Circular Wire Resonator as an Efficient Huygens Element

Sergei Kosulnikov,[1, 2, a)] Dmytro Vovchuk,[1, 3] Roman Noskov,[1] Amir Boag,[1] and Pavel Ginzburg[1, 4]

[1]Tel Aviv University, Israel
[2]ITMO University, Russia
[3]Yuriy Fedkovych Chernivtsi National University, Ukraine
[4]Moscow Institute of Physics and Technology, Russia

METANANO 2020
Tbilisi, Georgia

Small antenna limitations:

Chu–Harrington limit: $Q \geq \frac{1}{k^3a^3} + \frac{1}{ka}$

Maximal scattering cross-section of a lossless resonant subwavelength object does not depend on its size.

Single resonance case:
$(2l+1)\lambda^2/(2\pi) \rightarrow 3\lambda^2/(2\pi)$ ("dipolar" bound)

Point 1: How to bypath scattering limitation?
Involve several spectrally overlapping multipolar resonances!

Point 2: *resonant* Huygens elements are inherently narrowband :(
We do a *broadband resonant* Huygens element

HOW?
circular array of wires…

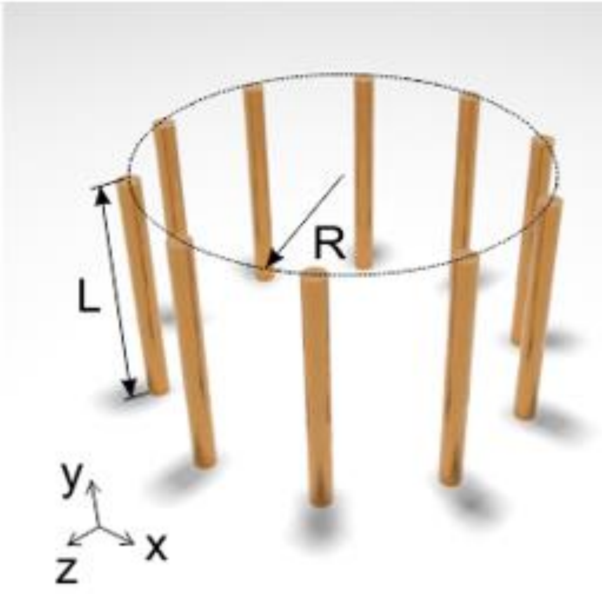
References

[1] R.F. Harrington, Time-Harmonic Electromagnetic Fields, 2nd ed. (Wiley-IEEE Press, New York, 2001).
[2] D. Filonov, et.al, Appl. Phys. Lett. 113, 123505 (2018)
[3] M. Kerker, D.-S. Wang, and C.L. Giles, J. Opt. Soc. Am. 73, 765 (1983).

