Antenna Based SDMA Schemes for Wireless Communications

Dr. J. R. Sanford

Smart Waves International

3385 Scott Boulevard

Santa Clara, CA 95054

Tel. (415) 412 8694

swaves@pacbell.net

Assumptions

- Wireless communication, that is not line of sight, has a limited usable spectrum due to propagation issues (0-3GHz)
- There is no limit to the amount of data we will wish to send
- Therefore, this spectrum must be used as efficiently as possible
  - All degrees of freedom must be used optimally

Outline

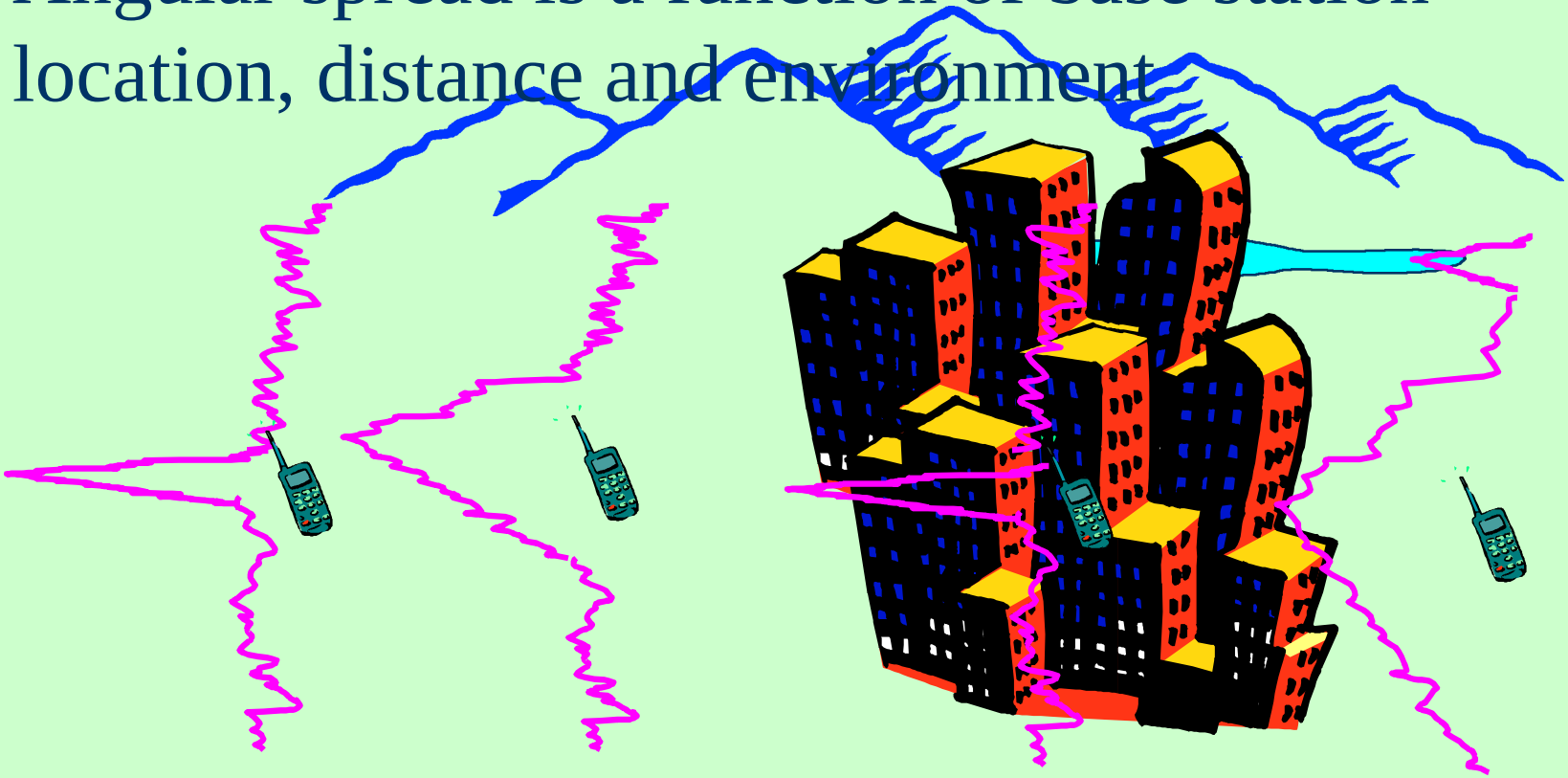
- Environment
- Goal
- Space Diversity Combining
- Multiple Beam Arrays
- Digital Beam Forming
- Frequency Scanned Systems
- Holographic Beam Forming
- Conclusions

} Overview

} New

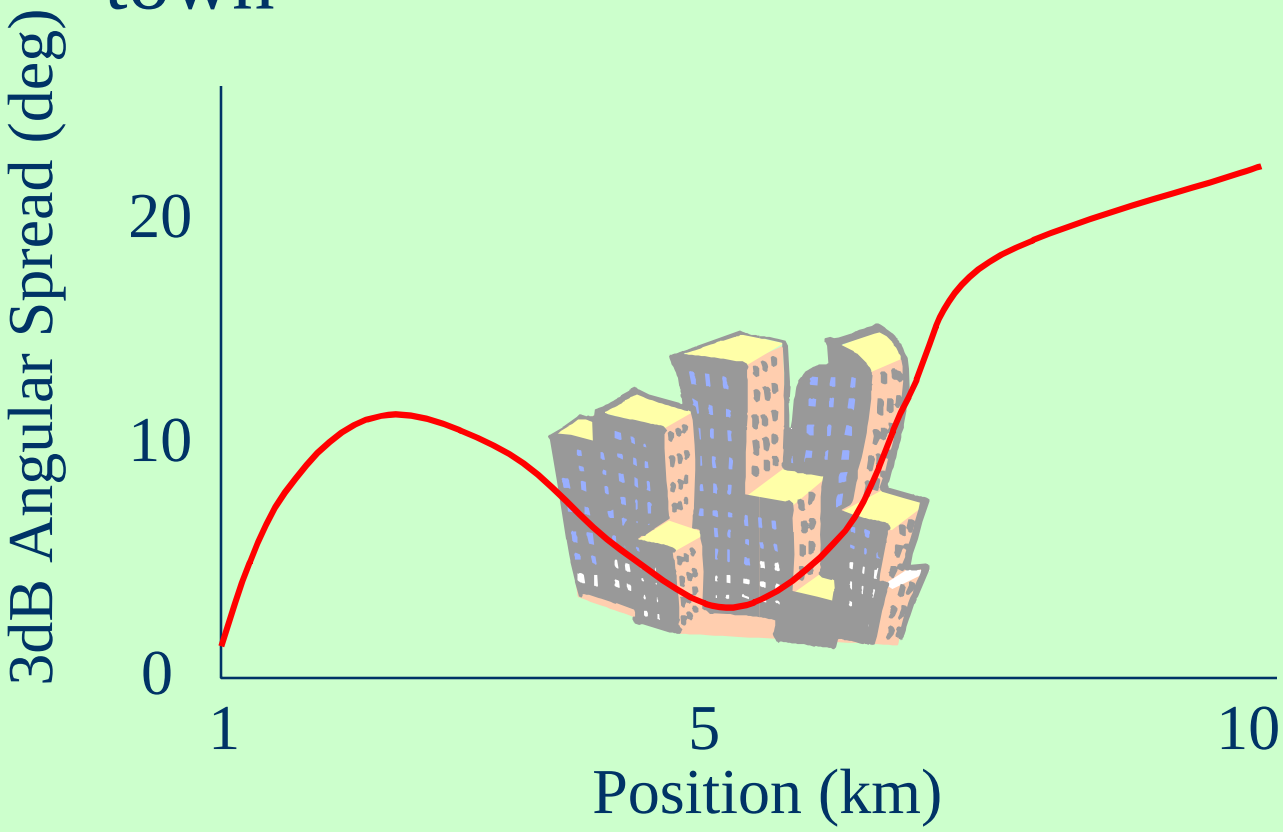
Angular Spread

- Angular spread is a function of base station location, distance and environment



