University of Calcutta

Mysteries of DRA Modes

Unresolved Issues for the Future

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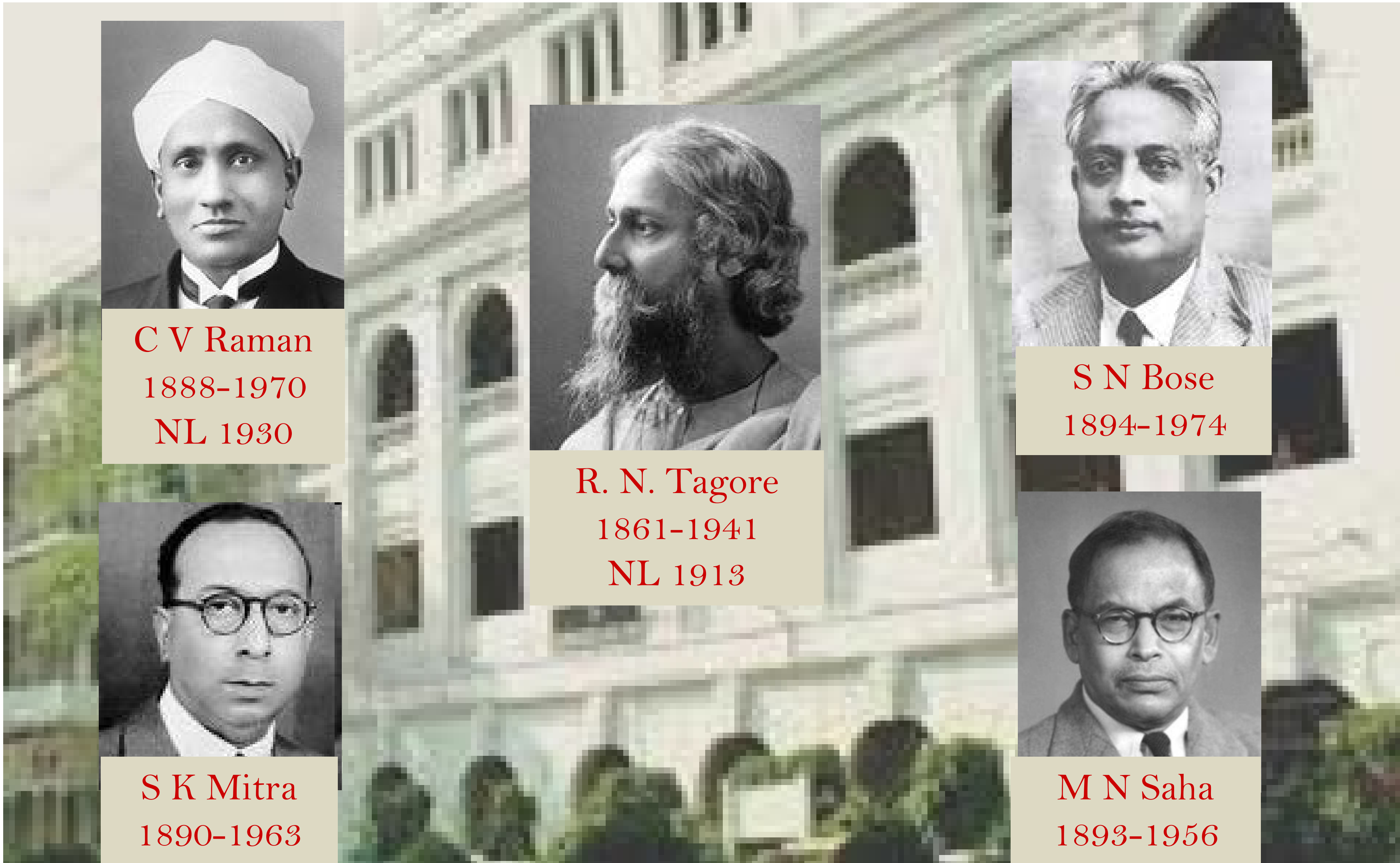
Institute of Radio Physics and Electronics,
University of Calcutta, India

University College of Science and Technology 1914-2014

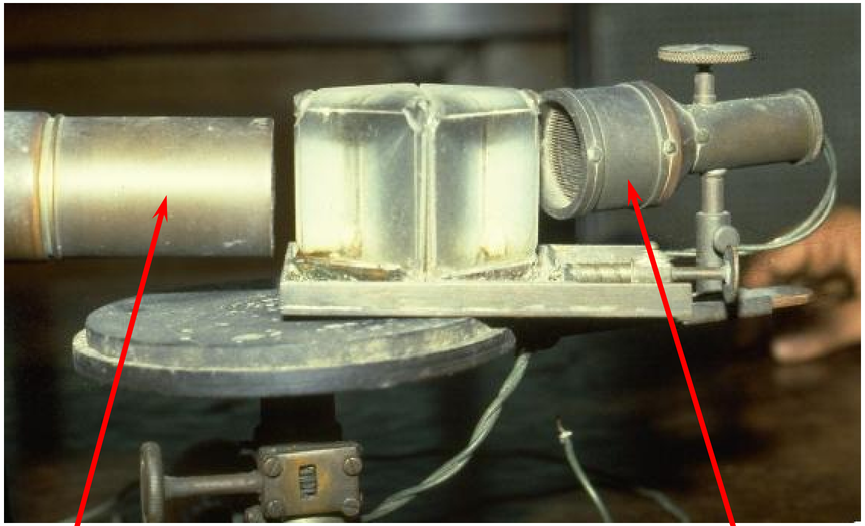
On the World Map

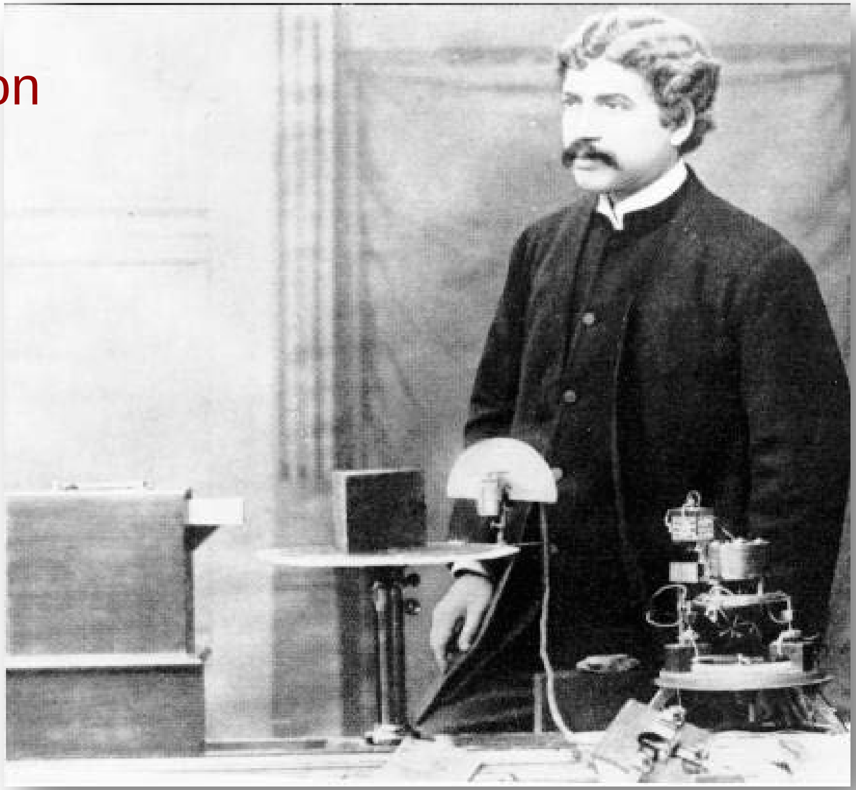
Our Teachers



1895

Demonstrated a mechanical operation using WIRELESS at 2.5 GHz

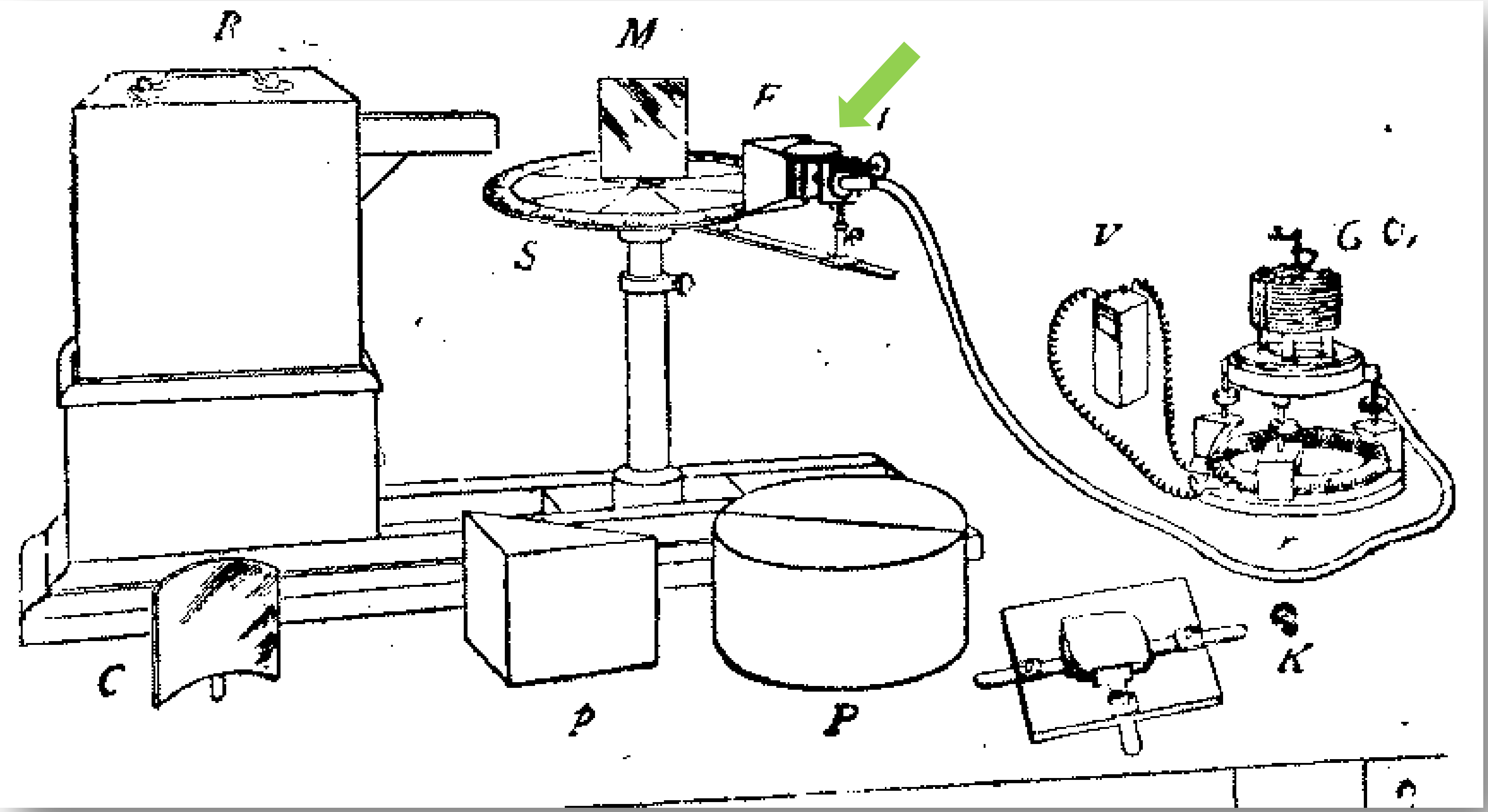




transmitting Horn

receiving Horn

Bose's Pyramidal Horn



Rest is History

Today’s Presentation

Unknown Mode in Known DRA

31 Years ago

1983-2014

IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. AP-31, NO. 3, MAY 1983

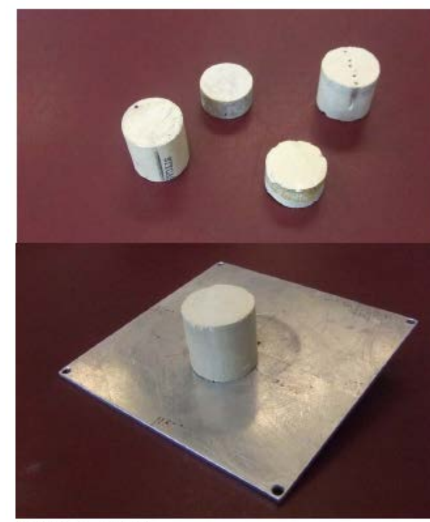
The Resonant Cylindrical Dielectric Cavity Antenna

STUART A. LONG, SENIOR MEMBER, IEEE, MARK W. McALLISTER, AND LIANG C. SHEN, SENIOR MEMBER, IEEE

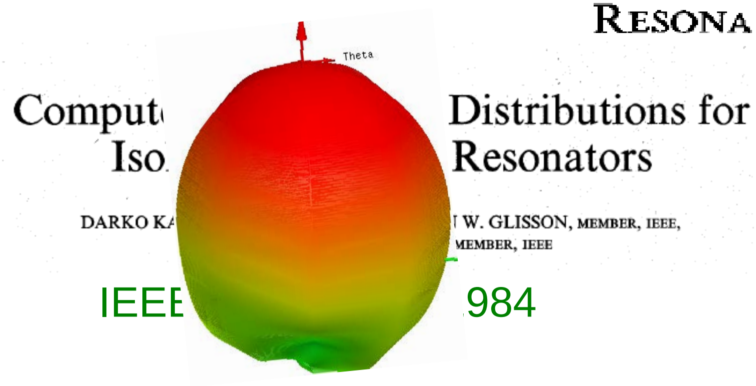
THE RECTANGULAR DIELECTRIC RESONATOR ANTENNA

Mark W. McAllister, Stuart A. Long, & George L. Conway
Department of Electrical Engineering
University of Houston
Houston, Texas 77004

CH1860-6/83/0000-0696$01.00 © 1983 IEEE

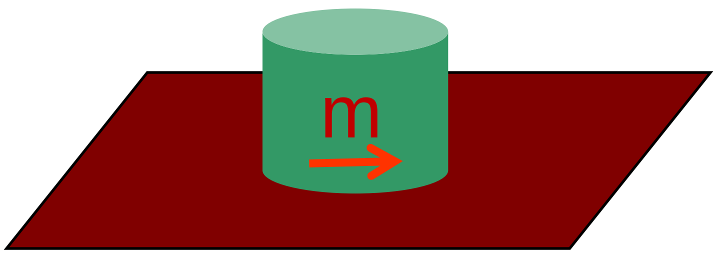


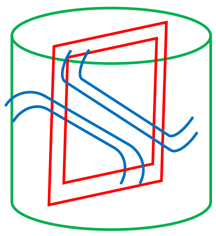
Cylindrical-DRA



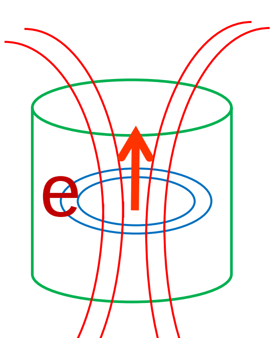
RESONANT FREQUENCIES AND Q FACTORS OF THE FIVE LOWE
MODES

Mode	f_{res} (GHz)	Q
$TE_{01\delta}$	4.829	45.8
$TM_{01\delta}$	7.524	76.8
$HEM_{11\delta}$	6.333	30.7
$HEM_{12\delta}$	6.638	52.1
$HEM_{21\delta}$	7.752	327.1

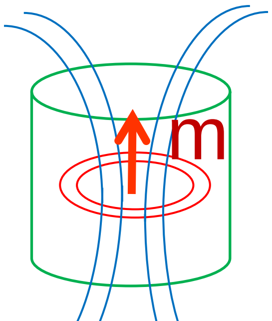




$HEM_{11\delta}$

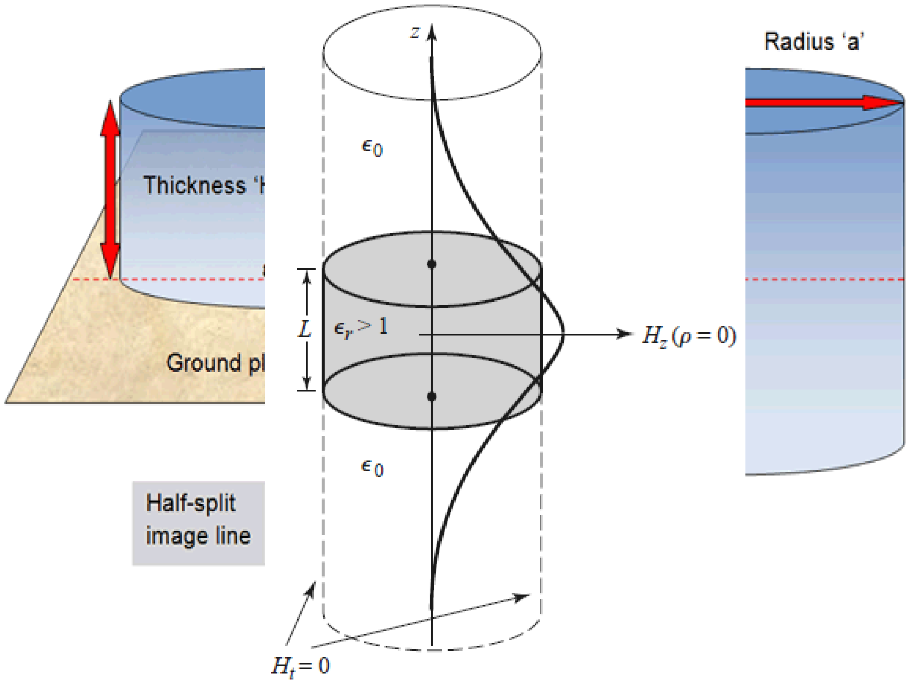


$TM_{01\delta}$



$TE_{01\delta}$

Mode Nomenclature



$TE_{0\ n\ p+\delta}$

$TM_{0\ n\ p+\delta}$

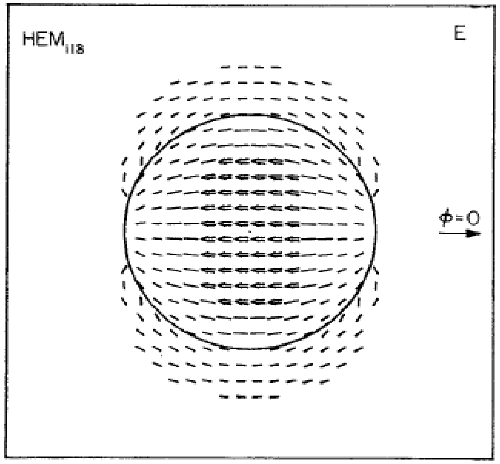
$HEM_{m\ n\ p+\delta}$

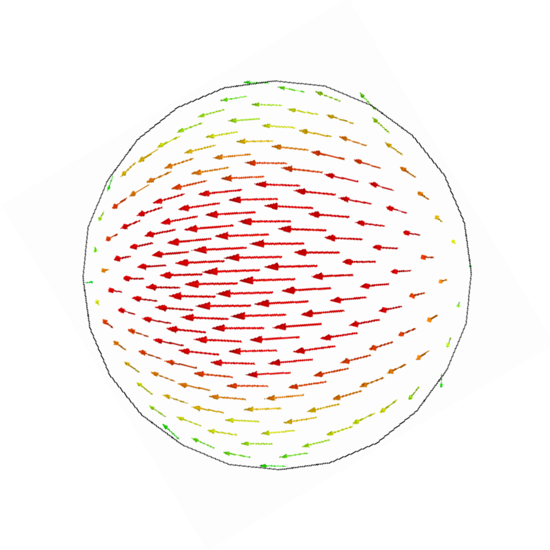
m: number of full-period variations of fields along the azimuth

n: half-wave variation along radius (field between center and the periphery)

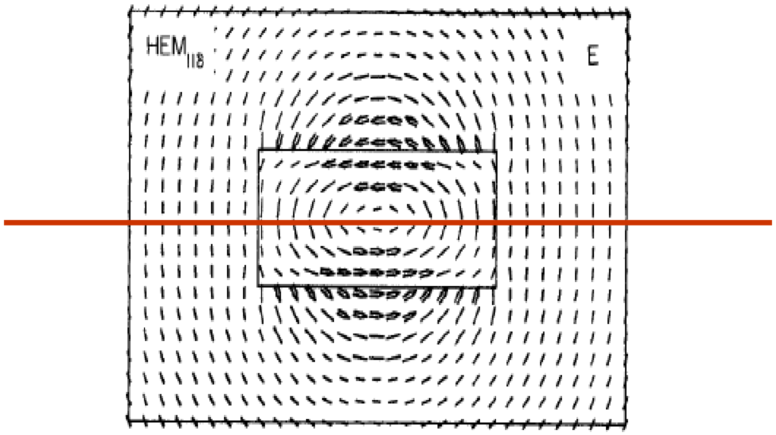
‘**p+δ**’: half-wave variation along z-axis of the cylinder

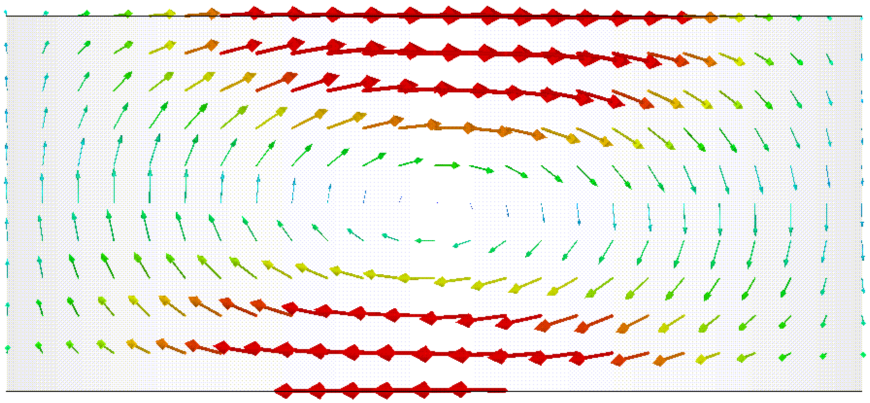
HEM $_{11\delta}$



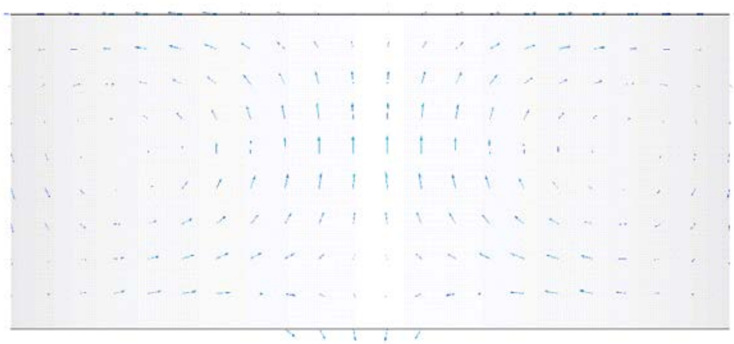


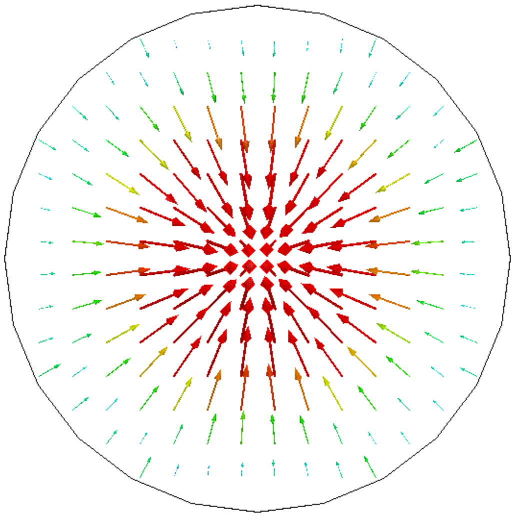
Isolated Resonator



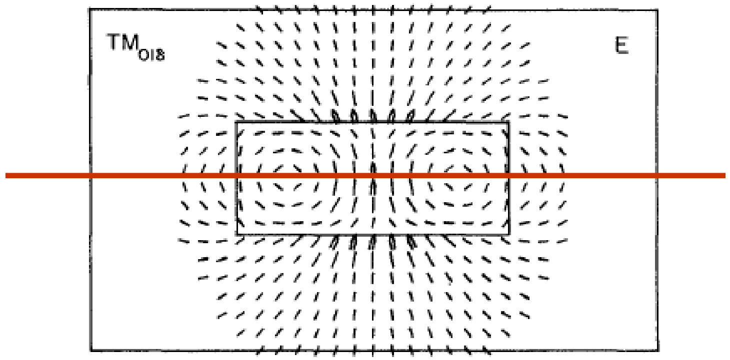


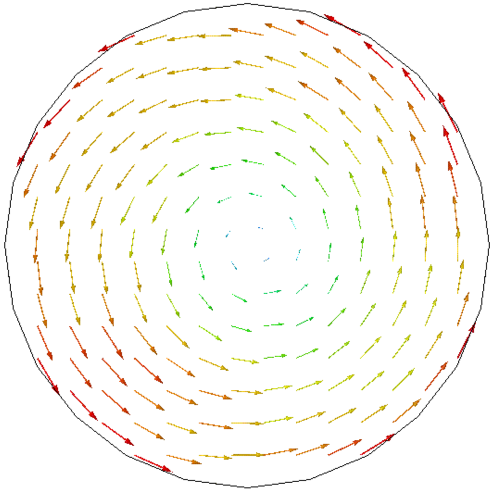
TM $_{01\delta}$





E



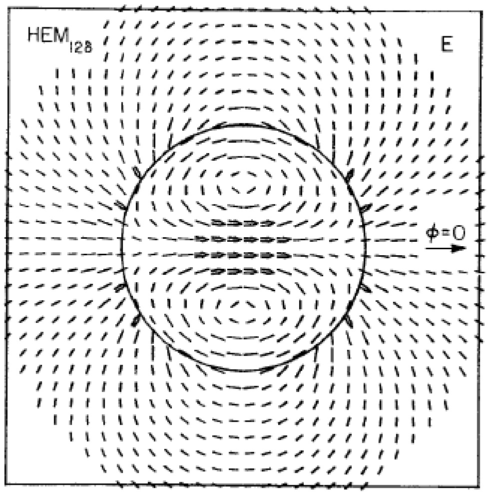


H

Isolated Resonator

Theoretical HEM $_{12\delta}$ Mode

Does it Radiate?



