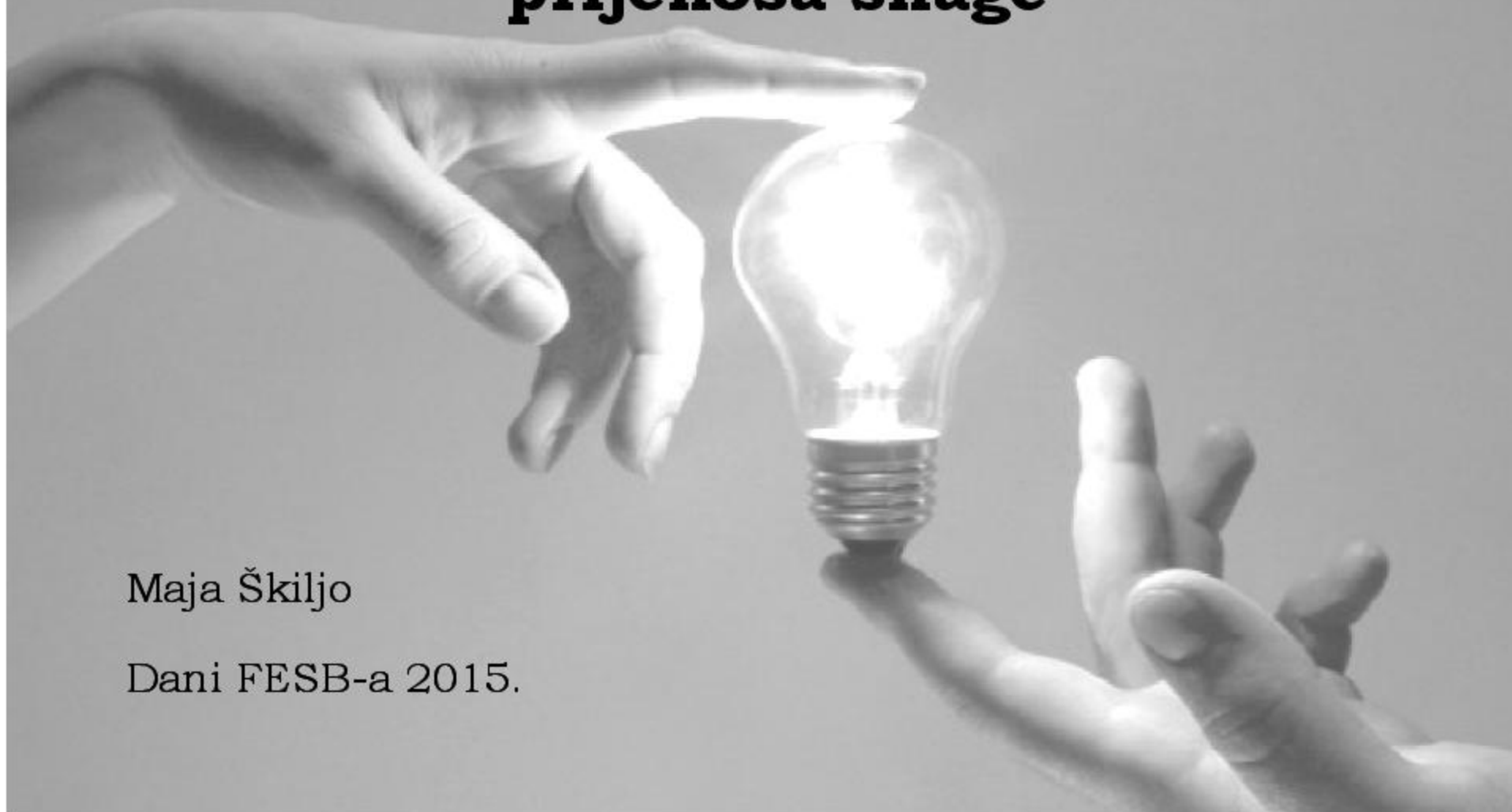




# Optimizacija sustava bežičnog prijenosa snage

Maja Škiljo

Dani FESB-a 2015.





# Uvod

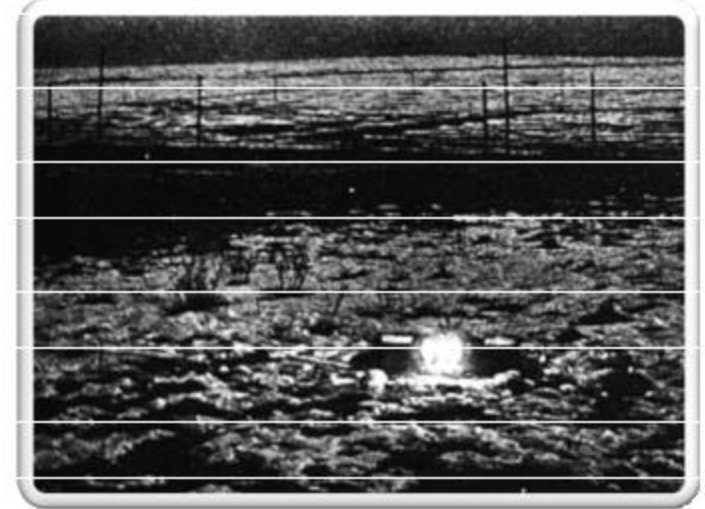
(fundamentalna eksperimentalna istraživanja)



a)



b)



c)

## **Teslini eksperimenti u Colorado Springsu:**

- a) *fotografija izmjene električne energije između Teslinih zavojnica*
- b) *rezonantni bežični prijenos na srednju udaljenost i*
- c) *na kratku udaljenost između Teslinog Colorado Springs odašiljača i petlje.*

# Uvod

(standard, tehnologija i primjena)

- **Sustavi bežičnog prijenosa energije:**

- prienos u bliskom induktivnom polju antena
- prienos u bliskom zračćem polju antena



