CBC/Radio-Canada

A FIRST LOOK AT THE POTENTIAL INTERFERENCE FROM MOBILES DEVICES OPERATION IN THE 3.5GHZ BAND ON DVB BASED SATELLITE LINKS OPERATING IN THE C BAND

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October 2015

IEEE BTS

OBJECTIVES

Can C-Band Receive coexist with
International Mobile Telecommunications (IMT)?

1. Background
   - Antennas, Link budgets, LNBs, C/N
2. Experiment
   - Test Methods, Results
3. Analysis
   - Minimum separation distance
4. Summary

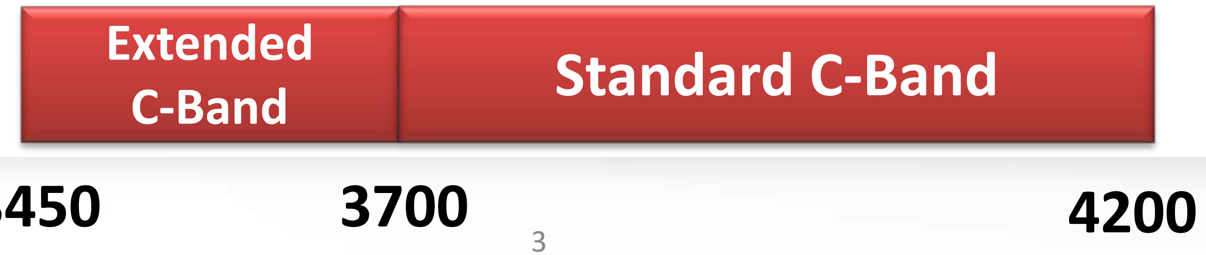
INDUSTRY CANADA CONSULTATION

Consultation on Policy Changes in the 3500 MHz Band (3475-3650 MHz) and a New Licensing Process in Rural Areas (AUGUST 2014)

3 450 - 3 500	FIXED C18 MOBILE RADIOLOCATION 5.433 Amateur **MOD** C15 **ADD** C18B
3 500 - 3 650	FIXED C18 FIXED-SATELLITE (space-to-Earth) MOBILE **MOD** C20 **ADD** C18B

Amendments proposed to **Canadian Table of Frequency Allocations 9 kHz to 275 GHz**

- **MOD C15 (CAN-03)** In the band 3 450-3 500 MHz, in certain locations in Canada the radiolocation service has priority over the fixed and mobile services. The Department will identify through spectrum policy the general area of radiolocation system operation.
- **C18 (CAN-03)** The band 3 450-3 650 MHz is designated for fixed wireless access applications under the fixed service allocation.
- **ADD C18B** In the band 3 450-3 650 MHz, the use of spectrum in certain areas by the mobile and fixed services will be subject to spectrum utilization policies and/or decisions.
- **MOD C20 (CAN-03)** In the band 3 500-3 650 MHz, the fixed-satellite earth-stations will be located in areas so as not to constrain the implementation of fixed wireless access and mobile systems.



BACKGROUND

Broadcasters have been relying on C band satellite communications for the fulfillment of their critical networking requirements since the late 60’s

- C Band receive systems are operating in the 3.7 to 4.2 GHz Band
- Since Satcom receive are using very high gain antennas (typically 3.7 to 4.5m) and very low antenna noise temperature, those systems are operating with signal levels that are critically low typically KTB + Dust
    - Making them very exposed to interference

How critical are C band receive systems?

Most broadcasters Emergency Alert Systems (EAS) are carried in C-Band

BACKGROUND – TYPICAL C-BAND LINK BUDGET

How low is the signal we receive

Thermal Noise (KTB across 10 MHz)	-103	dBm
Typical C /N ratio	15	dB
Typical signal at LNB Input	-88	dBm
Typical antenna Gain 4.5m	44	dB
Actual signal received from space	**-132**	**dBm**

Satmaster Pro Mk9.0b - [GEO Link Budget - C:\satmaster\c example.glb]

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Downlink Calculation	Clear	Rain Up	Rain Dn	Units
Satellite EIRP total	42.00	42.00	42.00	dBW
Transponder output back-off (total)	8.00	8.00	8.00	dB
Output back-off per carrier	12.72	12.94	12.72	dB
Satellite EIRP per carrier	29.28	29.06	29.28	dBW
Antenna mispoint	0.50	0.50	0.50	dB
Free space loss	196.08	196.08	196.08	dB
Atmospheric absorption	0.07	0.07	0.07	dB
Tropospheric scintillation fading	0.00	0.00	0.13	dB
Cloud attenuation	0.00	0.00	0.04	dB
Rain attenuation	0.00	0.00	0.03	dB
Total attenuation (gas-rain-cloud-scintillation)	0.07	0.07	0.23	dB
Other path losses	0.00	0.00	0.00	dB
Noise increase due to precipitation	0.00	0.00	0.25	dB
Downlink degradation (DND)	0.00	0.00	0.41	dB
Total system noise	125.28	125.28	132.69	K
Figure of merit (G/T)	21.66	21.66	21.41	dB/K
C/No (thermal)	82.90	82.68	82.49	dB.Hz
C/N (thermal)	14.45	14.23	14.04	dB
C/ACI	23.83	23.61	23.83	dB
C/ASI	23.83	23.61	23.83	dB
C/XPI	23.83	23.61	23.83	dB
C/IM	30.00	30.00	30.00	dB
C/(N+I) [= Es/(No+Io)]	13.07	12.86	12.77	dB
Eb/(No+Io)	10.10	9.89	9.80	dB

