

**QUAD POLARIZATION WIDEBAND
SINUOUS ANTENNA ELEMENTS AND
ARRAYS**

RAMANAN BALAKRISHNAN

NATIONAL UNIVERSITY OF SINGAPORE

2015

**QUAD POLARIZATION WIDEBAND
SINUOUS ANTENNA ELEMENTS AND
ARRAYS**

Ramanan Balakrishnan

(B.Eng. (Hons.), NUS)

**A THESIS SUBMITTED
FOR THE DEGREE OF MASTER OF
ENGINEERING
DEPARTMENT OF ELECTRICAL AND
COMPUTER ENGINEERING
NATIONAL UNIVERSITY OF SINGAPORE**

2015

DECLARATION

I hereby declare that the thesis is my original work and it has been written by me in its entirety.

I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

Ramanan Balakrishnan

5th February 2015

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

and there was light

Acknowledgment

Let's thank some people here.

Contents

Abstract	vii
List of Tables	viii
List of Figures	ix
1 The basics	1
1.1 A simple section	1
1.1.1 A sub-section	1
2 Figures, sub-figures and more	2
3 Let’s talk tables	5
4 Equations and code	8
Bibliography	9

Abstract

A section to summarize the main contributions of this thesis.

List of Tables

3.1	Sequential modes in four-arm sinuous antennas.	5
3.2	Role of design parameters in sinuous antennas.	6
3.3	Review of performances of various broadband antennas. . . .	7

List of Figures

2.1	Captions are also possible for figures.	2
2.2	A common caption is shown for both. Use (a) and (b) to refer to the subfigures.	3
2.3	A full page of figures!	4

List of Symbols

λ	wavelength
ϵ_r	relative dielectric constant
k	wave number, defined as $2\pi/\lambda$

List of Abbreviations

IEEE	Institute of Electrical and Electronics Engineers
PASS	Phased Array System Simulator
RF	Radio Frequency

Chapter 1

The basics

And so it begins ...

1.1 A simple section

A citation [\[1\]](#). Here is another citation [\[2\]](#).

1.1.1 A sub-section

Some more text here.

Chapter 2

Figures, sub-figures and more

A simple figure called [Fig. 2.1](#) is shown below.

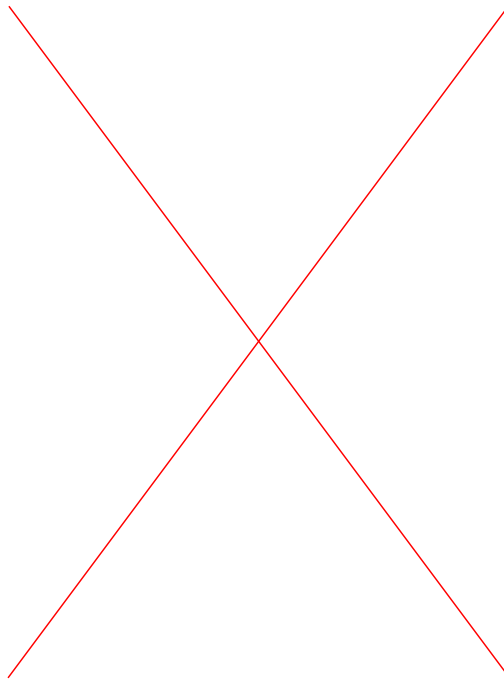


Fig. 2.1. Captions are also possible for figures.

More complicated layouts of multiple figures using `subfloat` are also possible as shown in [Fig. 2.2](#). Reference a subfigure directly as [Fig. 2.2a](#).

