Wireless Power Transfer with Knitted Coils

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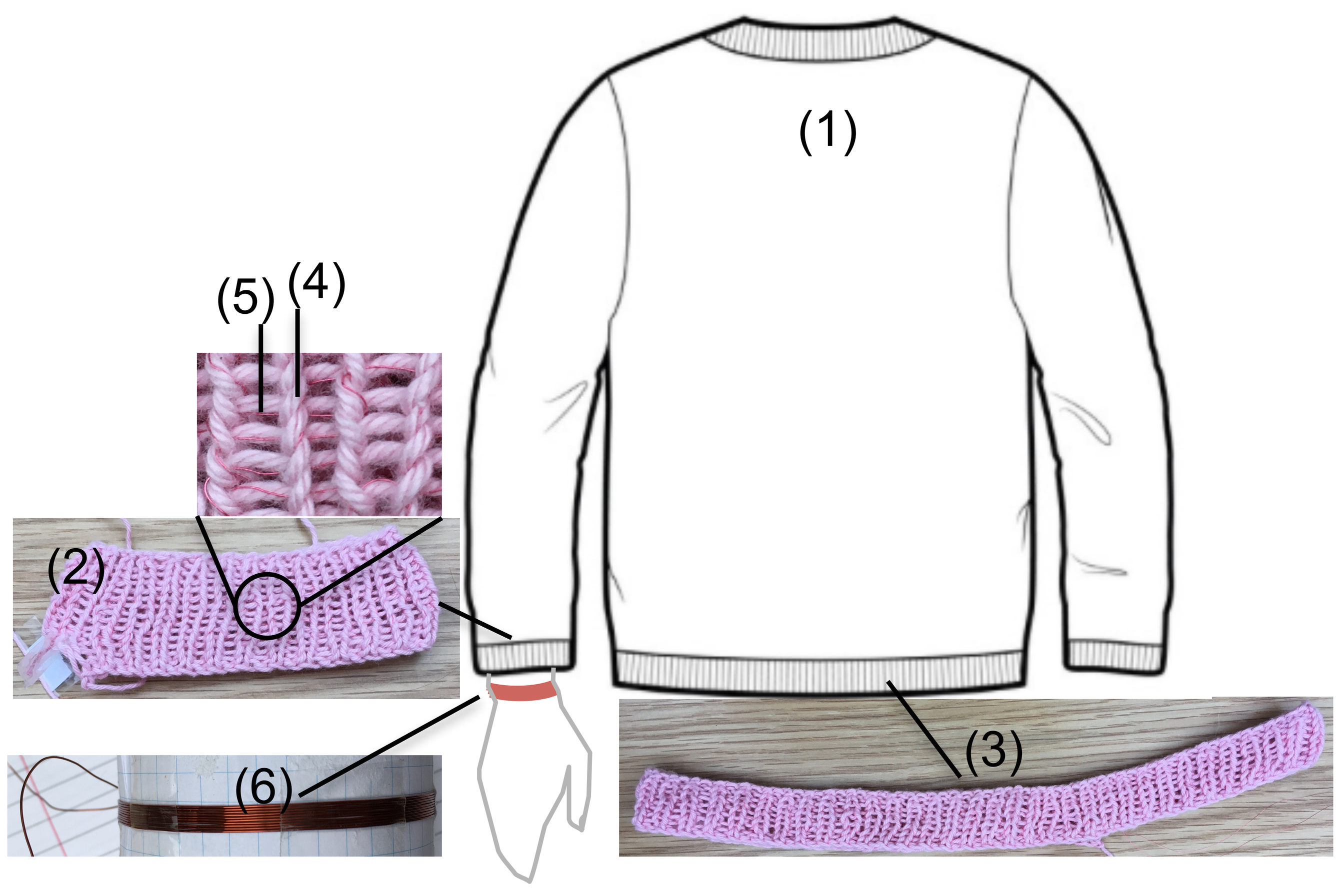
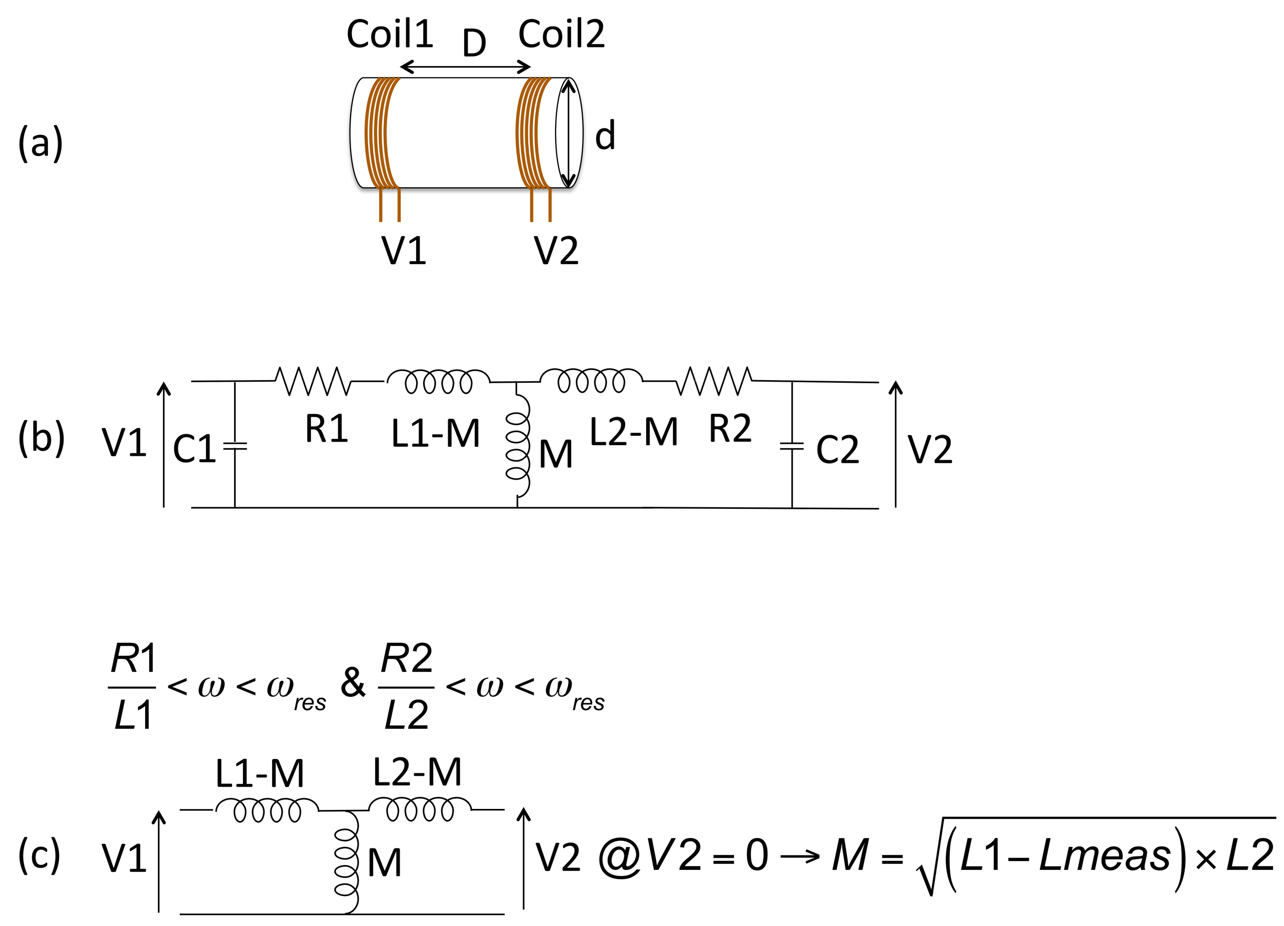
The aim of this study is to analyse magnetic coupling between a closely wound helical coil and a knitted helical coil. It is well known that efficient coupling between two or more coils allows applications such as wireless power transfer. This approach might be used to integrate flexible helical coils in the borders of knitted garments to wirelessly transfer power between e.g. a wristwatch and a cuff or a belt and the waist trim.
For the knit to act as a coil, circular weft knitting must be used. In this study, borders with different diameters and number of rows with integrated insulated metal wire (windings, *N*) were knitted in the round. Cotton yarn for needle size 3 mm and thin insulated Cu wire (~200 μm) was used. The coupling factor, *k* was studied and a simple WPT test conducted.