Totals per Carrier (End-to-End)	Clear	Rain Up	Rain Dn	Units
C/No (thermal)	82.38	82.16	82.01	dB.Hz
C/N (thermal)	13.93	13.71	13.56	dB
C/ACI	19.70	19.49	19.70	dB
C/ASI	19.70	19.49	19.70	dB
C/XPI	19.70	19.50	19.70	dB
C/IM	29.99	29.99	29.99	dB
C/I (total)	14.80	14.59	14.80	dB
C/(No+Io)	79.78	79.57	79.58	dB.Hz
C/(N+I) [= Es/(No+Io)]	11.33	11.12	11.13	dB
Eb/(No+Io)	8.36	8.15	8.16	dB
Implementation loss	0.00	0.00	0.00	dB
System margin	4.00	4.00	4.00	dB
Net Es/(No+Io)	7.33	7.12	7.13	dB
Required Es/(No+Io)	7.12	7.12	7.12	dB
Excess margin	**0.21**	**0.00**	**0.01**	**dB**

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BACKGROUND – LINK MARGINS

Link Margins

Typical System Margins (C Band)

All potential interference accounted for

- 3 to 5 dB

In practice (Typical Interference level)

- 7 to 9 dB

Is the delta between practical and calculated margins is getting lower?

- No…our prediction tools are not improving,
- More of the interference is getting realized every year

How much Terrestrial Interference can we bare ?

Considering the typical antenna gain of 44dB, and interference in the main beam will kill the service…

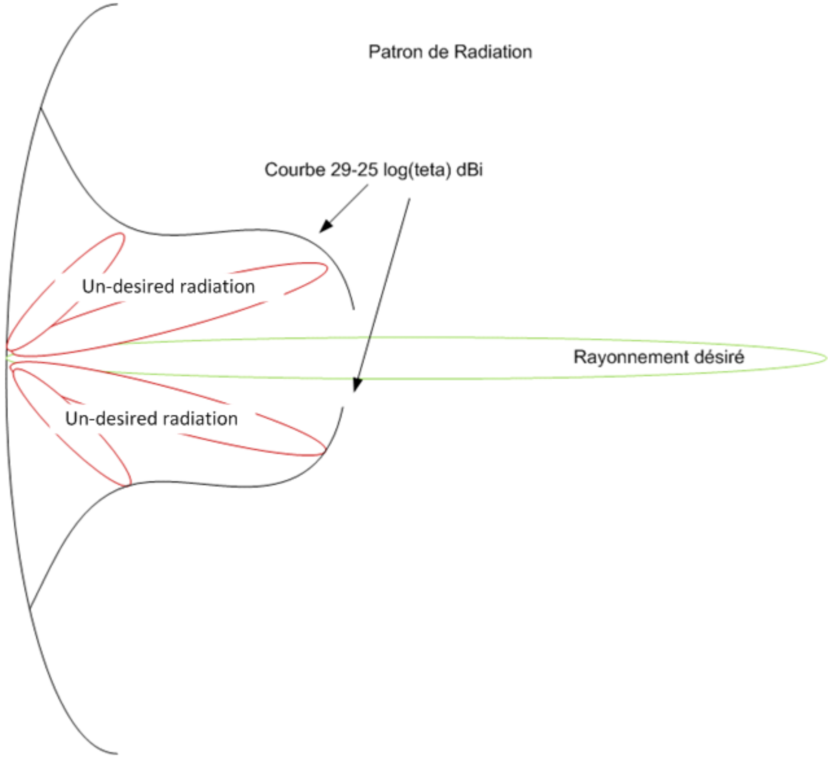
However the beamwidth of these antennas is around 1.2 degrees, and the antenna beams toward space, so the probability of main beam interference is low.

