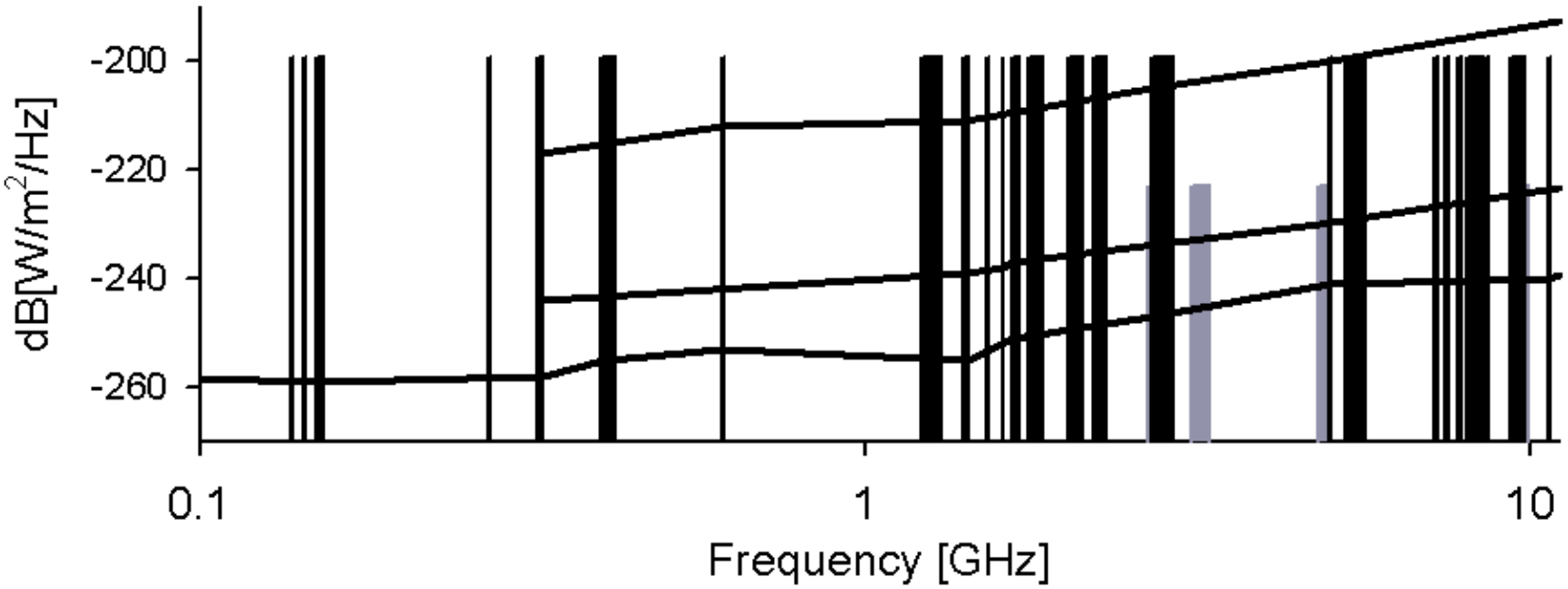
Low Frequency: RFI's Playground

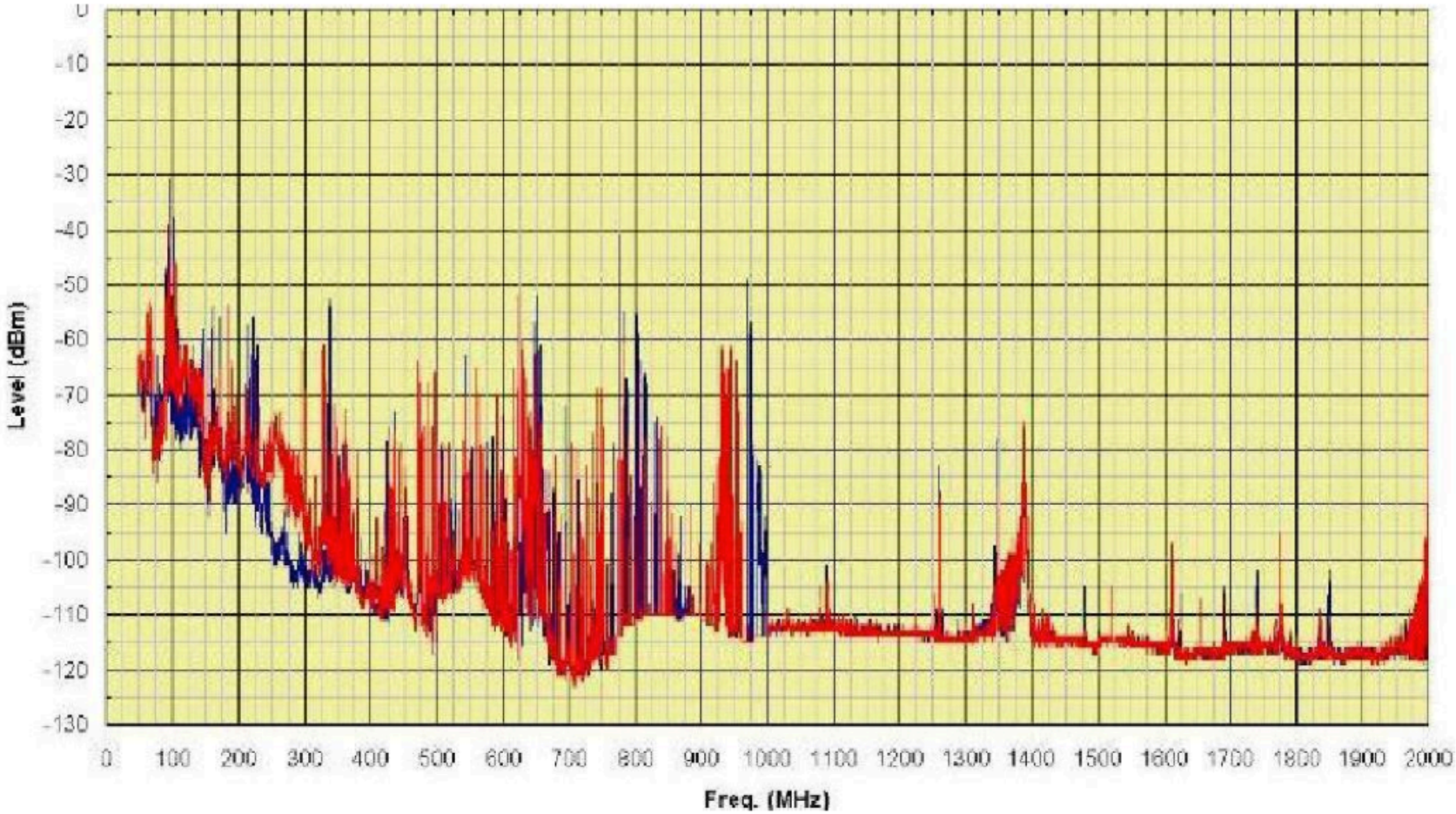
David R DeBoer

University of California Berkeley

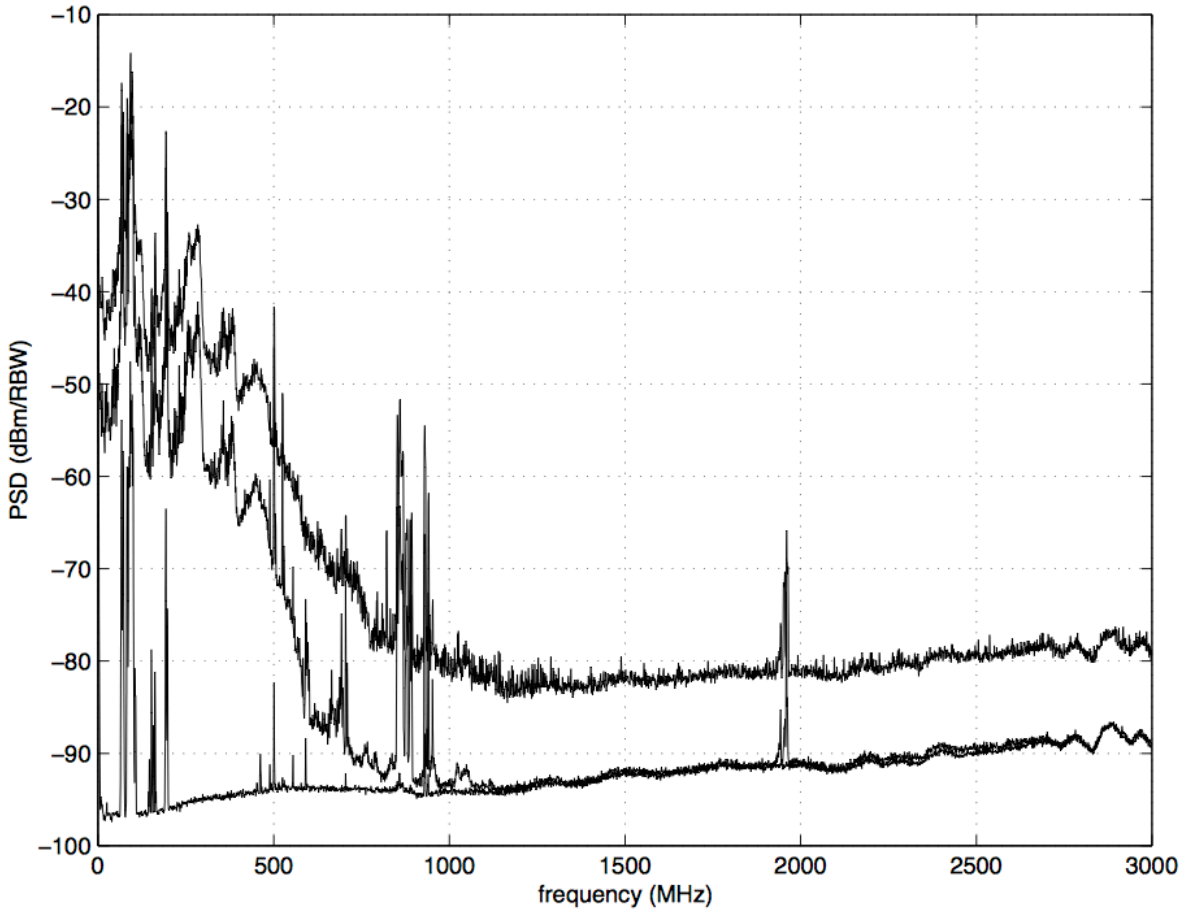
Allocations

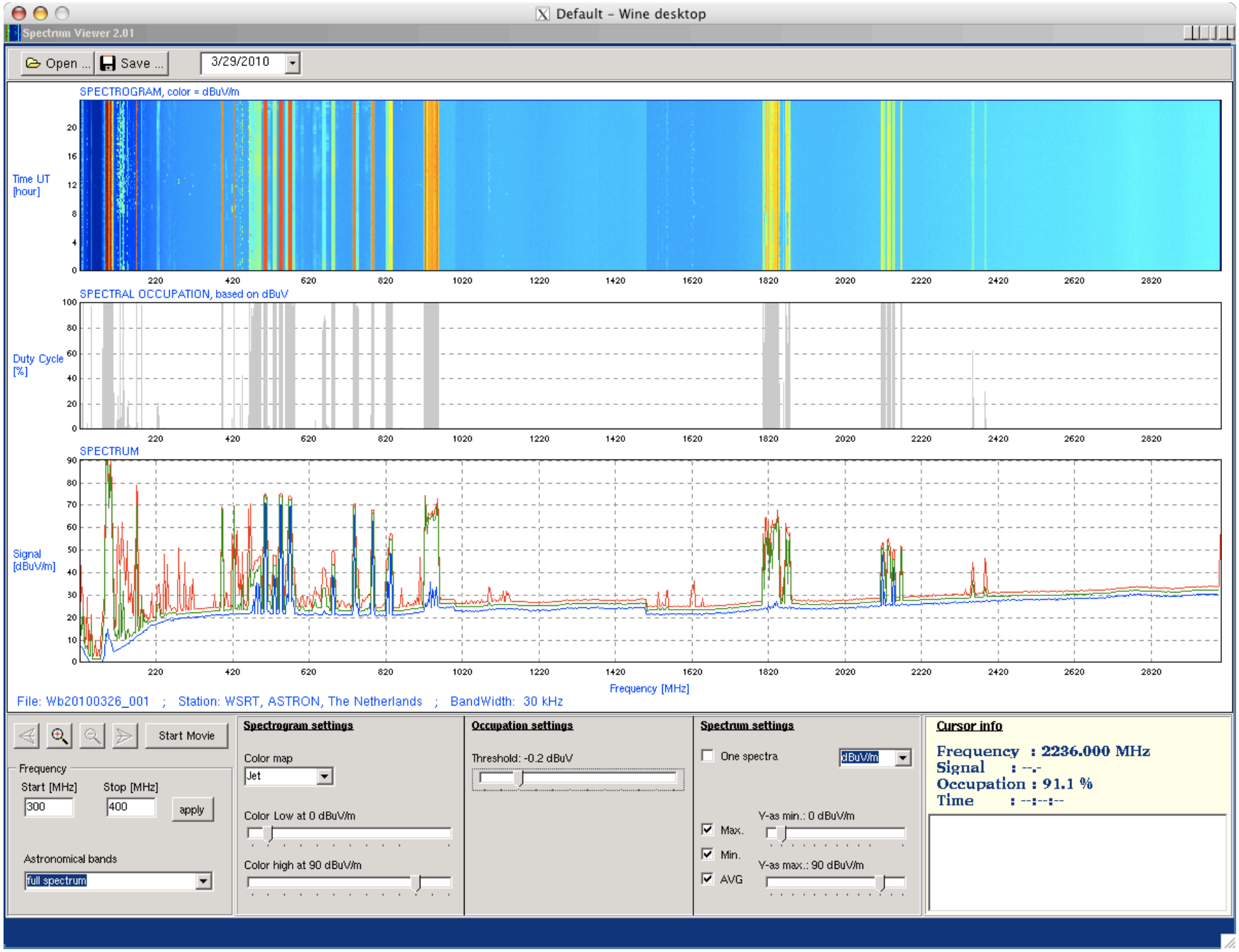


The Problem

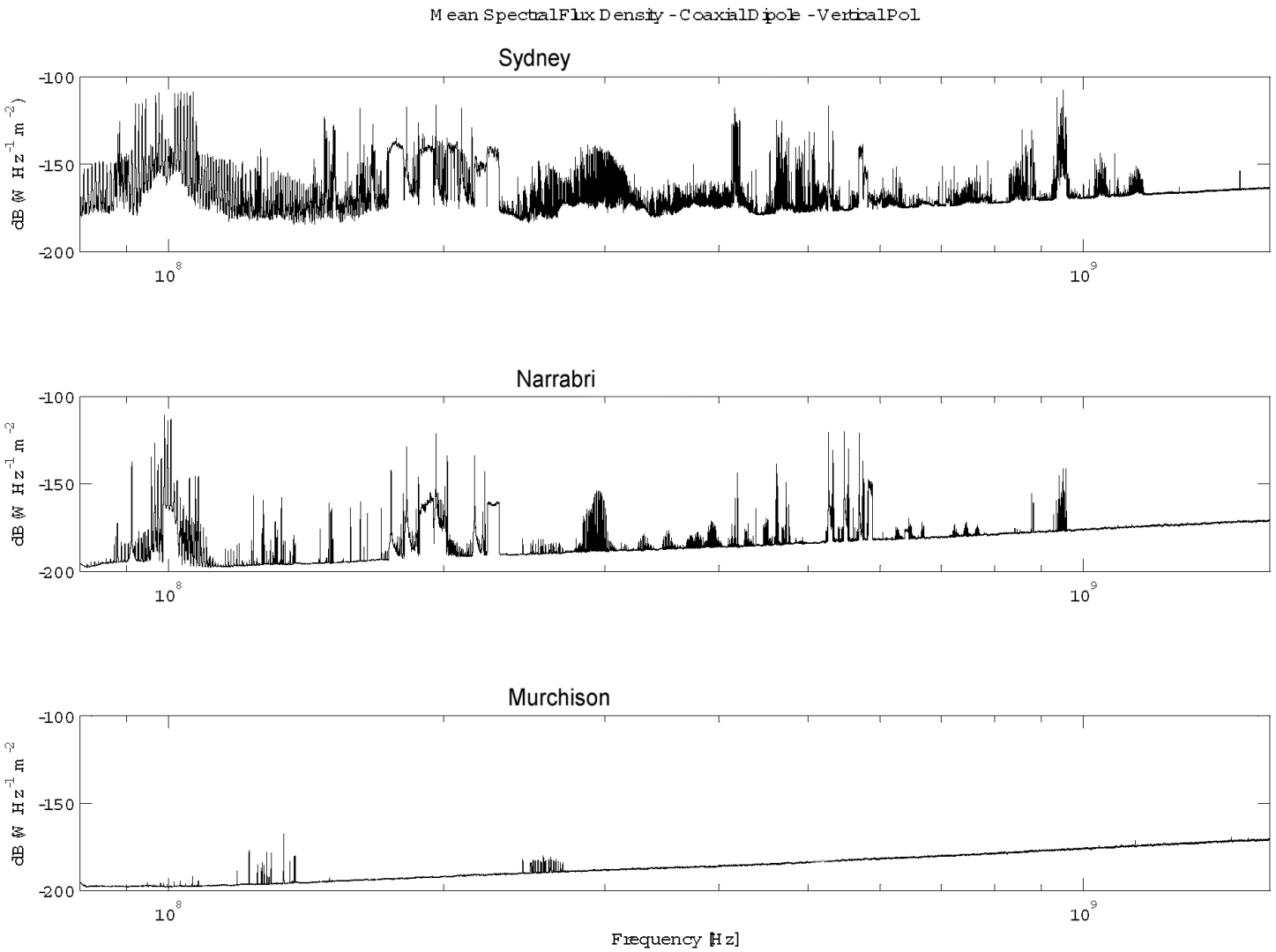

Level (dBm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Freq. (MHz)

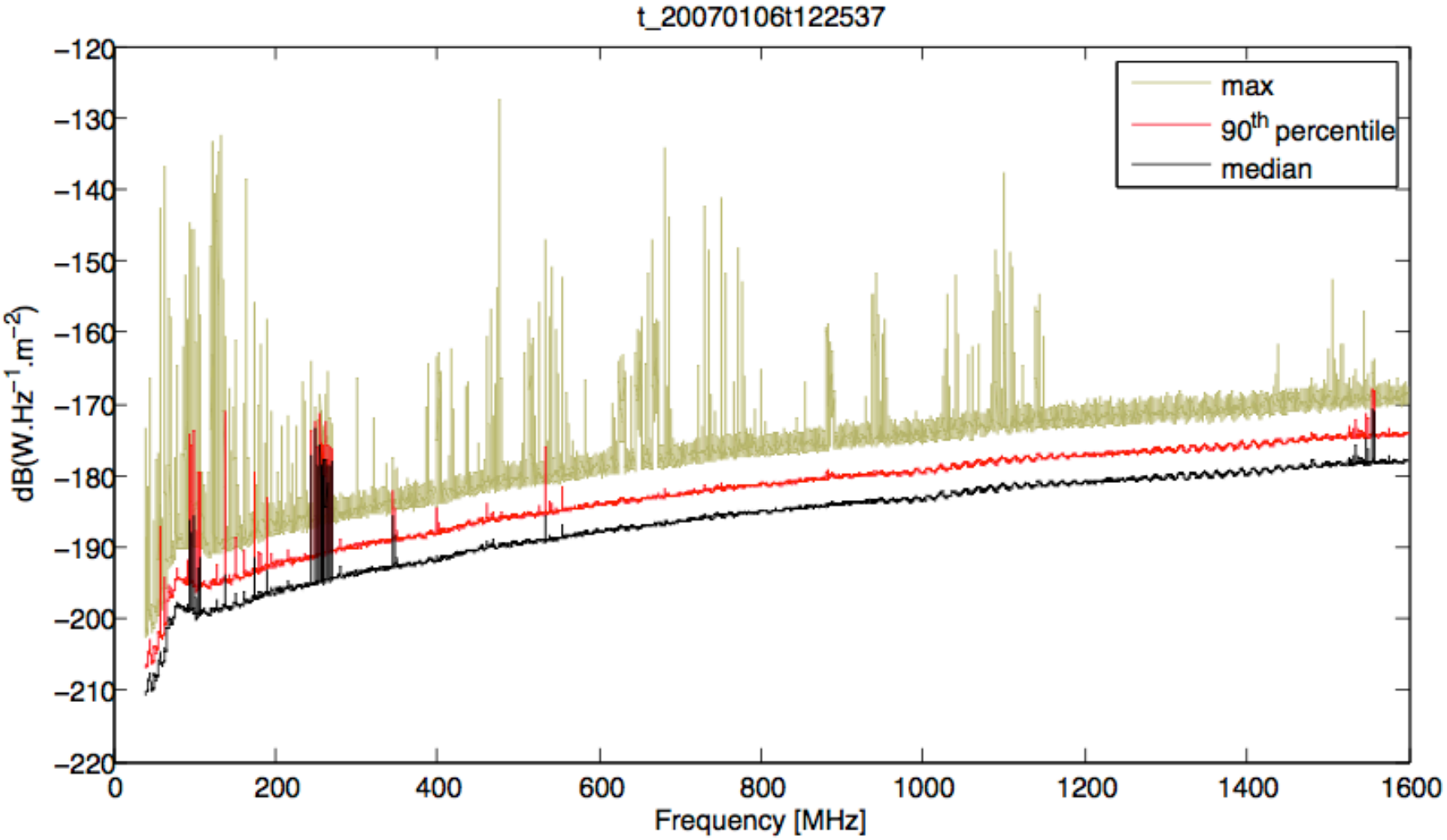
The Problem


PSD (dBm/RBW)
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
0
500
1000
1500
2000
2500
3000
frequency (MHz)

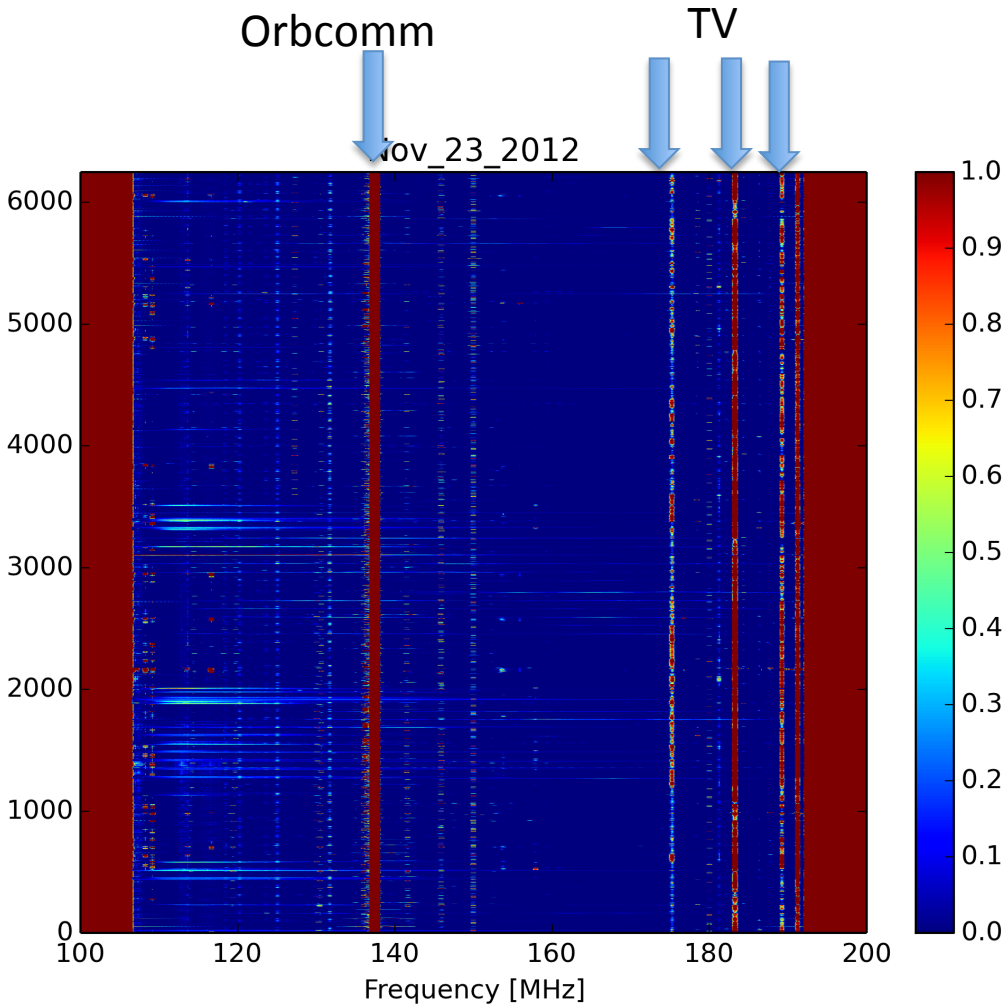

Default - Wine desktop
Spectrum Viewer 2.01
Open ...
Save ...
3/29/2010
SPECTROGRAM, color = dBuV/m
Time UT [hour]
SPECTRAL OCCUPATION, based on dBuV
Duty Cycle [%]
SPECTRUM
Signal [dBuV/m]
Frequency [MHz]
File: Wb20100326_001 ; Station: WSRT, ASTRON, The Netherlands ; BandWidth: 30 kHz
Start Movie
Frequency
Start [MHz]
Stop [MHz]
300
400
apply
Astronomical bands
full spectrum
Spectrogram settings
Color map
Jet
Color Low at 0 dBuV/m
Color high at 90 dBuV/m
Occupation settings
Threshold: -0.2 dBuV
Spectrum settings
One spectra
dBuV/m
Max.
Min.
AVG
Y-as min.: 0 dBuV/m
Y-as max.: 90 dBuV/m
Cursor info
Frequency : 2236.000 MHz
Signal : --.-
Occupation : 91.1 %
Time : --:--:--

Retreat!

