18W 5GHz band FM-ATV Tx (5.645 - 5.945GHz)

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The idea was to build a 5GHz FM-ATV Tx starting from existing drone TV transmitters, skipping some of the many technical problems related.

1 - SELECTION OF THE DEVICE

A big variety of commercial devices –generally of Chinese production- are available on the market. A total of eight rigs have been tested as to Pout (value and decay), operating frequencies, video to audio subcarriers ratio, cost.

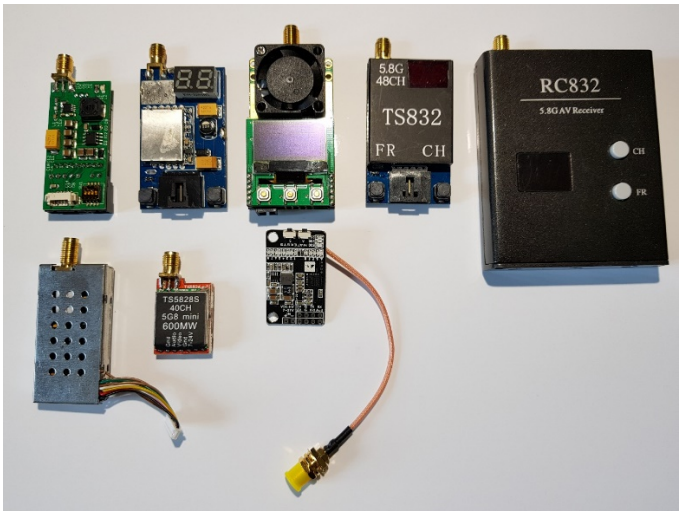


Fig. 1 – Some of the FM-TV transmitters tested.

Three basic issues came up and had to be considered.

A) Pre-emphasis. As all these devices work with specifically designed receivers –like RC832 or similar ones-, they don't make use of any pre-emphasis. The most serious consequence is that, as any FM-TV demodulator is originally equipped with a standard de-emphasis circuit, FM-TV transmission without a corresponding pre-emphasis results in a very poor reproduction of higher video frequencies (washed out, blurred images, major loss of details). Besides, the use of video pre-emphasis and de-emphasis results in substantial improvement in the received signal-to-noise ratio.

B) Audio subcarrier level. All these devices are based on highly sophisticated chips – like RTC6705, for the most recent ones- whose two modulated audio subcarriers (if present, at 6MHz and 6.5MHz respectively) are way too low and, unfortunately, not adjustable (-25dBc video carrier to audio carrier ratio with no video and audio signal in). Experience clearly shows instead that the ideal level of a (mono) audio subcarrier is around -15/-17dBc, as it ensures an understandable audio even with a "grainy" video.

C) Most of these devices produce an output power which is unacceptably lower than what declared. Furthermore, their cases get very hot (a drone cannot carry a proper heat sink because of its weight) and Pout decays to 50% or even less in a short time.

Eventually, at the end of this process of evaluation, the choice fell on Mateksys (http://www.mateksys.com) VIDEO TRANSMITTER 5.8G VTX-HV, the most modern device in the lot:

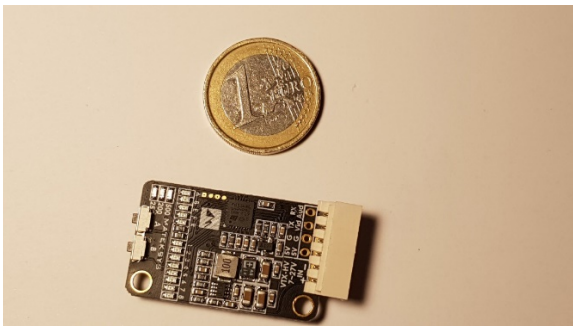


Fig. 3 – VTX-HV – the real size

Mateksys has many distributors in several countries, besides being available on on-line stores, Amazon, eBay and so on, at a very reasonable price.

Frequency Table (MHz)

BFOSD	LED	1	2	3	4	5	6	7	8
BOSCAM A	A	5865	5845	5825	5805	5785	5765	5745	5725
BOSCAM B	B	5733	5752	5771	5790	5809	5828	5847	5866
BOSCAM E	E	5705	5685	5665	5645	5885	5905	5925	5945
FatShark	F	5740	5760	5780	5800	5820	5840	5860	5880
Raceband	R	5658	5695	5732	5769	5806	5843	5880	5917

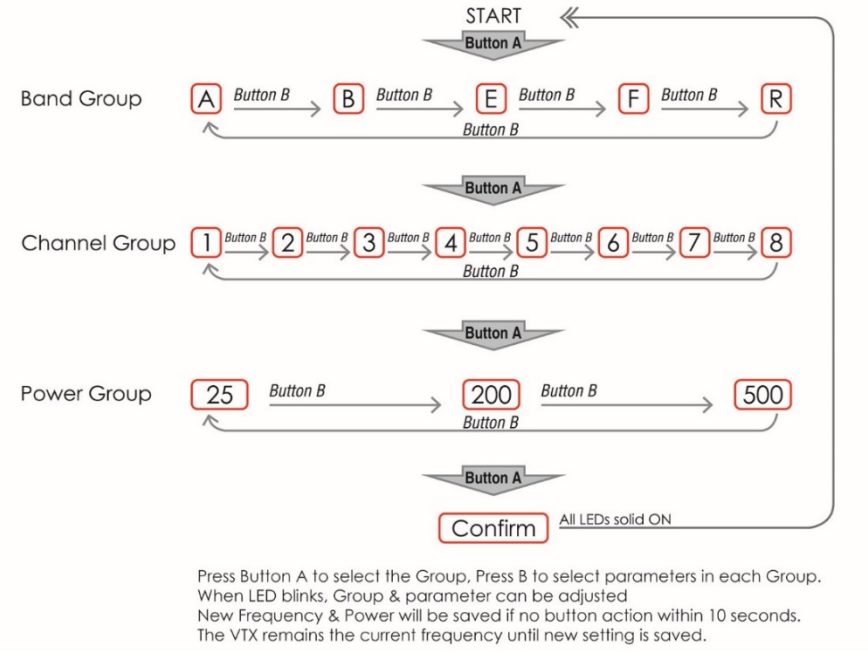


Fig. 4 – VTX-HV - Operating frequencies and menu

2 - 5.8GHz FM-TV SIGNAL GENERATION AND MODULATION

Issues A) and B) have been solved by means of a radical two-step solution: the strategy is to kill the two native audio subcarriers (by removing two tiny capacitors) and to replace these subcarriers with a brand new one, properly adjustable, mixed with the duly pre-emphasized video signal.