Circular Wire Resonator as an Efficient Huygens Element

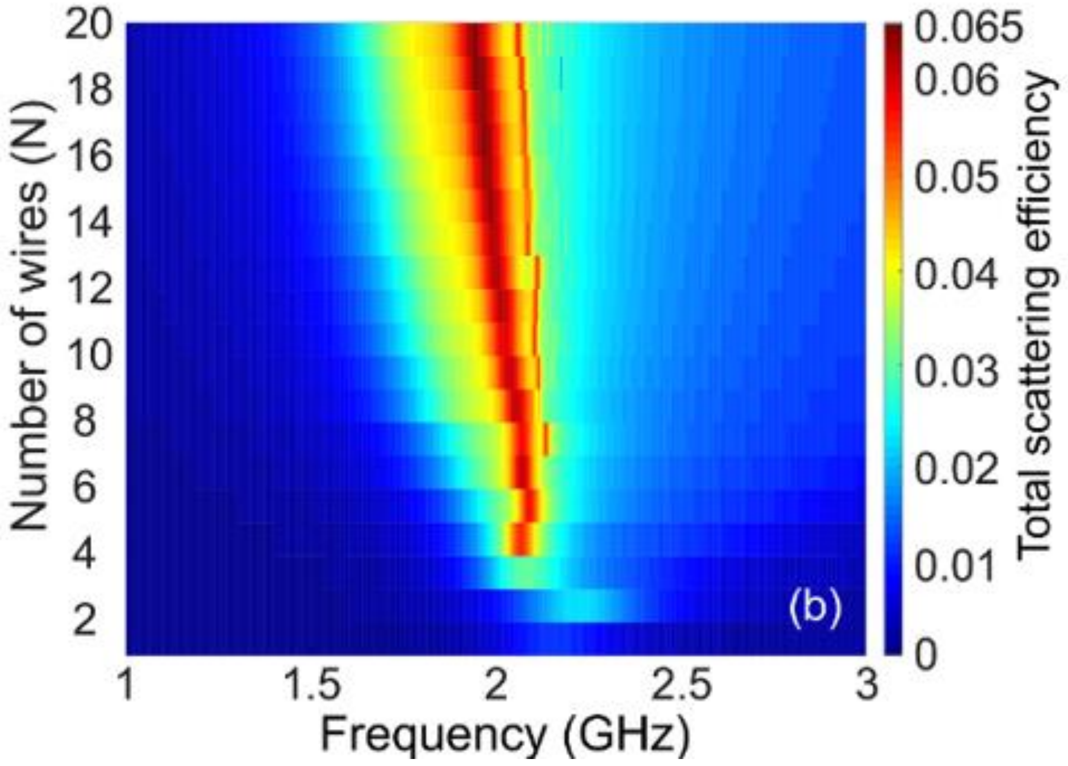
Sergei Kosulnikov, Dmytro Vovchuk, Roman Noskov, Amir Boag, and Pavel Ginzburg

Circular wire array



plane wave illumination, vertical polarization

Scattering efficiency

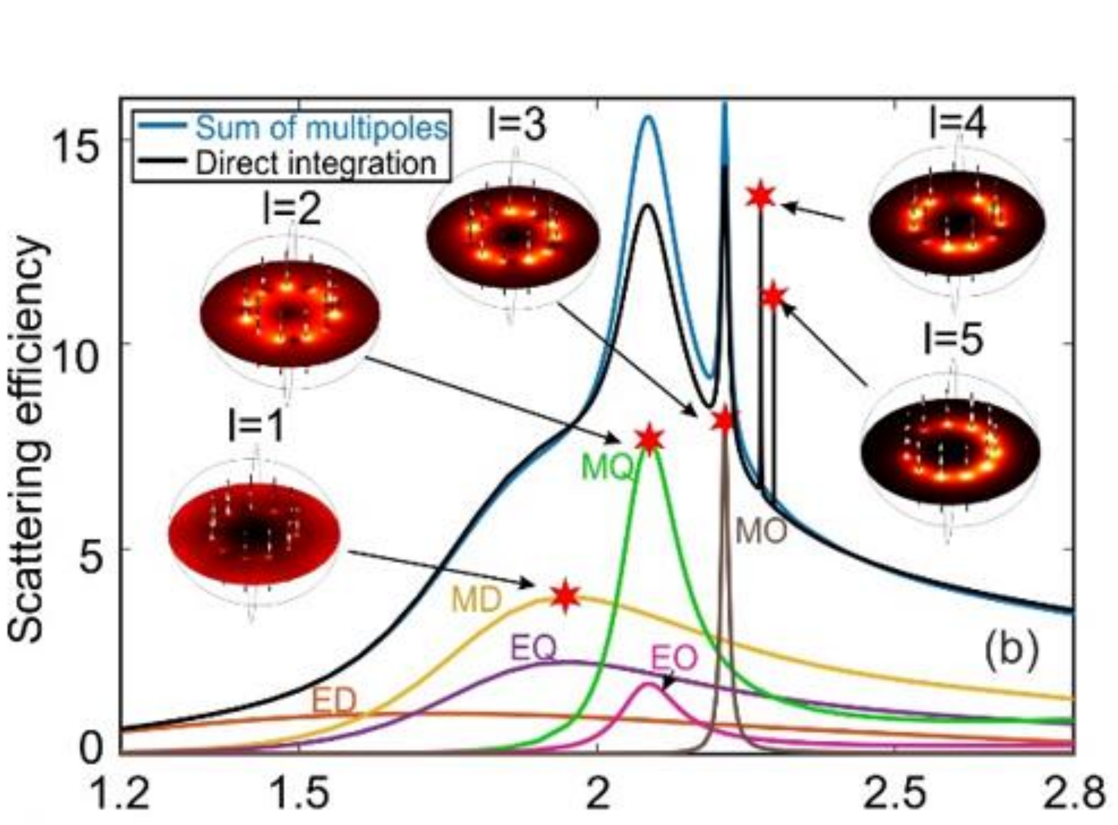


We proceed with 11 wires...

