System Architecture for a Dynamic-Spectrum Radio

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Dynamic-Spectrum Radio System
“Top Down Approach”

- Requires accurate transmitter and receiver databases
- Limited by accuracy of propagation models
- Sharing in frequency & location
- Improves spectrum usage for unlicensed but allocated spectrum
Dynamic-Spectrum Radio System
“Bottom Up Approach”

• Discover the actual usage
• Sharing in frequency, location, & time

• Lessens need for accurate databases and propagation models

• Maximizes spectrum reuse
 Paramount Goals for the Dynamic-Spectrum Radio System

• Designed to limit Interference
  – Work in with the existing spectrum users not against

• Transparent to existing spectrum users

• Realizable device
  – Cost (today)
Design Objectives of the Dynamic-Spectrum Radio System

• Link lengths greater than 10 km possible
  – Longer range than unlicensed services
    • Moderate Transmit Power
    • High Gain Directional Antenna

• Frequency from 500 MHz to 6 GHz
  – Low-Cost Receiver and Transmitter
  – Good Propagation Characteristics

• Temporary frequency use
  – No fixed location-frequency license
Radio Spectrum Environment

- Terrestrial Microwave
- Ku-Band Satellite
- Satellite
- Passive Radio Astronomy
- Mobile Services
- UHF Broadcaster
- C-Band Satellite
- Radio Navigation

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Fielded Dynamic-Spectrum Radio System
Transceiver Block Diagram

Antenna

GPS Receiver

System Controller

RF Subsystem
Base Station Control System

• Obtains:
  – The location of all the users stations
  – The spectrum heard by the users stations

• Has knowledge of:
  – Near by sensitive spectrum users (passive and low power users)
  – Local geographic terrain (propagation characteristics)
Spectrum Assignment Map for User Terminal

Power flux density [W/m²/Hz]

Frequency [MHz]

Spectrum determined by base station to be occupied by protected users

Spectrum determined by user terminal to be occupied by protected users

Assigned spectrum to user terminal
RF Front-end

Analog: octave and multi-octave operation

Not Software Defined!
Implementation Realities

• Intermodulation
  – LNA (Low Noise Amplifier)
    • Limit Available Spectrum Seen
  – PA (Power Amplifier)
    • Can cause Interference

• TDD preferred over FDD
  – Filter reuse
  – Listen interval

TDD = Time Division Duplexing
FDD = Frequency Division Duplexing
Intermodulation

![Diagram showing power and frequency relationship in intermodulation]

- Power vs. Frequency
- Intermodulation effect on frequency bands
Intermodulation Reduction Techniques

- **LNA**
  - High IP3
  - Attenuation (find optimum amount so that the thermal noise floor reaches the height of the intermodulation products)

- **PA**
  - Linearization
    - Predistortion
    - Feedforward
    - Feedback
Intermodulation

Octave Filter:
- Center Freq. 2400 MHz
- Bandwidth 1600 MHz
- Q = 1.5

Power [dBm] vs Frequency

2650 MHz - 2950 MHz
Unknown Variables

- What band to select?
- Will it be reliable over time?
- Will it work over the long term?
Spectrum Study Variables

- Frequency
- Time
- Polarization (Linear, Circular)
- Space (Latitude, Longitude, Altitude)
- Azimuth
- Location type (Urban, Suburban, Rural)
Atlanta Measurement Site
Time Usage Profile
Time Usage Profile: Duty Cycle
Time Usage Profile: Duty Cycle

3dB Above NF
7dB Above NF
10dB Above NF

802.11b Channel 1
802.11b Channel 6
802.11b Channel 11

NF = Thermal Noise Floor
Azimuthal Profile

![Azimuthal Profile Graph](image-url)

- Power [dBm] vs Frequency
- 0 Deg (North) vs 180 Deg (South)

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Polarization Usage

![Polarization Usage Graph]

- Vertical
- Horizontal

Frequency

Power [dBm]
Data Mine Spectrum Measurements

• Find inactivity
  – Frequency
  – Time
• Quantify the amount of reusable spectrum
• Examine periodic usage

• Given a dynamic-spectrum implementation
  – Determine its reliability
  – Predict its long term feasibility
Dynamic-Spectrum Radio System with Data Mining

- Improves its knowledge of the local spectrum environment over time and with increasing number of users

- Assigns spectrum with respect to the data rate and QoS requirements of the users

QoS = Quality of Service
Questions