Energy Detector Prototype for Spectrum Sensing in Cognitive Radio Systems

Sabita Maharjan, Kimtho Po and Jun-ichi Takada
Graduate School of Science and Engineering
Tokyo Institute of Technology

12th Dec. 2007

Contents

- Background/Motivation
- FCC Attention to the Issue
- Cognitive Radio
- Spectrum Holes
- Energy Detector
- ISDB-T signal
- Experimental Set-up and Parameters
- Results
- Issues and Future work

Background/Motivation

- With emerging new wireless technologies, demand for bandwidth is increasing
- Electromagnetic radio spectrum is limited
- Bandwidth is underutilized in some systems

Balance....?????

Federal Communications Commission (FCC) attention to the Issue

- Current Radio Spectrum Shortage is partially due to low usage of the available spectrum.
- May 2004

  Proposed new rules permitting unlicensed devices to operate in the TV broadcasting band while the spectrum is not being used by the primary user

FCC attention to the Issue

- November 2004

  IEEE 802.22 Working Group proposed IEEE 802.22 Wireless Regional Area Network (WRAN) standard, the first worldwide cognitive radio based standard

Cognitive Radio

- Proposed solution approach: Cognitive Radios

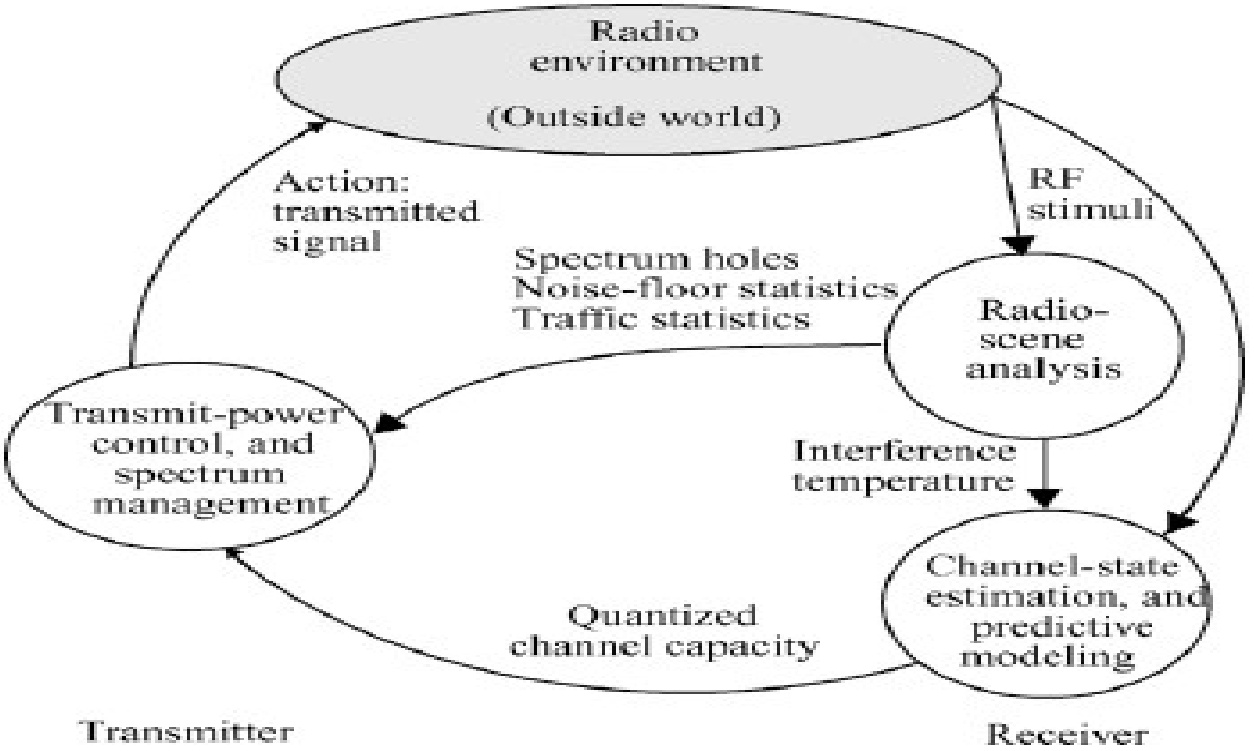
- An intelligent wireless communication system that is aware of its surrounding environment and that uses the methodology of understanding by building to learn from the environment and adapts its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters in real time. [Simon Haykin]

Cognitive Radio

- A Particular Extension of Software Radio that that uses model based reasoning about users, multimedia content and communications context.

- A goal driven framework in which the radio autonomously observes the radio environment, infers contexts, assesses alternatives, generates plans, supervises multimedia services and learns from its mistakes. [Joseph Mitola III]

