Multiband and Wideband Patch Antennas

Final presentation on chapter 15

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Outline

- Dual band design techniques
- Dual polarization techniques
- Circular polarization techniques
- Triple band design techniques
- Wideband design technique
- Practical applications in wireless communication
- Design Challenges for wireless communication

Patch antenna

- Patch antenna
- Printing conducting patch on a grounded dielectric substrate
- Light weight
- Easy fabrication
- Disadvantages: Narrow bandwidth

Patch antenna

- Question: As we know, patch antennas usually have narrow impedance bandwidth. Would you tell us the reason why? Make it brief and clear, please.

- Ans: the quality factor of patch antenna is high due to its cavity nature. The bandwidth is inversely proportional to Q factor. Therefore, it has a narrow bandwidth.

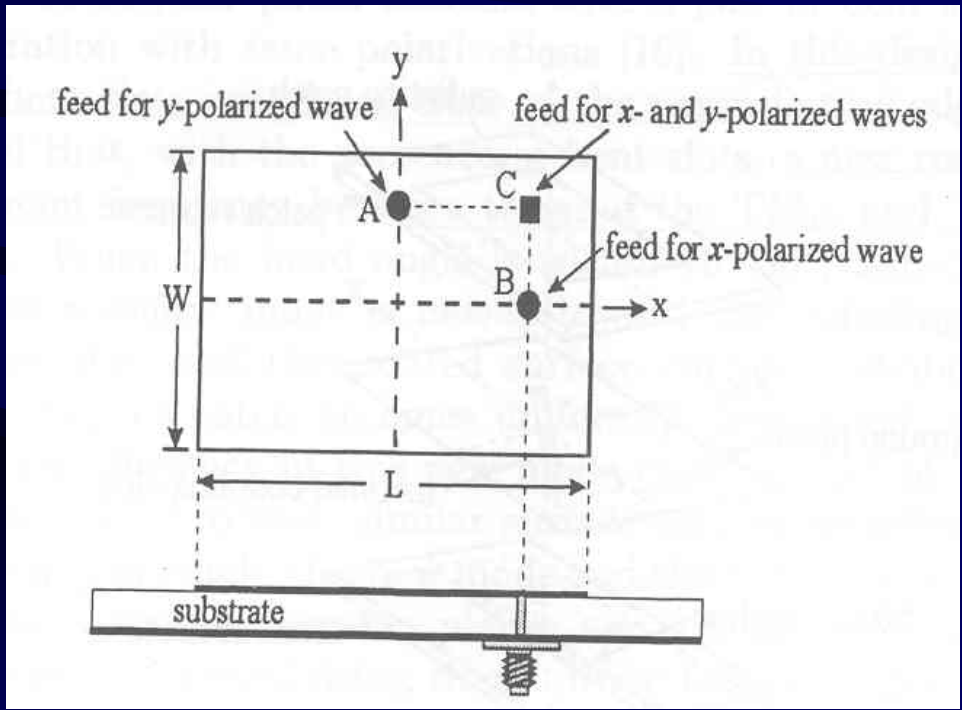
Patch antenna

- Question: To overcome such disadvantage, multiband technique has been applied.
- Can you explain how this technique do to the PA?

- Ans: Maybe it means that “wideband” techniques can be applied to overcome the narrow impedance problem.

Dual band design techniques
-orthogonal polarization

- Orthogonal polarization



Dual band design techniques
-orthogonal polarization

- Question: How to set the feed point? Through experiment or theory

- Ans: If the patch is not modified (purely rectangular or circular shape), the feed point can be found to match the fields in the cavity
- But for patches with slots or pins, the fields in the cavity are disturbed. The optimal feed point may be tuned through experimental data

Dual band design techniques
-orthogonal polarization

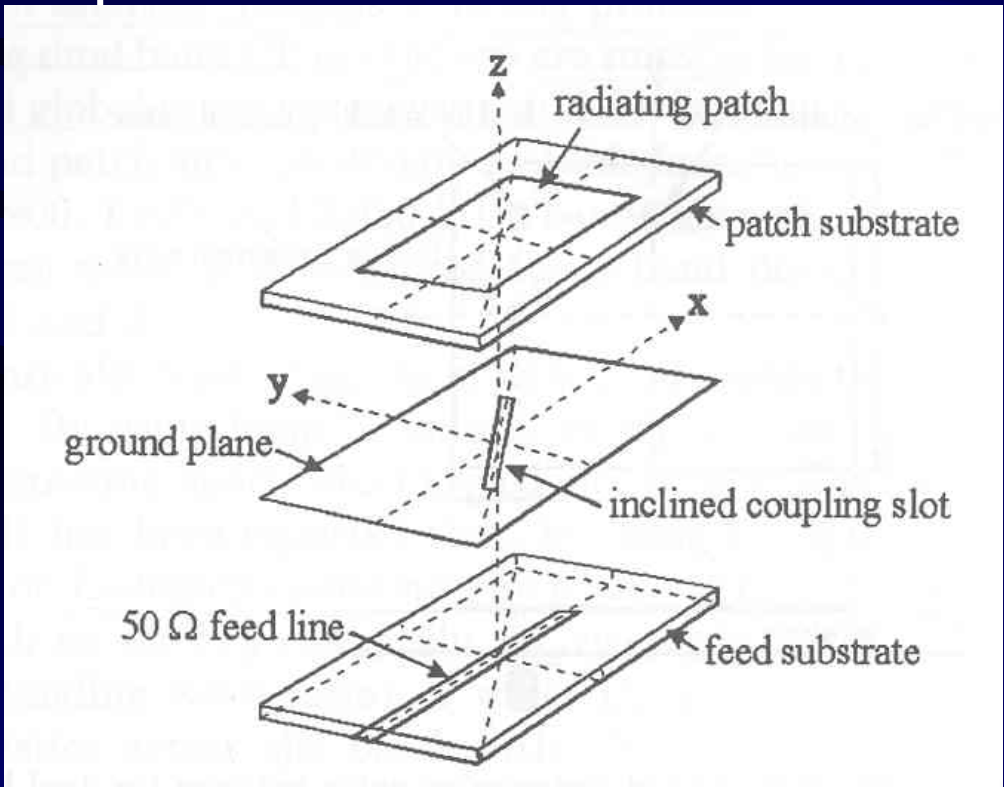
- Feed points A and B are used to excite the TM10 and TM01 modes
- The two resonant frequency are be estimated as

$$f_{01} = \frac{c}{2W\sqrt{\varepsilon_r}} \qquad f_{10} = \frac{c}{2L\sqrt{\varepsilon_r}}$$

- The formula is accurate for thin substrate
- Point C: effective excitation of both modes can be achieved

Dual band design techniques
-orthogonal polarization

- Fig 15.2
- Slot-coupled feed method



Dual band design techniques
-orthogonal polarization

- Question: Instead of using the probe feed method, similar dual band operation can also be obtained by using slot-coupled feed method.
- Does it mean that we can use either way to obtain this operation? And which one is better? (more efficient/accurate/etc ;in your opinion)

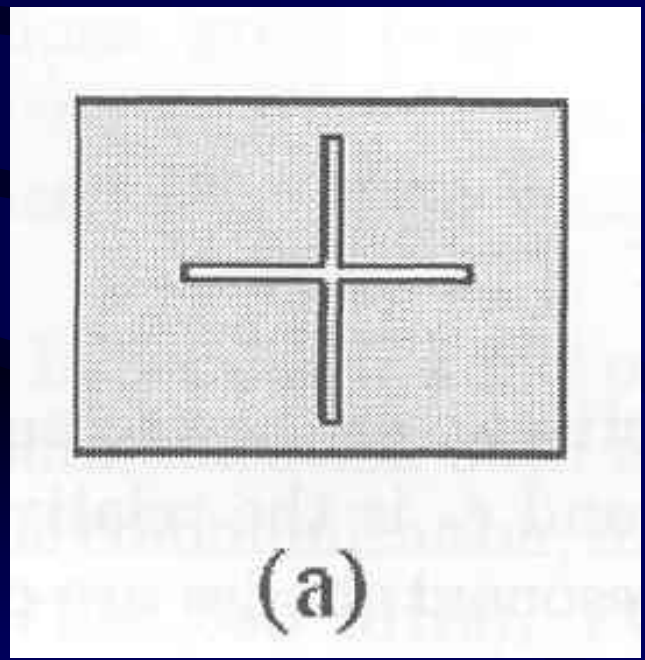
- Answer in the next page.

Dual band design techniques
-orthogonal polarization

- Ans:
- Both the probe and slot coupled feed method can obtain dual frequency operation and they have low spurious radiation.
- The choice of probe or slot coupled feed may depend on connections between antenna and other components in the circuits

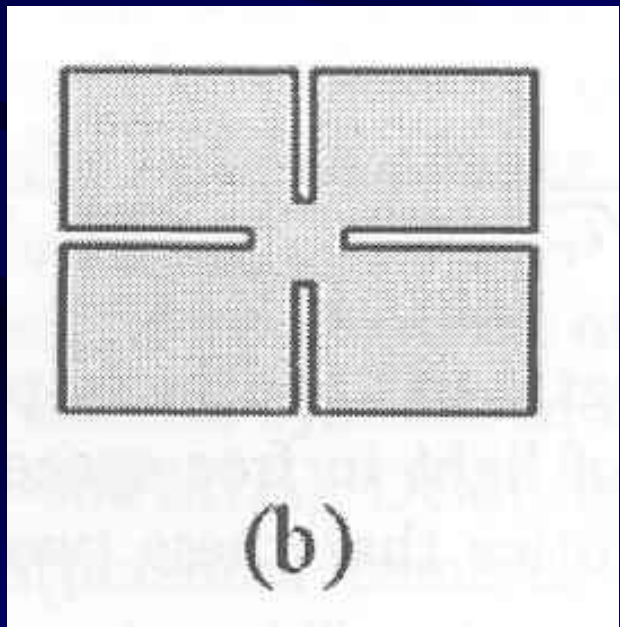
Dual band design techniques
-orthogonal polarization

- Fig 15.3(a)
- Cross slot embedded in the center of a rectangular patch



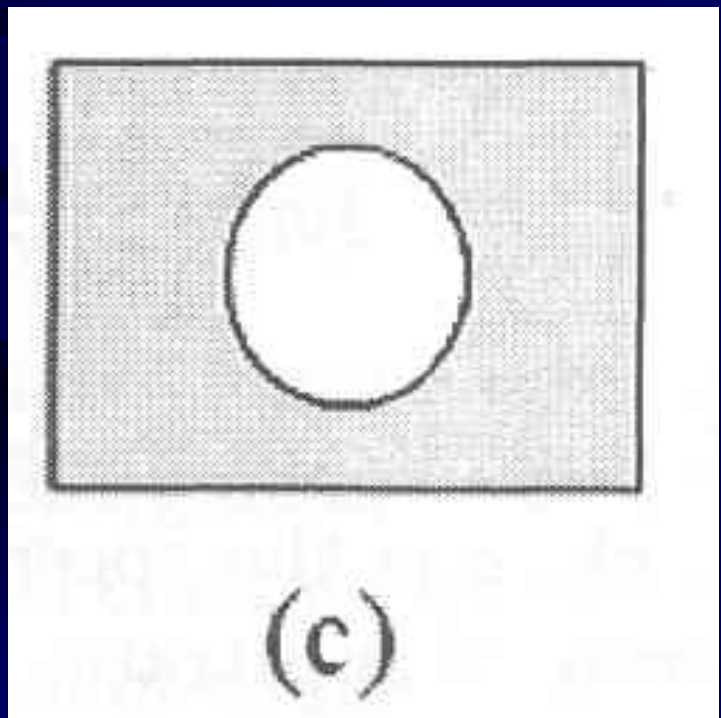
Dual band design techniques
-orthogonal polarization

- Fig 15.3(b)
- Inserting four narrow slits at the four edges of a rectangular patch



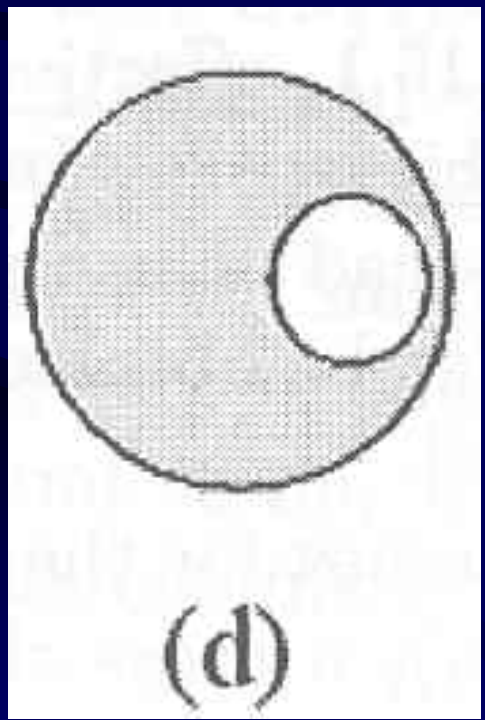
Dual band design techniques
-orthogonal polarization

