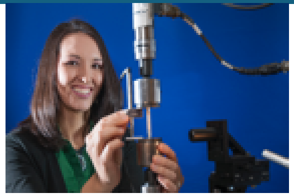
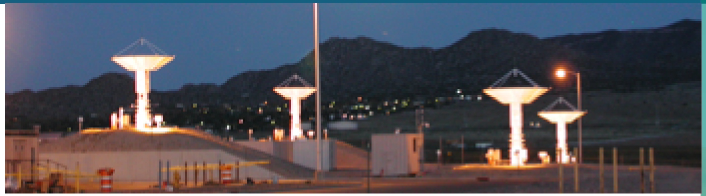
SAND2022-9050C

Sandia National Laboratories

Coupled Mode Theory as a Unifying Concept in Multi-Mode Patch Antenna Design





PRESENTED BY

John Borchardt jjborch@sandia.gov

U.S. DEPARTMENT OF ENERGY NNSA

SAND2022-XXXX

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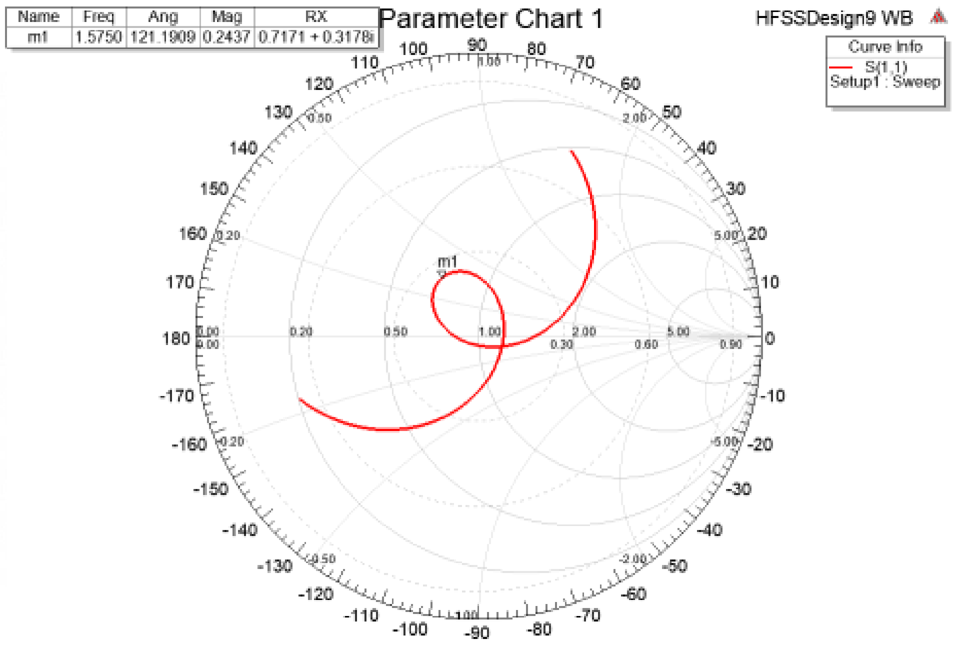
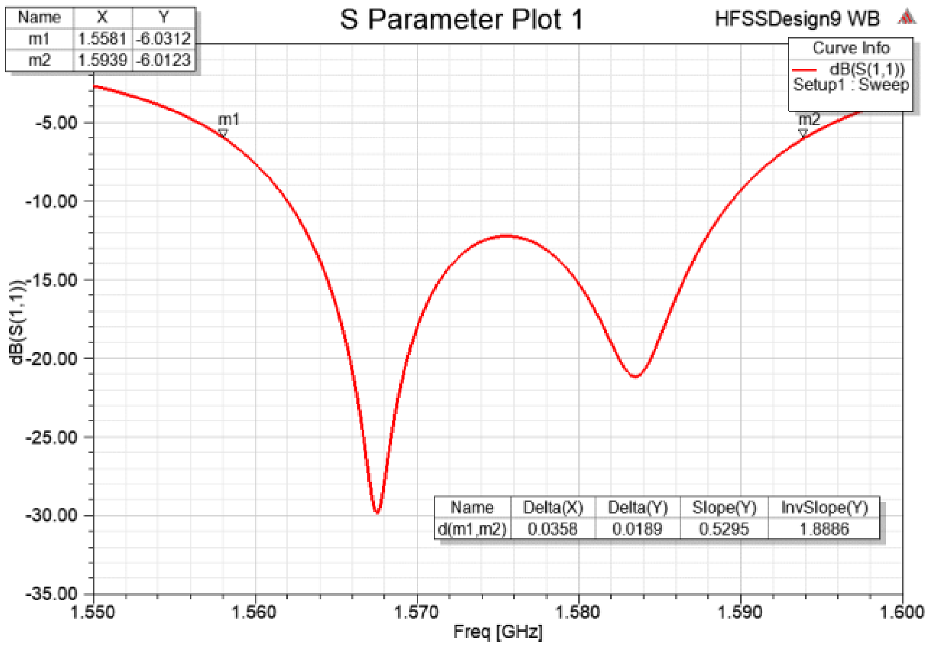
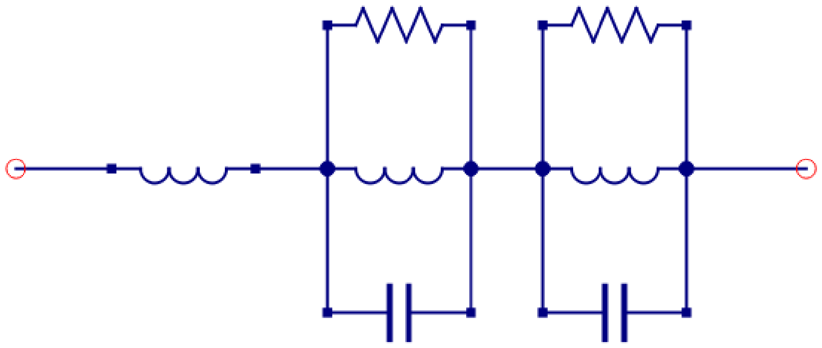
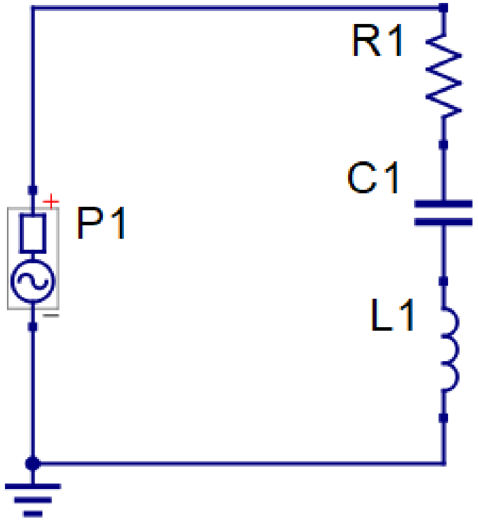
Antennas with multiple resonances