It should

Mode	f_{res} (GHz)	Q
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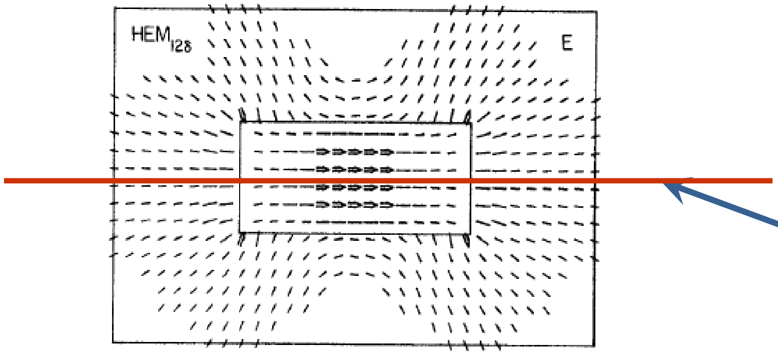
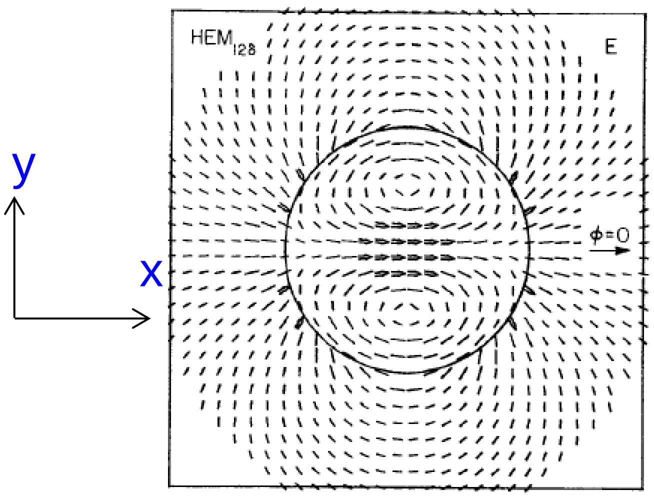
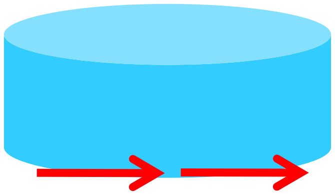


Isolated Resonator

Boundary condition does not allow any ground plane

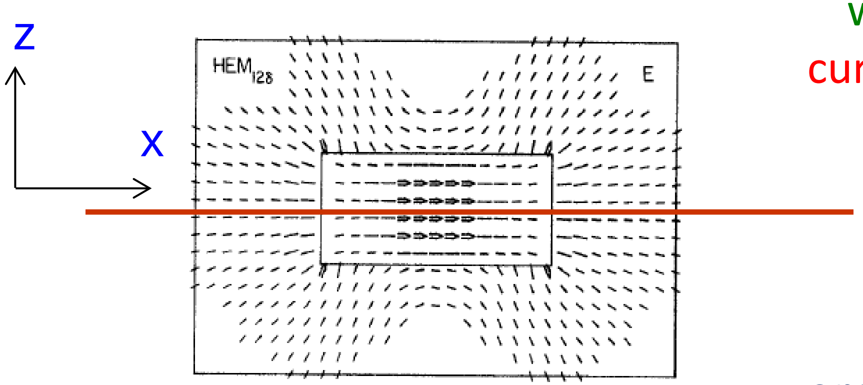
Address the Challange



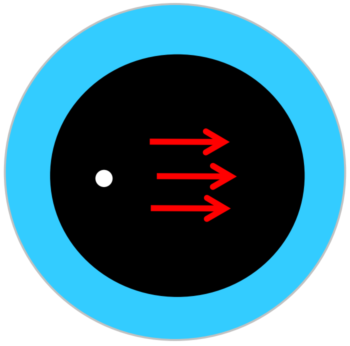


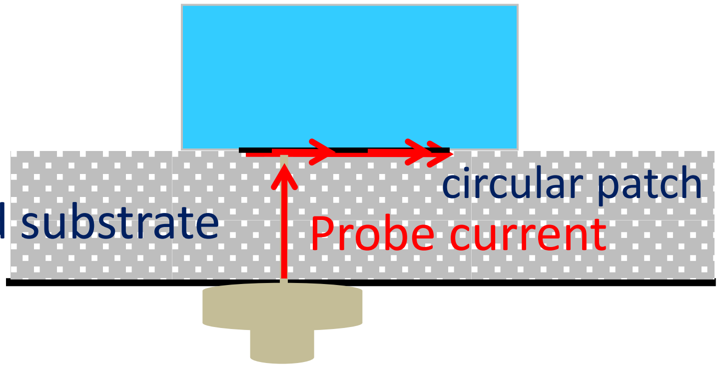
Boundary Condition demands Horizontal current in place metal

New approach to realize a current ribbon ??



Non-resonant Microstrip Patch working as a current ribbon

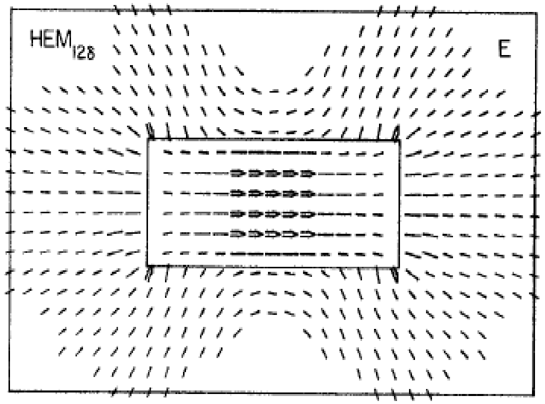


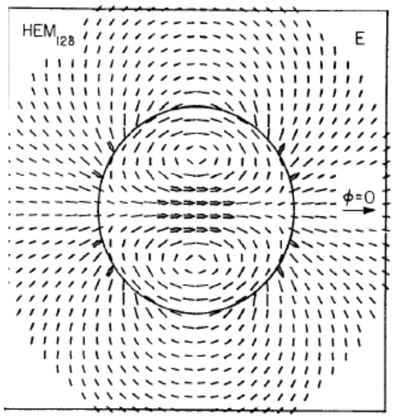


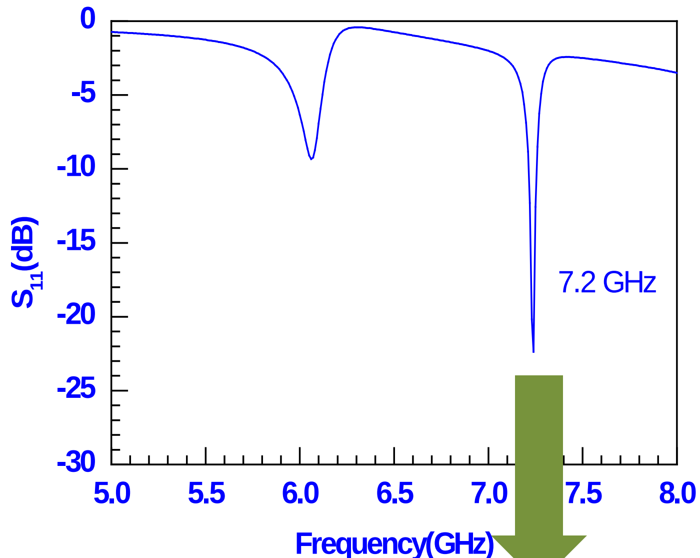
First Examination

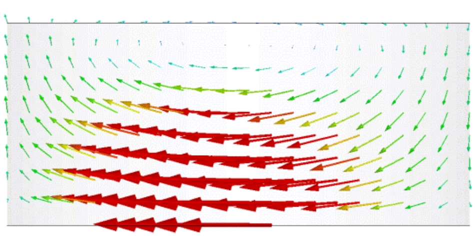
Kajfez's Sample + our Technique

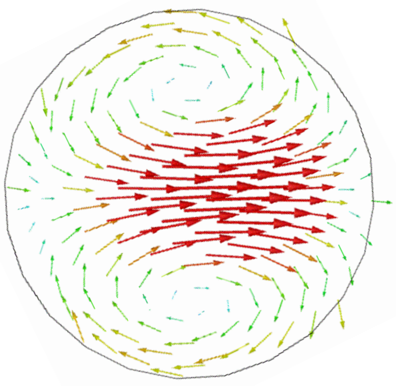
11.5 mm

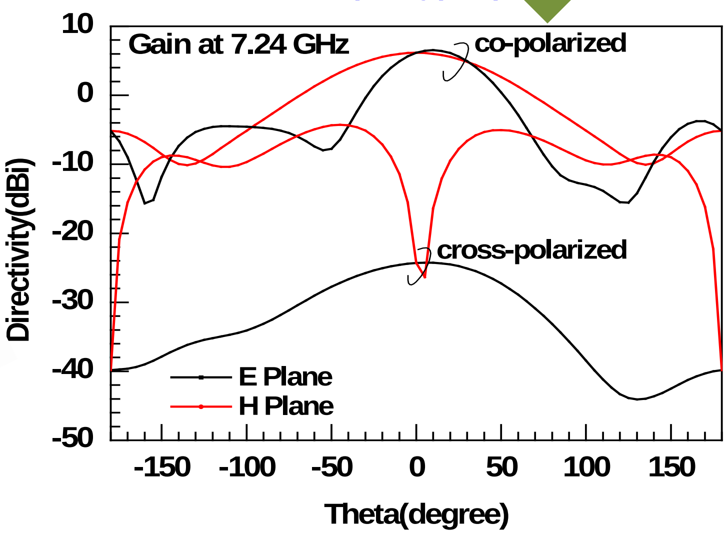




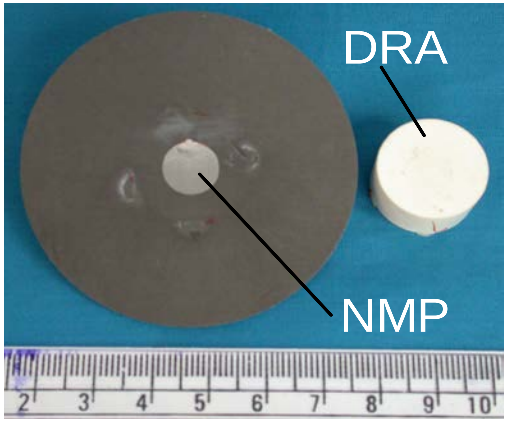






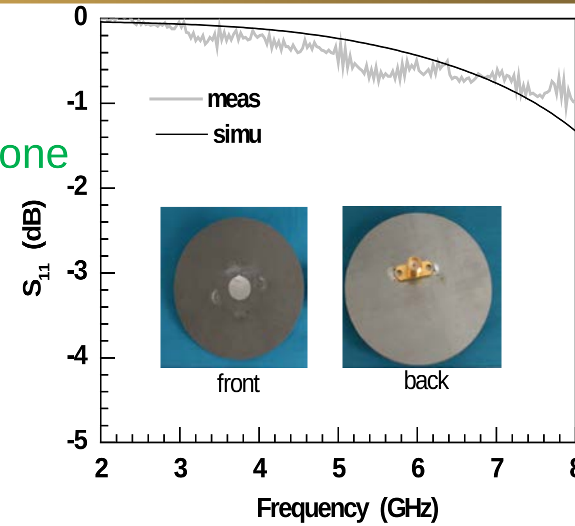


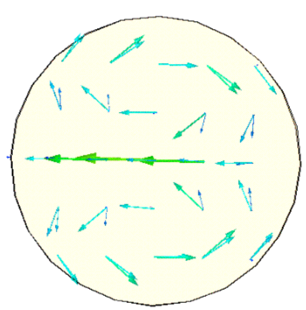
experiments

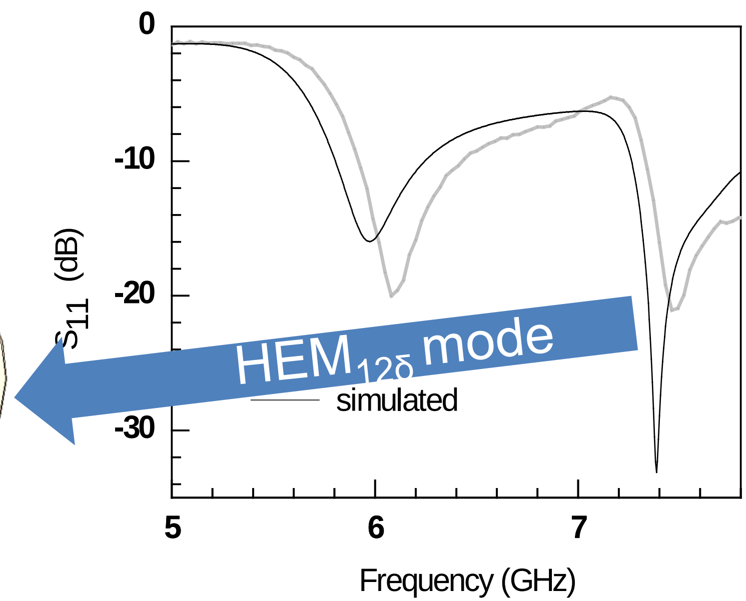


DRA: $\varepsilon_{r,d}$ = 10, *a* = 10 mm, *h* = 10 mm. NMP *r* = 5 mm, $\varepsilon_{r,s}$ = 2.33, *t*=1.575mm;

when the feed is alone



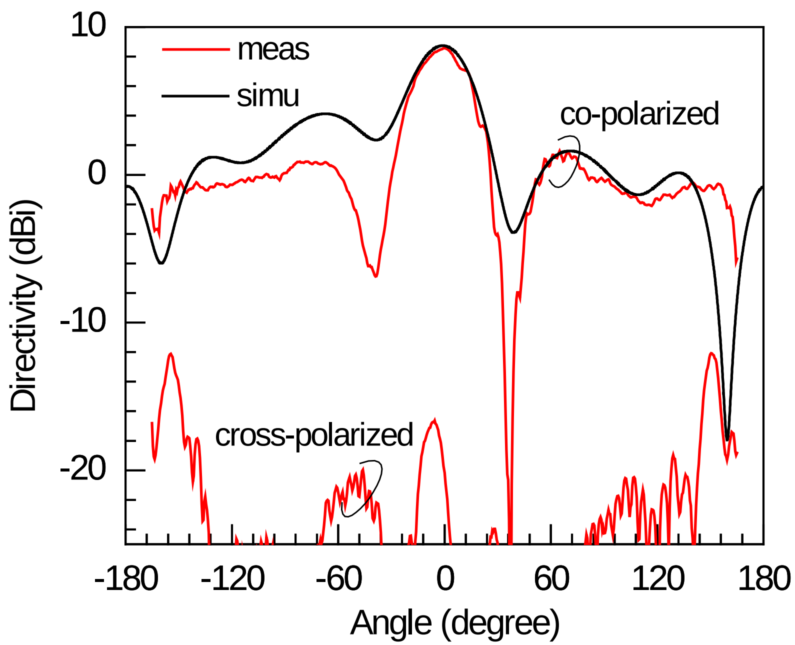




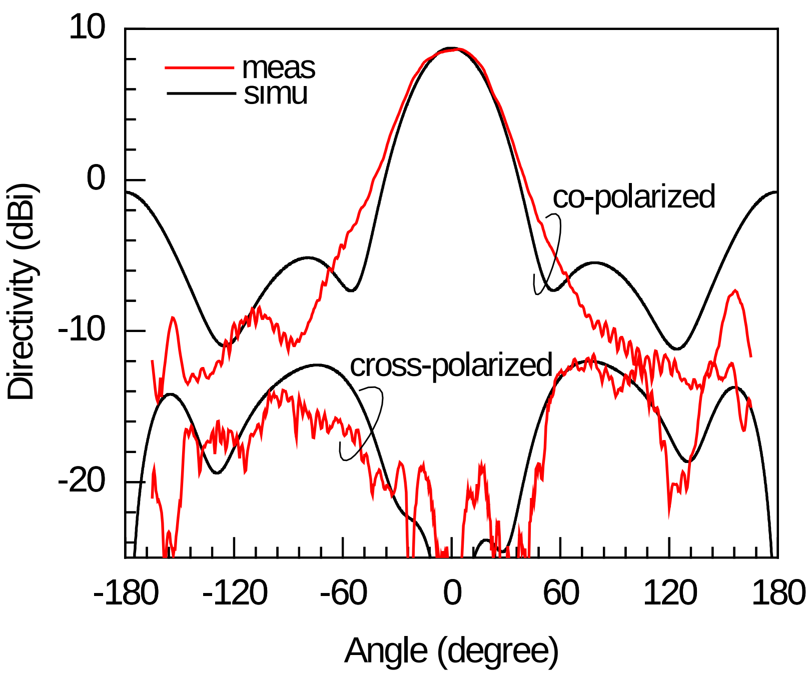
Radiations

after 3 decades

f = 7.4 GHz



E-plane



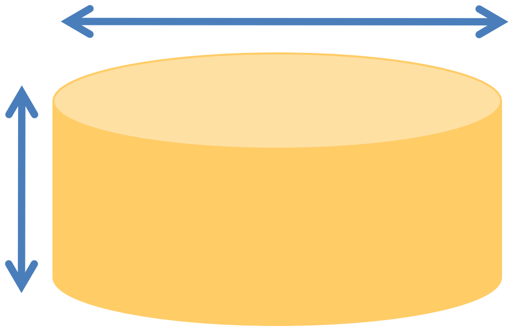
H-plane

D. Guha, et al. IEEE AP Transactions, January, 2012

Design Limitations?

Unknown Mysteries

Any limitation in DRA diameter?



Any limitation in DRA height?

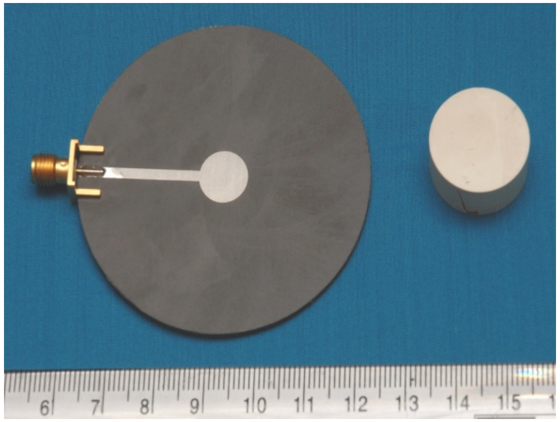
Any limitation imposed by the DRA material?

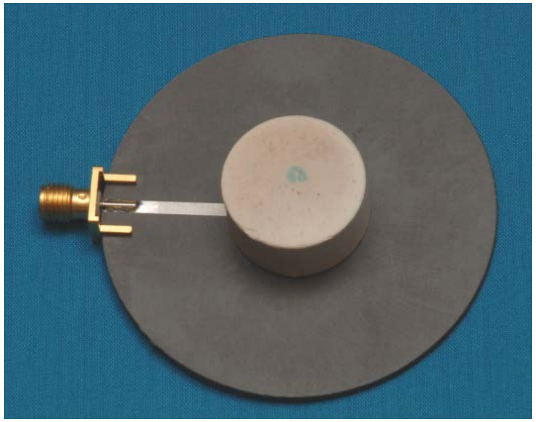
zinc tungstate composite

D. Guha, et al. IEEE AP Mag. August 2014

Any other Technique?

Fully planar should be most advantageous; should it be like this?





No, not so straight forward.

Mysteries lie in Current Ribbon with matching;
solution needs a different approach.

D. Guha, et al. IEEE AP-S Memphis, 2014

Yet any Other Technique?

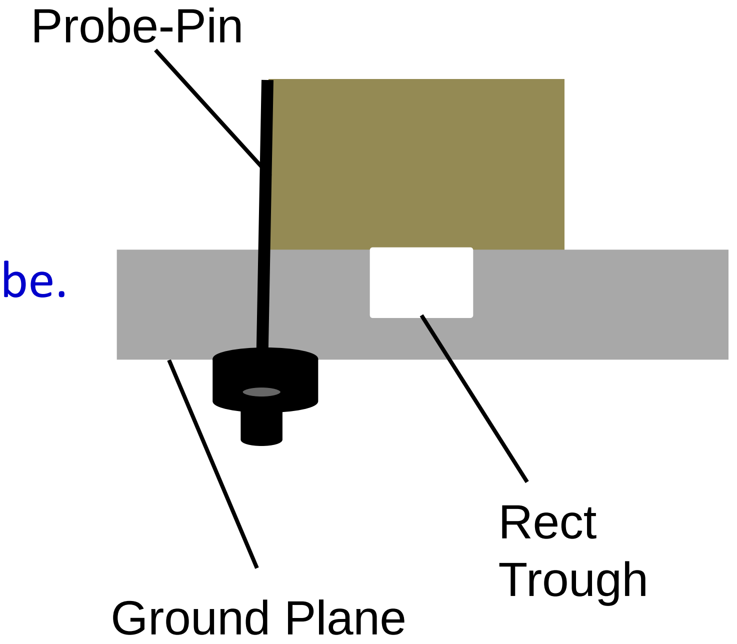
YES!

Much Easier and Robust Technique has been developed recently and reported

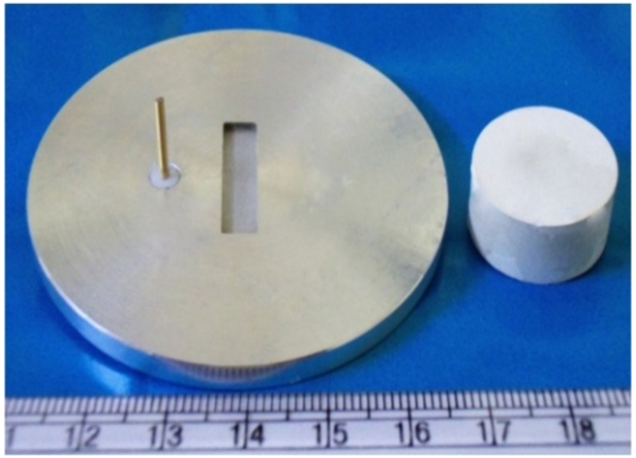
Excitation Mechanism?

