LULEÅ UNIVERSITY OF TECHNOLOGY
V. Barabash, A. Enmark / 2016

F7003R Optics and Radar Based Observations, 7.5 ECTS

Problems Part 4 (4 points)
Pulse modulation techniques and observations of the atmosphere

1 (3 points, A. Enmark)
Pulse coding techniques can be compared by studying the **auto correlation** and **ambiguity functions**. These are tools used in the quest for the best coding technique for a given application.

In this assignment you shall use these tools to discuss and compare the properties of some common pulse coding techniques used for matched filter applications. You shall study and compare the properties of long pulses, short pulses, phase coding with Barker code, complementary code and PRN code (if you have time you can also study combined Barker) and frequency coding with LFM.

For some of the codes closed expressions for the ambiguity function is fairly easy to determine, but for others it is more convenient to use a numerical program to vizulize the function an for code comparison. You will find MATLAB programs (**ambig2015.m** etc) on Canvas. The programs help you to calculate the ambiguity diagram and to make some different type of plots. But you may of course make your own type of plots using the variables calculated in the script:

```
% NOTE: Script clears all variables in workspace. Save on file after
%    each run
%
% Available relevant binary code variables after script:
%   rxx   - autocorrelation function
%   a     - ambiguity function
%   delay – normalized delay axis
%   freq  - normalized freqency axis
%   U     - code (for complementary code magnitude,
%                              both pulses are included in U]
%   P     - code phase for complementary code
```

The program ambig2016.m is based on code presented in Appendix 3A of the book: N. Levanon & E. Mozeson, *Radar Signals*, John Wiley & Sons, Inc., Hoboken, New Jersey (2004).

Your report shall include answers to the questions given below:

1) The three axes of the ambiguity diagram plotted by the assignment program for are normalized. How are they normalized? What would be the labeling and units of the axes if they were not normalized but based on the signal in a real radar system?

2) You can get the amplitude normalized auto-correlation function from the ambiguity diagram. How?

In the questions 7 - 11 below you shall compare the properties of radar systems with different types of pulse compression (or no compression). You shall compare

a) range resolution
b) frequency resolution
c) Doppler tolerance
d) ambiguities

3) What do the properties a) - d) mean?
4) Detectability cannot be determined from only studying the normalized ambiguity function used in this assignment. What determines the detectability?
5) Explain ***in general*** what is the properties of the ambiguity function , and why you consider the ambiguity function character to be like this, for codes with (relative to other):
   - High range resolution
   - High frequency resolution
   - High Doppler tolerance
6) How do possible ambiguities show up in the diagram?

*In questions 7-11: For each of the four properties a) – d) you **shall** back up your answers by relating the differences between the coding techniques to the differences in **the appearance of the auto-correlation function** and/or other parts of **the ambiguity function**. Mark the relevant features in the plots to clarify the answers. You shall **not** just include a plot without commenting on the special feature of interest, i.e. try to answer the question on what the diagram really tell you about the code. Do not cite directly from a reference without referring to the appearance of the ambiguity function or other plots in your figures*

7) Compare the properties of two radar systems with same pulse amplitude but **different pulse widths** (one pulse no coding).
8) Compare the properties of the radar systems with the same pulse width and pulse amplitude, when using **Barker** coding and **no coding**.
9) Compare the properties of the radar systems with the same pulse width and pulse amplitude, when using **Barker** coding and **complementary** coding. **IMPORTANT NOTE** the different scaling in the two diagrams! See lecturing notes for explanation regarding complementary code diagram.
10) Compare the properties of the radar systems with the same pulse width and pulse amplitude, when using **PRN** coding and **no coding**.
11) Compare the properties of the radar systems with the same pulse width and pulse amplitude, when using **LFM** coding and **no coding**.

Optional:
Study the properties of combined Barker.

2 (1 point V. Barabash)
Pulse coding is a signal-processing technique which allows the effective height resolution to be reduced while retaining the echo-strength of a longer pulse.

Folder “Codes”. ASCII files TXT_date_test3, TXT_date_test4 and TXT_date_test5 contain radar data with Barker coding, complementary coding and uncoded data, respectively. Each test has been run for 1 min. They were shifted by each other every minute:
Test 3 – 1 min
Test 4 – 1 min
Test 5 – 1 min
Test 3 – 1 min
….
Data format in the TXT-files:
- UT
- Altitude
- Signal amplitude (linear)
- Signal-to-noise ratio (SNR), dB
- Zonal wind, m/s
- Meridional wind, m/s
- Vertical wind, m/s

1. Make plots of signal-to noise ratio (SNR) as a function of universal time (UT) and altitude for each dataset. Use Matlab commands “pcolor”, “shading flat”, “colormap jet”. Matlab codes should be enclosed.
2. Analyse and discuss shortly the quality of the obtained datasets in terms of their usefulness for scientific observations.
3. Choose the best in your opinion dataset and estimate values and directions of the horizontal winds. What can be concluded about the dynamical state of the atmosphere?

Please note that using “copy-paste” techniques will result in report rejection. Plagiarism will be reported to LTUs lawyer according to the Swedish national legislation.