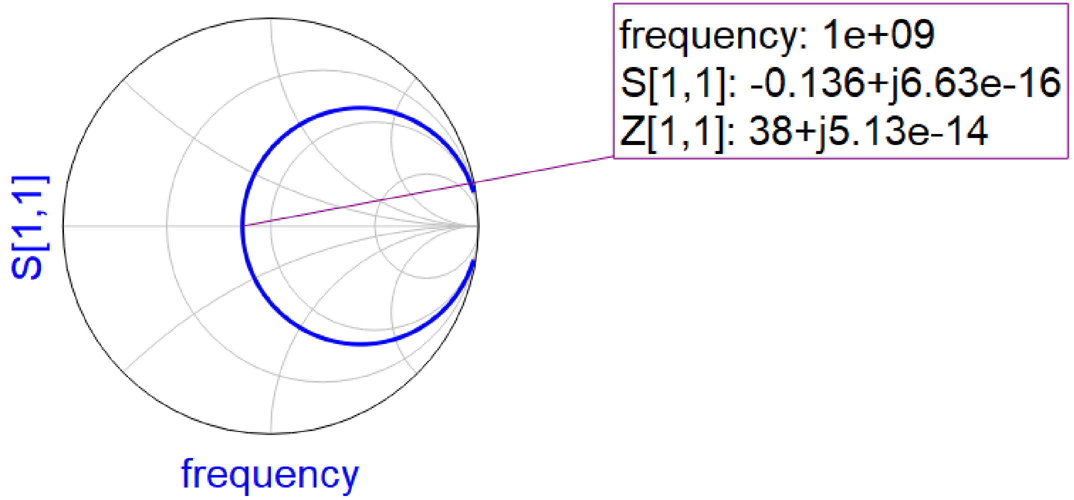






A simple resonator





$$Z_{c1} = \sqrt{L/C} = 380$$

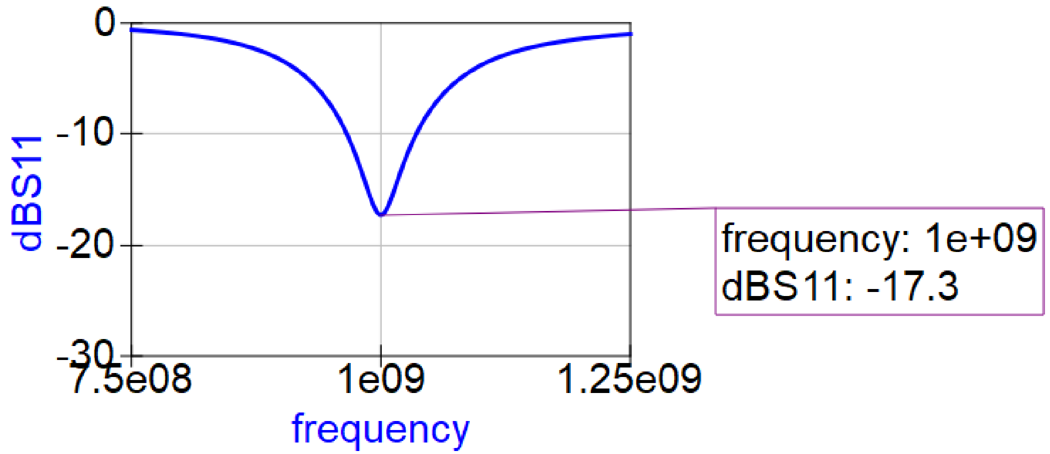
$$_1 = / = 10$$

$$\omega_{01} = 1/\sqrt{LC} = 2\pi\, 1e9$$

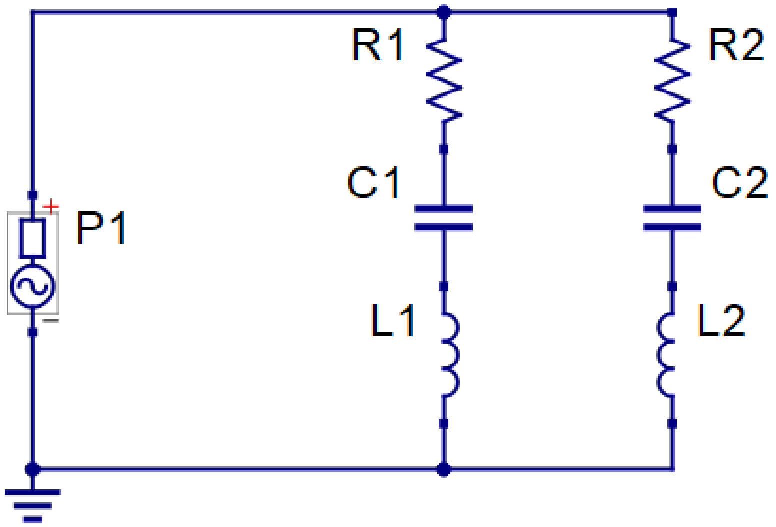
$$= /\ _0$$

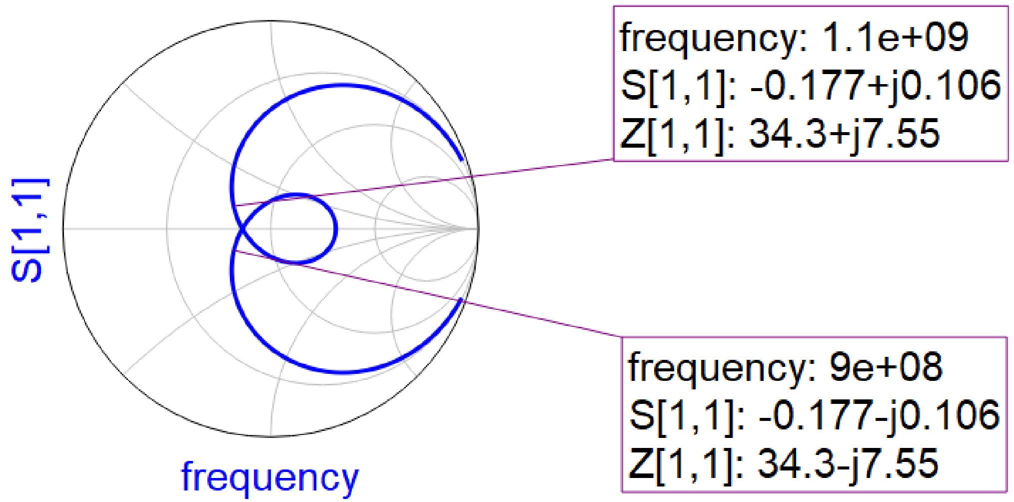
$$= 1/(\ _0\ )$$

$$= /$$



Multiple resonators can display interesting behavior





$Z_{c1} = \sqrt{L/C} = 380$

$_1 = \ / \ = 10$

$\omega_{01} = 1/\sqrt{LC} = 2\pi$ 0.9e9

$Z_{c2} = 380$

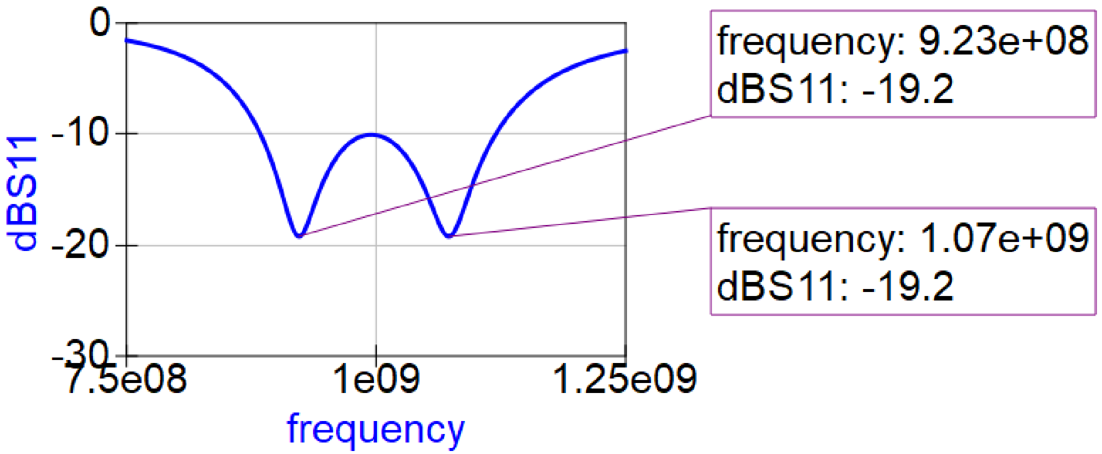
$_2 = 10$

$_{02} = 2$ 1.1e9

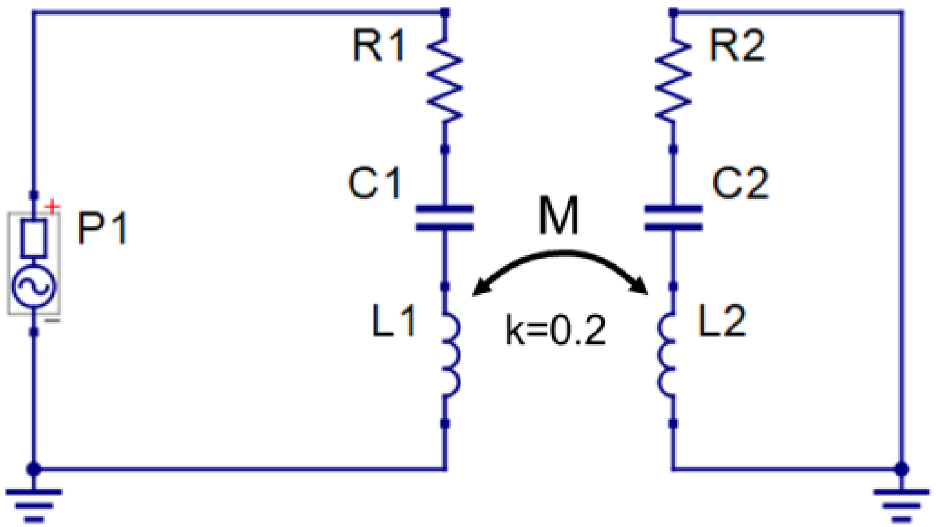