Completely NEW

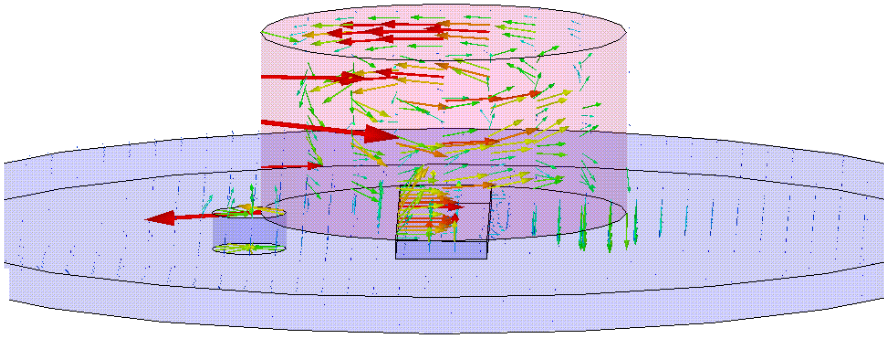
- Feed is conventional using vertical Probe.
- Ground plane (GP) is a metal sheet.
- **Boundary condition of GP has been modified favorably which can support $HEM_{12\delta}$ mode.**

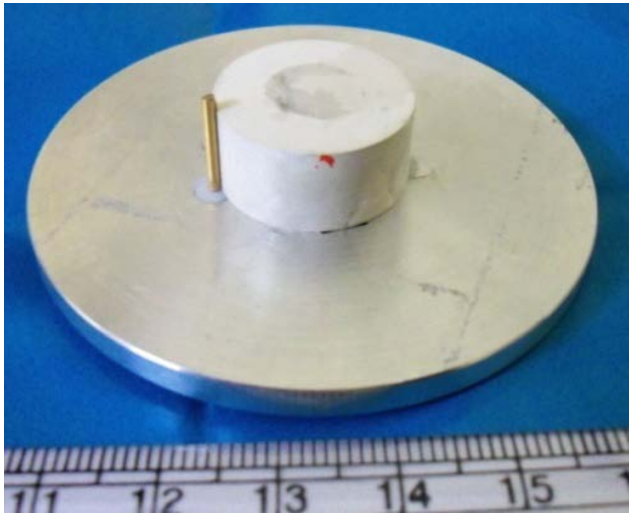


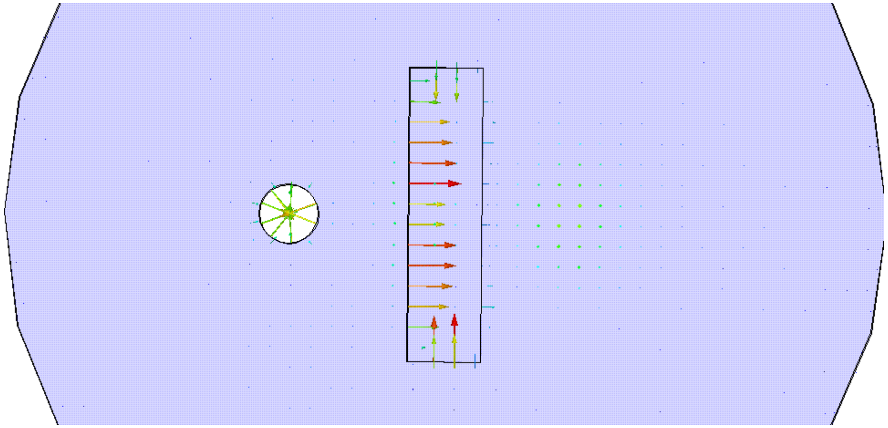
Role of Embedded Truough



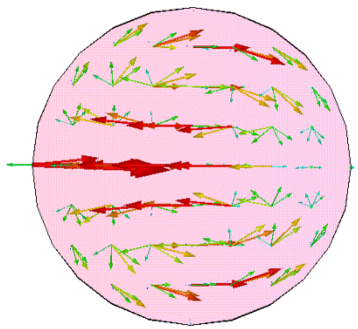
ground plane with trough

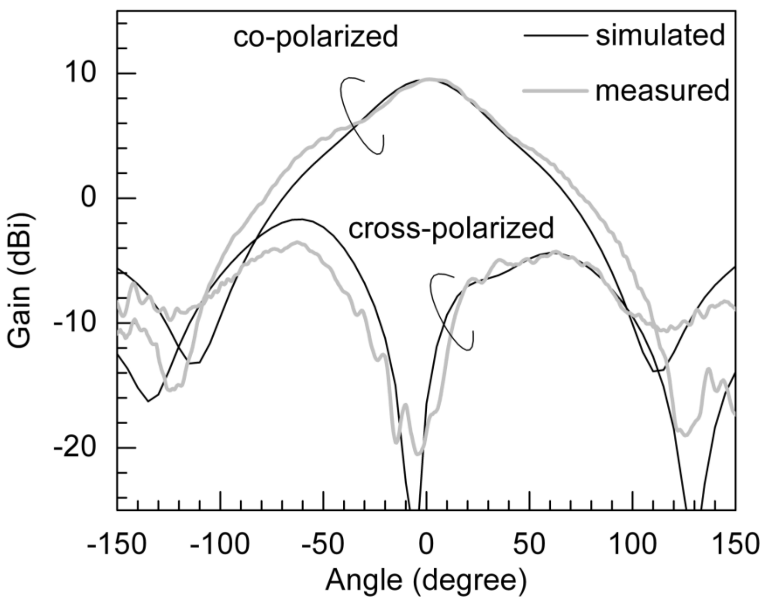


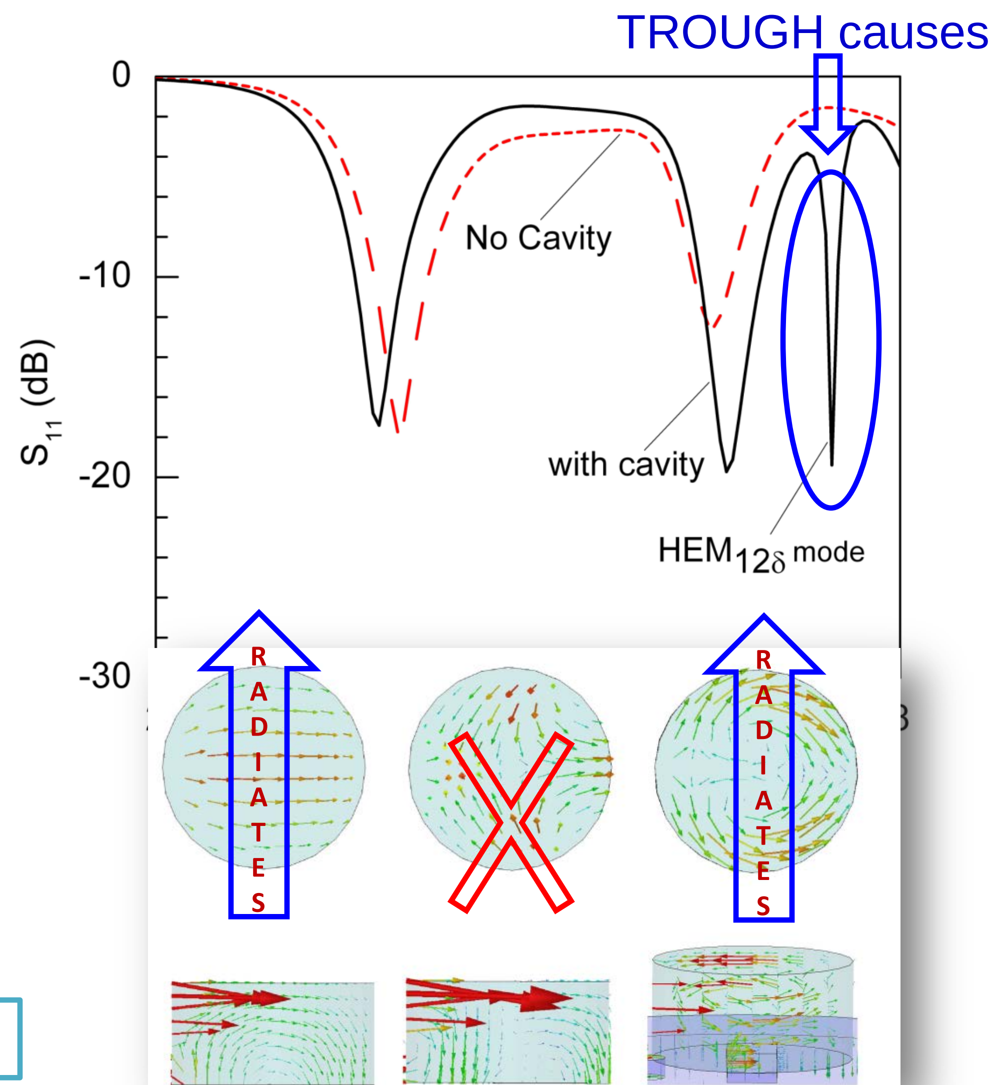




The Results







D. Guha, et al. IEEE AWPL, 2014

Yet Any Other?

Definitely YES

An Open Book to YOU

Two Different Techniques have been Explored Recently

1

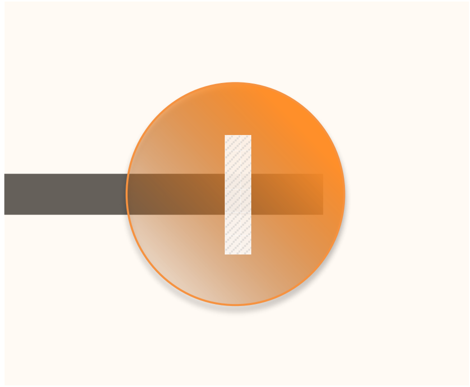
Composite Aperture – to realize equivalent Magnetic & Electric Dipoles as new Feed

2

Under investigation………

Suitable Aperture

Aperture Coupled

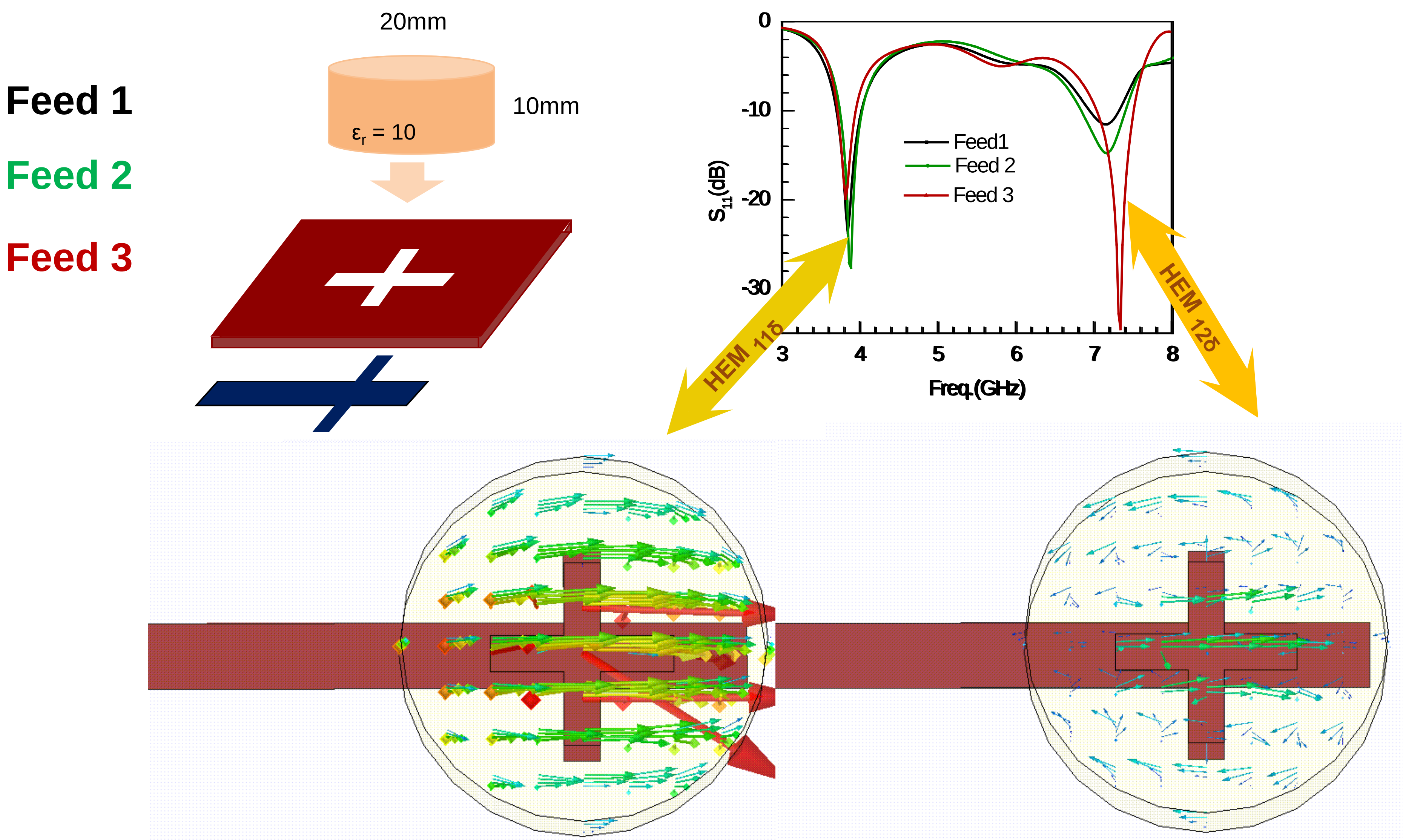


Why?

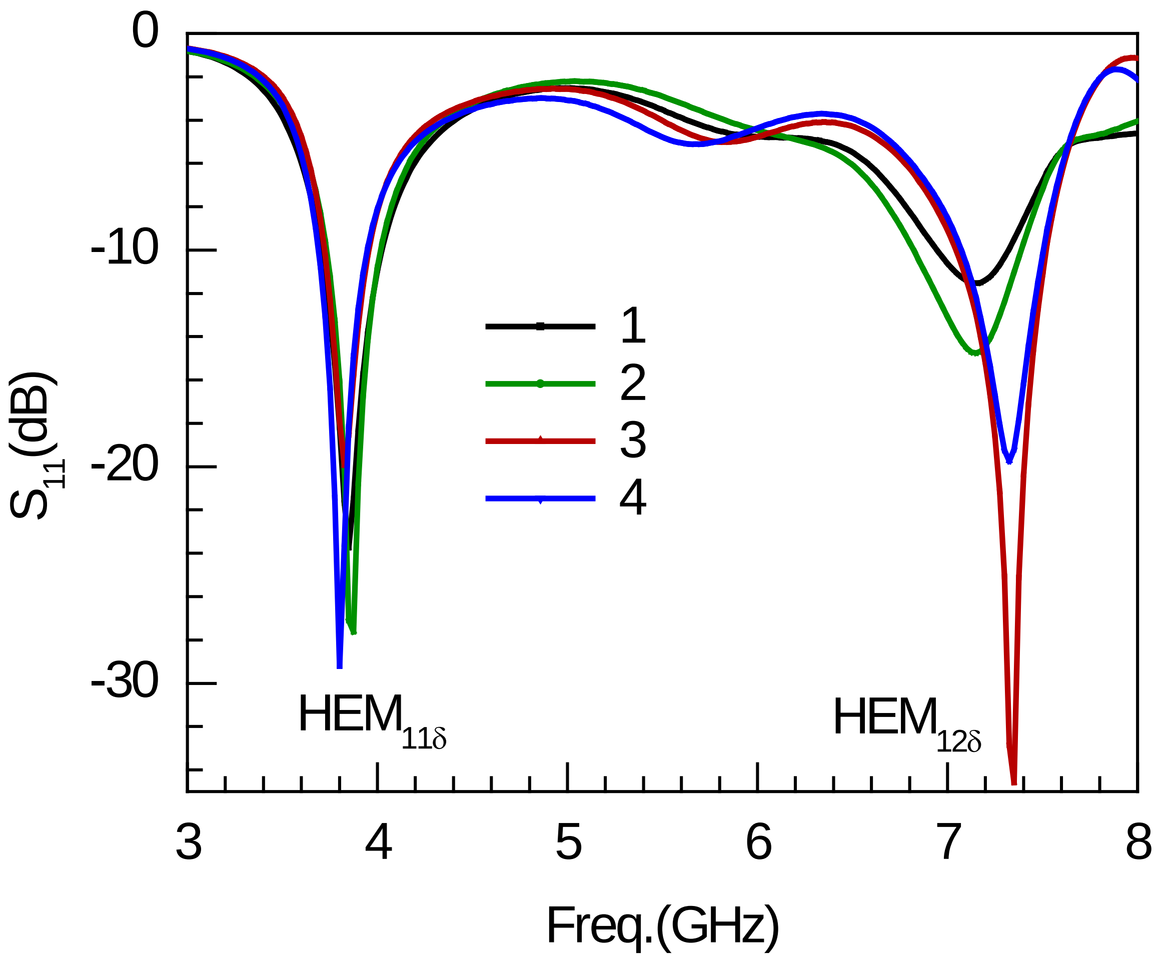
- Aperture introduces *no metal.*
- Favors required boundary condition for $HEM_{12\delta}$ mode.
- Suitable for $HEM_{11\delta}$ mode too.

Aperture-Feed Explored

$HEM_{12\delta} + HEM_{11\delta}$



Impedance vs Feed



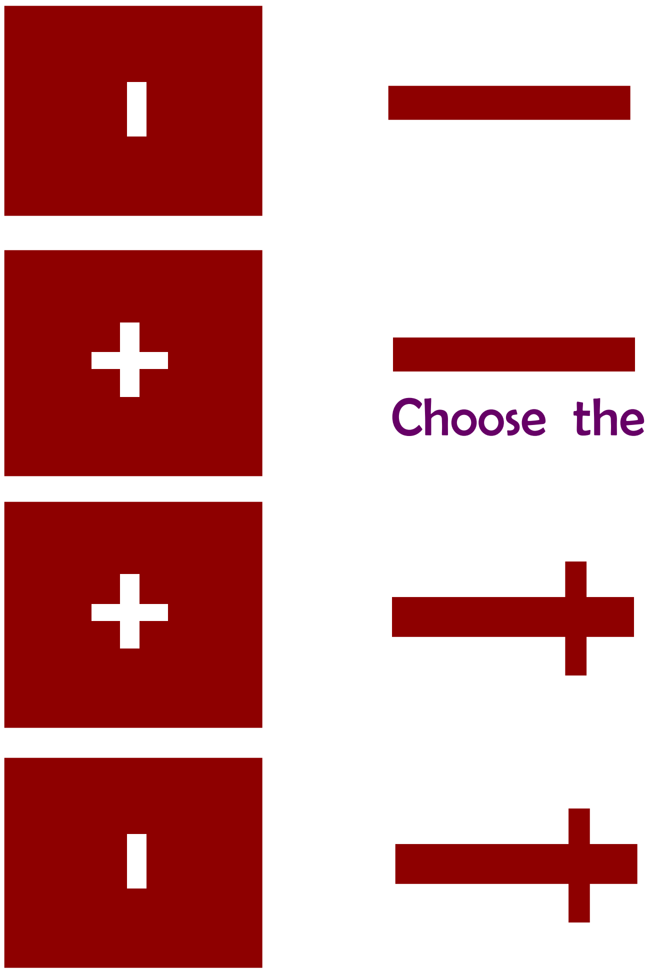
Characterize the Feed

1

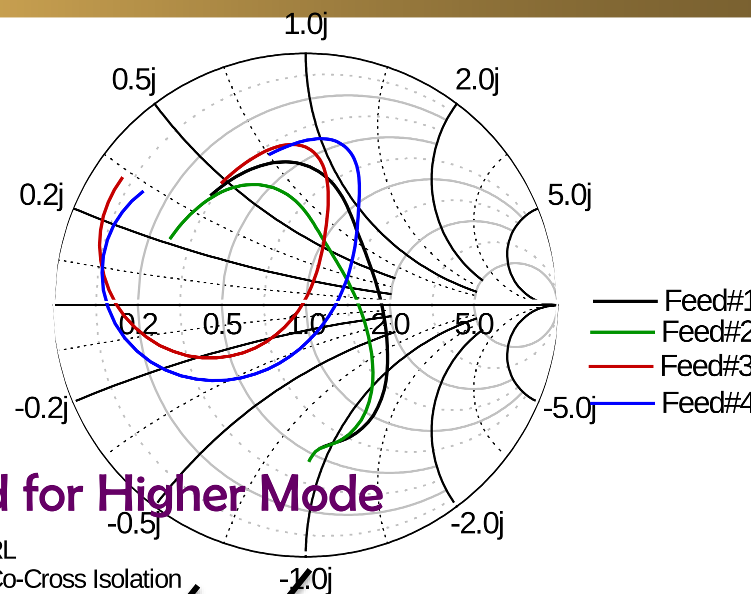
2

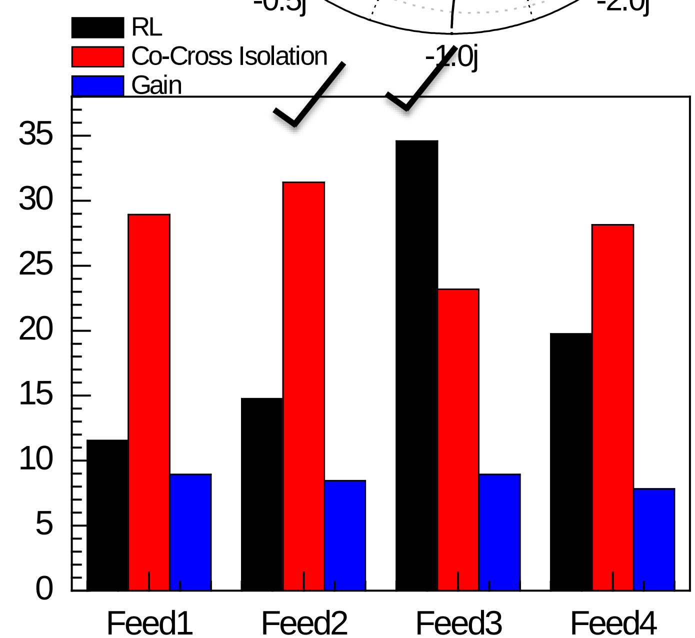
3

4

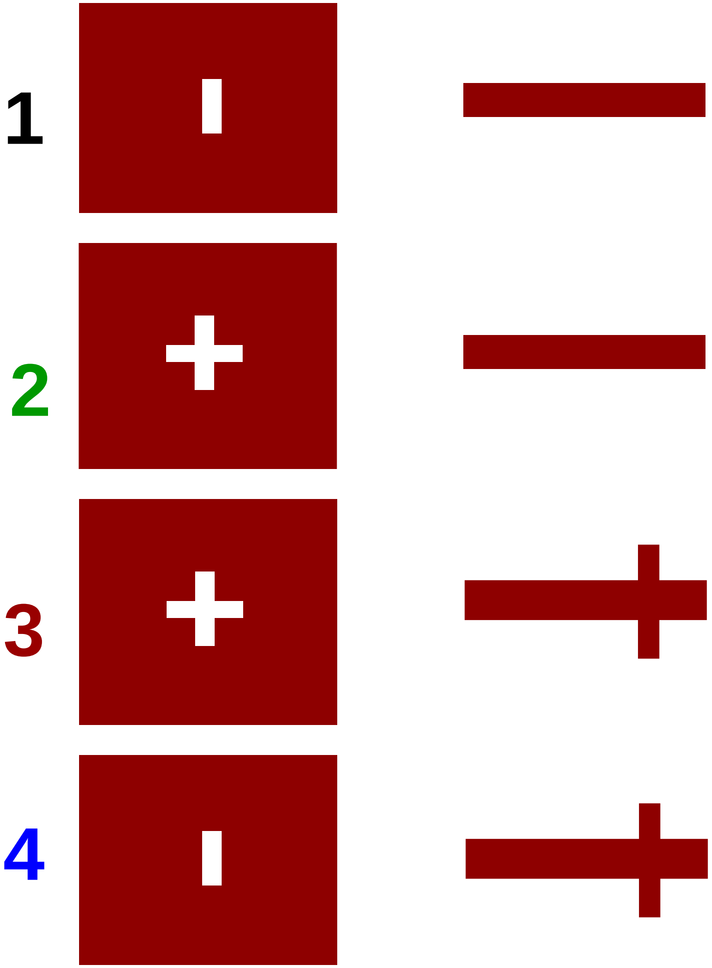


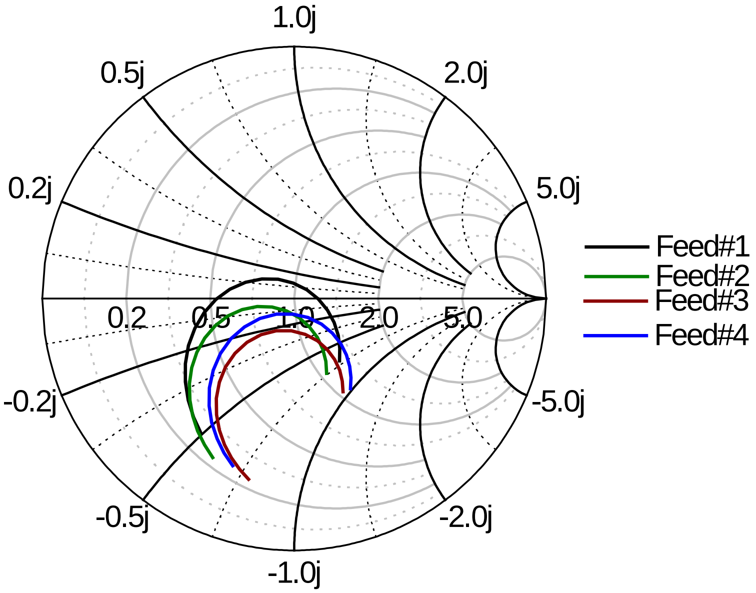
Choose the Right Feed for Higher Mode



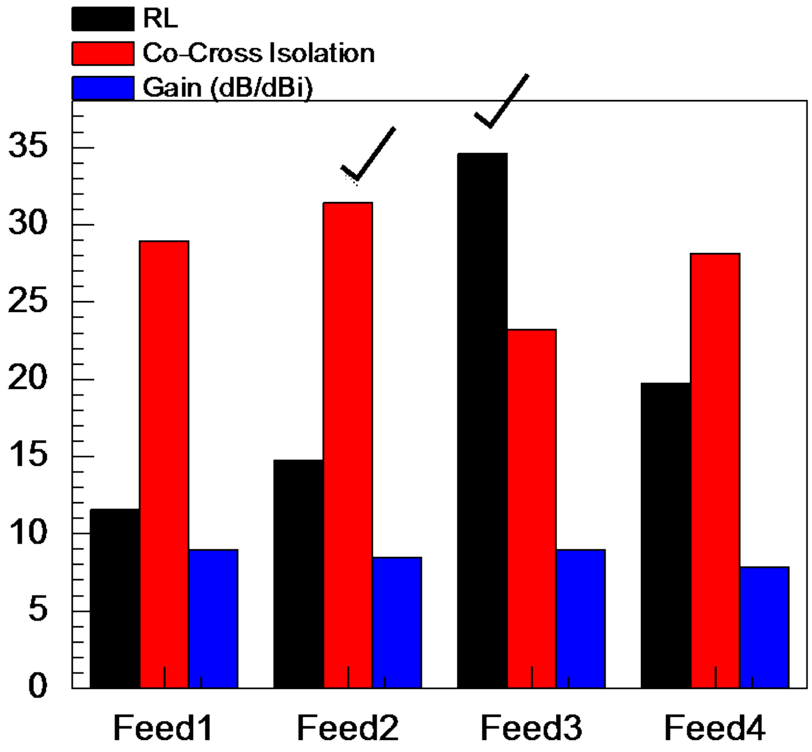


What about Dominant Mode?