The principle of the implementation



The equivalent circuits

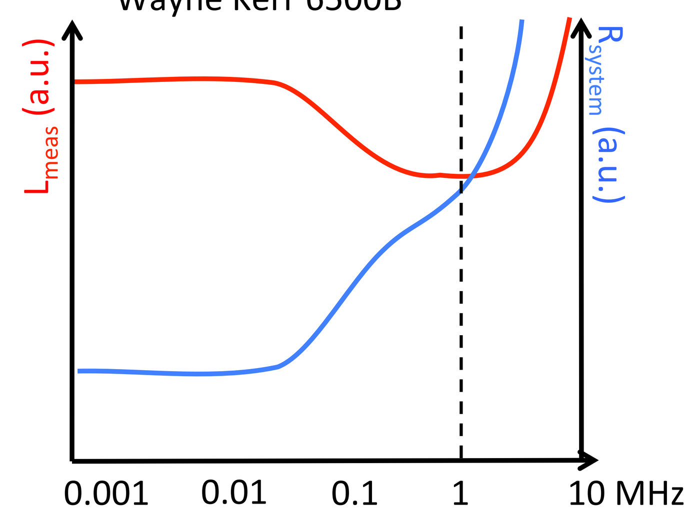


$$\frac{R1}{L1} < \omega < \omega_{res} \ \& \ \frac{R2}{L2} < \omega < \omega_{res}$$

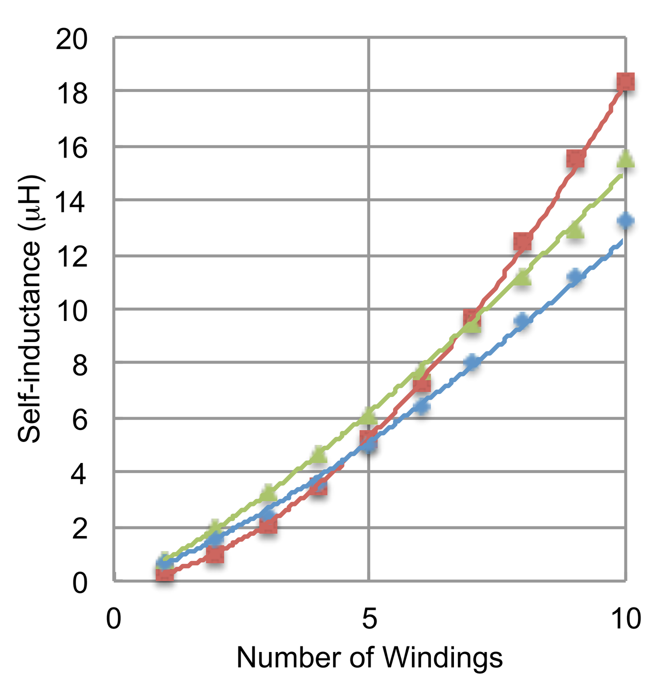
$$V2 \ @V2 = 0 \rightarrow M = \sqrt{(L1 - Lmeas) \times L2}$$

