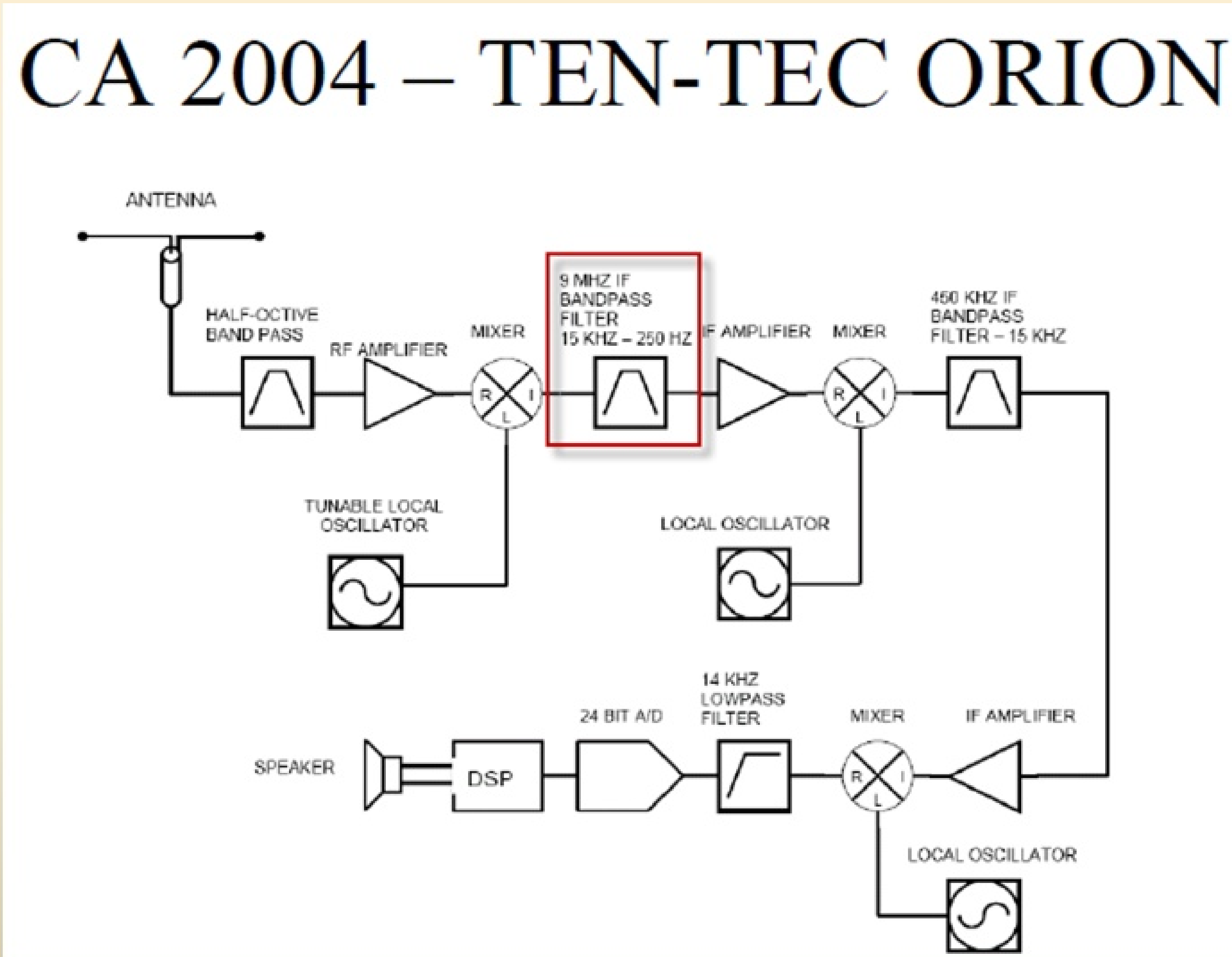
An Introduction to Roofing Filters

Jeff Blaine – ACØC
CADXA – 6 Oct 2011

First: The Required IMD Refresher

Virtually Math Free!

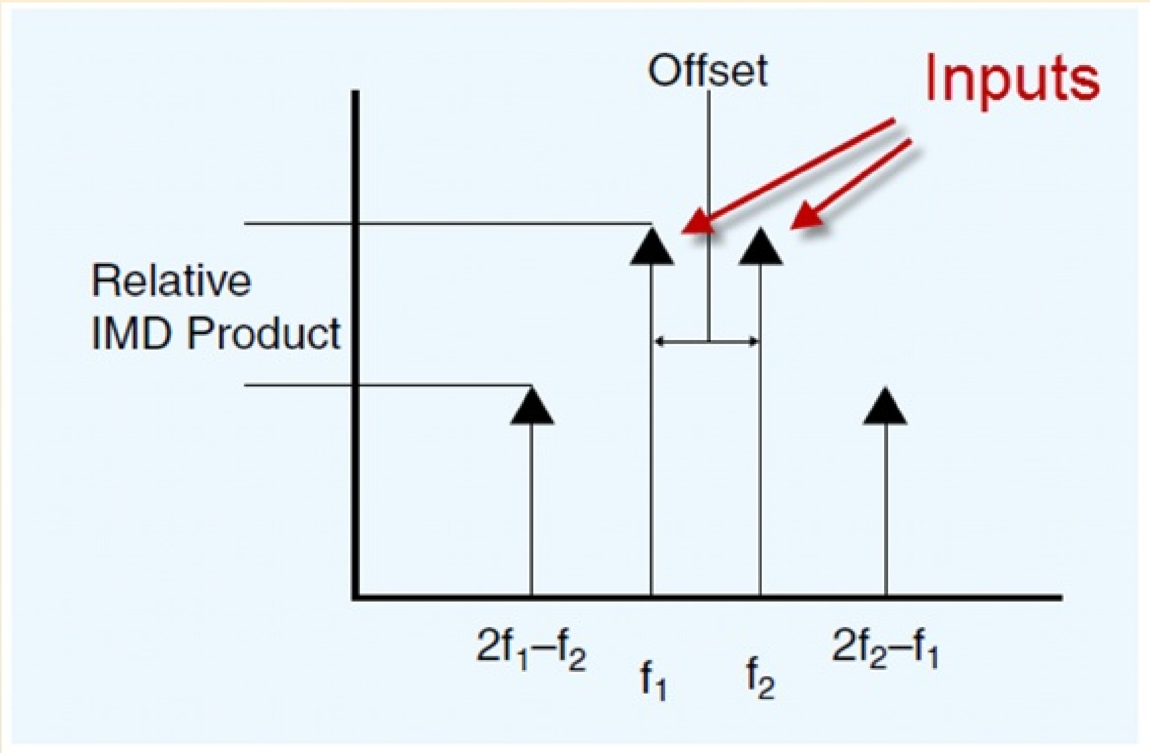
Heterodyne Receiver 101



IMD and the 3rd Order Rule

- IMD - Inter Modulation Distortion
- Caused by nonlinear processes – all components can be nonlinear
- 3rd Order Rule - IMD products increase at 3x signal levels
- IMDDR3 or **DR3** – Third Order Intermodulation Limited Dynamic Range
- Other "order" IMD products also exist – but 3rd order is the trouble maker

Third Order IMD - Graphically

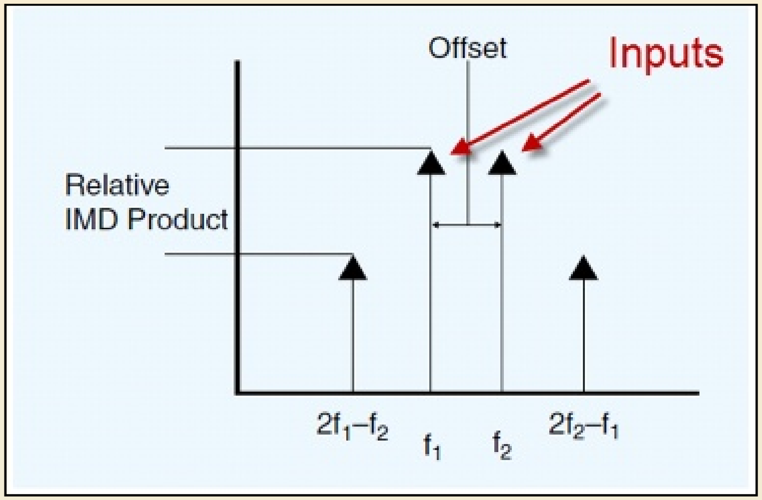


- Assume inputs at 7.010, 7.020
- IMD3 products located at 7.000, 7.030

3rd Order IMD Limited Dynamic Range

- IMDDR3: Standard term (written several ways)

- A measure of
  1)the strength needed for 2 signals
  2) which cause an IMD product that
  3) extends just above the noise floor



- Standard signal spacing –
  2/5/10/20 KHz → 2 KHz key

- Often called THE key receiver metric (for RX comparisons)

- Superhets – closer spacing, worse DR3 performance

In-Band vs. Out-of-Band DR3

Example Later

- Out-Of-Band:
  - Roofing filter width < test tone spacing width
  - Test tones are attenuated by roof
  - DR3 value is limited by UPSTREAM components (includes the roof)

- In-Band:
  - Roofing filter width >> test tone spacing
  - Test tones are not significantly attenuated by the roof
  - DR3 value is limited by DOWNSTREAM stages (2nd mixer ?)

What About IP3?

- IP3 is a calculation based on the SLOPE of input signal and IMD products:
  - IP3 = ½ (IMDDR3) + Input Power or 1.5 (IMDDR3) + noise floor
- Can also be extrapolated from rig measurements
- The point where the two lines cross is called the Intercept Point
- **Assumes the 3rd order law is followed**
- Further complicated: input (IIP3) and output (OIP3) definitions
- Personal opinion: IMDDR3 is typically a more precise term

