

Part 2

Directional Antenna Fundamentals

Mineo Takai

UCLA Computer Science Department
Scalable Network Technologies

mineo@cs.ucla.edu / mineo@scalable-netowrks.com

© 2003 Mineo Takai

Antenna Types (1)

- Isotropic
 - Spherical radiation pattern
 - Idealistic antenna to establish the baseline
- Omni-directional
 - Omni-directional radiation pattern on azimuth (horizontal) plane
 - Typically not uniform pattern on elevation (vertical) plane, thus it may have azimuth gain over isotropic antenna
 - Dipole antenna: 2.15 dBi
 - Omni-directional 3 degree down tilt: 10 – 15 dBi

Antenna Types (2)

■ Directional

- Directional radiation pattern on azimuth plane
 - Yagi
 - Sector
 - Patch
 - Parabolic
- 2-8 to 180 degree beamwidth
- 3 to 30-40 dBi gain
- Narrower beamwidth, higher gain

Antenna Terms: Gain

- dBi: gain over isotropic antenna
- A 20 dBi antenna can receive a signal with 100 times higher power than isotropic antenna
- dB: easier to use than linear values
 - $RP = TP + G_{Tx} + G_{Rx} - (PL_1 + PL_2 + \dots)$ in dB
 - $RP = TP \times G_{Tx} \times G_{Rx} / (PL_1 \times PL_2 \times \dots)$ in linear
 - RP : Reception Power
 - TP : Transmission Power
 - G_{Tx} : Transmitter Antenna Gain
 - G_{Rx} : Receiver Antenna Gain
 - PL_i : Pathloss

Antenna Terms: Beamwidth

- Beamwidth is the angular separation between the points on the antenna radiation pattern, where the gain is 3 dB less than the peak
- Why 3 dB?
 - 3 dB = 0.48 \approx 0.5: half of the peak
 - 3 dB beamwidth is also referred to as half power beamwidth
- X° beamwidth antenna does not mean that it does not cause high interference to other directions

Antenna Terms: Others

■ Signal information

- DOA (Direction of Arrival) \approx AOA (Angle of Arrival)
- Amplitude
- Phase

These are per path, not per transmitter

■ EIRP: Effective Isotropic Radiated Power

- $EIRP = TP + G_{Tx}(DOA)$
- This is what people should really care about, not transmit power or gain individually!

Directional Antenna Systems

- Collection of directional antennas
 - Covers up all directions with directional antenna elements
 - Omni-directional transmission possible (not perfect)
- Collection of omni-directional antennas
 - Electrical beamforming

Beamforming (1)

■ Mechanical

- Spinning? (6000 rpm = 10 milliseconds)
- MEMS (Micro-Electro-Mechanical Systems):
Beamforming time down to several milliseconds

