Lect 8

Smart antennas

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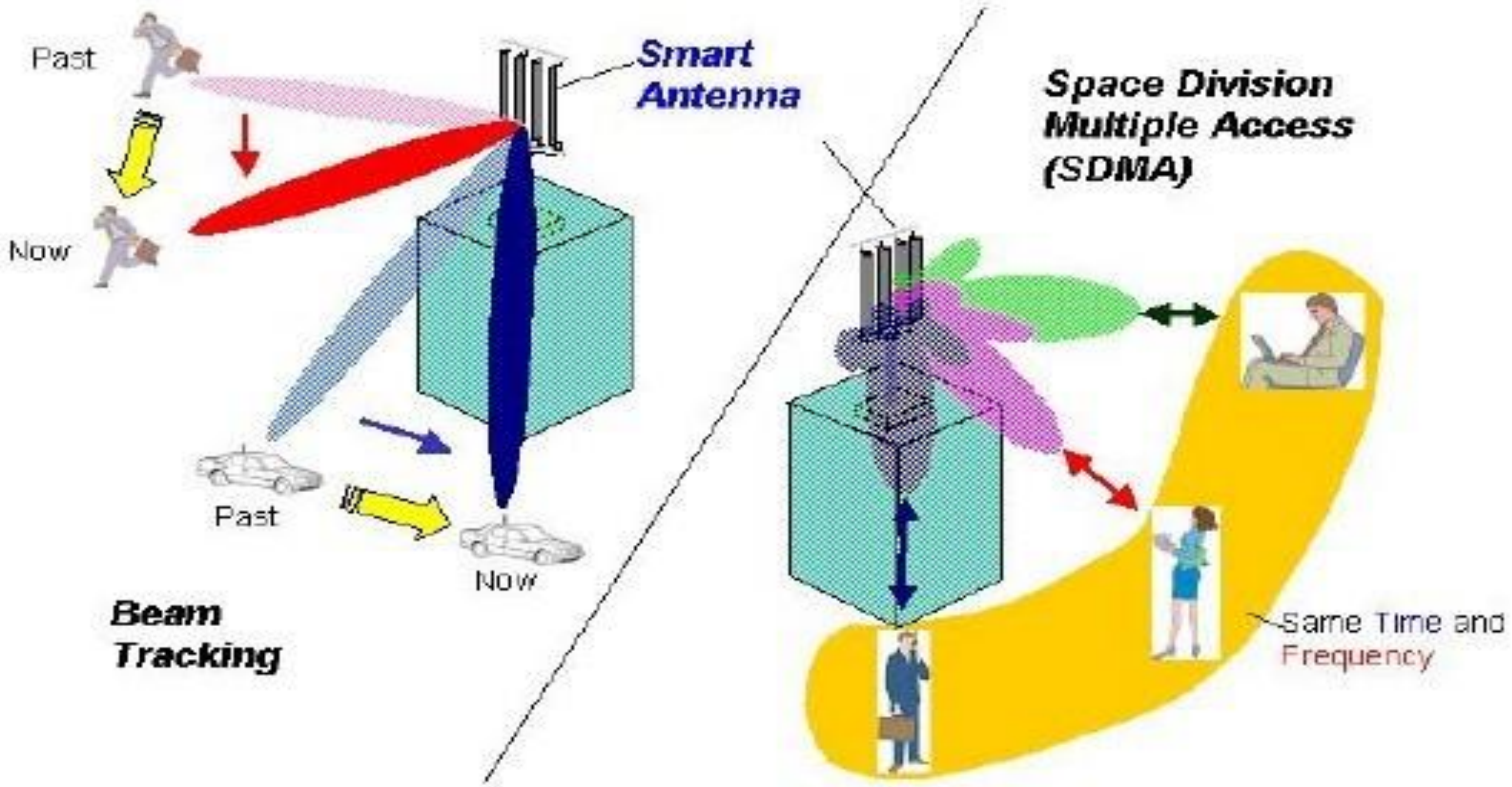
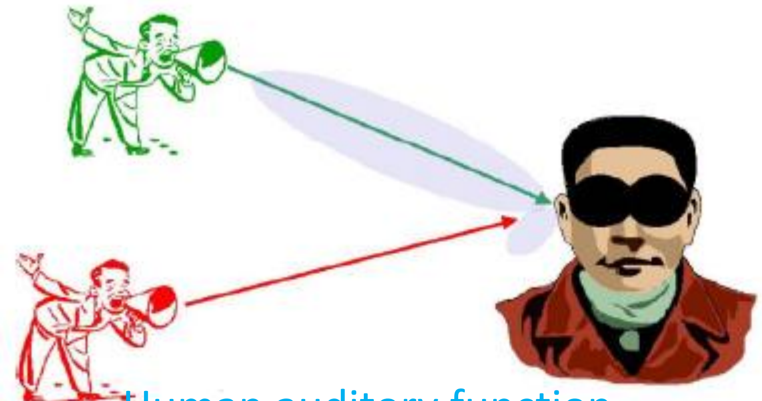
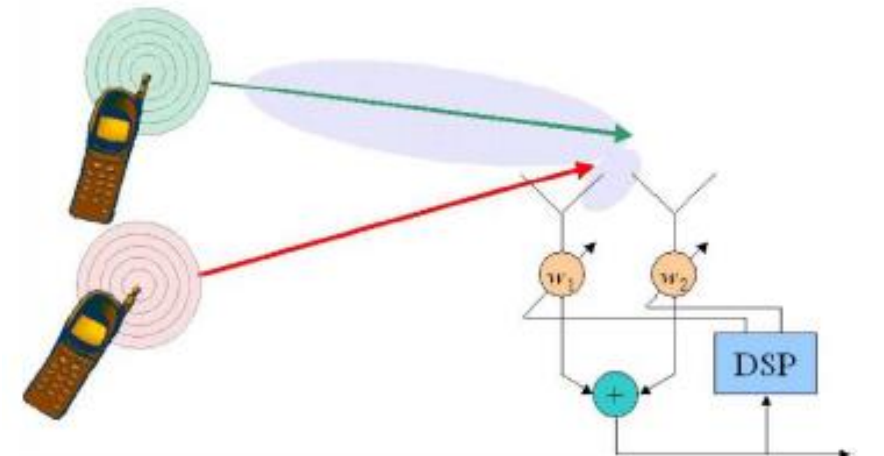