Step 1. A no-frills 6.5MHz-audio, 75uS pre-emphasis PAL, low cost video modulator has been developed (certainly not a revolutionary design, hundreds of similar schematics can be found on the web).

Step 2. A simple, yet delicate modification to VTX-HV is necessary in order to kill the two audio subcarriers, to replace them with the one purposely produced.

Step 1

Below, the no-frills 6.5MHz-audio, PAL 75uS pre-emphasis, low cost video modulator "BANDABASE", as it goes in Italian.

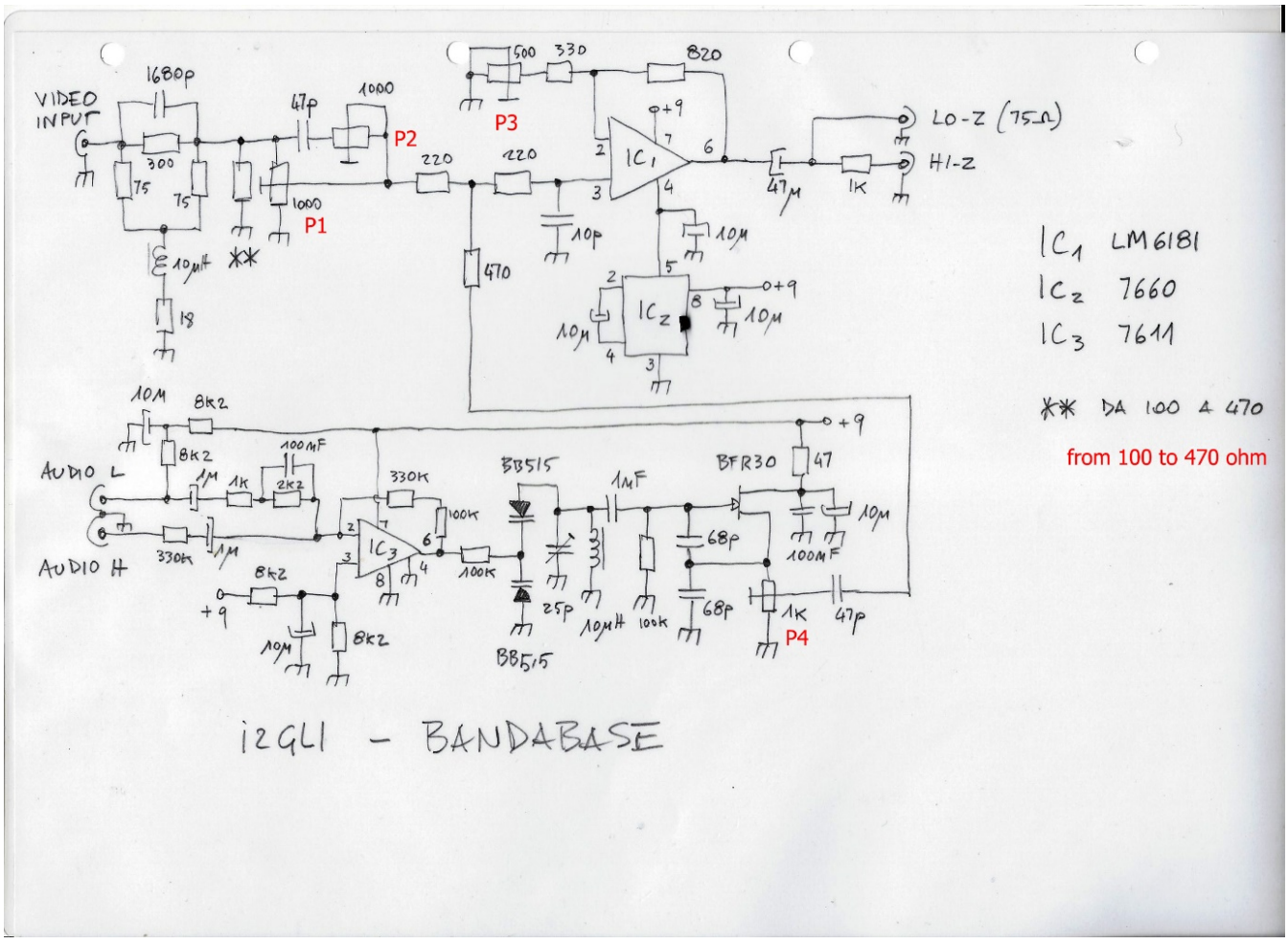


Fig. 5 – BANDABASE circuit diagram

In the upper left corner, the 75uS pre-emphasis, immediately after video input.

P1 adjusts the video level only.

P2 nudges the video higher frequencies.

P3 adjusts the whole envelope (audio and video together).
P4 adjusts the audio subcarrier level only.

Video input level is the standard 1Vpp video signal.
Audio L(ow) accepts electret microphones.
Audio H(igh) accepts 0.5Vpp audio, typically from video-cam or other sources.
Lo-Z output goes to Matek VTX-HV video input (which is, actually, video and audio together), or any similar drone FM-TV Tx.
Hi-Z has been designed to go to a PLL VCO control line. Not used, in this case.

Adjustments
Set P3 at around half-way. Adjust P1 and P4 so that the modulated output at 5GHz (no input video signal, no input audio signal!) shows the audio subcarrier 15-17dB below the video carrier. In order to adjust the correct video-audio level (to obtain the desired FM deviation) from now adjust P3 only.
Adjust P2 for a maximally flat passband. If it is not possible to obtain a satisfactorily flat band, increase R** step by step, up to 500ohm.

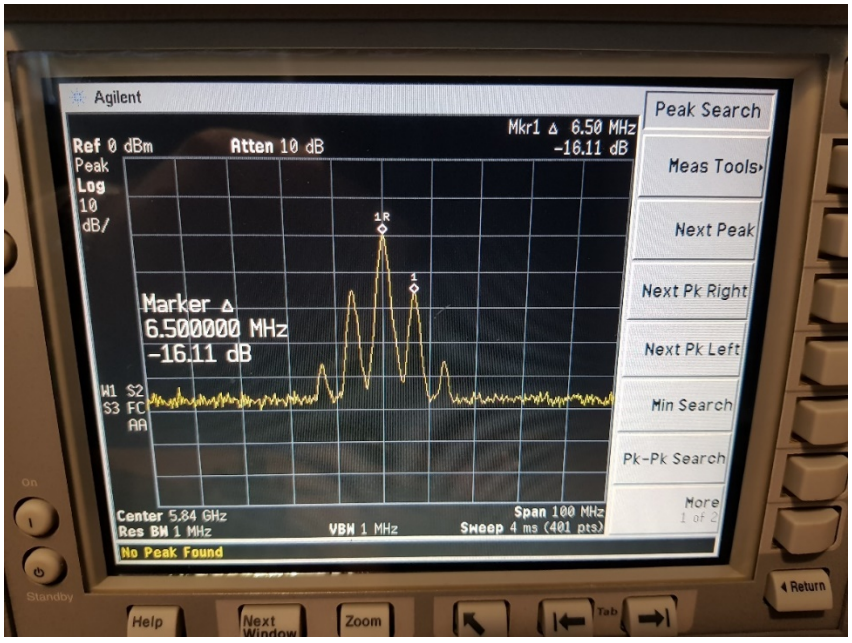


Fig. 6 - 16dBc video carrier to audio carrier ratio, with no video and audio signal in.

