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"Friendship through Radio"

I7SWX TWO-TRANSFORMER H-MODE MIXER WITH TRANSFORMER PASSIVE SQUARER

Giancarlo MODA, I7SWX

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July 2005

i7SWX, Licensed since 1963 – ex: I1SWX, I5SWX, I2SWX, I0SWX & swl I1-10089, also W1-I7SWX & CE3-I7SWX

First Ham Radio operating in 1952, at 12 years old, from my father's station "I1SWX"

I like home-brewing, modifying commercial equipment, test gears and experimenting with antennas

*Member of: A.R.I. (Italy) 1959 * R.S.G.B. (UK) 1965 * ex REF (F) 1999 * G-QRP #10241 * I-QRP #571*

F5VGU : Qth locator JN33J – Departement du VAR (83)

I7SWX TWO-TRANSFORMER H-MODE MIXER WITH TRANSFORMER PASSIVE SQUARER

I am sure, by now, the majority of home-brewers and non, are well aware of the H-Mode mixer using Fast Bus Switch 3125. Many of them have certainly selected the H-Mode Mixer, in the G3SBI (3 transformers) or I7SWX (2 transformers) versions, for their new designs or upgrades of old or commercial equipment. Well known and top of the range projects using the H-Mode Mixer are the CDG2000 (G3SBI version) and the PIC-A-STAR (with I7SWX or G3SBI version). As commented by Harold Johnson, W4ZCB, “The FST 3125 discovery was a Godsend in the mixer department and G3SBI has pretty well removed the mixer from being the weakest link in a radio”.

The June 2005 issue of RadCom sees in TT a note on “CDG2000 H-Mode Mixer modification” where G3SBI reports a simple AC-coupled modification from the divide-by-two squarer to the FST3125 H-Mode Mixer in the CDG2000 to improve balancing on switching the gates, resulting in a better minimum feed-through (70dB null) and maximum IP3, going from +42dBm at 30 MHz to +50dBm at 7 MHz ... Astonishing results.

During a visit to my good friend Bill Carver, W7AAZ, in 2004, I was informed that Paul Kiciak, N2PK, of N2PK VNA fame, was working on an idea to simplify the H-Mode Mixer squarer using only a transformer and not the 74AC86 or LVDS squarer to gate the FST3125; a very interesting idea. Having not seen anything published by N2PK and with my curiosity always high for nearly a year, one weekend I had one of those productive five minutes ... I could not wait longer and resists to check this further potential H-Mode Mixer simplification. Paul’s idea is very simple and clever. Why not to drive directly the FST3125 gates directly from the oscillator and with a simple passive component like a transformer? Although we have an additional transformer, one IC less is a point less of failure. Figure 1 reports the final tested solution.

As nothing is perfect, anything we do is always a compromise: to get something we have to give something, but what we do get maybe still a lot.

Looking at Figure 1 we have the squarer formed by transformer T3 and an adjustable bias circuit, formed by two resistors and a trimmer. The transformer secondary is central taped and drives directly the two groups of two FST 3125 switches, in the H-Mode mixer, complementary. The control gates do not switch at exactly $V_{dd}/2$ but somewhere around +1.5V. The bias will help to find the more suitable voltage for both gates groups. I used a 4T : 6T : 6T transformer, made on a balun ferrite core #43 (2402), to be sure there is enough drive for the gates. A minimum of around +7dBm seems valid, although I tested it up to +10dBm. A 50 ohm LO input termination is given by the 470 ohm loading resistor. Similar results, with a little higher drive, are given by a home-brew transformer with 1: 1: 1 ratios (three windings of 4 Turns); commercial transformers should be better but costly.

I have also tried a simpler transformer configuration as 4T : 6T and 4T : 4T (1:1), reported in Figure 2, but the performances are a little bit lower.

