A Phased Array Antenna Simulated by Wavenology EM

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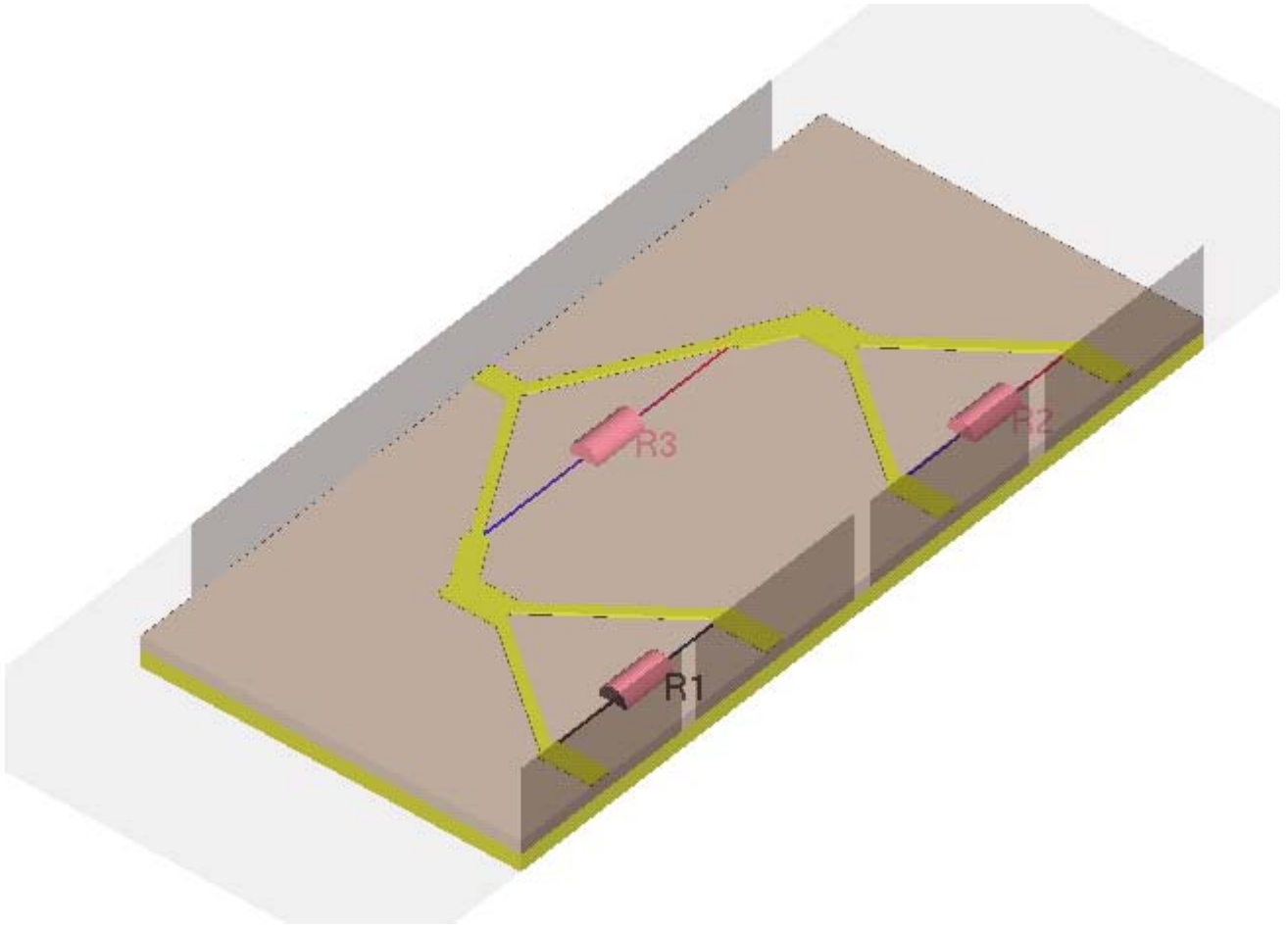
March 2012

