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Design of series-series oscillating circuits used in wireless transmission of electricity for battery charging

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Abstract. The paper presents the theoretical design fundamentals for a wireless power transmission system (WPT) with reactive components (inductance and capacitance) of oscillators connected in series both in transmission and reception systems. The equations of the mutually coupled oscillating circuits and relevant electrical parameters related to the sizing of the wireless system are presented and calculated. At the same time, several variants of electrical diagrams of the emission system were designed and simulated.

1. Introduction

Wireless power transmission (WPT) has become increasingly popular in the past few years due to its undeniable advantages in certain environmental conditions over galvanic coupling.

The versatility of WPT has increased the interest of large companies in research to optimize the process of wireless energy transmission, so it is necessary to achieve the highest possible efficiency of wireless energy transmission over long distances.WPT optimization depends on several aspects, firstly maintaining the magnetic coupling between the two coils (transmission-receiving) in resonant conditions, secondly is related to the correct sizing of the two oscillating circuits to reduce losses.

2. Mutual influence

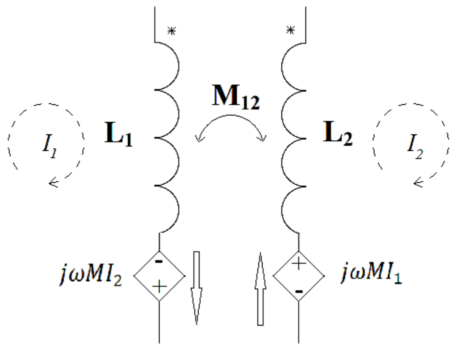

Figure 1. The mutual influence of two coils.

From figure 1, L_1, L_2 - represents the emission and reception coils in which are flowing the currents I_1 and I_2, the coils are mutually influenced by each other due to mutual coupling M; the coils have the same winding/polarization direction marked with *. I_1, the current from L_1 will induce in L_2 a voltage - $j\omega MI_1$ (and as a consequence an current I_2), opposite to the L_1 voltage.
In turn, I_2 will induce in L_1 a voltage - $j\omega MI_2$, opposite to L_2 voltage [1], [2].

3. The main equation of the Series-series oscillating circuit.

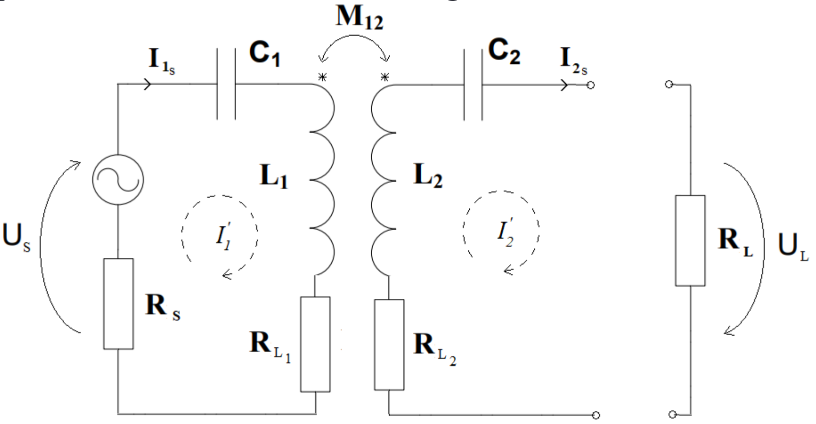

Figure 2. Series-series RLC circuit [2].

The first step is to choose the directions of sides currents of the two oscillating circuits (I_{1s} and I_{2s}), respectively the travel directions for the two fundamental eye (eye reference directions $I_1^{'}$, $I_2^{'}$).

The sign of mutual impedance ($j\omega M$) is subject to a sign convention given by the rules.

- the plus sign is if the directions of the side currents (I_{1s} and I_{2s}) coincide with the polarized terminals of the coils, or minus if they do not coincide.
- the plus sign is if the travel directions for the fundamental eye coincides with the direction of current through the side of the eye that containing the coil, relative to the polarized terminal of the coil and, or minus if the directions do not coincide.

The mutual influences of the circuits from figure 2 [4], [5]:

$$\bar{E}_2 = \bar{Z}_M\bar{I}_{1s} = -j\omega MI_{1s} \tag{1}$$

$$\bar{E}_{21} = \bar{Z}_M\bar{I}_{2s} = -j\omega MI_{2s} \tag{2}$$

where: $j\omega M = \bar{Z}_M$ - coupling impedance between the two circuits, with the sign according to the sign convention, I_{1s} and I_{2s} - primary and secondary series circuit currents, $\bar{E}_{21}$ - the influence of the secondary circuit to the primary (to L_1), $\bar{E}_2$ - the influence of the primary to the secondary (to L_2).

