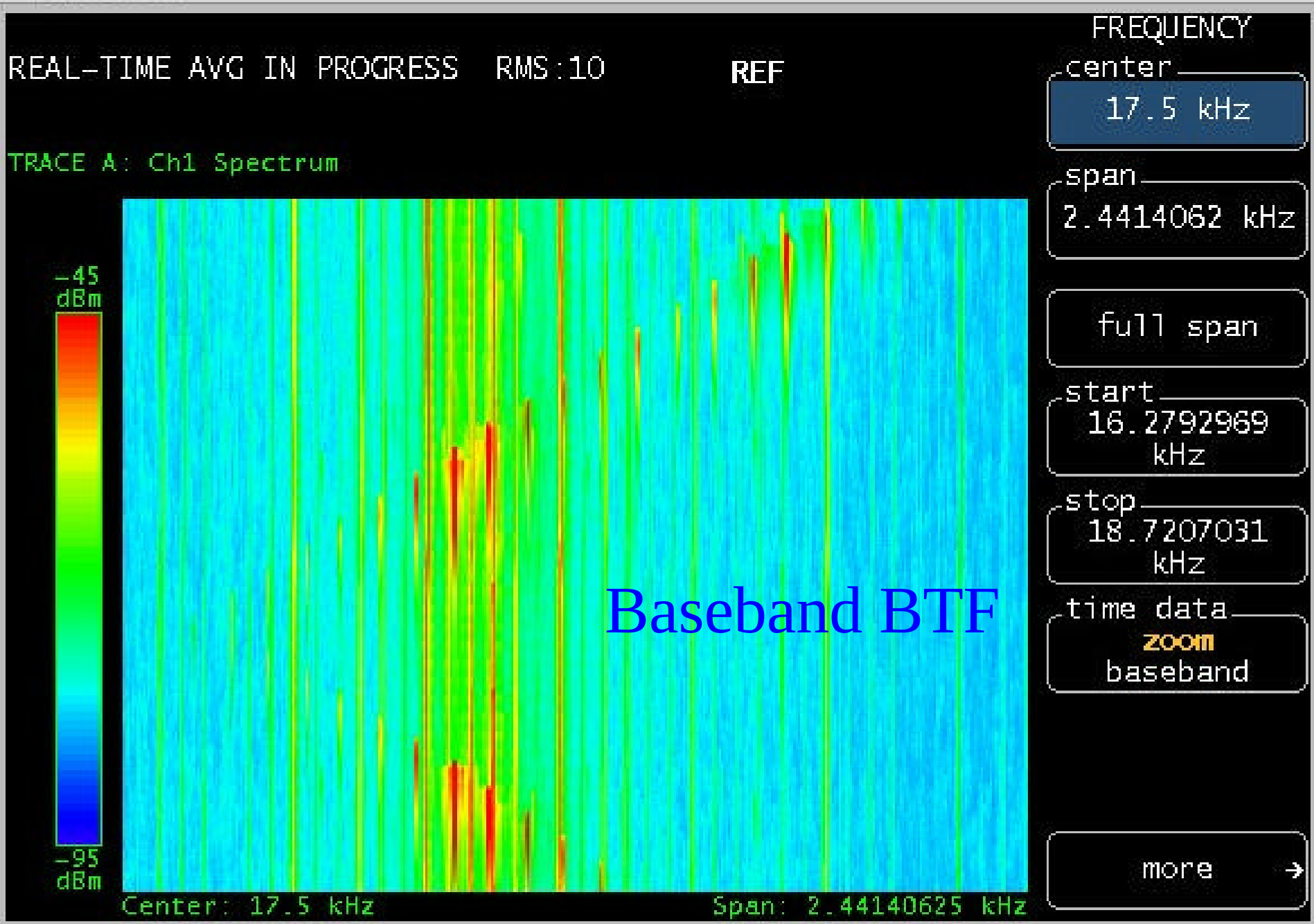
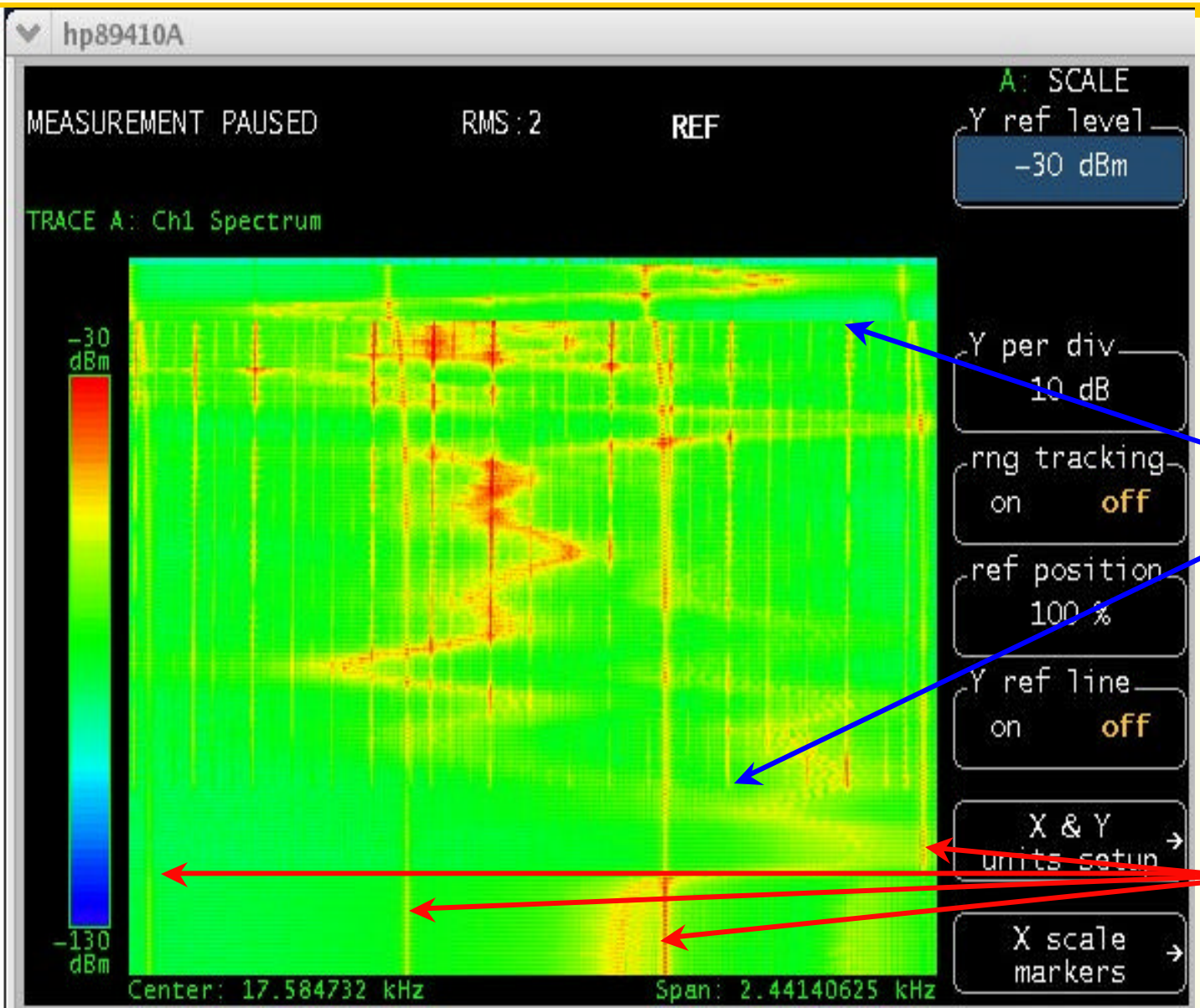
The 60Hz Problem

Peter Cameron

hp89410A


REAL-TIME AVG IN PROGRESS RMS:10
REF
TRACE A: Ch1 Spectrum
-45 dBm
-95 dBm
Baseband BTF
Center: 17.5 kHz
Span: 2.44140625 kHz
FREQUENCY
center
17.5 kHz
span
2.4414062 kHz
full span
start
16.2792969 kHz
stop
18.7207031 kHz
time data
zoom
baseband
more