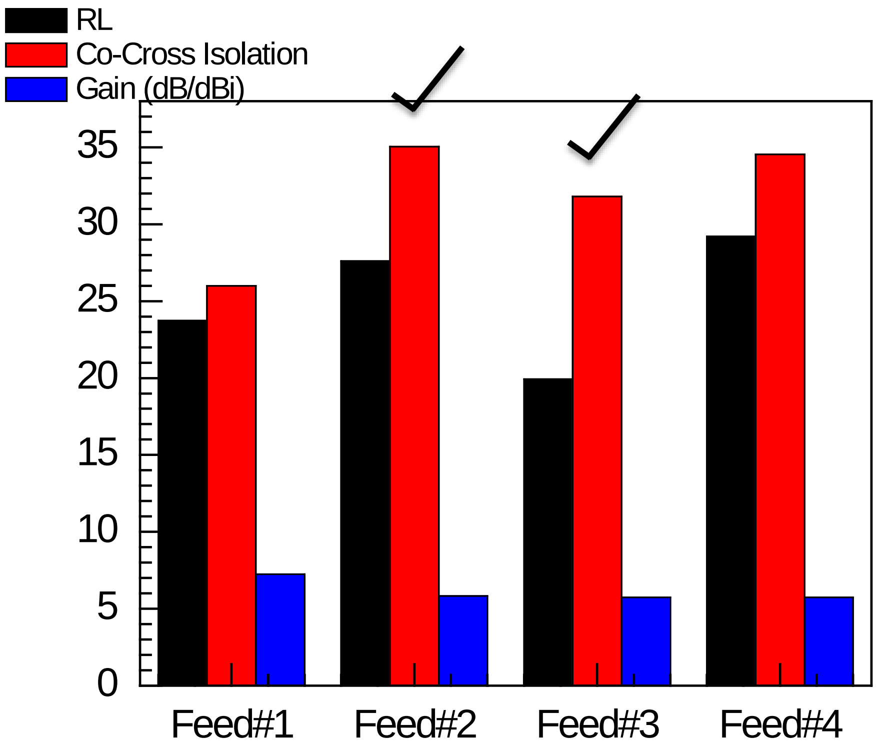




Select the Optimum One

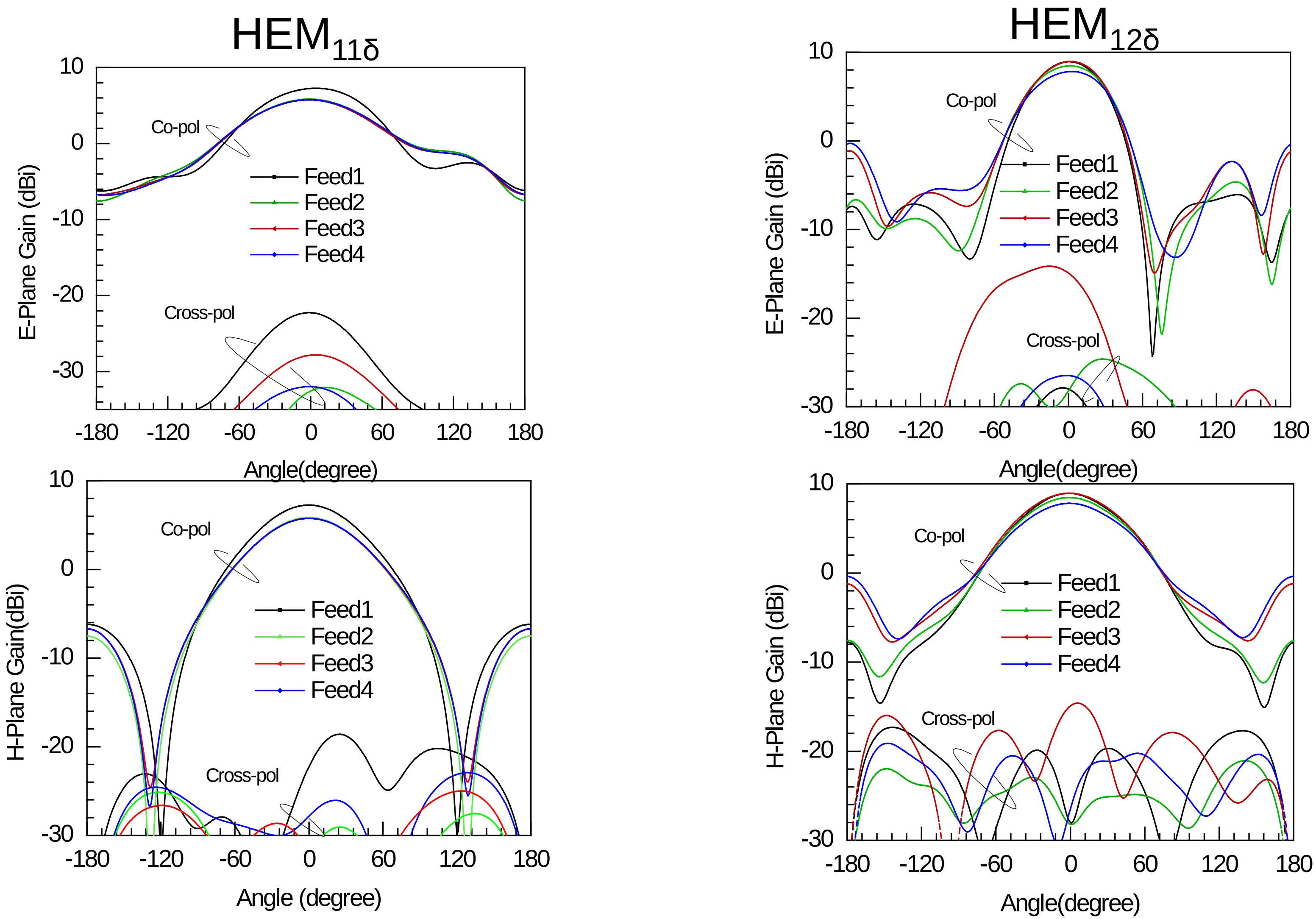


$HEM_{12\delta}$

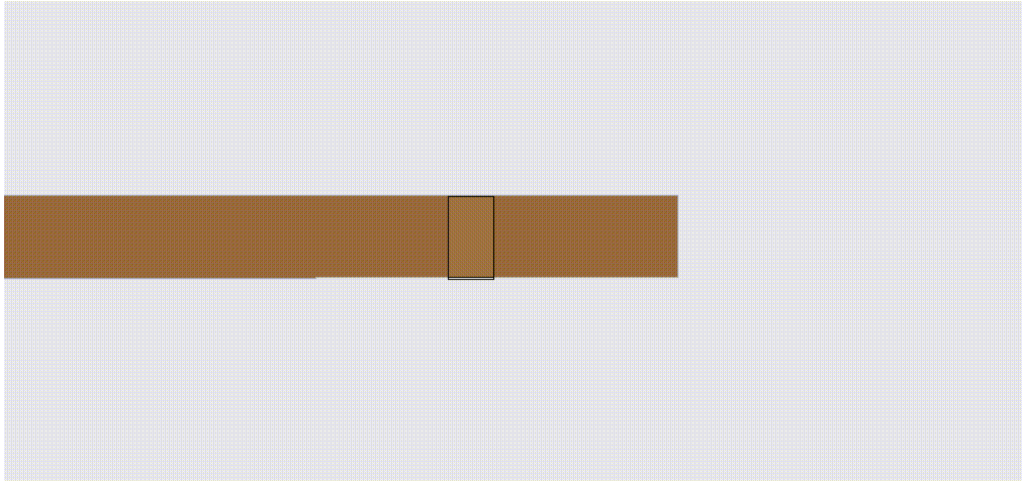


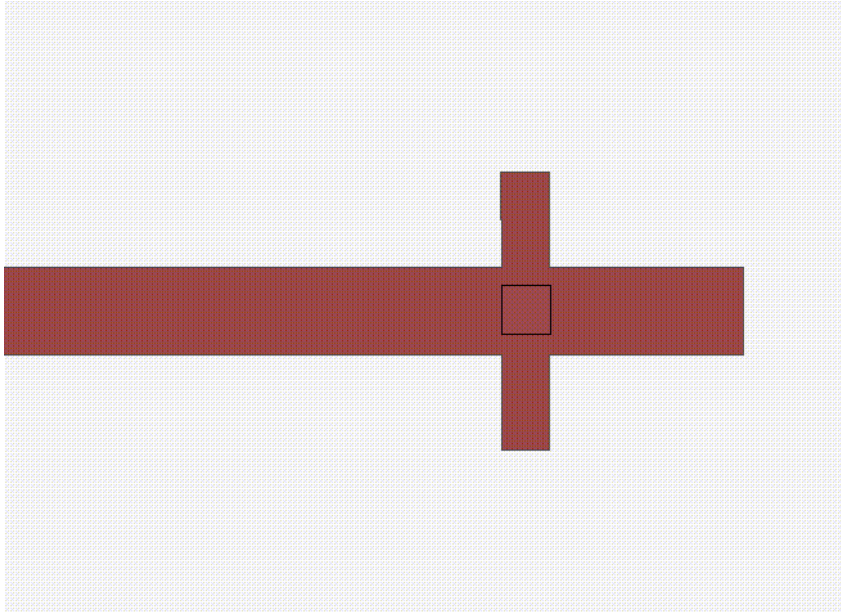
$HEM_{11\delta}$

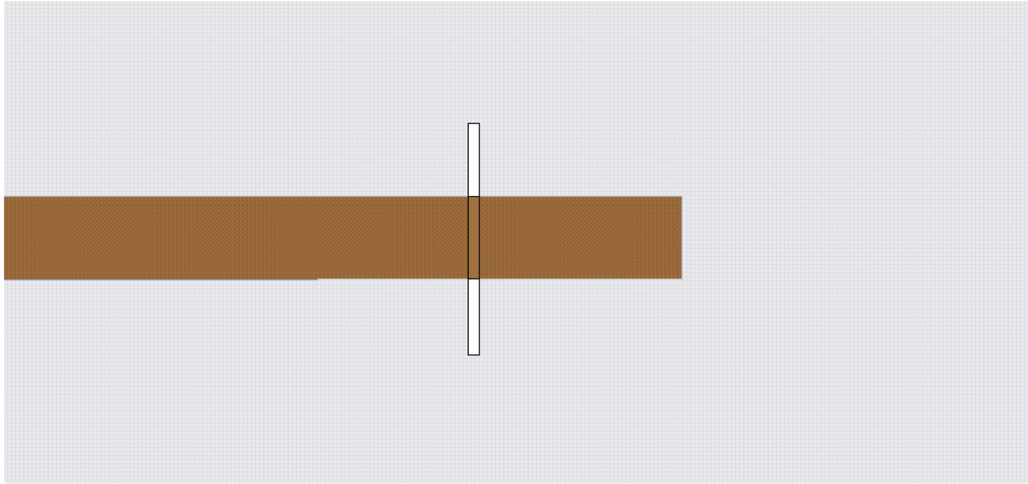
Radiation Patterns



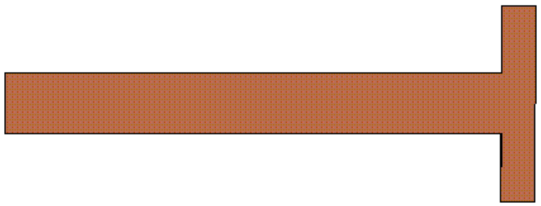
Optimized Aperture

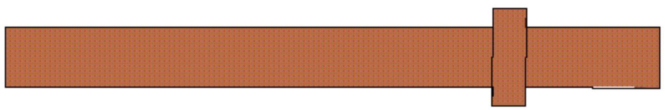




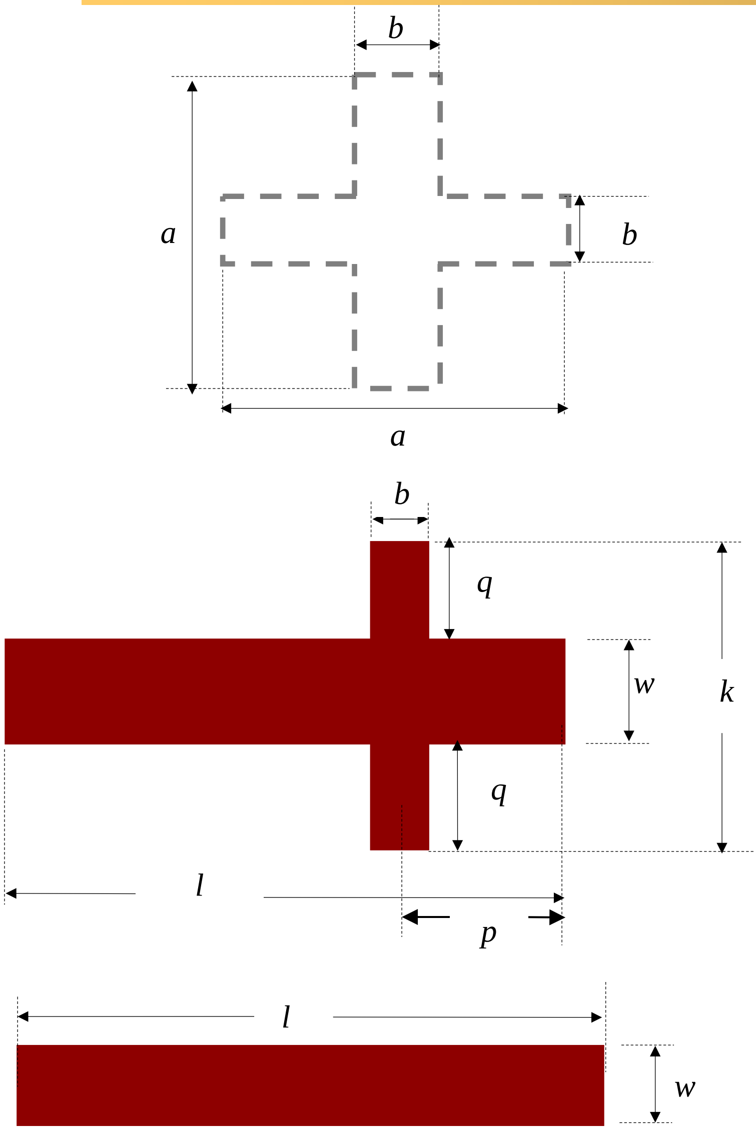


Optimized Feed Line





Optimum Parameters

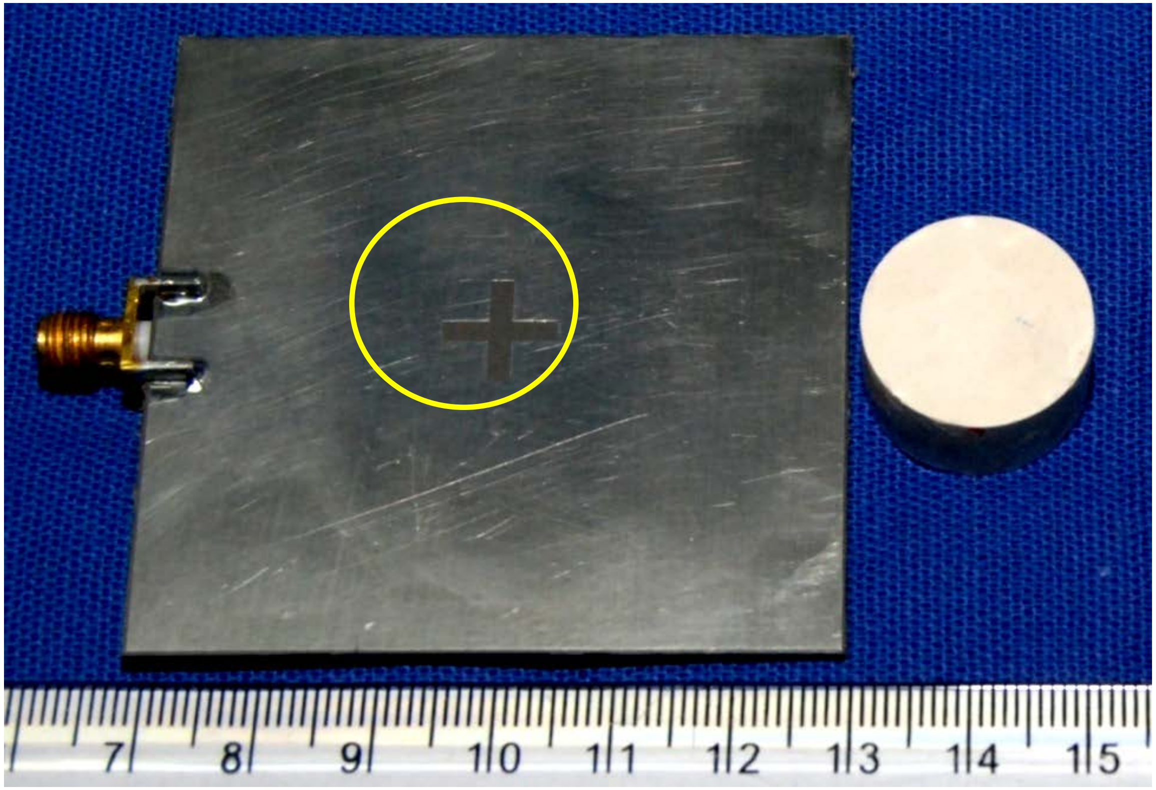


Frequency (f)	Wavelength (λ)
3.85GHz(f_1)	78mm (λ_1)
7.35GHz (f_2)	41mm(λ_2)

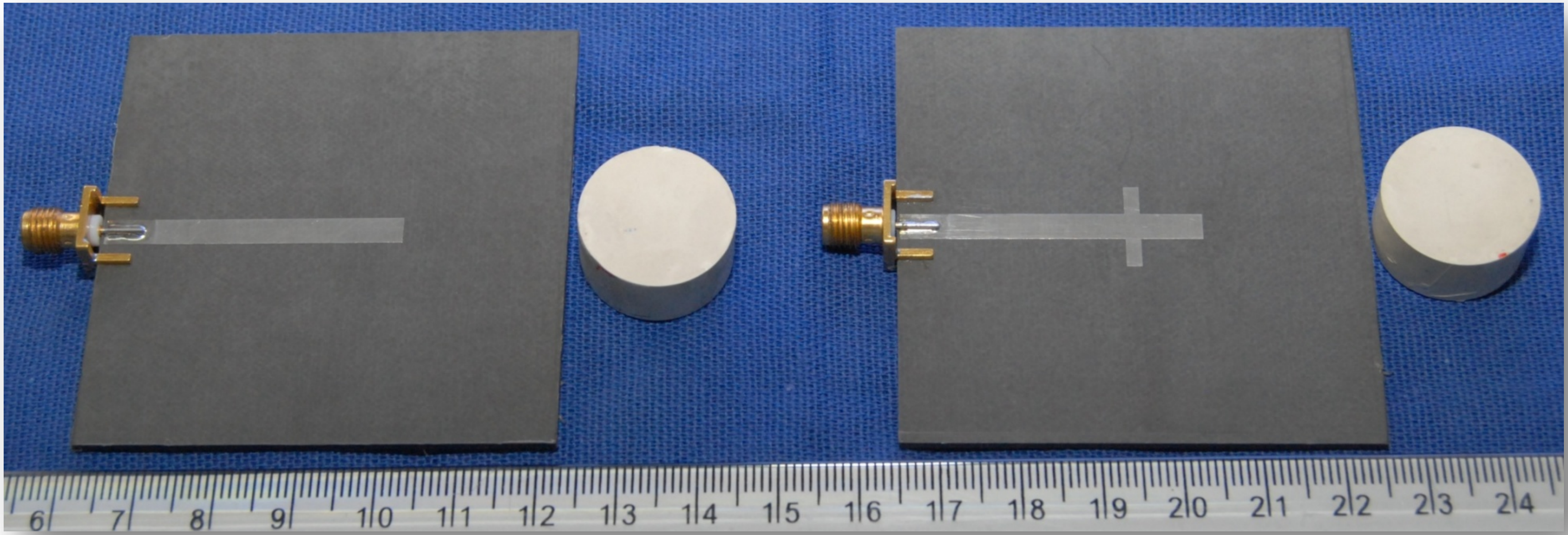
Table of Parameters

Parameters	Optimized Value (mm)	In Terms of λ
a	10	$0.13\lambda_1$ ($0.24\lambda_2$)
b	2	$0.03\lambda_1$($0.05\lambda_2$)
w	3.6	$0.05\lambda_1$($0.09\lambda_2$)
l	39	$0.5\lambda_1$($0.95\lambda_2$)
p	9	$0.12\lambda_1$($0.22\lambda_2$)
q	3.95	$0.05\lambda_1$($0.1\lambda_2$)
K	11.5	$0.15\lambda_1$($0.28\lambda_2$)

