

Test of the Large Signal Behaviour of some 144 MHz Radios

DF9IC & DARC [OV Durlach A35](#) - 27. 2. + 19. 3. + 23. 7. 2005 in Pforzheim / Germany

Disclaimer: this web page expresses the personal opinion of the author and is not authorized by any organization. The reader is encouraged to make his own mind based upon the information presented here. All measurement results have been carefully evaluated but stem from a single test session on a single sample of the radio.

The purpose of this test was to gather some information which radios are best suited for 144 MHz operation in large signal environments like VHF contests. Typical signal levels from other (high power large antenna) stations in such a situation are:

- 50 dBm (90 dB ref. to noise in SSB BW): a moderately strong station, maybe up to 100 km away near LOS, or up to 30 km away behind a hill
- 30 dBm (110 dB ref. to noise in SSB BW): a really strong station, maybe up to 30 km away near LOS
- 10 dBm (130 dB ref. to noise in SSB BW): an extremely strong station, e. g. 3 km away LOS

These figures assume that the antennas point to each other which may be true if the interfering stations uses a multi-antenna system and is located in your main direction. Otherwise signals are typically 20 dB weaker when one of the antennas is pointing completely off the other station. These are real world levels - the author measured at his home site in the Nov. 2004 Marconi contest signals from one station with up to -10 dBm and from three stations with up to -30 dBm, using a calibrated HP8558B spectrum analyzer directly connected to the antenna.

If you plan to use a radio for serious VHF contest operation both RX and TX should allow nearly interference-free operation with levels up to 110 dB ref. to noise in SSB BW. The test shows that there are radios on the market which reach this figure in the RX 50 kHz off the carrier, in the TX 200 kHz off. This may be just acceptable while at least the TX should be improved. Nevertheless it will result in a strong interference if another station is very closely nearby, and your antennas point to each other. For a nearly interference-free operation in all situations at least 130 dB ref. to noise in SSB BW must be handled - but there is not and was never any radio on the market with such a performance.

The IP3 is less important than LO and TX noise performance as there are usually only few strong and very strong signals on 144 MHz so that only few frequencies are corrupted by the resulting intermodulation products. This situation is very different from the situation on the lower HF bands where many stations including broadcast transmitters are present. On the other hand the necessary dynamic range (difference between the smallest and the largest signal) is bigger on 144 MHz - therefore the need for the best LO noise performance. Radios that are well suited for 160 m CW DX with good close-in large signal behaviour are not necessarily performing well with a transverter on 144 MHz. This page is on 144 MHz useability only.

In the following tables some measurements are summarized which we did in early 2005. It is not more than a first step, and gives some information which radios must be excluded for serious operation - in fact none are left when you are very serious :-).

There are quite some other critical points left like ALC operation, keyclicks, and discrete spurii which must be considered also but could not be evaluated because of the lack of time.

The measurement procedures and the test equipment is described at the end of this page.

144 MHz Allmode Radios:

TRX	Owner	NF	IP3	RX Blocking in USB mode (3 dB S/N reduction in typ. 2,5 kHz BW) dB			TX sideband noise level in 2,5 kHz BW (spurii not included) dBc		
		dB	dBm	20 kHz offset	50 kHz offset	200 kHz offset	20 kHz offset	50 kHz offset	200 kHz offset
IC275E	DF9IC	5.6	-7.5	98	110	117	-97	-104	-109
IC746	DJ0QZ / DK1VC	3.6	-7.5	87	95	109	-82	-91	-105
IC910H	DK9IP	3.7	-8.5	81	89	100	-78	-88	-98
IC202	DL3IAS	7.7	-14	100	104	107	-100	-102	-102
Hohentwiel	DL3IAS	11.4 (?)	-5.5	96	97	100	-96	-97	-101
FT817	DK2DB	5.4	-12	87	96	106	-83	-91	-96
TS700G mod. with GaAsFET	DK8SG	4.9	-13	100	108	111	-102	-106	-107

TS700S (preamp off)	DB6IR	6.6	-7	100	107	111	-96	-102	-104
TS790E	DJ5IR	4.5	-14.5	103	104	109	-84	-94	-95
DK2DB homemade 1976	DK2DB	-	-11	109	110	112	-103	-107	-110

Comment:

The table shows that there has been a substantial decrease in TX performance in the past decade(s). The oldest radios (TS700 - mid 70s design, and IC275E - mid 80s design) are 10...20 dB better than newer or currently available transceivers (TS790, IC910H).

The IC910H has a very poor LO design. It is well suited for FM repeater operation connected to an indoor HB9CV antenna. Other use should be prohibited. FT817 and IC746 are only slightly better.

