TX noise performance of modern HF transcievers

1. Introduction

There has been a lot of confusion about TX noise performance of modern HF transcievers after ARRL changed the way how they measure TX composite noise. Recent plots only show TX phase noise performance. Although one can design TX chain where LO phase noise is the main contributor to the composite TX noise (the optimal design), most, if not all, amateur HF transcievers do not fall in this category. In most cases the amplitude noise, coming from various sources, is the main contributor to the TX noise actually transmitted through antenna. Measuring TX phase noise, where the test method removes amplitude noise, does not give the right picture for nowadays very important HF transciever metric - how clean is the TX signal.

When choosing new transciever, many are still distracted by the RX performance ranking tables, where the RIG with higher rank is percieved as being better - which relly is missleading as the differences might only be a dB or so on the performance metric that is hard to repeatably measure with 1dB accuracy. It is time to get out of the woods and present full picture of the HF RIG performance. Kudos to ARRL and other independent reviewers for publishing complete test data.

2. TX noise measurement campagin

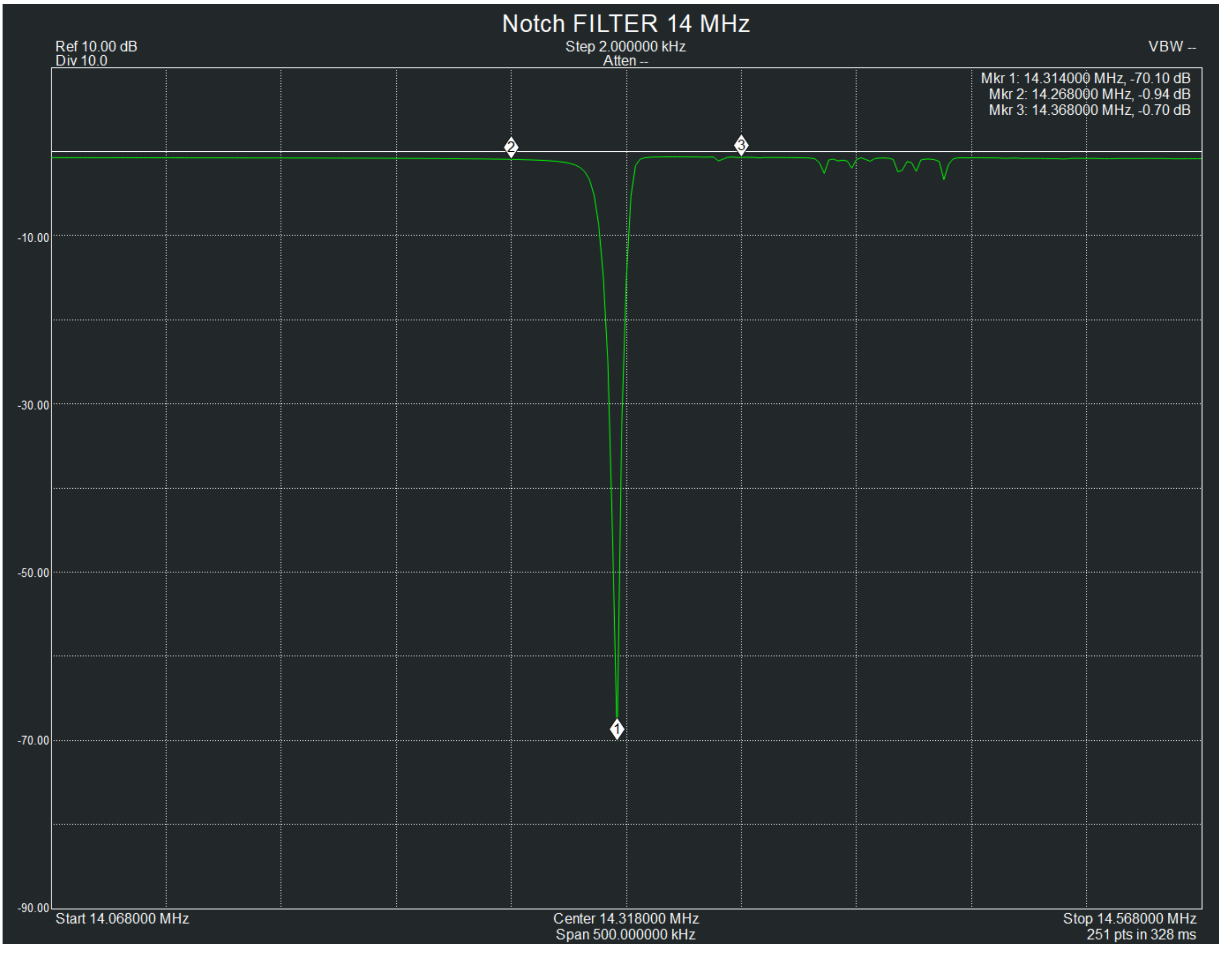
TK0C contesting concept relies on multiple in-band stations being able to operate without interference. Two most important HF RIG characteristics are RX blocking dynamic range and TX noise spectrum versus offset from TX carrier frequency. We have been using TS-590SG for most of the time as it was the best price-performance radio for this task. With the introduction of TS890 and FTDX101, it appeared (based on the ARRL test results) that these radios might be even better. Therefore we set for a measurement campaign @S57AL in December 2019. List of attendies and providers of various HF RIGs: S57AL, S51RM, S50K, S53MM, S53RM, S53WW, S53ZO, S55OO, S57C, S57K, S57L, S57NAW.

Group photo (from left to right: 1rm, 7naw, 7al, 7c, 3mm, 3rm, 3ww, 0k).

3. Test method

I used QS1R as a measurement receiver with 14.313 kHz crystal notch filter (tnx to Franci/s51rm) and 100W attenuator set to optimize measurement dynamic range. Afterwards I saw that QS1R dynamic range would be OK to accurately measure composite TX noise of all RIGs we had on the table except for the K3, which really is a superb radio.

