reflection.

In this model the idea is to construct a two-dimensional mock-up of the terrain in front of the PAR system and simulate a full PAR elevation system sweep with the aircraft in every position along its approach path. The PAR model employs GO technique to achieve this. Assumptions made in the algorithm are:

1) Reflections are assumed to be in the forward scatter direction only
2) Multiple scattering is not considered
3) When the topography is such that reflected signals from certain points on the terrain are effectively blocked by other parts of the terrain from the aircraft, it is assumed that false targets are not indicated.
4) Diffraction of signals at the edges of ground planes are considered as second order effects and as such negligible
5) If a beam width of zero is selected, the beam is modeled as a line of infinitesimal thickness.

Model Outputs

In order to properly analyze the results of the model several pictorial icons are used in the model output to aid the user. The user interface makes it possible to choose different options that may help the user in making final determinations about the performance of the PAR being simulated. During model execution, the aircraft location is indicated on the display by an aircraft icon. When a false target is encountered, a circle is displayed in its proper location. If selected, the incident and reflected energy paths are also displayed. These allow the user to see the signal path from the PAR antenna to the aircraft and as such be able to identify what section of the terrain contributes to the presence of false replies.

When the source of false replies has been identified, the model makes it possible to analyze methods of minimizing the effect of the offending terrain. One possibility is to build a fence or a screen that can effectively block the reflected signal from the approaching aircraft. The model offers a secondary feature that when selected will allow iteration such that the optimal point for the placement of the signal screen can be determined. Once the optimum point is identified, the model will also allow for the testing of the effectiveness of the screen.

SAMPLE RESULTS

A sample run of the model is now presented. The following table shows the required model inputs that have been used.

Parameter	Value
Antenna Height	14 feet
Beamwidth	0.55 degrees
Scan Angle	-1.6 to +3 degrees
Glide path	3 degrees
Aircraft Speed	200 knots
Setback	4500' from threshold
Touch down point	1000' from threshold

Table 1: PAR parameters used in model.

Table 2 shows the two-dimensional cross section of the terrain in front of the PAR and out into the approach area that is used in the example.

Distance(ft)	Elevation(ft MSL)
-4500	0
-4300	-4
-3500	1
-3100	-5
-2400	-9
-1800	-11
0	-15
1800	-10
24304	0

Table 2: 2-D cross section terrain used in example

A screen capture of the model following execution with the preceding parameters is shown in Figure 5.

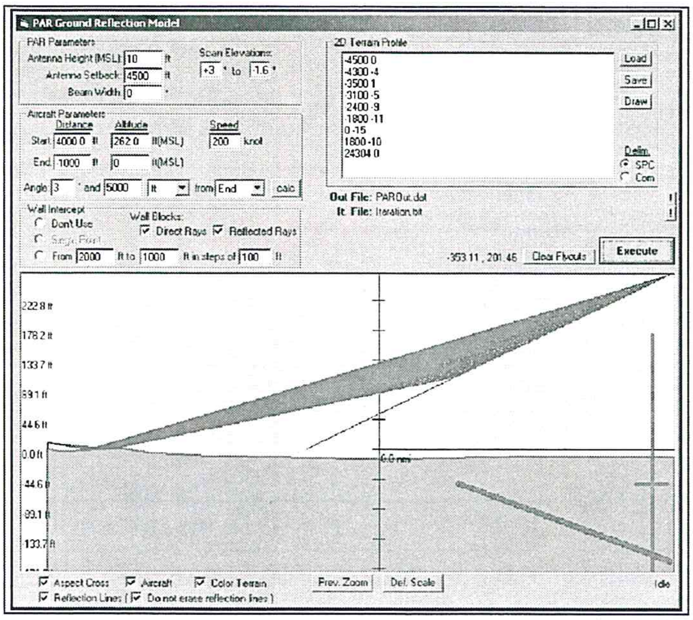

Figure 5: Execution screen for Example 1

The reflection lines for all the scan positions are shown. This example shows that the area of the terrain causing the false replies is between –3450 feet from threshold and –4075 feet from threshold.