Cognitive Tasks

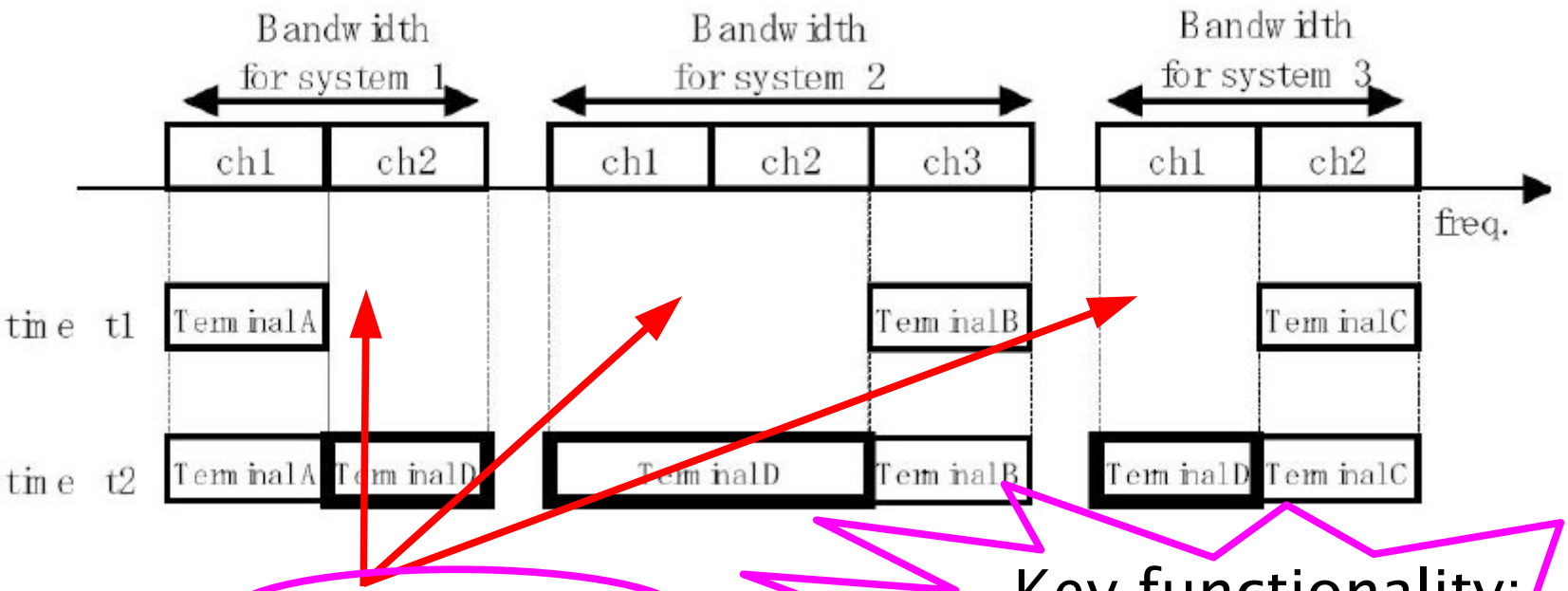


Three Fundamental Cognitive Tasks

(Cognitive Radio: Brain Empowered Wireless Communication Systems -Simon Haykin)

Fundamental Principle of Cognitive Radio System

- Dynamic spectrum sharing



Primary Concept of Cognitive Radio Functionality J. Mitola

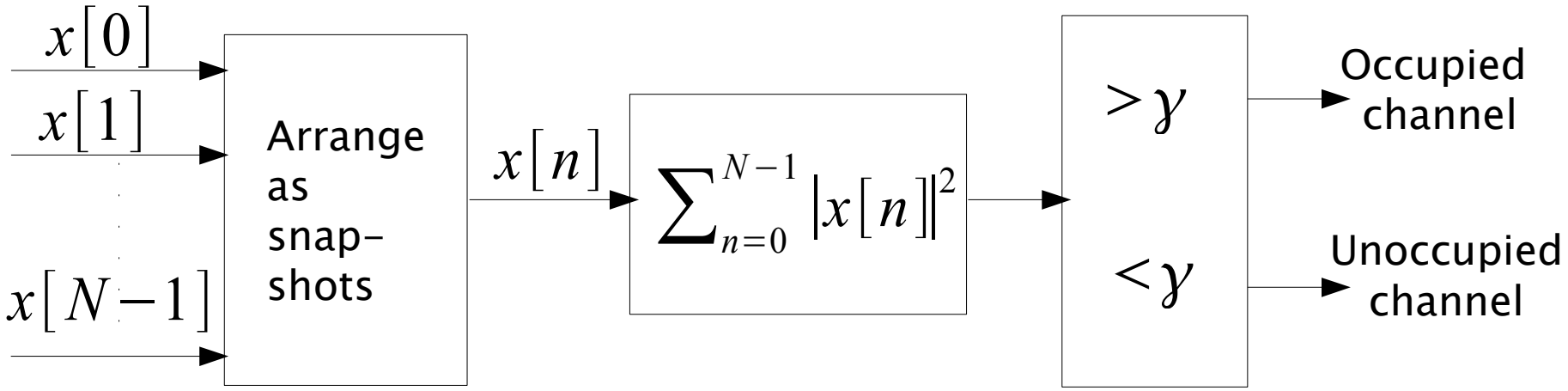
Spectrum Holes

- A band of frequencies that is assigned for a primary user, but at a particular time and at a specific geographical location, not being used by the primary user.

Categories

- Black Spaces: Occupied by high power local interferers often
- Gray Spaces: Partially occupied by Low power Interferers
- White Spaces: Free of RF Interferers except the ambient noise
- Candidates for use by unserviced operators: white spaces (for sure) and gray spaces (to lesser extent)

Energy Detector Concept



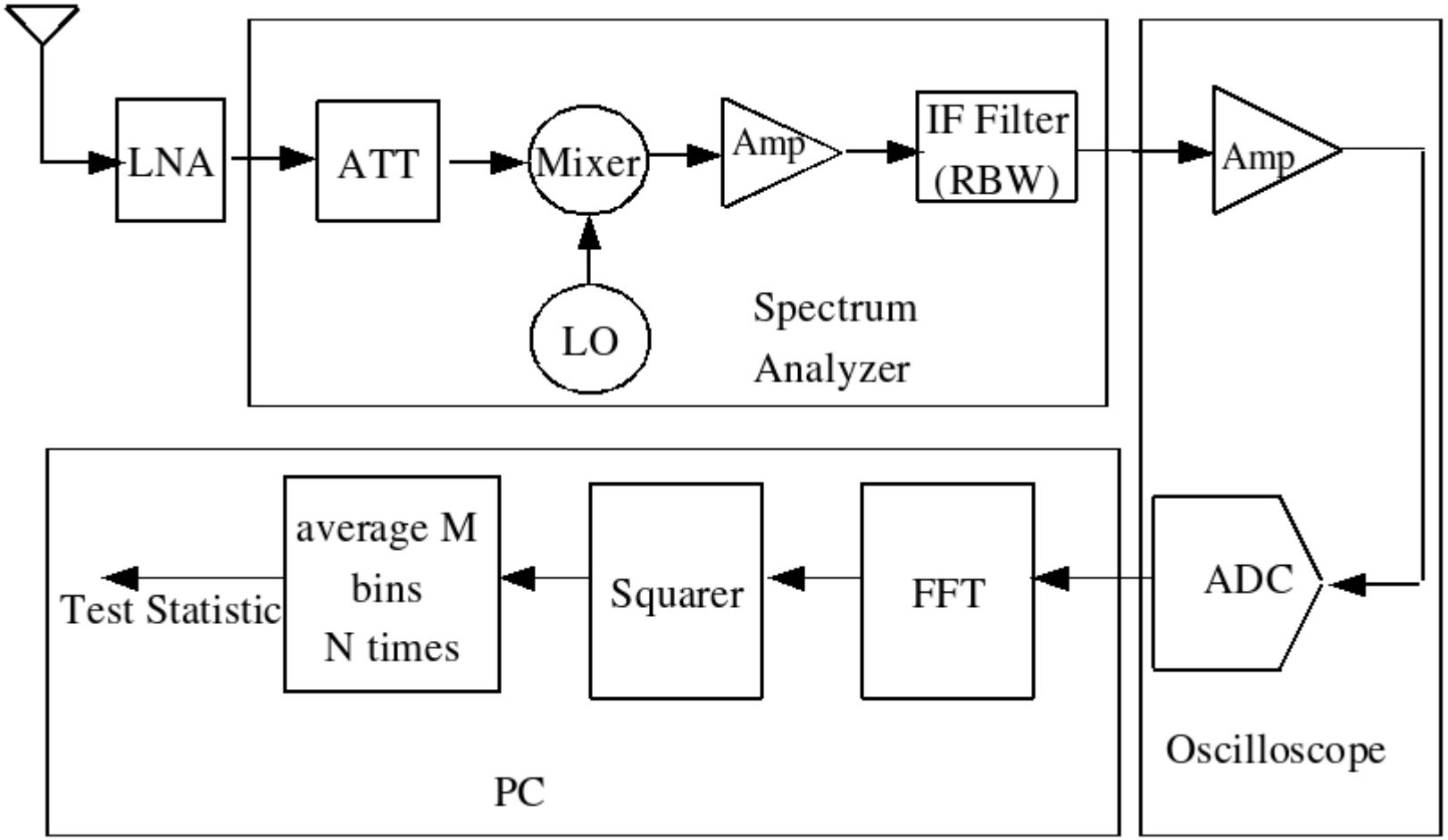
Test of two hypotheses:

$$H_0 : x[n] = w[n]; \text{ signal is absent}$$

$$H_1 : x[n] = s[n] + w[n]; \text{ signal is present}$$

$$n = 1,2,\ldots\ldots\ldots, N = \text{sample index}$$

Detector Prototype for Cognitive Radio Receiver



Energy Detector Prototype for Spectrum sensing

Primary system: ISDB-T

- ISDB-T (Integrated Digital Services Digital Broadcasting – Terrestrial) system was developed by the Association of Radio Industries and Businesses (ARIB) in Japan.

- ISDB is a new type of digital broadcasting intended to provide audio, video, and multimedia services.

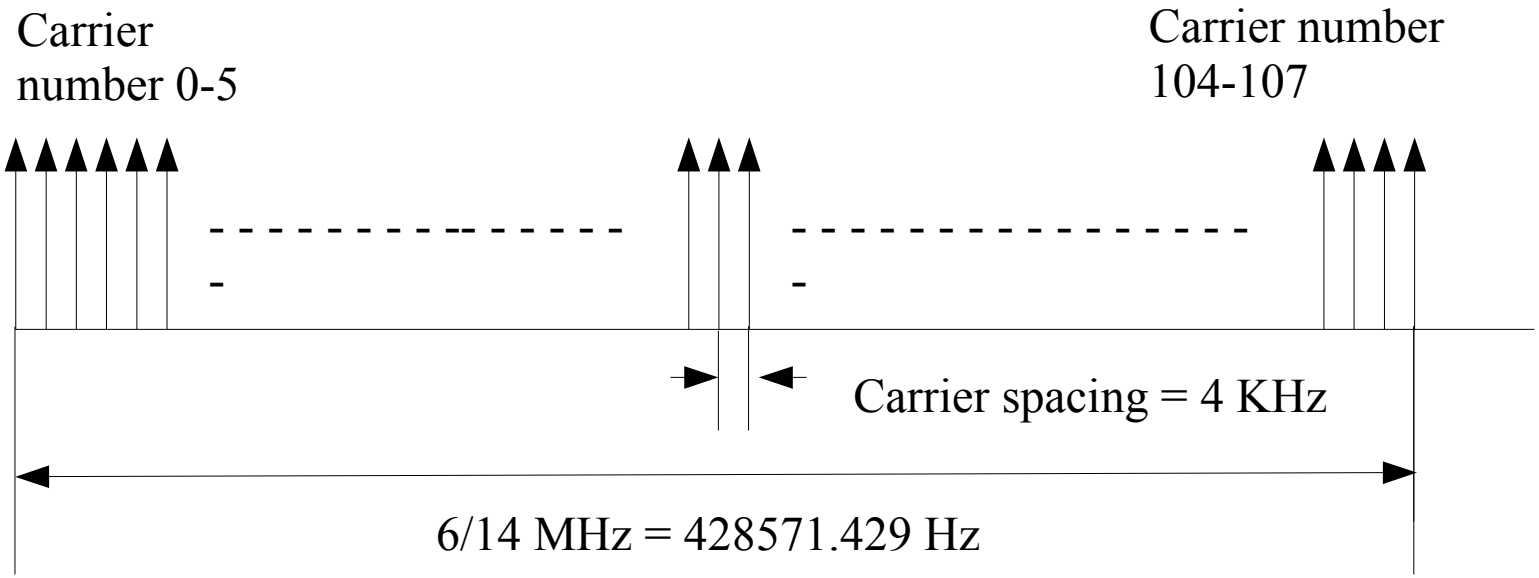
- ISDB-T uses a modulation method referred to as Band Segmented Transmission (BST) OFDM

ISDB-T Channels in Tokyo

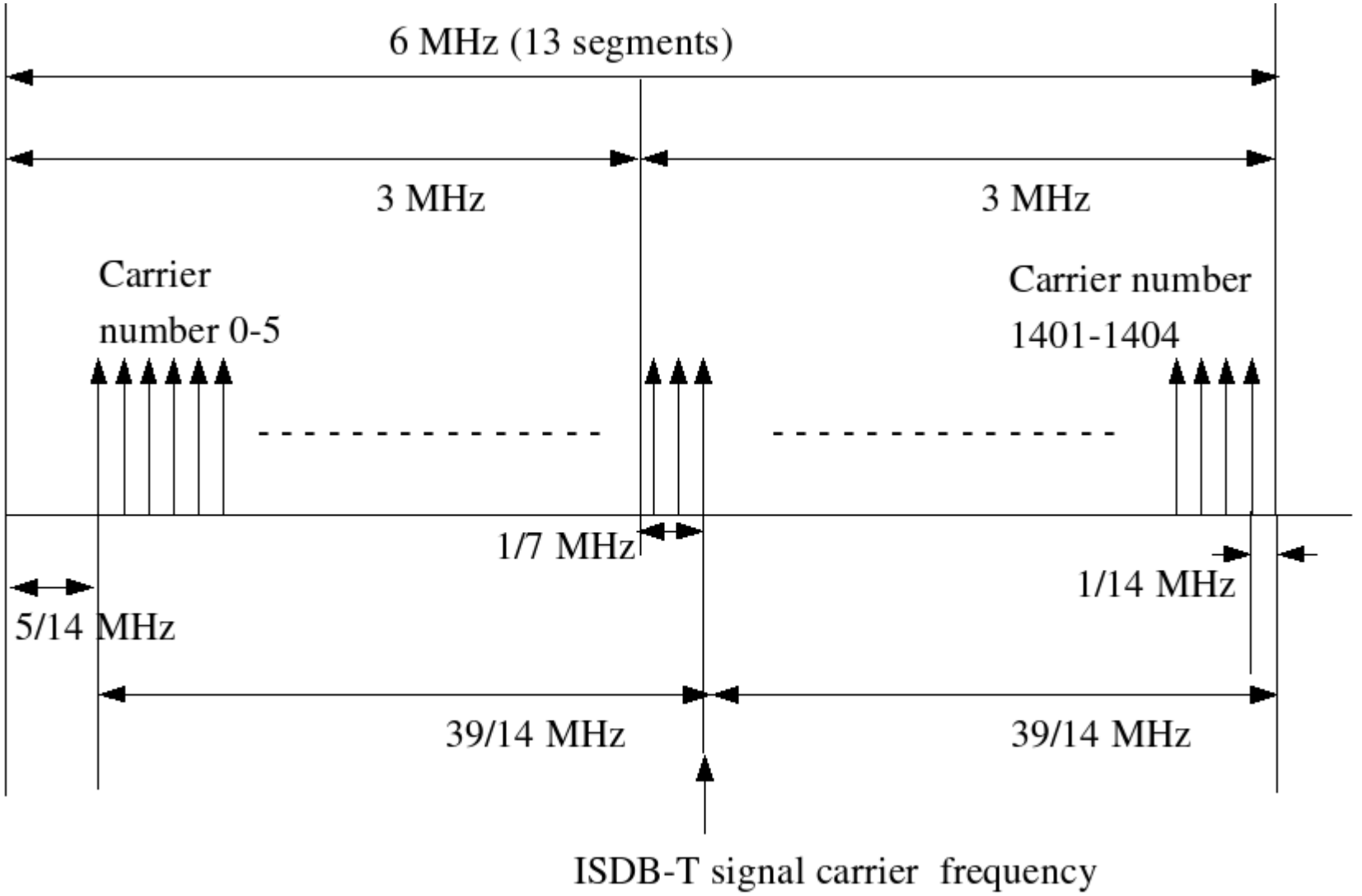
Channel no.	Center frequency
20	515
21	521
22	527
23	533
24	539
25	545
26	551
27	557
28	563