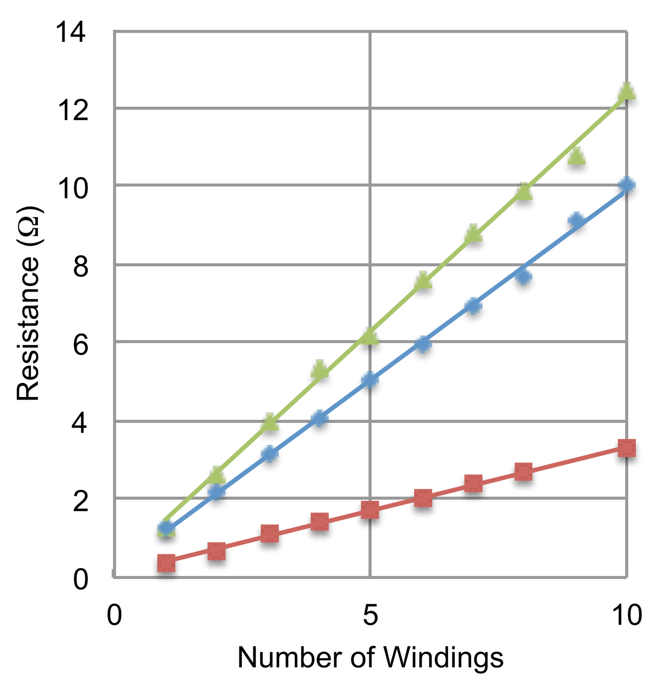
The measurement set-up

Wayne Kerr 6500B



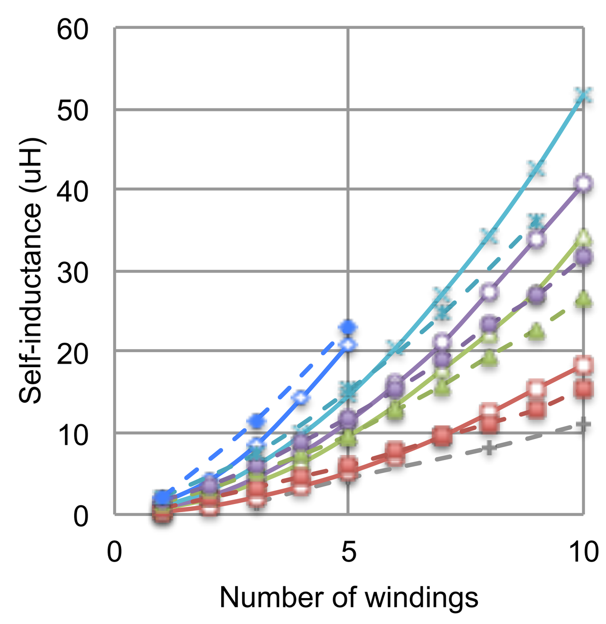
Knitted helical coil – influence of stitch type & N





Wound helical coil	$L = 0.3\ N^{1.8}$	$R = 0.3\ N + 0.09$
Knitted helical coil – 1/1 rib stitch	$L = 0.8\ N^{1.3}$	$R = 1.2\ N + 0.28$
Knitted helical coil – knit stitch	$L = 0.6\ N^{1.3}$	$R = N + 0.22$