- Fig 15.3(c)
- Embedding a circular hole in a rectangular patch



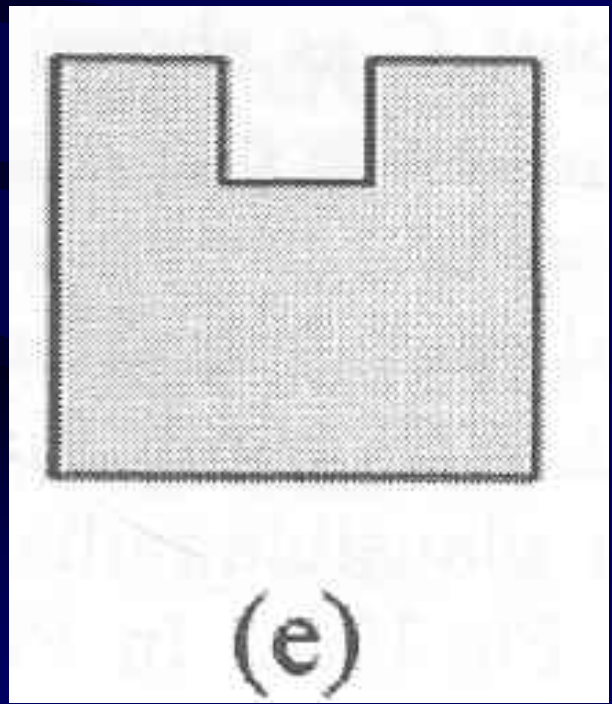
Dual band design techniques
-orthogonal polarization

- Fig 15.3(d)
- Embedding a circular hole in a circular patch



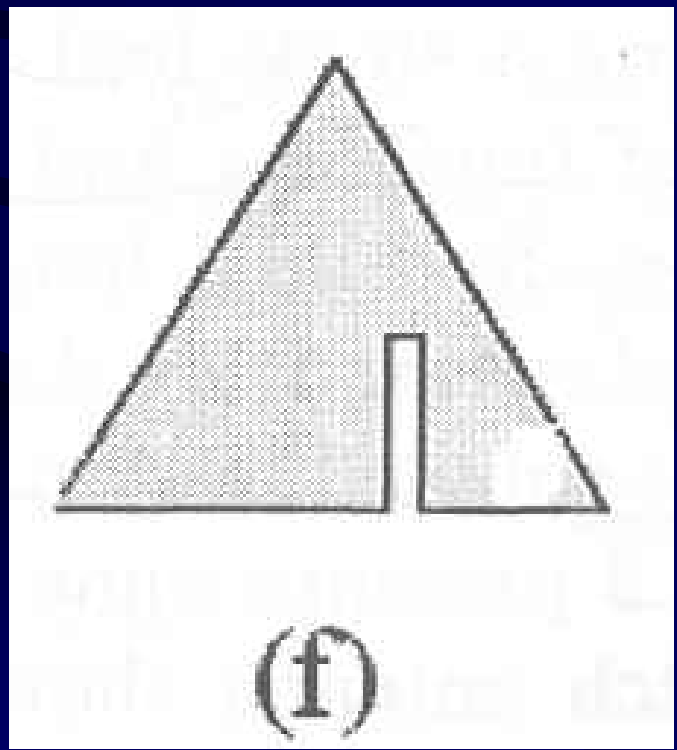
Dual band design techniques
-orthogonal polarization

- Fig 15.3(e)
- Notched square patch



Dual band design techniques
-orthogonal polarization

- Fig 15.3(f)
- Slit loaded triangular patch

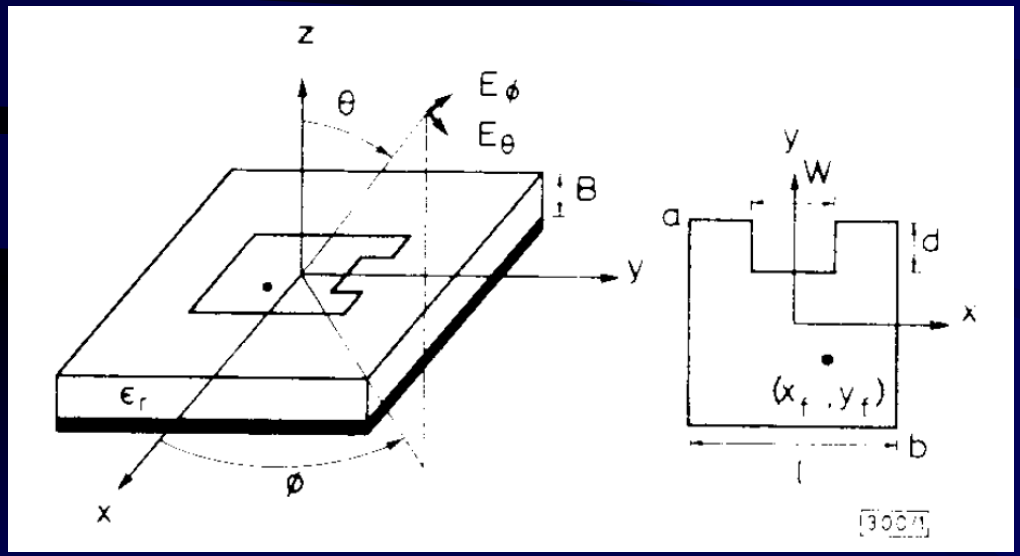


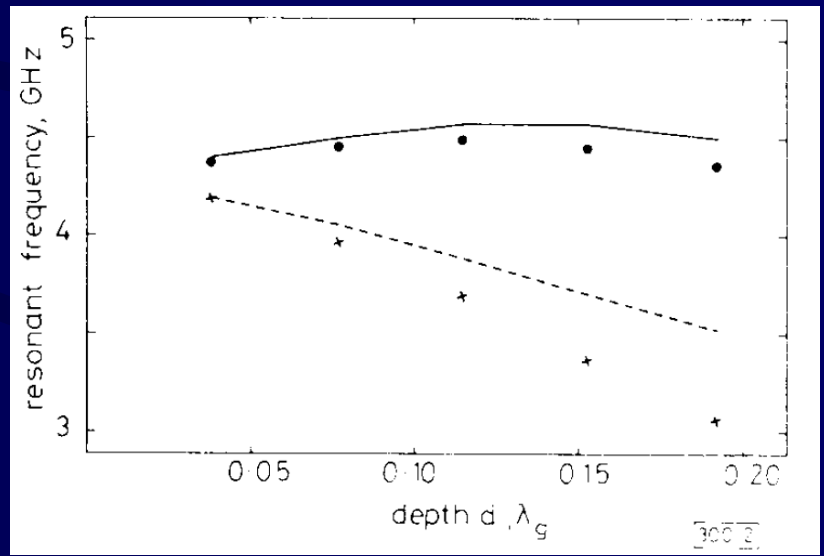
Dual band design techniques
-orthogonal polarization

- Question: Design using notched square patch and slit-loaded triangular patch are also promising in achieving single-feed dual band operations with orthogonal polarizations.
- What are those patches? Please introduce them briefly.

Dual band design techniques
-orthogonal polarization

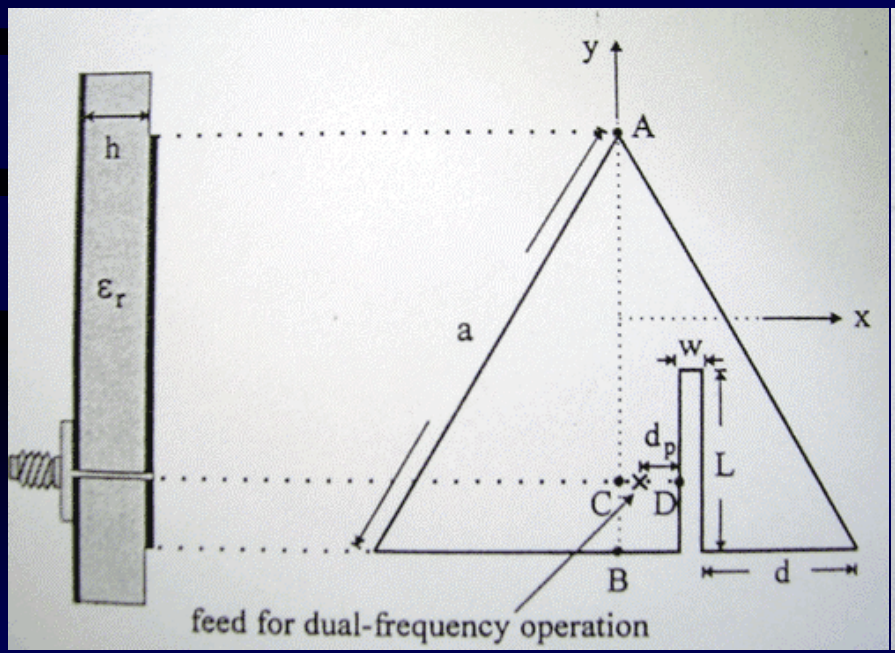
- Ans: (1) Notched square patch

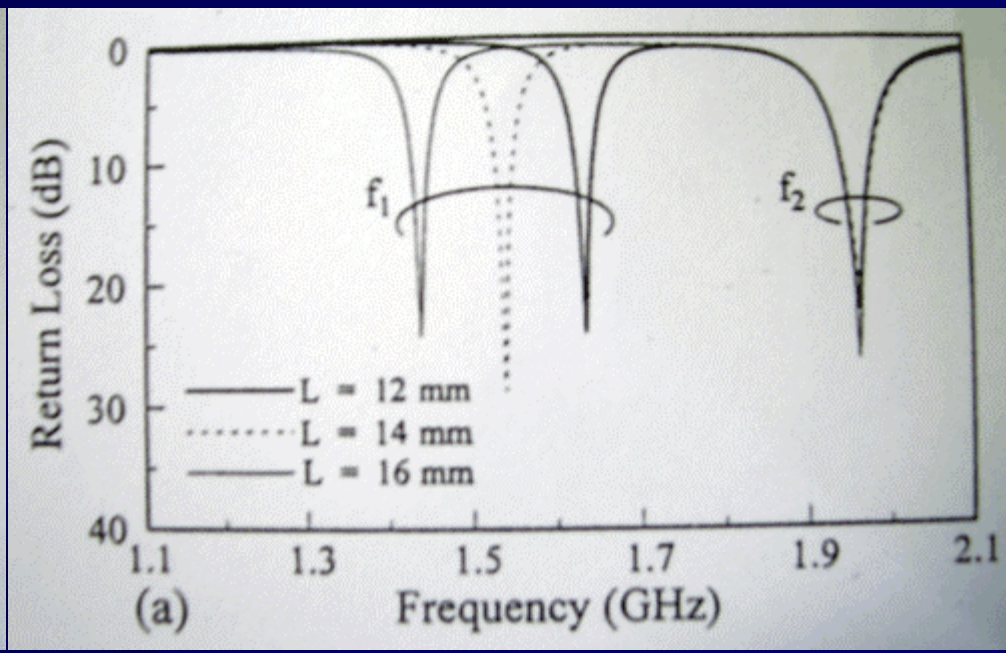




Dual band design techniques
-orthogonal polarization

- Ans: (2) slit-loaded triangular patch



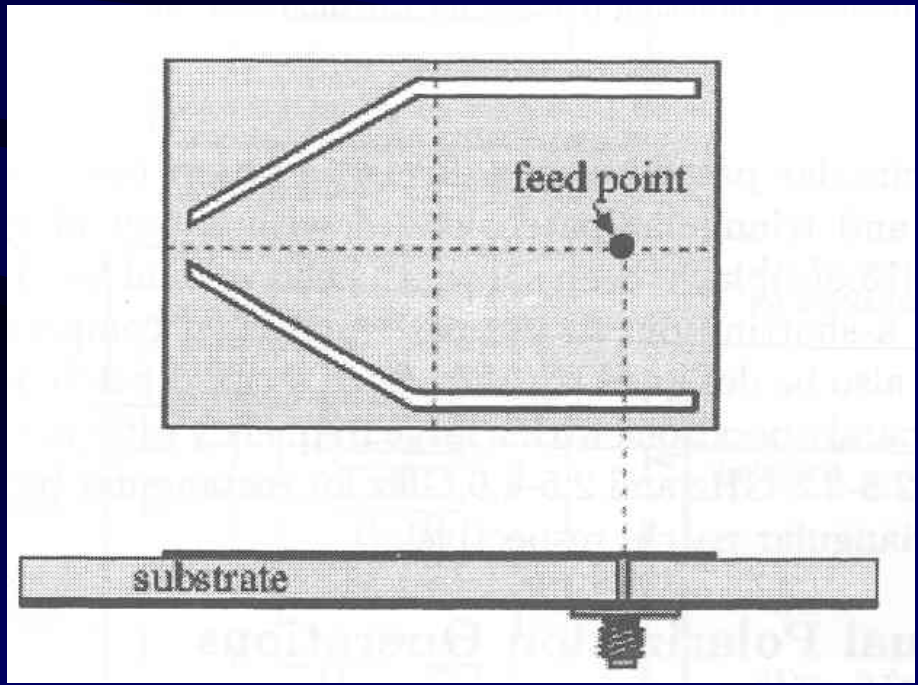


Dual band design techniques
-orthogonal polarization

- Ans: (2) slit-loaded triangular patch (continued)
- Two resonant frequencies:
- One is due to the fundamental TM10 mode of the triangular patch, whose current distribution is undisturbed
- The other is a new frequency due to the lengthening of the current path in the x direction, which can be adjusted by slot length.