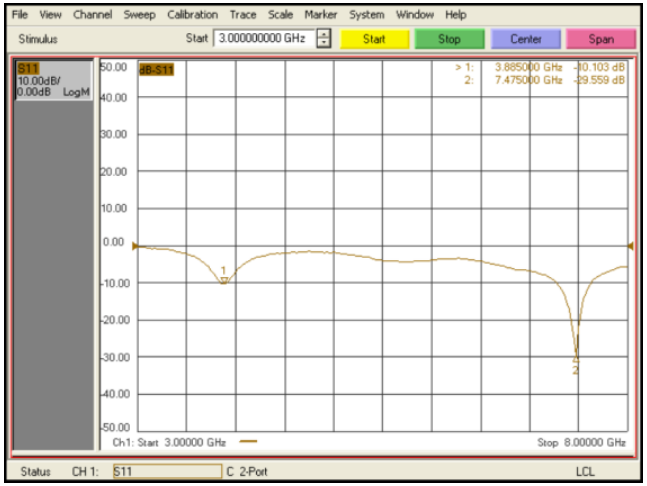
The Prototype

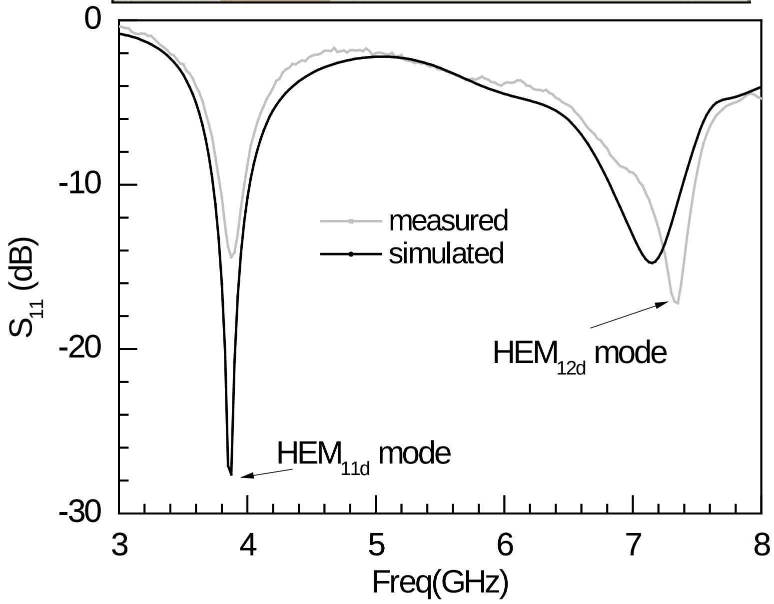


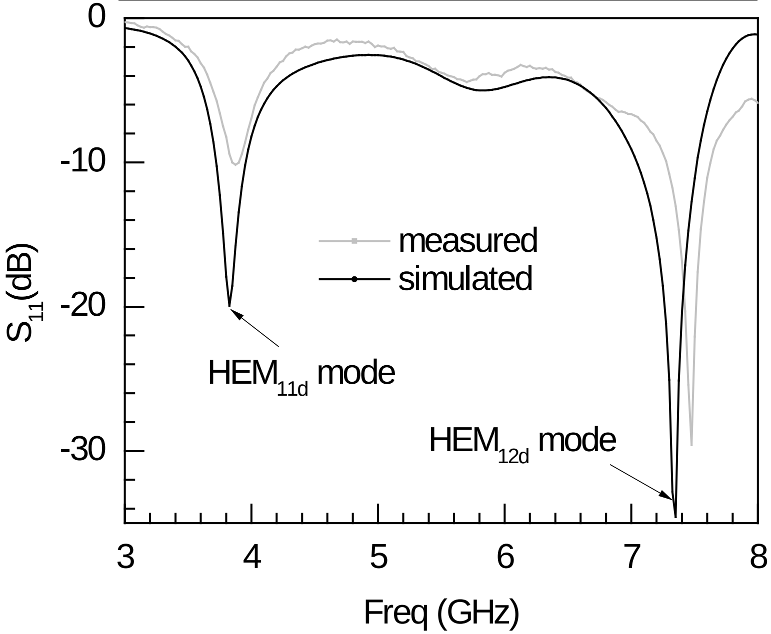
Viewed from Feed-line side



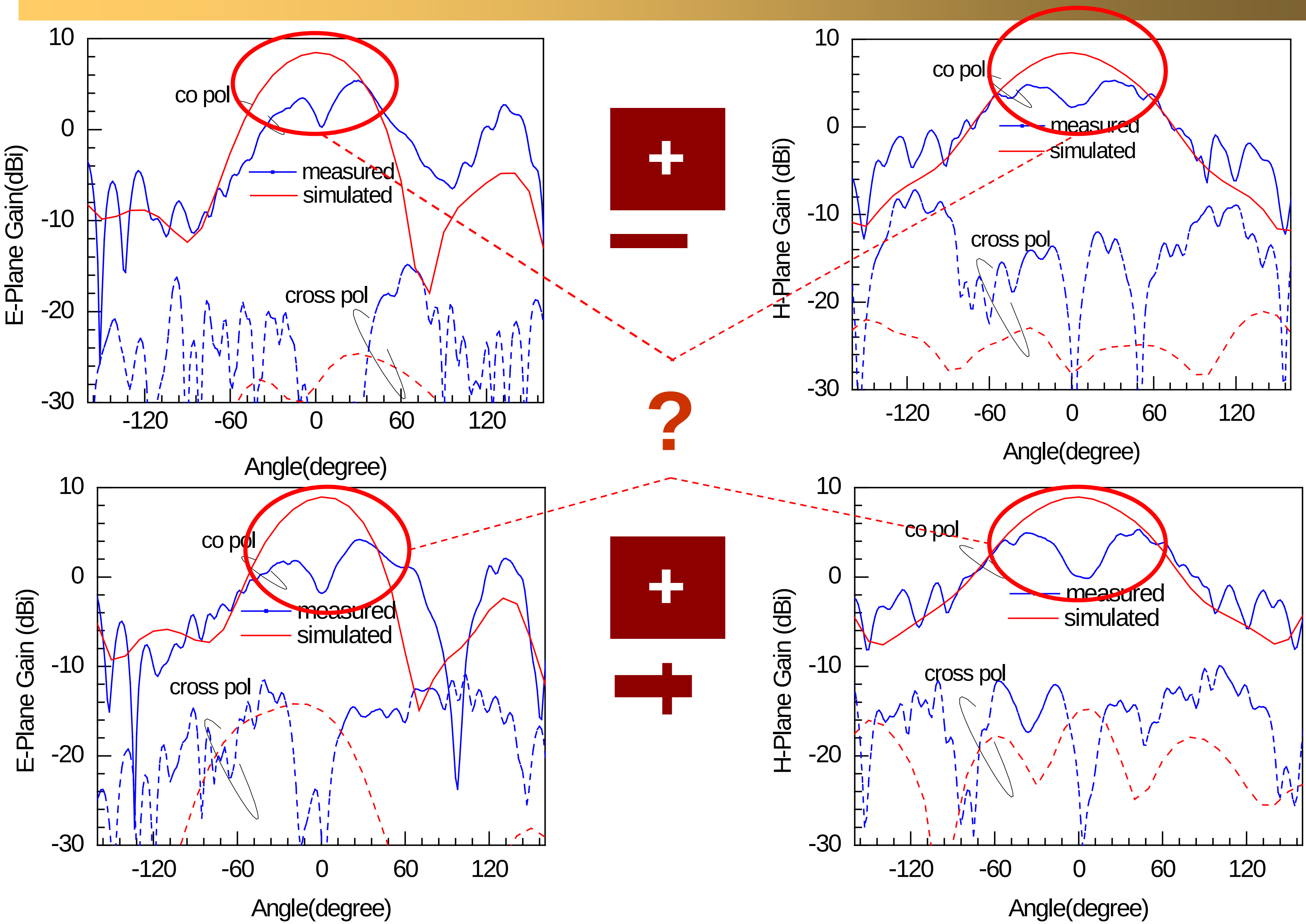
Measured Results



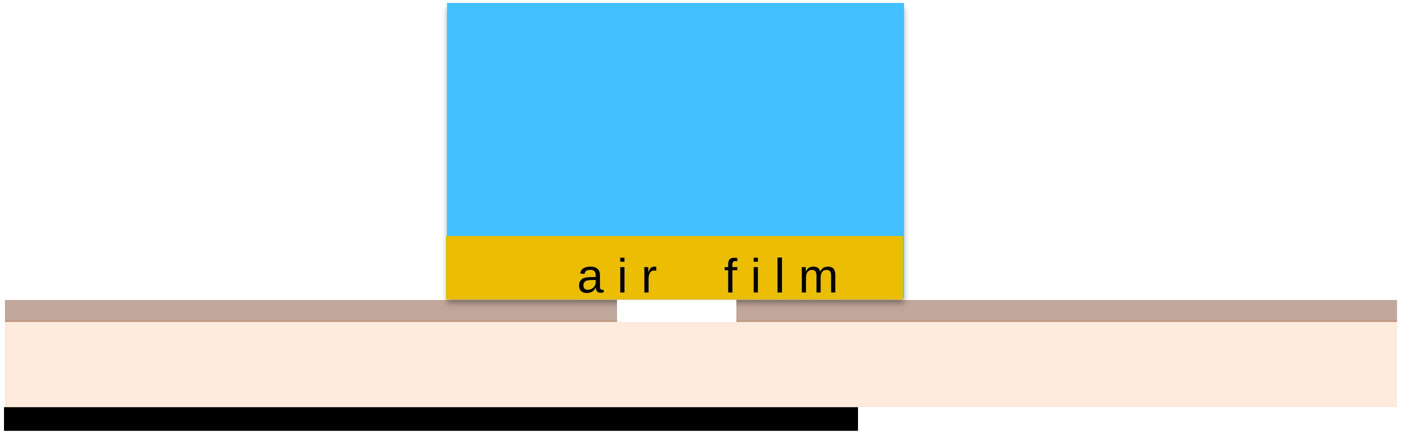




Measured Radiations



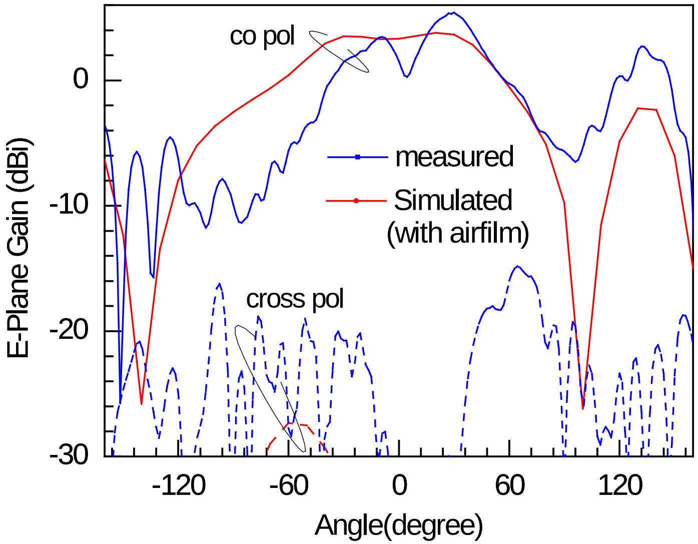
Interesting Observation

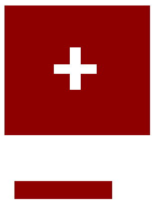


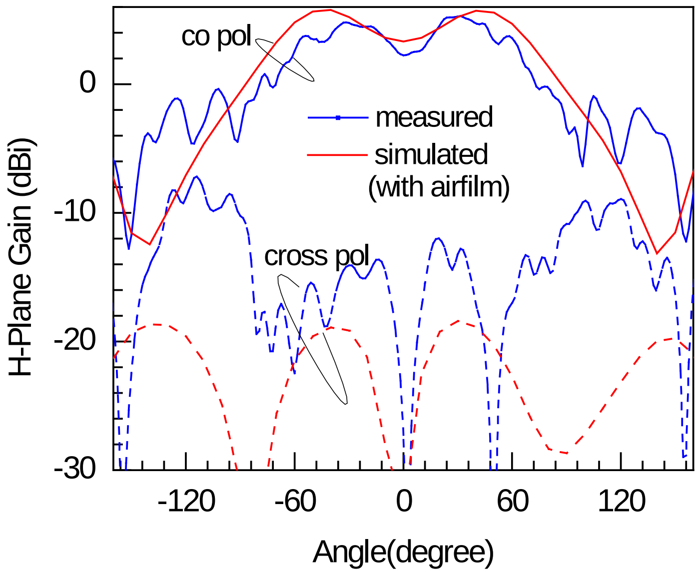
Air-film Thickness~ (0.02-0.04)mm

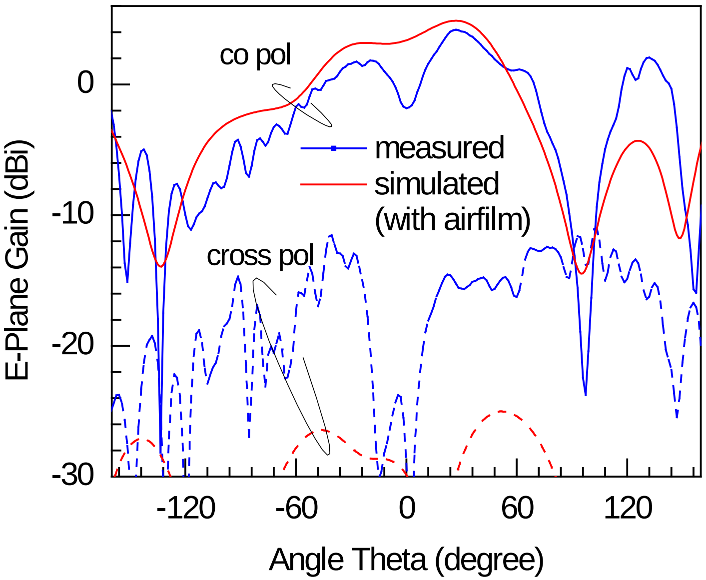
Closely Follow

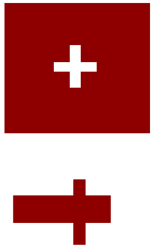
HEM$_{12\delta}$

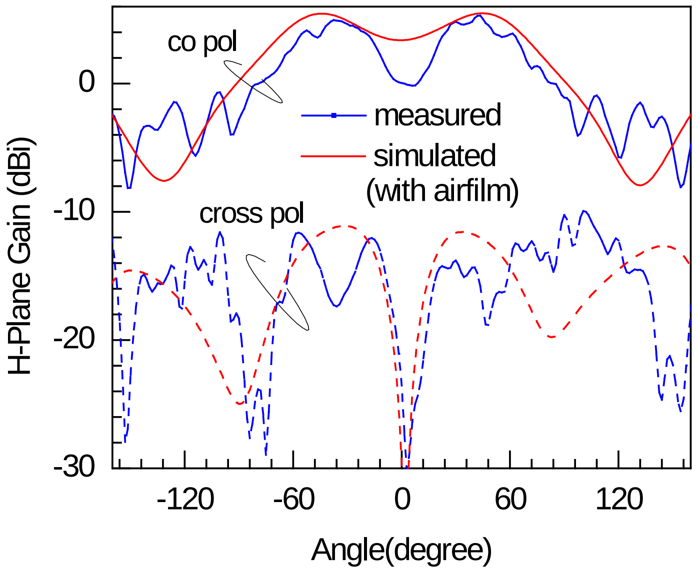






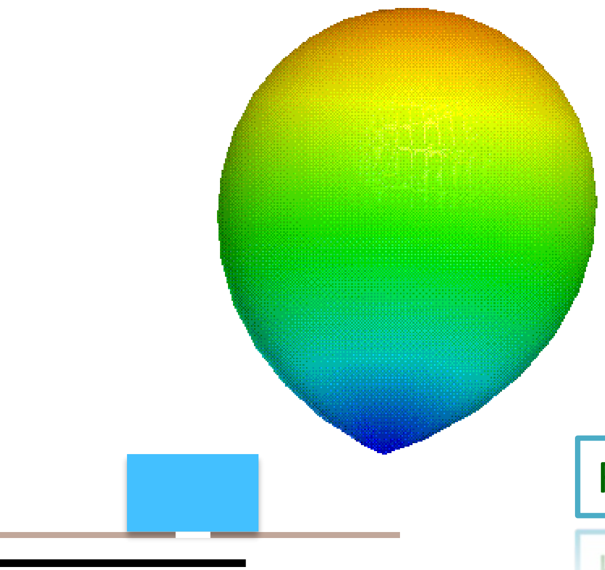


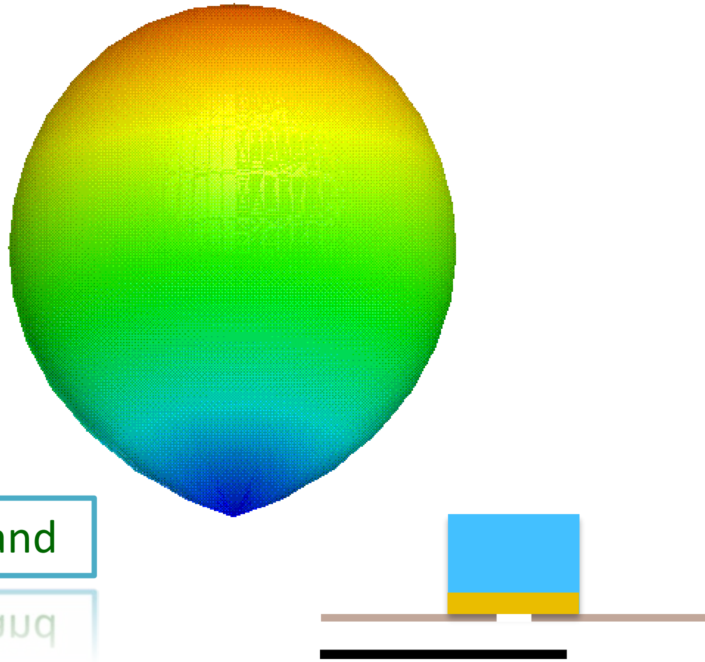




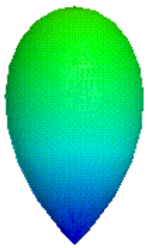
Effect of the air-film

$HEM_{12\delta}$

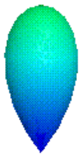




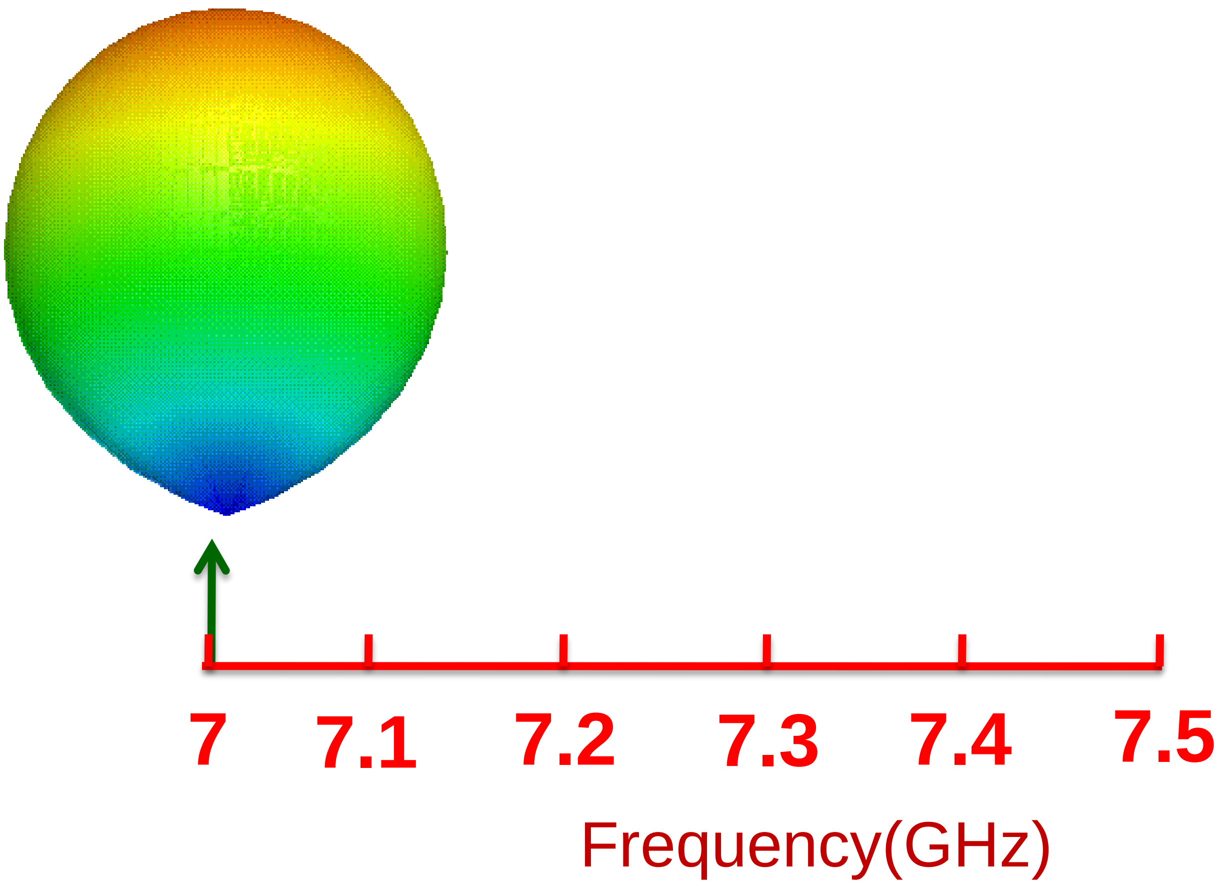
Radiation over the Operating Band



$HEM_{11\delta}$



Location on the spectrum



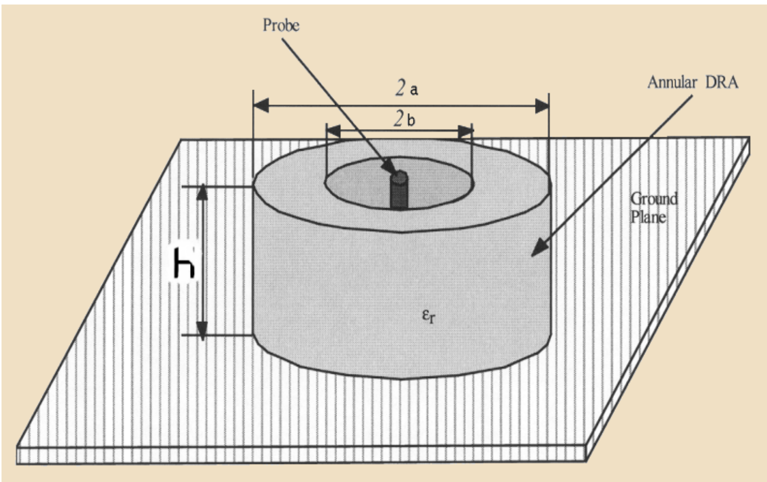
Interesting Features

- New feed for CDRA with $HEM_{11\delta}$ & $HEM_{12\delta}$ modes simultaneously.
- Both the modes with comparable Bandwidth, Gain and Patterns.
- Dual mode dual-band antenna with identical radiations
- Unavoidable air-gap is a new finding, which adds a new feature.

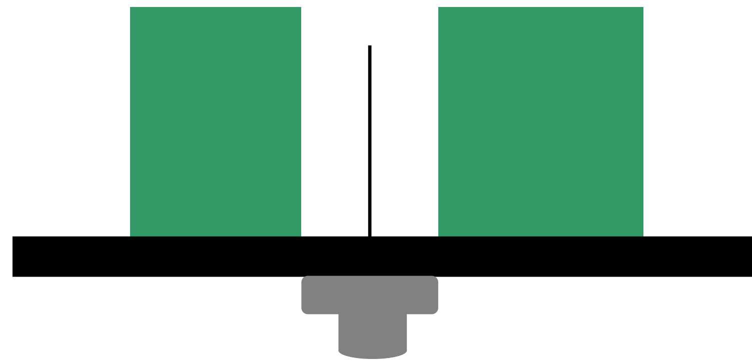
Unconventional Pattern providing larger Beamwidth

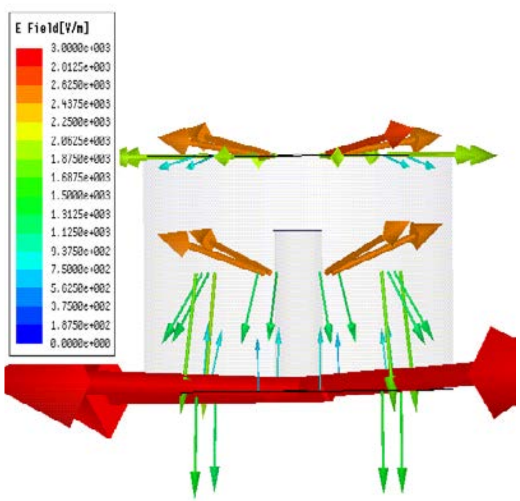
Known Modes in Unknown Structures

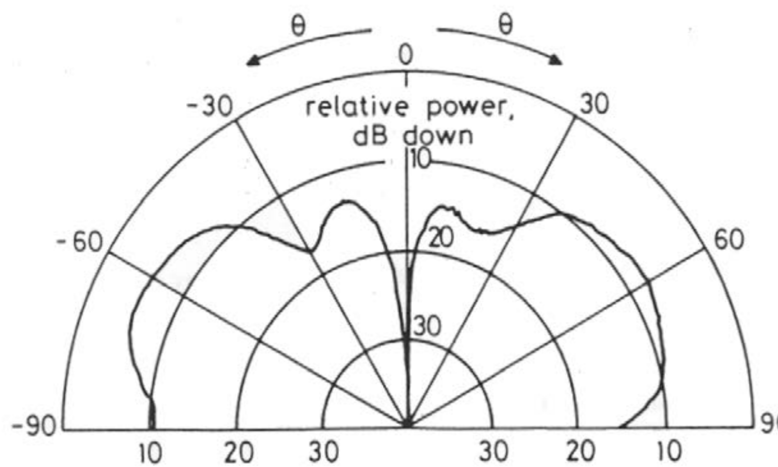
$TM_{01\delta}$ mode after a decade



Mongia et al *Elect. Lett.* 29(17) 1530-1531, 1993.

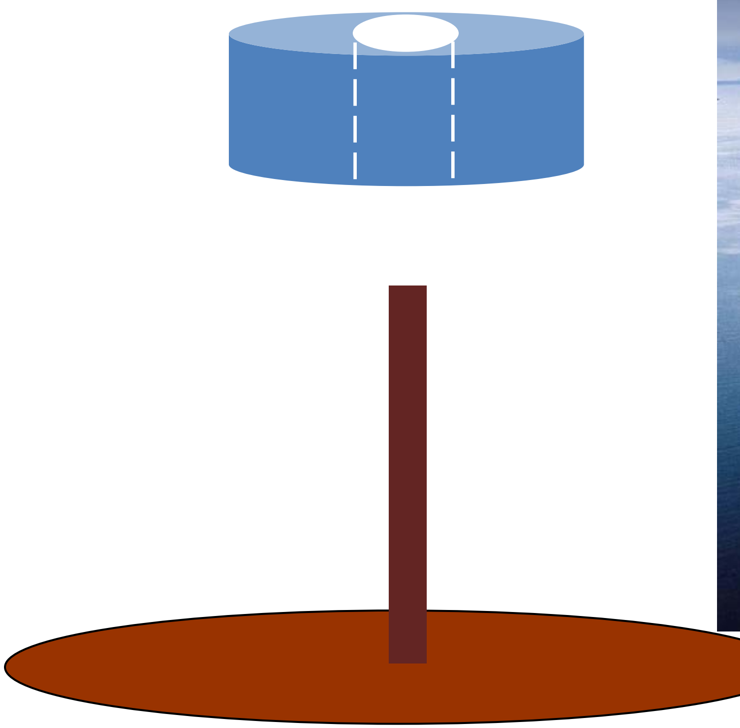


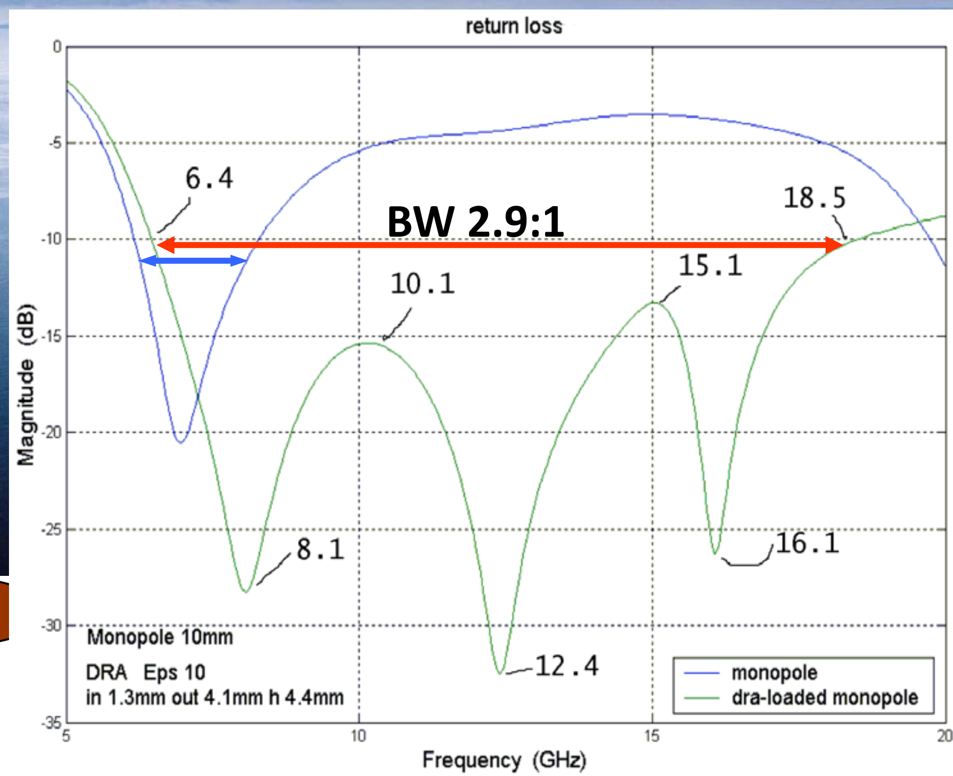




Marriage of two Monopoles

Lapierre, Antar, Ittipiboon, Petosa, *IEEE MWCL*, Jan. 2005.