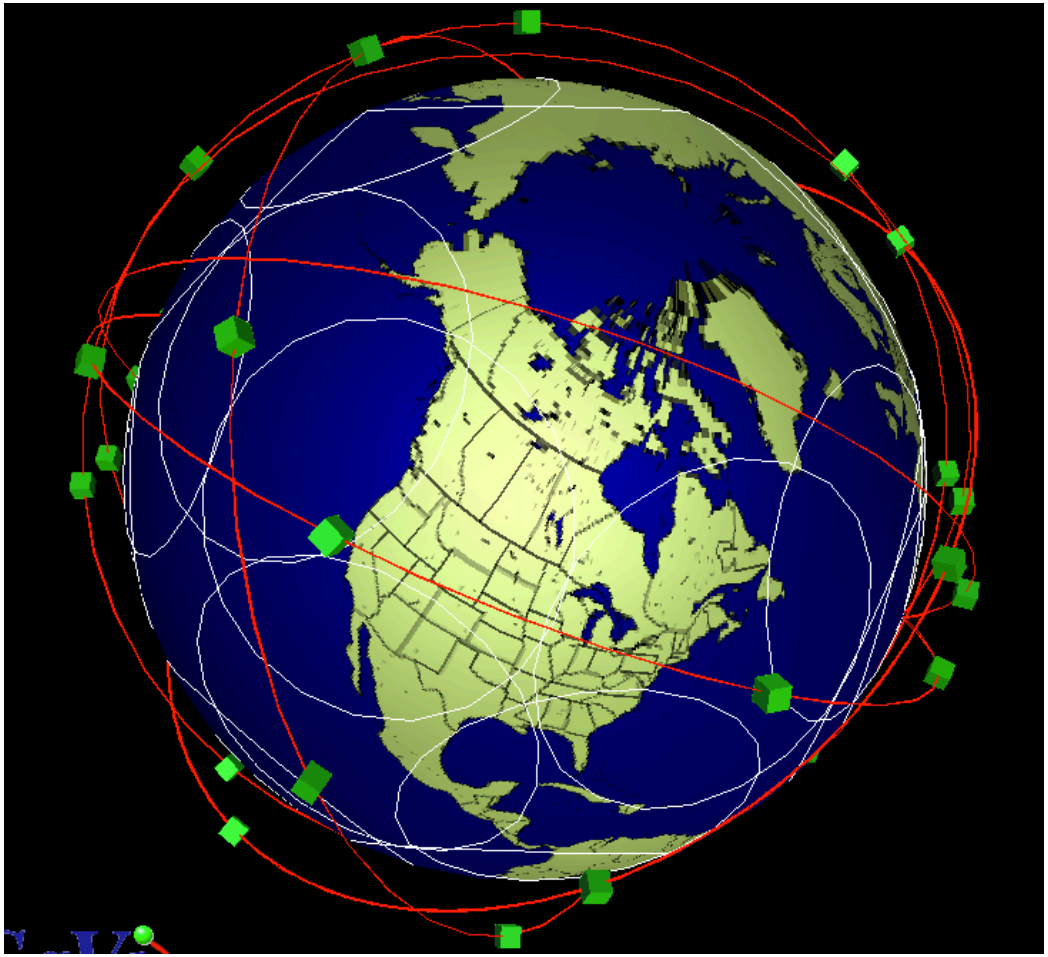

Mean Spectral Flux Density - Coaxial Dipole - Vertical Pol
Sydney
Narrabri
Murchison
dB (W Hz^{-1} m^{-2})
-100
-150
-200
10^8
10^9
Frequency [Hz]


t_20070106t122537
max
90th percentile
median
dB(W.Hz-1.m-2)
Frequency [MHz]
−120
−130
−140
−150
−160
−170
−180
−190
−200
−210
−220
0
200
400
600
800
1000
1200
1400
1600