IP3 Example – FT-1000 MP

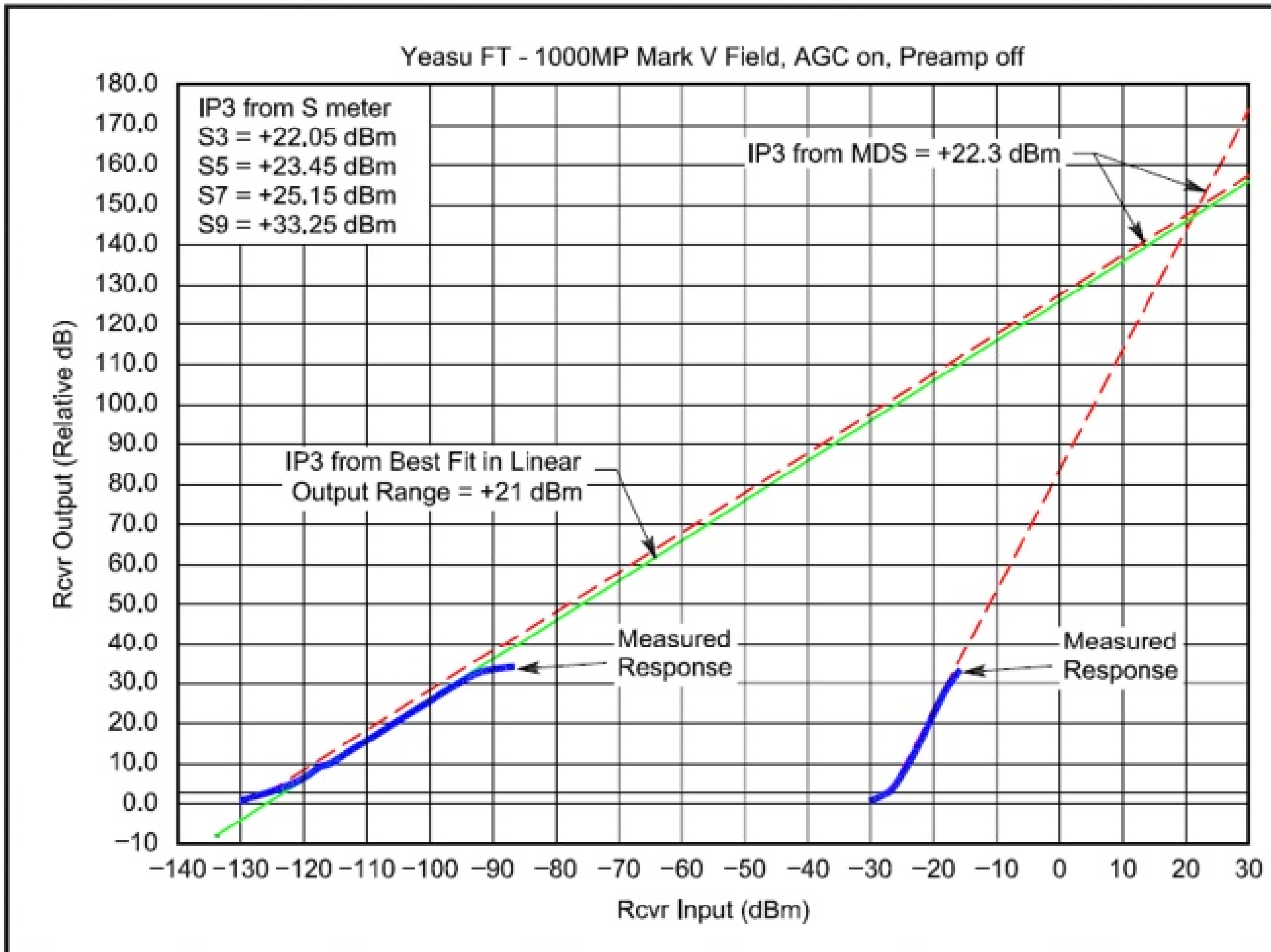
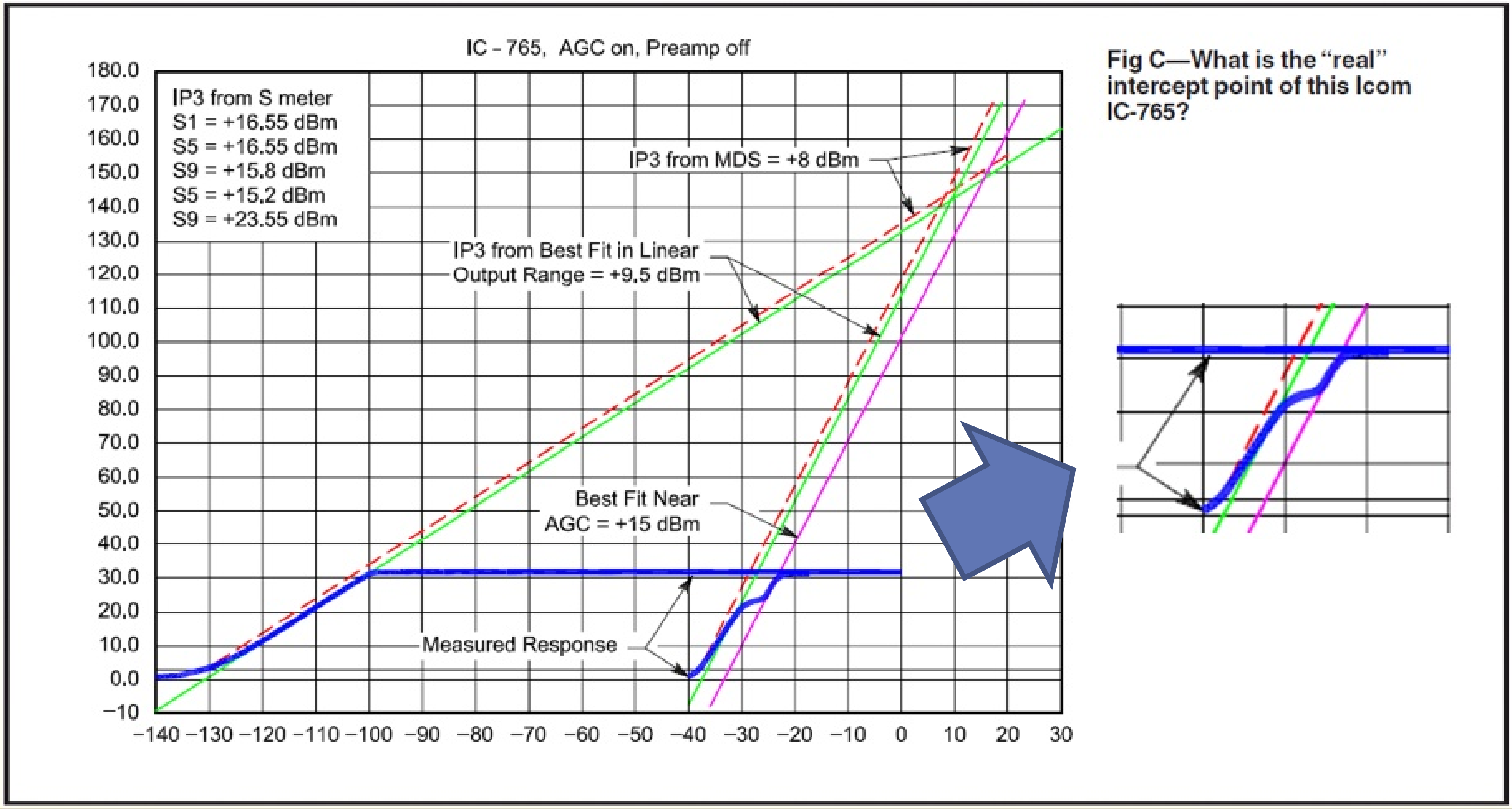


Fig A—The Yaesu FT-1000MP Mark V Field measured in the Lab for this sidebar shows a response that is pretty close to theoretical.

- From: Smith, Improved Dynamic Range, QEX Jul/Aug 2002 – data by W1RFI/ARRL

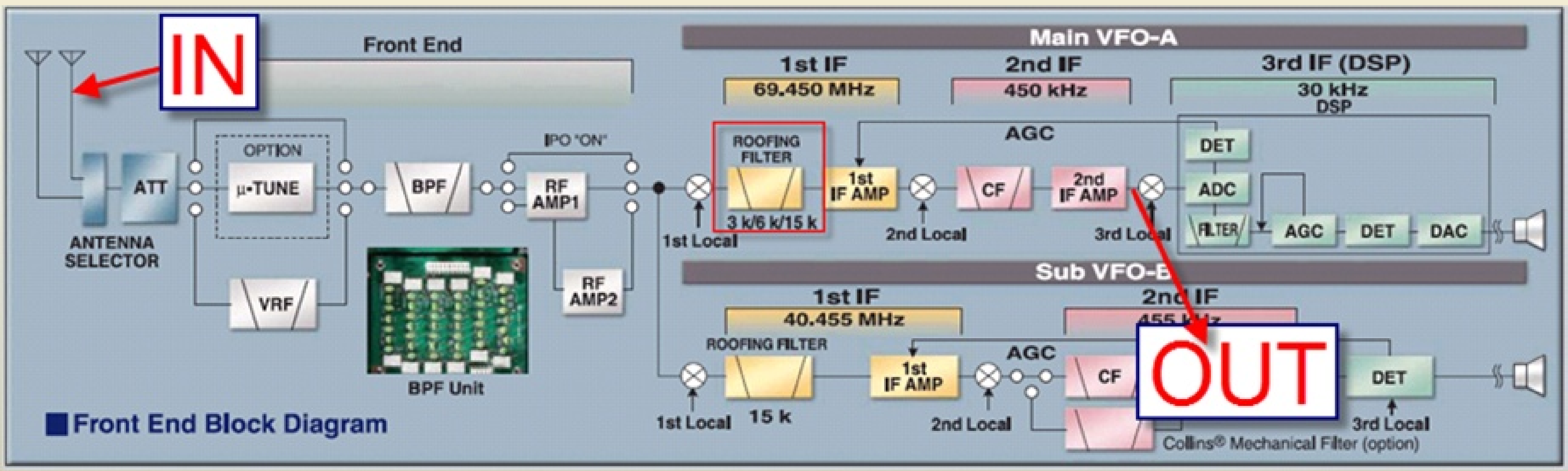
IP3 Example – IC-765



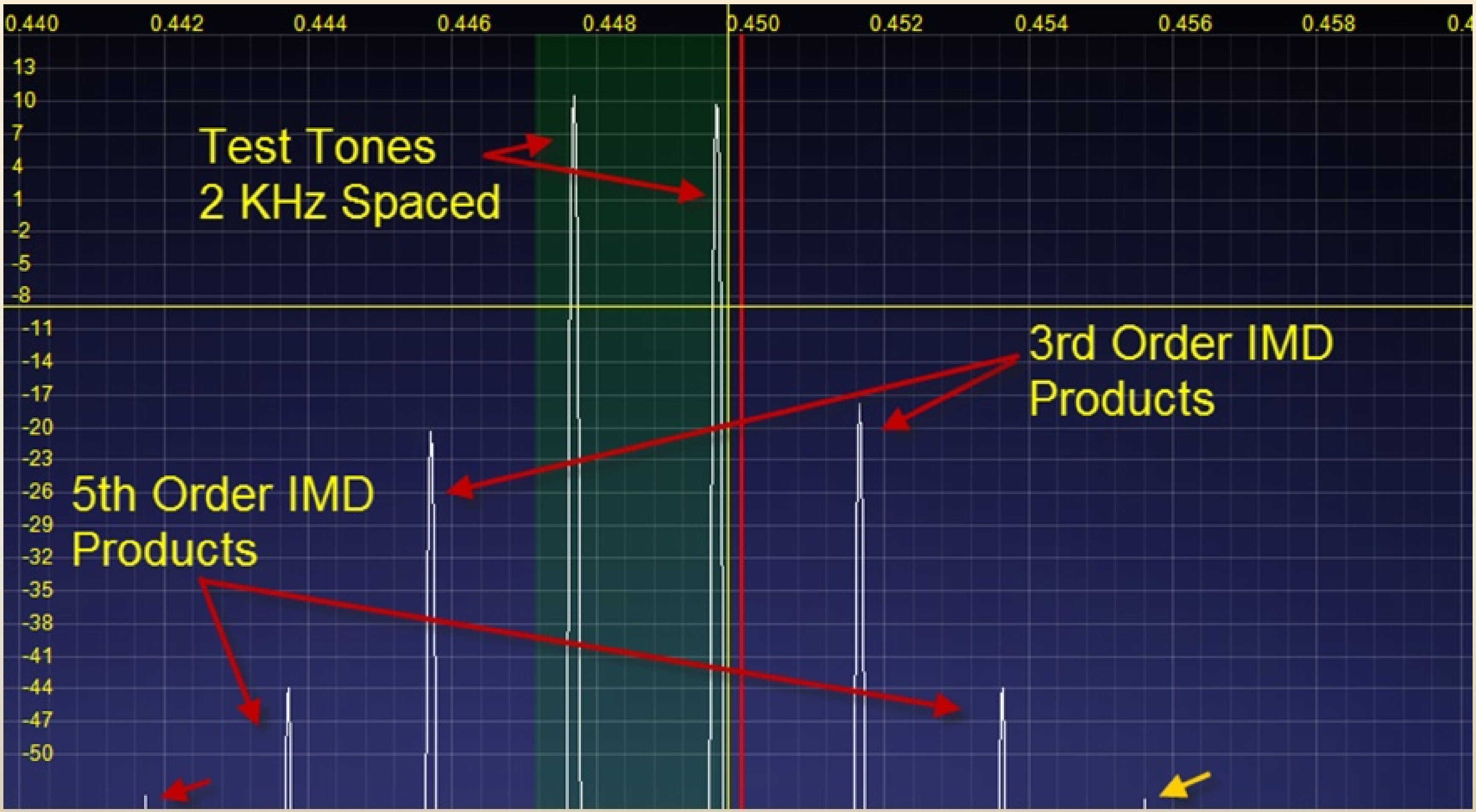
- From: Smith, Improved Dynamic Range, QEX Jul/Aug 2002 – data by W1RFI/ARRL

Sidebar: Understanding the Plots

- Signal generator → Antenna Input
- 450 KHz Spectrum Analyser tied to output of 2nd IF
- Shows what the 3rd mixer "sees" – isolates 1st IF
- Plots in this presentation – actual data – NOT simulated
- IMD testing setup is very difficult – especially the signal source



IMD Products: A Ghost in the Machine?



“Rare DX Here”