3D Ramp - 1 Jan 05

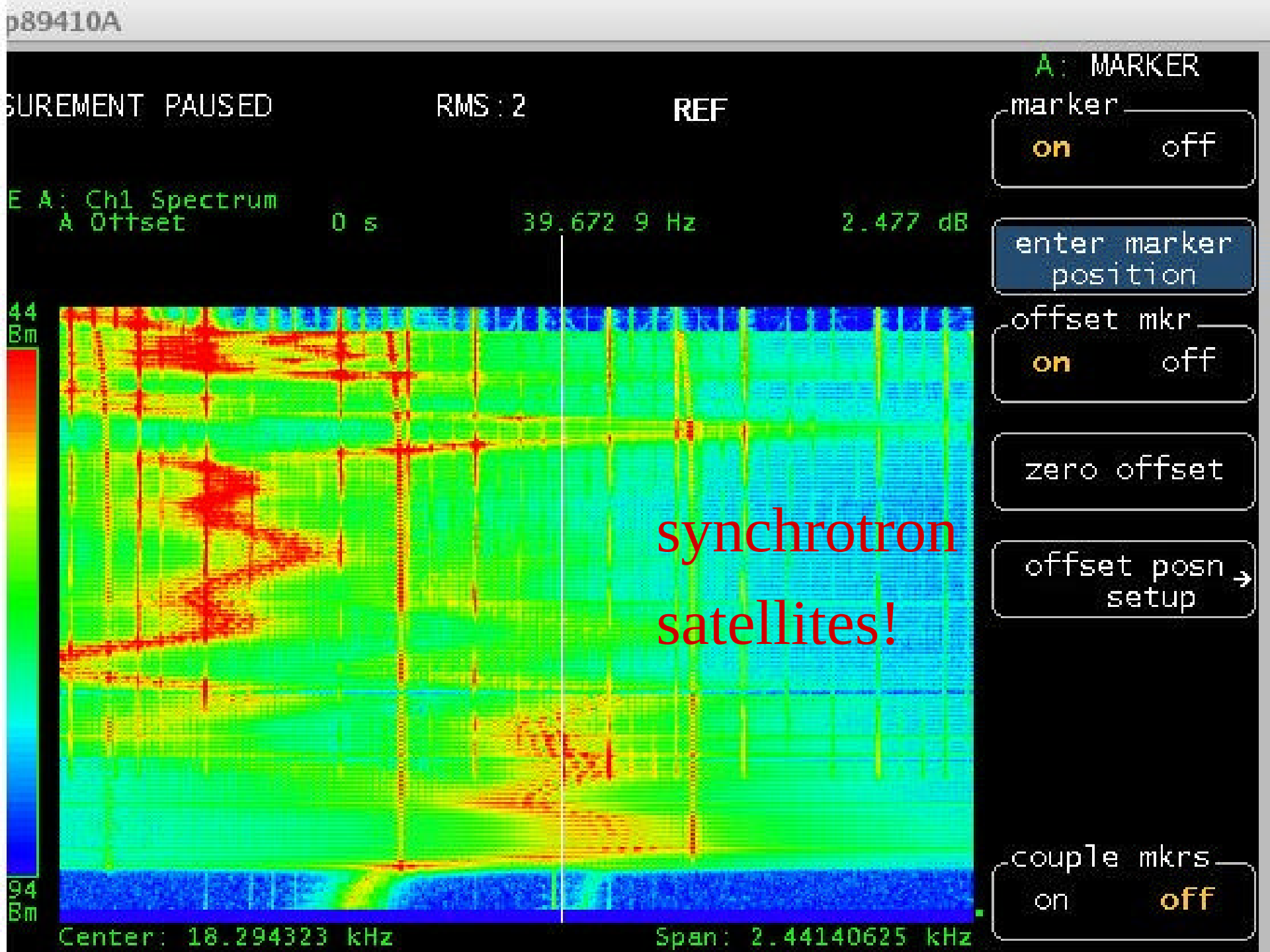


dominant spacing is 360Hz

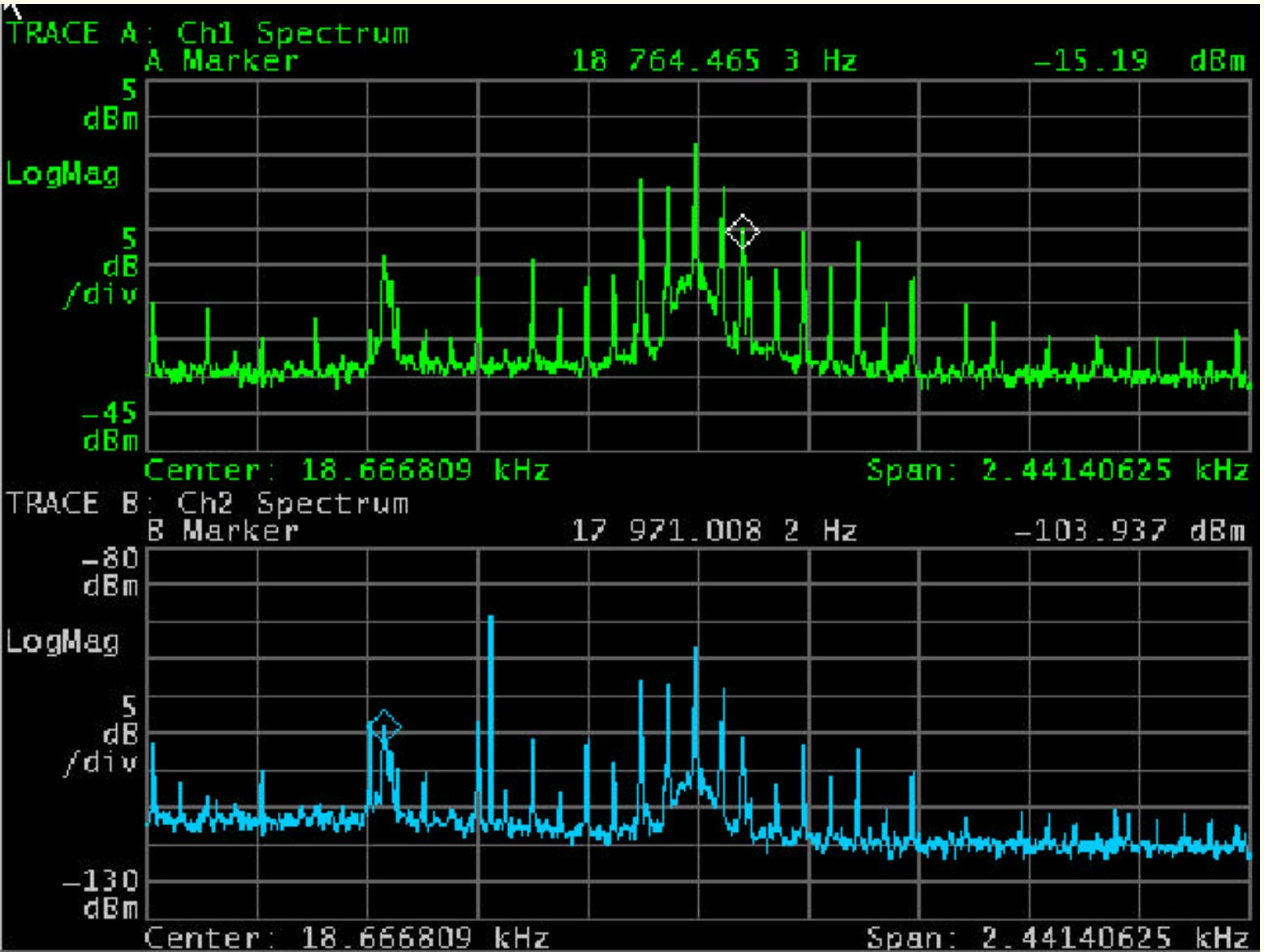
60Hz onset

60Hz end

IPM every 100 turns? (780 Hz)


p89410A
A: MARKER
SUREMENT PAUSED
RMS: 2
REF
marker
on
off
E A: Ch1 Spectrum
A Offset
0 s
39.672 9 Hz
2.477 dB
enter marker position
offset mkr
on
off
zero offset
offset posn setup
synchrotron satellites!
44 Bm
94 Bm
couple mkrs
on
off
Center: 18.294323 kHz
Span: 2.44140625 kHz

3D and Homodyne - 'identical'

