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How to generate a 4MHz triangle wave video signal used to modulate directly the amplitude of an UHF carrier up to 1GHz

(Carlo Mozetic – September 2010)

1. Argument

An UHF-AM direct modulator was requested. It shall modulate an 800MHz UHF carrier with a specific video signal composed by a 4MHz triangle wave internally generated. The circuits and the implementation of this device will be described in the following chapters.

2. Requirement specifications

The list of the device specifications is reported below.

- RF operating frequency: 801MHz (800.888MHz)
- RF output power: 0dBm ±10dB
- Modulating frequency: 4MHz ±100ppm
- Modulating waveform: triangle
- Modulation depth: 25% (±12.5%)
- RF connectors: SMA female

Furthermore the device shall have an auxiliary output connector for modulating signal monitoring and a manual switch to enable/disable the video modulation.

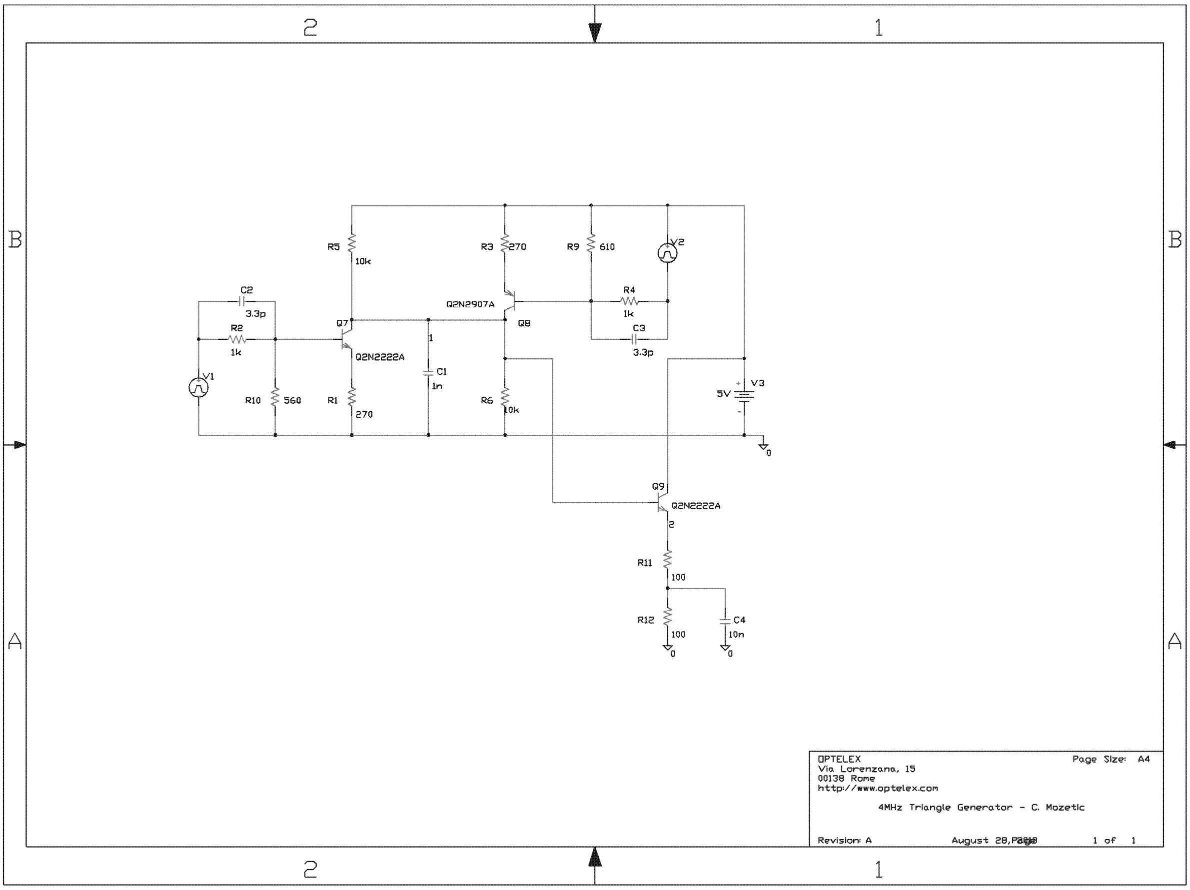
3. 4MHz triangle wave generator

To obtain a perfect triangle wave two constant current generators were implemented. Each generator is reverse polarized with respect to the other and both are connected to the same capacitor. The generators are switched on alternately by using a 4MHz square wave signal coming from a fast TTL divider which is used to divide the master clock (16MHz) by four.

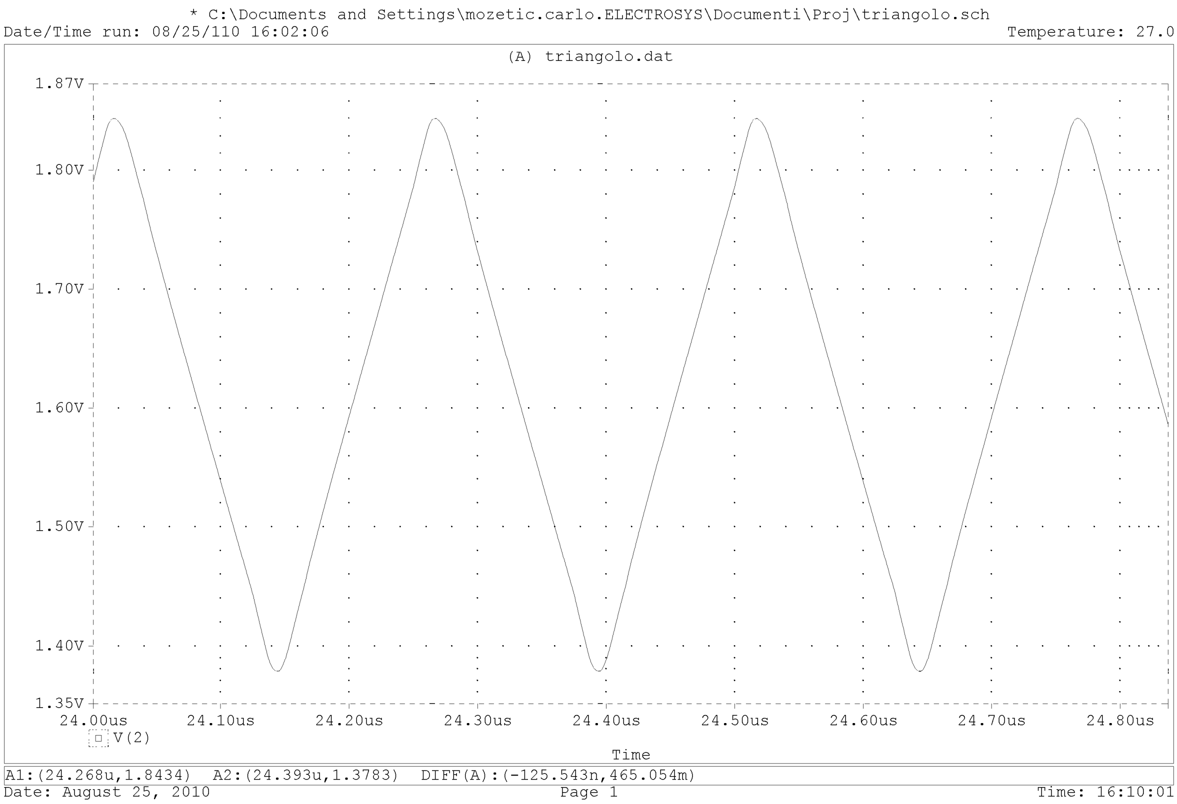
The amplitude of the output waveform depends from the setup current of the generators and the value of the capacitor, for this application the output voltage level needed is few hundred millivolts peak to peak. A buffered monitoring test point of the waveform generator is also available through an SMB coax connector.