Should 6MHz be the preferred choice for the audio subcarrier, the small 25pF variable capacitor can be trimmed accordingly.
IC1 -LM6181- is a 100MHz wide band amplifier (great, inexpensive device).
In order to fully exploit its characteristics, a dual supply voltage must be used. The easiest solution to generate a negative voltage –given the low current needed- is to use an ICL7660.
The supply voltage is 9volts (ICL7660 max operating supply voltage is 10.5volts).
The local 6.5MHz oscillator, despite not PLL, is stable enough to keep its frequency without any necessity to retune it.

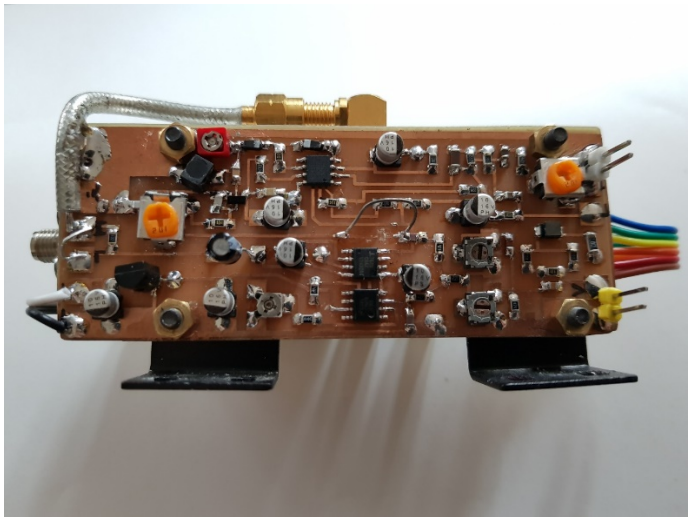
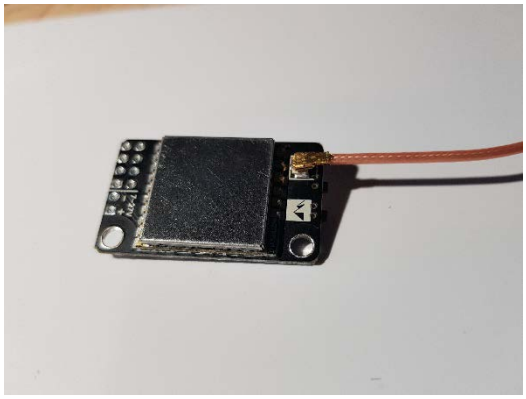


Fig. 7 - BANDABASE SMD pcb (layout by IW2FYT). Here it was used as a modulator of a 10GHz FM-TV exciter, firmly lodged in the rear.

Step 2

A simple, yet delicate, modification is necessary.
Take the device, just remove the lid.



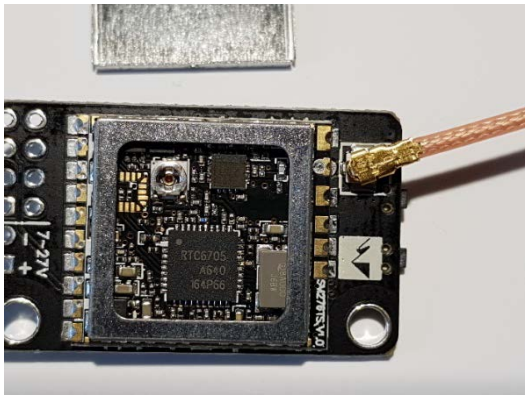


Fig. 8 – Inside VTX-HV

Everything in there is minuscule, tiny, minute, microscopic, almost infinitesimal and very important. Great care is required, together with a powerful magnifier or better still watchmaker's glasses.
The modification consists in the removal of two –almost hidden- capacitors, the ones in the red circles.

Fig. 9 – Inside the VTX-HV. The two capacitors to be removed.

