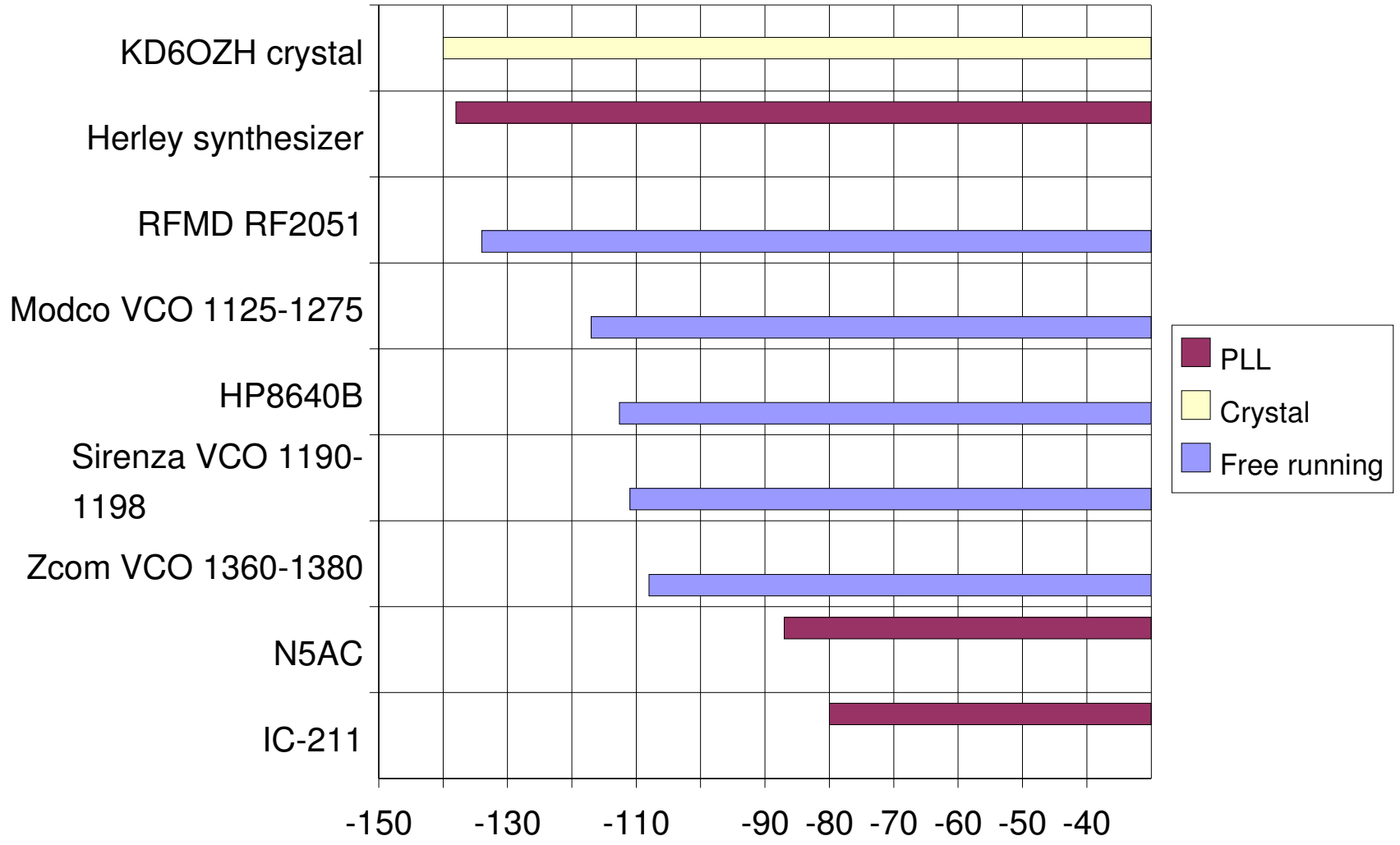
Some observations on phase noise from local oscillator strings.

By
KØCQ
Dr. Gerald N. Johnson, retired P.E.

