Harmful Levels of RFI

or

Topics in What Hurts about RFI

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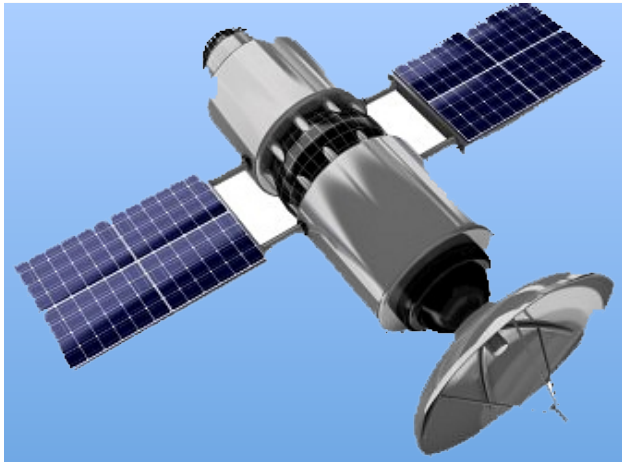
The Take Home

- Everything radiates
- There is no such thing as a linear device
- There are no such things as resistors, capacitors and inductors – only (non-linear) RLC circuits
- Packaging is usually the answer
  - shielding, grounding, matching, filtering
- Find it/flag it

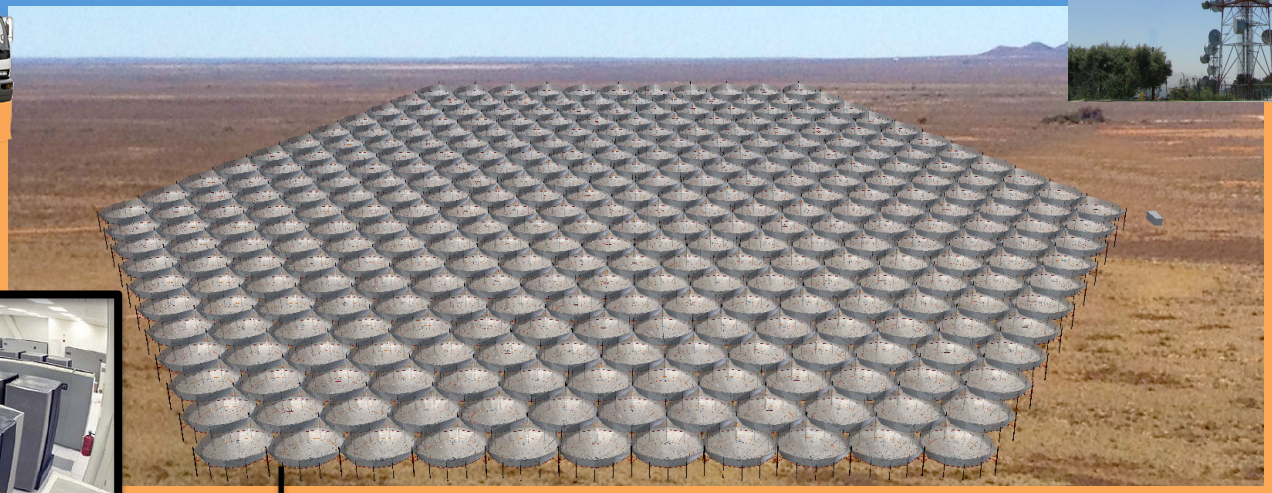
Bands

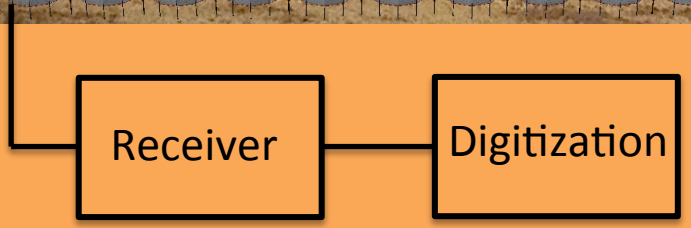
Band	Range	Origin
HF	3 – 30 MHz	**H**igh **F**requency
VHF	30 – 300 MHz	**V**ery **H**igh **F**requency
UHF	300 – 1000 MHz	**U**ltra **H**igh **F**requency
L	1 – 2 GHz	**L**ong wave
S	2 – 4 GHz	**S**hort wave
C	4 – 8 GHz	**C**ompromise between S and X
X	8 – 12 GHz	Cross-hairs **X**
Ku	12 – 18 GHz	**K**urz – **u**nder (>10.7 satellites)
K	18 – 26.5	**K**urz (short) (water)
Ka	26.5 – 40	**K**urz - **a**bove
V (Q/U/E…)	40 – 75	WG bands (oxygen)
W	75 – 110	(W follows V)