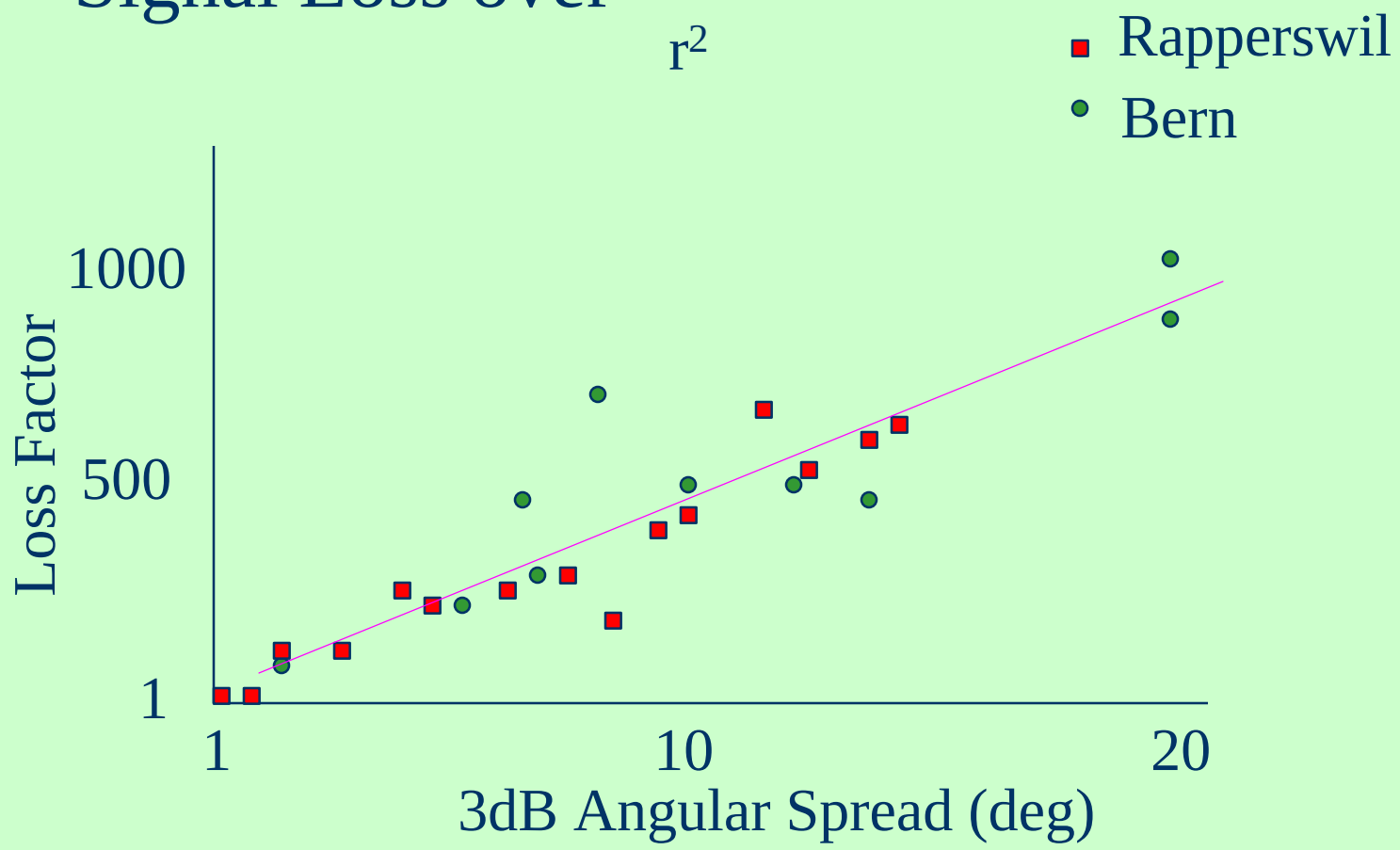
Angular Spread

- Suburban base station directed toward a town



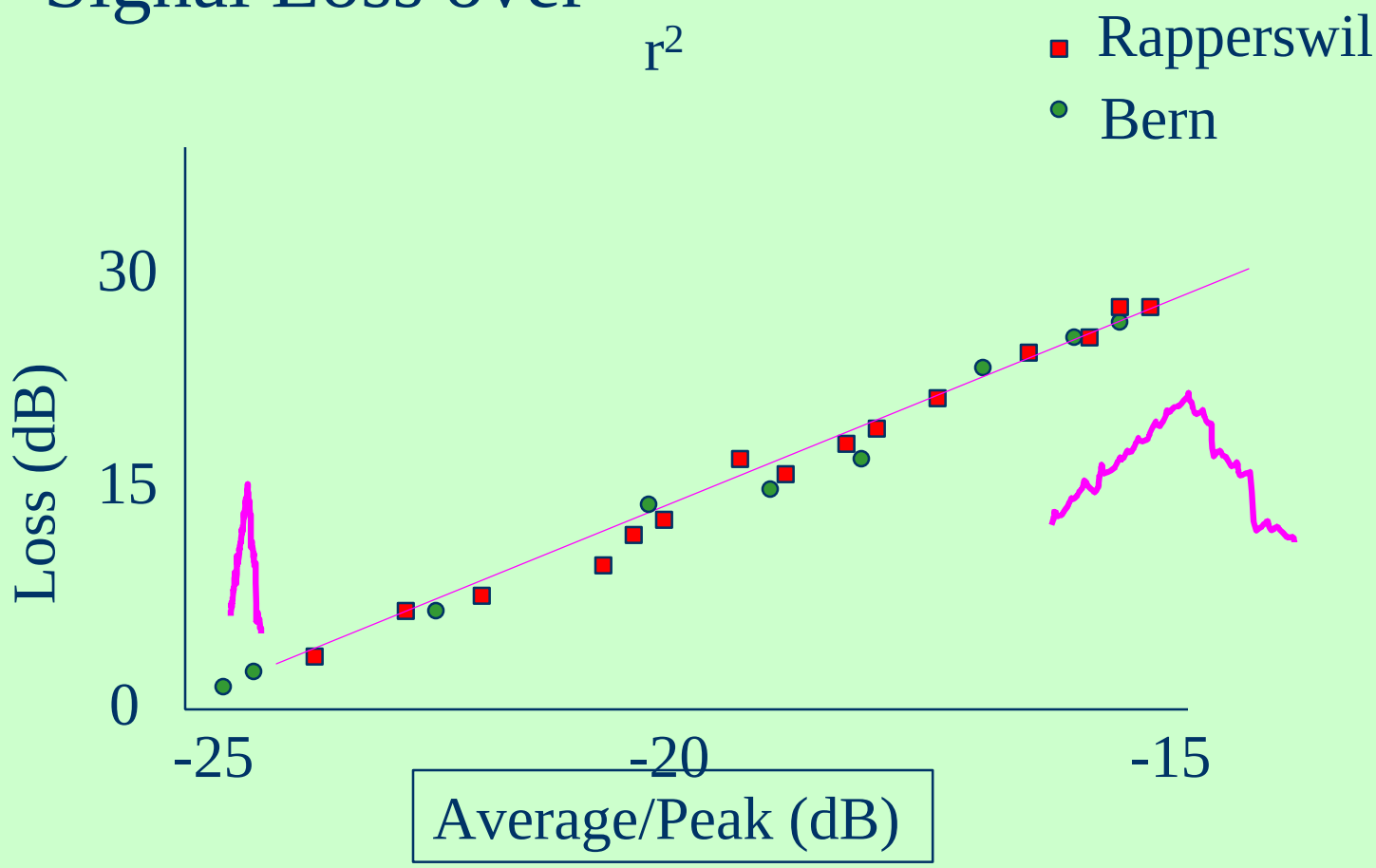
Angular Spread

- Signal Loss over $\frac{1}{r^2}$



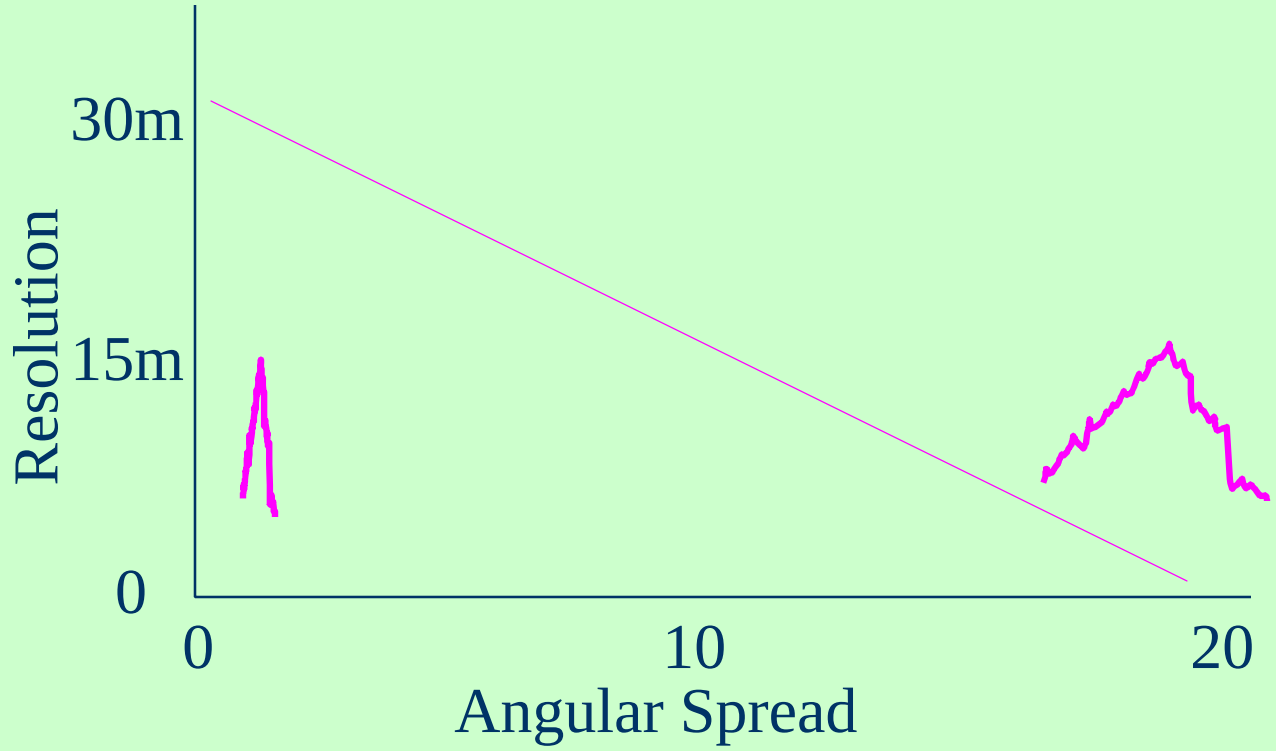
Link Directivity

- Signal Loss over $\frac{1}{r^2}$



Interference Rejection

- Resolution is directly related to interference rejection

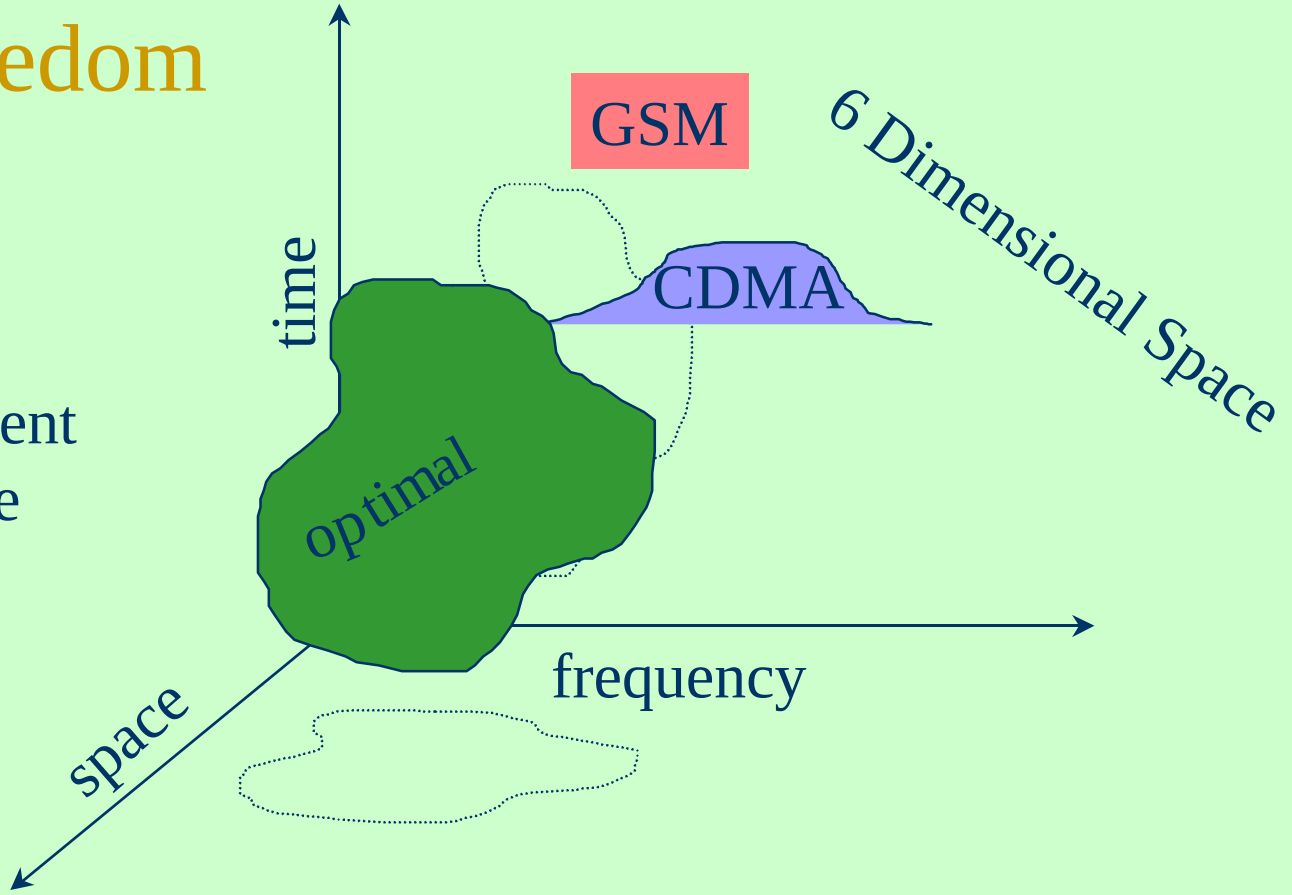


Smart Antenna Systems

- Main Goals:
  - Increase Capacity
  - Increase Range
  - Eliminate Down Time
- Additional Advantages
  - Emergency Tracking
  - Jamming Suppression