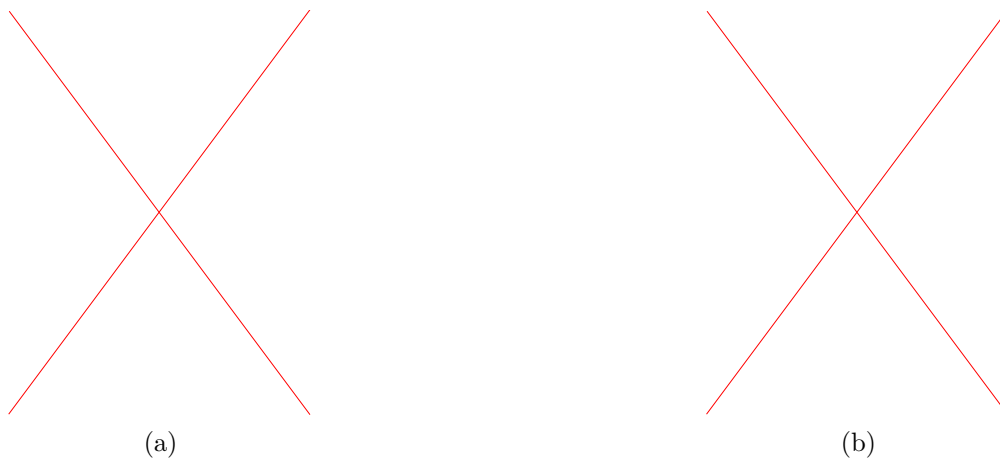
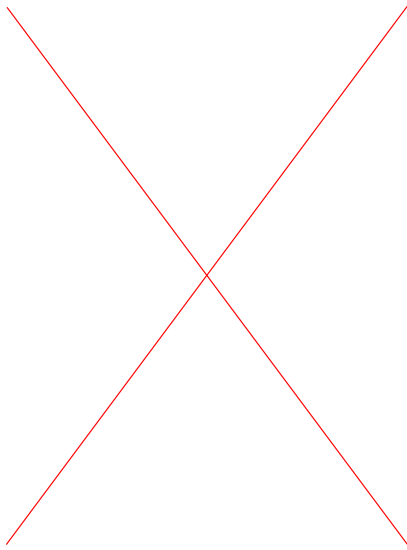
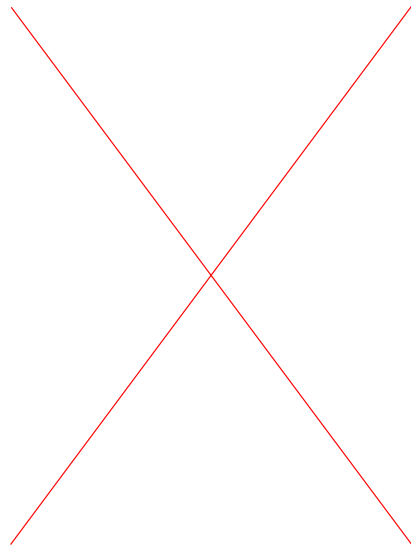


Fig. 2.2. A common caption is shown for both. Use (a) and (b) to refer to the subfigures.

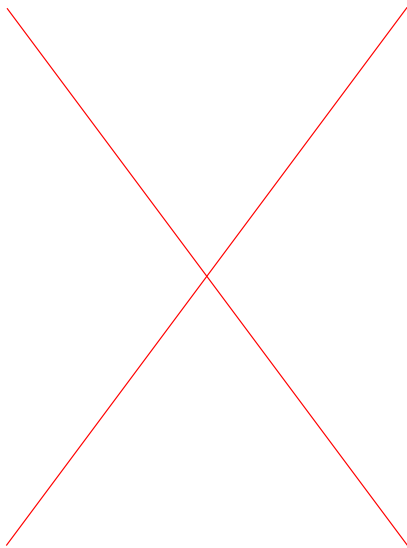
Finally, a full page of figures with a possible layout is shown in [Fig. 2.3](#).



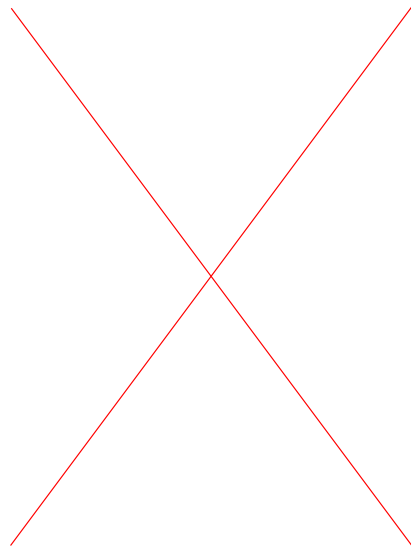
(a)



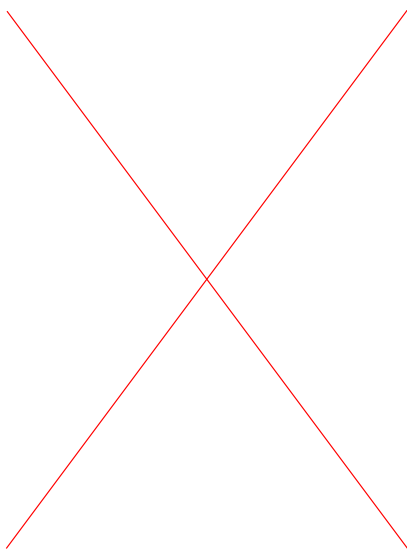
(b)



