Measurement of Ultra-Wideband Wireless Channels

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ARMMS Conference, April 2006

Overview

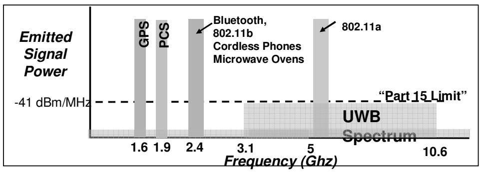
- Introduction
  - History of UWB
  - Modern UWB
- Antenna Measurements
  - Candidate UWB elements
  - Radiation patterns
- Propagation Measurements
  - UWB antennas
  - Pathloss
  - Radiation pattern
  - Angular spectrum
  - Signal distortion
- Conclusion
- References

History of UWB

- 1889
  - Heinrich Hertz's spark gap experiment
  - Spectrum not controllable
  - Subsequent use of heterodyne transceivers
- 1960's
  - US military experiments with pulses for system characterisation
  - Early wideband radars
- 1970
  - First UWB patent
- 1990's
  - Rapid growth in consumer electronics market and supporting industry
  - Emerging US start-up companies developing UWB equipment
- 2001
  - US FCC allows UWB transmissions
  - Rapid global growth of interest in UWB technology
- Today
  - Awaiting global release of UWB spectrum
  - UWB technology R&D continues at a rapid pace

Ultra-Wideband Technology

- The UWB Philosophy
  - High fractional bandwidth
  - Multipath resolution
  - Low fading powerloss
  - Very high capacity
- Applications
  - WPANs & WBANs
  - Through-wall radars, GPRs
  - Covert communications
  - Sensor networks

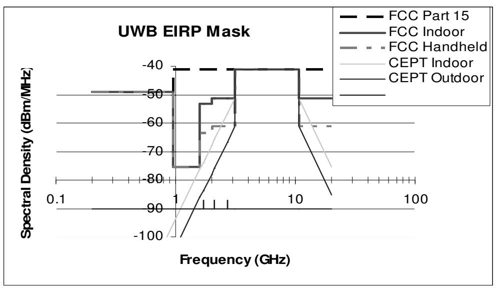


UWB Communications

- For short-range, high-rate indoor wireless
- Applications from wireless USB to displays and computer peripherals
- Proposed implementations
  - Impulse radio
  - Multiband OFDM
  - DS-CDMA
  - Less popular: FH-SS and chirped signals
- Initial prototypes offer over 1 Gbps throughput

Emission Bands

USA: 3.1 to 10.6 GHz for indoor communications



UWB – what is different?

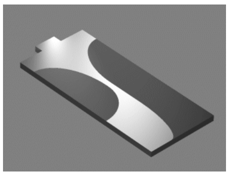
- Conventional wireless systems transmit with a 20MHz MAX bandwidth (WLAN)
- UWB has a 500MHz MIN bandwidth
- Should consider frequency dependency of antennas and channel
  - Radiation pattern and pulse distortion
  - Path loss, reflection coefficient, fading characteristics

Antenna Measurements

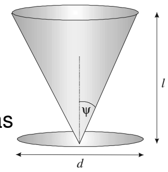
Antenna Characterisation

- In terms of
  - Transmission line characteristics (return loss, VSWR, impedance)
  - Radiation characteristics (far-field radiation pattern)
- These may vary with frequency!
- Such characterisation valid only for narrowband antennas
- Frequency-dependent effects significant in UWB antennas

UWB Antennas



Directional Antennas
(e.g. Vivaldi)

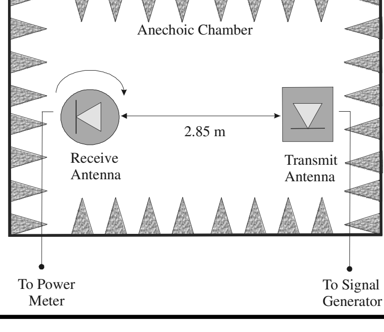


Omni-directional Antennas
(e.g. discone)

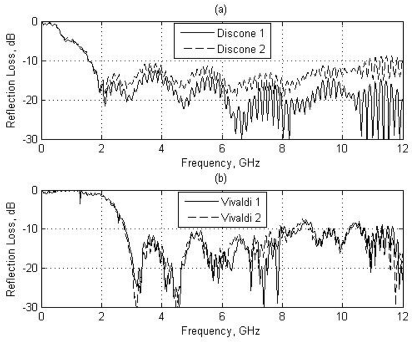
Measurement Methodology

- Measure radiation pattern versus frequency
  - 3-10GHz
  - 360deg azimuth, +/-90deg elevation
- Evaluate impact of real antennas of system performance

Measurement Configuration



Return Loss



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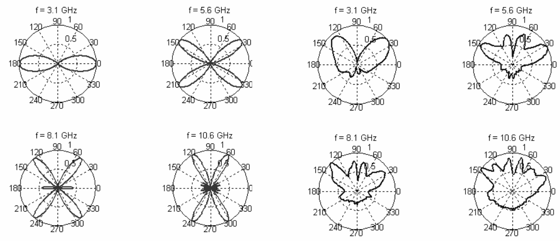
Radiation Pattern Variation



Vertical Dipole and Discone
Elevation Plane Radiation Patterns at Various Frequencies

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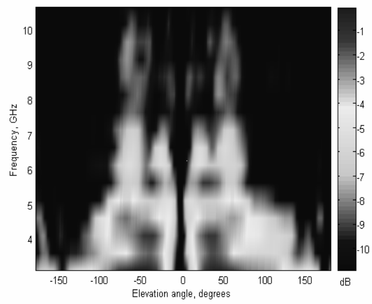
Discone Antenna Pattern