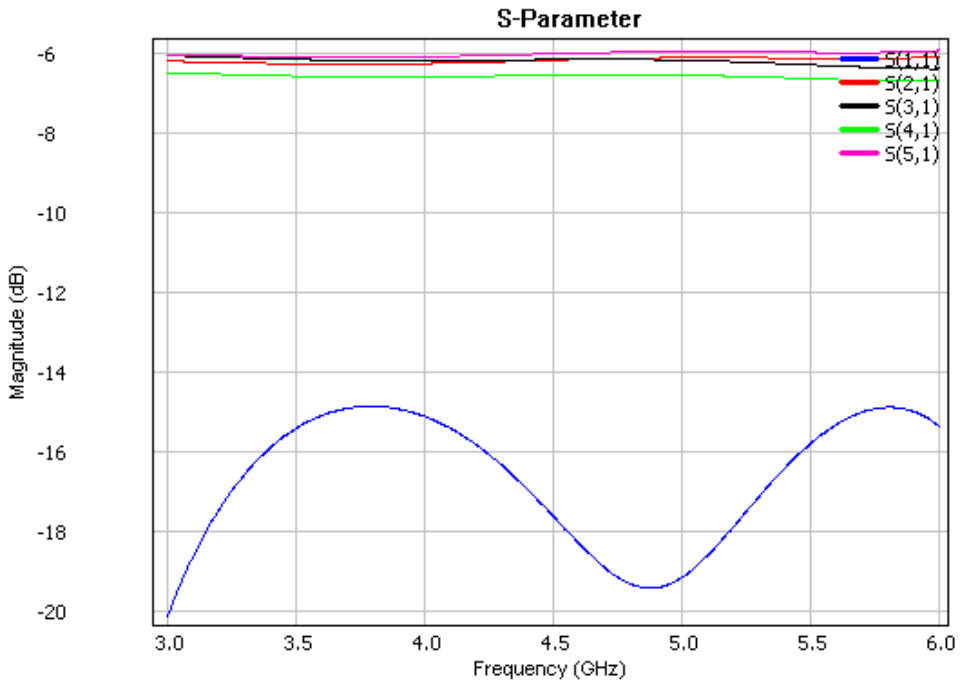
Configuration of the phase array

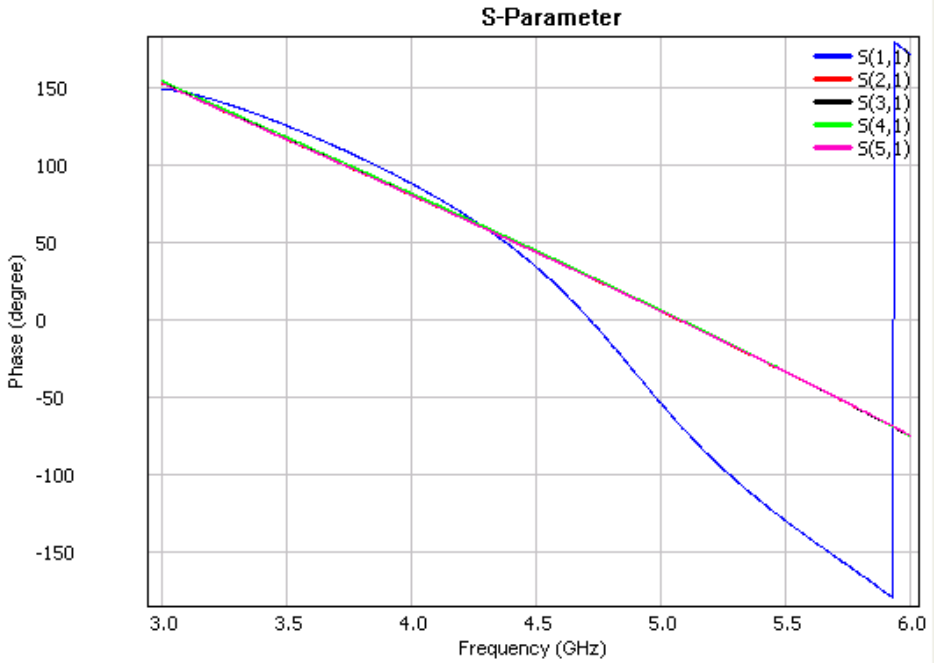
- The phased array consists of three main components, including a power divider, four digital phase shifters and four patch antennas.
- The Wilkinson power divider distributes the input power to four output branches equally.
- The digital phase shifter controls the signal phase shift by the digital switches.
- Four patch antennas forms the far field radiation beam and changes the main lobe direction according to the feed signal phase difference.
- The center frequency of the whole system is 4GHz. The system is realized by microstrips.