The Issues



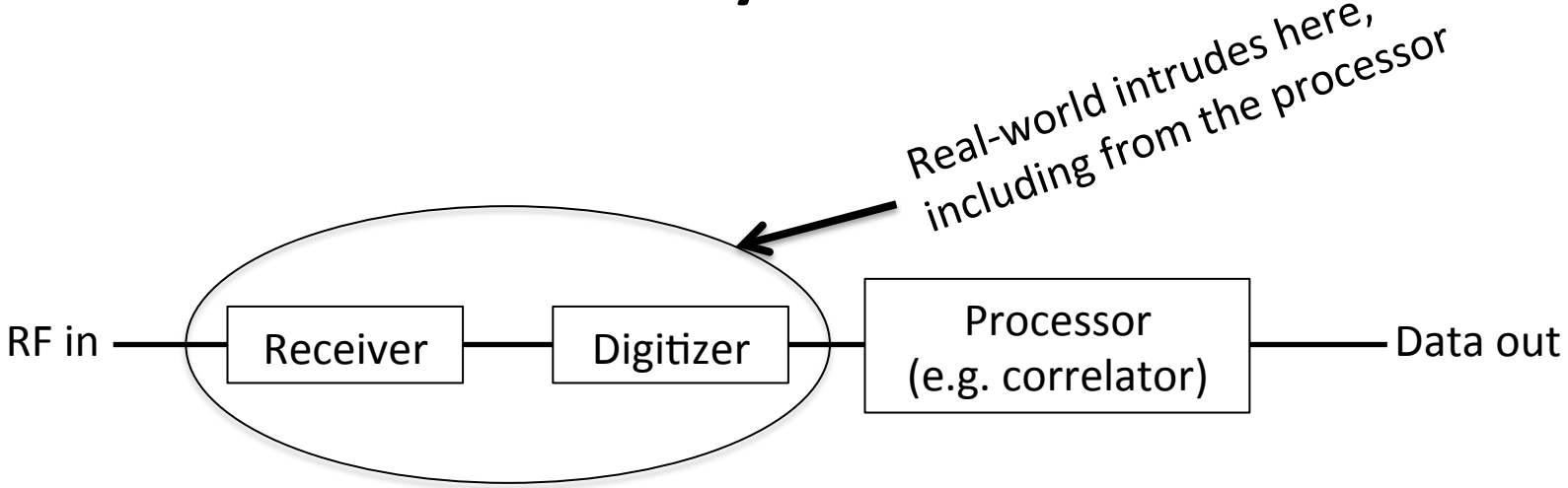
Obscuration/interruption





Non-linearities

System

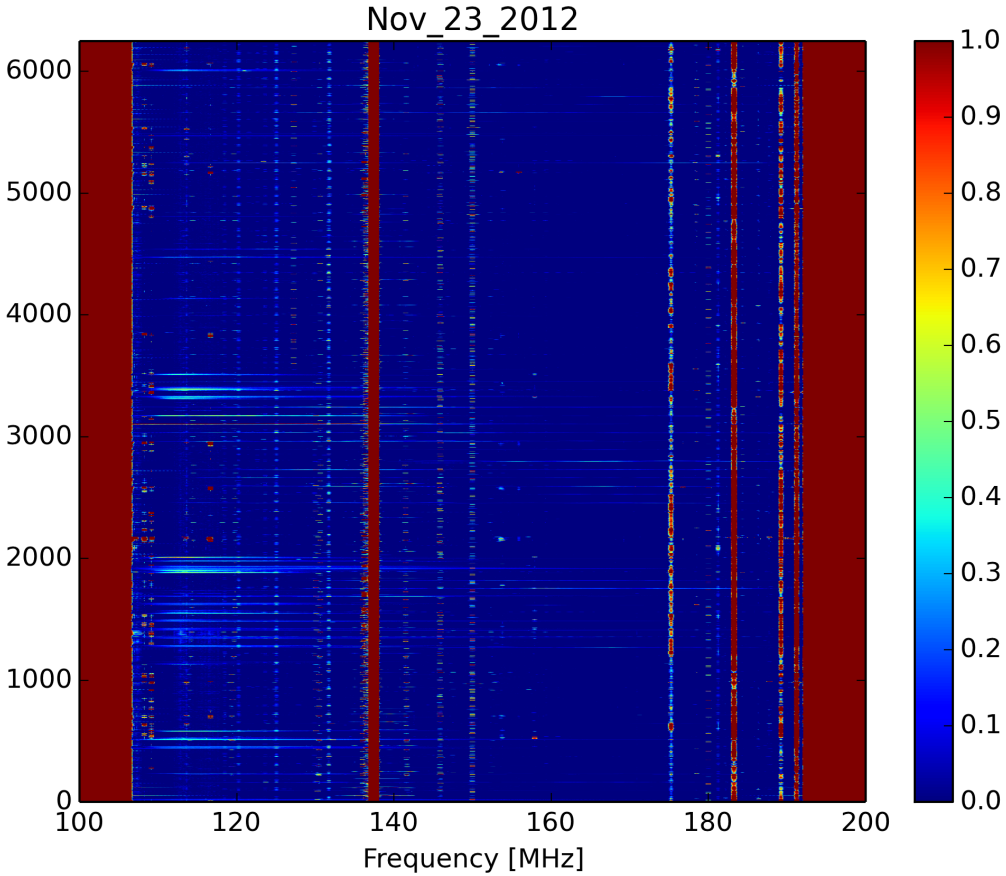


- Data is a number per recorded time interval and frequency channel indexed somehow and stored in a file.
- These are looked at to determine whether they are usable or not (flagging).
- If you can detect it and flag it (and there isn't too much of it) it is not viewed as "harmful".
- Otherwise it is.

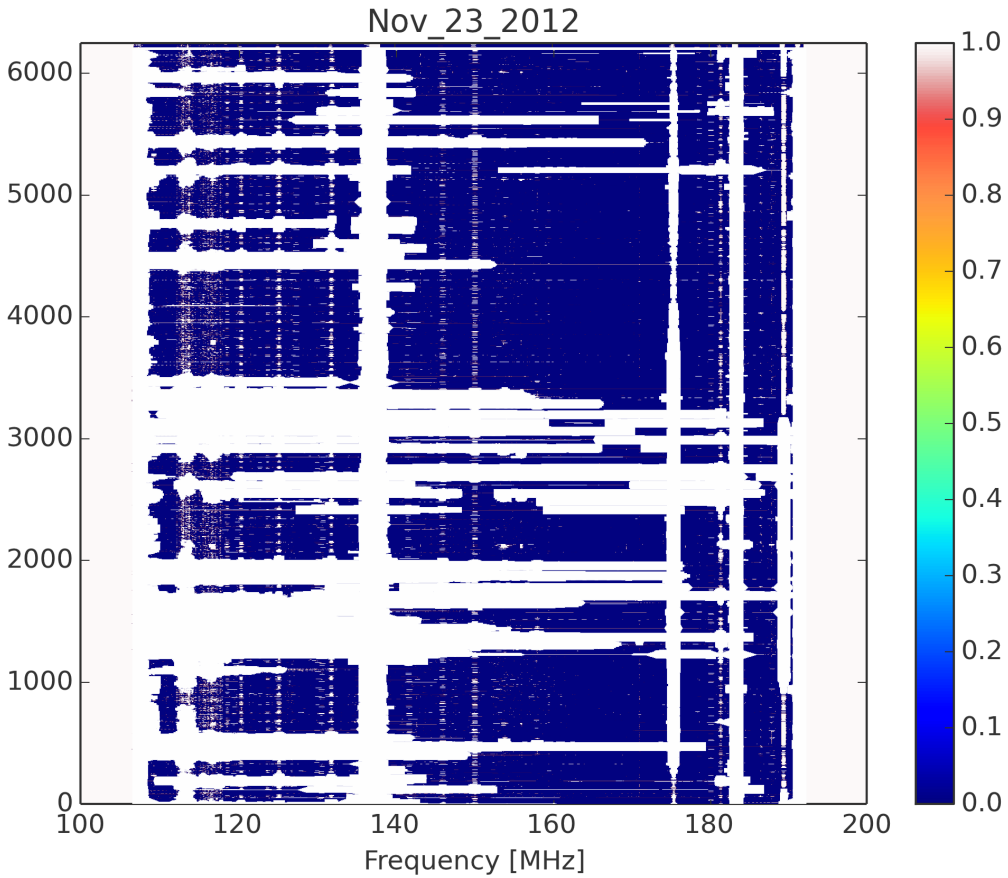
Power Level Regimes

- **Large** – saturates receiver/digitizer such that the data are not usable over the band.
  - You'll need to talk to the interferer or maybe can handle it via a major system change or moving.
- **Medium** – eliminates a small-ish subset of channels and/or over a limited time.
  - Flag and maybe improve system (more channels, faster dump time, more bits, …).
- **Small** – is somewhere buried in there and may be confused with signal.
  - Higher good graduate students.

