Radar subsystem

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You will receive a small radar module that you can use to locate underground alien infrastructure. Our intelligence sources reveal that aliens use subsurface fans to pump air underground. Your radar can detect moving objects, and you should use it to locate the blades of a rotating fan.

Figure 1 HB100 doppler radar module

The radar operation is based on the Doppler effect. We won't explain the effect in detail here, and it is worth your while to read about it. Briefly, when a wave of a frequency f_0 is incident on a moving object, the frequency of the reflected wave is shifted by an amount of Δf that is proportional to the object velocity relative to the incidence direction. The frequency Δf is or the order of $v/c\, f_0$ (where v is the target velocity and c is the speed of light) and is therefore much smaller than the carrier frequency f_0.

A block diagram of the radar is shown below. A source generates a signal of a frequency $f_0 \approx$ 10.5 GHz. The signal is then split into two branches. One branch is connected to a Tx antenna. The other branch is connected to a mixer. The mixer is also connected to an Rx antenna. The antennas are identical; each is formed by two rectangular patches and a ground plane, which you can see. (The voltage source, splitter and mixer are behind the metal shield.) The signal radiated by the Tx antenna reflects from a moving target and is captured by the Rx antenna. The received signal has a frequency of $f_0+\Delta f$. For the two input signals, one at f_0 and another at $f_0+\Delta f$, the mixer outputs a harmonic signal at a frequency Δf. The mixer output is marked IF on the diagram and the radar itself. The signal at Δf can be displayed on a picoscope and processed by the low-frequency methods you are familiar with.

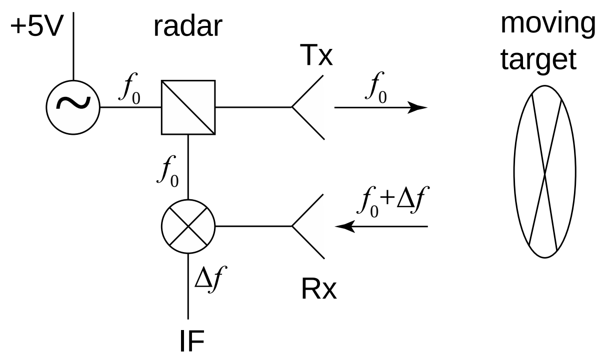

Figure 2 Block diagram of doppler radar module

When working with the radar you will need to consider the following factors:

- the radar output will have a dc component (think why), which is likely to be stronger than the target signature (think why)
- the target has multiple moving parts (rotating blades) so that its signature will not be a pure harmonic signal
- the target signature that is output by the radar is weak. You can expect ~10mV amplitude when the radar is next to the target. A target buried underground will produce a weaker signal, as will a more distant target.
- The radar will measure reflections not only from the target but also from the surrounding objects, resulting in clutter. Think what signals stationary and non-stationary clutter will produce. The module is designed to detect people entering or leaving an area. How will the clutter change when the rover is moving?

We suggest that you start your work with the following:

1. Use a power supply to power the target at 10-12V and the doppler radar module at 5V. Check the voltages and polarity carefully to avoid damaging your components
2. Place the radar next to the target and connect the output (IF) to a picoscope. Compare the output with dc and ac coupling. Use a low sampling rate to filter out high-frequency noise. Investigate the signal shape and magnitude (a figure below shows an example).
3. Switch to the spectrum-analyser mode and investigate the signal spectrum (switch the target on/off or adjust its voltage (speed) to see which harmonics it produces; see a figure below for an example).
4. Move the radar (a) away and (b) sideways from the target. Observe the evolution of the signal.
5. Then use the knowledge you gained to:
    a. suggest a method for clutter rejection
    b. estimate the signal amplification required (use the radar range equation to estimate the effect of distance)
6. Implement the solution devised.
7. Having conditioned the signal, use the 'scope to measure the effects of the distance and orientation to the target. Use the knowledge gained to design your rover to locate a hidden target. Since the signal will be weak compared to the noise, you will need a method, digital or analogue, of isolating the frequency of interest.