Smart Antenna Technology

IDEA OF SMART ANTENNA SYSTEM



Human auditory function

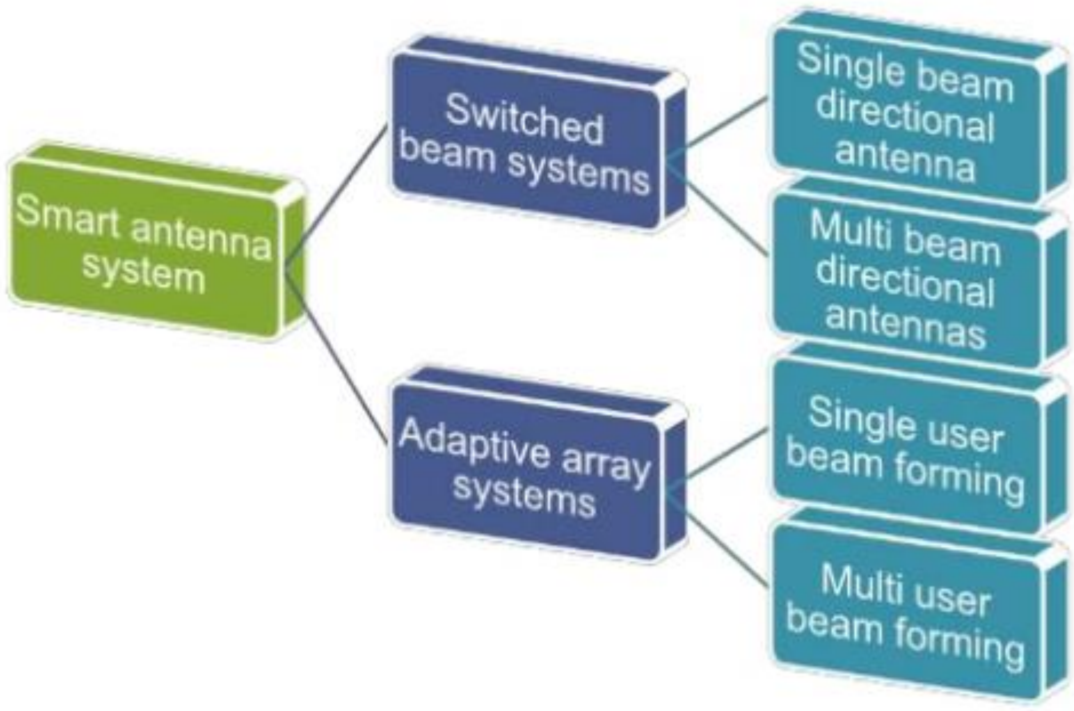


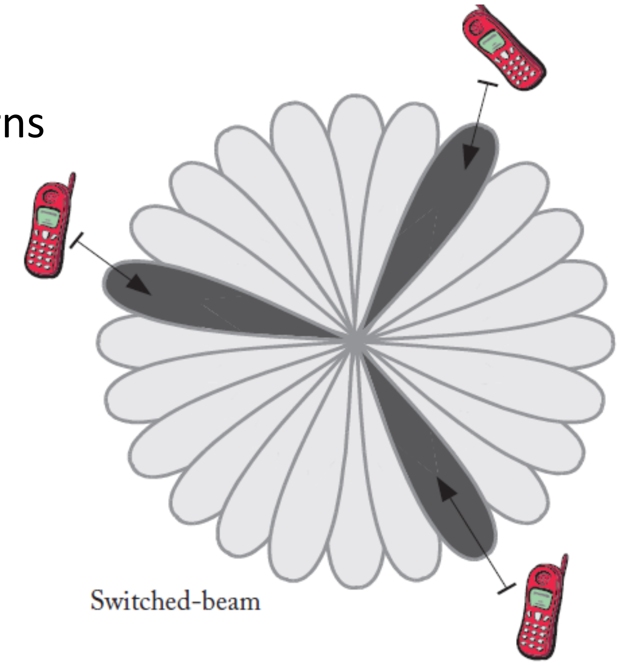
A two-element electrical smart antenna

ears act as acoustic sensors and receive the signal.	
Because of the separation between the ears, each ear receives the signal with a different time delay	time delays due to the impinging signals onto the antenna elements, the digital signal processor computes the direction-of-arrival (DOA)
The human brain, a specialized signal processor, does a large number of calculations to correlate information and compute the location of the received sound.	computes the direction-of-arrival (DOA) of the signal-of-interest (SOI}
human brain is capable of distinguishing between multiple signals that have different directions of arrival. Thus, if additional speakers join the conversation, the brain is able to enhance the received signal from the speaker of interest and tune out unwanted interferers	then it adjusts the excitations (gains and phases of the signals) to produce a radiation pattern that focuses on the SOI
concentrate on one conversation at a time.	tuning out any interferers or signals-not-of-interest (SNOI).
Conversely, the listener can respond back to the same direction of the desired speaker by orienting his/her transmitter, his/her mouth, toward the speaker.	

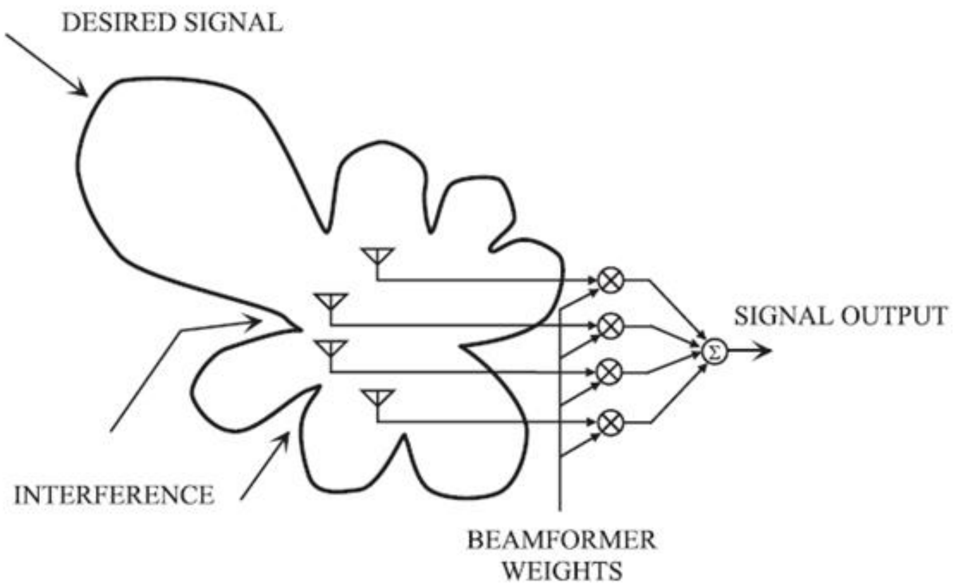
Types of smart antennas (two configurations)