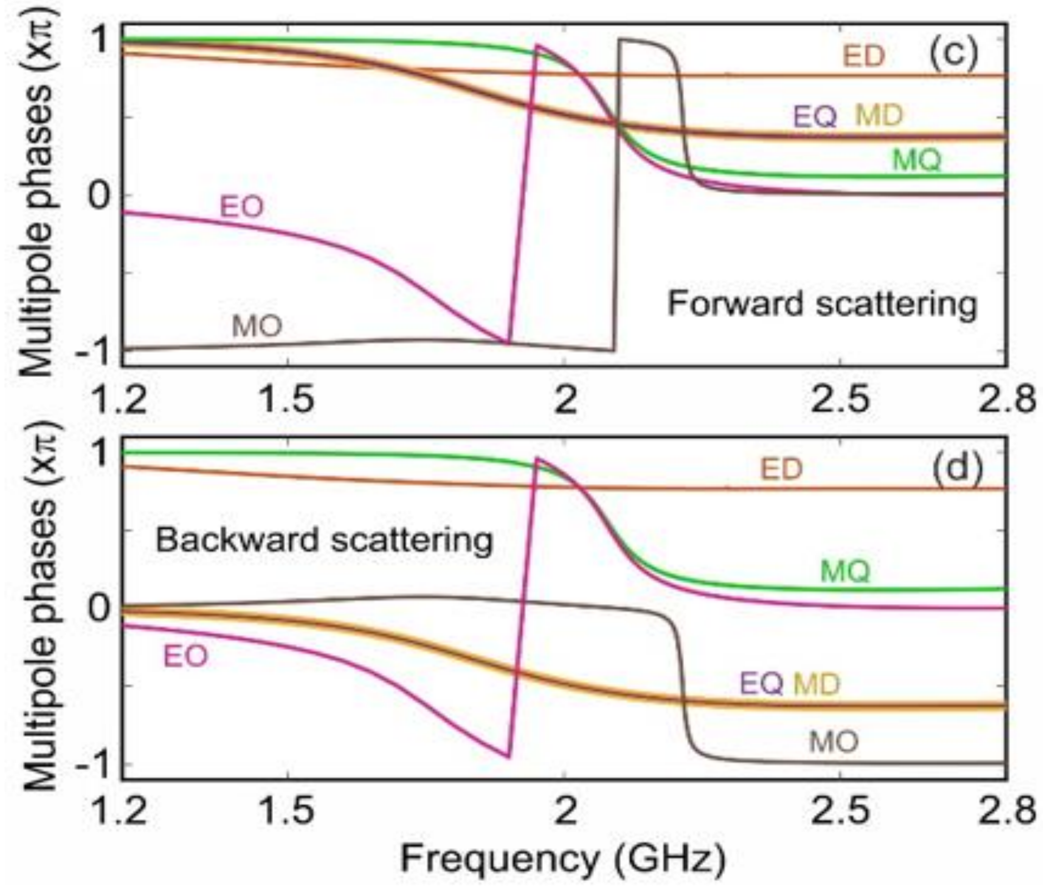
Circular Wire Resonator as an Efficient Huygens Element

