Wireless power transmission based on resonant electrical coupling

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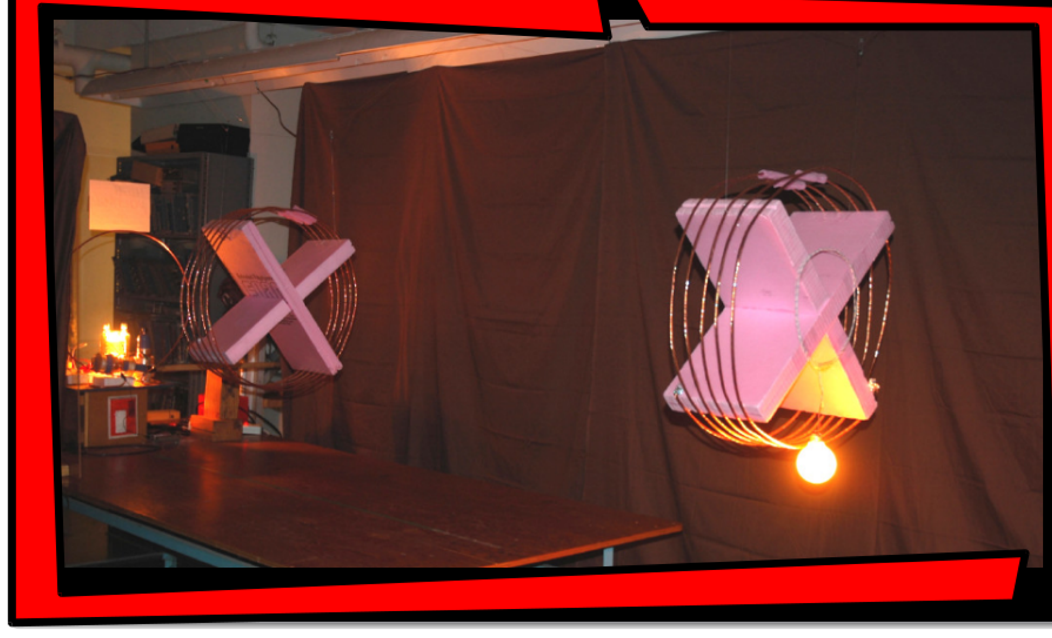
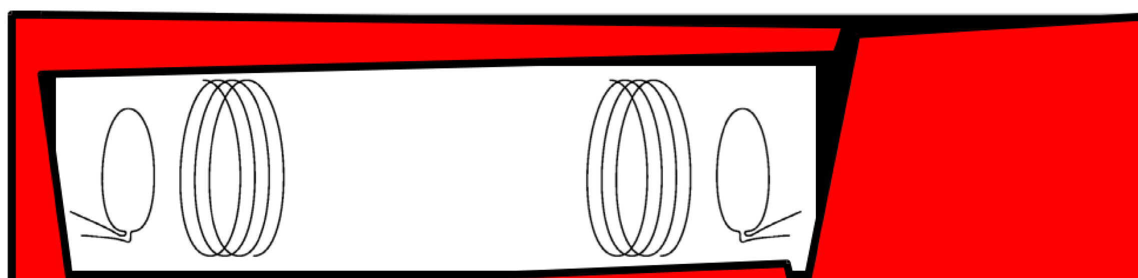
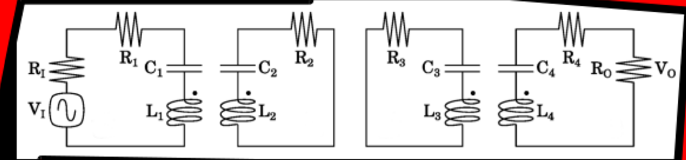
Resonant magnetic coupling (2007): 4 coils (largest diameter of 60 cm, cross-sectional diameter of 6 mm), a 60 W light bulb, distance of 2 m, efficiency of 40%

Balanced trade-off between efficiency, range, simplicity, size and power transfer capability







$$\frac{V_O}{V_I}=\frac{-jw^3M_{12}M_{23}M_{34}R_O}{M_{12}{}^2M_{34}{}^2w^4+Z_1Z_2Z_3Z_4+w^2\left(M_{12}{}^2Z_3Z_4+M_{23}{}^2Z_1Z_4+M_{34}{}^2Z_1Z_2\right)}$$

