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"Friendship through Radio"

I7SWX IMPROVED TWO-TRANSFORMER H-MODE MIXER

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THE I7SWX TWO TRANSFORMERS SIMPLIFIED H-MODE MIXER

Recently we have seen an increase on home construction and a lot of interest, worldwide, has been focused on the now well known H-Mode mixer using the Fast Bus Switch 3125. One of the very recent application of this mixer has been on the CDG2000 transceiver, published on RadCom and made available on the internet on the Warrington Amateur Radio Club Web: www.warc.org.uk/home.htm.

I have been working on modifications of mixers on some of the well known Japanese Black Boxes and particularly on mi Icom IC751. I also distributed 3125, not so easy to buy, to some Italian friends to "corrupt" them in modifying their equipments (IC781, 765, FT1000).
I first modified my IC751 3rd mixer (Dual Gate Mosfet), using a 74HC4066 to see the validity of this component versus the FST3125, being very easy to purchase. I published my work on Radio Rivista, April 2002 issue: "Modifiche al ricevitore dell'IC751 per migliorarne l'IP3". This was based on the circuit diagram published on TT, RadCom, Sept.98. The results were very positive. This article was key to "wake-up" many Italian Hams regarding Jap Black Boxes potential modifications and improvements. Also home construction focused on the use of the H-Mode Mixer. Following Colin Horrabin, G3SBI, search for top IP3 performances, many have been blocked by the difficult and expensive purchase of the Mini Circuit transformers recommended. The H-M Mixer can have an IP3 around +45dBm, nothing possible with commercial products. With the CDG2000 project we have discovered that now the IP3 limit is not given by the mixer anymore. Now we have to deal with the preamplifiers, the post mixer and if amplifiers, the filters and the passive components like the transformers or coils!
As nothing is perfect on this world, we have two groups of people, one like Colin, G3SBI, escalating to the maximum IP3 values possible, measuring to the 0.1dBm and the other one, like me, that look more for a compromised solution and could not care much for the 1dBm difference and home brew as much as possible. This wonderful H-mode mixer has plenty to give in dynamic range, leaving us with the problems due to the other components in a receiver. With this kind of idea I have been working on home made transformers, using balun cores, as they are easier to wind and to get hold of, respect to toroids.
Having been "infected" by my friend Maurice, F5NRZ, with his laboratory filled up of test equipment, and after my visit to Bill Carver, W7AAZ, I began saving money to put together some second hands equipment as to "see and check" what I am doing, reducing guesses. The first mods were only done using a meter, an oscilloscope and an home made two tones generator (vy nice one with possibility of test at 20 and 10 kHz spacing, output -10dBm)…not much, certainly. Having acquired the HP 141T spectrum analyser (Thanks a lot Maurice) and got hold of not one but two HP8640, I decided again to review the 3rd mixer mod on my IC751, using, this time, the FST3125. Every time I was experimenting with the transformers (number of turns), to find the best solution I had to rewind them all. Particularly the two transformers, with the primary in parallel, were always different. I decided, then, to experiment the solution of a single transformer. It would have five turns and certainly all the windings would be with similar characteristics. It was a nightmare at the beginning. The mixer loss was so high and changed so much that I nearly gave up. Finally I decided to make the two transformers with same number of turns. The magic number was 4. The results were very positive and like the "hoped" ones. I compared the two mixers, the one with 3 transformers and the new simplified one, with 2. The simplified version has an loss higher than the G3SBI one, of circa 1dB. I declare it at 6dB (measures say something like 5.5dB). The bandwidth seems to be a little bit narrower, but certainly nothing to worry about.

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I have just completed the replacement of the 3rd mixer in my IC751, with this simplified version, with good results and quite a difference with the previous one, classic H-mode with 74HC4066, regarding loss and IP3.
The transformers are, as I mentioned before, made using ferrite balun cores type -43, a gift from W7AAZ. The windings are done using a sewing needle. The wires are not twisted together, this to reduce capacitance and inductance leakage between windings. The circuit diagram reports the complete mixer as assembled to replace the original dgm. You will see that there is a jfet buffer amplifier in front of mixer. This is necessary to connect the 50 ohm input mixer to the output of the second IF amplifiers with a 1kohm load (9.1 MHz). The output of the mixer is connected to a 50 ohm and 455kHz diplexer driving a transformer 1:9, which is connected to a 470 ohm resistor at the gate 1 of the dgm 3SK74, ex original mixer, and now post mixer amplifier. The jfet has some attenuation, reduced by the amplifying factor of the 1:9 transformer. The total loss is less than -10 dB.
I have done some additional tests to the basic simplified mixer, with input ranging from <2 MHz to 52MHz. I tested this range at IFs of 10, 21, 46 and 70 MHz. Mixer loss is around -5-6 dB. At 70 MHz output loss increases of -1dB, maybe a little more. Probably this is due to the switching limits of the 3125 gates. The input-output bandwidth of 3125 is over 300MHz.
I even tested input at 146 MHz. The loss is around -20dB! I have done a quick test at 460kHz input (MW band), IF at 10 MHz (att -8dB) and at 46MHz (att = < -9dB).
We can say that the H-mode mixer, even with two transformers, it is good from MW up to 50 MHz input.

Looking at the circuit diagram we can see that the 74AC86 is quite different from the original mixer presented in TT, Sept. 98. There is no balancing adjustment. Only two xor gates work in the linear band and amplify the local oscillator or VFO signal. The remaining two gates are driven through a capacitor. This circuit gives two complimentary outputs quite symmetric from low frequencies up to 100MHz. The diode connected between the input with the resistor connected to +Vc and +Vc is there to clamp the ac signal; I blew several 74VHC, while the 74AC86 have no problems. Another positive aspect of the circuit is that, due to having only two gates being polarized linearly, there is no too high overheating when input signal is missing. Figure 1 shows the simplified H-mode mixer.
I sent a two transformers mixer to a good friend of mine for proper testing, someone that does not guess but is able to give the 0.1dBs info. As he is quite busy and I do not know when he will find the space on his desk to do the tests, I decided to anticipate the circuit and then see, later on, for further details. Other colleagues can do the test themselves.

