Part 1 — Technology review on printed antennas

1 Antenna constituents

1.1 Indirect feedings through aperture coupling

1.2 Dielectric substrate selection criteria

1.2.1 Bandwidth/Radiation efficiency/Scan blindness

1.2.2 Final trade-off

2 Electrical functions to be implemented

2.1 Circular polarisation

2.2 High gain

2.3 Beam scanning

3 Design guidelines

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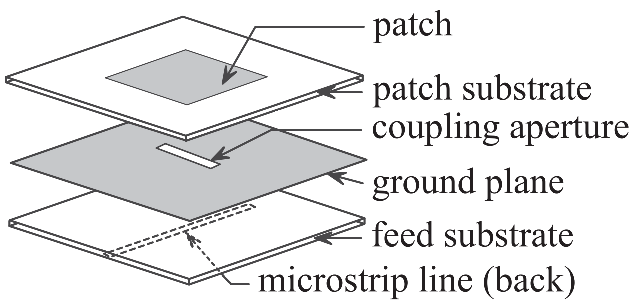
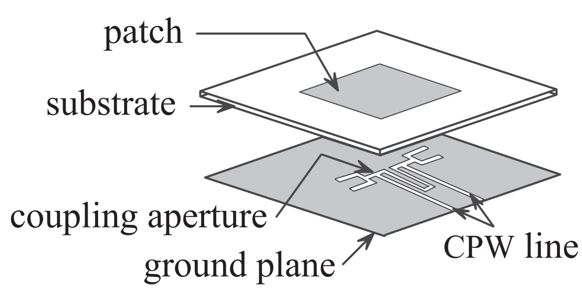
1.1 Indirect feedings through aperture coupling

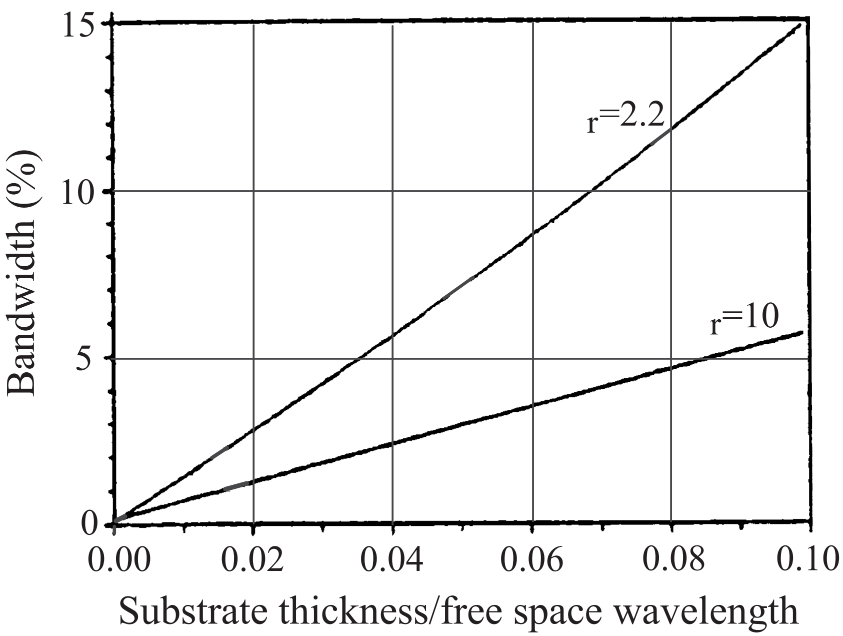
Technique	Advantages	Drawbacks
Microstrip feeding  	• 2 substrates for 2 different electrical functions, radiation and feed/circuitry • Ground plane isolates radiating elements from the spurious feed radiation	• Costly and complicated multi-layer fabrication
CPW feeding  	• Easy to manufacture • CPW lines versus microstriplines: - smaller dispersion - lower losses at higher impedance and for high-ε_r • Device integration with no via holes	• Possible radiation from feed structure • Air-bridges necessary to short parasitic mode

minimum 4 degrees of freedom* $\Rightarrow$ convenient for impedance matching/tuning