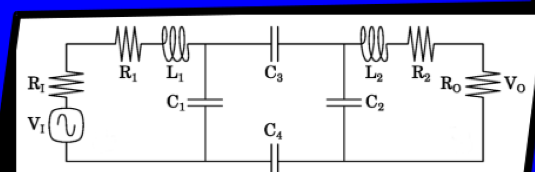
$$Z_1=R_I+R_1-\frac{j}{wC_1}+jwL_1$$

$$Z_2=R_2-\frac{j}{wC_2}+jwL_2$$

$$Z_3=R_3-\frac{j}{wC_3}+jwL_3$$

$$Z_4=R_O+R_4-\frac{j}{wC_4}+jwL_4$$

$$M_{12}=k_{12}\sqrt{L_1L_2}$$
$$M_{23}=k_{23}\sqrt{L_2L_3}$$
$$M_{34}=k_{34}\sqrt{L_3L_4}$$



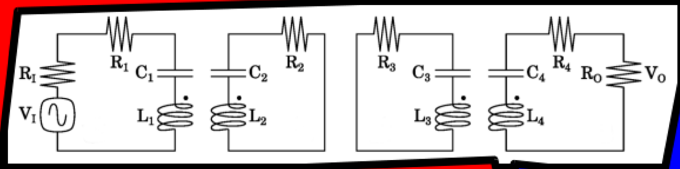
$$\frac{V_O}{V_I}=\frac{R_OZ_3}{Z_1Z_2\left(Z_3\left[jw(C_1+C_2)+\frac{1}{Z_1}+\frac{1}{Z_2}\right]-w^2C_1C_2+jw\left[\frac{C_1}{Z_2}\frac{C_2}{Z_1}\right]+\frac{1}{Z_1Z_2}\right)}$$

$$Z_1=R_I+R_1+jwL_1$$

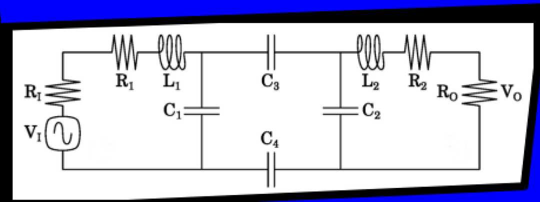
$$Z_2=R_O+R_2+jwL_2$$

$$Z_3=jw\frac{C_3C_4}{C_3+C_4}$$

Available power gain: $\frac{P_O}{P_A}=\frac{4R_I}{R_O}\left|\frac{V_O}{V_I}\right|^2$

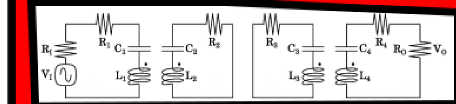


Parameter	Value
R_I, R_O	50 Ω
R_1, R_4	2 Ω
R_2, R_3	10 Ω
L_1, L_4	1 μH
L_2, L_3	28 μH
C_1, C_4	140 pF
C_2, C_3	5 pF
K_{12}, k_{34}	0.1