■ Electrical

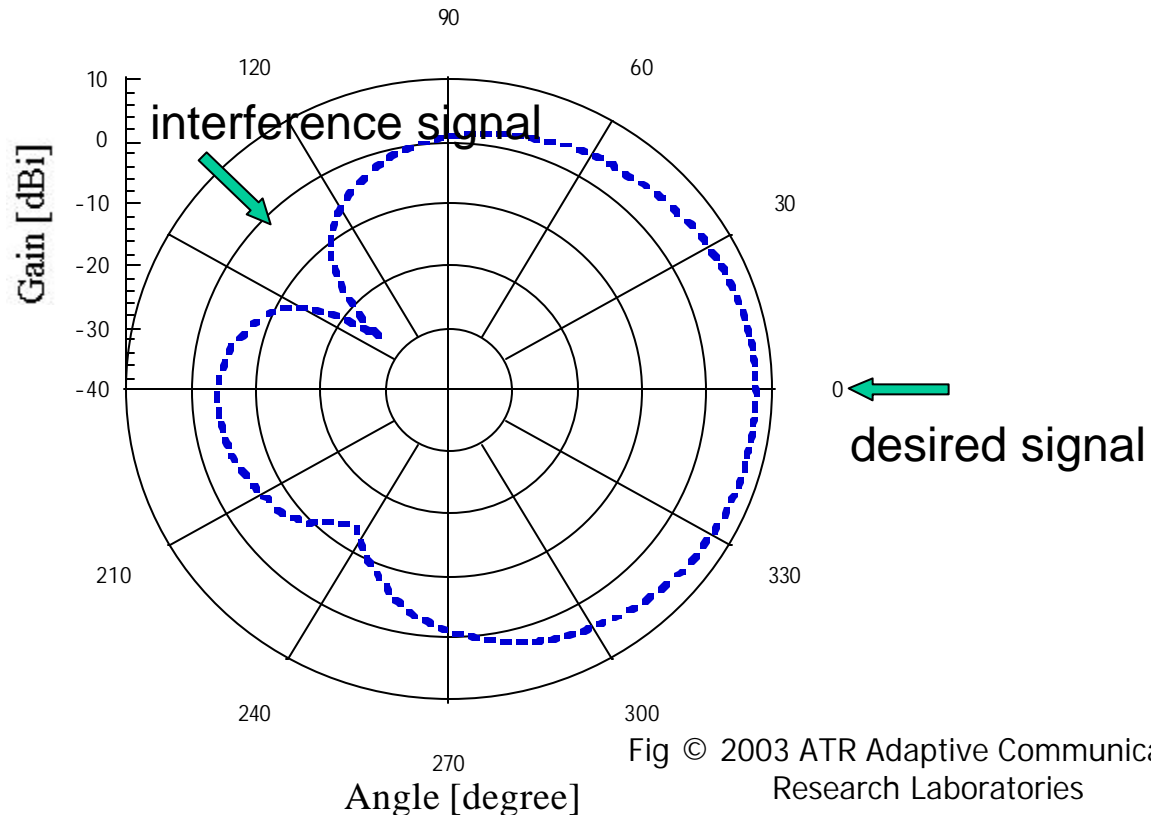
- Switched (Steered): finite number of patterns
 - Switching directional elements to use
 - Switching preconfigured patterns (weight vectors)
- Adaptive: patterns on the fly
 - Flexible but requires more signal processing

Beamforming (2)

- Beamforming direction
 - Switch (directional): boresights of elements
 - Switch (omni): can be arbitrarily set
 - Adaptive: multiple beams + nulls possible
- Time for beamforming
 - Switch (directional): per frame
 - Switch (omni): instantaneous
 - Adaptive: almost instantaneous (depending on algorithm)
- Side lobes
 - Switch (directional): up to each antenna element
 - Switch (omni): large side lobes
 - Adaptive: large side lobes, but may have less effects

Adaptive Beamforming (1)

- Better SINR (Signal to Interference and Noise Ratio) than non-adaptive beamforming



Adaptive Beamforming (2)

■ DBF: Digital beamforming

- Conventional:
Used at base stations
of cellular systems
- N antenna elements:
N beams or nulls
possible