Block Diagram

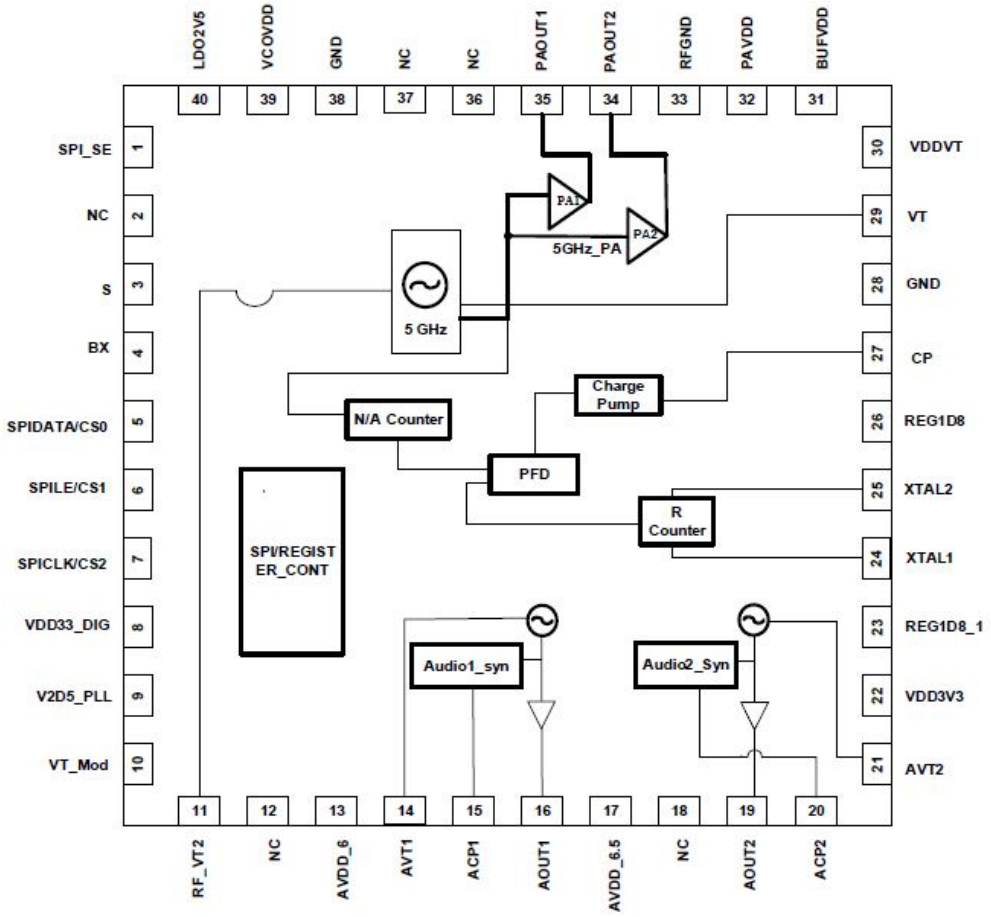


Fig. 10 – RTC6705 Block Diagram

These two capacitors are connected to pins 16 and 19. By removing them, the two subcarriers are physically eliminated.
In order to remove these two capacitors, a very thin and rigid pin must be used. Gently push on the side of these two capacitors, they will offer a very weak resistance and will come off without leaving any visible scar.
An extra thin soldering iron, too, could be used, but at a much higher risk of killing other essential components nearby, out of “friendly fire”.

As to Issue C), the three selectable output powers reasonably reflect what declared in the datasheet. Its small case can be efficiently soldered to a metal surface to dissipate the heat produced.

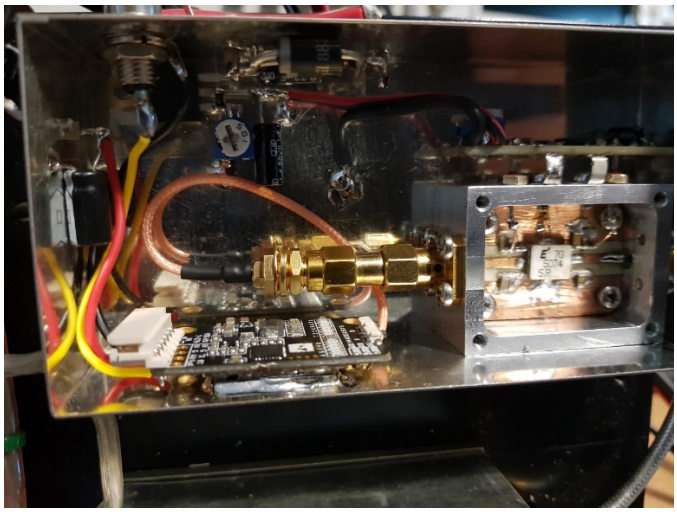
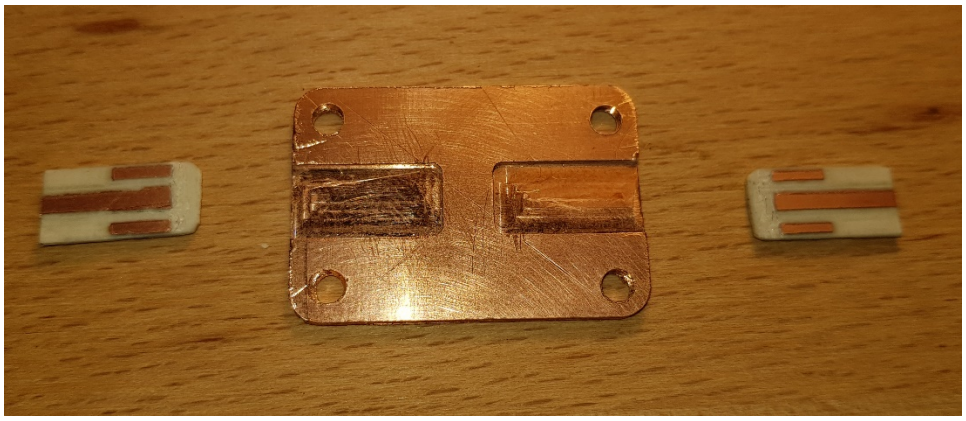


Fig. 11 – The lid can be soldered to the metal box to dissipate the heat produced

3 - INCREASE THE OUTPUT POWER: THE BOOSTERS

Two boosters increase the output power to 2.5W (by using a MMIC EMM5074) and, finally, up to 18-20W (with a FLM5964-18F).

No tune EMM5074



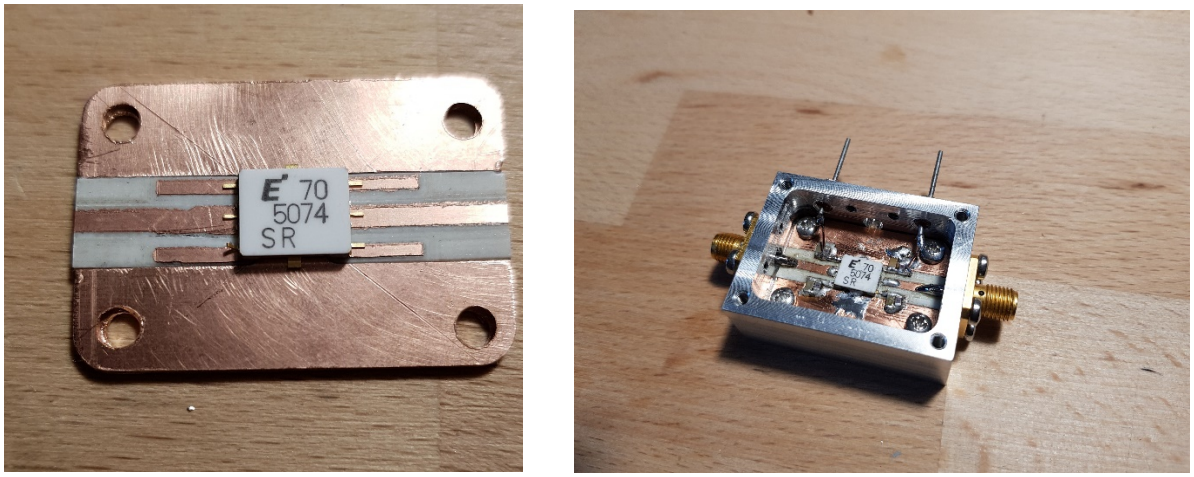


Fig. 12 – EMM5074 pcb and its metal case.