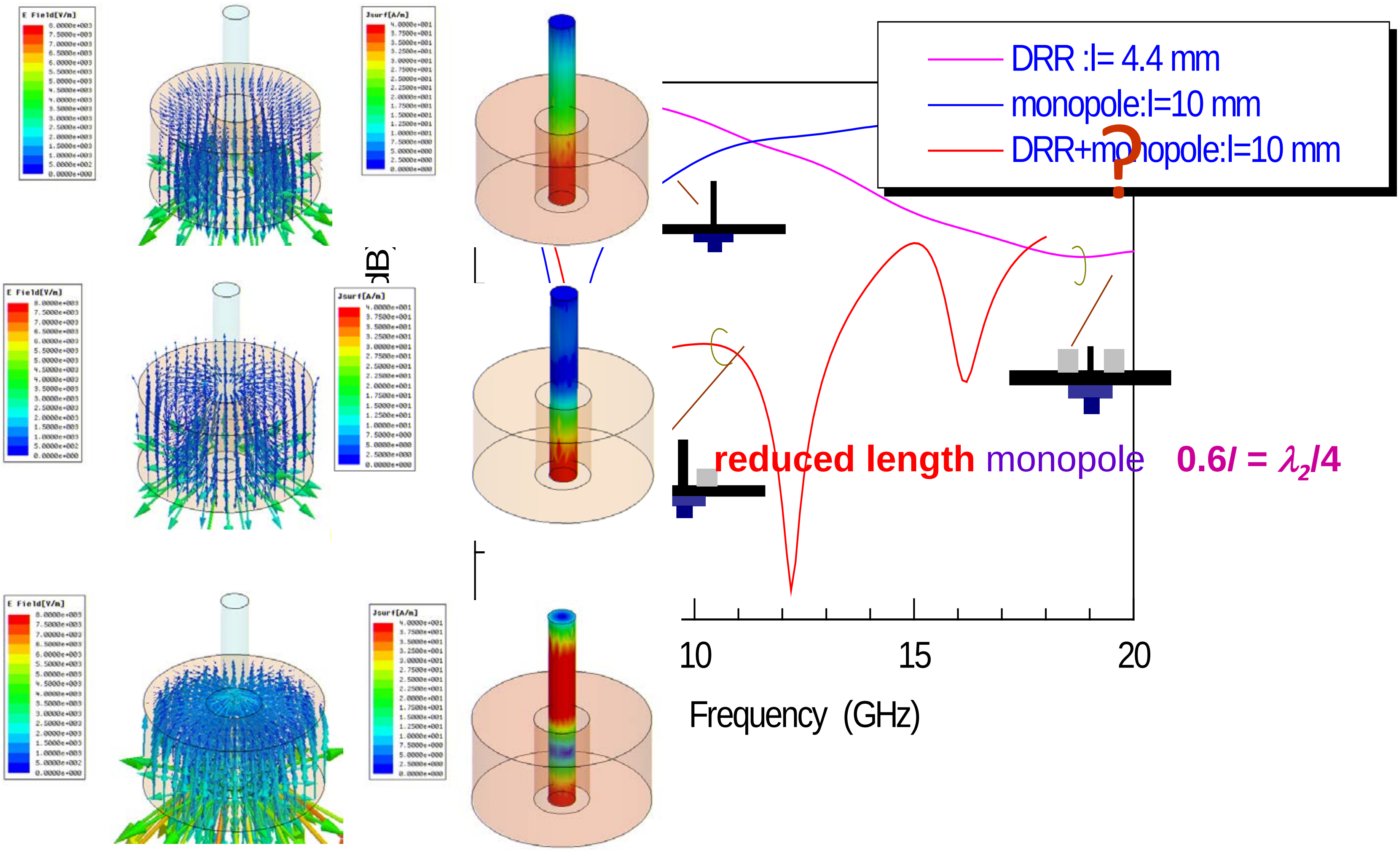


Ittipiboon, Petosa, Thirakoune, Bandwidth enhancement of a monopole using dielectric antenna resonator loading, ANTEM, Canada, Aug. 2002

US patent no.6940463 Sept. 2005

Problem bestowed upon

Mystery of BW? **Inside**  **the Modes**



Design Becomes Easy

<u>Guha</u>, Antar, Ittipiboon, Petosa, Lee, IEEE AWPL, vol. 5, 2006.

a) *Design Frequency*

first resonances: f_1 , third resonances : f_3 are related as $f_H \approx 2.5 f_L$.

b) *Monopole Parameters :*

Length : $l = \lambda_L/4$

Radius : $s \geq r \geq s/2$

(c) ***DRA Parameters :***

Spacing s is important for second and third resonances and it is optimum when $0.016\lambda_L \geq s \geq 0.013\lambda_L$ and

$b = r + s$, $a = b/0.3$,

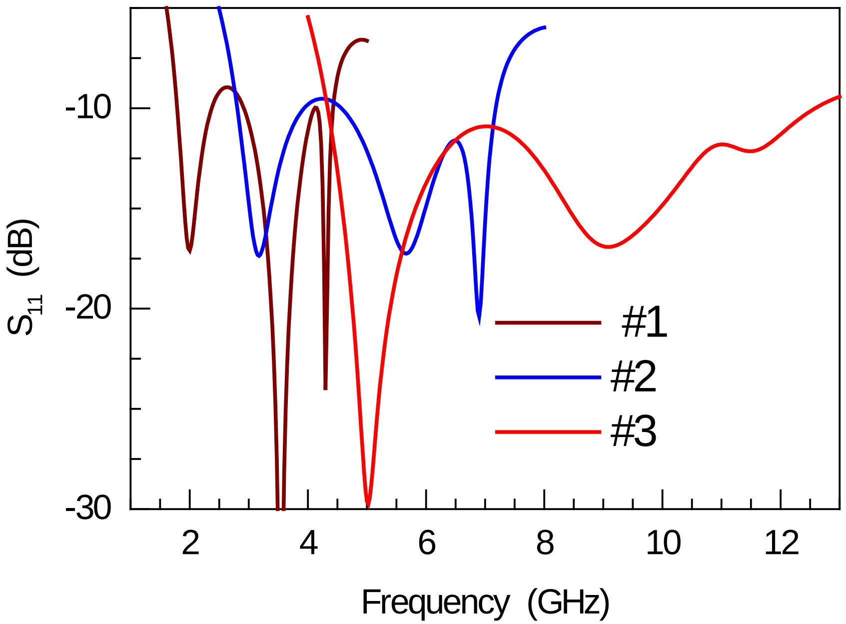
$0.5l \geq h \geq 0.4l$.

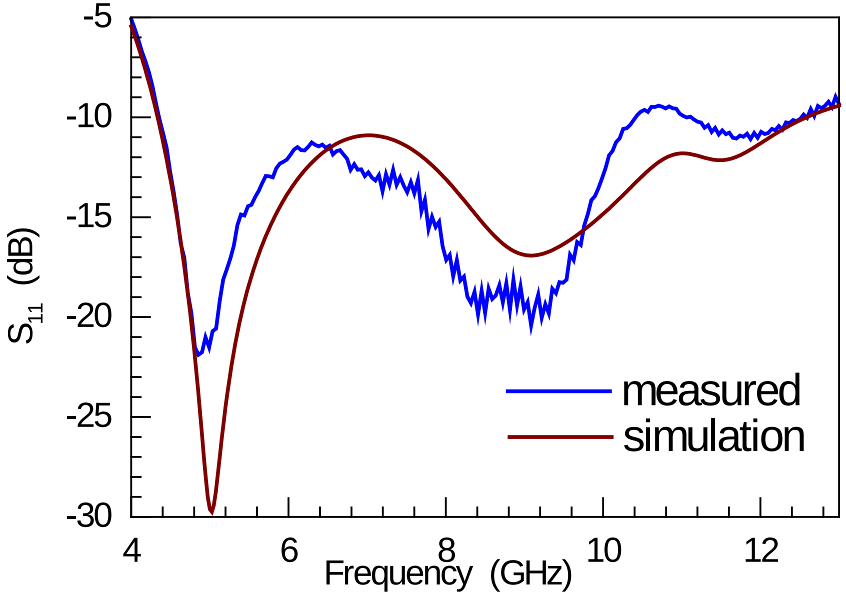
Finally, ε_r value is extracted from the TM_{01} resonance formula

Verification

Paper design as per Design Guideline

Design	Freq. GHz	λ_L mm	Antenna Parameters						
			l	*s*	*r*	*b*	*a*	*h*	ε_r





Improved Bandwidth?

Definitely Yes!

If we can add identical mode(s)

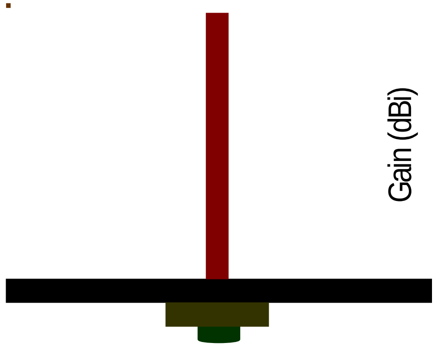
How ?

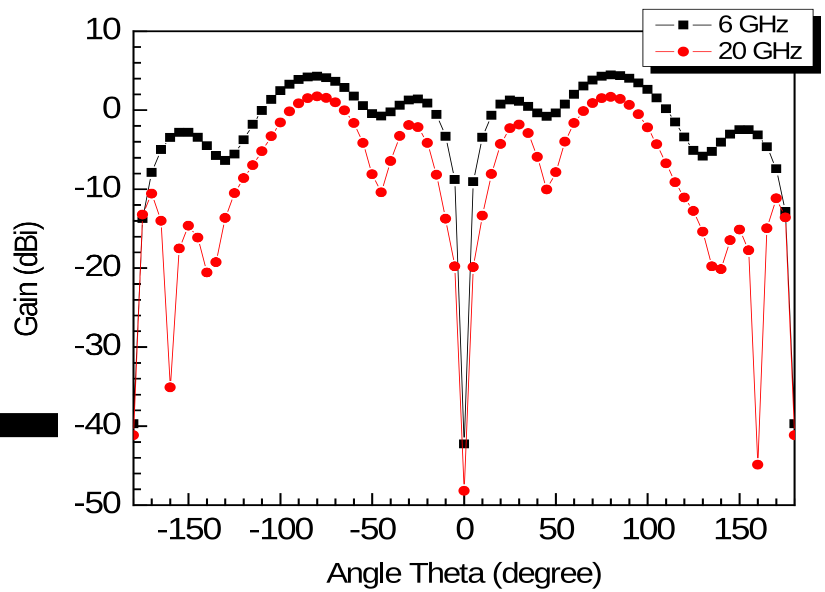
Adding resonators?

or

Resonances?

Let's examine the primary resonator if it can help!

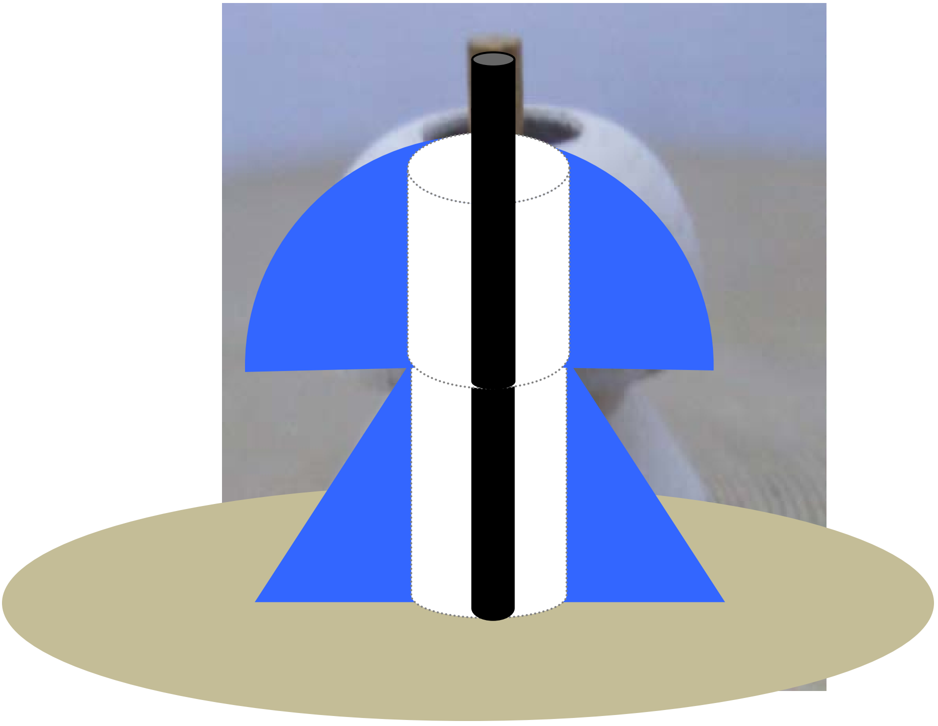


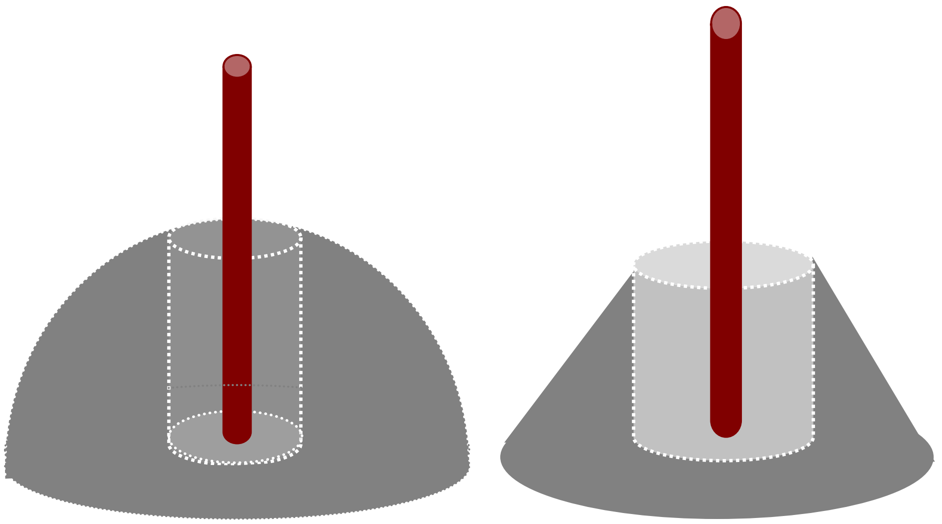


How to accommodate **that mode**?

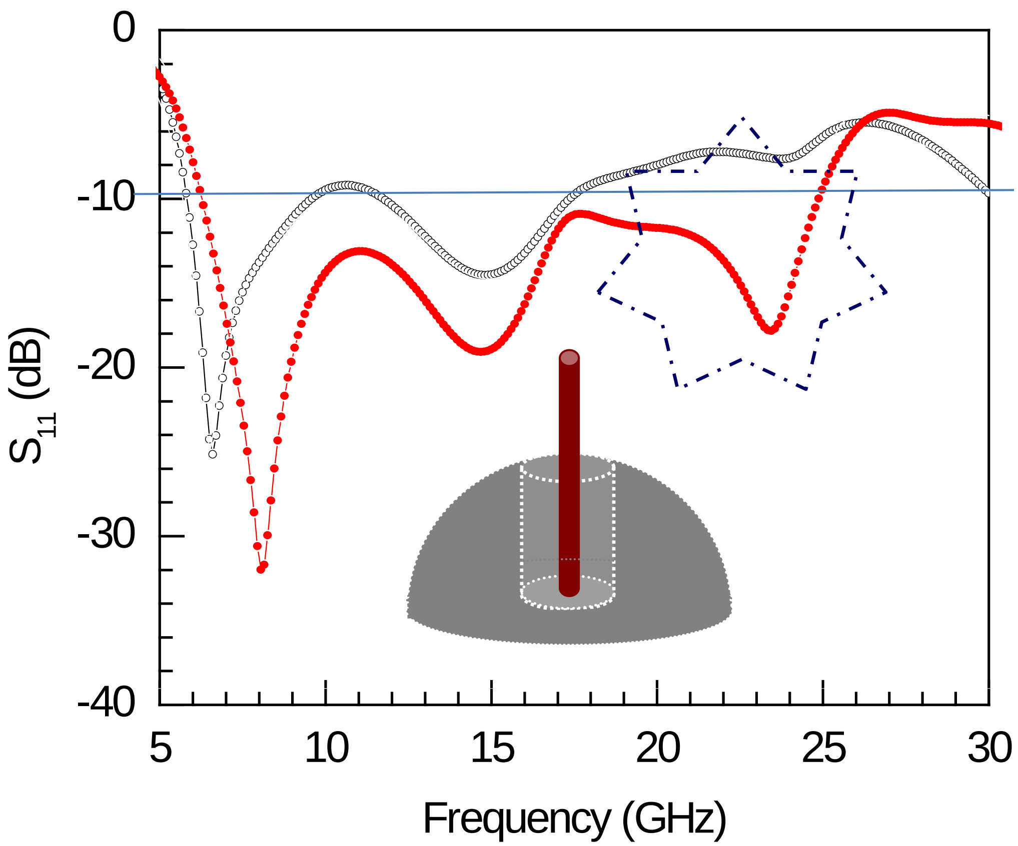
By shaping the DRA

2009-12





What's New?



DRR radius = 4.2 mm

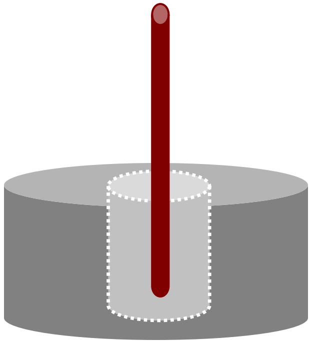
DRR height = 4.4 mm

inner cut rad=1.3 mm

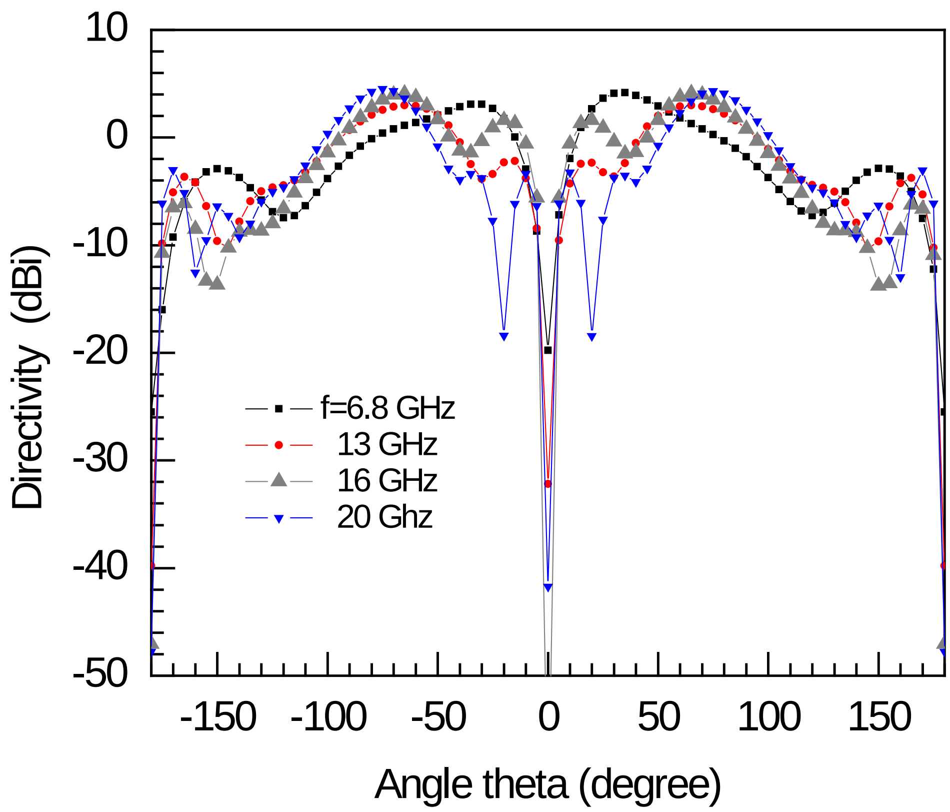
ε_r=10

MP height=10 mm

MP rad=0.65 mm

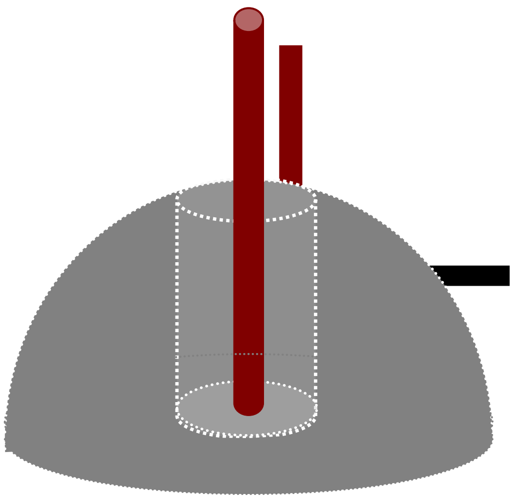


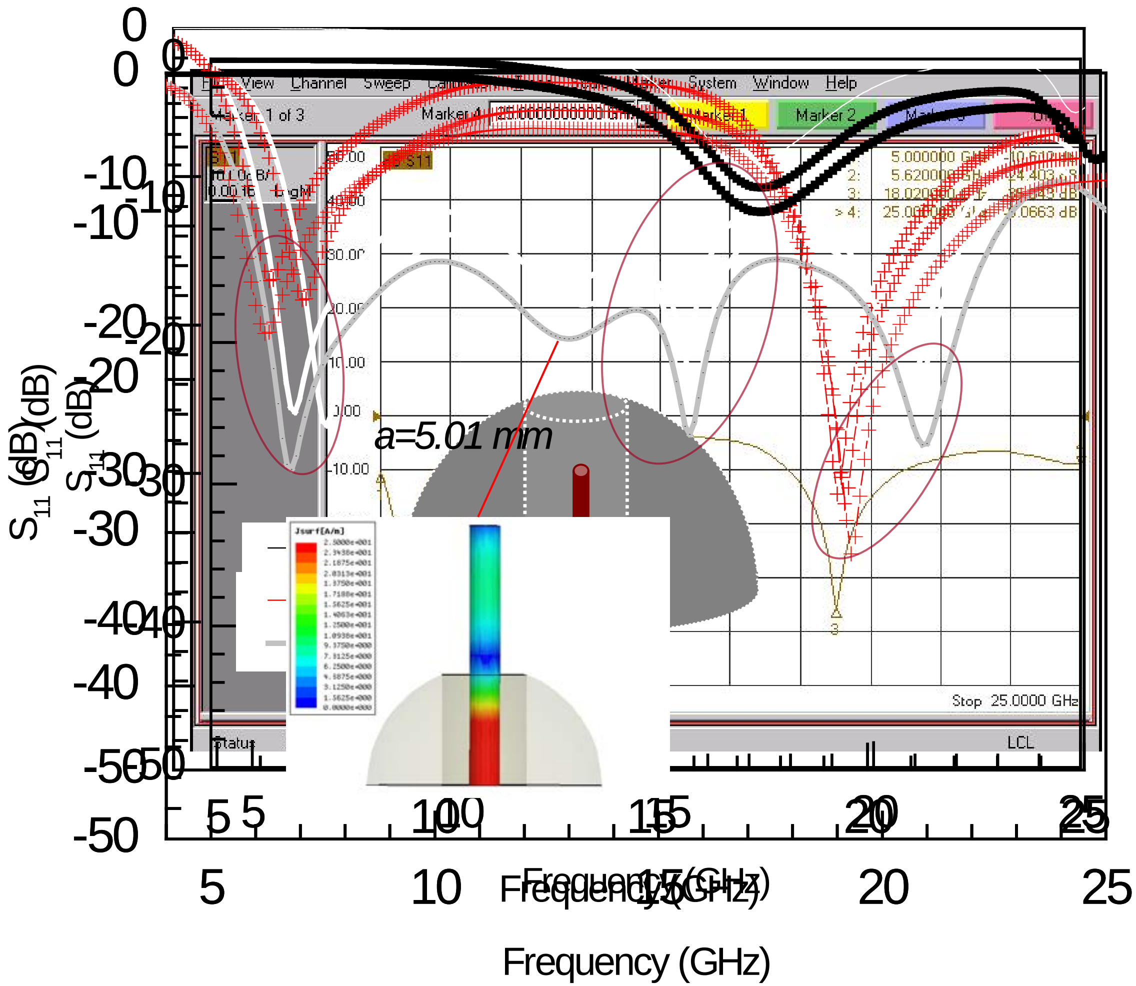
Radiations over the Band



The Physical Insight

UWB ?





Newer Modes?

Detailed Studies

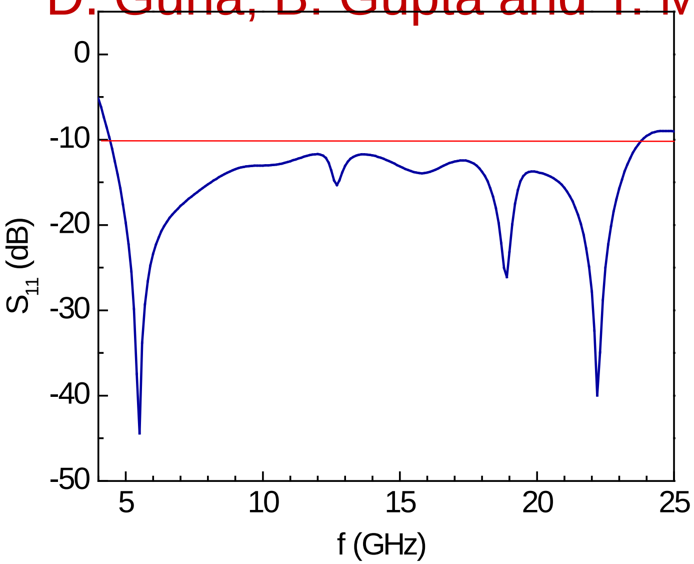
and wider Bandwidth?