Degrees of Freedom

<u>Knowns:</u>
Propagation environment
Hardware performance
Component cost
Regulations



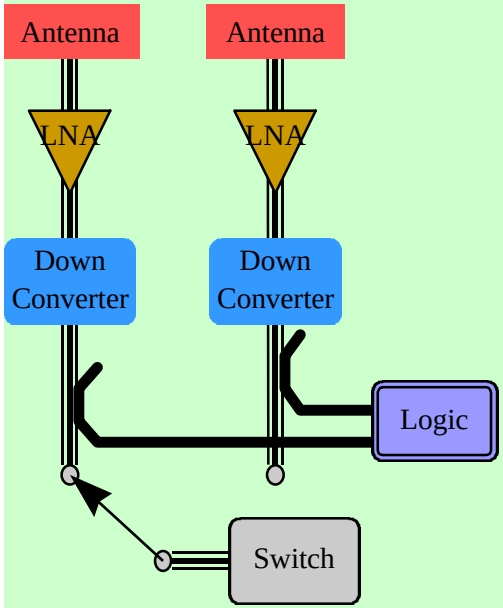
- GSM, AMS, CDMA all reside in two dimensions
- Space is four dimensional (x,y,z, polarization)
- Code is a subset of the time-frequency space

Optimization

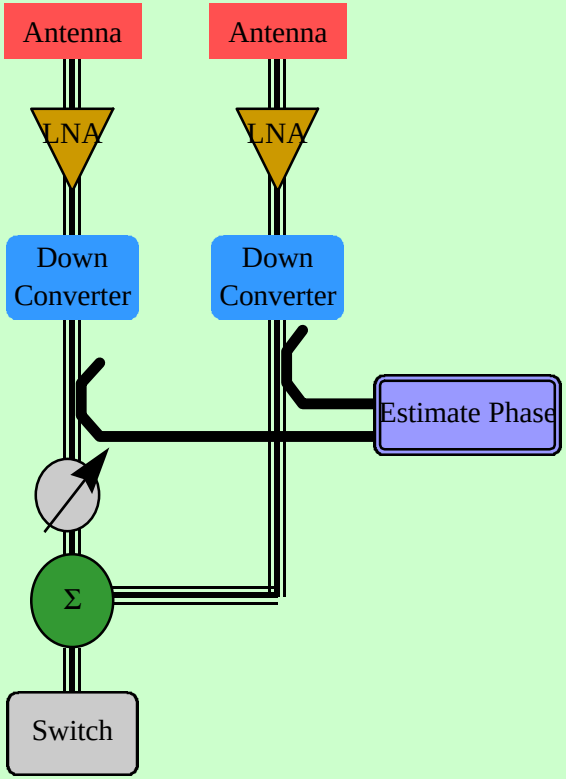
Present Standard Trends

- UMTS plans services and features
- Wide Band CDMA is the leading future standard
  - TD-CDMA as a subset for smart antennas
- Data over Voice
- Down link limits performance
  - why not allocate more bandwidth to the down link