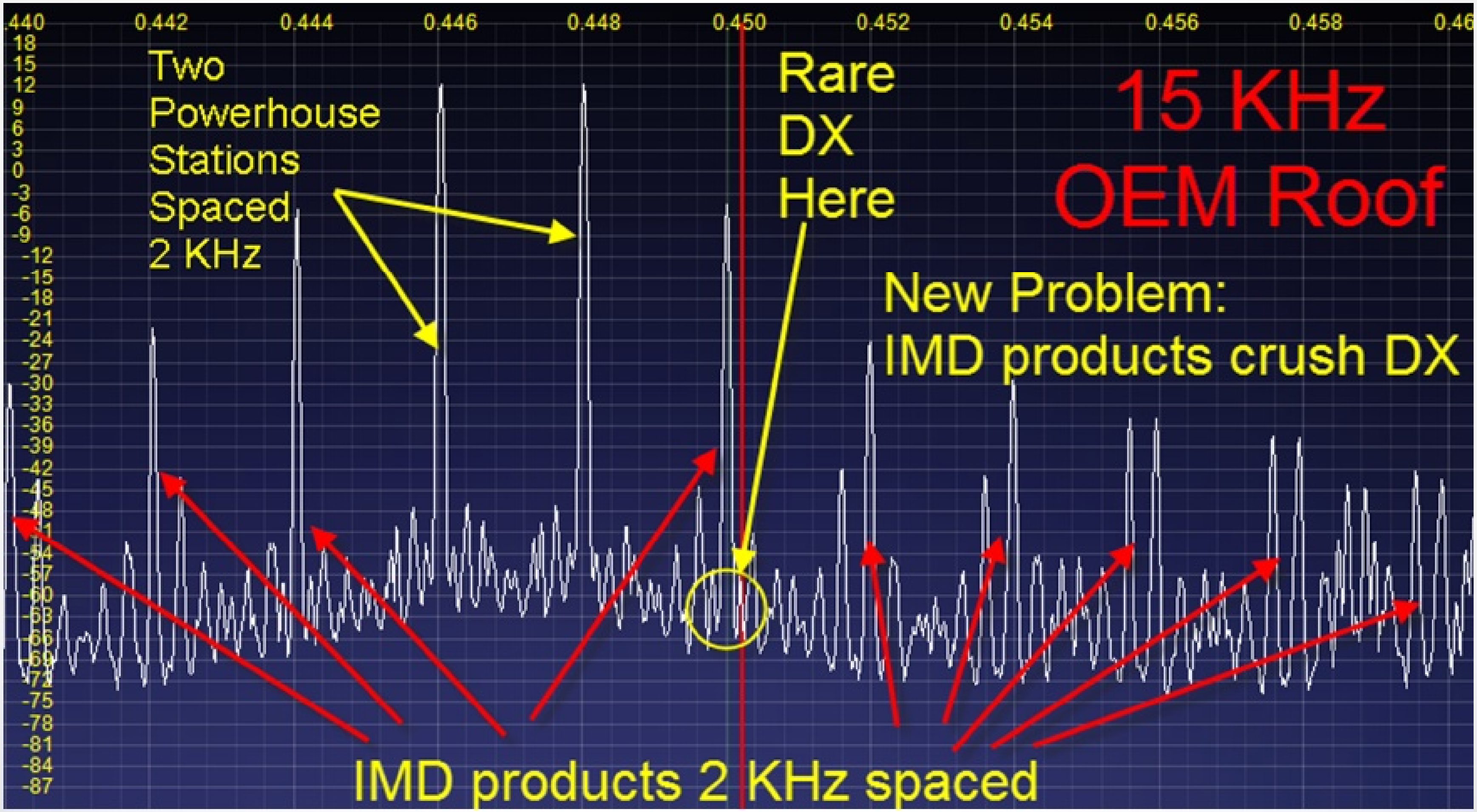
A Roofing Filter Story in Pictures

A Quiet Day in DX Land

What the 3rd Mixer Sees – Lone DX station – IMD products not a factor

Until N7DD and N6SS Arrive

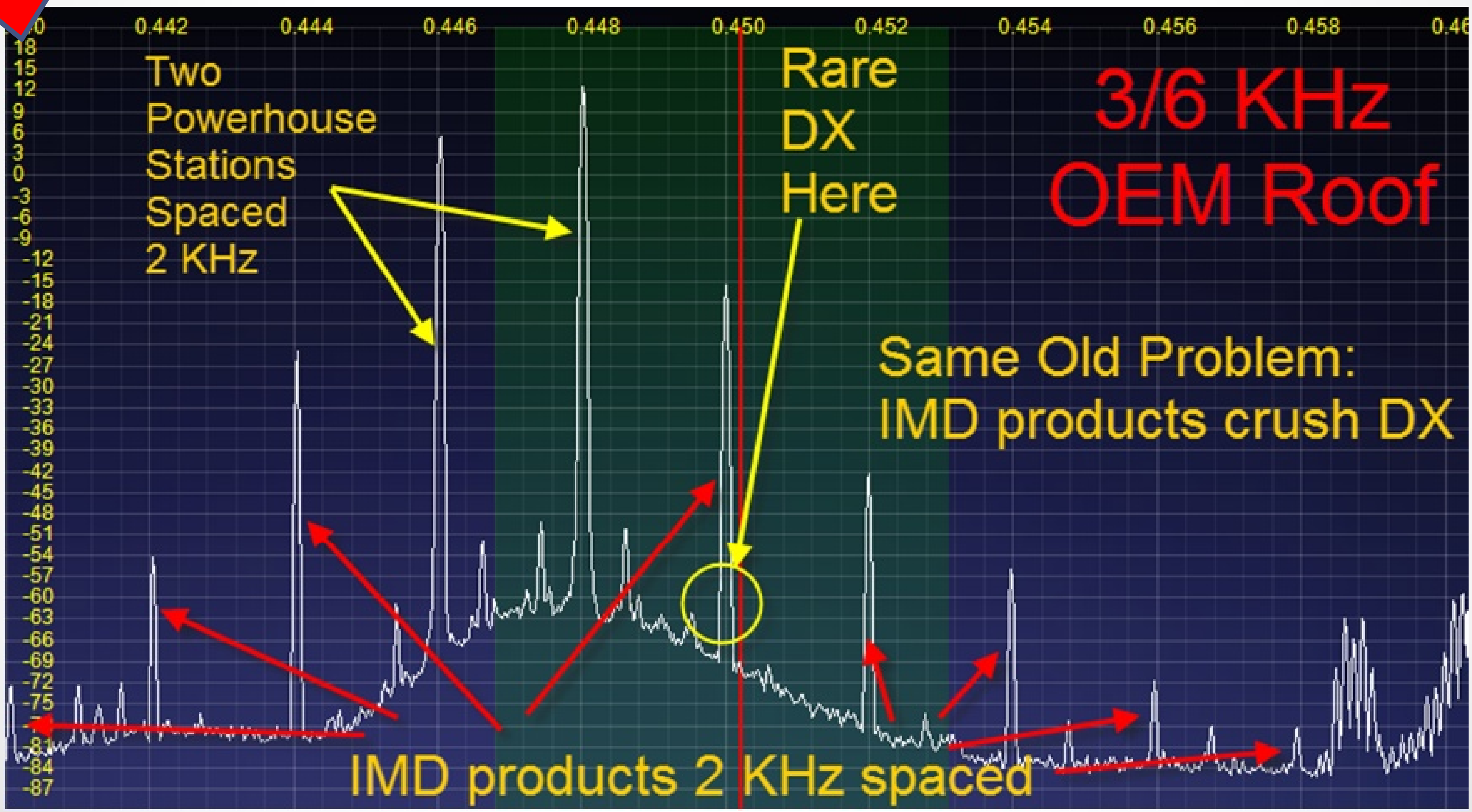
What the 3rd Mixer Sees – Two strong signals in-band – IMD everywhere



Engaging Our OEM Roofing Filter (~6+ Khz)

In-Band DR3

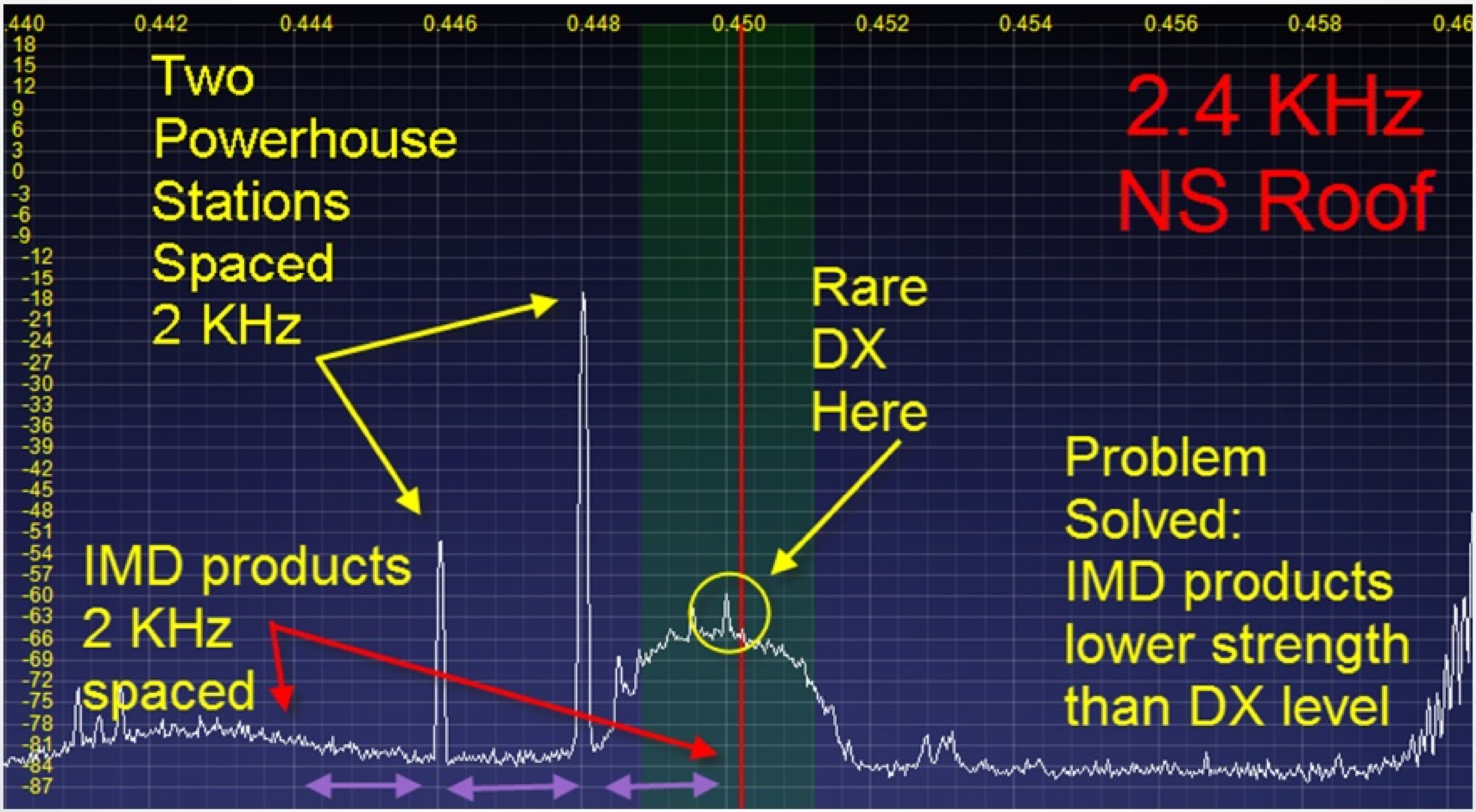
the 3rd Mixer Sees – 6 KHz BW roof – minor reduction in signals → IMD



Out-Of-Band DR3

Finally, the 2.4 Khz Filter

What the 3rd Mixer Sees – 2.4 KHz NS roof – Significant sig reduction → IMD ▼

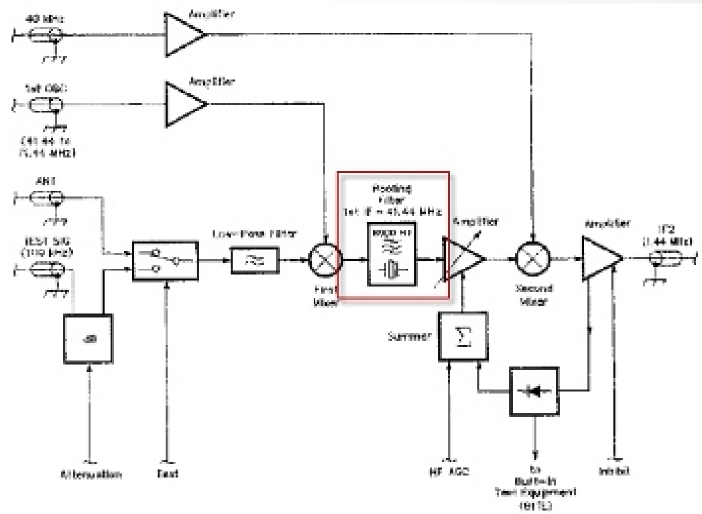


Roofing Filters

Basics, Capabilities, Limitations

Roofing Filter Basics

- Where: First filter, as close to the antenna as possible – 1st IF typical
- Why: Protects following circuits from nonlinear operation due to strong out of band signals
- What: MCF or discrete crystal construction
- Width: Sized to pass the widest mode of operation
- Improve DR3 begins with spacing ¼ filter width, or more



Rodhe, Recent Advances in Receiver Design, QST Nov 1992

Roofing Filter Capabilities

- IMD products
  - Result from non-linear operation (overload)
  - ***Key point → IMD products are generated <u>within the RX </u>chain***
  - Typical IMD sources: pre-selector, mixer and switching