Dual band design techniques
-same polarization

- Fig 15.4
- Probe fed rectangular patch antenna



Dual band design techniques
-same polarization

- A pair of *properly bent slots* are placed close to the non-radiating edges of patch
- A *new resonant mode* with frequency between TM10 and TM20 modes is excited
- *Null current point* of the new mode is moved toward the radiating edge closer to the bent slot

Dual band design techniques
-same polarization

- The excited surface current distribution on the central portion of the patch is uniformly distributed
  - The radiation characteristic is *close to the TM10 mode*
  - Similar patterns and polarization planes
- Single feed
- Good impedance matching
- Frequency ratio: 1.29~1.60

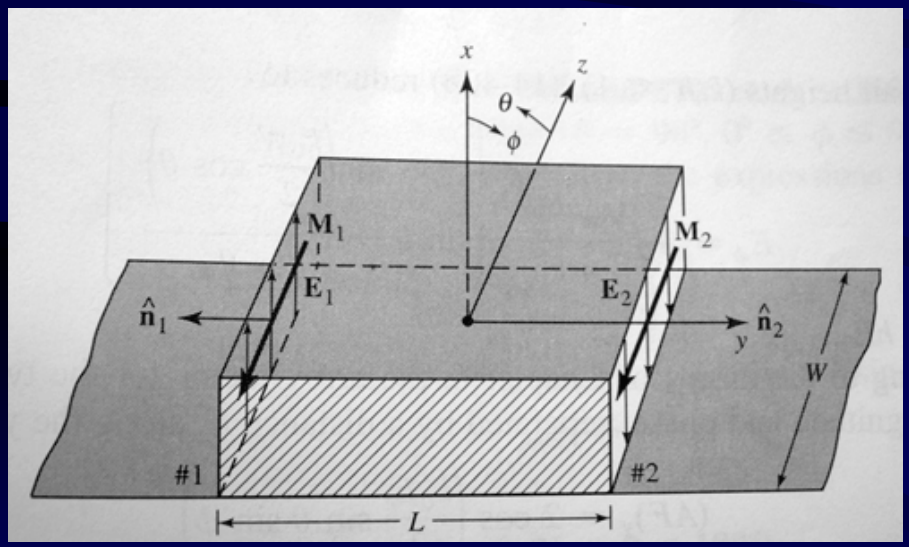
Dual band design techniques
-same polarization

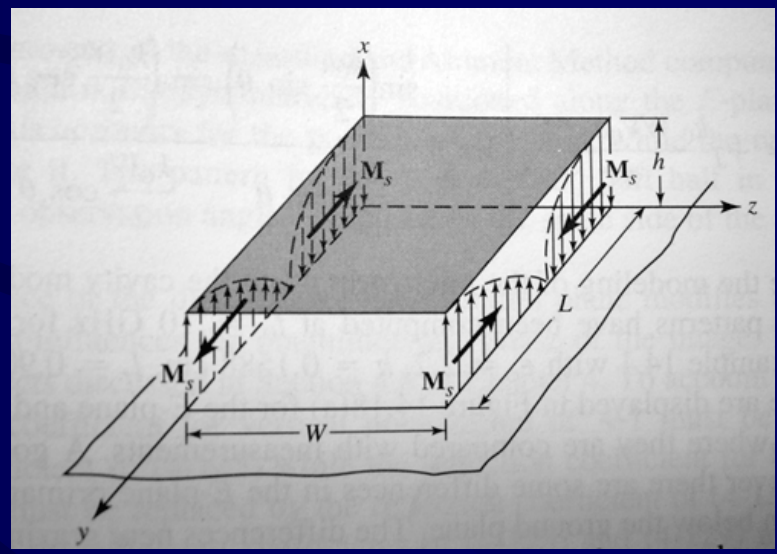
- Question: There are radiating / non-radiating edges. How to judge them? (To tell them from one another.)

- Ans: The radiating edges are where there are effective radiating sources. The radiating sources on non-radiating edge are cancelled and have no contribution to the radiation pattern.

Dual band design techniques
-same polarization

- Comparison between the radiating and non-radiating edges





Dual band design techniques
-orthogonal polarization

- Question: Is it important to locate the bend precisely? What's the difference if the bend changes?

- Ans: Yes, the bent slots have to be precisely adjusted to ensure correct operating frequency.
- If the bent slots are misplaced from the original design location, the frequency of the patch will be shifted.

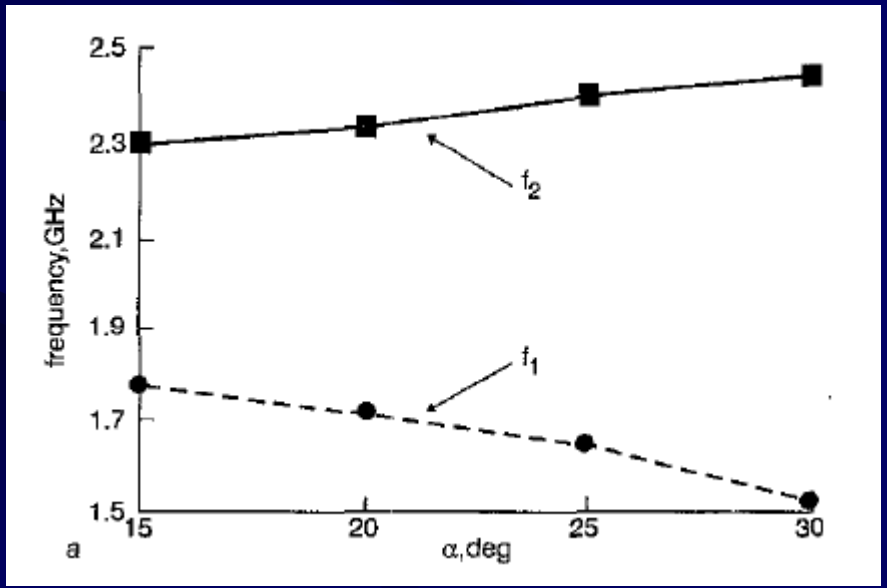
Dual band design techniques
-same polarization

- Question: A pair of properly bent slots are placed close to the nonradiating edges of patch; with the presence of bent slots, a new resonant mode is excited.
- How do the bent slots affect the resonant mode?

- Answer in the next page.

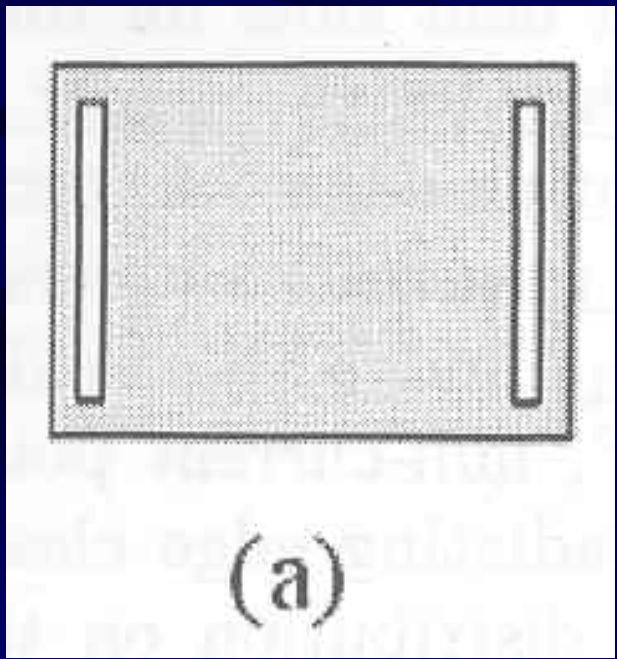
Dual band design techniques
-same polarization

- Ans: From original paper, we can find that the two resonant modes are shifted as the angle of the bent slots changes.



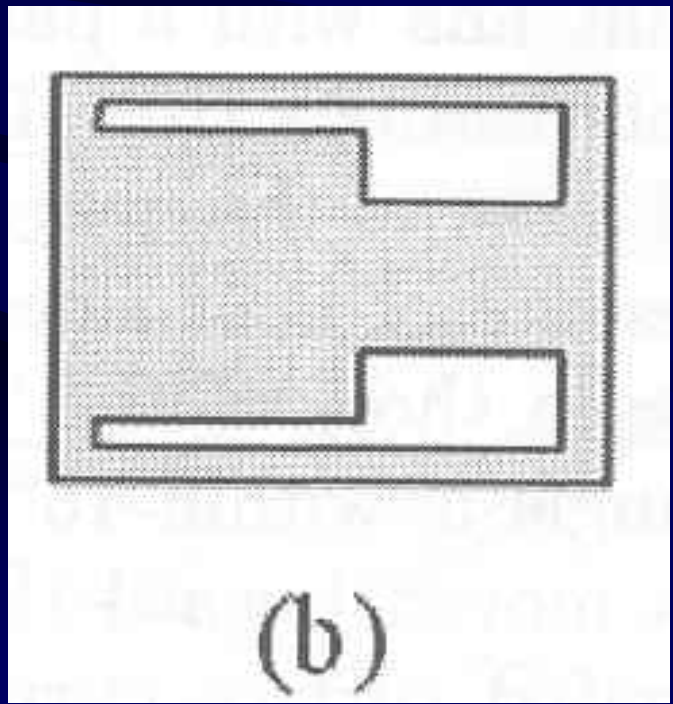
Dual band design techniques
-same polarization

- Fig 15.5(a)
- A pair of narrow slots embedded close to the non-radiating edges



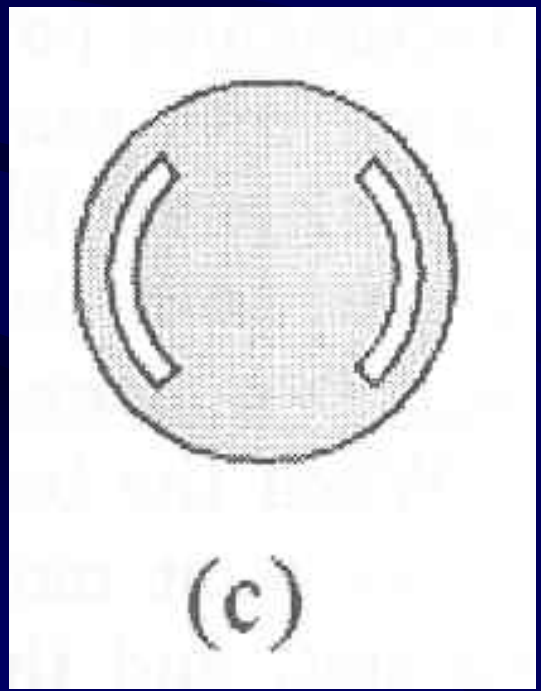
Dual band design techniques
-same polarization

- Fig 15.5(b)
- A pair of step slots embedded to the non-radiating edges



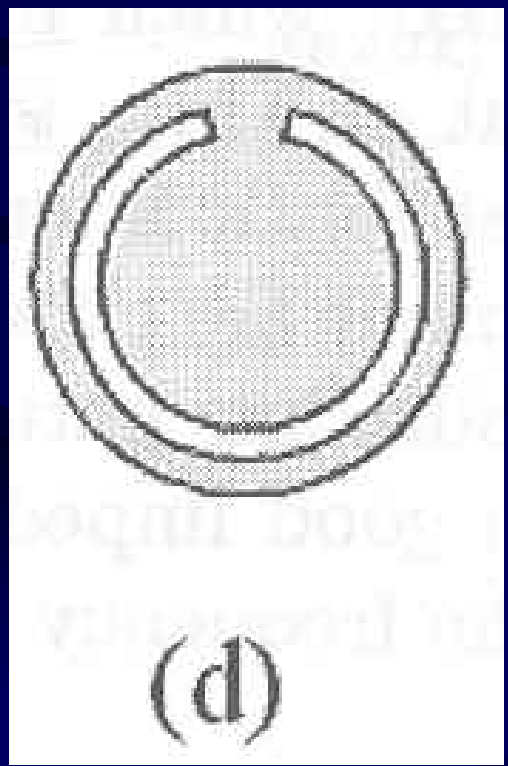
Dual band design techniques
-same polarization

- Fig 15.5(c)
- A pair of arc-shaped slots are embedded in a circular patch



Dual band design techniques
-same polarization

- Fig 15.5(d)
- Circular patch with a ring slot



Dual band design techniques
-same polarization

- Question: In the Fig.15.5 (d), does the slot hole matter?