**Wireless Power Consortium: Qi standard**



**Witricity:**

- “park-and-charge” system
- wireless charging and direct powered systems



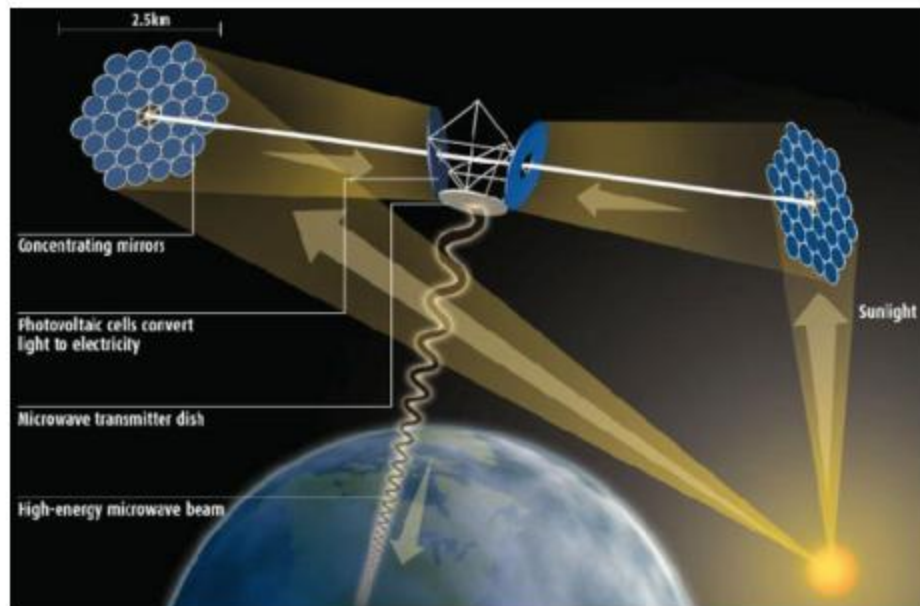
Alliance for Wireless Power (A4WP) Rezence™  
specification for consumer electronics devices

# Uvod

(standard, tehnologija i primjena)

- prijenos u dalekom polju antena

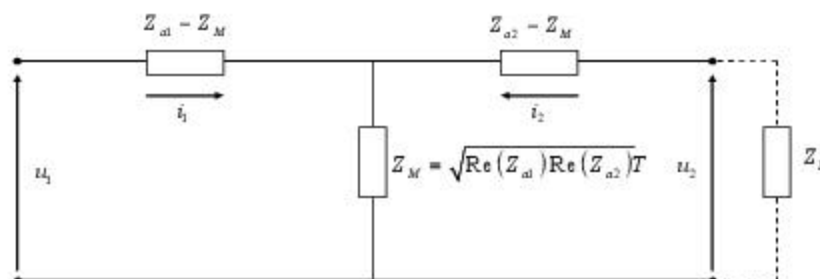
prijedlog standarda za 'Solar power satellite systems' [1]



[1] K. Hashimoto, "Frequency allocations of solar power satellite and international activities," in *Proc. IWS-IWPT 2011*, 83–86, May 2011.

# Električni male antene i njihova sprega

(Antenski model na temelju teorije sfernih modova)



$$\mathbf{Z} = \begin{bmatrix} Z_{a1} & \sqrt{\text{Re}(Z_{a1})\text{Re}(Z_{a2})}T \\ \sqrt{\text{Re}(Z_{a1})\text{Re}(Z_{a2})}T & Z_{a2} \end{bmatrix}$$

- Koeficijent prijenosa snage između dvije različite antene:

$$T = \sqrt{\eta_1 \eta_2} \frac{1 + \sqrt{\alpha_1 \alpha_2}}{\sqrt{(1 + \alpha_1)(1 + \alpha_2)}} \cdot \left( A'_{10,10} + \frac{\sqrt{\alpha_1} + \sqrt{\alpha_2}}{1 + \sqrt{\alpha_1 \alpha_2}} B'_{10,10} \right)$$

$$A'_{10,10} = \frac{3}{2} \cos \theta_1 \left\{ -\sin^2 \theta_0 \frac{1}{jk r_0} + (3 \cos^2 \theta_0 - 1) \times \left[ \frac{1}{(jk r_0)^2} + \frac{1}{(jk r_0)^3} \right] \right\} e^{-j k r_0} + \frac{3}{4} \sin \theta_1 \cos(\phi_1 - \phi_0) \sin 2\theta_0 \times \left\{ \frac{1}{jk r_0} + 3 \left[ \frac{1}{(jk r_0)^2} + \frac{1}{(jk r_0)^3} \right] \right\} e^{-j k r_0}$$

$$B'_{10,10} = -j \frac{3}{2} \sin \theta_1 \sin(\phi_1 - \phi_0) \sin \theta_0 \times \left\{ \frac{1}{jk r_0} + \frac{1}{(jk r_0)^2} \right\} e^{-j k r_0}$$

# Električki male antene i njihova sprega

(Antenski model na temelju teorije sfernih modova)

## Maksimalni prijenos snage

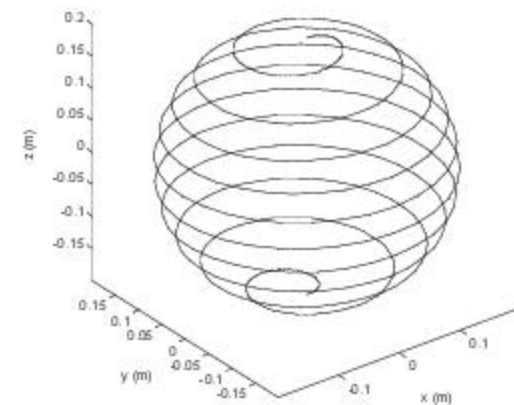
- Ulazna impedancija odašiljačke antene:  $Z_{in} = Z_{a1} - \frac{Z_M^2}{Z_{a2} + Z_L}$
- Efikasnost prijenosa snage PTE:  $PTE = \frac{P_L}{P_{in}} = \left| \frac{Z_M}{Z_{a2} + Z_L} \right|^2 \frac{\text{Re}(Z_L)}{\text{Re}(Z_{in})}$
- Postupak prilagođenja:  $\frac{\partial PTE}{\partial [\text{Im}(Z_L)]} = 0$        $\frac{\partial PTE}{\partial [\text{Re}(Z_L)]} = 0$
- Optimalni teret i maksimalni PTE:

$$X_L^{opt} = \frac{1}{2} \text{Re}[Z_{a2}] \text{Im}[T^2] - \text{Im}[Z_{a2}] \quad R_L^{opt} = \text{Re}[Z_{a2}] \sqrt{1 - \text{Re}[T^2]} - \frac{1}{4} \text{Im}^2[T^2]$$

$$PTE_{\text{maks}} = \frac{|T|^2}{2 - \text{Re}[T^2] + \sqrt{4 \{1 - \text{Re}[T^2]\} - \text{Im}^2[T^2]}}$$