A few weeks ago, I was going through Technical Topics Scrap Book 1990-1994 and I found the original reporting by Colin Horrabin, G3SBI, on his H-Mode mixer with the SD5000, with the following comment “It is possible that a special five-windings transformer might give even better results, but so far the intercept points achieved with a home made transformer have been unsatisfactory; it is probably a question of having the right ferrite material”. That mixer was around +50 dBm of IP3. I do not know what the results found by G3SBI were. I am not in the condition to test the IP3 of the simplified H-mode mixer I assembled. The results on the IC751 are quite important. To give an idea, with two tones spaced 20kHz, at 10 MHz, the IP3 are: +27dBm and +20dBm (the rx circuit is not symmetric) and at 10kHz spacing: +2.5dBm and -0.5dBm. These figures are with a 1.8kHz bw 455kHz xtal filter (FL222). The IP3 tests I did long time ago, with the original dgm mixer, were, at 20 kHz spacing, circa 0dBm; at 10kHz, circa -14dBm. With the 74HC4066 I had an improvement of 10 dBm. Quite a good difference!

For those interested on the IC751 mixer, see Figure 2, the jfet buffer circuit, powered from the +13.8V and with the 51 ohm in series between source and transformer primary, was suggested to me by W7AAZ to improve linearity of stage (higher voltage and source feedback). I tried to parallel a 1nF capacitor on the 51 ohm resistor; results are that the total circuit attenuation is reduced of approximately 3dB, but the IP3 is reduced also of same 3dB, for both spacing. The +13.8V to the jfet buffer is controlled by the Rx bus +8V, through the two switching transistors, a rich man option. The MSD of the IC751 is now, w/o and with preamp (+13dB):

1.9	-125	w/o
	-131	with
14.1	-126.5	w/o
	-130	with
30	-126.5	w/o
	-132	with

I am sure this new H-mode with 2 transformer mixer will works out for many hams. There are no more technical excuses for not using an H-Mode mixer, as to mention a comment from Peter Rhodes, G3XJP, and, as Bill Carver, W7AAZ, says, it is about time there is another big leap forward in simplicity and cost. Maybe this circuit could increase the H-mode mixer fans and facilitate home design and, why not, modification of old and new commercial equipment and the replacement of NE603, uPC1037, with proper post mixer amplifier (the IC751 mod can be the basis) and schottky mixers.
For the black boxes fans, I report, below, the findings of Nicola Milillo, IZ7ANL, on the replacement of the first mixer (worst case) on his IC781 (IF = 46MHz), with classic H-mode mixer and latest 74AC86 circuit mod:
Fo=14.200 MSD -125 dbm (no preamplifier)
IP3(20 khz)= +20.5 dBm
IP3(25khz)= +25 dBm
IP3(10 khz)= +10 dBm, with original mixer was = +0.5dBm
IP3(5khz)= -5 dBm
Nicola has found out that the IMD is now limited by the IF amplifiers (first IF), filters and following mixers and certainly transformers.

IZ7ANL experimented, previously, the replacements of switching diodes with PIN diodes, but got only +3dBm improvement at 25kHz spacing. From my point of view it is an investment not worth. Probably feeding the actual diodes with at least 5mA current would deliver a similar improvement.
I hope the H-mode mixer virus, in both solutions, will spread fast for the benefits of the ham fraternity.

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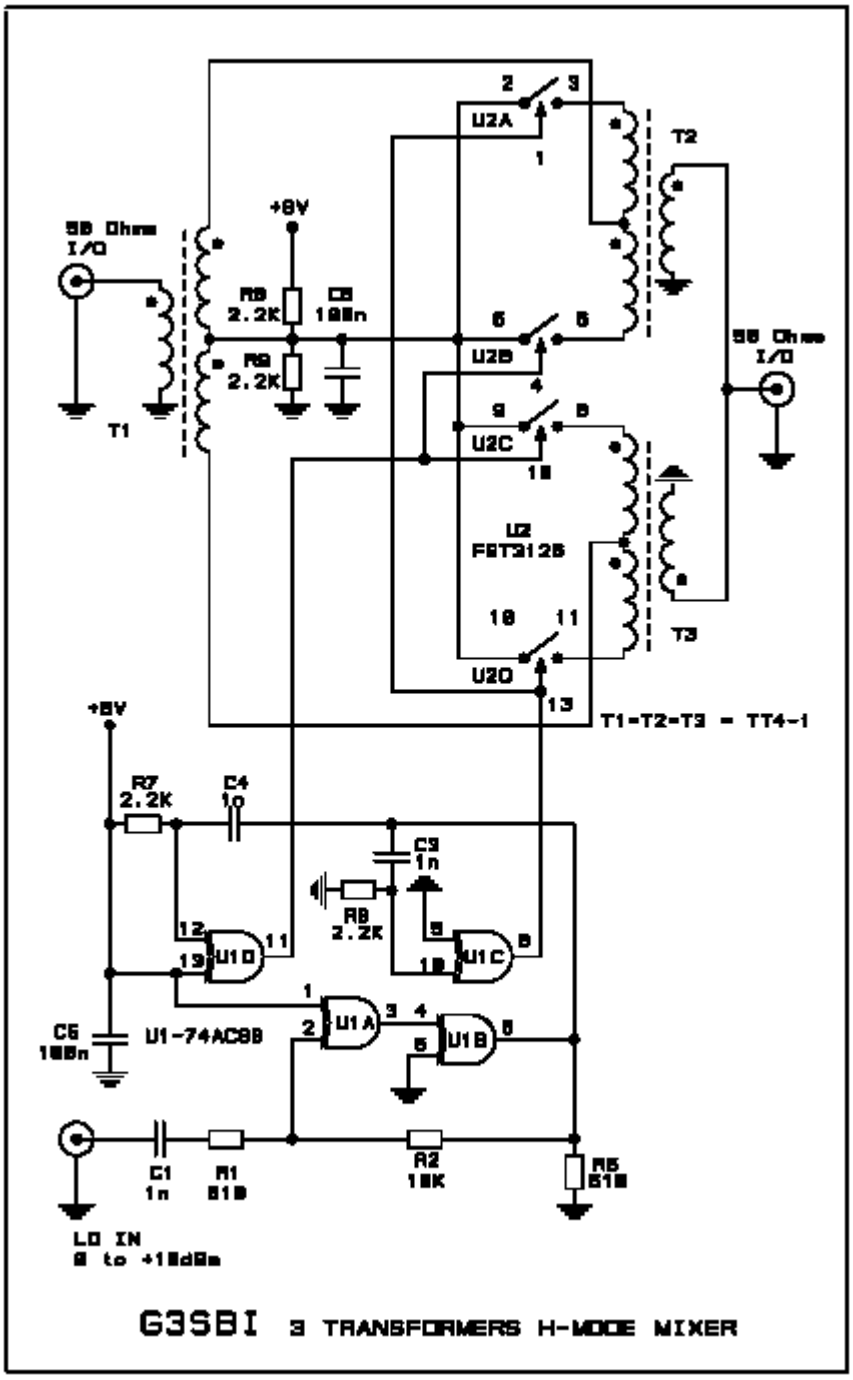