- Directivity
- Mainlobe width
- Number of sidelobes

vary with frequency in the elevation plane



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Angular Dispersion

- The radiated power is angularly non-uniform for practical antennas
- Affects both narrowband and UWB
- Asymmetric power reception, varying with location

- But UWB antenna transfer function also varies with direction
- Result: asymmetric signal waveform distortion

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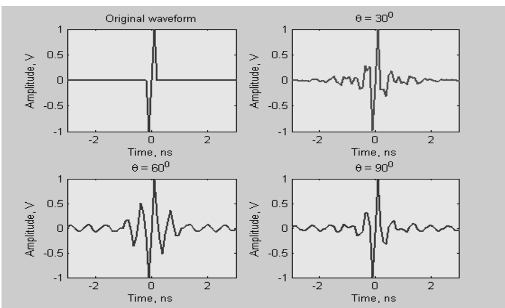
Angular Signal Distortion

(Gaussian Monocycle)



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Mitigation

- As angular and spectral antenna distortion is coupled, direction-of-arrival information can be used for normalization
- Cognitive radios can sense the spectral distortion dynamically and compensate for it

Propagation Channel Measurements

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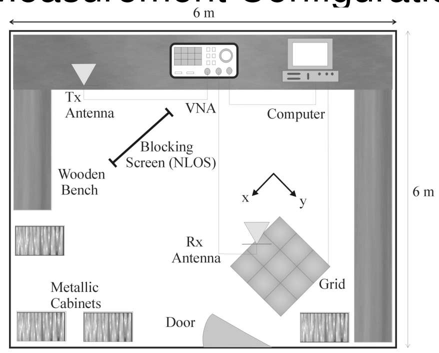
Measurement Configuration



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Measurement Parameters

- 3-10GHz
- 2500 spatial points
- 2 polarisations (V and H)
- Discone antenna
- 50 cm x 50 cm grid at 1 cm resolution
- -25 dB noise threshold
- Line-of-sight and non-LOS propagation
  - Insert grounded metal sheet for non-LOS

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Why VNA-based measurements?

- Consider
  - DS-SS ~ long correlation time, not available
  - Chirp-based channel sounder ~ not available
- VNA
  - Available and convenient
  - Unprecedented bandwidths and centre frequencies
  - Easy operation
- BUT
  - Requires stationary channel ~ OK for UWB applications
  - Requires short range (although can be extended using optical fibre) ~ OK for UWB due to approx 10m range

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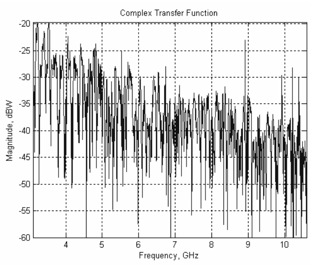
Directivity Effects on Powerloss

- With frequency:
  - Gain of directional antennas increases
  - Aperture of omni-directional antennas increases

  (Assuming ideal antenna behaviour)
- For broadcast antennas, high frequencies suffer greater attenuation
- Signal spectrum is modified as a result



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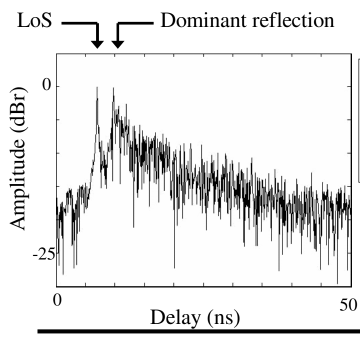
Spatial Impulse Response

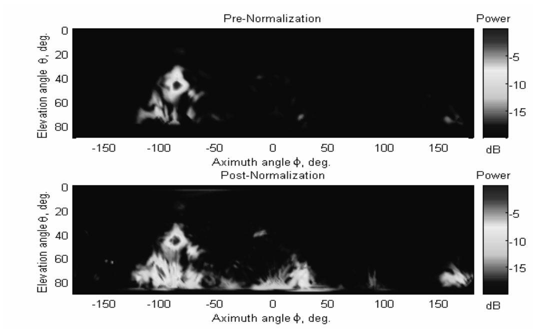


- <5dB fading
- Lots of path diversity (Rake)
- Illustrates mobility
- Insight into MIMO performance

Array-Based Imaging

- Antenna array imaging used for multipath characterization, radar image formation, radio snapshots of environment
- Angular spectrum formed from coherent array data at each frequency component
- Angular spectra filtered by the antenna transfer function
- Thus lens aberration is introduced due to UWB antenna
- Can be normalized by antenna deconvolution

Image Distortion



Conclusion

- Antennas are a source of distortion in UWB communications systems
- Signal waveform distortion caused due to
  - Antenna frequency-dependent power loss
  - Variation of radiation patterns with frequency
- Antenna effects can be mitigated and even exploited
- Observed <5dB fading
- Array image distortion (lens aberration)

References

[1] B Allen et at (Editors), “Ultra-wideband Antennas and Propagation for Communications, Radar and Imaging”, Wiley, June 2006

[2] W.Q Malik, D.J Edwards, C.J Stevens, “Angular-spectral Antenna Effects in Ultra-wideband Communications Links”, IEE Proc. Communications, February 2006

[3] W.Q Malik, D.J Edwards, C.J Stevens, “Synthetic Aperture Analysis of Multipath Propagation in the UWB Communications Channel”, IEEE Workshop Sig.proc Adv. Wireless Comms, June 2005