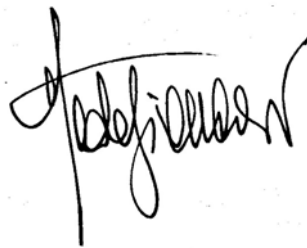
With or without a Spectrum Analyzer (use a general coverage RX, look for the L.O. signal on the mixer IF output and adjust the bias for the deepest null possible. I used a one turn trimmer and the adjustment maybe a little bit tricky; a multi-turn trimpot maybe better but it will require more

space and it will be more expensive unless available in the junk box. Figure 5 shows the IF output signals (9MHz and Upconversion) plus the RF in and LO leakage after balance adjustment done.

Table 1 gives my findings. It is not easy to measure high performance mixers like the H-Mode. My Spectrum Analyzer has an IIP3 of +25dBm and adding input attenuation lowers the signals value measurable. The IIP3 measured at 7MHz at 0dBm input is around +33dBm, see Figure 6. Up-conversion is possible but it looks like the conversion losses are higher particularly for IFs over 9 MHz, as reported in Table 1 (Upconversion).

This type of transformer squarer can be applied also to the original G3SBI H-Mode Mixer, using 3 transformers. All transformers can be commercial (expensive). I suggest to homebrew transformers and as it is not so easy to have two identical ones (electrically) and for this I recommend the H-Mode Mixer version with two with just a marginal reduction in performances. The total cost should be around 2-3 Euro (2 GBP), where the most expensive item is the FST3125. For those seeking higher performances, with this oversimplified H-Mode Mixer, I suggest to try a two bias arrangement with AC coupling, as sketched in Figure 3. I have done a quick test and seen that at the low HF bands RF input the results are similar to the single adjustment circuit, while an interesting change is well visible with a test at RF=28MHz and IF=9MHz with a LO=37MHz. At the IF mixer output the IF signal is around -5dBm (RF in 0dBm), the leakage RF is at -45dBm and the LO leakage at -55/58dBm (see Figure 7). I do not like adjustments and particularly when are more than one. We have to keep a project KISS and get out of it as much as possible ... and be happy... then if one is “looking for the hair in an egg”, well any complex solution is welcomed. In Figure 8 you can see the set-up to perform this test ... if it works like that with a more professional assy could squeeze out some additional performance.

In Figure 4 I have reported a possible application using only one single IC FST3125 and a total of 4 transformers to implement a single conversion RX, with 1st mixer and demodulator. The mixer and demodulators are double balanced (see “I7SWX Double Balanced Mixer-Demodulator” RadCom, TT, June 04, with an IP3 of at least +25dBm). I do not believe there are high performance solutions more KISS and cheaper than this one. The DBM and H-Mode Mixer are bi-directional and for this are also valid in RTX applications.