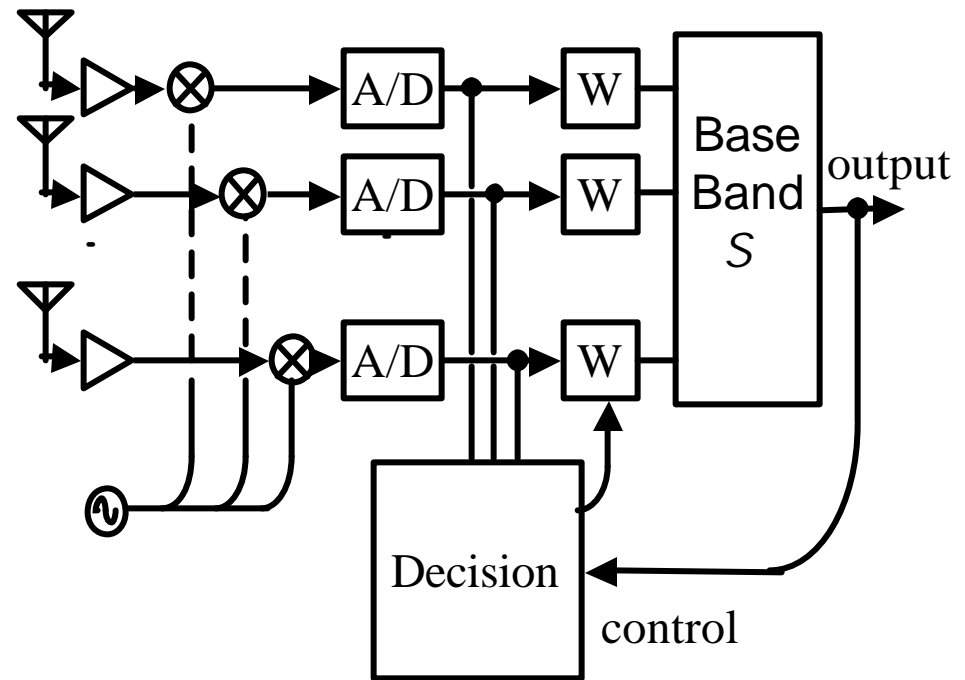


Fig © 2003 ATR Adaptive Communications
Research Laboratories

Adaptive Beamforming (3)

■ ABF: Aerial beamforming

- Compared to DBF:
 - Lighter
 - Smaller
 - Simpler
 - Cheaper
 - Less power consuming
 - Non-linear adaptation algorithm

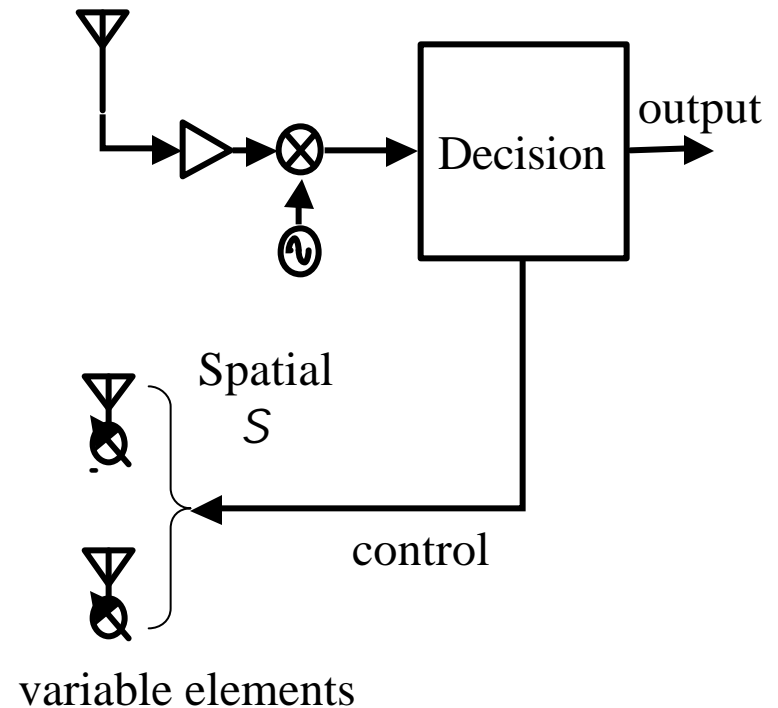
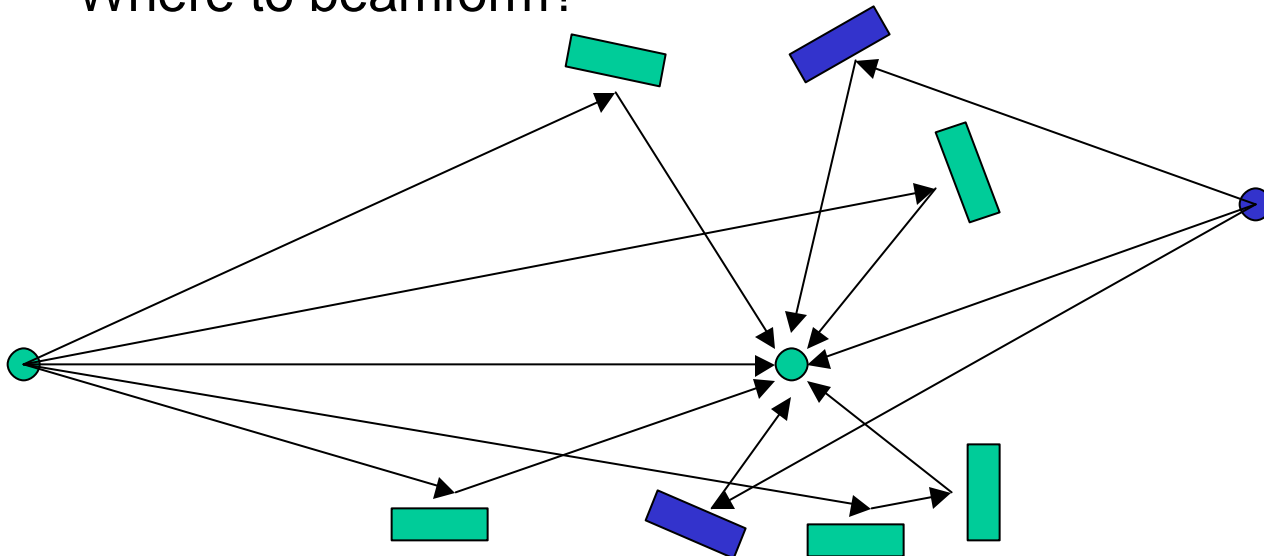