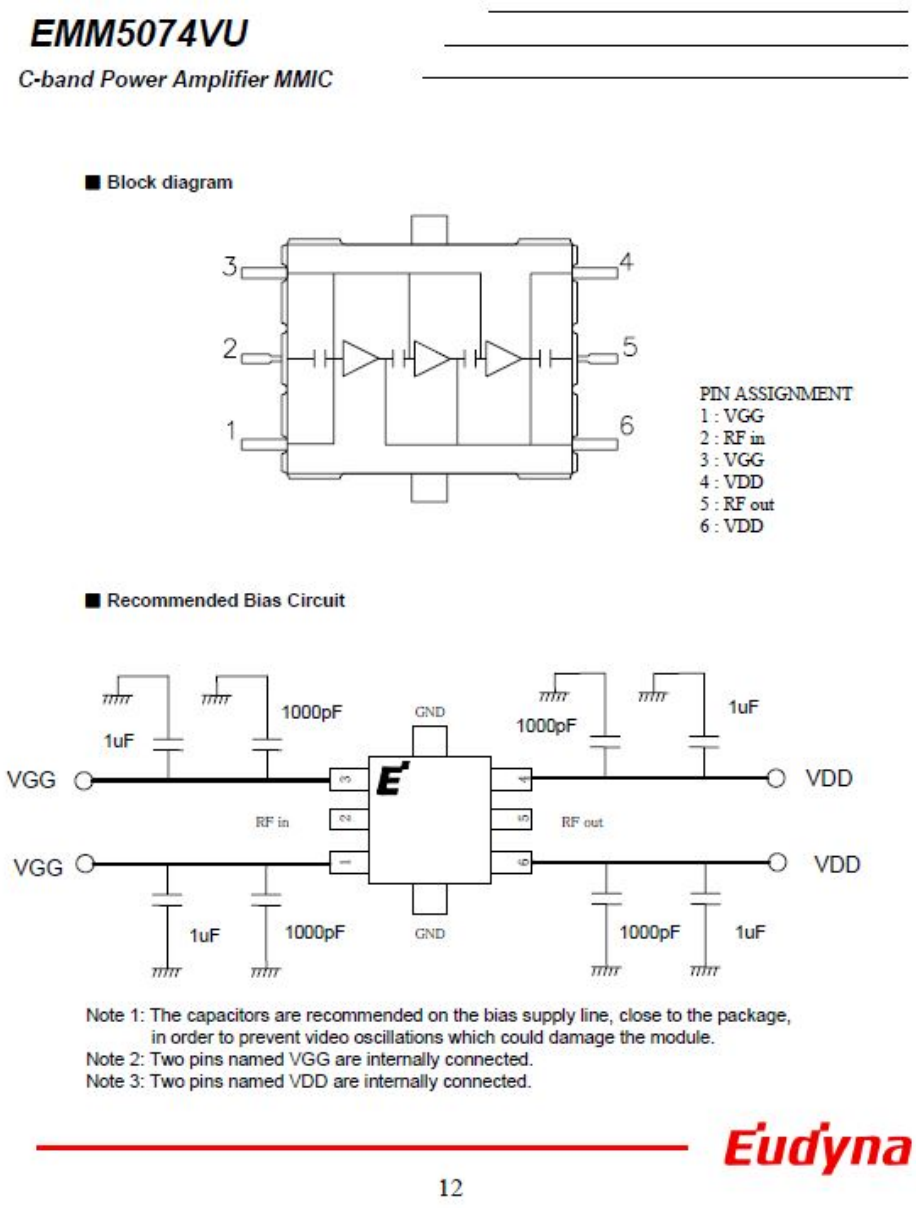


Fig. 13 – EMM5074 Block Diagram

The EMM5074VU is a low cost wide band power amplifier MMIC that contains a three stage amplifier, internally matched, for standard communications band in 5.8 to 8.5GHz frequency range. It shows a gain of 26dB and an output power of 34dBm at 5.8GHz. Therefore, an input power of roughly 8/10dBm is sufficient to produce an output power of 2.5W.
The VTX-HV output power must be set at 25mW (the lowest level). The small piece of semi-rigid cable, the SMA adaptors and other minor inevitable imperfections realize a suitable power match. Obviously this GaAs Fet MMIC requires a negative voltage Vgg in the range of -1 to -2volts (for instance by means of another ICL7660), **adjusted to ensure a quiescent 1200mA drain current, at 6volt drain voltage, Vdd**. Usual precaution: apply negative voltage first, positive drain voltage only afterwards.