Applying Kirchhoff's second theorem to the circuits of figure 2, we obtain the following equations:

$$\begin{cases} \bar{U}_s = \bar{Z}_{1s}\bar{I}_{1s} + \bar{Z}_M\bar{I}_{2s} \\ 0 = \bar{Z}_{2s}\bar{I}_{2s} + \bar{Z}_M\bar{I}_{1s} \\ \bar{Z}_M = -j\omega M \end{cases} \rightarrow \begin{cases} \bar{U}_s = \bar{Z}_{1s}\bar{I}_{1s} - j\omega M\bar{I}_{2s} \\ j\omega M\bar{I}_{1s} - \bar{Z}_{2s}\bar{I}_{2s} = 0 \end{cases} \tag{3}$$

decompressing equations (3), we can determine the voltage applied to the secondary circuit load R_L [6]:

$$\begin{cases} \bar{U}_s = j\left(\omega L_1 - \frac{1}{\omega C_1}\right)\bar{I}_{1s} + R_{L_1}\bar{I}_{1s} - j\omega M\bar{I}_{2s} \\ j\omega M\bar{I}_{1s} - j\left(\omega L_2 - \frac{1}{\omega C_2}\right)\bar{I}_{2s} = \bar{U}_{Ls} \\ \bar{U}_L = \bar{I}_{2s}R_L \end{cases} \tag{4}$$

where: $\bar{Z}_{1s}$ - series primary circuit impedance, $\bar{Z}_{2s}$ - series secondary circuit impedance, $\bar{U}_s$ - primary voltage source, $\bar{U}_{Ls}$ - voltage drop on the load of the series secondary circuit, C_1 and C_2 - transmission and reception capacitors, L_1 and L_2 - transmission and reception inductances, R_L - load resistance, R_{L_1} și R_{L_2} - resistances of L_1 și L_2.

Circuit impedances ($\bar{Z}_{1s}$ and $\bar{Z}_{2s}$) regarding to equations (3) are defined as follows [7]:

- in complex

$$\bar{Z}_{1s} = r_{1s} + jX_{1s} \tag{5}$$

$$\bar{Z}_{2s} = r_{2s} + jX_{2s} \tag{6}$$

- real and imaginary parts

$$r_{1s} = R_{L_1}, X_{1s} = \left(\omega L_1 - \frac{1}{\omega C_1}\right) \tag{7}$$

$$r_{2s} = R_{L_2}, X_{2s} = \left(\omega L_2 - \frac{1}{\omega C_2}\right) \tag{8}$$

where: X_{1s} and X_{2s} - primary and secondary circuit reactances, r_{1s} and r_{2s} - primary and secondary circuit resistors.

3.1 Reflected impedances and currents calculation

The reflected impedances constitute the resistances induced to each other by two coils from different circuits, mutually coupled; represents the effect that the transmitting and receiving coil have on each other [7], [8].

3.1.1 Equivalent primary circuit:

$$\text{From: } \begin{cases} \bar{U}_s = \bar{Z}_{1s}\bar{I}_{1s} + \bar{Z}_M\bar{I}_{2s} \\ 0 = \bar{Z}_{2s}\bar{I}_{2s} + \bar{Z}_M\bar{I}_{1s} \\ \bar{I}_{2s} = -\frac{\bar{Z}_M\bar{I}_{1s}}{\bar{Z}_{2s}} \end{cases} \rightarrow$$

$$\bar{U}_s = \bar{Z}_{1s}\bar{I}_{1s} + \left(-\frac{\bar{Z}_M{}^2}{\bar{Z}_{2s}}\right)\bar{I}_{1s} \rightarrow \bar{U}_s = \bar{I}_{1s}\left(\bar{Z}_{1s} - \frac{\bar{Z}_M{}^2}{\bar{Z}_{2s}}\right) \tag{9}$$

where: $-\frac{\bar{Z}_M{}^2}{\bar{Z}_{2s}} = R_{1ref}$ - reflected impedance by secondary to primary.

From equation (9) we extract the apparent impedance of the primary circuit in the presence of the secondary [7], [8]:

$$\bar{Z}_{1eS} = \bar{Z}_{1s} - \frac{\bar{Z}_M{}^2}{\bar{Z}_{2s}} \tag{10}$$

Equation (10) shows that the primary circuit does not provide only its impedance $\bar{Z}_{1s}$ to its source, on this is added an impedance reflected by the secondary R_{1ref}, forming the apparent impedance of the primary circuit $\bar{Z}_{1eS}$ - which can be expressed from equation (5) and (10) as:

$$\bar{Z}_{1eS} = r_{1s} + jX_{1s} - \frac{j^2\omega^2M^2}{r_{2s} + jX_{2s}} = r_{1s} + jX_{1s} + \frac{\omega^2M^2}{r_{2s} + jX_{2s}} = r_{1s} + jX_{1s} + \frac{(r_{2s} - jX_{2s})\omega^2M^2}{r^2{}_{2s} + jX^2{}_{2s}} \rightarrow$$

$$\bar{Z}_{1eS} = r_{1s} + r_{2s}\frac{\omega^2M^2}{r_{2s}^2 + x_{2s}^2} + j\left(X_{1s} - X_{2s}\frac{\omega^2M^2}{r_{2s}^2 + x_{2s}^2}\right) \tag{11}$$