The Wilkinson Power Divider



S Magnitude and Phase





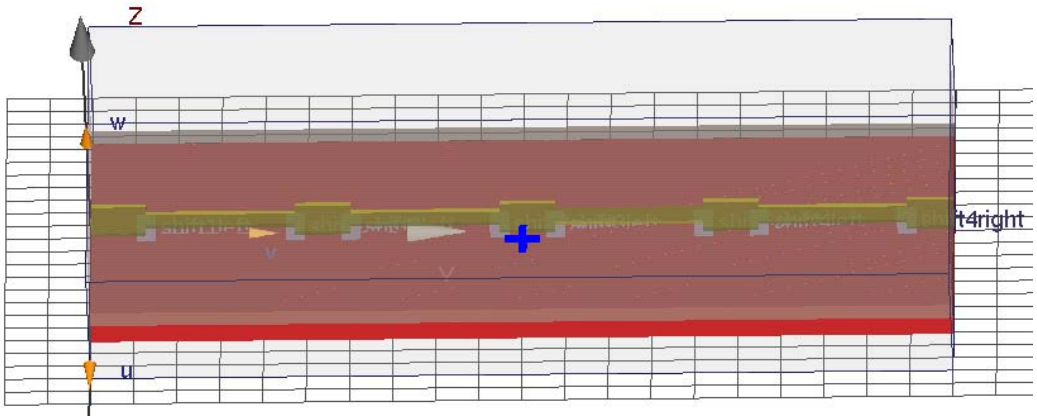
S11 is less than -15dB in a wide band and the phase difference of the four outputs is less than 1.5 degrees

The Digital Phase Shifter

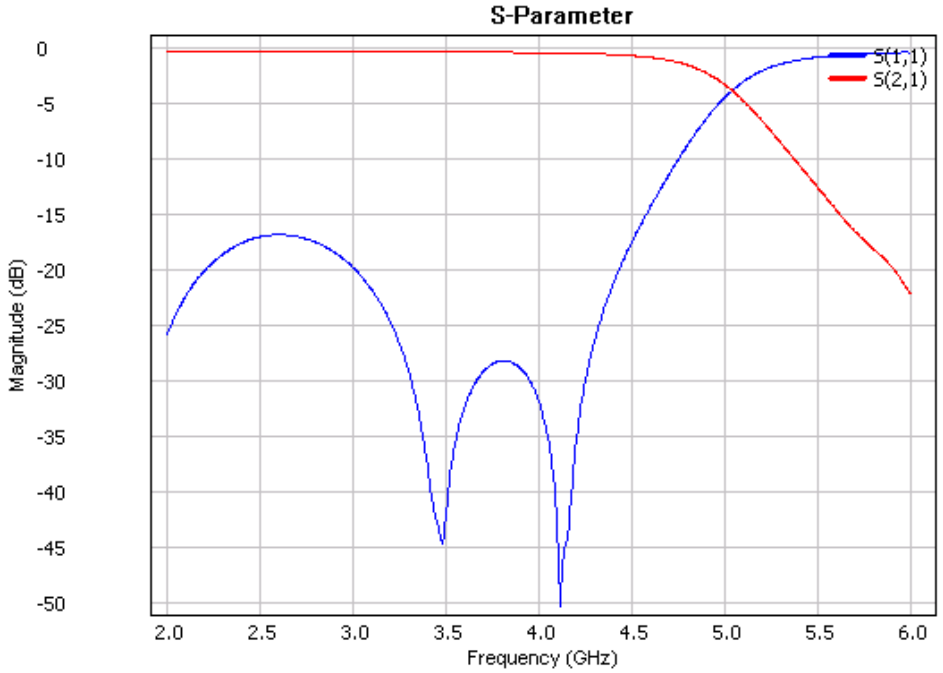
- The phase shifter is a loaded microstrip. When both switches changes their connects from C1 to C2, the equivalent electrical length changes but the impedances keep the same.