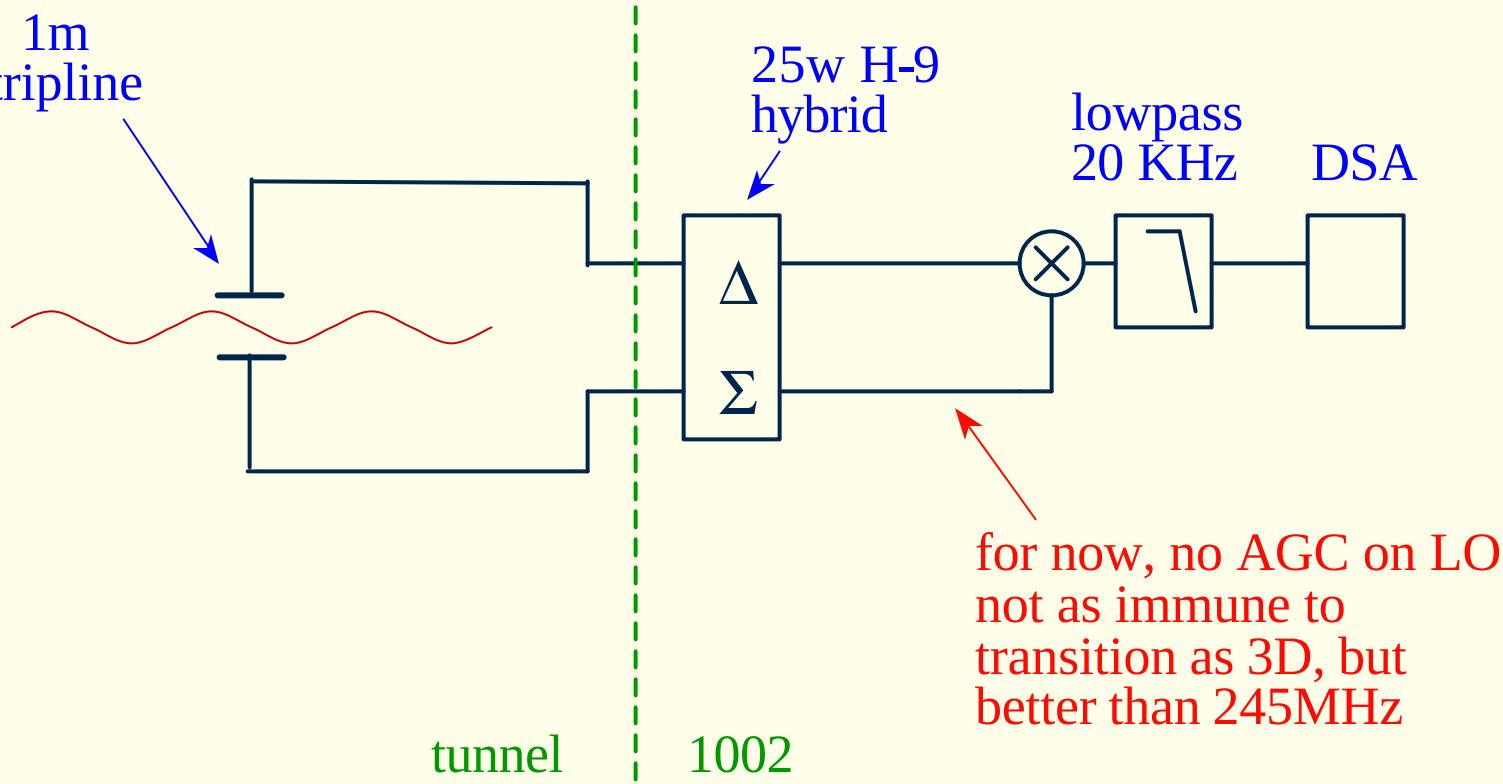


3D

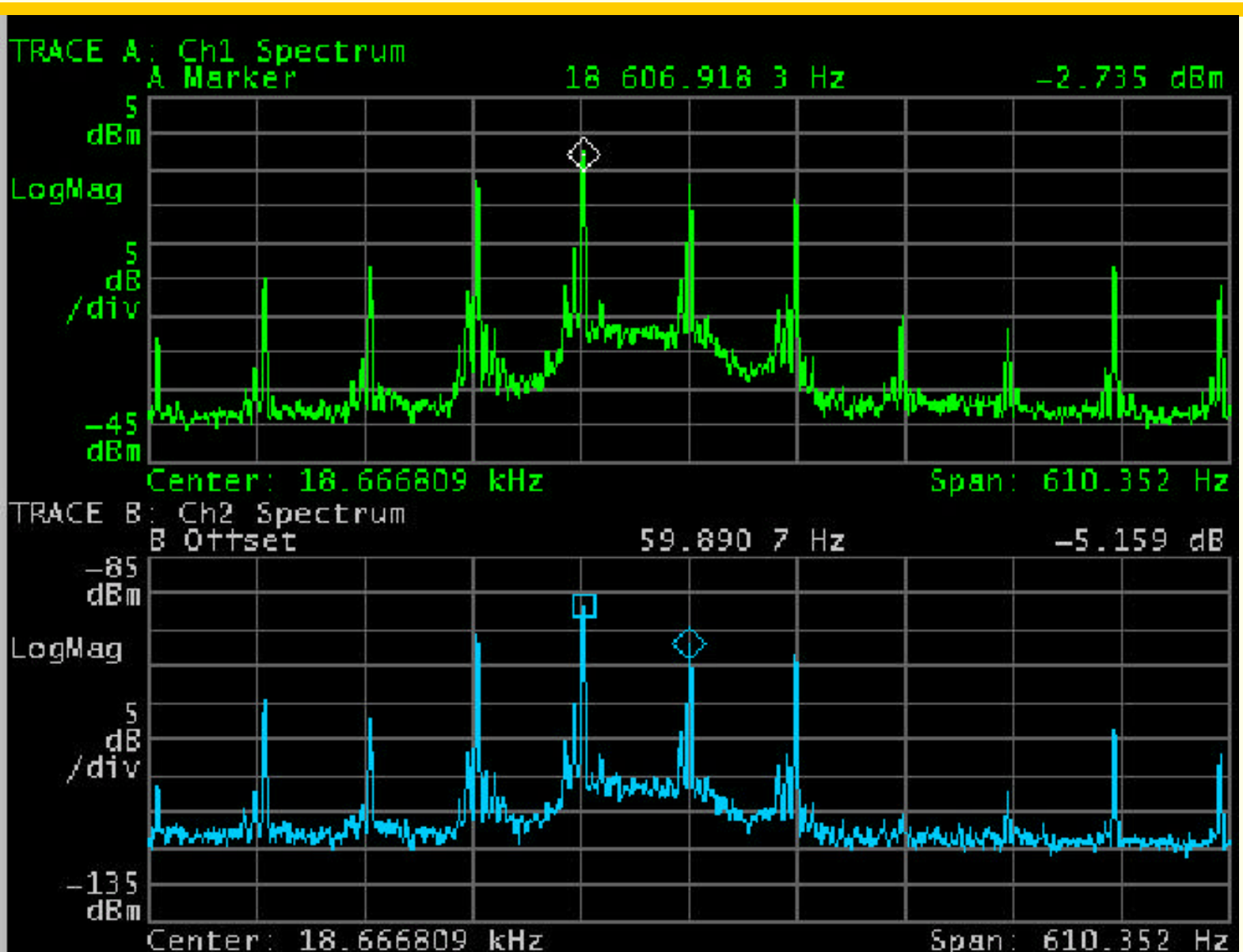
at store
37 bunches
200MHz on

hdyne

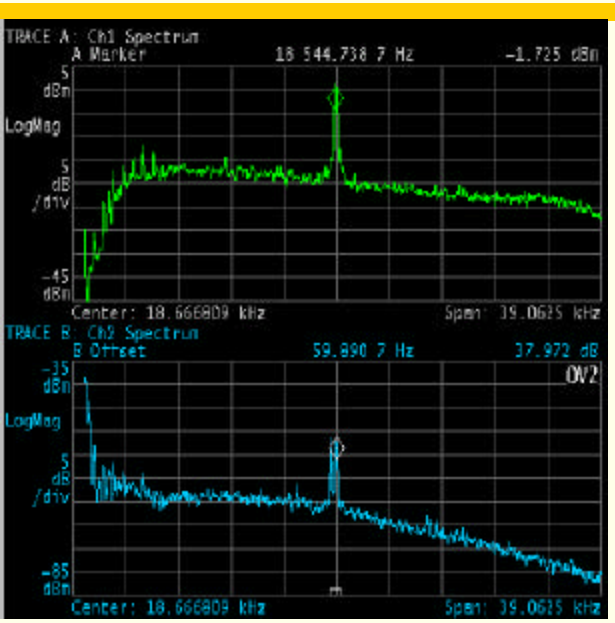
Homodyne detection method

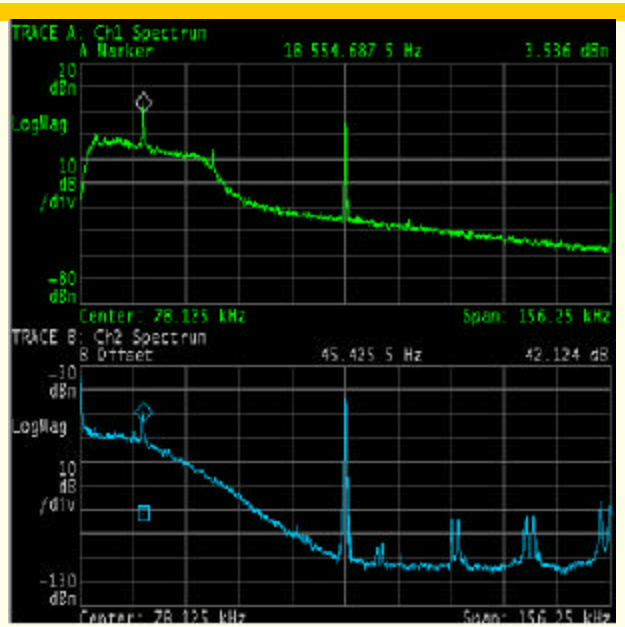


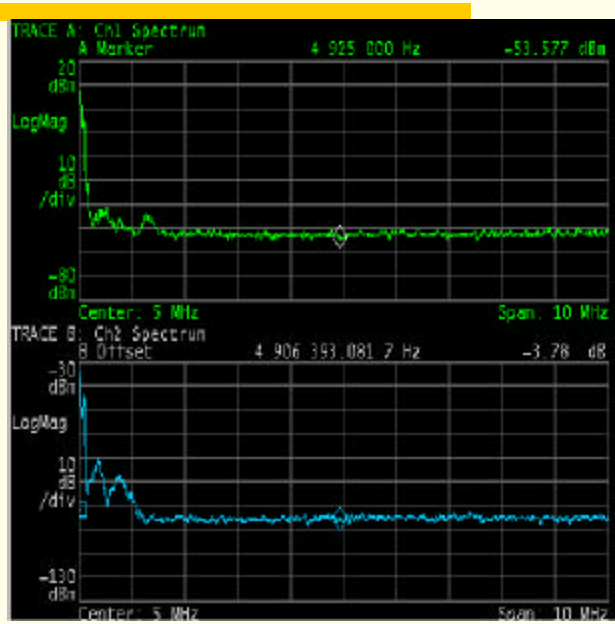
3D and Homodyne - 'identical' 2



3D and Homodyne - 'identical' 3







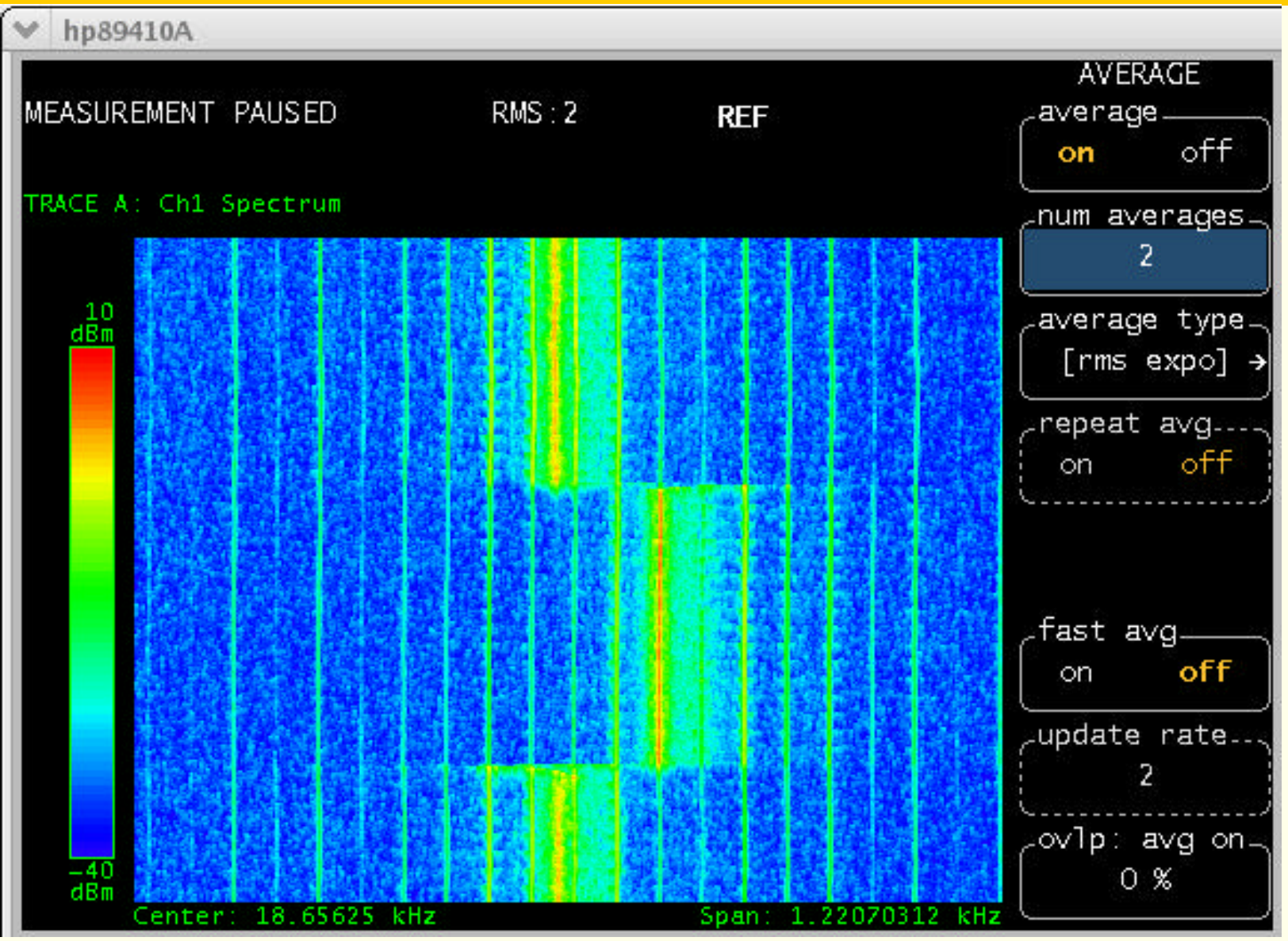
span 39KHz

span 156KHz

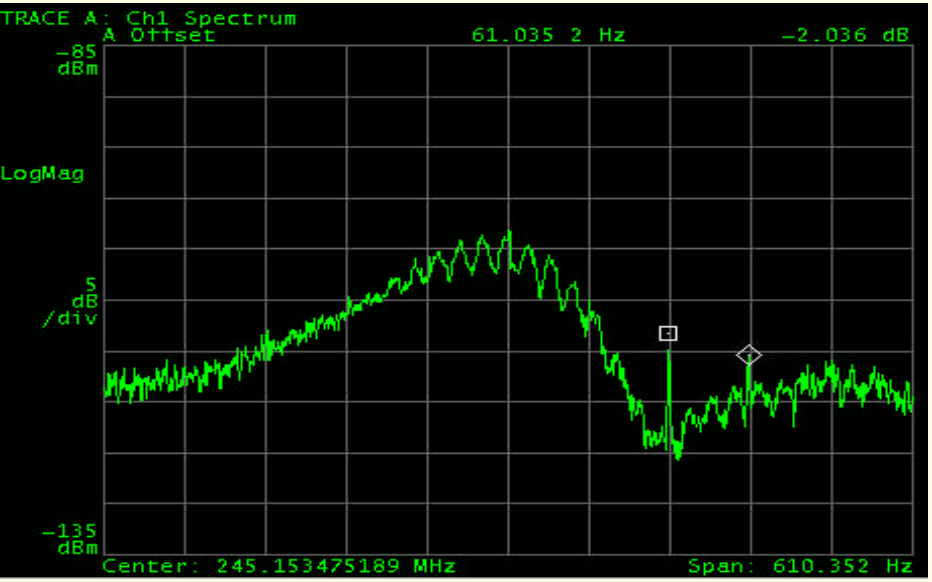
span 10MHz

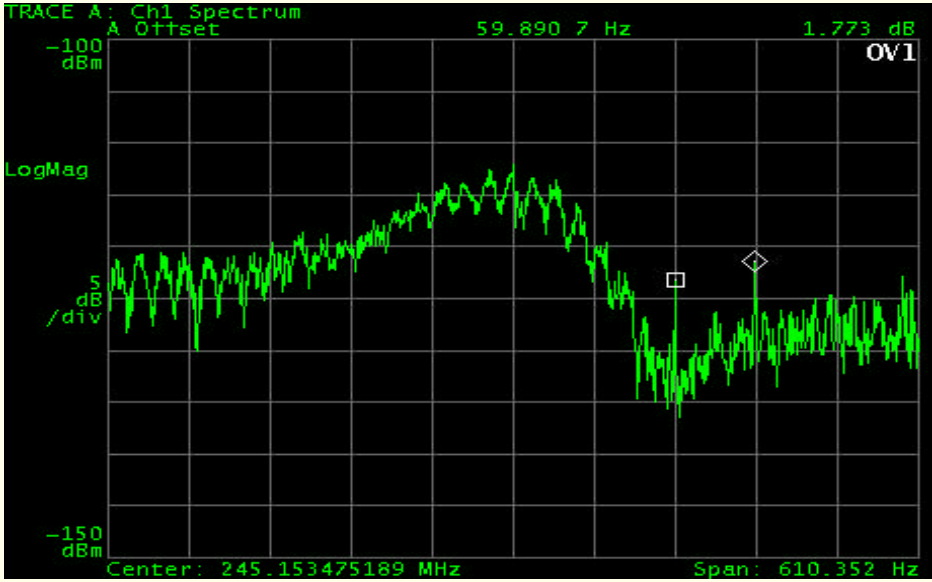
no obvious evidence (noise floor rising, additional lines,...) of non-linearity