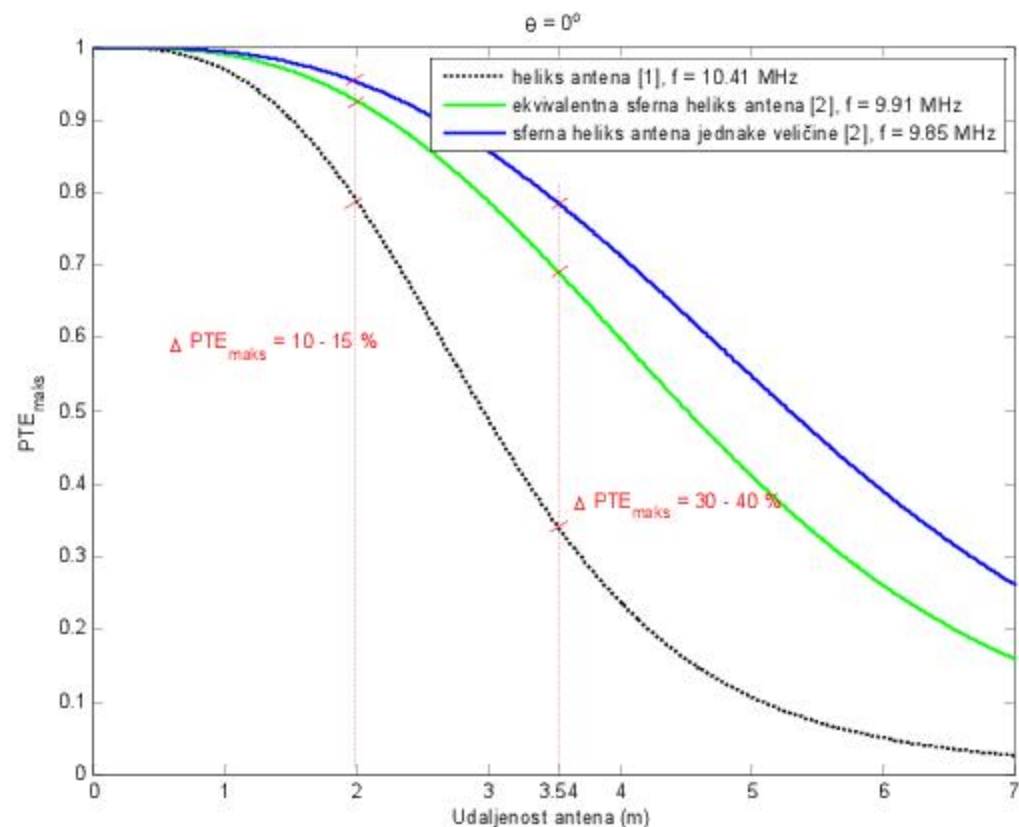
# Proračun sferne helikoidne antene za bežični prijenos snage

- **Osnovni zahtjevi za primjenu u bežičnom prijenosu snage:**
  - što veća efikasnost zračenja električki male antene
  - što niža rezonantna frekvencija
- **Sferna helikoidna antena**
  - višestruko savijanje antenskih izdanaka
  - geometrija koja najbolje iskoristava zadani volumen
  - induktivno napajanje
- **Utjecaj propagacijskog kanala na performanse bežičnog prijenosa**
  - utjecaj idealnog i realnog tla
  - problem elektromagnetske kompatibilnosti sustava



## Poboljšanje PTE-a predloženim dizajnom SHA

- Cilindrična heliks antenna,  $r = 30$  cm,  $h = 20$  cm,  $ka = 0.064$ ,  $\eta_{rad} = 21$  %
- Četverostruko savijena sferna heliks antenna ekvivalentna cilindričnoj prema Wheeleru,  $r = 20.8$  cm,  $ka = 0.044$ ,  $\eta_{rad} = 51$  %
- Četverostruko savijena sferna heliks antenna jednake veličine sfere kao i cilindrična,  $r = 30$  cm,  $ka = 0.064$ ,  $\eta_{rad} = 68$  %

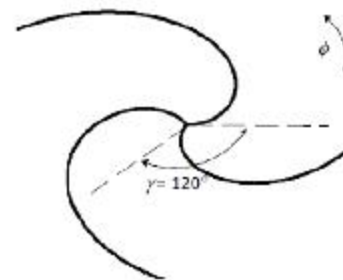
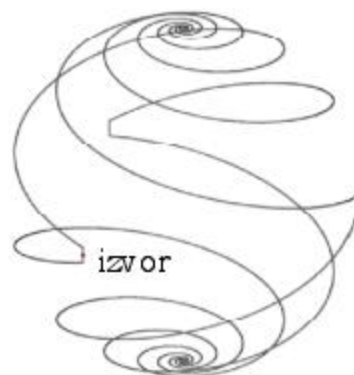
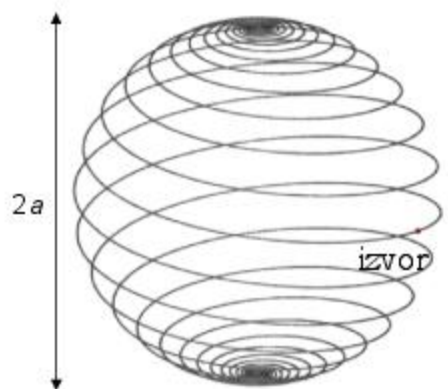


- [1] Kurs A., A. Karalis, R. Moffat, J. D. Joannopoulos, P. Fisher and M. Soljačić, "Wireless power transfer via strongly coupled magnetic resonances", *Sci.*, Vol. 317, 83-86, 2007.
- [2] Škiljo, M., Blažević, Z., "Increasing the radiation efficiency and resistance of electrically small spherical helical antenna for wireless power transfer", *Proceedings of SoftCOM 2013*, 1-5, 18-20 Sept. 2013.

