TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

Twin-Grid Array Antenna for 5G Wearable Applications

Jack Hughes, Cecilia Occhiuzzi, Gaetano Marrocco and John Batchelor

School of Engineering
EDA, University of Kent
Pervasive Electromagnetics Lab
DICII- University of Roma «Tor Vergata»

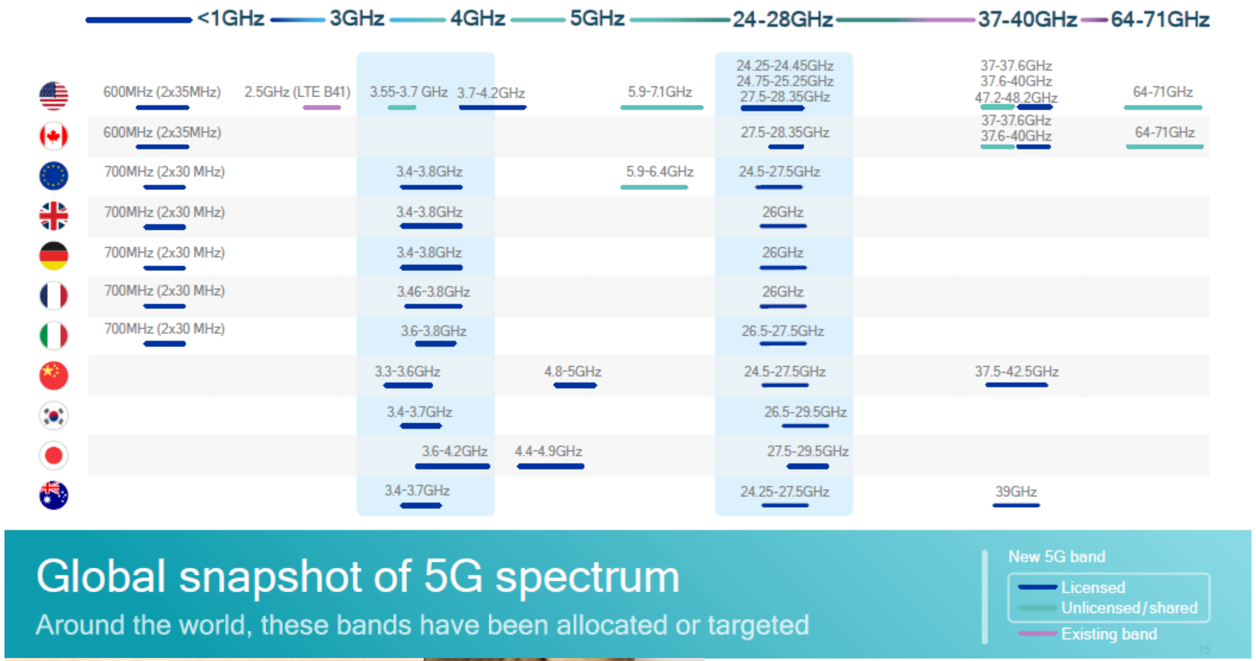
Pervasive Electromagnetics Lab

University of Kent

Wearable Systems in 5G Bands

Studies have shown despite higher free space attenuation, the newly allocated 5G band at 3.6 GHz is suitable to provide comparable read distance as on-skin UHF (1-2m).

- 5G Benefits
  - Gigabit-per-second data rate
  - Low latency
  - Larger bandwidths
  - Wide-scale interoperability
  - Reduced antenna size