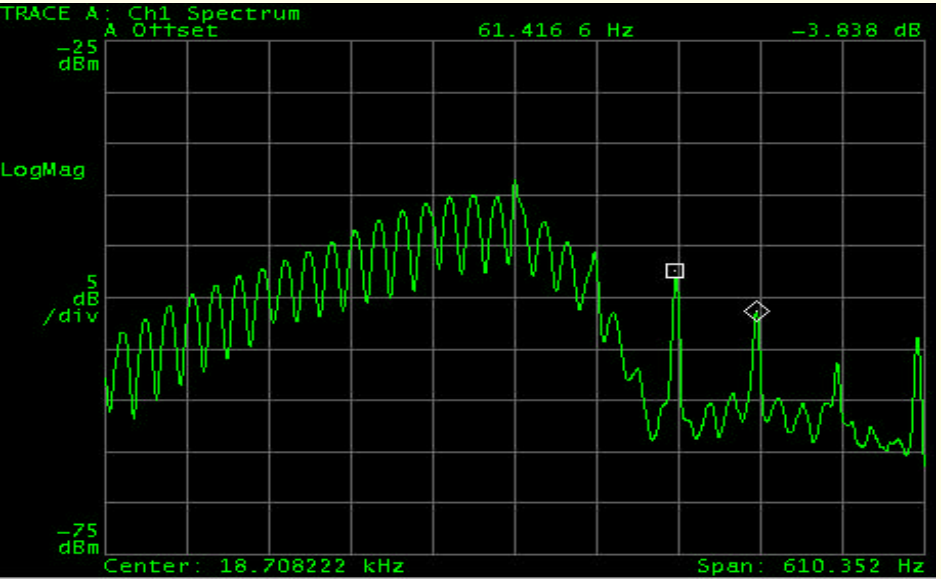
Tune Shift - 60Hz lines don't move

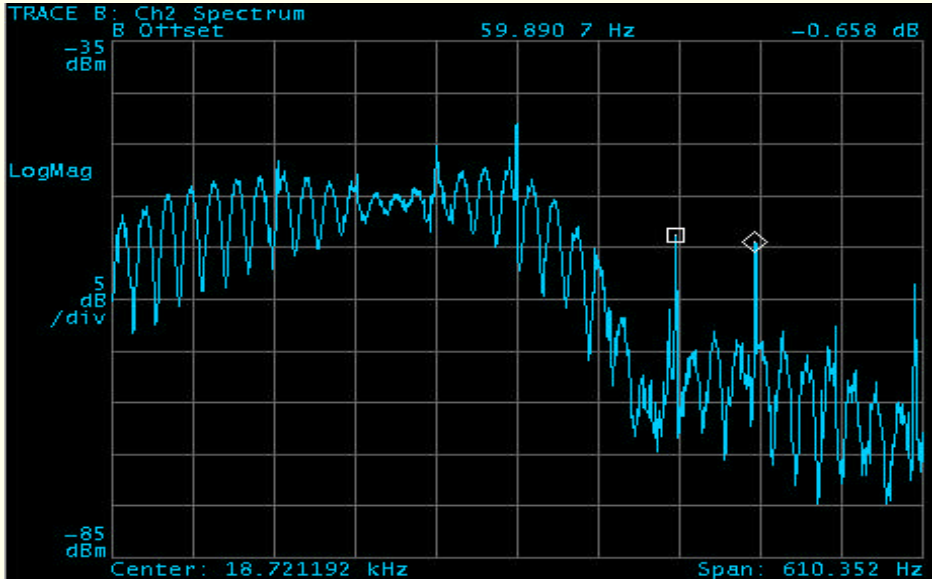


3D and 245MHz - need 200MHz RF!

