Spectrum Occupancy Detection for Cognitive Radios Using Wavelet Transform Analysis

Duminda Thilakawardana & Klaus Moessner

University of Surrey
UK

CCSR | Mobile Communications Research Group

Overview

- Introduction.
- Spectrum hole detection.
- Wavelet transform technique.
- Edge detection using wavelet transform techniques.
- Test apparatus setup.
- Methodology.
- Experimental results.
- Conclusions.

Introduction

- Cognitive Radios (CR) extend the functionalities of Software Radios to adapt intelligently to achieve reliable communications.
- They efficiently use unoccupied licensed frequencies.
- Recent surveys indicated that less than 2% of the spectrum is used in the USA at a given time.
- Spectrum usage of the licensed frequencies below 3MHz shows enormous variations.
- This variation provides CR terminals to opportunistically use such bands to combat apparent spectrum scarcity problem.

Spectrum hole detection

- Generally, spectrum hole detection is done by sensing and analyzing transmitted signals.

- Current spectrum sensing techniques includes:
  - Fast Fourier Transform (FFT).
  - Energy Detection.
  - Cyclostationary Feature Detection.

- The most popular technique is FFT, however it is more suitable for stationary signals.

- From the CR point of view, spectrum holes must be detected within **a short period of time.**

Why wavelet technique?

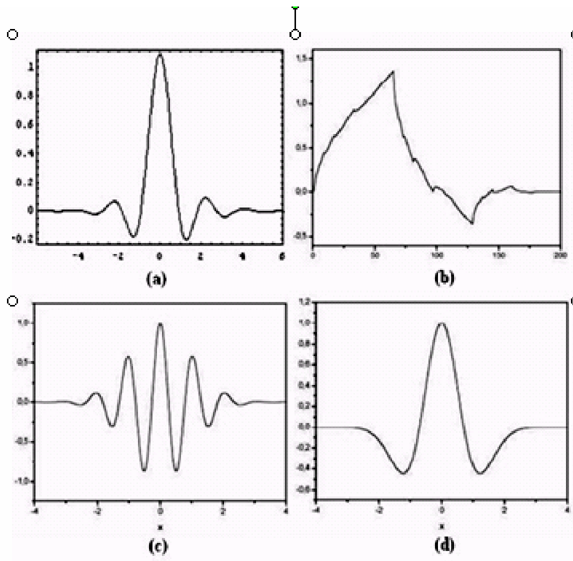
- Signals at the cognitive terminals are non-stationary, and they show different characteristics in time and space domain.
- To analyse such signals, both time and frequency information is needed simultaneously.
- Wavelet approach provides a low cost solution for detecting signals in time and frequency domain.
- Wavelet technique does not require a great deal of computation and therefore, data can be processed and analysed rapidly.

UNIVERSITY OF SURREY

Wavelet transform (1/2)

- Wavelet analysis uses a small wave like function known as a **Wavelet** with finite energy.
- The original wavelet function is known as a **mother wavelet**, and it is used to generate all the basis functions.
- Commonly used wavelets are:

  (a) Coiflet wavelet
  (b) Daubechies Wavelet
  (c) Morlet Wavelet
  (d) Mexican hat Wavelet



UNIVERSITY OF SURREY

Mobile Communications Research Group

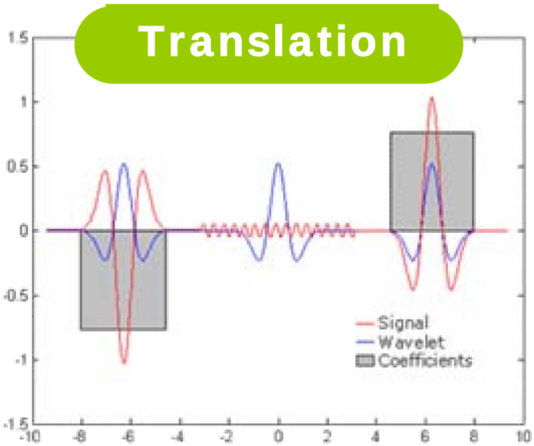
Wavelet transform (2/2)

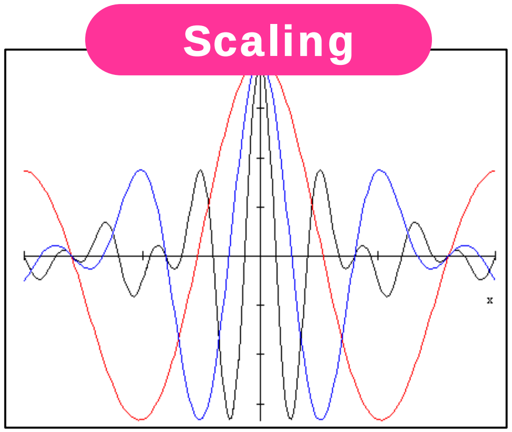
- Wavelets can be manipulated in two ways:

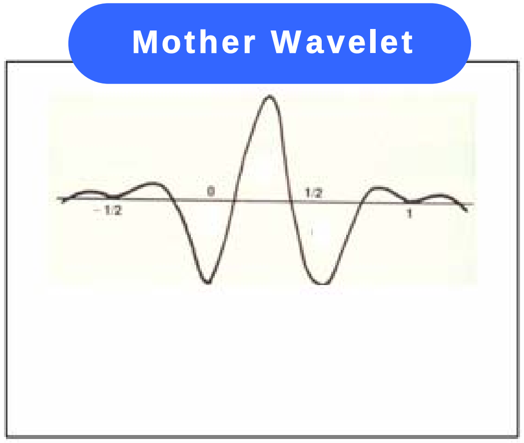
  (a) It can be moved along the frequency axis to various locations – **Translation.**

  (b) It can be stretched or squeezed - **Scaling**

- Wavelet transform is computed at various locations of the signal and for various scaling factors to fill the transform plane.

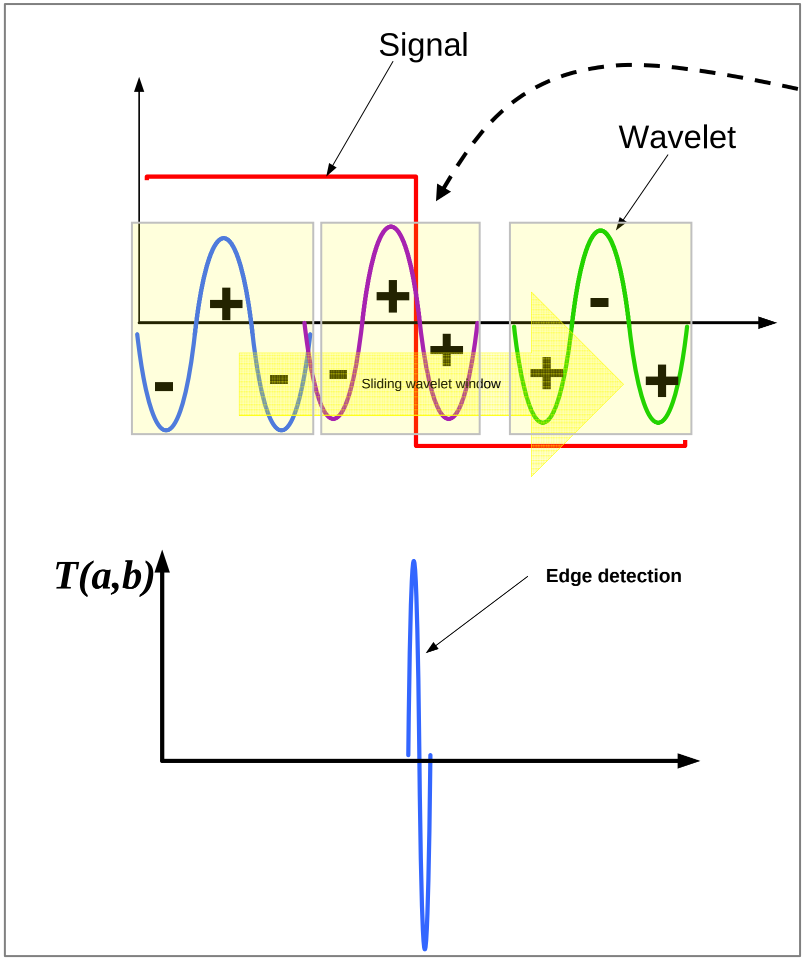






UNIVERSITY OF SURREY

Edge detection



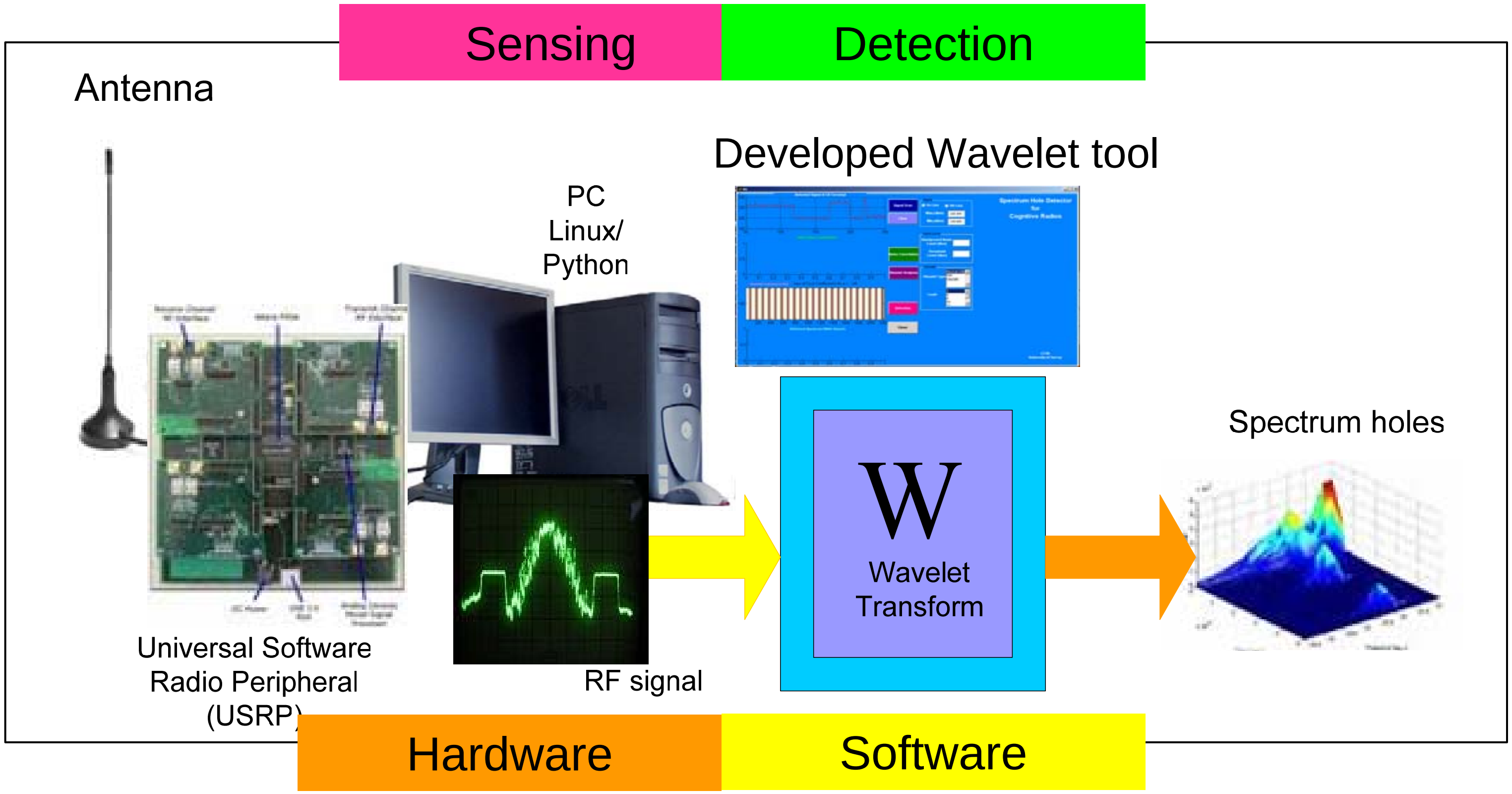
discontinuity