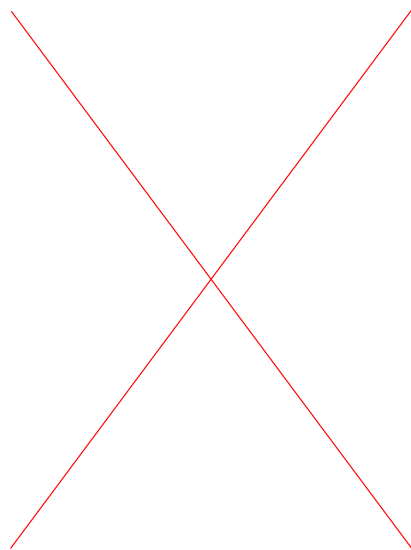
(c)



(d)



(e)



(f)

Fig. 2.3. A full page of figures!

Chapter 3

Let's talk tables

A simple table, with my personal tastes on borders and widths is shown below.

Table 3.1
Sequential modes in four-arm sinuous antennas.

Mode number	Port 1	Port 2	Port 3	Port 4
M_{-2}	0°	-180°	0°	-180°
M_{-1}	0°	-90°	-180°	-270°
M_{+1}	0°	90°	180°	270°
M_{+2}	0°	180°	0°	180°

All the usual features of L^AT_EX are possible, such as merging cells, wrapping / aligning text etc ...

Table 3.2
Role of design parameters in sinuous antennas.

Parameter	Denotes	Typical values	Role
N	Number of arms	4, 6, 8	Determines the number of modes obtainable.
R_1	Outer radius	$\frac{\lambda_L}{2\pi}$ to $\frac{\lambda_L}{3\pi/4}$	Sets the lower frequency limit.
τ	Growth factor	0.6 to 0.9	Controls the ratio between adjacent cells and number of cells given a fixed size.
α	Angular span	22.5° to 90°	These two parameters together control the angular span, interleaving and input impedance of the antenna.
δ	Angular spacing	11.25° to 45°	

Finally, a large table, represented in landscape mode is shown in the next page.

Table 3.3
Review of performances of various broadband antennas.

Aspect	Dipole-based designs (biconical, discone, ...)	LPDA	Spiral	Sinuous
Frequency bandwidth	Typically max at around two octaves.	Comparable to dipole-based designs, extendable by increasing elements.	Ratios of up to 40 : 1 are possible.	Ratios comparable to spiral designs.
Multiple Polarization	Only possible if crossed elements are added.	Only possible if crossed elements are added.	Possible with cavity-backing.	Possible with reconfigurable feed network.
Planar	Planar versions possible with maximum extents of order $\lambda/2$.	3-D array of dipole ($\lambda/2$) sized elements with maximum extent determined by required bandwidth.	Planar versions possible with extent of order of λ	Planar versions possible with extent of order of λ
Radiation pattern	Cavity required for unidirectional radiation.	Cavity not required for unidirectional radiation.	Cavity required for unidirectional radiation.	Cavity required for unidirectional radiation.

Chapter 4

Equations and code

The `equation` environment is the answer to all your complex greek formatting requirements.

$$\phi = (-1)^p \alpha_p \sin \left[\frac{180^\circ \log(r/R_p)}{\log \tau_p} \right], \quad R_{p+1} \leq r \leq R_p \quad (4.1)$$

I prefer to use the simple `verbatim` environment for capturing my code segments.

```
r_total = zeros(0,0);
phi_total = zeros(0,0);
for p=1:length(R)-1
    r = linspace(R(p),R(p+1)+eps,10000);
    phi = ((-1)^p) * alpha *(sin(pi*log(r/R(p))/log(tau)));
    r_total = horzcat(r_total,r);
    phi_total = horzcat(phi_total,phi);
end
```

Bibliography

- [1] D. R. Hofstadter, *Godel, Escher, Bach: An Eternal Golden Braid*. New York, NY, USA: Basic Books, Inc., 1979.
- [2] R. Balakrishnan, K. Mouthaan, I. Hinostroza, and R. Guinvarc'h, "Dual-circular polarized planar array of connected sinuous antennas," in *Antennas and Propagation Society International Symposium (AP-SURSI), 2014 IEEE*, July 2014, pp. 941–942.