However we have to worry about interfering carries coming off beam as well

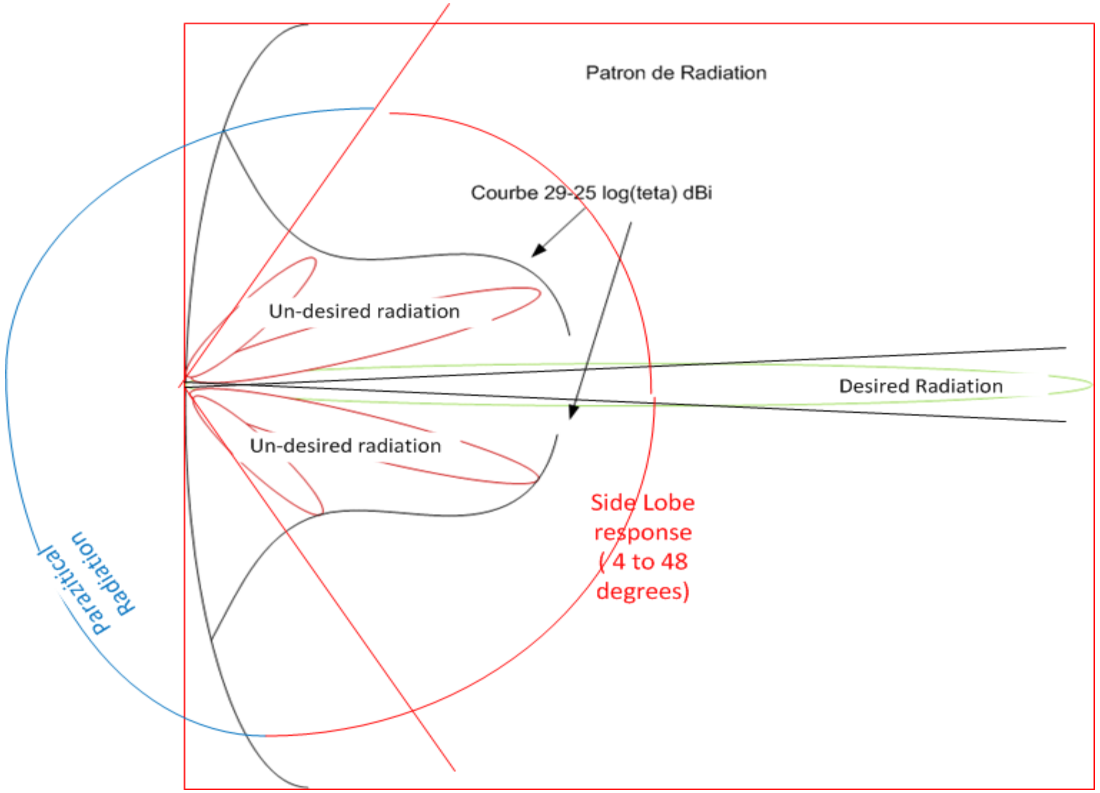
BACKGROUND – ANTENNA

Antenna

Radiation Pattern

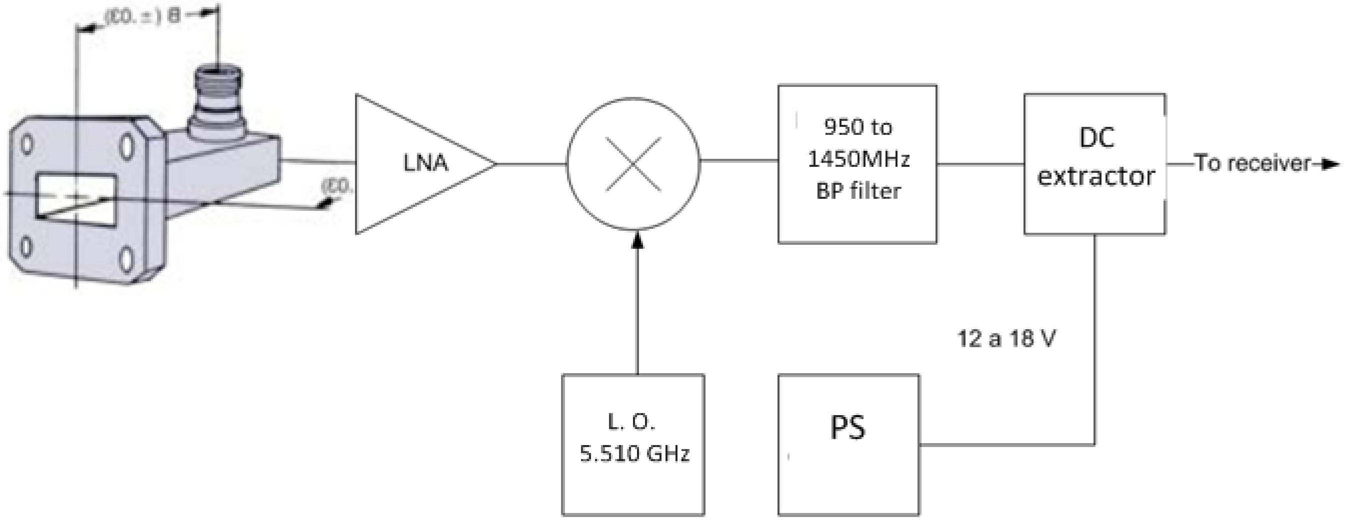


BACKGROUND – RADIATION PATTERN



Reference pattern 2 to 20 GHz ITU 465-5		
Desired radiation	Main Beam	Antenna Gain
Side Lobe area	$\varphi_{min} \leq \varphi < 48°$	$32 - 25 \log \varphi$ dBi
Parasitical Radiation	for $48° \leq \varphi \leq 180°$	-10 dBi