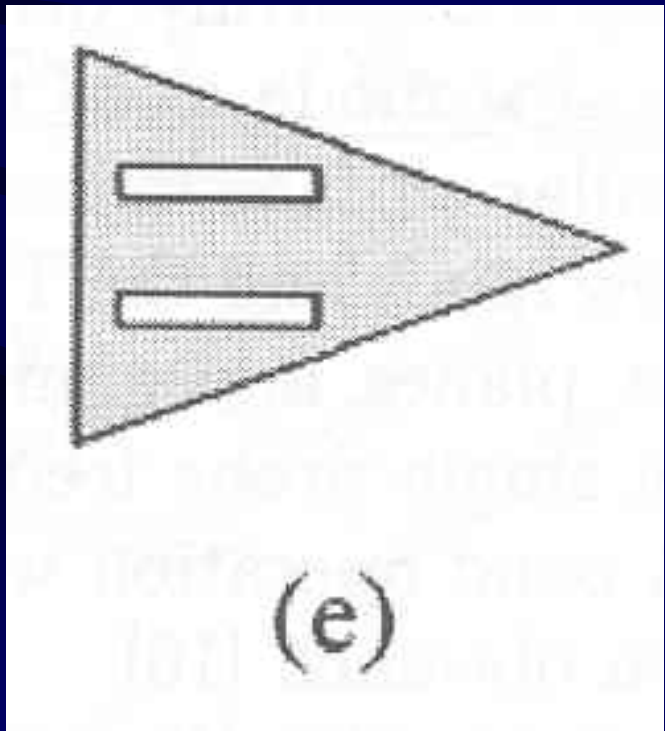
- Ans: the two resonant frequency of this antenna is determined by the ratio of the inner radius and outer radius of the circular patch
- Both use the TM11 mode of the circular patch

Dual band design techniques
-same polarization

- The slot “hole” of the ring is chosen to be small (small than one-tenth the radius of the patch)
- The original paper does not discuss the effect on the ring gap (slot “hole”)

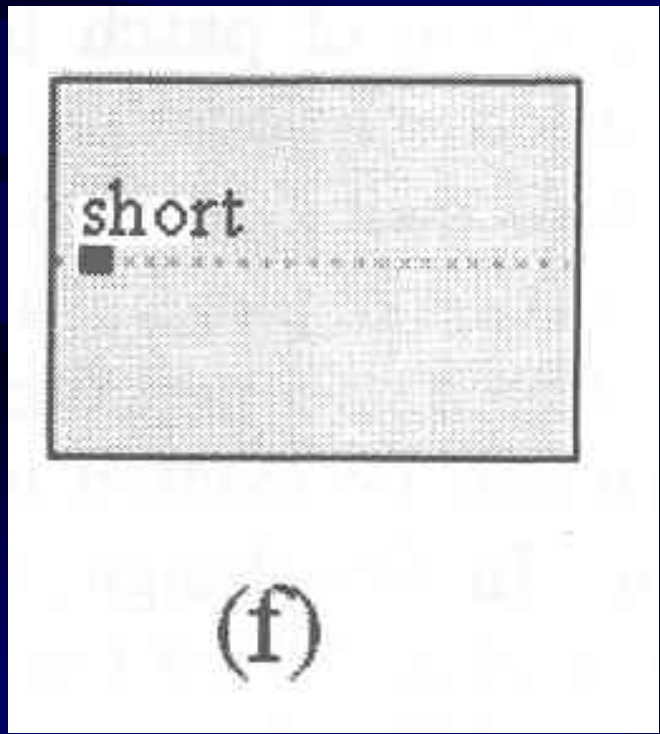
Dual band design techniques
-same polarization

- Fig 15.5(e)
- Triangular patch loaded with a pair of narrow slots



Dual band design techniques
-same polarization

- Fig 15.5(f)
- Attaching a shorting pin to the patch antenna



Dual band design techniques
-same polarization

- Shorted patch antennas can achieve dual band operations with a large frequency ratio

Dual band design techniques
-same polarization

- Question: With pin, frequency ratio will be larger. Would you please tell us the reason?

- Ans: The position of shorting pin has a critical effect on the antenna characteristic
- In fig15.5(d), the feed is located at (L/4, W/2). This results in two resonant frequencies, which are approximately 1/2 and 3/2 times the f10.

Dual band design techniques
-same polarization

- As a result, the frequency ratio is enlarged to around 3

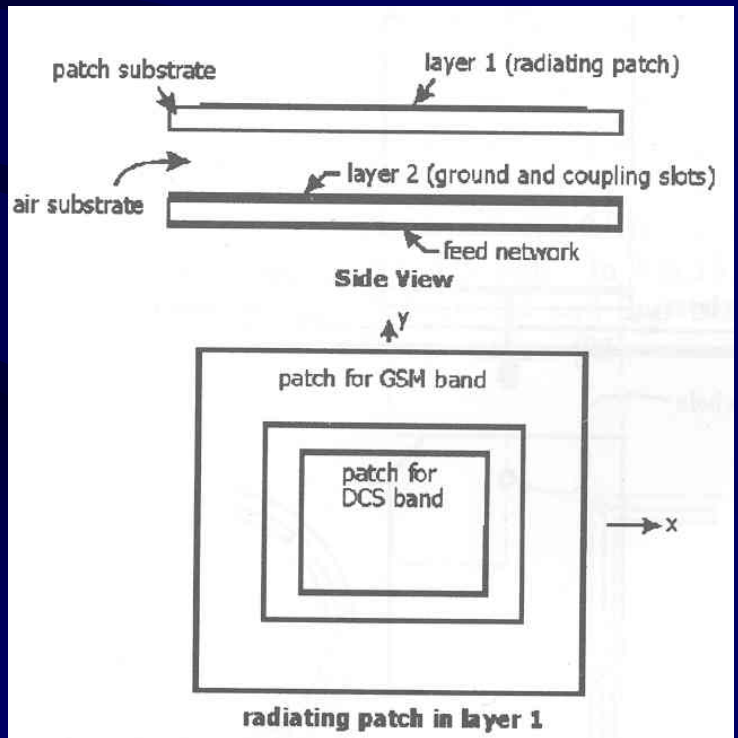
Dual band design techniques
-same polarization

- Question: There are many promising radiating patches for the dual band patch antenna.
- Can you explain them in detail?

- Ans: In class presentation we only discuss how to achieve dual band operation with the same polarization in brief. More detail information such as radiation patterns and return losses can be accessed by reference papers in the textbook.

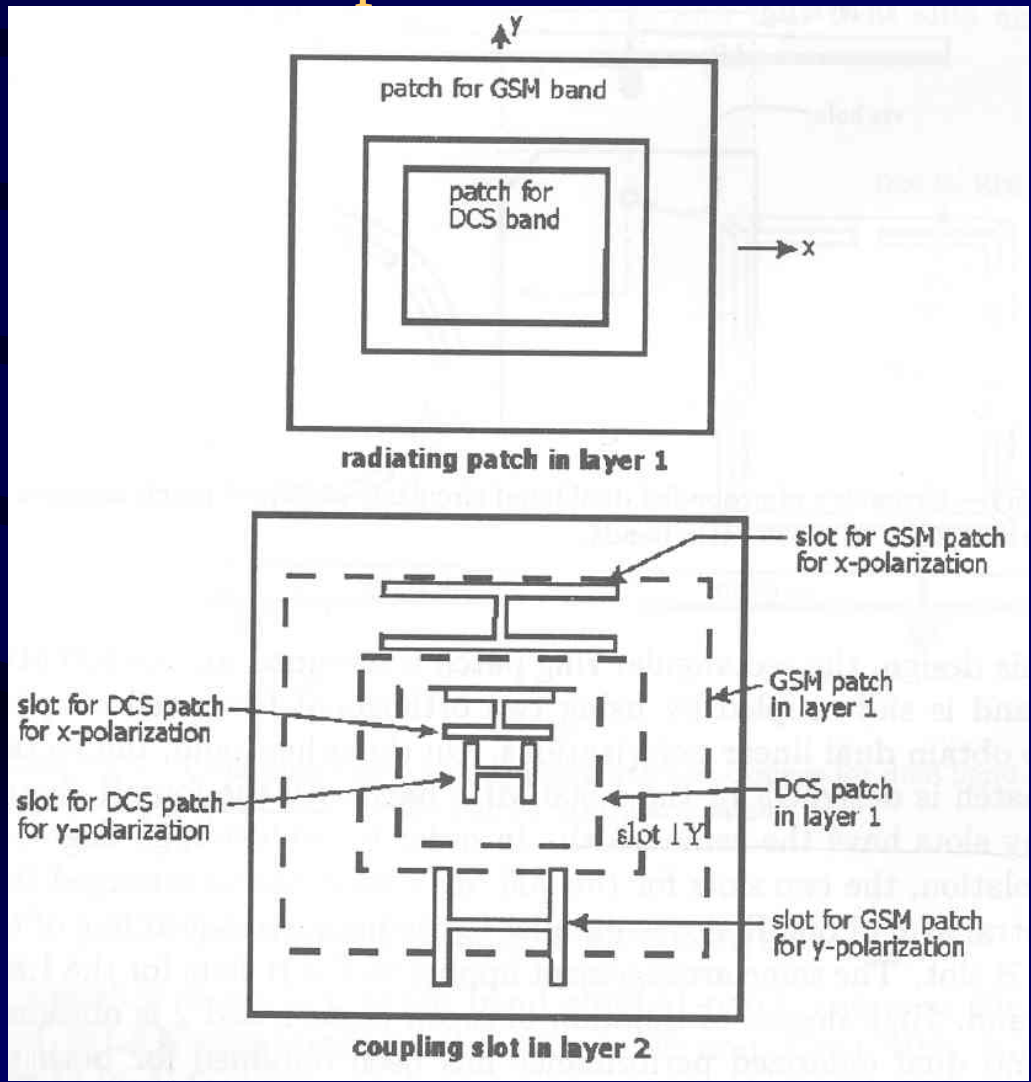
Dual band design techniques
-dual polarization

- To mitigate *multi-path fading problem*, slot coupled, dual band and dual polarized patch antenna has been proposed
- Fig 15.6(a),(b)



Dual band design techniques
-dual polarization

- Fig 15.6
- (b),(c)



Dual band design techniques
-dual polarization

- The two patches are printed on *the same substrate*
- Rectangular patch is placed within the rectangular ring for 900 and 1800 MHz
- Compact structure
- Coupling slots arrangement
- Feed network design
- High isolation between the two polarizations are obtained

Dual band design techniques
-dual polarization

- Question: There are several major factors in dual polarization operations, dimensions of the patch for 900/1800 MHz bands, arrangement of coupling slots, and the feed network design.
- Will you please show how these factors works?

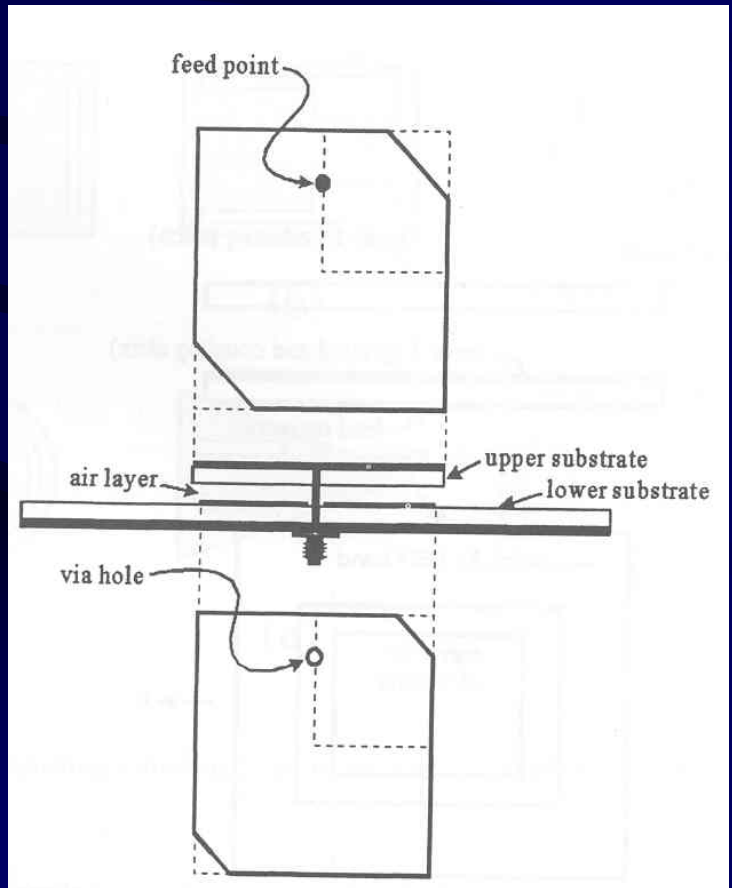
- Answer in the next page.