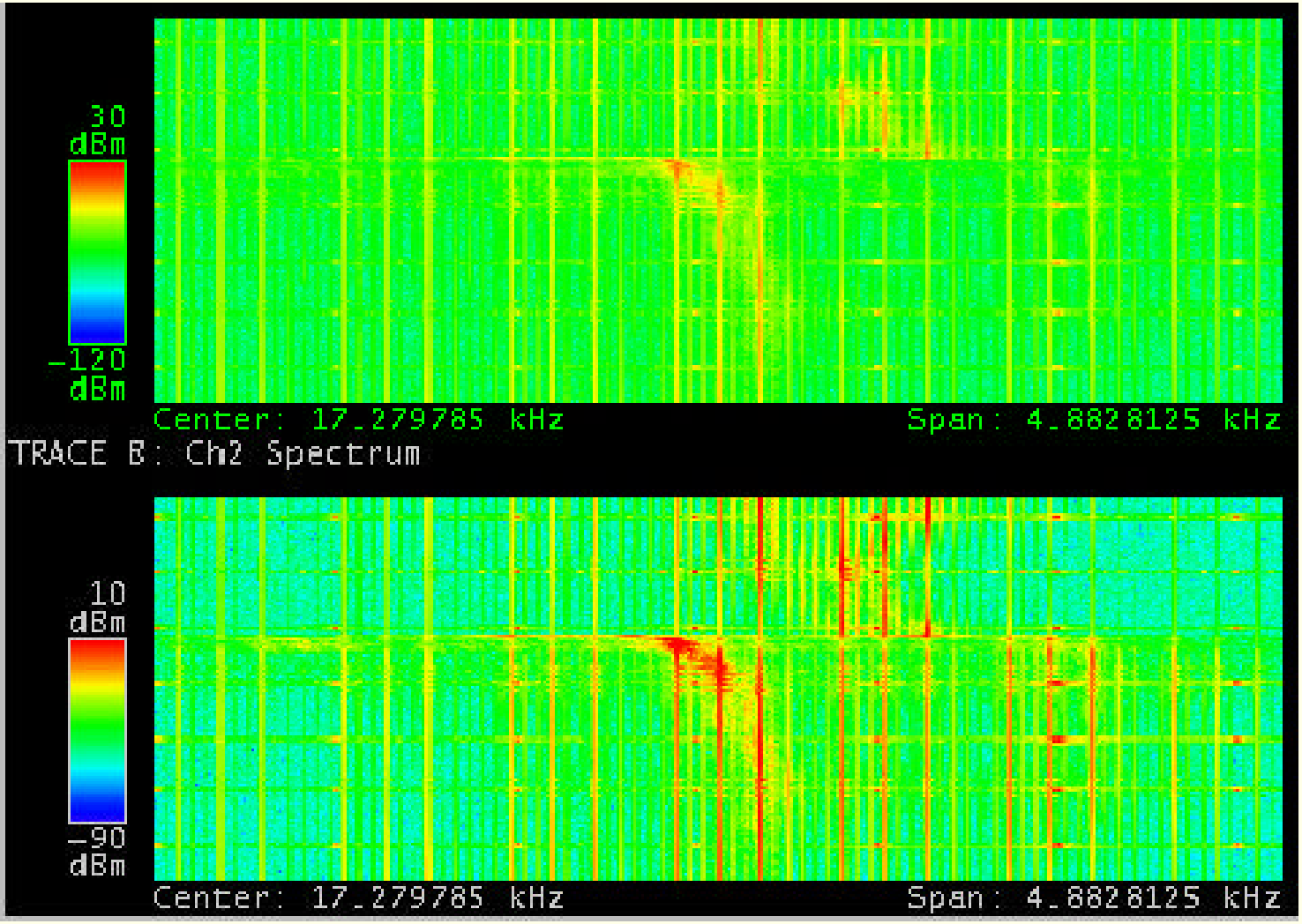








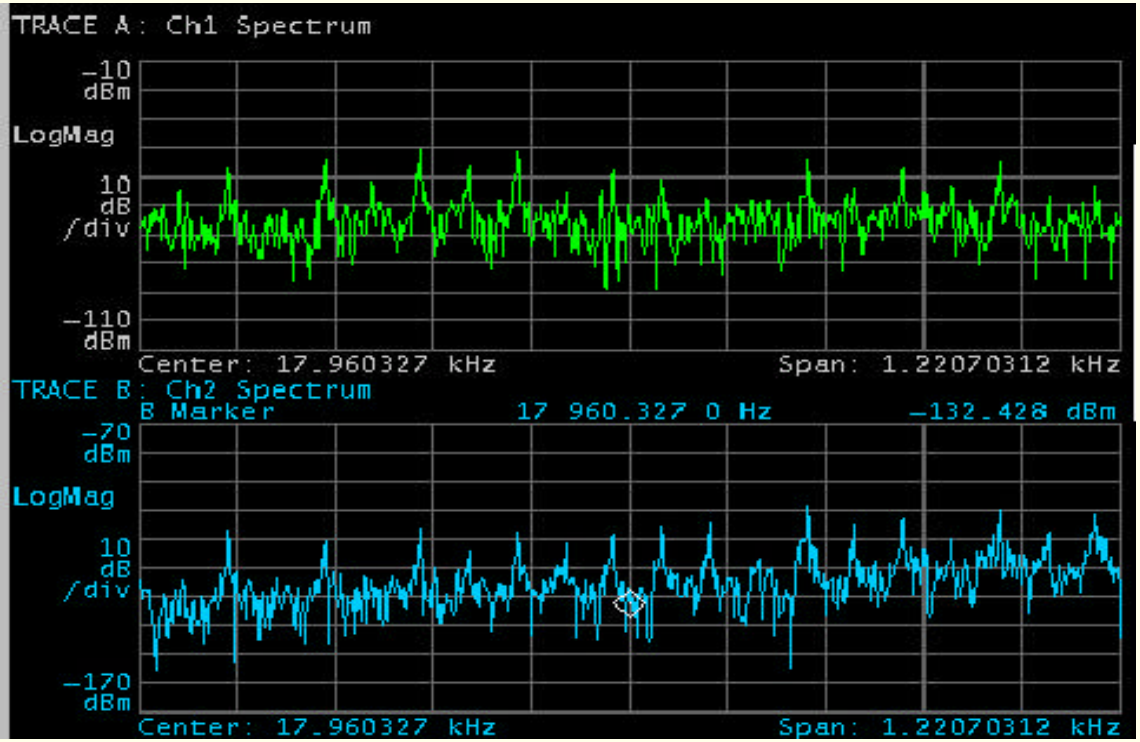
3D with 50MHz high pass



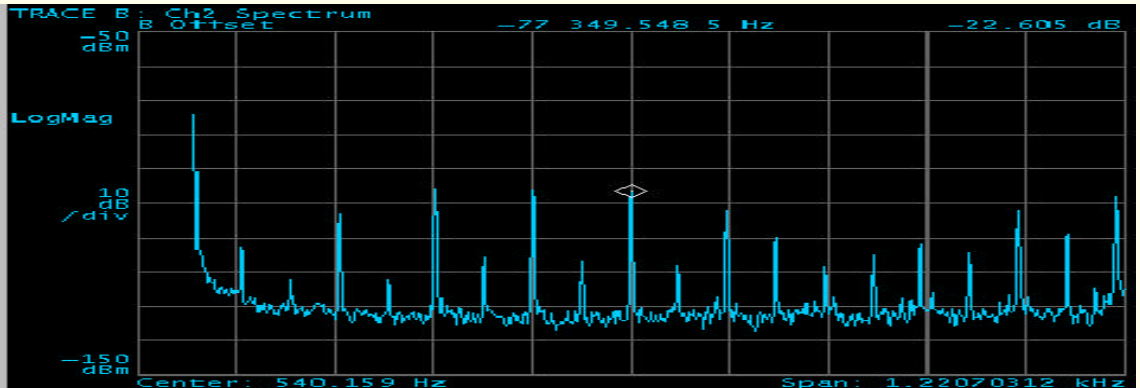
3D
horiz

3D
vert,
with 50MHz
hipass

Comparison with DC

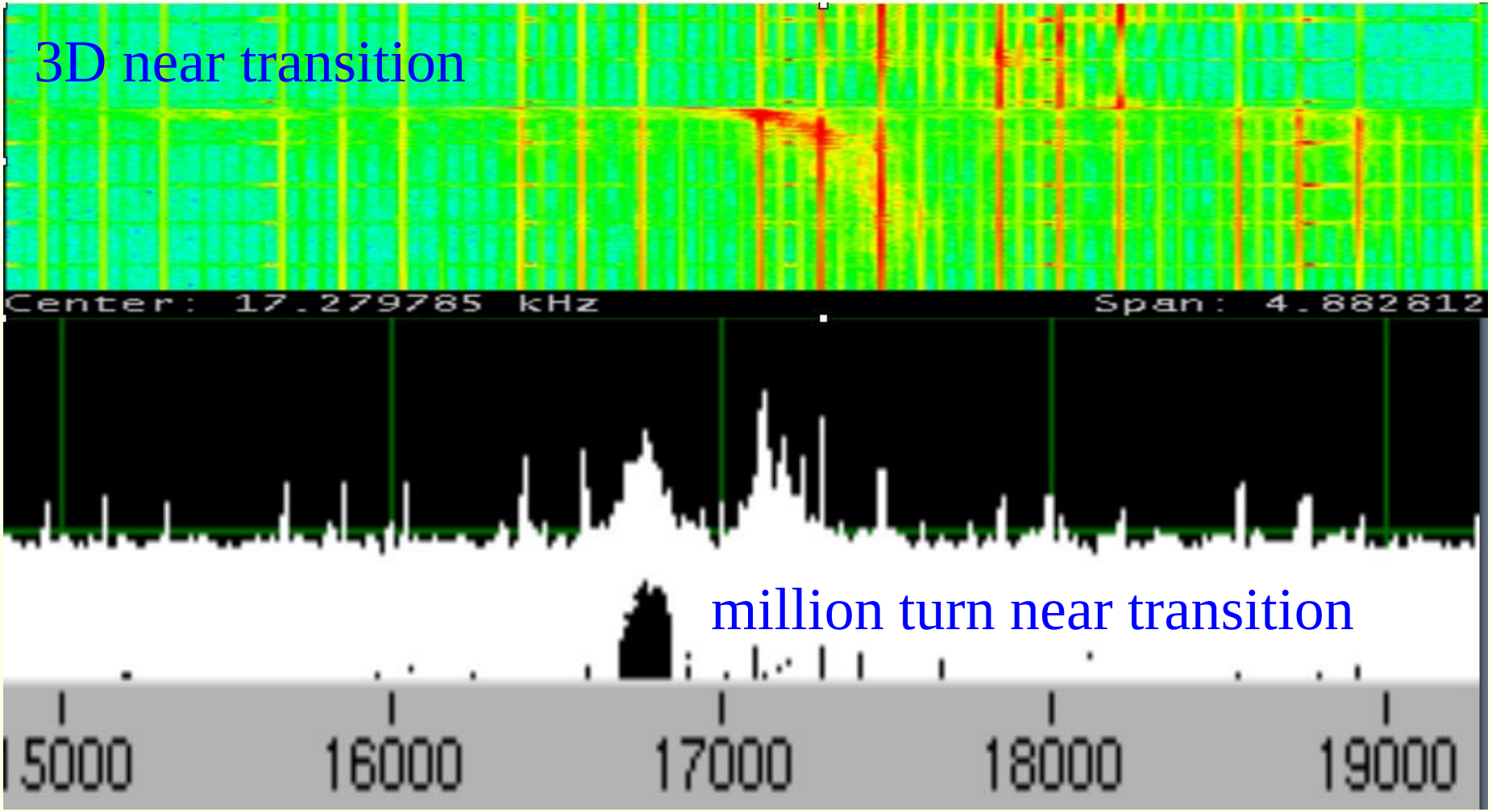


3D blue H and
V (w/ 50MHz hipass),
at betatron line



homodyne
yellow horiz,
at DC

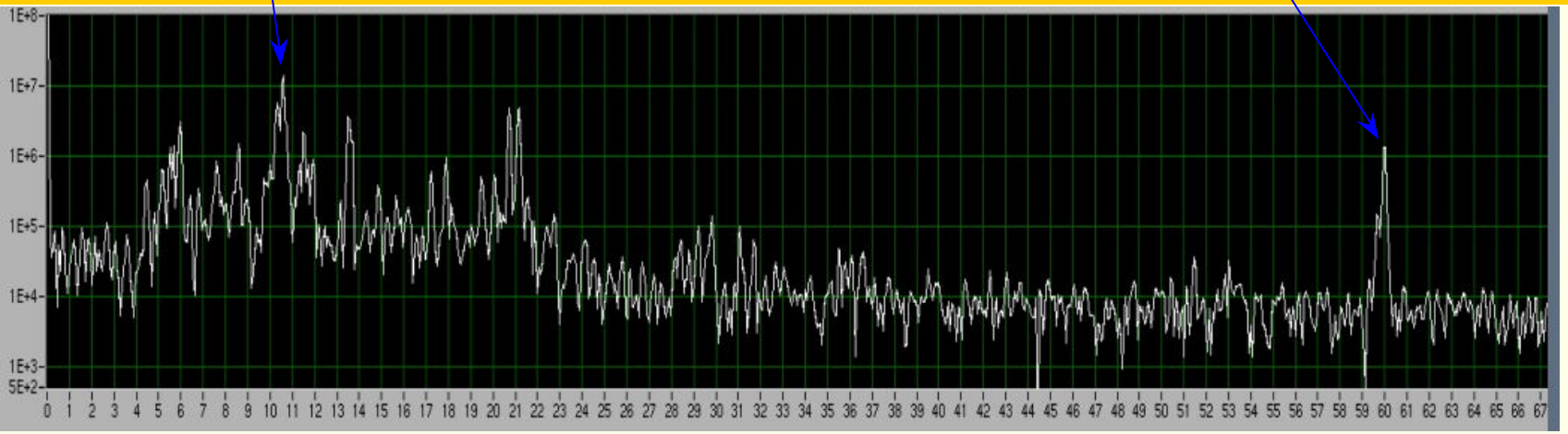
Million Turn BPM 1



estimate ~5m at betatron line

300 micron 10Hz cryostat vibration (0dB)

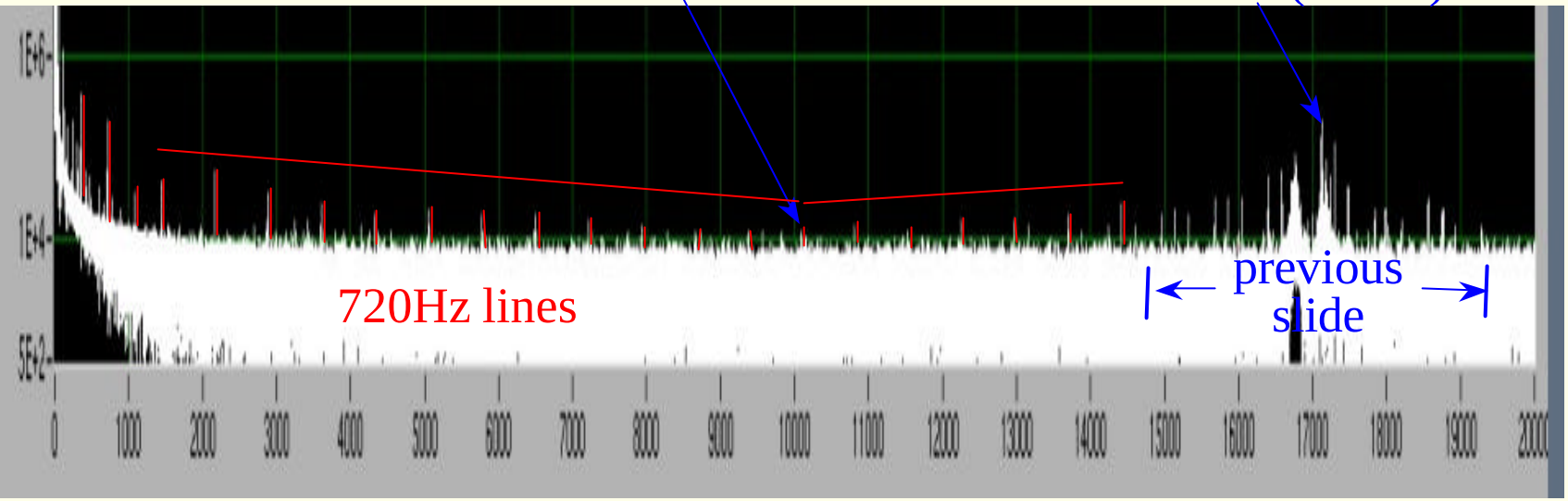
60Hz (-20dB)



40dB

720Hz x 14 (-60dB)

betatron line (-35dB)



720Hz lines

previous slide

the same 40dB

From Todd (Million Turn BPM)