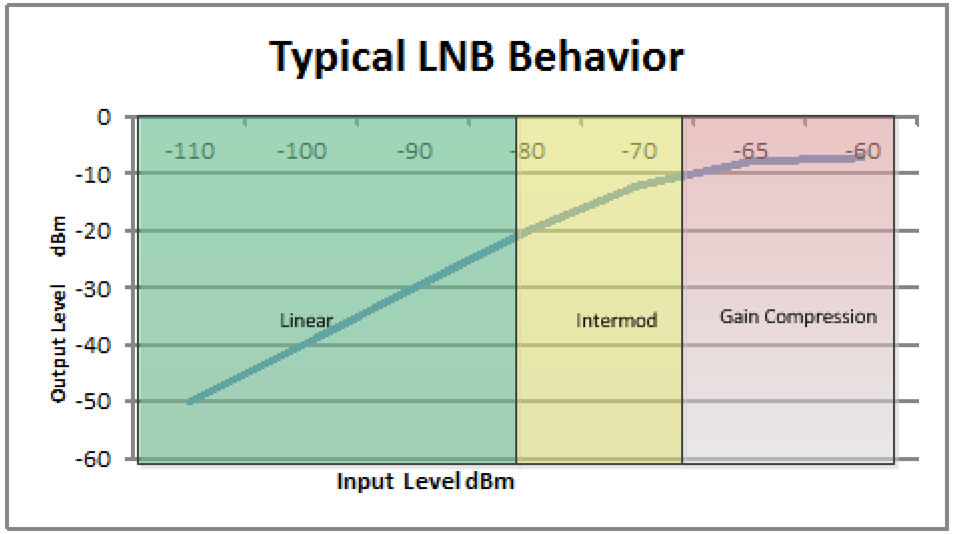
BACKGROUND – INSIDE THE LNB

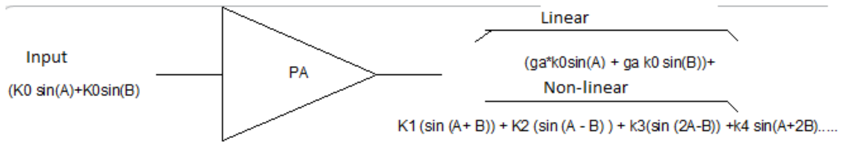


BACKGROUND – LNB BEHAVIOR

The LNB is made of an

- An amplifier
- A Mixer
- None of which are notorious for their linearity
- As the graph shows:
- The linear zone is fine
- The intermod zone last about 16 dB
- At the beginning the IMD are acceptable
- The gain compression zone is where more that 4 dBm of gain is missing, by this point the intermod has killed the service already





BACKGROUND – C/N

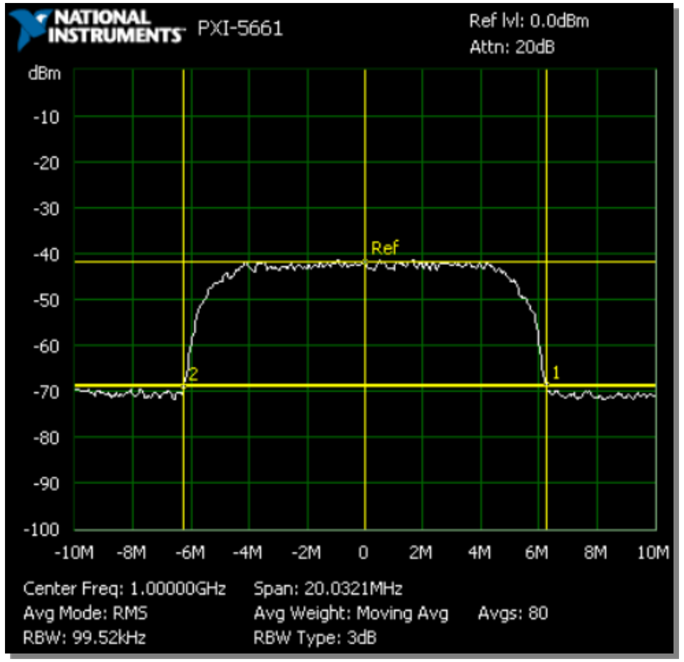
Reference Link

A reference link is used all through this study.

It describe a healthy satellite link operating artifact free under normal noise dominated environment.

<u>The reference link carrier-to-noise ratio has been established at 15 dB</u>

Carrier-to-noise measurement

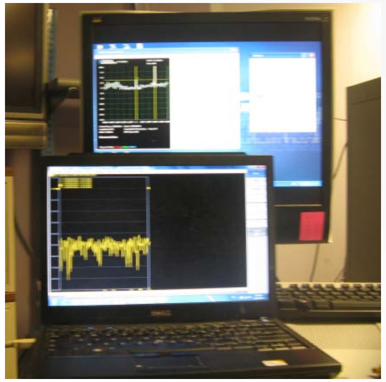


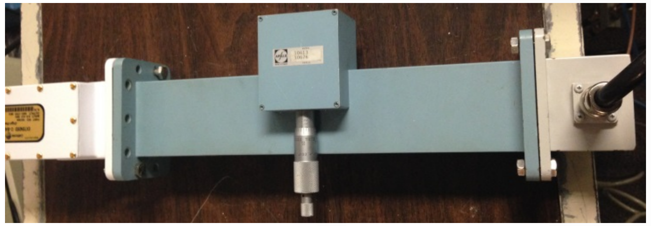
BACKGROUND – C/N

Typical receiver thresholds (C/N)			
MOD	FEC	DVB-S	DVB-S2
Q-PSK	2/3	5.8	3.6
	9/10	8.4	6.4
8-PSK	2/3	9.8	7.1
	9/10	15.5	11.1