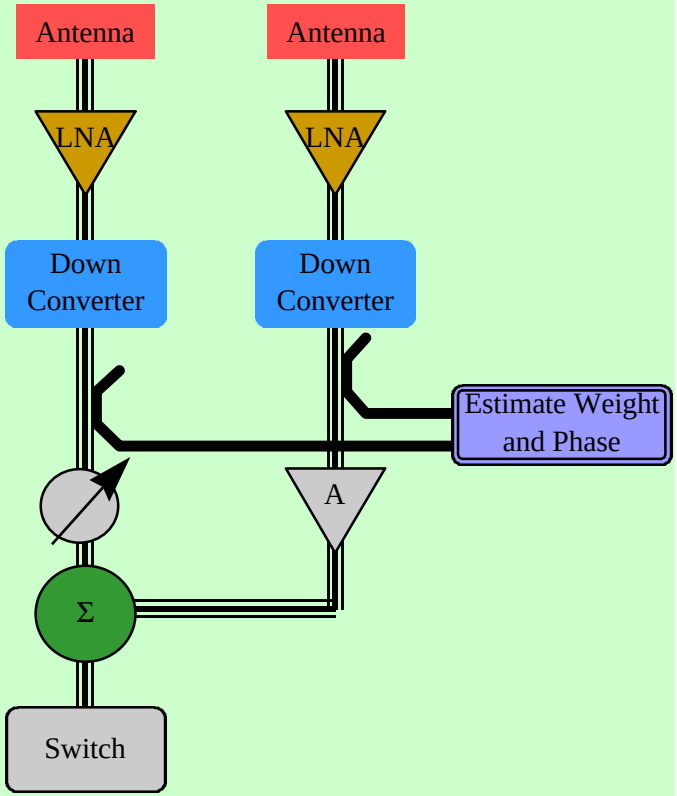
Common Space Diversity Combining Techniques



Selection Combining



Maximum Ratio Combining

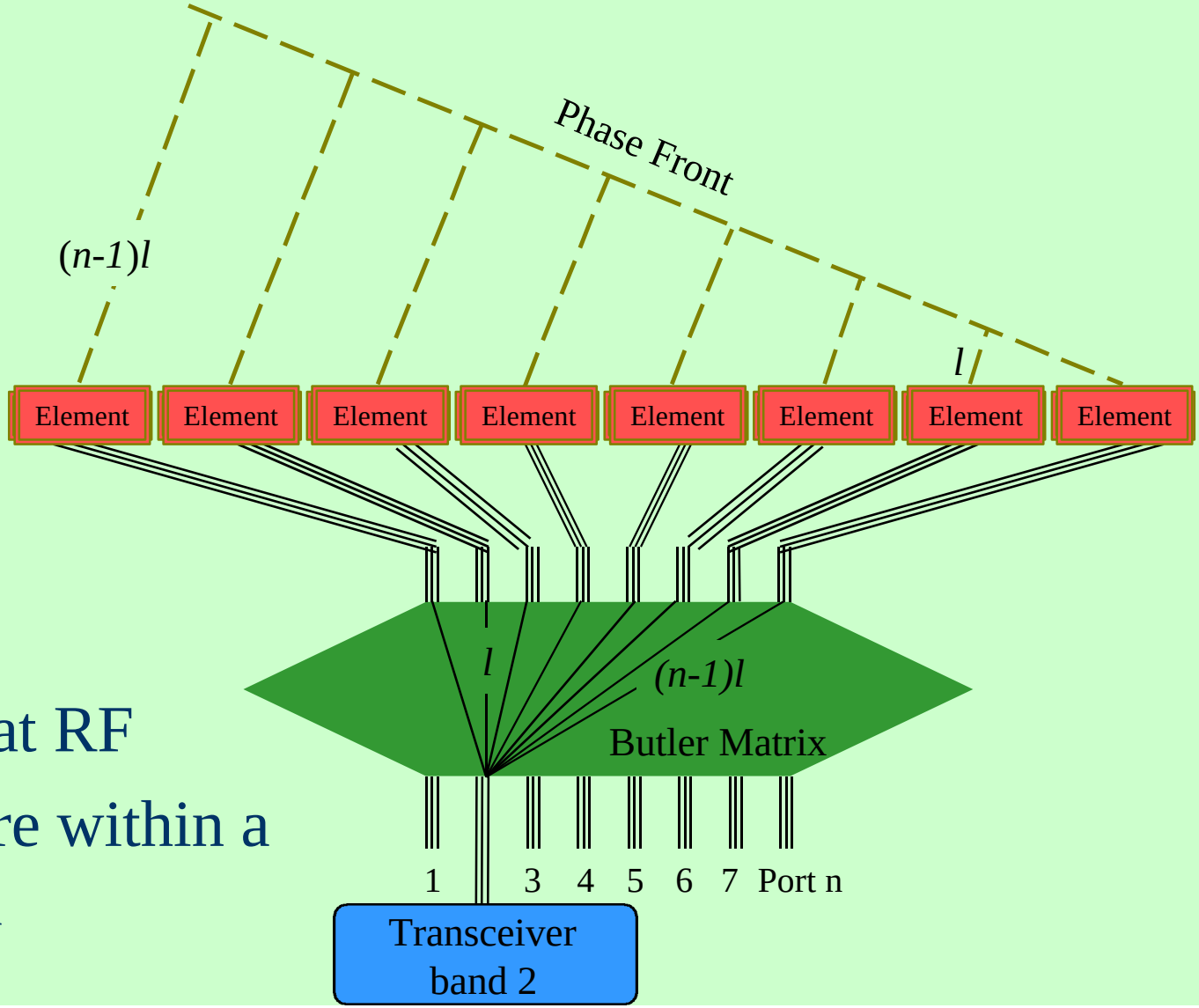


Equal Gain Combining

Space Diversity

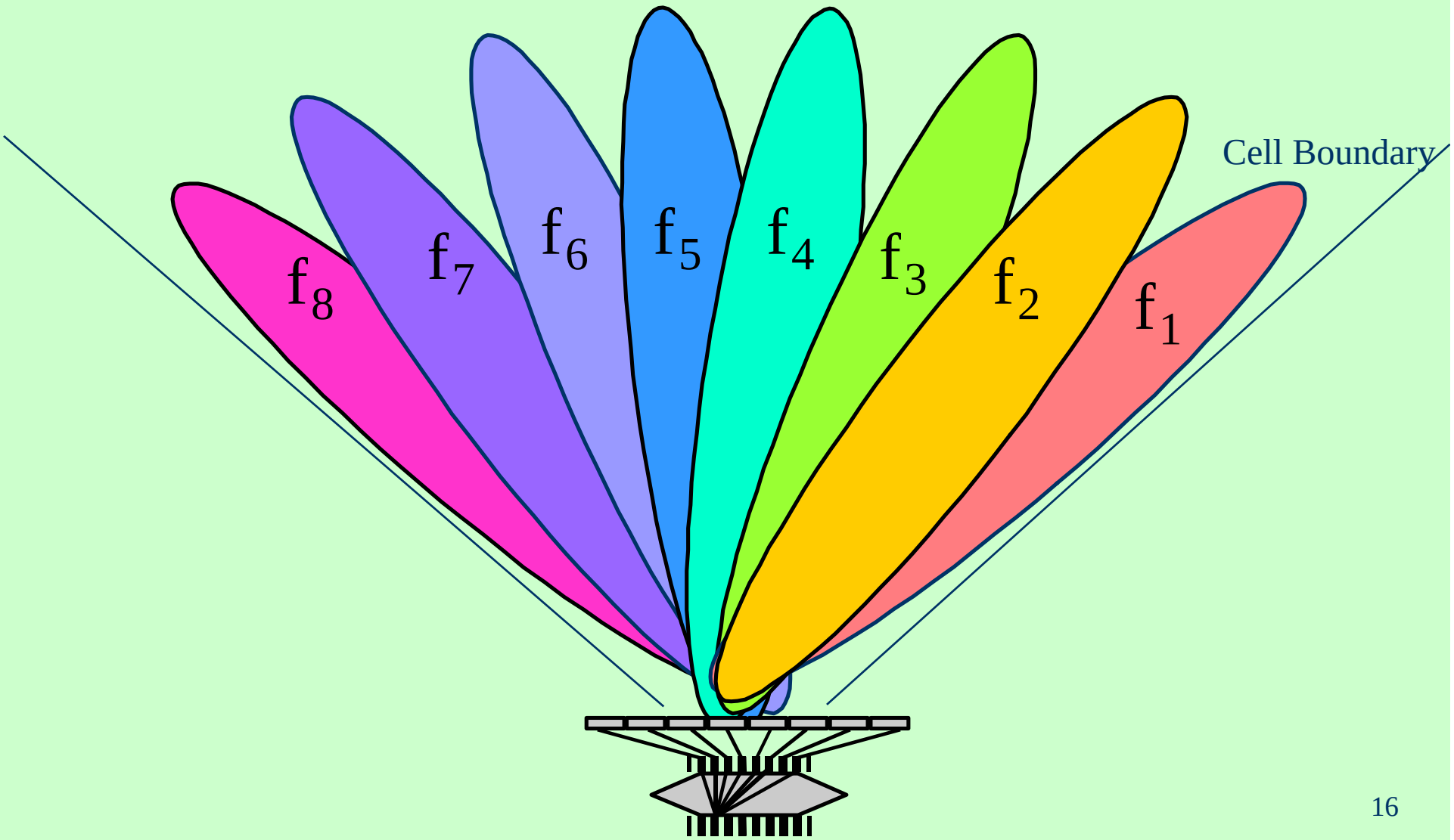
- Configuration can be considered 2 element array
- Optimized when antennas are maximally spaced
  - more than 2 wavelengths
  - decorrelated noise
- Maximum ratio is preferred in basic combiners
- A dual polarized antenna may be used instead of two antennas
  - polarization diversity

