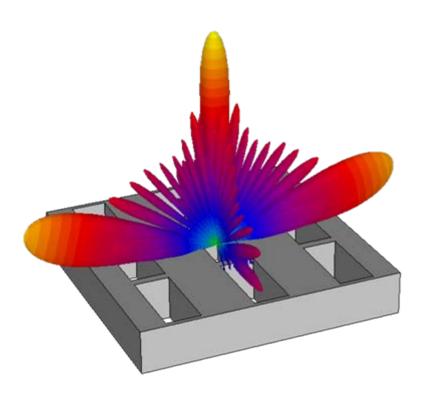
CST STUDIO SUITE™ 2006B Application Note

Antenna Arrays



- Introduction
- Finite Arrays
 - Simultaneous excitation
 - Combine Results
 - Farfield-Array
- Infinite Arrays
 - Unit Cell Modeling

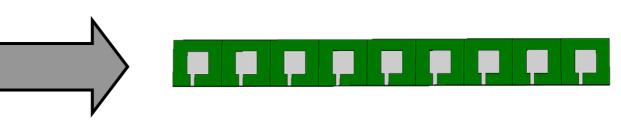


Introduction

Rectangular Patch Antenna

Linear Array





- 1. Equal excitations: more gain
 - Channel capacity ~log(N)
 - Less expensive amplifiers
 - 2. Phased excitation:
 - Multiple beams: Channel capacity ~(N)
 - Adaptive beamforming
 - Reduced Multipath propagation
 - Tracking of objects (e.g. Radar)



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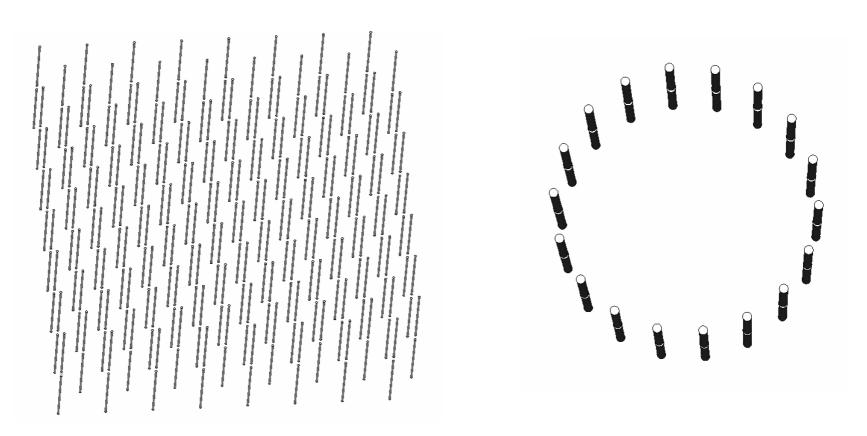
Advantage: Freedom of excitation

2

Array Types

Planar Arrays

Circular Arrays



Focus on planar arrays



Antenna Array Terminology

- Element = One antenna element of the antenna array
- Scan = Phased excitation / change direction of incident wave
- Endfire = Scan at $\theta = \pi/2$
- Pattern Synthesis: Determine excitation function for the desired beam pattern.
- Mutual Coupling = Coupling from one element to others



Topics in Array Design

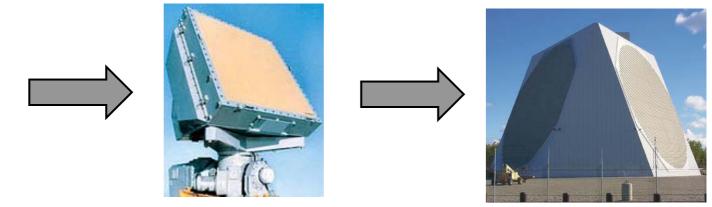
- Beamforming, Blind spots, Coupling between elements, Active impedance
- Pattern optimization, Side lobe suppression
 - Circular Pattern Synthesis (Taylor, Bayliss)
 - Planar Pattern Synthesis (Fourier, Schelkunov, Woodward, Dolph-Chebyshev, Taylor, modified sinc, Bayliss line source, Elliot iterative)
- Signal processing, Adaptive arrays