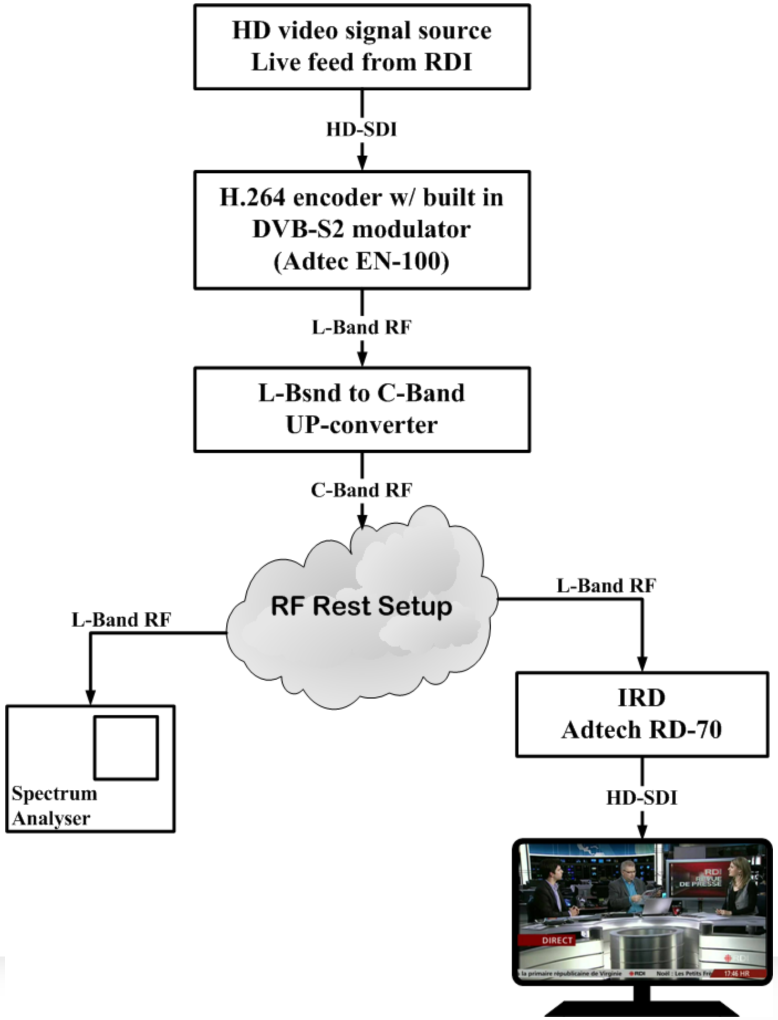
- Modulation and Coding affects C/N thresholds
- Reference 15dB C/N is sufficient for all MODCODs tested

EXPERIMENT





EXPERIMENT – ARTIFACT FREE PICTURE



Threshold of Visibility (TOV)

An artifact free service was monitored for a minimum of 1 minute with the lab engineer's un-divided attention.

The sound is monitored as well.

PS: The sound is usually impaired first

EXPERIMENT – ASSUMPTIONS

- We assume a typical link budget for broadcast distribution.
- Assume a balanced link budget in a noise dominated environment.
- North American satellite with CONUS coverage.
- The link uses the same percentage of bandwidth than transponder power
- The following modulation were tested
  - DVB–S, QPSK mod at 3/4 FEC
  - DVB–S2, 8PSK mod at 2/3 FEC
  - LNB noise figure under 35 K
  - Antenna aperture 4.5 & 3.7m
  - Antenna installed 2m from ground
  - Antenna hooked to house ground

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EXPERIMENT – OBJECTIVE

The goal of this test is to asses whether an out-of-band undesired signal can interfere with the desired signal service via overload of the LNB device.

EXPERIMENT – TEST METHOD

Reference Environment

- Establish a reference environment representative of typical field conditions, the latter defines 2 signals flowing in the same path:
  - Desired Signal
  - Un-desired Signal.
- Both of those signals will be passed trough our device under test—the LNB.
  - The effective gain of the device at both desired and un-desired signal frequencies needs to be determined.

Vary Un-desired signal level

- The main test will be to vary the undesired signal level until an impact is felt on the desired service
  - This level is then recorded and analyzed to derive what would be the **minimal separation distance** required between a potential mobile device using the undesired frequency and the antenna.

EXPERIMENT – TEST METHOD

Realistic Conditions

This study uses typical operating parameters currently used by satellite links.

We could have chosen to analyze the case where the interference source is 2 degrees off from the antenna main beam, the results would not be realistic as a typical 25 degrees elevation angle would put the interferer several tens of meters above ground. Although this case is possible it is unlikely in practice.

We choose to analyze the case of a bystander or station employee wearing the mobile device on its belt, the latter would be in the parasitical radiation beam of the antenna, exposed to a gain of –10 dBi.