ISDB-T Frequency Range = 470 MHz-770 MHz

An OFDM segment in Mode 1



ISDB-T Signal Arrangement in Mode 1



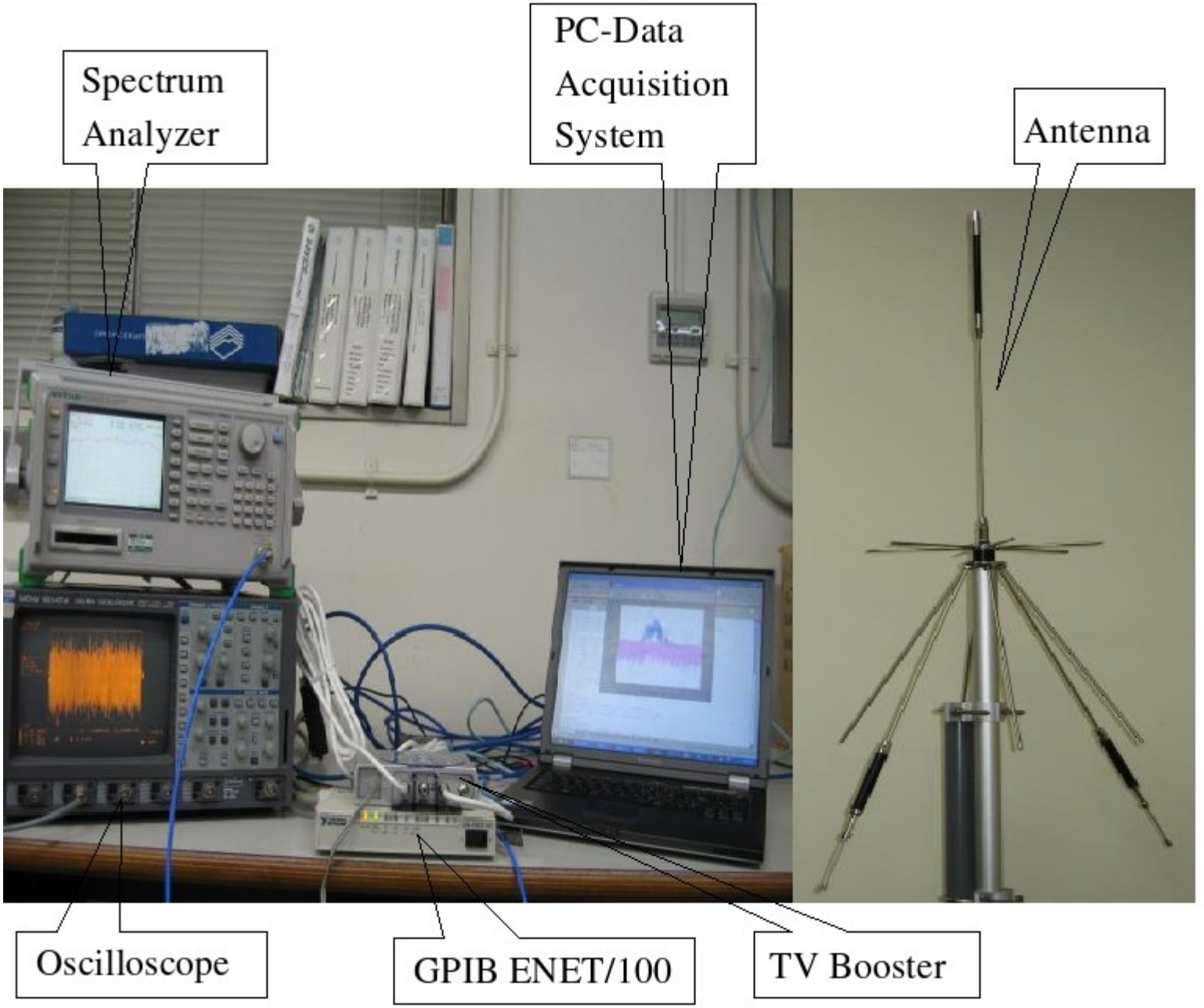
OFDM segment configuration

- Duration of 1 OFDM symbol = 252us
- Guard Interval = 63us
- Total Symbol length = 315us
- Symbols per frame = 204
- No. of carriers per segment = 108
- Frame length = 64.26ms

Symbols: 1 scattered pilot (SP) is introduced in every fourth position

Carriers: 1 SP is introduced in every 12^{th} position

Experimental Set up



Instrument Specification

Instrument	Specification	
Antenna (DA753G)	Frequency range	75MHz – 3GHz
Booster (VB33CW)	Gain	22dB – 32dB
	Noise figure	< 4dB
Spectrum analyzer (Anritsu MS2665C)	Frequency range	9KHz – 21.2GHz
	Noise figure	-90dB
	IF	10.69MHz
	RBW	30Hz – 3MHz
Oscilloscope (Lecroy 9354TM)	Sampling rate	50KHz – 0.5GHz
	Quantization bits	8
	Memory size	5MB