- The contribution to the transform integral ***T(a,b)*=sum of area under the wavelet**

a = translation

b= scaling factor

Test apparatus setup



Methodology

- Entire wide band can be represented as a train of continuous frequency sub bands.

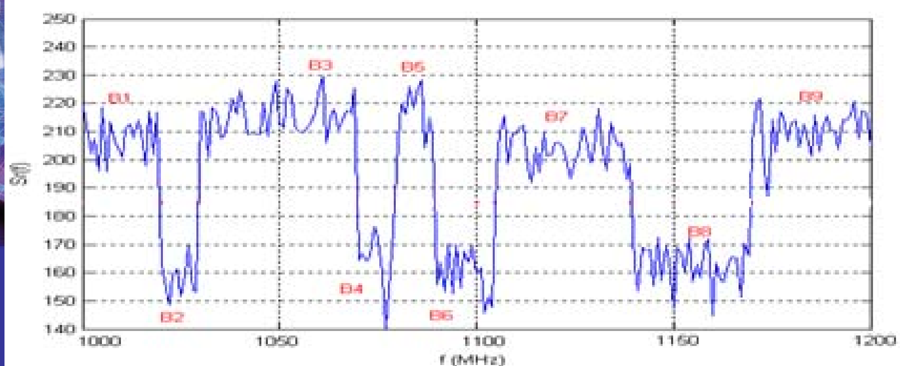
- PSD of the observed signal at the receiver $S_y(f)$ of each i^{th} sub band is represented as follows, where $S_w(f)$ is the PSD of the additive noise component , α_i^2 is the signal power density of the i^{th} spectrum sub band.