From equation (11) the following values were expressed as:

$$\Delta r_{1s} = r_{2s}\frac{\omega^2M^2}{r_{2s}^2 + x_{2s}^2} \tag{13}$$

$$\Delta X_{1s} = -X_{2s}\frac{\omega^2M^2}{r_{2s}^2 + x_{2s}^2} \tag{14}$$

where: Δr_{1s} - resistance induced by the secondary circuit effect in primary, ΔX_{1s} - reactance induced by the secondary circuit effect in primary [7].

Replacing equations (13) and (14) in equation (11), equation (11) can be expressed as:

$$\bar{Z}_{1eS} = r_{1s} + \Delta r_{1s} + j(X_{1s} + \Delta X_{1s}) \rightarrow \bar{Z}_{1e} = r_{1e} + jX_{1e} \tag{15}$$

From equation (15) the following terms were expressed as [7]:

$$\begin{cases} r_{1e} = r_{1s} + \Delta r_{1s} \\ X_{1e} = X_{1s} + \Delta X_{1s} \end{cases} \tag{16}$$

$$\begin{cases} \Delta r_{1s} = +t_2^2 r_{2s} \\ \Delta X_{1s} = -t_2^2 X_{2s} \end{cases} \tag{17}$$

where: r_{1e} - equivalent apparent resistance of the primary circuit in the presence of the secondary circuit, X_{1e} - equivalent apparent reactance of the primary circuit in the presence of the secondary circuit.

From equation (11), the following term $\frac{\omega^2 M^2}{r_{2s}^2+x_{2s}^2}$ will be expressed as [7]:

$$t_2^2 = \frac{\omega^2 M^2}{r_{2s}^2+x_{2s}^2} \rightarrow t_2 = \frac{\omega M}{\sqrt{r_{2s}^2+x_{2s}^2}} = \frac{Z_M}{Z_{2s}}, \tag{18}$$

where: t_2 – transfer ratio from the secondary circuit to the primary circuit.

The apparent impedance of the primary circuit in the presence of the secondary, with t_2 involvement, is expressed as[7]:

$$\bar{Z}_{1e} = r_{1s} + t_2^2 r_{2s} + j(X_{1s} - t_2^2 X_{2s}) \tag{19}$$

Regarding theoretical exposition of the secondary circuit reaction in the primary circuit, from equation (19) we can conclude that:

- the primary circuit resistance variate with a fraction of $+t_2^2$ from the secondary circuit resistance.
- the primary circuit reactance variate with a fraction of $-t_2^2$ from the secondary circuit reactance.

The reactance of the secondary circuit X_{2s} can be positive or negative, thus, the apparent reactance of the primary circuit X_{1e} can be higher or lower than the reactance of the primary circuit X_{1s}.

The magnetic coupling between the two circuits, transfers (reflects) an impedance by the secondary circuit to the primary circuit, this additional impedance has the expression [7]:

$$\Delta Z_1 = \Delta r_{1s} + j\Delta X_{1s} \tag{20}$$

The source of the primary circuit consumes additional energy on the supplementary resistance Δr_{1s} reflected by the secondary circuit, expressed by the equation:

$$\Delta P_1 = \Delta r_{1s} I_{1_{efs}}^2 = t_2^2 r_{2s} I_{1_{efs}}^2 = r_{2s}\left(t_2 I_{1_{efs}}\right)^2 \tag{21}$$

where: $I_{1_{efs}} = I_{1s}$ - series primary circuit effective current, ΔP_1 - power consumed on Δr_{1s}.

From equations:
$$\begin{cases} \bar{U}_s = \bar{Z}_{1s}\bar{I}_{1s} + \left(-\frac{\bar{Z}_M{}^2}{\bar{Z}_{2s}}\right)\bar{I}_1 \rightarrow \bar{I}_{1s} = \frac{\bar{Z}_{2s}\bar{U}_s}{\bar{Z}_{1s}\bar{Z}_{2s}-\bar{Z}_M^2} \\ \begin{cases} \bar{I}_{1s} = \frac{\bar{U}_s}{\bar{Z}_{1s}+\bar{Z}_{1r}} = \frac{\bar{U}_s}{\bar{Z}_{1s}-\frac{\bar{Z}_M^2}{\bar{Z}_{2s}}} \rightarrow \bar{I}_{2s} = \frac{-\bar{Z}_M\bar{U}_s}{\bar{Z}_{1s}\bar{Z}_{2s}-\bar{Z}_M^2} \\ \bar{I}_{2s} = \frac{-\bar{Z}_M I_1}{Z_{2s}} \end{cases} \end{cases} \rightarrow \tag{22}$$