Pervasive Electromagnetics Lab

TOR VERGATA
UNIVERSITÀ
DEGLI STUDI
DI ROMA

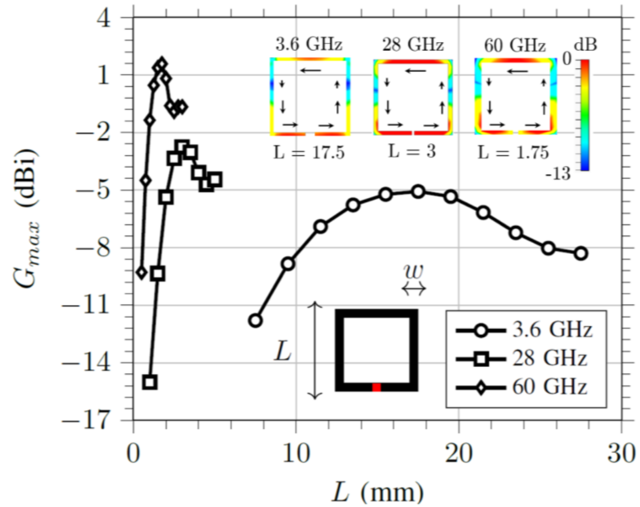
5G Epidermal Loop Antenna

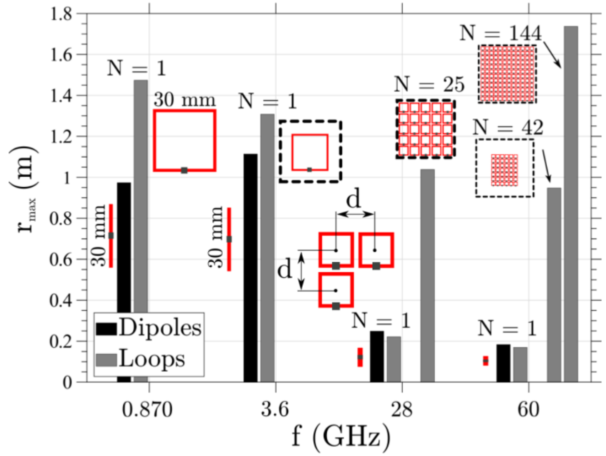
One lambda loop antennas have been widely accepted as suitable for epidermal antennas:

- Simple design, naturally miniaturised
- Works well passively, functional without battery working on backscattering alone
- Better performing than dipoles as wearables
- Provides large breathable area capable of hosting sensors directly attaching to the skin
- Read distance of 1.3m achievable at 3.6 GHz, corresponding to a maximum radiation gain of -5.1dB

Read distance is limited by losses:

- Body loss
- Path loss





Pervasive
Electromagnetics Lab

TOR VERGATA
UNIVERSITÀ
DEGLI STUDI
DI ROMA

Origin: Kraus (1964)

To mitigate the losses, an array is employed. In 1964 Kraus considered a continuous wire grid that acted as a travelling-wave (non-resonant) antenna, sending a scanning beam in the backward direction. Later the feed point was moved to the central point on the grid network, providing broadside radiation.

The Kraus Grid offers attractive features for adapting into a wearable antenna:

- Essentially an array of loop antennas
- Monolithic, simple structure
- Avoids complex feed network systems

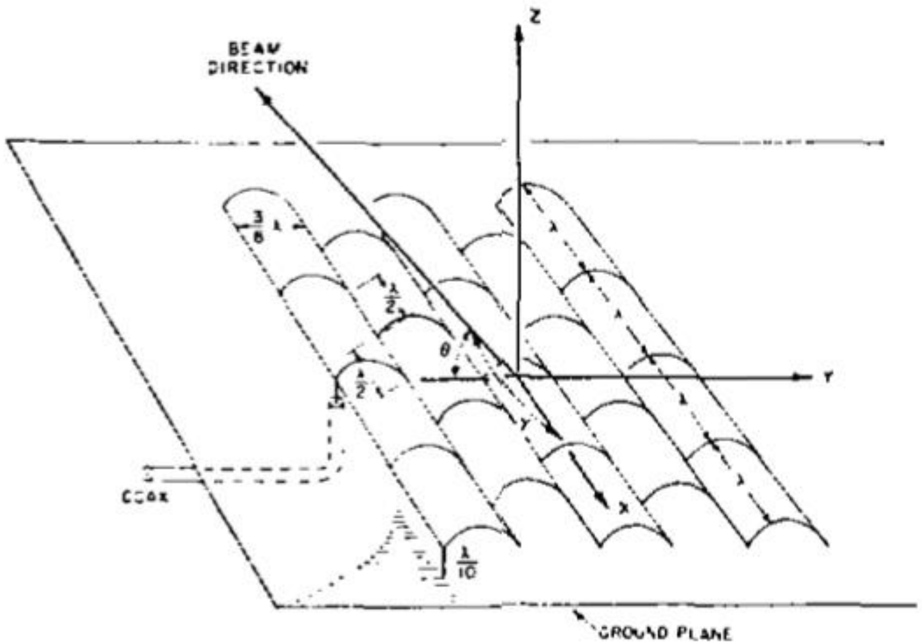


Fig. 1—Sketch showing typical dimensions for backward angle-fire antenna.