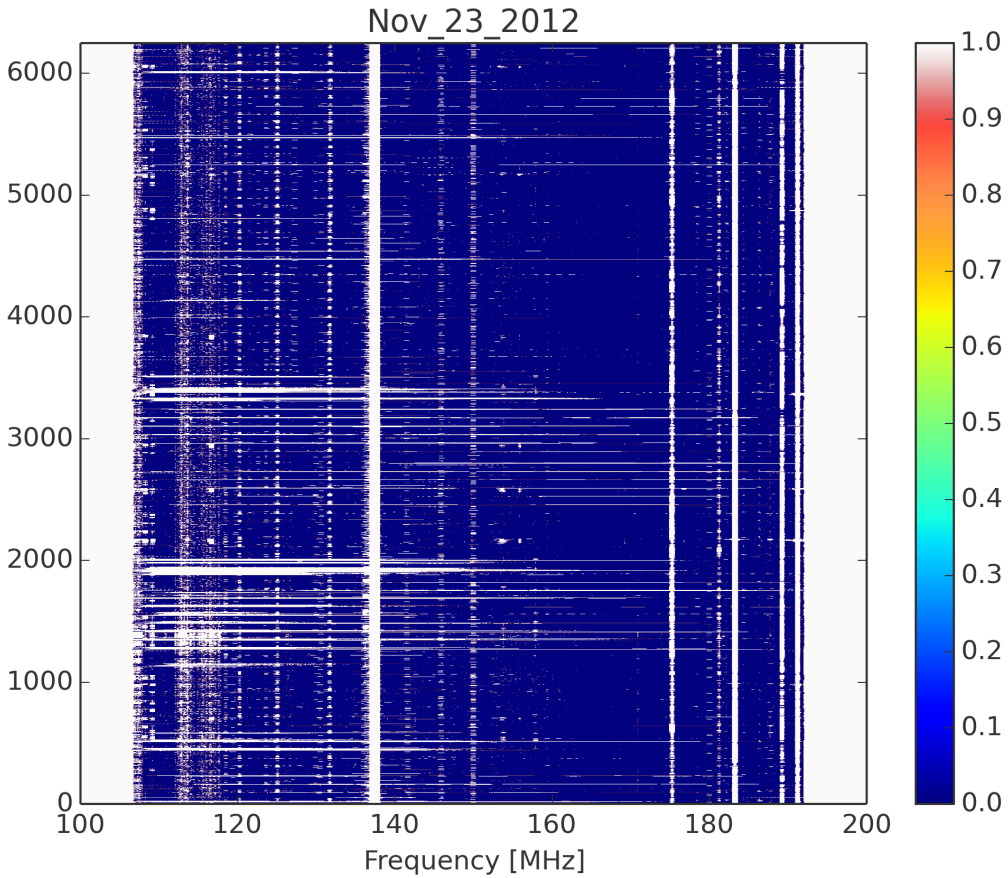
A Nice Waterfall



Flagging


Nov_23_2012
6000
5000
4000
3000
2000
1000
0
100
120
140
160
180
200
Frequency [MHz]
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

Flagging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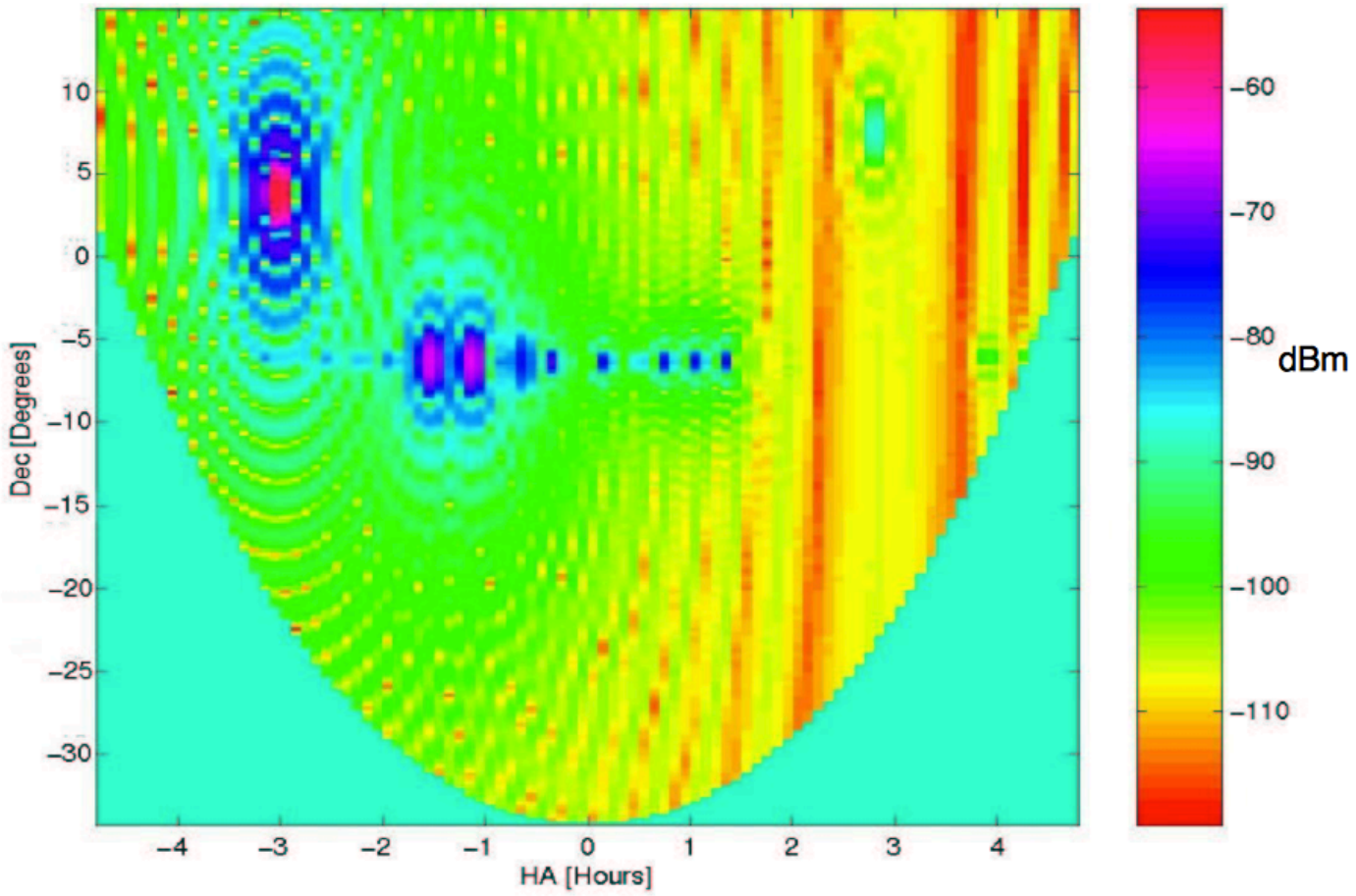
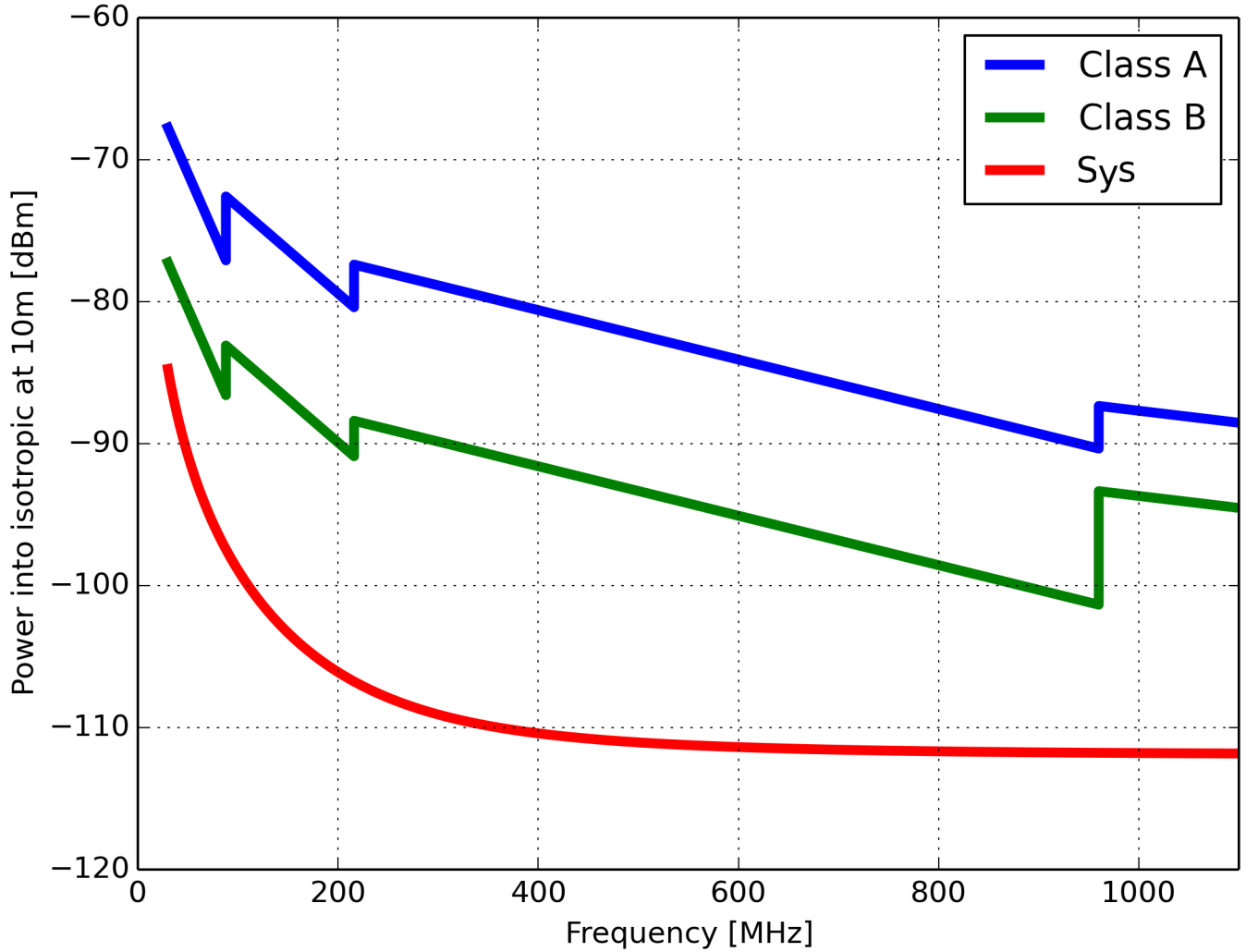
The Satellite Sky



