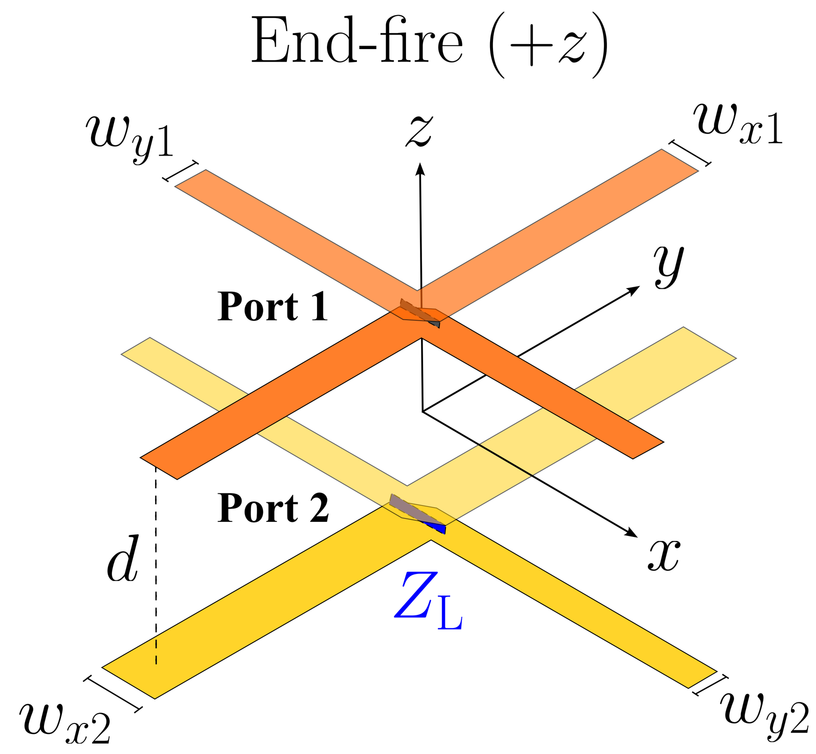
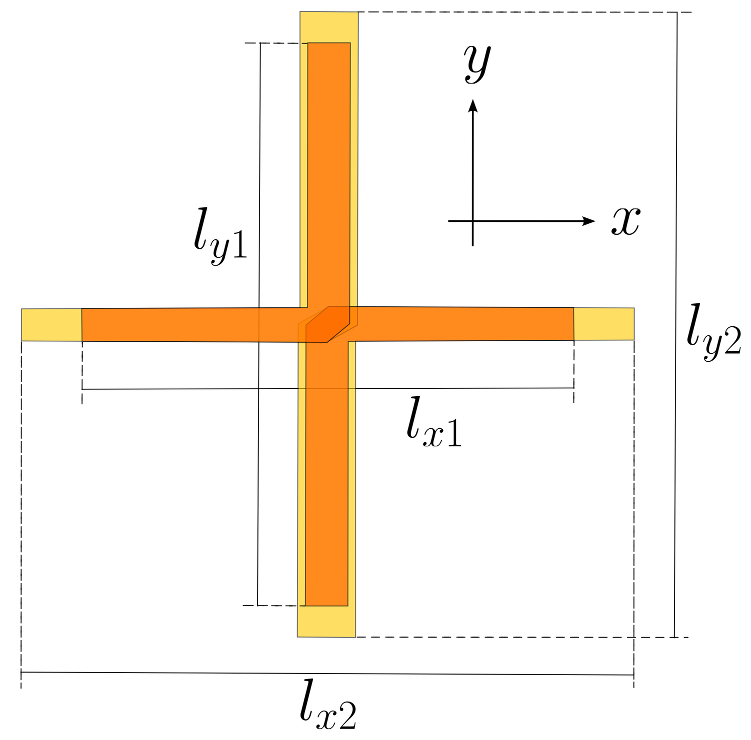
Single-Feed Circularly Polarized Super Realized Gain Antenna