Pervasive Electromagnetics Lab

Resonant Adaption

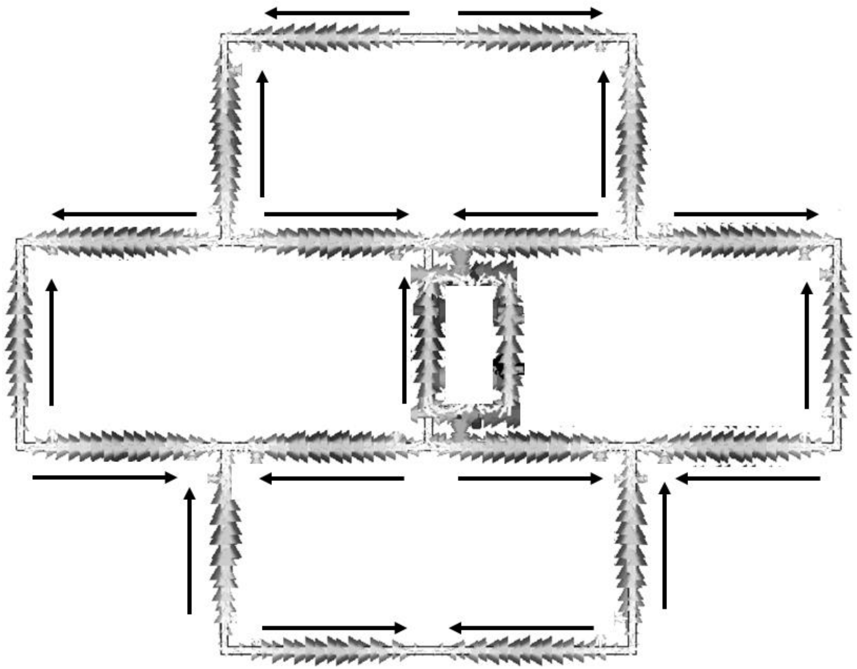
Optimal performance from resonant Kraus grid is achieved under specific parameters.

- Electrical length of the mesh sides should be one wavelength by half a wavelength in the dielectric
- Instantaneous currents are to be out of phase on the horizontal lengths of wire and in phase on the vertical lengths

At 3.6 GHz, λ = 83.3mm before dielectric effect, very large for wearable applications.

Silicone Rubber was chosen as the substrate for highest dielectric k whilst maintaining a durable flexible structure:

- $\varepsilon_r = 3$
- tand = 0.0014

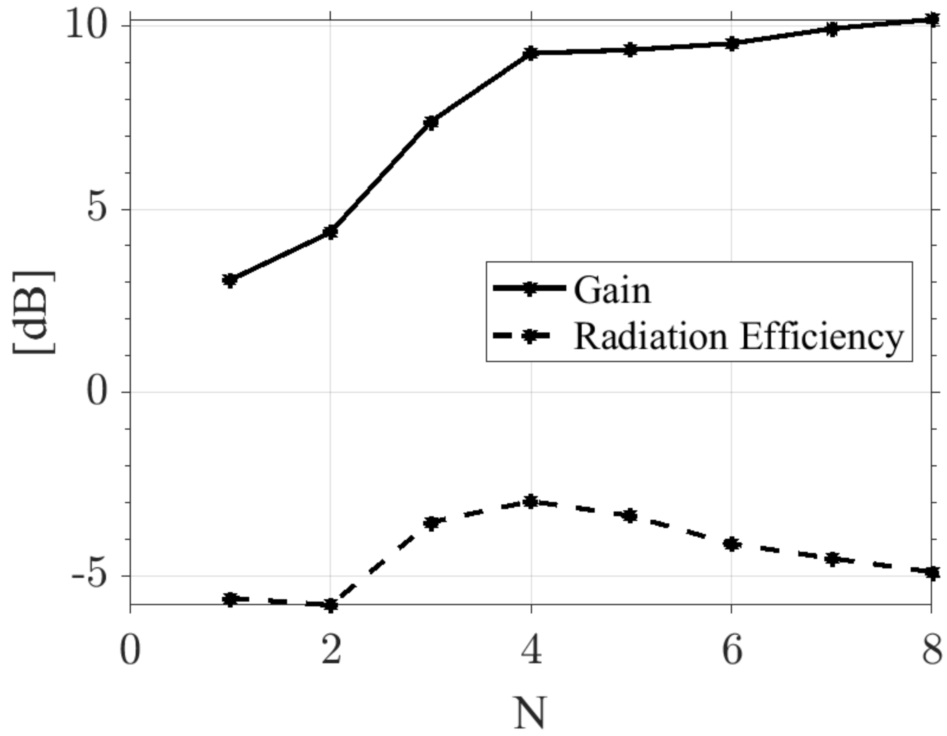


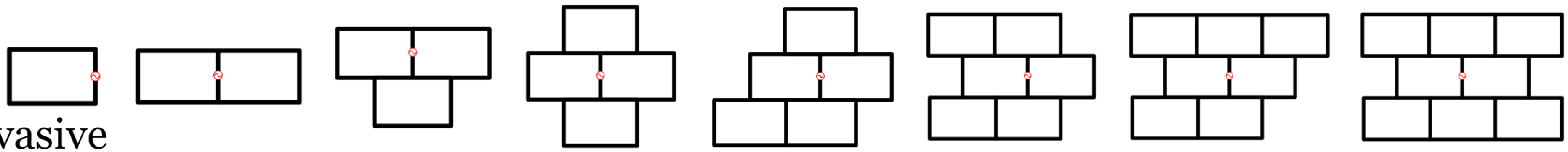
Grid-Array Driver Size

The number of cells is considered to maximise radiation performance whilst not having the dimensions too unreasonable to attach to the body.

Four-cells were found to have the best efficiency and also seeing a plateauing point for the gain, providing negligible improvement without drastic size increase after this point.

Given the ground plane beneath the driver is a larger than the total grid for complete reflecting, the dimension of the four-cell GAA is ~12.4cm x 9.6cm.