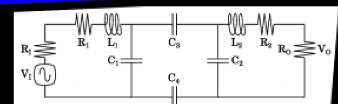


Parameter	Value
R_I, R_O	50 Ω
R_1, R_2	12 Ω
L_1, L_2	28 μH
C_1, C_2	5 pF

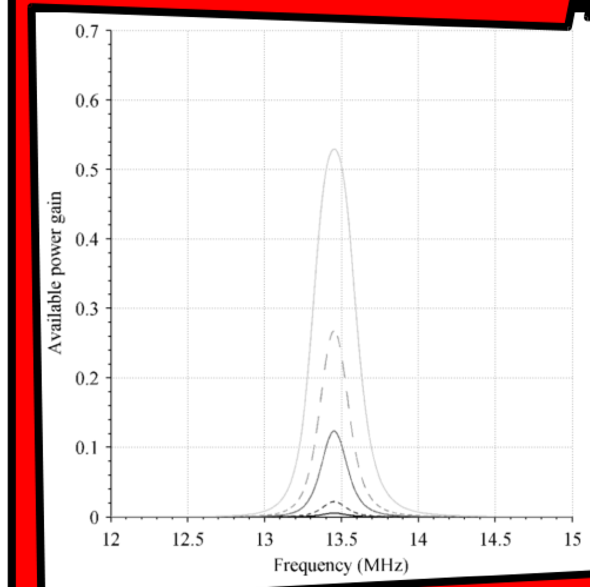
$C_4=C_3$

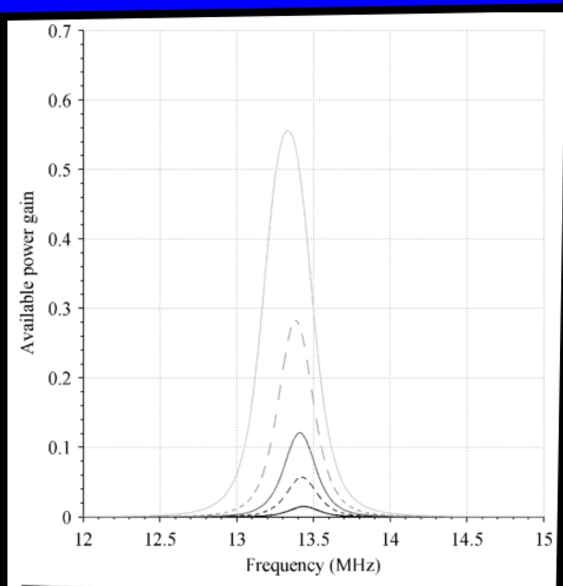


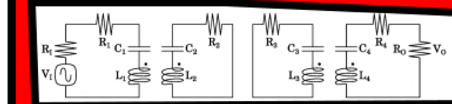
k_{23}	0.001	0.002	0.005	0.008	0.015



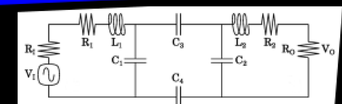
C_3 (pF)	0.02	0.04	0.06	0.1	0.18



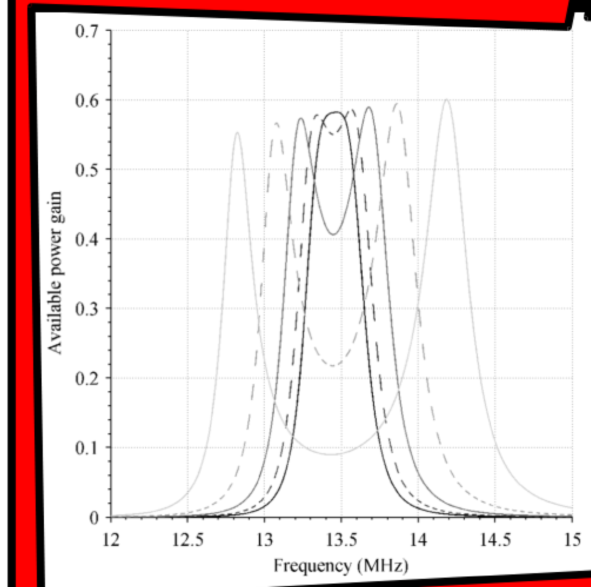


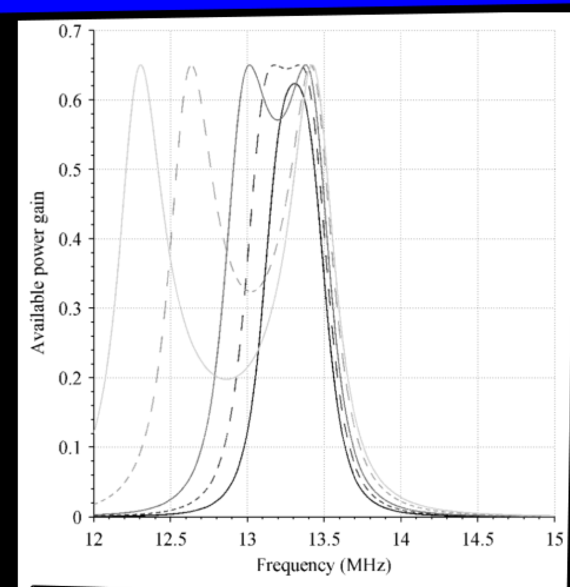