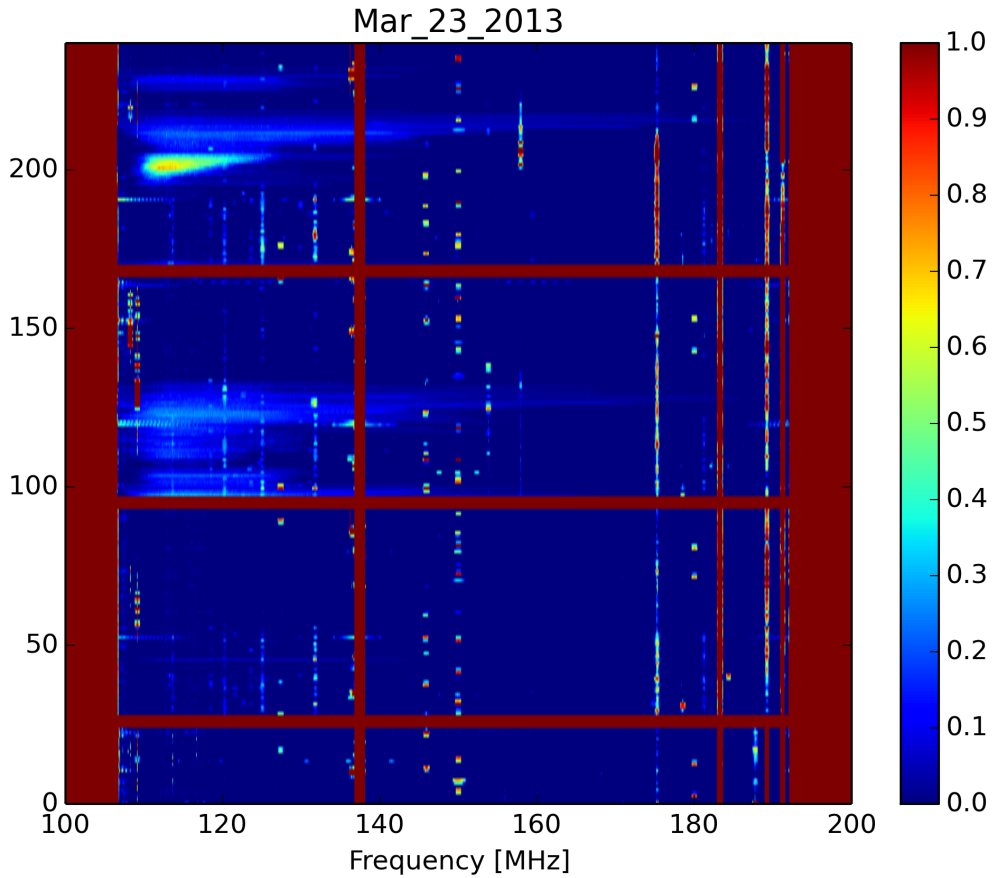
Time/Frequency



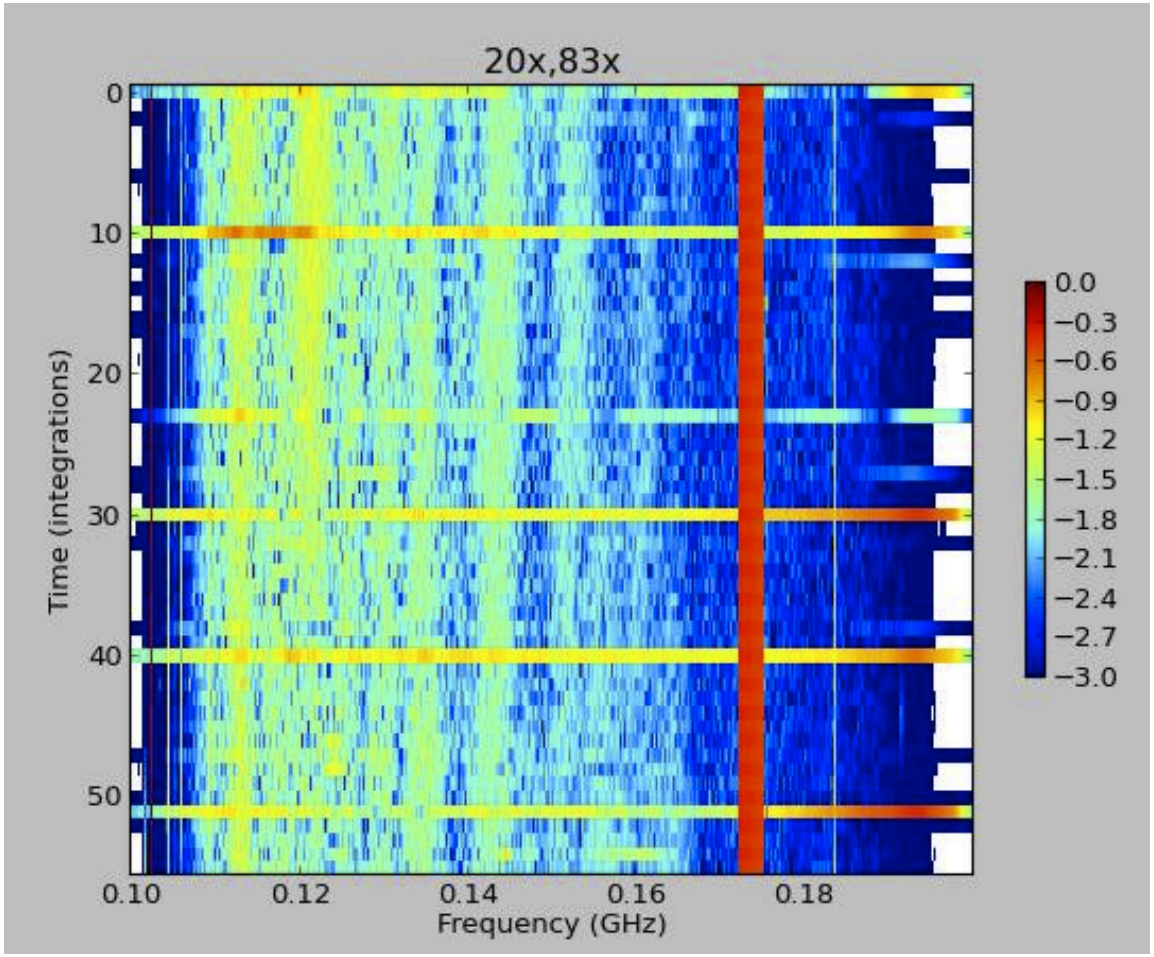
Satellites – the great equalizers



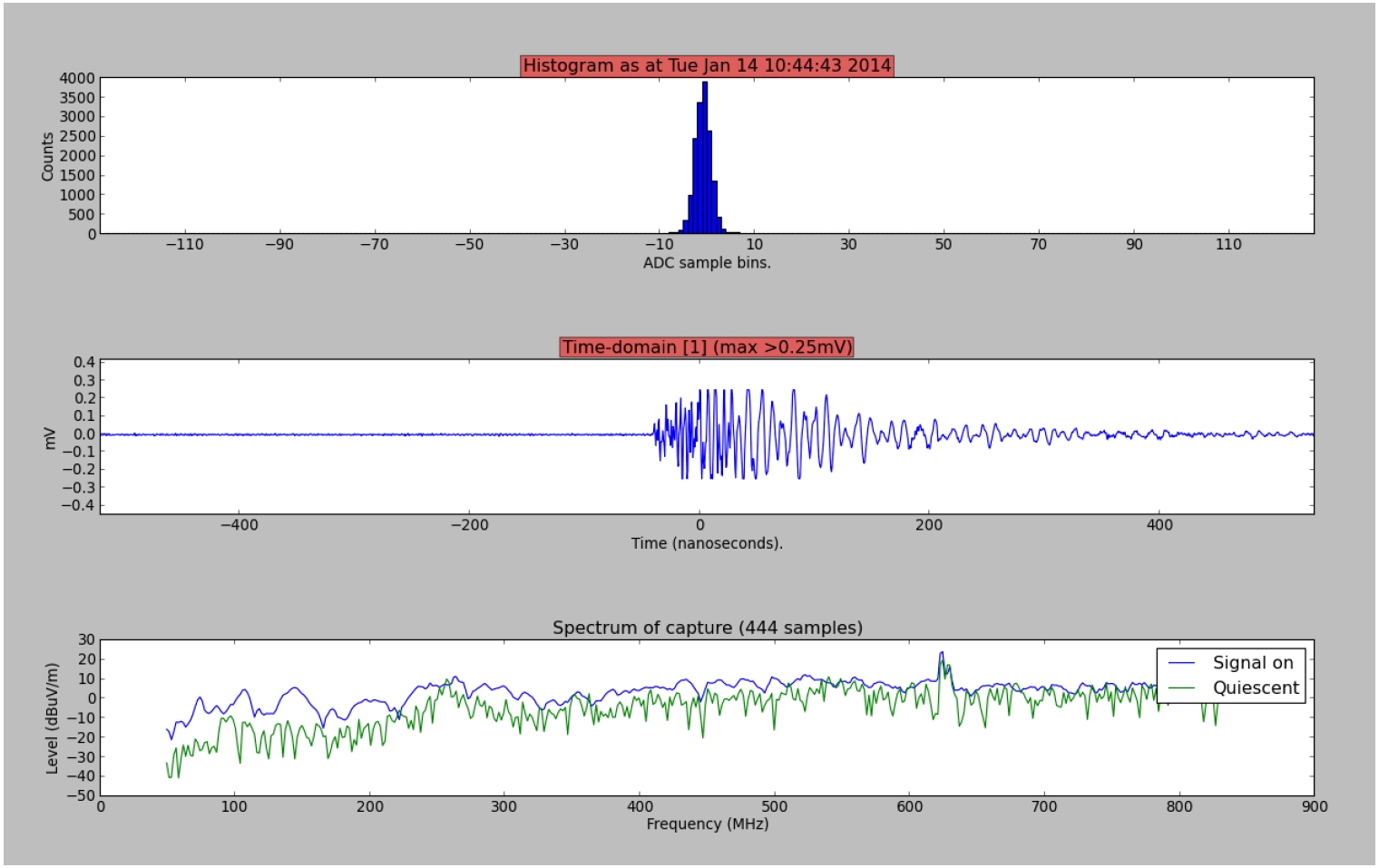
A Pulse Problem



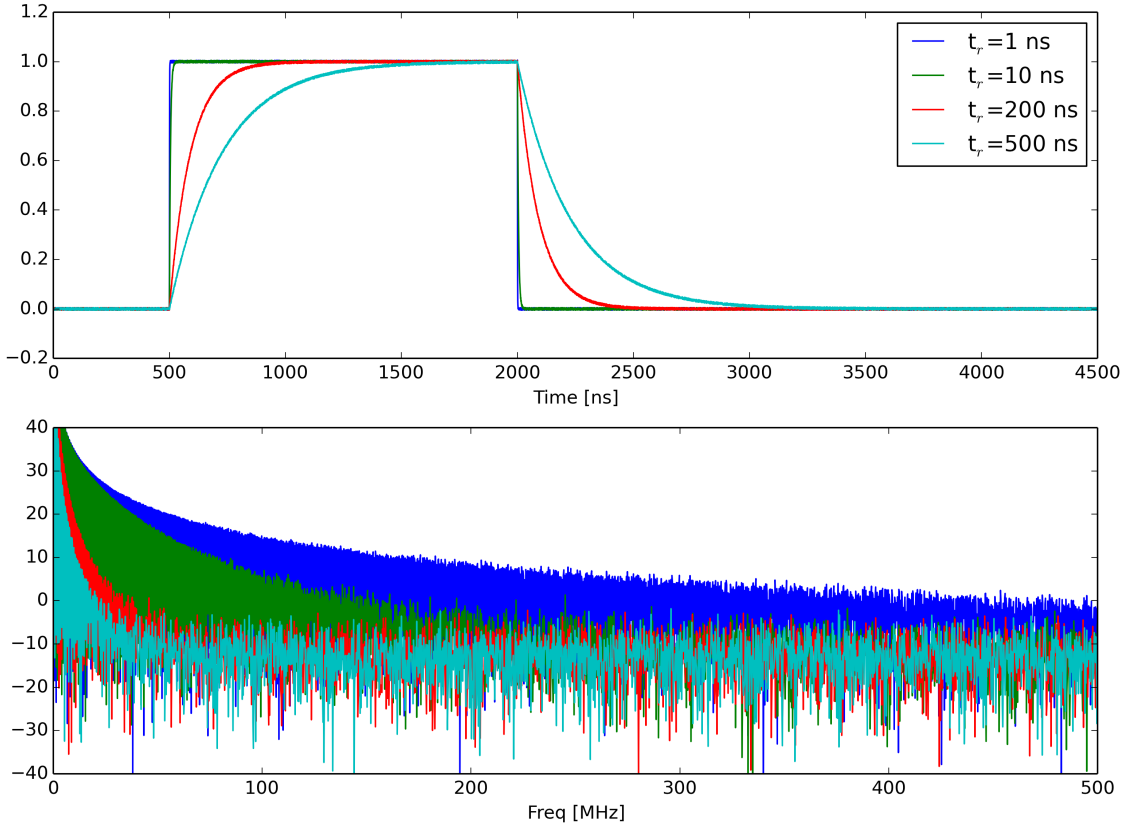
A Pulse Problem



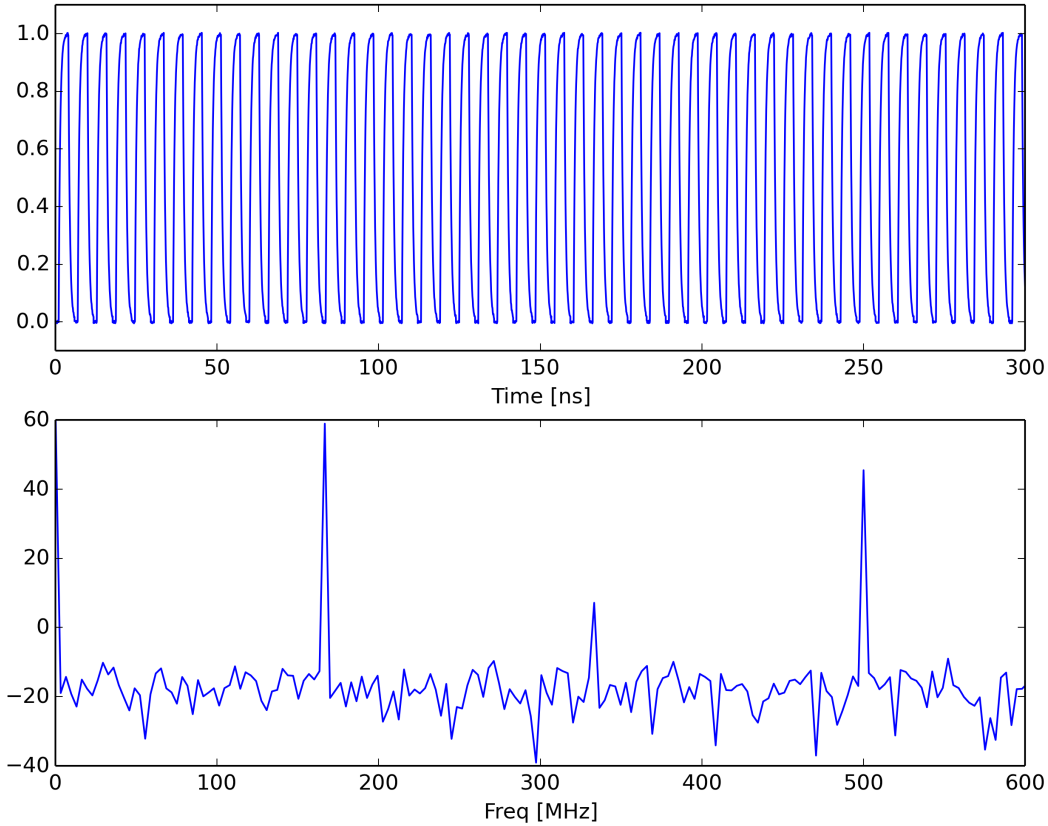
A Pulse Problem



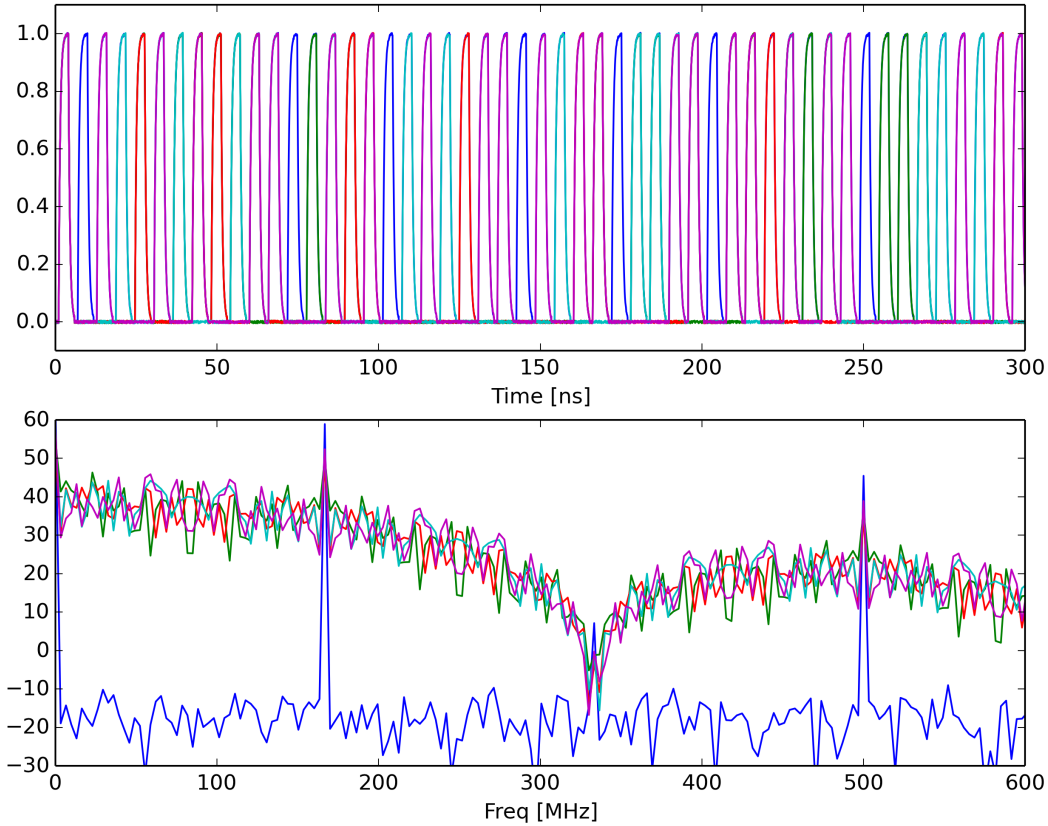
The Reasons


1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time [ns]
t_r=1 ns
t_r=10 ns
t_r=200 ns
t_r=500 ns
40
30
20
10
0
−10
−20
−30
−40
0
100
200
300
400
500
Freq [MHz]

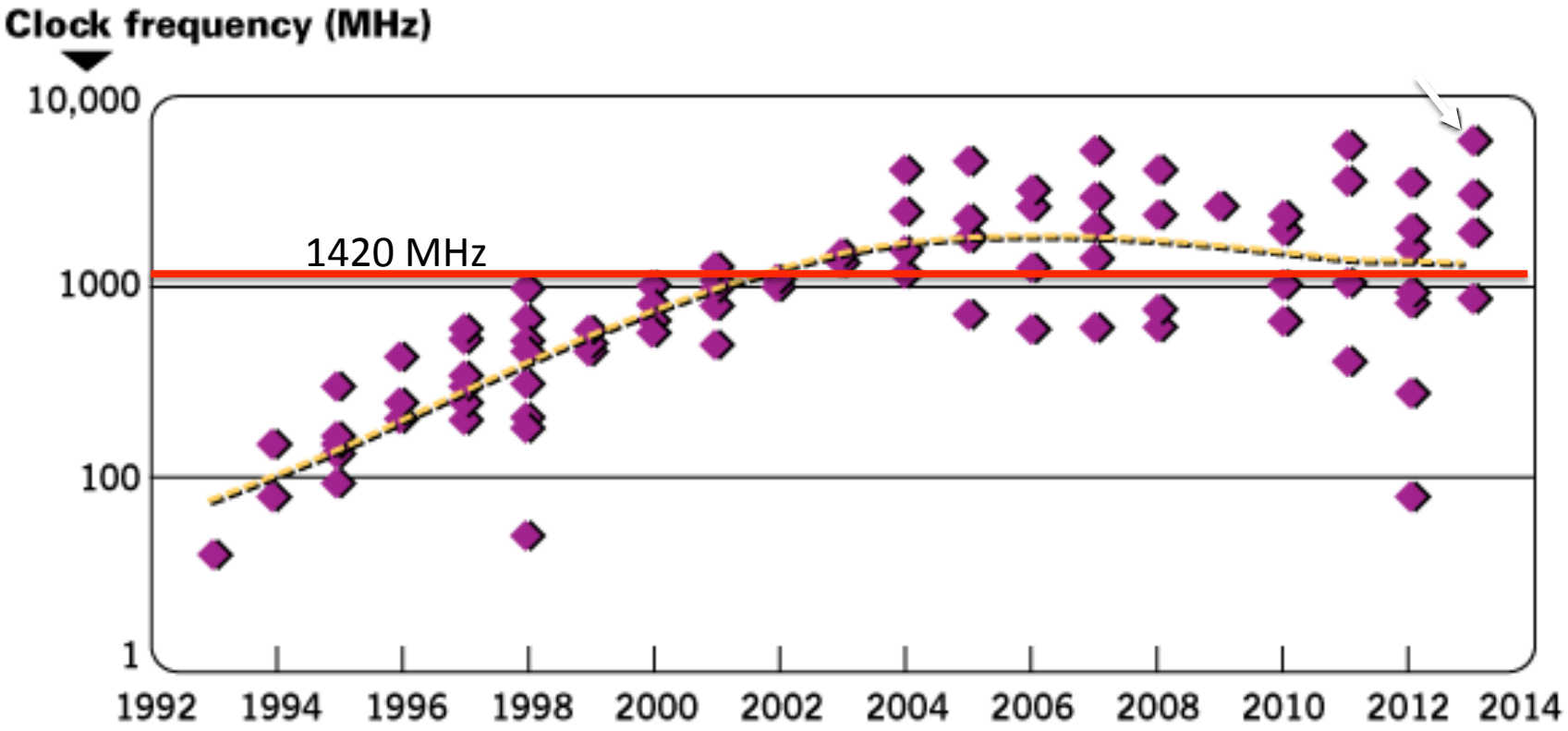
The Reasons


1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
Time [ns]
60
40
20
0
−20
−40
0
100
200
300
400
500
600
Freq [MHz]