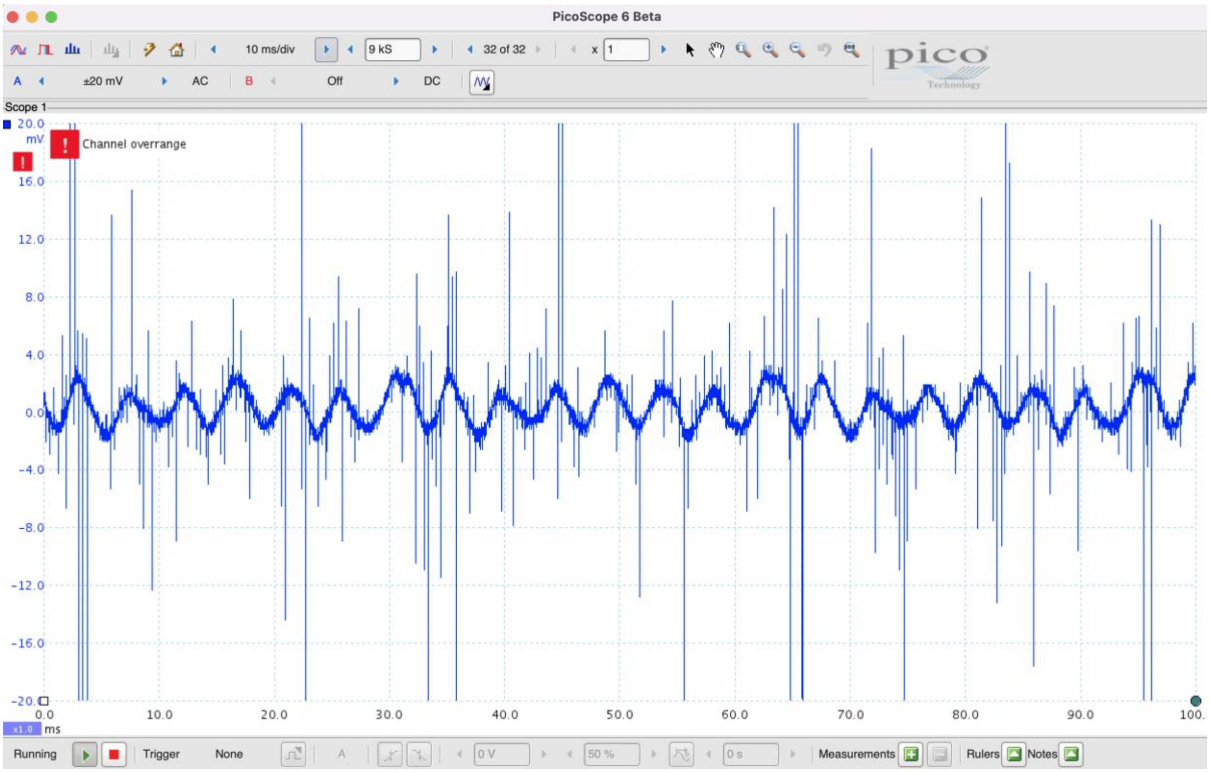

Figure 3 Time-domain signal from a nearby spinning target

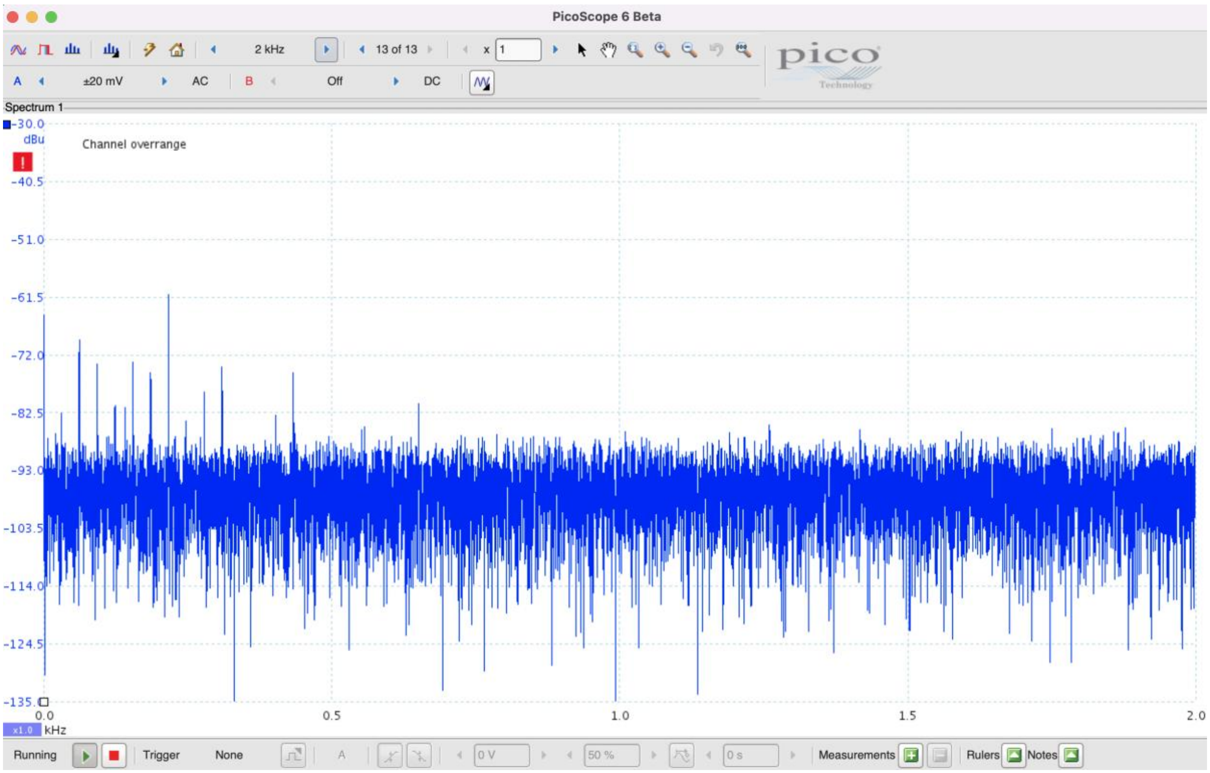

Figure 3 Fourier transform of reflected signal