For reference, here is the QS1r phase noise: -146dBc/Hz@10kHz, -148dBc/Hz@20kHz, -149dBc/Hz@50kHz. With XTAL notch filter the measurements were done 30 dB above the QS1r noise floor.



4. List of tested gear

TS590sg
TS590s - 2pcs
TS890 - 2pcs
FTdx101D
FLEX6600
FT1000mp
FT2000 - 2pcs
FLEX1500
IC7600
IC7610
IC7300
K3
KX3

SUNSDR

5. Test results

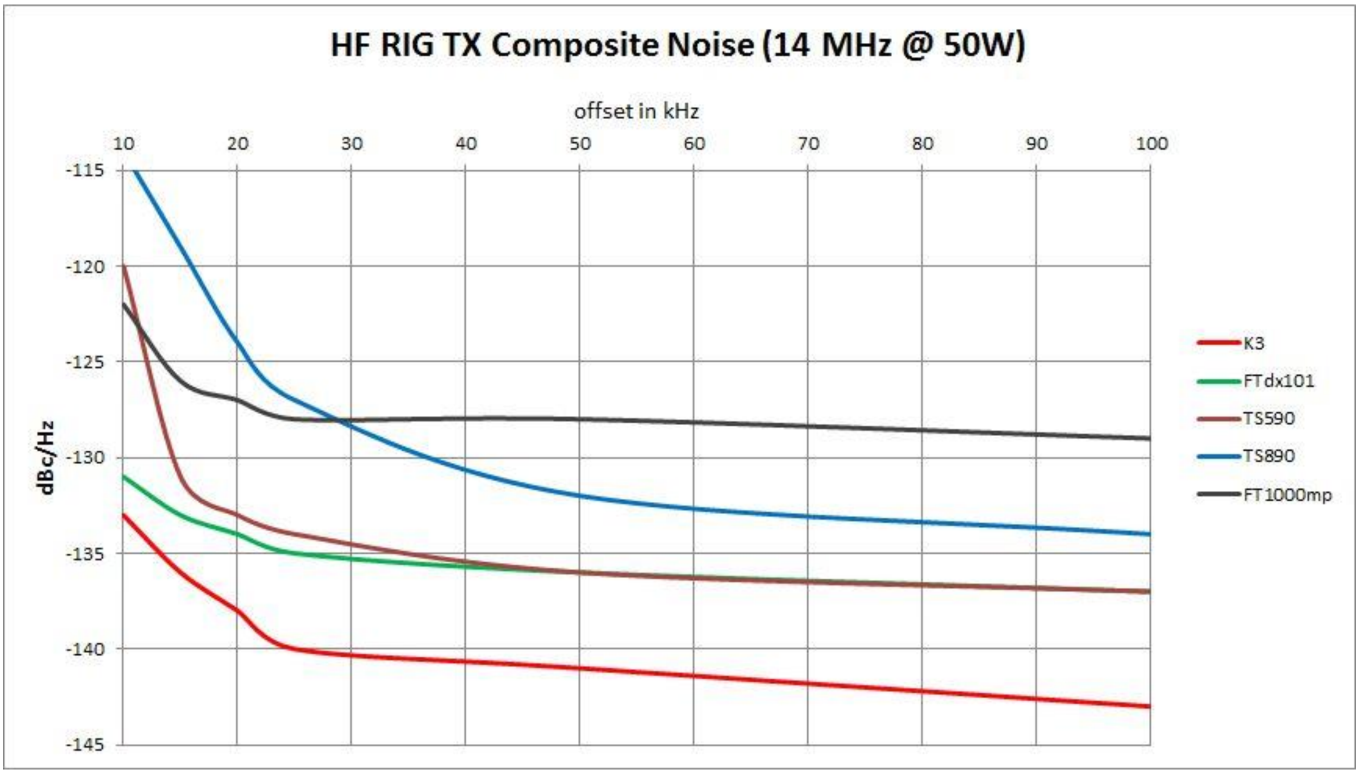
I set for 3 different TX tests:

- TX composite noise (CW tone at 100W, 50W and 10W)
- Keying cliks
- SSB splatter using pink noise generator with 6:1 peak-to-average ratio

5.1 TX composite noise

Results are presented for 50W output power as this is the most common PA drive level. TX composite noise at 100W is theoretically 3dB lower and some radios are close to that value, but some are quite different (TS590s shows almost no difference between the 100W and 50W, while IC7610 shows 7dB).

In the first plot I am presenting comparison of 5 radios to show the evolution of this very important TX parameter with FT1000mp representing an old technology, K3 being the best and then the two flagship radios from Yaesu (FTDX101d) and Kenwood (TS890). And of course the TK0C working horse (TS590s).



The bigest surprise was the TS890 TX composite noise - not sure how Kenwood managed to make it worse than TS590. The FTDX101d is very good but only beats TS590 at offsets less than 15 kHz (still an important part of the band when playing in-band). And both are more than 10dB behind K3.

The ARRL test data for TS890 would suggest this radio has superb transmitter and FTDX101d should even beat K3 - unfortunately this is not so.