Completing the ratio of the currents $\bar{I}_{2s}$ and $\bar{I}_{1s}$ from equations (22) in the form of effective values, ΔP_1 can be expressed as [7]:

$$\begin{cases} \frac{I_{2s}}{I_{1s}} = \frac{Z_M}{Z_2} = t_2 \rightarrow I_{2s} = I_{1s}t_2 \\ \Delta P_1 = r_{2s} I_{2_{efs}}^2 \\ I_{2_{efs}} = I_2 \end{cases} \rightarrow \Delta P_1 = r_{2s} I_{2_{efs}} = P_2 \tag{23}$$

where: $I_{2_{efs}}$ - series secondary circuit effective current, P_2 - power transferred from primary circuit to secondary circuit.

Therefore, the power consumed by the primary circuit ΔP_1, in the resistance Δr_{1s}, represents the power P_2 transmitted from the primary circuit to the secondary circuit by magnetic coupling [7].

3.1.2 Equivalent secondary circuit

From equation (3):
$$\begin{cases} \bar{U}_s = \bar{Z}_{1s}\bar{I}_{1s} + \bar{Z}_M\bar{I}_{2s} \\ 0 = \bar{Z}_{2s}\bar{I}_{2s} + \bar{Z}_M\bar{I}_{1s} \\ \bar{I}_{1s} = -\frac{\bar{Z}_{2s}\bar{I}_{2s}}{\bar{Z}_M} \end{cases} \rightarrow \bar{U}_s = \bar{Z}_{1s}\left(-\frac{\bar{Z}_{2s}}{\bar{Z}_M}\right)\bar{I}_{2s} + \bar{Z}_M\bar{I}_{2s} \rightarrow$$

$$\bar{U}_s = \bar{I}_{2s}\left(\bar{Z}_M - \frac{\bar{Z}_{1s}\bar{Z}_{2s}}{\bar{Z}_M}\right) \tag{24}$$

where: $\bar{Z}_{2e} = \bar{Z}_M - \frac{\bar{Z}_{1s}\bar{Z}_{2s}}{\bar{Z}_M}$ - secondary circuit apparent impedance in the presence of the primary circuit.

Amplifying both terms of equation (24) with $\left(-\frac{\bar{Z}_M}{\bar{Z}_{1s}}\right)$, results [8]:

$$\left(-\frac{\bar{Z}_M}{\bar{Z}_{1s}}\right)\bar{U}_s = \bar{I}_{2s}\left(\bar{Z}_{2s} - \frac{\bar{Z}_M{}^2}{\bar{Z}_{1s}}\right) \tag{25}$$

$$\bar{E}'_2 = \bar{I}_{2s}\left(\bar{Z}_{2s} - \frac{\bar{Z}_M{}^2}{\bar{Z}_{1s}}\right) \tag{26}$$

$$\left(-\frac{\bar{Z}_M}{\bar{Z}_{1s}}\right)\bar{U}_s = \bar{E}'_2 \tag{27}$$

where: $-\frac{\bar{Z}_M{}^2}{\bar{Z}_{1s}} = R_{2ref}$ - reflected impedance by the primary circuit in the secondary circuit,
$\bar{E}'_2$ - total voltage induced by primary circuit in secondary circuit, under the effect of the primary circuit on the secondary circuit, as exposed in figure 3.

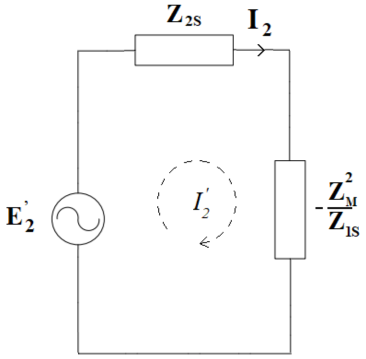

Figure 3. The total voltage induced by the primary circuit in the secondary circuit, under the influence of the primary on the secondary [8].

The impedance reflected by the primary in the secondary can also be expressed as:

$$\begin{cases} \bar{I}_{2s} = -\dfrac{\bar{Z}_M\bar{I}_{1s}}{\bar{Z}_{2s}} \\ \bar{I}_{1s} = \dfrac{\bar{U}_s\bar{Z}_M}{\bar{Z}_{1s}\bar{Z}_{2s} - \bar{Z}_M{}^2} \end{cases} \rightarrow \bar{I}_{2s} = -\frac{\bar{U}_s\bar{Z}_M}{\bar{Z}_{1s}\bar{Z}_{2s} - \bar{Z}_M{}^2} = \left(-\frac{\bar{Z}_M}{\bar{Z}_{1s}}\right)\bar{U}_s\left(\frac{1}{\bar{Z}_{2s} - \frac{\bar{Z}_M{}^2}{\bar{Z}_{1s}}}\right) \rightarrow$$

$$\bar{I}_{2s}\left(\bar{Z}_{2s} - \frac{\bar{Z}_M{}^2}{\bar{Z}_{1s}}\right) = \left(-\frac{\bar{Z}_M}{\bar{Z}_{1s}}\right)\bar{U}_s$$