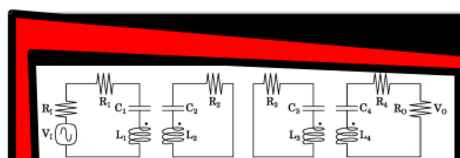
k_{23}	0.02	0.026	0.038	0.06	0.1



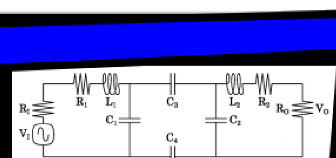
C_3 (pF)	0.22	0.3	0.4	0.7	1







$R_1=R_2=R_3=R_4=0$



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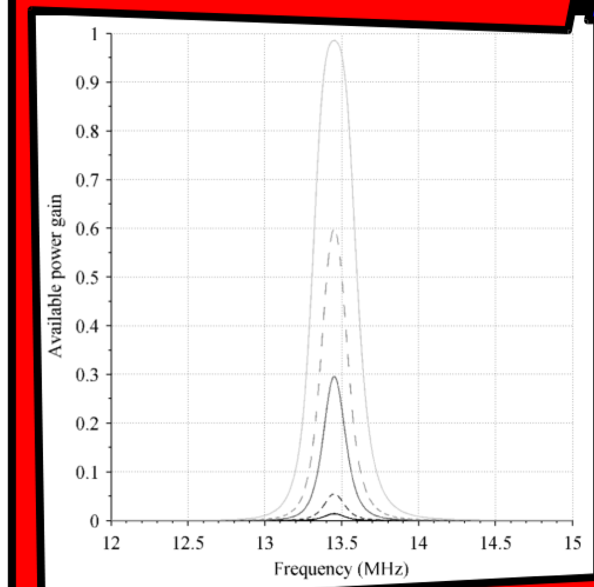

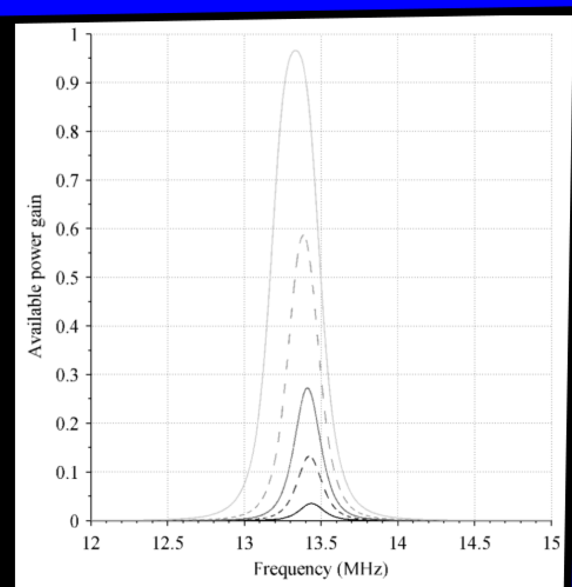

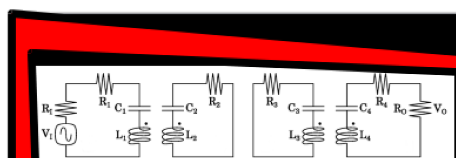

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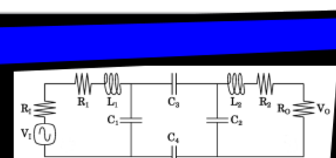