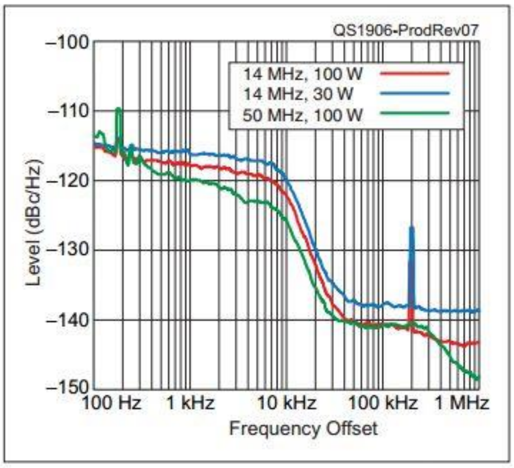


Figure 7 — Spectral display of the Kenwood TS-890S transmitter output during phase-noise

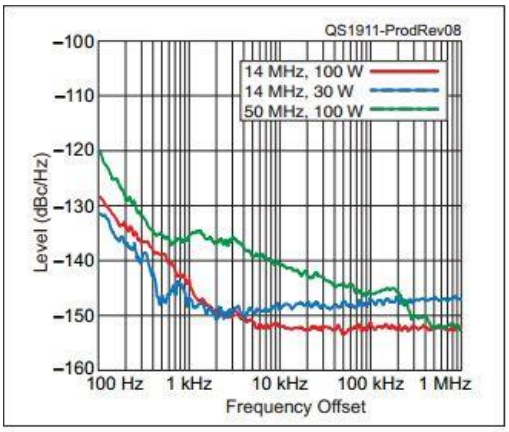
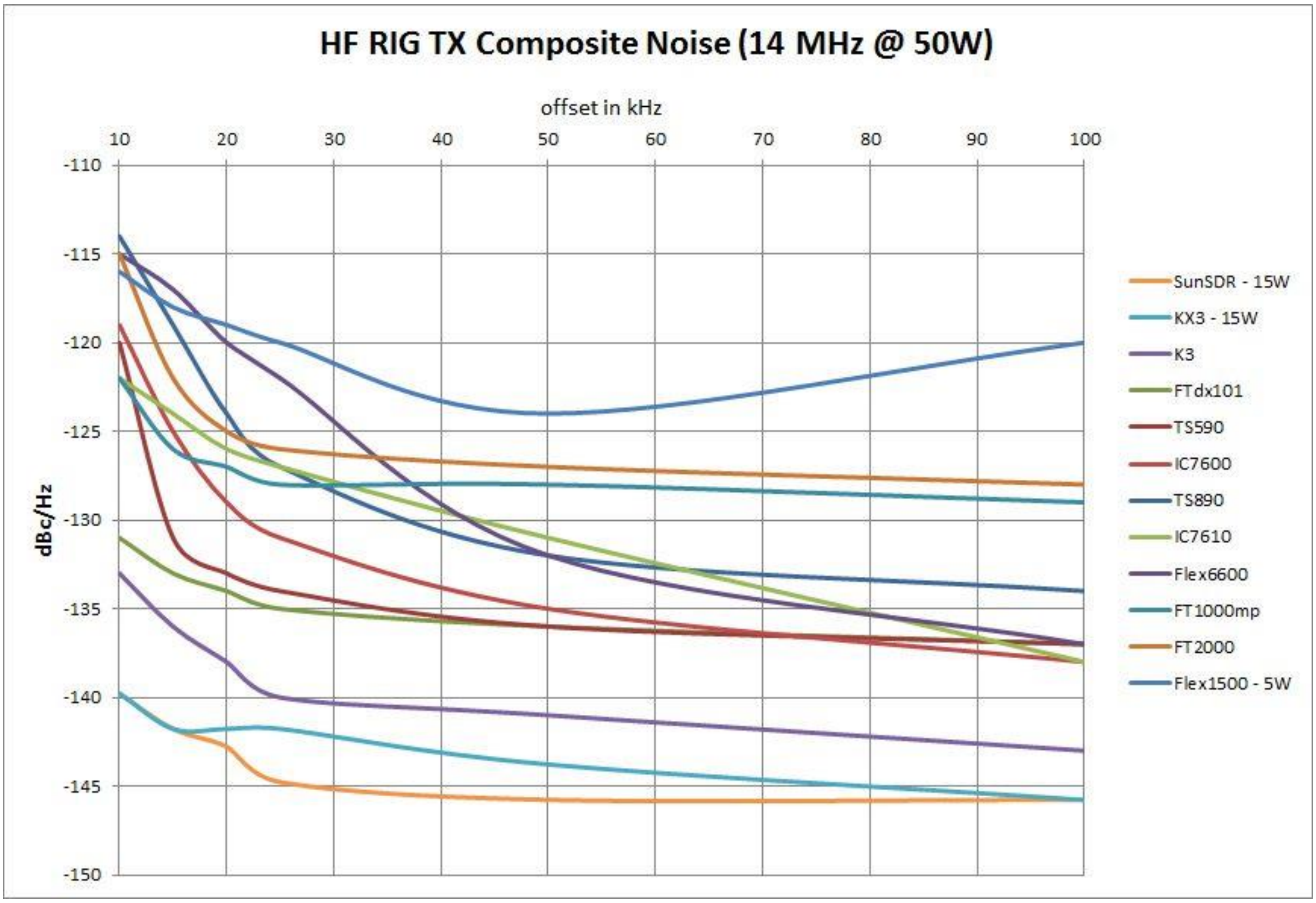
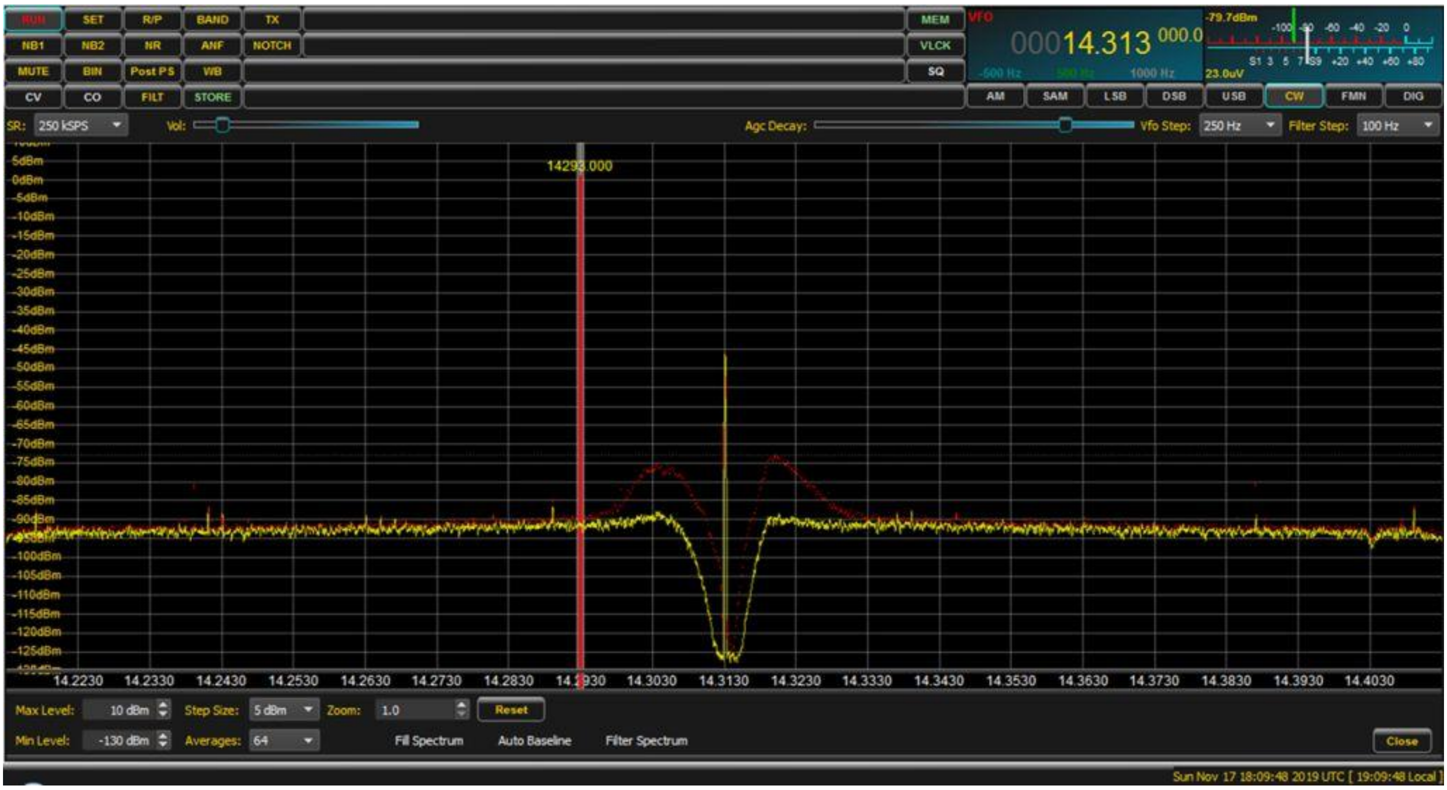