Expression of currents $\bar{I}_{1s}$ and $\bar{I}_{2s}$ regarding the primary circuit source $\bar{U}_s$ can be expressed from equations (9) and (24) as:

$$\bar{I}_{1s} = \frac{\bar{U}_s}{\bar{Z}_{1s} - \frac{\bar{Z}_M{}^2}{\bar{Z}_{2s}}} \tag{28}$$

$$\bar{I}_{2s} = \frac{\bar{U}_s}{\bar{Z}_M - \frac{\bar{Z}_{1s}\bar{Z}_{2s}}{\bar{Z}_M}} \tag{29}$$

The ratio of the currents $\bar{I}_{2s}$ and $\bar{I}_{1s}$ from equations (28) and (29) can be expressed as t_2 [7]:

$$\begin{cases} \frac{I_{2s}}{I_{1s}} = \frac{Z_{1e}}{Z_{2e}} \\ \frac{I_{2s}}{I_{1s}} = t_2 \end{cases} \rightarrow \frac{Z_{1e}}{Z_{2e}} = t_2 \tag{30}$$

From equation (30), the secondary circuit apparent impedance Z_{2e} can be expressed in terms of Z_{1e} and t_2, as follows:

$$Z_{2e} = \frac{Z_{1e}}{t_2} = \frac{\sqrt{(r_{1s} + t_2^2 r_{2s})^2 + (X_{1s} - t_2^2 X_{2s})^2}}{t_2} \rightarrow$$

$$Z_{2e}^2 = \left[\frac{r_{1s}}{t_2} + t_2 r_{2s}\right]^2 + \left[\frac{X_{1s}}{t_2} - t_2 X_{2s}\right]^2 \quad (31)$$

Based on the symmetry of the equivalent impedance $\bar{Z}_{2e}$ concerning to $\bar{Z}_{1s}$ and $\bar{Z}_{2s}$ from the equation $\bar{Z}_{2e} = \bar{Z}_M - \frac{\bar{Z}_{1s}\bar{Z}_{2s}}{\bar{Z}_M}$, the square of the impedance modulus can be expressed as [7]:

$$Z_{2e}^2 = \left[\frac{r_{2s}}{t_1} + t_1 r_{1s}\right]^2 + \left[\frac{X_{2s}}{t_1} - t_1 X_{1s}\right]^2 \quad (32)$$

The transfer ratio from primary to secondary t_1, being expressed as:

$$t_1 = \frac{Z_M}{Z_{1s}} = \frac{M\omega}{\sqrt{r_1^2 + X_1^2}} \quad (33)$$

where: t_1 - transfer ratio from primary to secondary.

From equations (31) and (32), it follows that the primary also reflects part of its impedance to the secondary circuit.

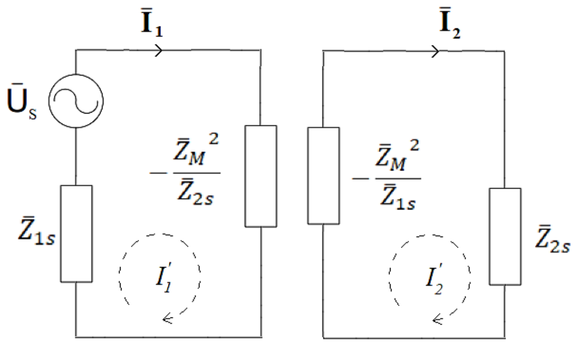

Figure 4. Reflected Impedances by magnetically coupled oscillating circuits [8].

4. Oscillating circuit resonance

When the supply frequency of the RLC oscillator increases, the capacitance reactance decreases, and the coil reactance increases; there is a frequency for which the two reactances are equal in absolute value being also opposite, and the reactance of the circuit will be zero. In this case, the impedance of the circuit, which usually has a complex character, becomes resistive and the phase shift between the voltage and current becomes zero. This phenomenon is the resonance of the circuit and the frequency at which it occurs is called the resonant frequency, expressed as [7]:

$$\begin{cases} X = \omega_0 L - \frac{1}{\omega_0 C} = 0 \to \omega_0 L = \frac{1}{\omega_0 C} \to f_0 = \frac{1}{2\pi\sqrt{LC}} \\ \omega_0 = 2\pi f_0 \end{cases} \quad (34)$$

where: ω_0 - resonance pulsation, f_0 - resonance frequency.

4.1 Total resonance of mutual coupled series-series oscillating circuits

Due to the supply constant frequency f_0 of the emission circuit, the values of the two circuits reactive elements will have no variations, the magnetic coupling M will remain constant; it can speak of a total resonance of circuits.