Sergei Kosulnikov, Dmytro Vovchuk, Roman Noskov, Amir Boag, and Pavel Ginzburg

Multipole decomposition of the scattering efficiency



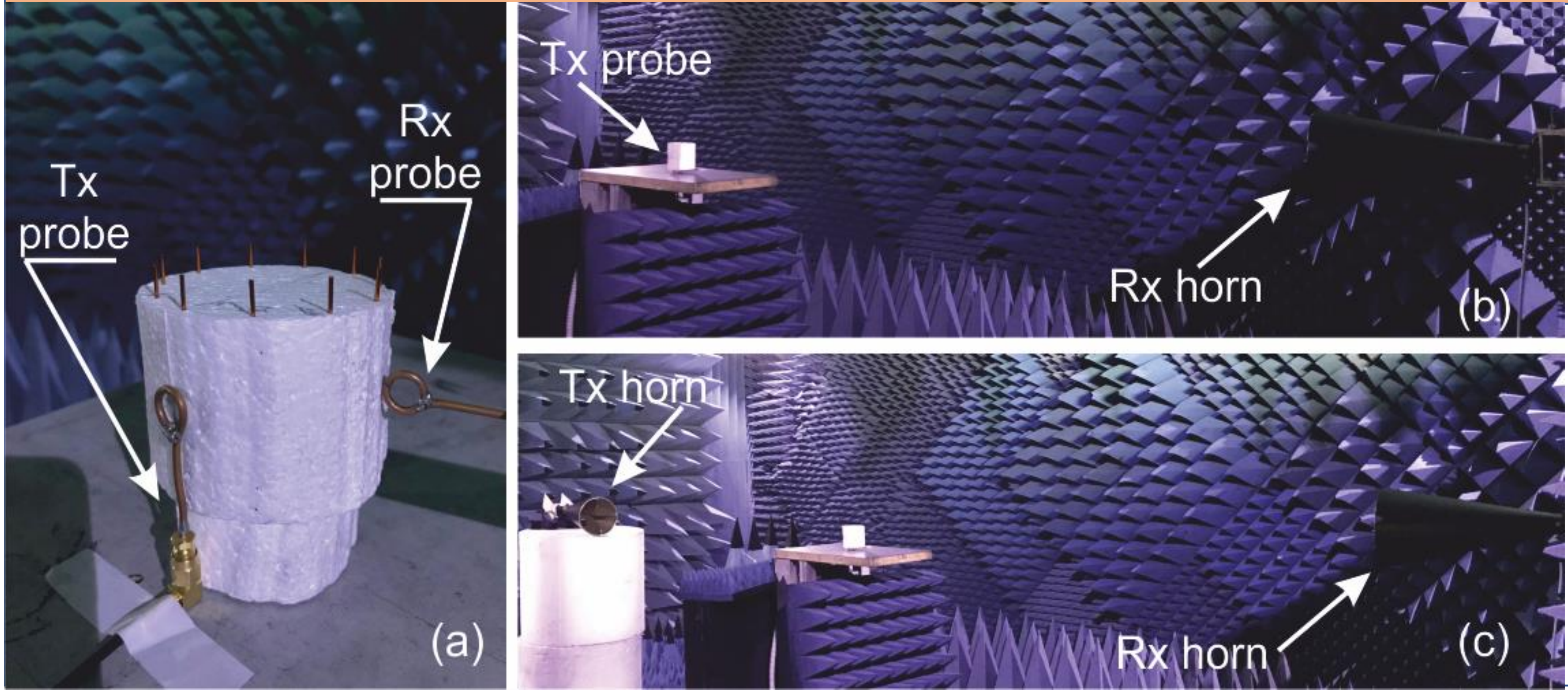
Forward / backward directions with respect to the wave incidence