Figure 8 — Spectral display of the Yaesu FTDX101D transmitter output during phase-noise testing. Power output is 100 W on the

Combined plot of all tested radios shows that KX3 and SunSDR @15W are even better than K3 @50W.



The spectrum below is an example how TX noise measurement looks like when using narrow notch filter. Plot shows comparison between TS590s (red) and FTDX101d (yellow) - 10 kHz per division. In the middle of the notch residual carrier is seen. TS590s has a 15dB noise pedestal +/-15 kHz around the carrier (always clearly heard during TK0C operation).

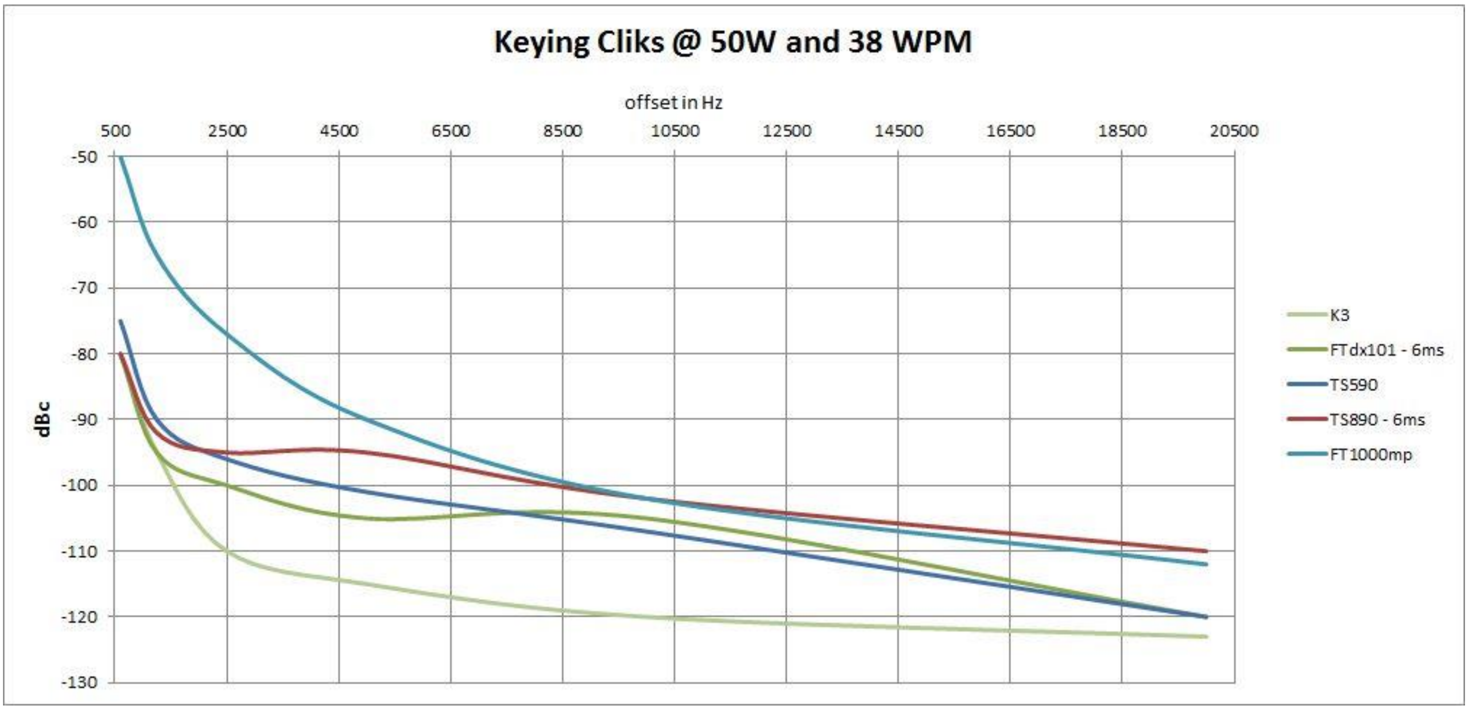


For those of you that love a lot of data, here is the complete table also showing TX noise at 500kHz offsett which is of importance when using HF RIG as a base station for VHF/UHF transverter. Table also shows RX NF and blocking DR to help select the right radio for in-band operation (you need BDR of more than 135dBc at as low NF as you can get - when using preamp, BDR goes down by the preamp gain level).

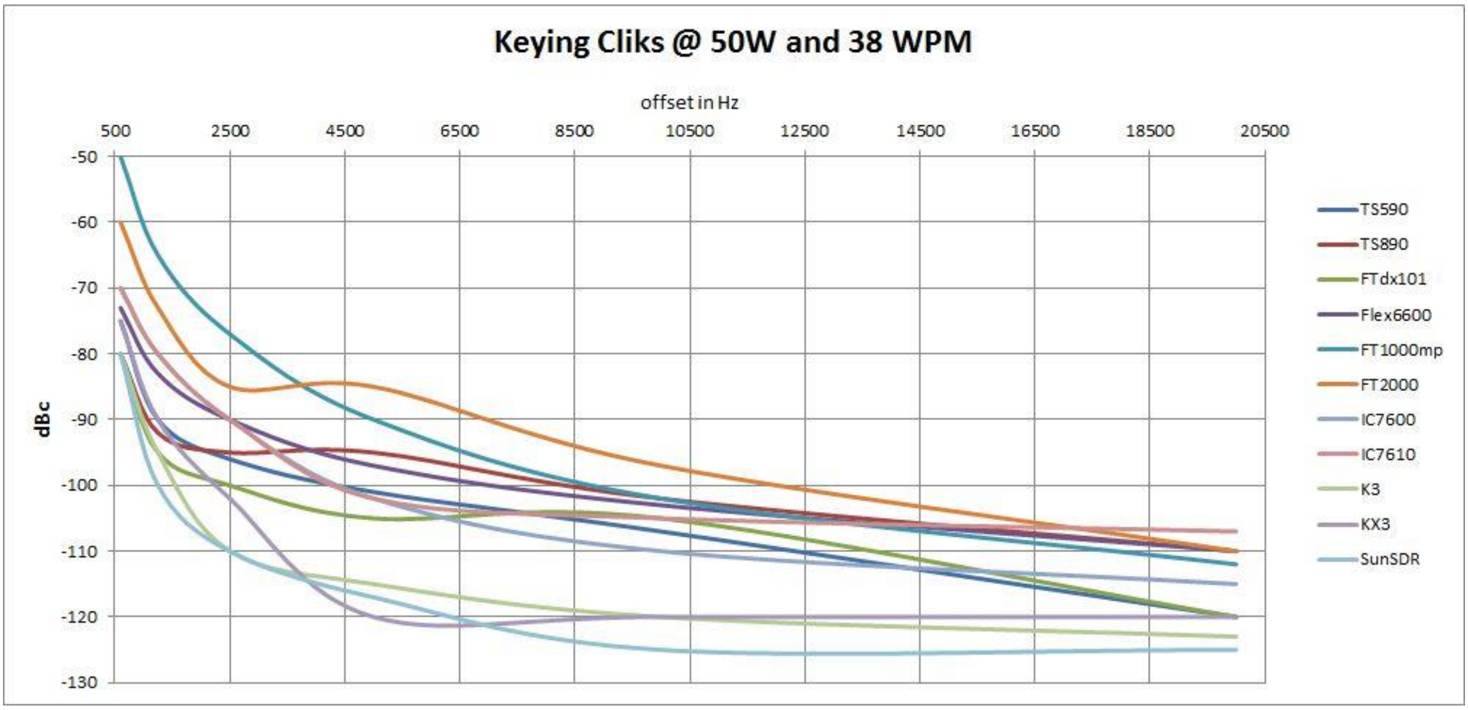
	RX BDR @20 kHz & NF			dBc/Hz @ offset (kHz)						
RIG	NF		Pout (W)	10	15	20	25	50	100	500
TS590sg	18	139	100	-119	-128	-133	-135	-138	-139	
			50	-118	-127	-132	-134	-136	-137	-138
			10	-116	-125	-130	-130	-131	-132	
TS590s	16	>140	100	-119	-128	-132	-133	-135	-136	