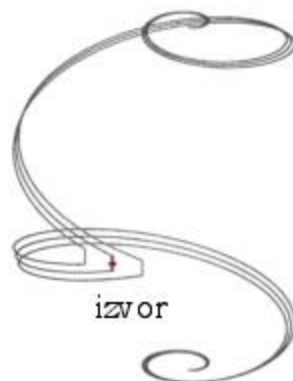
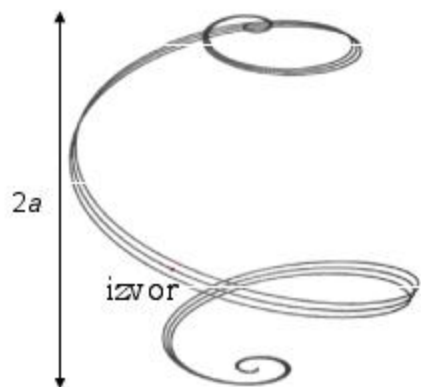


# Proračun sferne helikoidne antene za bežični prijenos snage

(Višestruko savijena sferna helikoidna antena)



*a) EA-SHA geometrija*

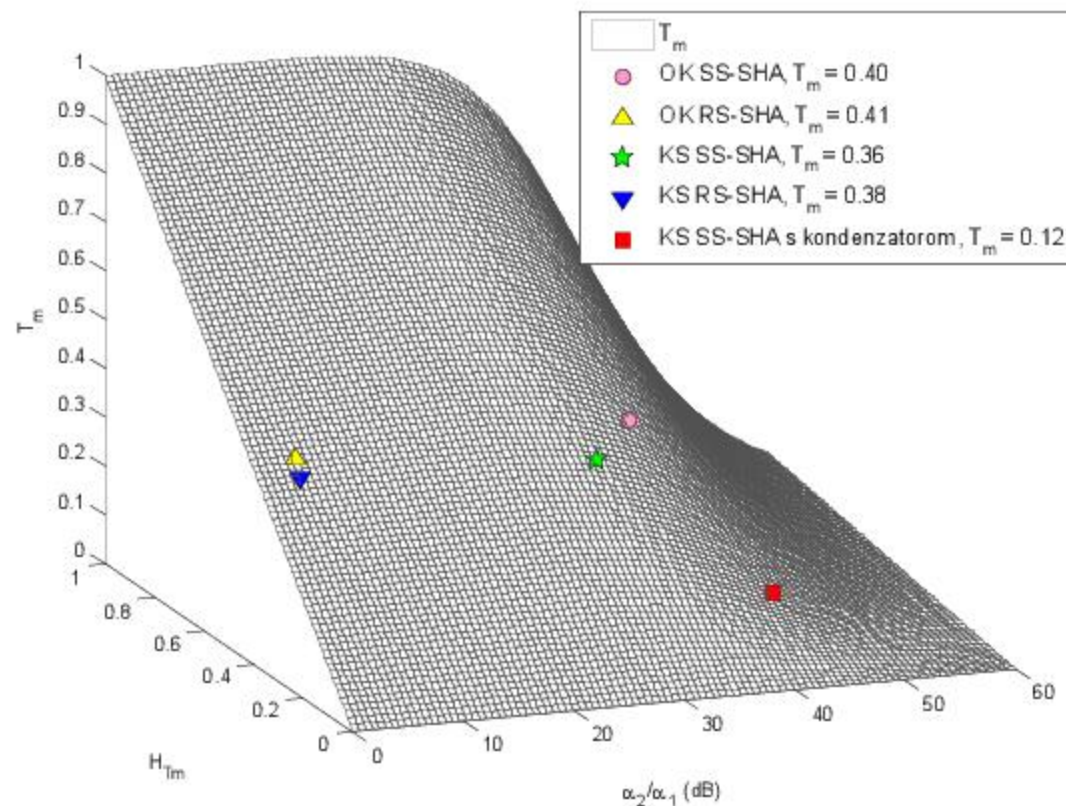


*b) CA-SHA geometrija*

*Primjeri izdvojenih geometrija SHA s tri izdanka.*

# Proračun sferne helikoidne antene za bežični prijenos snage

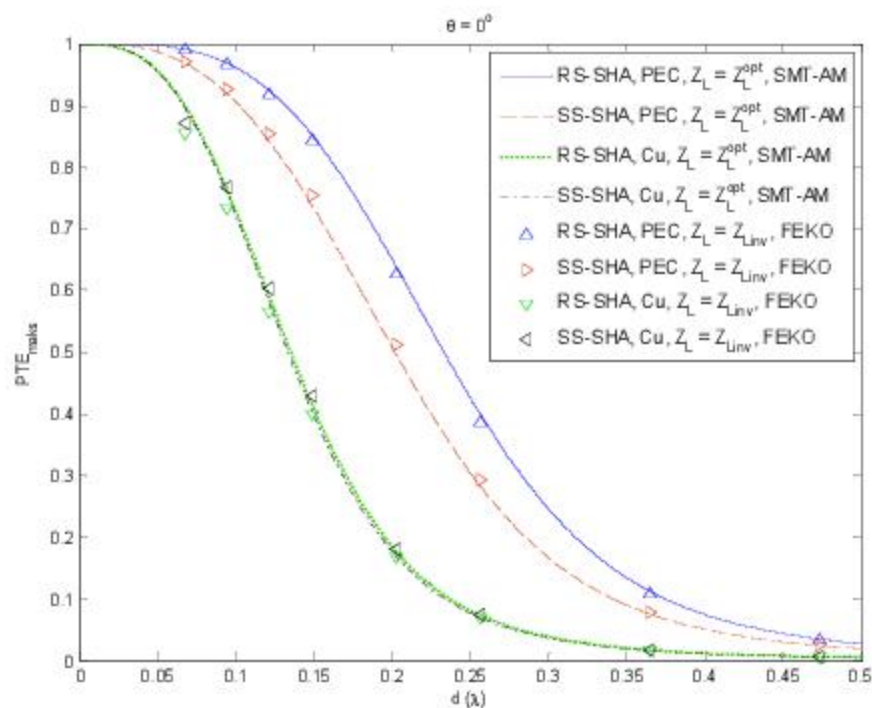
(Višestruko savijena sferna helikoidna antena)