Injection:

beta*gamma=12, emittance=10 pi um, betax(bpm)=49m

=> sigma(beam at bpm) = 2.6 mm

Peak-peak oscillations observed at bo2-bh10: about 350 um

=> Injection vibrations are about 10-15% of beam size

Store:

beta*gamma=108, emittance=20 pi um, betax(bpm)=45m

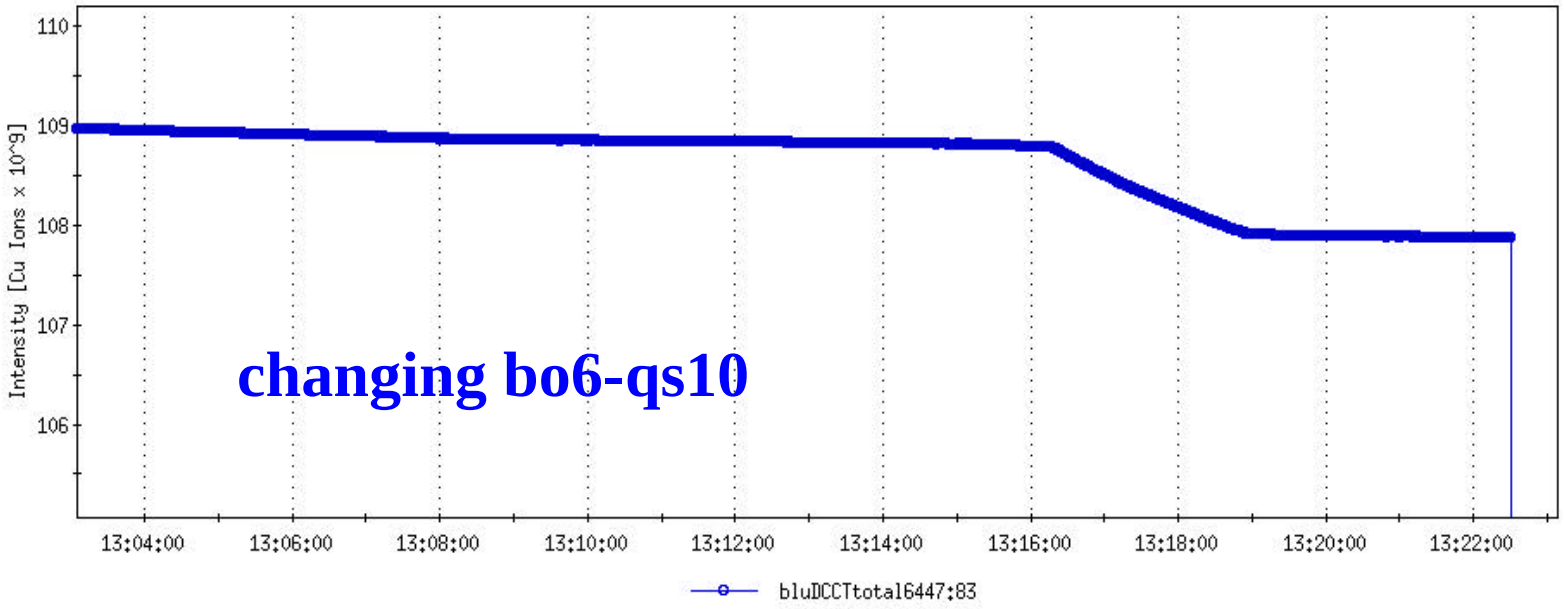
=> sigma(beam at bpm) = 1.2 mm

Peak-peak oscillations observed at bo2-bh8: about 350 um

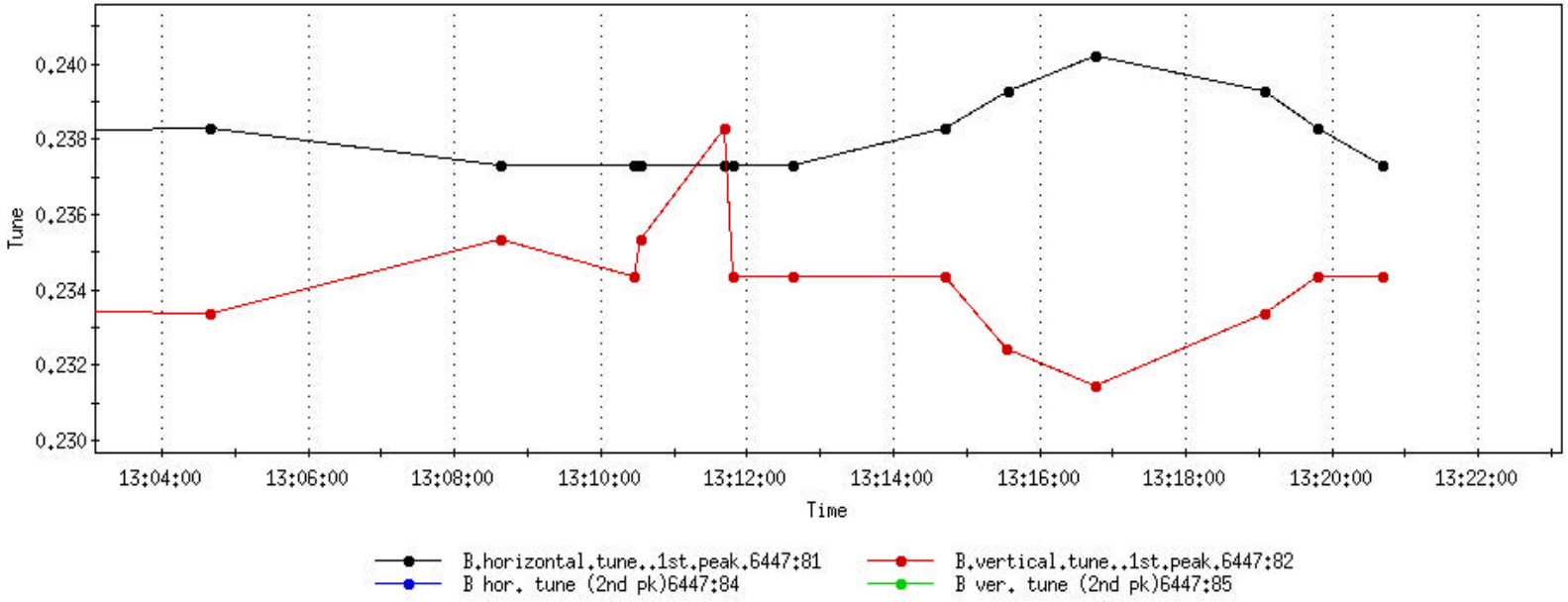
=> Storage oscillations are about 30% of beam size