Figura 1 – H-Mode Mixer G3SBI a tre trasformatori. Il circuito dello squadratore e' I7SWX. Chi ha necessita' di regolazione, per ottenere quanto piu' possibile un bilanciamento delle due onde quadre, puo' utilizzare il circuito di Figura 3.

G3SBI 3T H-Mode Mixer with I7SWX 74AC86 Squarer (No Balance adjust – see fig 3.

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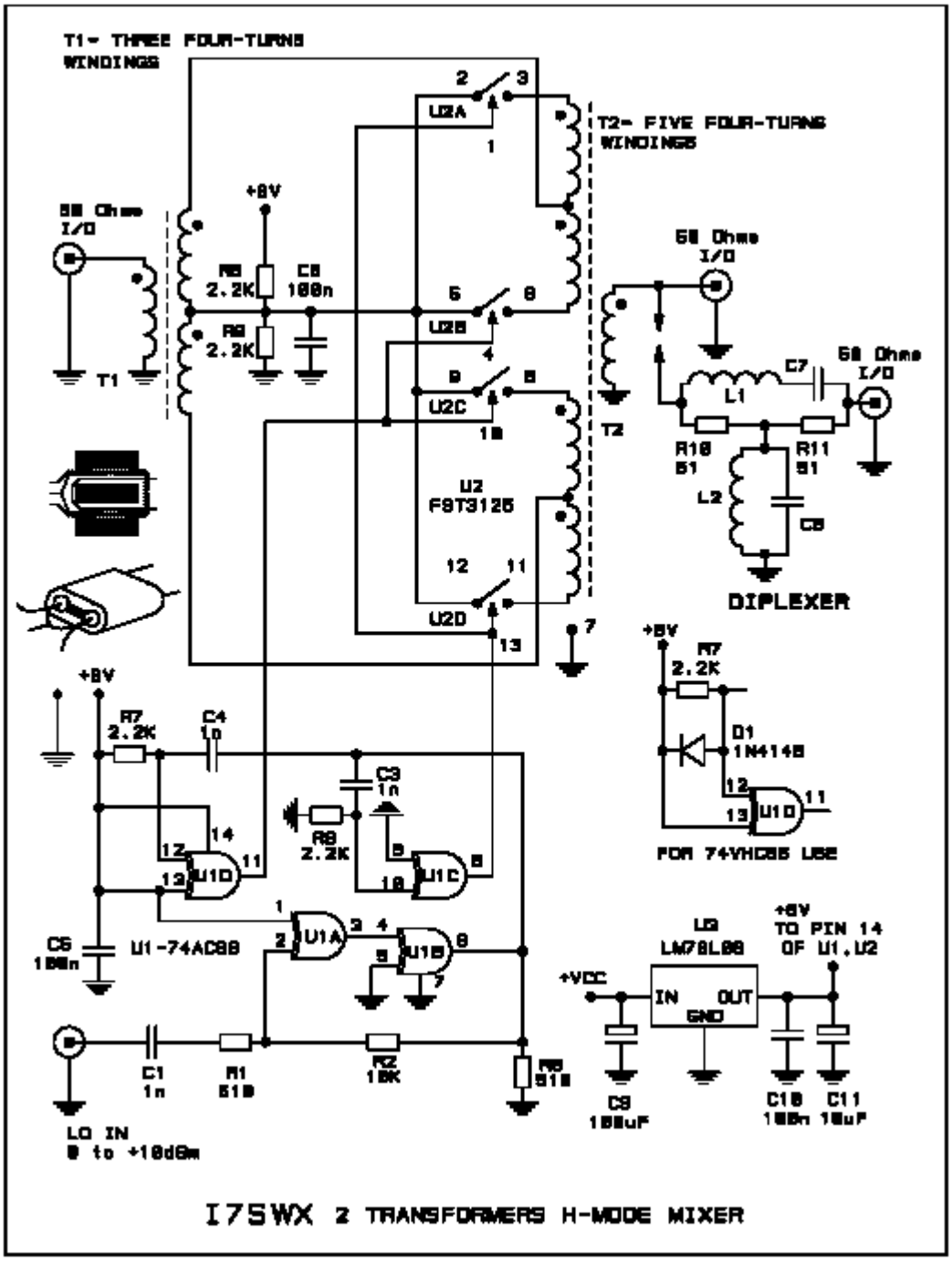

Figura 2 – H-Mode Mixer I7SWX a due trasformatori.