Antenna Arrays for Radar

Evolution





Goals:

- Reduction of mechanical parts
- ➢Flexible Resolution
- ➤Tracking of multiple objects



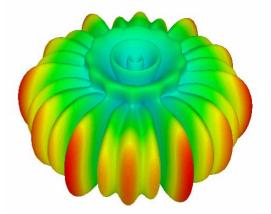


Antenna Arrays for Communication Smart antennas



Switched Beam Approach:

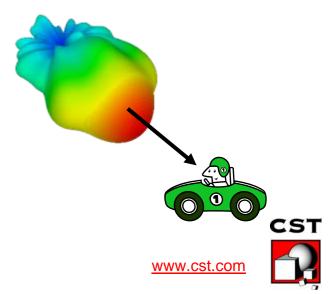
Switching between a finite number of predefined patterns





Adaptive Array Approach:

Continuously adapting the pattern towards the optimal characteristic



Finite Arrays Simultaneous Excitation

	Excitation	Ampli.	Time delay	Signal		^	Set All
	Port 1	1.0	0.0	default	•	ſ	
	Port 2	1.0	0.0	default	•		Set Non
x	Port 3	1.0	0.0	default	•		
	Port 4	1.0	0.0	default	•		
x	Port 5	1.0	0.0	default	•		
	Port 6	1.0	0.0	default	•	١,	
x	Port 7	1.0	0.0	default	-		OK
	Port 8	1.0	0.0	default	•	ſ	Cancel
	Port 9	1.0	0.0	default	•	l	Caricei
_	ultaneous excitatio Activate el: 3[1.0,0.0]+5[1.0,0.0]	V Automatic	labe	ling	
List	e					~	
	itation offset						

- Simultaneous port excitation with certain amplitude/phase relationships between ports.
- Produces F-Parameter
- Phase shift valid for one frequency only.
- Recommended if Number of elements > Number of excitations



Finite Arrays

Combine Results-Farfields

Combine C	alculation Resu	lts			
- Monitor se	ttings			Combine	
Type:	Frequency	🔘 Time		Combine	
Offset:	💿 Time delay	🔿 Phase shift		Close	
Phase refe	erence frequency:	10		Help	
- Monitor se	lection				
E Farfield	l only			Set All	
Frequency	c All		~	Clear	
List:					
1 (1)	Amplitude 1	0			
2(1)	1	90			
3(1)	1	0	=		
4 (1)	1	90			
5(1)	1	0			
6 (1)	1	90			
7 (1)	1	0	~		

- Calculation of all ports and "combine results" in post-processing.
- All desired amplitude/phase relationships between the ports can be easily calculated as a postprocessing step.
- Broadband phase shift possible.
- Compute active S-Parameters/Impedances by given excitation and known S-Parameters.
- Recommended if Number of excitations > Number of elements
- Distributed Network Computing shortens the simulation time.

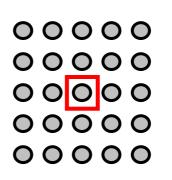


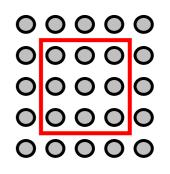
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Finite Arrays Farfield-Array

Farfield Calculation of Antenna Arrays									
Rectangular array: O Edit antenna list OK									
- Rectangula	Rectangular array								
Direction:	X Y Z					ancel			
Number:	9	9		1 🗢		lelp			
Spaceshift:	A	В		0]				
Phaseshift:	0	0		0]				
←Antenna list									
No.	×	Y	Z	Amplitude	Phase				
1	-0.121	-0.121	0.000	1.00	0.00	^			
2	-0.121	-0.091	0.000	1.00	0.00				
3	-0.121	-0.060	0.000	1.00	0.00				
4	-0.121	-0.030	0.000	1.00	0.00				
5	-0.121	0.000	0.000	1.00	0.00				
6	-0.121	0.030	0.000	1.00	0.00				
7	-0.121	0.060	0.000	1.00	0.00				
8	-0.121	0.091	0 000	1 00	0.00	~			
	Mo	odify	Add	Delete					

- No coupling between the simulated elements.
 Simulation of a bigger array part necessary
- Different excitations easily realized by using the macro language for the Antenna Array feature