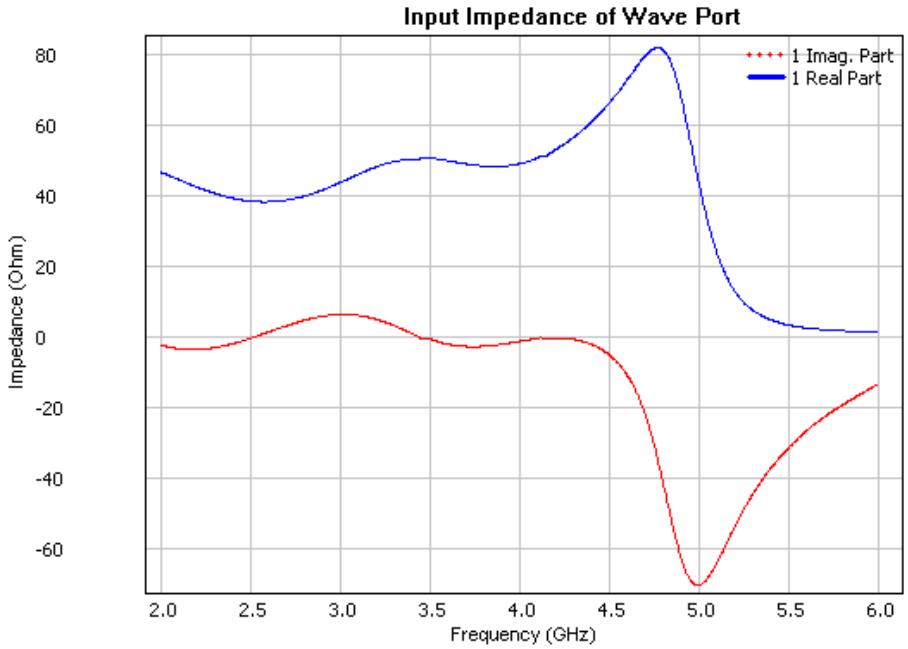
- The phase shifter in this system includes four loaded lines, corresponding to 45/8, 45/4, 45/2 and 45 four phase shift amounts.

- Four loaded lines are separated by standard 50 Ω microstrips.



S parameter and impedance

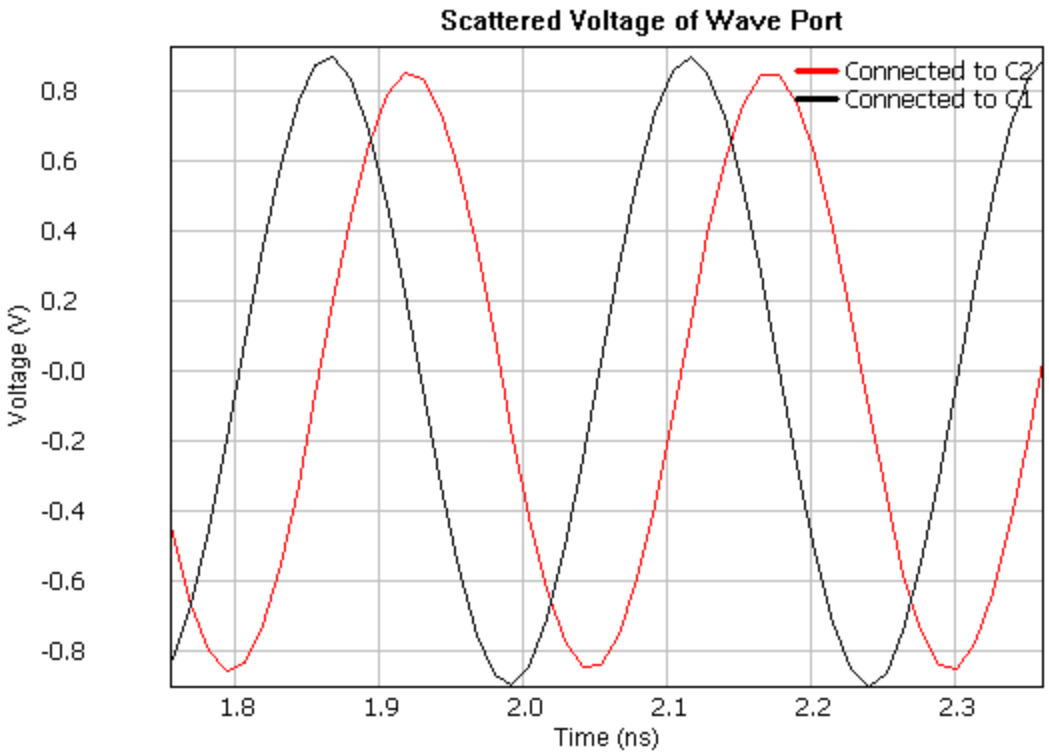




S11 is less than -30dB near 4GHz and the input impedance is near 50 Ω.

