A WIDEBAND SPECTREM SENSING METHOD FOR COGNITIVE RADIO USING SUB-NYQUIST SAMPLING

By

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ABSTRACT

Spectrem sensing can be the elemantary element in the psychological feature radio. The band spectrem sensing structure is confered as such that it utilizes the subNyquist sampling scheme to bring subsstantial saving in terms of rate. Compresed Sensing (CS) approach permit sampling of signals below standard Nyqust rate, if signal square measure distributed in some of the basis. With event of wireless communications, demand for the Signal Analyzers with a higher characteristics conjointly will increase. We tend to propose the multicoset emulation as way to scale back the reconstruction quality for the (SingleChannel inhomogeneous Sampler) SNS acquisition. reckoning on acquistion state of affairs, the multicoset emulation might retain, improve or degrades reconstruction quality. However, for all the situations, this emulation reduce reconstruction quality by the minimum of associate order of magnitude

CERTIFICATE OF CORRECTNESS AND APPROVAL

This is to officialy state that thesis work contained in this report *"A WIDEBAND SPECTREM SENSING METHOD FOR COGNITIVE RADIO USING SUBNYQUIST SAMPLING"* is carried out by Bisma Javed, Hira Bint-e-Asim and Moeez Ahmed under my supervision and that in my judgment, it is fully ample, in scope and excellence, for the degree of Bachelors of Electrical (Telecom) Engineering from National University of Sciences and Technology (NUST), Islamabad.

Approved By:

Signature:________________

Supervisor: Lt Col Faisal Akram

MCS, Rawalpindi

DECLARATION

work in this thesis or any of its portion written in thesis has not been submited for provsion of another award or any qualification, either at this institutiton or elsewhere.

Dedicated to...

All the assiduous and hardworking people

All who portray sheer devotion and perseverance

All who remain resilient in the face of adversity

All who spread light in moments of darkness

Dedicated to all who...

Never Give Up

ACKNOWLEDGMENTS

Thanks to Allah Almighty, The Most Beneficent, The Most Merciful.

We are grateful to our parents who supported us in times of need.

Thanks to the faculty and staff of MCS who guided us in our work and to our supervisor, Lt Col Faisal who gave us reasons to count our blessings every single day.

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CHAPTER 1

Introduction

1 Introduction

1.1 Overview

1.1.1 Spectrem Sensing

Spectrem sensing is important function which is used in cognetive radios to detect the spectrem which is not utilized by the primary users and improve the overall spectrem efficiency.

1.1.2 Cognetive Radio

A cognetive radio is a radio that efficiently changes its transmitter parameters based on spectrem sensing in an environment in which it operate. In other words cognetive radio is a smart radio that can sense its environment electromagnetically and then utilize the available wireless spectrem around it, by dynamicaly changing it operating parameters.The wireles spectrem is balanced out by this technology. This in turn allow more user with wireles technologies. This is done by using nonutilized band of wireles spectrem.

Cognetive radio has some vital areas of appllication in todays world still as wanting into long run. a numbers of immediate application area unitas are TV white areas, militery use, and emergency response and public safety. Efective comunication is imperative for consecutive generation war fighter. Militery forces should be able to comunicate with multiple units that always need the utillization of many diferent radios with varied operativse parameters to speak. A software definned radio exploitation psychollogical feature radios technology will consolidate there comunications wants into one moveable radio.

Future psychollogical feature radios ought to be capable of scaning a wideband of frequencies, within order of few rate. In the wideband regime, the radio front-end will use a bank of bandpass filters to pick out band so exploit existing techniques for every narrowband, however this methodology require the oversized variety of RF parts.

1.1.3 Analog-to-Digital Converters

Signal within this real world have associate analogue nature, that means that theyre delineate as a continous operate of your time, space etc. However, most of trendy telecomunication and procedure platforms area unit digital. Therefore, analogue signal need to be reborn into a digital type before process. This method is named associate Analog-toDigital (AD) conversion. a accurate conversion implie that any analogue signal incorporate an unique digital ilustration and so is properly reconstructed. the foremost common way of the digital ilustration of analogue signal could be a time discretization followed by a quantisation [11]. The operation is completed by a tool referred to as digitiser (ADC).

1.2 Problem Statement

Since the Nineteen Thirty, many AD approach are developed. The evolution of these approach is ilustrated in Fig. 1-1. The clasical sampling corespond to uniform sampling at an rate which is beyond double the very best frequency component in a exceed signals. This rate is termed as a sampling rate (NR). In telecomunication application, RF signals ar principaly multiband instead of baseband. Multiband signal will after all be sampled at NR. However, in somme cases it is redundant. NR sampling will be too expensive for wideband signal. during this case, subNyqust bandpass sampling can be used.

Part's name	Sampling rate GSPS	Full Power BW, GHz	Resolution, Bits	Power Consumption W	Price USD
ADC12D800RF1	1.6	2.8	13	2.6	2100
ADC12D16001	3.25	2.85	12	3.9	3100
LM976001	5.1	1.35	9	4	3400
AD66412	0.51	0.35	13	0.8	140
AD96832	0.26	1.1	15	0.55	80

Table 1-1: Specification of few state of-the-art high speeds ADCs

In a NR acquisition, signals are filtered with a lowpass antialiasing filter previous to sampling [1]. Though, high speed and a wide input bandwidth ADCs area unit accesible, there area unit obstacles in the direct use of the NR sampling in telecomunication applications:

1. industriall easily accesible ADCs dont cowl the whole vary up to 3GHz.
2. High speeds ADCs offer output knowledges at high rates. This introduce further needs to regulates units.
3. High speeds ADCs have an high price and higher power consumption.

1.3 Approach

The ilustrious NyqustShannon sampling therem [13] state that any signals of finite informations measure B coulld also be reconstruct from samples at uniform interval 1/2B. In [8], Landeu show that an mean interval of 1/2 $\tilde{B}$ is so necesary for reconstructions from any sampling patterns (uniform or not), wherever $\tilde{B}$ is that the Lesbesgue live of the spectrals supports of the signals. In general, $\tilde{B}$ could also be abundants smaller than *;* one could simply constructs examples during which the Landeu. Meshali and Eldarr [11] use compresive senssing concept [10] to recommenda new spectrel support recovery algorithm, moreover on prove that no sampling theme will have worst-case performance higher than the multicoset one.