The bias of the whole circuit is regulated in order to setup the correct voltage across the capacitor (about 2.4Vdc), in this situation the waveform distortion is reduced to the minimum. Furthermore, two speed-up capacitors are used to compensate the base junction capacitance to increase the on/off response of both constant current generators during transitions, and this will improve the corner tips of the triangle.

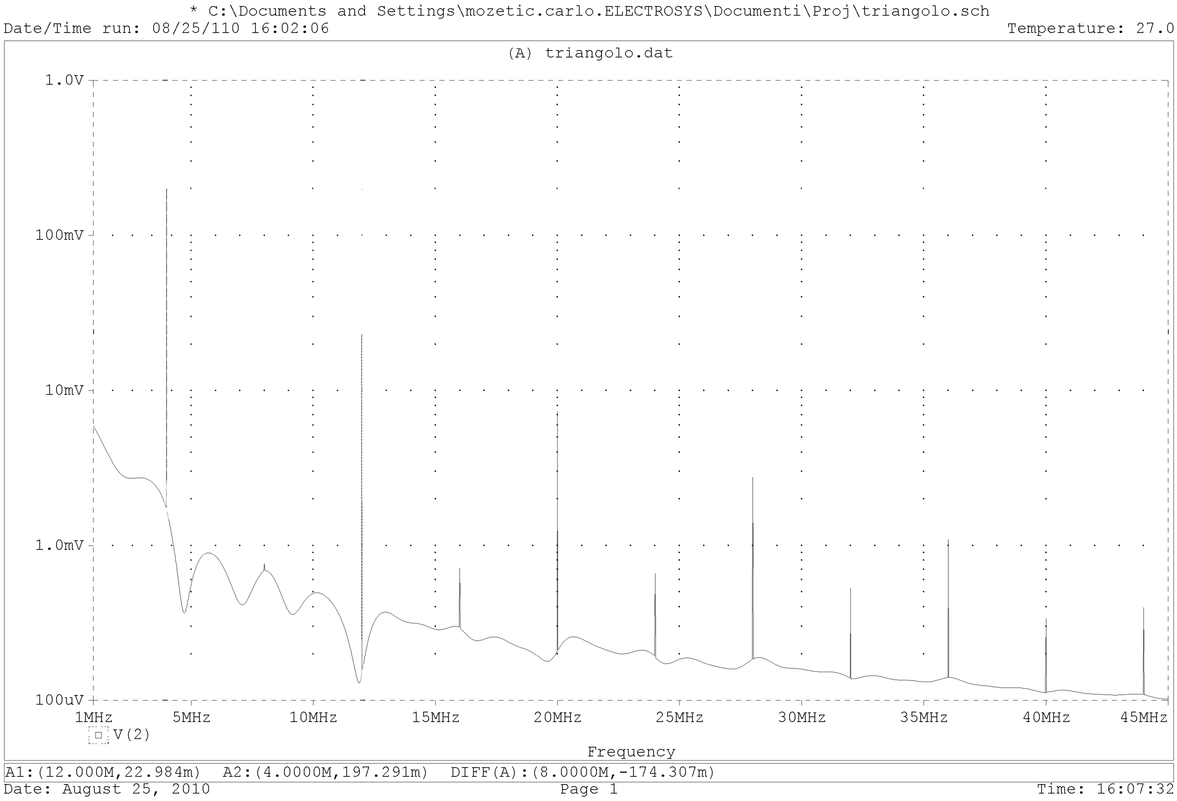
The schematic diagram of the triangle wave generator circuit is shown below. The circuit was also simulated by using a SPICE engine in order to evaluate its performances. As you can see two VHF bipolar models were used. The pulse generators simulate the 4MHz square wave signal coming from the TTL divider.



The output waveform evaluated by the simulator is shown below.



And below there is the same triangle waveform showed in the frequency domain (FFT)



4. Direct UHF-AM modulator

To perform the direct AM modulation of an UHF carrier a Gilbert cell transistor array was used, in particular the Intersil HFA3101 connected as balanced modulator.