Dual band design techniques
-dual polarization

- Ans:
- The dimension of the patches directly affects the operating frequency of the dual band antenna
- The arrangement of coupling slots ensures isolation between the two different frequencies and polarizations.
- The design of feeding networks depends on how the coupling slots are arranged

Dual band design techniques
-circular polarization

- Dual band CP designs
- Fig 15.7

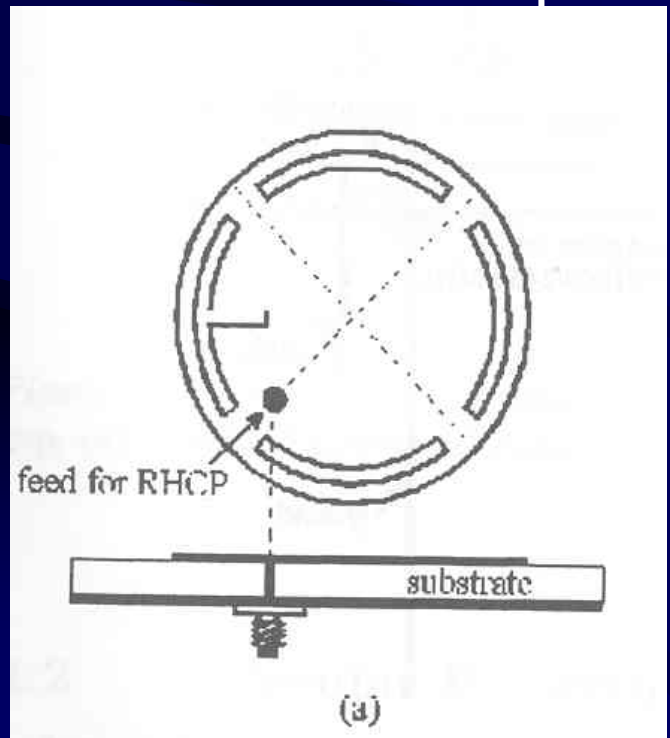


Dual band design techniques
-circular polarization

- Stacking two *corner-truncated* square patch antennas
- Design for GPS operations
- CP bandwidths are defined by 3dB *axial ratio*
- 1.2% for 1227MHz band and 1.1% for 1575 MHz band

Dual band design techniques
-circular polarization

- Fig 15.8(a)
- Embedding two pairs of arc-shaped slots close to the perimeter of a circular patch

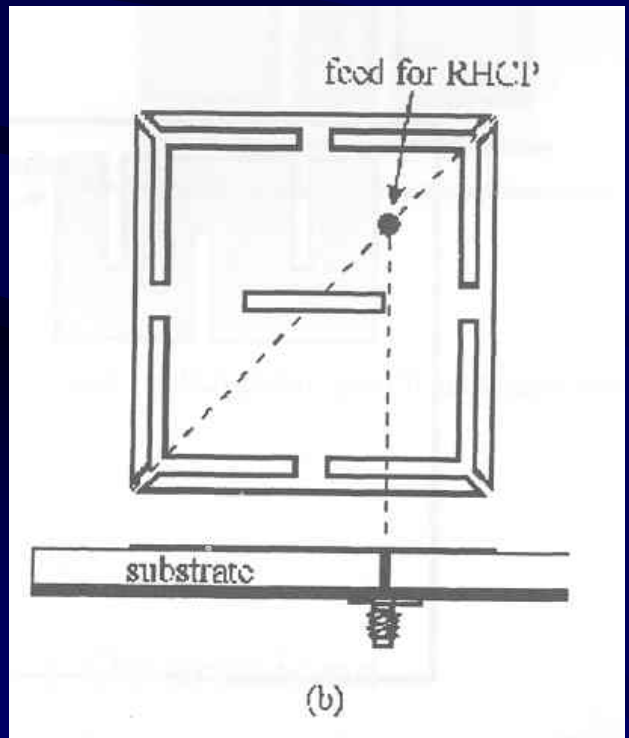


Dual band design techniques
-circular polarization

- Extending one of the arc-shaped slot with a narrow slot
- Probe feed point for right-hand circular polarization
- CP bandwidths:
- 1.3% for 1561MHz and 1.1% for 2335MHz

Dual band design techniques
-circular polarization

- Fig 15.8(b)
- Probe-fed square patch antenna with a center slot and four bent slits



Dual band design techniques
-circular polarization

- Questions: Good CP radiation patterns and antenna gain have also been obtained.
- How do you define good? Please make a definition.

- Ans: The quality of circular polarization is usually specified by 3dB axial ratio, which is the ratio of the two linear polarized components.

Dual band design techniques
-circular polarization

- Questions: In the text, there are orthogonal polarizations, same polarizations, dual polarized , and circular polarization.
- Please allow me to ask you for making a comparison list.

- Answers in next page

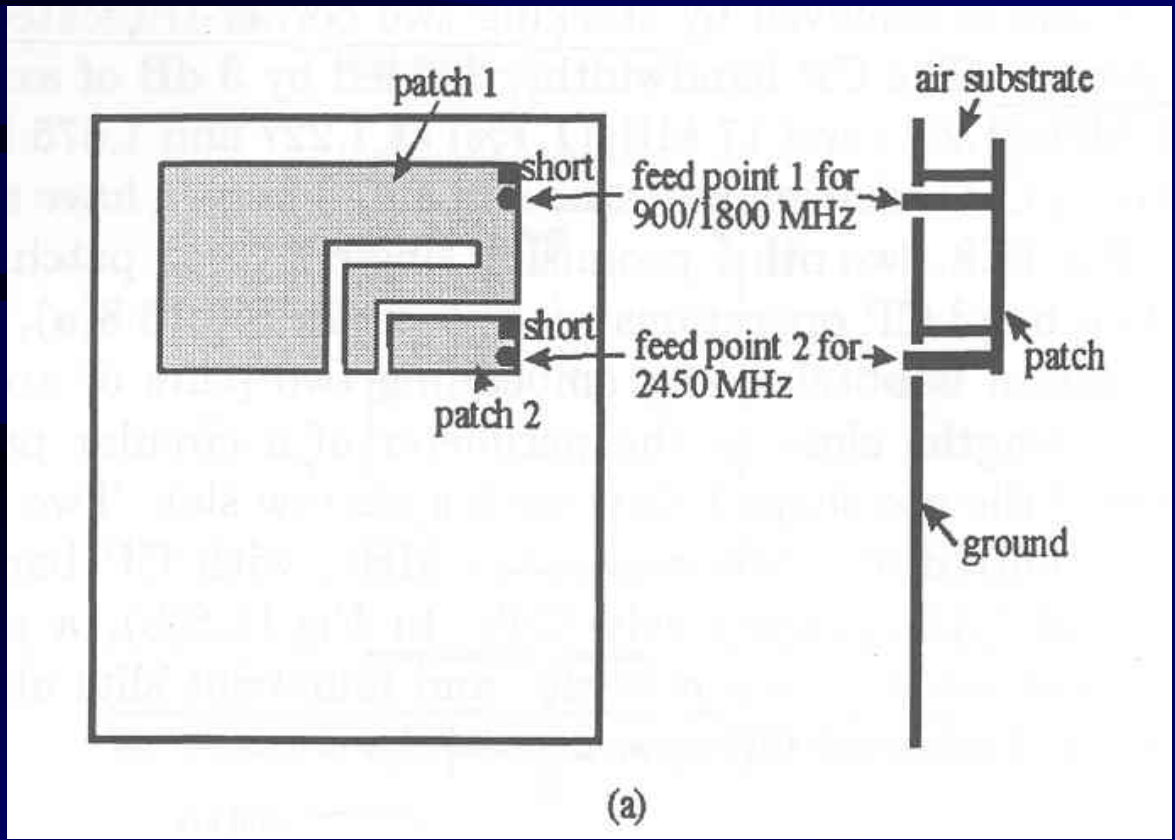
Dual band design techniques
-circular polarization

- Ans: comparison table of these polarizations

Polarization	*Description*
Orthogonal	The polarization directions of the two different bands in dual band antenna are orthogonal to each other
Same	The polarization directions of the two different bands in dual band antenna are the same
Dual	Two different polarizations can be used in the same band in single or dual band antennas
Circular	The field vector of the EM wave at some fixed point traces a circle as a function of time

Multi-band design techniques
-triple band operation

- Fig 15.9(a)

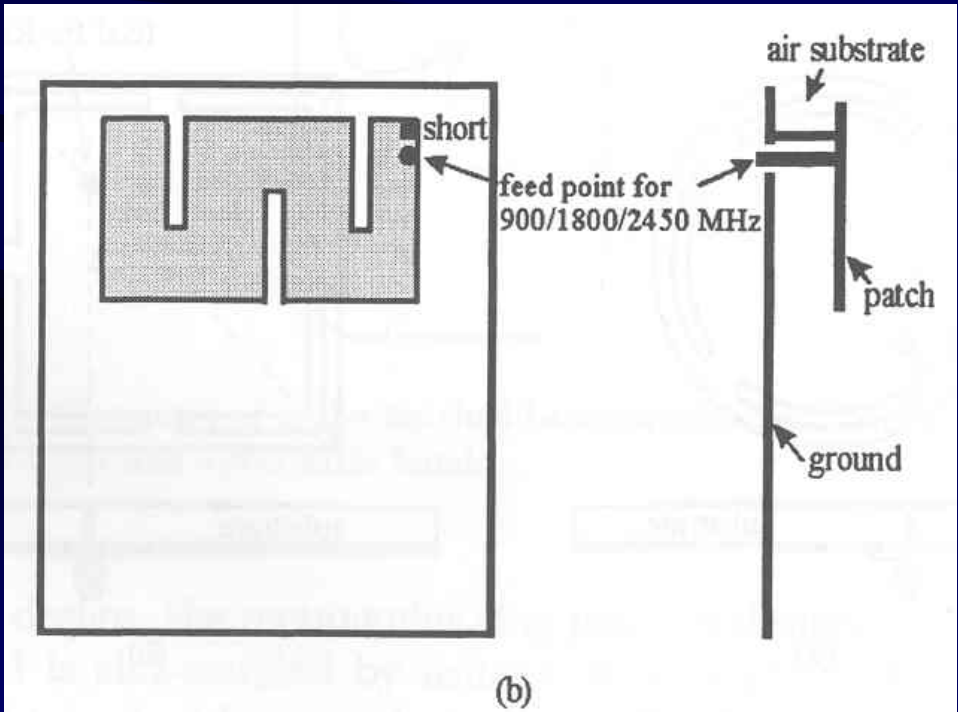


Multi-band design techniques
-triple band operation

- Feed point 1 drives the larger patch for the 900/1800 MHz bands
- Feed point 2 drives the smaller patch for the 2450 MHz WLAN band

Multi-band design techniques
-triple band operation

- Fig15.9(b)
- Single feed design for triple band operation



Multi-band design techniques
-triple band operation

- Meandered rectangular patch with a shorting pin
- More compact size
- The first three resonant frequencies of the antenna are strongly affected
- The resonant frequencies can be adjusted to be around 900, 1800 and 2450 MHz for cellular and WLAN applications.

Multi-band design techniques
-triple band operation

- Questions:
- Meandered rectangular patch with a shorting pin.
- Such meandering leads to a more compact size of patch and strongly affects the first three resonant frequencies of antenna.
- What is meandered rectangular patch?
- And what is the first three resonant freq.?