$= \ / \ _0$

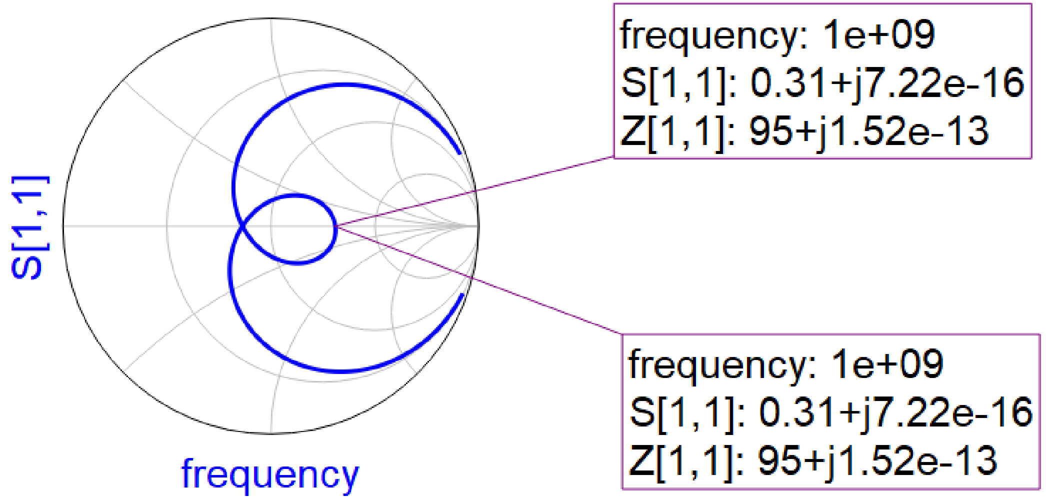
$= 1/(\ _0 \ )$

$= \ /$



Another way to get a Smith chart loop





$Z_{c1} = \sqrt{L/C} = 190$

$_1 = \;/\; = 10$

$\omega_{01} = 1/\sqrt{LC} = 2\pi$ 1.0e9

$Z_{c2} = 190$

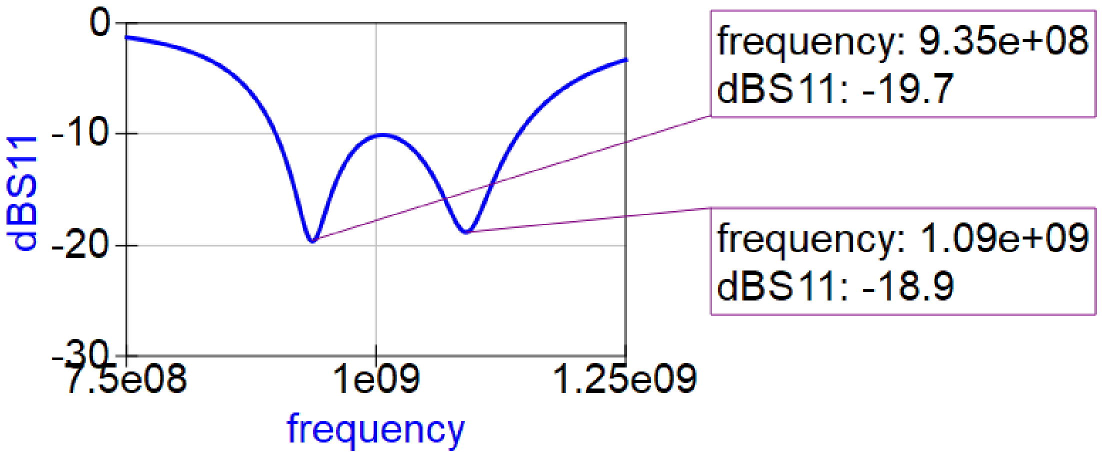
$_2 = 10$

$_{02} = 2$ 1.0e9

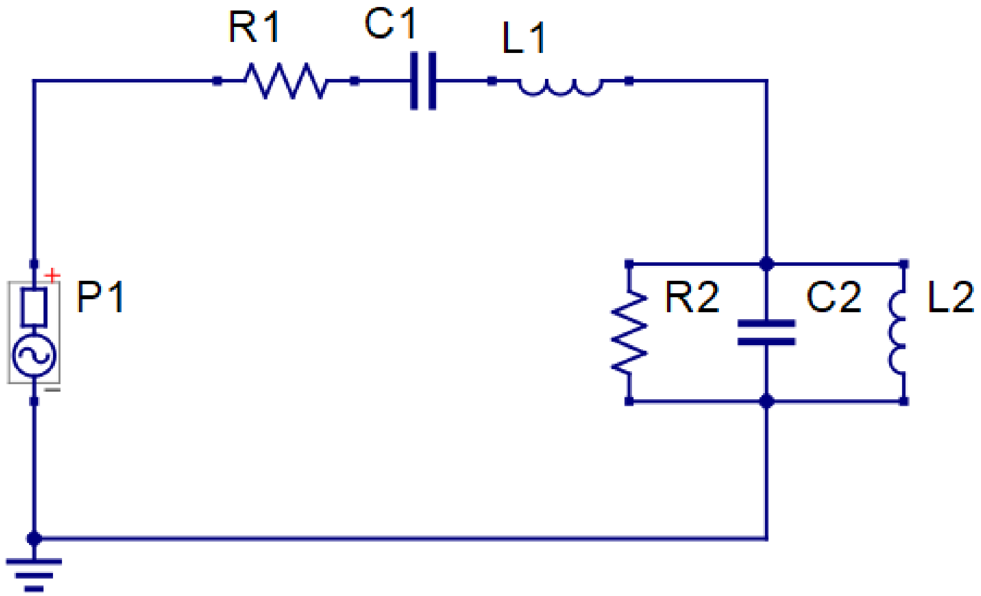
$= \;/\; _0$

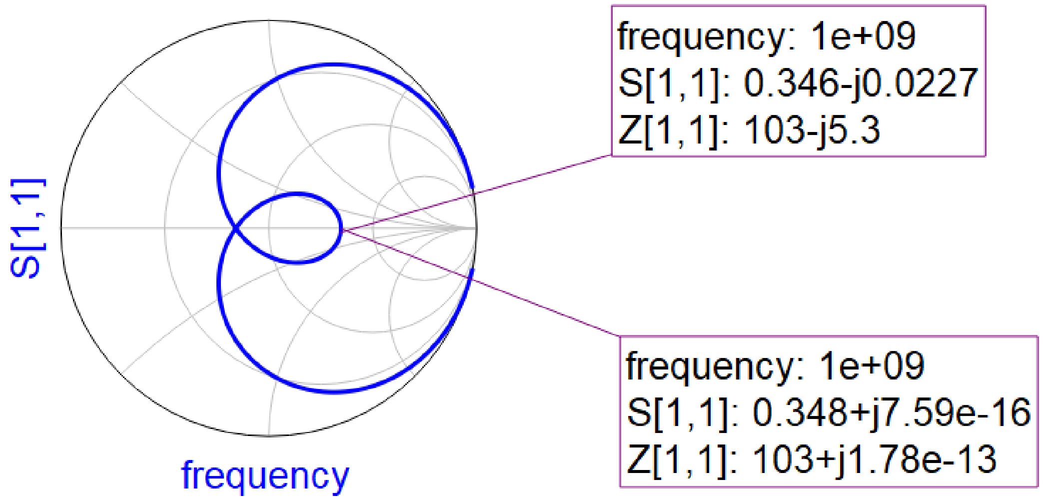
$= 1/(\; _0 \;)$

$= \;/\;$



Yet another way to get a Smith chart loop





$$Z_{c1} = \sqrt{L/C} = 330$$

$$Q_1 = Z_{c1}/R_1 = 100$$

$$\omega_{01} = 1/\sqrt{LC} = 2\pi\ 1.0e9$$

