

# Moving Target Analysis Utilizing Side-Looking Airborne Radar

The AN/APS-94C side-looking airborne radar (SLAR) system has the capability to distinguish signal return from stationary objects from those signals reflected by moving targets.

THE AN/APS-94C side-looking airborne radar (SLAR) is utilized solely in the OV-1B (Mohawk) aircraft which has been a U.S. Army intelligence asset since the mid-1960's (Figure 1). This real-aperture SLAR system provides dual imagery modes, known as the 'fixed target' and 'moving target' modes. Whereas most radar interpreters are familiar

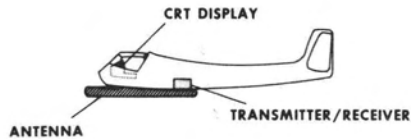


FIG. 1. Configuration of the AN/APS-94C SLAR system in the OV-1B (Mohawk) aircraft.

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**ABSTRACT:** *The AN/APS-94C side-looking airborne radar (SLAR) system has the capability to distinguish signal return from stationary objects from those signals reflected by moving targets. Experience has shown that vehicles traveling over 5 km/hr with a minimum spacing of 80 m will be detected, with the exact resolution limit a function of speed, direction of movement, and range. The operational principle of moving target mode SLAR is discussed, as are several potential applications.*

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with the fixed target imagery characteristics of SLAR systems, the moving target mode has only recently been declassified by the military (*Declassification of AN/APS-94C (OV-1B) SLAR*, MSG 182105 November 1976, Headquarters, Department of the Army).

The AN/APS-94C differs from conventional SLAR systems in its ability to discriminate signals reflected from moving versus immobile objects (see, for example, Moore (1975), McDonald and Lewis (1976), or Leberl (1975)). Pulsed signals are trans-

mitted at 1.3 millisecond intervals (Figure 2) along a scan line normal to the flight path of the aircraft. This signal, when reflected from solid objects, becomes signal return which is received, amplified, and analyzed by the transmitter/receiver unit and converted to a coherent image on the CRT display in the cockpit. The CRT console also contains a film recorder and photo processor and, in addition, the processed signal may be retransmitted to a similar ground console, providing a real-time telemetry capability (specifications and functioning of the AN/APS-94C SLAR system are discussed in TM 11-1510-204-35/2, Dept. of the Army, April 1969).

The discrimination of moving targets is accomplished by comparing successive sig-

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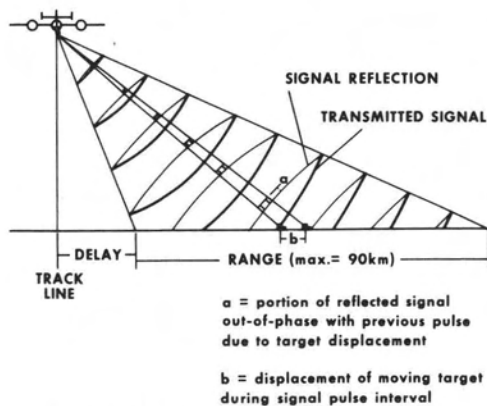


FIG. 2. Principle of moving target signal generation.

nal returns. Each signal received (Figure 3) is amplified and delayed 1.3 milliseconds, enabling it to pass simultaneously with the following signal through a phase comparator. Successive "in phase" signals indicate a stationary target and are passed to the fixed target video amplifier, whereas each "out of phase" sequence triggers the moving target indicator. Because moving target signals are actually derived from successive fixed target

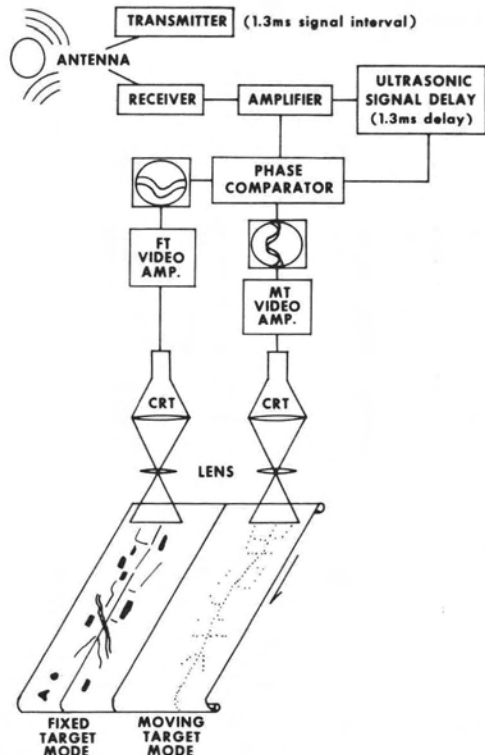


FIG. 3. Principal components of AN/APS-94C SLAR system.

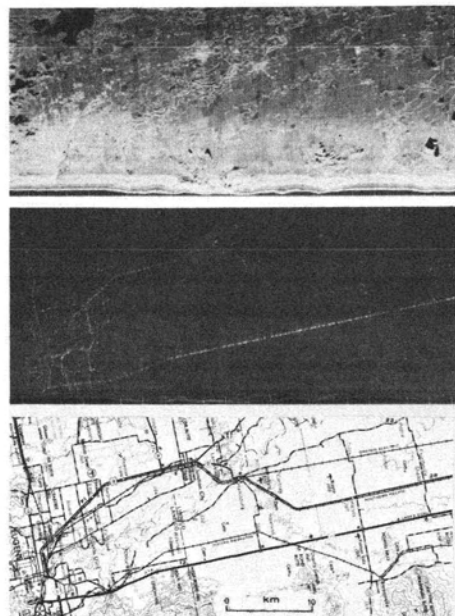


FIG. 4. AN/APS-94C imagery of the southern Willamette Valley, north of Eugene, Oregon (west-looking antenna); (top) fixed target mode, (middle) moving target mode, (bottom) map.

responses the two modes are synchronous and the moving target image is displayed adjacent to its location on the fixed target terrain image (Figure 4).