Knitted helical coil – 1/1 rib influence of diameter & N



$$L = (\alpha \times D - \beta) \times N^{\gamma}$$

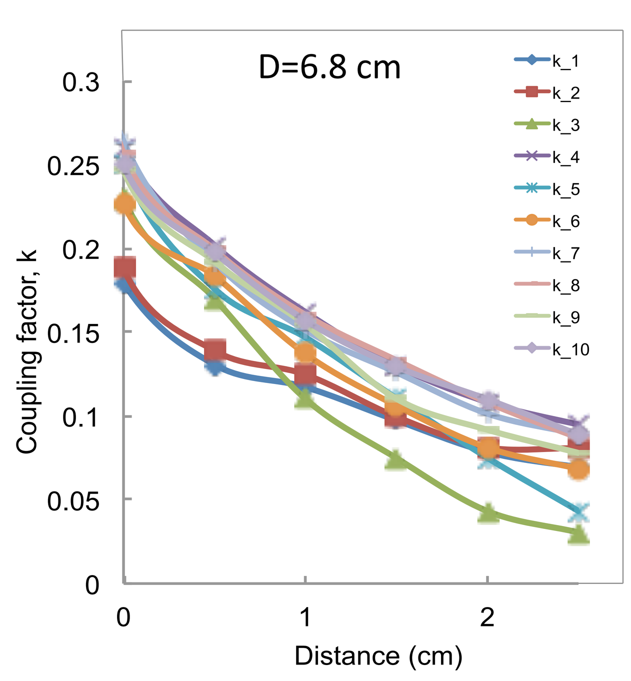
$$R = \kappa \times D \times N$$

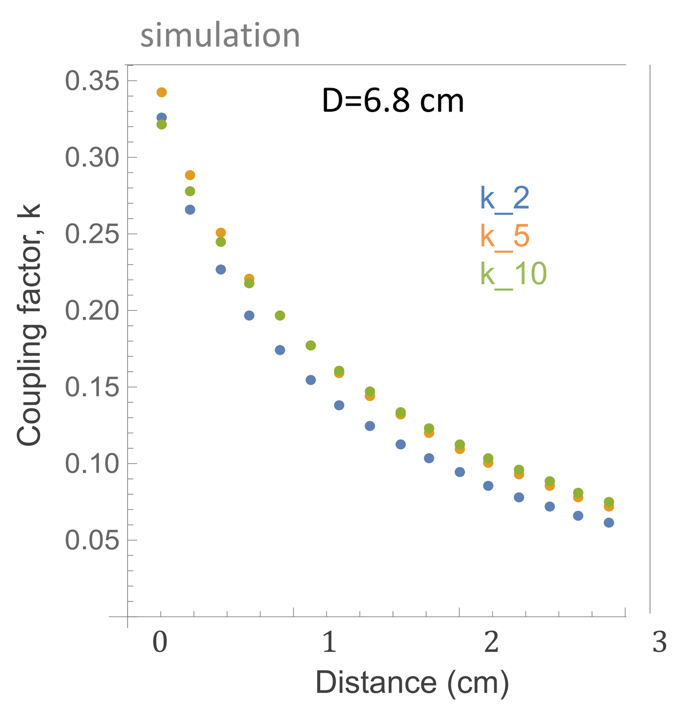
$$Q = \omega \left(\alpha/\kappa - \beta/D \right) \times N^{\gamma - 1}$$

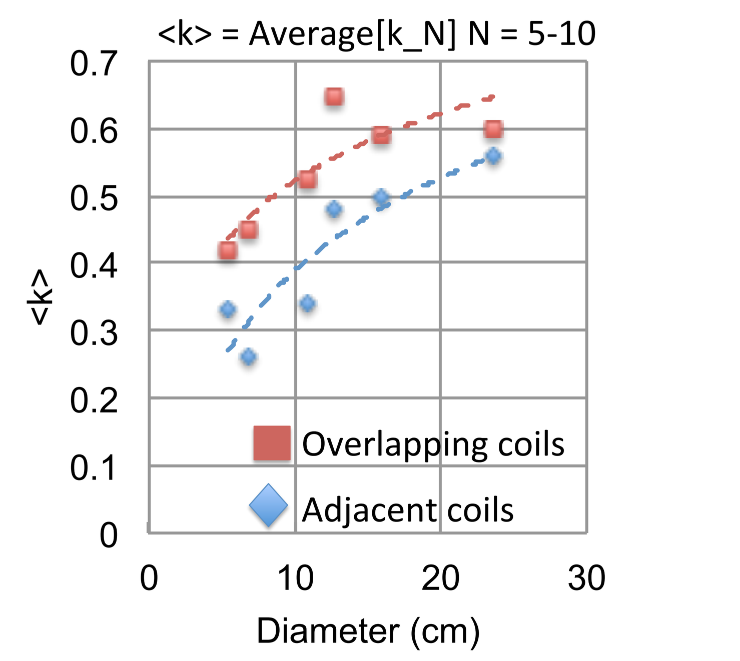
Coil type	α (mH/cm)	β (mH)	γ	κ (Ω cm)
1/1 rib	0.13	0.113	1.3	0.17
Winding	0.065	0.128	1.8	0.09

Full line fits: wound helical coil
Dashed line fit: 1/1 rib knitted coil
D = 5.5, 6.8, 10.8, 12.7, 15.9 and 23.6 cm ± 1 mm