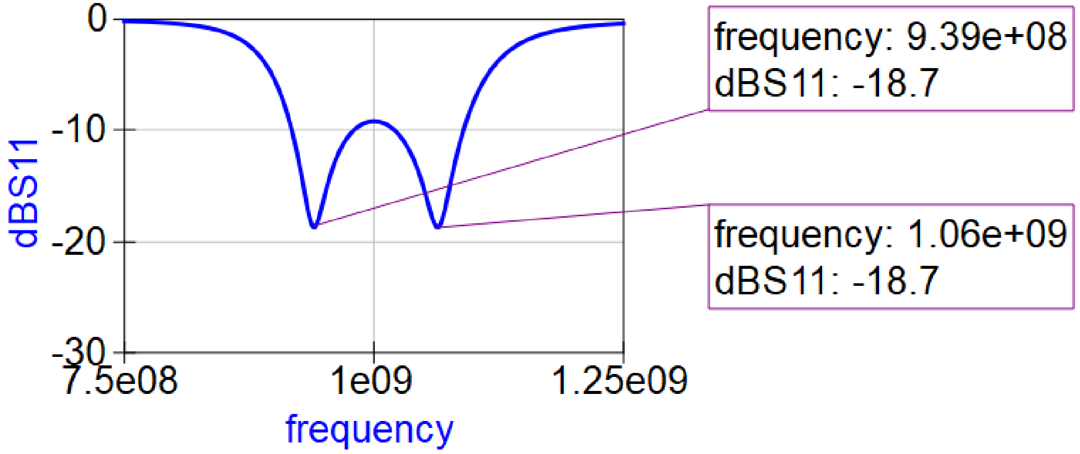
$$Z_{c2} = 10$$

$$Q_2 = R_2 Z_{c2} = 10$$

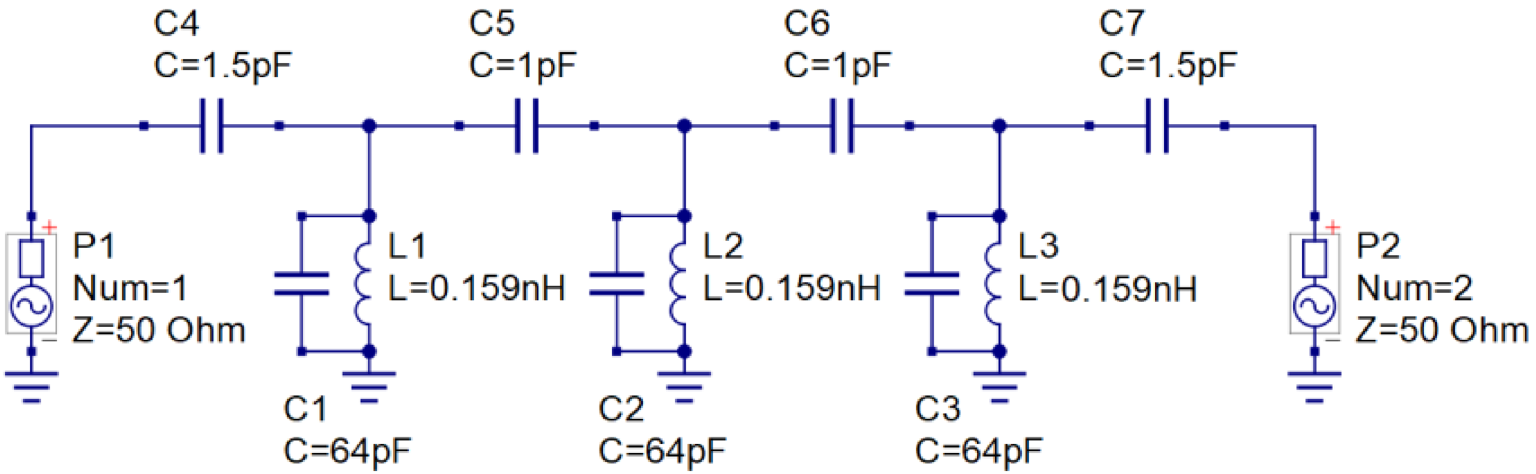
$$_{02} = 2\ 1.0e9$$

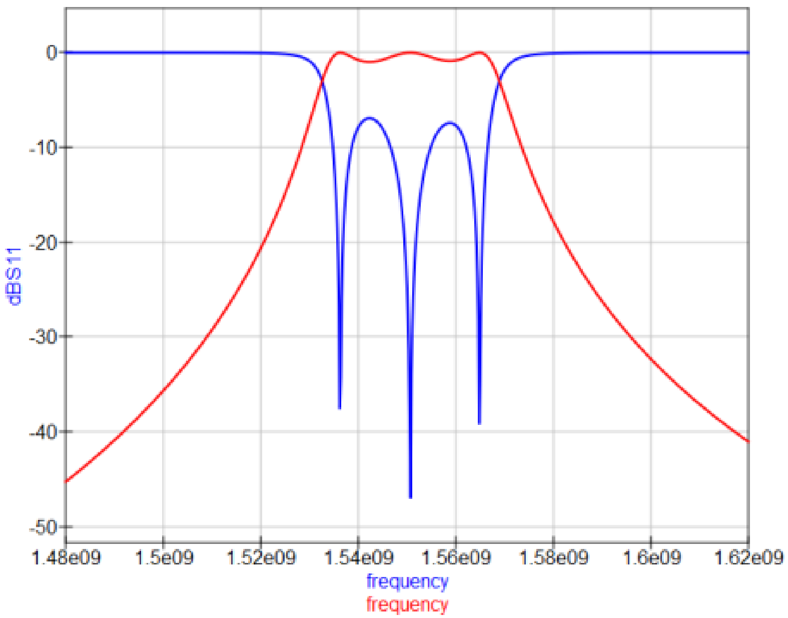
$$= / \ _0$$

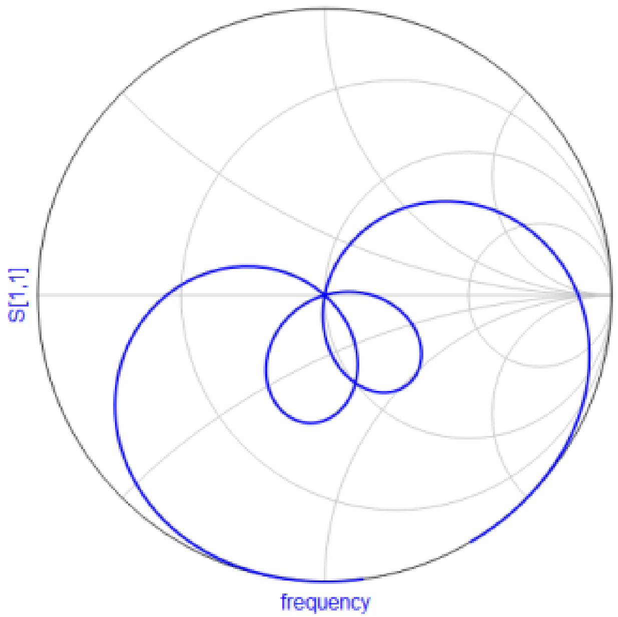
$$= 1/(\ _0 \ )$$



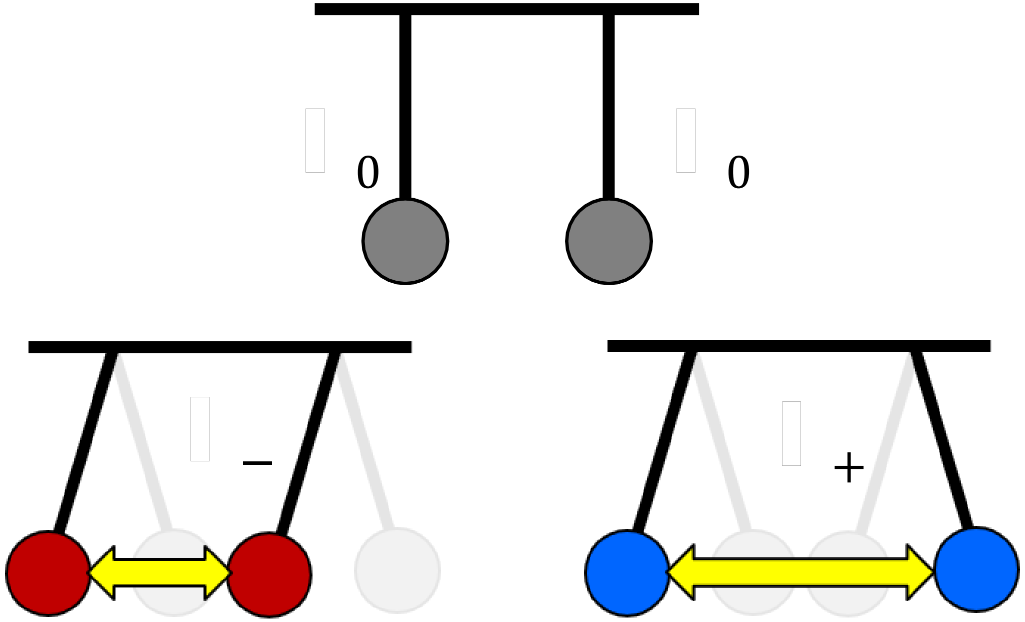
“N” coupled resonators



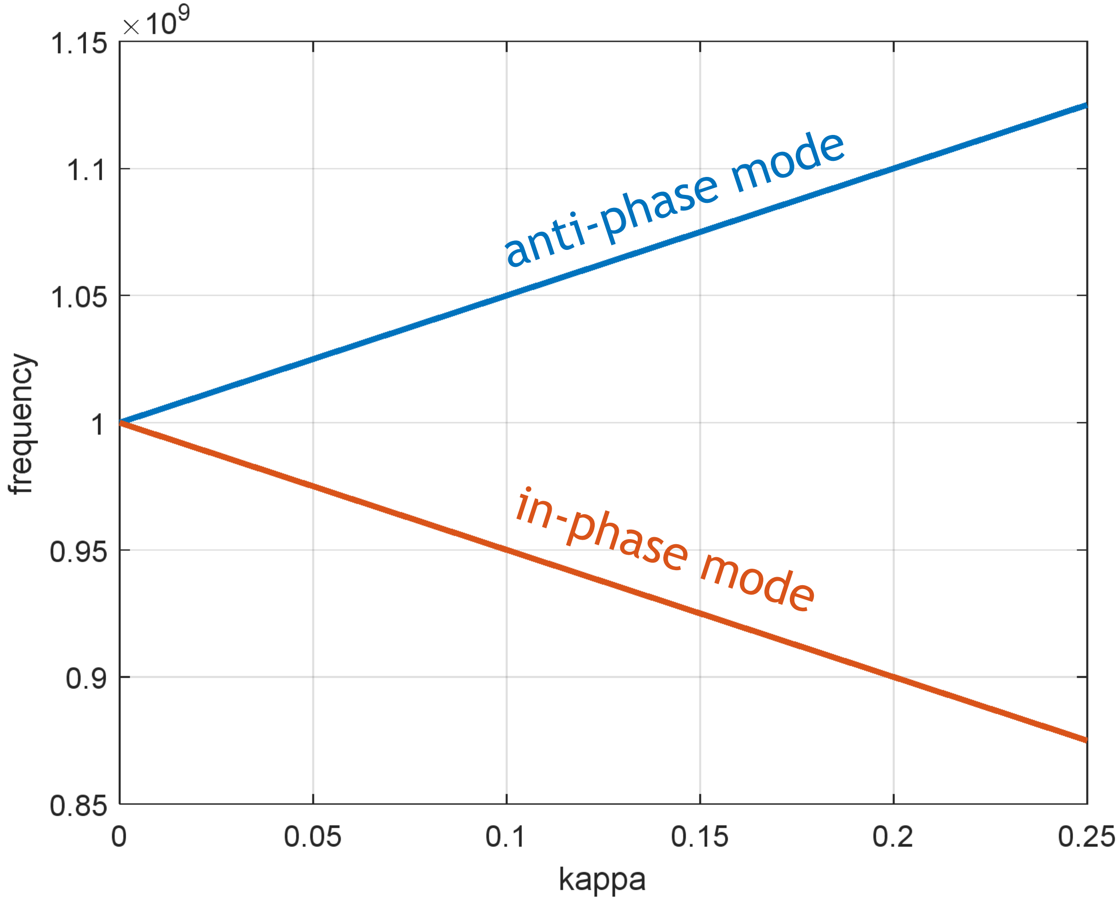




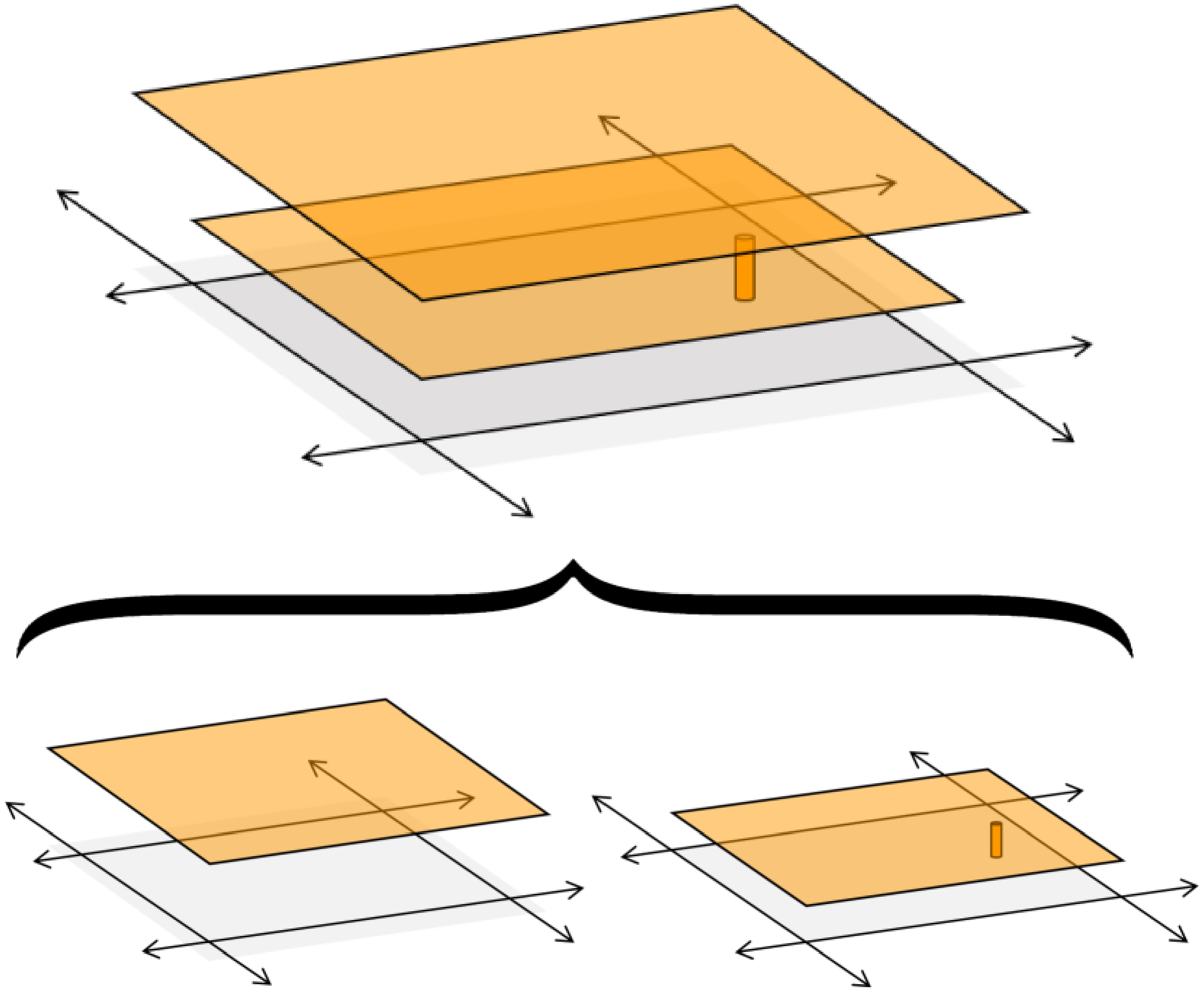
Coupled Mode Theory

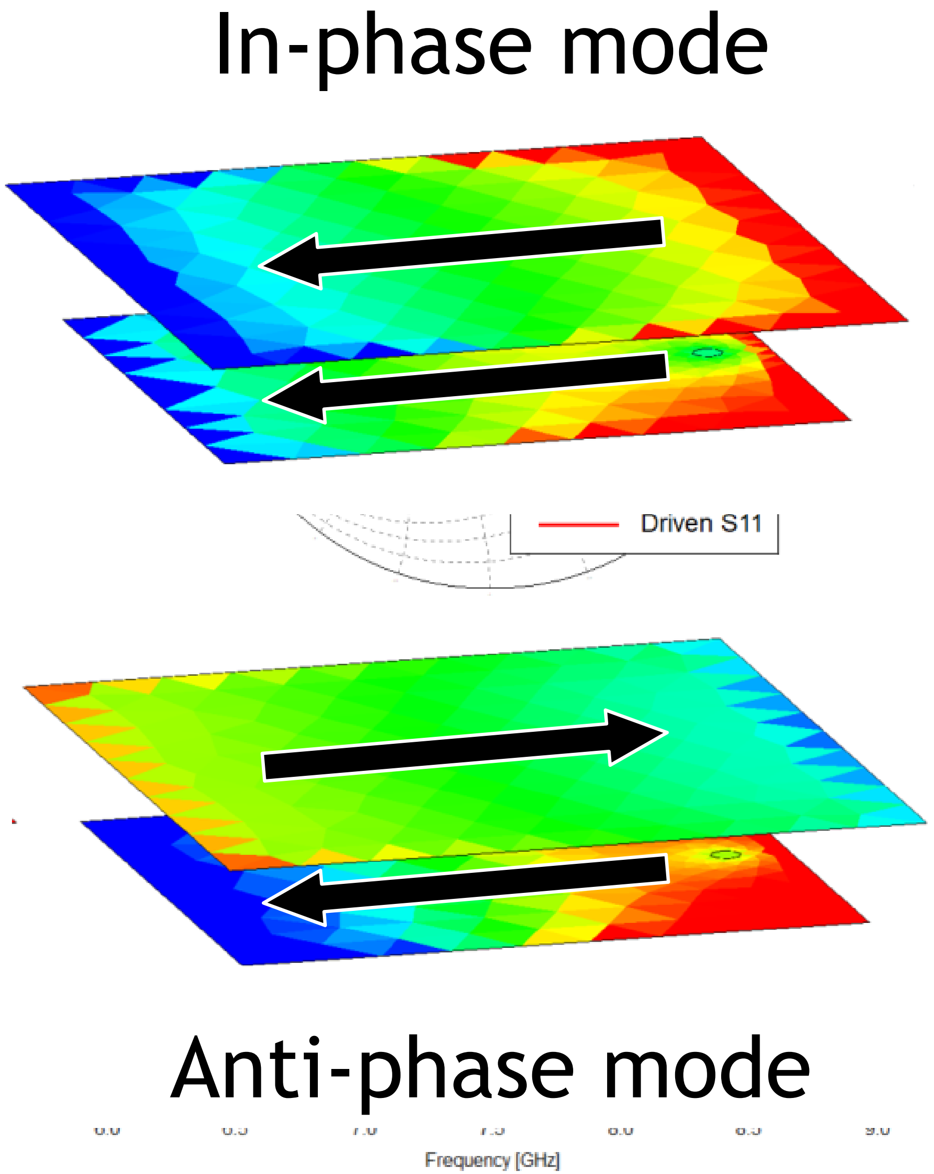


$$\omega_{\pm} = \omega_0 \pm |K|$$



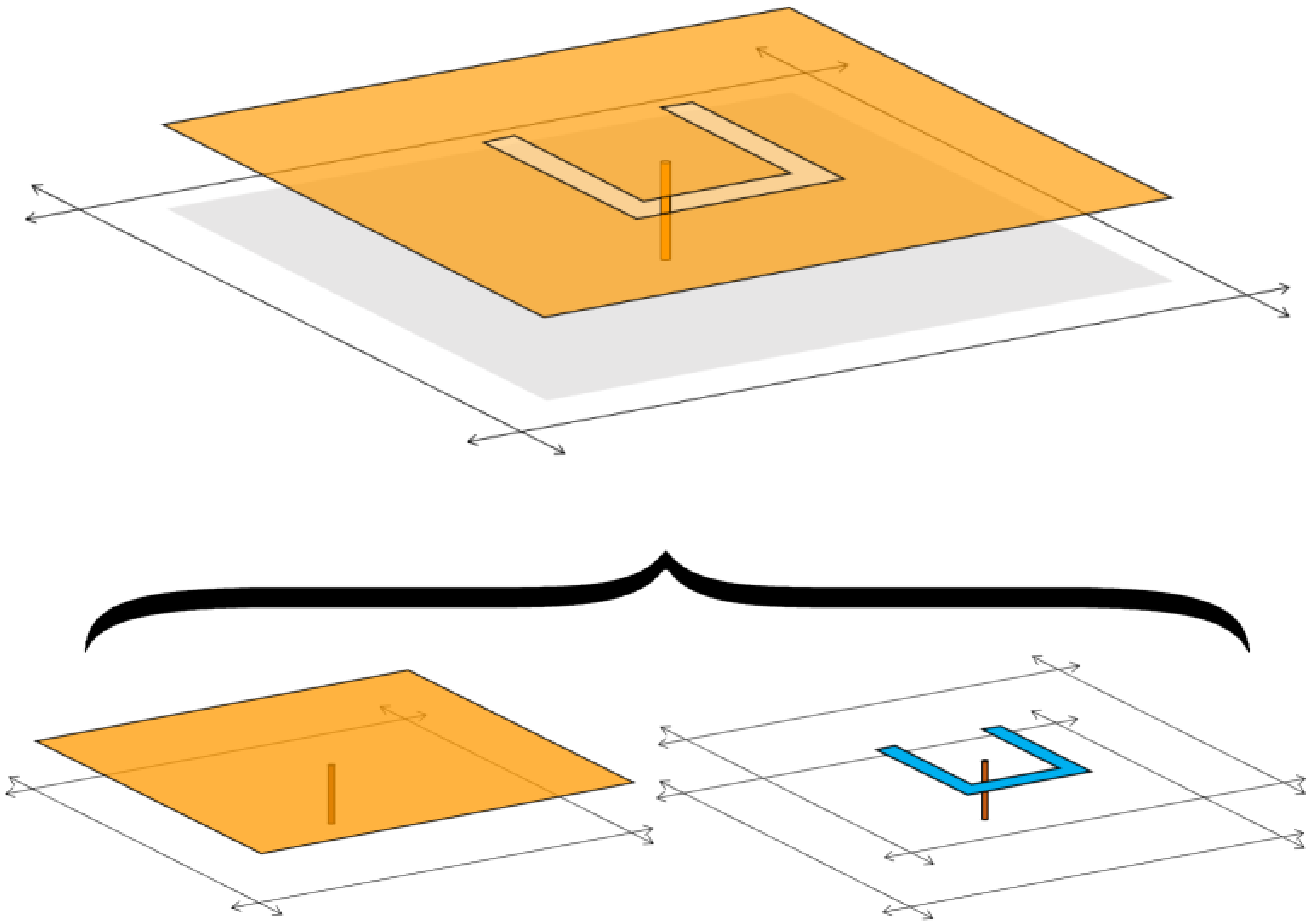
Stacked patches