1.4 Scope

This project has an very vast scope in the field of Telecomunication as it allows the samplling of signal below an conventional sampling rate. The mains applications for comunication systems is for recovering wideband signal at subNyqust rate; most widely used in cognetive radios.

1.5 Objective

The project uses concept of Analogue Comunication Systems, Digital Comunication Systems and Mobile Comunication. We will implement compresed sensing in wideband spectrem sensing in USRP SDR platforms. We are also using GRC GSL toolkit for simulations. So through this project we wish to integrate our theoretical knowledge with practicality to gain further insight and refine our skills in all the fields mentioned above.

CHAPTER 2

Literature Review

2 Design and Development

The analogue recieved signal at the sensing cognetive radio is samples by the multicoset sampler at a samplling rate lower than the Nyqust rate. The samplling reduction ratio is afected by the chanel ocupancy and multicoset samplling parameters. The outputs of the multicoset sampler are partialy shifted using a multirate systems, which contains the interpolation, delaying and down samplings stages.

2.1 Technical Specifications

- **Visual Studio 8**: Used for conversion of MATLAB code in C++, which was further incorporated in GRC blocks
- **USRP 1**: Provides high bandwidth, high dynamic range processing capability. We are using it for transmission and reception of signal via antenna Vert 900
- **Vert 900**: Vertical antena operating on frequency between 824-960 MHz
- **Linux Ubuntu**: Open source operating system providing us GNU interface to work on GNU Radio Companion
- **GNU Radio Companion**: Open source software toolkit that provides signal procesing blocks to implement software defined radios

2.2 Development Stages

1. **MATLAB**: The available code simulation of research paper was executed and comprehended.
2. **Visual Studio**: The MATLAB code was conceptualized and framed in C++ using

various libraries such as *Armadillo*, *complex* and *sigpack* to achieve a running C++ executable file with similar results as MATLAB.

3. **GRC**: Chunks of C++ code (formed in Visual Studio) were converted to blocks in GRC. As built-in GRC blocks are coded in "python" and our blocks were coded in "C++", there was a need to convert our C++ code to python for smooth execution in GRC. Hence Swig[1] was used, which ensured compatibility of our customized blocks with built-in GRC blocks.

---

[1] The Simplified Wrapper and Interface Generator (SWIG) is an open-source software tool used to connect computer programs or libraries written in C or C++ with scripting languages such as Lua, Perl, PHP, Python etc.

2.3 Flowgraph

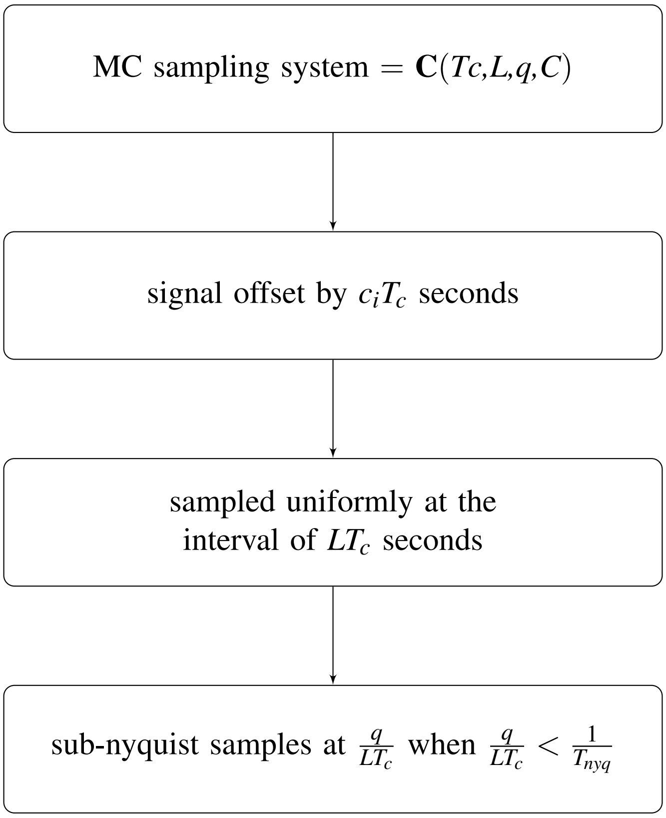


Figure 2-1: Multi Coset Sampling Block Diagram

Where T_c is a "base" samplling interval that is less than or equal to the input signals uniform Nyquelst sampling interval T_{nyq}, $L > 0$ is a integer, q is an number of MC channels, and the set $\mathbf{C}$ contain q distinct integer c_i such that $0 \leq c_i \leq L-1$.