Some oscillator phase noise levels

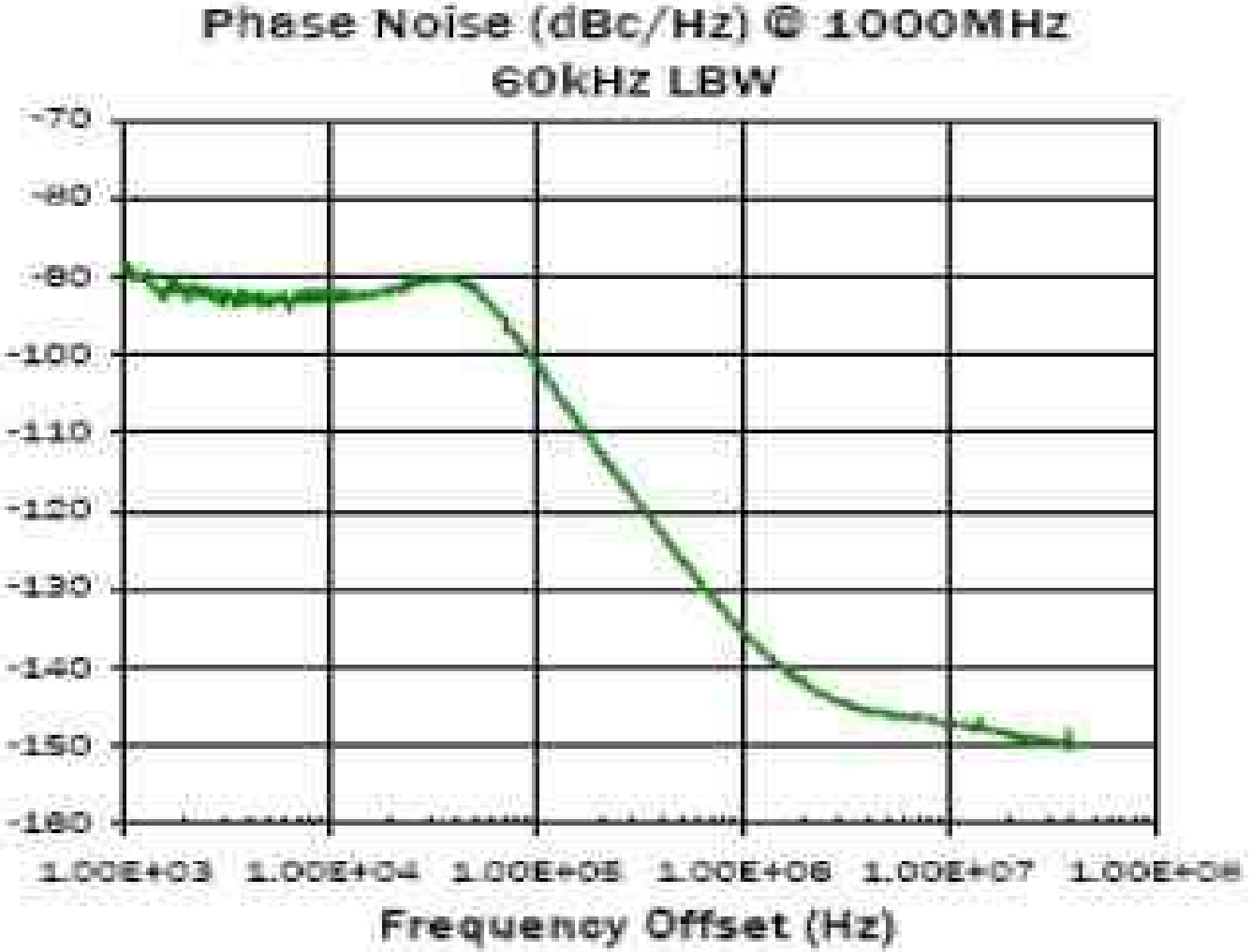


Noise dBc/Hz for 10 KHz offset at 1 to 1.2 GHz

Say what?