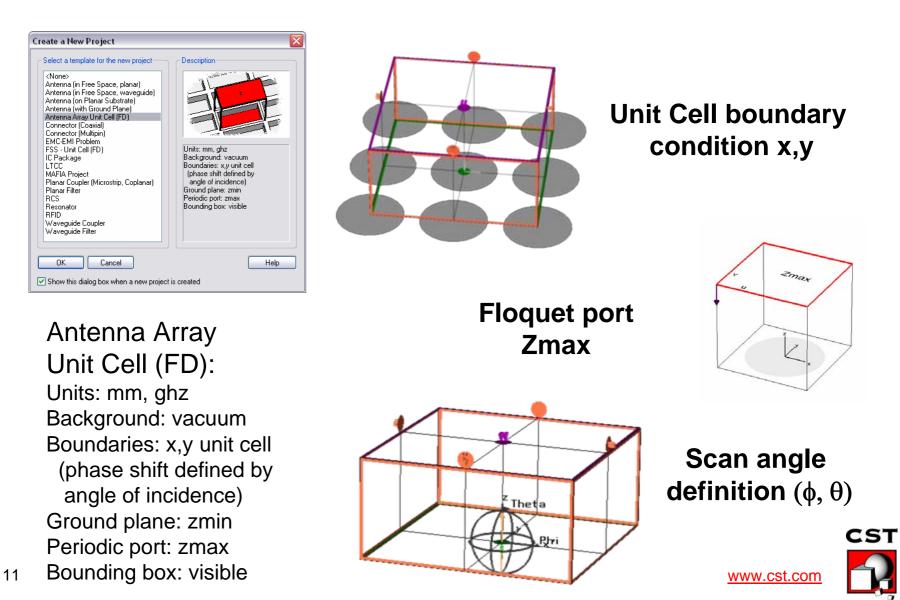


no coupling between elements

coupling to next elements considered **CST**



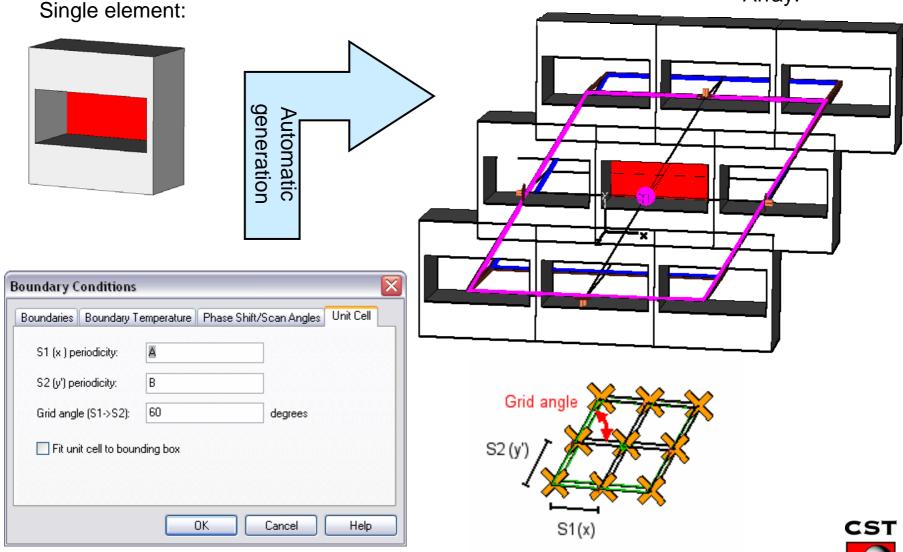
Infinite Arrays Unit Cell Project Template



Infinite Arrays Unit Cell Definiton

Array:

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Infinite Arrays Templates

0D Result Template

🔜 Phased Array Result	
	OK
💿 Axial Ratio 🔿 Tilt 🔷 Act.Elem.Pattern	
Power Value (only Act.Elem.Pattern)	Cancel
● TE ○ TM ○ Total	
The Act.Element Pattern requires parameter "theta"	
Output Floquet Port Zmax Mode: 1	
Frequency point	
automatic (center of calculated frequency band) userdefined Frequency:	