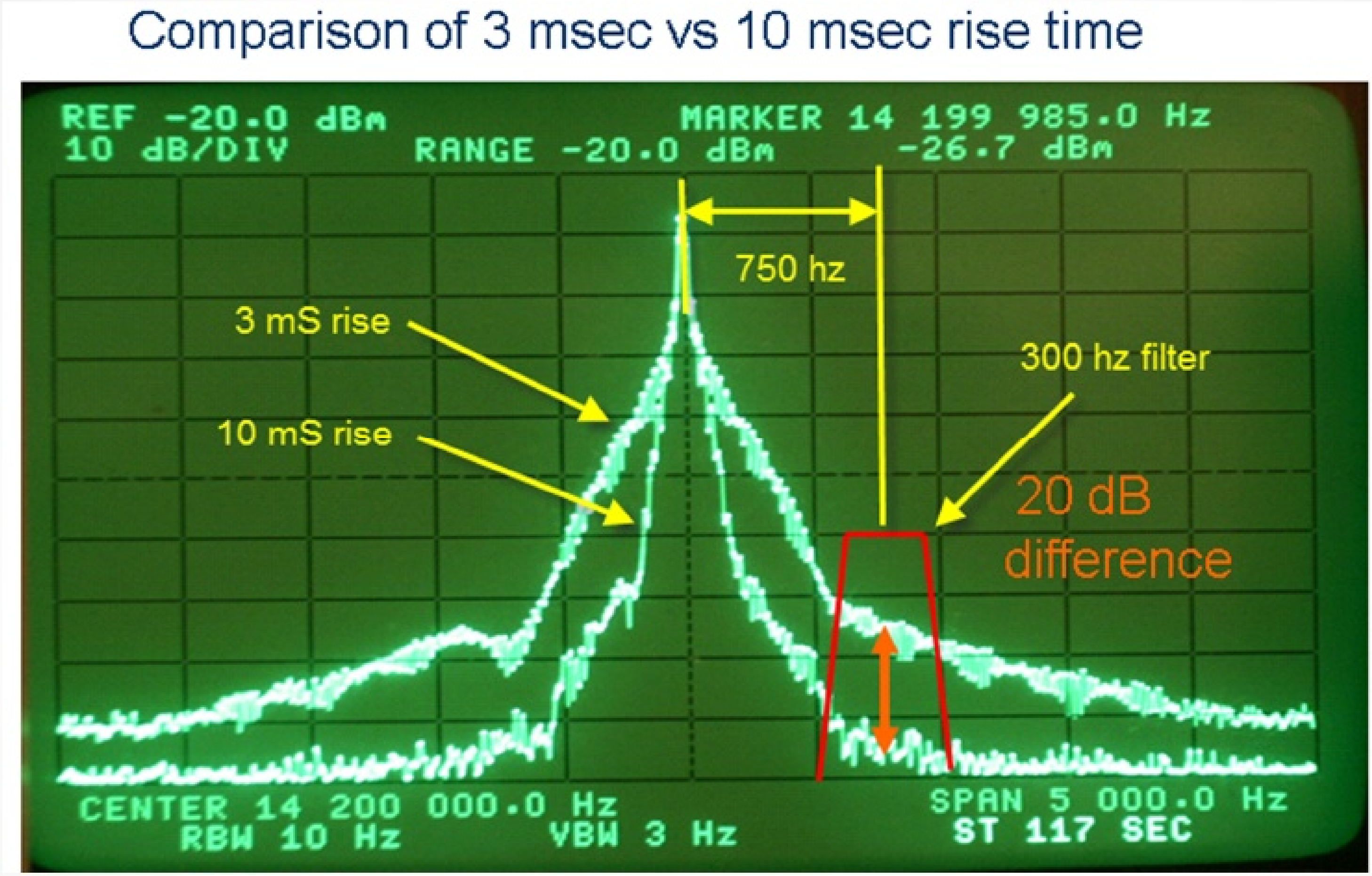
- Action: Attenuates adjacent strong signals → reduces / eliminates IMD products

- Other benefits
  - Reduce AGC pumping → AGC loop after the roof
  - DSP has less bandwidth (information content) to process

Roofing Filter Limitations

- Originally not intended as selectivity filters
- Rather, supplement to DSP (final) filtering
- Cannot improve in-band DR3
- A good filter reveals the next weaker link in the chain
- Cannot filter in-band interference (splatter, key clicks)

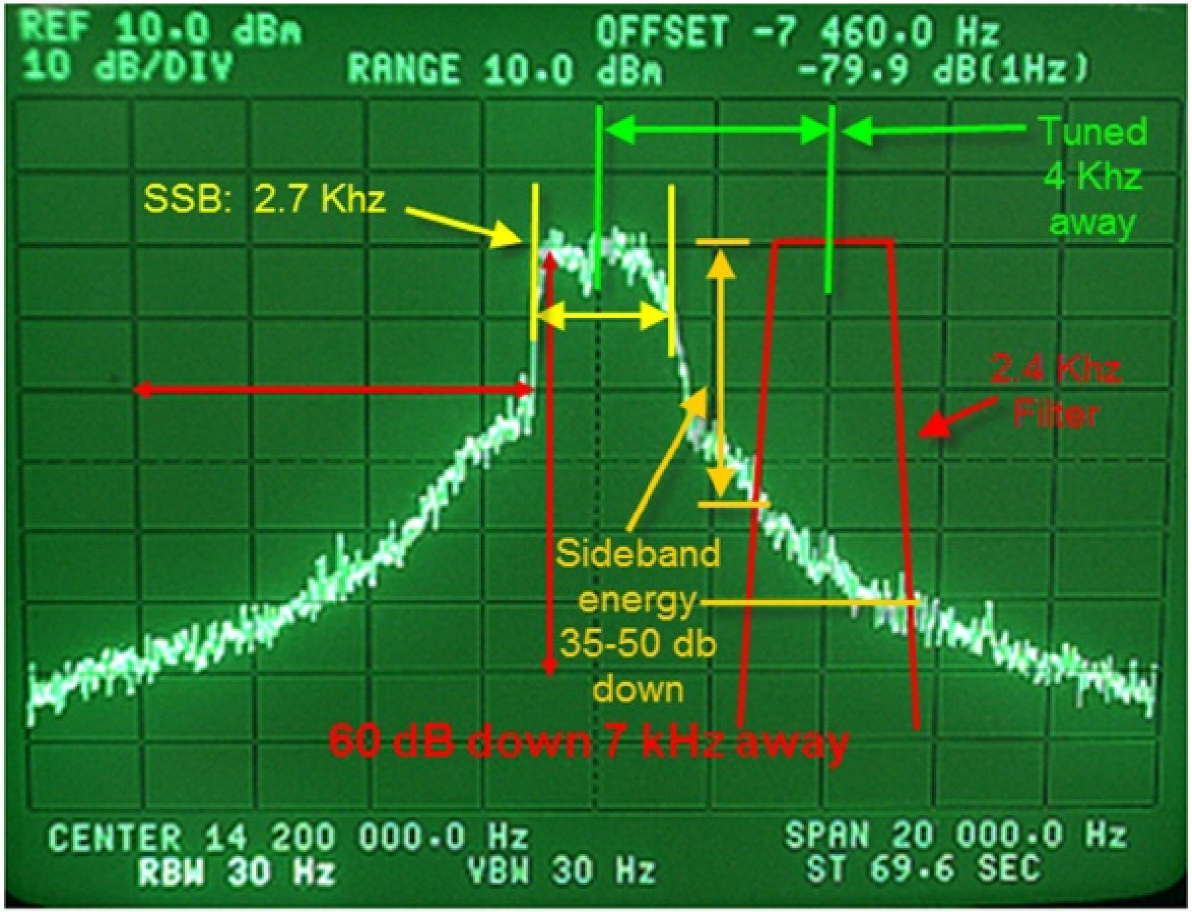
Roofing Filter Limitations – Key Clicks



Courtesy NC0B Rob Sherwood

- Faster rise time, wider bandwidth -> more "clicks"
- Clicks are not filterable – the energy is "in-band"

Roofing Filter Limitations – Sidebands



Courtesy NC0B Rob Sherwood

- Even properly adjusted transmitters not perfect
- Splatter not filterable – the energy is "in-band"

What About

Up Conversion vs. Down Conversion?

Down Conversion vs. Up Conversion

- Up Conversion Architecture – 70 Mhz typical 1st IF
  - Uniform performance over entire frequency range
  - Needs VHF roofing filters (wide/cheap **or** narrow/expensive)
  - **Excellent image rejection**
  - Close-in DR varies
- Down Conversion Architecture – 9 Mhz typical 1st IF
  - Performance near IF is not uniform
  - Image rejection near ham bands requires design attention
  - **Needs only HF roofing filters (narrow/cheap)**
  - Close-in DR generally good, even in lower end models
- Roofing filters found in both architectures – serving the same purpose - protection

What's Driving Down-Conversion Rigs?

1) Market focus on close-in specs vs. image rejection

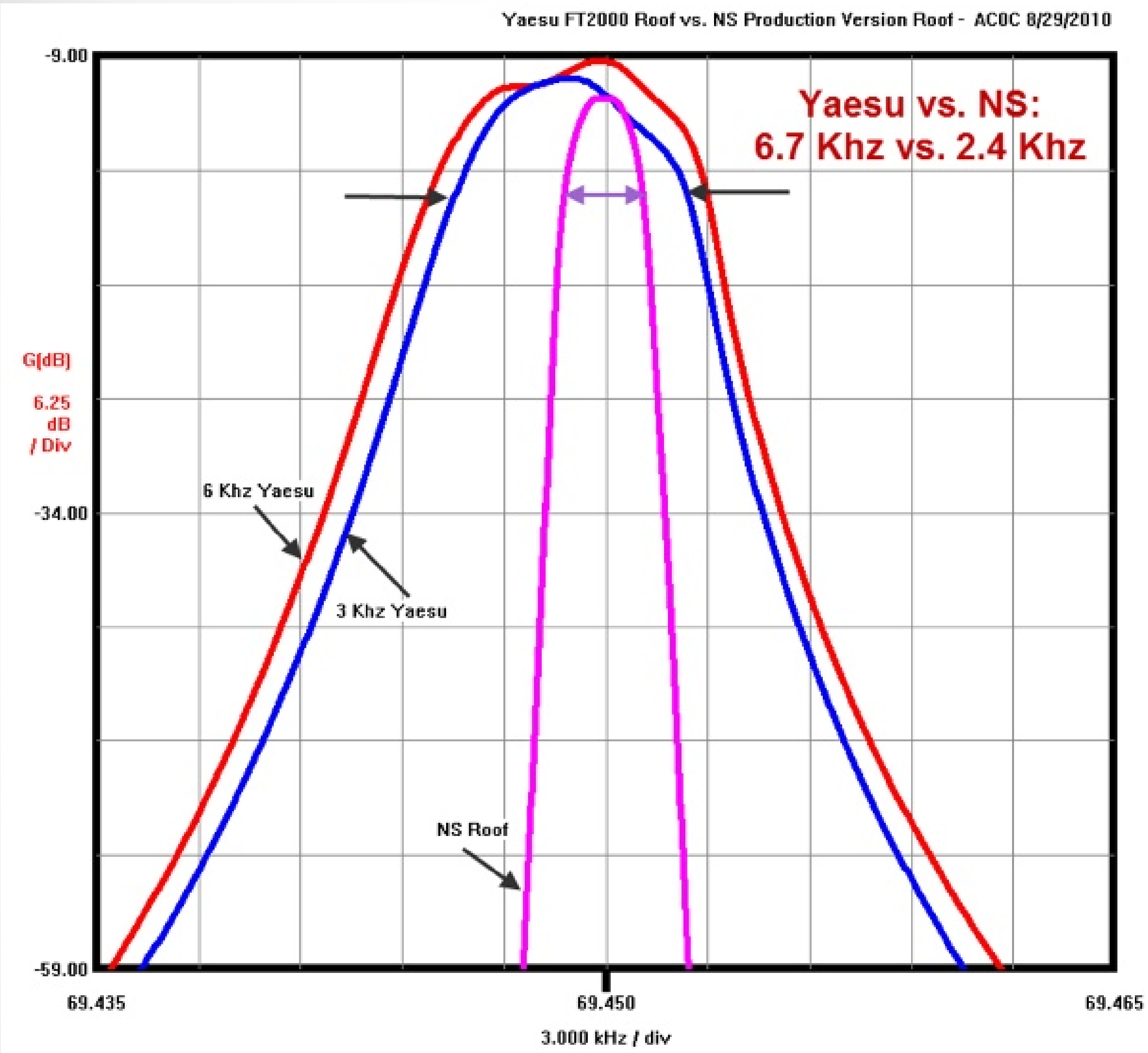
2) Crystal Performance vs. Cost - optimal around 9 Mhz

3) Crystal cost increases with frequency:

- ~ 3x going up
- ~ 2x going down

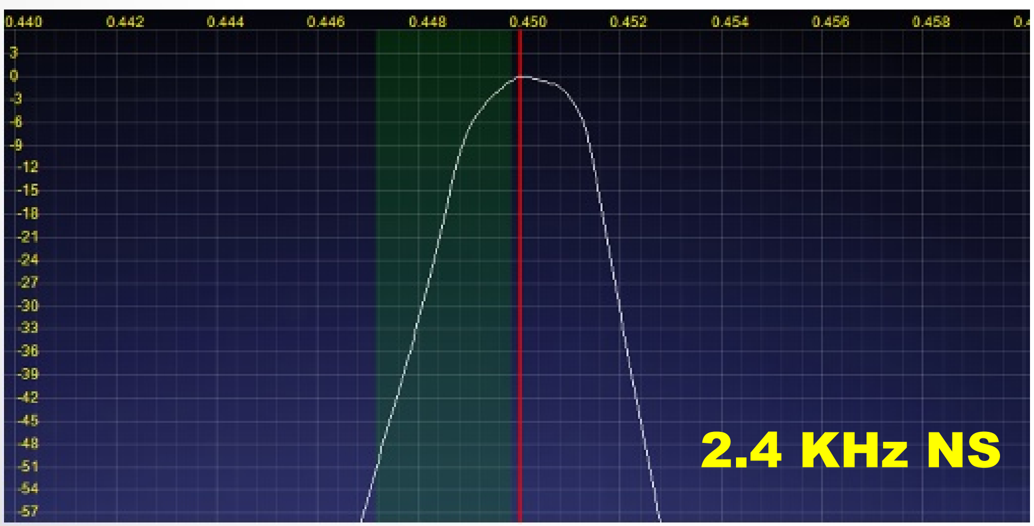
4) HF vs. VHF front ends are cheaper in most other ways

Up-conversion VHF OEM Filters – **Filter on VNA**



- 3/6 KHz OEM filters:
  6-7 KHz @ -6 db
  15-18 KHz @ -50 db
- NS roofing filter:
  2.4 KHz @ -6 db
  5.6 KHz @ -50 db
- Single signal selectivity for SSB
- Improves DR3 on all spacing's from 600 Hz and up – great for CW/digi