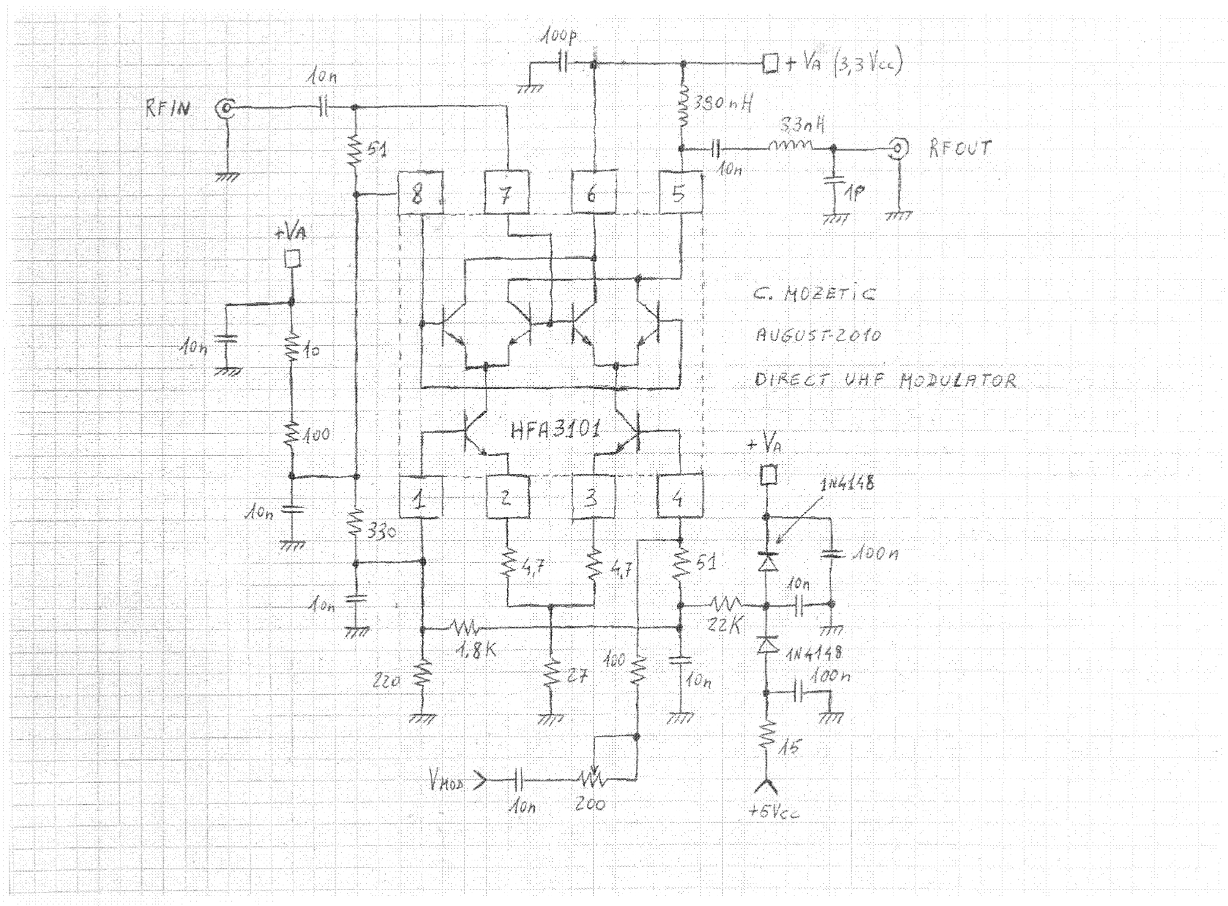
To improve the modulation linearity the bias of each branch was regulated to 15mA (totally about 30-33mA) and the input power level was properly chosen to -10dBm. This will guarantee a good S/N ratio too.

The percentage level of the residual carrier depends from the bias unbalance between branches, from the modulation input level and from the carrier level. To perform a 25% of modulation depth all parameters were properly defined in order to maintain good amplitude modulation linearity.

The output matching was not centered to the operating frequency in order to have wideband performances of the circuit, between 400MHz and 1GHz. Within these limits most of the main parameters of the circuit don't change so much (like gain and modulation depth), but some other are more sensitive to frequency changes, like level of harmonics. For this reason the gain could not be evaluated only by using a simple power meter, it shall be measured by using a spectrum analyzer too.

Both inputs were dc decoupled and wideband matched by using a proper resistive termination, the modulation input is very sensitive, few tens millivolts are enough to modulate the carrier.

The schematic diagram of the whole modulator circuit is shown below.



The power supply was properly filtered in order to reduce noise coming from the other stages. Furthermore the voltage needed for the modulator is reduced to about 3.3Vdc by using a series of two silicon diodes and a 15 ohm resistor.

The emitter degeneration of both branches was necessary to reduce high order intermodulation levels and to prevent unwanted spurious emissions.

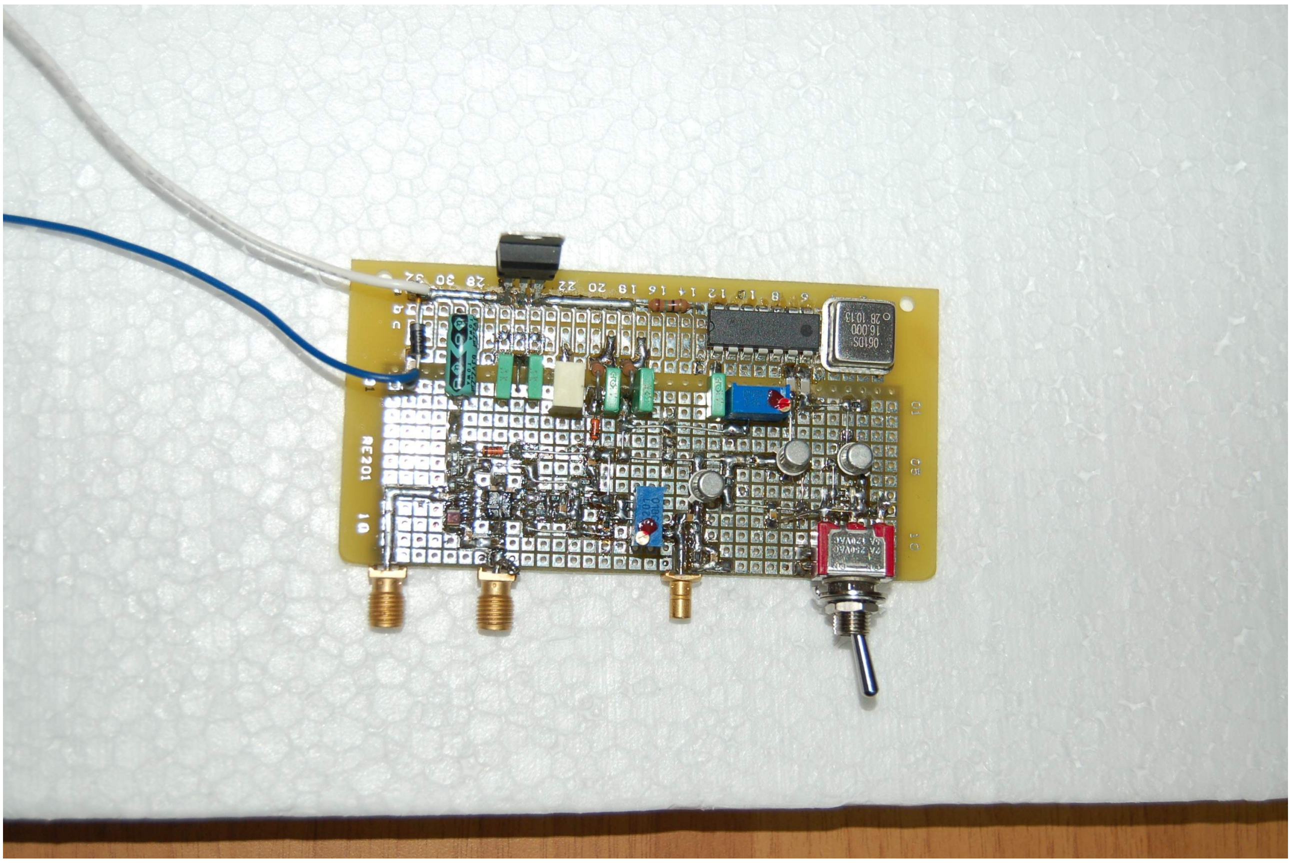
The modulation depth of the triangle waveform can be regulated from 20% to 40% by the 200 ohm trimmer. Anyway, for higher modulation depth could be necessary to reduce the residual carrier setup by change the branch unbalance of the modulator.