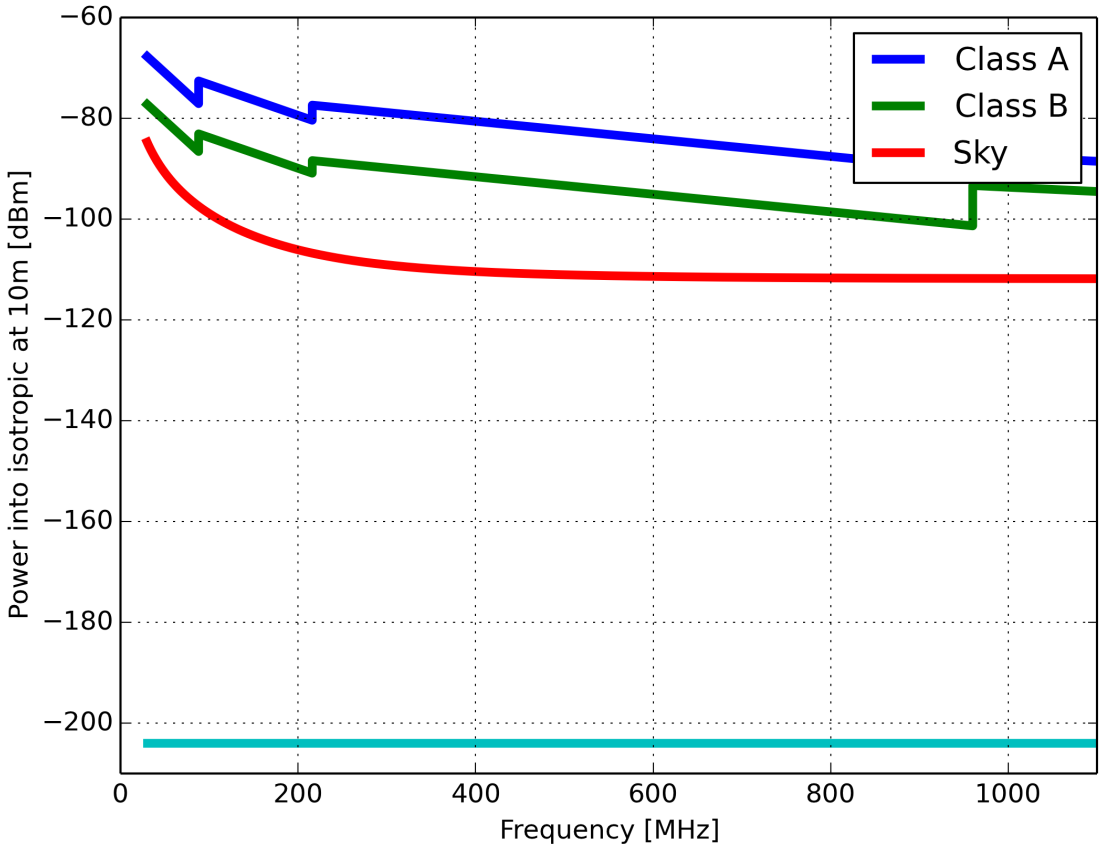
The Satellite Sky

Table I

		GPS	Iridium	Satellite radio	Radarsat
Power density (dBm/m^2)		-95	-60	-76	0
MB	**Power available at LNA (dBm)**	-83	-48	-64	+12
	Dynamic range (dB)	2.5	34	18	!!!
	Source equivalent in 11 GHz band	2.9 kJy 140 Hyd A	9MJy 3.5 Quiet Suns	230 kJy 212 Cas A	9 TJy 39k Active Suns
10dBi	**Power available at LNA (dBm)**	-110	-75	-91	-26
	Source equivalent in 11 GHz band	5 Jy	16 kJy 15 Cas A	455 Jy 5 Vir A	13 MJy 6 Active Suns


−60
−70
−80
−90
−100
−110
−120
0
200
400
600
800
1000
Power into isotropic at 10m [dBm]
Frequency [MHz]
Class A
Class B
Sys