D. Guha, et al, **IEEE AWPL**, vol. 5, 2006.

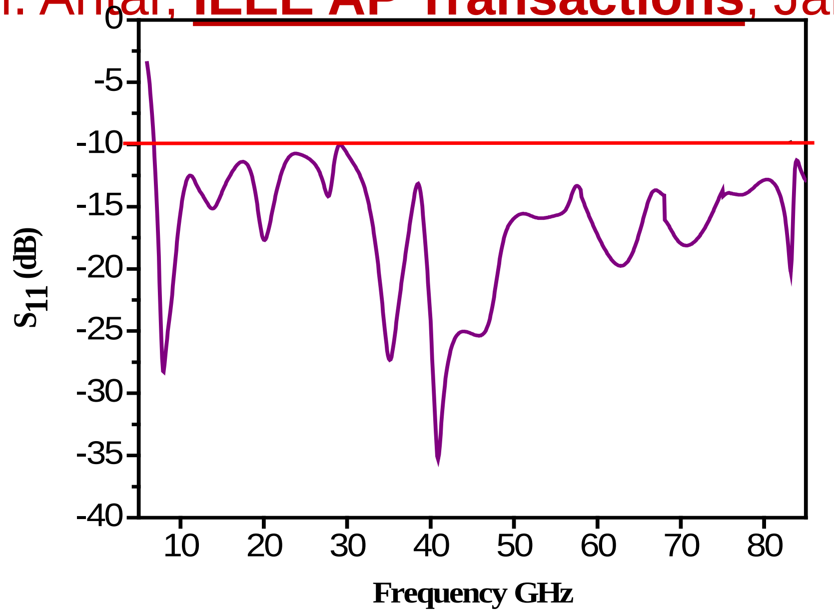
Yes, Possible

D. Guha, B. Gupta and Y. M. M. Antar, **IEEE AWPL**, vol. 8 , 2009

D. Guha, B. Gupta and Y. M. M. Antar, **IEEE AP Transactions**, Jan., 2012



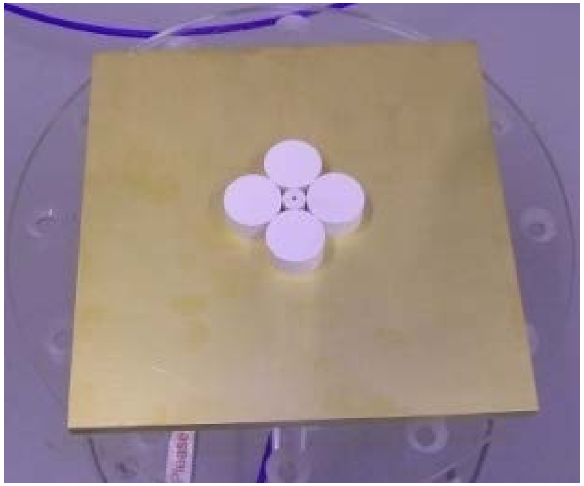
BW 148.4%



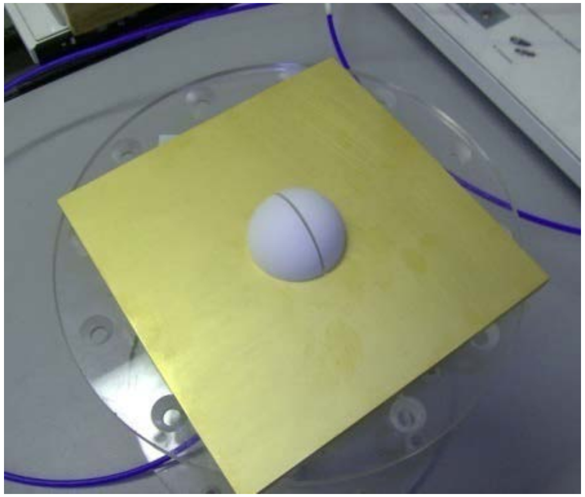
BW 177.5%

Composite DRA Structure

Monopole-like Pattern



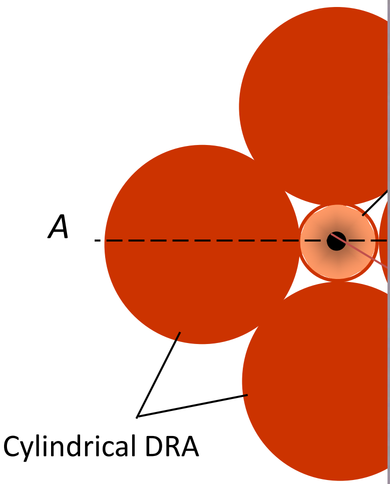
D. Guha and Y. Antar:
IEEE AP Transactions Oct. 2006

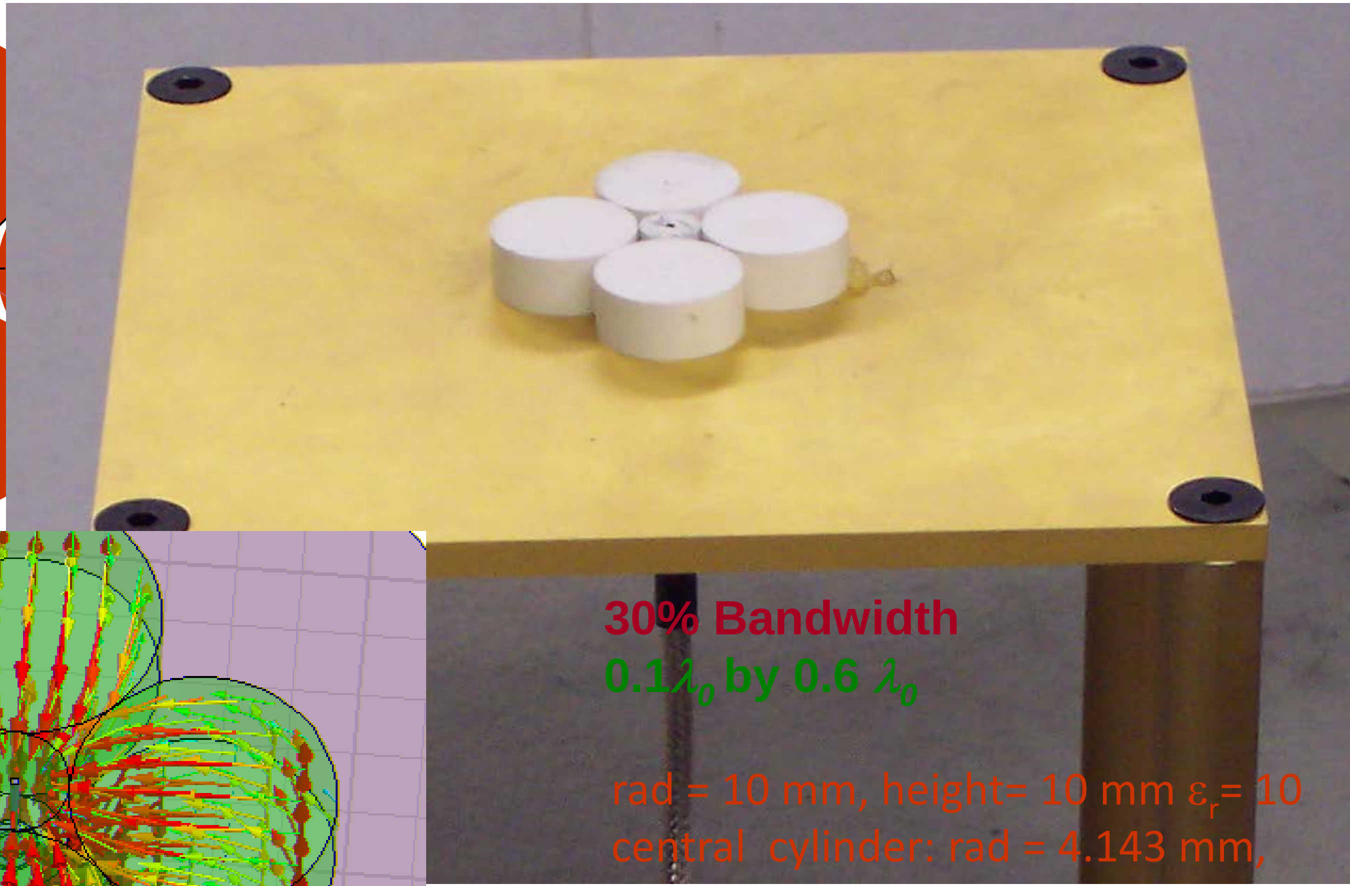


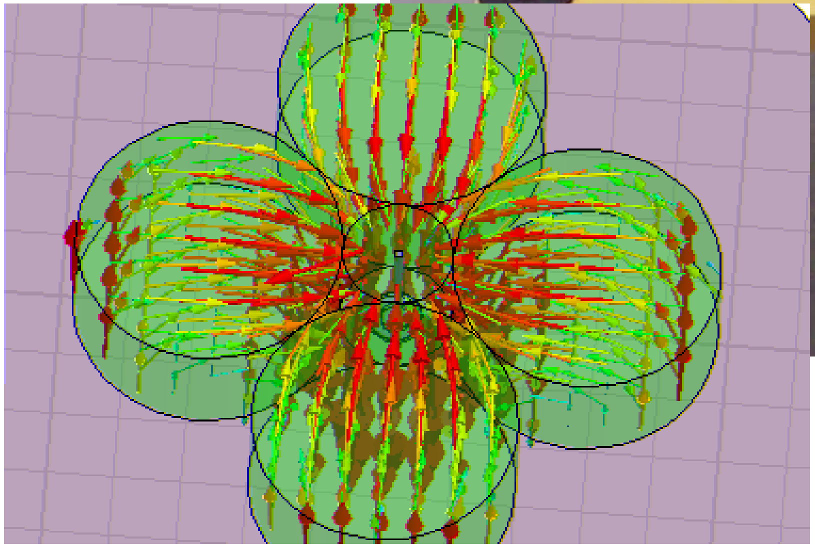
D. Guha and Y. Antar:
IEEE AP Transactions, Dec. 2006

New Approach

New Configurations





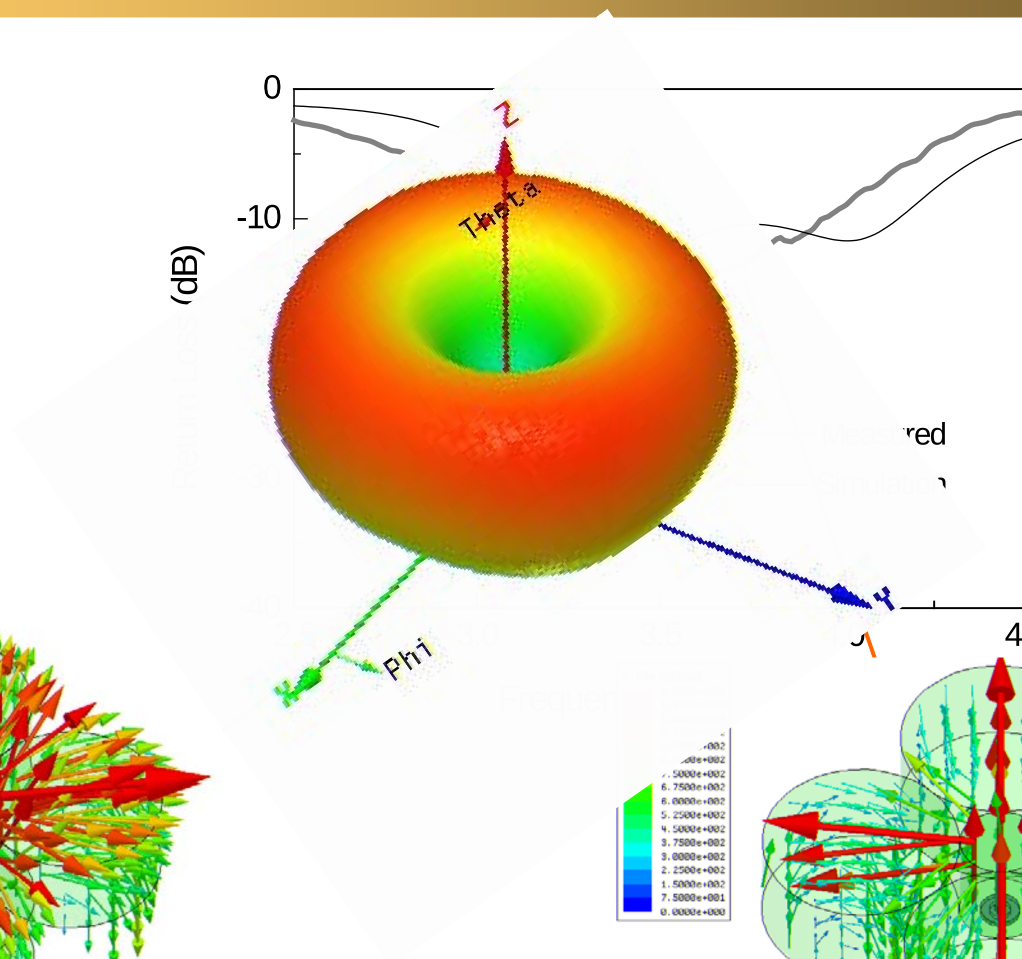


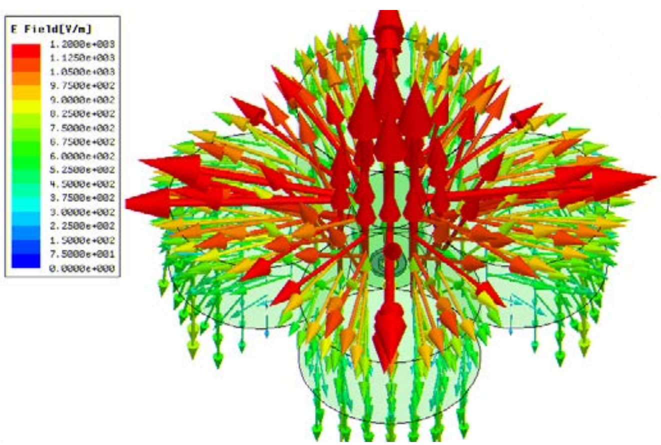
30% Bandwidth

$0.1\lambda_0$ by $0.6\ \lambda_0$

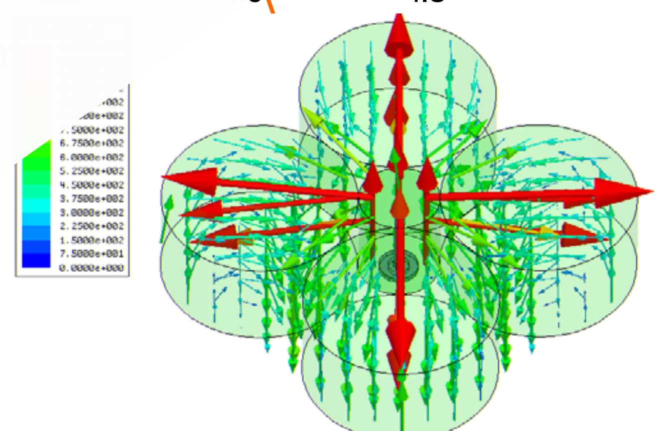
rad = 10 mm, height= 10 mm ε_r= 10
central cylinder: rad = 4.143 mm, height= 10 mm ε_r= 12
probe length = 9.2 mm, radius = 0.55 mm.

The Resonances



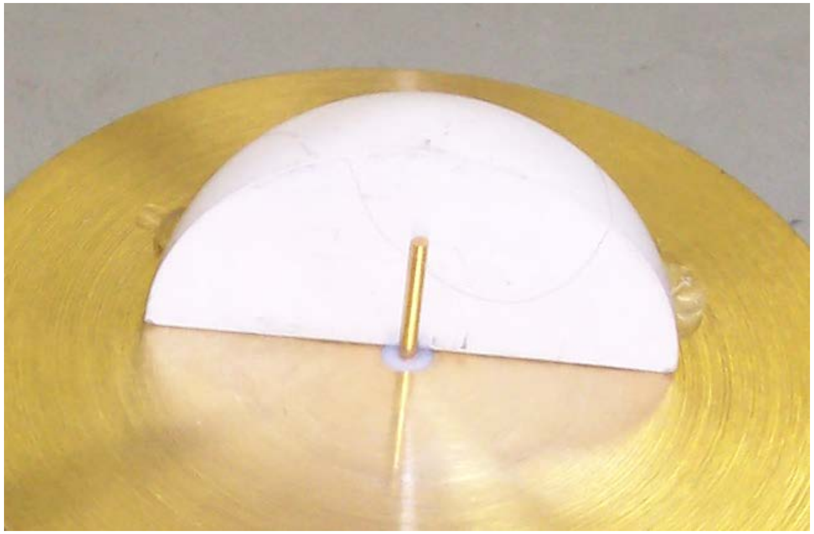


Probe as monopole

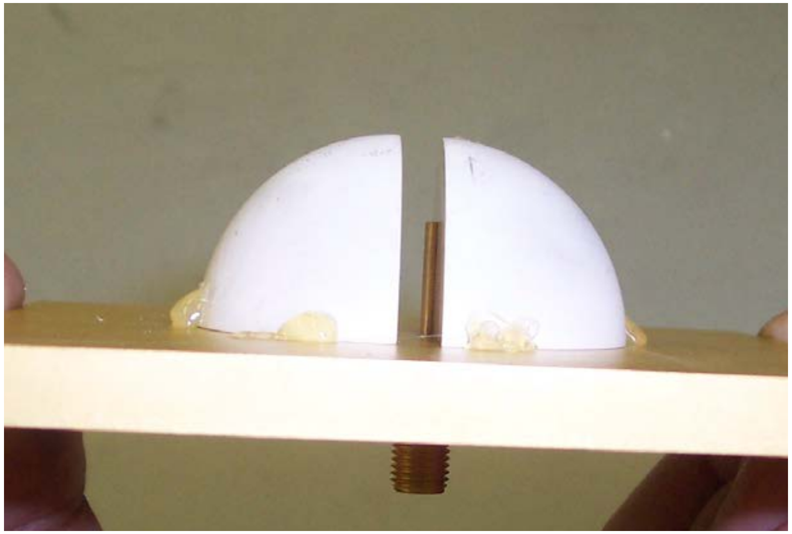


HEM $_{11d}$ mode

Half of a Hemisphere

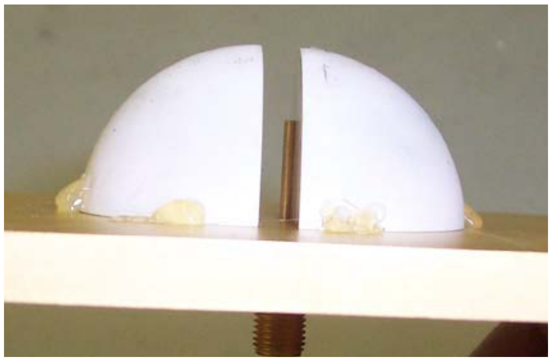


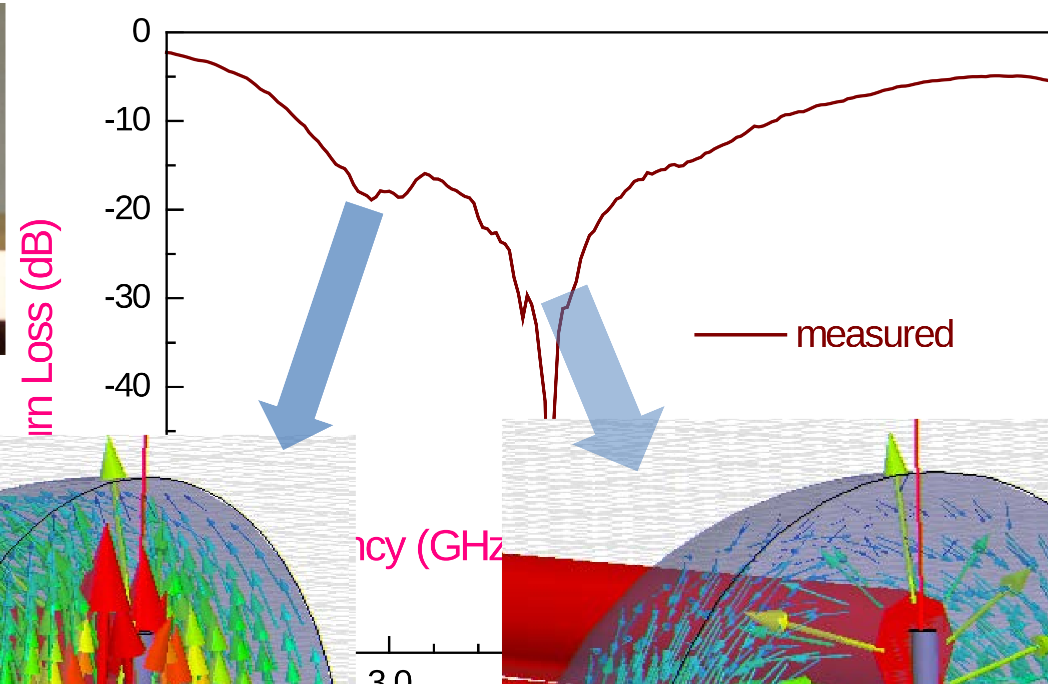
Half of a Hemisphere



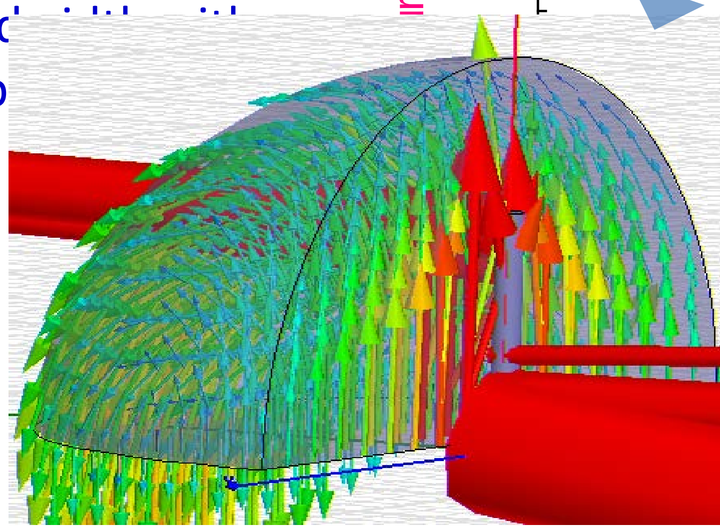
Electromagnetically coupled two Half- Hemispherical DRAs

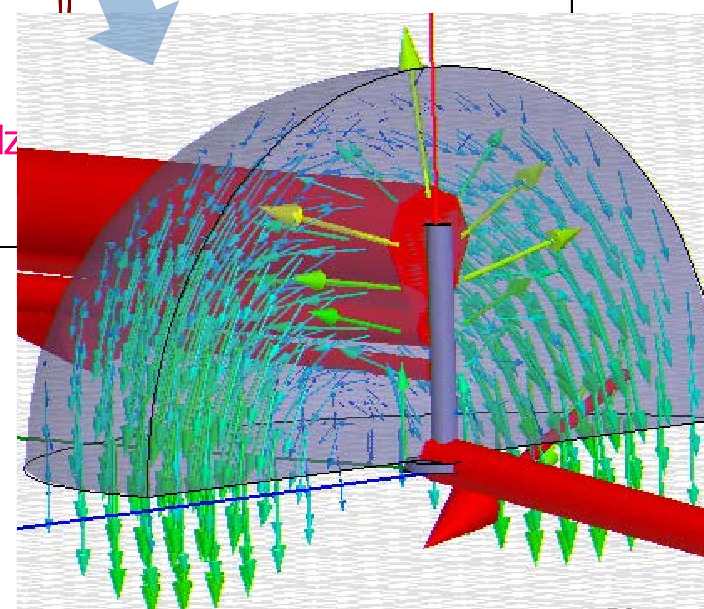
Composite DRA



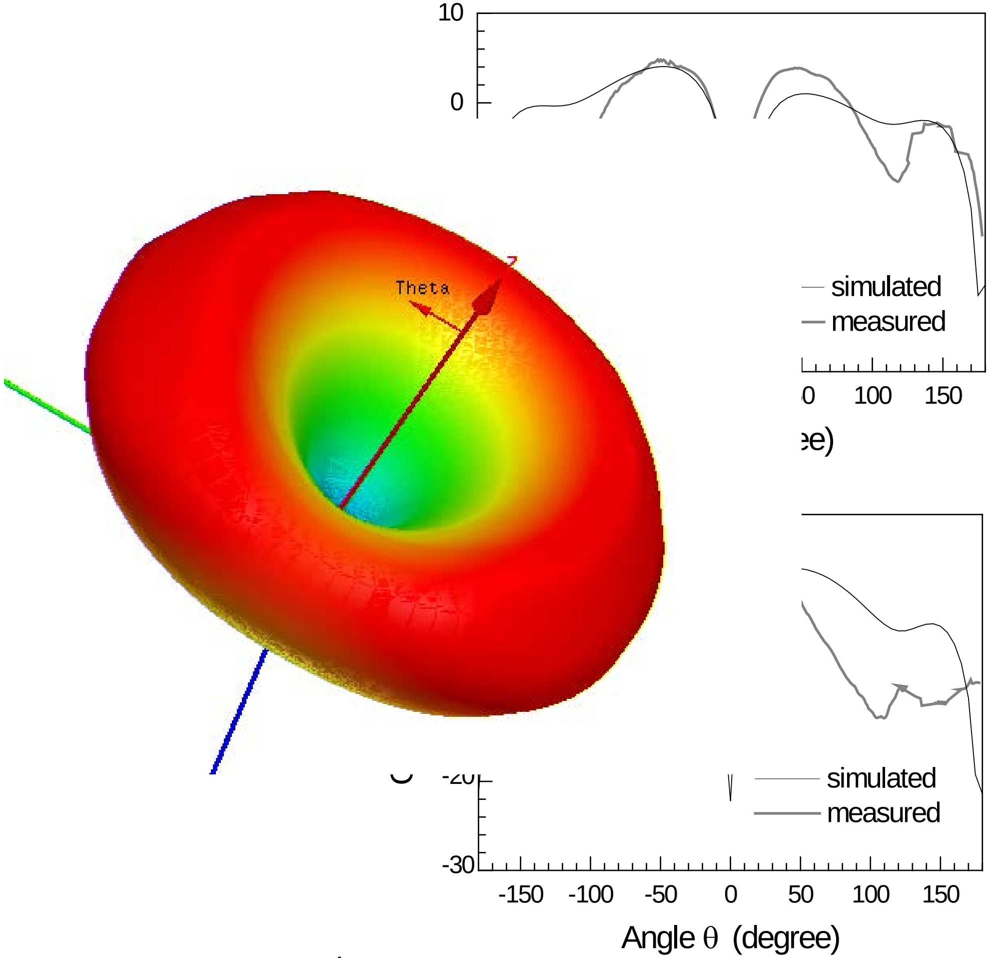


40% Band
4.8 dBi p

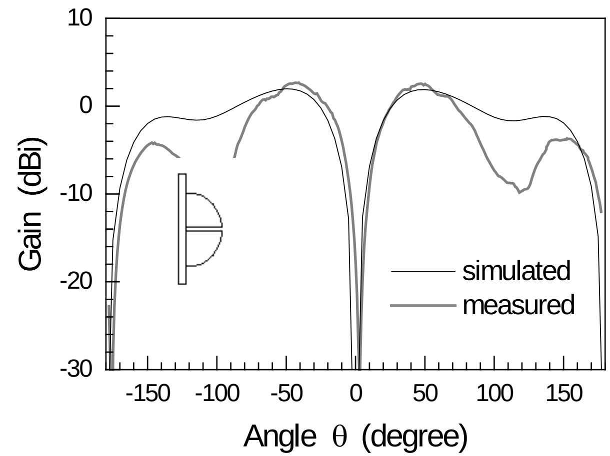


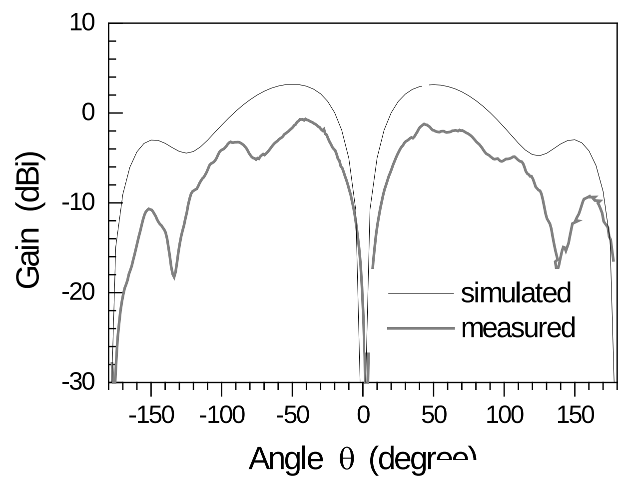


Radiation Patterns



ϕ = 0°

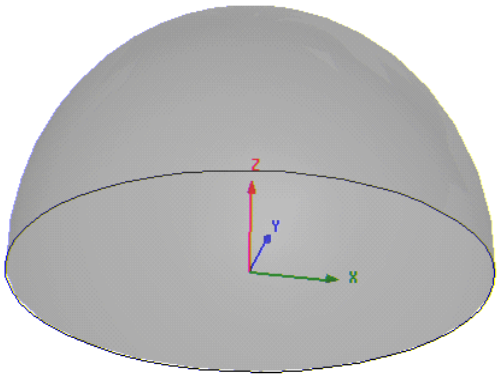




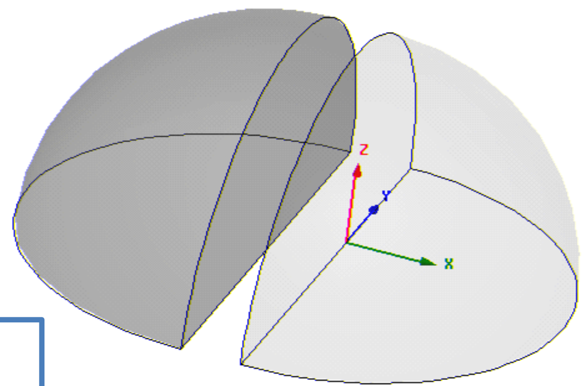
ϕ = 90°

Symmetric Patterns? how to obtain

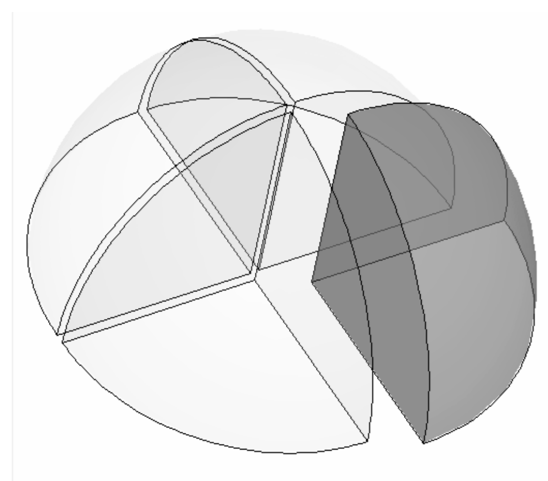
Need Modal Symmetry ⟵ **Structural Symmetry**