Butler Matrix Fed Array



- Combined at RF
- Elements are within a wavelength

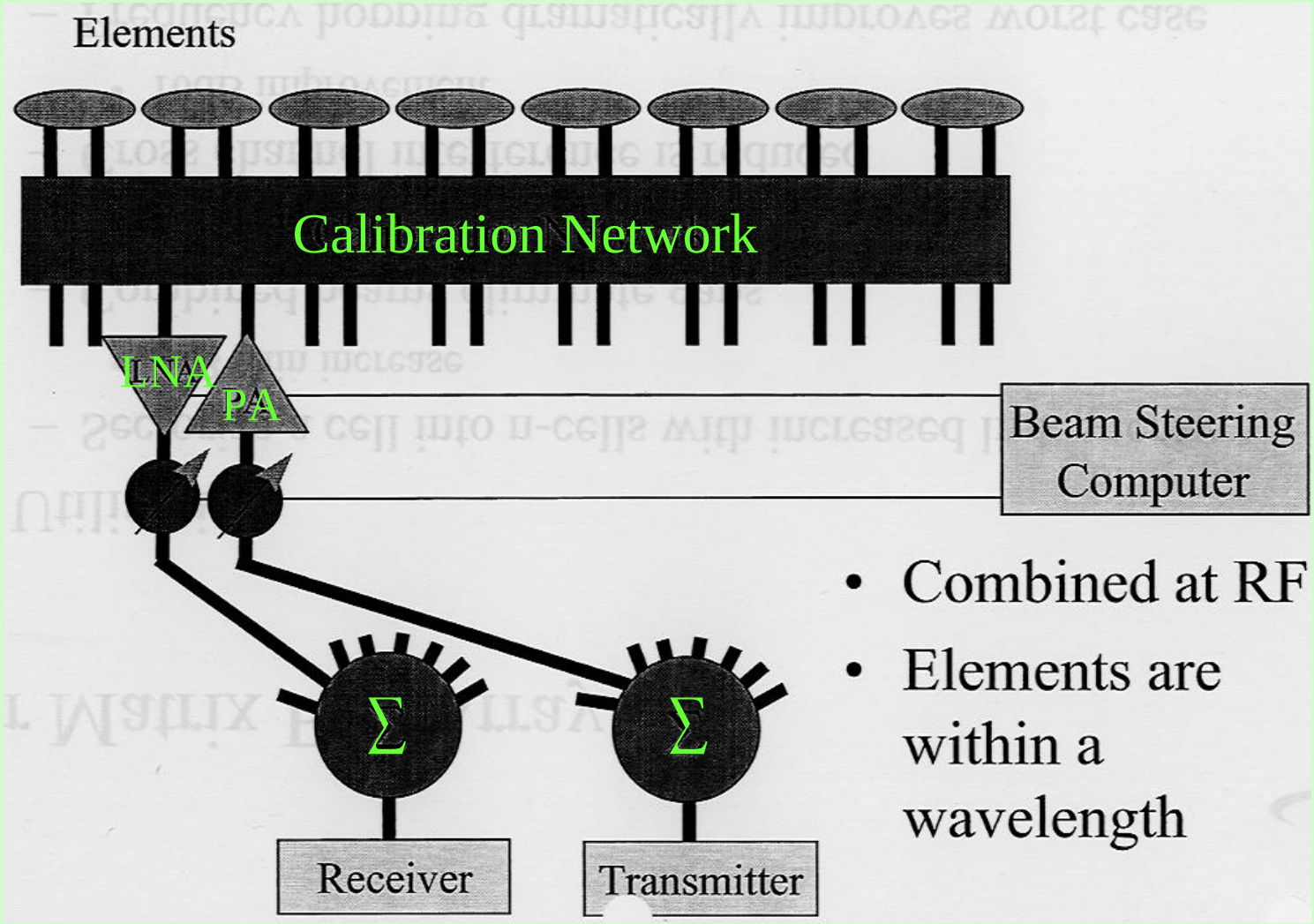
Beam Distribution



Butler Matrix Fed Array

- Utilization
  - Sectorize a cell into n-cells with increased link energy
    - 3dB gain increase
  - Combined beams eliminate gaps
    - 6dB gain increase
  - Cross channel interference is reduced
    - 10dB improvement
  - Frequency hopping dramatically improves worst case fading
- Application
  - Low density sites with large cells