Definitions: $\delta_{\phi\theta} = \pi + \psi_{TE} - \psi_{TM}$ $\gamma = \tan^{-1} \frac{\left| E_{\phi} \right|}{\left| E_{\theta} \right|} = \tan^{-1} \frac{\left| A_{00}^{TE} \right|}{\left| A_{00}^{TM} \right|}$ $\varepsilon = \frac{1}{2} \sin^{-1} \left(\sin 2\gamma \sin \delta_{\phi\phi} \right)$

Axial Ratio:

Tilt:

$$:= \cot(\varepsilon) \qquad := \frac{1}{2} \tan^{-1} \left(\frac{\sin 2\gamma \cos \delta_{\phi \theta}}{\cos 2\gamma} \right)$$

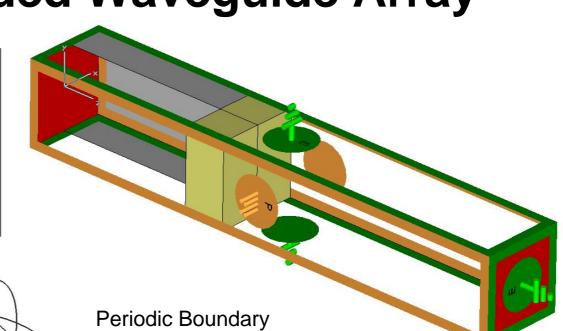
Active element pattern:

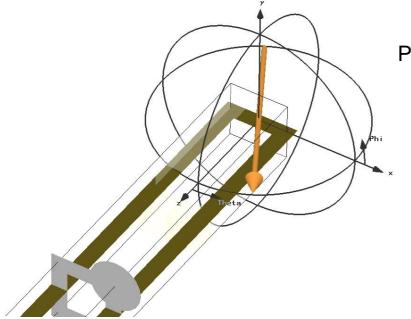
 $TE \coloneqq \left| A_{00}^{TE} \right|^{2} \cos^{-1}(\theta)$ $TM \coloneqq \left| A_{00}^{TM} \right|^{2} \cos^{-1}(\theta)$ $total \coloneqq \left(\left| A_{00}^{TE} \right|^{2} + \left| A_{00}^{TM} \right|^{2} \right) \cos^{-1}(\theta)$



Open-ended Waveguide Array

B	oundary Conditio	Ins				>
	Boundaries Symr	netry Planes	Peri	iodic Boundar	y Phase Shift	
	X: <mark>el_phase</mark>	Deg. 🔽	Cor	nstant angles:		
	Y: 0.0	Deg. Ti	heta:	0.0	Deg.	
	Z: 0.0	Deg. Pl	hi:	0.0	Deg.	
						5
		[ок	Cancel	Help





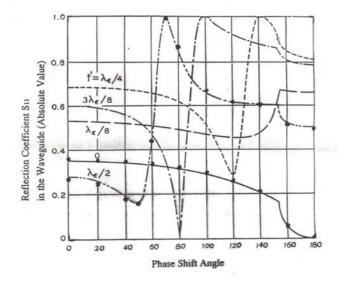
Periodic Boundary Conditions

Boundary Conditions									
Boundaries Symmetry Planes Periodic Boundary Phase Shift									
Xmin:	periodic	•	Xmax:	periodic	•				
Ymin:	electric (Et = 0)	Ŧ	Ymax:	electric (Et = 0)	•				
Zmin:	electric (Et = 0)	•	Zmax:	electric (Et = 0)	J				
Cond.:	0		S/m	Open boundary					
		OK		Cancel Hel	P				

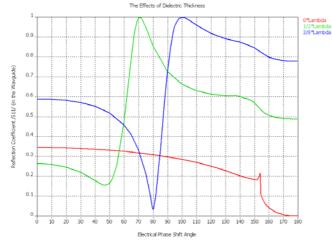


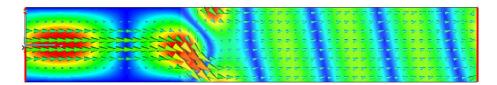
Open-ended Waveguide Array

Published results:

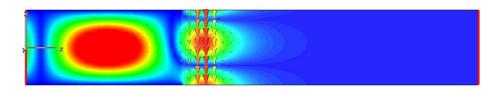


Simulation:

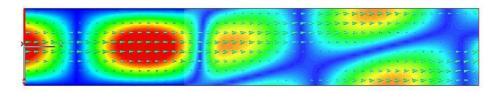




Electrical Phase Shift Angle = 45 deg



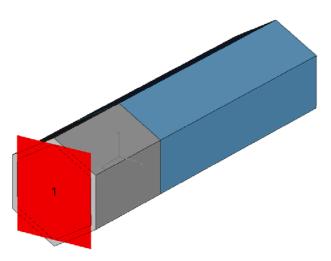
Blind Spot occurs at an electrical Phase Shift Angle = 71 deg



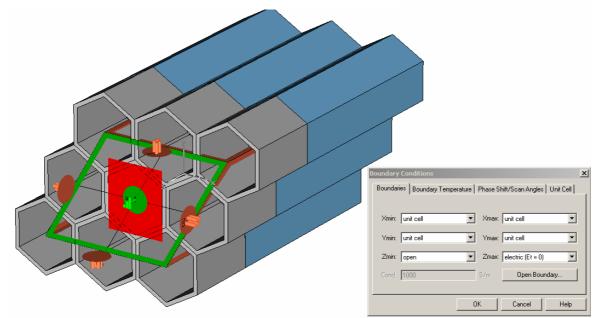
Grating lobes occur at electrical Phase Shift Angles > 150 deg



Infinite Arrays Honeycomb Example

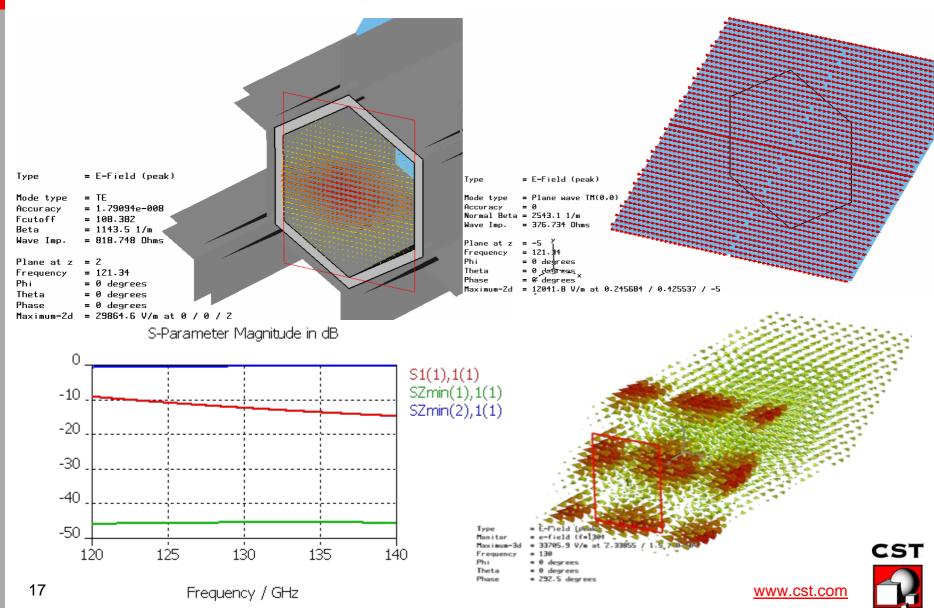


Boundai	y Conditions					×
Bound	aries Boundary	Temperature	Phase Shift/	Scan Angles	Unit Cell	_
S1	(x) periodicity:	r*sqr(3)				
S2	(y') periodicity:	r*sqr(3)				
Grid	d angle (S1->S2):	60		degrees		
	Fit unit cell to bou	unding box				
		0	к	Cancel	Help	





Infinite Arrays Honeycomb Example



Summary

Antenna array simulations with CST MICROWAVE STUDIO®

- The time domain solver is a powerful tool for the simulation of finite antenna arrays. The array size is only limited by the available memory resources.
- The features simultaneous excitation, combine results and farfield array offer a variety to find the best approach for a given problem.
- The frequency domain solver can simulate arbitrary infinite arrays using a unit cell. Project and result templates are helpful to model and extract results.