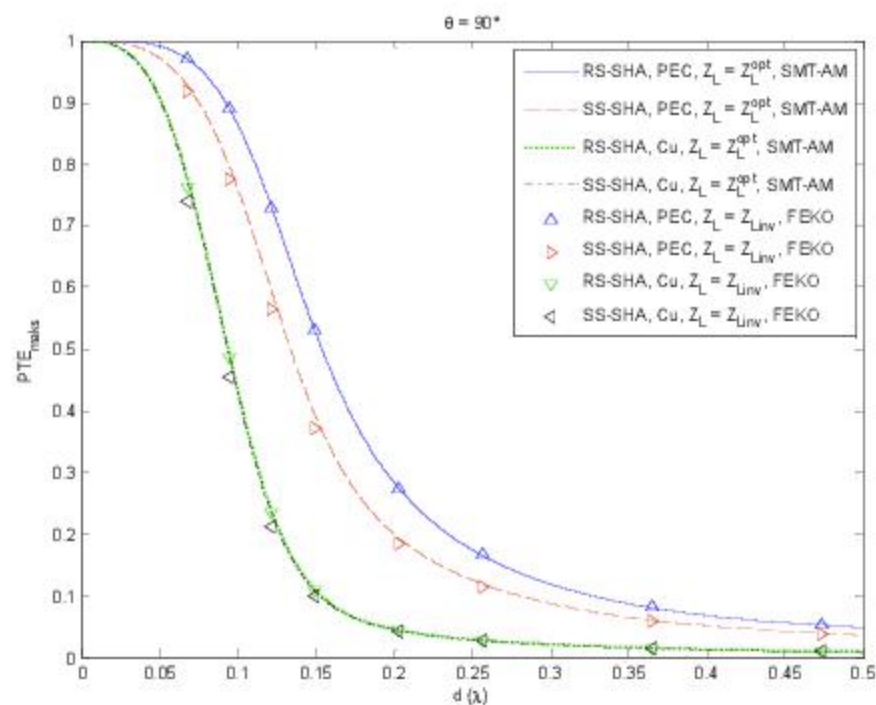
*Koeficijent  $T_m$  u ovisnosti o faktoru efikasnosti zračenja  $H_{T_m}$  i neusklađenosti modova  $\alpha_2/\alpha_1$  za **odašiljač CARS-SHA s tri izdanka.***

# Proračun sferne helikoidne antene za bežični prijenos snage

(Višestruko savijena sferna helikoidna antena)



a) koaksijalni položaj antena

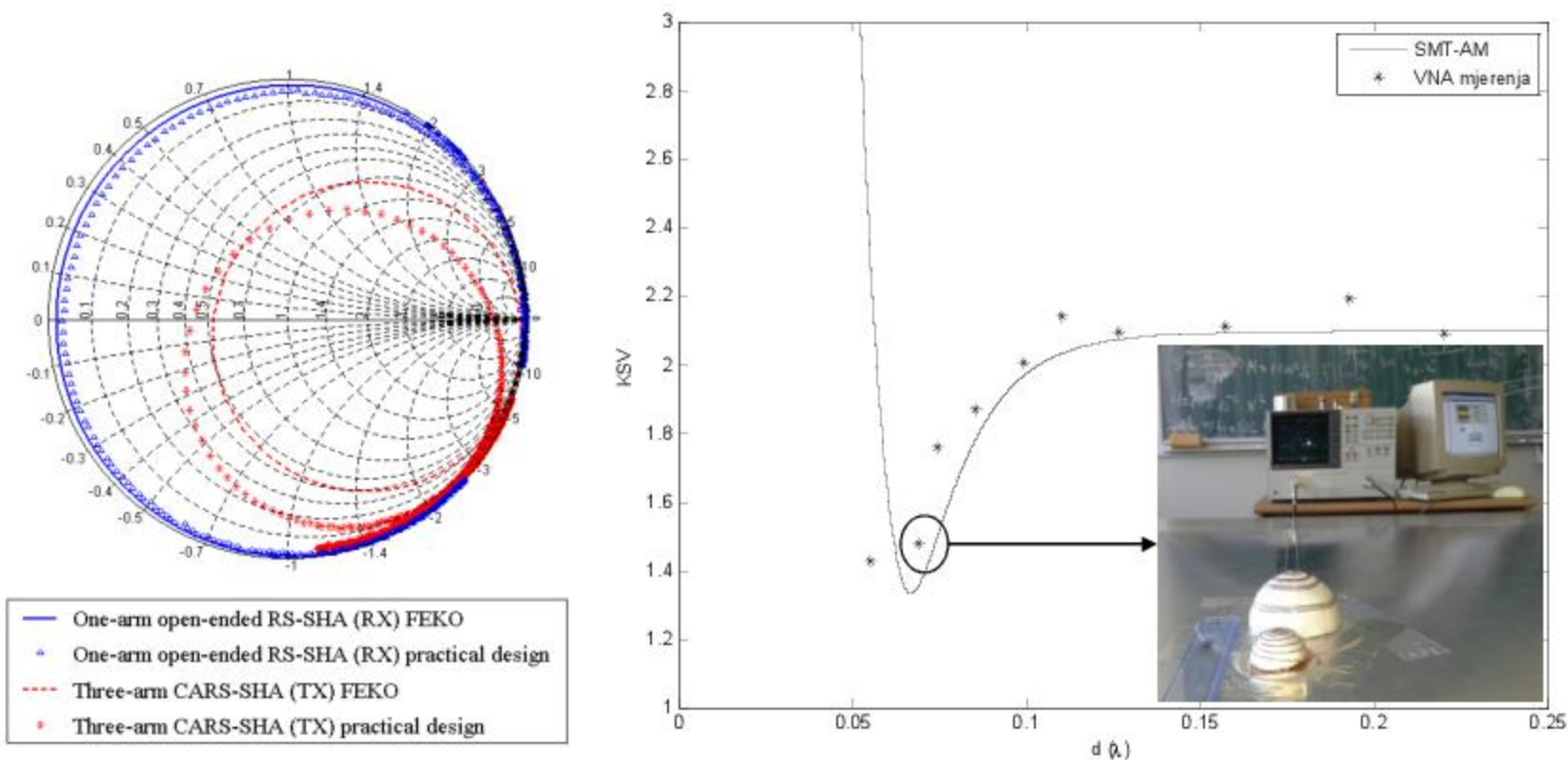


b) kolinearni položaj antena

$PTE_{maks}$  za OK SHA prijernike i odašiljač CARS-SHA s tri izdanka na 162.3 MHz.