22 July 2005

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Rev 2

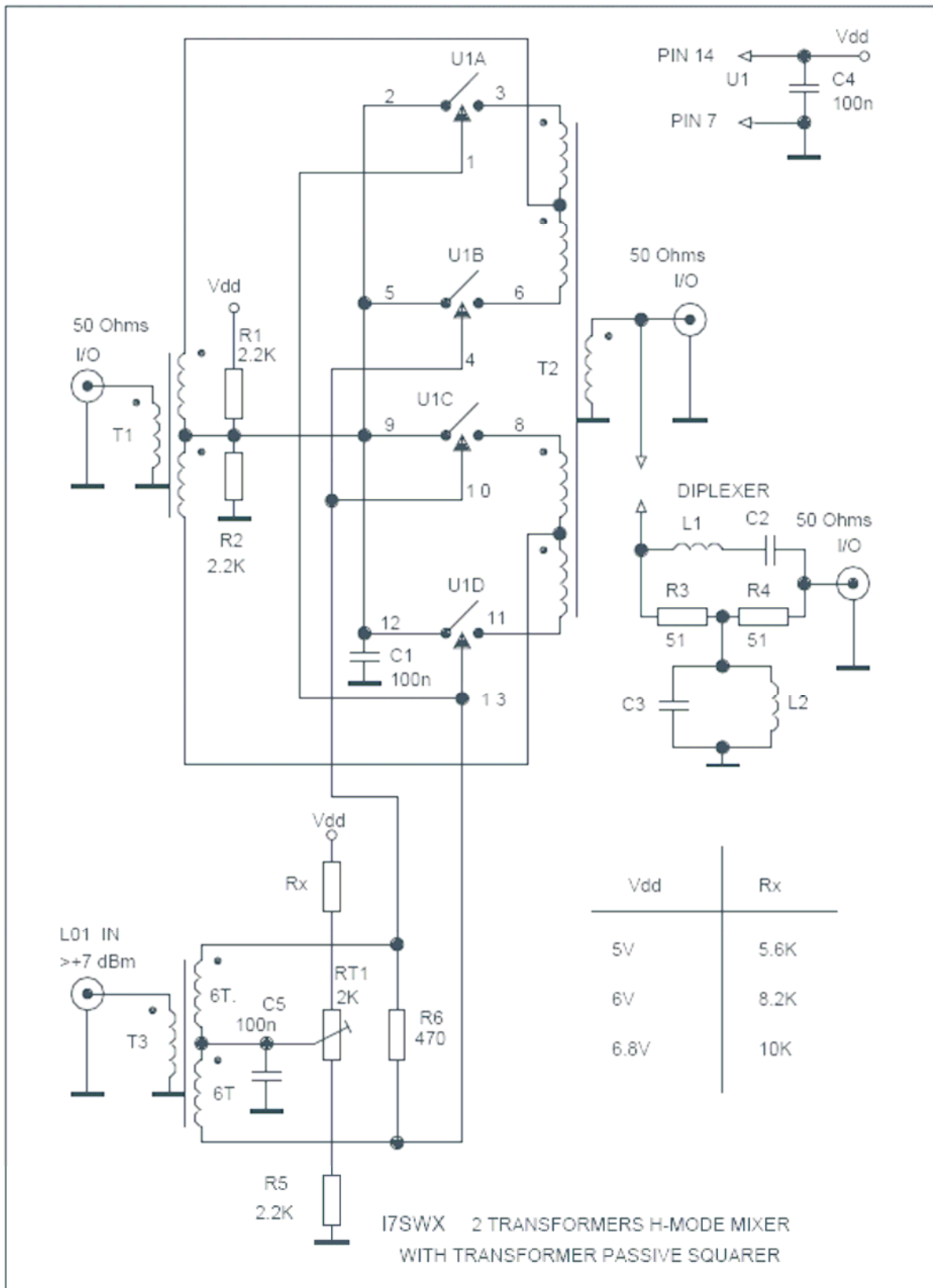


Figura 1 – I7SWX 2T H-Mode Mixer with passive transformer squarer. Balance adjustment is done checking for the highest null of the L.O. signal at the mixer IF output. If using a 1:1:1 (1:4 CT) transformer the 470 ohm resistor needs to be 200 to 220 ohm.