The TS790E can be used as RX in a large signal environment like a contest but please do not transmit with this radio.

IC202 and Hohentwiel (home made kit from Germany) have low phase noise close to the carrier but do not improve for larger spacing, resulting in mediocre overall performance. The Hohentwiel is some dB worse than the IC202.

Other radios currently produced have not yet been tested. Published test results from e.g. ARRL indicate that their performance may be in the same range with the IC910. The RX blocking in 20 kHz offset can be approximately derived from the ARRL BDR which is defined differently, by subtracting 34 dB (for BW conversion from 1 Hz to 2.5 kHz) and adding 6 dB (for the correction from 1 dB noise increase to 3 dB noise increase) - in total subtracting 28 dB from the ARRL BDR value. This conversion should be correct as long as noise increase is the limiting factor which is supposed to be true.

Data for some of these radios taken from [DK9VZ's web page](#) is listed here (compare this with RX blocking in USB mode at 20 kHz offset in above table):

- IC7400: 86 dB

- IC910: 78 dB (within 3 dB what we measured)

- IC706MKIIG: 83 dB
- TS2000: 87 dB
- FT817: 80 dB
- FT847: 75 dB
- FT857: 74 dB

None of these radios is useable for serious VHF operation. If you own any "modern" 144 MHz radio you are invited to join me for a measurement to gather more data about it (write an e-mail to <call sign>@adacom.org).

I use an IC275E and know why, though being aware of its limitations. It is good enough at least for 23 cm transverter operation :-)

HF Allmode Radios with transverter:

TRX	IF MHz	Owner	NF	IP3	RX Blocking in USB mode (3 dB S/N reduction in typ. 2,5 kHz BW) dB			TX sideband noise level in 2,5 kHz BW (spurii not included) dBc		
			dB	dBm	20 kHz offset	50 kHz offset	200 kHz offset	20 kHz offset	50 kHz offset	200 kHz offset
Elecraft K2 + XV144 preamp in the TRX "On"	28	DJ5IR + DJ5IR	6.0	-26.5	95	100	101	-93	-92	-93
Elecraft K2 + Kuhne TR144H+40	14	DJ0QZ + DJ0QZ	1.0	-9	96	103	114	-90	-95	-96
Orion main RX + Javorrnik Orion sub RX + Javorrnik	14	DK9IP + DK8SG	-	0 -7	-	-	-	-93 -	-88 -	-99 -

TS850 (preamp off) + LT2S TS850 (preamp on) + LT2S	28	DL6WT + DL6WT	- 3.7	-1,5 -26,5	101 100	104 102	107 104	-93	-100	-103
TS870 (preamp off) + LT2S	28	DK8SG + DK8SG	4.9	-6	98	104	112	-95	-100	-104
TS870 (preamp off) + Javornik	14	DK8SG + DK8SG	1.9	-1.5	95	103	112	-92	-97	-99
IC735 (preamp off) + LT2S	28	DF9IC + DK8SG	-	-	101	106	113	-	-	-
IC735 (preamp off) + Javornik	14	DF9IC + DK8SG	-	-3.5	106	115	117	-	-	-
IC746 (preamp off) + Kuhne TR144H+40	14	DJ0QZ + DJ0QZ	1.2	-5.5	99	106	119	-	-	-
FT1000 Mark V main RX (preamp off/on) + Kuhne TR144H	28	DK9VZ + DK9VZ	6.0 1.7	-9.5 -12.5	97	106	118	-91	-99	-101
FT1000 Mark V main RX (preamp off/on) + Kuhne TR144H+40	14	DK9VZ + DJ0QZ	1.3 2 (?)	-3 -10.9	104	113	120	-	-	-
FT1000MP main RX (preamp off) + LT2S	28	DK9IP + DK8SG	-	-	97	104	113	-	-	-
FT1000MP main RX (preamp off) + Javornik	14	DK9IP + DK8SG DK8SG + DK8SG	1.4 0.9	+1 +1	100 104	115 113	118 120	-98 -98	-106 -105	-110 -110
FT1000MP main RX (preamp off) + Kuhne TR144H+40	14	DK8SG + DJ0QZ	1.4	-1	-	-	-	-	-	-
FT1000MP sub RX (preamp off) + Javornik	14	DK9IP + DK8SG DK8SG + DK8SG	2.0 1.2	-4.5 -5	88 88	95 97	109 111	-	-	-
LT2S has about 17dB gain, 1 dB NF, -6 dBm IIP3 and uses an IF of 28 MHz. Javornik has about 27 dB gain, 1 dB NF, +3 dBm IIP3 and uses an IF of 14 MHz. Kuhne TR144H+40 has about 27 dB gain, <1 dB NF, +9 dBm IP3 with 14 MHz IF.										