Part 15 Devices



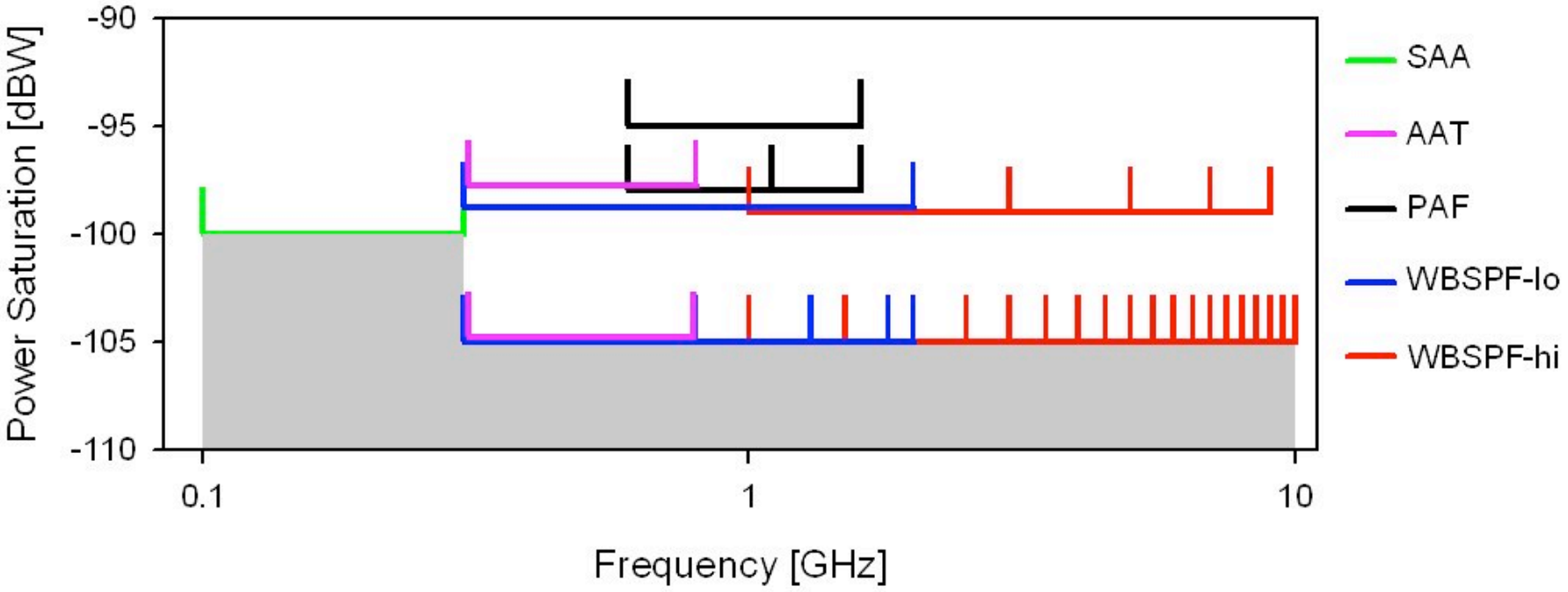
- http://www.arrl.org/part-15-radio-frequency-devices

What Happens to that Power?

- **Nonlinearities [LNA, mixer and gain stages]**
  - Intermodulation cross products from interferers
    - [i.e. |N*F1 +/- M*F2|]
  - Cross-modulation of interferer envelope onto the desired signal
  - Dynamic range reduction from saturation driven gain change
  - Dynamic range reduction due to elevated noise level due to reciprocal mixing
  - Variation to conversion loss and spurious generation due to mixer asymmetry
- **ADC quantization and non-idealities**
  - Spectral variation due to differential and integral ADC nonlinearities
  - Frequency response variation due to slew rate limiting
  - Input match variation as signal magnitudes transition from the small signal to large signal regimes for the sample and hold input stage
  - Effective number of bits [ENOB]
- **RF over fibre characteristics**
  - Random Intensity Noise [RIN] and high level optical nonlinearities within the sources, detectors and transport medium limit available dynamic range
  - Amplitude/Phase stability with fibre deformation [flexure] and recovery
  - Amplitude/Phase stability with differentials and changes in temperature

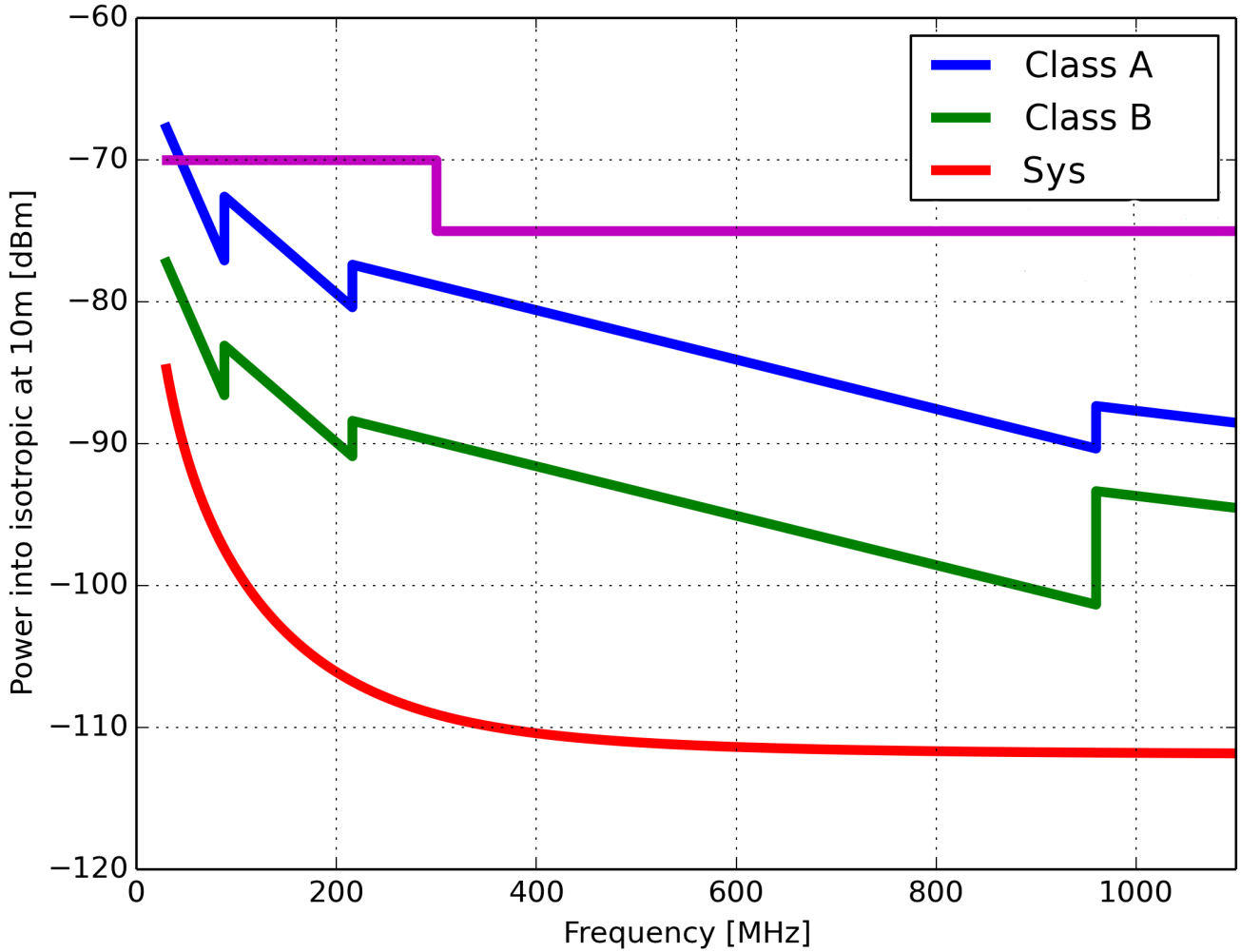
Saturation Levels

Limit harmonic power relative to the total system power



Operate >~35 dB below the system 1% compression point (Perley 2004, EVLA Memo 82)

