# Radar as a tool for conservation ecology: applications, utility and refinements

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## Background

Radar has been widely used for many surveillance applications, although it has seldom been used for the detection of wildlife and conservational ecology. Radars have been used for the detection of birds and bats in order to establish their migratory routes in order to deconflict with the positioning of wind farms; these radars have often been based on commercial marine radars [1]. Such radars are long range, non-coherent systems and hence do not measure target velocity directly (target velocity may be calculated on the basis of track information built up over several scans taking several seconds of data). Alternatively, the use of harmonic radar is widespread in zoological studies but requires the capture of the animal, fitting of a transducer and its subsequent release. Furthermore, harmonic radar lacks resolution and accuracy. Traditional infra-red based sensors used for ecological applications also struggle to detect small objects, especially those with a low thermal contrast to the background, such as any cold-blooded animal or aquatic mammals recently emerged from cold water.

Radar offers the ability to maintain surveillance over a wide area without any operator intervention and, through the use of low power microwave radiation, goes undetected by animals. In particular, continuous wave (CW) Doppler sensing radar has the ability to detect target motion and to discriminate between target returns by virtue of the radial velocity of the target. Unlike non-coherent radar systems, coherent Doppler sensing radars return an almost instantaneous measurement of the target velocity. This is crucial for the immediate indication of a target moving between preset velocity limits. Both non-coherent and coherent Doppler sensing radars can detect the wing beat frequency [2, 3], although the mechanism differs somewhat in each case.

Low power CW Doppler sensing radars offer excellent target discrimination abilities for the rapid indication of small, fast moving animals over short detection ranges, which are advantageous over other radar technologies and infra-red based sensors. The low cost of modern commercially available products makes them an attractive and novel proposition for conservational ecological applications.

## Theory [4]

The radar reflection from a target moving with a radial velocity of $V_r$ with respect to the radar is subject to a Doppler shift, $f_d$ given by:

$$f_d = -\frac{2V_r}{\lambda} \tag{1}$$

in which $\lambda$ is the wavelength of the radar signal and is, in turn, given by:

$$\lambda = c/f_t \tag{2}$$

whereby $c$ is the speed of propagation in free space (= $3 \times 10^8$ m/s) and $f_t$ is the transmitted frequency.

Coherent down-conversion of the received signal with a sample of the transmitted signal in a homodyne receiver into quadrature channels yields an output of the complex signal at a frequency equal to the Doppler frequency, $f_d$. The quadrature outputs are time sampled over a given duration (and digitised) and then processed using a fast Fourier transform (FFT) in order to extract the Doppler frequency. The Doppler resolution, $\Delta f_d$, is given by the inverse of the sampling period, i.e.

$$\Delta f_d = 1/t_{\text{int}} \tag{3}$$

where $t_{int}$ represents the sampling period (also known as the *integration time*). The corresponding velocity resolution, $\Delta V_r$, is therefore given by:

$$\Delta V_r = \frac{\lambda . \Delta f_d}{2} \tag{4}$$

Returns from static (or near-stationary) objects fall at zero (or very low) Doppler frequencies, whereas returns from rapidly moving targets exhibit a high Doppler frequency. Hence it becomes possible to discriminate between stationary ground clutter and near-stationary objects such as wind blown vegetation and rapidly flying insects, birds and mammals.

## Method

In this study, we used a small commercially available CW Doppler sensing radar [5] operating at a frequency of 24GHz in order to automatically trigger a camera to take a photograph of the target detected by the radar. Applying the transmitter frequency in (1) and (2) results in a Doppler shift of 160Hz for every 1m/s of target velocity. The radar has a beamwidth of $25^0$ in azimuth by $7^0$ in elevation and this determines its field of view. The radar data is passed to a sound card which digitises the data and passes it to a lap-top computer via a USB link. The data is sampled at 44.1kHz over intervals of 200ms, giving an unambiguous indication of velocity for target velocities up to 138m/s with a velocity resolution of 0.03m/s. Data is processed on the lap-top by taking the FFT and imposing velocity and amplitude limits. All returns below 0.5m/s were rejected as, from experience, this rejects unwanted returns from vegetation in light wind conditions, which were prevalent at the time of the experiments, but does not reject targets of interest. Returns above 5m/s were also rejected. A threshold level was set which achieves a threshold to noise ratio of approximately 25dB since this provides resilience against noise generated false alarms and yet remains adequately sensitive to detect a walking human at a range of 75 to 90 metres and a honey bee at a range of 1 to 2 metres. Any target return with a velocity between 0.5 and 5 m/s and with a return sufficiently strong so as to exceed the detection threshold is therefore registered as a target of interest and triggers the camera (Canon EOS 1000D) to take a photograph. No distinction was made between closing and receding targets, even though the radar and data processing can resolve these cases. The response speed of the system is estimated to be approximately 200ms between the threshold being crossed and the picture being taken.

For trials on the insect visitation of Himalayan Balsam the radar was positioned approximately 70cm from a cluster of five flower heads and the camera was positioned about 1 metre distant along a line of sight thought best to capture the visit. For the trials against *Podarcis muralis*, the radar and camera were co-located at a range of between 1.5 and 3 metres. For both sets of trials the radar and camera were set up and left in-situ with no human operators in the vicinity of the test site (in fact it is preferable for operators to be well out of the radar range / beamwidth).

## References


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