EXPERIMENT – EFFECTIVE GAIN

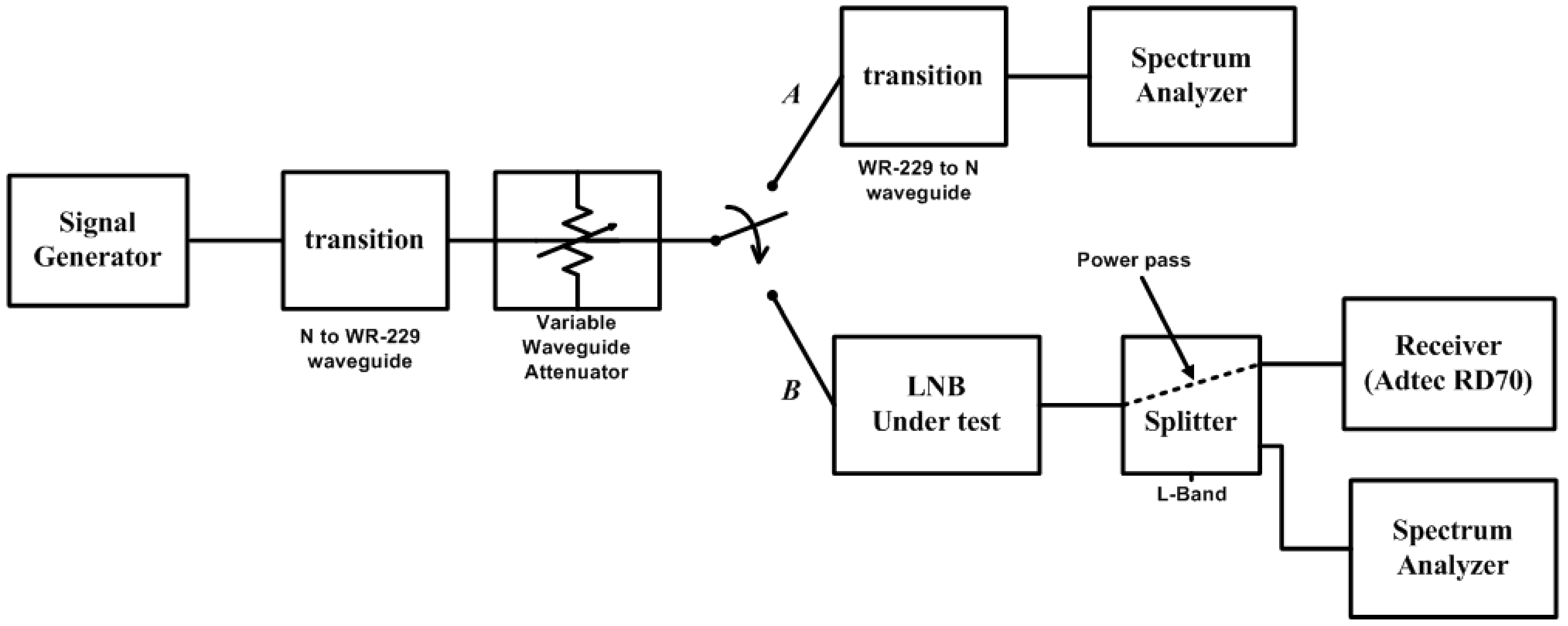
Determining Effective Gain

- In order to make the analysis possible it is important to obtain the effective gain of each LNB devices we are testing.
- The effective gain of the devices is a function of the conditions under which the device is operating—
  - input levels,
  - output levels,
  - frequency,
  - Inter–Modulation Distortion (IMD),
  - input match etc.

Test Procedure

- The level feeding the LNB is assessed by measuring the input level straight from the output of the attenuator (WR–229 flange) @ 3.6 GHz
- Measure the level at the output of the LNB under test. @ 1550 MHz (L-Band)
- Compare both figures

EXPERIMENT – EFFECTIVE GAIN SETUP



EXPERIMENT – EFFECTIVE GAIN RESULTS

		Device gain (dB)	
Device	LO	3.6 GHz	3.9 GHz
Norsat 3125	PLL	78	68
Norsat 3120C	PLL	74	66
Cal Amp 5200C	DRO	83	73
Cal Amp 140194	PLL	82	76

- It is significant to note at this point that all the LNBs we tested had more gain at 3.6 GHz than at 3.9 GHz.
- The gain measurement results show approximately 8dB gain at 3.6 GHz compared to 3.9 GHz.