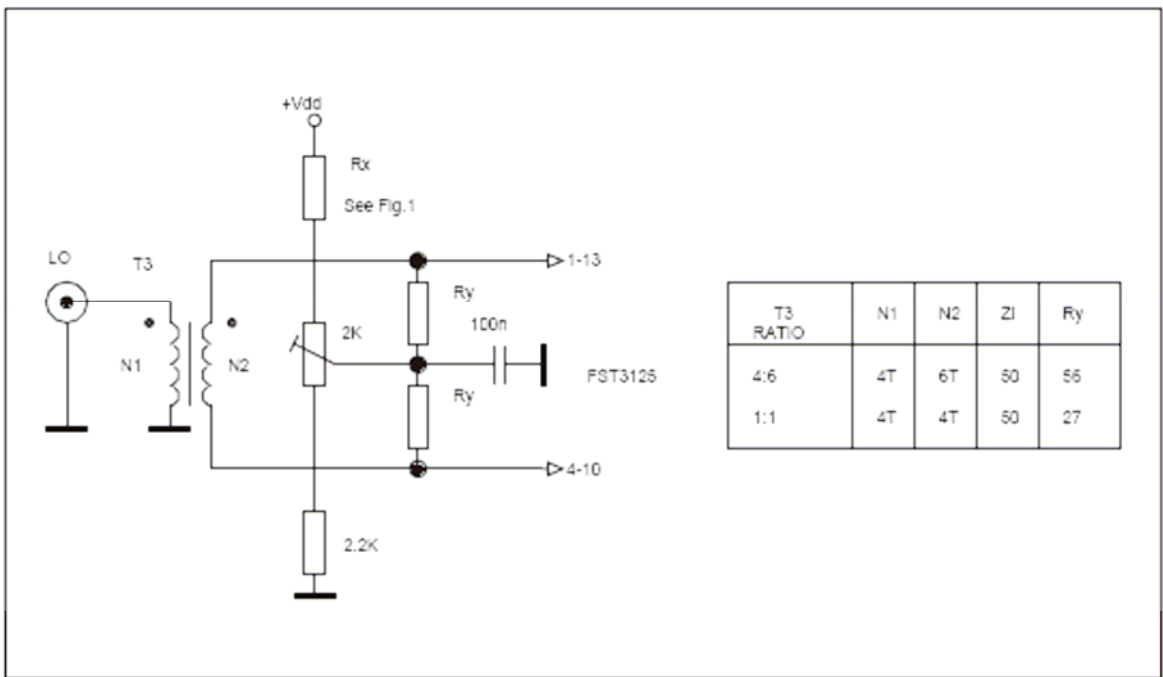


Figura 2 – Other possible passive squarer configuration. The single secondary winding squarer has lower performance (lower nulls) versus the configuration in Fig.1.

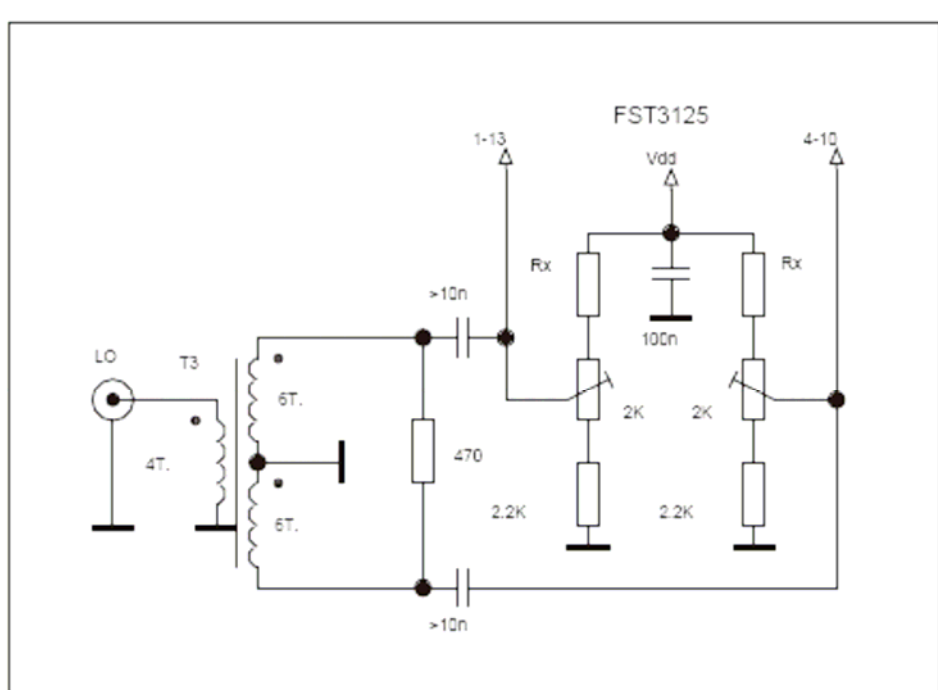


Figura 3 – H-Mode Mixer passive transformer squarer possible double bias control and AC-coupling for higher performance. Circuit suggested. For T3 refer also to Fig.1.