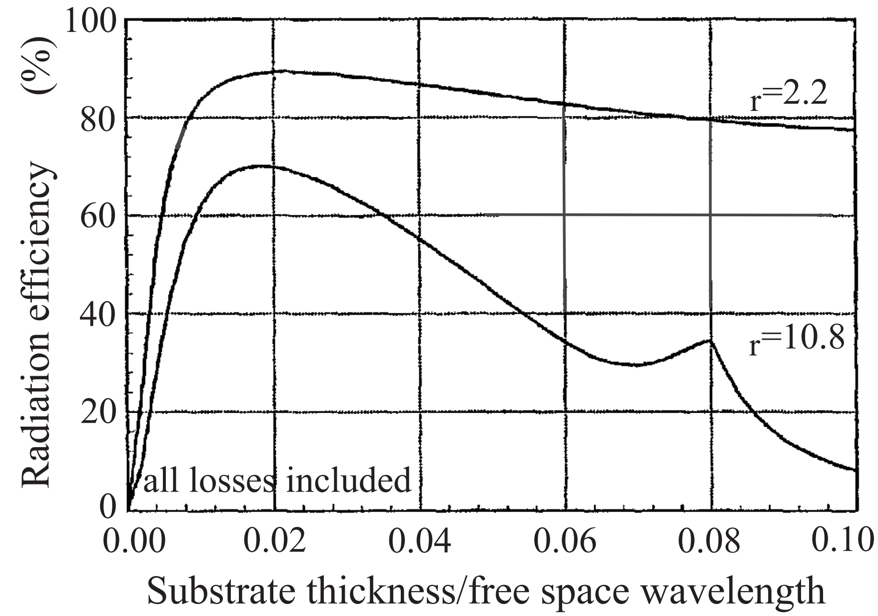
* slot size and position, feeding stub length, feed lines width

1.2 Dielectric substrate selection criteria

Impedance bandwidth

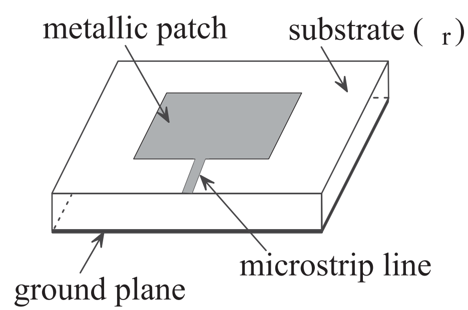


Radiation efficiency



Microstrip patch

at the resonant frequency

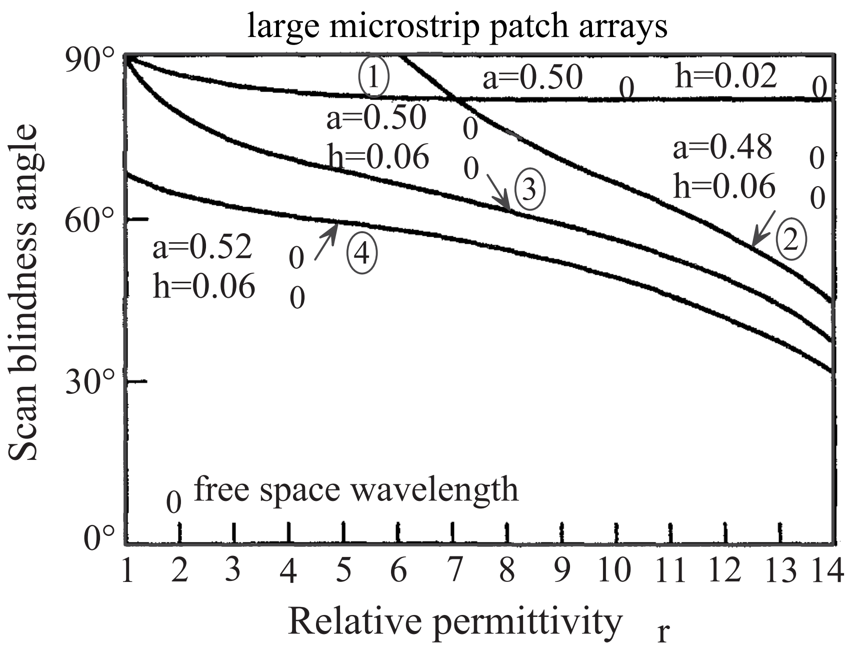


$$\eta = \frac{P_r}{P_r + P_{losses}}$$

losses: metal, dielectric, surface waves

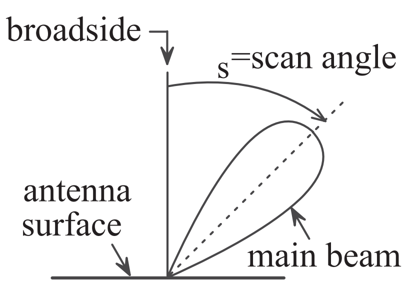
1.2 Dielectric substrate selection criteria