Sat Mar 12 07:28:21 - Sat Mar 12 13:40:43

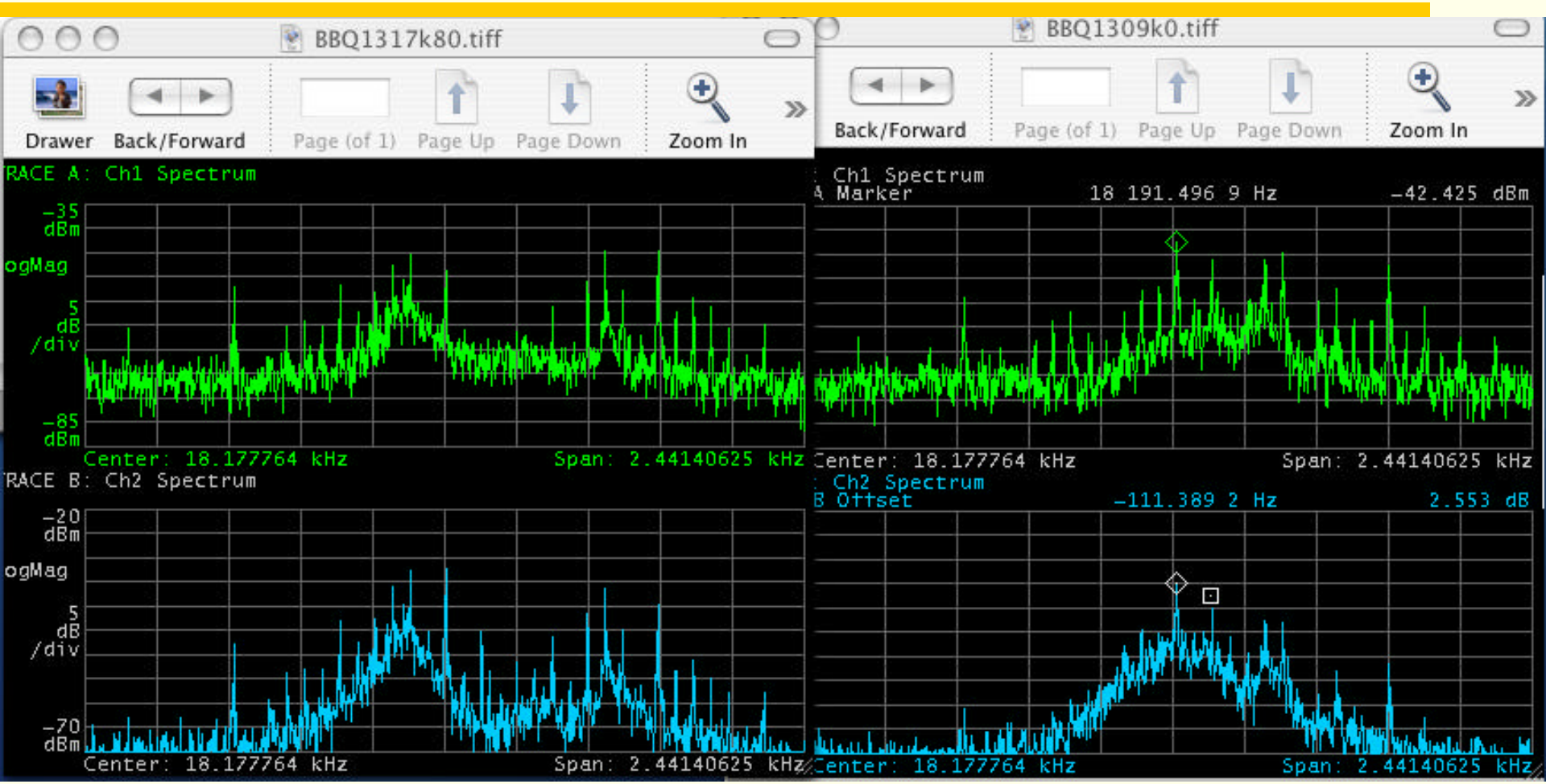
Window Event



changing bo6-qs10



Effect of Coupling on Spectrum

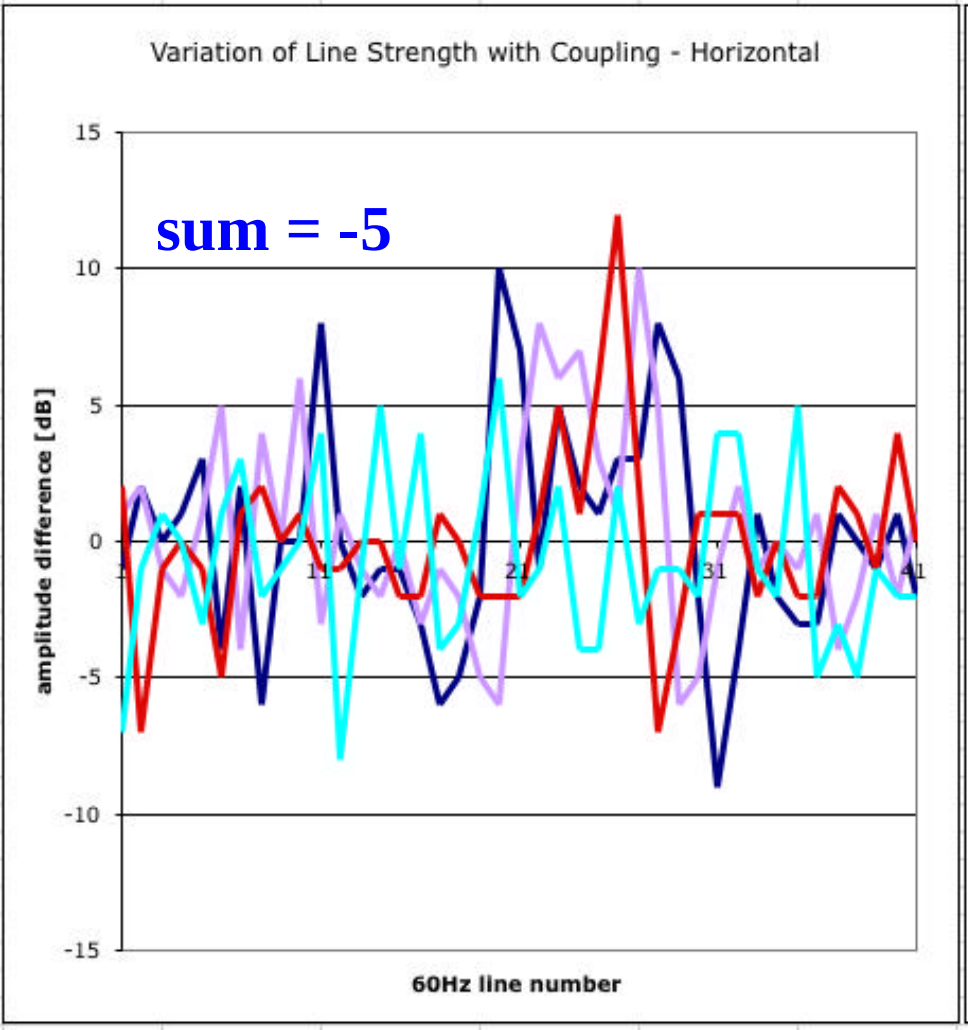


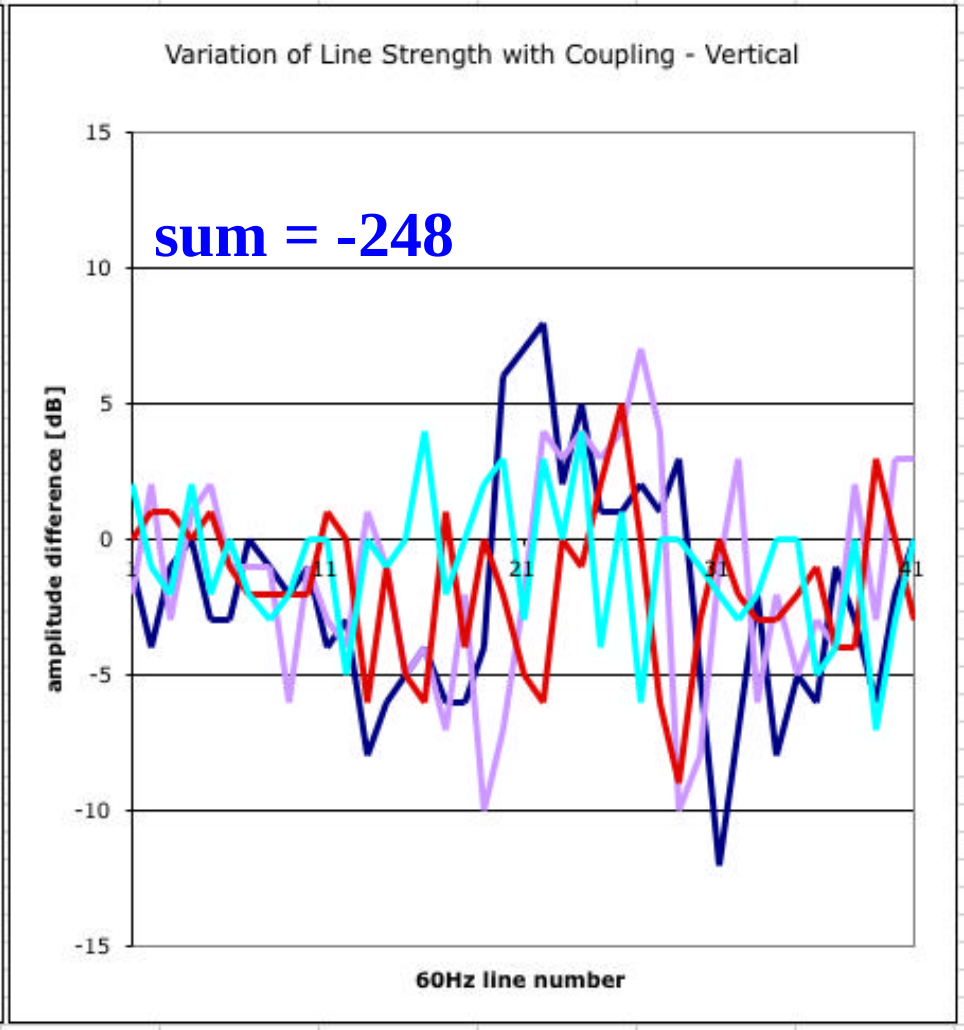
k = -.0008

k = 0

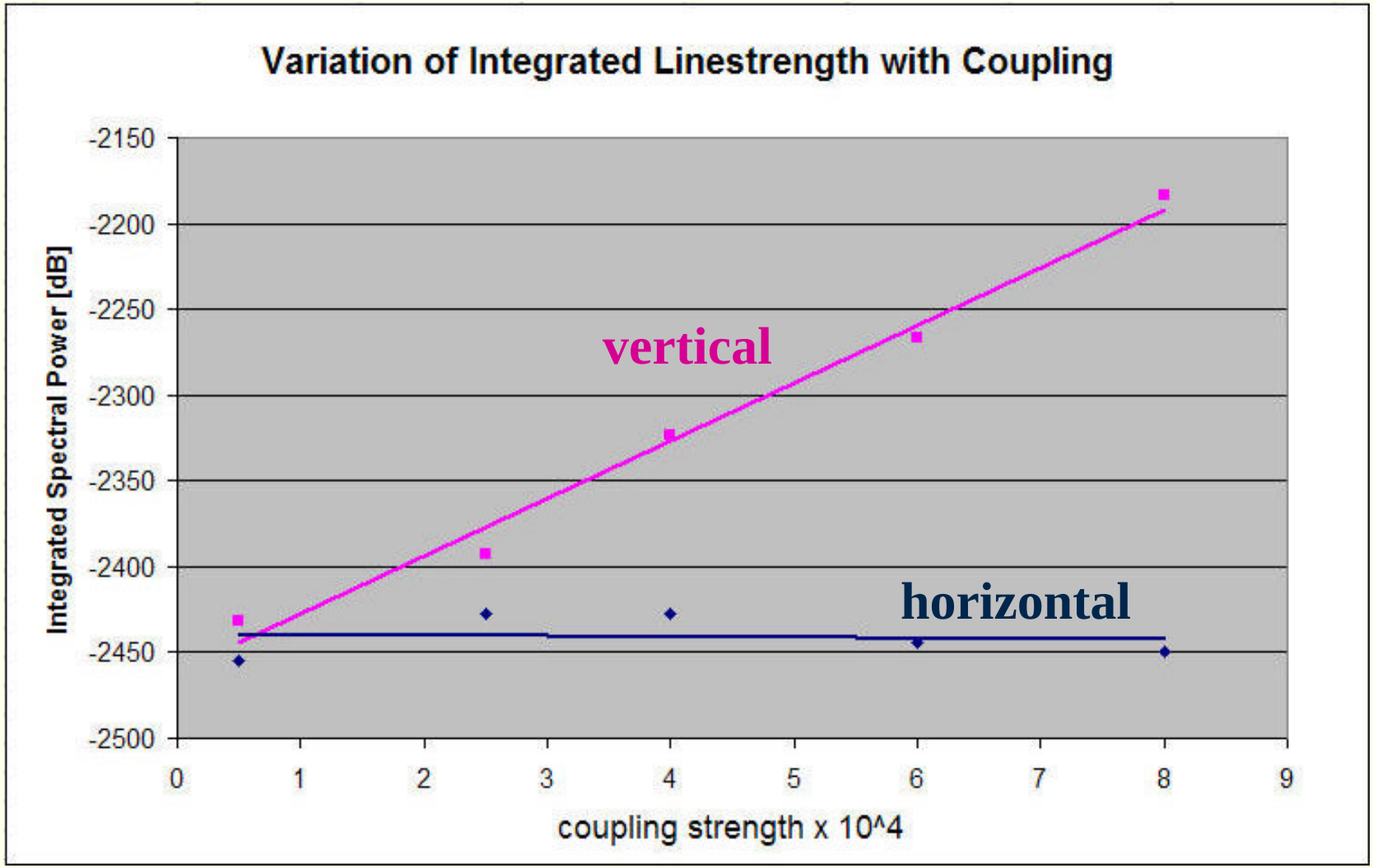
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1		k80 H	k60 H	k40 H	k25 H	k0 H		diff86	diff 64	diff425	diff250		k80 V	k60 V	k40 V	k25 V	k0 V		diff86	diff64	diff425	diff250
2																						
3	line						line					line						line				
4	1	-67	-66	-67	-65	-72	1	-1	1	2	-7	1	-64	-65	-67	-67	-65	1	-1	-2	0	2
5	2	-68	-66	-64	-71	-72	2	2	2	-7	-1	2	-66	-70	-68	-67	-68	2	-4	2	1	-1
6	3	-61	-61	-62	-63	-62	3	0	-1	-1	1	3	-63	-64	-67	-66	-68	3	-1	-3	1	-2
7	4	-67	-66	-68	-68	-68	4	1	-2	0	0	4	-68	-68	-67	-67	-65	4	0	1	0	2
8	5	-69	-66	-65	-66	-69	5	3	1	-1	-3	5	-66	-69	-67	-66	-68	5	-3	2	1	-2
9	6	-68	-72	-67	-72	-71	6	-4	5	-5	1	6	-63	-66	-67	-68	-68	6	-3	-1	-1	0
10	7	-66	-64	-68	-67	-64	7	2	-4	1	3	7	-65	-65	-66	-68	-70	7	0	-1	-2	-2
11	8	-66	-72	-68	-66	-68	8	-6	4	2	-2	8	-63	-64	-65	-67	-70	8	-1	-1	-2	-3
12	9	-52	-52	-52	-52	-53	9	0	0	0	-1	9	-48	-50	-56	-58	-60	9	-2	-6	-2	-2
13	10	-72	-72	-66	-65	-65	10	0	6	1	0	10	-65	-66	-67	-69	-69	10	-1	-1	-2	0
14	11	-72	-64	-67	-68	-64	11	8	-3	-1	4	11	-59	-63	-66	-65	-65	11	-4	-3	1	0
15	12	-60	-60	-59	-60	-68	12	0	1	-1	-8	12	-54	-57	-61	-61	-66	12	-3	-4	0	-5
16	13	-59	-61	-62	-62	-63	13	-2	-1	0	-1	13	-53	-61	-60	-66	-66	13	-8	1	-6	0
17	14	-60	-61	-63	-63	-58	14	-1	-2	0	5	14	-53	-59	-60	-61	-62	14	-6	-1	-1	-1
18	15	-52	-53	-53	-55	-56	15	-1	0	-2	-1	15	-43	-48	-53	-58	-58	15	-5	-5	-5	0
19	16	-57	-60	-63	-65	-61	16	-3	-3	-2	4	16	-47	-51	-55	-61	-57	16	-4	-4	-6	4
20	17	-53	-59	-60	-59	-63	17	-6	-1	1	-4	17	-42	-48	-55	-54	-56	17	-6	-7	1	-2
21	18	-47	-52	-54	-54	-57	18	-5	-2	0	-3	18	-36	-42	-44	-48	-48	18	-6	-2	-4	0
22	19	-45	-47	-52	-54	-53	19	-2	-5	-2	1	19	-33	-37	-47	-47	-45	19	-4	-10	0	2
23	20	-60	-50	-56	-58	-52	20	10	-6	-2	6	20	-45	-39	-46	-48	-45	20	6	-7	-2	3
24	21	-48	-41	-38	-40	-42	21	7	3	-2	-2	21	-32	-25	-27	-32	-35	21	7	-2	-5	-3
25	22	-61	-62	-54	-53	-54	22	-1	8	1	-1	22	-54	-46	-42	-48	-45	22	8	4	-6	3
26	23	-64	-59	-53	-48	-46	23	5	6	5	2	23	-45	-43	-40	-40	-40	23	2	3	0	0
27	24	-63	-61	-54	-53	-57	24	2	7	1	-4	24	-58	-53	-49	-50	-46	24	5	4	-1	4
28	25	-61	-60	-57	-51	-55	25	1	3	6	-4	25	-51	-50	-47	-45	-49	25	1	3	2	-4
29	26	-64	-61	-60	-48	-46	26	3	1	12	2	26	-53	-52	-48	-43	-42	26	1	4	5	1
30	27	-56	-53	-43	-41	-44	27	3	10	2	-3	27	-46	-44	-37	-37	-43	27	2	7	0	-6
31	28	-68	-60	-55	-62	-63	28	8	5	-7	-1	28	-56	-55	-51	-57	-57	28	1	4	-6	0
32	29	-51	-45	-51	-54	-55	29	6	-6	-3	-1	29	-41	-38	-48	-57	-57	29	3	-10	-9	0
33	30	-44	-46	-51	-50	-52	30	-2	-5	1	-2	30	-36	-41	-49	-52	-53	30	-5	-8	-3	-1
34	31	-53	-62	-63	-62	-58	31	-9	-1	1	4	31	-45	-57	-58	-58	-60	31	-12	-1	0	-2
35	32	-62	-66	-64	-63	-59	32	-4	2	1	4	32	-56	-63	-60	-62	-65	32	-7	3	-2	-3
36	33	-44	-43	-44	-46	-47	33	1	-1	-2	-1	33	-39	-41	-47	-50	-52	33	-2	-6	-3	-2
37	34	-57	-59	-59	-59	-61	34	-2	0	0	-2	34	-53	-61	-63	-66	-66	34	-8	-2	-3	0
38	35	-54	-57	-58	-60	-55	35	-3	-1	-2	5	35	-51	-56	-61	-63	-63	35	-5	-5	-2	0
39	36	-56	-59	-58	-60	-65	36	-3	1	-2	-5	36	-55	-61	-64	-65	-70	36	-6	-3	-1	-5
40	37	-61	-60	-64	-62	-65	37	1	-4	2	-3	37	-57	-58	-62	-66	-70	37	-1	-4	-4	-4
41	38	-66	-66	-68	-67	-72	38	0	-2	1	-5	38	-65	-68	-66	-70	-70	38	-3	2	-4	0
42	39	-60	-61	-60	-61	-62	39	-1	1	-1	-1	39	-57	-63	-66	-63	-70	39	-6	-3	3	-7
43	40	-69	-68	-70	-66	-68	40	1	-2	4	-2	40	-68	-70	-67	-67	-70	40	-2	3	0	-3
44	41	-67	-69	-68	-68	-70	41	-2	1	0	-2	41	-70	-70	-67	-70	-70	41	0	3	-3	0
45								6	16	1	-28								-83	-56	-70	-39
46																						
47									**-5**											**-248**		