The example illustrated in Figure 4 images the southern part of the Willamette valley north of Eugene, Oregon. The topography of this area consists of a flat alluvial plain pierced occasionally by residual volcanic buttes. Such landscape is well suited to a SLAR mapping test because there is little terrain shadowing and it contains a road network with several different road types including a four-lane interstate, several two-lane state highways, and an urban street network.

Moving target interpretations are limited by the scale and resolution ability of the AN/APS-94C system. The imagery utilized in this article was originally printed from negatives produced by the on-board CRT console at a scale of 1:438,000. Minimum target size for motion detection varies because size is inversely proportional to speed; examples of detected targets include large trucks moving at 5 km/hr to bicyclists moving at 30 km/hr. Minimum discrete target interval is another important consideration because multiple targets detected within minimum distances appear as a single target signature on the imagery. The critical interval varies with the direction of target motion

relative to the flight path of the aircraft, as well as with the resolution of the film recorder. Guidelines for the AN/APS-94C, derived from experimental flights, indicate a minimum discrete target interval of 80 m throughout the range (maximum range = 90 km) for vehicles moving perpendicular to the flight path. Resolution decays with range if the motion is parallel or oblique to the flight path. In such cases 10 m must be added to the minimum interval for each 10 km distance from the track line.

In Figure 4, the imagery has a range of 25 km with no delay. The track line forms the lower side of the image, as evidenced by the 'altitude window' which forms a terrain profile. The range line, above the center, indicates a distance of 20 km from the track line. Heavy traffic on Interstate-5 has produced numerous coalescing target signatures in the moving target mode. Because the direction of traffic flow is oblique to the track line, the minimum discrete target interval is 80-90 m as the highway lies from 5 to 15 km from the track line. Whereas the limitations imposed by the minimum target interval virtually eliminate the possibility of exact traffic counts, the capability for obtaining an 'instantaneous' view of relative traffic volume for entire regional road networks holds potential for traffic engineers and transportation planners.

Qualitative assessments of traffic volume may be used to identify the function of linkages within a road network at different peak traffic periods. Major arterial roads are easily identified, as are their primary feeders, as illustrated by the concentrations of moving target signatures within the city of Eugene (Figure 4). The timing of overflights could correspond to various types of peak flows, such as rush-hour commuter traffic, sports events, weekend recreational traffic, etc., for which different traffic flow patterns may develop.

Relative road use during peak traffic flows may be evaluated by using quantitative ratios in place of traffic counts. For example, the effect of a specific area on traffic generation could be evaluated by using a traffic density measure such as

$$D_t = \frac{n}{a} = \frac{\text{Number of moving targets}}{\text{Area of traffic district}}$$

Similarly, congestion or traffic use along linear highway segments could be classified by a use intensity ratio in the form of

$$R_o = \frac{\sum Mt}{\sum L}$$

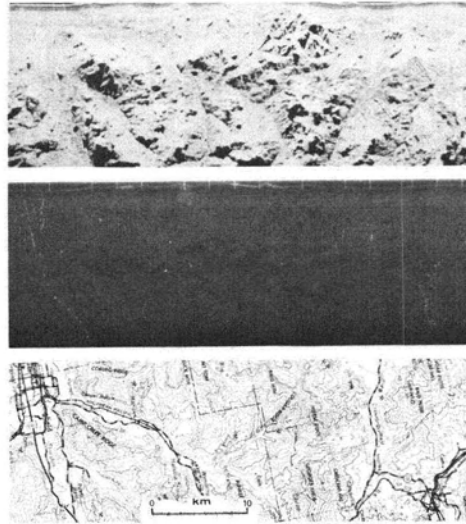


FIG. 5. AN/APS-94C imagery of the Santiam, Mackenzie, and Willamette Pass areas of the western Cascade mountains (east-looking antenna); (top) fixed target mode, (middle) moving target mode, (bottom) map.

$$= \frac{\sum \text{length of moving target signatures}}{\sum \text{length of road segment}}$$

where the intensity (i.e., cluster of vehicles spaced closer than the critical target interval) is expressed as a percentage of segment length. Such measures are conducive to manual interpretation or may be converted to automated techniques by using a digitizer or scanning densitometer.

Sinuous roads in rough terrain may be analyzed (Figure 5) provided that the angle of incidence is adjusted to provide for minimum terrain shadowing. As the angle of incidence reduces with distance from the track line, shadowing increases. Thus, the ability to detect moving targets tends to decrease with distance. The direction of radar illumination relative to key terrain features greatly affects moving target detection in rough terrain, whereas targets along valley bottoms are easily sensed when the track line is perpendicular to the valley axis.

Other possible applications include the identification of open roads and moving vehicles following natural disasters, surveillance of offshore fishing activity, or recreational boating surveys on rivers, lakes, and reservoirs.

## CONCLUSIONS

Despite the problems presented by the small scale and critical target interval, the

moving target discrimination capability of the AN/APS-94C presents a new dimension in SLAR applications. Whereas non-tactical applications appear promising, they require the development of specialized data interpretation techniques to accommodate the system limitations. A few elementary measures have been suggested for transportation network studies, but more advanced manual or digital techniques are required for the actual employment of this sensor system. At present, availability is limited to Grumman OV-1B (Mohawk) aircraft assigned to the U. S. Army as well as to the Oregon and Georgia National Guard.

#### ACKNOWLEDGMENTS

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