			50	-120	-131	-133	-134	-136	-137	-141
			10	-120	-129	-131	-132	-134	-135	
TS890	16	>140	100	-117	-124	-127	-131	-136	-138	
			50	-114	-119	-124	-127	-132	-134	-134
			10	-108	-113	-118	-121	-126	-128	
FTdx101D	22	>140	100	-134	-136	-137	-138	-139	-140	
			50	-131	-133	-134	-135	-136	-137	-145
			10	-129	-131	-132	-132	-134	-135	
FLEX6600	21	117	100	-118	-120	-123	-126	-135	-141	
			50	-115	-117	-120	-122	-132	-137	-143
			10	-109	-112	-114	-116	-123	-127	
FT1000mp	19	>140	100	-123	-127	-129	-130	-131	-133	
			50	-122	-126	-127	-128	-128	-129	-134
			10	-117	-120	-120	-120	-120	-120	
FT2000	19	126	100	-117	-124	-127	-128	-130	-130	
			50	-115	-122	-125	-126	-127	-128	-125
			10	-112	-121	-122	-122	-123	-123	
FLEX1500	21	107	5	-116	-118	-119	-120	-124	-120	-112
IC7600	16	122	100	-122	-126	-130	-132	-138	-142	
			50	-119	-125	-129	-131	-135	-138	-138
			10	-122	-125	-127	-127	-127	-128	
IC7610	17	120	100	-129	-131	-133	-135	-138	-141	
			50	-122	-124	-126	-127	-131	-138	-138
			10	-116	-117	-119	-120	-122	-124	
IC7300			50	-112	-112	-112	-114	-122	-118	
K3	12	>140	100	-133	-138	-140	-142	-145	-149	
			50	-133	-136	-138	-140	-141	-143	-142
			10	-134	-138	-141	-143	-146	-148	
KX3	22	>135	15	-140	-142	-142	-142	-144	-146	-144
SUNSDR	24	129	15	-140	-142	-143	-145	-146	-146	-140