# Proračun sferne helikoidne antene za bežični prijenos snage

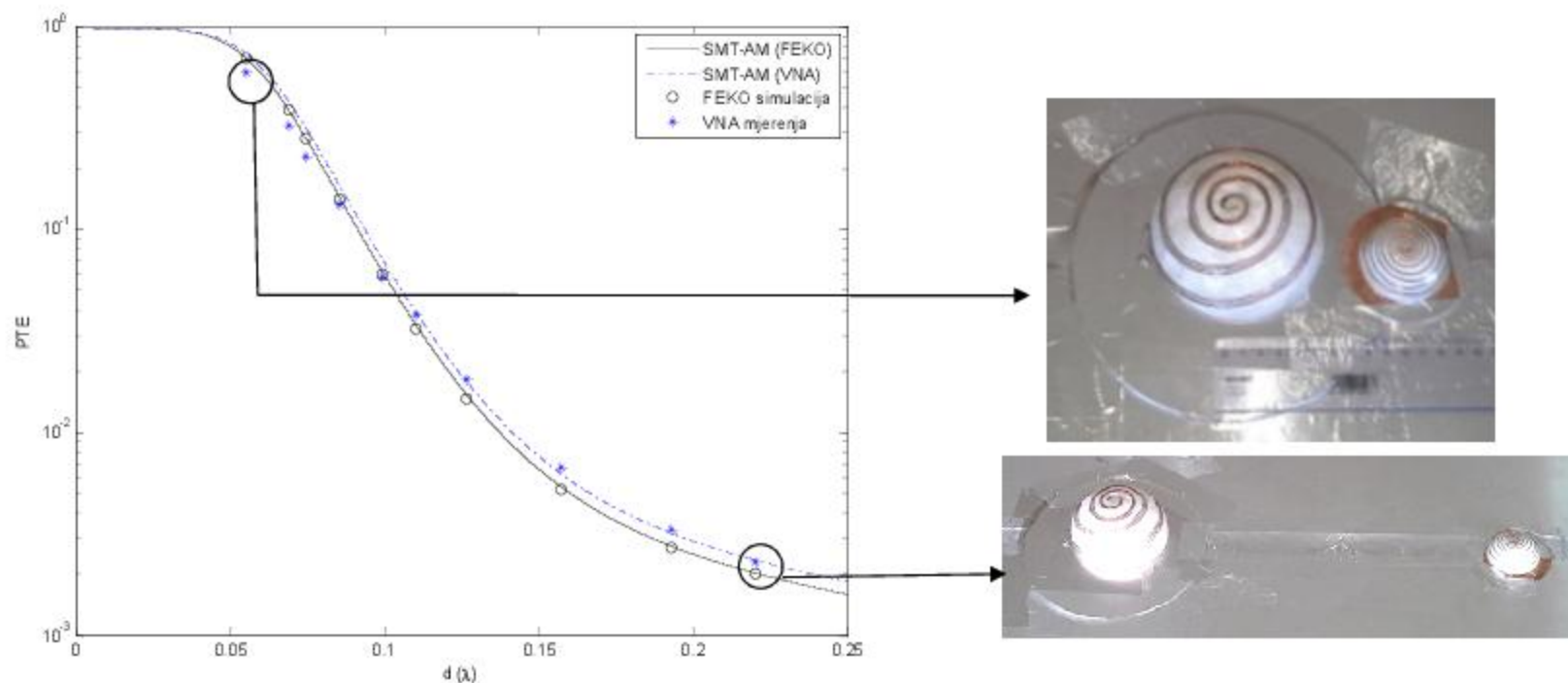
(Višestruko savijena sferna helikoidna antena)



M. Škiljo and Z. Blažević, "Spherical helices for resonant wireless power transfer", International Journal of Antennas and Propagation, 2013, Vol. 2013, 1-12, 2013.

# Proračun sferne helikoidne antene za bežični prijenos snage

(Višestruko savijena sferna helikoidna antena)

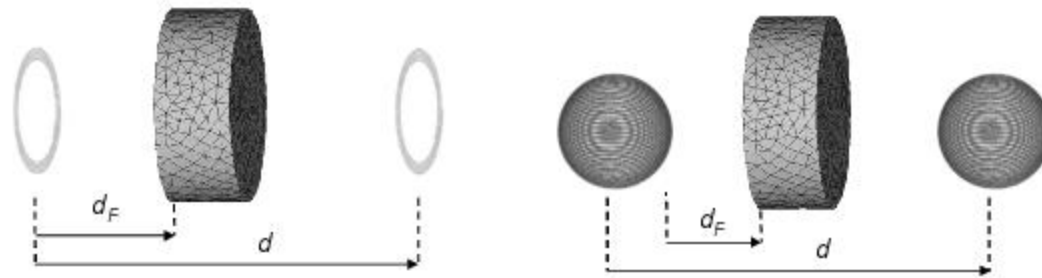


Izmjereni PTE između izrađenih SHA i njegova usporedba sa simulacijom i teorijom na  $f_{rez} = 165.3$  MHz.

# Utjecaj propagacijskog kanala na performanse bežičnog prijenosa

(Problem interakcije ljudi i WPT sustava)

- **Utjecaj ljudi na efikasan WPT sustav** s fiksnim i optimalnim opterećenjem i **procjena izloženosti ljudi** efikasnom i neefikasnom WPT sustavu