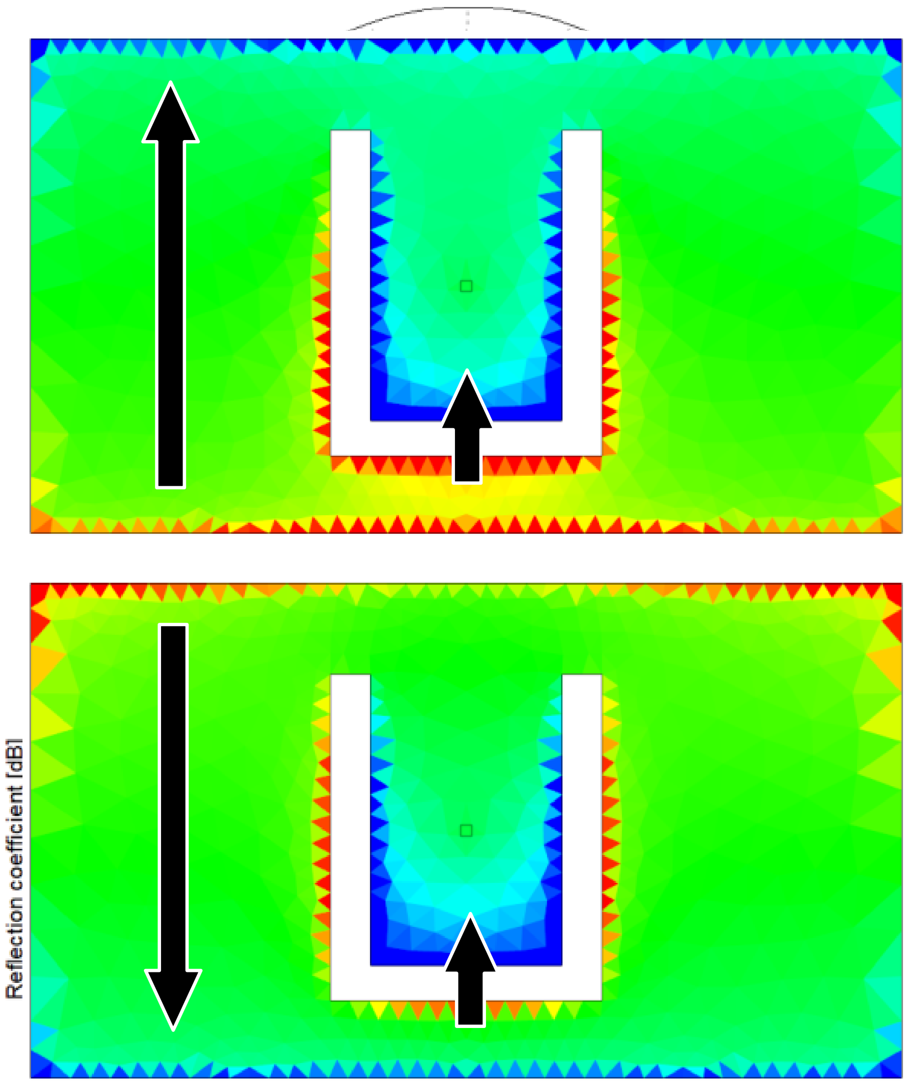


R. B. Waterhouse, "Design of probe-fed stacked patches", *IEEE TAP*, vol.47, no.12, Dec. 1999.

U-slot patch



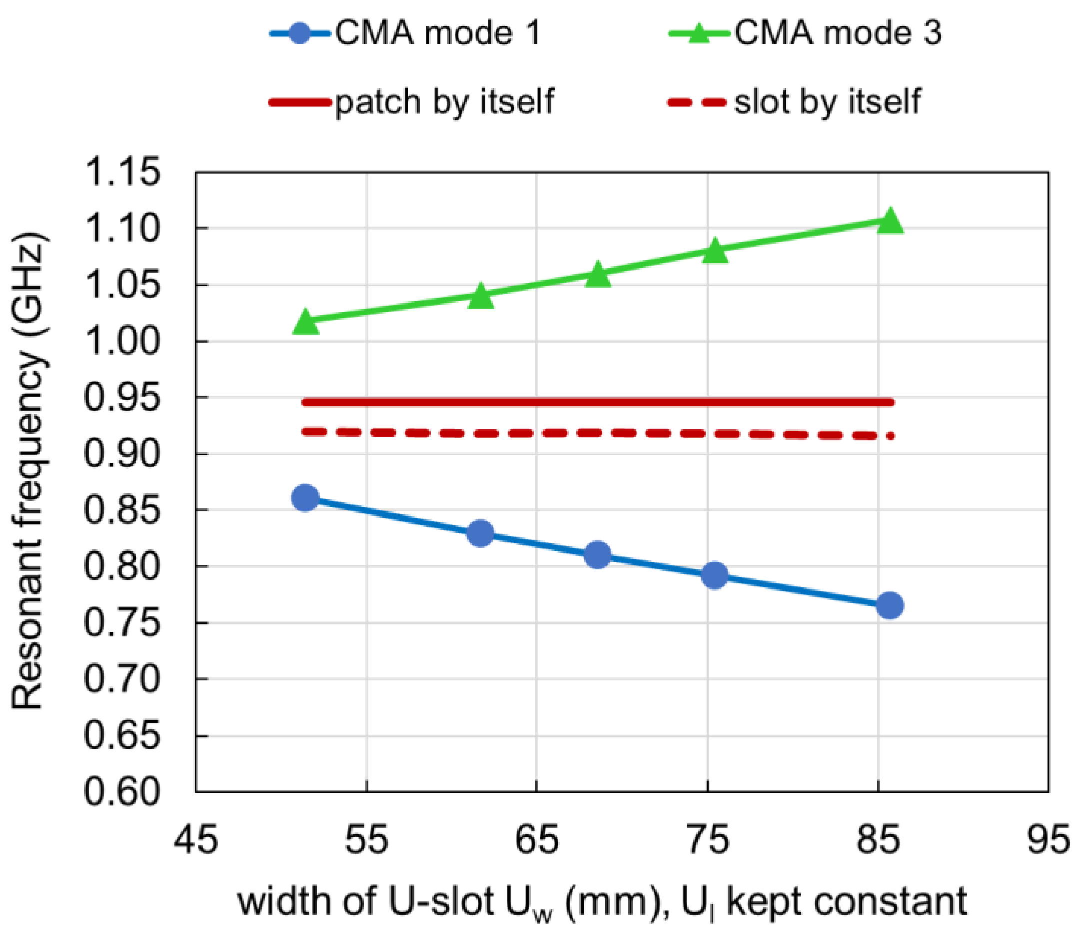
In-phase mode

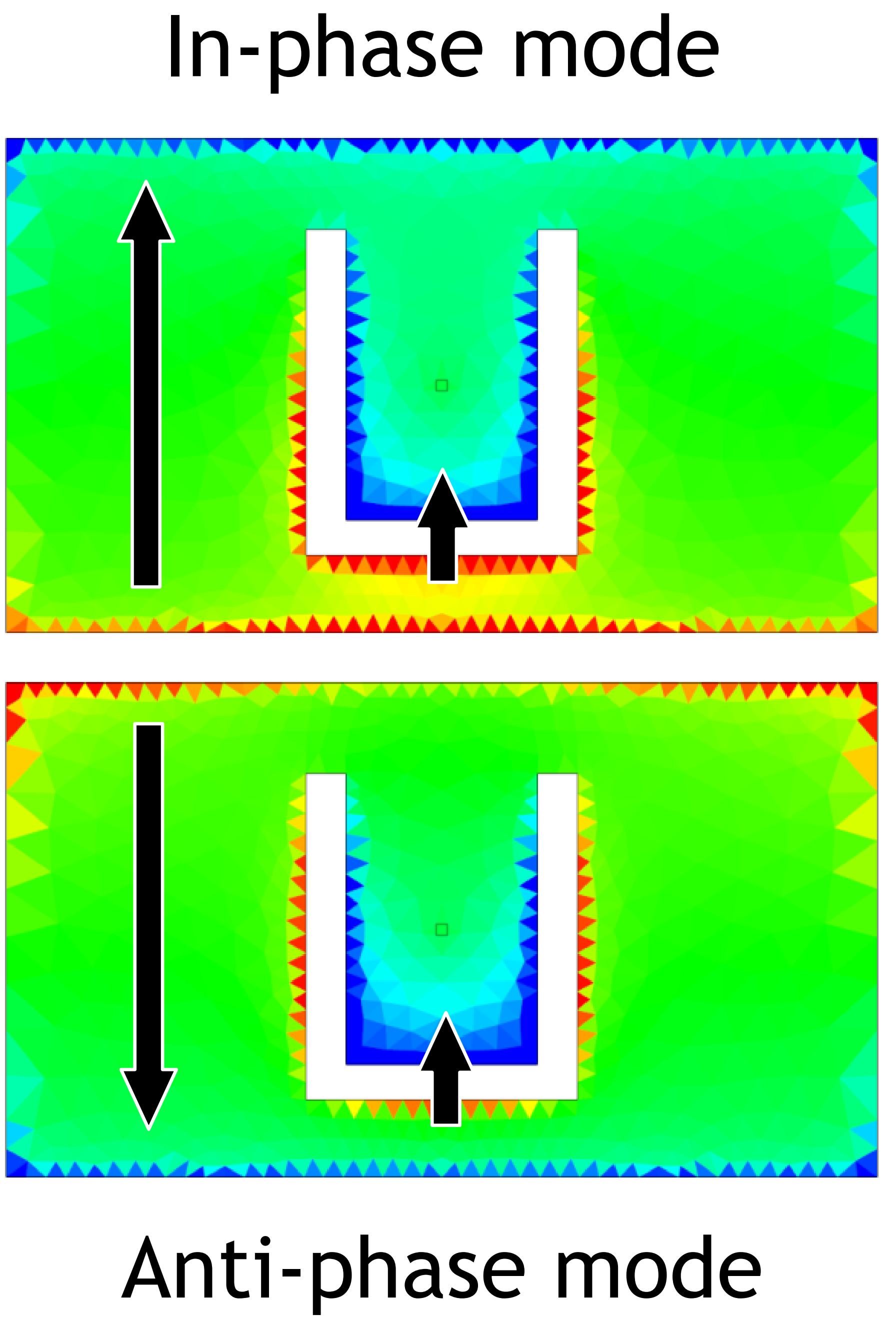


Anti-phase mode

T. Huynh and K. F. Lee, "Single-layer single-patch wideband microstrip antenna", *Electron. Lett.*, vol. 31, Aug. 1995.

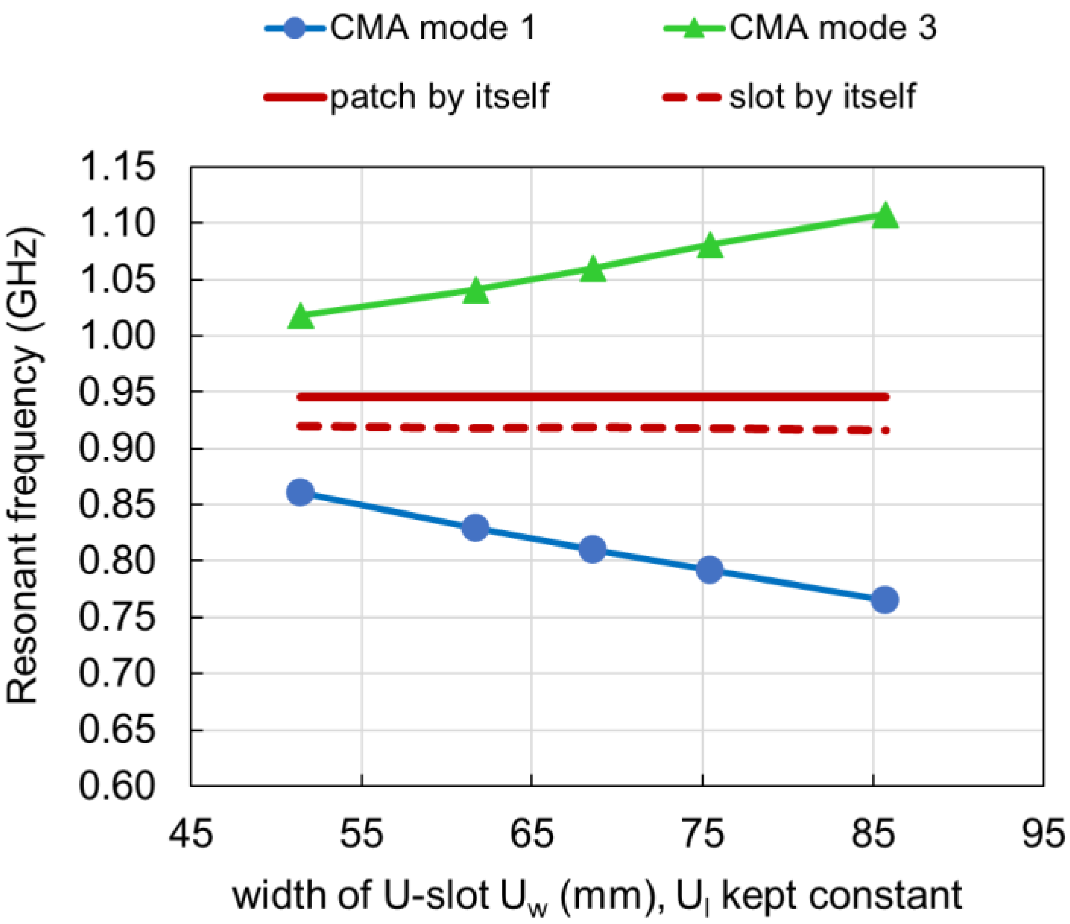
U-slot patch





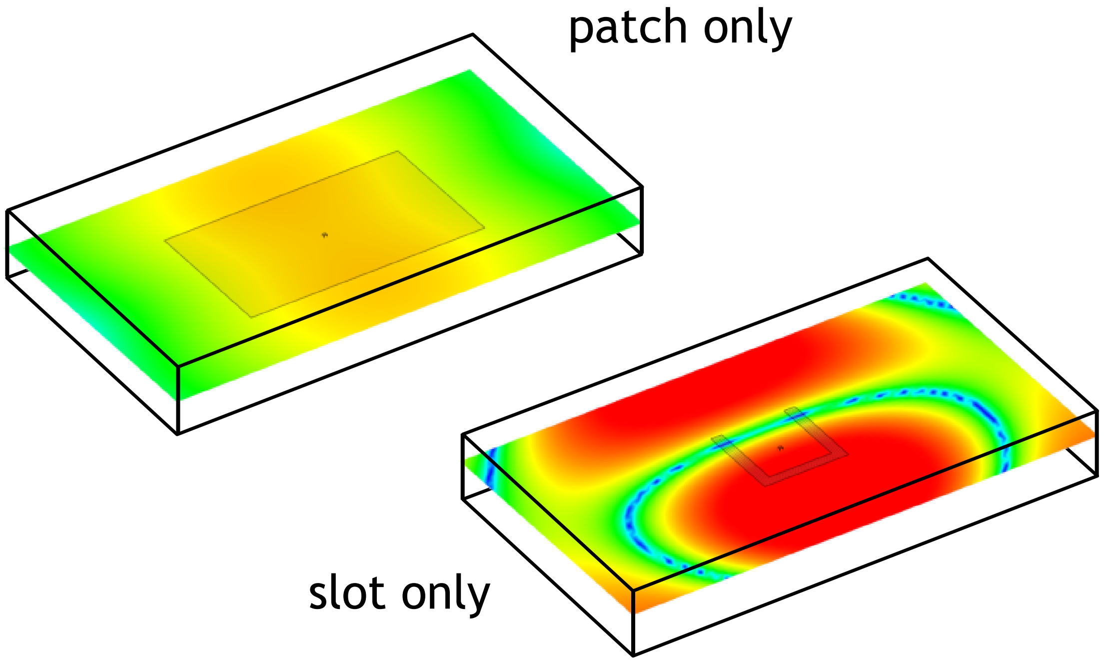
T. Huynh and K. F. Lee, "Single-layer single-patch wideband microstrip antenna", *Electron. Lett.*, vol. 31, Aug. 1995.