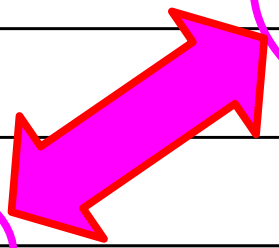
Parameters of the measurement system

Selected channel	No.	23
	Center frequency	533MHz
	Bandwidth	6MHz
Spectrum analyzer set up	Frequency span	Zero span
	RBW	3MHz
Oscilloscope set up	Sampling rate	50MSps

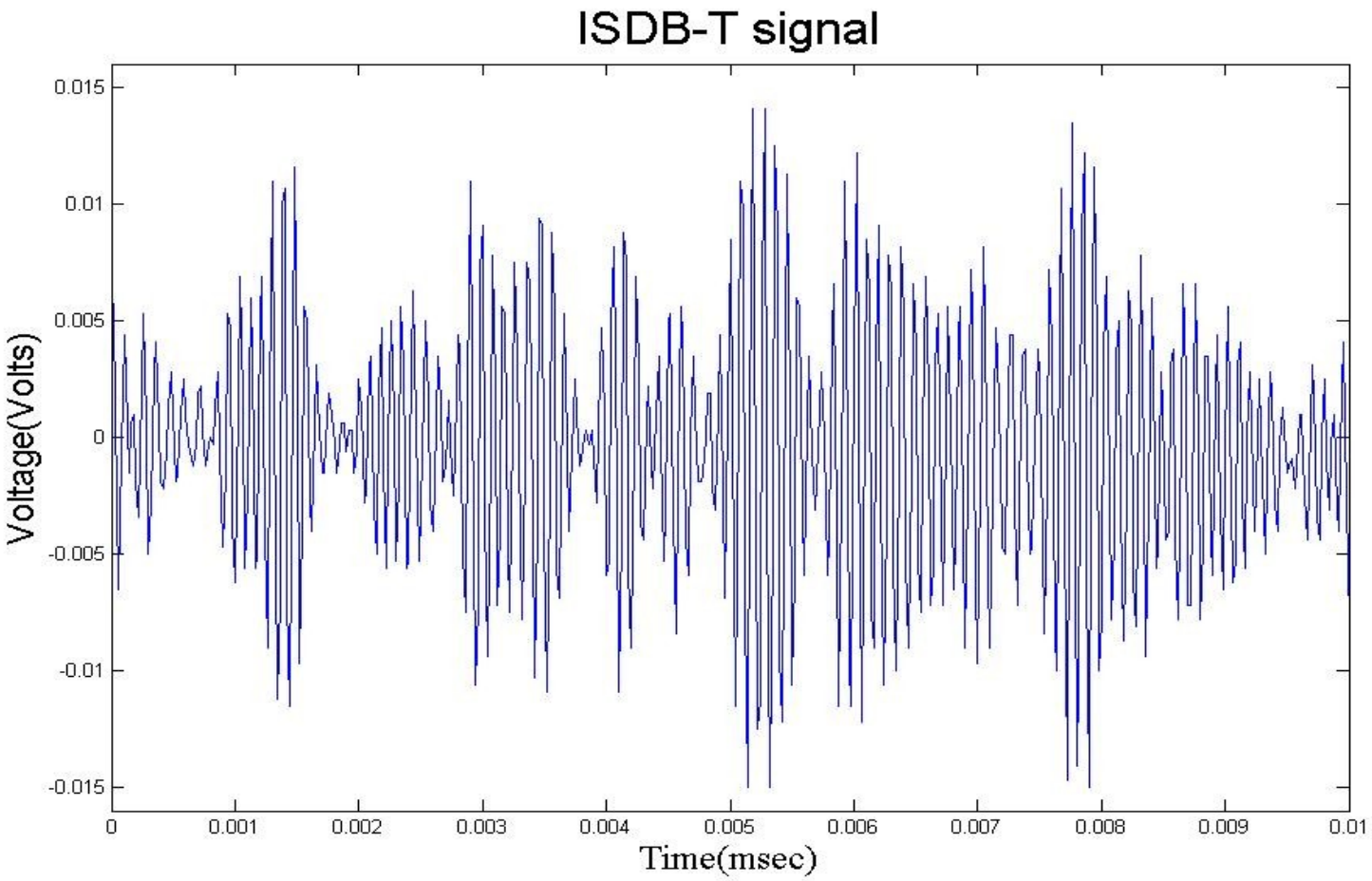
Trade off

Time Interval (ms)	Sampling Frequency (MHz)
0.05	500
0.1	500
0.2	250
0.5	100
1	50
2	25
5	10
10	5
20	2.5
50	1