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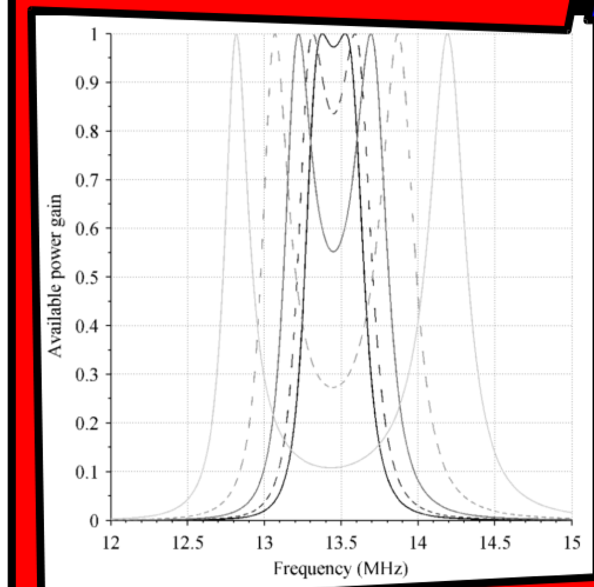
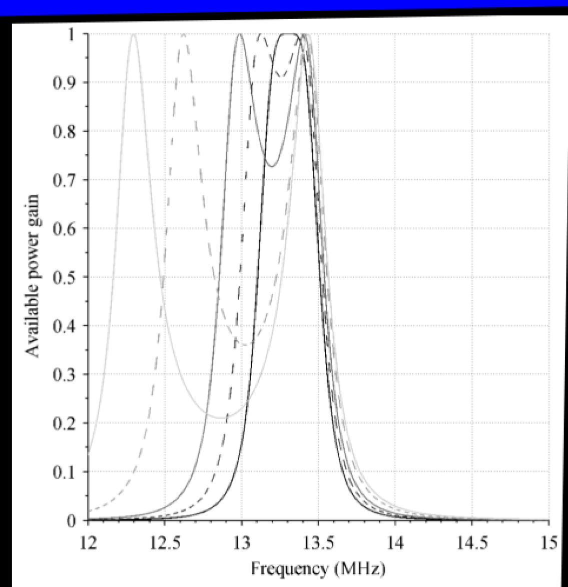
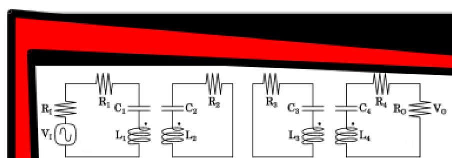
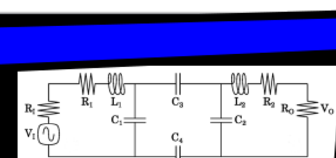






$L_2=0.9L_3$



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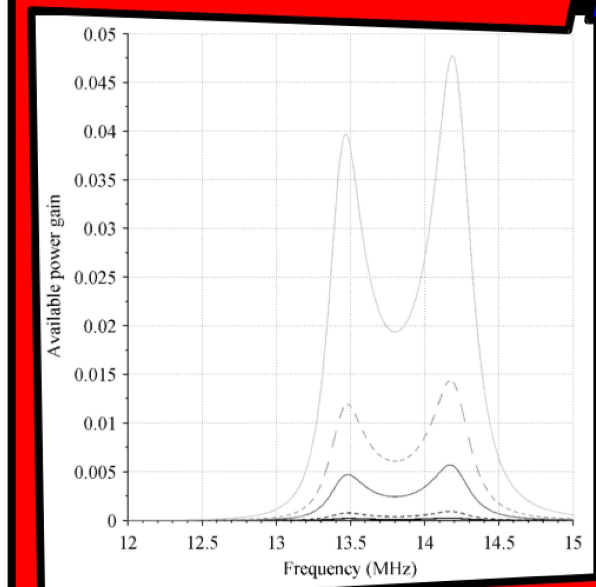