Switched-Beam: A finite number of fixed, predefined patterns





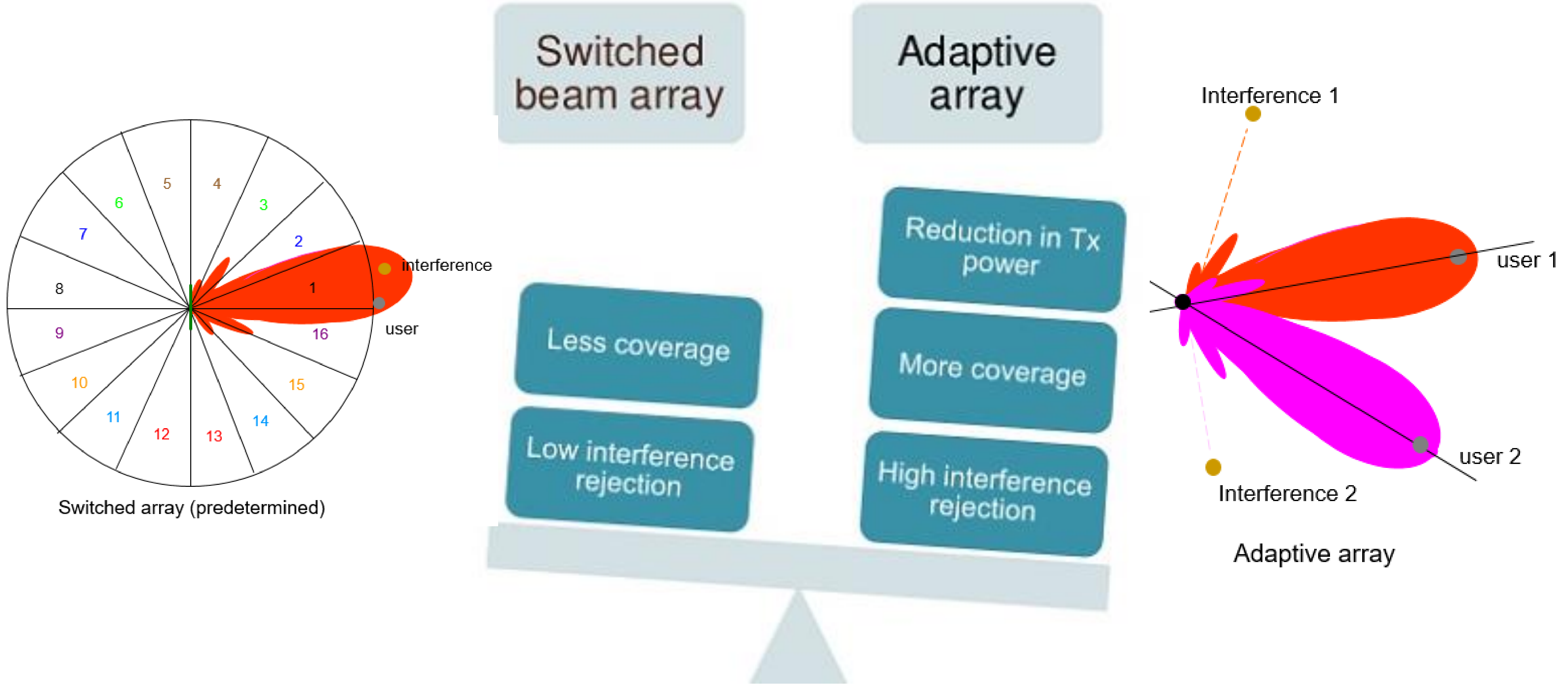
Switched-beam



Adaptive array

Adaptive Array: A theoretically infinite number of patterns (scenario-based) that are adjusted in real time according to the spatial changes of SOIs and SNOIs.

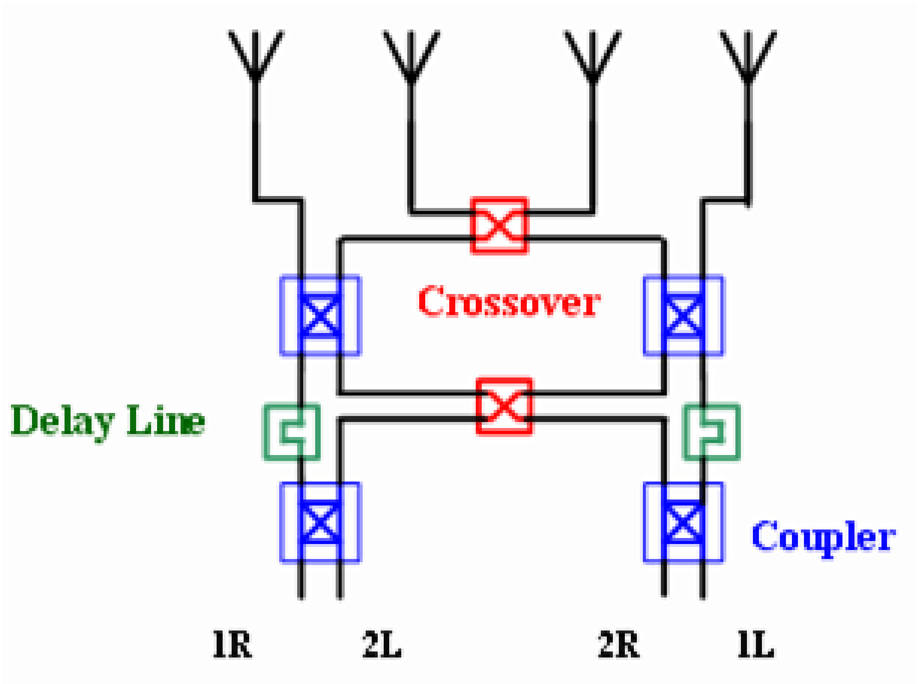
Comparing switched beam and adaptive array

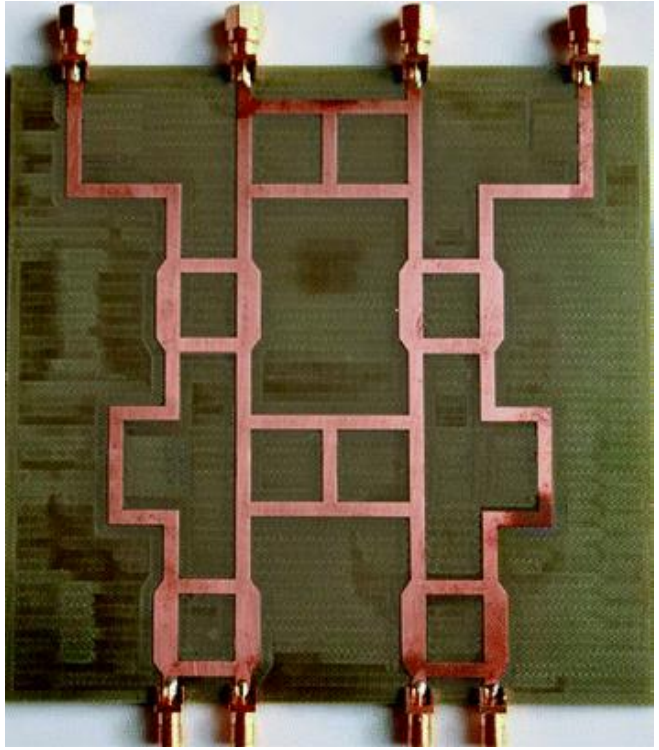


SWITCHED BEAM SYSTEM

- the base station determines the beam that is best aligned in the signal-of-interest direction and then switches to that beam to communicate with the user. The switched-beam, is based on a basic switching function, and select the beam that gives the strongest received signal

Switched beam=phased array = multi beam antenna: it consists of single beam (formed by phase adjustment only) that is steered toward the desired signal.