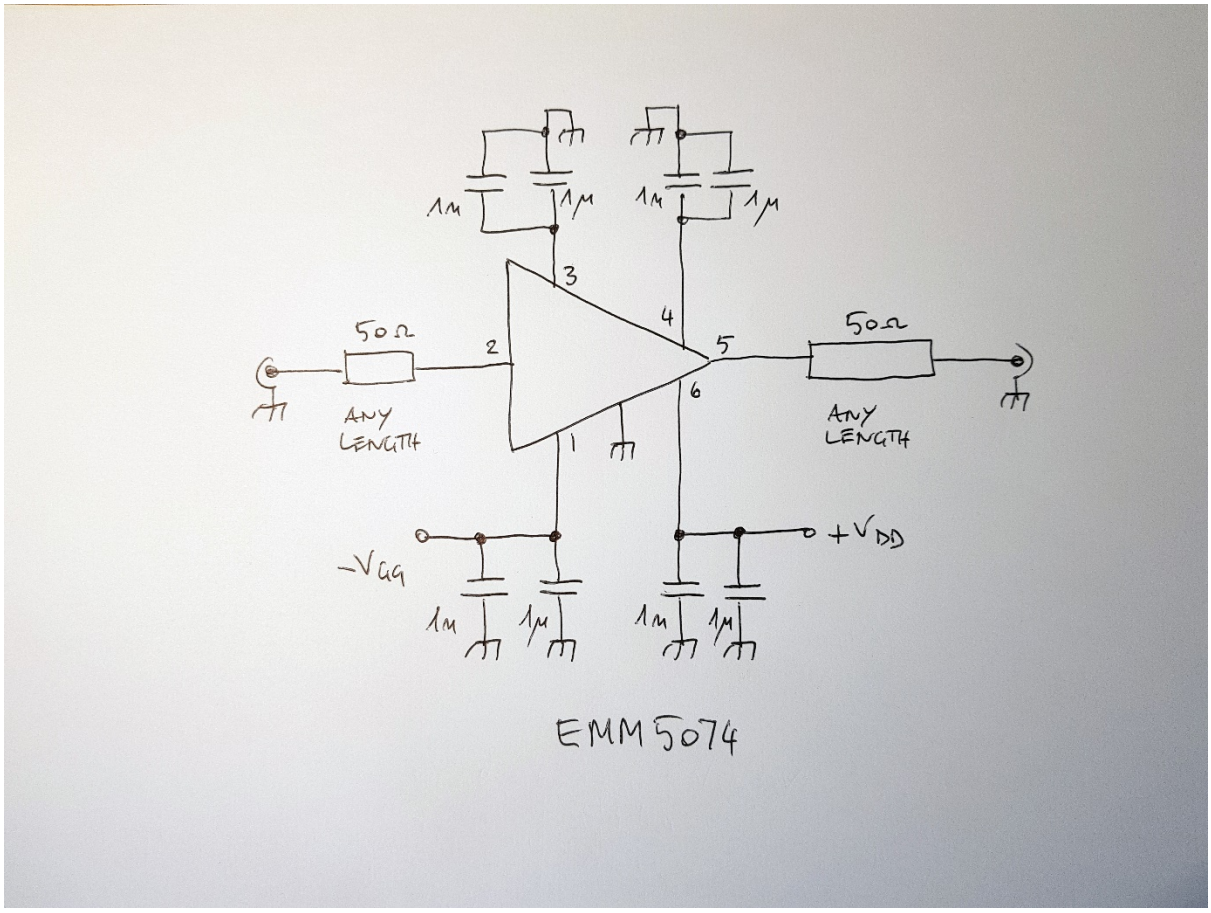


Fig. 14 – EMM5074 2.5W booster circuit diagram

The EMM5074 booster requires a good quality pcb laminate. At 5.8GHz the standard FR4 is not good enough. The circuit shown in Fig. 11 is realized on Rogers RO4003 1oz, 32mil thick. Should through-hole technology be available, 20mils of thickness would certainly be better, helping heat dissipation. Besides, the complicated milled copper radiator and its two pcb inserts (shown in fig. 11) wouldn't be necessary (in a few weeks a proper through-hole pcb will be available, should anybody be interested).

No tune FLM5964-18F

The FLM5964-18F is a power GaAs FET that is internally matched for standard communication bands to provide optimum power and gain in a 50ohm system.
It exhibits high Pout (43.0dBm @P1dB), a gain of 10dB, a broad band from less than 5.9 up to 6.4GHz and, last but not least, an impedance matched Zin/Zout of 50ohm.
Therefore, an input power of roughly 33/34dBm has proven sufficient to produce an average output power of 20W. Actually, at around 5.7GHz 22W have been measured and at 5.9GHz as low as 18W. Probably the tolerances in the pcb line dimensions play a role in the impedance matching. A Vgg -1.5 to -2.5Volts (for instance by means of another ICL7660), **adjusted to ensure a quiescent 5000mA drain current, at 10.5volt drain voltage**. Again, usual precaution: apply negative voltage first, positive drain voltage only afterwards.

Strictly speaking, as the input and output impedance of the device are 50ohm matched, a pcb is not essential to mount the FLM5964-XX. Input, output and bias lines can be easily obtained by pieces of semi-rigid cable.