Levels


Class A
Class B
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−70
−80
−90
−100
−110
−120
0
200
400
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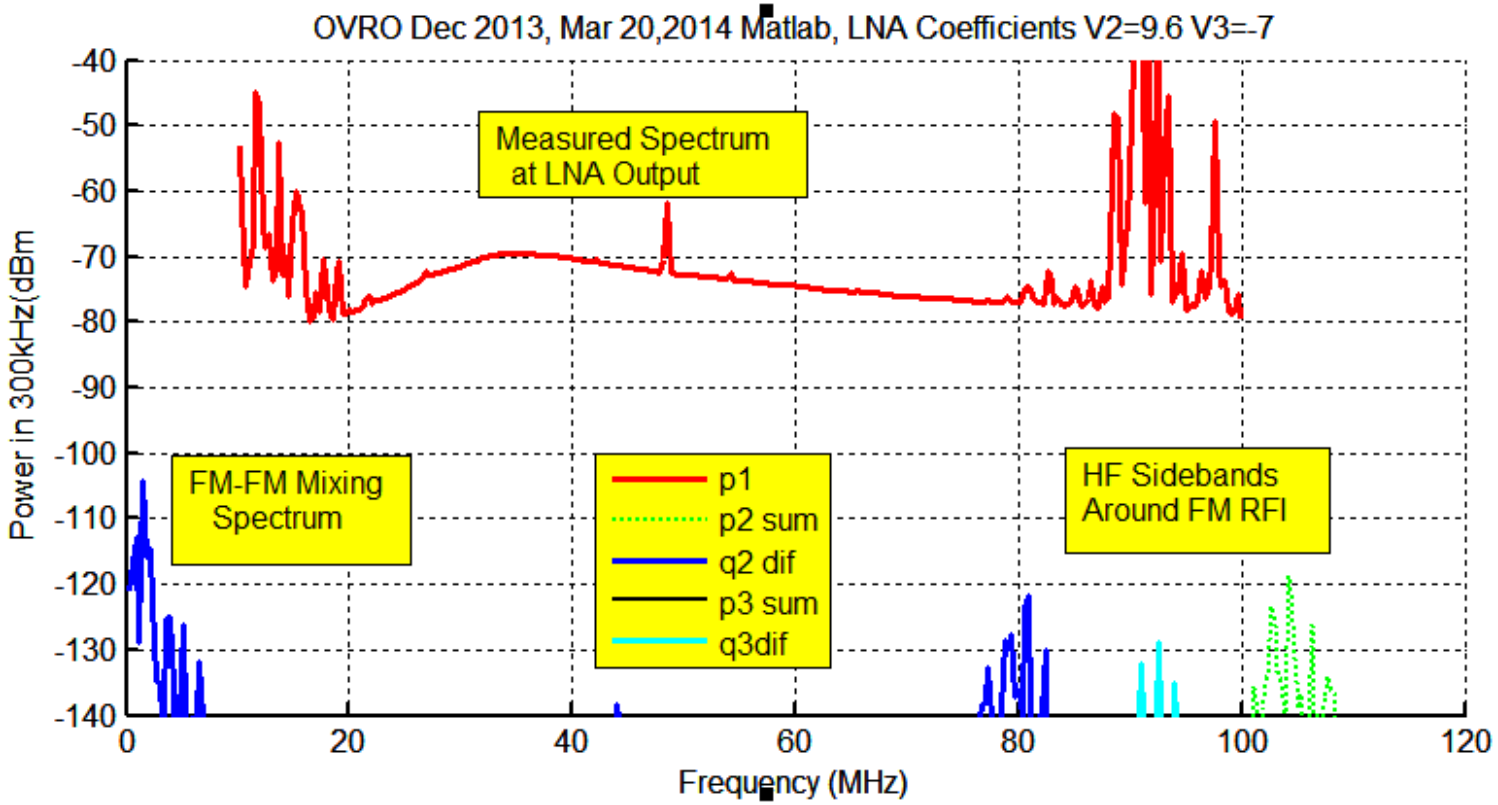
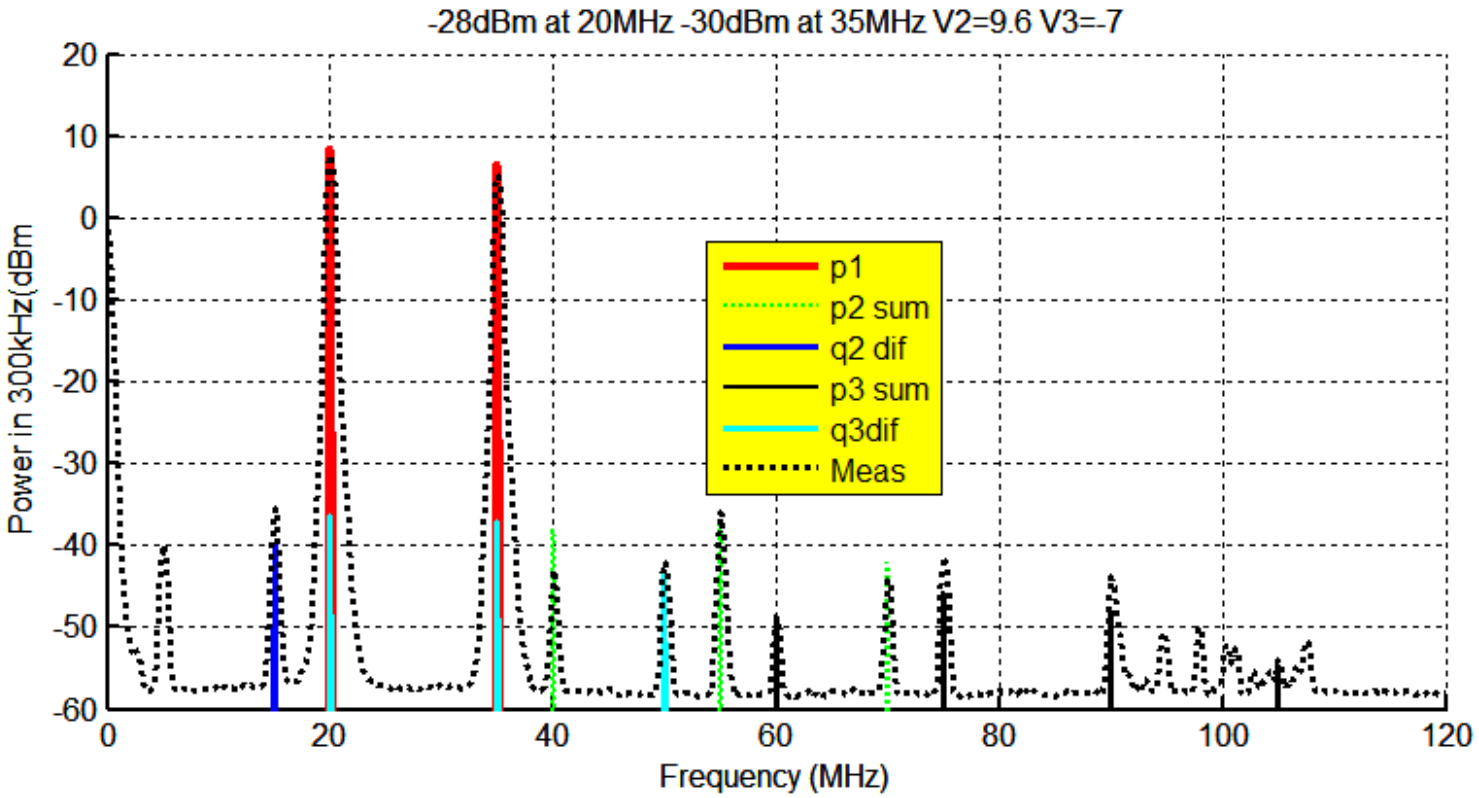
800
1000
Power into isotropic at 10m [dBm]
Frequency [MHz]