Circular Wire Resonator as an Efficient Huygens Element

Sergei Kosulnikov, Dmytro Vovchuk, Roman Noskov, Amir Boag, and Pavel Ginzburg

Three types of the experimental setups



a) Near-to-near
b) Near-to-far
c) Far-to-far

Circular Wire Resonator as an Efficient Huygens Element

Sergei Kosulnikov, Dmytro Vovchuk, Roman Noskov, Amir Boag, and Pavel Ginzburg

Characterization of the resonant modes

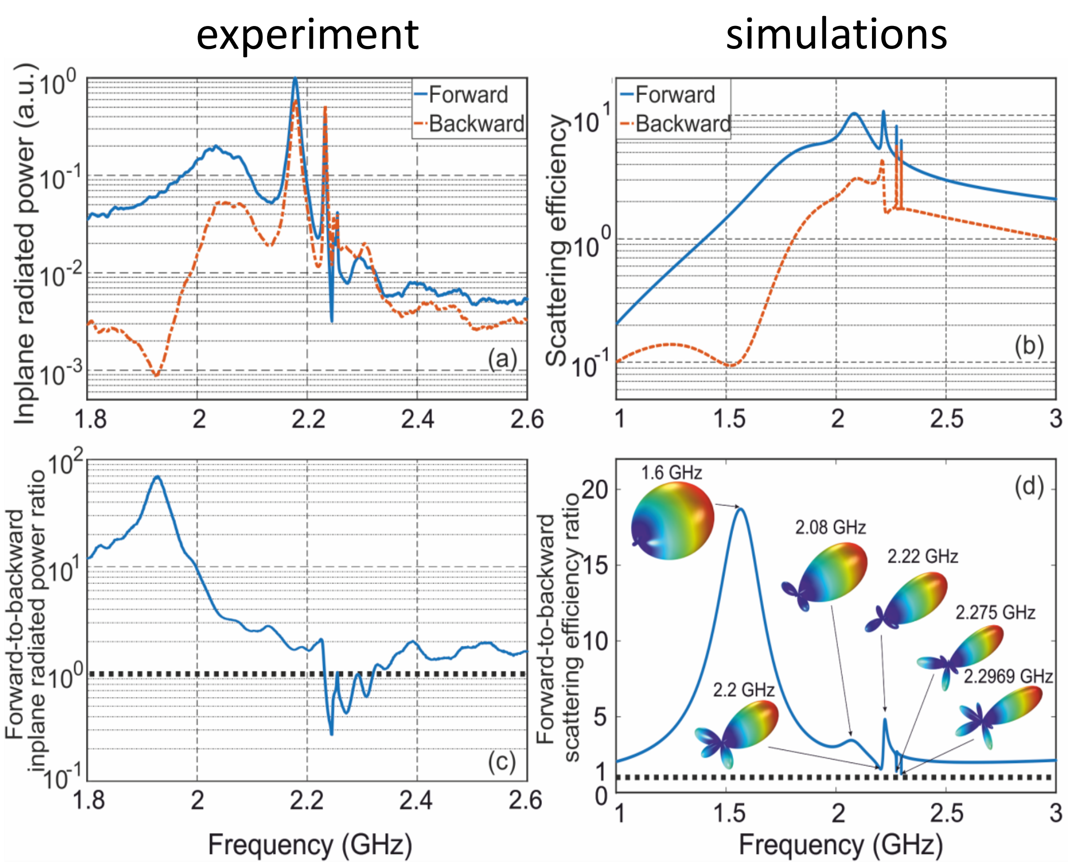
Experimental data

Az. order	0	1	2	3	4	4	5	5
f, GHz	-	-	2.055	2.181	2.23	2.239	2.253	2.258
Q-factor	-	-	32.5	220	1316	1595	1211	2579

Numerical data

M-poles	ED	MD+EQ	MQ+EO	MO	M16-pole	M16-pole	M32-pole	M32-pole
f, GHz	1.773	1.887	2.094	2.217	2.273		2.295	
Q-factor	1.1	3.8	20	120	873		5599	

Forward and the backward scattering efficiency



Circular Wire Resonator as an Efficient Huygens Element

Sergei Kosulnikov,[1, 2, a)] Dmytro Vovchuk,[1, 3] Roman Noskov,[1] Amir Boag,[1] and Pavel Ginzburg[1, 4]

[1]Tel Aviv University, Israel
[2]ITMO University, Russia
[3]Yuriy Fedkovych Chernivtsi National University, Ukraine
[4]Moscow Institute of Physics and Technology, Russia

METANANO 2020
Tbilisi, Georgia

Introduction | Structure optimization | Simulation | Setup | Results | Conclusion

1. Multipoles analysis shows predominant contribution of magnetic multipoles with respect to electric ones for almost all eigenmodes except from the lowest one.
2. Multipoles contribution to the Huygens element performance have been shown.
3. Scattering efficiency of the demonstrated configuration is 15 times larger than its geometrical cross section and, at the same time, the device demonstrates broadband forward scattering capabilities, obtained at a bandwidth ~ 10% of the carrier frequency in the GHz range.

https://arxiv.org/abs/2006.14006

sergeik@mail.tau.ac.il