Measurement and simulation of the coupling factor, k



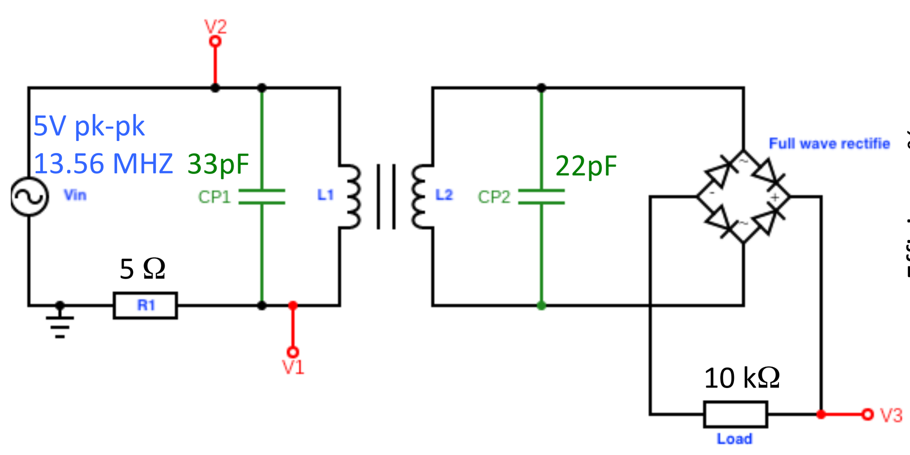


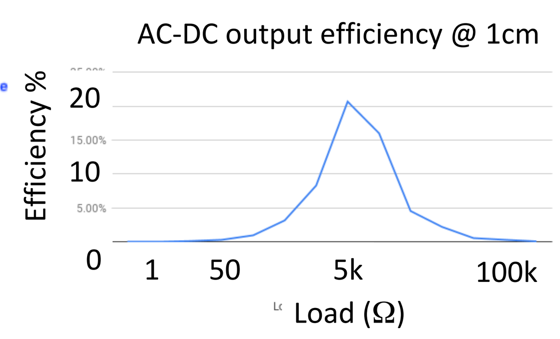


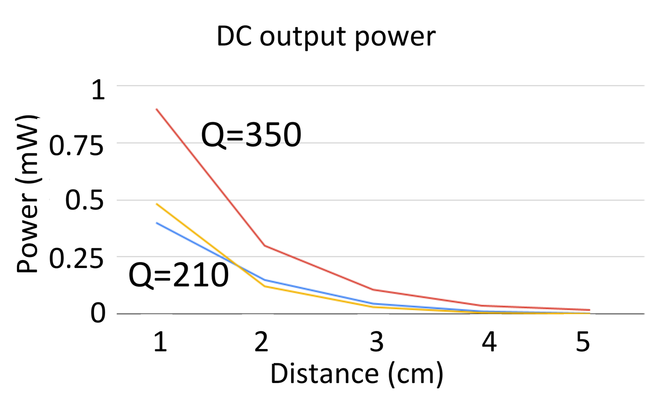
$$\langle k \rangle = 0.2 \ln(D) - 0.06 @ d = 0cm$$

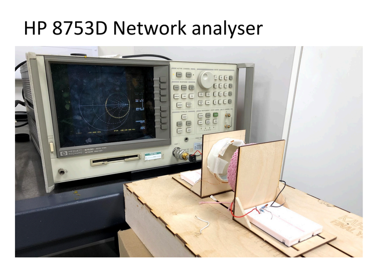
$$\langle k \rangle = 0.14 \ln(D) + 0.19 @ overlap$$

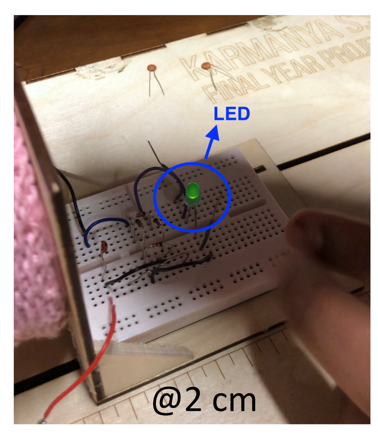
Wireless power transfer











Conclusion: Knitted and wound coils have approximately equal self-inductance for 1 < N < 10 but due to the undulating character of the stitches the length of the metal required in the knit is longer resulting in higher parasitic resistance and lower quality factor. Rib knit gives a higher self-inductance compared to stockinette. Both the self-inductance as well as the resistance increase linearly with diameter however the power factor for *L* is higher than 1. Thus using belt and garment waist border will give better power transfer efficiency. Measurements and simulations show that the coupling factor becomes nearly independent of *N* for *N*>5. The coupling factor increases logarithmically with coil diameter. A simple experiment has demonstrated successful AC-DC power transfer enabling a green LED to light up at a distance of 2 cm.
The advantage of knitted coils is that nearly perfect alignment of coils can be achieved naturally.