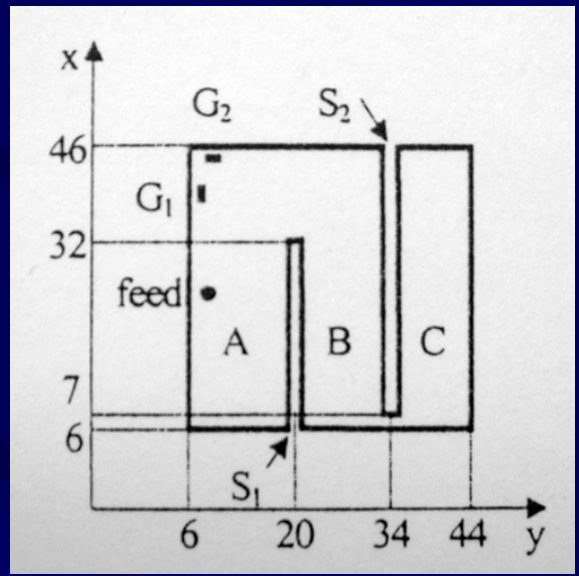
Multi-band design techniques
-triple band operation

- Ans:
- Because the current flow on the rectangular patch must be meandered due to the shape of the patch, so it is called “meandered rectangular patch”

Multi-band design techniques
-triple band operation

- Ans: (continued)
- The reference 23 in the textbook is incorrect
- In the paper of reference 23, the PIFA (planar inverted F antenna) is as follows:

Point:
The PIFA in ref 23 has only two slots and two shorting pins.

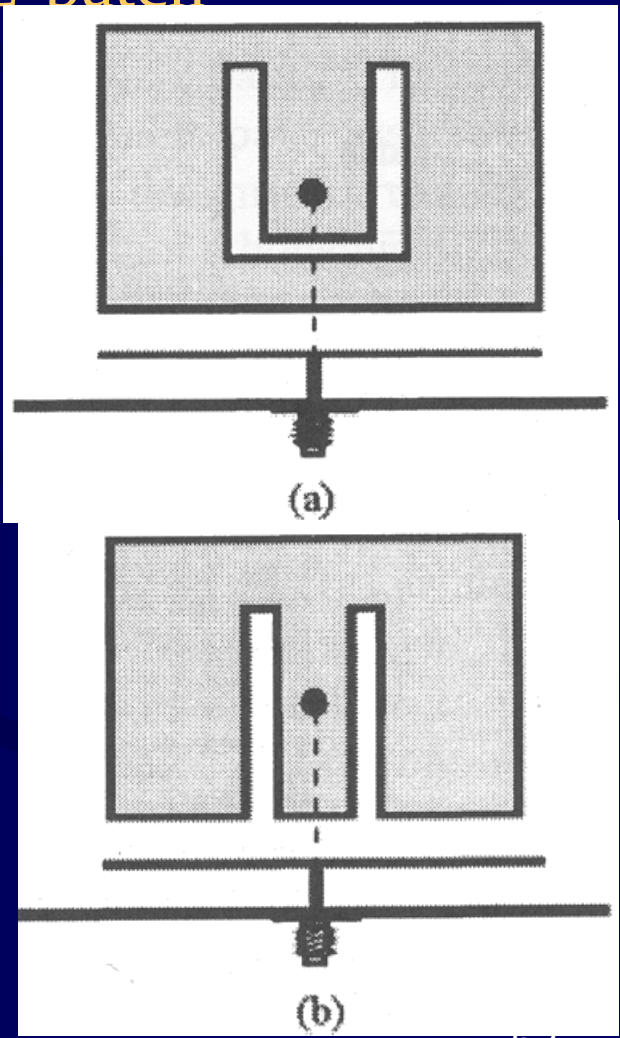


- Wideband design technique
- Practical applications in wireless communication
- Design Challenges for wireless communication

Linear Polarization operations

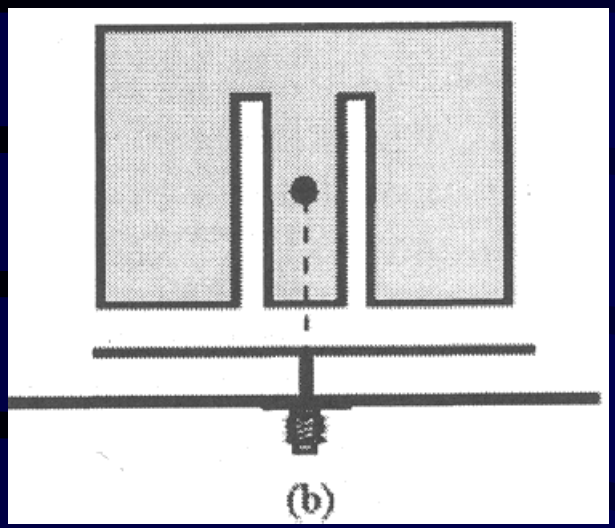
— U-slot patch and E-patch

- Patch with air gap
  - less expensive to fabricate
  - wideband
- Disadvantage: long probe
  - high reactance
  - hard to match over a wide band
  - could be solved by the slots



	Impedance BW
(a) U-slot patch	24 %
(b) E-patch	24 %

E-patch Antenna



- BW=24 %
  @fc=1644 MHz

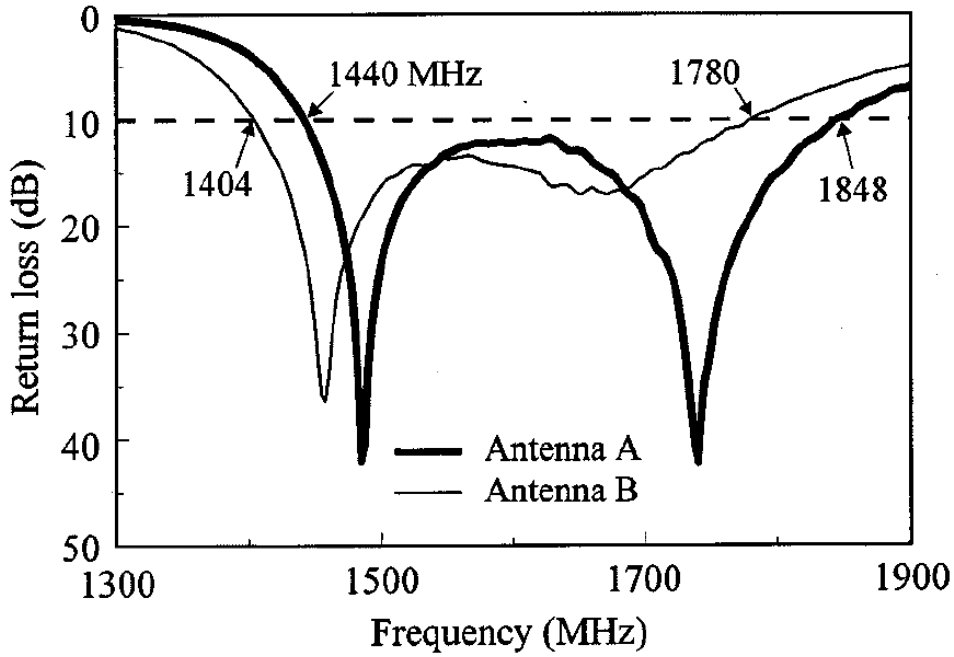


Fig. 2. Measured return loss for the proposed broad-band patch antenna; $L = 65$ mm, $W = 105$ mm, ground-plane size $= 150$ mm $\times$ 150 mm. Antenna A: $h = 14.3$ mm, $\ell = 47$ mm, $w_1 = 6.3$ mm, $w_2 = 15.3$ mm, and $d_p = 10$ mm. Antenna B: $h = 15.7$ mm, $\ell = 53$ mm, $w_1 = 10$ mm, $w_2 = 8$ mm, and $d_p = 13$ mm.

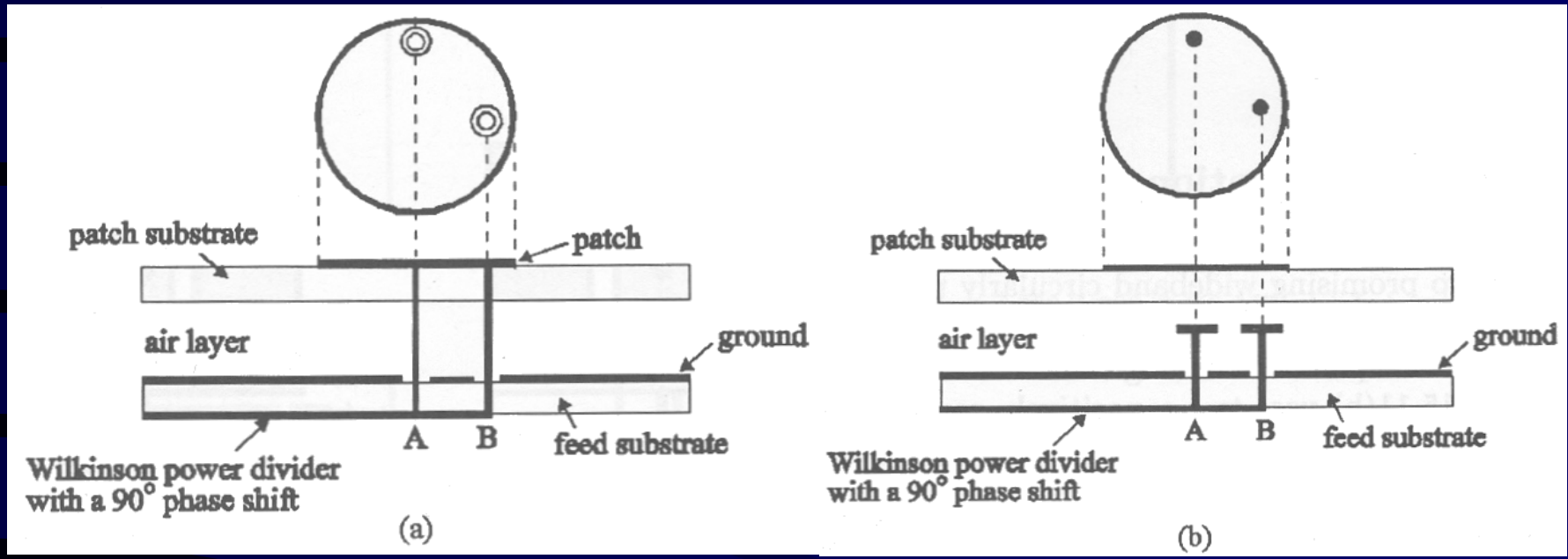
Q: Linear Polarization Operations

- Reactance due to the long probe in the air gap is high and impedance matching over a wide band is difficult to achieve.

- Q: What does the “long probe in the air gap” do?

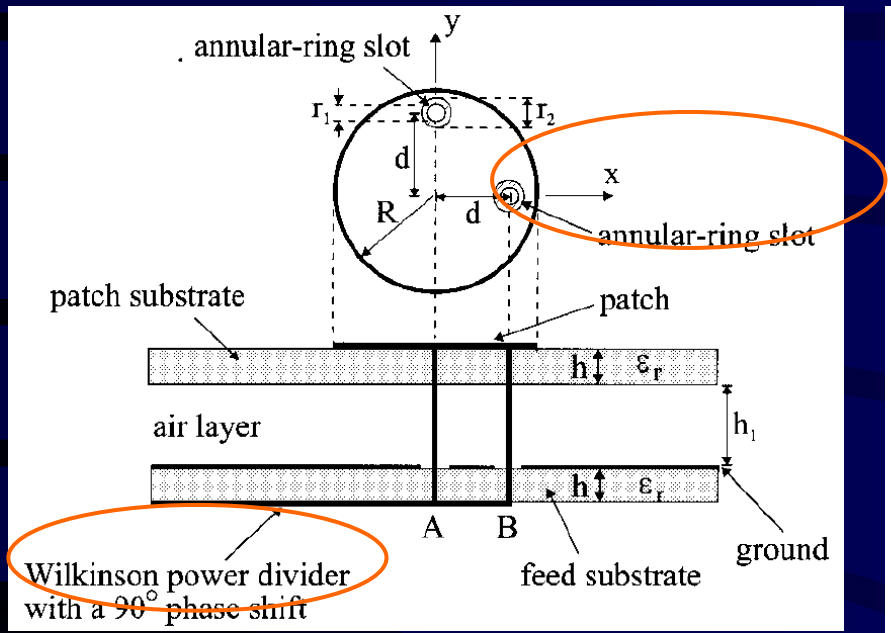
- Ans.
  The long probe in the air gap is inductive, which means the impedance matching point is single or narrow band

Circular Polarization Operations



	Impedance BW	3-dB axial CP BW	3-dB of peak antenna gain
(a) gap-coupled probe fed	65%	46 %	44,6 %
(b) capacitive coupled fed	49%	35 %	28 %

Antenna with Gap-coupled Probe Fed [3]