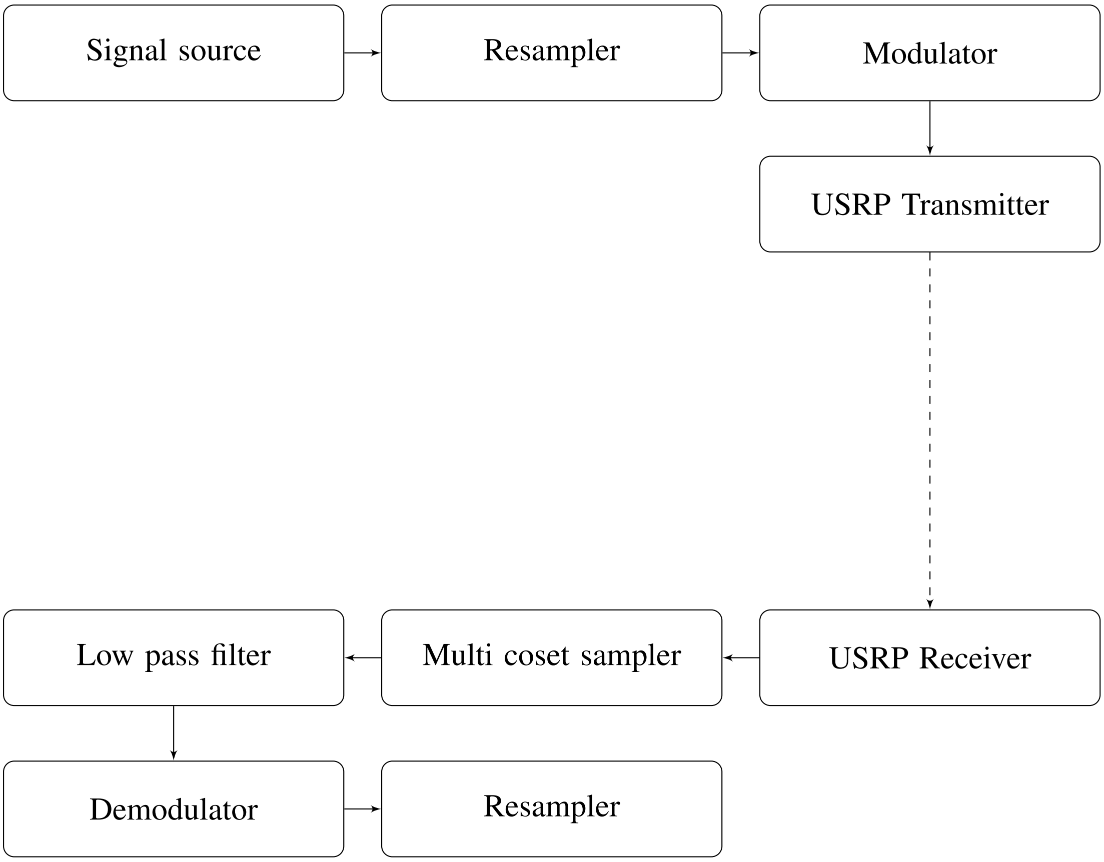


Figure 2-2: Wideband Spectrem Sensing Model

2.4 Algorithm

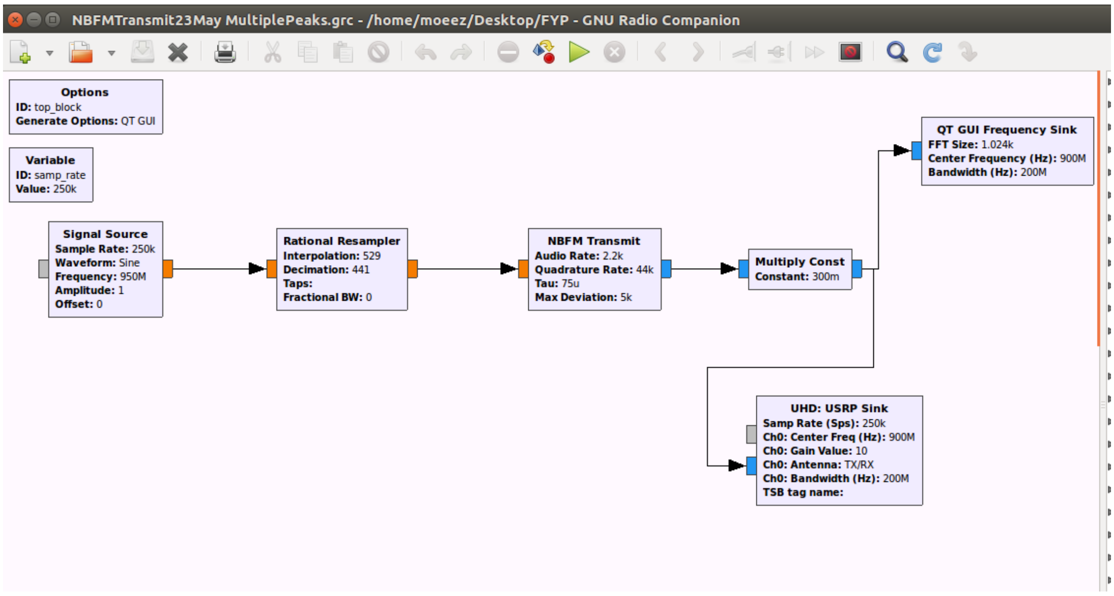
```
procedure WIDEBAND SIGNAL SPECTREM SENSING($F, q, A, P$)
    Input: $\mathbf{x} \in \mathbb{C}^{1\times A}$    ▷ Original signal
    $A$    ▷ Length of signal
    $q$    ▷ Max no. of active channels
    $P$    ▷ No. of data sequences
    $\mathbf{C} \in \mathbb{R}^{1\times P}$    ▷ Sample pattern
    Output: $\mathbf{X_t} \in \mathbb{C}^{1\times A}$    ▷ Reconstructed signal
    $\mathbf{M}(\mathbf{b})(i,k) = Be^{j2\pi c_i b_k/L}$ where $\mathbf{M}(\mathbf{b}) \in \mathbb{C}^{P\times C}$    ▷ Equation for modulation matrix
    $\mathbf{x_c}$ = zeros(P,A)
    for $k = 1 : P$ do    ▷ Multi coset sampler
        for $m$=$\mathbf{C}(\mathbf{k})$+1:A-$\mathbf{C}(\mathbf{k})$ do
            $\mathbf{x_c}(k,m) = \mathbf{x}(m)$
        end for
    end for
    $\mathbf{x}_c$ where $\mathbf{x}_c \in \mathbb{C}^{P\times A}$    ▷ Multi coset samples
    $\mathbf{h} \in \mathbb{C}^{1\times 384}$    ▷ FIR Filter Implementation
    $\mathbf{Y} = \mathbf{x_c} * \mathbf{h}$    ▷ Filter Coset samples
    $\mathbf{R} \leftarrow \mathbf{YY^H}$    ▷ Correlation matrix
    $\mathbf{U} \leftarrow eig\mathbf{R}$    ▷ Eigenvalue decomposition
    $\mathbf{S}$ where $\mathbf{S} \in \mathbb{C}^{1\times q}$    ▷ Spectral support
    $\mathbf{X_t}$    ▷ Reconstructed signal from S
    MSE=$\|x\text{-}x_t\|/\|x\|$    ▷ Mean Squared Error
end procedure
```

CHAPTER 3

Project Analysis and Evaluation

3 Project Analysis and Evaluation

We transmited an Narrow Band FM signal via USRP 1 at diferent central frequencies and recieved transmited signal using multicoset sampling at wider frequency band comprising of 200 MHz (due to USRP antenna constraints). Multicoset sampling block has been incorporated and highlighted by show of an arrow in Fig 4-6.