Figure 6 shows the expansion of the reflection area in the terrain causing the false targets to give more detail. The area that appears to be the most ideal for the placement of a screening wall is around -3810 feet from threshold. This point can also be determined using the blocking wall iteration ability of the PAR model.

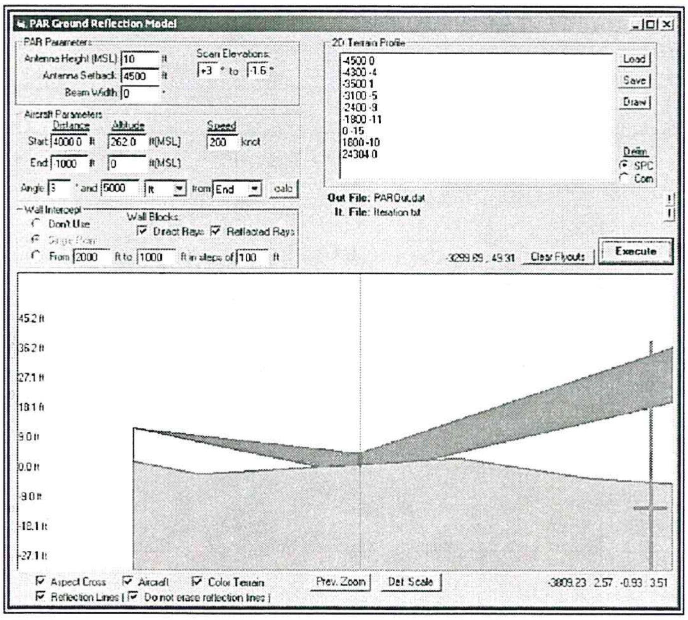

Figure 6: Display zoomed to show detail – Screening wall added

Figure 7 illustrates the results of stepping the blocking wall between –3800 feet from threshold and –3820 feet from threshold. Hovering the cursor over the top and bottom of the wall with the least height then gives a location of -3810 feet , and a height of –0.9(base) + 2.6(height) = 3.5 feet. If the resulting wall were large enough to cause blockage of the direct signal, or to violate obstacle clearance requirements, the use of multiple walls of lesser height could be investigated using the same method.

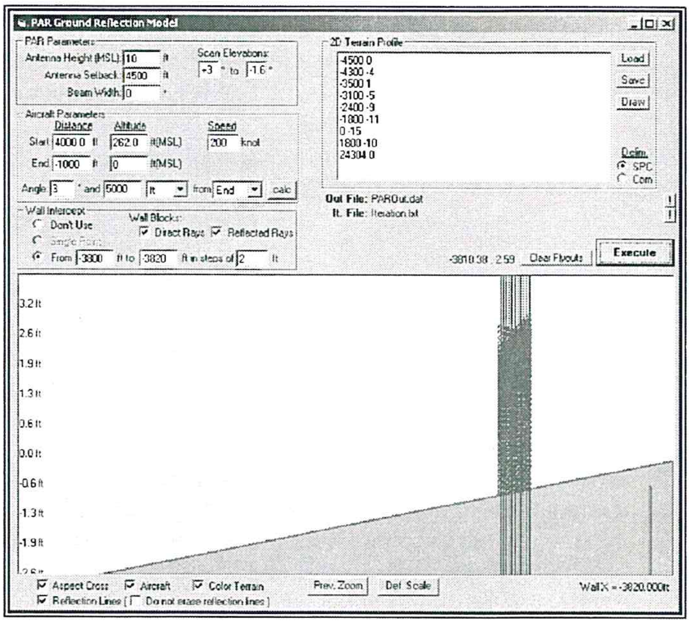

Figure 7: Illustration of screening wall iteration

CONCLUSIONS

A viable model that allows for the identification of sources of false targets on the vertical portion of a PAR has been developed. This model is capable of not only identifying the source of the false replies, but can also be used to investigate mitigation options.

REFERENCES

[1]Simbo A. Odunaiya, "SEATAC Airport: Verification of ASR-9 Reflection Model through Alternative Model Analysis", Technical Memorandum OU/AEC 99-16TM-SEATAC. Avionics Engineering Center, School of Electrical Engineering and Computer Science, Ohio University, Athens, Ohio, September 1999