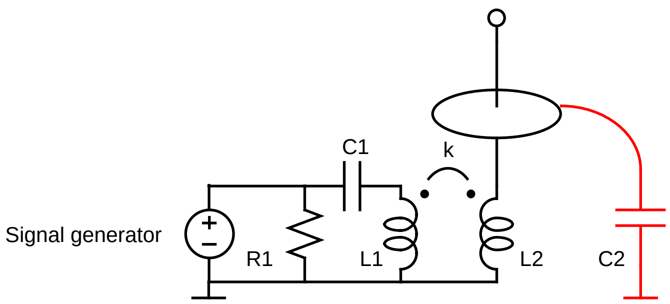
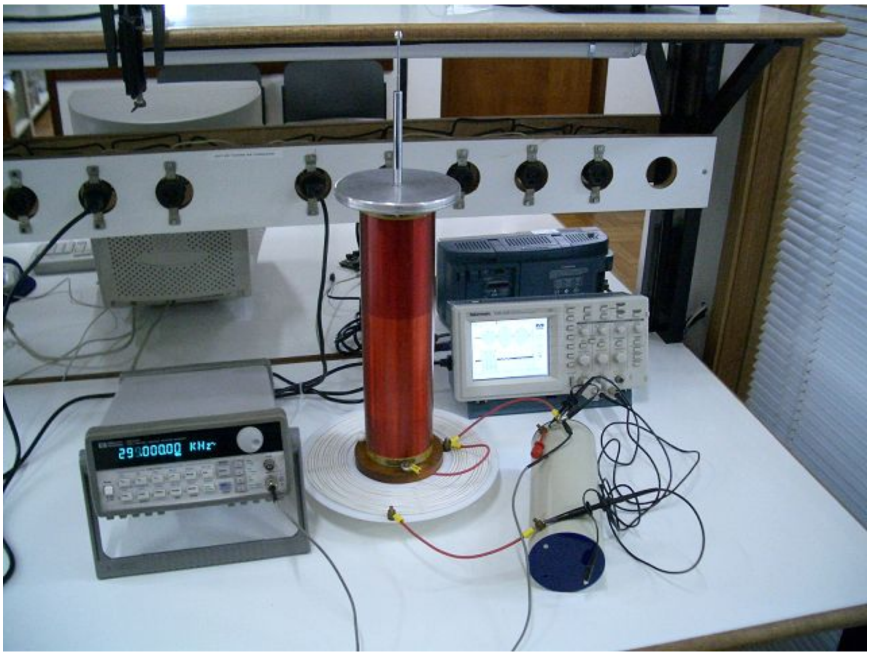
Low power experiments with a “Double resonance solid-state Tesla coil”

Antonio Carlos M. De Queiroz

I will describe some tests made about a double resonance solid-state Tesla coil. The setup is as shown below. A programmable signal generator with 50 Ohms output impedance is connected as the driver of the system. It is programmed to generate a sine wave burst with adjustable frequency, number of cycles, and burst frequency. R1 is an 1.1 Ohm resistor used to lower the impedance of the generator. C1 is an “MMC” capacitor with 5.07 nF. L1 is a flat spiral coil with 58.7 uH. L2 a long solenoidal coil with 28.2 mH. C2 is the composition of the distributed capacitance of L2 and the capacitance of a terminal with an adjustable telescopic antenna at its top, with about 10 pF. The coupling coefficient between L1 and L2 is 0.12.