- IF of Spectrum Analyzer = 10.69MHz
- RBW = 3MHz
- Signal BW = 6MHz

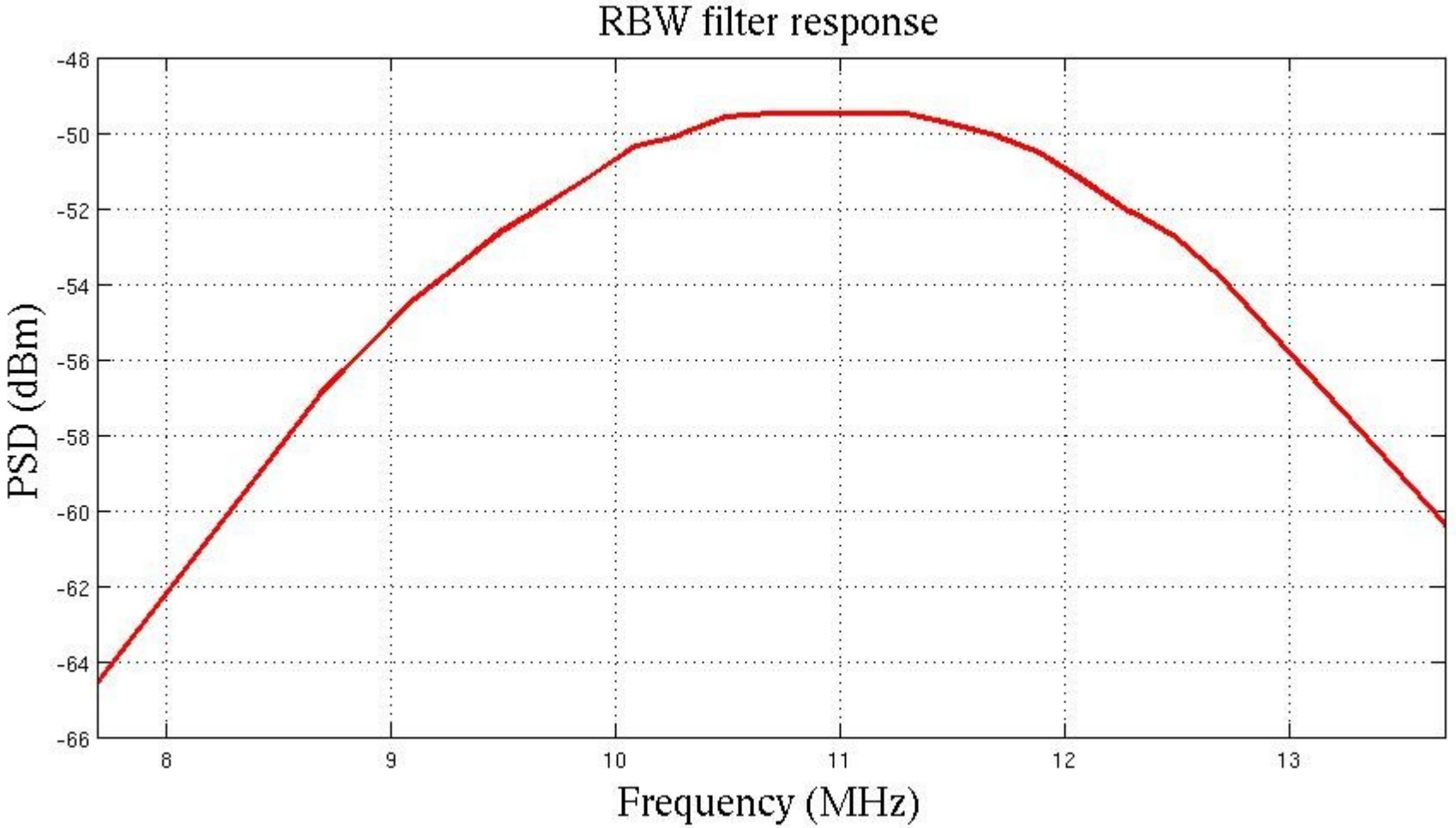


Results (1)



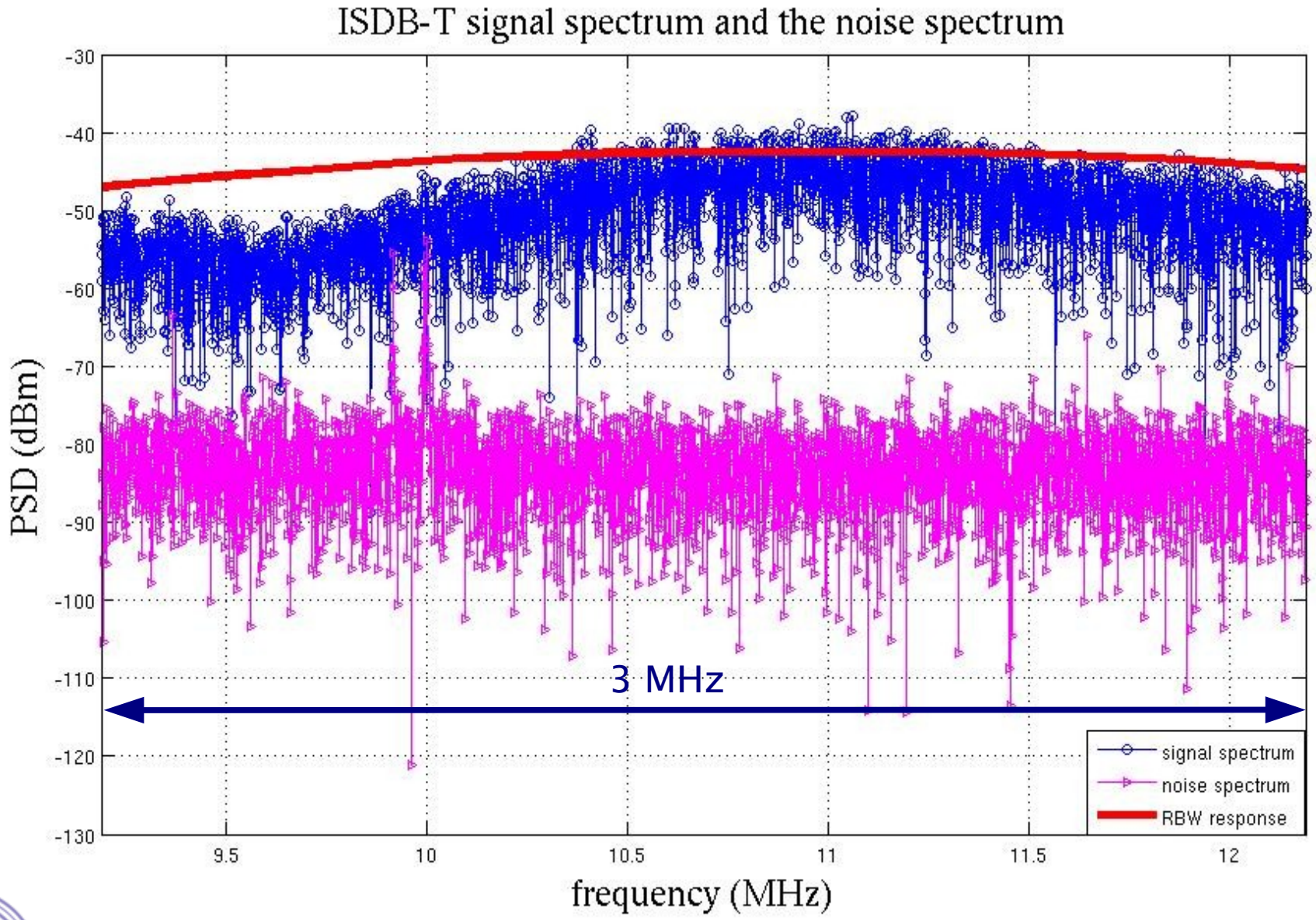
Received ISDB-T signal with Sampling frequency of 50MSps and RBW of 3 MHz

Results (2)

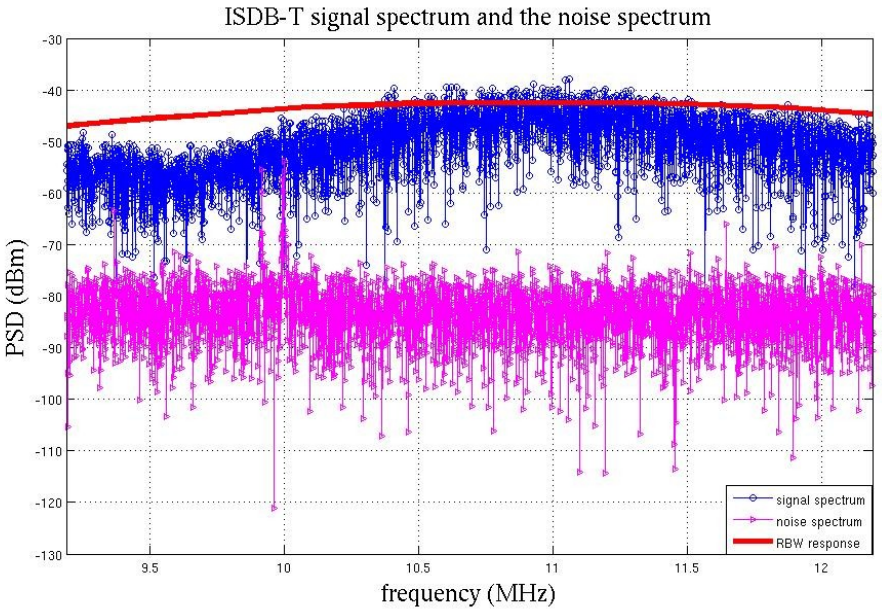


Response of the RBW filter of Spectrum Analyzer used for the experiment

Results(3)