RF Phased Array

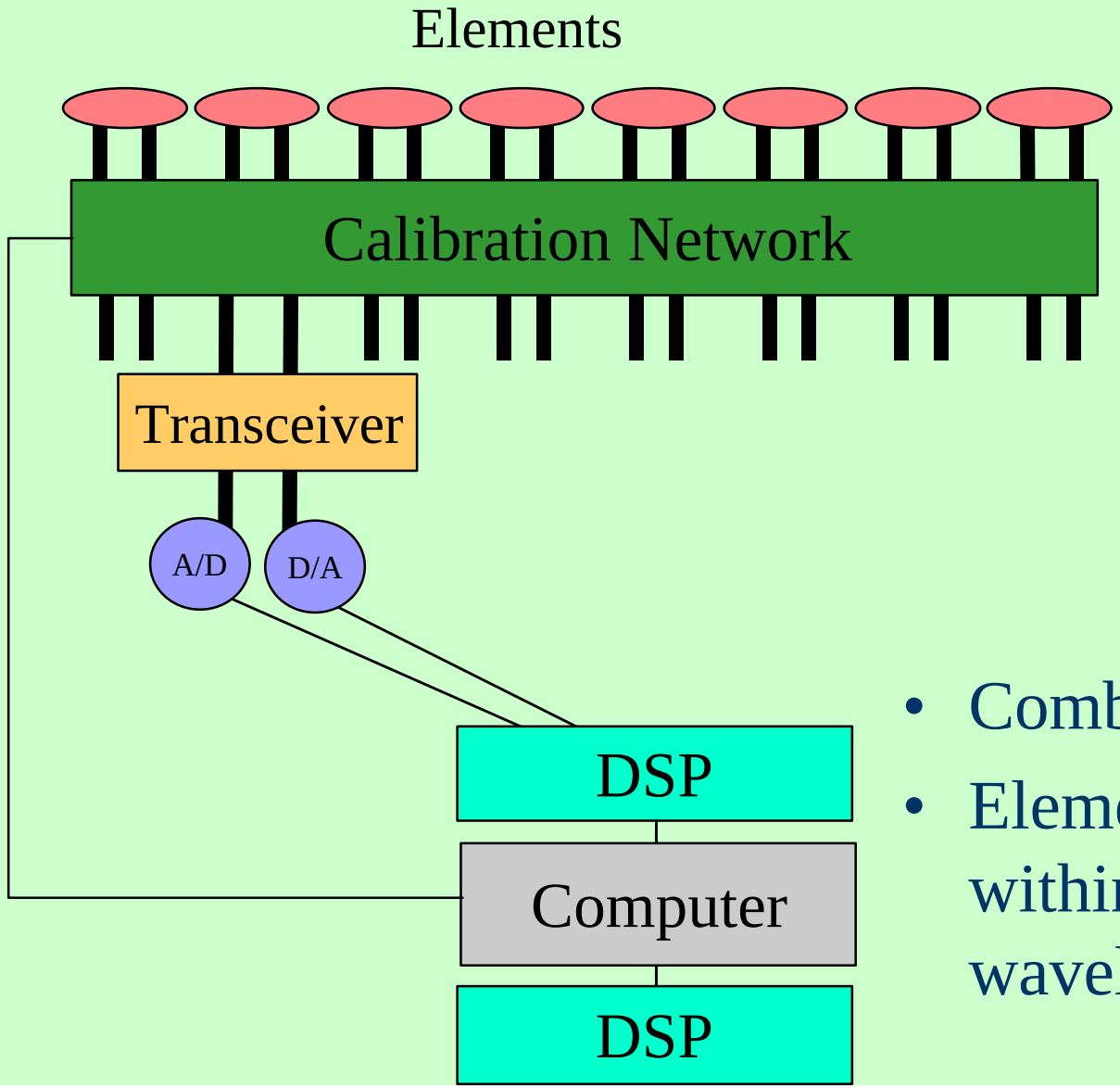


- Combined at RF
- Elements are within a wavelength

RF Scanning Array

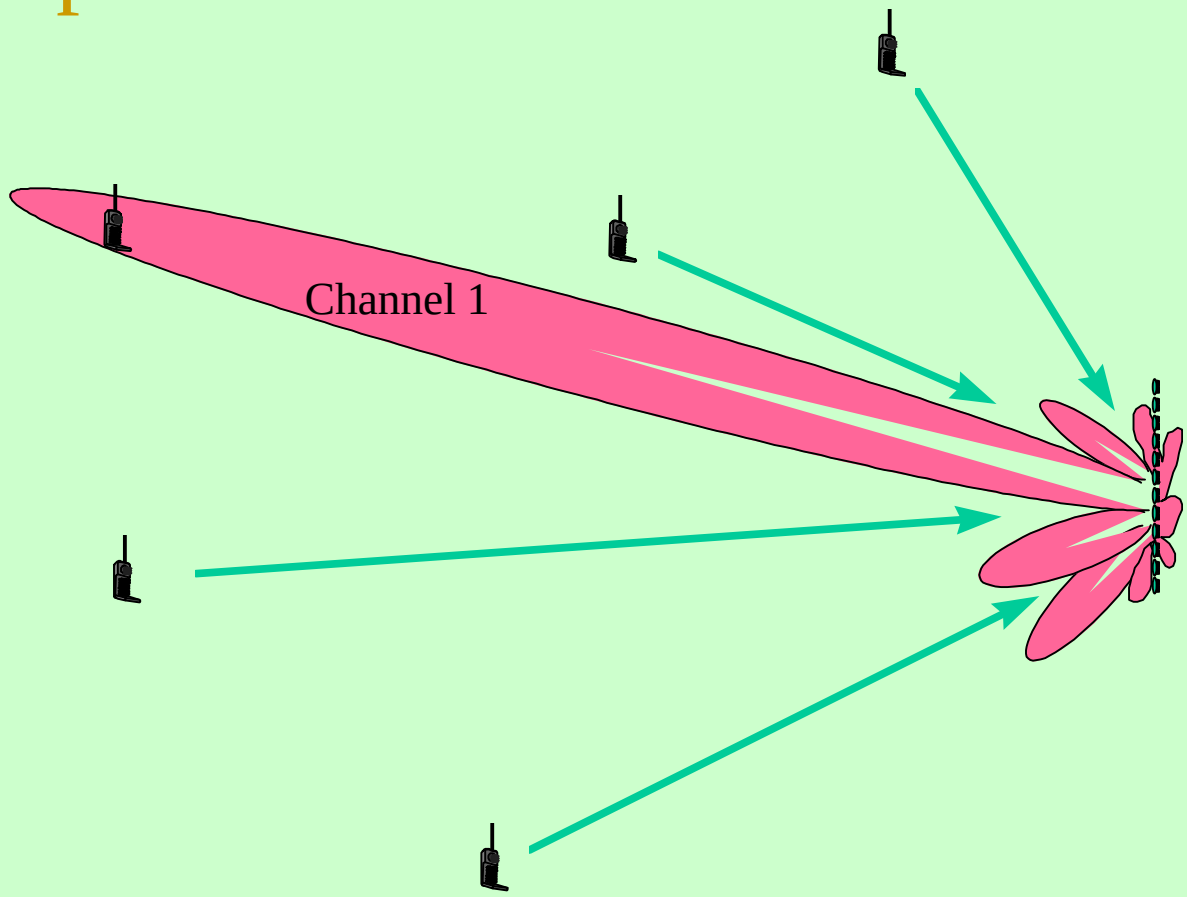
- All channels are directed together
- Best for broad band TDMA packeted information

Digital Beam Forming Array



- Combined at IF
- Elements are within a wavelength

SDMA Concept

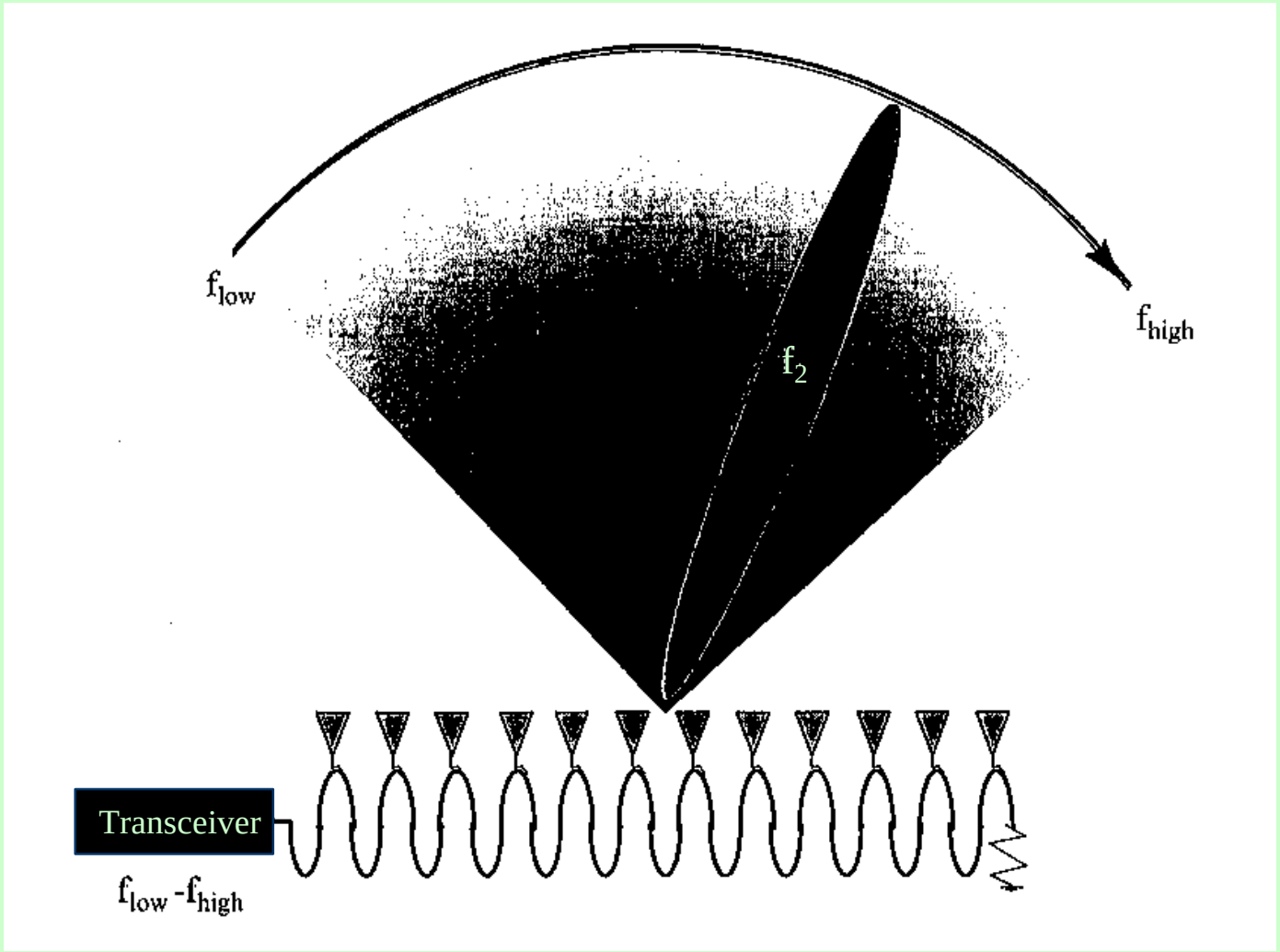


- Gain
- Interference suppresion
- Fade compensation

Digital Beam Forming Array

- Total independent channels
- Channel bandwidth limited
  - DSP speed relates to bandwidth
  - Wide band CDMA?
- Allows distributed power
  - One low power amp per element
- Very good interference rejection
  - *channels*(*elements*-1) “nulls”