Up-conversion VHF Roofing Filters – **Filter In Rig**

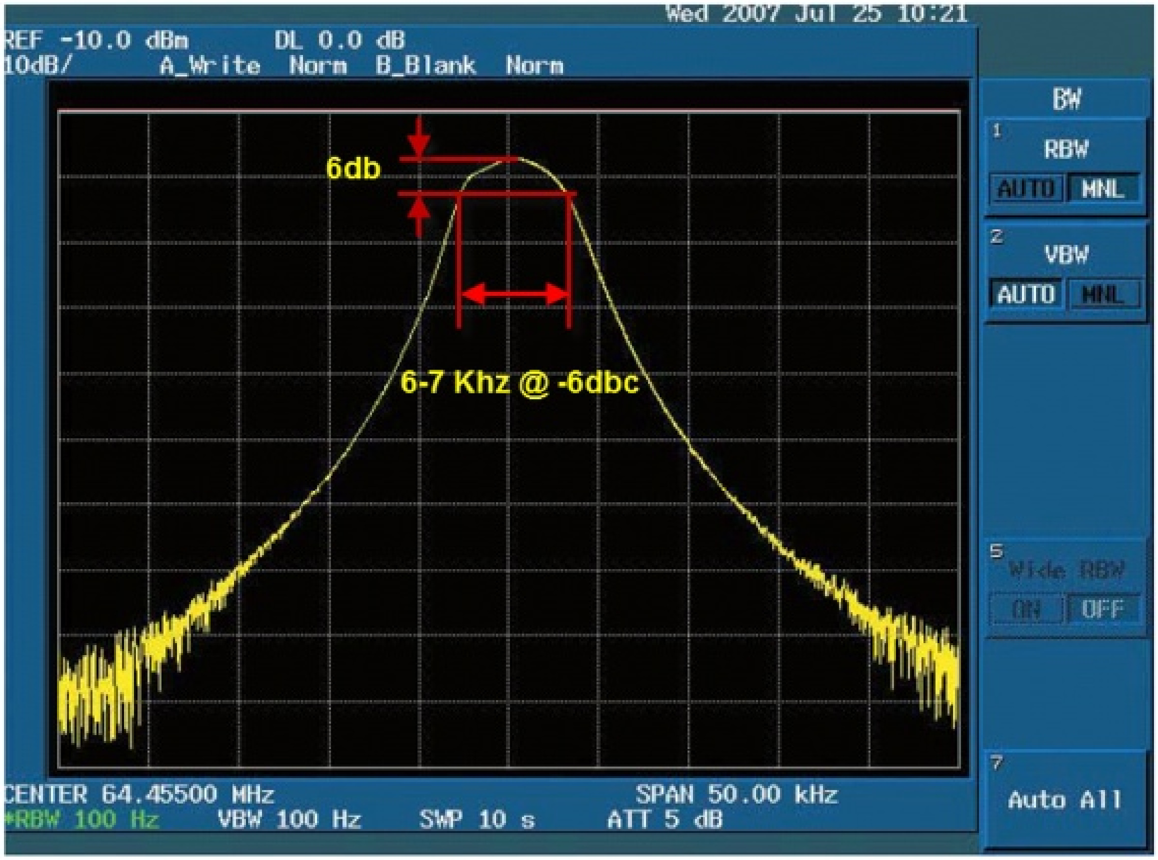


- Lot 19 FT-2000D
- Measured values

- *3 KHz OEM Filter*
  - **6.3 KHz @ -6 db**
  - 18.5 Khz @ -50 db
  - $11

- *2.4 KHz NS Filter*
  - 2.2 KHz @ -6 db
  - 5.3 KHz @ -50 db
  - $300

Icom Has Better Marketing Luck Than Yaesu???



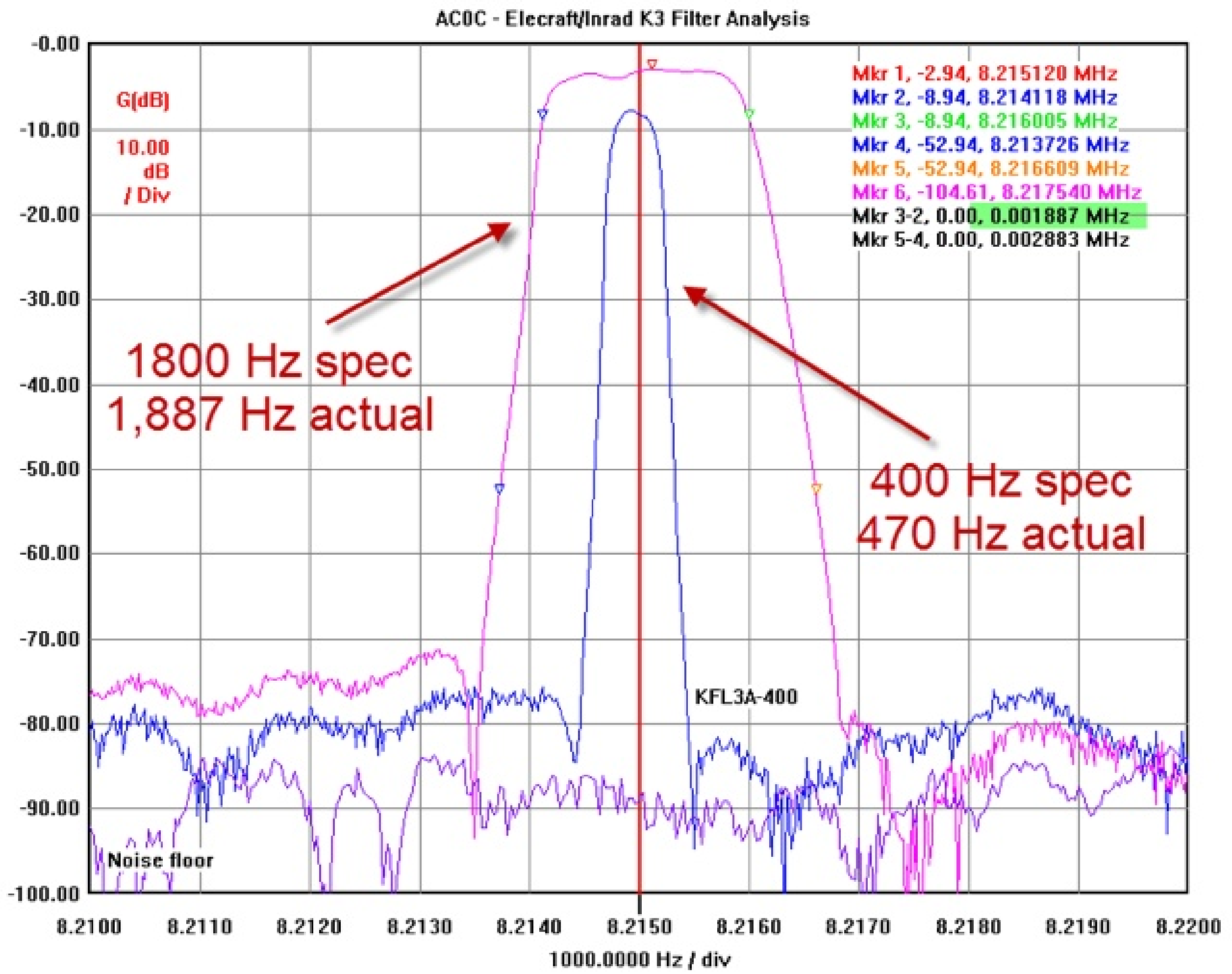
3kHz filter characteristics (50kHz span)

VHF Roof From Icom IC-7600 and IC-7700 Brochures

- "3 Khz" seems to mean different things to different companies…

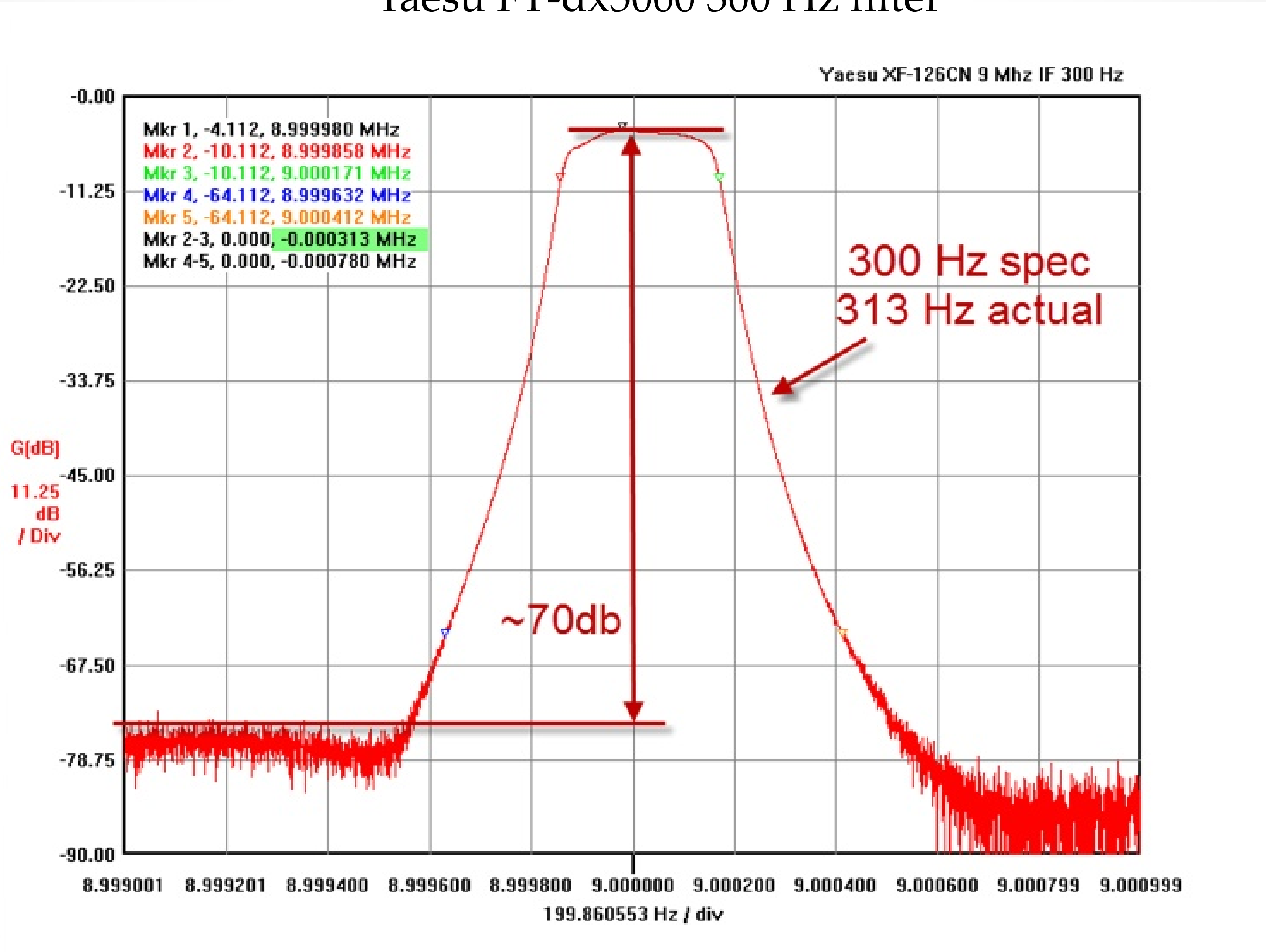
Down-Conversion HF Roofing Filters - VNA

Elecraft 8-pole 400 Hz & 1.8 KHz Inrad Filters



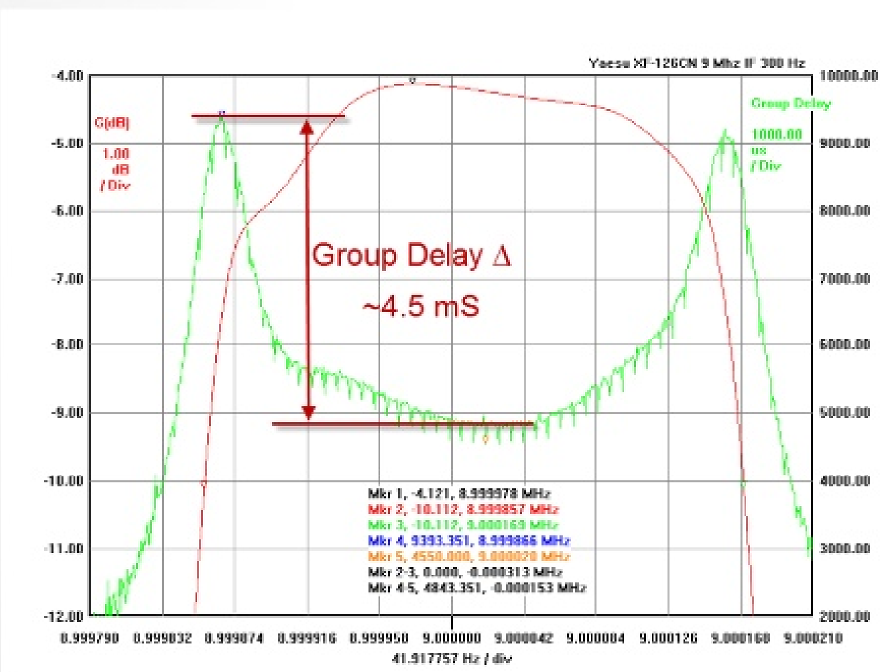
Down-Conversion HF Roofing Filters - VNA