ISDB-T signal spectrum and the noise spectrum
PSD (dBm)
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
9.5
10
10.5
11
11.5
12
frequency (MHz)
3 MHz
signal spectrum
noise spectrum
RBW response

SNR in the band of concern

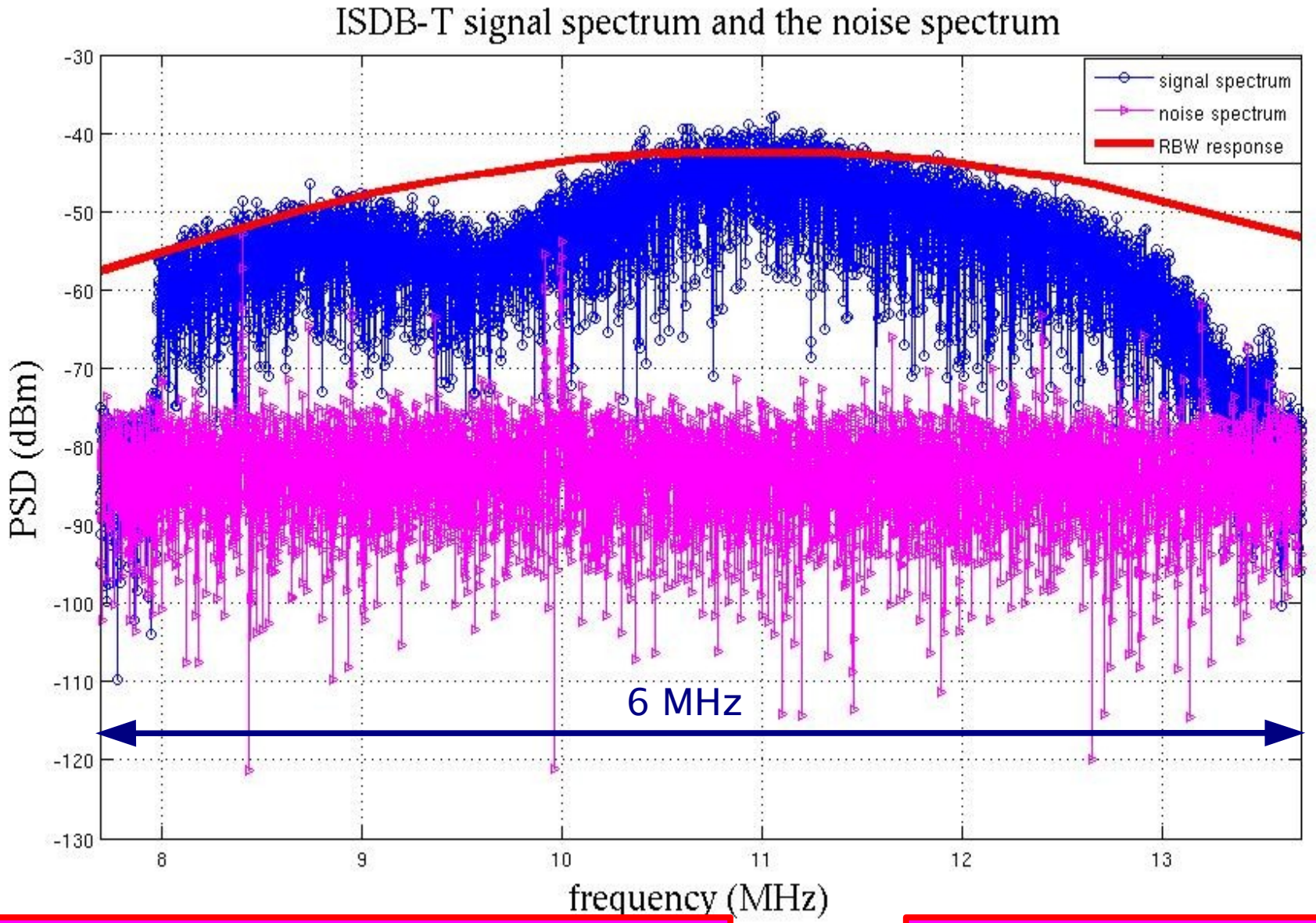


- Time Interval of capture=1ms
- Sampling Frequency=50MSps
- Does not include SP

$$SNR = \sum_{i=1}^{N} \left(\frac{((\Re(P_s[i]))^2 + (\Im(P_s[i]))^2)}{((\Re(P_n[i]))^2 + (\Im(P_n[i]))^2)} \right) = 30.88\,dB$$

within 3 MHz bandwidth

Results (4)