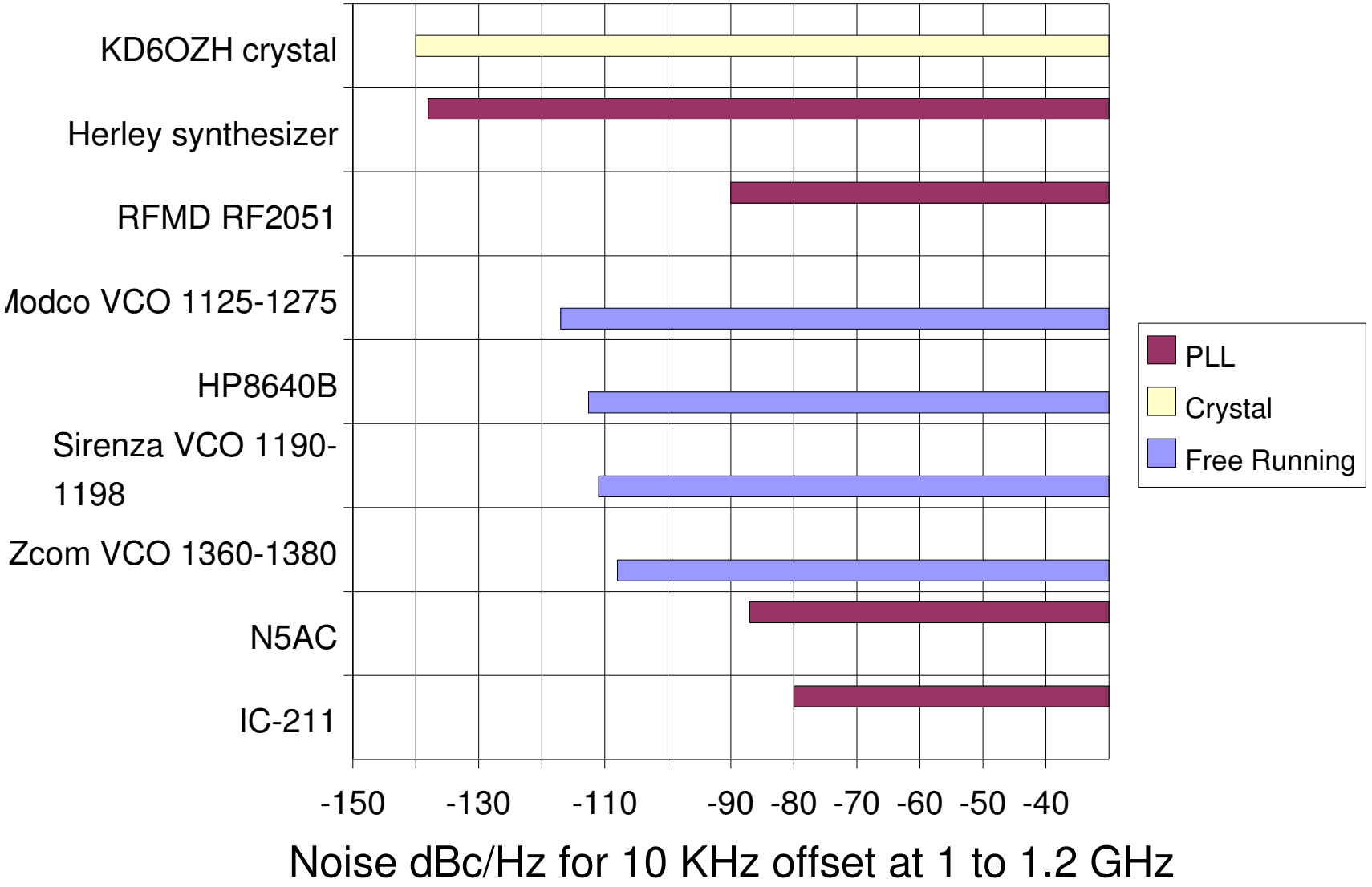
What was the real offset for that RFMD chip? -140 dBc/Hz is good for a crystal oscillator. Really superb for a free running oscillator!

From the RFMD 2501 data sheet.