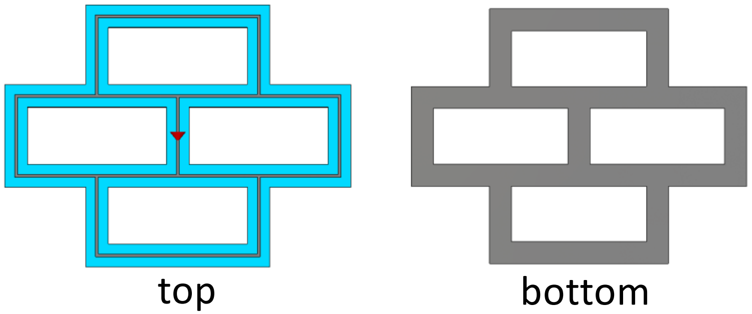
N

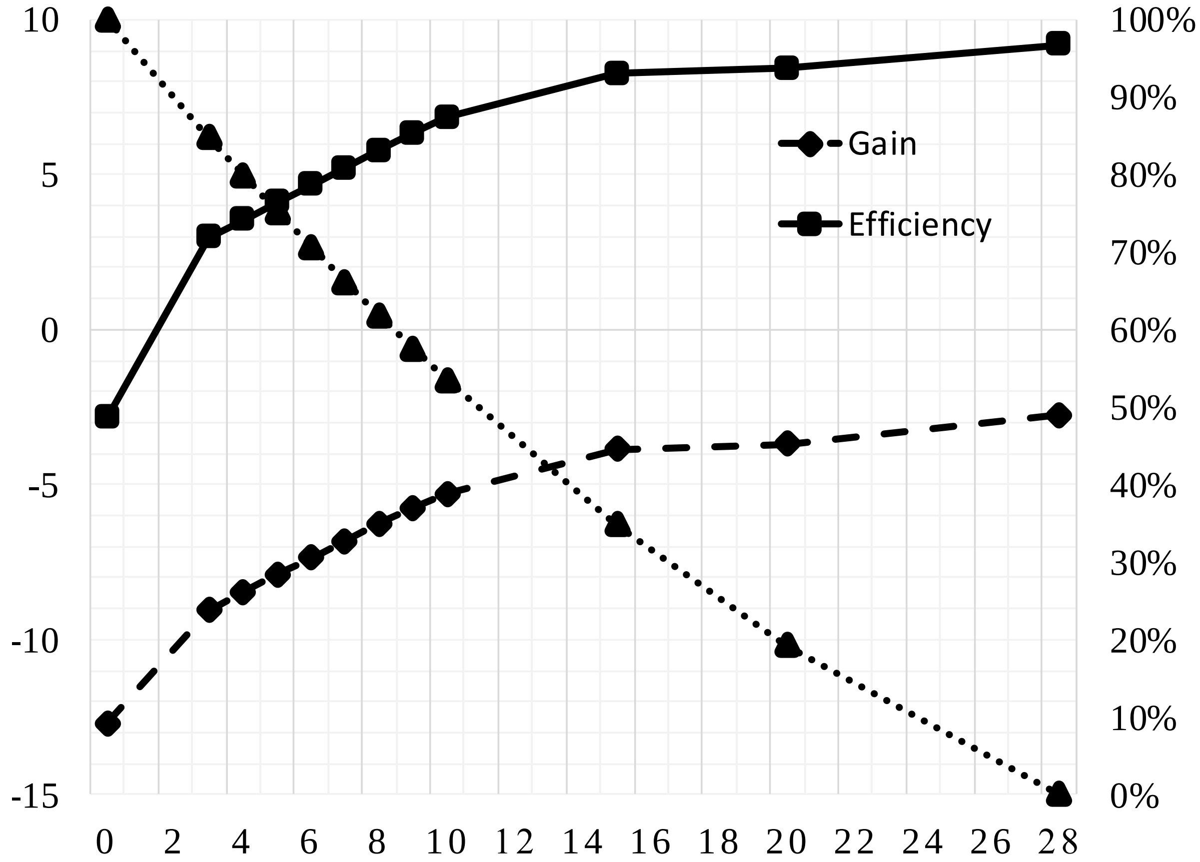
TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

Breathability and Reflector Size

The grid array structure uses a ground plane to completely back the antenna blocking access to the skin.

Balance must be found between maintaining as large of a ground and as possible to maximise performance whilst also maximising breathable area, becoming the 'Twin-Grid' array.