I7SWX 2T H-Mode Mixer with I7SWX 74AC86 Squarer no balance adjust

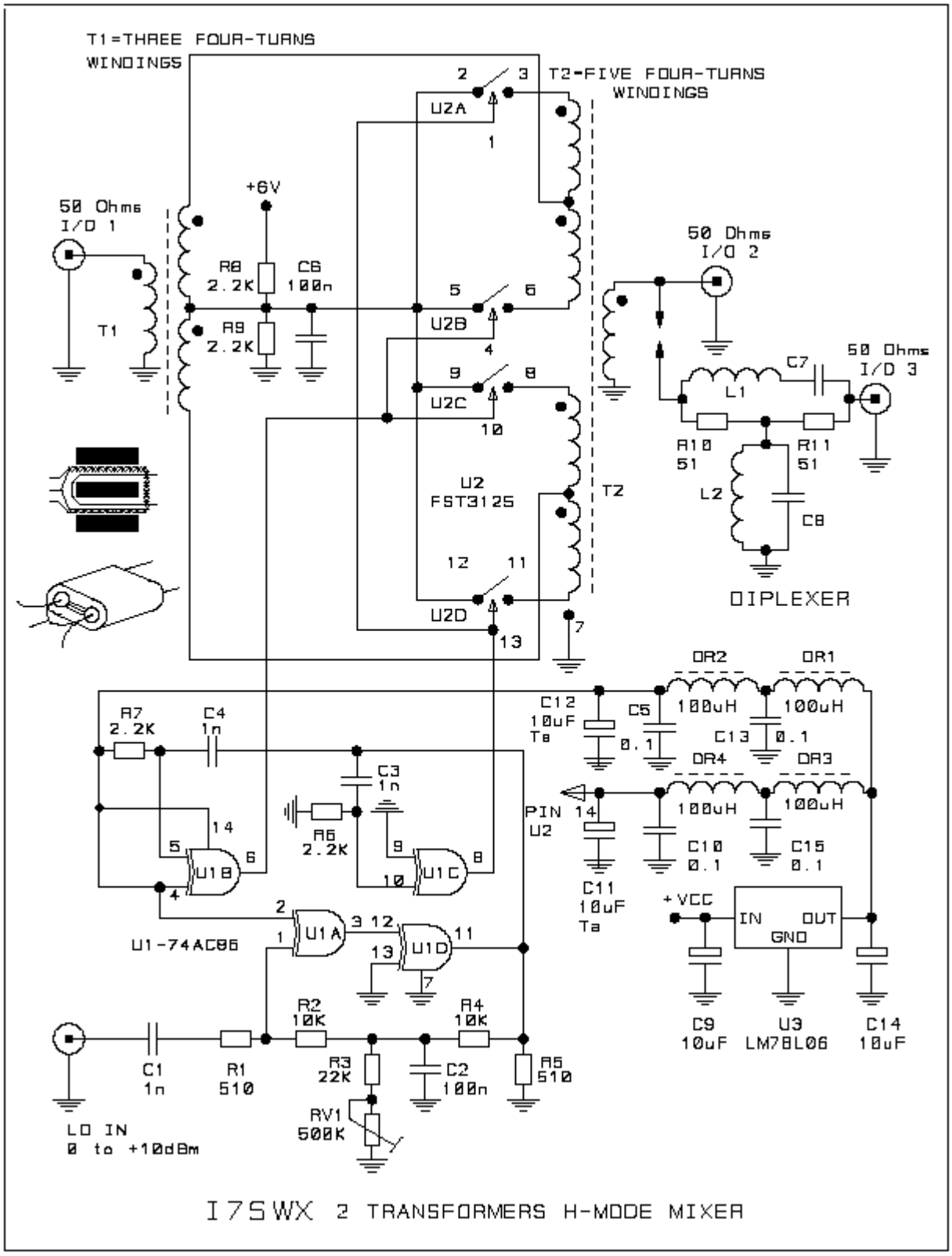

Figura 3 – H-Mode Mixer I7SWX a due trasformatori, con controllo del bilanciamento delle onde quadre che pilotano l'integrato FST3125. In questo schema abbiamo anche la presenza di filtri passa-basso sulle linee di alimentazione, una precauzione per ridurre possibili interferenze.
I7SWX 2T H-Mode Mixer with 74AC86 squarer with Balance Adjust