Options
ID: top_block
Generate Options: QT GUI

Variable
ID: samp_rate
Value: 250k

Signal Source
Sample Rate: 250k
Waveform: Sine
Frequency: 950M
Amplitude: 1
Offset: 0

Rational Resampler
Interpolation: 529
Decimation: 441
Taps:
Fractional BW: 0

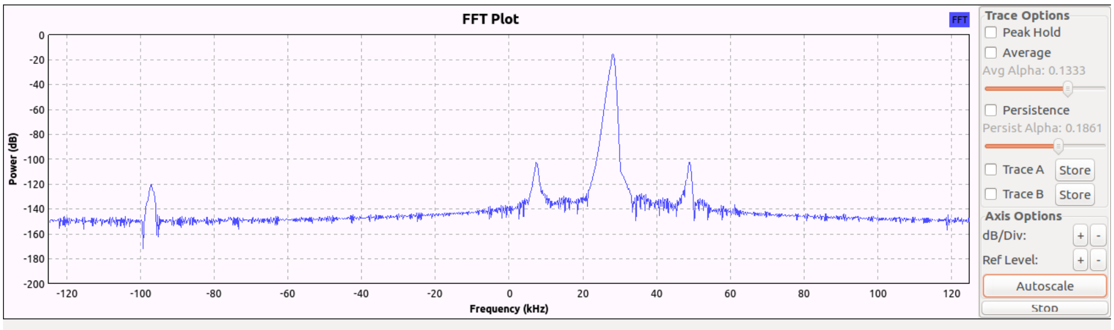
NBFM Transmit
Audio Rate: 2.2k
Quadrature Rate: 44k
Tau: 75u
Max Deviation: 5k

Multiply Const
Constant: 300m

QT GUI Frequency Sink
FFT Size: 1.024k
Center Frequency (Hz): 900M
Bandwidth (Hz): 200M

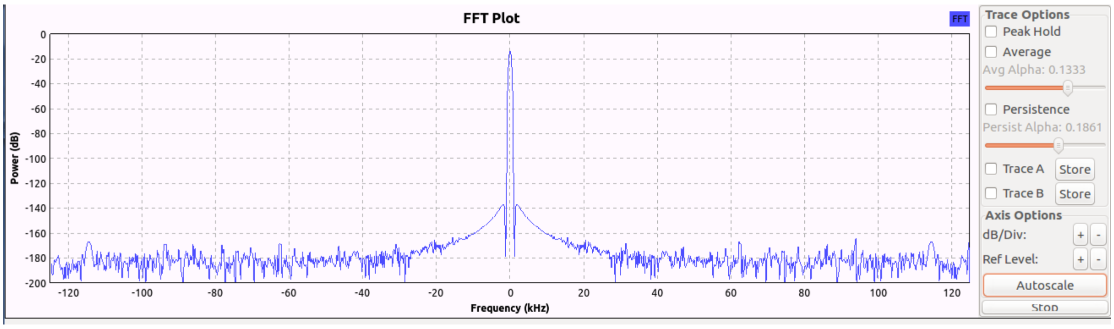
UHD: USRP Sink
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 900M
Ch0: Gain Value: 10
Ch0: Antenna: TX/RX
Ch0: Bandwidth (Hz): 200M
TSB tag name:

Figure 3-1: Transmitter GRC Model



Avg Alpha: 0.1333
Persist Alpha: 0.1861

Figure 3-2: FFT of Transmitted Signal 1



Avg Alpha: 0.1333

Persist Alpha: 0.1861

Figure 3-3: FFT of Transmitted Signal 2

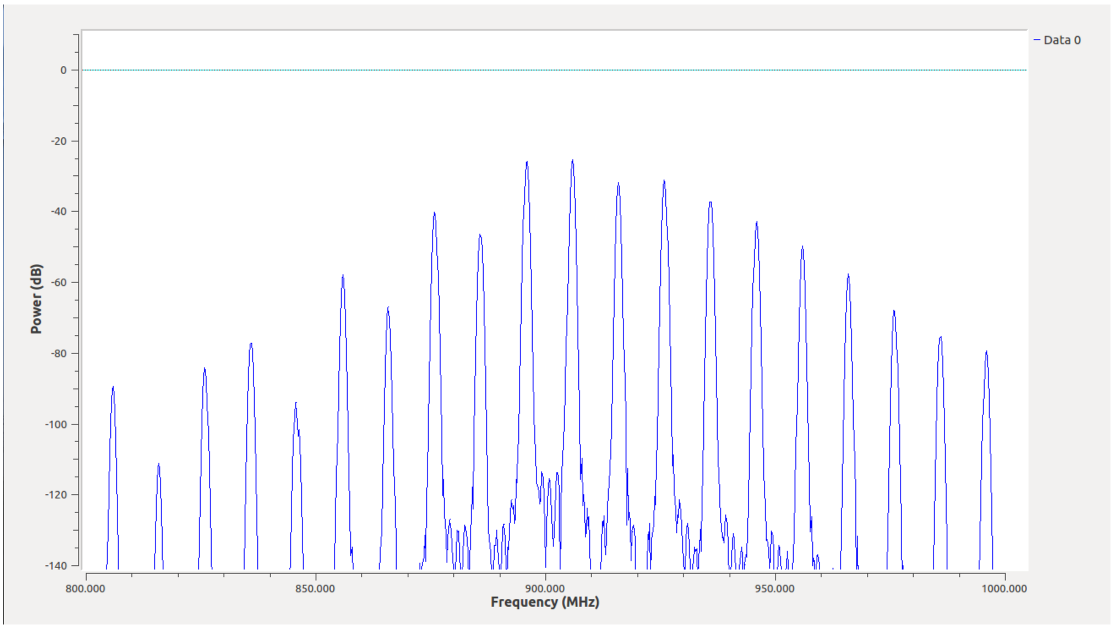
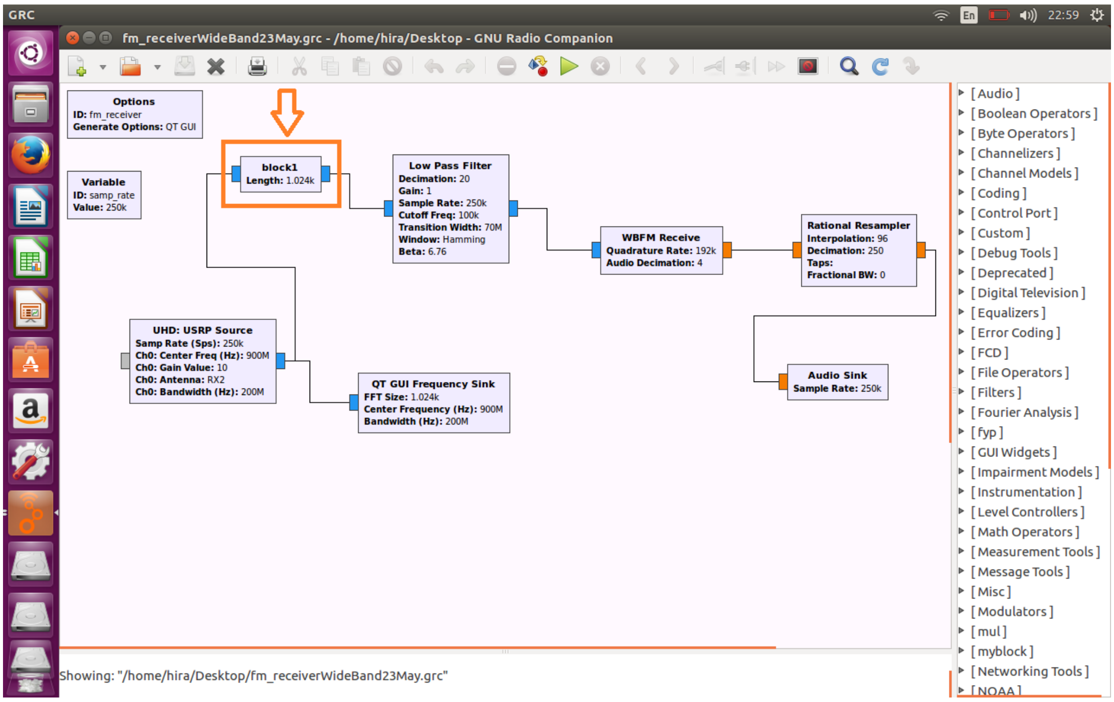


Figure 3-4: FFT of Transmitted Signal 3



fm_receiverWideBand23May.grc - /home/hira/Desktop - GNU Radio Companion

Options
ID: fm_receiver
Generate Options: QT GUI

Variable
ID: samp_rate
Value: 250k

block1
Length: 1.024k

Low Pass Filter
Decimation: 20
Gain: 1
Sample Rate: 250k
Cutoff Freq: 100k
Transition Width: 70M
Window: Hamming
Beta: 6.76

WBFM Receive
Quadrature Rate: 192k
Audio Decimation: 4

Rational Resampler
Interpolation: 96
Decimation: 250
Taps:
Fractional BW: 0

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 900M
Ch0: Gain Value: 10
Ch0: Antenna: RX2
Ch0: Bandwidth (Hz): 200M

QT GUI Frequency Sink
FFT Size: 1.024k
Center Frequency (Hz): 900M
Bandwidth (Hz): 200M

Audio Sink
Sample Rate: 250k

Showing: "/home/hira/Desktop/fm_receiverWideBand23May.grc"