Out-of-Band Mixing



Mixing Tests



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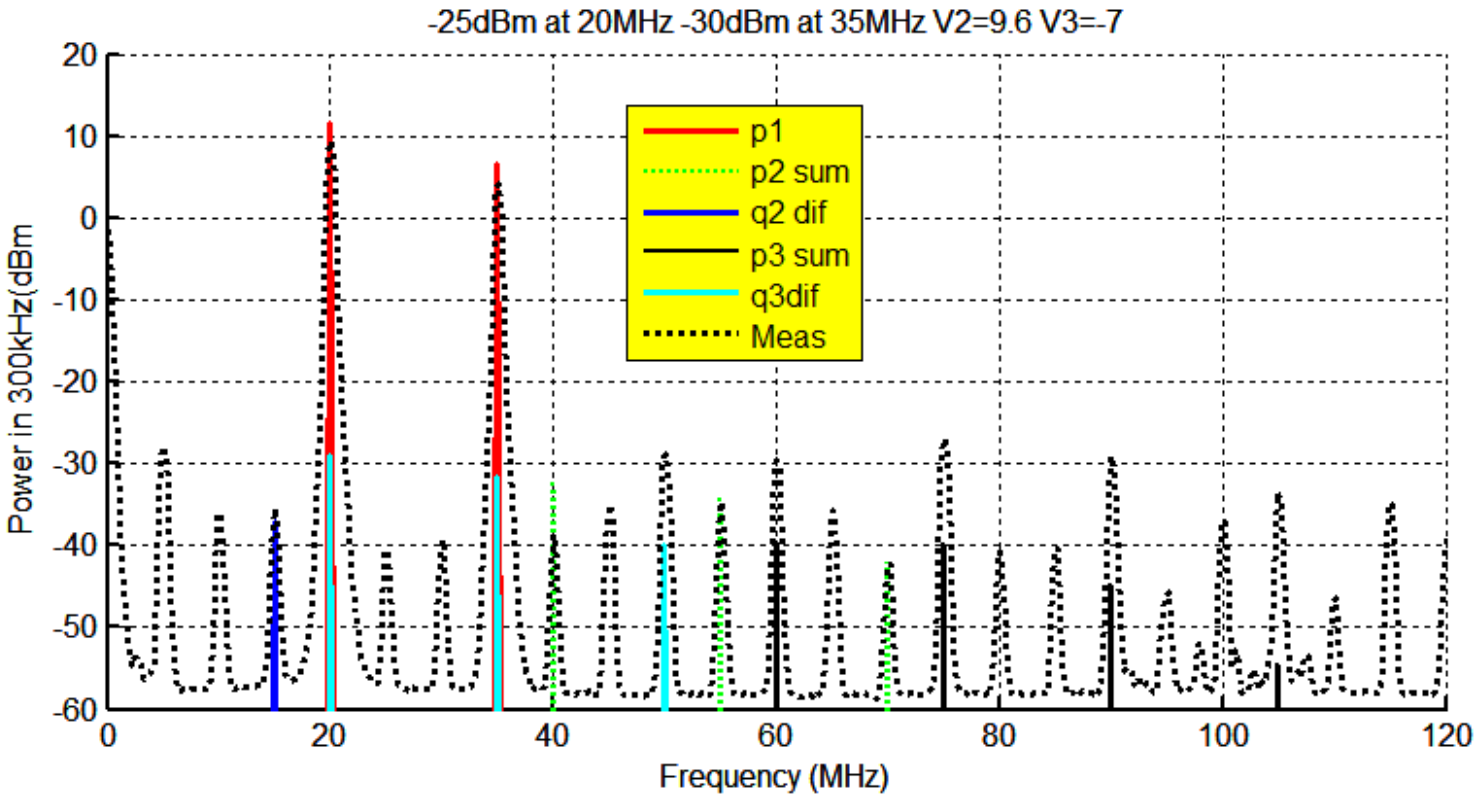
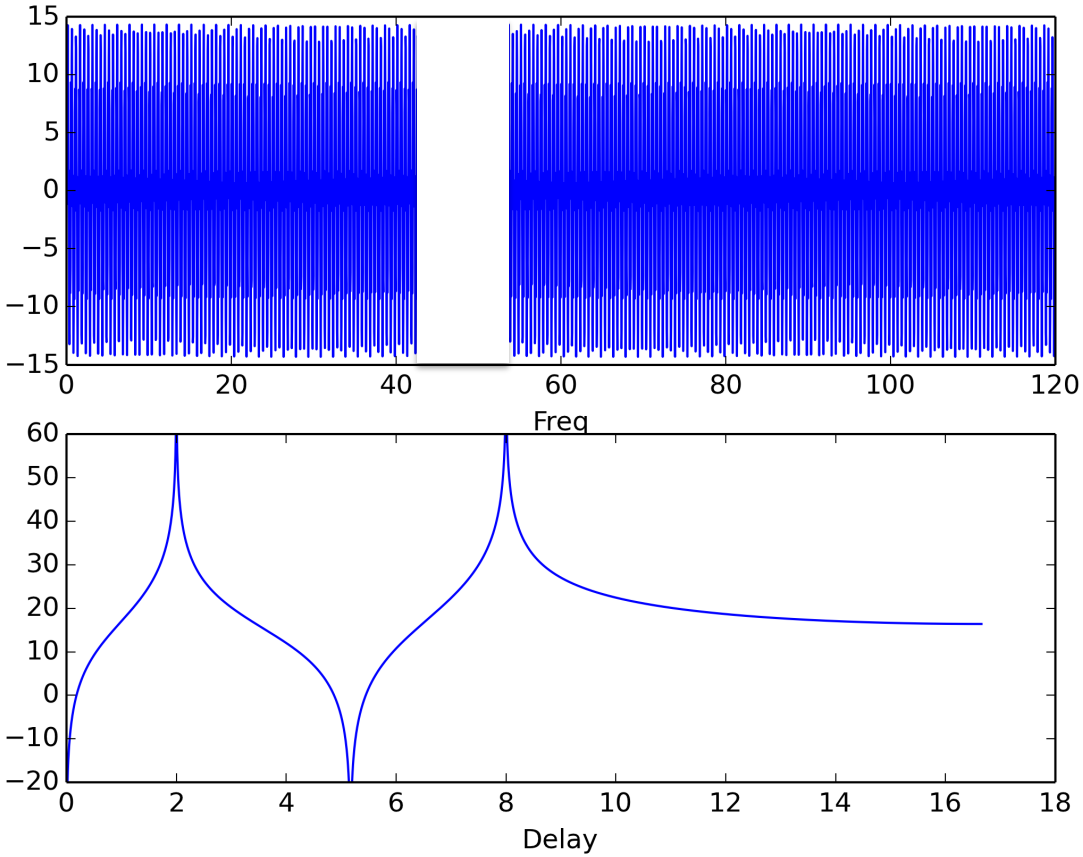