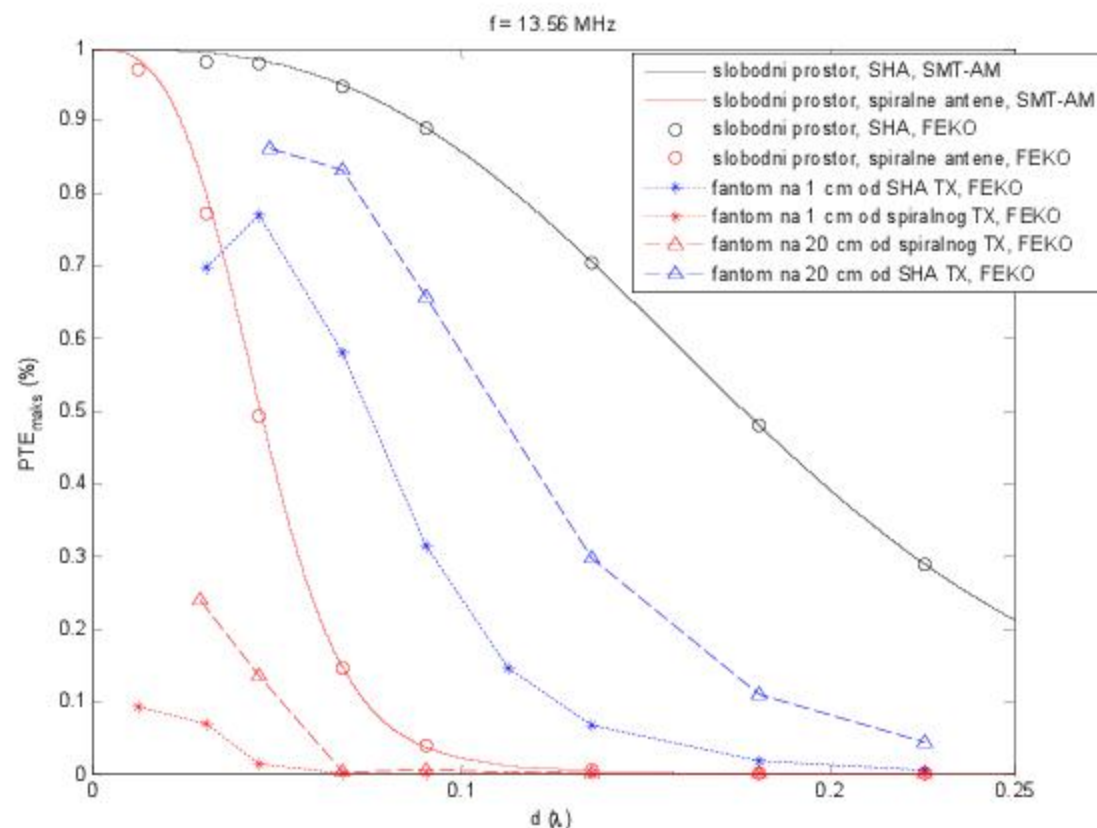


$f = 13.56 \text{ MHz}$	$d_F \text{ (cm)}$	$\eta_{rad} \text{ (\%)}$	$Z_{in} \text{ (\Omega)}$	$P_{od, 10g-SAR} \text{ (W)}$
Spiralne antene	$\infty$	2.14	$0.71 + j0.59$	-
	1	0.02	$113.68 + j157.711$	13.32
	20	0.25	$5.93 - j0.37$	53.10
SS-SHA s četiri izdanka	$\infty$	69.02	$3.24 + j0.36$	-
	1	1.08	$144.01 + j1195.34$	46.65
	20	7.72	$30.80 + j123.23$	64.68

*Karakteristike spiralne antene i SS-SHA s četiri izdanka u slobodnom prostoru i pod utjecajem fantoma na udaljenosti  $d_F$  od odašiljača.*

# Utjecaj propagacijskog kanala na performanse bežičnog prijenosa

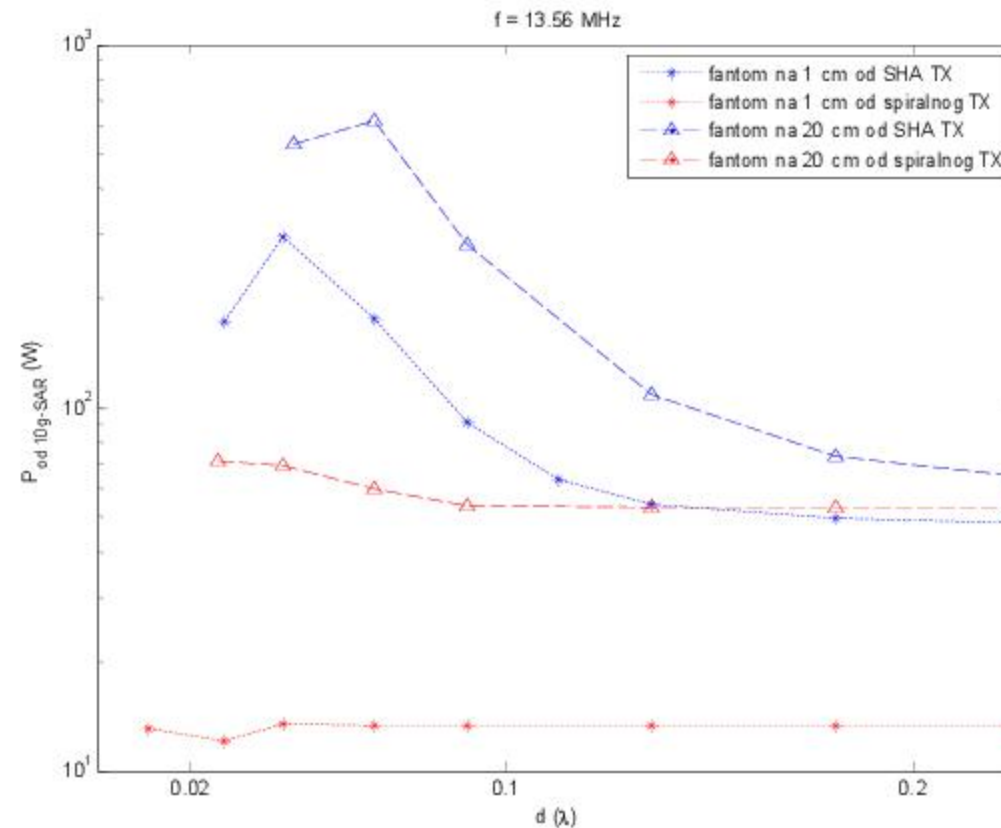
(Problem interakcije ljudi i WPT sustava)



*Maksimalni PTE između direktno napajanih SS-SHA s četiri izdanka u slobodnom prostoru i s fantomom između njih te usporedba s neefikasnim WPT sustavom.*