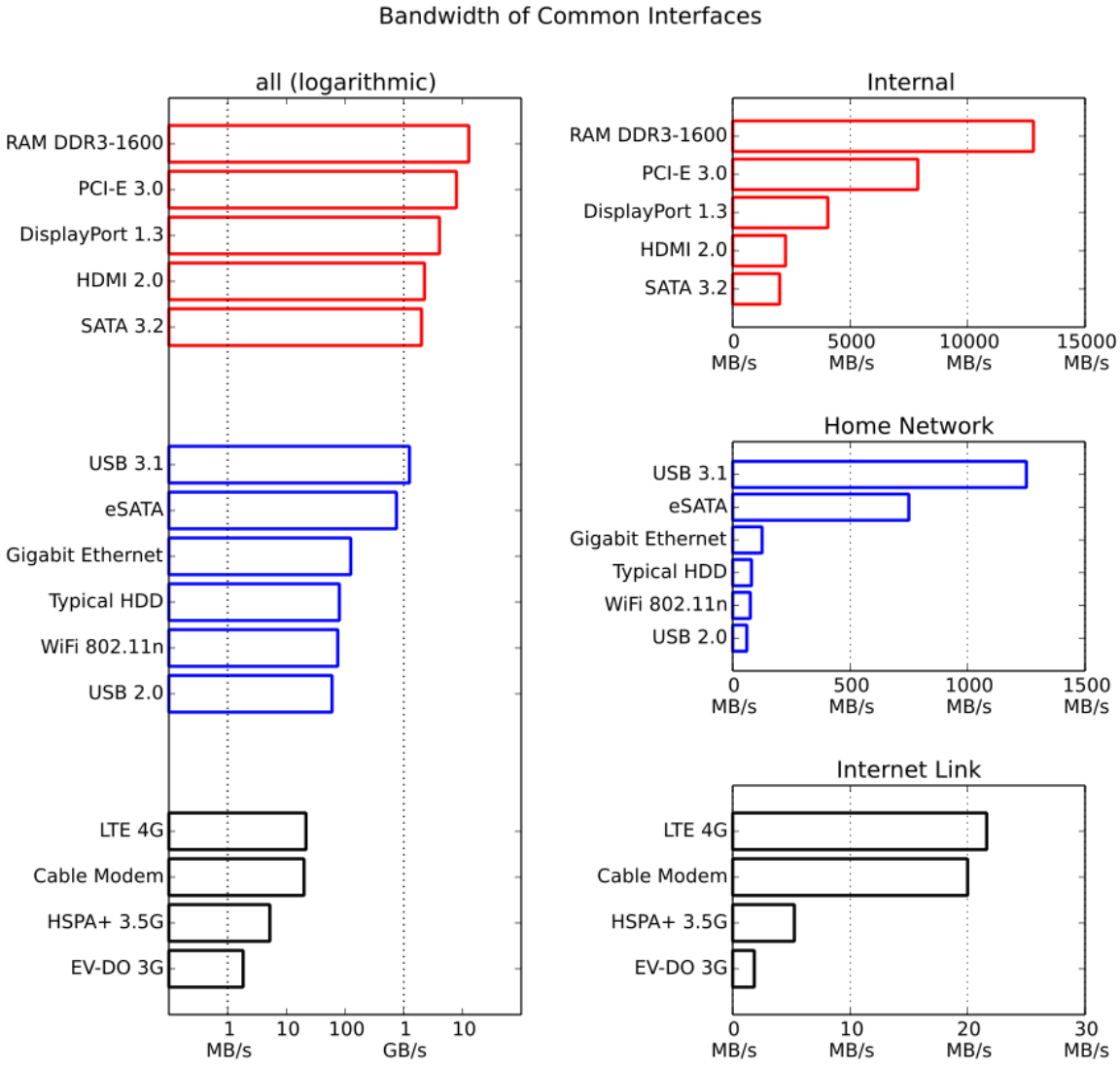
The Reasons


1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
Time [ns]
60
50
40
30
20
10
0
−10
−20
−30
0
100
200
300
400
500
600
Freq [MHz]

The Reasons

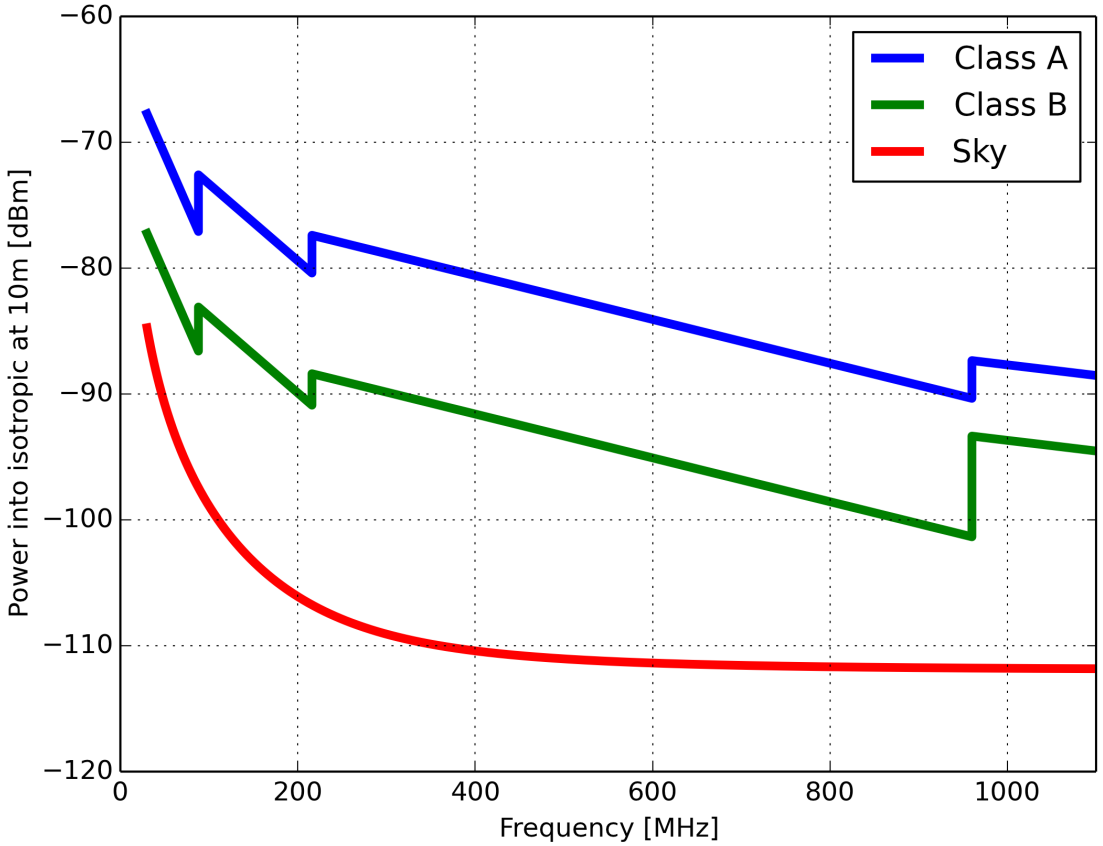

Clock frequency (MHz)
10,000
1000
100
1
1420 MHz
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

The Reasons



source: http://en.wikipedia.org/wiki/List_of_device_bit_rates

Part 15 Devices



- http://www.arrl.org/part-15-radio-frequency-devices

Power Lines

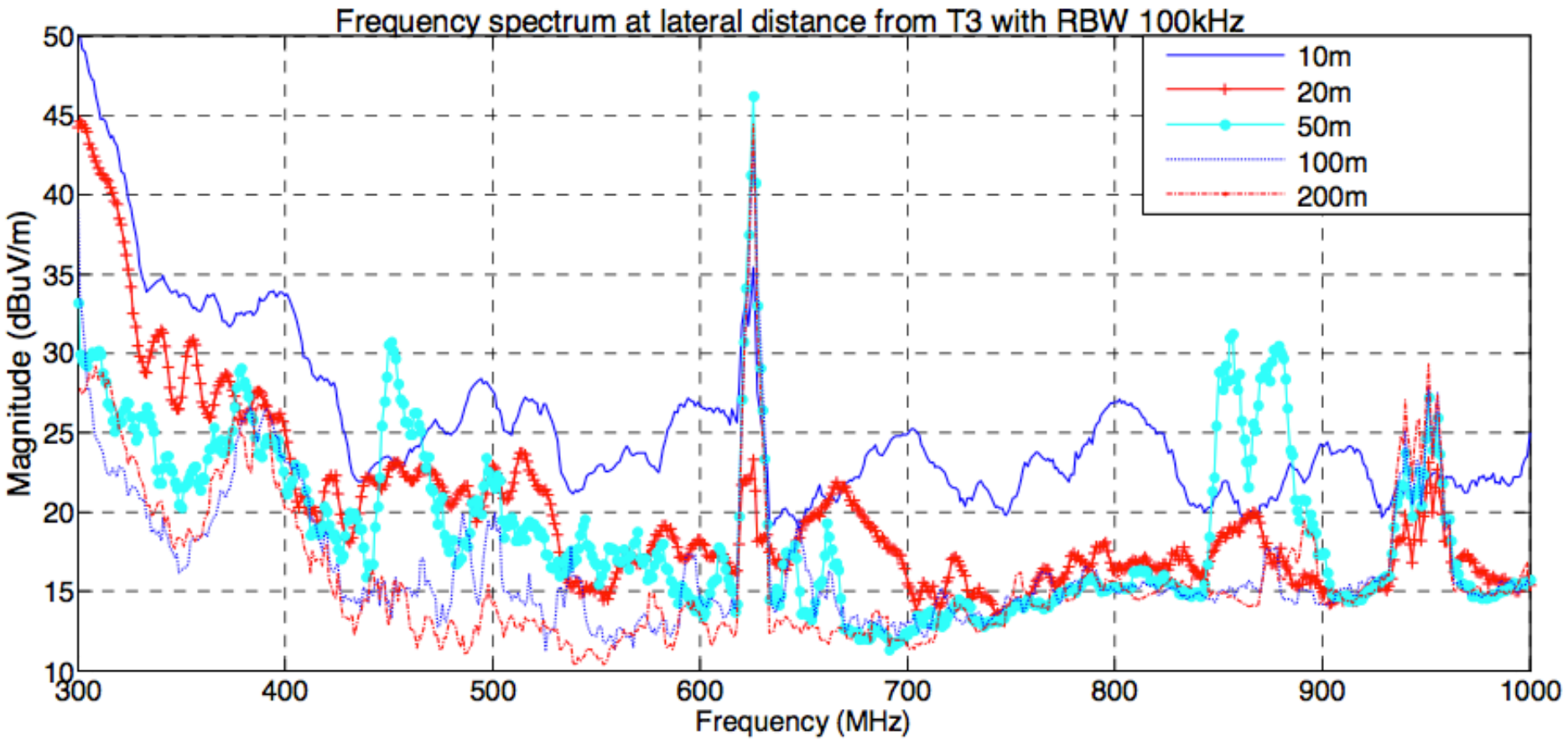
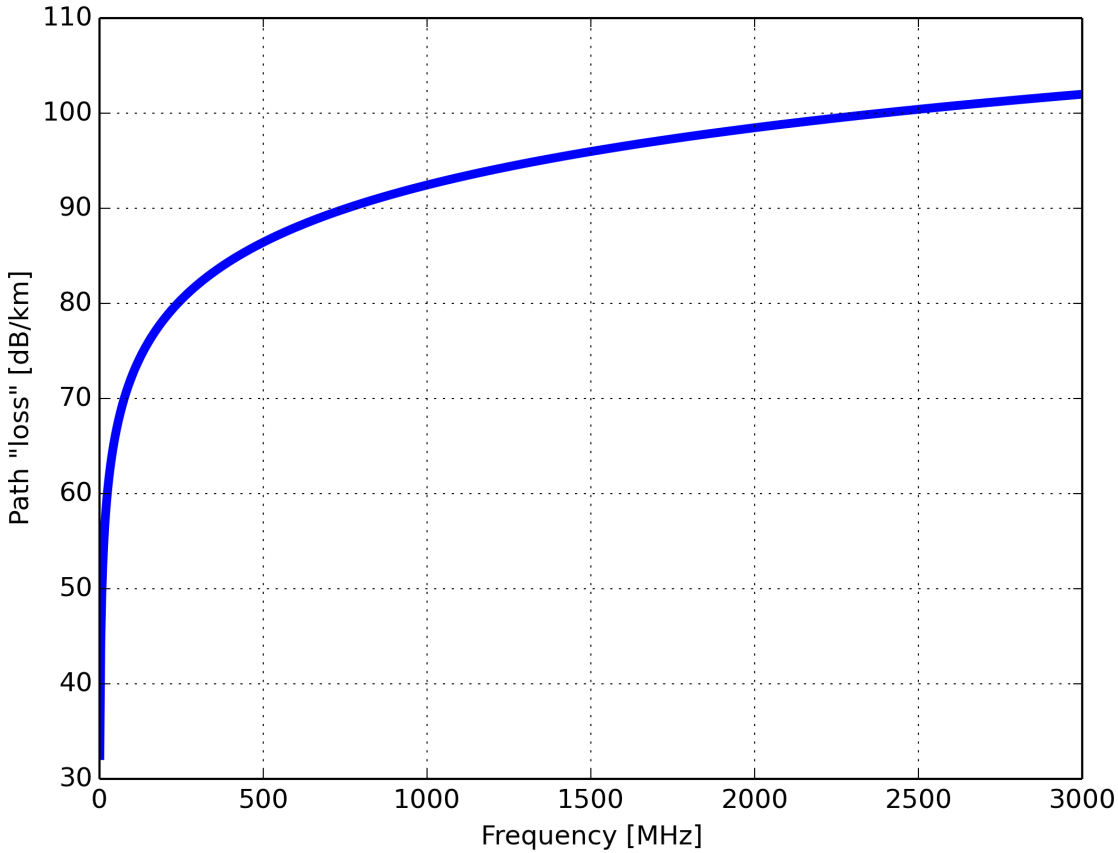


Figure 2-2: Frequency spectra for single corona current pulses (from equation 2.5)