Scan blindness



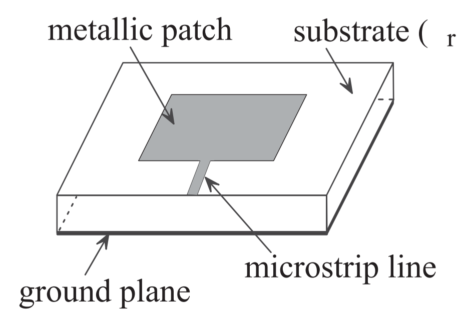
Final trade-off

Substrate parameters — Requirements
• Radiation viewpoint - thick → increased bandwidth - low-ε_r → enhanced radiation
• Feed/circuitry viewpoint - thin → reduced losses - high-ε_r → smaller circuit dimensions
• Array application scan blindness easier to avoid with smaller thickness and lower ε_r



h substrate thickness
a element spacing

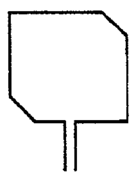
To avoid grating lobes → $a < \lambda_0/2$



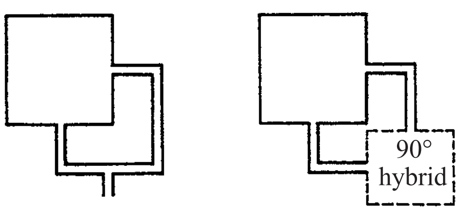
2.1 Circular polarisation

- **Square patch**
  - symmetry
  - less cumbersome

- **Number of feed points**



axial ratio bandwidth < 1%

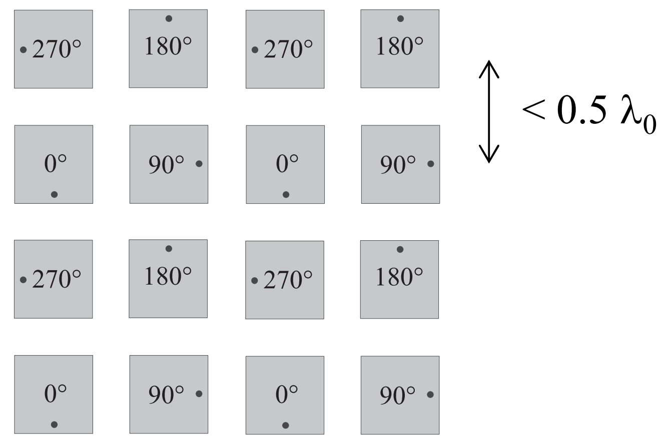


axial ratio bandwidth ~ impedance bandwidth

2 orthogonal modes excited by a single patch

- **Sequential rotation**

2 orthogonal modes supported by two patches



(+) cross-polarisation cancellation - principal planes

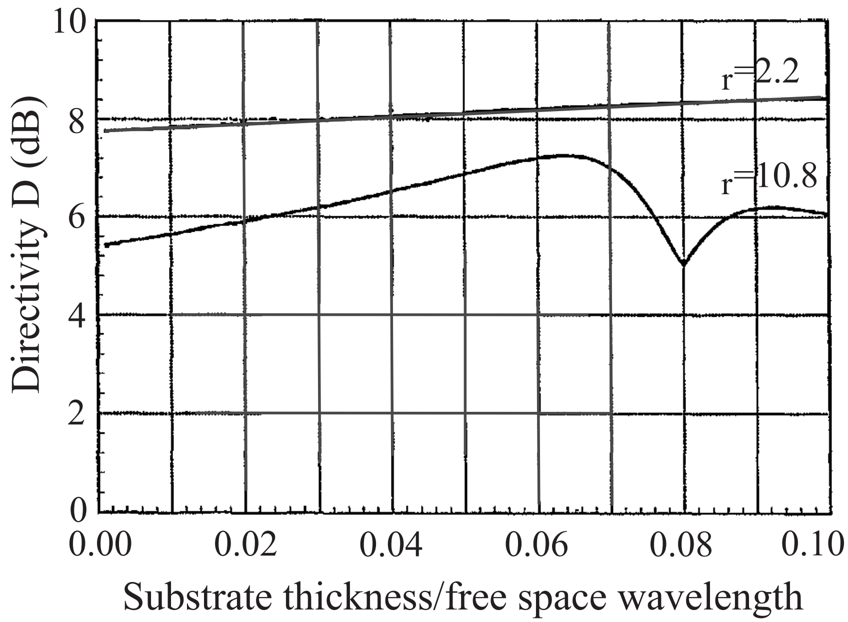
(−) high lobes in the diagonal plane

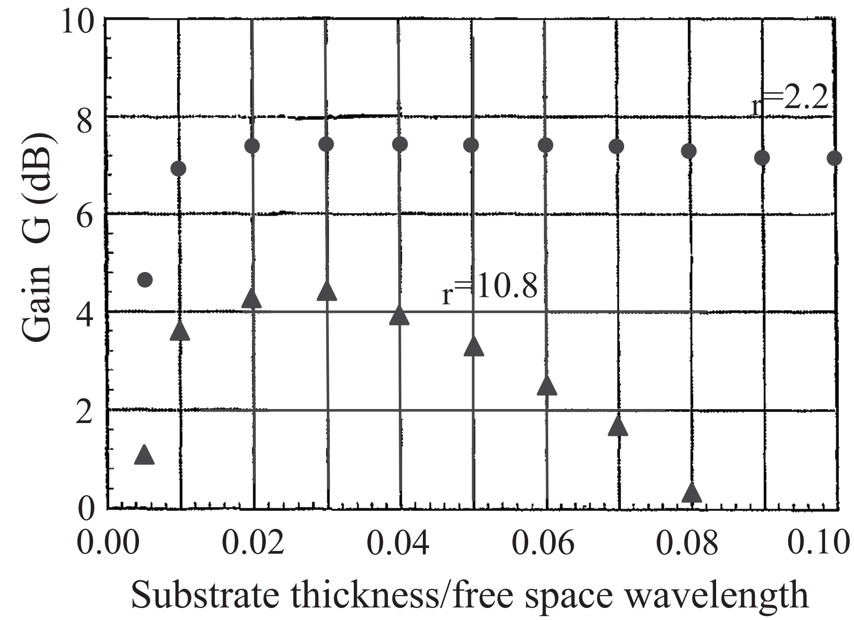
Solutions
- subarray spacing < λ_0
- perform sequential rotation on subarrays
- increase number of elements