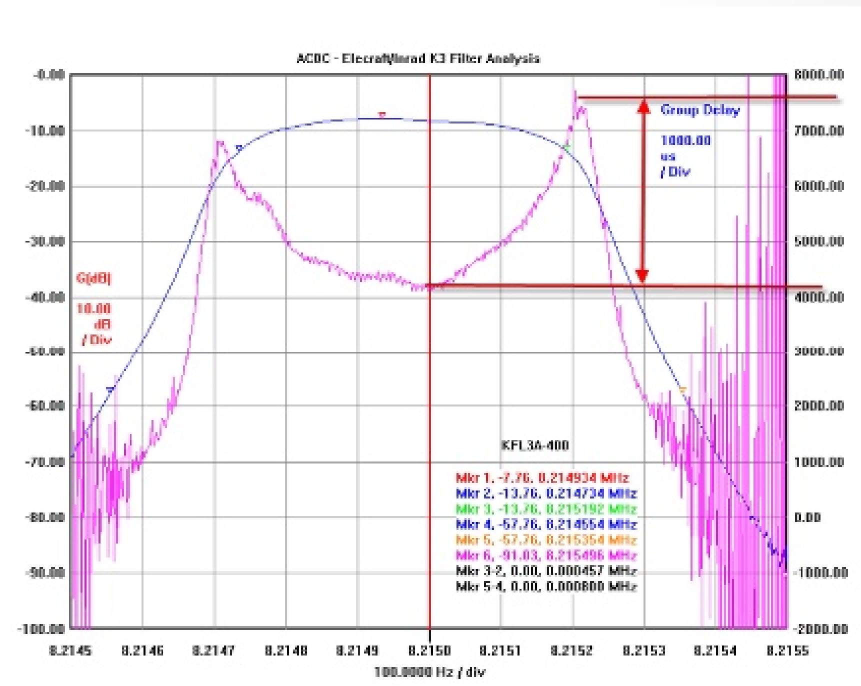
Yaesu FT-dx5000 300 Hz filter



Roofing Filters – Bandwidth Tip

- **Use a wider roof if conditions allow – less fatigue**
- Crystal filter designs → focus on steep skirts
- Trade-off is uneven "group delay" → ringing
- Group delay is a problem for RTTY
- DSP implementations (regarding ringing) vary → IIR types best





The Last Word on the DR3 Spec

How Much is Enough?

DR3 – How Much is Enough?

- Expert Opinion
  - NC0B Rob Sherwood: 80 db @ 2 Khz CW, 70 db SSB
  - W8JI Tom : 80-85 db @ 2 Khz

- Contest Community Examples
  - K3LR – Runs IC-7800 (85 db)
  - W3LPL – Mix of 10 FT-1000 (78 db) + 2 K3
  - K5G0 – Runs mix of 3 K3 + 6 IC-765 (DR3???)
  - NR5M – Mix of IC-7800, IC-7700, ProIII
  - P49X – Mix of Pro3, FT990, FT1K, K3
  - WRTC 2010 – 5 of top 10 teams ran FT-1000

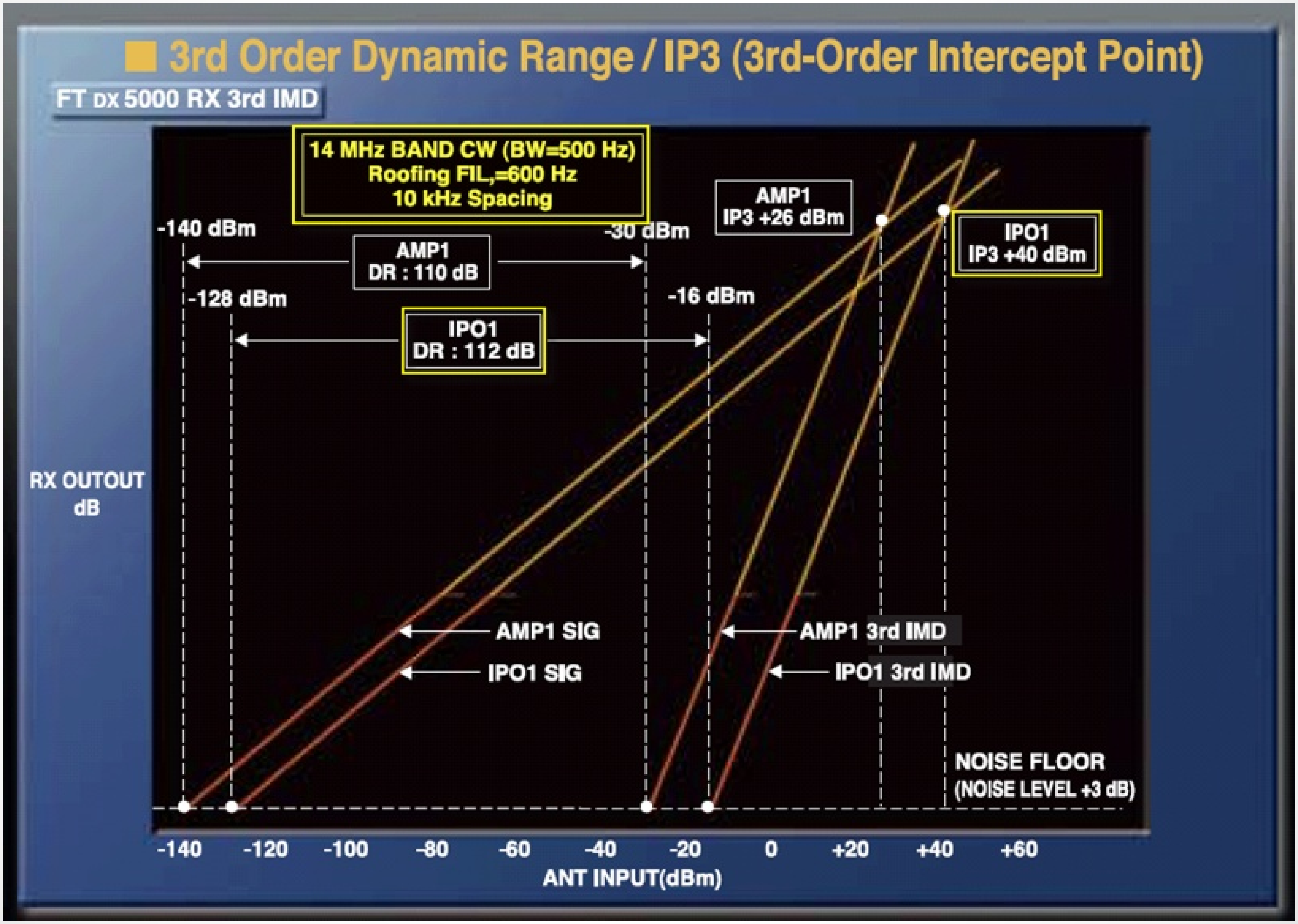
- How much is enough?

80 db CW + 70 db SSB   **most of the time**

Published Test Result Example

Yaesu FT-dx5000

Yaesu Representations



ARRL – December 2010

Table 1

Yaesu FTdx5000, serial number 00020034

Manufacturer's Specifications	Measured in the ARRL Lab
Frequency coverage: Receive, 0.03-60 MHz; transmit, 1.8-2, 3.5-4, 5.3305, 5.3465, 5.3665, 5.3715, 5.4035, 7-7.3, 10.1-10.15, 14-14.35, 18.068-18.168, 21-21.44, 24.89-24.99, 28-29.7, 50-54 MHz.	Receive and transmit, as specified.
Power consumption at 117 V ac: receive, no signal, 70 VA; signal present, 80 VA, transmit, 200 W output, 720 VA.	Receive, no signal, 61 VA; receive signal present, max audio, 66 VA; transmit, 481 VA at 200 W RF output.
Modes of operation: SSB, CW, AM, FM, RTTY, PKT.	As specified.
Receiver	***Receiver Dynamic Testing, Receiver "A"***
SSB/CW sensitivity: 2.4 kHz bandwidth, 10 dB S+N/N: 0.5-1.8 MHz, 2.0 µV; 1.8-30 MHz, 0.2 µV (Amp 2); 50-54 MHz, 1.25 µV (Amp 2). Preamp not available below 1.8 MHz.	Noise floor (MDS), 500 Hz bandwidth, 600 Hz roofing filter: *Preamp* / *Off (dBm)* / *1 (dBm)* / *2 (dBm)* 0.137 MHz −116 — — 0.505 MHz −117 — — 1.0 MHz −118 — — 3.5 MHz −126 −136 −143 14 MHz −126 −136 −142 50 MHz −120 −131 −140
Noise figure: Not specified.	14 MHz, preamp off/1/2: 21/11/5 dB
AM sensitivity: 6 kHz bandwidth, 10 dB S+N/N: 0.5-1.8 MHz, 6 µV; 1.8-30 MHz, 2 µV (Amp 2); 6 meters, 1 µV (Amp 2).	10 dB (S+N)/N, 1-kHz, 30% modulation, 9 kHz filter, 15 kHz roofing filter: 1.0 MHz 8.60 µV 3.8 MHz 0.47 µV (Preamp 2 on) 50 MHz 0.59 µV (Preamp 2 on)
FM sensitivity: 15 kHz bandwidth, 12 dB SINAD: 0.1-30 MHz, 0.5 µV (Amp 2); 50-54 MHz, 0.35 µV (Amp 2)	For 12 dB SINAD, preamp 2 on: 29 MHz 0.22 µV 52 MHz 0.23 µV
Spectral display sensitivity: Not specified.	−115 dBm maximum with optional SM-5000 station monitor.
Blocking gain compression: Not specified.	Gain compression, 500 Hz bandwidth, 600 Hz roofing filter: *20 kHz offset, Preamp off/1/2* / *5/2 kHz offset, Preamp off* 3.5 MHz 136*/146/142 dB 136*/136* dB 14 MHz 136*/146/142 dB 136*/136* dB 50 MHz 130*/141/137 dB 130*/127 dB
Reciprocal Mixing (500 Hz BW): Not specified.	20/5/2 kHz offset: −109/−109/−104 dBc.

ARRL Lab Two-Tone IMD Testing (300 Hz bandwidth, 300 Hz roofing filter)**

Band/Preamp	*Spacing*	*Input Level*	*Measured IMD Level*	*Measured IMD DR*	*Calculated IP3*
3.5 MHz Off	20 kHz	−17 dBm	−126 dBm	109 dB	+38 dBm
		−11 dBm	−97 dBm		+32 dBm
14 MHz/Off	20 kHz	−12 dBm	−126 dBm	114 dB	+45 dBm
		−5 dBm	−97 dBm		+41 dBm
		0 dBm	−84 dBm		+42 dBm
14 MHz/Pre 1	20 kHz	−24 dBm	−136 dBm	112 dB	+34 dBm
		−22 dBm	−97 dBm		+28 dBm
14 MHz/Pre 2	20 kHz	−36 dBm	−143 dBm	107 dB	+18 dBm
		−22 dBm	−97 dBm		+16 dBm
14 MHz/Off	5 kHz	−12 dBm	−126 dBm	114 dB	+45 dBm
		−6 dBm	−97 dBm		+40 dBm
		0 dBm	−82 dBm		+41 dBm
14 MHz/Off	2 kHz	−12 dBm	−126 dBm	114 dB	+45 dBm
		−6 dBm	−97 dBm		+40 dBm
		0 dBm	−82 dBm		+41 dBm
50 MHz/Off	20 kHz	−14 dBm	−120 dBm	106 dB	+39 dBm
		−8 dBm	−97 dBm		+37 dBm

Second-order intercept point: Not specified.	14 MHz, Preamp off/1/2: +85/+71/+71 dBm.
DSP noise reduction: Not specified.	Variable, 30 dB maximum.
Notch filter depth: Not specified.	Manual: >70 dB, auto: >70 dB. Attack time: 60 ms.
FM two-tone, third-order IMD dynamic range: Not specified.	20 kHz offset, Preamp 2: 29 MHz, 100 dB[1]; 52 MHz, 96 dB[1]. 10 MHz channel spacing: 52 MHz, 91 dB.

ARRL Lab Two-Tone IMD Testing (300 Hz bandwidth, 300 Hz roofing filter)**

Band/Preamp	*Spacing*	*Input Level*	*Measured IMD Level*	*Measured IMD DR*	*Calculated IP3*
3.5 MHz Off	20 kHz	−17 dBm	−126 dBm	109 dB	+38 dBm
		−11 dBm	−97 dBm		+32 dBm
14 MHz/Off	20 kHz	−12 dBm	−126 dBm	114 dB	+45 dBm
		−5 dBm	−97 dBm		+41 dBm
		0 dBm	−84 dBm		+42 dBm
14 MHz/Pre 1	20 kHz	−24 dBm	−136 dBm	112 dB	+34 dBm
		−22 dBm	−97 dBm		+28 dBm
14 MHz/Pre 2	20 kHz	−36 dBm	−143 dBm	107 dB	+18 dBm
		−22 dBm	−97 dBm		+16 dBm
14 MHz/Off	5 kHz	−12 dBm	−126 dBm	114 dB	+45 dBm
		−6 dBm	−97 dBm		+40 dBm
		0 dBm	−82 dBm		+41 dBm
14 MHz/Off	2 kHz	−12 dBm	−126 dBm	114 dB	+45 dBm
		−6 dBm	−97 dBm		+40 dBm
		0 dBm	−82 dBm		+41 dBm
50 MHz/Off	20 kHz	−14 dBm	−120 dBm	106 dB	+39 dBm
		−8 dBm	−97 dBm		+37 dBm

RSGB – June 2010

TABLE 1: Yaesu FTDX5000 measured performance.