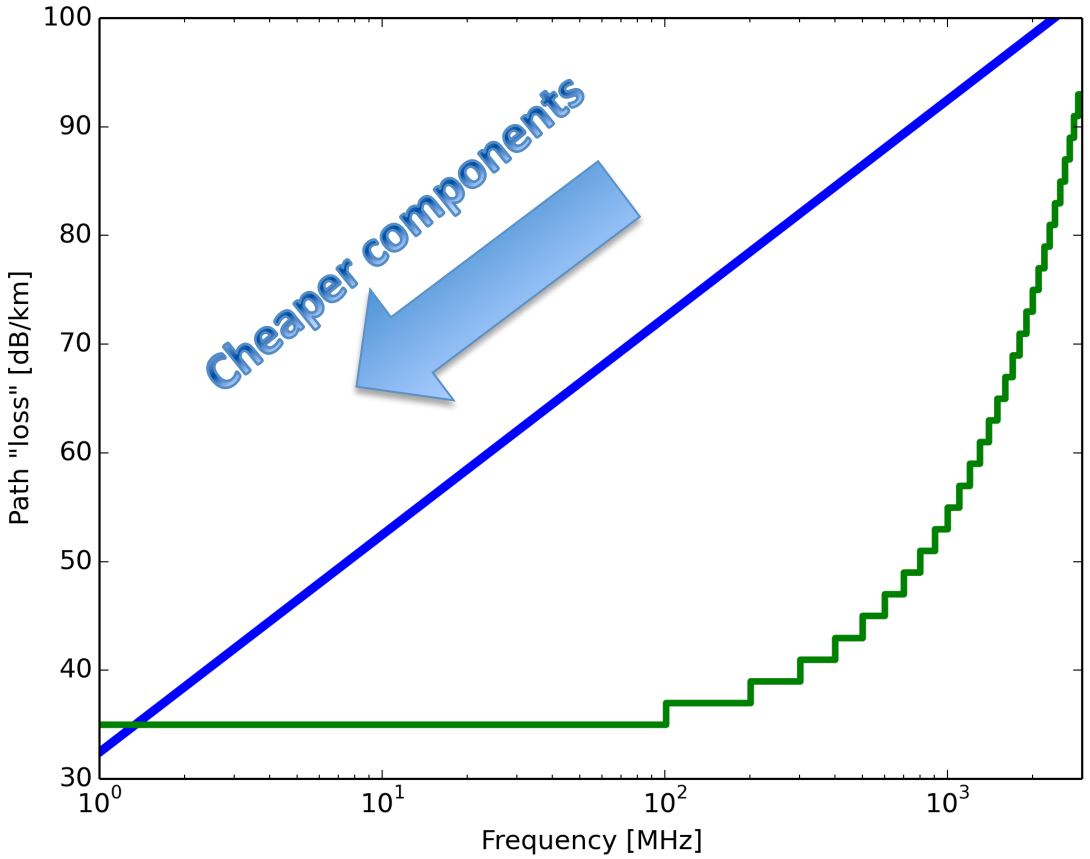
Langet 2011

The Reasons

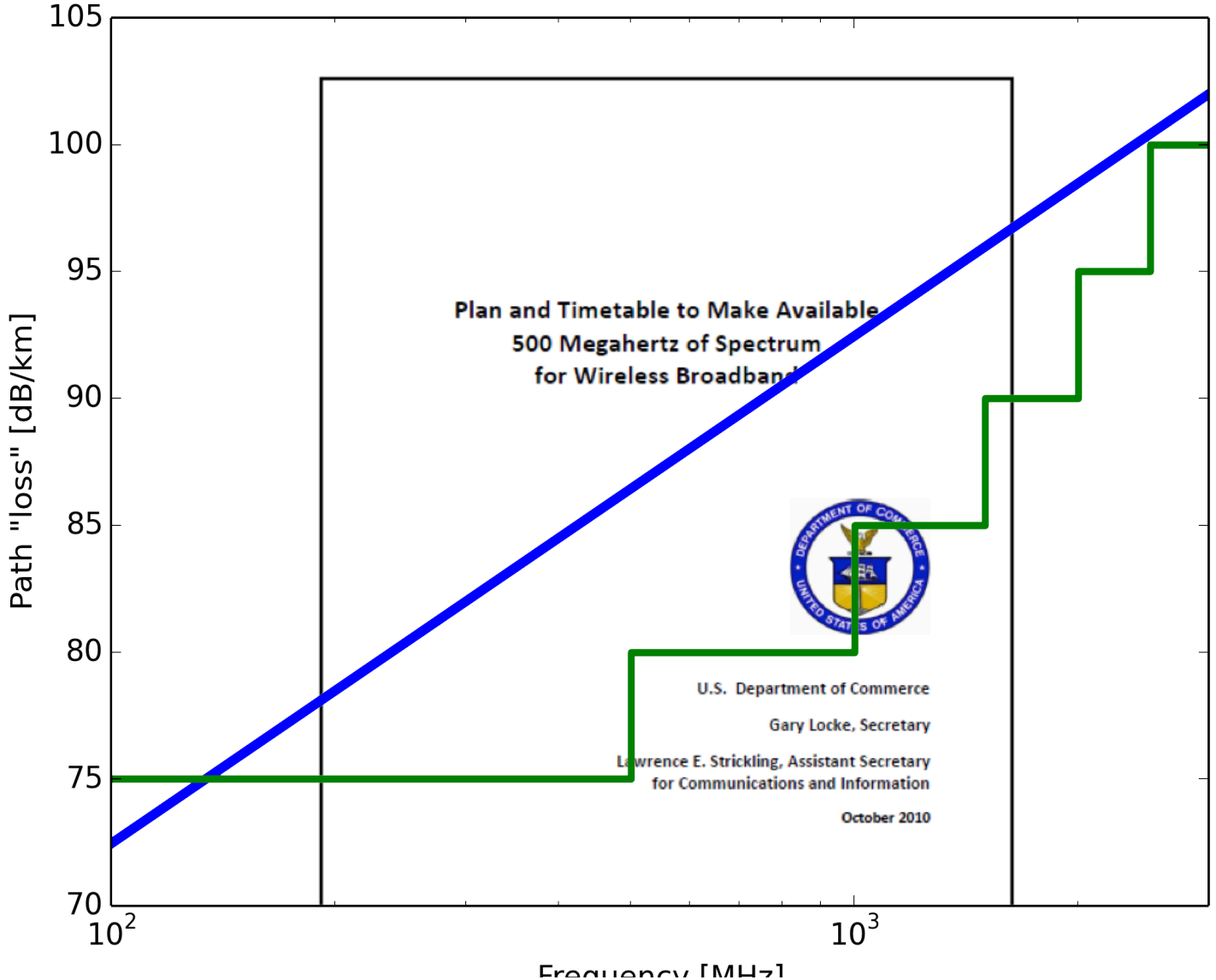
The broadcast “problem”



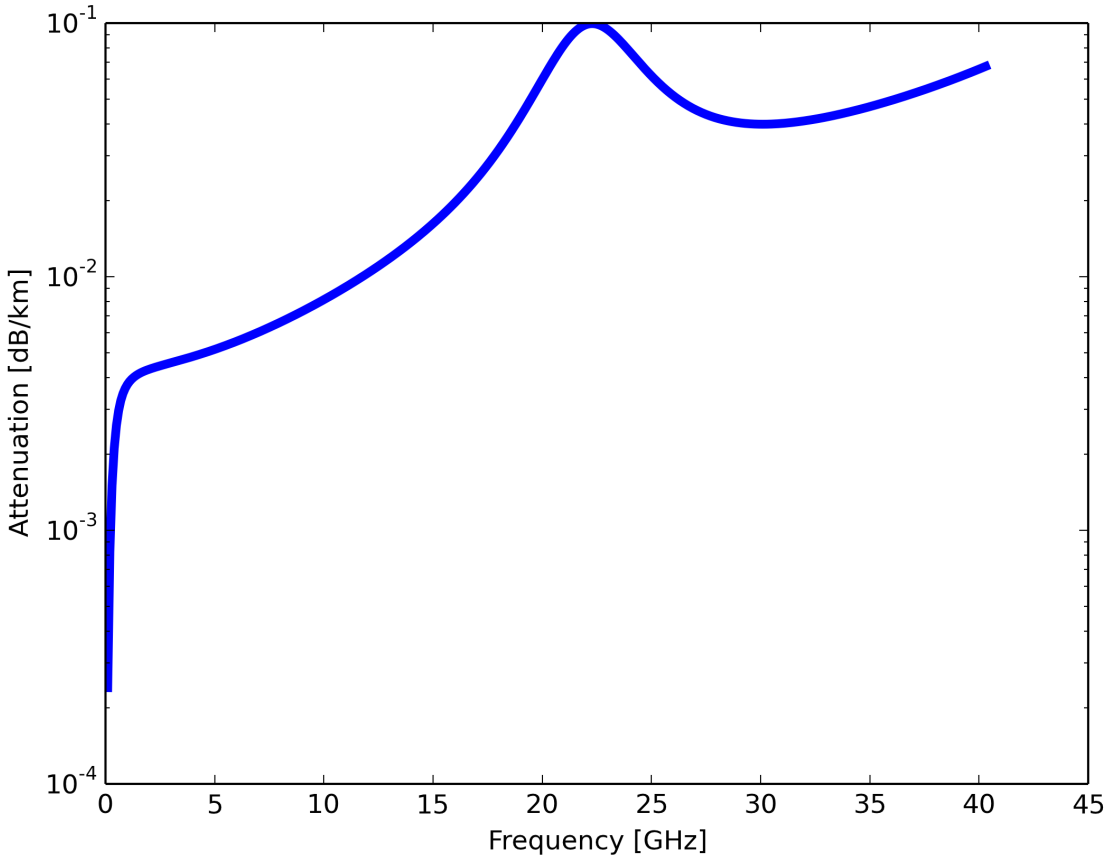
The Reasons


Cheaper components
Path "loss" [dB/km]
Frequency [MHz]
100
90
80
70
60
50
40
30
10^0
10^1
10^2
10^3

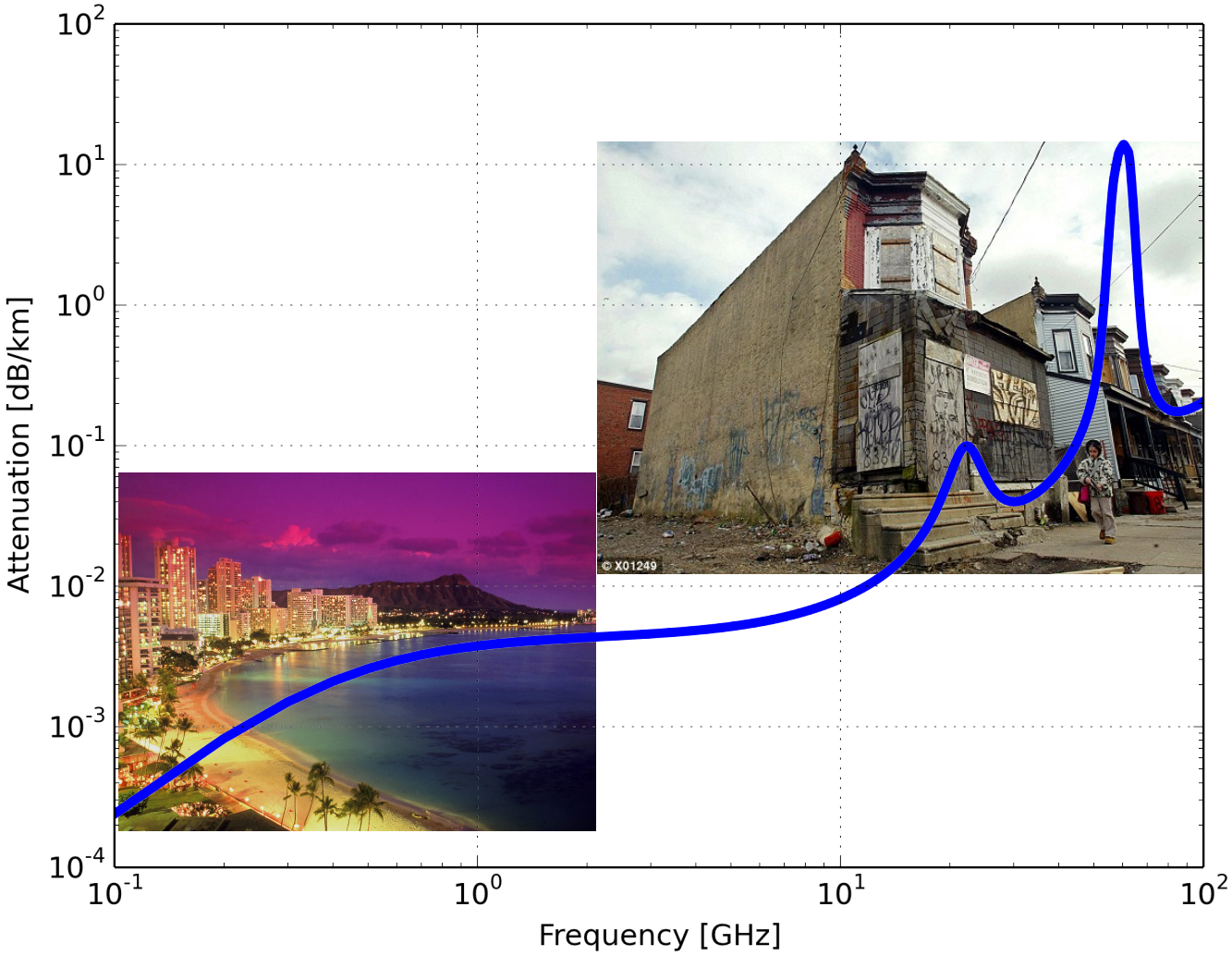
They Want It


105
100
95
90
85
80
75
70
Path "loss" [dB/km]
10^2
10^3
Plan and Timetable to Make Available
500 Megahertz of Spectrum
for Wireless Broadband
U.S. Department of Commerce
Gary Locke, Secretary
Lawrence E. Strickling, Assistant Secretary
for Communications and Information
October 2010