Other Effects

- Power spectrum ripple from RFI flagging



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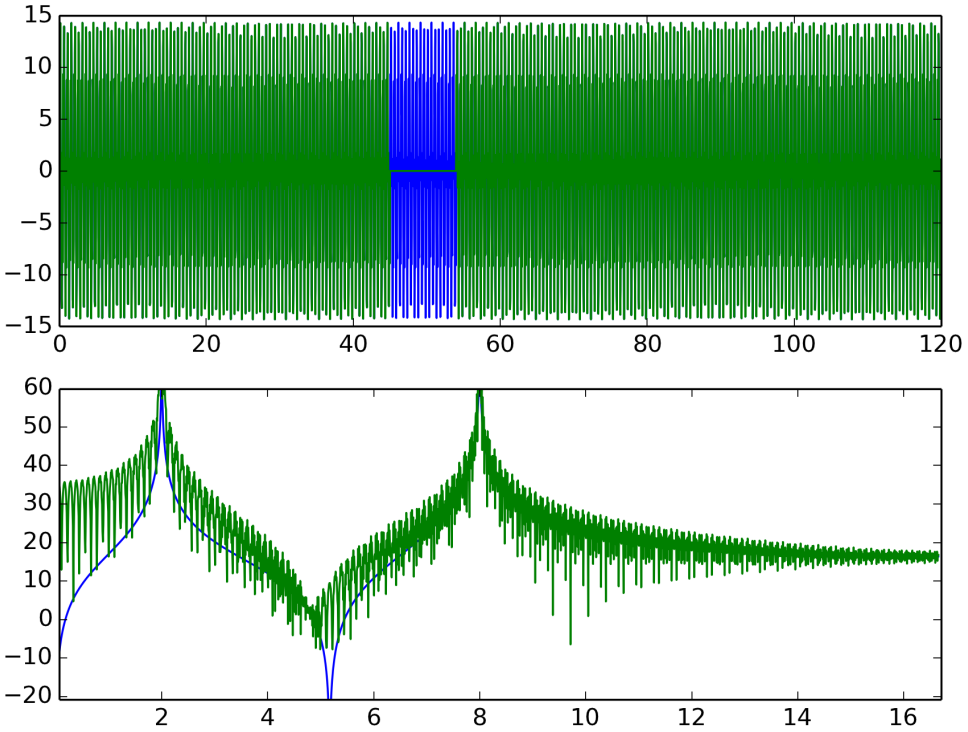

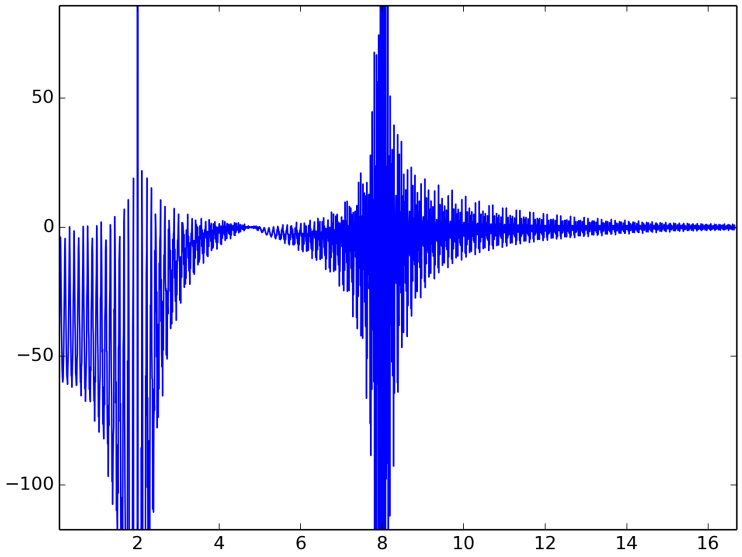

Radio Frequencies: Policy and Management

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***Abstract*—The electromagnetic spectrum is a valued shared resource. Its scientific use allows us to learn about our universe, measure and monitor our planet, and communicate scientific data. The use of the spectrum is managed by national, regional, and global regulatory frameworks. There are increasing demands for new or extended allocations because of vast technological advances in the past few years. Understanding spectrum management is important in the successful planning and execution of missions and instruments, as well as in determining the potential source of radio frequency interference in existing data and instruments, and in working to ameliorate its impact. This paper provides a summary of this framework for radio scientists and engineers.**

***Index Terms*—Radio astronomy, radio frequency interference, radio science, spectrum management.**

I. Introduction

THE electromagnetic spectrum is a vital resource shared by many communities. In the regulatory world, use of the spectrum for a specified purpose by a community is defined

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TABLE I
SCIENCE SERVICES OF THE RADIOCOMMUNICATIONS SECTOR OF THE ITU-R

Service	Abbreviation	Description
Earth Exploration-Satellite Service	EESS	Both active and passive remote sensing from orbit; and the data up- & downlinks ITU-R RR 1.51
Radionavigation Satellite Service	RNSS	Accurate position and timing data ITU-R RR 1.54, Article 26
Meteorological Aids Service	MetAids	Radio communication for meteorology *e.g.* weather balloons ITU-R RR 1.50
Meteorological Satellite Service	MetSat	Earth exploration satellite service for meteorological applications; Weather satellites data communications ITU-R RR 1.52
Radio Astronomy Service	RAS	Passive ground-based observations for the reception of radio waves of cosmic origin ITU-R RR 1.58, Article 29
Space Research Service	SRS	Both active and passive science satellite telemetry and data up- & downlinks, space-based radio astronomy and other services ITU-R RR 1.55

Conclusions

- If you can find it and flag it, RFI is considered "harmless" in low doses – unless it happens to be *YOUR* data.
- To keep it low:
  - External RFI gets "managed" through regulators and system choices.
  - Internal RFI is your problem (and often is the problem)
- Every device is non-linear, so you must engineer the system to handle it to a threshold.