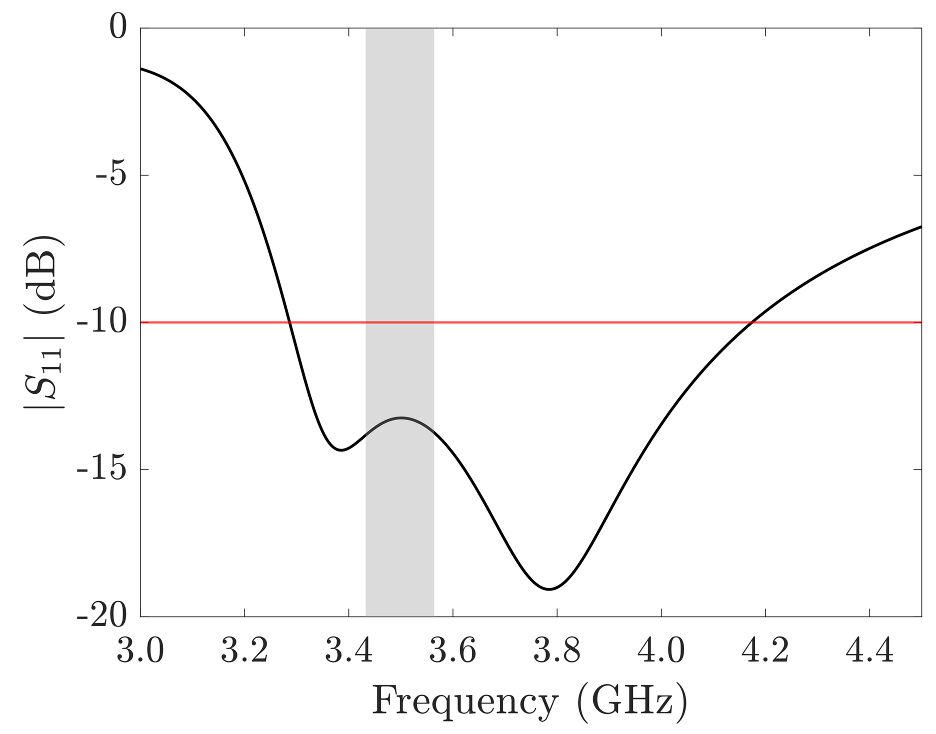
Georgia Psychogiou[1], Donal P. Lynch[2], Spyridon N. Daskalakis[3], Manos M. Tentzeris[4], George Goussetis[3], and Stylianos D. Asimonis[1]
[1] Department of Electrical and Computer Engineering, University of Patras, Greece
[2] Centre for Wireless Innovation (CWI), Queen's University Belfast, United Kingdom
[3] School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom
[4] School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA
Contact: dlynch27@qub.ac.uk