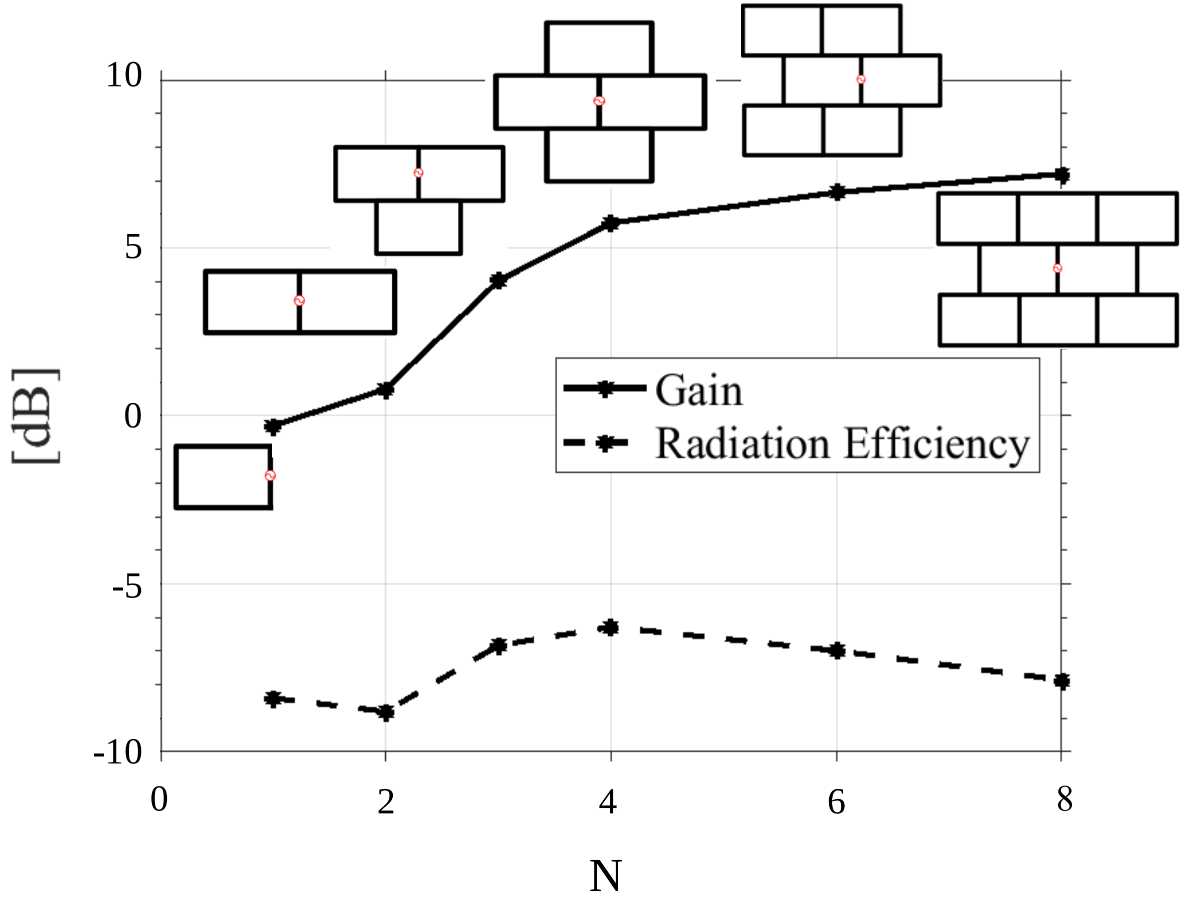


Pervasive Electromagnetics Lab

Twin-Grid Driver Size

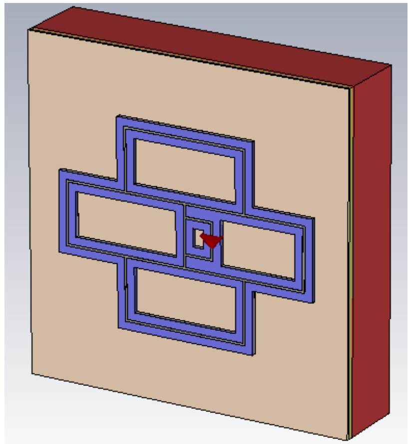
The driver size is reconsidered using the 8mm ground track.

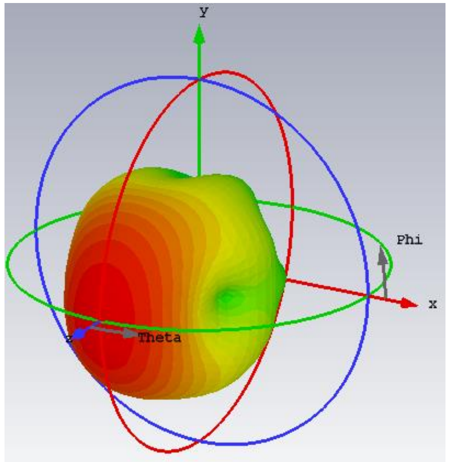
- The results align with the original findings with four-cells again having the best balance between efficiency and gain to overall size
- Reduction of the ground incurs a 3dB loss of gain and efficiency