Fig © 2003 ATR Adaptive Communications Research Laboratories

Issues: Base Stations to CE (1)

- Antenna height: tens of meters to one
 - Higher path loss
 - More scatters near-by:
Larger angular spread for multipath components
 - Paths for N transmissions \gg N paths
 - Where to beamform?



Issues: Base Stations to CE (2)

- One-side directional to both-side directional
 - Now: directional base station – omni-directional mobile
 - Future: directional mobile – directional mobile
 - Beamforming much harder
 - When transmitter changes the pattern, receiver sees different signature
 - Multipath components not always bad: receiver can combine them and get more power for the desired signal

Issues: Base Stations to CE (3)

- Connection based to ad hoc communications: much easier to track mobiles if connection oriented
- Station-to-mobile to mobile-to-mobile
- Many other issues
 - Weight: no mast to hold!
 - Power: more antenna elements + signal processing means more power consumption
 - Size: laptops – PDAs – handsets
 - Cost: over tens of \$1000 to less than \$100

Issues: Base Stations to CE (4)

- ESPAR: Electrically Steerable Parasitic Array Radiator
 - One power-element & parasitic M elements with varactors
 - Low power-consumption, compact & low-cost and adaptive beam & null forming

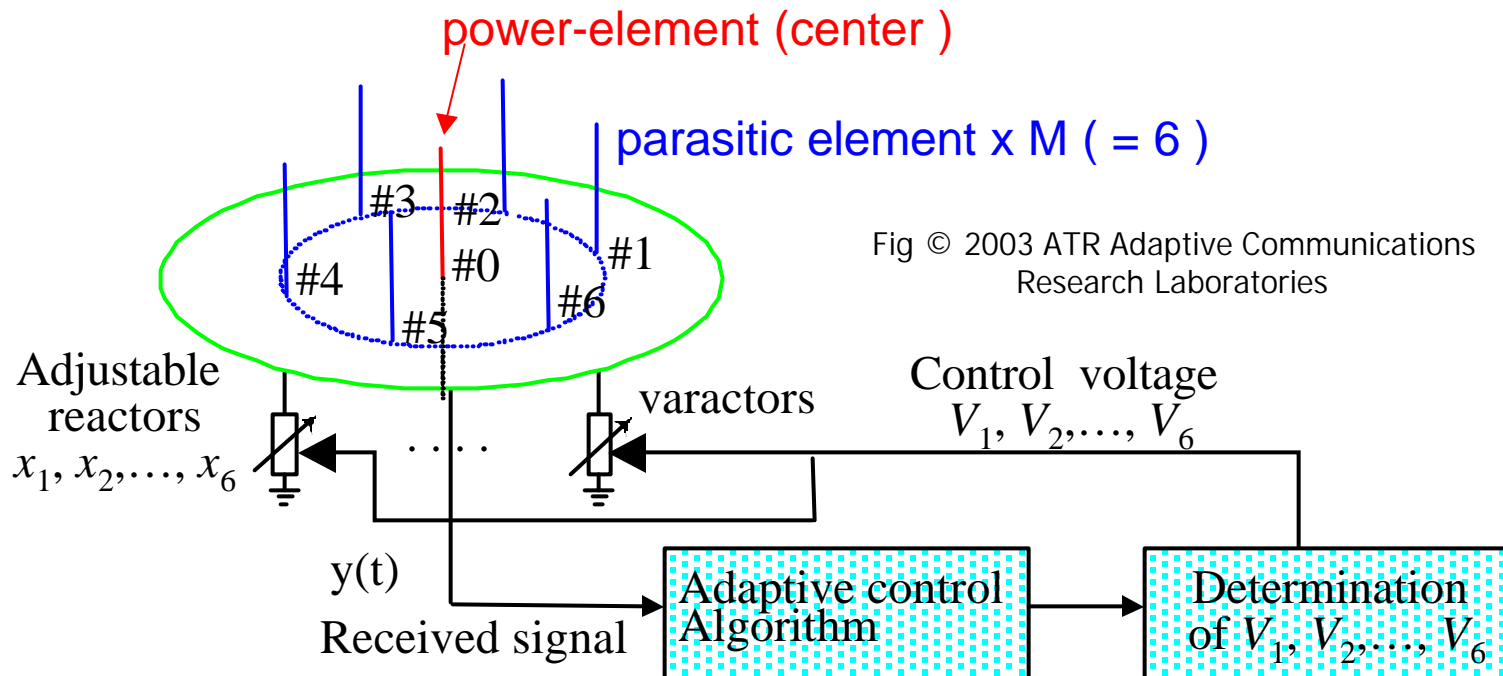


Fig © 2003 ATR Adaptive Communications Research Laboratories

Issues: Base Stations to CE (5)

- ESPAR antenna prototypes



FAQs (1)

- Receiver beamforming = Transmitter beamforming
 - Receiver has an incoming signal
 - Coherence time
- Adaptive beamforming: N beams or nulls
 - Does not mean it can reject $N - 1$ interfering signals
 - Number of multipaths & Angular spread
- Less number of strong multipath components
 - Not always a good thing

FAQs (2)

- SDMA (Space Division Multiple Access)
 - Processing gain may be necessary
- Reducing power consumption by beamforming
 - Transmit power may not be the primary factor
- DOA vs GPS
 - GPS info can be a good guess for rural environments
 - They can hardly be the same
 - Multiple DOAs for a signal

References (1)

- S. R. Saunders, “Antennas and Propagation for Wireless Communication Systems,” Wiley, John & Sons, 1999.
- T. S. Rappaport, “Wireless Communications: Principles & Practice,” Prentice Hall, 1995.
- J. C. Liberti, T. S. Rappaport, “Smart Antennas for Wireless Communications: IS-95 and Third Generation CDMA Applications,” Prentice Hall, 1999.
- T. S. Rappaport, “Smart Antennas: Adaptive Arrays, Algorithms, and Wireless Position Location,” IEEE Press, 1998.

References (2)

- Antenova: <http://www.antenova.com>
- ATR Adaptive Communications Research Laboratories: <http://www.acr.atr.co.jp/acr/top-e.html>
- Tantivy Communications: <http://www.tantivy.com>

- IEEE 802.11 Wireless Local Area Networks: <http://www.ieee802.org/11>
- IEEE 802.20 Mobile Broadband Wireless Access: <http://www.ieee802.org/20>