Hemispherical DRA
HDRA

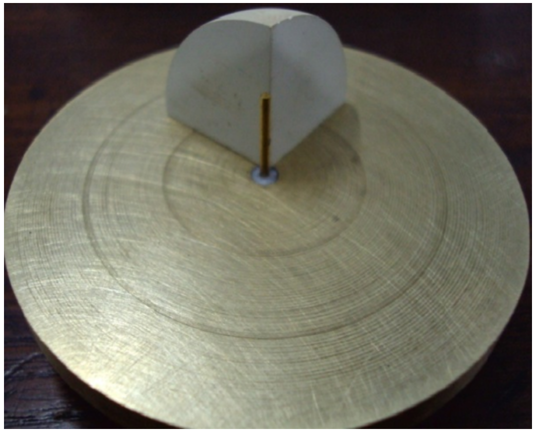


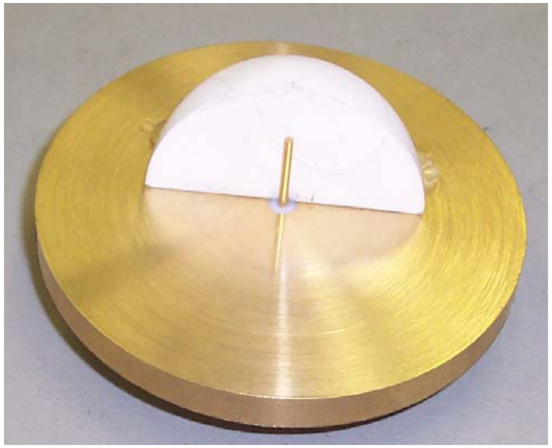
Half-HDRA
h-HDRA



Quarter-HDRA
q-HDRA

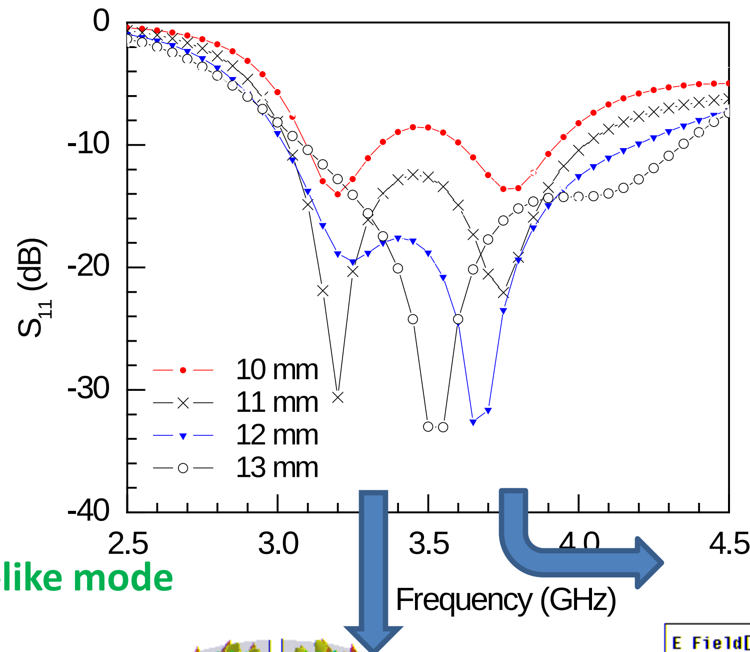
Quarter and Composite



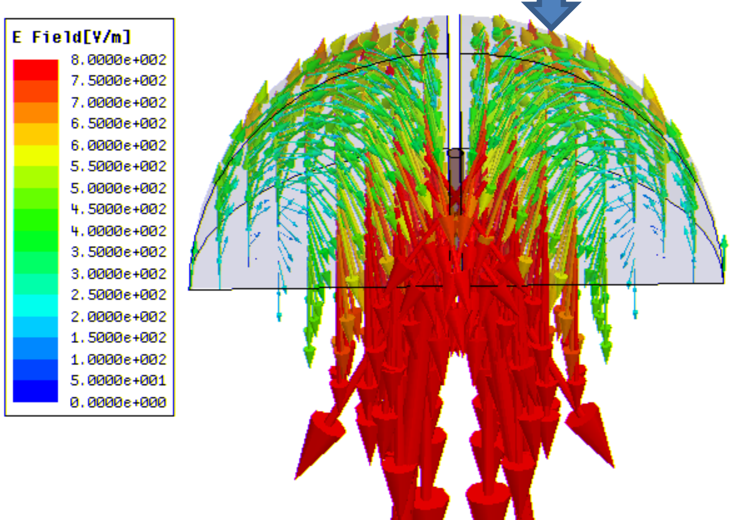


Introduces Modal Symmetry

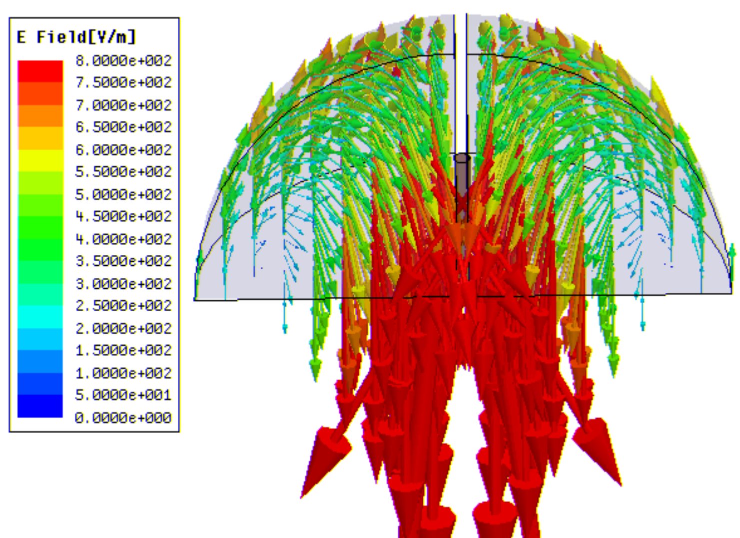
Are they Different Modes ?



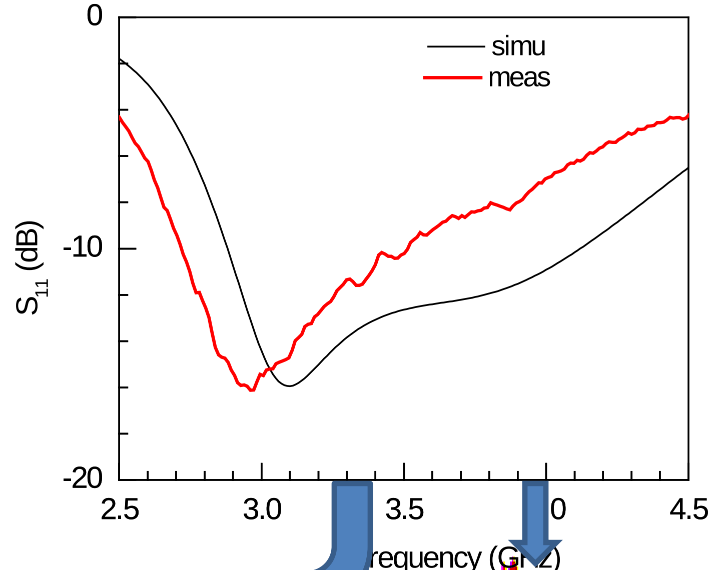
$HEM_{11\delta}$ -like mode

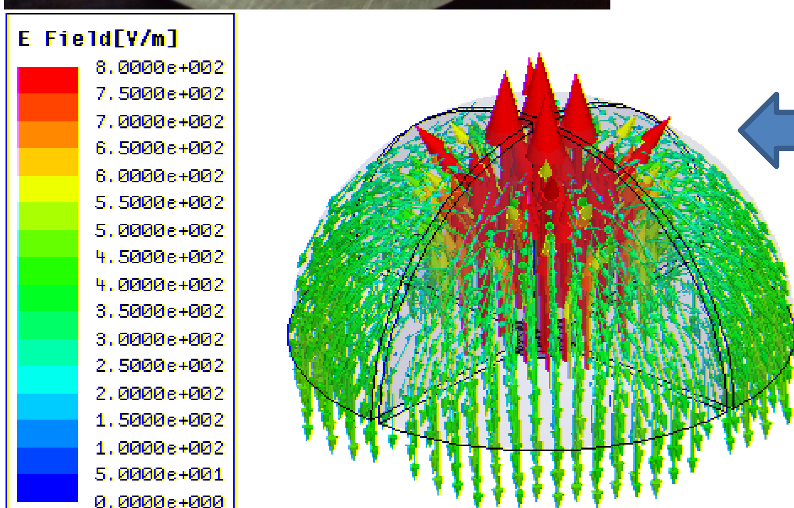


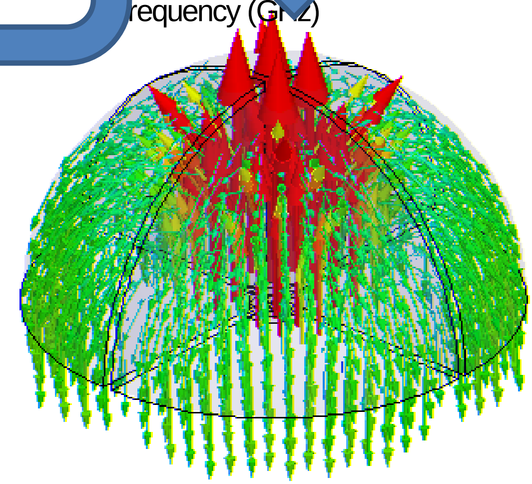
TM_{101} mode



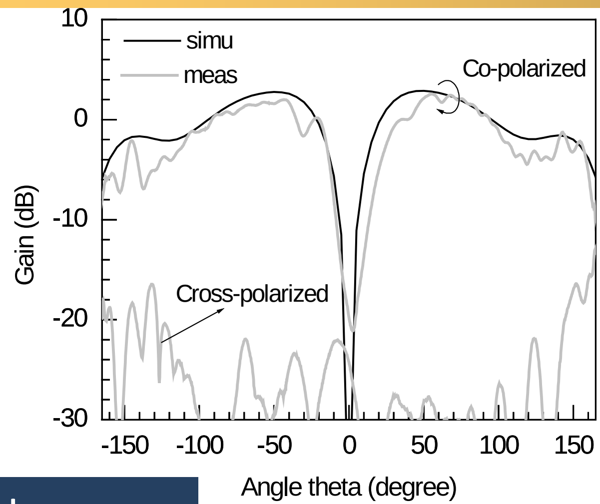
Perfect Symmetry

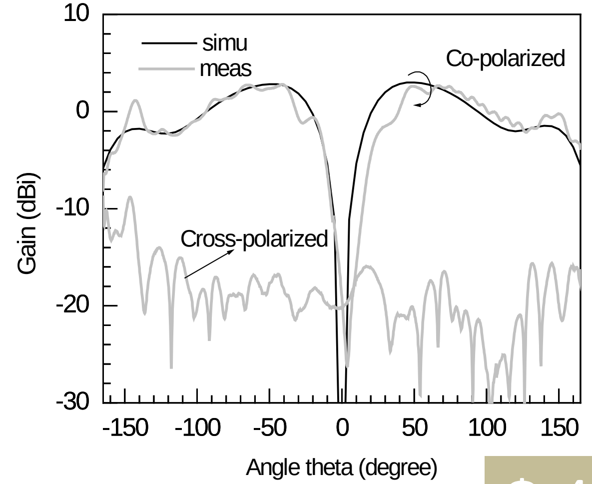






Radiation Patterns

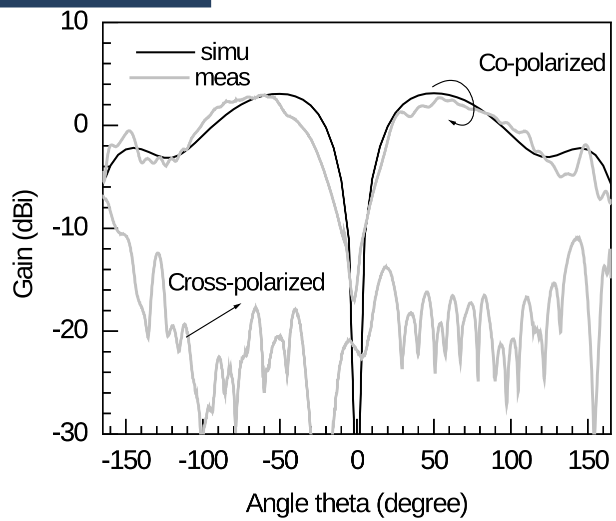




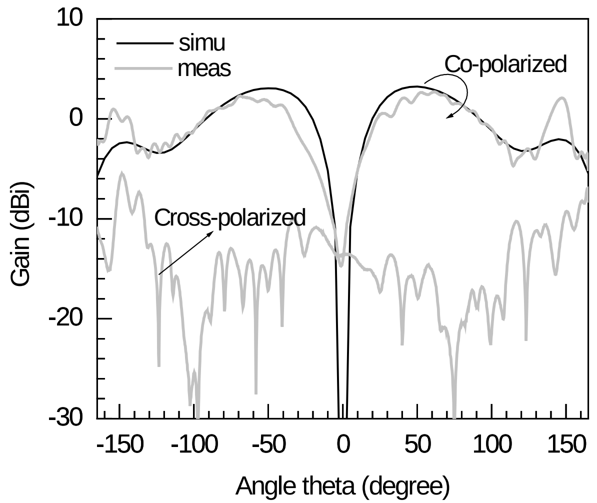
3.1 GHz

Φ=0 deg

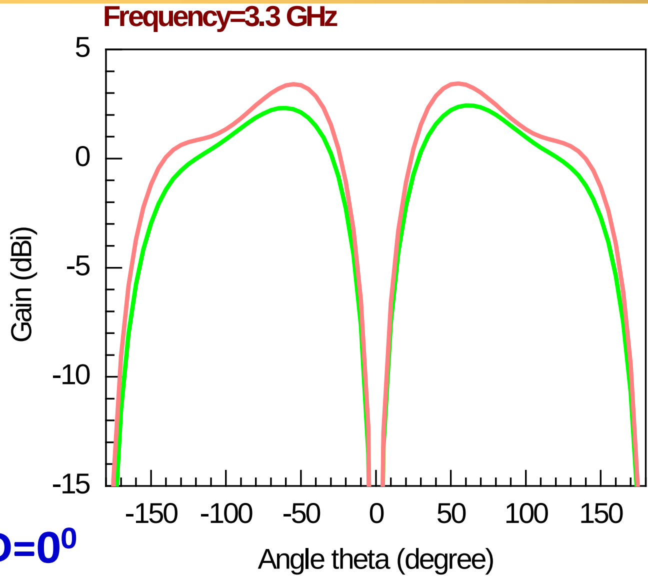
Φ=45 deg

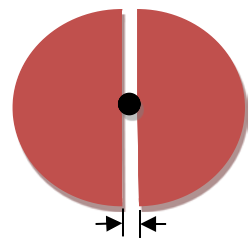


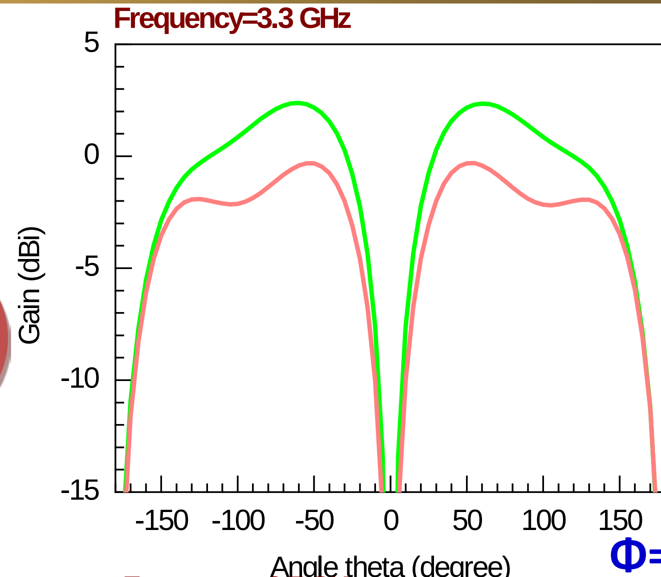
3.51 GHz



Compare

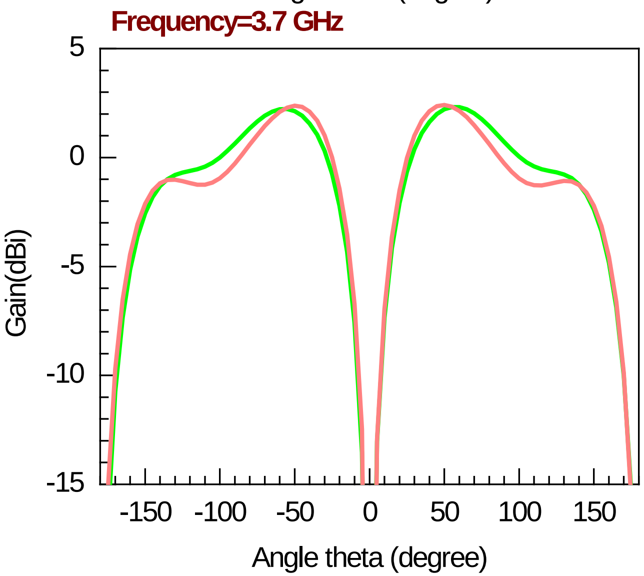


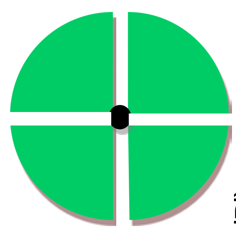


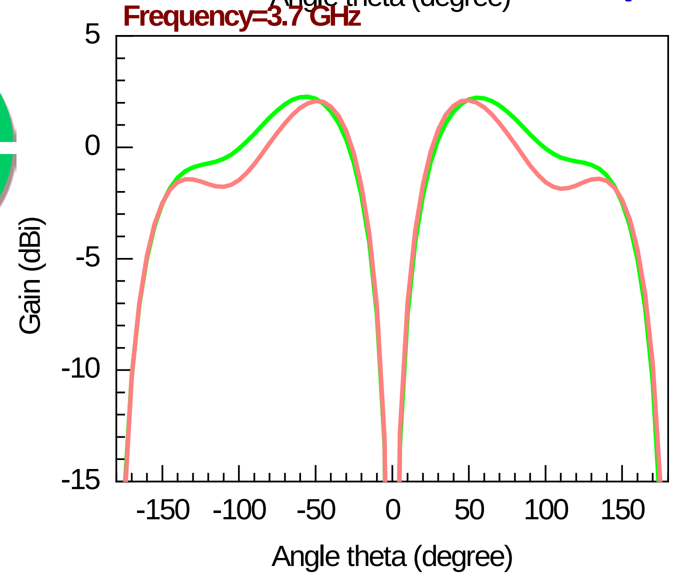


Φ=0⁰

Φ=90⁰







Concluding Remarks

DRA is still an Open Book; Not event its 30% Explored.

DRA researchers should have more insight and serious attention

Resonator, Material, and Antenna need to be addressed together

Next Breakthrough Awaiting New Dielectric Materials

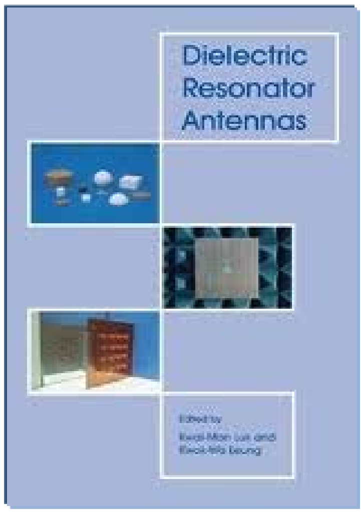
I hope to come with new information for you shortly :

Mode filtering technique as a potential tool for DRA engineers.

Newer Feed to resolve major DRA issues in integrated platform - which is supposed to be very hard task.

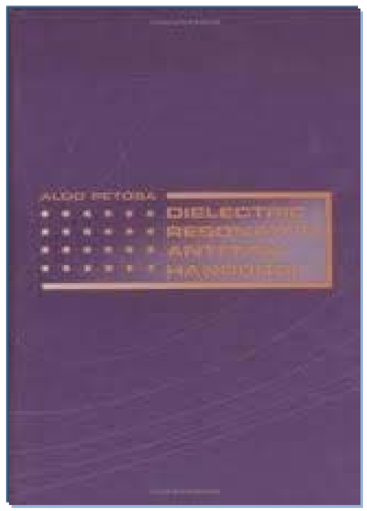
Related Books

Dielectric Resonator Antennas: K. M. Luk & K. W. Leung



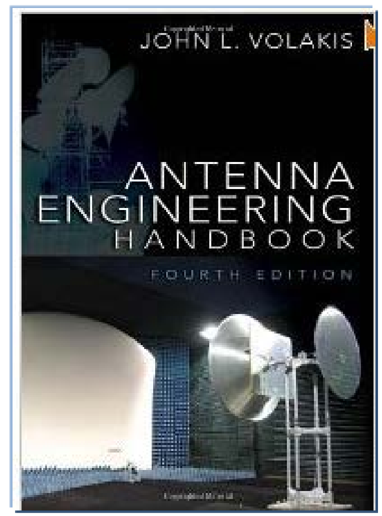
2002 Research Studies Press

Dielectric Resonator Antenna Handbook: A. Petosa



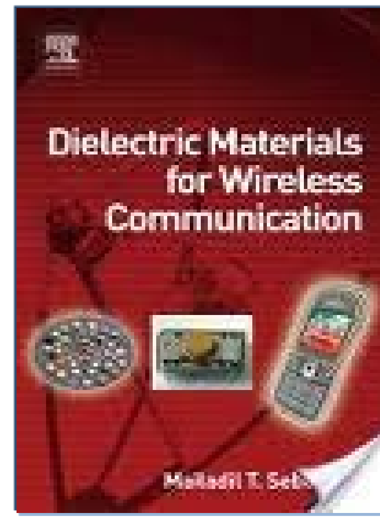
2007Artech House

Antenna Engineering Handbook: J. L. Volakis Ed.



2007 McGraw Hill

Dielectric Materials for Wireless Comm: M. T. Sebastian



2008 Elsevier

Behind this small contribution