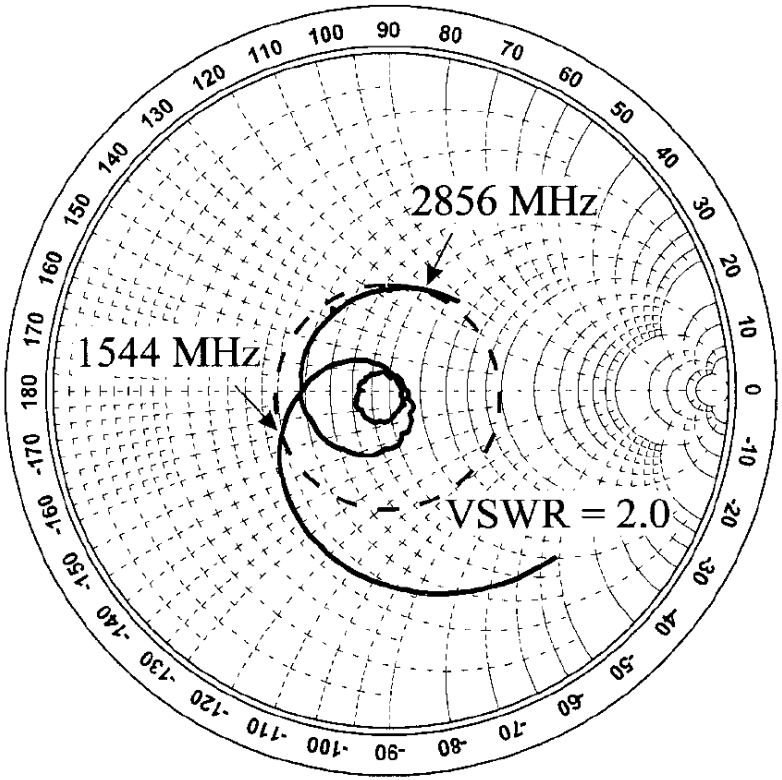
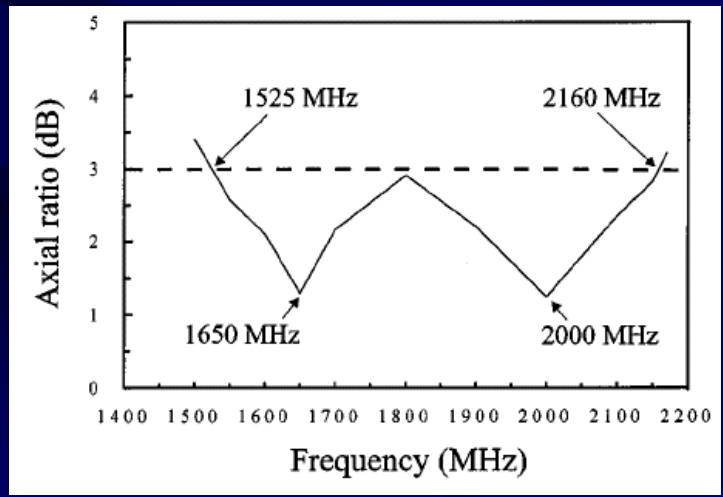


Figure 2 Measured input impedance on a Smith chart for the proposed antenna; $h_1 = 12.8$ mm, $h = 0.8$ mm, $\varepsilon_r = 4.4$, $R = 26.25$ mm, $d = 11$ mm, $r_1 = 4$ mm, $r_2 = 4.5$ mm, ground-plane size = 100 mm × 100 mm

- BW=65 % for VSWR=2

Q: Circular Polarization Operations

- For the latter, impedance bandwidth of about 49% and 3 dB axial ratio CP bandwidth of about 35% have been achieved.
- Q: What is the “axial ratio CP bandwidth”?
- A: It represents the bandwidth when the axial ratio is below 3-dB

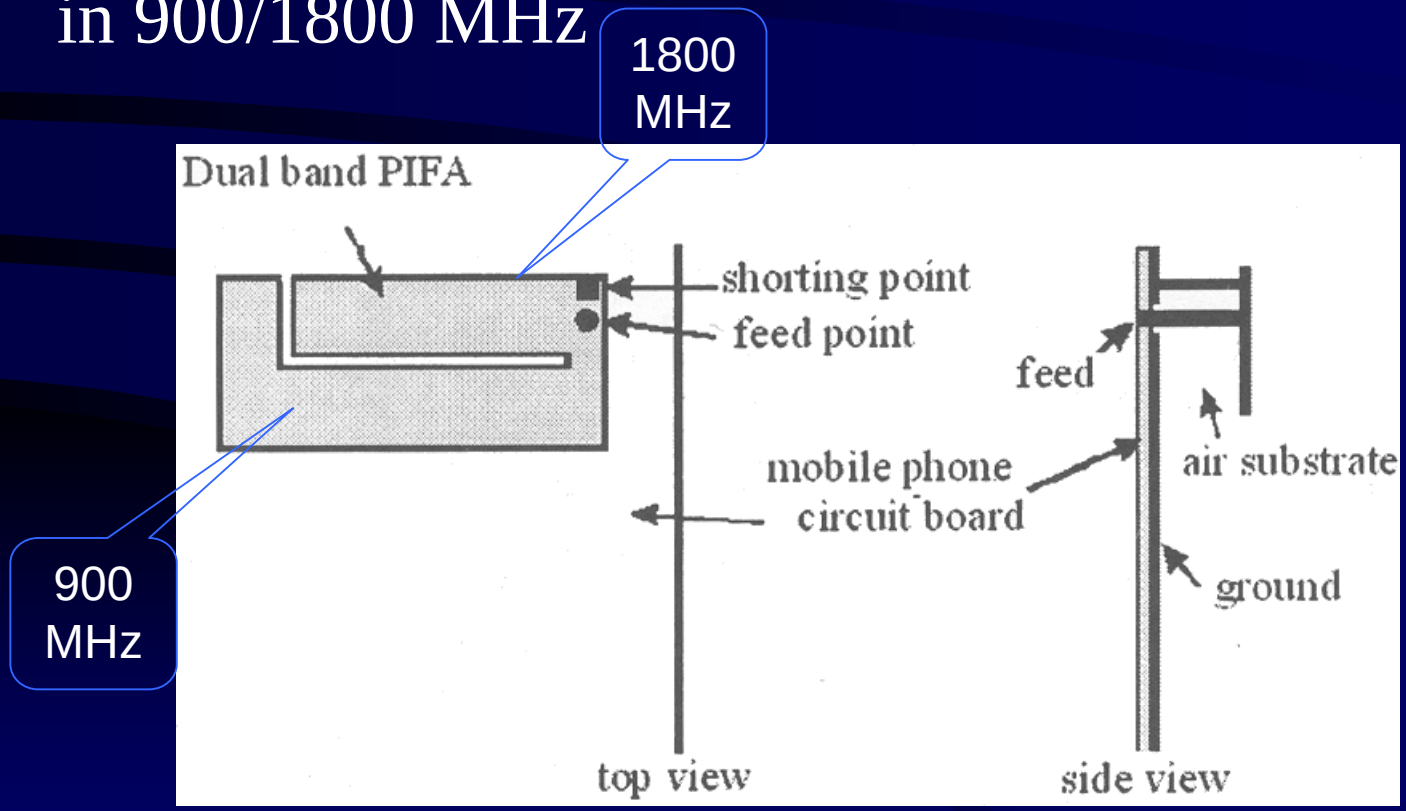


- Wideband design technique
- Practical applications in wireless communication
- Design Challenges for wireless communication

Practice Applications (1)

— Antenna for Dual Band Internal Mobile Phone

- Dual band planar inverted-F patch antenna (PIFA) in 900/1800 MHz



Characteristics of PIFA

- Compact, and can be integrated within the mobile housing
- Also called concealed or internal antennas
- Compared to conventional rod antennas for mobile phones
  - Lower SAR（Specific Absorption Rate）
  - Electromagnetic energy absorbed by the user's head is reduced

Q: Design Challenges for Wireless Communication

- What is radiating mechanism of PIFA ?
- What is difference between PIFA and the general patch antenna?
- How about introducing a PIFA more details.

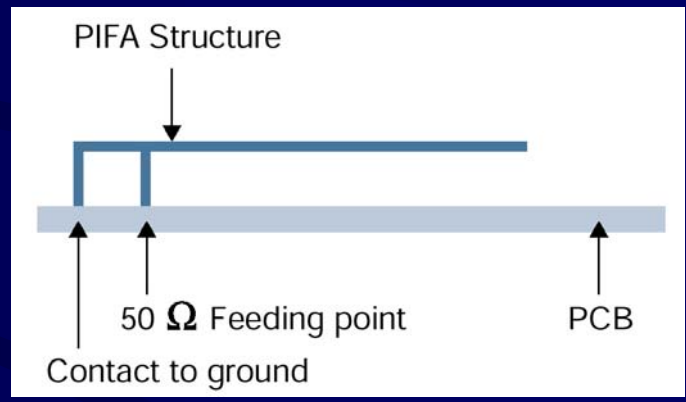
PIFA

PIFA = **P**lanar **I**nverted "**F**" **A**ntenna

Represents a solution optimized for small size requirements, large bandwidth and efficient gain.

Common characteristics

- planar structure at maximum distance to the ground
- Fed by two galvanic contacts



- Size can be significantly decreased by using ceramic material or by changes in the metal structure.
- smaller size means less bandwidth and gain performance.

BASIC PIFA GEOMETRY

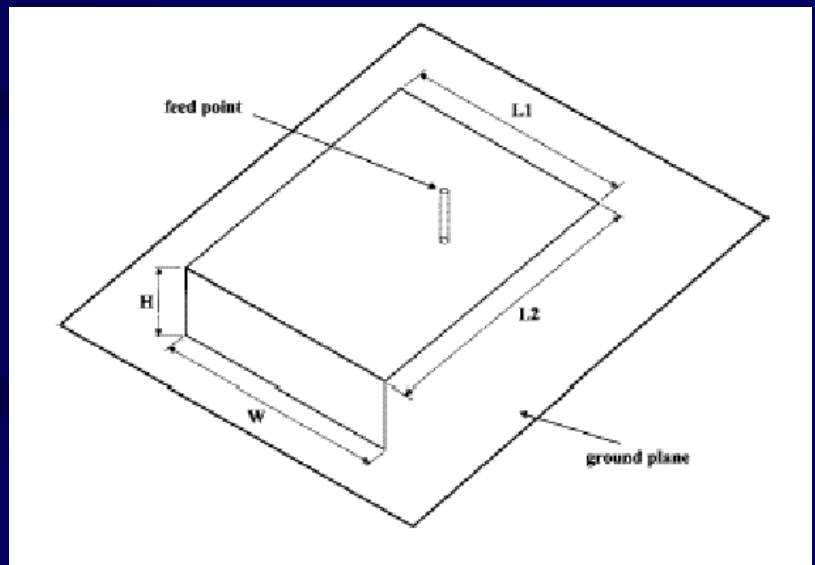
- The structure is similar to a *shorted rectangular microstrip patch antenna* with air as dielectric
- They can resonate at a much smaller patch size for fixed operating frequency compared to the conventional patch antenna
- The resonant frequency can be calculated by

  f (resonant)=C/4(l1 + l2).

  C=velocity of light(3*108 m/sec)

  L1 =width of the conducting element

  L2 =length of the conducting element



- Easy to match (position of the feed)
- Easy to tune (adjusting the length of the arm)

Antennas for Dual Band Internal Mobile Phone 2/2

- Moreover, PIFAs usually render lower specific absorption rate(SAR) [33],[34] than conventional whip antennas

- Q: Would you give us the introduction about SAR and relationship between SAR and antennas?