Dr. L. Richard

2.2 High gain

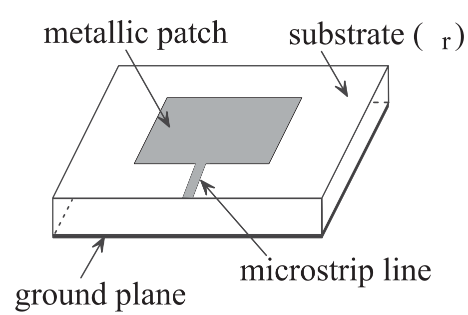
Intrinsic gain of a microstrip patch





Microstrip patch

at the resonant frequency



$$G = \eta D$$

η radiation efficiency

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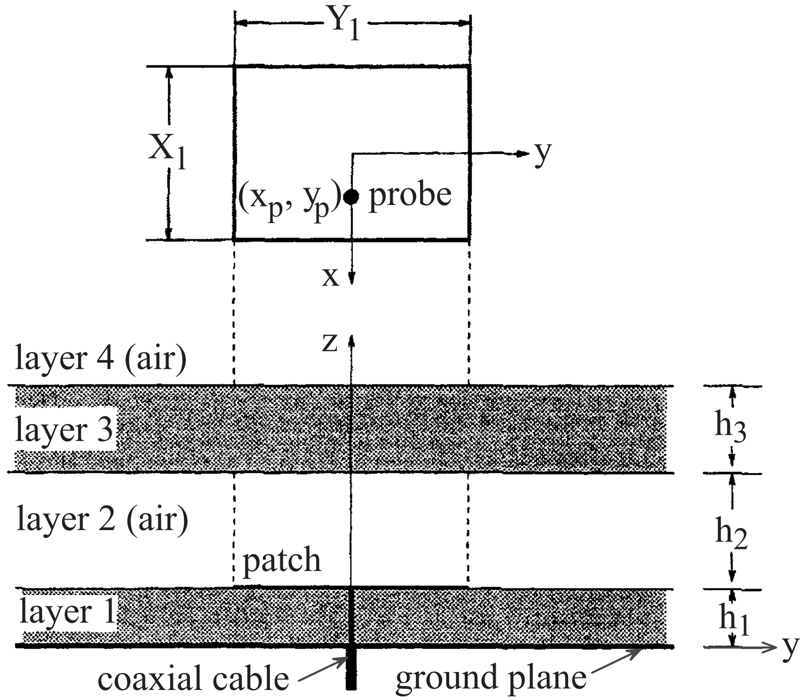
2.2 High gain — Gain enhancement technique

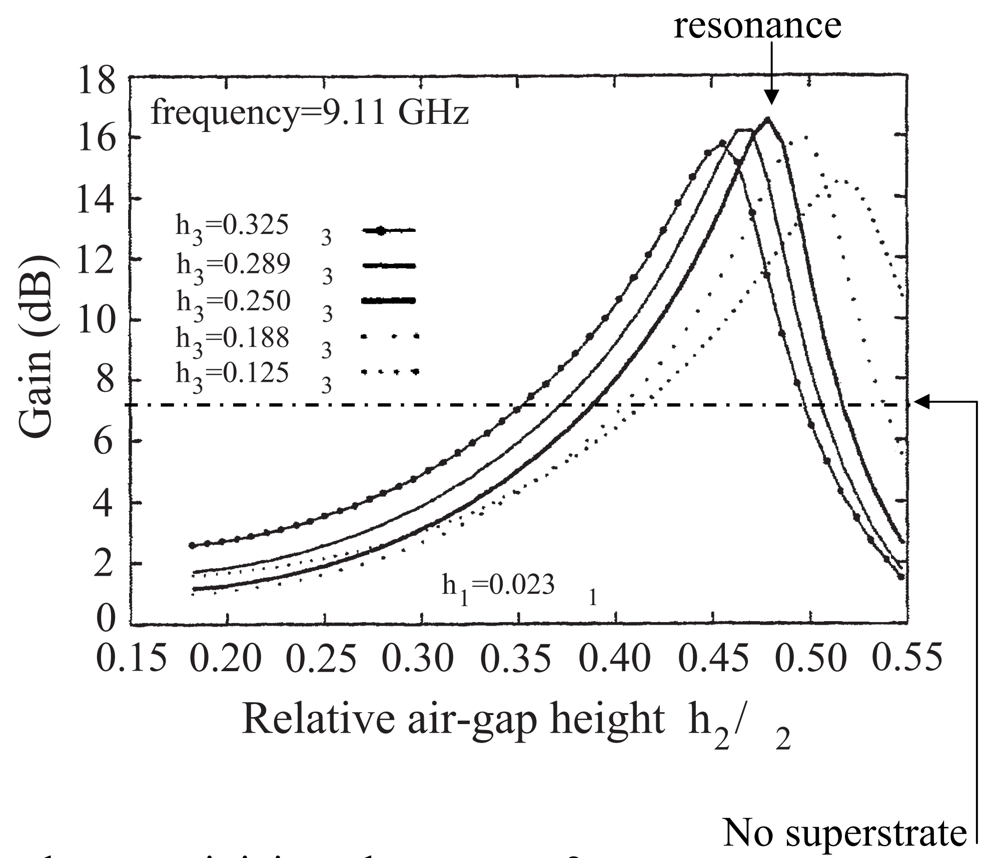
Multiple superstrates above microstrip patch