A more generalized to the Switched-Lobe concept is the Dynamical Phased Array (DPA). In this concept, a direction of arrival (DOA) algorithm is embedded in the system. The DOA is first estimated and then different parameters in the system are adjusted in accordance with the desired steering angle.

Butler matrix for narrowband switching (fixed) beamforming

- When it is connected to an array antenna, it will act so that the array will have a uniform amplitude and constant phase shift between the element of the array. This will result in radiation at one of N different discrete predefined directions covering a 180° angular sector of space

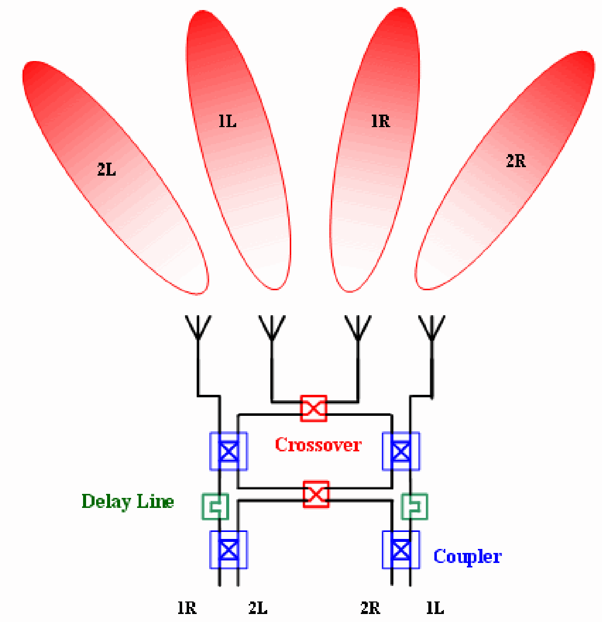
-when one of the input ports is excited by an RF signal, all the
output ports feeding the array elements are equally excited but with a progressive phase between them.
- This results in the radiation of the beam at a certain angle
- If multiple beams are required, two or more input ports need to be excited simultaneously.
- In that case the beams should be orthogonal (the angle minima of one beam pattern corresponding with the main beam angle of all of the other beams) The phase difference between the array radiating elements due to the path difference and also the beam location are given by

$\frac{2\pi d}{\lambda} \cos \gamma_{max} = -\boldsymbol{\beta}$; γ_{max} angle between array axis and $\hat{a}_r$

$$\gamma_{max} = cos^{-1} \frac{-\boldsymbol{\beta}}{kd}$$

this law appropriate

for input name (from my view)
if +ve beta selected approperiate
input name at fig next slides (for back view)



The Butler matrix contain $\frac{N}{2}log_2(N)$ 90°hybrid couplers (-90 in coupled and 0 in through) and $\frac{N}{2}(log_2(N)-1)$fixed phase shifter to form the beam pattern ,where N number of array element.

Example: if number of array element is 4 oriented on y axis and d/λ=0.5, compute number of couplers Number of phase shifters phase shifts between array elements

Solution:

Number of couplers= $\frac{4}{2}log_2(4)$=4

Number of phase shifters=$\frac{4}{2}(log_2(4)-1)$=2

1R (+1) $\beta=\frac{180^o}{4}=45^o$

1L (-1) $\beta=-\frac{180^o}{4}=-45^o$

2R (+2) $\beta=\frac{3x180^o}{4}=135^o$

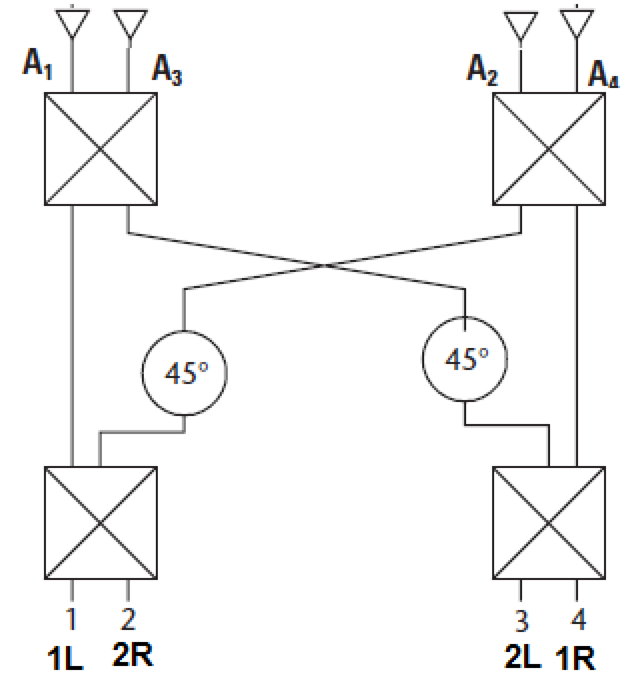
2L (-2) $\beta=-\frac{3x180^o}{4}=-135^o$