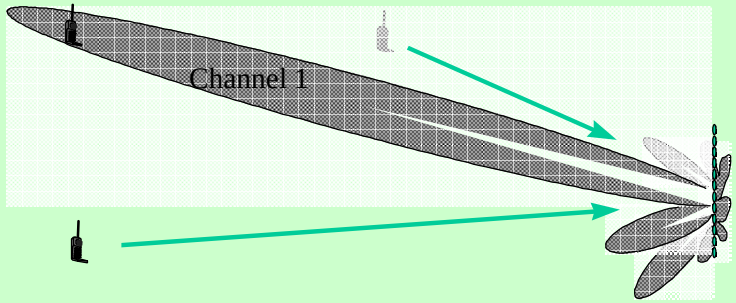
Frequency Scanned Array

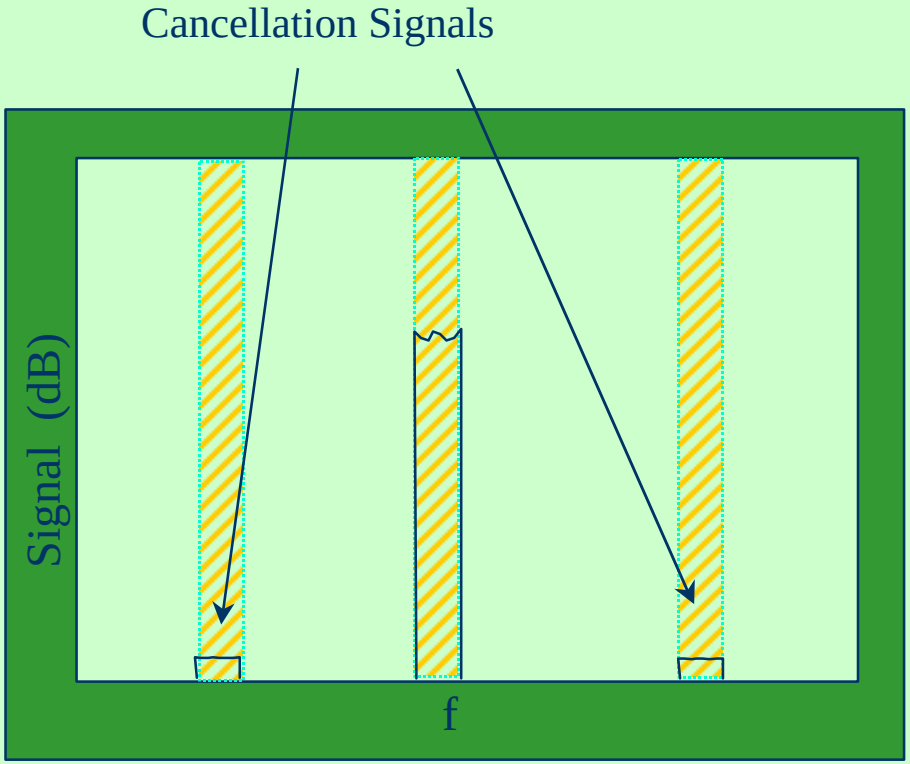


Frequency Scanned System

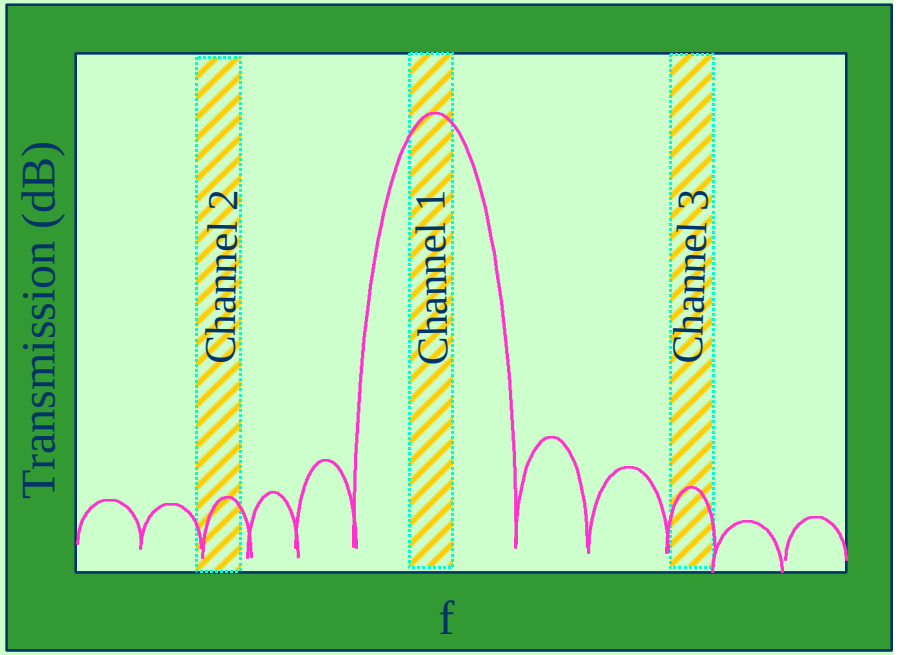
- Employs frequency tracking mobiles
  - Radio chooses the optimal channel band
- Improves range
  - High gain frequency scanned antennas are easily constructed
- Adaptive nulling through frequency channel selection
  - Each direction corresponds to a frequency
- Best used in wide band systems

Frequency Scanned



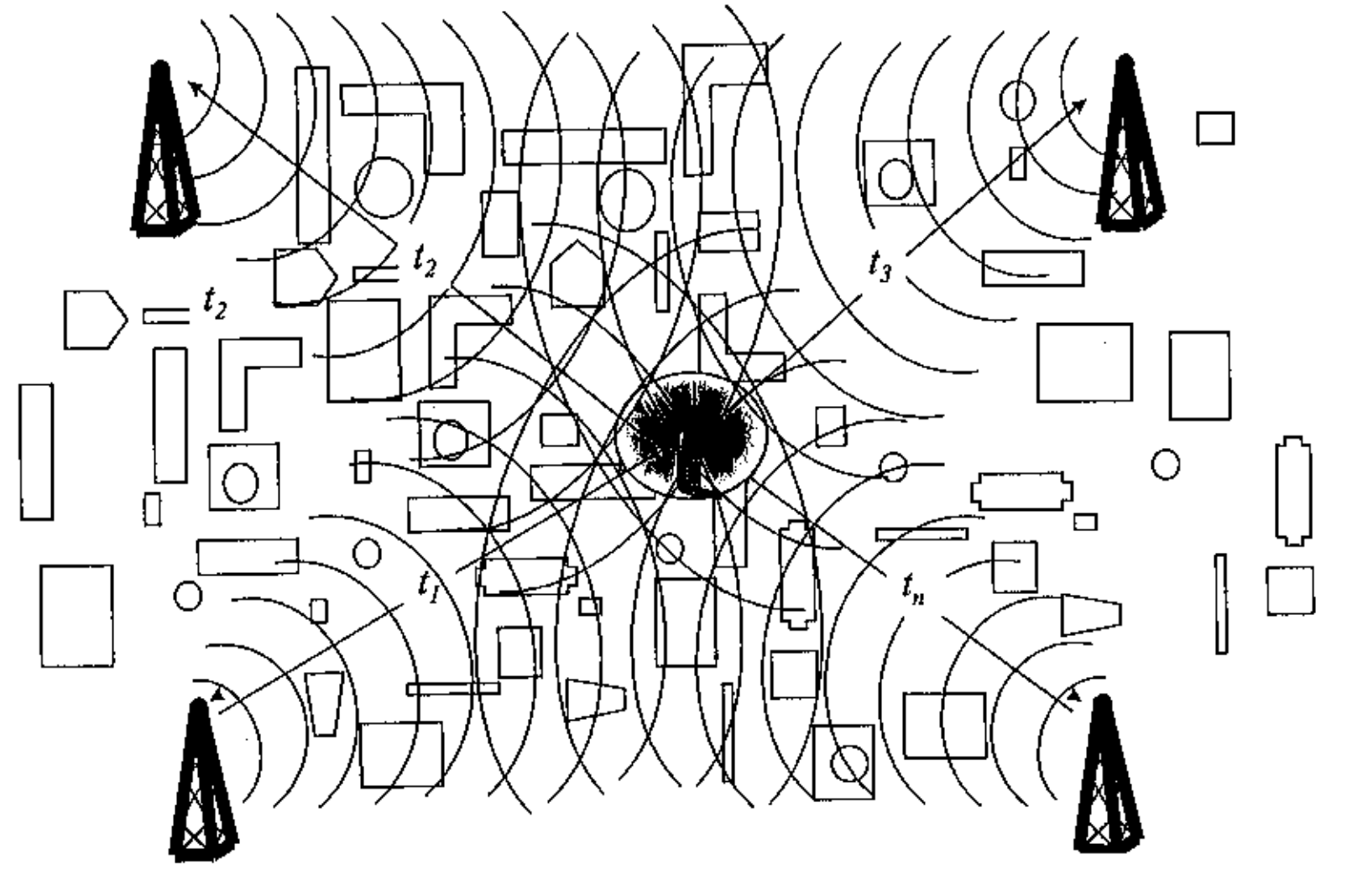


Channel 1



Radio 1 Reception

Holographic Communications Concept



Holographic

- VLBI applied to wireless communications
- Local signal maxima are formed on transmit
- Fades are uncorrelated at the base stations
- Offers the maximum capacity and range increase of any conceivable system
- Allows tracking, and jamming suppression (GPS like)