U-slot patch



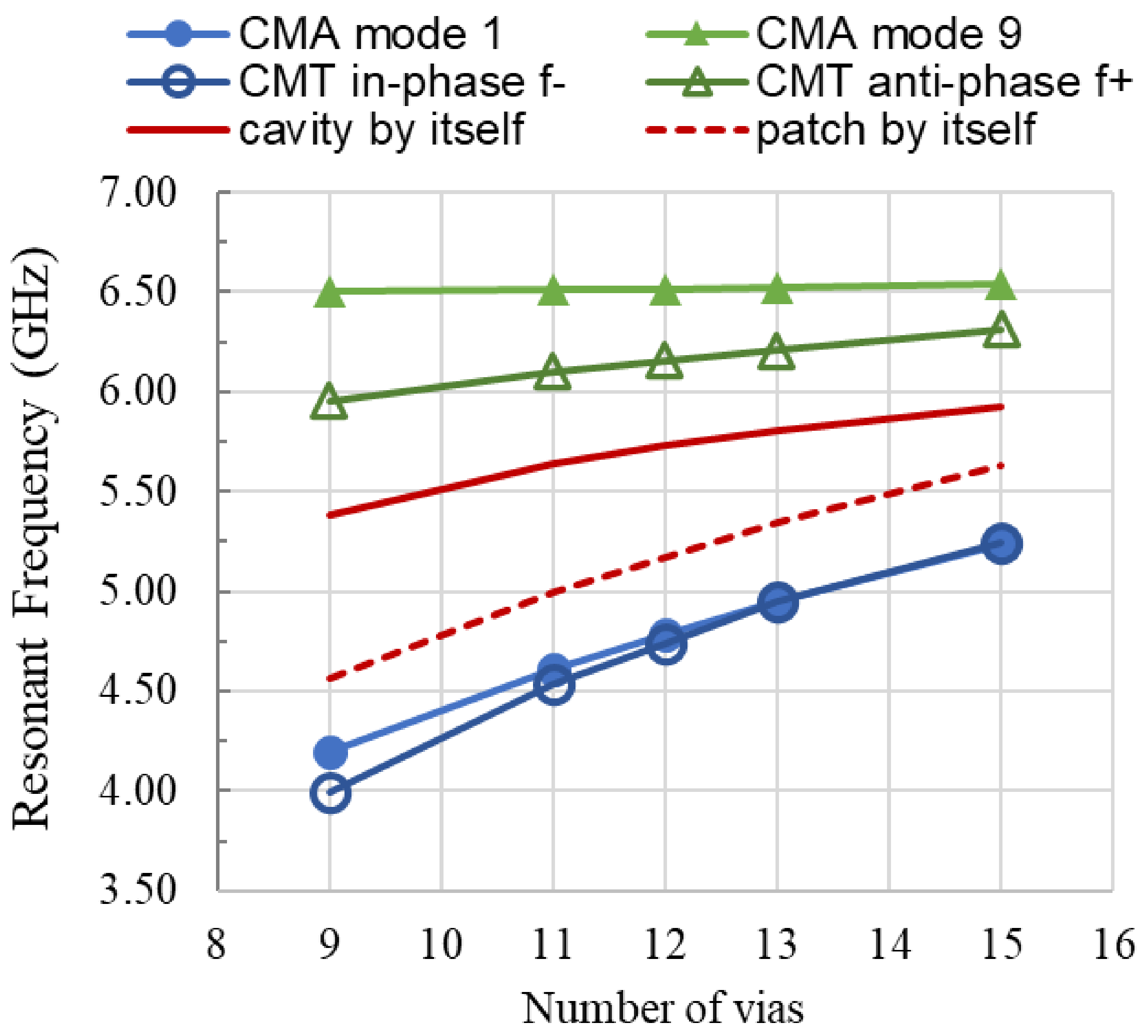
$$\kappa = \frac{\int \epsilon E_1 \circ E_2 \, dV}{\sqrt{W_{e1} W_{e2}}} + \frac{\int \mu H_1 \circ H_2 \, dV}{\sqrt{W_{m1} W_{m2}}}$$

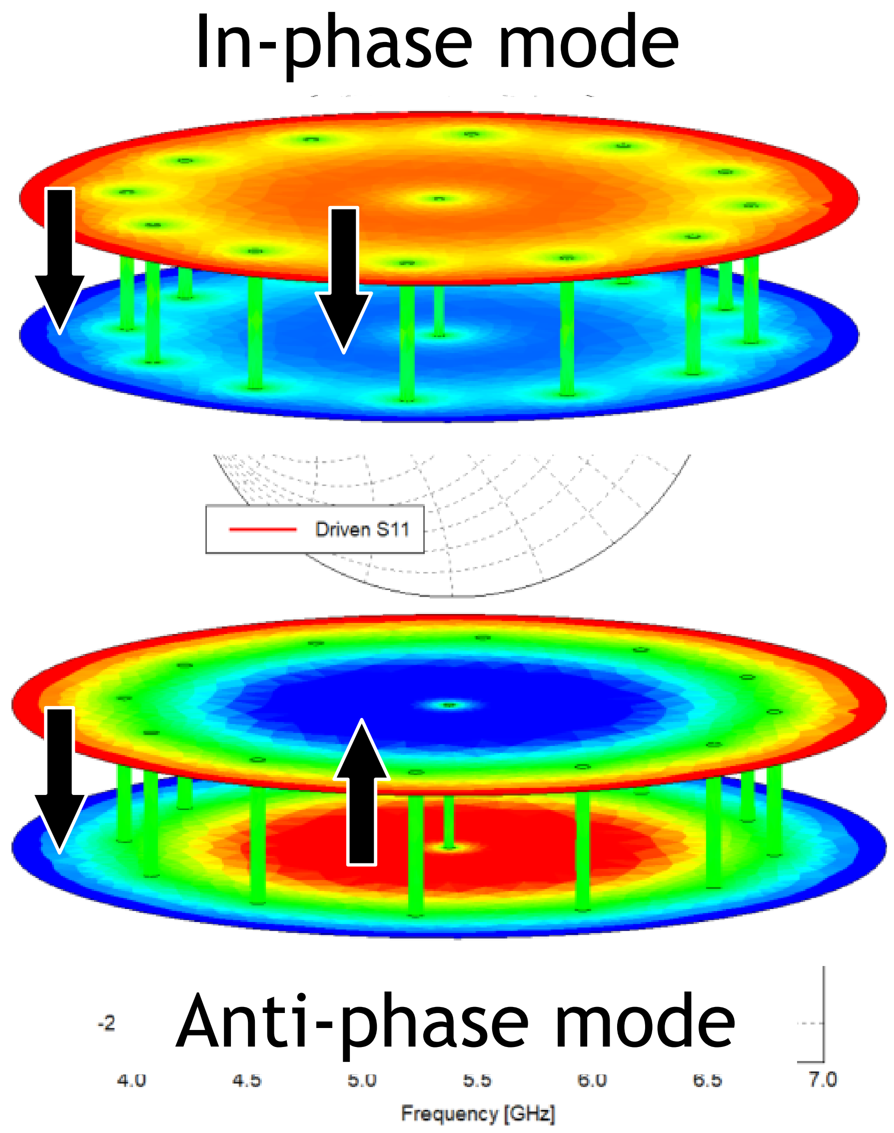
$$W_{e1,2} = \int \epsilon \left| E_{1,2} \right|^2 dV \qquad W_{m1,2} = \int \mu \left| H_{1,2} \right|^2 dV$$



T. Huynh and K. F. Lee, "Single-layer single-patch wideband microstrip antenna", *Electron. Lett.*, vol. 31, Aug. 1995.

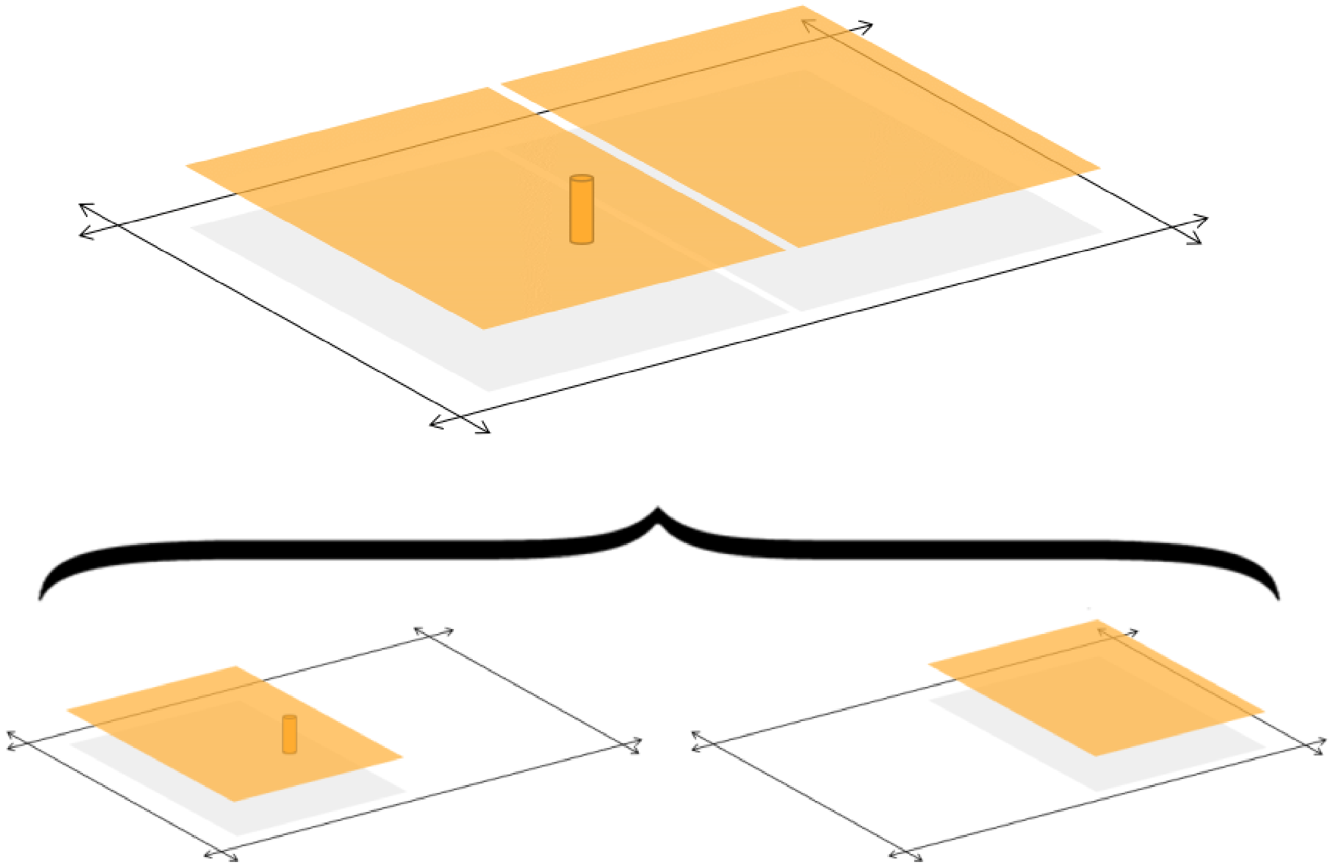
Annular coupled patch

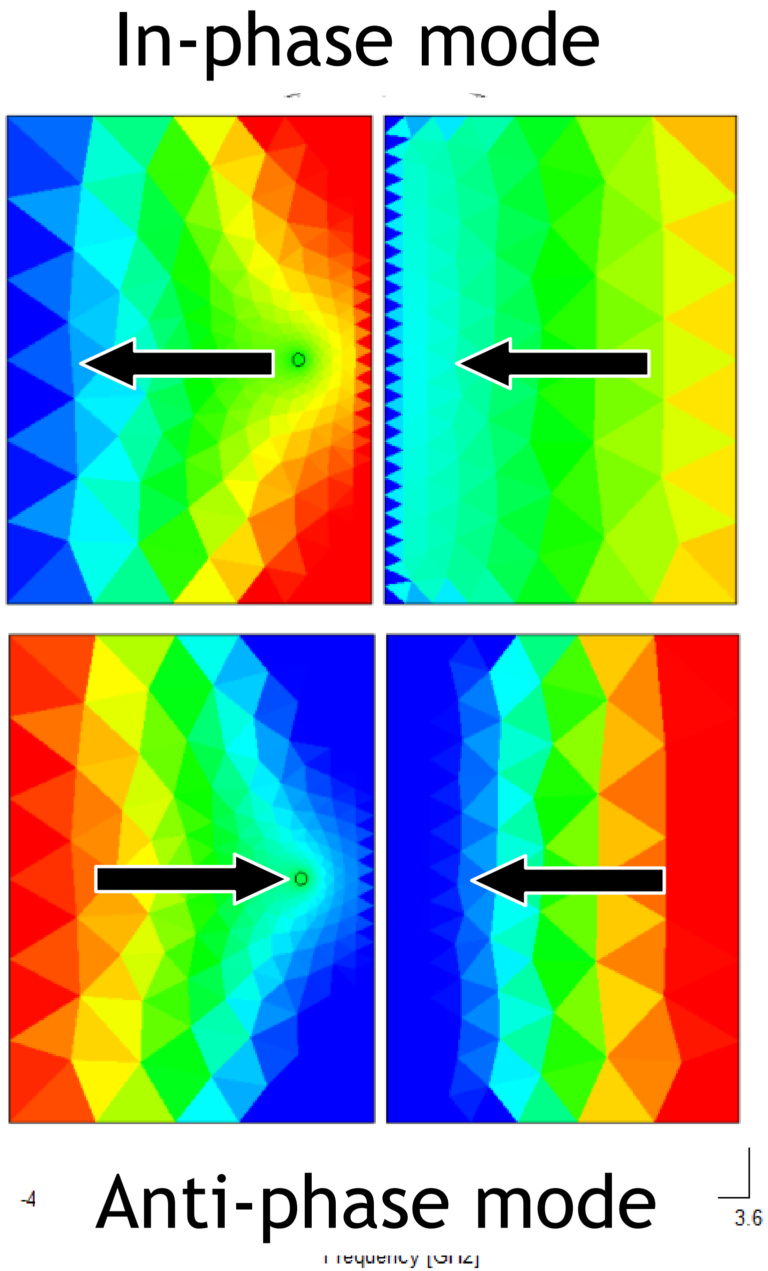




Similar to J. Liu et al., "Design & Analysis of a Low-Profile & Broadband Microstrip Monopolar Patch", *IEEE TAP*, vol. 61, no. 1, Jan. 2013.