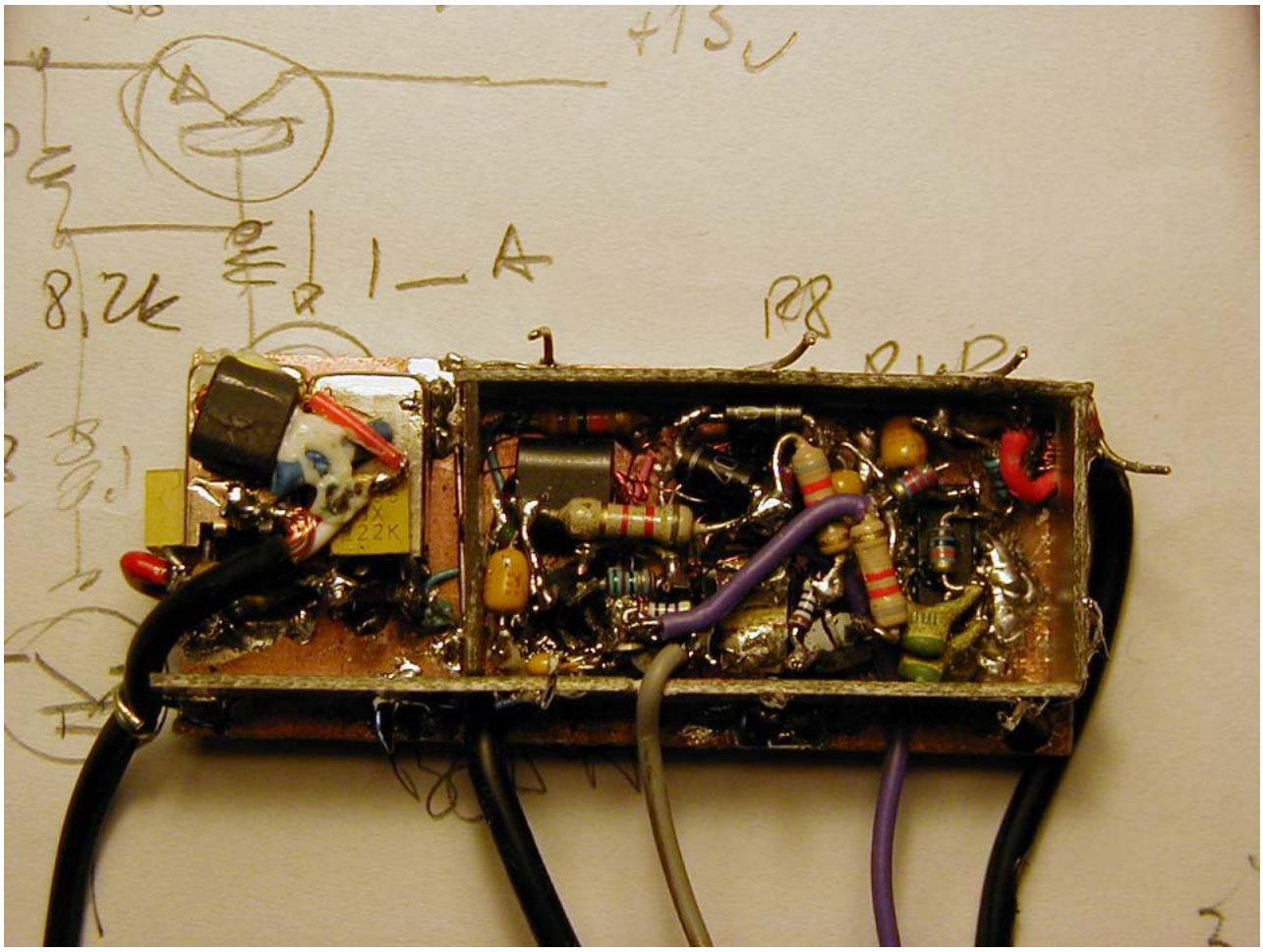

Figura 4 – Foto dell'H-Mode Mixer a due trasformatori assemblato in stile "dead bug". Questo e' l'assemblaggio relativo alla modifica del terzo mixer dell'IC751. All'interno della parte schermata abbiamo, oltre i componenti del mixer I7SWX, due transistori di commutazione Rx-Tx ed il circuito JFET di buffer d'ingresso. Sulla sinistra e' il diplexer a 455kHz ed il trasformatore di adattamento impedenza d'uscita, 50 a 450 ohm.

View of the 3rd of the 3rd Mixer replacement in the IC751

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Foto A

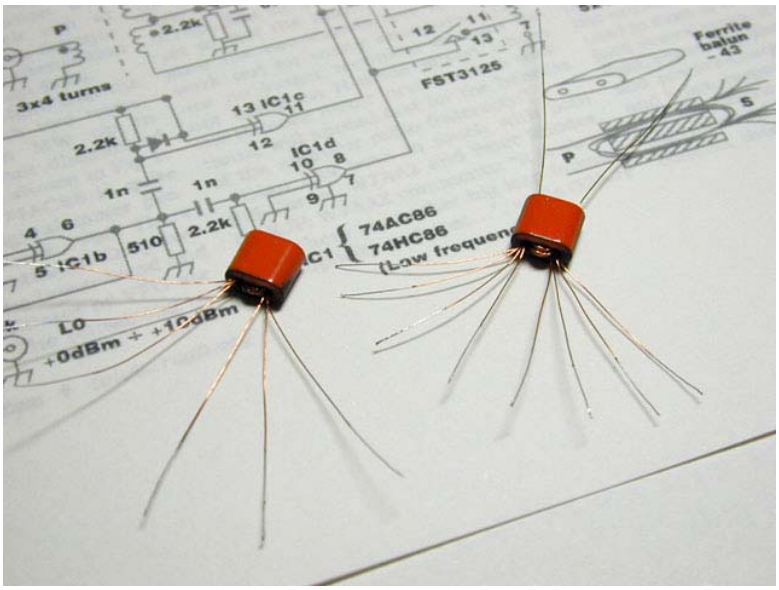

Foto B

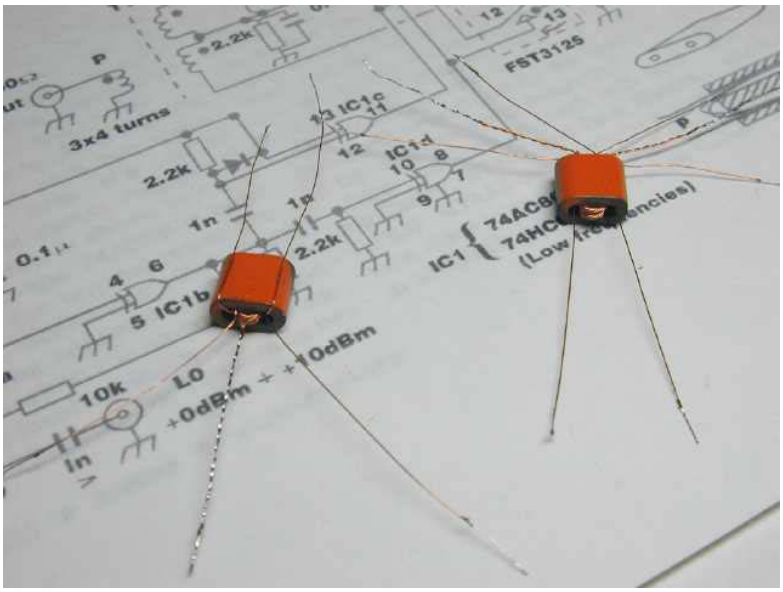

Figura 6 – Le foto mostrano la costruzione dei trasformatori come effettuata da Takahiro Kato, JA9TTT. La foto A mostra i trasformatori dopo l'avvolgimento delle spire. La foto B mostra i due trasformatori dopo la selezione dei secondari . I nuclei binoculari sono del tipo BLN-73-2402 ad elevato mu.