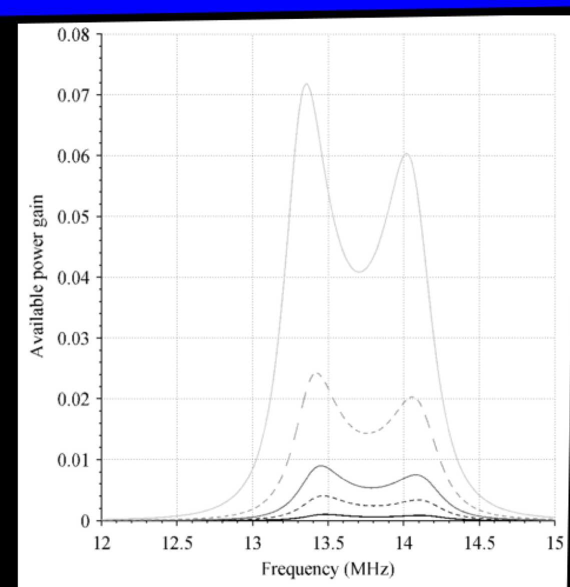

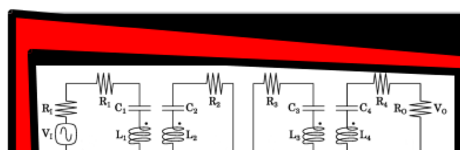

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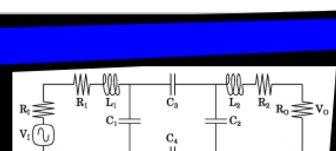

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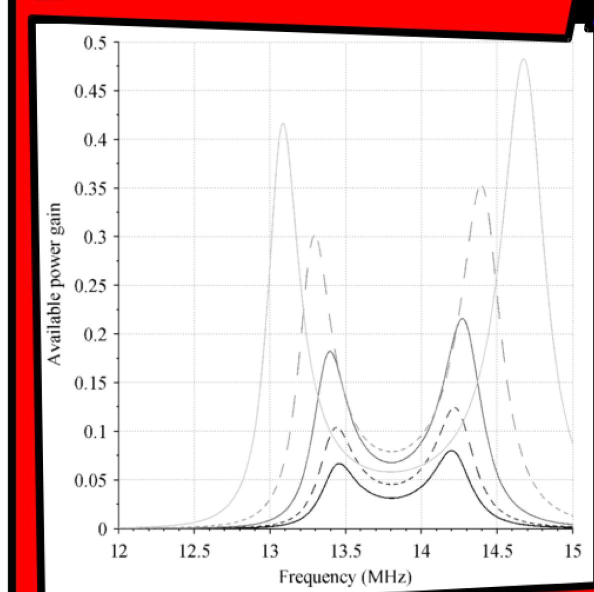
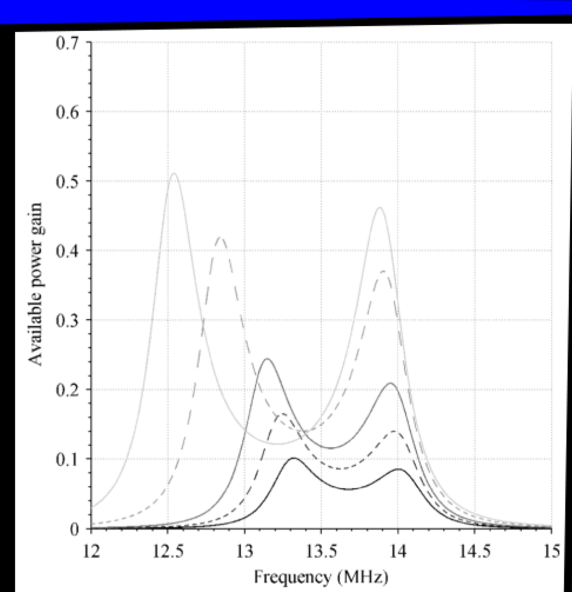
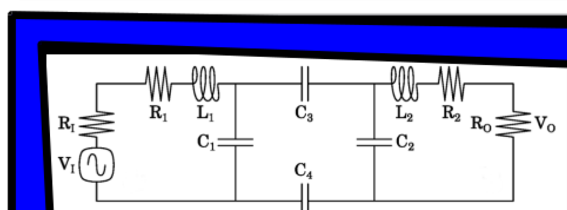
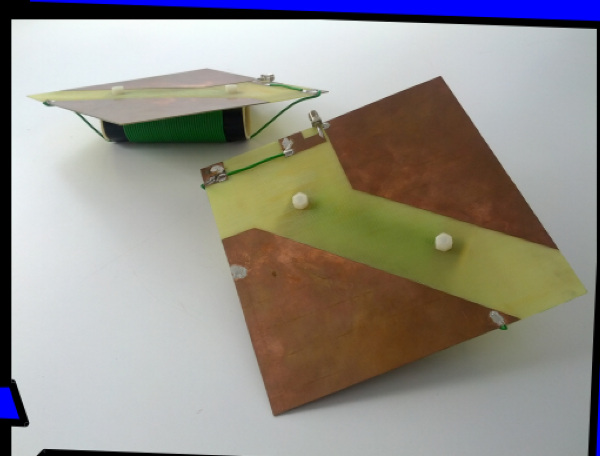
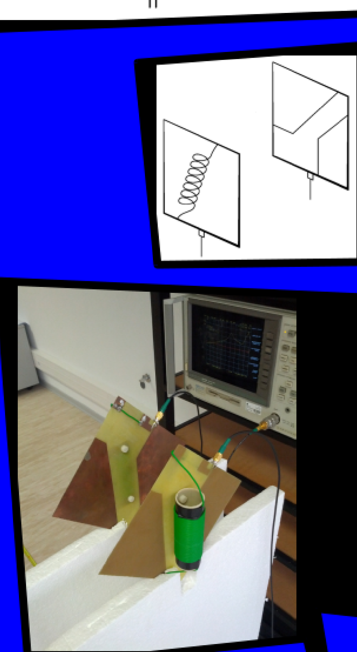


