Antenna Based SDMA Schemes for Wireless Communications

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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 $\frac{1}{r^2}$

![Graph showing Angular Spread]

- Loss Factor vs. 3dB Angular Spread (deg)
- Data points for Rapperswil and Bern
Link Directivity

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

![Graph showing signal loss over distance with data points representing Rapperswil and Bern.](image)
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

**Knowns:**
- 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

- Demodulator
- Channel Model
- ASP Algorithm
- Rx and Tx Bands
- Antenna
- Polarization
- LNA
- A/D Converter
- DSP
- Modulation
- Power Amplifier
- Site Planning
- Filtering
- Site Planning
- Power Amplifier
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

Transceiver band 2
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

Calibration Network

Elements

LNA
PA

Beam Steering Computer

Σ
Receiver

Σ
Transmitter
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 suppression
- 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
  - $\text{channels(}\text{elements}-1\text{)}$ “nulls”
Frequency Scanned Array

Transceiver

$f_{low} - f_{high}$
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

Cancellation Signals

Signal (dB)

Channel 1

Transmission (dB)

Radio 1 Reception

Channel 1

Channel 2

Channel 3
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

- 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