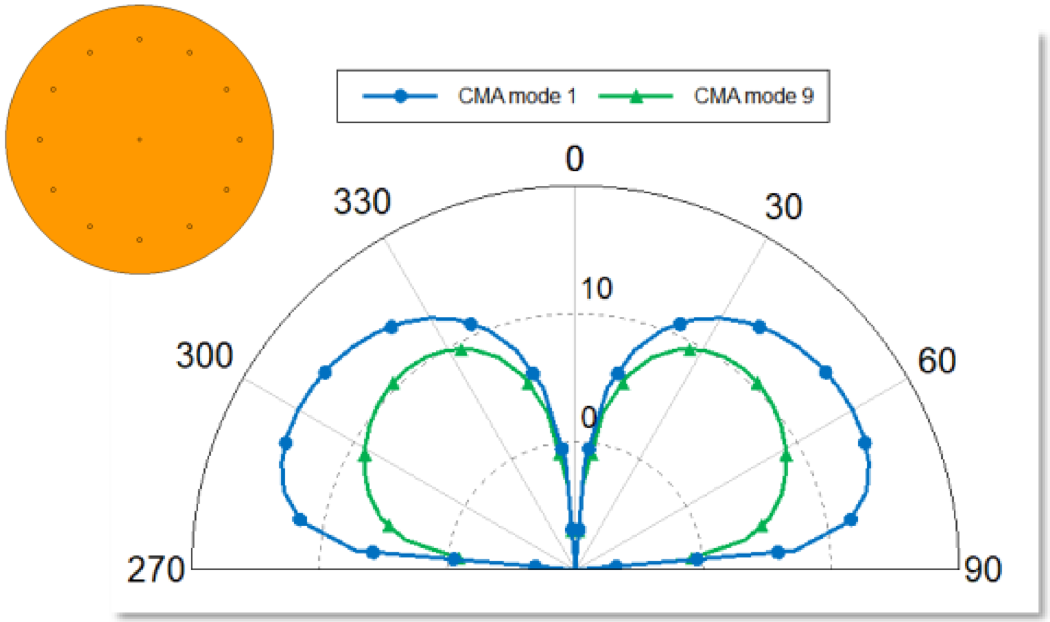
Coplanar patches

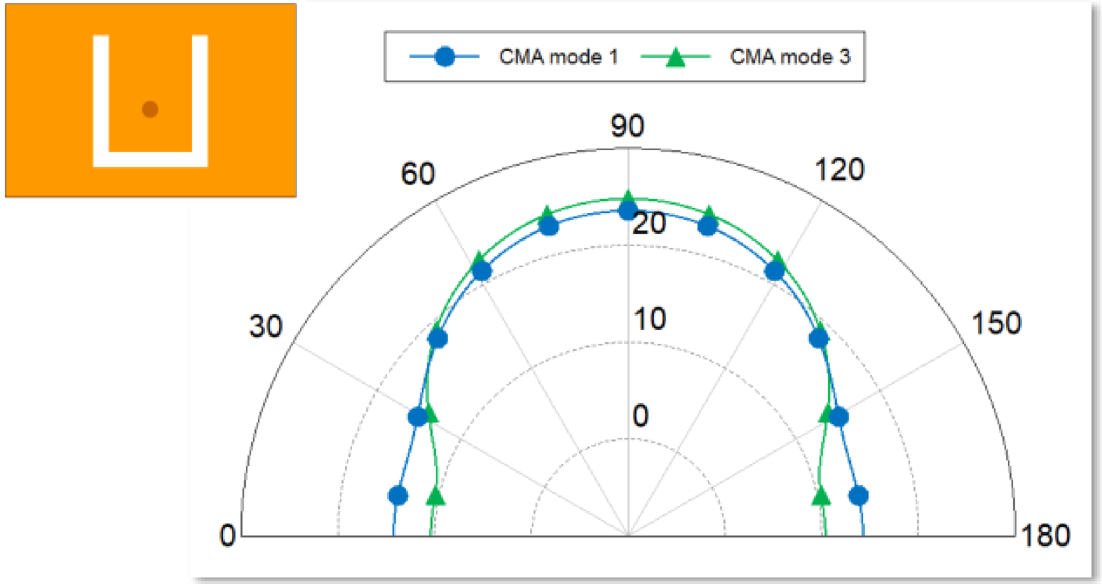


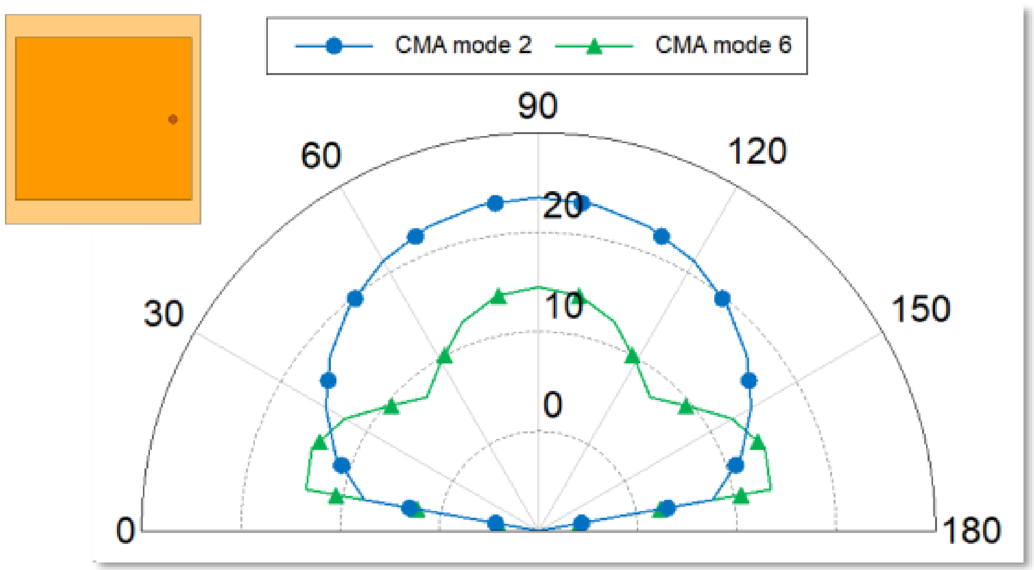


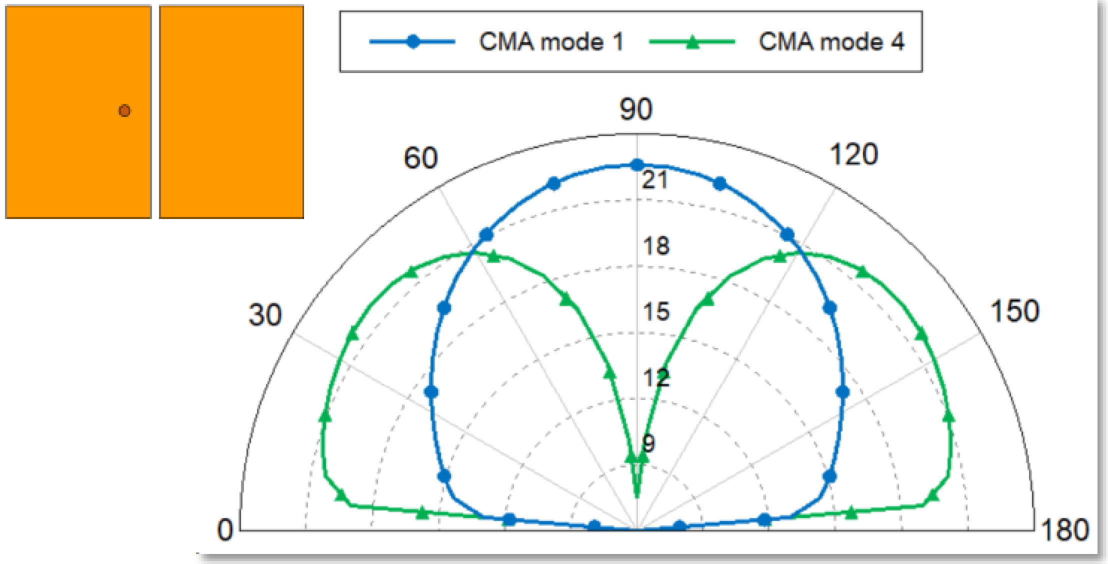
G. Kumar and K.P. Ray, "One Parasitic Patch", *Broadband Microstrip Antennas*, vol. 3, no. 3.3.1.1, pp. 91, 2003.