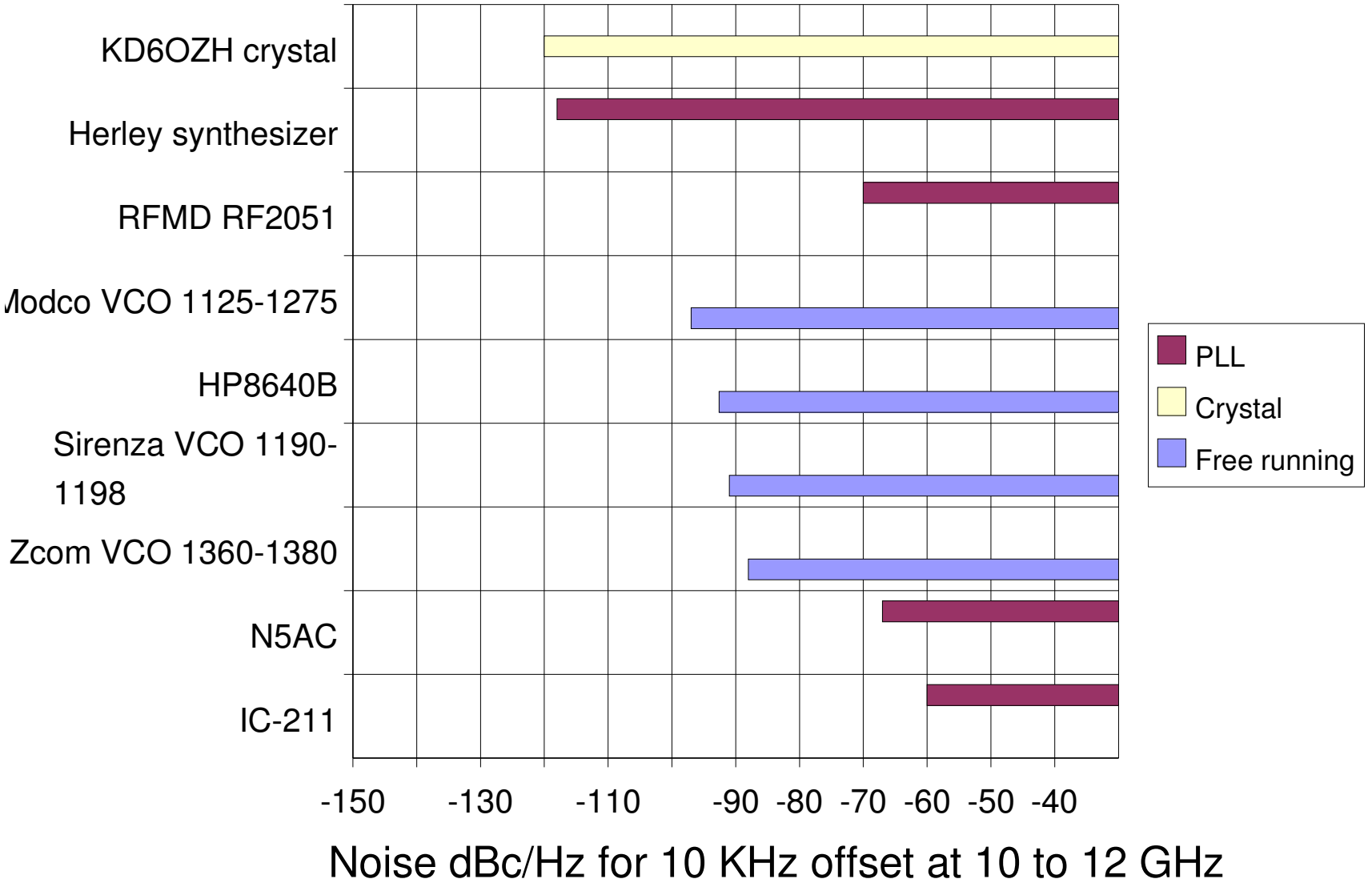


That's not so great. And it took a wide control loop bandwidth to achieve -90 dBc/Hz at 1 GHz.