Pervasive Electromagnetics Lab

Twin-Grid with T-Match



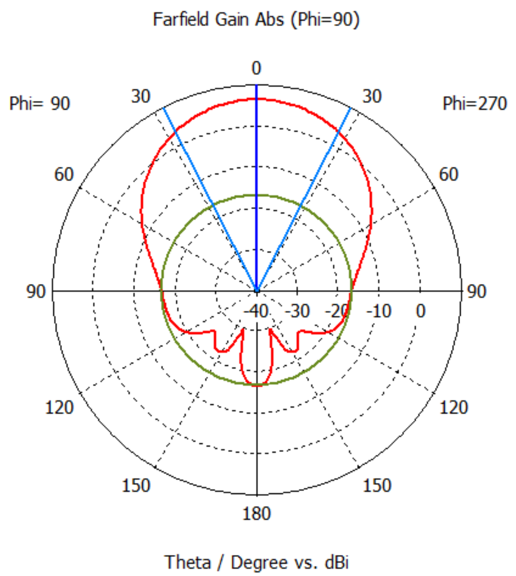


farfield (f=3.6) [1]

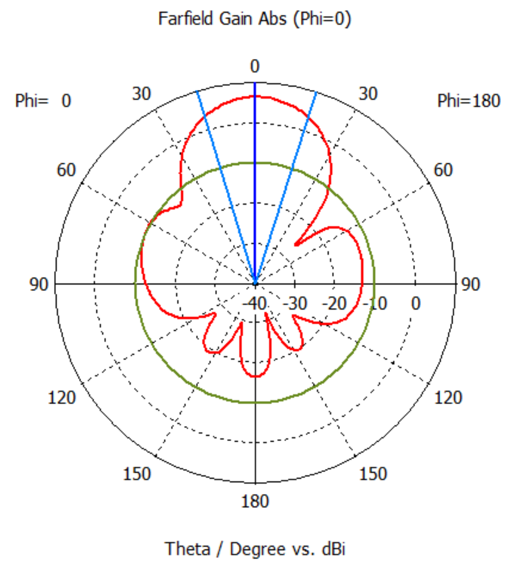
Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Directivity
Frequency	3.6 GHz
Rad. Effic.	-5.478 dB
Tot. Effic.	-5.483 dB
Dir.	11.87 dBi

farfield (f=3.6) [1]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Gain
Frequency	3.6 GHz
Rad. Effic.	-5.478 dB
Tot. Effic.	-5.483 dB
Gain	6.390 dBi

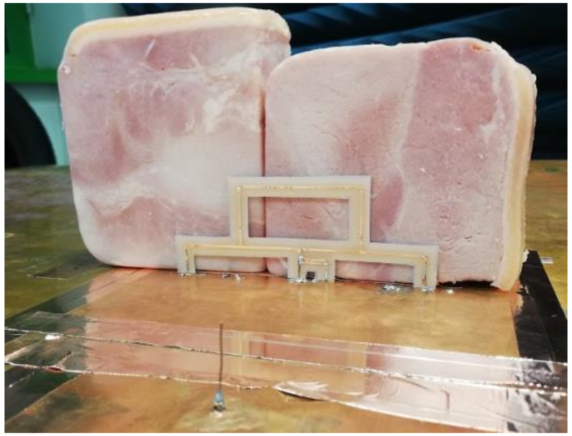


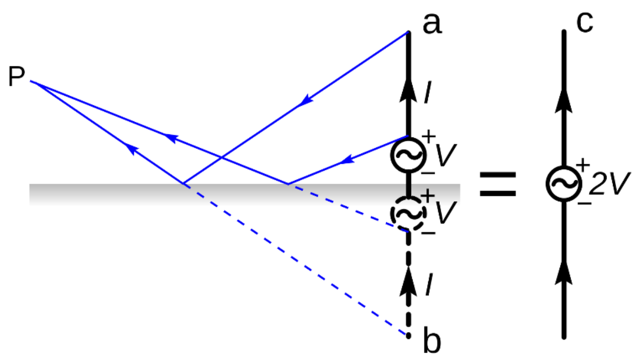
Frequency = 3.6 GHz
Main lobe magnitude = 6.39 dBi
Main lobe direction = 0.0 deg.
Angular width (3 dB) = 54.6 deg.
Side lobe level = -23.0 dB