JA9TTT examples of home made transformers (Best #43)

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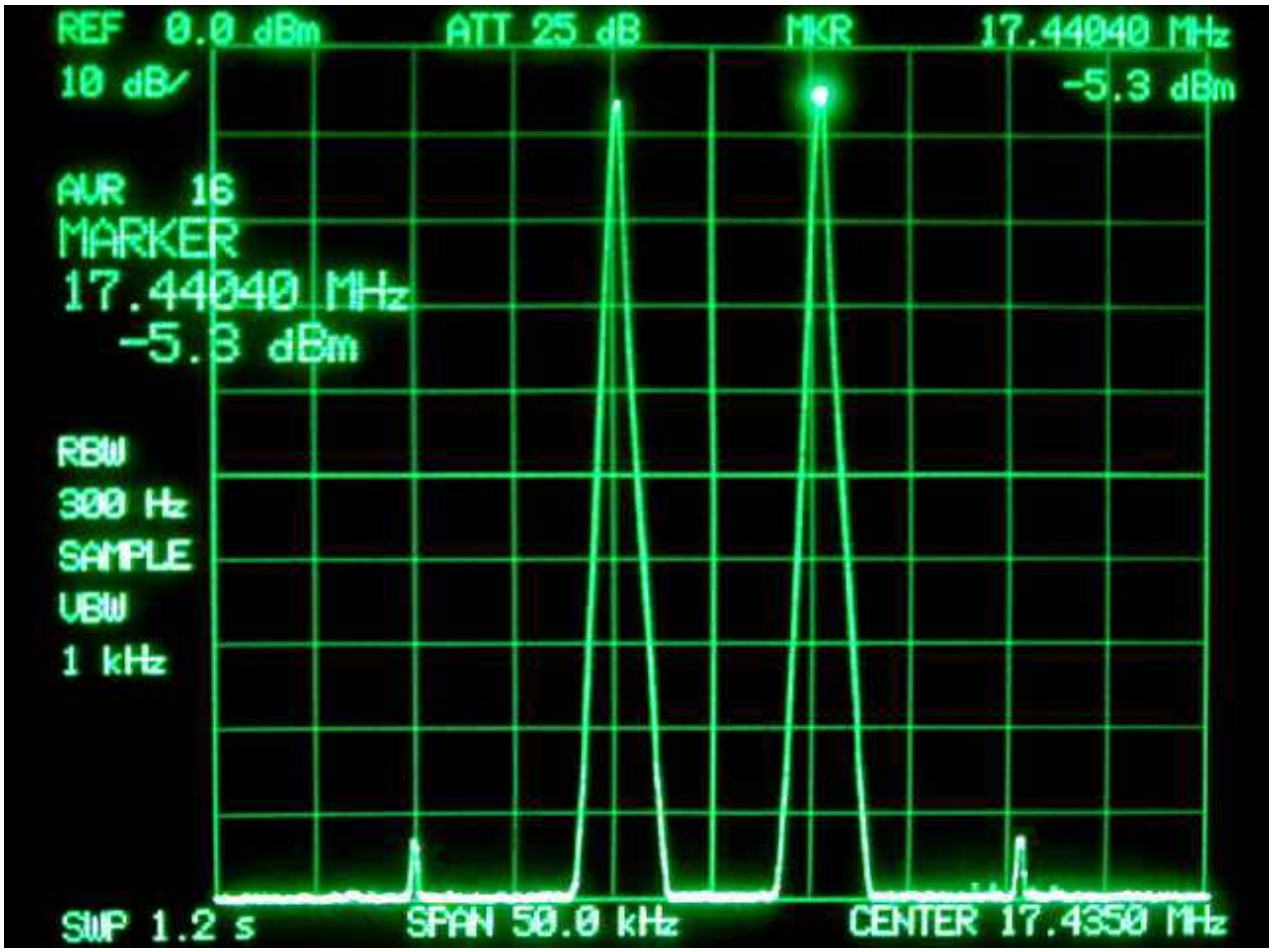

Figura 7 – Misura di IMD del Mixer H-Mode I7SWX, per il calcolo della IP3, rilevata su analizzatore di spettro, con ingresso a due toni, a 0dBm, ed uscita in media frequenza a 17.4 MHz. Sono visibili i due prodotti di intermodulazione di terzo ordine a circa –93dBm. La perdita di conversione del mixer e' di –5.3dB. La misura e' stata effettuata da Takahiro Kato, JA9TTT.