To obtain the maximum current in the secondary circuit, with constant voltage and frequency in the primary circuit, from the expression $\bar{I}_{1s} = \frac{\bar{U}_s}{\bar{Z}_{1s} - \frac{\bar{Z}_M{}^2}{\bar{Z}_{2s}}} = \frac{\bar{U}_s}{\bar{Z}_{2e}}$, $\bar{Z}_{2e}$ must be minimal [7].

The total resonance is obtained by tuning each circuit (primary and secondary) to the frequency of the primary voltage source [7].

$$\omega_1 = \omega_0 = \omega_2 \quad (35)$$

$$\begin{cases} X_{1s} = 0 \\ Z_{1s} = r_{1s} \end{cases}, \begin{cases} X_{2s} = 0 \\ Z_{2s} = r_{2s} \end{cases} \quad (36)$$

where: ω_1 and ω_2 - resonant pulsation of the primary and secondary circuit.

Developing equation (31), it is obtained:

$$Z_{2e}^2 = 2(r_{1s}r_{2s} - X_{1s}X_{2s}) + \frac{r_{1s}^2+X_{1s}^2}{t_2^2} + t_2^2(r_{2s}^2 + X_{2s}^2) \tag{37}$$

Replacing the term t_2^2 defined in equation (12) and substituting the values of $Z_{1s}^2 = r_{1s}^2 + X_{1s}^2$, $Z_{2s}^2 = r_{2s}^2 + X_{2s}^2$, $Z_M^2 = M\omega$, it is obtained [7]:

$$Z_{2e}^2 = 2(r_{1s}r_{2s} - X_{1s}X_{2s}) + \frac{Z_{2s}^2}{M^2\omega^2}(Z_{1s}^2) + \frac{M^2\omega^2}{Z_{2s}^2}Z_{2s}^2 \rightarrow$$

$$Z_{2e}^2 = 2(r_{1s}r_{2s}) + \frac{Z_{2s}^2Z_{1s}^2}{M^2\omega^2} + M^2\omega^2 \tag{38}$$

Applying to the equation (38) the resonance condition of oscillating circuits from equation (36), Z_{2e}^2 is expressed as [7]:

$$Z_{2e}^2 = 2r_{1s}r_{2s} + \frac{r_{1s}^2r_{2s}^2}{M^2\omega^2} + M^2\omega^2 \tag{39}$$

From equation (39), it is deduced that the secondary circuit maximum current is achieved when the equality is fulfilled [7]:

$$M^2\omega^2 = r_{1s}r_{2s}, \tag{40}$$

Fulfilling the condition from equation (40) in equation (39), the secondary circuit apparent impedance at resonance condition for maximum current, is expressed as:

$$Z_{2e_{rez}}^2 = 2r_{1s}r_{2s} + r_{1s}r_{2s} + r_{1s}r_{2s} \rightarrow Z_{2e_{rez}}^2 = 4r_{1s}r_{2s} \tag{41}$$

where: $Z_{2e_{rez}}$ - secondary circuit apparent impedance at full resonance for maximum current.

Consequently, from equation (41), the secondary circuit maximum current is achieved when the value of the secondary circuit equivalent impedance is equal to:

$$Z_{2e_{rez}} = 2\sqrt{r_{1s}r_{2s}} \tag{42}$$

The secondary circuit maximum current will be expressed as:

$$I_{2_{MM}} = \frac{U_s}{2\sqrt{r_{1s}r_{2s}}} \tag{43}$$

5. Designing and simulation models of wireless electricity emission circuits

The wireless transmission circuits diagrams and simulations were designed in the Proteus program. A virtual signal generator from the Proteus program library was used to generate control signals. Alternatives of constructive wireless transmission models will be presented. For all experiments a 12v d.c. power supply was used, so wireless systems can be powered from batteries.

5.1 Diagram with optocoupler and mosfet driver

To highlight a transition between the previous theoretical sections and the following simulated models, the values of the inductors and the capacities of the oscillating elements L and C were calculated to fulfill the resonance condition from the formula (34).

Thus for a frequency of 10 Mhz, the calories of components L and C at resonance will be L = 180 µH, C = 0.0000014 µF.

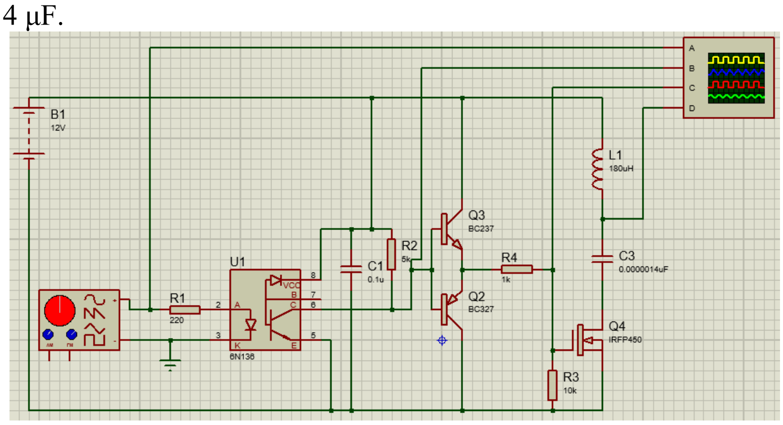

Figure 5. Diagram with optocoupler and mosfet driver.