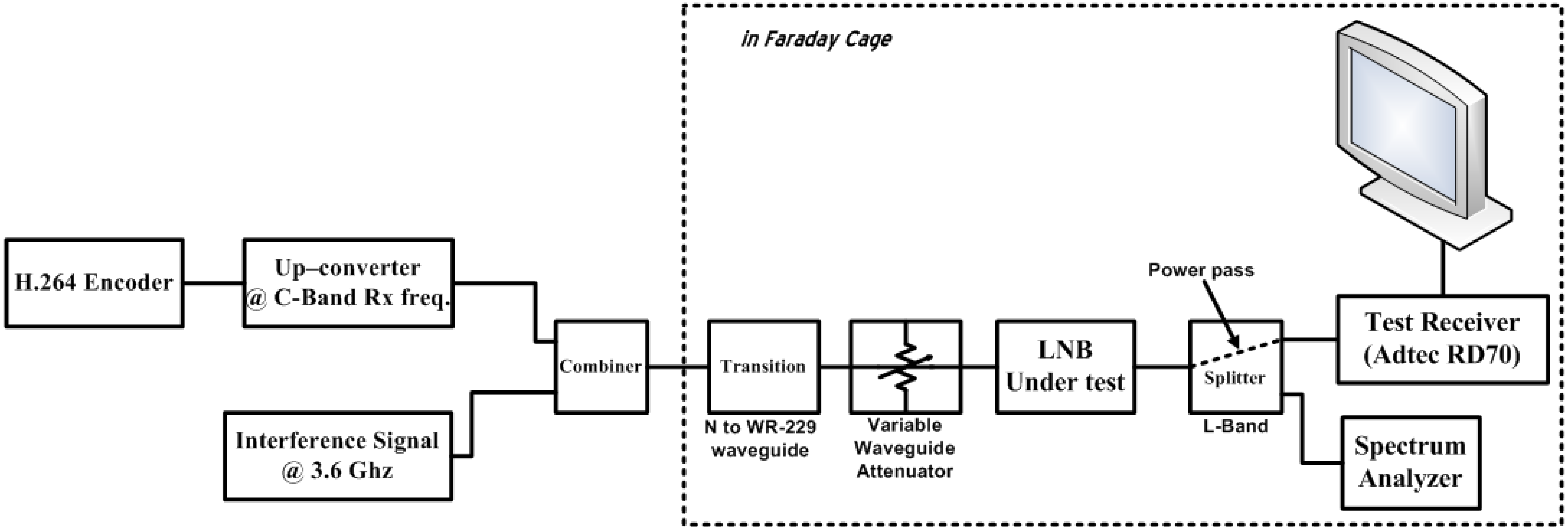
EXPERIMENT – INTERFERENCE TEST

- Feed the desired signal and confirm adequate decoding at the end of the chain.
- Feed the undesired signal at low level
  - –40 dBm
- Raise level until visible artifacts appears on the decoded signal.
- Measure the level of the interfering signal at 1550 MHz from the LNB output
- The test is repeated for each modulation, input level conditions
- Note the power of the interfering signal when the TOV is reached.

Baring in mind that a C band LNB uses a Low conversion (LO Higher) with an L.O. frequency of 5150 MHz, the following frequency conversions apply

Component	C-Band	L-band (LNB out)
Desired signal	4000 MHz	1150 MHz
Desired Signal	3920 MHz	1230 MHz
Un desired Signal	3600 MHz	1550 MHz

EXPERIMENT – INTERFERENCE TEST SETUP



EXPERIMENT – RESULTS

	DESIRED			UNDESIRED	DEVICE TESTED		
	Frequency (MHz)	Amplitude (dBm)	ModCod	Frequency (MHz)	LNB type	Model	Undesired Sig. level
A	4000	–35	S_QPSK 3/4	3600	PLL	Norsat 3025	–9.0
B	3900	–55	S2_8PSK 2/3	3600	PLL	Norsat 3025	–7.1
C	4000	–55	S2_8PSK 2/3	3600	PLL	Cal Amp 140194	–9.5
D	4000	–55	S2_QPSK 1/2	3600	PLL	Cal Amp 140194	–8.4
E	3900	–55	S_QPSK 3/4	3600	PLL	Cal Amp 140194	–6.5
F	3880	–55	S2_8PSK 2/3	3600	PLL	Cal Amp 140194	–11.0
G	3880	–55	S2_8PSK 2/3	3600	PLL	Norsat 3120C	–16.7
H	3880	–55	S2_QPSK 1/2	3600	PLL	Norsat 3120C	–16.3
I	3900	–55	S2_8PSK 2/3	3600	DRO	Cal Amp 5200C	–6.1
J	3820	–55	S2_QPSK 1/2	3600	PLL	Norsat 3120C	–16.1

ANALYSIS – MINIMUM SEPARATION DISTANCE

The goal of this test is to asses whether an out-of-band undesired signal can interfere with the desired signal service via overload of the LNB device.

What is the minimum separation distance that any mobile device can be, to ensure non-interference based on an earth station antenna that meets Rec. ITU–R S.580–6 ?

for the purpose of this analysis a side interference from +48 to -48 degrees will be considered (effective gain –10dBi)

ANALYSIS

Power @ antenna input

Determine the corresponding level at the antenna input according to,

$$P_{Rx} = P_{INT} + G_{LNB} + G_{ANT,AZ}$$

where

- *P_{Rx} is the Corresponding Level at receive antenna in dBm*
- *P_{INT} is the interference signal at LNB output*
- *G_{LNB} is the effective gain of the LNB*
- *$G_{ANT,AZ}$ is the effective antenna gain in the desired azimuth*

Free space path loss (FSPL)

The P_{Rx} figure then obtained will be used to evaluate the distance from the potential interfering device using free space propagation loss (FSPL) model:

$$FSPL = 32.44 + 20\log f + 20\log d$$

where,

- *f is frequency in MHz*
- *d is distance in km.*

ANALYSIS – MINIMUM SEPARATION DISTANCE

Case	EIRP (dBm)	Interfering Signal level P_{INT} (dBm)	Antenna gain at bearing $G_{ANT,AZ}$ (dBi)	Effective LNB Gain G_{LNB} (dB)	Level at Rx antenna P_{Rx} (dBm)	Required path loss FSPL (dB)	Equivalent separation distance (m)
A	24	–9.0	–10	78	–77.0	101.0	744
B	24	–7.1	–10	78	–75.1	99.1	601
C	24	–9.5	–10	82	–81.0	105.0	1,179
D	24	–8.4	–10	82	–80.0	104.0	1,051
E	24	–11.0	–10	82	–83.0	107.0	1,485
F	24	–16.7	–10	74	–80.0	104.0	1,051
G	24	–16.3	–10	74	–80.3	104.3	1,088
H	24	–6.5	–10	82	–78.5	102.5	884
I	24	–6.1	–10	83	–79.1	103.1	943
J	24	–16.1	–10	74	–80.0	104.0	1,051