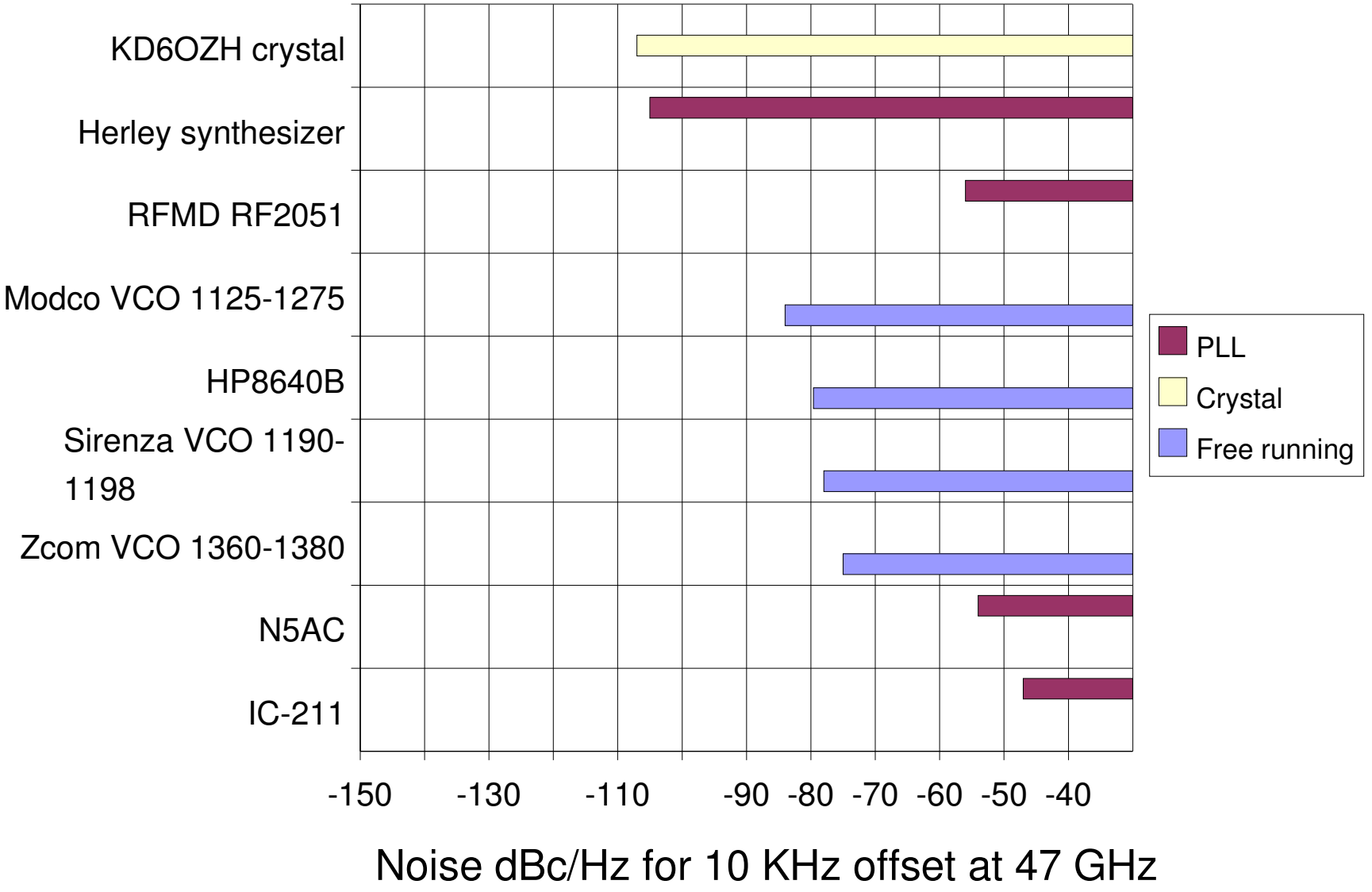
Revised oscillator phase noise levels



At 10 to 12 GHz



At 47 GHz.


KD6OZH crystal
Herley synthesizer
RFMD RF2051
Modco VCO 1125-1275
HP8640B
Sirenza VCO 1190-1198
Zcom VCO 1360-1380
N5AC
IC-211
-150
-130
-110
-90
-80
-70
-60
-50
-40
PLL
Crystal
Free running
Noise dBc/Hz for 10 KHz offset at 47 GHz

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Frequency Offset from Carrier	Phase Noise (dBc/Hz)			
	5 GHz	10 GHz	20 GHz	40 GHz
100 Hz	-86	-80	-74	-68
1 kHz	-116	-110	-104	-98
10 kHz	-124	-118	-112	-106
100 kHz	-126	-120	-114	-108
1 MHz	-141	-135	-129	-123
10 MHz	-150	-150	-146	-140

VCO

These economical VCOs offer very low phase noise in the industry standard ½" square package. Model MD110MST, featuring a frequency range of 1175 to 1275 MHz, is rated -118 dBc @ 10 kHz offset. Custom designs can be supplied with no NRE. ➤ 51

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Model	MD108MST
Freq	902-928MHz
Vcc	5V
Vt	0.5 to 4.5V
Current	16ma
Power	+4dBm
2nd Harmonics	-45dBc
Pushing	0.4MHz/V
Pulling	0.6MHz with a 12dB return loss
Phase Noise	-117dBc @ 10KHz

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L-Band VCO

Model CLV1370A-LF operates from 1360 to 1380 MHz (L-band) with a tuning voltage range of 0.5 to 4.5 Vdc. This VCO features a typical phase noise of -108 dBc @ 10 KHz offset and a typical tuning sensitivity of 24 MHz/V. Size is 0.50 x 0.50 x 0.22".