IMD Measure on I7SWX 2T H-M Mixer by JA9TTT Imd –93dBm and C.L. –5.3dBm

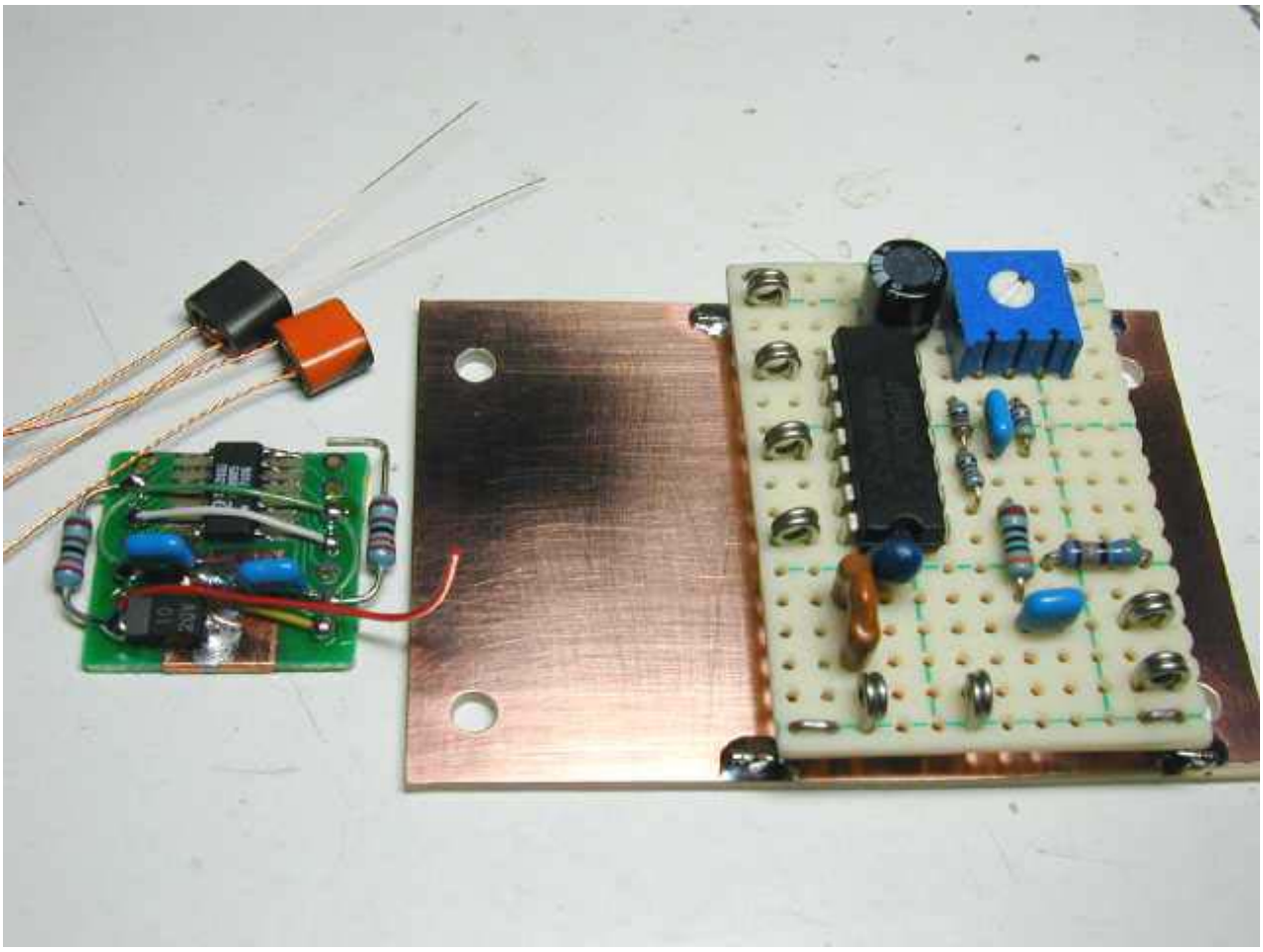

Figura 8 – Assemblaggio dell' H-Mode Mixer I7SWX da parte di JA9TTT. Il mixer e' in via di assemblaggio sulla piastrina sul lato sinistro della foto. Il circuito sulla destra e' quello relativo allo squadratore con 74AC86, utilizzante un integrato in configurazione DIP.
How the 2T and Squarer was assembled by JA9TTT

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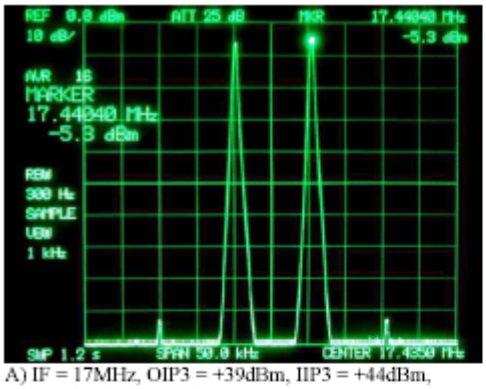
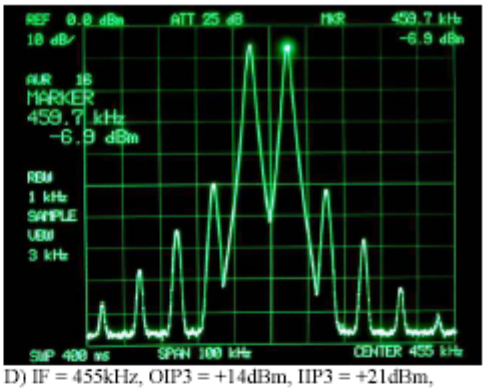
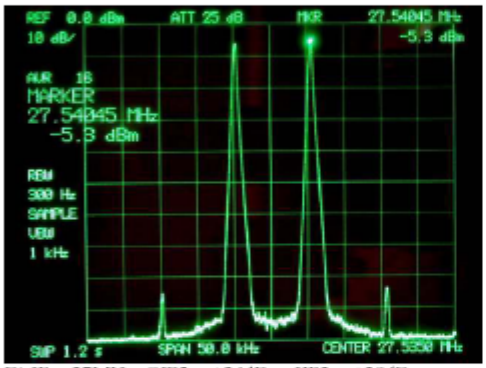


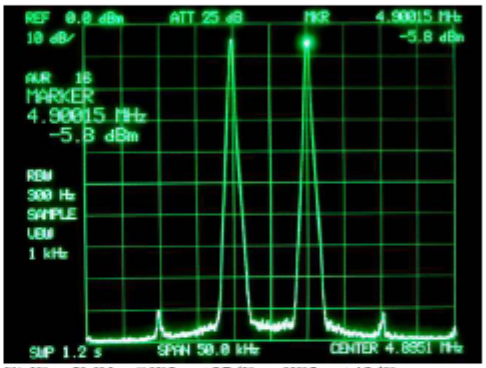
A) IF = 17MHz, OIP3 = +39dBm, IIP3 = +44dBm, Conversion loss = 5.3dB.



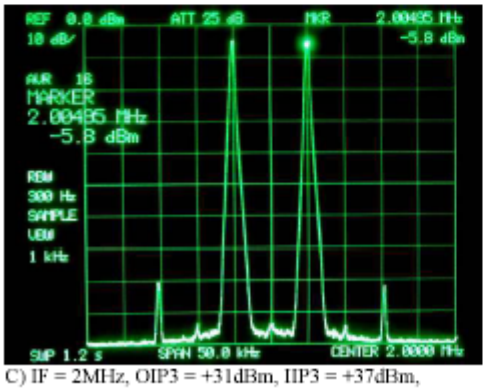
D) IF = 455kHz, OIP3 = +14dBm, IIP3 = +21dBm, Conversion loss = 6.9dB.