More Reasons

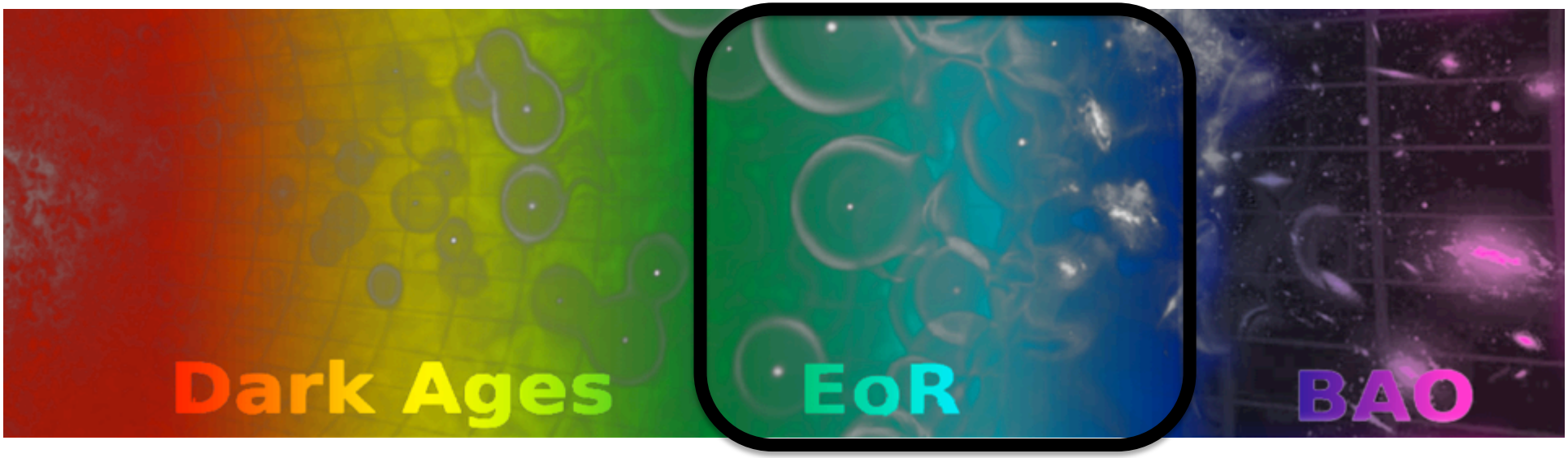


More Reasons



21cm EoR Science Goals

- Probing the history of the Universe via the 21cm emission from HI
- Focus primarily on the Epoch of Reionization (EoR)
- Key Questions:
  - What objects first lit up the Universe and reionized the neutral IGM?
  - Over what redshift range did this occur?
  - How did the process proceed (wrt heating, feedback, scale-dependence)?
  - How did this lead to the large scale galaxy structure seen today?

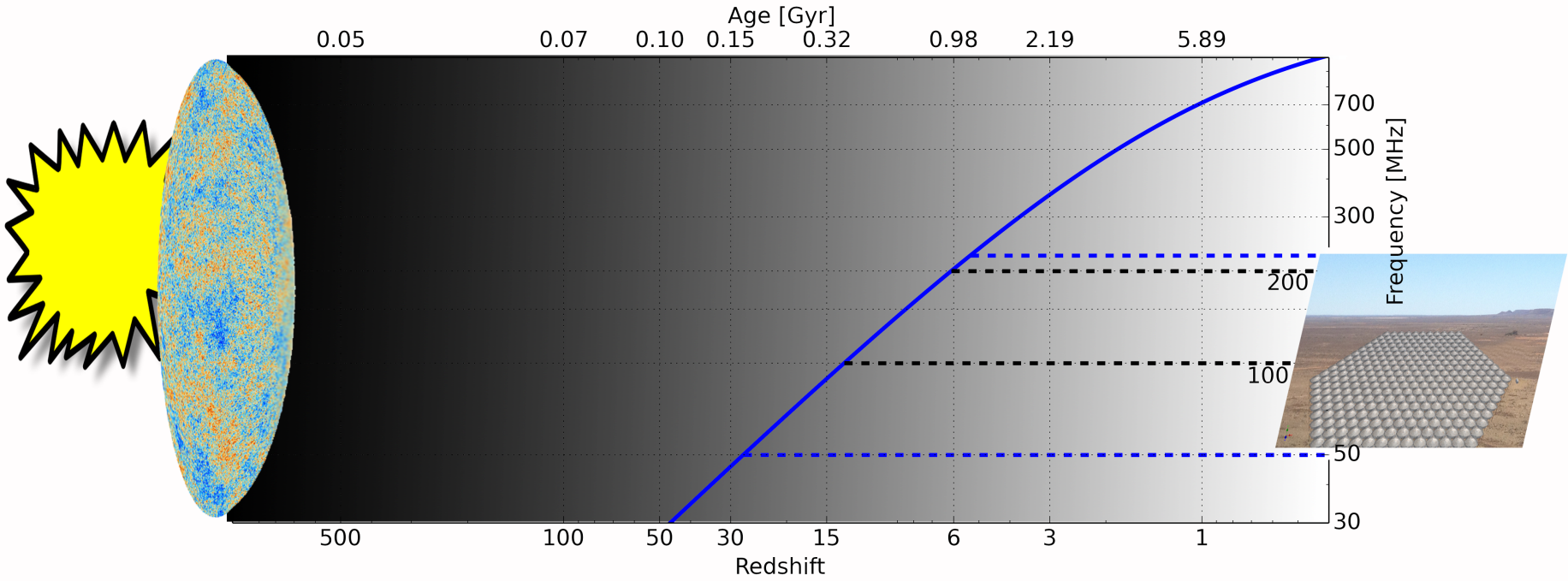


z = 100 to 20
15 to 70 MHz

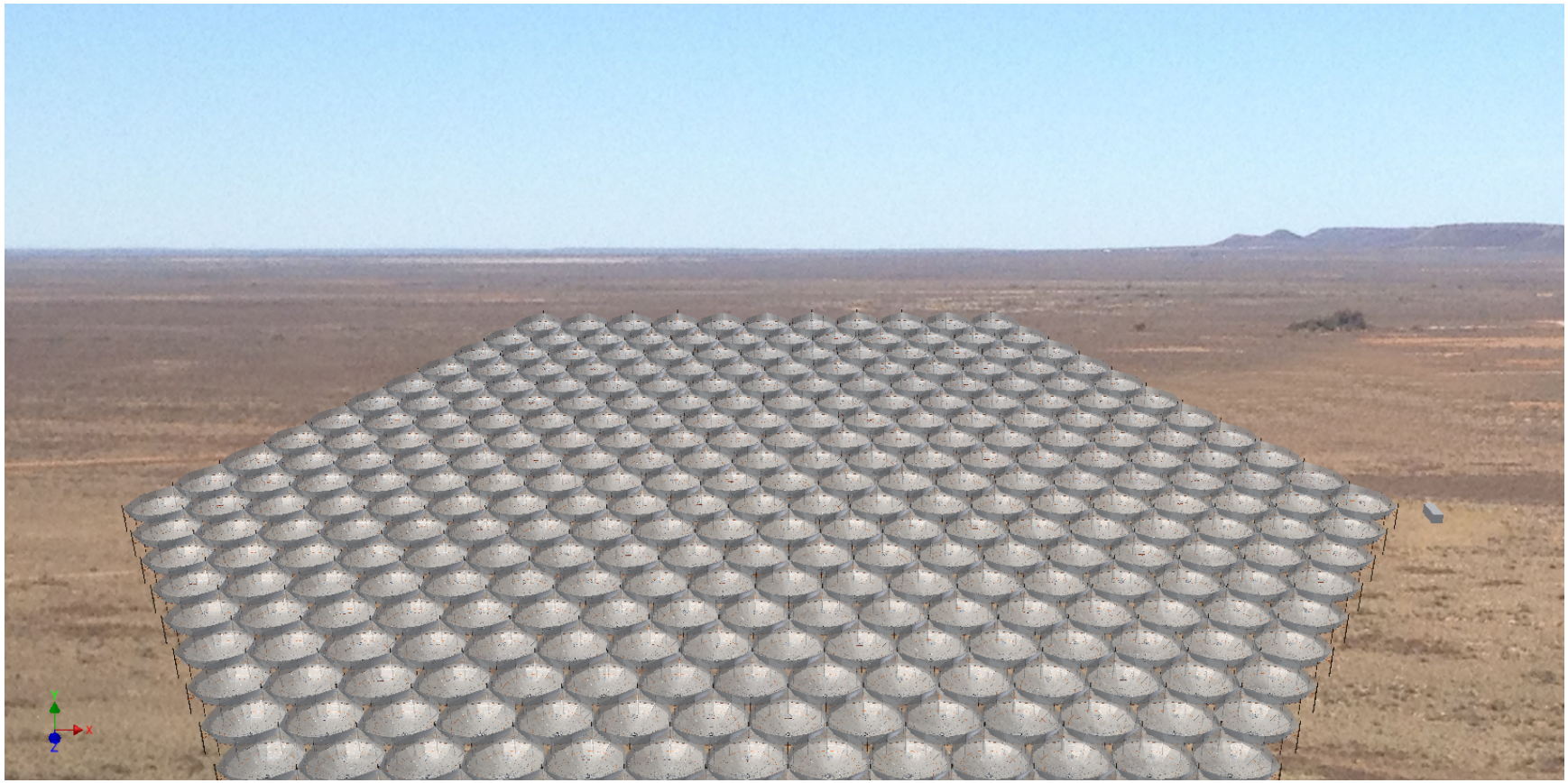
z = 20 to 5
70 to 240 MHz

z = 5 to 0
240 to 1400 MHz

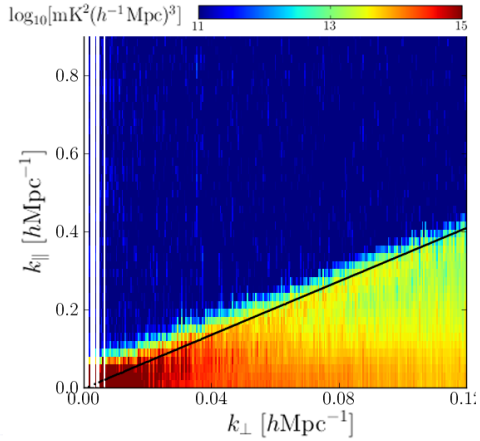
Why We Care

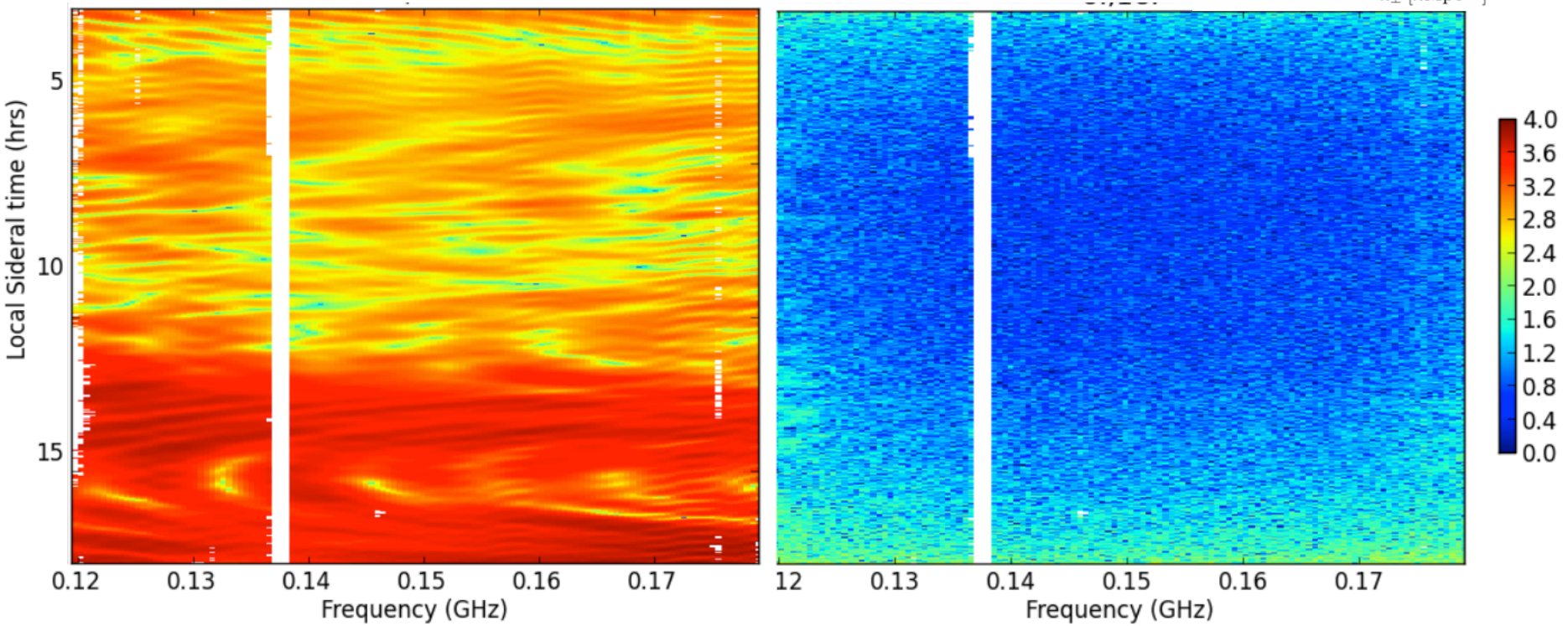

Age [Gyr]
0.05
0.07
0.10
0.15
0.32
0.98
2.19
5.89
700
500
300
200
100
50
30
Frequency [MHz]
500
100
50
30
15
6
3
1
Redshift