Figure 3-5: Receiver GRC Model

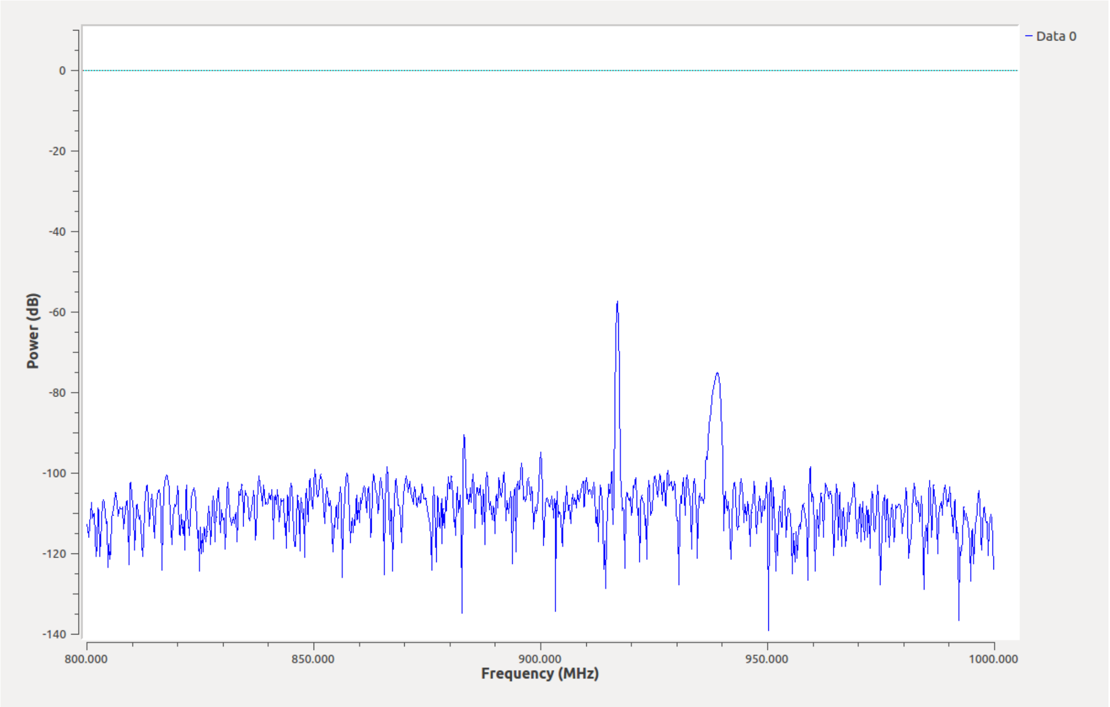


Figure 3-6: FFT of Received Signal 1

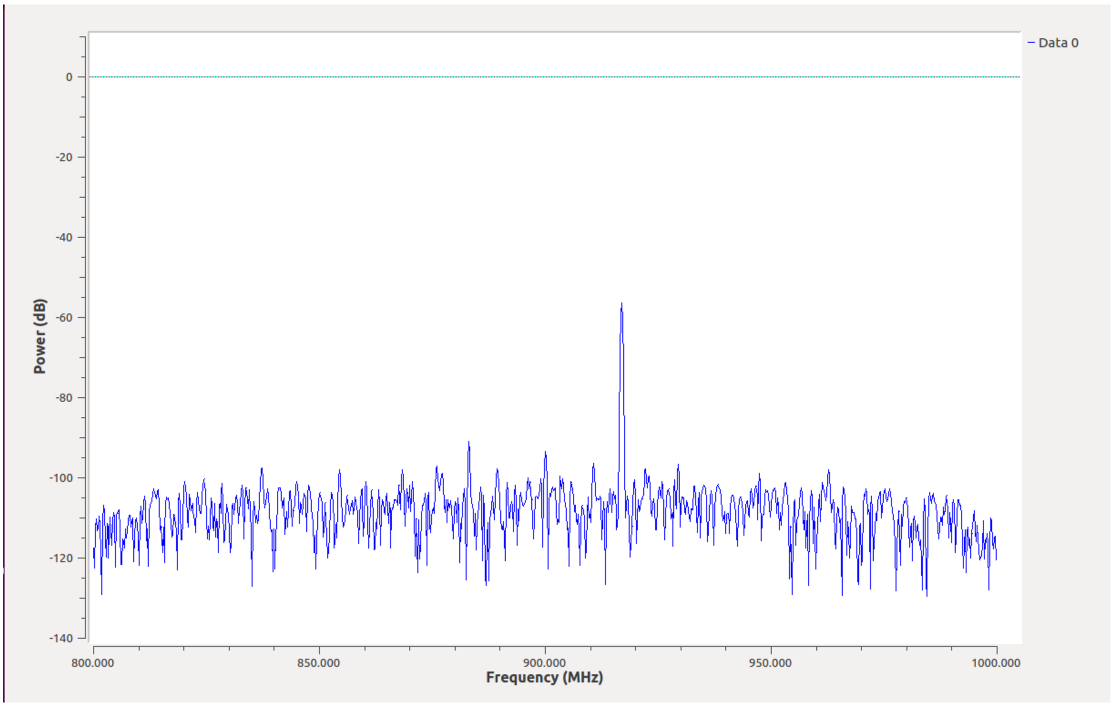


Figure 3-7: FFT of Received Signal 2

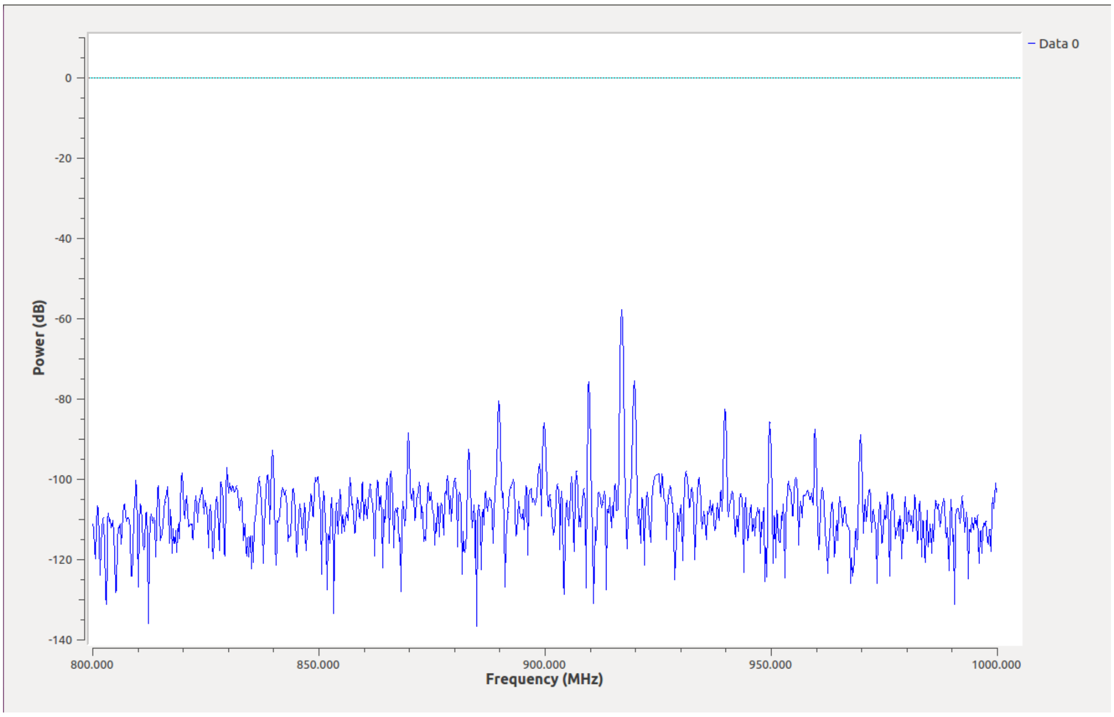


Figure 3-8: FFT of Received Signal 3

Figure 3-9: Hardware Setup

CHAPTER 4

Conclusion and Future Work

4 Conclusion

A method of wideband spectrem sensing for cognetive radio is propose to mitigated the limitation of high sampling rate, high compllexity and noise uncerttainty. The propose techniq utilizes a multicoset samplling scheme that can use arbitrarilly low sampling rate close to the chanel occupancy. With low spectrem utilization asumption, this would bring substtantial saving in terms of the samplling rate.