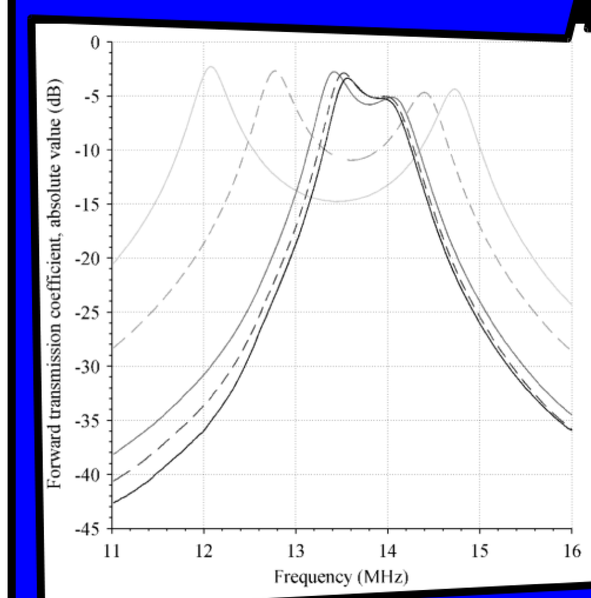


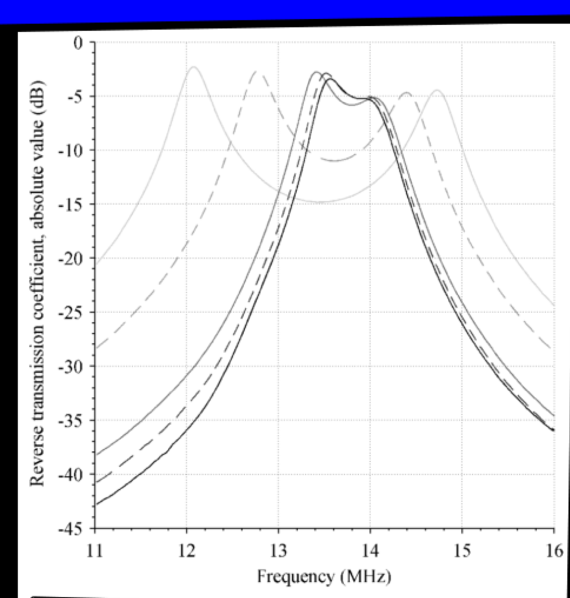






distance (cm)	10	20	60	90	500





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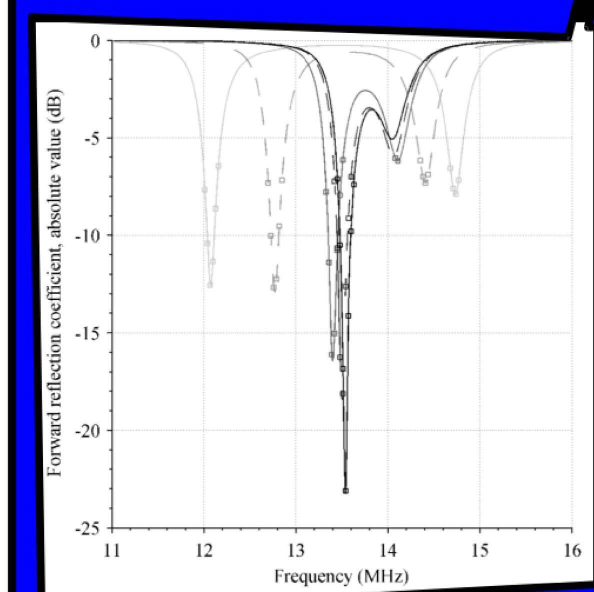
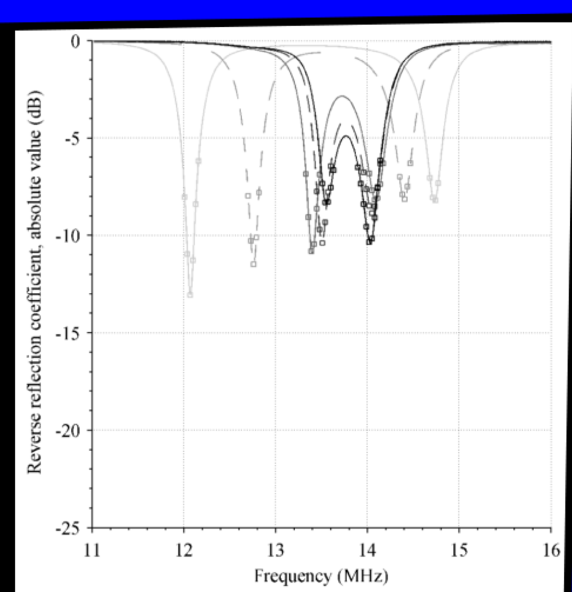
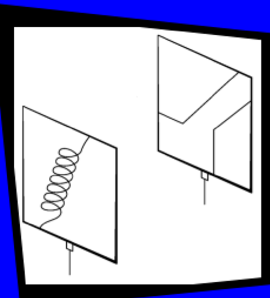
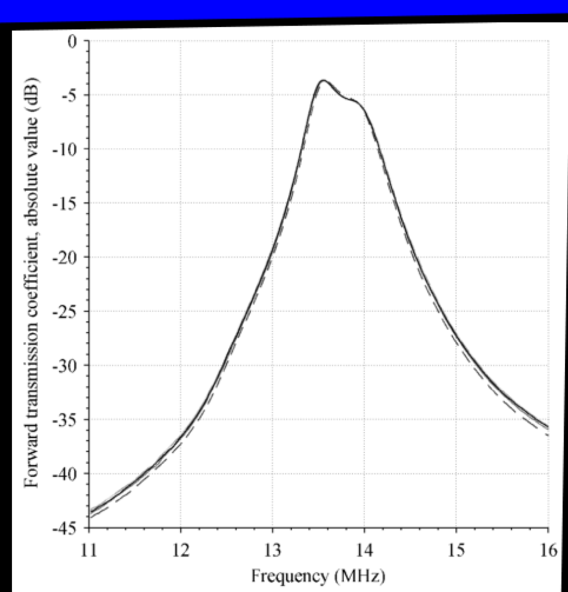




angle (°)	0	40	90	180	270



distance (cm)	500



Conclusions:

Systems based on resonant magnetic coupling are currently very popular in the literature, systems based on resonant electrical coupling are not;
The duality between resonant magnetic coupling and resonant electrical coupling is quite noticeable;
It was not yet possible to obtain a complete match between experimental results and theory, but some key aspects were confirmed.

Existing technology – resonant magnetic coupling (🔴), proposal – resonant electrical coupling (🔵), conclusions (🟡)

COST — European Cooperation in Science and Technology; European Science Foundation; WIPE COST IC1301; FCT Fundação para a Ciência e a Tecnologia, Ministério da Educação e Ciência; instituto de telecomunicações