Why We Care



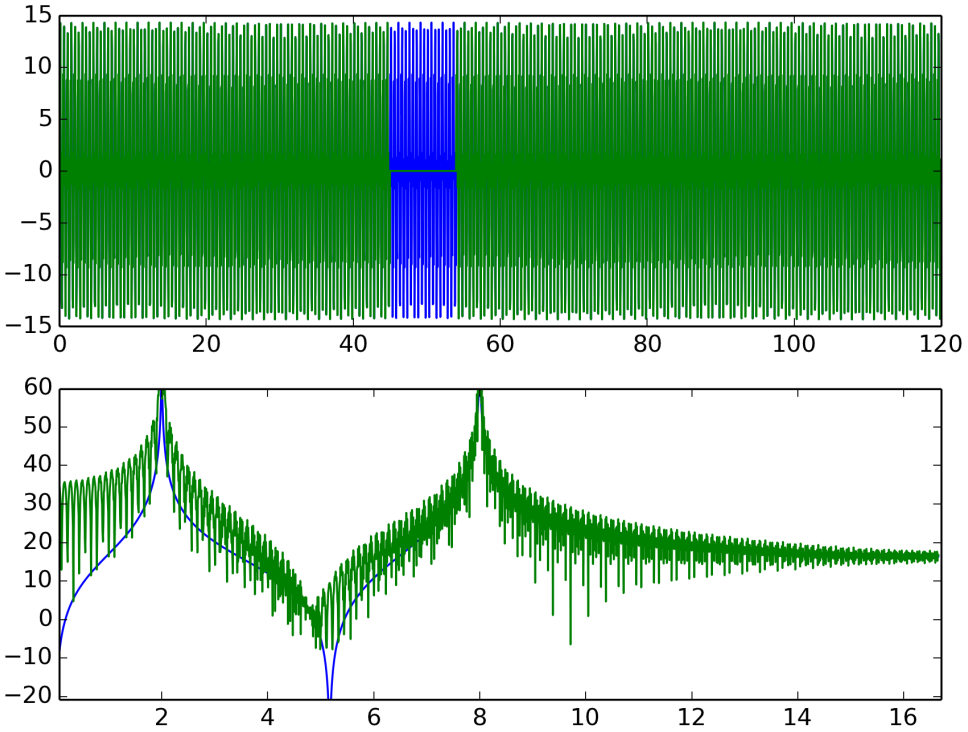
Impact of the Wedge

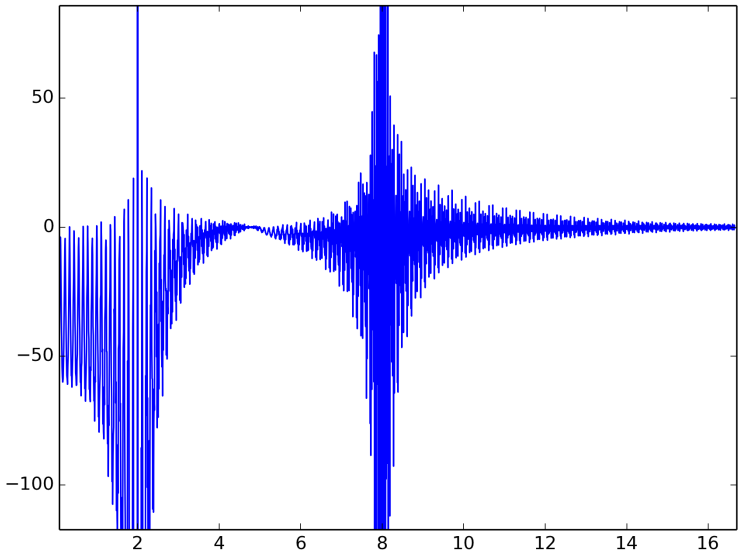




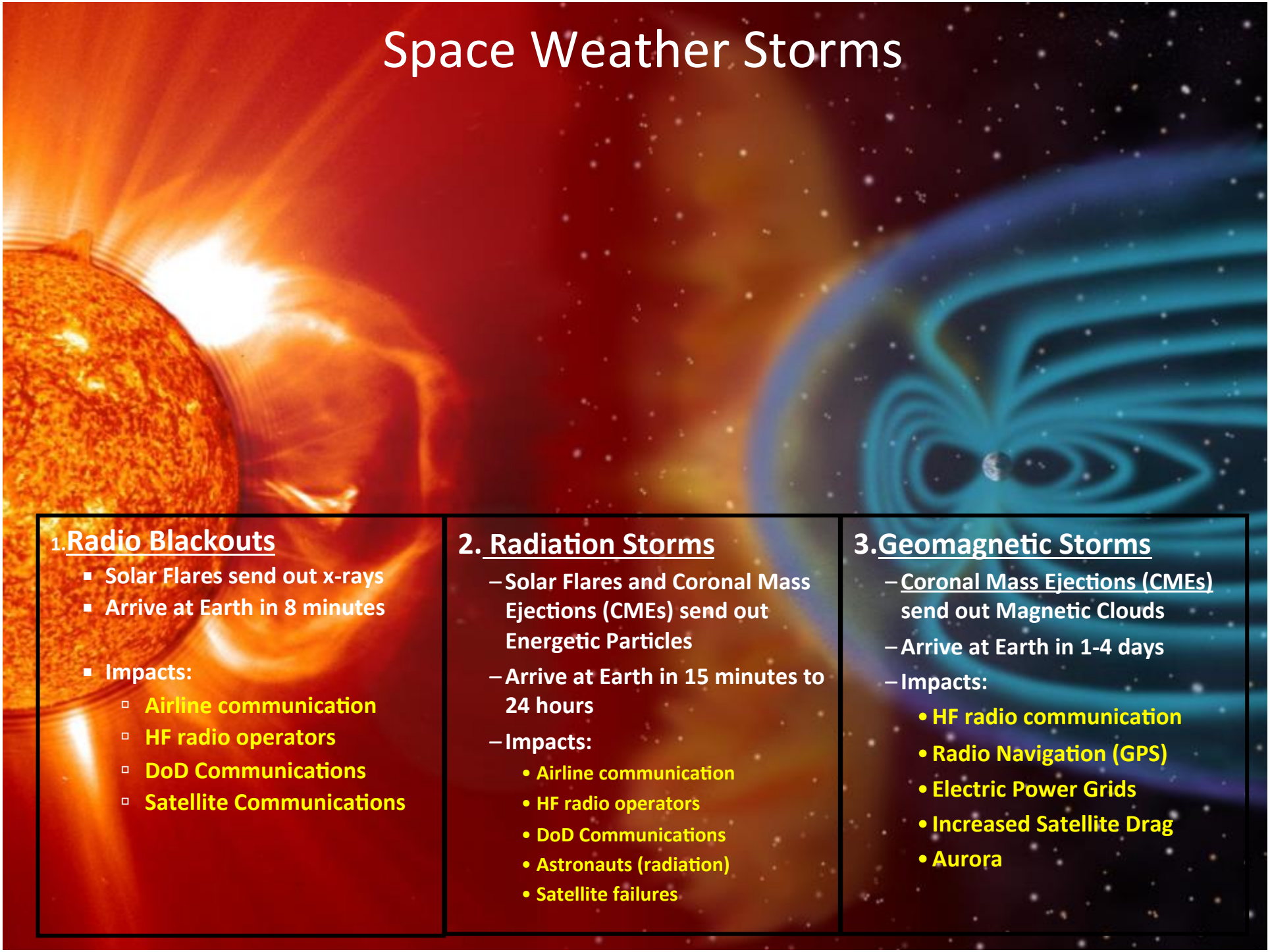
Other Effects

- Power spectrum ripple from RFI flagging





Space Weather Storms



1. Radio Blackouts

- Solar Flares send out x-rays
- Arrive at Earth in 8 minutes
- Impacts:
  - Airline communication
  - HF radio operators
  - DoD Communications
  - Satellite Communications

2. Radiation Storms

- Solar Flares and Coronal Mass Ejections (CMEs) send out Energetic Particles
- Arrive at Earth in 15 minutes to 24 hours
- Impacts:
  - Airline communication
  - HF radio operators
  - DoD Communications
  - Astronauts (radiation)
  - Satellite failures

3. Geomagnetic Storms

- Coronal Mass Ejections (CMEs) send out Magnetic Clouds
- Arrive at Earth in 1-4 days
- Impacts:
  - HF radio communication
  - Radio Navigation (GPS)
  - Electric Power Grids
  - Increased Satellite Drag
  - Aurora

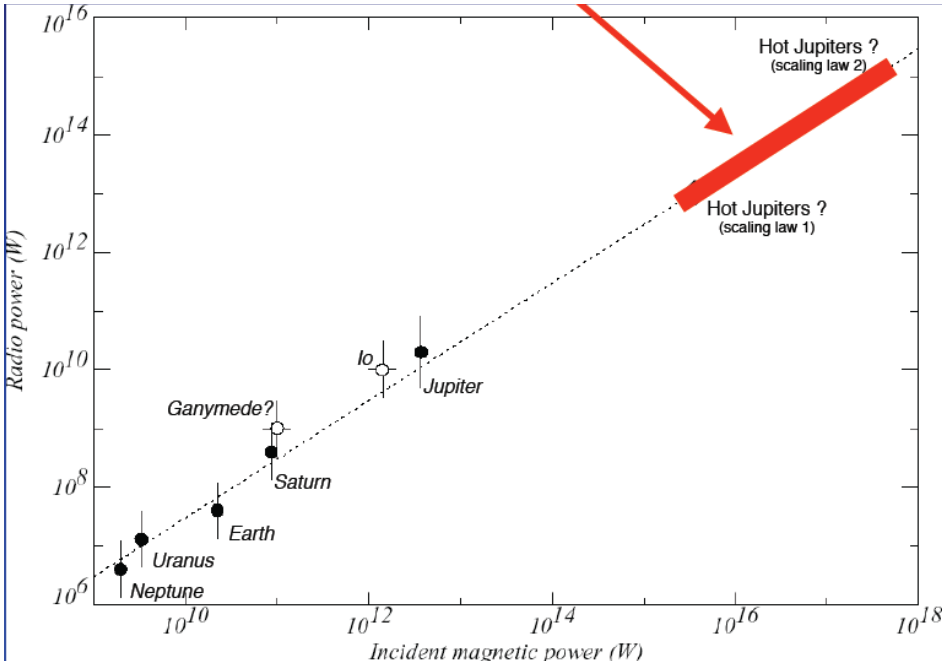
March 1989
Hydro Quebec Loses Electric Power for 9 Hours

Radiometric Bode's Law

- Jupiter at 5pc would have average flux of 20 μJy and 0.2 mJy when active – some S bursts up to 20 mJy

- 'Hot Jupiters' with expected radio luminosities many thousands of times brighter than Jupiter

- 100s of mJy predicted in some case



Zarka et al, ApSS. 2001

Why look for radio emission from exoplanets?

- It's a direct detection

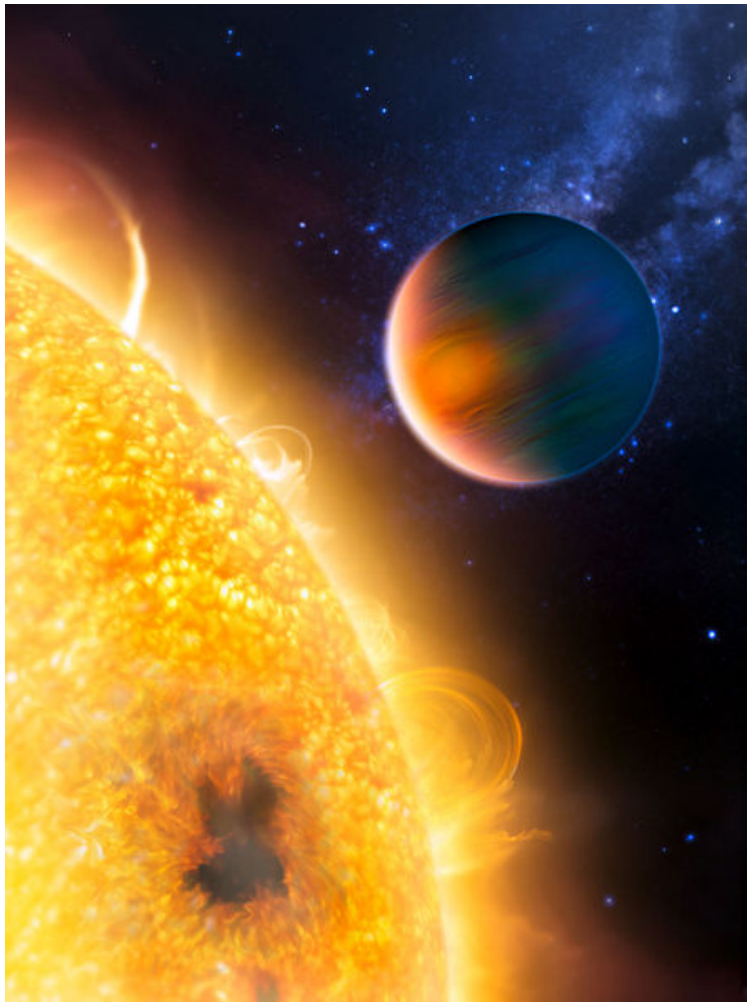
- Allows measurement of rotation rate

- Possible use as a detection method for exoplanets

- The only method currently viable for measurement of magnetic field strengths for exoplanets...

a) Leads to constraints on scaling laws based on magnetic fields of solar system planets

b) Provides insight into internal structure of planet.



To Thine Ownself Be RFI True

- Packaging/system integration
  - Grounding
  - Shielding
  - Matching
  - Filtering
- Good engineering on power supplies and clocks

KEEP

Collaboration

llocation

ocation

itigation