# Utjecaj propagacijskog kanala na performanse bežičnog prijenosa

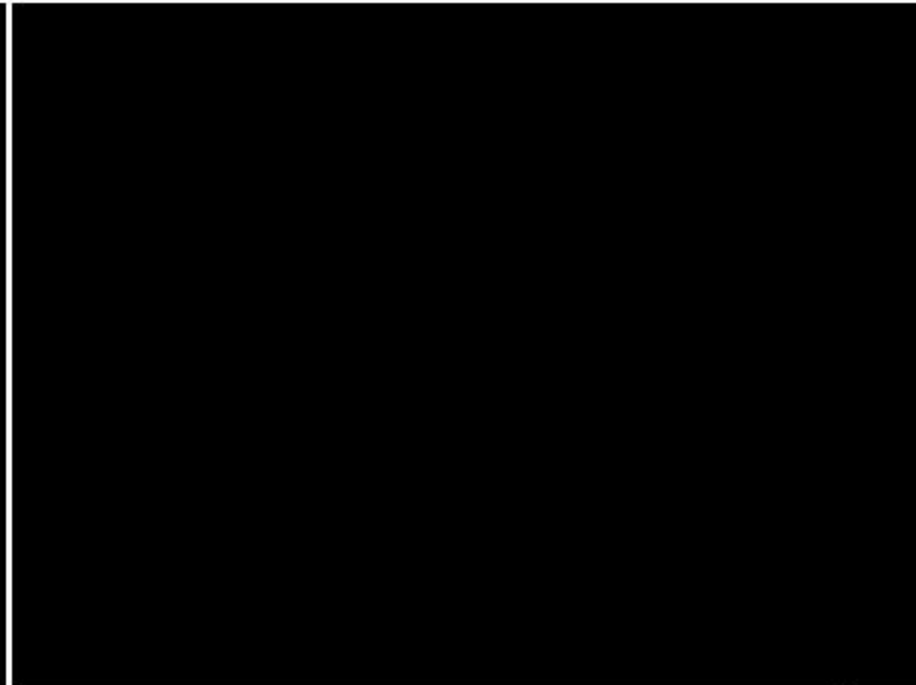
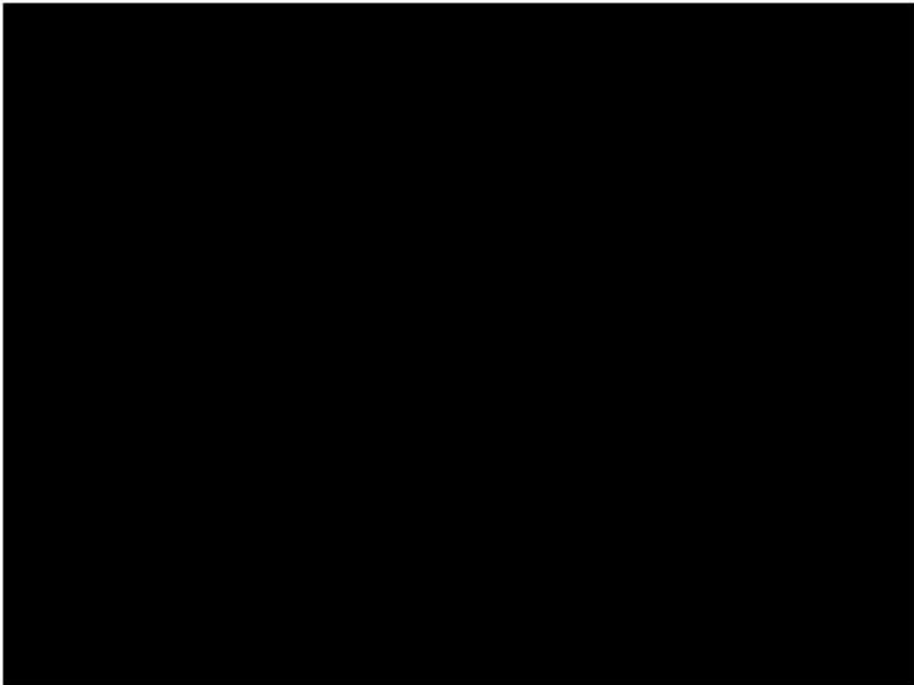
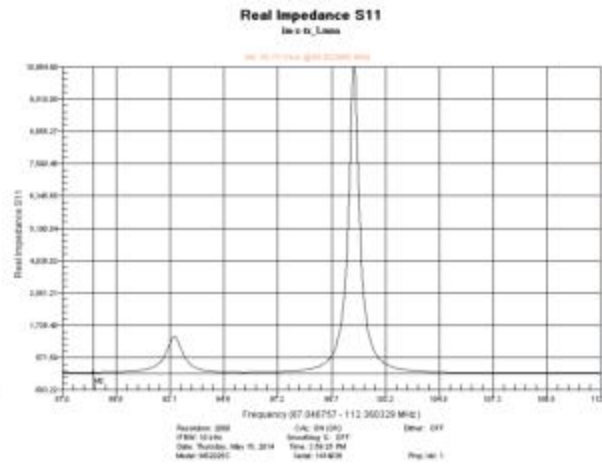
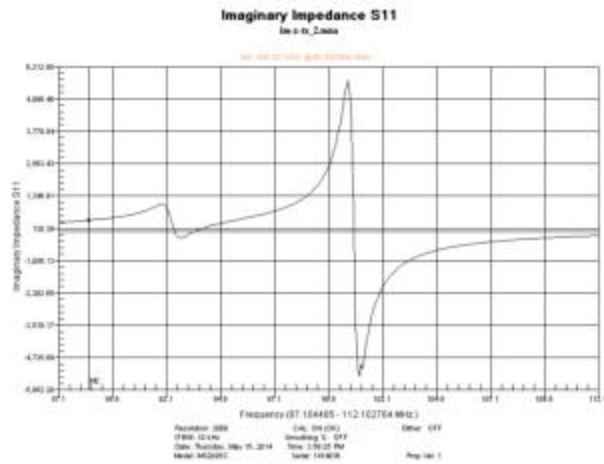
(Problem interakcije ljudi i WPT sustava)



$P_{od\_10g-SAR}$  za svaku udaljenost fantoma i prijarnika od odašiljača.



# Demonstracija- dokaz koncepta



**Hvala na pozornosti!**