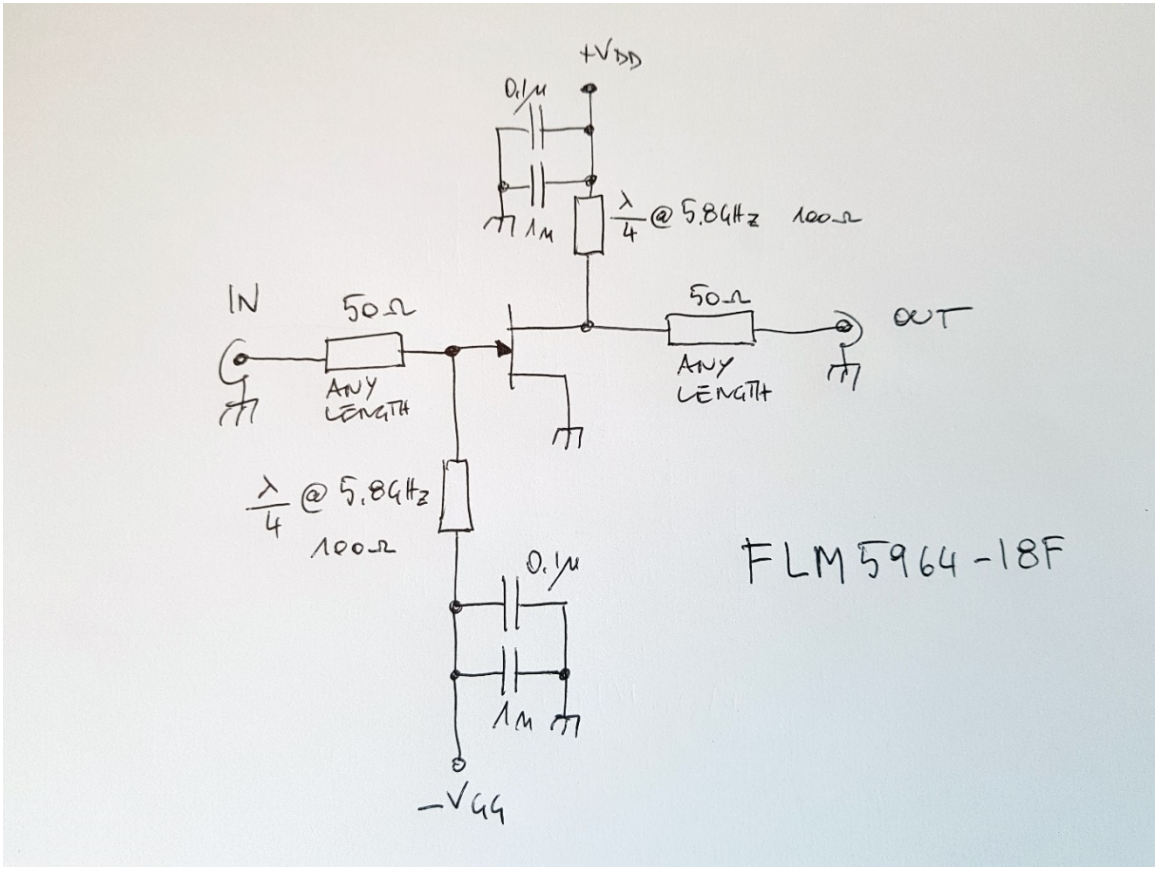


Fig. 15 – FLM5964-18F 18W booster circuit diagram

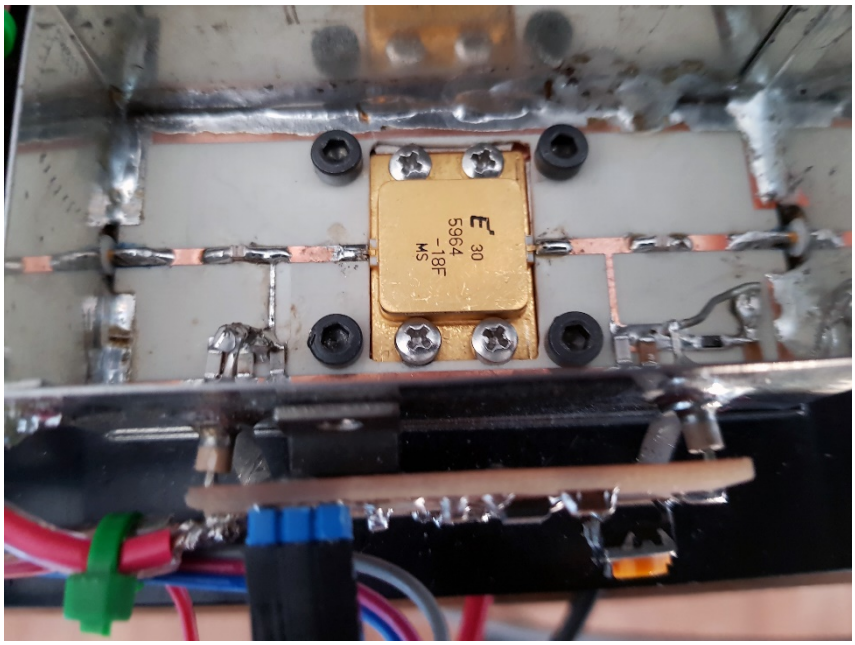


Fig. 16 – FLM5964-18F 18W booster pcb

4 - THE FINAL RESULTS

Four figures to summarize the job done.

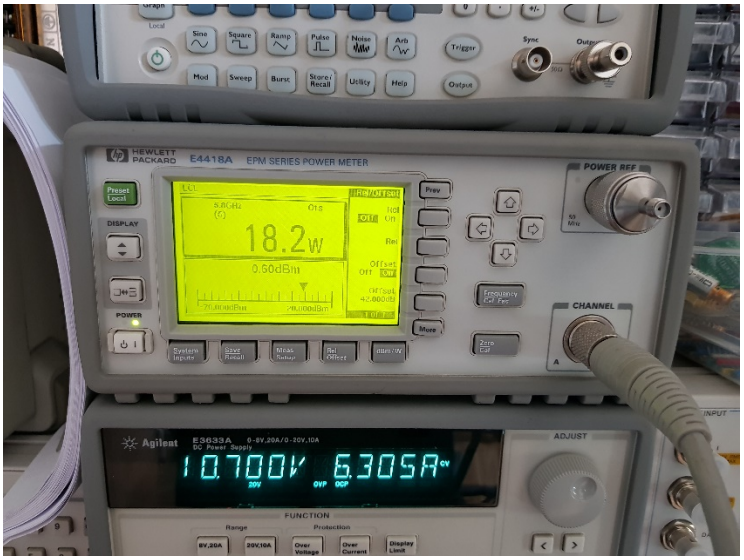


Fig. 17 – Total Pout @5.840GHz

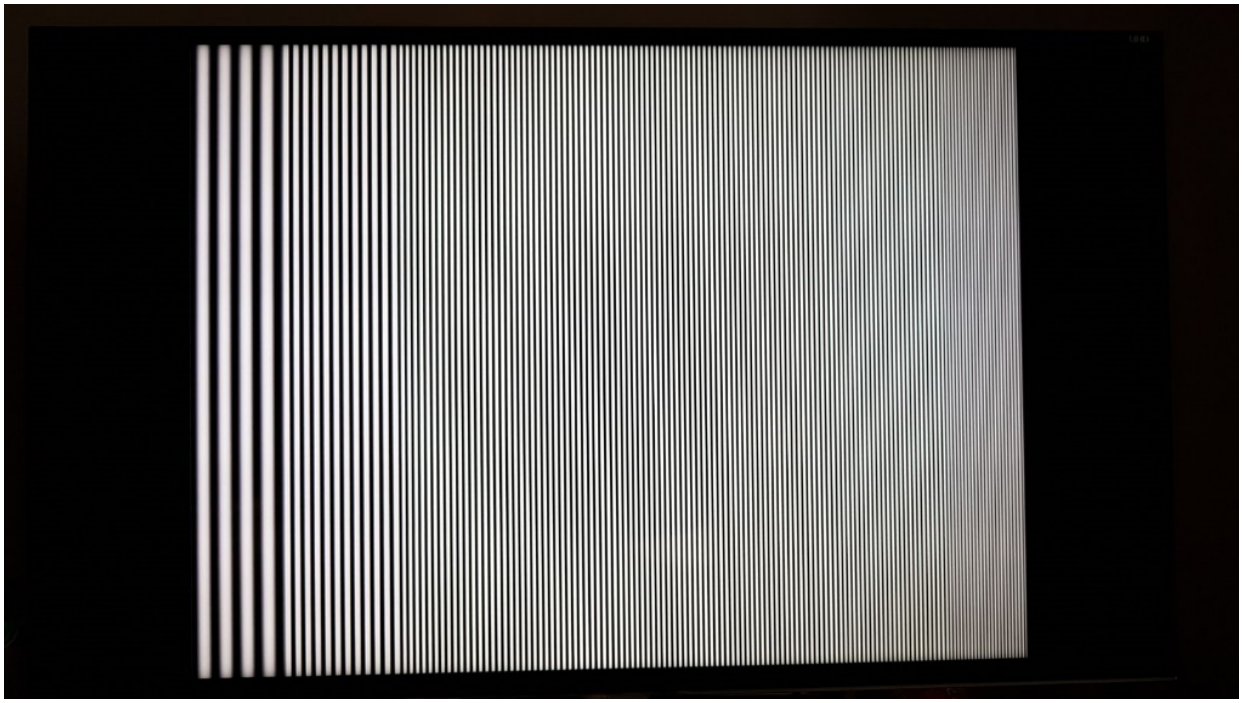


Fig. 18 – Demodulated bars. The leftmost bars represent a signal at 800KHz, the rightmost ones 5.5MHz (some moire effect due to the picture resolution). The receiver used is a RO.VE.R SAT SR 900R professional receiver preceded by a DG0VE downconverter.