➤ 60

Z-COMMUNICATIONS

205x SERIES SPECIFICATIONS

	Units	RF2051	RF2052	RF205
Fractional-N PLL		Yes	Yes	Yes
On-chip VCOs		Yes	Yes	No
RF Mixers		2	1	1
DC Parameters				
Supply voltage	V	3.0	3.0	3.0
Supply current (low current setting)	mA	55	55	55
VCO and Synthesizer				
Input Reference Frequency	MHz		10 to 104	
LO frequency	MHz	300 to 2400	300 to 2400	-
Open loop VCO phase noise at 500 MHz LO frequency	dBc/Hz	-140	-140	-
RF Mixer				
RF and IF port frequency range	MHz		50 to 2500	
Noise figure (low current setting)	dB	-	9.5	-
Input IP3 (high linearity setting)	dBm	-	20	-

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- Fractional-N synthesizer—1.5 MHz resolution
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- Three-wire serial control interface

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What are the effects?

LO phase noise can increase the receiver noise floor by mixing in RF noise using the entire LO noise spectrum and RF spectrum. Consider that for each if bandwidth of LO noise at some offset, there is RF noise to be mixed to the IF frequency. While many talk about this, none show numbers and the rough numbers I calculate show its not a problem unless the phase noise is obnoxiously strong and the system noise temperature is extremely low.

What are the effects?

The main effect in the real world comes from reciprocal mixing where that LO phase noise mixes with RF signals outside the IF passband to make noise at the signal frequency. The stronger the phase noise, the more numerous the unwanted signals, and the stronger the unwanted signals, the stronger this effect.

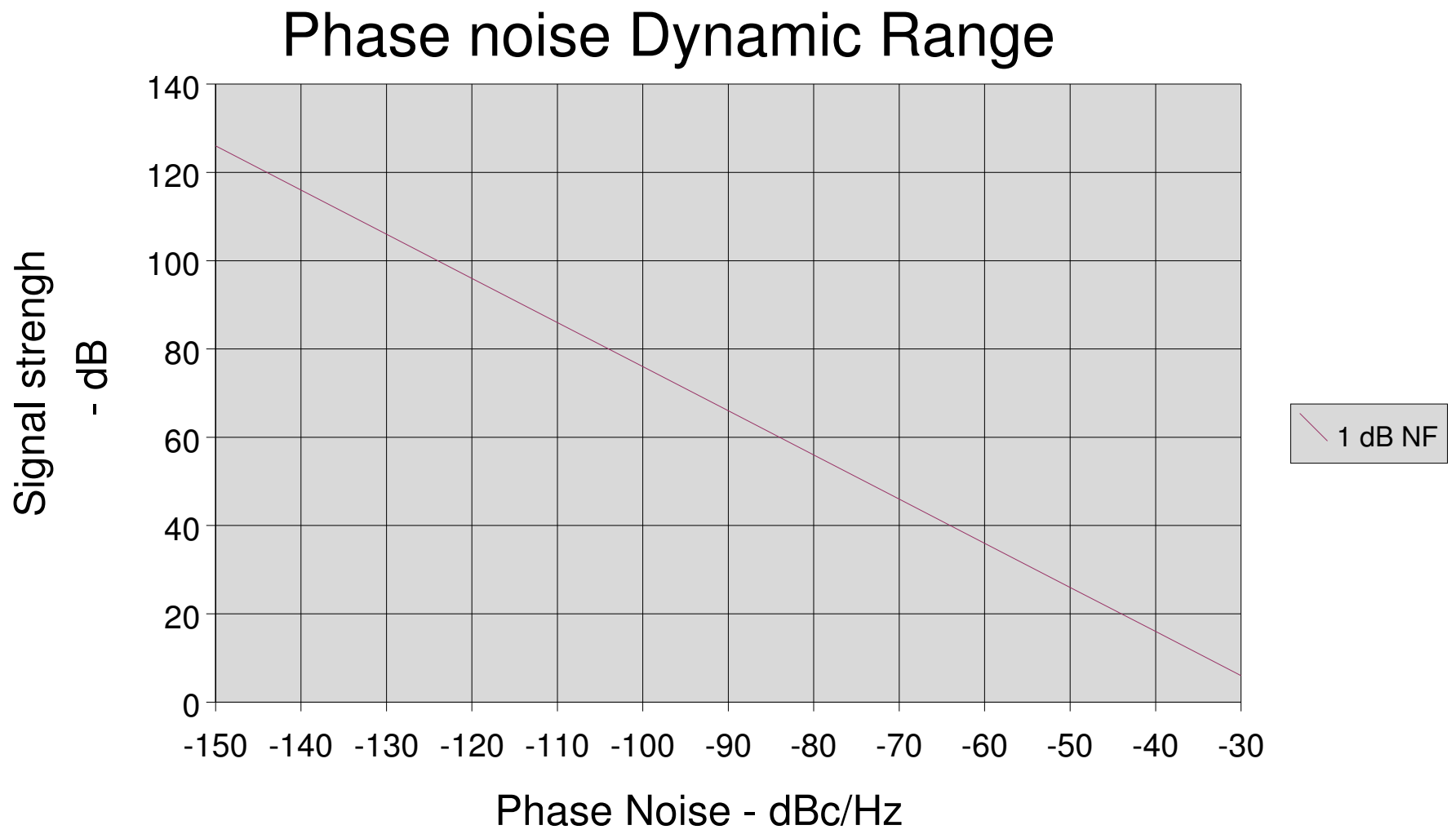
What are the effects?