SAR（Specific Absorption Rate）

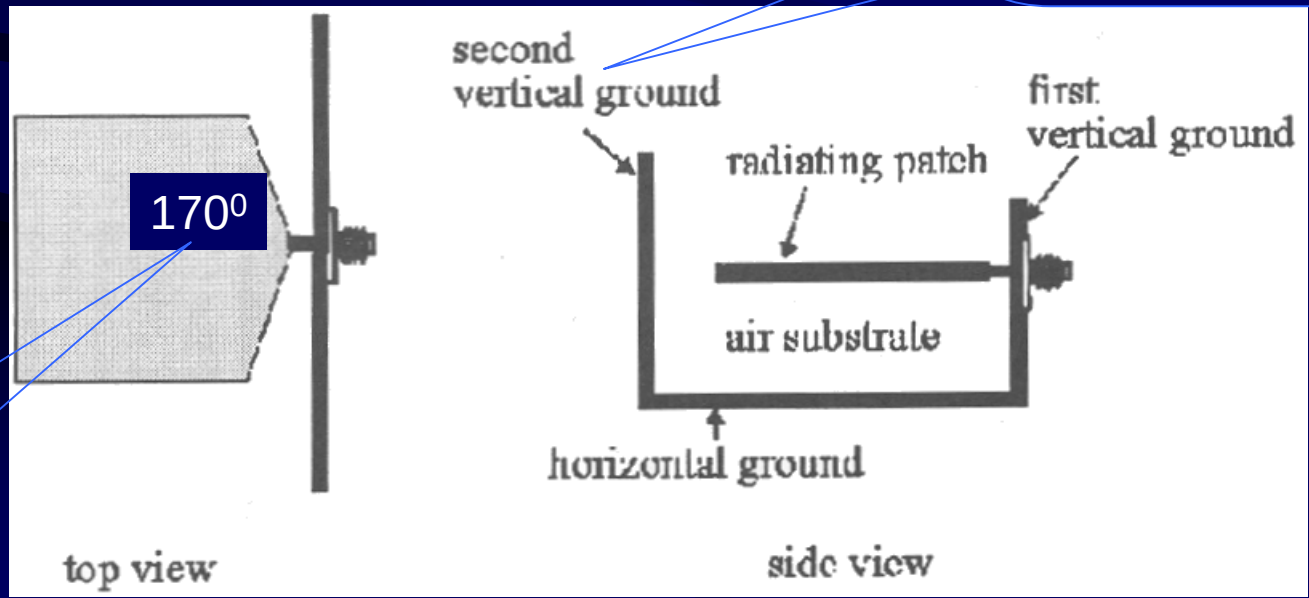
- 一般電磁輻射環境中（該設備與人體保持在20公分以內距離）生物體單位質量對電磁波能量吸收比值係稱為SAR（Specific Absorption Rate）
- 電信總局將採用美國FCC之SAR標準值1.6W/Kg為我國手機SAR之規範值

Practice applications (2)

— Base Station Antennas in Cellar Systems (1/2)

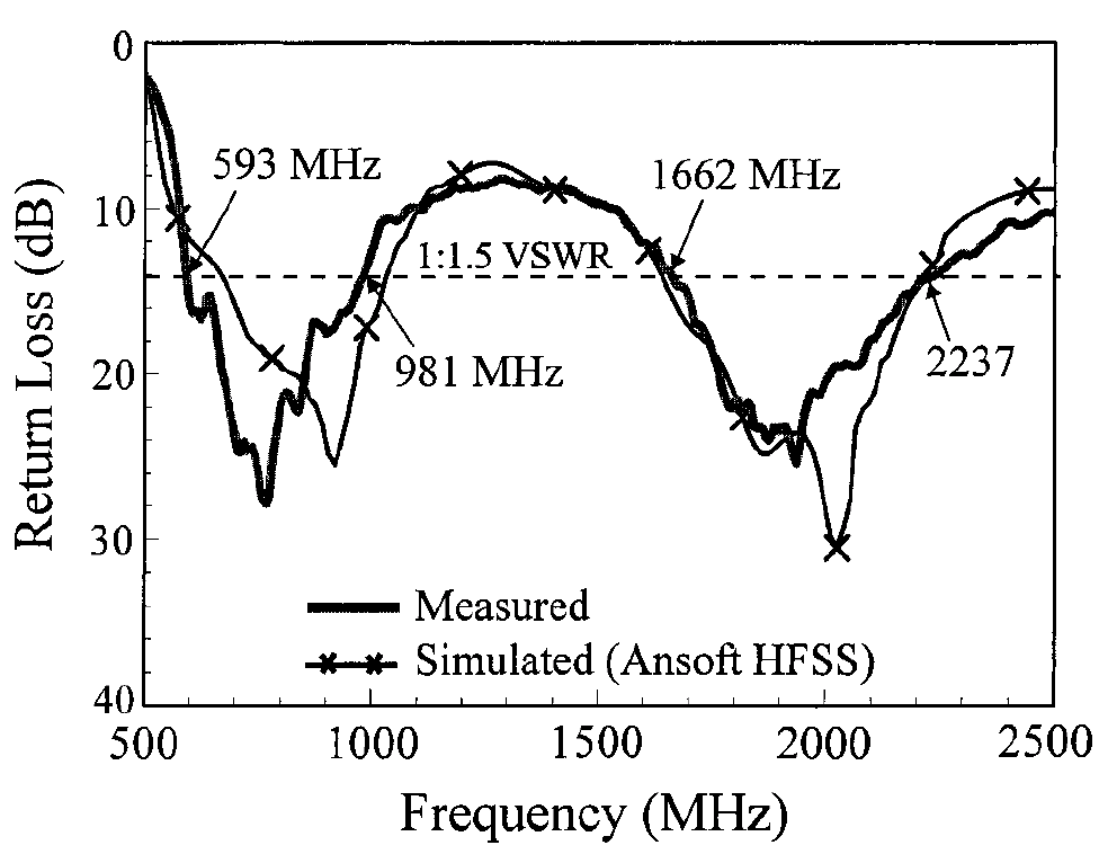
- Coplanar probe-fed patch antenna with U-shaped ground plane
- For GSM/DCS/PCS triple band operation
- Impedance BW=50% (1.5:1 VSWR)

Improve the matching of two resonant modes



flare angle : impedance matching

Base Station Antennas in Cellar Systems (2/2)



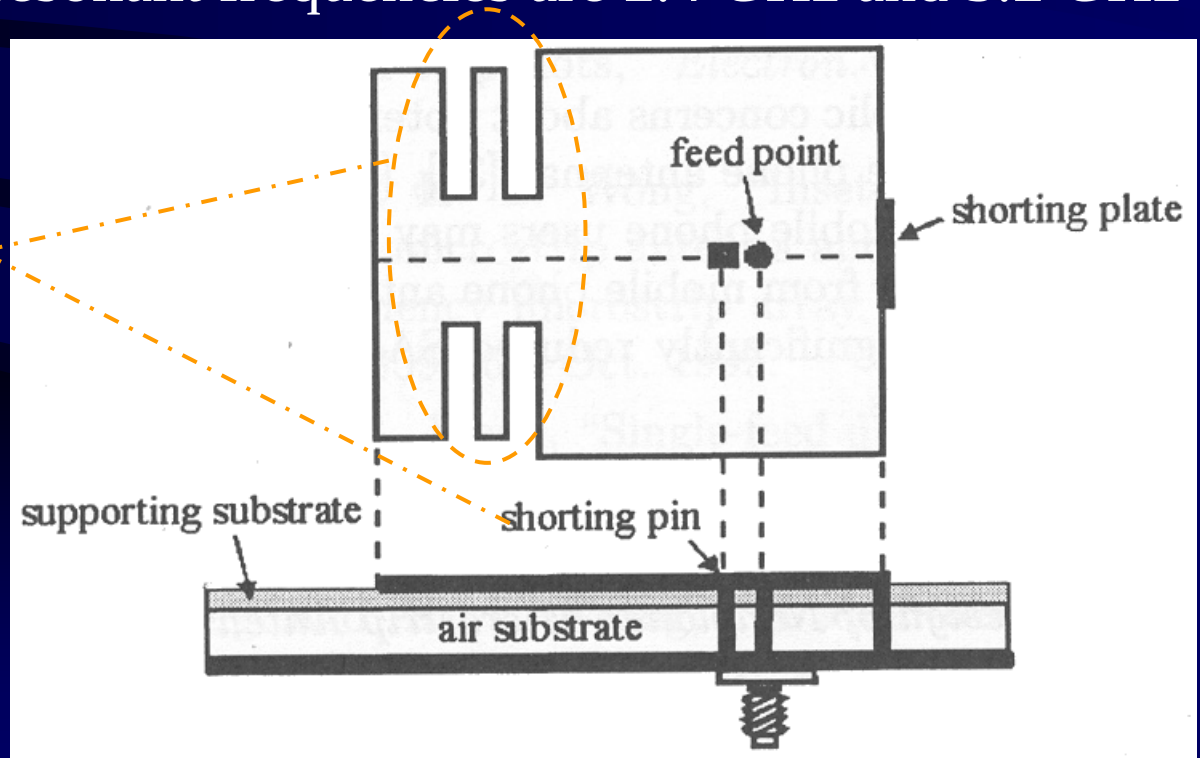
- impedance bandwidth (1:1.5 VSWR)
  - lower band reaches 50% @ fc=787 MHz
  - upper band has a bandwidth as large as 30% @ fc=1950 MHz

Practice applications (3)

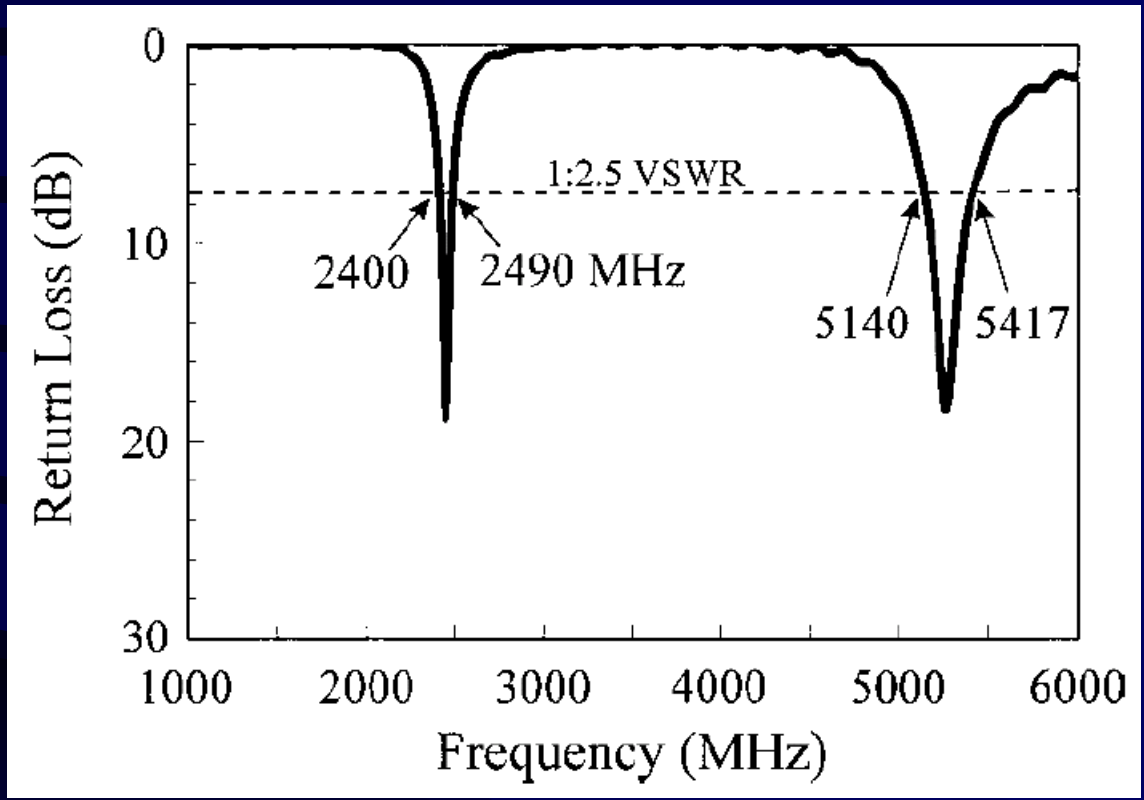
— WLAN Antennas (1/2)

- For compact size,
  - shorted patch antenna and PIFA are attractive
- First two resonant frequencies are 2.4 GHz and 5.2 GHz

Control resonant frequencies



WLAN Antennas (2/2)



- impedance bandwidth (1:2.5 VSWR)
  - lower band reaches 3.7% @ fc=2.45 GHz
  - upper band reaches 5.3 % @ fc=5.25 GHz

- Wideband design technique
- Practical applications in wireless communication
- Design Challenges for wireless communication

Design Challenges for wireless communication

- Gain
  - Competition persists to reduce the size of portable communication devices
  - at fixed frequency, if antenna sizes $\downarrow$, than gain $\downarrow$
- Cost
  - for low cost, FR4 substrate is used
  - high loss at high frequency which degrades the antenna performance
  - new dielectric materials with low cost and loss are desirable

射 频 和 天 线 设 计 培 训 课 程 推 荐

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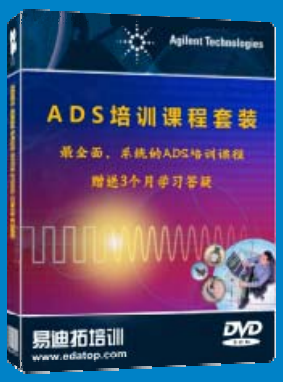

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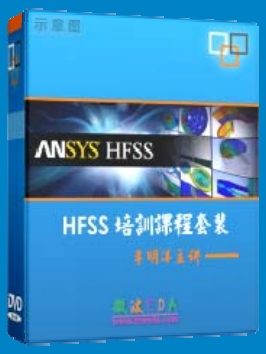

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