5. Implementation

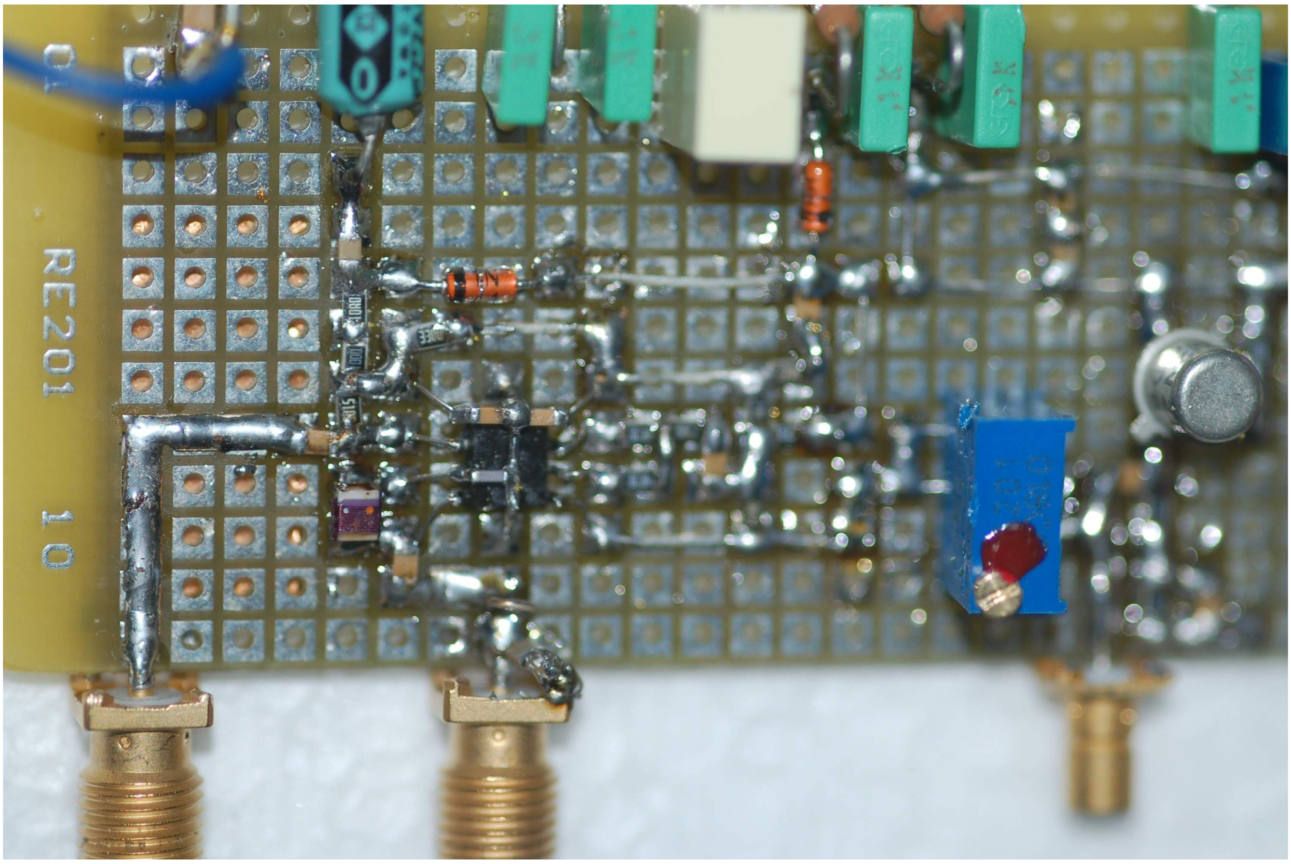
The circuit was made by using a special breadboard with laminated copper distributed over the whole solder side. In order to use only available components a mixed technology was implemented, traditional and SMD. Obviously, for the UHF direct modulator is used only SMT components.