You say your rover hill top is quiet? Are you sure? What about all those part 15 noises on 902, 2.4 and 5.6 Ghz? What about those WiFi servers using those bands partly for users and partly for point to point links?

And at MUD 2004, KK7B reminded us that our transverters may supply all the spurs we need to have such reciprocal mixing, especially in the IF radio.

Reciprocal Mixing

Signal strength to raise the receiver noise floor 3 dB in 2 KHz IF bandwidth..



Questions?

What to do?

What to do?

1. Consider not using the N5AC synthesizer as a LO, its noisy for signal populated environments. It makes receivers more sensitive to reciprocal mixing and it makes transmitters broad. Use crystals instead.

What to do?

2. Consider adding to its the N5AC frequency agility but use it only as a marker. Ham gear from 1920 until digital radios worked with crystal markers or frequency meters. Microwave gear still can. Say, set up the PIC chip to allow for outputs on 902, 903, 1152, 1200, and 1296. With the many harmonics of 1152 that set of frequencies gives markers from 902 to 24,192, possibly higher.

What to do?

3. Use a better VCO. On-chip VCOs historically have been poor, often cross coupled RC free running flipflops accompanied by much digital noise and with a wide tuning range making the tuning sensitivity a MHz per 10 millivolts. That sensitivity demands the tuning line noise be nanovolts and that level of quiet is not possible in a chip. Thermal noise is more than that.

What to do?

3. (cont) Consider VCOs by Modco or Serenza, with narrow band tuning they claim phase noise levels 25 dB better than the N5AC result.

These choices do have very narrow tuning ranges so different transverters may need different VCOs, which shifts concerns back to the custom crystal problem and that custom crystal may be cheaper than the custom low noise VCO.

What to do?

4. Consider a different PLL package. RFMD claims -140 dBc/Hz phase noise from their free running VCO at 500 MHz ***at 1 MHz offset***. Its a lot worse at 10 Khz, even with a wide control loop its only -100 dBc/Hz at 500 MHz.

What to do?

5. Use a much wider control loop bandwidth. This does limit the step size because in traditional PLL the phase detector reference frequency needs to be significantly higher than the loop bandwidth.

What to Do?

6. Consider using a fractional-N-division synthesizer chip. Vendors and Ulrich Rohde both show the technique can produce much quieter phase noise. In the 2001 edition of his receiver book, Rohde shows the fractional-N-division synthesizer can have 25 to 45 dB less phase noise with the same reference source.

What to Do?

7. Be certain that the noise from the oscillator voltage regulator isn't modulating the oscillator at any frequency. The common 78L family isn't perfectly quiet. F9HX uses one as a noise source to modulate clean oscillators to demonstrate the effects of phase noise. Lots of wide band filter capacitors seem most appropriate. A BIG tantalum and some monolithic types should do. But watch out for piezoelectric dielectrics.

But get ON the air!

73, Jerry, K0CQ