5 Future Work

The future work can be caried out for further eficient results by using higher frequency bands antenas as we could not sense a wider spectrem due to Vert 900 antena constraints.

Due to the multichannel architecture of an MC sampler, we didnot address issues asociated with nonidentical chanel characteristics such as nonideal ADCs and imperffect clock synchronization resulting in incorrect samplling instant across chanels. However, we believe there exist calibration techniq in the field of time-interleaved ADCs which could possiblly address this issue.

Recieved power of signal may be increased.

6 Bibliography

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SYNOPSIS

Extended Title: A Wideband Spectrem Sensing Method Using SubNyquist Sampling.

Brief Description of The Project / Thesis with Salient Specifications: Spectrem sensing is an crucial operates to find underutillized spectrem authorized to first system and improve the spectrem potencys. An band spectrem sensing model utilizes a subNyquist sampling theme to bring substanttial saving in term of the rate.

Scope of Work : Clasical sampling of broadband signals desire high rate Analogue to Digital Convertor (ADCs) that got to operates at or on top of Nyquist rate, to beat these downside compresed sensing is employed. so as to spot locations of the vacant frequncy band, the compllete broadband is sculptural as train of consecuttive frequency subbands and also the broadband is sampled mis-treatment compresed sensing. Compresed sensing is to beat the matters of high sampling rate.

Academic Objectives:

- Significant aspect of comunication knowledge implement on hardware.
- Working in Linux environment, exploiting Radio Frequency (RF) Antennas and Universal Software Radio Peripheral (USRP).
- Learning Software-defined radio (SDR)

Application / End Goal Objectives:

- Spectrem sensing is use in all sorts of wireles comunication
- Direction of arrivals of signal (the direction from which usually a propagate wave arrives at a point)
- Radio environments monitoring

Previous Work Done on The Subject: Final year projects in MCS have been done on USRP but to the best of our knowledge no work has been done on wideband sensing on SDR using compresed sensing.

Material Resources Required:

- USRP
- Linux
- RF components
- SDR

No of Students Required : 3

Group Members:

Bisma Javed

Hira Binte Asim

Moeez Ahmed

Special Skills Required: Linux

USRP

MATLAB

C++

Python

Approval Status

Supervisor: Lt Col Faisal Akram

Signature:________________

Assigned to:

NC Bisma Javed

NC Hira Binte Asim

PC Moeez Ahmed

HoD Signature:________________

R&D SC Record Status

File No:

Coordinator Signature:________________

MATLAB

```
%% initial parametrs
Fs=20;
T=1/Fs;
LL = 1024;
t = (0:LL-1)*T;
th_norm=20;
NFFT = 2^nextpow2(LL);

fi=[4.8  10.45  15.4];
%fi=[12.5189     16.6941     18.4194];
B=0.9;
F=union(fi-B/2,fi+B/2);
%number of bands
N=length(fi);
ti=[6,13,19]*2;
Ei=[1,1.2,.9,1.3]*4;
Bi=[];
for k=1:2:N*2
Bi=[Bi F(k+1)-F(k)];
end
B=max(Bi);
%% lebesque measurement
lamda=sum(F(2:2:2*N))-sum(F(1:2:2*N));
%Occupancy
omega=lamda/Fs;
%% maximom number of active cells
L=floor(Fs/B);
q_max=N+N*ceil(B*L/Fs);
q_min=ceil(N*B*L/Fs);
```

```
p=q_max+1;
%% support set of signal
S=[];
FF=ceil(F*L*T);
for h=1:2:N*2
S=[S, max(FF(h)):FF(h+1)];
end
S=unique(S)-1;
%% pick a sample pattern with SFS
C=SFS_C(L,p,S+1,Fs);
%% A matrix
k=1:L;
A=1/(L*T)*exp(1i*2*pi*C'*(k-1)/L);
As=A(:,S+1);
%% check for low condition number
while cond(As)> 10
C=pickn(L,p);
k=1:L;
A=1/(L*T)*exp(1i*2*pi*C'*(k-1)/L);
As=A(:,S+1);
end
%% input signal generation
x=zeros(1,LL);
for n=1:N
x=x+sqrt(Ei(n)*Bi(n)) * sinc(Bi(n)*(t-ti(n))).*
  exp(1i*2*pi*fi(n)*t);
end
sigma=1/256;
%%sigma=0.00390625
%w=sigma*(randn(1,LL)+1i*randn(1,LL))/sqrt(2);
```

```
%x=x+w;
%% fft of original signal
Xf=fft(x,NFFT);
%% multi coset sampling
xci=zeros(p,LL);
for k=1:p
for m=C(k)+1:L:LL-C(k)
xci(k,m)=x(m);
end
end
%% fir filter
Ntap=191*2+1;
hr=fircls1(Ntap,1/L,0.02,0.008);
n=0:Ntap;
h=hr.*exp(i*pi*n/L);
xci_h=zeros(p,LL);
%% filter coset samples
d1=(Ntap+1)/2;

for k=1:p
xfilter=conv(xci(k,:),h);
xci_h(k,:)= xfilter(d1+1:end-d1+1)
end
% sigma=1/256;
% w=sigma*(randn(p,LL)+i*randn(p,LL))/sqrt(2);
% xci_h=xci_h+w;
%% R=<x,x>
R= xci_h * xci_h';
%% eigen value decomposition
% find eigenvalues and eigenvectors
```

```
[Us, Gamma]=eig(R);
ev=eig(R);
%% find number of active slots with MDL
q_hat=mdl_function(R,LL);
%q_hat=aic_function(R,LL);
%% find location of active slots
%create Un:matrix eigenvectors correspond to zero eigenvalues
Un=Us(:,1:p-q_hat);
UnA=Un'*A;
for k=1:L
nUnA(k)=norm(A(:,k)'*Un);
%       nUnA(k)=norm(UnA(:,k),2);
end
% find q minimom norm of Un A to find spectral support
pmu=1./nUnA;% element wise right division
[pmus,loc]=sort(pmu);
Sr=loc(end-q_hat+1:end);
Sr=sort(Sr)-1;
q=length(Sr);
%title(['Sr=[',num2str(Sr),']','   q_I_C=',num2str(q_hat)]);
%% save only Sr culumns
As=A(:,Sr+1);
pAs=pinv(As);
K_As=cond(As)
%% reconstruction in time domain
t = (0:NFFT-1)*T;  % Time vector
xt=zeros(1,NFFT);
for n=1:NFFT
for m=1:q
for l=1:p
```

```
xt(n)=xt(n)+pAs(m,l)*xci_h(l,n)*exp(i*2*pi*Sr(m)*(n-1)/L)/T;
end
end
end
%% DFT of reconstructed signal
Xtf=fft(xt,NFFT);
```