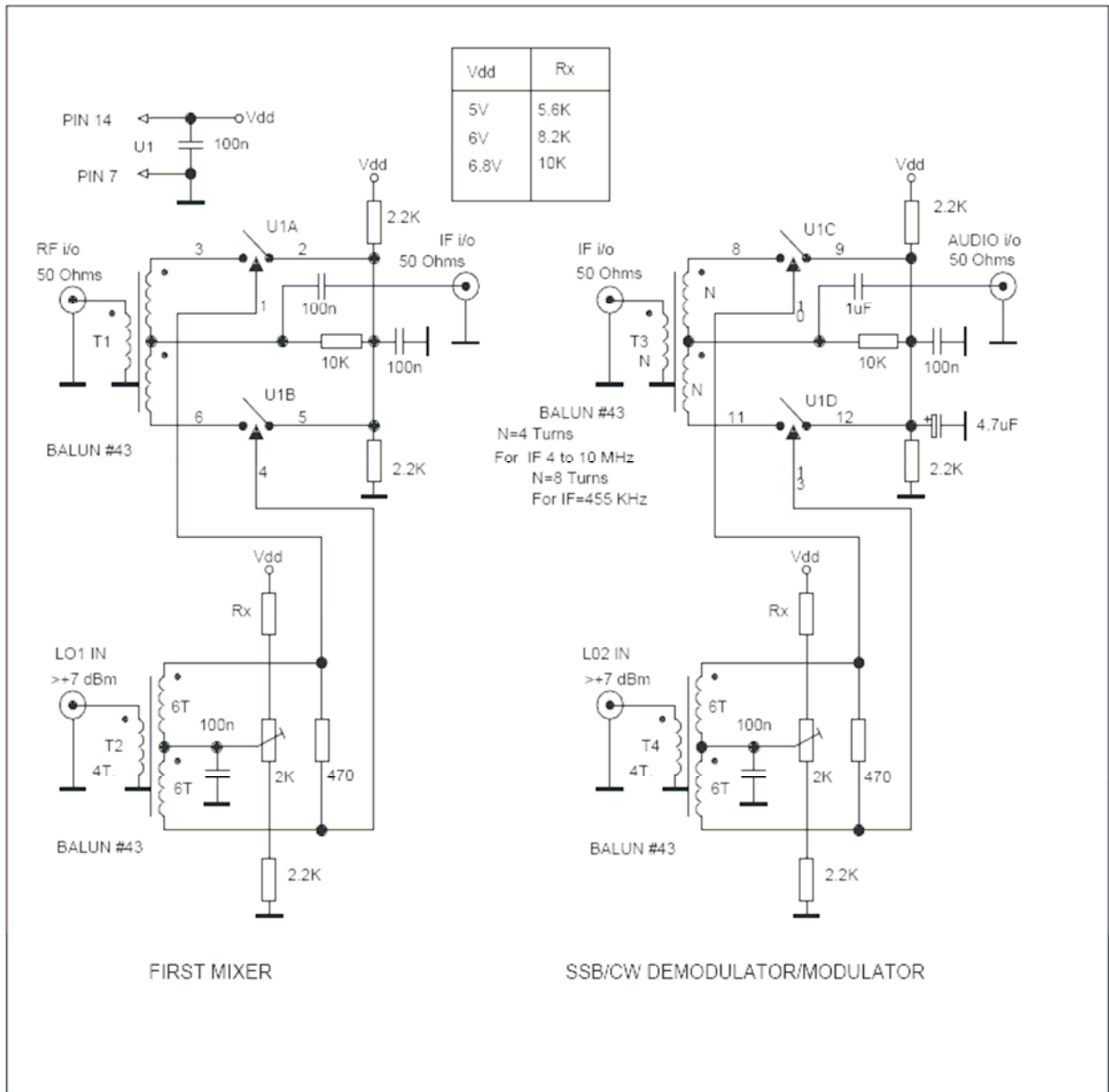


Figura 4 – Suggested mixer and demodulator circuit for a simple one conversion receiver, using the I7SWX 1 T Double Balanced Mixer-Demodulator with FST3125 and transformer passive squarers.

Table 1

RF IN at 0 dBm	2 MHz	7 MHz	14 MHz	21 MHz	30 MHz	50 MHz	
<i>Conversion Loss dB for Downconversion at 9 MHz</i>	- 5.5	- 5	- 5	- 5.5	- 6	-7	
<i>Conversion Loss dB for Upconversion (RF + LO)</i>	-5.5	- 6	-7	-7.5	- 8	-15	
<i>LO Null dB @ IF</i>	- 53	- 50	-53	-56	-51	- 26	
<i>RF IN Null dB@IF</i>	- 41	-44	-30	-35	-37	-35	

The data in Table is referred to an IF output at 9 MHz (IF = LO – RF).
The Upconversion is IFup = RF + LO, i.e. 14 MHz + 23MHz = 34MHz.