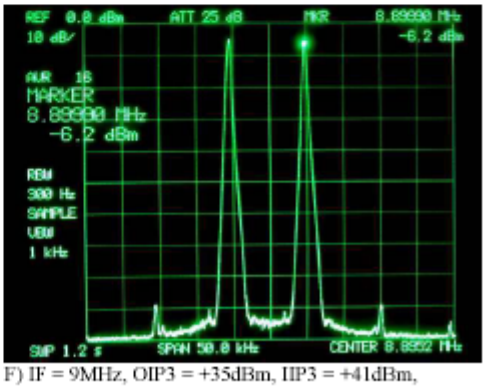
B) IF = 27MHz, OIP3 = +34dBm, IIP3 = +39dBm, Conversion loss = 5.3dB.



E) IF = 5MHz, OIP3 = +37dBm, IIP3 = +43dBm, Conversion loss = 5.8dB.



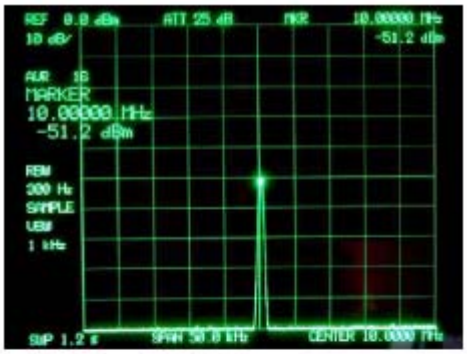
C) IF = 2MHz, OIP3 = +31dBm, IIP3 = +37dBm, Conversion loss = 5.8dB.



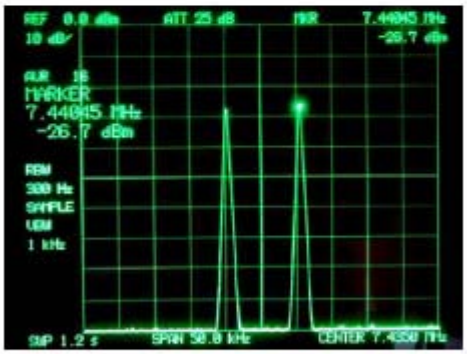
F) IF = 9MHz, OIP3 = +35dBm, IIP3 = +41dBm, Conversion loss = 6.2dB.

Figura 9 – Rilevamenti oscillografici effettuati da JA9TTT, con Analizzatore di Spettro, sull'H-Mode Mixer I7SWX

Spectrum Analyzer Pictures taken by JA9TTT – 455 IF o/p ??? I had no problems



A) Nell'oscillogramma all'analizzatore di spettro e' rilevabile il segnale di leakage dell'oscillatore locale, alla frequenza di 10MHz, come misurato all'uscita IF del mixer. Il valore e' superiore ai –50dBm. Un valore simile e' rilevato sul mixer a tre trasformatori. Il mio rilevamento, per una frequenza L.O. di 18MHz e' stato di –48dBm.



B) L'oscillogramma mostra il leakage dei due segnali d'ingresso a RF rilevati all'uscita IF del mixer a due trasformatori. Il valore e' di circa -27dBm. Il mixer a tre trasformatori presentava un leakage di circa –36dBm.

Figura 10

a – LO leakage

b - IP signals at IF OP

TABELLA 1

Transf 1:1 - Balun core -43 T2=5 x 4Turns +T1=3 x 4T		
IF Out Freq. MHz	**Output dBm**	**Conversion Gain dB**
9	-16	-6
0.5	-16	-6
1	-16	-6
2	-16	-6
3	-16	-6
4	-15.5	-5.5
7	-15.5	-5.5
8	-16	-6
11	-16	-6
15	-16	-6
20	-15.5	-5.5
30	-16	-6
40	-17.5	-7.5
46	-17.5	-7.5
50	-16	-6
60	-17	-7
70	-17	-7
80	-18	-8

La tabella mostra i valori di perdita di conversione dell'H-Mode Mixer, come rilevati dall'autore, per un segnale d'ingresso a RF a 10 MHz, a –10dBm.

Conv Loss as measured by I7SWX – RF in 10MHz –10dBm (home made X.O. vy low noise and 2nd harmonic)

Tabella 2

FREQ IF [MHz]	IIP3 [dBm]	OIP3 [dBm]	Perdita Conv [dB]	Balun Core Nucleo
17	**+44**	**+39**	**-5.3**	**#43**
	+38	*+33*	*-4.9*	*#61*
	+24	*+17*	*-6.5*	*#73*
3 transformers	***+47***	***+41***	***-6***	***#43***
27	**+39**	**34**	**-5.3**	**#43**
	+32	*+27*	*-5.1*	*#61*
	+23	*+17*	*-6.9*	*#73*
3 transformers	***nr***	***nr***	***nr***	***#43***
9	**+41**	**+35**	**-6.2**	**#43**
	+37	*+32*	*-5.5*	*#61*
	+24	*+18*	*-5.6*	*#73*
3 transformers	***+42***	***+36***	***-6***	***#43***
5	**+43**	**+37**	**-5.8**	**#43**
	+40	*+34*	*-5.4*	*#61*
	+24	*+18*	*-5.5*	*#73*
3 transformers	***nr***	***nr***	***nr***	***#43***
2	**+37**	**+31**	**-5.8**	**#43**
	+38	*+33*	*-5.4*	*#61*
	+24	*+19*	*-5.3*	*#73*
3 transformers	***+32***	***+26***	***-6***	***#43***
0.455	**+21**	**+14**	**-6.9**	**#43**
	+24	*+28*	*-5.9*	*#61*
	+24	*+19*	*-5.3*	*#73*
3 transformers	***nr***	***nr***	***nr***	***#43***

La tabella riporta i dati di IP3 (input = IIP3, output = OIP3), la perdita di conversione ed i nuclei dei balun (BN/BLN-#XX-2402) relativi ai trasformatori utilizzati da JA9TTT per le misure effettuate sull' I7SWX Two-Transformer H-Mode Mixer, in riferimento a vari valori di media frequenza (IF). Nella linea « 3 transformers » sono riportati i dati rilevati sull'H-Mode Mixer a tre trasformatori. Il basso valore di IP3 per la IF di 2MHz e' forse dovuto ai trasformatori.

Comparisons by JA9TTT on the I7SWX 2T H-Mode mixer using different cores.