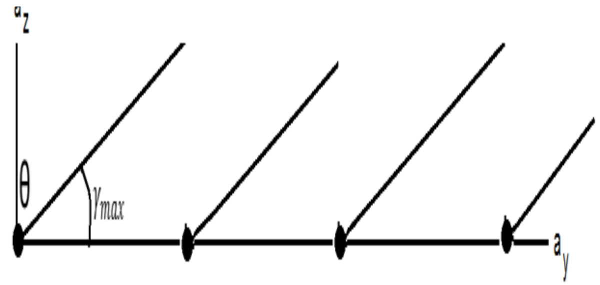
$$\gamma_{max}=cos^{-1}(\frac{\beta}{kd})$$

Output Port		A_1	A_2	A_3	A_4
P_1	1L	0°	–45°	–90°	–135°
P_2	2R	–90°	45°	–180°	–45°
P_3	2L	–45°	–180°	45°	–90°
P_4	1R	–135°	–90°	-45°	0°

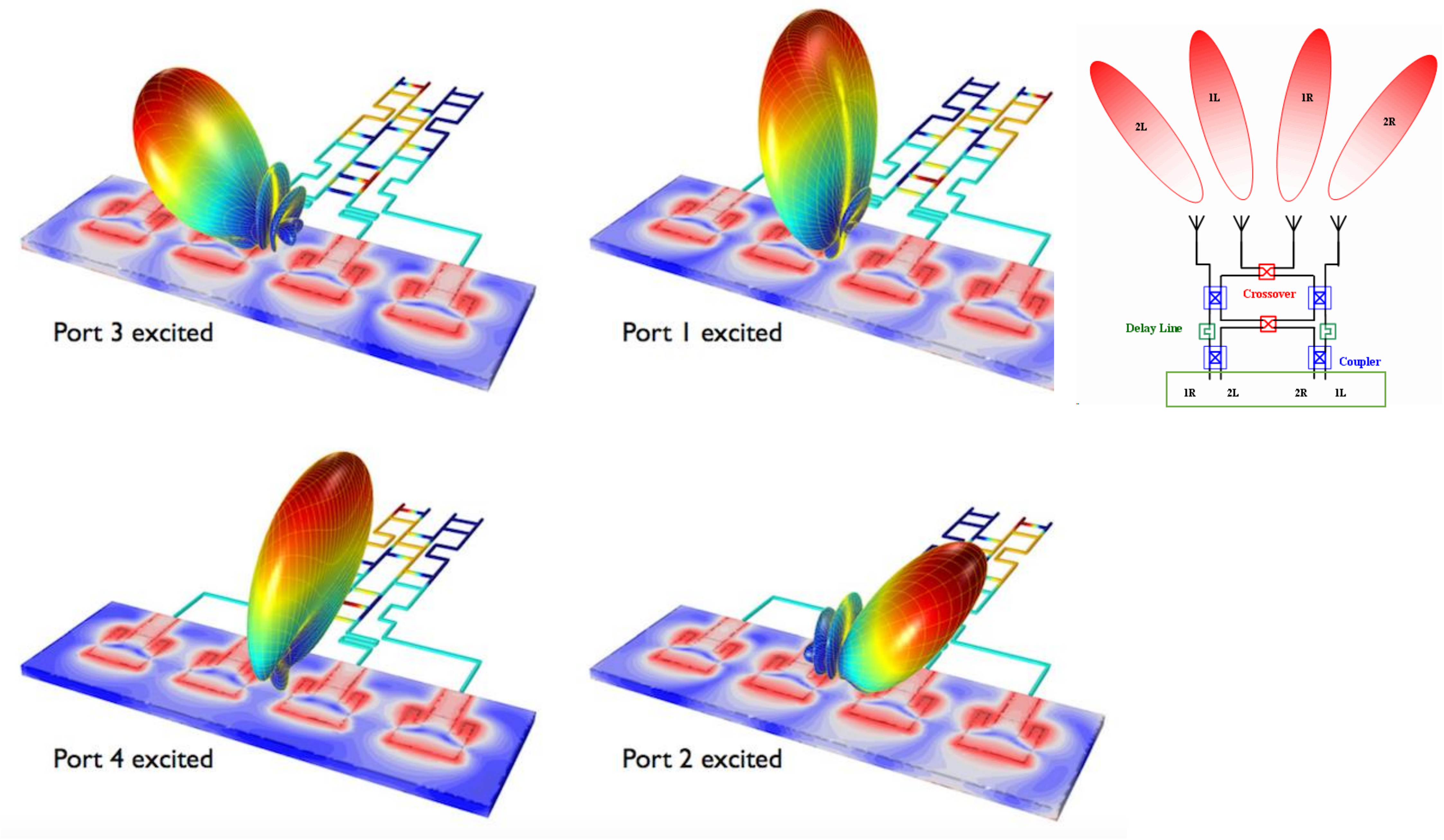
Table Beam Locations

Beam Index p	Phase Shift β	Beam Location γ_{max}
–2	–135°	138.6°
–1	–45°	104.5°
1	45°	75.6°
2	135°	41.4°