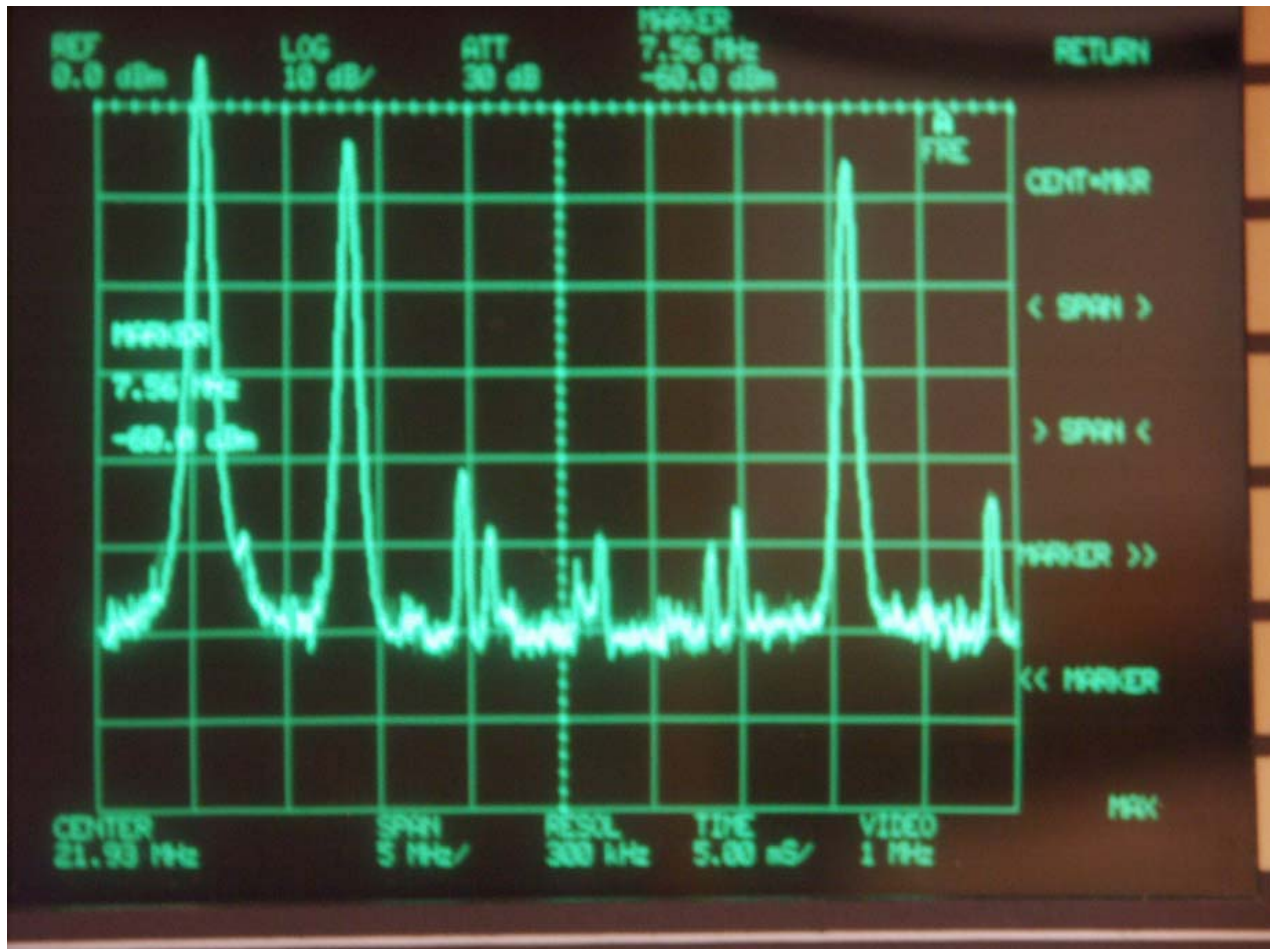


Figure 5 – Spectrum Analyzer view of H-Mode Mixer output configured as in Fig. 1 with an RF input of 0 dB. Visible are the IF output the RF and LO leakage on IF output and Upconversion