Coupling Cameron - difference

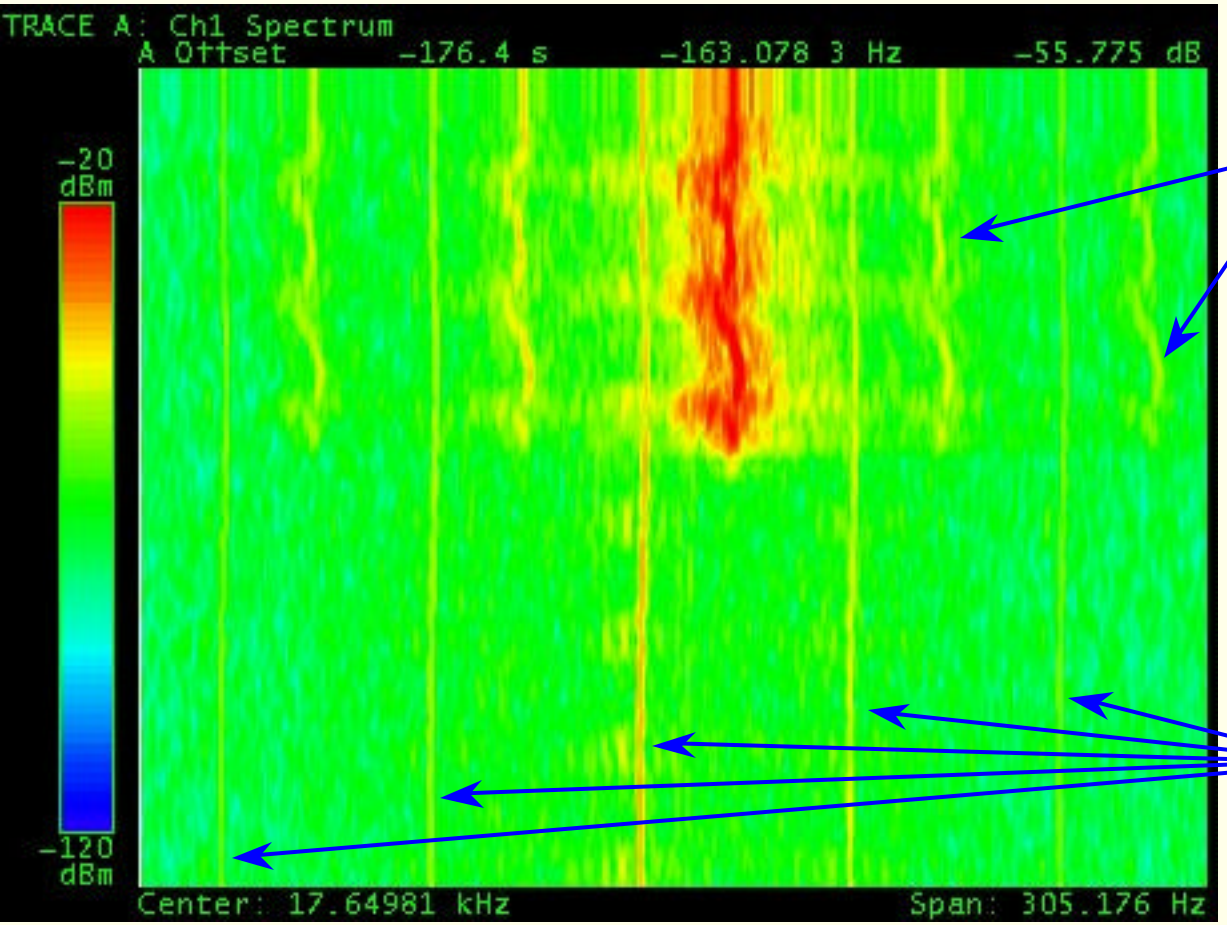




coupling 60Hz plot



Tune sidebands at 60Hz

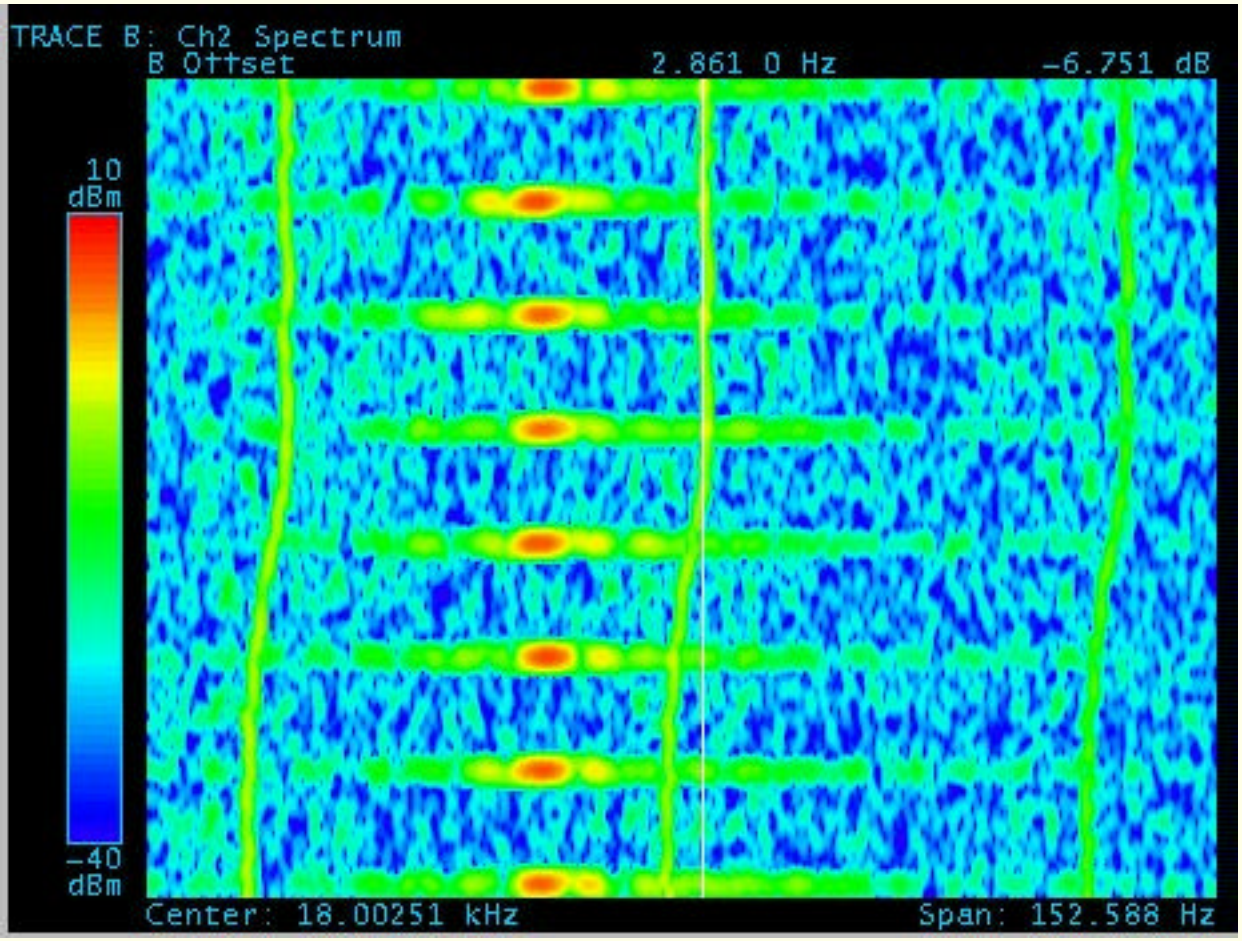


sidebands

← Kicker off

continuous 60Hz lines

60Hz lines move (but not sidebands)!



over 30 seconds, variation is ~3Hz at h~300, or 0.01Hz at 60Hz

span = 152Hz

Things we've tried

- Tune shift - 60Hz lines don't move
- Look for 60Hz **at betatron line** on other pickups
  - seen on homodyne
  - seen on RHIC 245MHz LF Schottky
  - seen on CERN SPS 400MHz and FNAL 21.4MHz Schottky
  - seen on million turn BPM
- Isolation transformers in the signal path
- Running the 3D on batteries (Tevatron)
- 50MHz high pass in front of the diodes
- UAL simulation (Nikolay Malitsky) - in progress

60Hz Conclusions

- 60Hz **IS** on the beam
- Statement of excellent sensitivity of BBQ (and million turn BPM)
- It is at baseband, will show up everywhere in the spectrum - we can't escape it
- High Priority - Carl Schultheiss - 720Hz balancing circuit
- Filtering is difficult
- Possible solution - park tune between lines (effective only with TF on)