

## SYNTHETIC APERTURE RADAR (SAR)

Roger S. Picton

**Abstract.** In order to achieve high-resolution pictures of the ground, it is necessary to achieve high resolution along the radar beam (range resolution), and across the beam (cross-range resolution). High range resolution is achieved by the use of pulse compression. Cross-range resolution is a function of antenna beamwidth and target range. High cross-range resolution, therefore, is achieved by producing a radar antenna with a very narrow effective beamwidth. To achieve this, a real antenna would have to be made impracticably large. The solution is to find some way of synthesising the performance of a very large antenna out of one that is physically far smaller. This review article outlines the principles behind Synthetic Aperture Radar, and discusses the processing techniques used in the production of the final imagery. The technique of Inverse SAR (ISAR) is also briefly discussed.

### INTRODUCTION

In the field of airborne reconnaissance, it would be a great advantage to have a radar available that could produce a high resolution picture of the ground and provide detailed information about troop movements, building works, railhead activities, and so. This sort of information can of course be obtained by photographic imaging infra-red techniques. These, however, require the reconnaissance aircraft to at best fly near, and at worst fly over, the ground of interest. An imaging radar, on the other hand, could achieve the same result at a large stand-off range by using its superior atmospheric attenuation properties, and its relative immunity to weather effects. This paper deals with the theory and practice of such radars.

In order to achieve high-resolution pictures of the ground, it is necessary to achieve high resolution along the radar beam (range resolution), and across the beam (cross-range resolution). High range resolution is achieved by the use of pulse compression – a technique that is not discussed further in this paper. Cross-range resolution is a function of antenna beamwidth and target range. High cross-range resolution, therefore, is achieved by producing a radar antenna with a very narrow effective beamwidth. To achieve this, a real antenna would have to be made impracticably large. The solution is to find some way of synthesising the performance of a very large antenna out of one that is physically far smaller. A technique for doing this is described below.

#### Formation of a Synthetic Array

The beamwidth ( $\theta_B$ ) of a real antenna is given by:

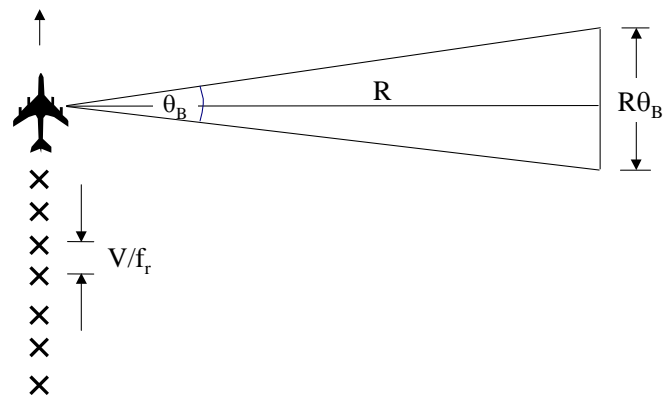
$$\theta_B = \lambda / D$$

where  $D$  is the antenna width, and  $\lambda$  is the wavelength of operation. This gives a cross-range resolution,  $\delta_{cr}$ , of:

$$\delta_{cr} = R\lambda / D$$

where  $R$  is the target range. High cross-range resolution therefore requires very large antennas – normally impracticable on most realistic platforms.

Figure 1 illustrates the production of a synthetic array, where the motion of the platform is utilised during transmission of the ranging pulses to give an effectively long antenna – a so-called synthetic aperture.



**Figure 1.** Illustration of the production of a synthetic array.

The aircraft is flying a constant velocity ( $V$ ), sending out pulses (at frequency  $f_r$ ) at  $90^\circ$  to the flight line. Each pulse is sent from a different location on the flight line, and defines one element of the synthetic array. The total array consists of all positions at which an echo is received from a particular target. All the echoes from this target are then processed to form the synthetic array beam pattern. The beamwidth of the array is given by:

$$\theta_s = \lambda / 2L_e$$

where  $L_e$  is the effective length of the synthetic array. (This differs from a real array beamwidth by a factor of two. This is because synthetic array beamwidths are determined by a two-way phase pattern, while real arrays use a one-way pattern.)

The cross-range resolution available from the synthetic array is thus given by:

$$\delta_{cr} = R\lambda / 2L_e$$

The effective length of the array is determined by the distance along the flight line over which a particular target is in the beam of the real antenna. This given by:

$$L_e = R\theta_B$$

and is a function of target range, being longer for more distant targets. Since  $\theta_B = \lambda / D$ , the cross-range resolution is:

$$\delta_{cr} = D / 2$$

which is independent of range.