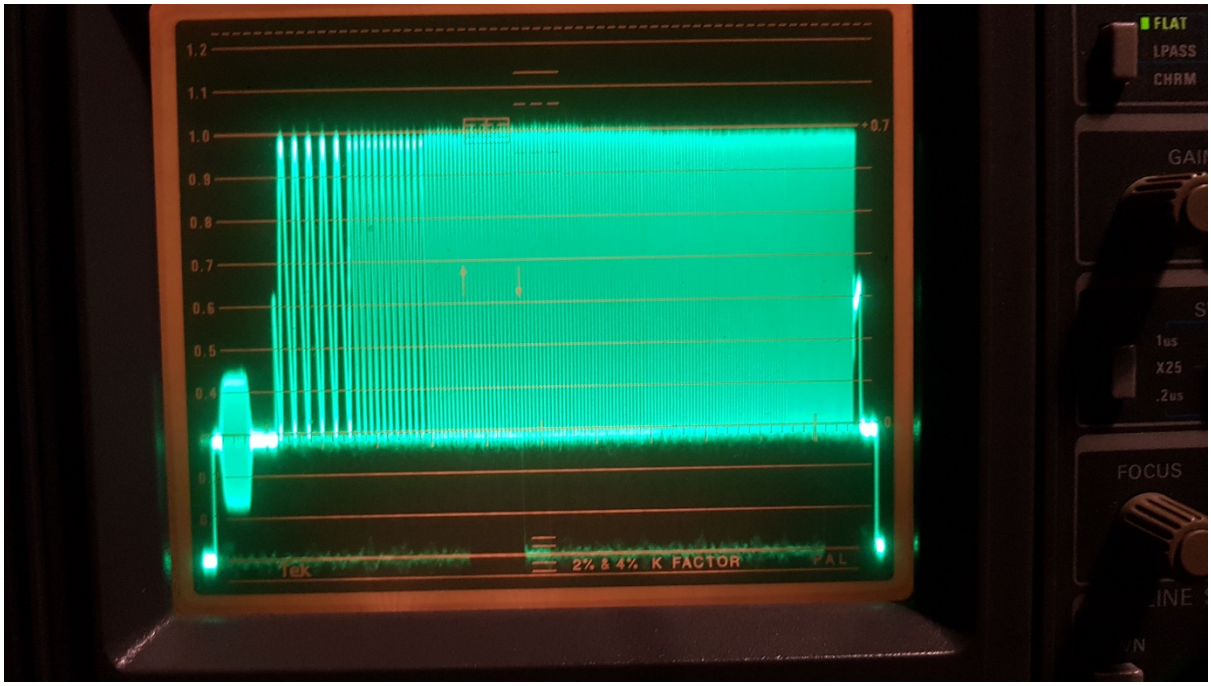


Fig. 19 – The corresponding demodulated band flatness. The leftmost bars are 800KHz, the rightmost ones 5.5MHz, as it appears on a Tektronix 1731 Waveform monitor.

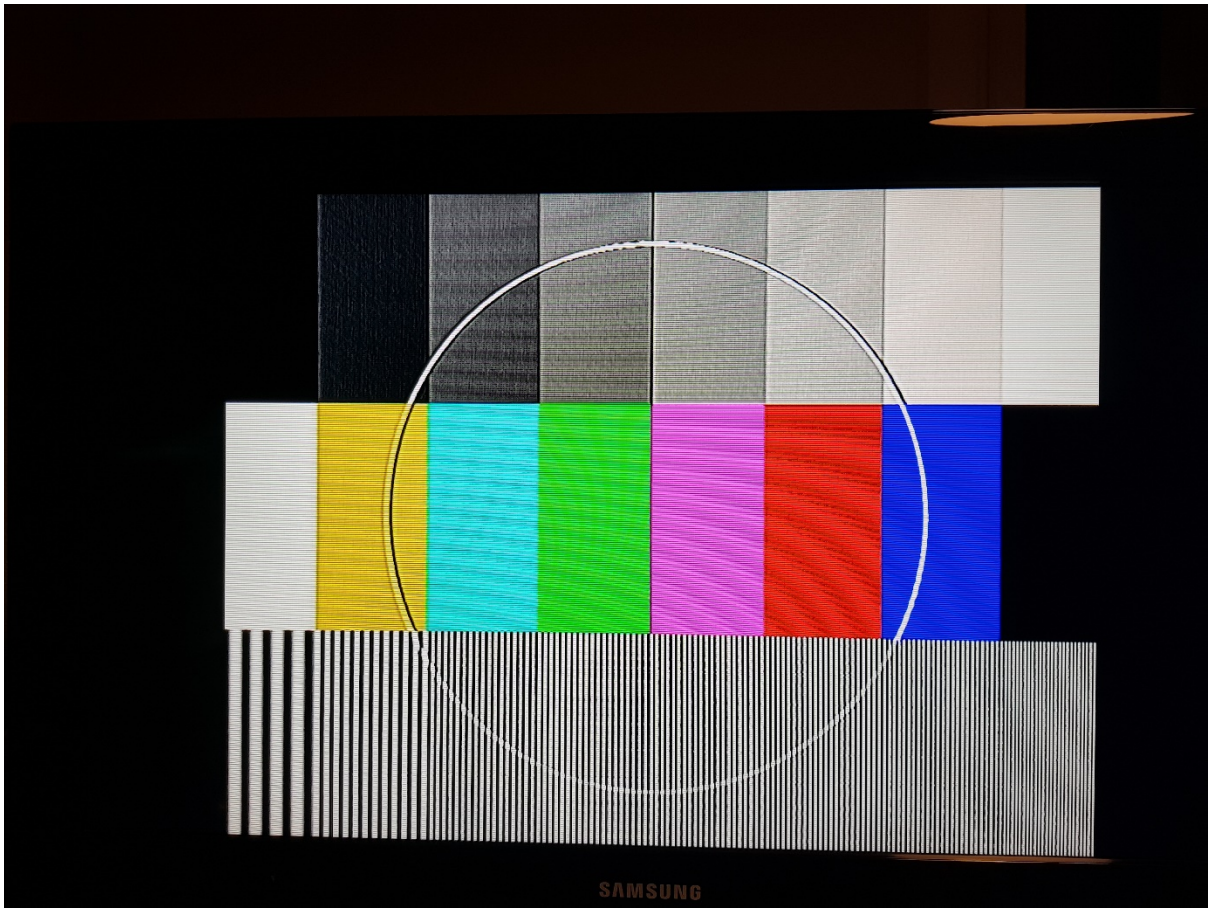


Fig. 20 – Composite test pattern, 18W @5.840GHz

5 - FINAL CONSIDERATIONS

The only adjustments required concern BANDABASE. The Matek VTX-HV does not require any retouch. The two boosters require only a simple adjustment of their quiescent currents. No other difficult or critical tuning. A pretty attractive advantage.

BANDABASE has been used in a variety of FM-TV exciters (on 10GHz, 2.3GHz) and it has proven to be easy to build, not critical at all, flexible.

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