5.2 Keying clicks

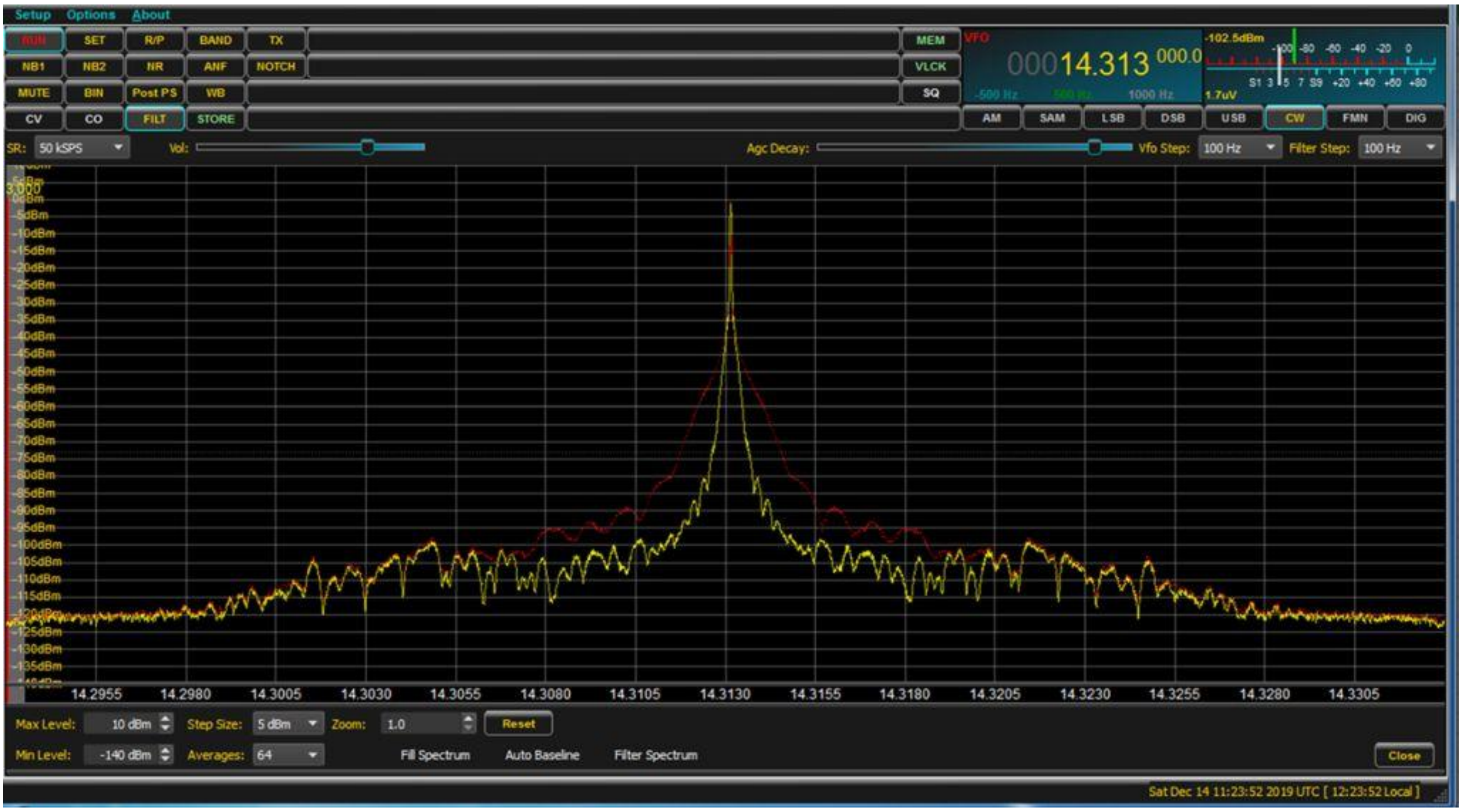
Keying clicks results for the same 5 radios used to compare TX noise. The modified FT1000mp is still very poor as compared to more recent companions.