RECEIVER MEASUREMENTS, VFO-A

FREQUENCY	SENSITIVITY SSB 10dBs+n:n IPO1	PREAMP 1	PREAMP 2	INPUT FOR S9 IPO1	PREAMP 1	PREAMP 2
1.8MHz	0.8µV (-109dBm)	0.2µV (-121dBm)	0.14µV (-124dBm)	125µV	32µV	10µV
3.5MHz	0.6µV (-111dBm)	0.16µV (-123dBm)	0.09µV (-128dBm)	140µV	35µV	10µV
7MHz	0.7µV (-110dBm)	0.18µV (-122dBm)	0.1µV (-127dBm)	140µV	35µV	10µV
10MHz	0.9µV (-108dBm)	0.22µV (-120dBm)	0.11µV (-126dBm)	140µV	35µV	10µV
14MHz	0.6µV (-111dBm)	0.18µV (-122dBm)	0.09µV (-128dBm)	140µV	35µV	10µV
18MHz	0.7µV (-110dBm)	0.18µV (-122dBm)	0.1µV (-127dBm)	140µV	35µV	10µV
21MHz	0.7µV (-110dBm)	0.18µV (-122dBm)	0.09µV (-128dBm)	140µV	35µV	10µV
24MHz	0.8µV (-109dBm)	0.2µV (-121dBm)	0.09µV (-128dBm)	140µV	35µV	10µV
28MHz	0.8µV (-109dBm)	0.2µV (-121dBm)	0.09µV (-128dBm)	140µV	35µV	10µV
50MHz	1.1µV (-106dBm)	0.3µV (-118dBm)	0.11µV (-126dBm)	140µV	30µV	8µV

AM sensitivity (28MHz) Preamp 1: 1.3µV for 10dBs+n:n at 30% mod depth
FM sensitivity (28MHz) Preamp 1: 0.4µV for 12dB SINAD 3kHz pk deviation
AGC threshold Preamp1: 3µV
100dB above AGC threshold for <1dB audio output increase
AGC attack time: 1-2ms
AGC decay time: approx as specified
Max audio at 1% distortion: 3.5W into 4Ω
In-band intermodulation products: -40 to -50dB

S-READING (7MHz)	PREAMP 1	BANDWIDTH/ROOF SET TO	BANDWIDTH -6dB	-60dB	-70dB	-80dB
S1	2.8µV	2.4kHz/3kHz roof				
S3	5.6µV	Steep	2507Hz	3044Hz	3101Hz	3142Hz
S5	8.9µV	Medium	2561Hz	3249Hz	3344Hz	3442Hz
S7	18µV	Gentle	2683Hz	3710Hz	3889Hz	4097Hz
S9	35µV	500Hz/600Hz roof				
S9+20	350µV	Steep	525Hz	660Hz	683Hz	767Hz
S9+40	3.5mV	Medium	535Hz	709Hz	745Hz	849Hz
S9+60	28mV	Gentle	558Hz	788Hz	852Hz	1020Hz

INTERMODULATION (50kHz tone spacing) 2400Hz bandwidth 6kHz roof USB

Frequency	IPO1 3rd order intercept	2 tone dynamic range	PREAMP 1 3rd order intercept	2 tone dynamic range	PREAMP 2 3rd order intercept	2 tone dynamic range
1.8MHz	+33dBm	101dB	+21dBm	101dB	+1dBm	90dB
3.5MHz	+34.5dBm	104dB	+22.5dBm	104dB	+11dBm	99dB
7MHz	+37.5dBm	105dB	+26dBm	105dB	+18dBm	103dB
14MHz	+36dBm	105dB	+24dBm	104dB	+12dBm	100dB
21MHz	+36dBm	104dB	+24dBm	104dB	+13dBm	101dB
28MHz	+35dBm	103dB	+22.5dBm	102dB	+12dBm	100dB
50MHz	+38dBm	103dB	+25dBm	103dB	+12dBm	99dB

CLOSE-IN INTERMODULATION ON 7MHz BAND 500Hz bandwidth CW IPO1

Spacing	---15kHz ROOFING--- 3rd order intercept	2 tone dyn range	----6kHz ROOFING---- 3rd order intercept	2 tone dyn range	----3kHz ROOFING---- 3rd order intercept	2 tone dyn range	---600Hz ROOFING--- 3rd order intercept	2 tone dyn range
0.5kHz	-8.5dBm	77dB	-8.5dBm	77dB	-5dBm	80dB	+30.5dBm	104dB
1kHz	-8.5dBm	77dB	-8.5dBm	77dB	+6.5dBm	88dB	+36.5dBm	108dB
1.5kHz	-8.5dBm	77dB	-8.5dBm	77dB	null	null	+37dBm	109dB
2kHz	-8.5dBm	77dB	-4dBm	80dB	+33.5dBm	106dB	+37dBm	109dB
3kHz	-8.5dBm	77dB	+3.5dBm	85dB	+36.5dBm	108dB	+38dBm	109dB
4kHz	-2.5dBm	81dB	+24.5dBm	99dB	+37dBm	108dB	+38dBm	109dB
5kHz	null	null	+39.5dBm	109dB	+38dBm	109dB	+38dBm	109dB
7kHz	+21.5dBm	97dB	+39dBm	109dB	+38dBm	109dB	+38dBm	109dB
10kHz	+38dBm	108dB	+39dBm	109dB	+38dBm	109dB	+38dBm	109dB
15kHz	+38dBm	108dB	+38dBm	108dB	+38dBm	109dB	+38dBm	109dB
20kHz	+38dBm	108dB	+38dBm	108dB	+38dBm	109dB	+38dBm	109dB

FREQUENCY OFFSET	RECIPROCAL MIXING FOR 3dB NOISE 500Hz BW VFO-A	VFO-B	BLOCKING AMP1 15kHz ROOF	6kHz ROOF	3kHz ROOF
0.5kHz	86dB	not meas	-32dBm	-32dBm	-32dBm
1kHz	96dB	89dB	-32dBm	-32dBm	-32dBm
2kHz	104dB	97dB	-32dBm	-32dBm	+6dBm
3kHz	107dB	100dB	-32dBm	-32dBm	+14dBm
5kHz	112dB	104dB	-32dBm	-15dBm	+14dBm
10kHz	114dB	108dB	0dBm	+14dBm	+14dBm
15kHz	112dB	109dB	+4dBm	+15dBm	+15dBm
20kHz	111dB	109dB	+13dBm	+15dBm	+15dBm
30kHz	106dB	109dB	+15dBm	+15dBm	+15dBm
50kHz	103dB	108dB	+15dBm	+15dBm	+15dBm
100kHz	98dB	106dB	+15dBm	+15dBm	+15dBm
200kHz	96dB	107dB	+15dBm	+15dBm	+15dBm

TRANSMITTER MEASUREMENTS

FREQUENCY	CLASS AB POWER OUTPUT	CLASS A POWER OUTPUT	INTERMOD. PRODUCTS CLASS AB 3rd/5th order	CLASS A 3rd/5th order	HARMONICS
1.8MHz	200W	75W	-34/-46dB	-40/-56dB	<-70dB

Intermodulation product levels are quoted with respect to PEP.

CLOSE-IN INTERMODULATION ON 7MHz BAND 500Hz bandwidth CW IPO1

Spacing	---15kHz ROOFING--- 3rd order intercept	2 tone dyn range	----6kHz ROOFING---- 3rd order intercept	2 tone dyn range	----3kHz ROOFING---- 3rd order intercept	2 tone dyn range	---600Hz ROOFING--- 3rd order intercept	2 tone dyn range
0.5kHz	-8.5dBm	77dB	-8.5dBm	77dB	-5dBm	80dB	+30.5dBm	104dB
1kHz	-8.5dBm	77dB	-8.5dBm	77dB	+6.5dBm	88dB	+36.5dBm	108dB
1.5kHz	-8.5dBm	77dB	-8.5dBm	77dB	null	null	+37dBm	109dB
2kHz	-8.5dBm	77dB	-4dBm	80dB	+33.5dBm	106dB	+37dBm	109dB
3kHz	-8.5dBm	77dB	+3.5dBm	85dB	+36.5dBm	108dB	+38dBm	109dB
4kHz	-2.5dBm	81dB	+24.5dBm	99dB	+37dBm	108dB	+38dBm	109dB
5kHz	null	null	+39.5dBm	109dB	+38dBm	109dB	+38dBm	109dB
7kHz	+21.5dBm	97dB	+39dBm	109dB	+38dBm	109dB	+38dBm	109dB
10kHz	+38dBm	108dB	+39dBm	109dB	+38dBm	109dB	+38dBm	109dB
15kHz	+38dBm	108dB	+38dBm	108dB	+38dBm	109dB	+38dBm	109dB
20kHz	+38dBm	108dB	+38dBm	108dB	+38dBm	109dB	+38dBm	109dB

Yaesu Published Conditions

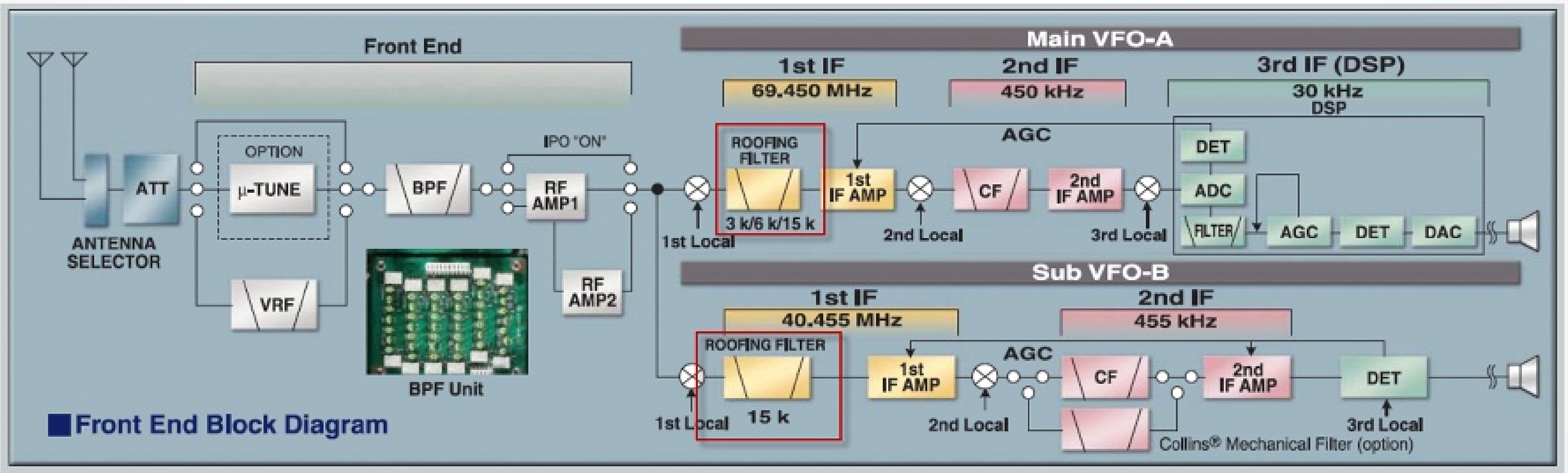
When Comparing Review Numbers…

- DR3 results vary with many conditions
- Conditions usually not consistent between reviewer
- Factors may include:
  - DSP bandwidth (RSGB 500 hz vs. ARRL 300 hz)
  - Roof bandwidth (RSGB 600 hz vs. ARRL 300 hz)
  - IMD product measurement (RSGB AF voltmeter vs. ARRL 3 hz RBW SA)
  - MDS floor (ARRL uses 3 different ones)
  - Frequency of test (RSGB 7 Mhz vs. ARRL 14 Mhz)
  - Preamp setting (default, in both cases)
  - Preselector settings (IPO1, in both cases)
  - Equipment and setup
  - Measurement methods for one source - may change over time