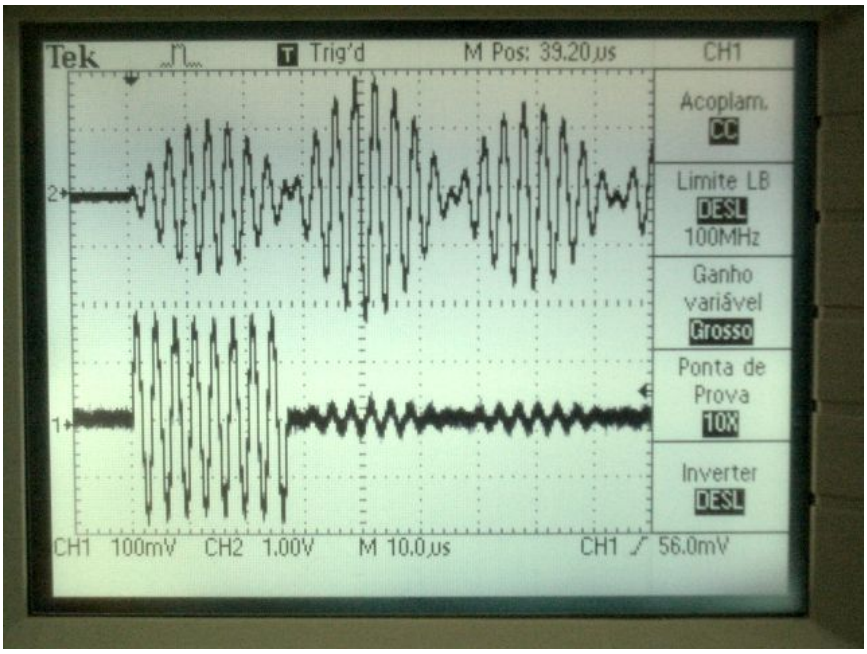


The system was designed to operate in mode 31:33:35 with sinusoidal excitation, with values:

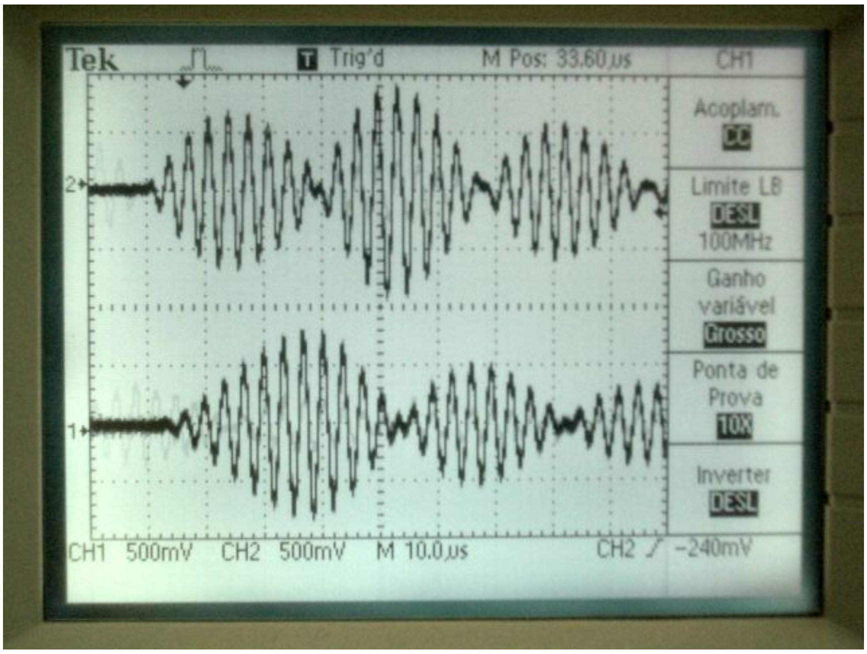
C1 = 5.07 nF
L1 = 58.7 uH
C2 = 10.4 pF
L2 = 28.2 mH
k = 0.12

The system resonates at 277 kHz and 312 kHz, and the excitation is at 294 kHz. The three frequencies are in the ratio 31:33:35. Complete energy transfer occurs with 8.25 cycles of the excitation frequency. Note that wiring inductances were not considered. But the system can be easily retuned by changing the length of the antenna.

Programming the generator to produce 8 cycles, the results are shown below:

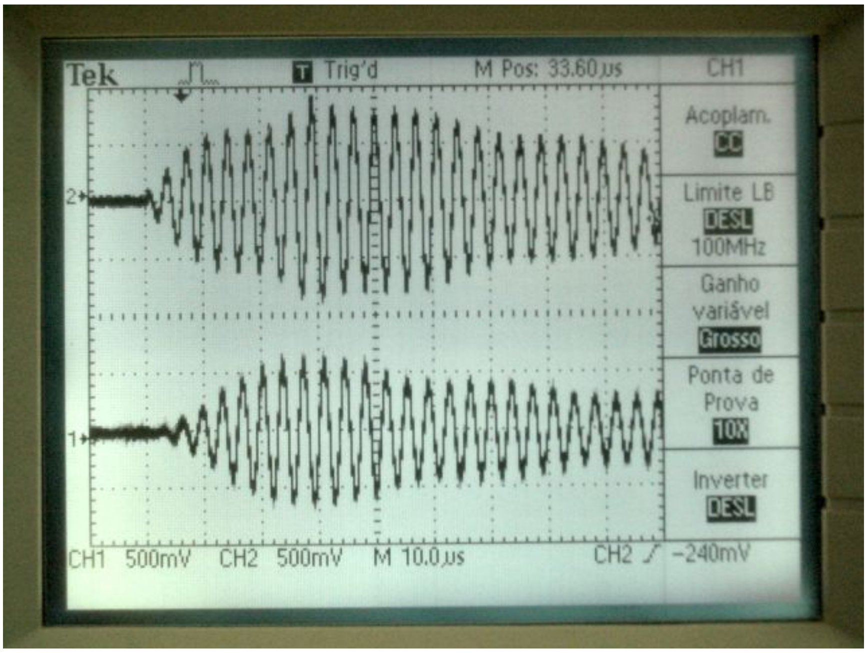


Voltage over L1 and input voltage.



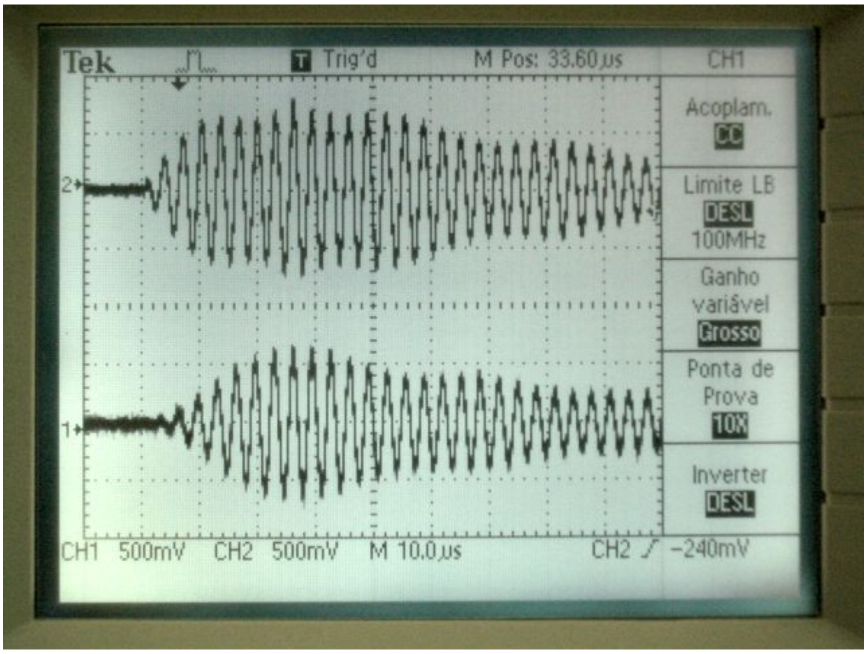
Voltage over L1 and output voltage (uncalibrated. Oscilloscope probe near the top of L2).

At the end of the burst, the driver acts as a short circuit. The energy returning from the secondary circuit is not returned to the driver, and so produces a beat with almost two times larger amplitude. In actual high-power driver, the driver would not be short-circuited, and the behavior would be different.



Input at the lower resonance frequency.

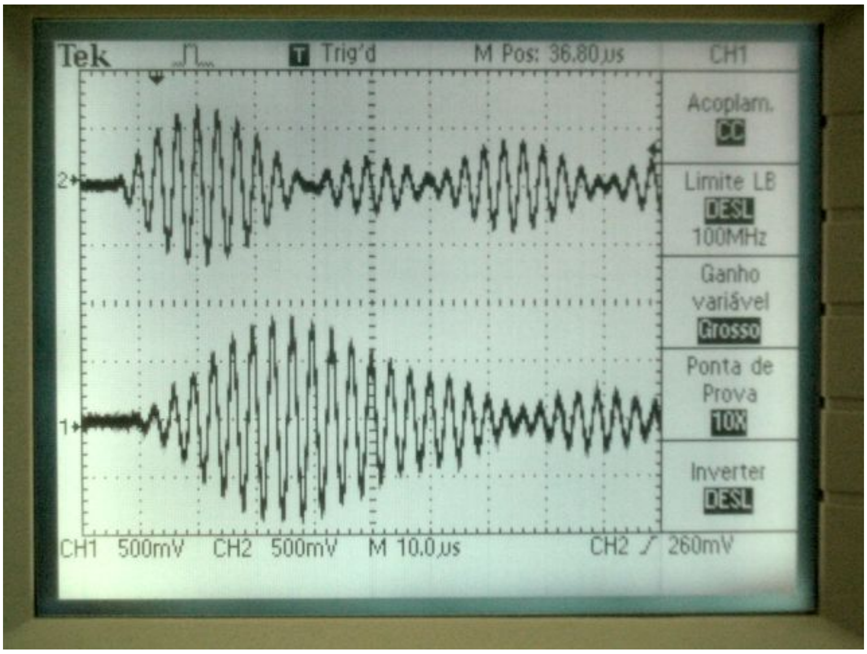
The maximum output voltage is smaller than with excitation at the central frequency. It would grow with more cycles applied, but the input current, that grows in proportion to the voltage over L1 shown, would grow too.