-ve sign is multiplied at Beta to adjust right and left beam from other view



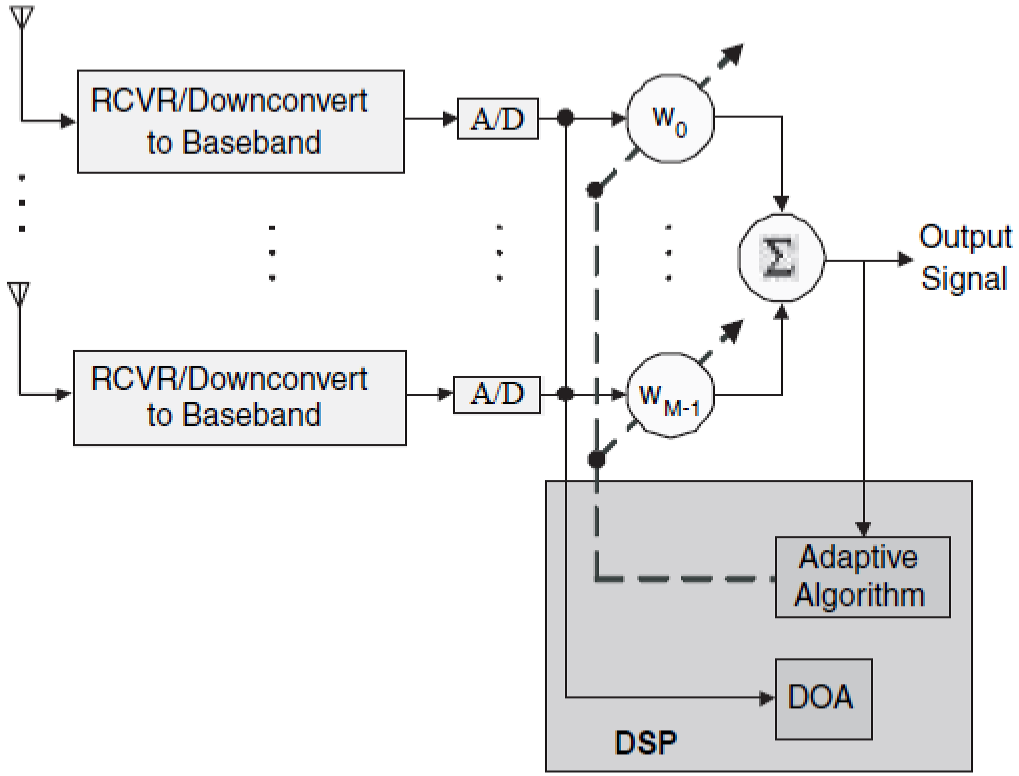
Port 3 excited
Port 1 excited
Port 4 excited
Port 2 excited
2L
1L
1R
2R
Crossover
Delay Line
Coupler
1R
2L
2R
1L

when different signals are fed to or applied at all output ports, corresponding radiation patterns will be produced, the superposition of which will result in multiple simultaneous beams along different angles.

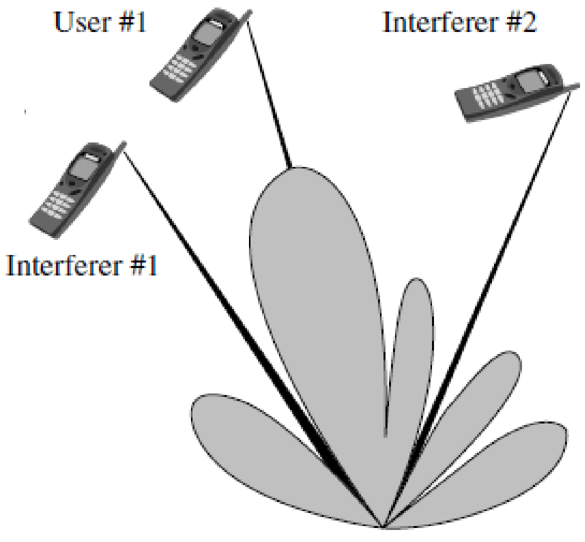
When the peak of a radiation pattern is directed along the nulls of other patterns, the beam_former is called ***orthogonal*.**

Adaptive array systems they have the ability to adapt in real time the radiation pattern to the RF signal environment

-Because of the ability to control the overall radiation pattern in a greater coverage area for each cell site adaptive array systems can provide great increase in capacity.



Functional block diagram of an adaptive array system.



(b) Adaptive scheme

- Adaptive array systems can **locate** and **track** signals (users and interferers) and dynamically adjust the antenna pattern to enhance reception while minimizing interference using signal processing algorithms

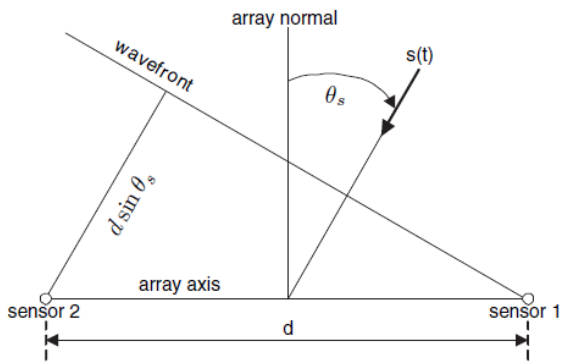
1- compute DOA direction-of-arrival by: **time delays** between the antenna elements

2- the adaptive algorithm, using a cost function, computes the appropriate **complex weights** that result in an optimum radiation pattern.