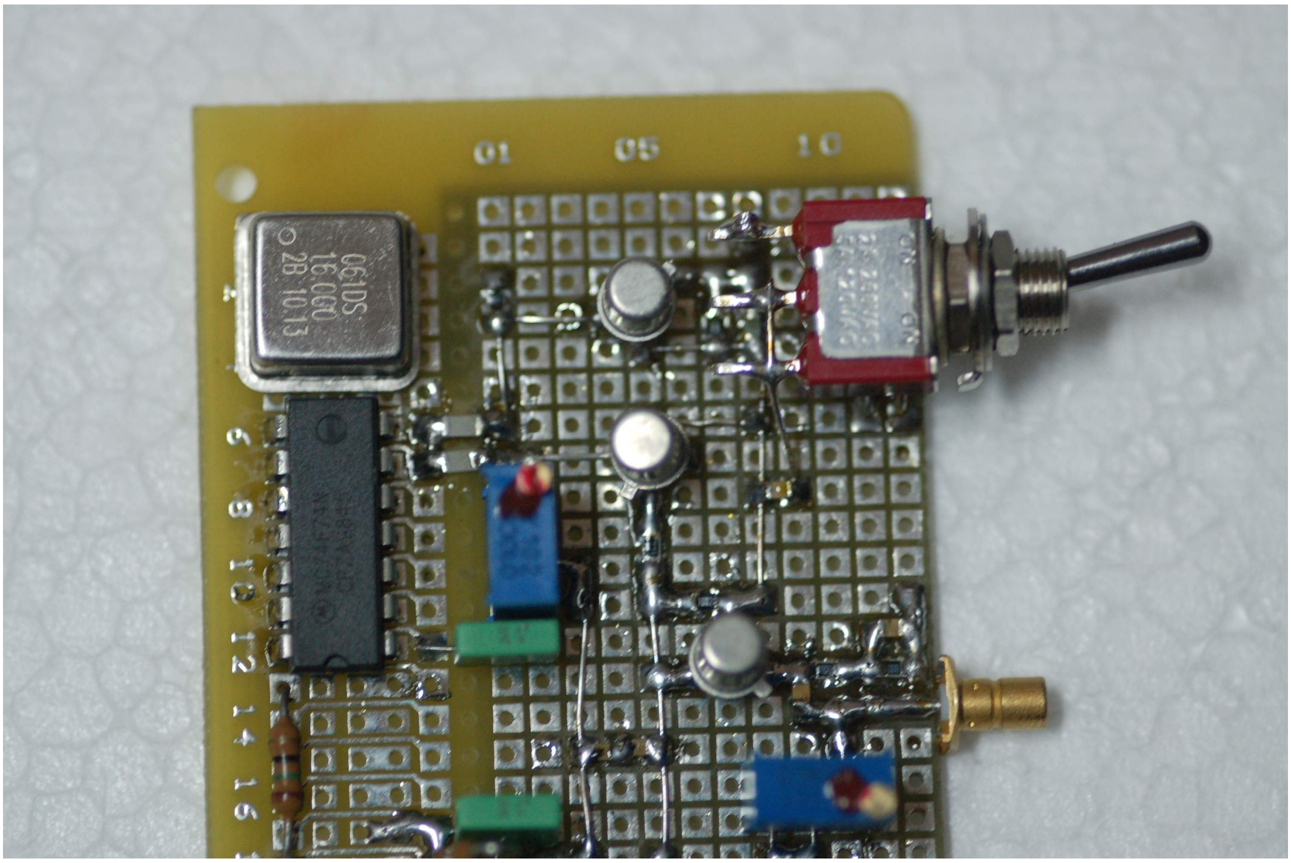
To generate the modulating waveform a master clock of 16MHz TTL crystal oscillator was used. Then, a double fast TTL D type flip-flop was used to divide it by four.

The following pictures show the circuits. The variable resistors are needed to adjust the bias of the triangle wave generator and the other is used to adjust the modulation depth.

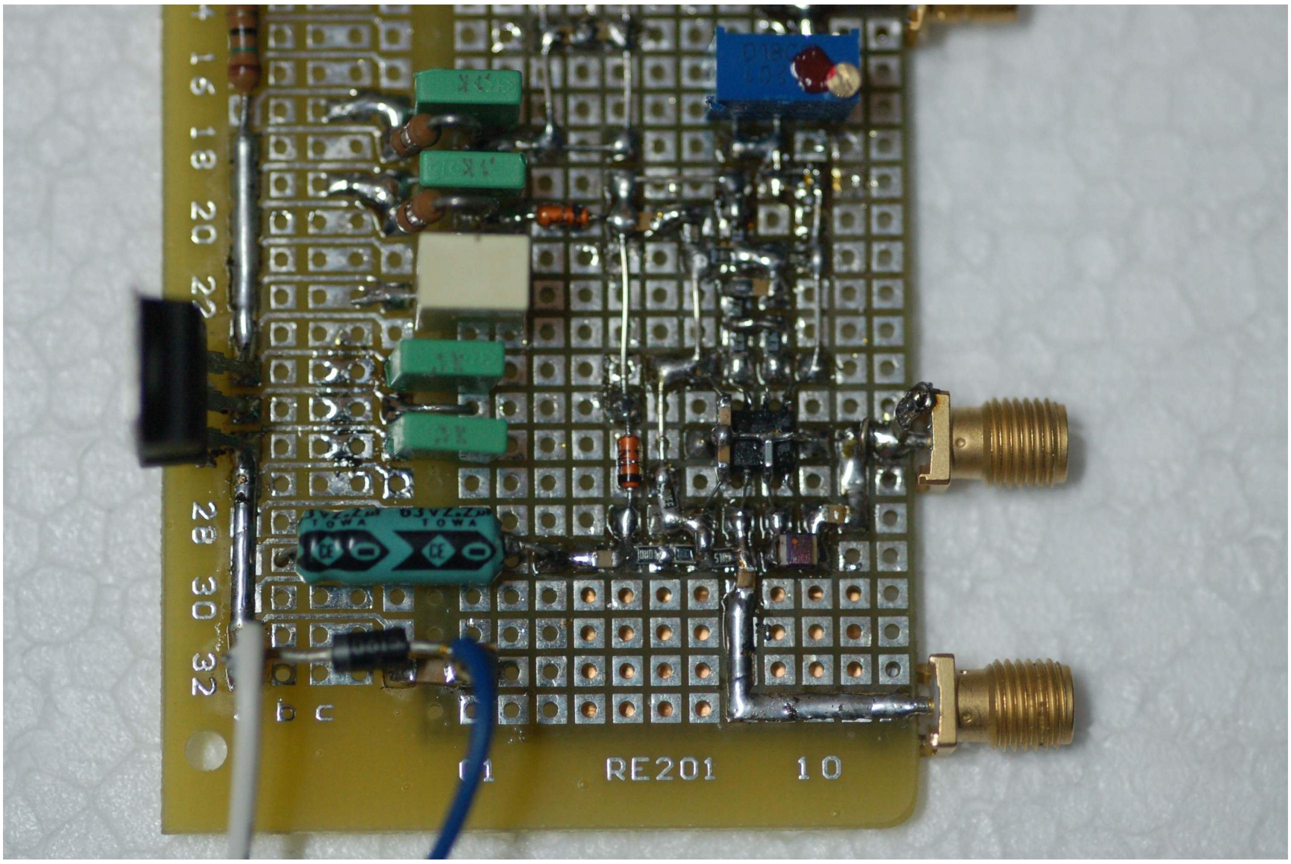


It’s easy to identify the circuit blocks, the voltage regulator, the fast TTL divider and the crystal oscillator on the top side, the four quadrant multiplier and the triangle generator on the bottom side. The following pictures show the UHF modulator circuit and the 4MHz triangle wave generator:





The power supply regulator and the bias filters are shown below:

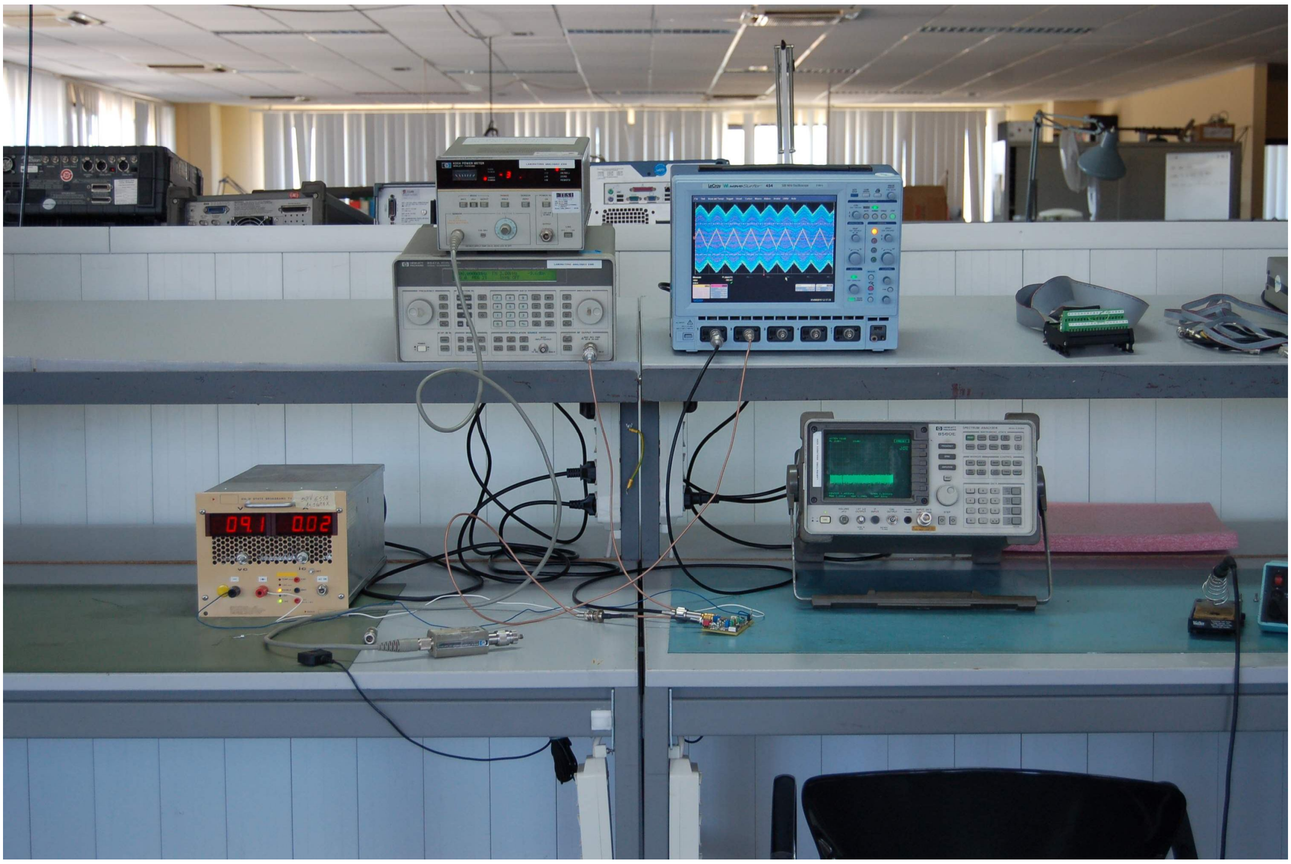


6. Performances

The circuit is capable to modulate an external UHF carrier at 800MHz with a video modulating signal composed by a 4MHz triangle wave internally generated. The power modulation depth is 25% (±12.5%); this means the difference between the level of the un-modulated output signal and the peak level of the output RF envelope (in modulating conditions) will be about +0.58dB (+12.5%) but the rms power will remains the same.

Since initially it was not available a proper oscilloscope to analyze all modulating performances at 800MHz, the modulator was tested with a carrier of 500MHz, then the main modulation parameters (RF output levels vs. tome beat levels) were compared with those at nominal frequency by using the spectrum analyzer.

All of performances were evaluated by using the test bench shown below.