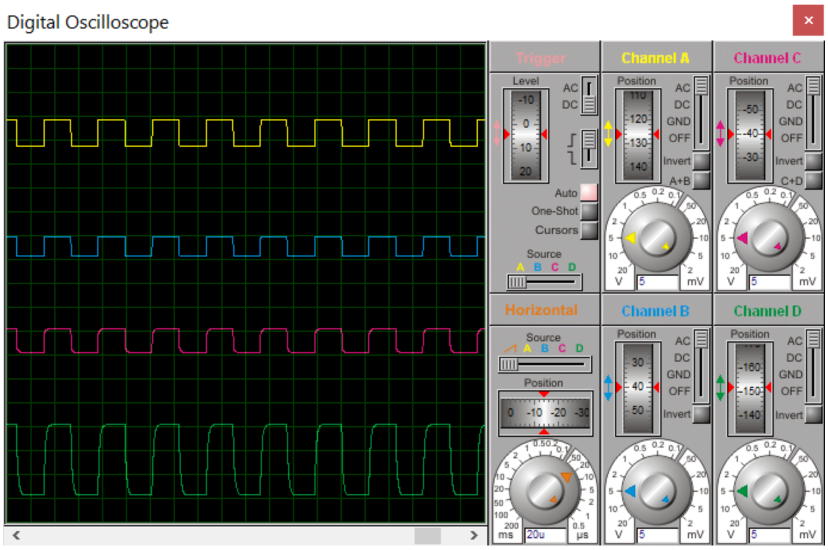

Figure 6. Waveform of Diagram with optocoupler and mosfet driver:
Channel A: signal generator, Channel B: optocoupler output to class B amplifier, Channel C: class B amplifier output to power mosfet transistor, Channel D: generated signal to LC oscilator.

It is recommended for applications that operate at frequencies up to 100KHz. It has the advantage of simplicity in design and construction, being used for low power. A Class B Amplifier was used as the MOSFET driver.

5.2 Diagram with dual high-speed, power mosfet drivers

In the following case, a resonant frequency of 1Mhz was chosen, for which the capacity value is modified compared to the previous experiment from C = 0.0000014 µF to C = 0.00014 µF.

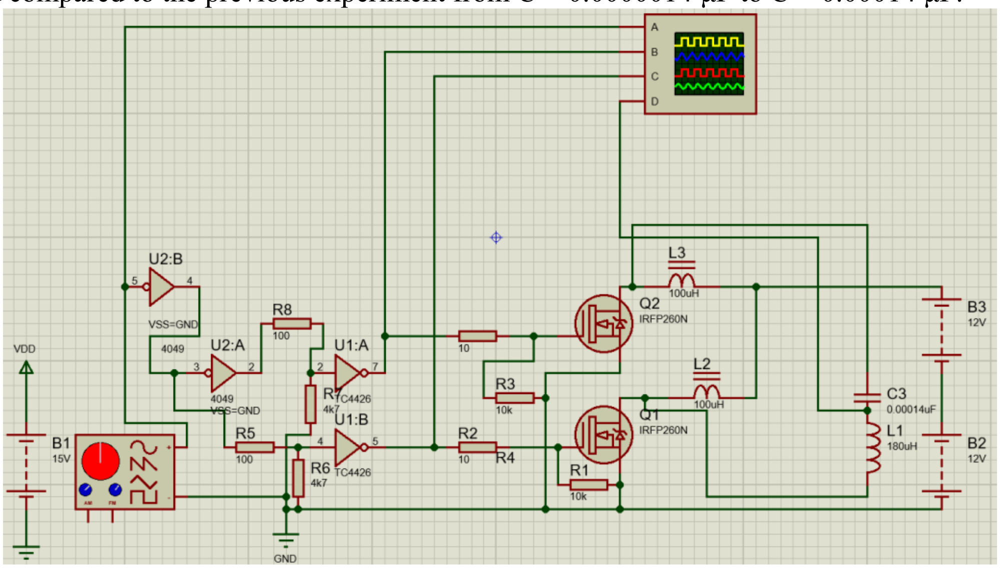

Figure 7. Dual high-speed power mosfet drivers.