$$S_y(f) = \sum_{i=1}^{N} \alpha_i^2 S_i(f) + S_w(f)$$

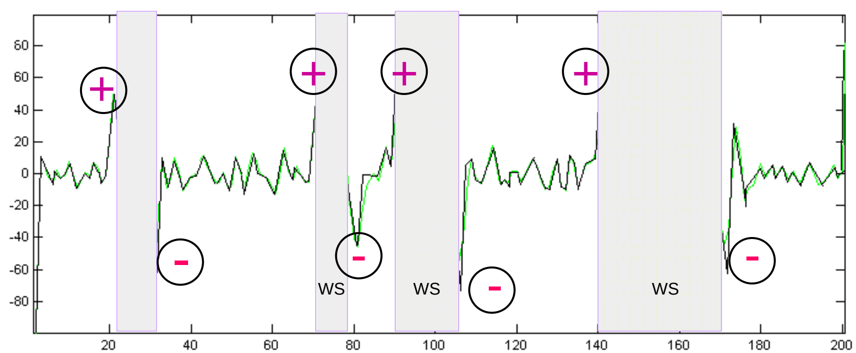
  – *Where Power levels of each sub band can be calculated using a simple estimator method as specified in the literature*

- Use of CWT (Continuous Wavelet Transform) to recognize the edges of each sub band.

Experimental results 1



(a)



(b)

Wide band of interest is 200MHz

The range [1000, 1200]MHz

The Noise floor of the PSD is 150

Total no. of bands (*N*) = 9

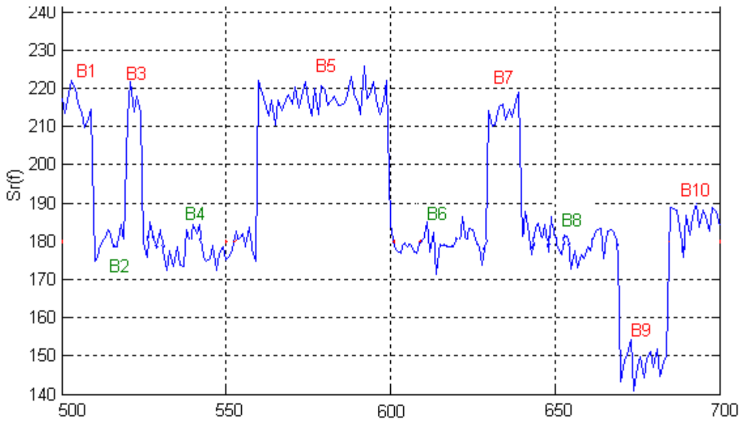
Harr mother wavelet

Scale factor 2^4

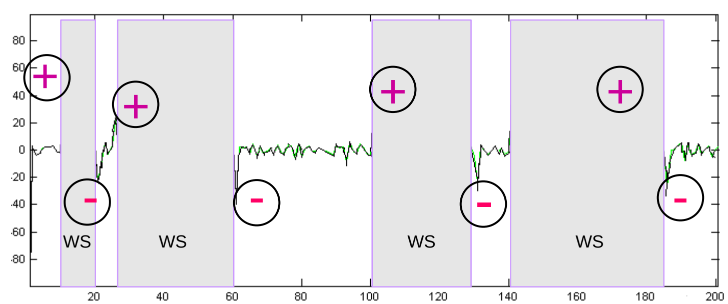
(+) → (-) **Spectrum white space**

(-) → (+) **Signal**

Experimental results 2

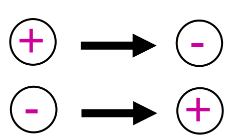


(a)



WS = White Space

(b)



Spectrum white space

Signal

Wide band of interest is 200MHz

The range [500, 700]MHz

The Noise floor of the PSD is 180

Total no. of bands (*N*) = 9

Mexican hat mother wavelet

Scale factor 2^4

Conclusions

- Wavelet edge detection is a reliable candidate for sub band detection.
- Signal irregularities in PSD (rising and falling edges of signals) can be detected using wavelet analysis.
- Harr and Mexican hat wavelet families were useful for the transform plots.
- Harr wavelet is more suitable than Mexican hat.
- Currently, the developed tool only supports signals generated off-line.
- Extending the model to handle real, online signals has been initiated.