Phase Shift Test

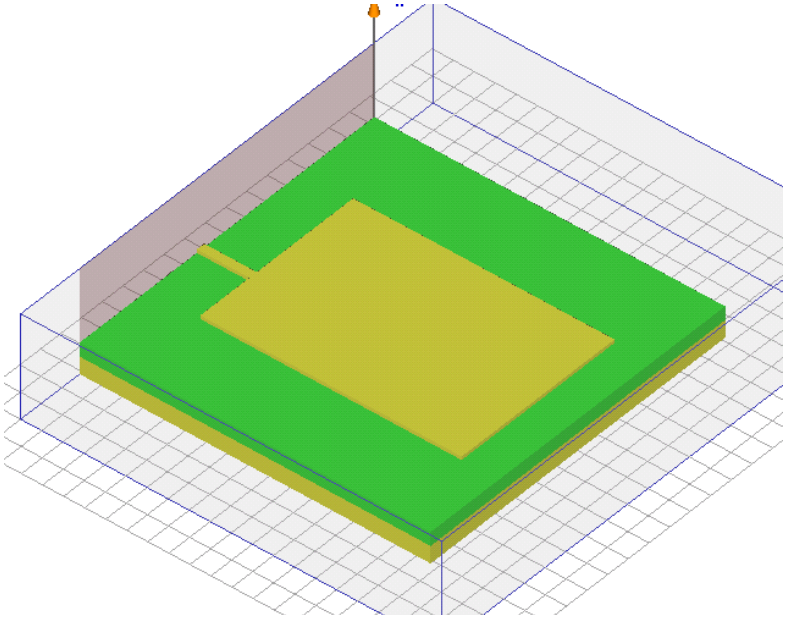
- The phase delay caused by all switches to C1 changed to all switches to C2 is 45*(1+1/2+1/4+1/8)=84.37 degrees. At 4 GHz frequency, this corresponds to 0.5859 ns time delay.
- The right picture shows the simulated two 4 GHz sinusoidal signals. The time delay is almost the same as the calculated.
- We also test other phase shifts using simulated S parameter phases and found the error to the calculated is less than 0.8 degrees.

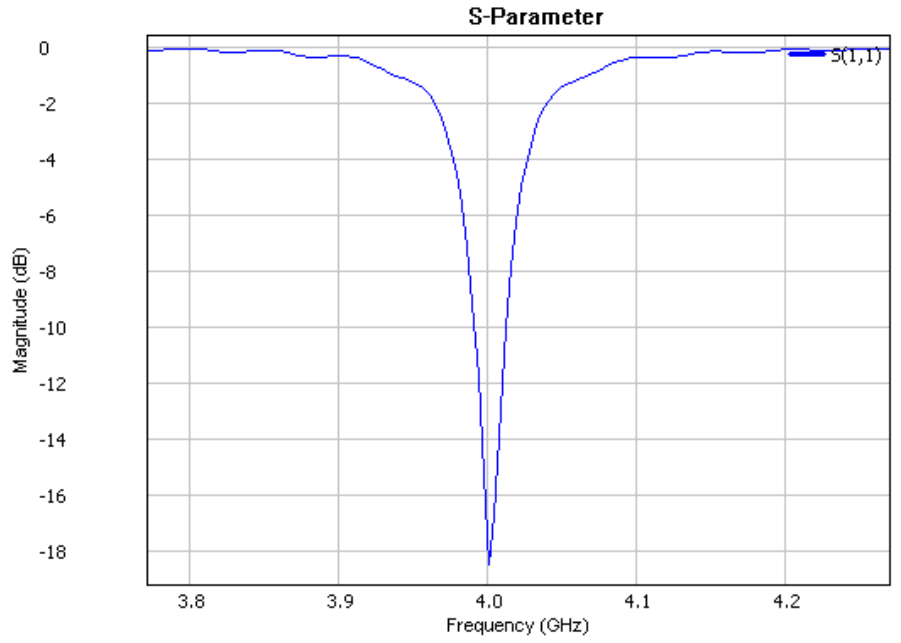


The Patch Antenna

- In order to decrease the patch antenna dimension, we use silicon as the substrate material.