BASIC PRINCIPLES

Horizontal array (on y or x axis)

$$\Delta\tau = \frac{d\sin\theta_s}{\upsilon_0} \longrightarrow \theta_s = \sin^{-1}\left[\frac{\upsilon_0\Delta\tau}{d}\right]$$



vertical array (on z axis)

Example 16.1

Derive the DOA of a two-element array. Show that the angle of arrival/incidence can be determined on the basis of time delays and geometry of the system.

Solution: On the basis of the geometry of Figure 16.24, the time difference of the signal arriving at the two elements can be written as

$$\Delta t = (t_1 - t_2) = \frac{\Delta d}{\upsilon_0} = \frac{d\cos(\theta)}{\upsilon_0}$$

where υ_0 is the speed of light in free-space. This equation can be rewritten as

$$\cos(\theta) = \frac{\upsilon_0}{d}\Delta t = \frac{\upsilon_0}{d}(t_1 - t_2)$$

This clearly demonstrates that the angle of incidence θ (direction of arrival) can be determined knowing the time delay between the two elements ($\Delta t = t_1 - t_2$), and the geometry of the antenna array (in this case a linear array of two elements with a spacing d between the elements).

vertical array (on z axis)

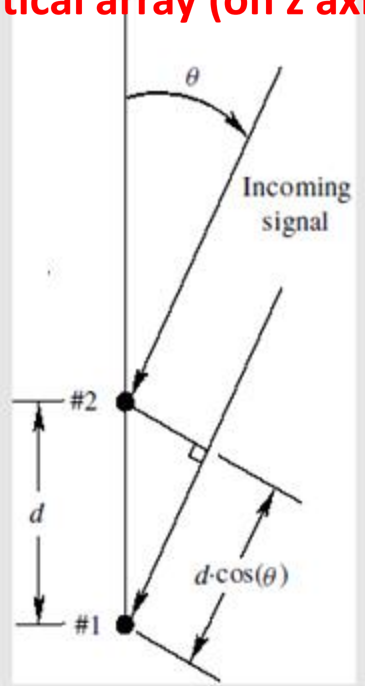


Figure 16.24 Incoming signal on a two-element array.

Example

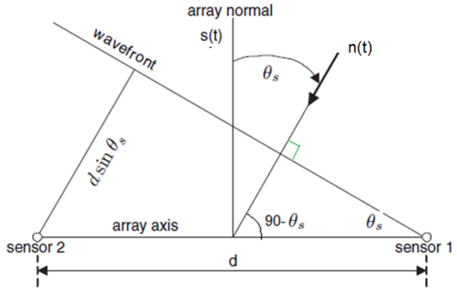
Determine the complex weights of a two-element linear array, half-wavelength apart, to receive a desired signal of certain magnitude (unity) at $\theta_0 = 0°$ while tuning out an interferer (SNOI) at $\theta_1 = 30°$, as shown in Figure The elements of the array are assumed to be, for simplicity, isotropic and the impinging signals are sinusoids.

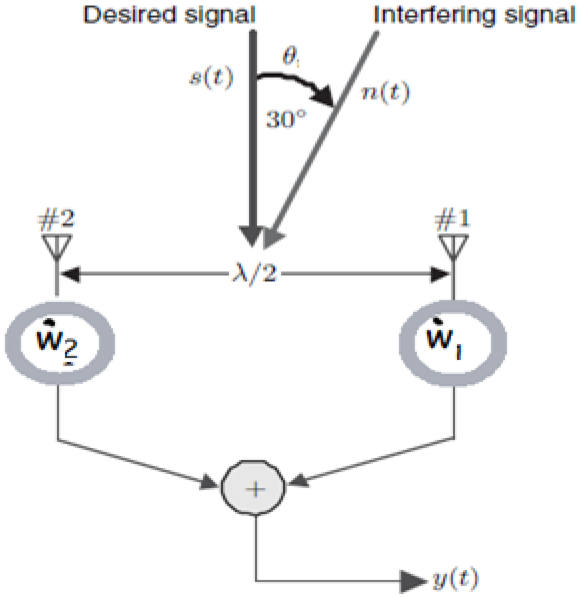
w1=r1+jX1

w2=r2+jx2

$S(t)=s(t)\,[\ w1+w2\ ]$

$N(t)=n(t)\,[\ w1-jw2\ ]$





w1+w2 =1 (1+j)w2=1

w1-jw2=0 (1+j)(r2+jx2)=1

real r2-x2=1
imag r2+x2=0] 2r2=1 r2=0.5, x2=-0.5

w1+w2=.5-j.5+r1+jx1=1

real .5+r1=1 r1=0.5
imag -.5+x1=0 x1=0.5