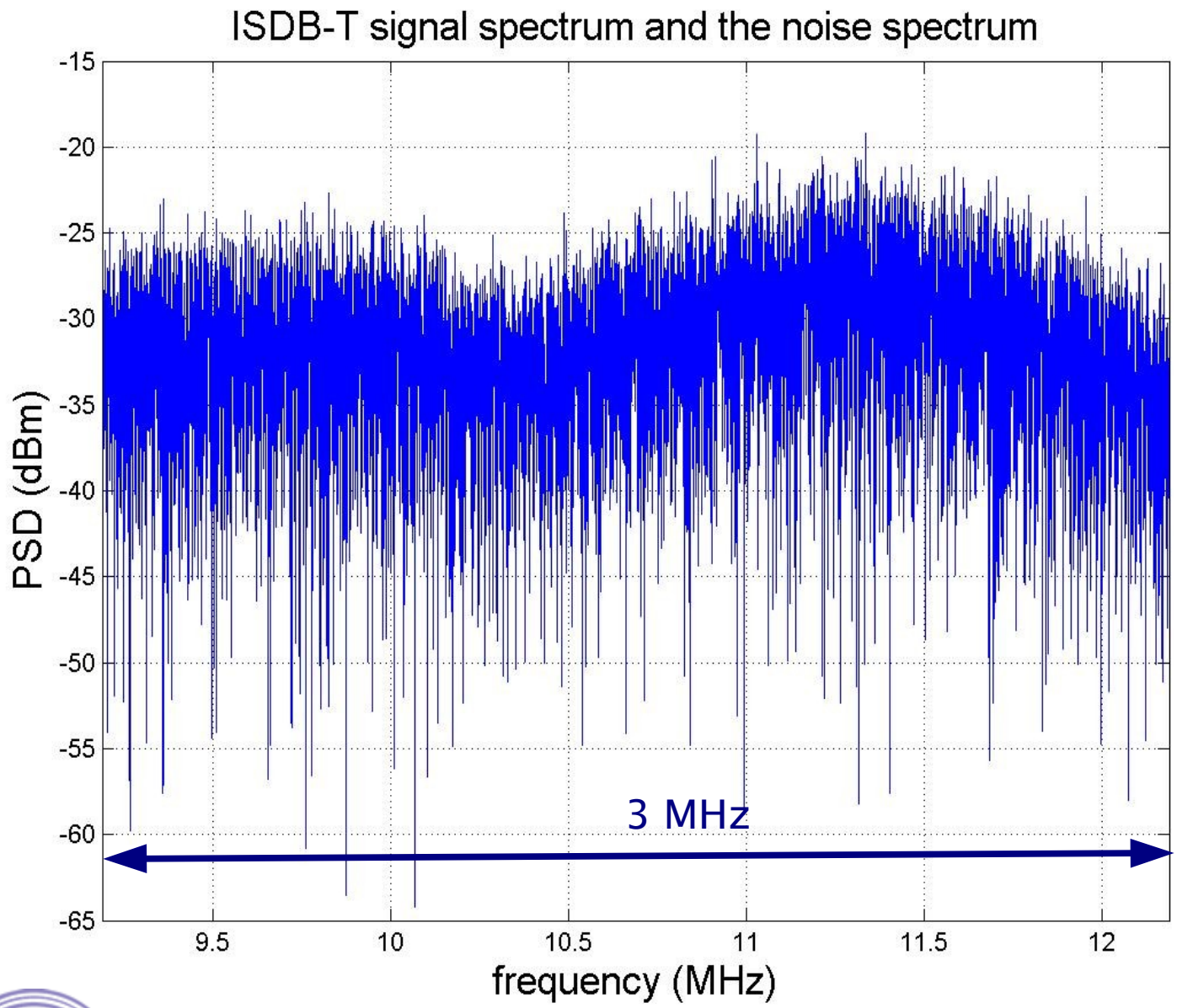


- Time Interval of capture=1ms
- Sampling Frequency=50MSps

th Dec. 2007

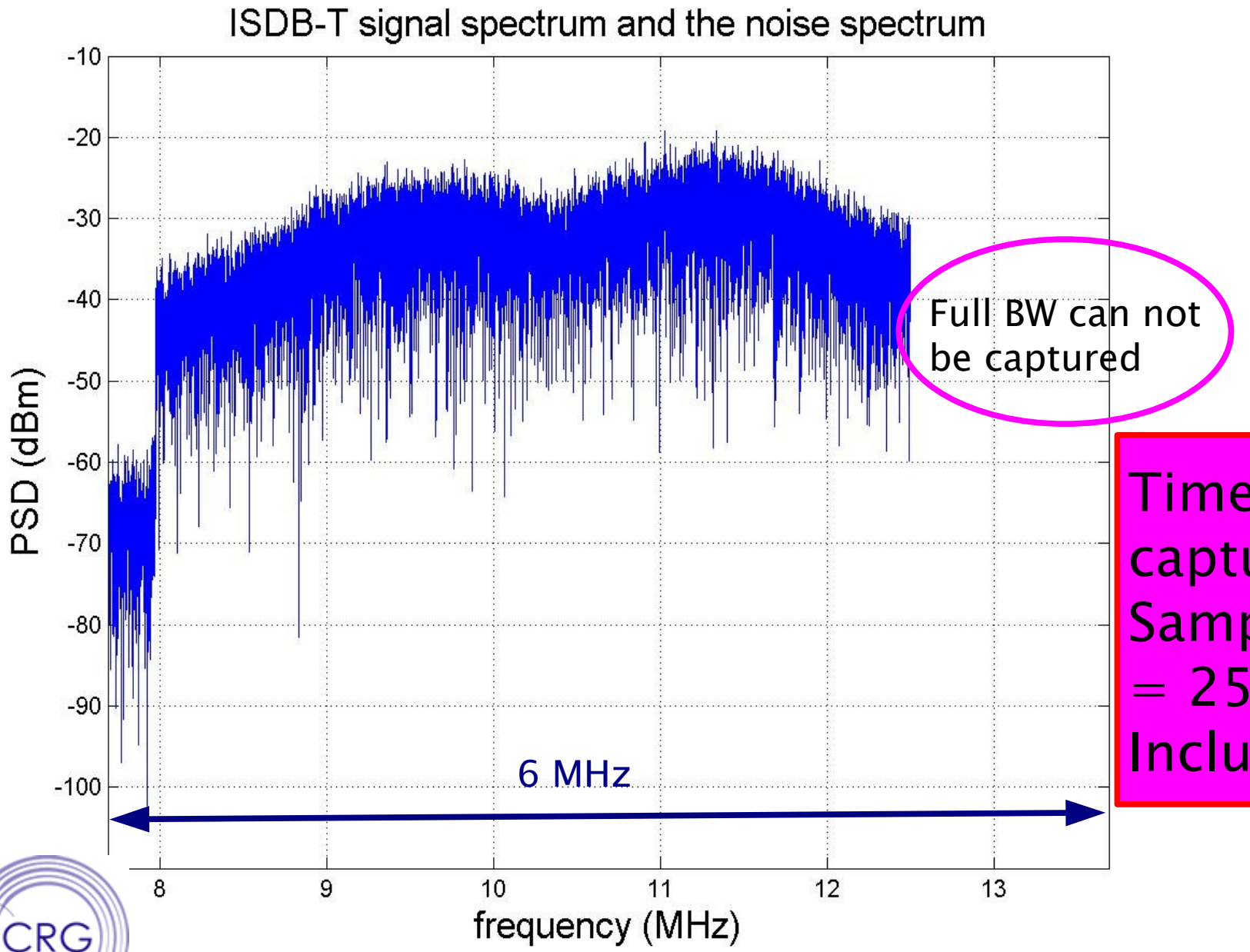
- Does not include SP

Results (5)



Time Interval of capture = 2ms
Sampling Freq. = 25MSps
Includes SP

Results (6)



Time Interval of capture = 2ms
Sampling Freq. = 25MSps
Includes SP

MCRG Tokyo Tech

Issues and Future work

- Record the data so that the scattered pilots are included.
- Concatenate the data to form a segment equivalent
- Compare ISDB-T spectrum with the threshold for spectrum density computation
- Perform Channel Modeling

Thank you for your attention