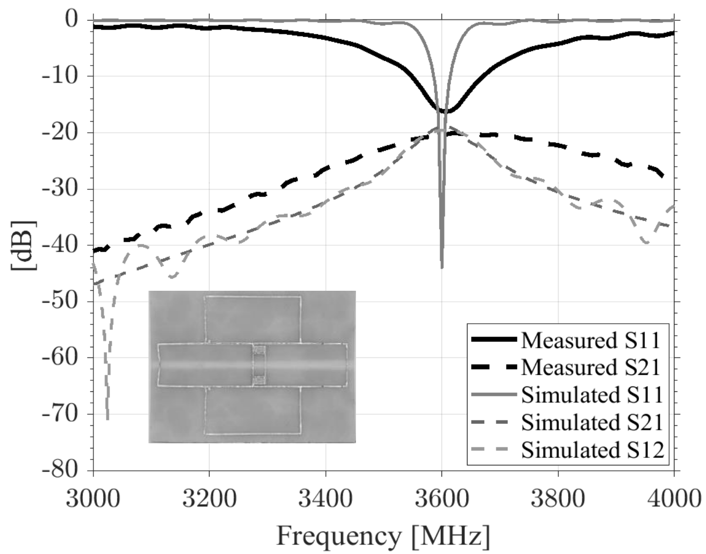
Frequency = 3.6 GHz
Main lobe magnitude = 6.39 dBi
Main lobe direction = 0.0 deg.
Angular width (3 dB) = 34.5 deg.
Side lobe level = -16.3 dB

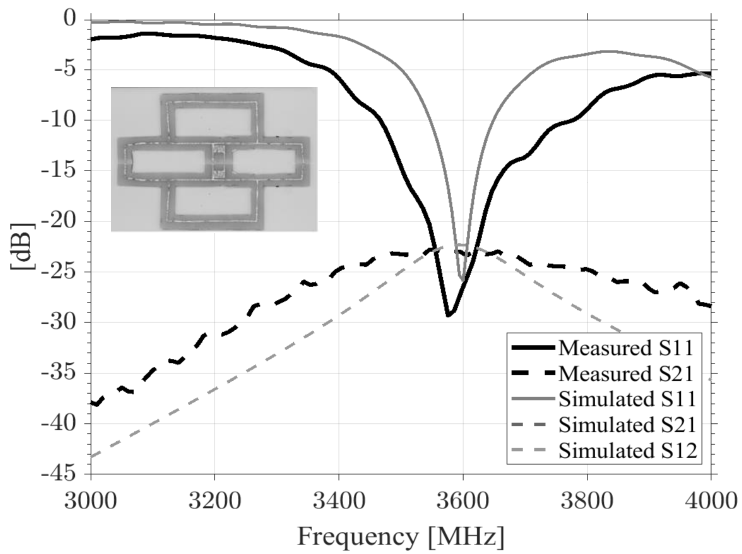
Measurement Setup

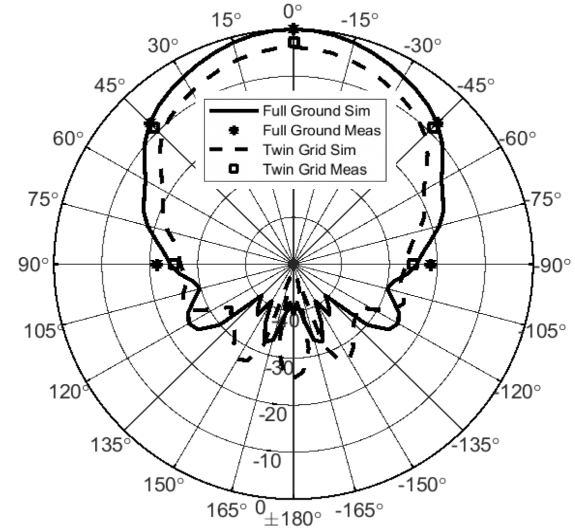




Measurement Results







TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

Contact Information

Jack Hughes

jdh23@kent.ac.uk

John Batchelor

J.C.Batchelor@kent.ac.uk

University of Kent,
EDA, Jennison Building,
Canterbury, Kent,
CT2 7NT

Cecilia Occhiuzzi

cecilia.occhiuzzi@uniroma2.it

Gaetano Marrocco

gaetano.marrocco@uniroma2.it

University of Roma "Tor Vergata"
DICII, Via del Politecnico 1

Pervasive Electromagnetics Lab