Far-field E-plane cuts

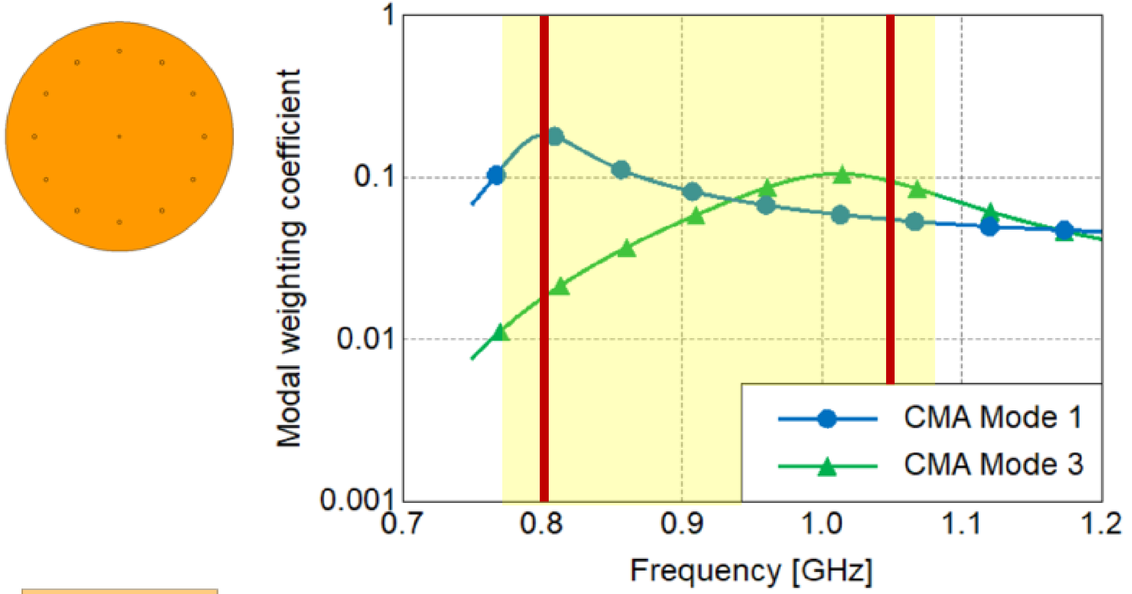


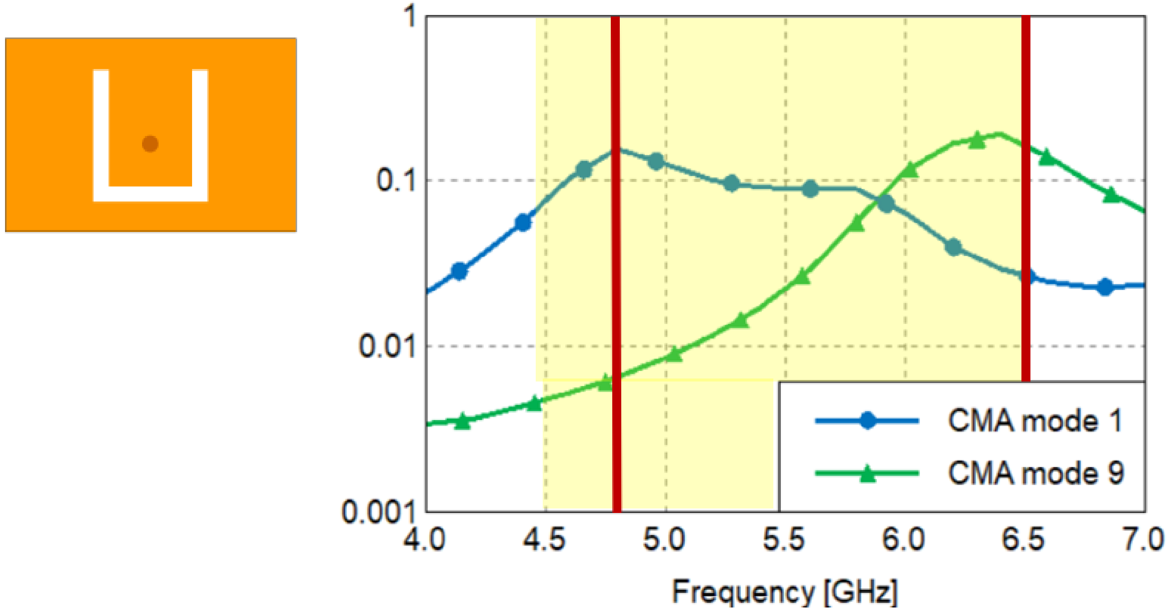


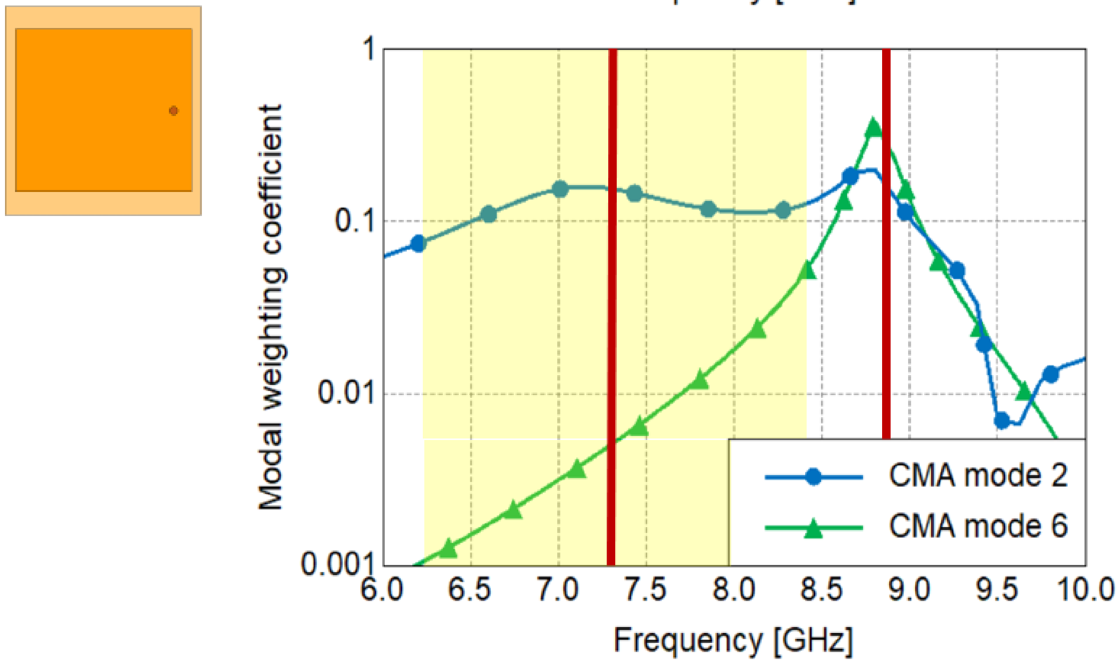


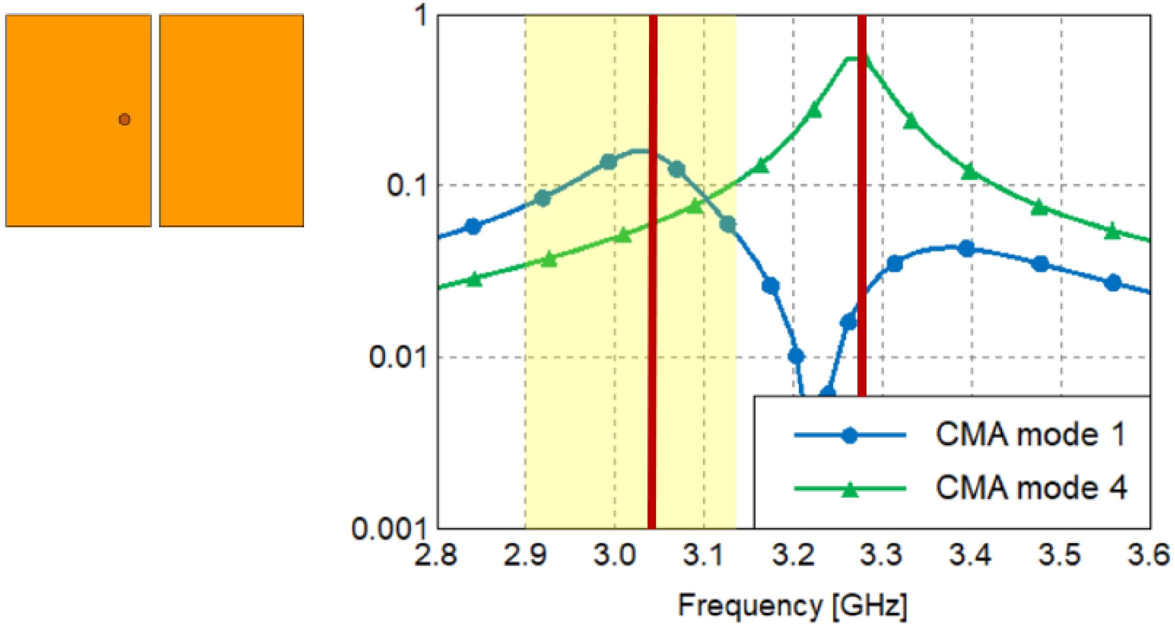


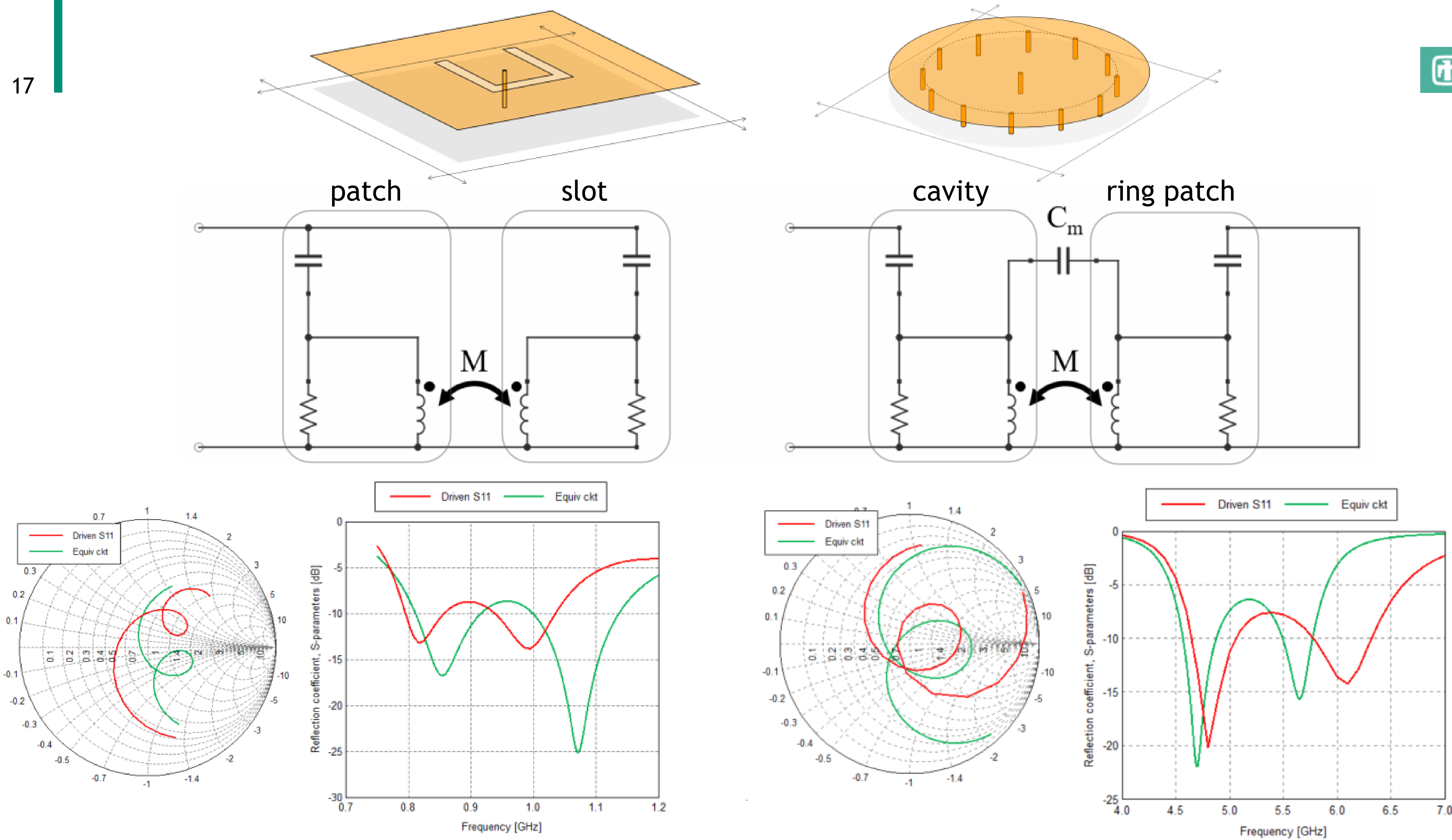
Comparing modal weighting coefficients





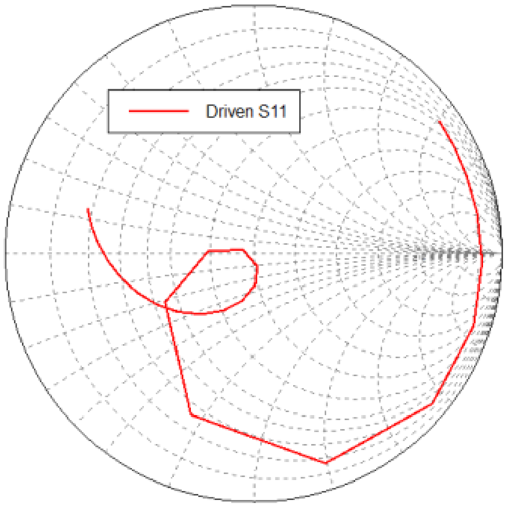




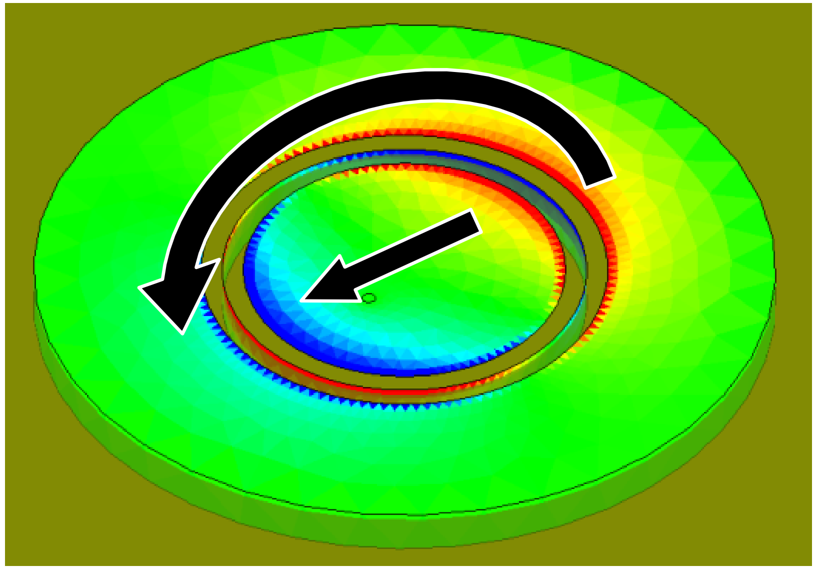


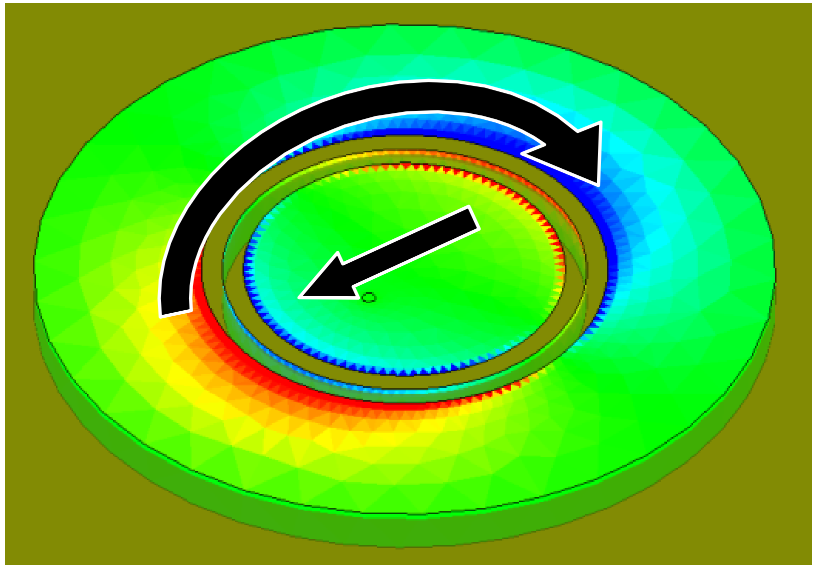
patch
slot
M
cavity
ring patch
C_m
M
Driven S11
Equiv ckt
Reflection coefficient, S-parameters [dB]
Frequency [GHz]
Driven S11
Equiv ckt
Driven S11
Equiv ckt
Reflection coefficient, S-parameters [dB]
Frequency [GHz]
Driven S11
Equiv ckt

Summary



- CMT explains many different multi-mode patches
- This insight can be used to create systematic design methodologies and generate new broadband radiator concepts





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