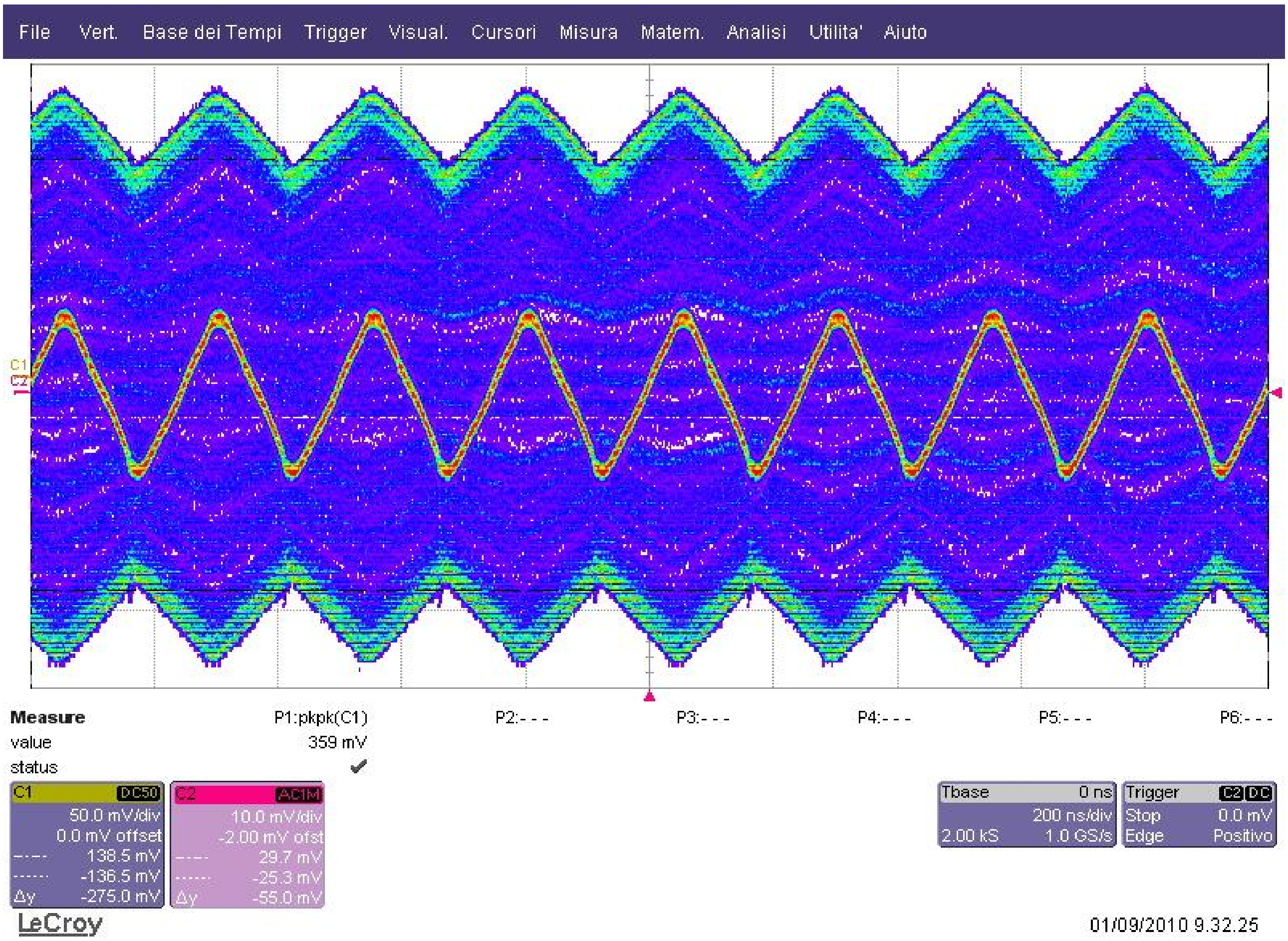


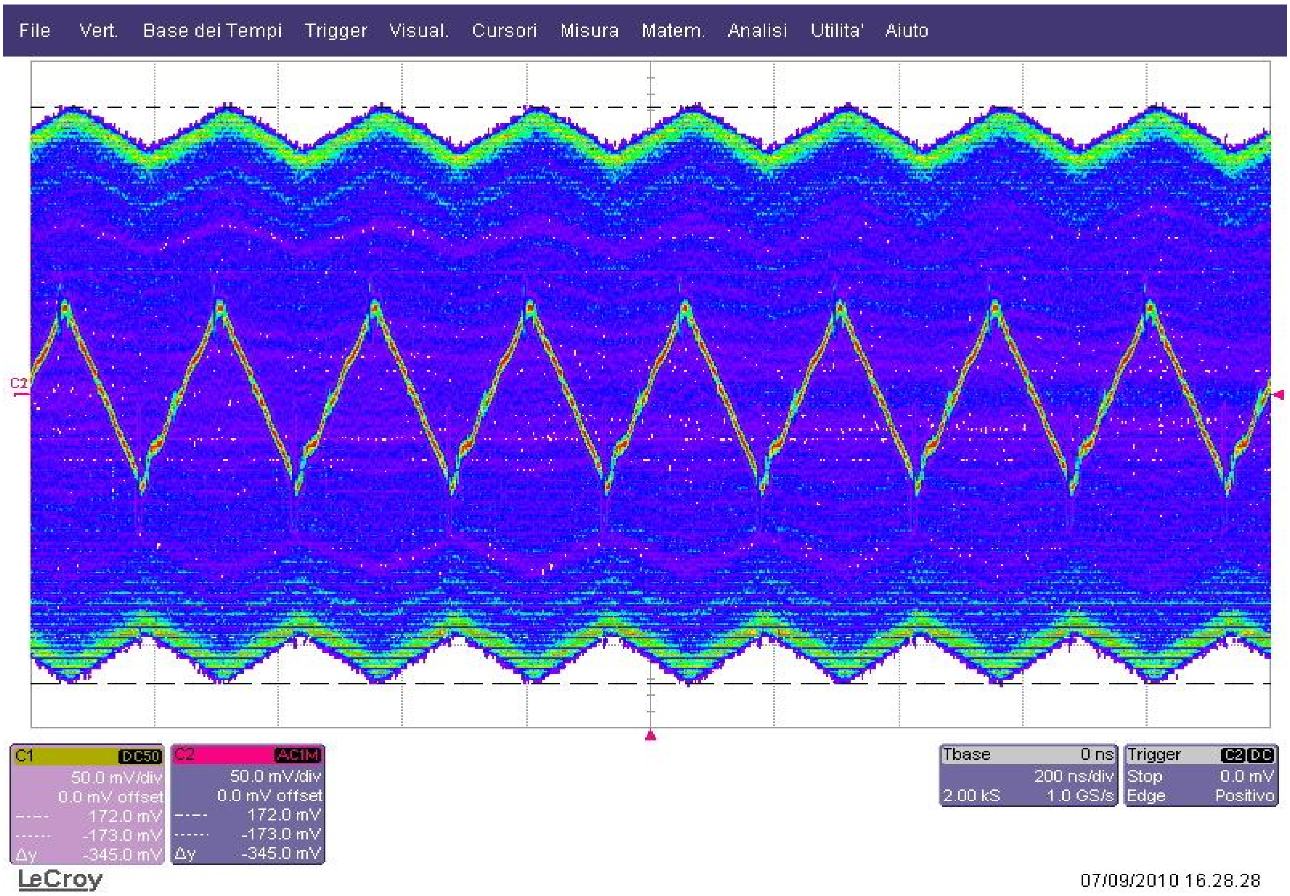
The test equipments are reported in the following list:

- Power Meter: HP436A
- RF generator: HP8647A
- Spectrum Analyzer: HP8560E
- Digital Oscilloscope: LeCroy WS454

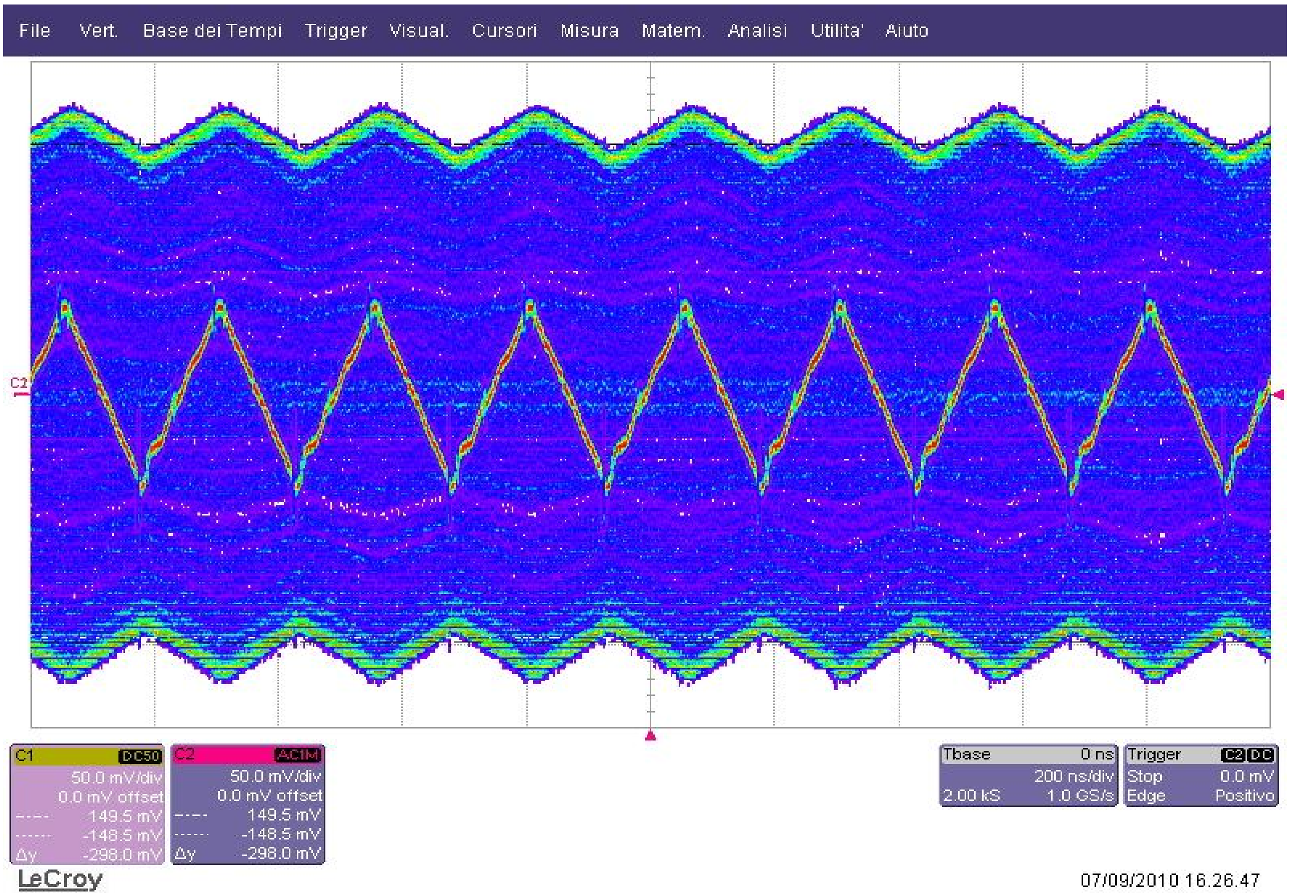
The best way to view the RF modulation by using a digital oscilloscope is to synchronize the trigger to the modulating waveform and view the RF envelope with infinite persistence.

The RF modulation and the modulating signal are shown in the following snapshots.





The Δy difference of the cursors shows about 1.25dB from max and min levels of RF envelope.



Some parameters at 500MHz and at 800MHz (operating frequency) are reported below:

Power Supply = 9-15 Vdc

500MHz
Input level = -10 dBm;
output level = -3.8 dBm;
gain = 6.2 dB
2nd harmonic = -15.5 dBc;
3rd harmonic = -25.5 dBc;
1st mod. Tone beat (±4MHz)= -22.3 dBc;
2nd mod Tone beat (±12MHz)= -42.5 dBc.

800MHz
Input level = -10 dBm;
output level = -3.15 dBm (modulated);
output level = -3.2 dBm (unmodulated);
eval. error due to higher 2nd harmonic = +0.45 dB
gain = 6.85 dB (thermal)
gain = 6.4 dB (fundamental tone)
2nd harmonic = -10 dBc;
3rd harmonic = -33.8 dBc;
1st mod. Tone beat (±4MHz)= -23.3 dBc;
2nd mod Tone beat (±12MHz)= -42.8 dBc;
modulation depth: 25% (±12.5%) internally adjustable.

The difference between thermal gain and fundamental tone gain (0.45dB) is due to the power contribute of the second harmonic which increases the level measured by using a power meter.

RMS Second Harmonic Power Impact			
Delta_f0/2f0_(db)	Pmeas(dbm)	P(W)	Pfundam(dbm)
	-3.2	0.00047863	
10	-13.2	4.7863E-05	
		0.000430767	-3.657574906

The circuit has been shielded by using a metallic box which foresees the following accesses:

a) An SMA input female connector for the UHF carrier to be modulate at -10dBm;
b) An SMA output female connector for the output UHF modulated signal;
c) An SMB male connector for the modulated tone monitoring (triangle 4MHz);
d) A switch to enable or disable the carrier modulation;
e) A D-SUB 9 pin female connector for the 9-15Vdc power supply.

The positive power supply voltage input is connected to the pin n.5 of the D-SUB connector; the ground reference is instead connected to the pin n.1 and it is electrically connected to the metallic box too, via an RF choke to improve EM immunity.

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September 2010