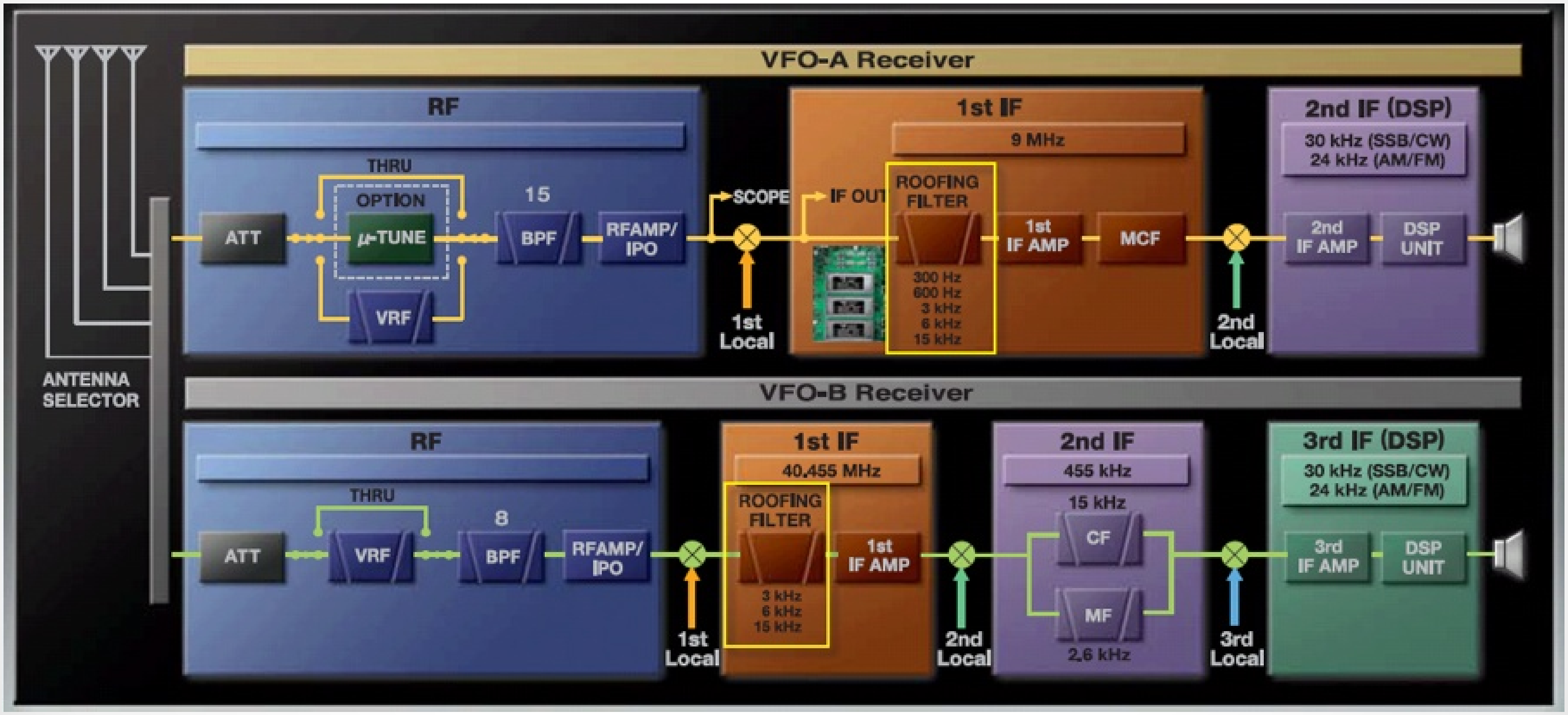
Rig Examples

Where the Roofs Are

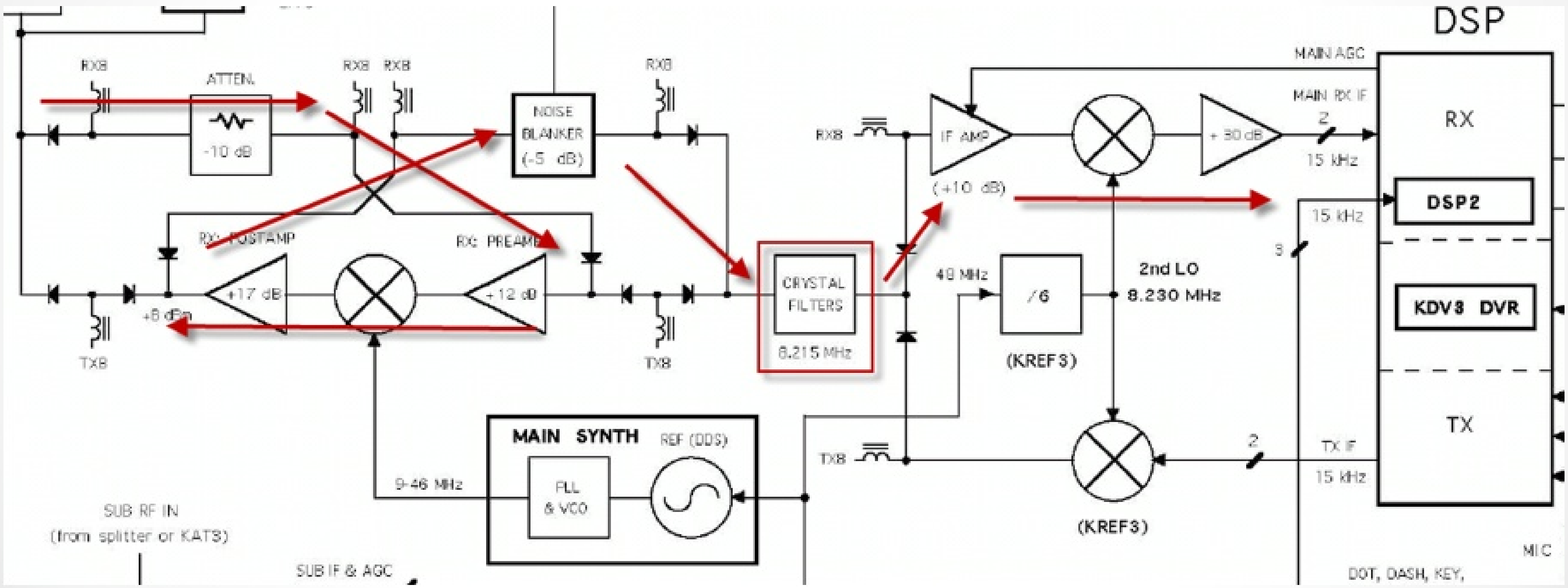
Roofing Filter: FT-2000



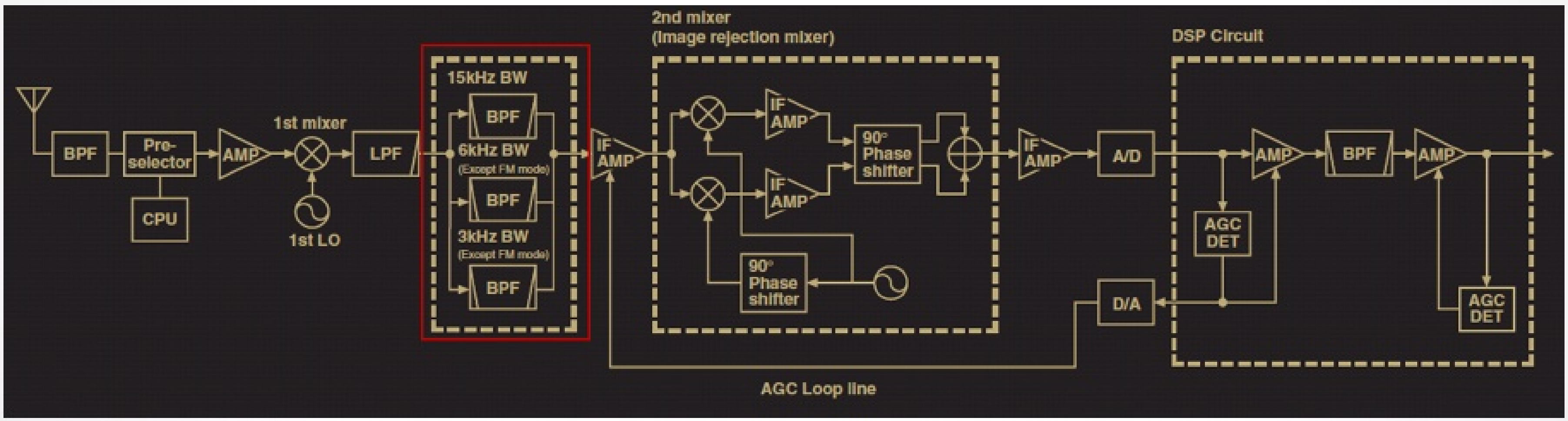
Roofing Filter: FT-5000



Roofing Filter: K3



Roofing Filter: IC-7800 / IC-7700



A Secret Weapon

Free Insurance for your Roof

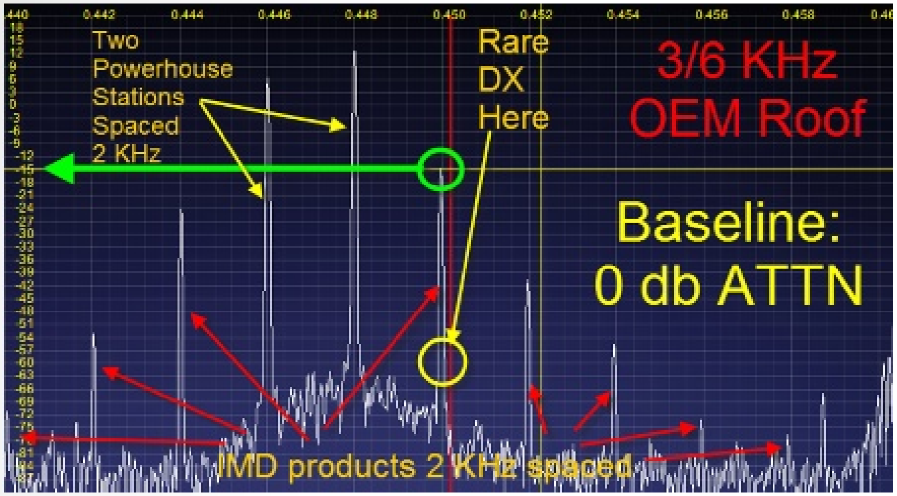
Secret Weapon: Use ATTN + Preamps Off

- No soldering iron required
- Free "virtual" DR3 improvement
- Set IPO mode (preamps off)
- Add ATTN

- IMD products drop by 3x the selected attenuation value!

Secret Weapon: Use ATTN

What the 3rd Mixer Sees – With varying ATTN



- Effect of ATTN on IMD product levels ~ 3:1 ratio

ATTN	IMD Level
-6 db	▼ 15 db
-12 db	▼ 30 db
-18 db	▼ 45 db

Secret Weapon: Use Preamps With Caution

What the 3rd Mixer Sees – With varying PRE

- Effect of PRE on IMD product levels ~ 3:1 ratio

PREAMP	IMD Level
IPO (no pre)	<Baseline>
PRE 1 (+11 db)	▲ 30 db
PRE 2 (+17 db)	▲ 50 db

Secret Weapon: Attenuation with Band

Lot 19 FT-2000D @ AC0C tested 7/21/2011

Band	Attn possible	IMD level drop by
160m	12-18 db	36-54 db
80m	12 db	36 db
40m	6-12 db	18-36 db
20m	6 db	18 db
15m	0-6 db	0-18 db
10m	0	0

- Shows ATTN switch range possible <u>without loss of useable sensitivity</u>

- Table ignores phase noise limits

Closing Thoughts

- Roofs serve a critical function → beware marketing spin
- Specs (DR3, etc) are hard to compare → on 100% same-same basis
- Fact: Mid-tier modern rigs will give you the QSO in most cases → use attenuation on the low bands when needed
- Personal testimonials ("buddy hype") are almost never unbiased
- Am I insuring for the possible exception – or paying up for real utility?
- Sports vs. luxury outlook – know your operating style
- Ergonomics and aesthetics ARE important
- The perfect rig has yet to be built
- Any rig is FB – if you don't operate…

Thanks to the CADXA!

Contact AC0C

Web: www.acØc.com

Email: jeff@acØc.com

References

- Rohde, Ulrich L., KA2WEU, Key Components of Modern Receiver Design – Parts 1-3, QST May-Jul 1994
- Rohde, Ulrich L., KA2WEU, Key Components of Modern Receiver Design: A Second Look, QST Dec 1994
- Smith, Doug., KF6DX, Improved Dynamic Range Testing, QEX Jul/Aug 2002
- Asbrink, Leif, SM5BSZ, Blocking Dynamic Range in Receivers, QEX Mar/Apr 2006
- Rohde, Ulrich L., KA2WEU, Theory of Intermodulation and Reciprocal Mixing: Practice, Definitions and Measurements in Devices and Systems, Parts 1-2, QEX Nov/Dec 2002, Jan/Feb 2003
- Chadwick, Peter, G3RZP, HF Receiver Dynamic Range: How Much Do We Need?, QEX May/Jun 2002
- Cartoceti, Sergio, IK4AUY, A Doubly Balanced "H-Mode" Mixer for HF, QEX Jul/Aug 2004
- Sherwood, Rob, NC0B, Roofing Filters, Transmitted IMD and Receiver Performance, BARC 2008 presentation
- Hayward, Wes, W7ZOI, Campbell, Rick, KK7B, Larkin, Bob, W7PUA, Experimental Methods in RF Design, Revised First Edition, 2009
- Bakker, Martein, PA3AKE, WWW: martein.home.xs4all.nl/pa3ake/hmode/receiver_intro.html
- Rohde, Ulrich L., KA2WEU, Recent Advances in Receiver Design, QST Nov 1992
- Fishk, James, W1DTY, Receiver Noise Figure Sensitivity and Dynamic Range – What the Numbers Mean, Ham Radio, Oct 1975
- Rauch, Tom, W8JI, WWW: w8ji.com/receiver_tests.htm
- WRTC 2010 Result Table, WWW: wrtc2010.ru/result_table.php
- Smith, Pete, N4ZR, World HF Contest Station Database, WWW: conteststations.com
- Anritsu, Intermodulation Distortion, Application Note 13, WWW: downloadfile.anritsu.com/RefFiles/en-US/Services-Support/Downloads/Application-Notes/Application-Note/IMDanREVc.pdf