Short-range UWB radar
Some thoughts on edge position sampling

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1 WARNING

This is not a scientific paper, it is only meant to be used in our discussions of this topic. THERE MIGHT VERY WELL BE MAJOR ERRORS HERE.

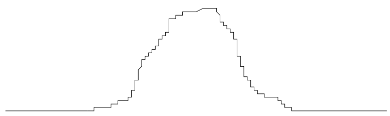
2 Impulse radar

Conventional radar systems send bursts of sine waves to probe its targets. However, a much simpler approach is to simply use impulses to probe the target. This allows for simpler systems, as they almost only have to detect the received voltage at the antenna at certain point in time in order to detect the strength of the reflection at a certain distance from the radar system. Disadvantages are frequency regulations limiting the allowed transmitted power and no channelization in its simplest form.

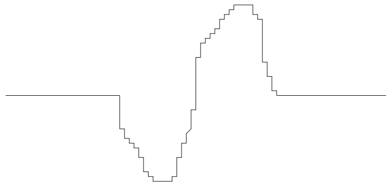
2.1 Signals

The signals in use in ultra wideband impulse radio (UWB-IR), are the gaussian pulse, see figure 1, and its derivatives, the first of which is the monocycle, see figure 2. After that, the derivatives toggle between shapes that look like these two.

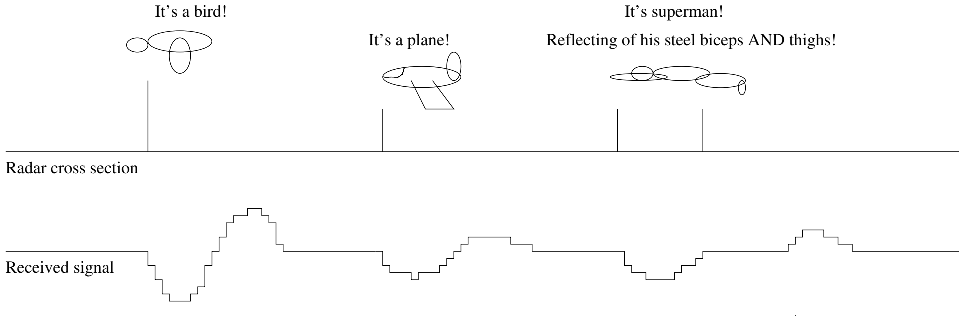
The returned radar signal, looking something like what's seen in figure 3, is a convolution of the impulse and the radar cross sections as a function of time along the signal path. Do retrieve the radar cross sections again, we simply need to do a deconvolution of the received signal. For simple targets or simple demands on the radar system, however, it would suffice to look at the zero crossings. This works well if you're measuring the distance to a frying pan pointing right at you, but for medical imaging purposes the reflections are probably so complex that you will lose a lot of information in the process.



Figur 1: Gaussian pulse



Figur 2: Monocycle pulse



Figur 3: Radar return

2.2 Sampling

Since we want to extract as much information as possible from our return signal, the ideal approach would be to sample the entire signal at a sufficiently high sampling rate. This would, however, require one of these:

- Extreme sampling rate. Pulses are about 100ps long, and we need to at least twice per pulse, so we're looking at sampling rates of 20GHz or more.
- Massive parallell sampling hardware. Allowing each sampling unit to run at a lower speed at the cost of greater die size.
- Range-gating

  $$McEwans - MicropowerImpulseRadar)$$

  . Making one sample per transmitted pulse, and varying the time of sampling from pulse to pulse. This is a huge waste of power and time, as we're constantly discarding like 99% of our signal!