Resonance condition
for broadside maximum radiation

superstrate thickness = $h_3 = \lambda_3 / 4$

Broadside maximum gain



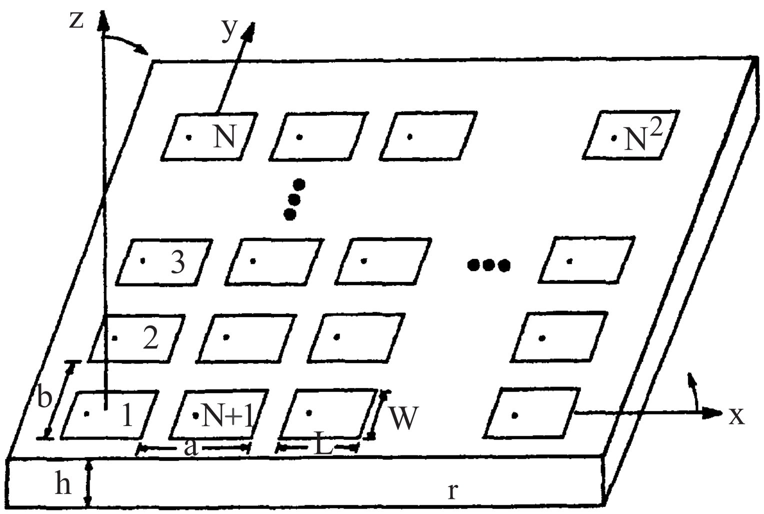
low permittivity substrate, $\varepsilon_{r1} \sim 2$

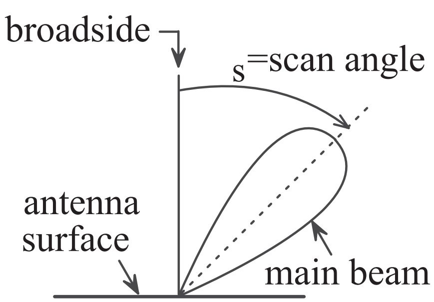
high permittivity superstrate, $\varepsilon_{r3} \sim 10$