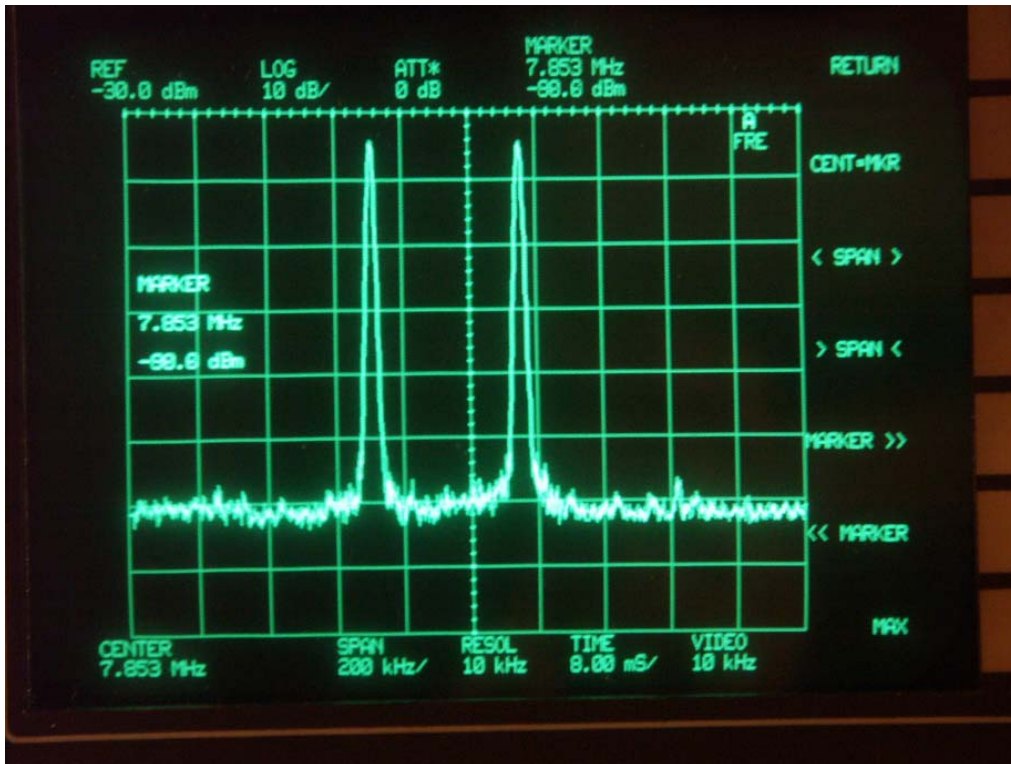


Figura 6 – IMD measurement of I7SWX 2T H-Mode Mixer with transformer passive squarer. Two tones input at 7.0 and 7.5 MHz with IF output at 9 MHz. Conversion loss is around -5 dB, resulting in an IIP3 of around $+33$ dBm. To avoid Spectrum Analyzer problems (IIP3 $+25$ dBm) an external attenuation of 30 dB was used at its input.