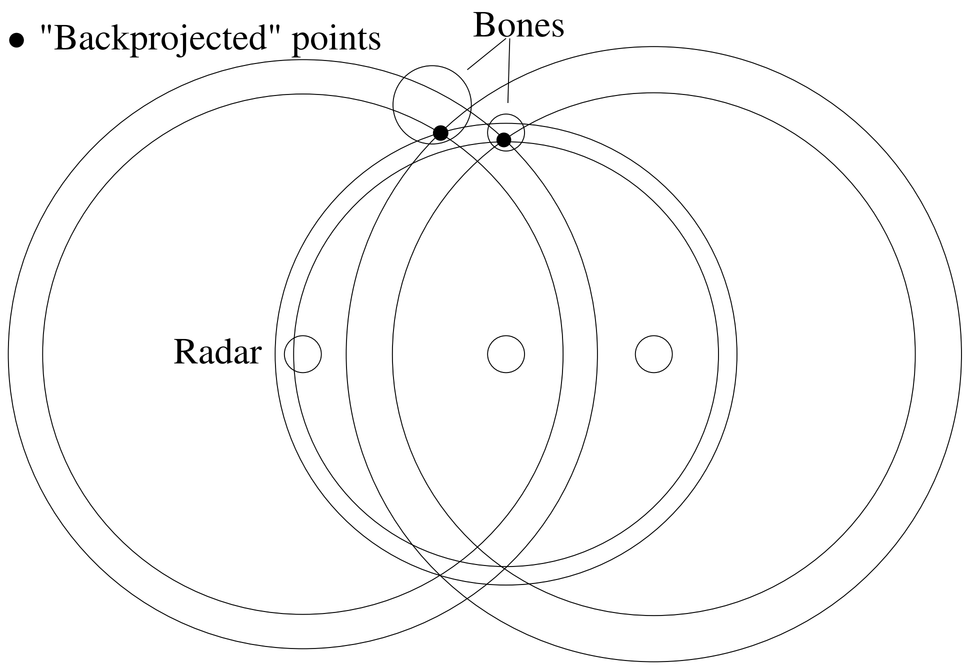
2.3 Edge position sampling

Since an ideal solution proves so costly, let's reconsider the idea of detecting the zero crossings. By measuring the time at which the zero crossing occurs, rather than probing the return signal at predetermined points in time, we achieve much greater time resolution in the information about the zero crossings than we would with conventional sampling. And after all, this is really the key value one wants from a radar system. By using interpolation, however, we could probably measure the zero crossings after conventional sampling, although that would require a high sampling frequency, guaranteeing at least two samples per slope.

Voltage sampling	Time sampling
Handles complex signals	Best for few, important zero-crossings
Requires a lot of data to calculate zero crossings	Compact information about zero crossings

3 Usage

As mentioned earlier, the edge zero crossing works well for measuring a frying pan, but in the real world, in a medical application, two problems arise. The first is noise. Noise will make the zero crossing jump back and forth for each probe. This should be easily fixed, though, by averaging the time of zero crossing. The second problem i multiple reflections. In medical use, there will be all kinds of tissue, cartlidge and bone to make complex reflection patterns. As seen in the third target in figure 3, the zero crossings might not have an exact meaning any more when multiple reflections combine.



Figur 4: “Backprojection”

In order to use this to create an image, we have to probe the patient from different angle. Each of these radar reflections then say something about the properties of the image. The digital signal processing required to do this is probably quite heavy, but if one is only interested in strong reflections (maybe bone gives that?), it might just be that the processing will be significantly simplified. This, of course, at the expense of detailed view. See figure 4.

4 Practical considerations

Actually how sampling of time should be done, is still unclear as of this writing. If there was only one strong reflection, it would probably be easy to measure this one. However, there will be many, and all must be measured. But in order to do averaging of the time, one has to “lock” on the edges, and not get confused if an extra edge suddenly appears in the middle of a train of edges. Or, of course, maybe the unlisted option, which is something really smart :) Sampling the time itself is probably not as hard as it sounds. A capacitor charging or discharging will provide a voltage which is related to time. To sample this should be known technology.

5 Extending

The concept could be extended to allow for variation of the threshold at which a crossing is detected. This way, one could build up several crossing-layers, and maybe use that to extract valuable information which we have thrown away earlier. A point to be aware of here, though, is that in doing this, we mix time and amplitude. A 100mV signal will cross the 20mV line earlier than a 50mV signal, even though they were reflected off objects at the same distance from the radar.