C++

```
#include <iostream>
#include <conio.h>
#include <stdio.h>
#include <math.h>
#include <armadillo>
#include <string.h>
#include <complex>
#include <sigpack.h>
#include <array>
#define pi  3.141592653589793238462643383279502884
using namespace std;
using namespace arma;
using namespace sp;
using dcomp = complex<double>;
int main(int argc, char** argv)
{
float Fs = 20;  \\input parameters
float T = 1 / Fs;
float LL = 1024;
cx_mat t(1, 1024);
for (int w = 0; w < 1024; w++)
{
t[w] = w*T;
}
mat C; \\randomly selected sample pattern
C << 0 << 5 << 6 << 8 << 11 << 16 << 17 << endr;
mat CC;
CC = C.t();
double fi[] = { 4.8000, 10.4500, 15.4000 };
```

```
double B = 0.9;
float F[6];
double ti[] = { 12, 26, 38 };
double Ei[] = { 4, 4.8000, 3.6000 };
int N = 3;
int v = 0;
double q_hat = 6;
dcomp i = -1; \\declare complex
i = sqrt(i);
for (int k = 0; k < N; k++)
{
F[v] = fi[k] - B / 2;
v++;
F[v] = fi[k] + B / 2;
v++;
}
float L = floor(Fs / B);
float qmax = ceil(N + (N*(B*L / Fs)));
float qmin = N;
float p = qmax + 1;
float FF[6];
float S[6];
for (int h = 0; h < N * 2; h++)
{
FF[h] = ceil(F[h] * L*T);
S[h] = FF[h] - 1;
}
cx_mat A(7,22); \\modulation matrix


for (int g = 0; g < 7; g++)
```

```
for (int k = 0; k < 22; k++)
{
A(g, k) = 1/(22 * 0.05)*exp(i*(2 * pi * CC(g, 0)*(k) / 22));
}
cx_mat x(1, LL, fill::zeros);
double Bi[] = { 0.9000, 0.9000, 0.9000 };
for (int n = 0; n < N; n++)

\\input signal
x= x+sqrt(Ei[n]*Bi[n])*(sin(pi*(Bi[n]*
(t-ti[n])))/(pi*(Bi[n]*(t-ti[n]))))%exp(i*(2*pi)*fi[n]*t);
double sigma = 0.00390625;
cx_mat w(1, LL);
w = sigma*(randn(1, LL) + i * randn(1, LL)) / sqrt(2);
x = x + w;
cx_mat Xf = fft(x, LL);
cx_mat xci(p, LL, fill::zeros);
for (int k = 0; k < p; k++)
for (int m = C[k]; m < (LL - C[k] - 1); m = m + 22)
xci(k, m) = x(m); \\multi coset samples
```

GRC

```
#ifdef HAVE_CONFIG_H
#include "config.h"
#endif
#include <gnuradio/io_signature.h>
#include "block1_impl.h"
#include <stdio.h>
#include <math.h>
#include <gsl/gsl_matrix.h>
#include <gsl/gsl_vector.h>
#include <iostream>
#include <armadillo>
#include <string.h>
#include <complex>
using namespace std;
using namespace arma;

namespace gr {
namespace fyp {

block1::sptr
block1::make(int length)
{
return gnuradio::get_initial_sptr
(new block1_impl(length));
}
/*
* The private constructor
*/
block1_impl::block1_impl(int length)
```

```
: gr::block("block1",
gr::io_signature::make(1,1, sizeof(cx_float)),
gr::io_signature::make(1,1, sizeof(cx_float))),
my_length(length)
{}
/*
* Our virtual destructor.
*/
block1_impl::~block1_impl()
{
}
void
block1_impl::forecast (int noutput_items, gr_vector_int
 &ninput_items_required)
{
ninput_items_required[0] = noutput_items ;
}
int
block1_impl::general_work (int noutput_items,
gr_vector_int &ninput_items,
gr_vector_const_void_star &input_items,
gr_vector_void_star &output_items)
{
const cx_float *in = (const cx_float* ) input_items[0];
cx_float *out = (cx_float* ) output_items[0];
cx_mat xci(7, 1024, fill::zeros); //multi coset matrix
mat C; //sample pattern
C << 0 << 5 << 6 << 8 << 11 << 16 << 17 << endr;
for (int k = 0; k < 7; k++)
for (int m = C[k]; m < (1024 − C[k] − 1); m =m+22)
```

```
xci(k, m) = in[m];
for(int i=0;i<my_length;i++)
out[i]=xci[i];
consume_each (noutput_items);
// Tell runtime system how many output items we produced.
return my_length;
}
} /* namespace fyp */
} /* namespace gr */
```