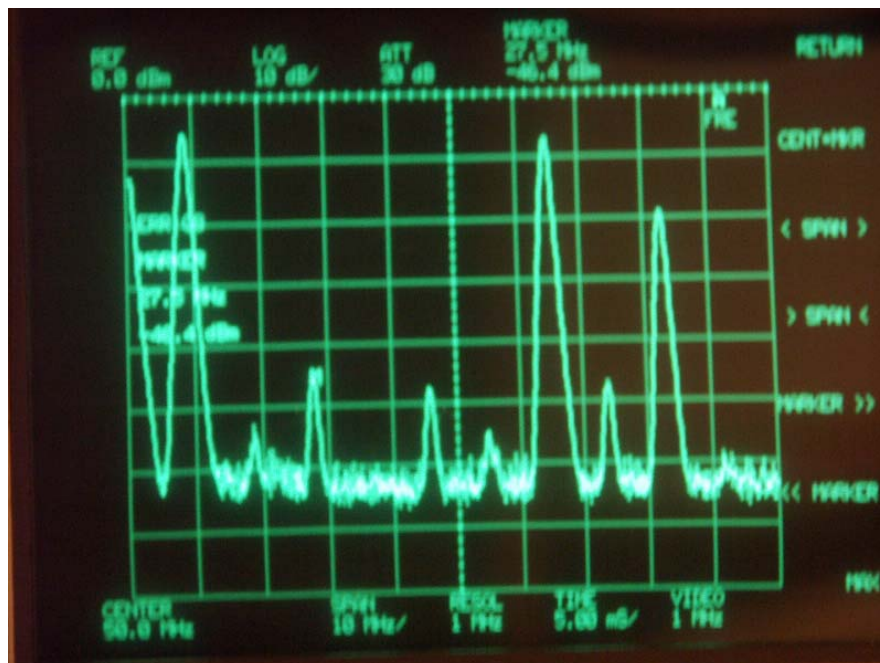


Figura 7 – Spectrum Analyzer view of the signals at the mixer IF output. The first one on the left is the IF signal at circa -5 dBm, followed by the RF leakage nulled at -45 dBm (-37 dBm with single adjustment) and the LO leakage (LO in $+10$ dBm) in the noise at $-55/58$ dBm (-51 dBm with single adj). The upconversion IF signal of 51 MHz is visible at circa -7 dBm.

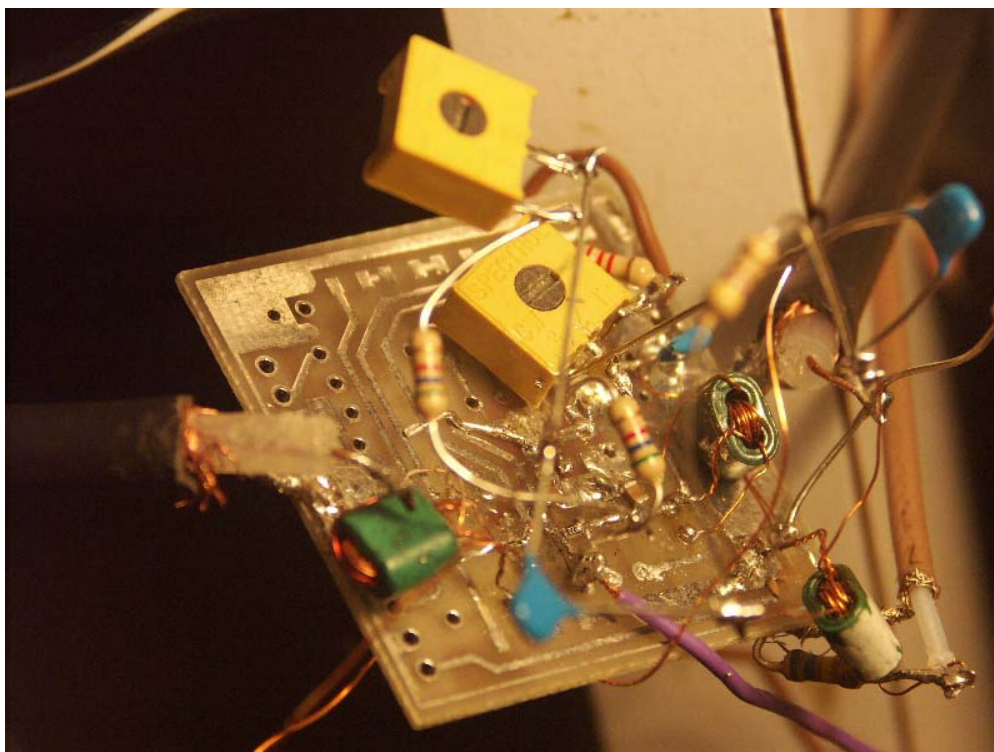


Figura 8 – View of the I7SWX 2T H-Mode Mixer with passive squarer and double adjustment in a real experimental set-up. If something like this works