ANALYSIS – DISCUSSION

Our study shows that even with our conservative assumptions—

- interferer not in the main beam
- antenna on the ground with no base elevation differential

interference exists!

Overload interference will present itself in two ways:

- Gain compression: the gain of the LNB device is compressed up to a point where the margin left is insufficient. The effect of gain compression will result in a raised noise floor across the entire band.
- Intermodulation products may present as frequency specific interfering signal.

Even if a significant EIRP reduction is imposed—ex. 20 dB, this will reduce the minimal separation distance by 90%, however, 10% of 700m is 70m and is very likely to harm satellite reception. Remember that we analyzed the case of a bystander or station employee wearing the mobile device on its belt.

Based on our findings, we believe the 3.5 GHz frequency band is unusable for mobile to base communications in a context where C–band reception has to be protected.

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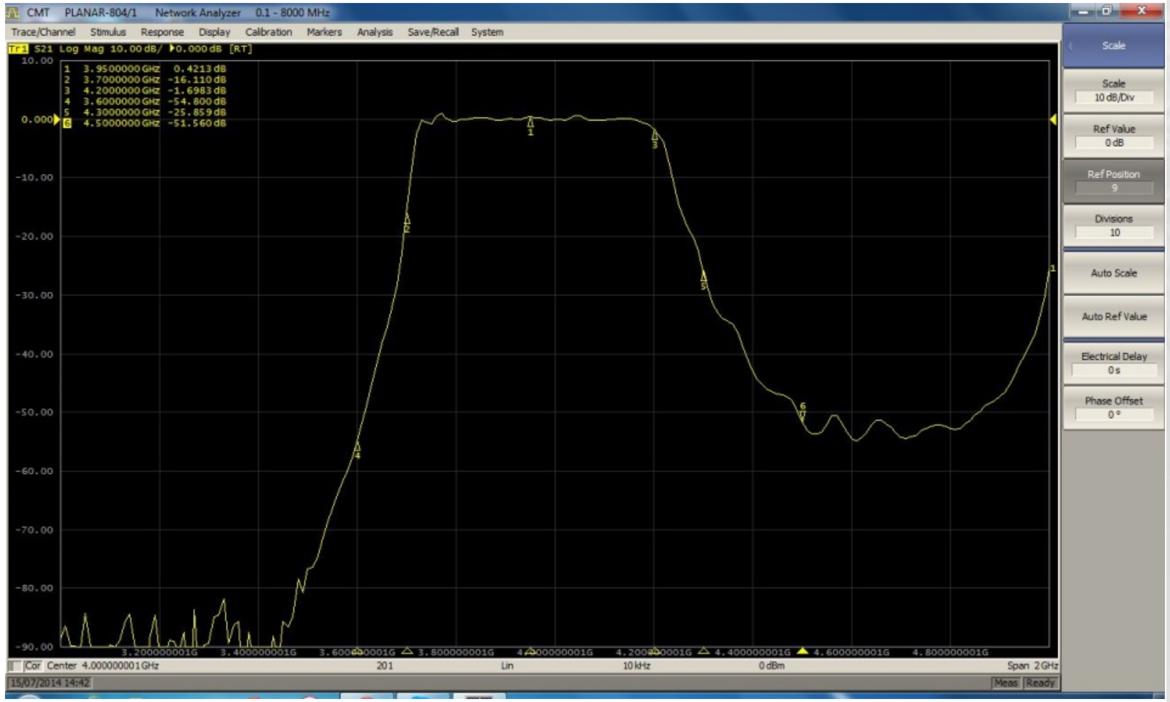
ANALYSIS – POTENTIAL SOLUTIONS

Filters to the rescue?

- One potential solution to increase the probability of proper operation may involve the addition of a waveguide filter at the satellite receive site, however, this solution would be expensive in both margin and capital.
- Results in 0.5-1dB loss in margin!



SUMMARY

The goal of this study was to asses whether an out-of-band undesired signal can interfere with the desired signal service via overload of the LNB device.

- By testing various LNB devices we have demonstrated that :
  - using free space path loss that a separation distance of at least 1.5 kilometers may be required for mobile devices operating in the 3.5 GHz (3400–3700 MHZ) band to not interfere with satellite services operating in the 4 GHz (3700-4200 MHZ) band.
- This is a particularly concerning result because while the location of base stations can be coordinated to reduce interference, it is nearly impossible to coordinate the location of mobile devices to reduce the interference they will ultimately cause to existing services.
- Further study is needed to establish a livable frequency sharing scenario, taking in account LNB overload.

CONTACT INFO

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