Input at the higher resonance frequency.

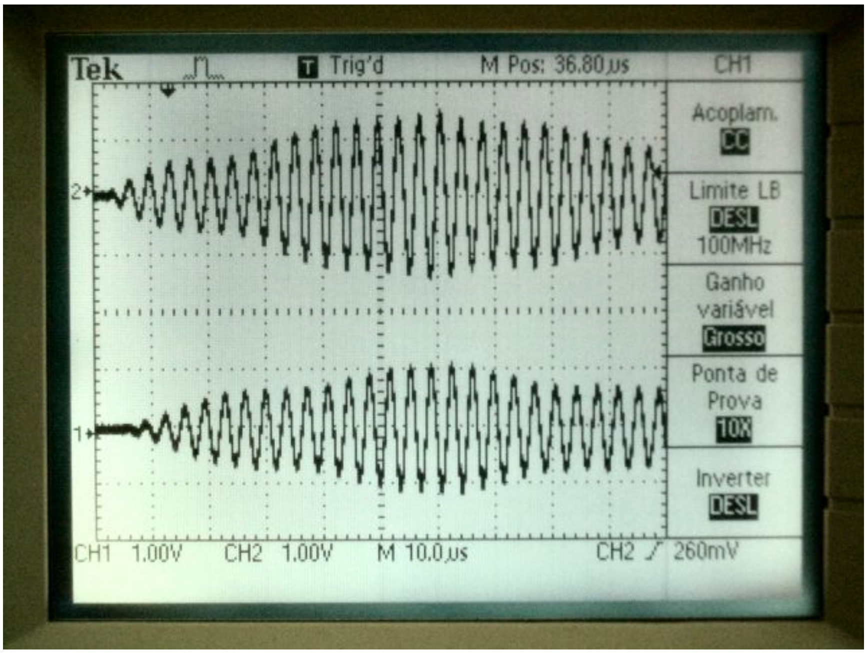
Similar result. Lower output voltage, for this number of cycles.

Changing now the number of input cycles to 17, that ideally would return most of the energy to the driver, in the absense of losses, and is more similar to what a driver with free-wheeling diodes would do:



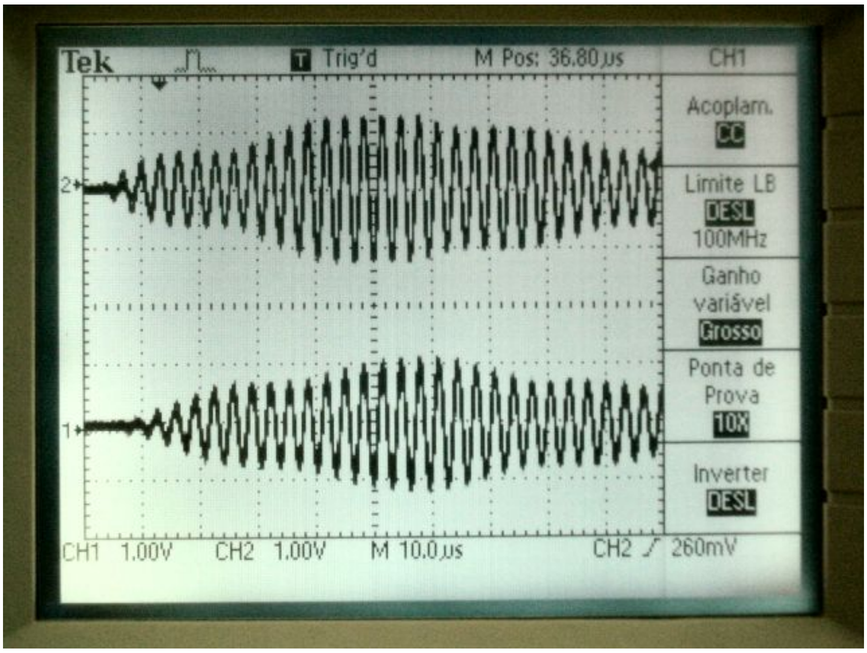
Excitation at the central frequency, 17 cycles at the input. VL1 and VL2.