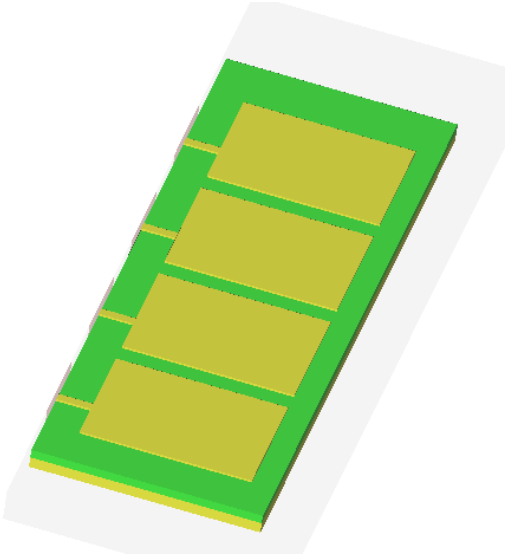
- The lower right picture shows the simulated S parameter. Near 4 GHz, S11 is less than -18 dB.

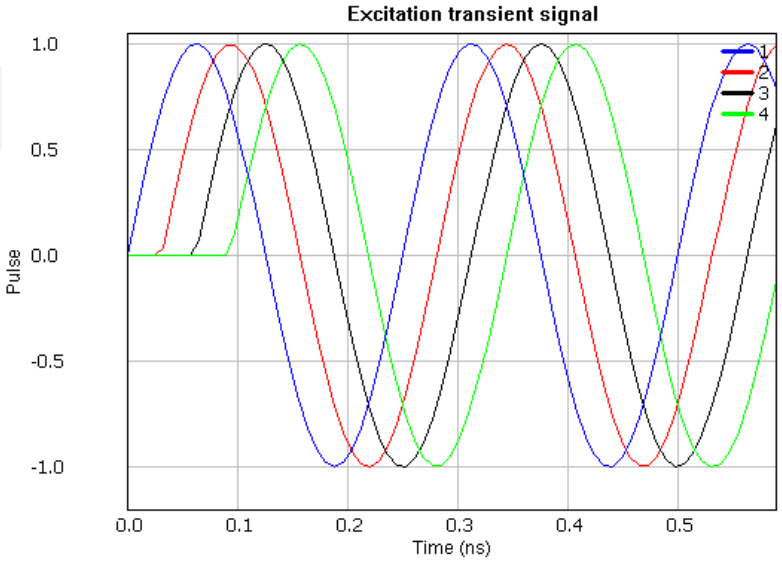


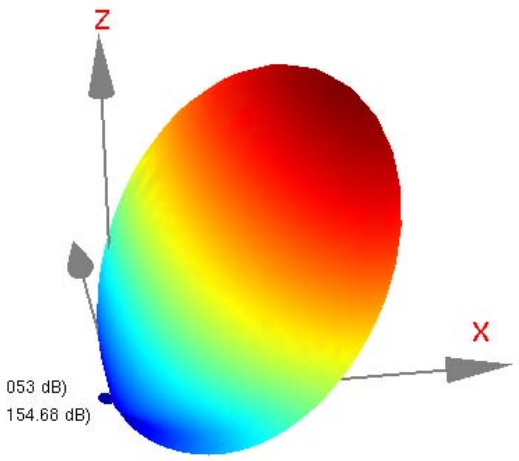


Antenna Array

- The antenna array is composed of 4 patch antennas.
- We feed the 4 antennas simultaneously but with 1/8 period time delay, i.e. 45 degrees phase difference, as is shown in lower middle picture.
- The main lobe approximately deviates to 40 degrees instead of in the positive Z direction.