2.3 Beam scanning

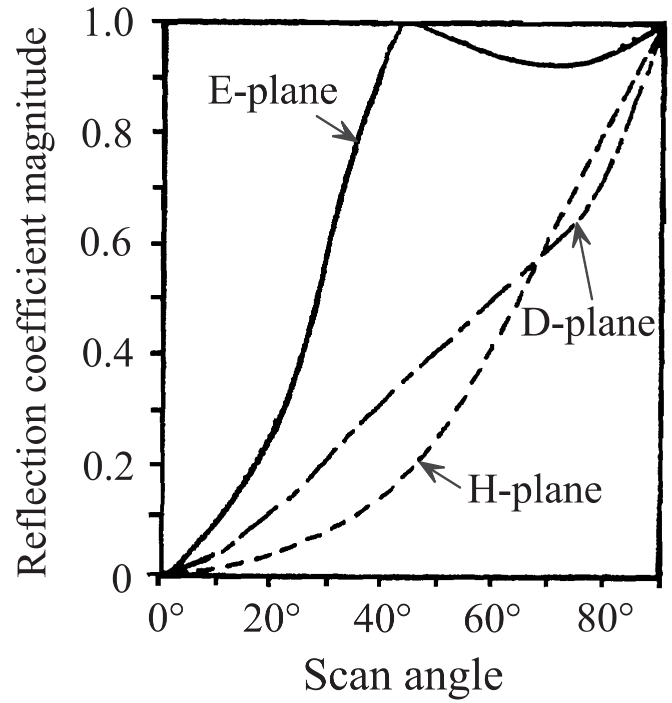
Scan blindness

Array geometry





Infinite array of rectangular patches



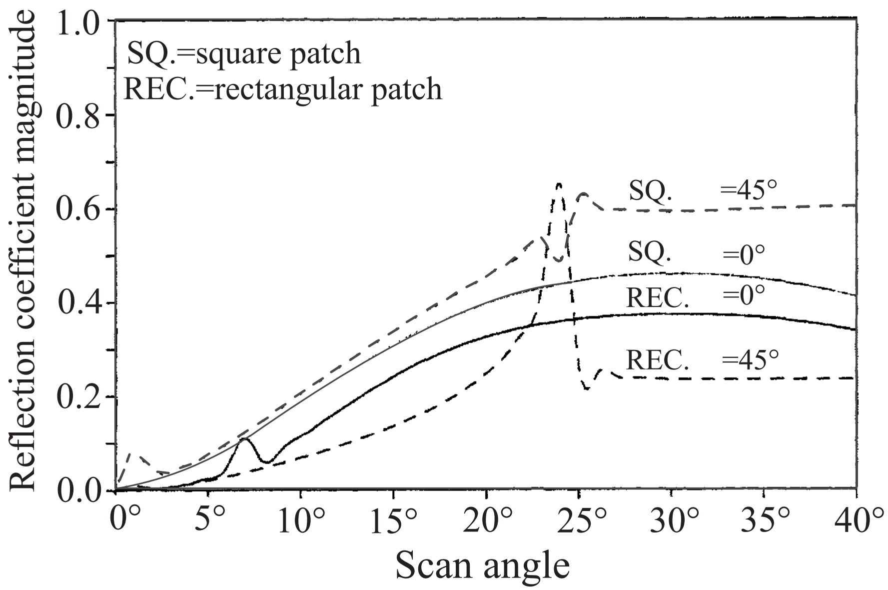
high substrate permittivity $\varepsilon_r \sim 13$

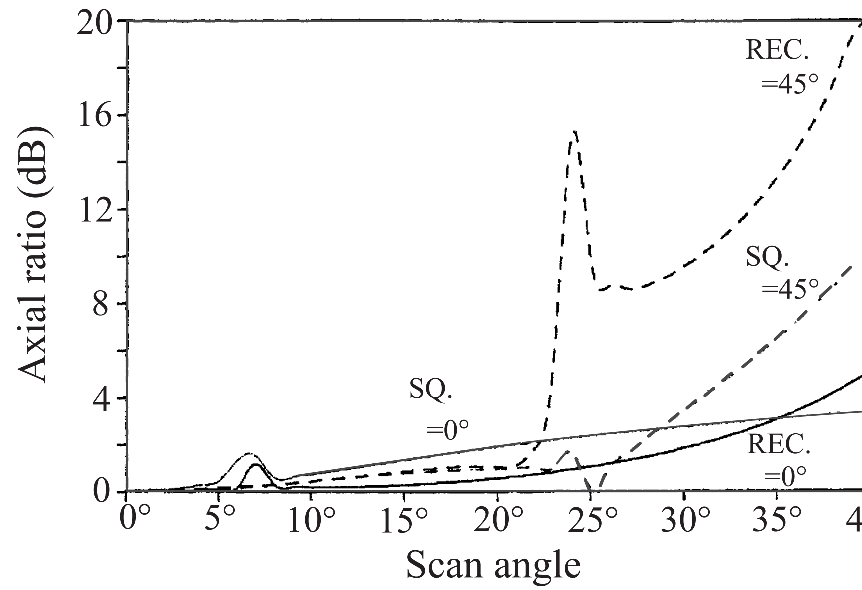
substrate thickness $\sim 0.06\ \lambda_0$

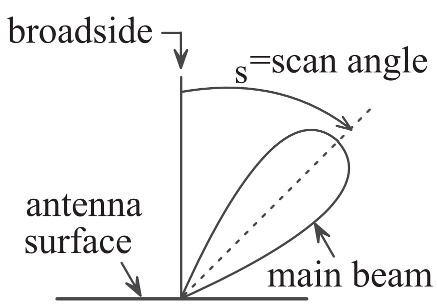
2.3 Beam scanning

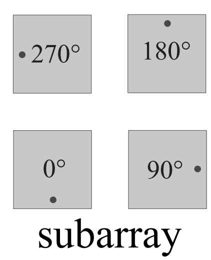
Subarraying

Infinite arrays of 2×2 circularly polarised subarrays — Sequentially rotated linearly polarised elements









- Square patches
  scan angle up to 25° → axial ratio ≤ 2
- Data

subarray spacing = λ_0
substrate permittivity = 2.55
substrate thickness = 0.03 λ_0

3 Design guidelines

Antenna component	Proposal	Main reasons
Radiating element	square microstrip patch	• simple to design • symmetry • circular polarisation
Feeding primary network	aperture coupling + coplanar waveguide feed	• single-layer substrate • easy to fabricate • several degrees of freedom
Substrate	low permittivity	• good efficiency • avoid scan blindness
	high permittivity	• fully exploit CPW lines • facilitate device integration
Architecture	tile-type	• broadside radiating element
	hybrid brick-tile type	• may be useful to add the secondary feeding network