Comment:

The possible IP performance of a transverter / HF radio system is inferior to that of a 144 MHz transceiver with a crystal filter on the first IF because two frequency conversions are needed until the first narrow filter blocks off-channel signals. When you compare the test results you will find nevertheless that the IP of the transverter / HF radio combos is usually better than that of the 144 MHz radios. This shows the bad design of the VHF radios - using the same quality of the preamp and the mixer as they are used now in mid-class HF radios an IP of +5 dBm could be obtained with a single conversion 144 MHz receiver of 3...5 dB NF.

The LO performance of a HF radio with upconversion to a high IF should be slightly better than that of a 144 MHz LO because its frequency is a bit lower. In practice this difference is quite large which again shows the bad design of most 144 MHz LOs.

The LT2S transverter has an IF of 28 MHz like most 2 m transverters. The Javornik uses a 14 MHz IF because it was optimized for operation with a FT1000, and this radio is substantially better on 20 m than on 10 m. There is no special reason for a such a difference in performance of the HF radios between 14 and 28 MHz operation as long as the radios use upconversion to a high IF. But in fact some radios perform better on 14 MHz, others on 28 MHz. Thus the transverter should be selected accordingly. Kuhne offers versions for both 14 and 28 MHz.

All transverters have crystal LOs which are so much better than the LOs of the HF radios that they should never contribute substantially to the total noise. Nor should the transverter contribute to the TX noise when driven with the correct level (do not use optional TX IF preamps) but we observed some problems with wideband TX noise on the tested Kuhne transverters. The Javornik transverter is very well matched to the FT1000 in gain and IF band and has a better IP than the LT2S. Nevertheless the performance of any combo is determined mainly by the HF radio.

The TenTec Orion's TX noise was quite bad so that we stopped further tests. Maybe there was a defect in our sample radio or insufficient internal filtering of the 12 V line power coming in the test from an external switched mode PSU (because the ORION has no internal PSU). But even [TenTec's published graph](#) for the LO sideband noise (RX) shows a very moderate performance never reaching more than 107dB @ 2.5 kHz (= 141 dBc/Hz) - this is 10 dB worse than a FT1000MP in 200 kHz offset from the carrier. It stems from the wideband noise floor of the prescaler used as a part of its LO system. Our sample also showed unstable behaviour and had to be rebooted once during the test because the PLL seemed to be unlocked continuously without indication (firmware bug ?).

The Elecraft K2 also has a low IF design using conventional VCOs which should result in a good LO noise suppression but does not do so well. We had two radios on the bench, one from 1999 (DJ5IR) and one from 2004 (DJ0QZ). The last one was tested on 14 MHz and showed better results than the older one on 28 MHz. You may compare the ARRL test results of the LO noise that [Elecraft publishes on their own website](#) and which is closely within our blocking test result (our measured -95 dB RX blocking in 20 kHz offset is equivalent to -129 dBc/Hz LO noise). The high level of TX noise shows that there seem to be design flaws choosing too low signal levels internally. The AGC threshold is ridiculously high (subjective

impression). I also do not understand why it uses low quality ladder crystal filters instead of a filter from monolithic duals like any other radio does. Overall it was the worst HF radio in the test (OK, a 144 MHz IC910H is still worse...).

All combinations are worse in the TX noise than in the RX noise which means that the level in some TX stages is too low so that additional wideband TX noise adds to the LO phase noise. This seems to be a general design flaw of nearly all tested radios.

The FT1000MP / Javornik is the best available combination. Nevertheless they are still far off what could be realized. We measured two different samples of the FT1000MP which performed very close to each other. The Mark V seems to be also quite close to the MP but SM5BSZs measurements indicate that the TX may produce more noise, as well as the FT1000D. But these measurements were done on 14 MHz including the PA stage, so it has to be compared again with the same TVTR setup.

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References:

SM5BSZ has done many similar measurements and reported about them both in magazines (DUBUS, UKW-Berichte) and [in the web](#). Please note that his TX noise and RX blocking values are normalized to 1 Hz and look therefore 34 dB better. The IC275E from SM5BSZs measurement in Annaboda (S/N 01744) is the authors sample as reported above, and shows reasonable agreement which increases the confidence in our measurements.

It is very useful to read the SM5BSZ reports but you need enough technical background. Take a look also into his [file list](#) where you can find many interesting topics. There is a [QEX article](#) about LinRad and large signal behaviour and needs on 144 MHz available.

A description of the Javornik transverter is available on [S53WWs website](#).



Bernhard DB6IR (back), Helmut DK8SG (front) and Henning DF9IC (right)

(photo courtesy of DK9IP)