And for full set of tested radios:



Spectrum below shows keying clicks of FTDX101d for two raise time configurations - 4ms (yellow) and 1ms (red) @1,5 kHz/div:

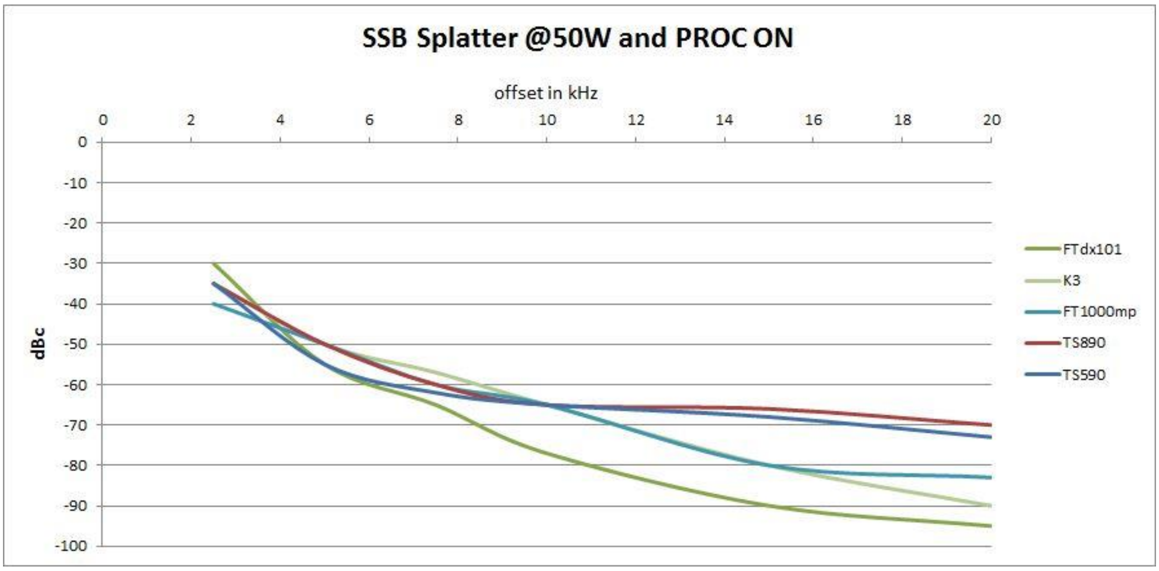


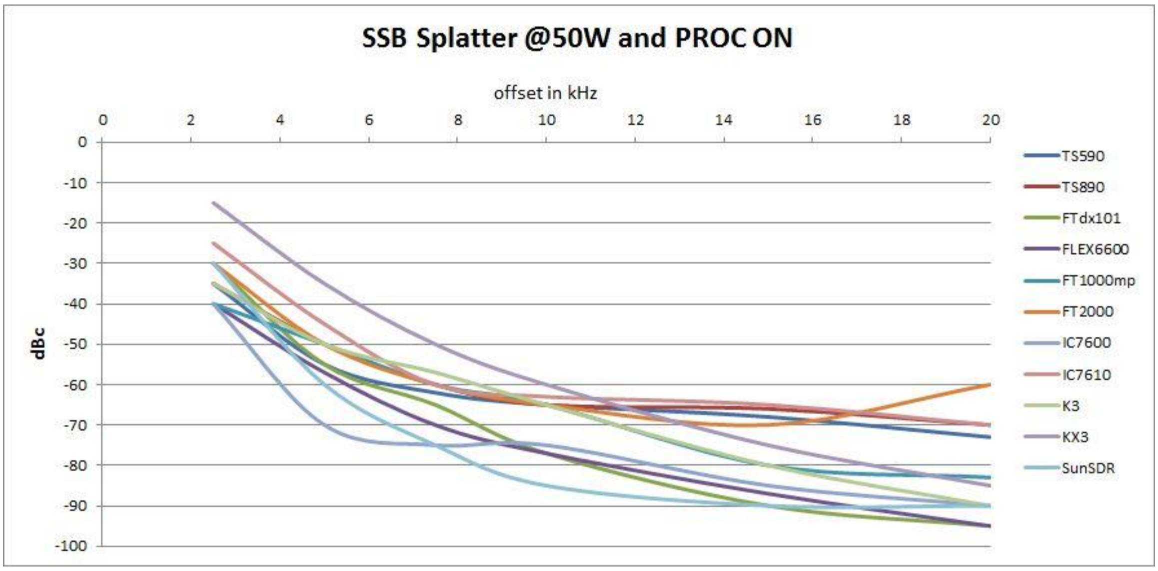
And the table:

	RX BDR @20 kHz & NF			dBc in 500Hz @ offset (Hz)					
RIG	NF		Pout (W)	600	1250	2500	5000	10000	20000
TS590sg	18	139	50	-75	-90	-96	-101	-107	-120
TS890	16	>140	50	-80	-92	-95	-95	-102	-110
FTdx101D	22	>140	50	-80	-95	-100	-105	-105	-120
FLEX6600	21	117	50	-73	-83	-90	-97	-103	-110
FT1000mp	19	>140	50	-50	-65	-77	-90	-102	-112
FT2000	19	126	50	-60	-73	-85	-85	-97	-110
IC7600	16	122	50	-70	-80	-90	-102	-110	-115
IC7610	17	120	50	-70	-80	-90	-102	-105	-107
K3	12	>140	50	-80	-95	-110	-115	-120	-123
KX3	22	>135	15	-75	-90	-102	-120	-120	-120
SUNSDR	24	129	15	-80	-100	-110	-117	-125	-125

5.3 SSB splatter

The last test was the level of SSB splatter. Pink noise generator was used with 6:1 PAPR settting ([Test Tone Generator]()).