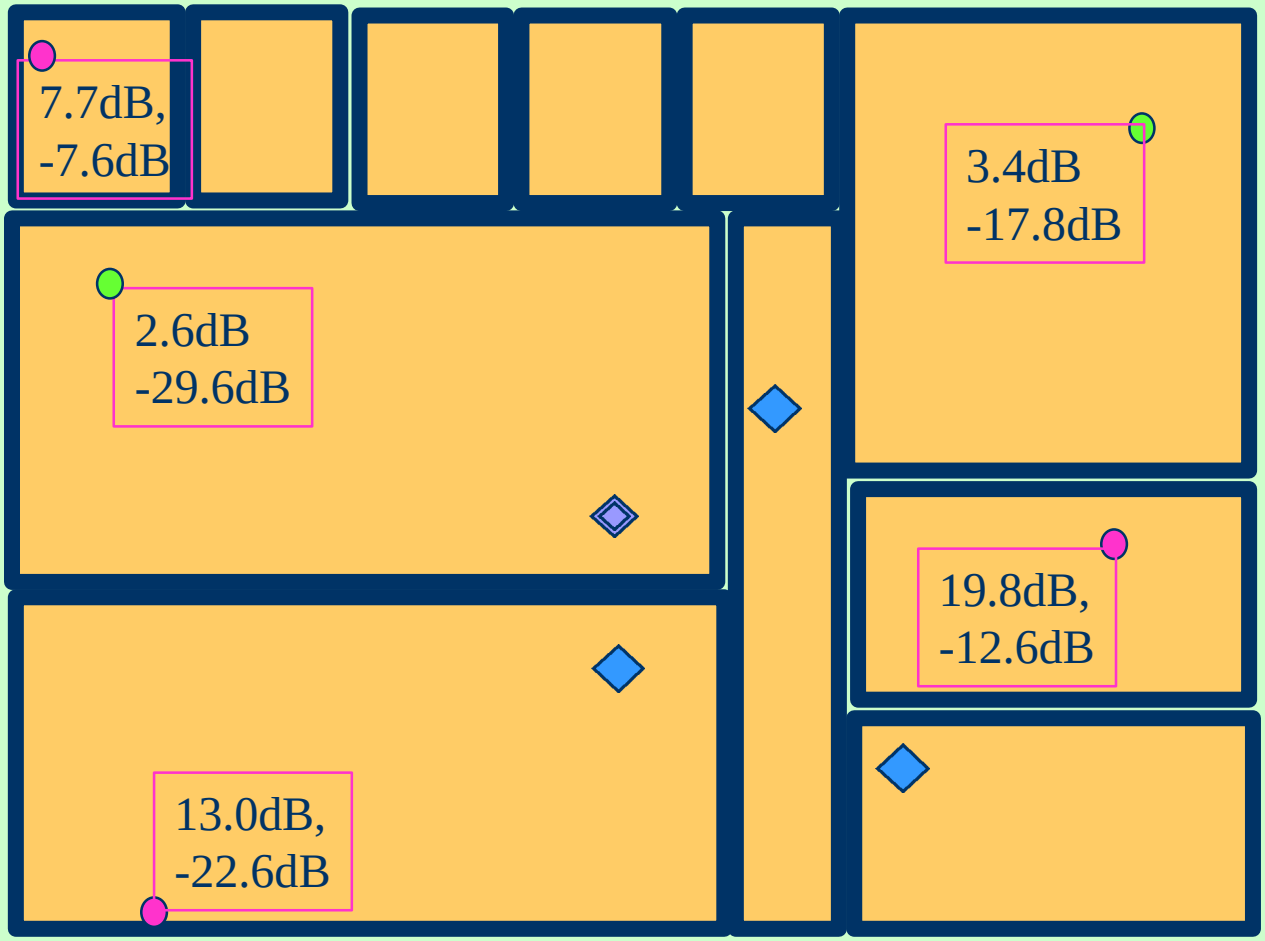
Holographic

Single Omni

Array Element

Measurement CH1

Measurement CH2

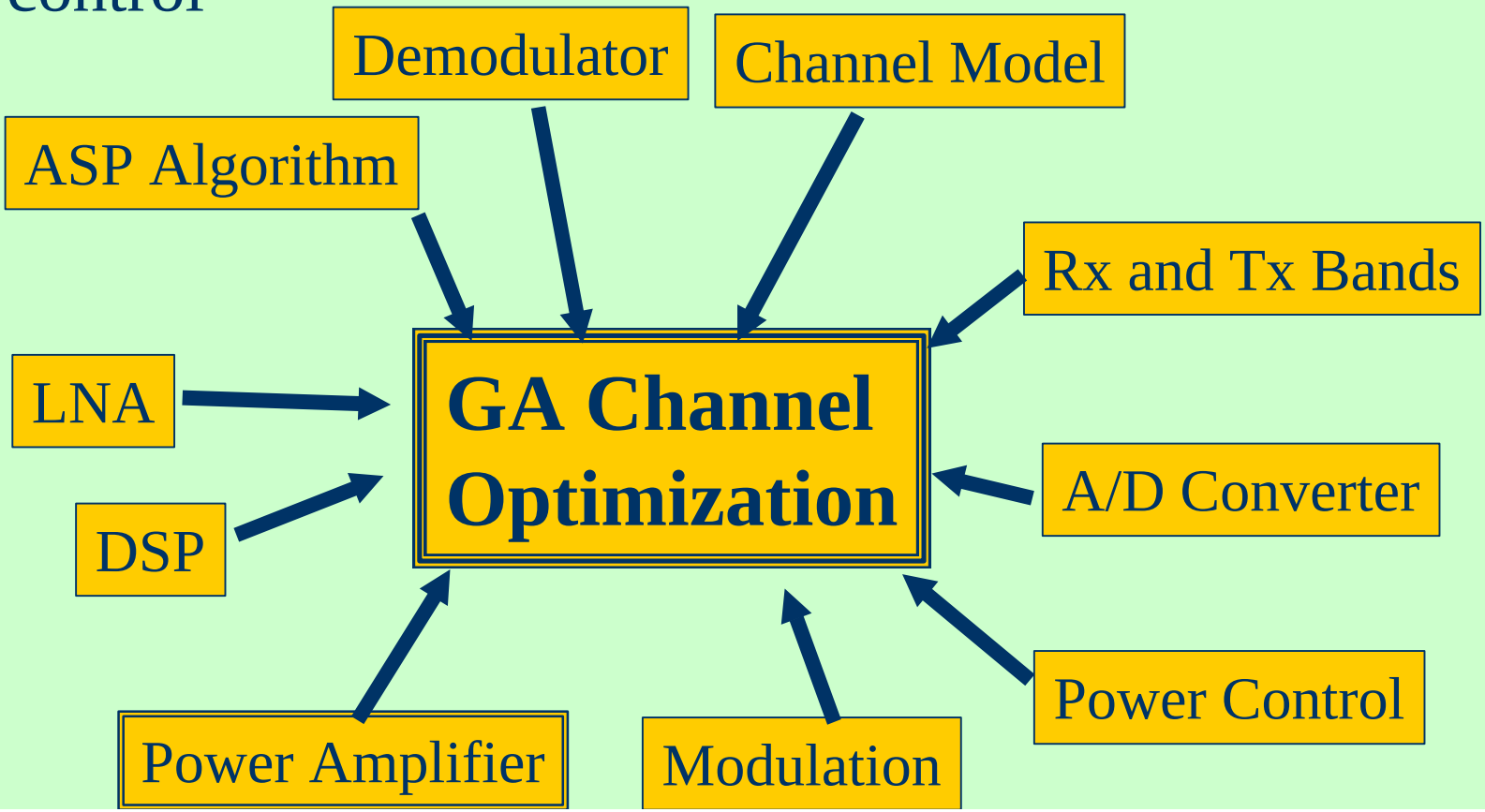


62.6dB,
-

- Channel link improvement
- Adaptive nulling (WSF)

Optimized Hardware Control

- Create the best link through optimized hardware control



Conclusions

- We will use SDMA schemes as they become cost effective
- SDMA implementation becomes more cost effective as new DSPs become available
- SDMA will be necessary to improve capacity
- TDMA (ATM) combines nicely with SDMA
- Holographic techniques provide the greatest potential