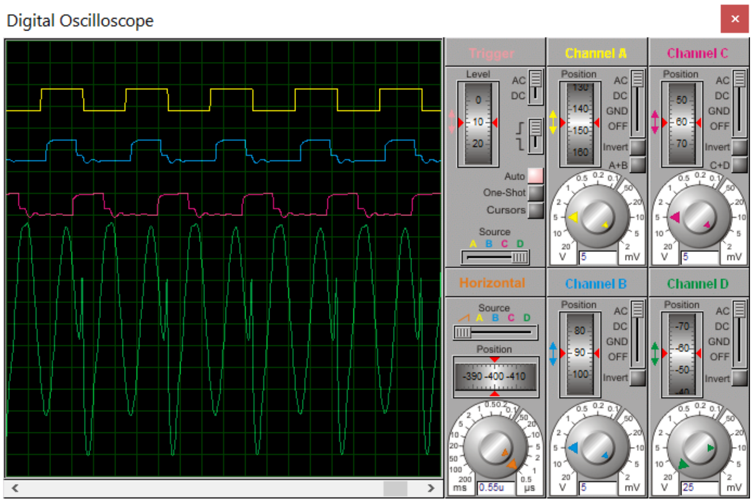

Figure 8. Waveform of Diagram with Dual high-speed, power mosfet drivers: Channel A: signal generator, Channel B: Dual high-speed drivers, Channel C: Dual high-speed drivers, Channel D: generated signal to LC oscilator.

This half-bridge system is used for higher wireless transmission powers, the two MOSFET transistors are controlled by a TC4426 driver. A major amplification of the voltage in the oscillating circuit is observed.

5.3 H bridge mosfet driver high frequency

For diagram designing the following main components were used, 4 IRFP240 MOSFET transistors, as power driver - IR2110, and a hex inverter 74ac14N to transform slowly changing input signals into sharply defined and level shifting. This circuit can be used at frequencies above 1MHz, at much higher powers.

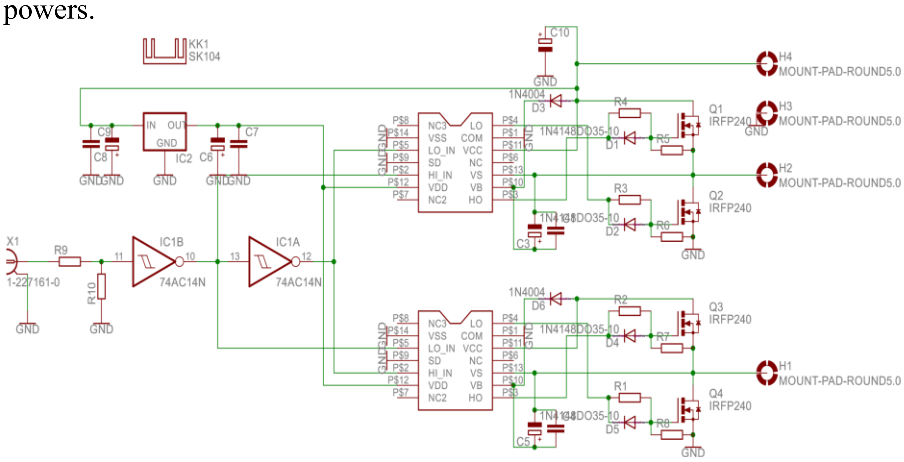

Figure 9. H bridge mosfet driver high frequency [9].

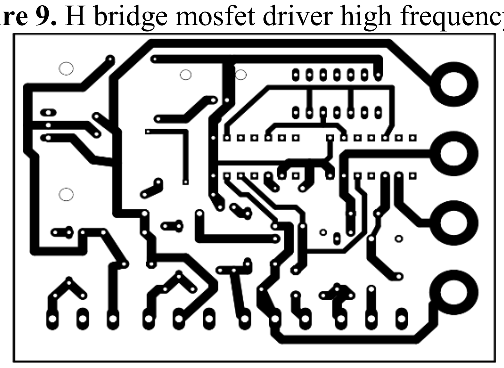

Figure 10. PCB - H bridge mosfet driver high frequency.

6. Conclusions

All theoretical aspects for a wireless energy transmission system presented in this paper must be taken into consideration, the dimensioning of the oscillating emission and reception systems represents a motivation for good efficiency in wireless power transmission.

The design of an electronic diagram for a wireless emission system depends on the needs. It can be used the mono-alternating diagrams controlled by an optocoupler but it is limited in frequency command signal due to the phototransistors which can distort the control signal at high frequencies figure 5, another disadvantage is the limitation in power. A more complex alternative for wireless emission system diagrams is the dual high-speed systems, with power MOSFET drivers figure 7, presents the advantage of high-frequency operation in good condition and greater power in emission coil than the example from figure 5.

For a higher level of accuracy, an attempt was made to design a more complex scheme with hex inverter, driver, and H-bridge; this diagram is preferred for complex wireless transmission systems, high stability applications.

In conclusion, this paper presents the theoretical aspects related to the design of series-series high-frequency oscillators used in wireless power transmission. At the same time, two electrical diagrams are presented, figures 5 and 7, which have very good simulated results, and a third electrical diagram, which is still in the unsimulated stage.

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