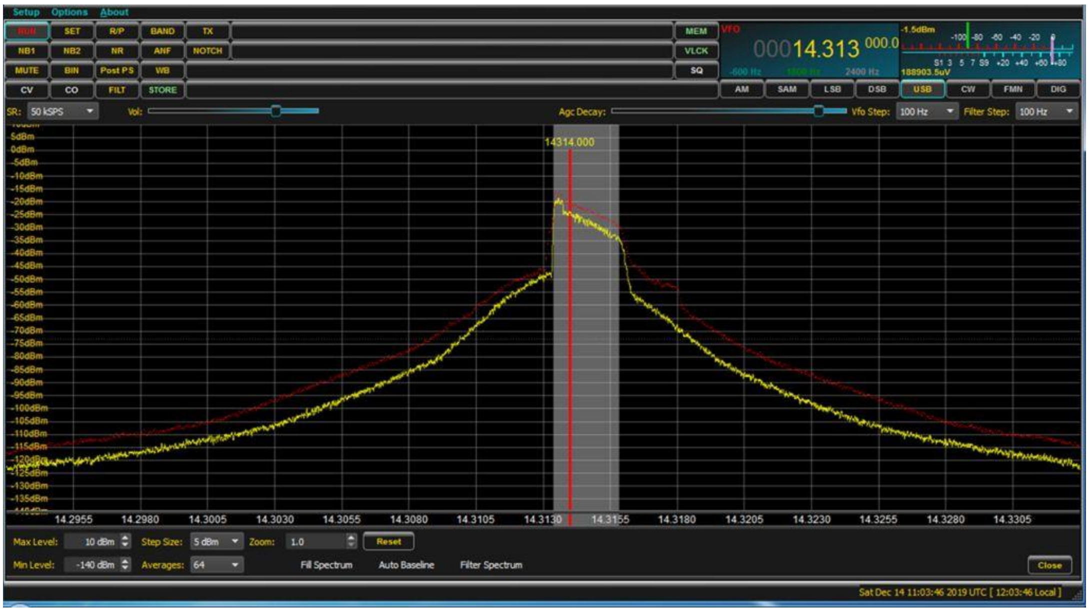




	RX BDR @20 kHz & NF			dBc in 2500Hz @ offset (kHz)					
RIG	NF		Pout (W)	2,5	5	7,5	10	15	20
TS590sg	18	139	50	-35	-55	-62	-65	-68	-73
TS890	16	>140	50	-35	-50	-60	-65	-66	-70
FTdx101D	22	>140	50	-30	-55	-65	-77	-90	-95
FLEX6600	21	117	50	-40	-57	-70	-77	-87	-95
FT1000mp	19	>140	50	-40	-50	-60	-65	-80	-83
FT2000	19	126	50	-30	-50	-60	-65	-70	-60
IC7600	16	122	50	-40	-70	-75	-75	-85	-90
IC7610	17	120	50	-25	-45	-60	-63	-65	-70
K3	12	>140	50	-35	-50	-57	-65	-80	-90
KX3	22	>135	15	-15	-35	-50	-60	-75	-85
SUNSDR	24	129	15	-30	-60	-75	-85	-90	-90

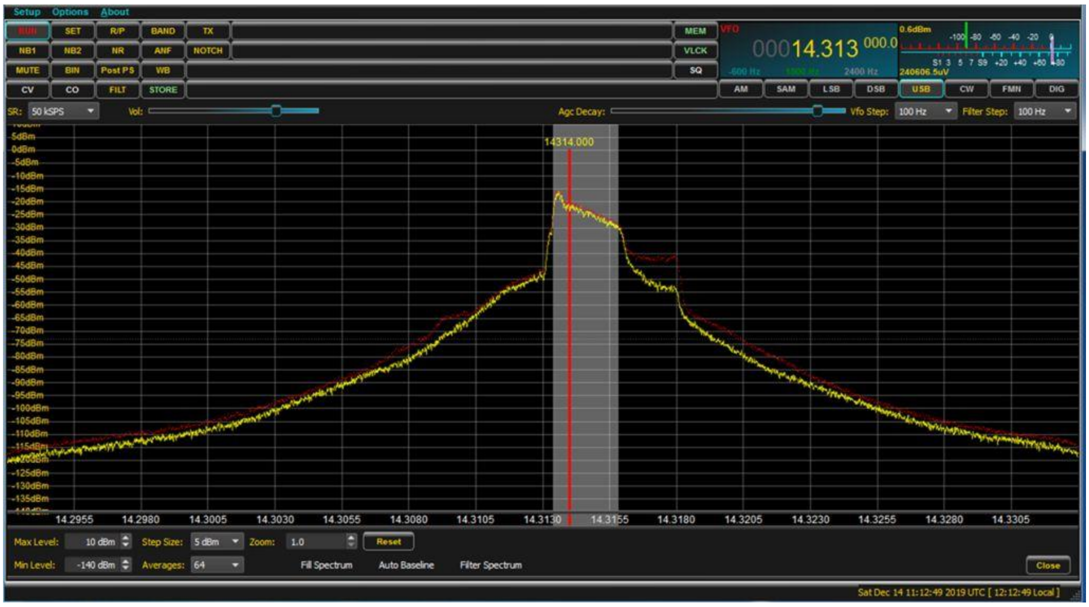
Three examples of FTDX101d SSB TX spectrum for various settings of PROC and AMC:

- PROC on (yellow) @PROC GAIN 50, PROC off (red) @MIC GAIN 50



- PROC on: AMC OUT 50 (yellow), AMC OUT 100 (red)

- PROC on: PROC GAIN 50 (yellow), PROC GAIN 100 (red)



6. Conclusion

The test campaign was really succesful - cool social gathering in pre-Covid era, fine wine and beer, few plays of billiard afterwards, and yes, we learned some new stuff and refreshed what we already knew.

It is surprising to me that after so many fine articles on the importance of the low TX noise levels, even in 2020 the best radios from the "big three" suppliers still lag big time behing K3. I believe that it would be possible to design TX chain with 10...20 dB lower composite noise level than K3.

Nevertheless, never buy a radio by consulting ranking tables - first decide what your needs are and then go for best price-performance radio shopping.

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http://lea.hamradio.si/~s53ww/TX%20noise/TX_noise.html