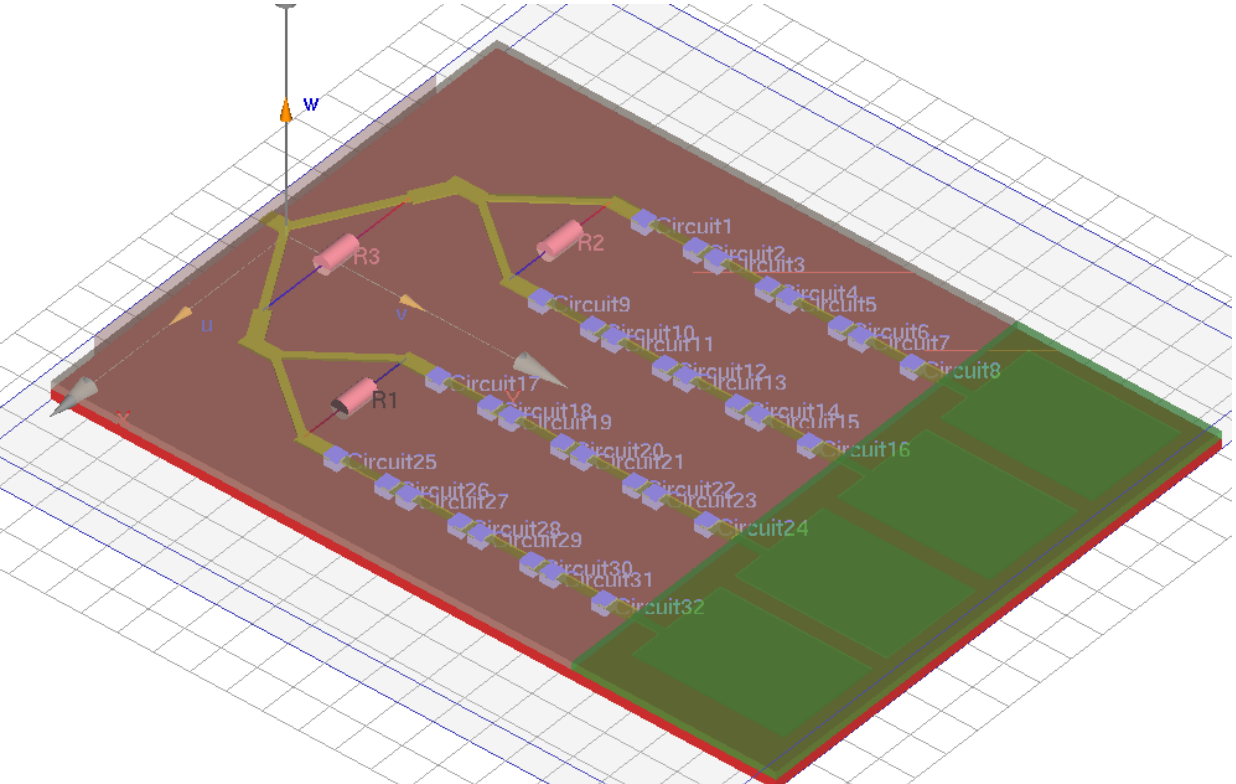


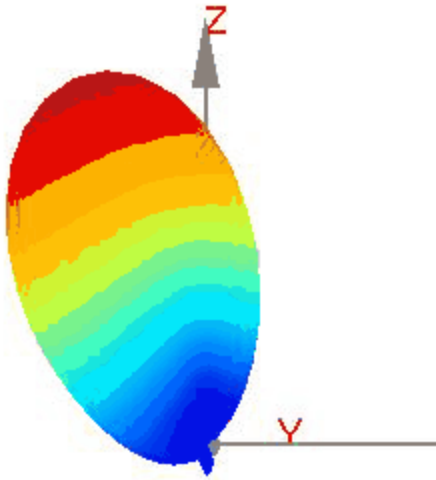
The Whole System Simulation

- We simulated the whole system in different digital switch states. Totally there are 5 phase difference states, including 1/8*45，2/8*45，3/8*45，4/8*45，5/8*45 degrees.

- If we consider the opposite direction main lobe deviations as well as the zero phase shift, there are 11 phase shift states.

- The synthesized radiation main lobe cartoon is shown in the lower right picture.





Conclusions

- Wavenology EM can co-simulate complicated EM fields and lumped circuits efficiently.
- The system contains 32 independent circuits; each circuit contains 4 capacitors, 2 resistors and two digital controlling switches.
- The systems contains 53 microstrips and two kinds of subtrates.