The second beat at the input returns energy to the driver. It would be ideally of the same amplitude of the first, but losses cause the decrease. The third beat would not exist in an ideal lossless system. The energy that was not extracted from the system until the end of the burst oscillates between the primary and secondary tanks until exhausted.



Excitation at the lower resonance. 17 cycles at the input. VL1 and VL2. Note the change in scale.

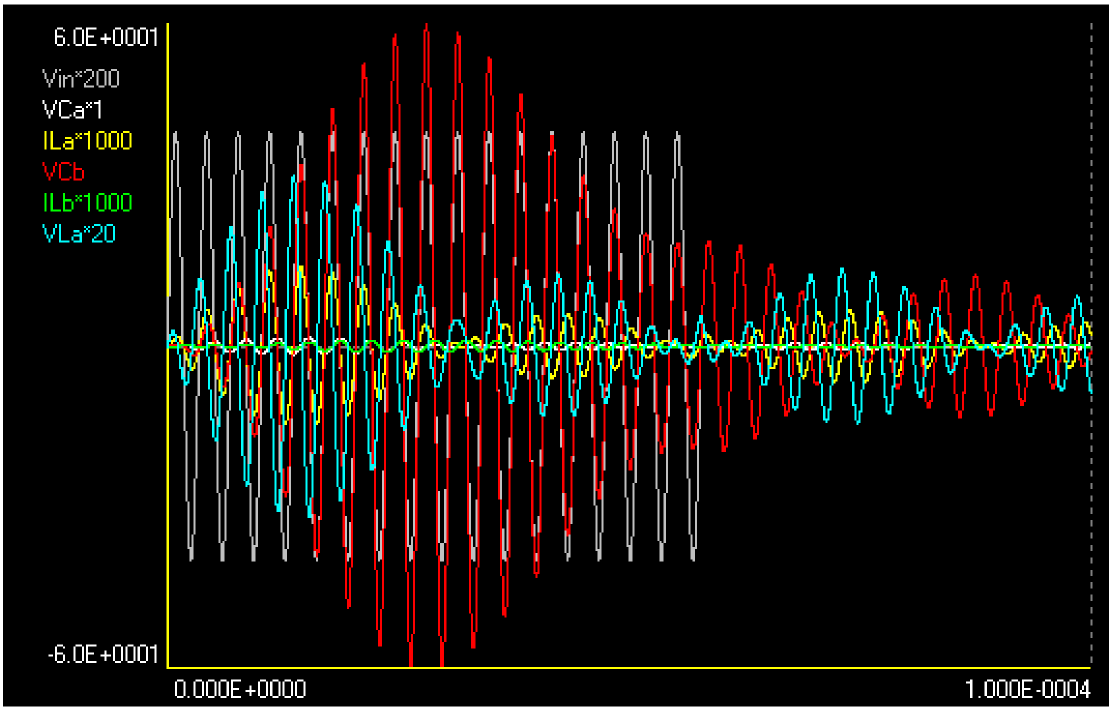
The first peak of the output voltage is a bit smaller. The larger peak is twice larger, but the input current is twice larger too.



Excitation at the upper resonance, 17 cycles. VL1 and VL2.

Similar results are obtained with excitation at the higher resonance. Less voltage at the first peak, and more voltage with more cycles, at the expense of proportionally higher input current.

The obtained waveforms agree closely to the ones obtained by modeling the losses as 1.1 Ohms in the primary circuit (driver) and 1000 Ohms in the secondary system (L2).



Excitation with 17 cycles at the central frequency. Simulation. With 200 mV of input peak voltage, the output reaches 60 V.

Conclusion: With limited input current, the best mode of operation when the objective is to concentrate maximum energy at the output capacitance is to run the driver between the two resonances of the system.

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