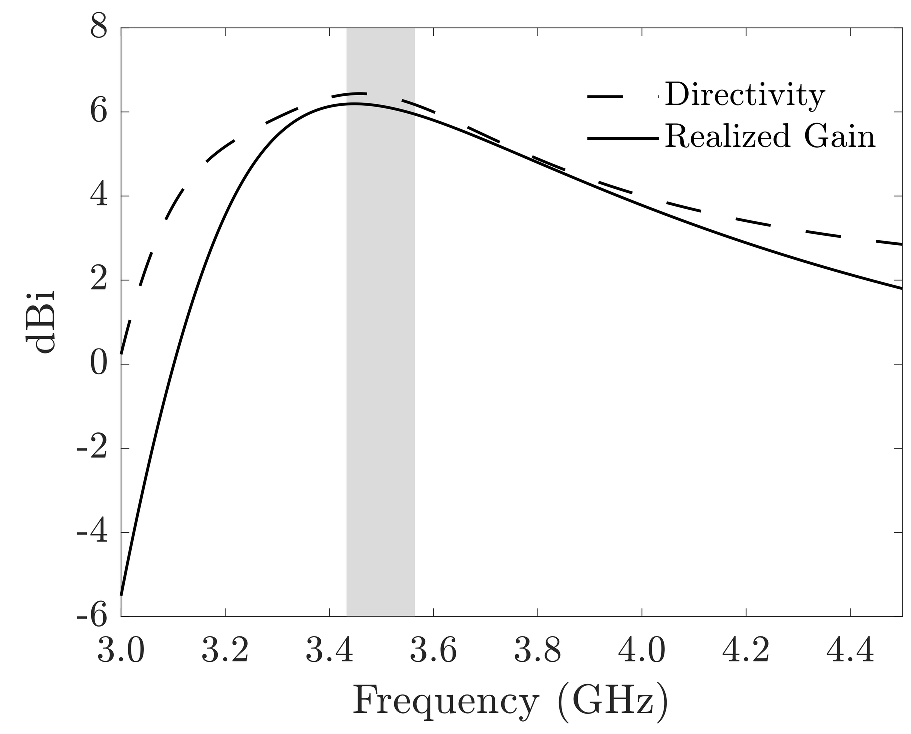
Abstract

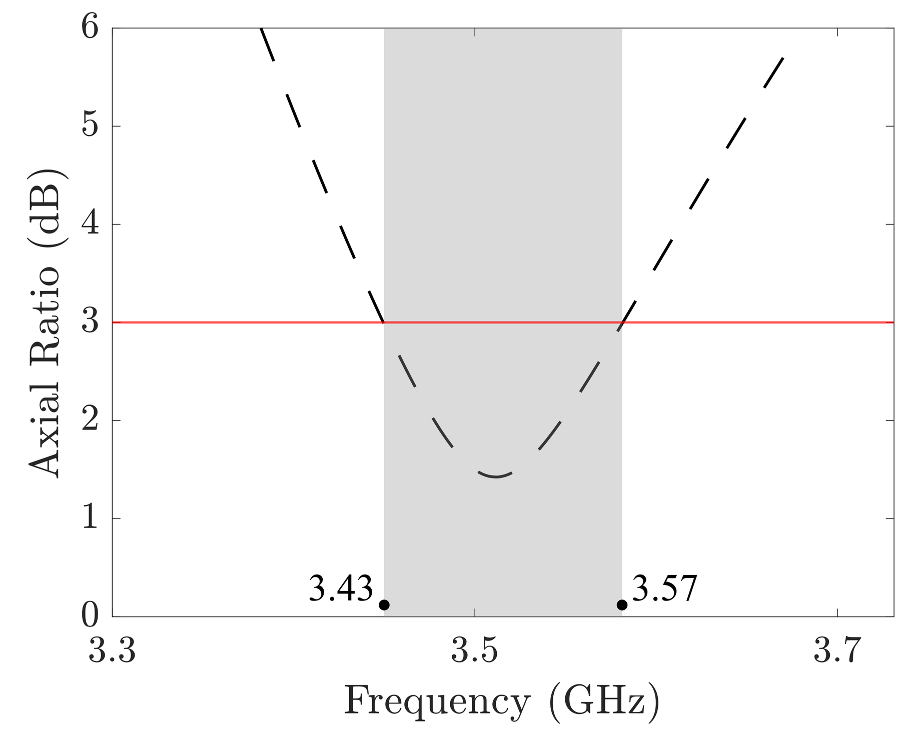
This paper presents a super-realized-gain, circularly polarized strip-crossed dipole antenna operating at 3.5 GHz. Superdirective behavior is achieved by leveraging strong inter-element mutual coupling through careful adjustment of the strip dimensions. The antenna features a single driven element, with the other element passively loaded with a reactive impedance. The structure is optimized to maximize left-hand circularly polarized (LHCP) realized gain, ensuring high polarization purity and good impedance matching. The optimized design exhibits a -10 dB 50 Ω impedance bandwidth of 3.29–4.17 GHz (23.75%) and a 3 dB axial-ratio bandwidth of 3.43–3.57 GHz (4%). At 3.5 GHz, the antenna achieves a peak realized gain of 6.1 dB ($ka \approx 1.65$), with a 3 dB axial ratio of 1.4 dB. These results demonstrate that circular polarization and superdirectivity can be simultaneously realized in a geometrically simple, low-profile ($0.15\lambda_0$) antenna, rendering it suitable for integration into compact sub-6 GHz wireless and sensing platforms.











Key Performance Data

Parameter	Value
Operating frequency	3.5 GHz
Polarization	LHCP
Peak realized gain	6.1 dB
Electrical size	$ka \approx 1.65$
Impedance bandwidth ($\lvert S_{11}\rvert < -10$ dB)	3.29–4.17 GHz (23.75%)
3 dB axial-ratio bandwidth	3.43–3.57 GHz (4%)
Axial ratio at 3.5 GHz	1.4 dB
Profile	$0.15\lambda_0$

Motivation

- Superdirectivity is attractive for compact antennas because it enables high directivity from a limited physical aperture, but it is typically difficult to realize in practice due to bandwidth, matching, and sensitivity constraints.
- Circular polarization is desirable in wireless systems because it reduces sensitivity to polarization mismatch and multipath propagation.
- Compact directional CP antennas are relevant to sub-6 GHz wireless links, sensing platforms, UAV payloads, IoT nodes, and space-constrained MIMO front-ends.
- Achieving circular polarization, superdirectivity, and compact size simultaneously remains a key design challenge.

Optimisation

- Full-wave optimization was carried out in ANSYS HFSS using the built-in multi-objective genetic algorithm (MOGA).
- The objective was to maximize LHCP realized gain in the end-fire $+z$ direction at 3.5 GHz.
- Optimization variables included the crossed-dipole arm lengths, strip widths, and the reactive load applied to the parasitic element.
- An inter-element spacing of $0.15\lambda_0$ provided the best trade-off between matching, axial ratio, and super-realized-gain performance.

$$\text{Maximize:}\quad G_{\text{LHCP}}(l_{x1}, l_{x2}, l_{y1}, l_{y2}, w_{x1}, w_{x2}, w_{y1}, w_{y2}, Z_L)$$

$$\text{Subject to:}\quad \begin{cases} l_i \in [0.3,\ 0.6]\ \lambda_0, \\ w_i \in [0.005,\ 0.05]\ \lambda_0, \\ Z_L \in [-5000,\ +5000]\ \Omega, \end{cases}$$

TABLE I
OPTIMIZED PARAMETERS OF THE CROSSED–DIPOLE ARRAY @ 3.5 GHZ
All dimensions are in millimetres (mm).

l_{x1}	l_{x2}	l_{y1}	l_{y2}	w_{x1}	w_{x2}	w_{y1}	w_{y2}
35.21	43.83	40.17	44.64	2.95	4.14	3.30	3.29

Applications

- Sub-6 GHz wireless terminals
- Compact sensing platforms
- UAV communication payloads
- Space-constrained IoT nodes
- Compact MIMO front-ends