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CHANNEL MODELS, INTERFERENCE PROBLEMS AND THEIR MITIGATION, DETECTION FOR SPECTRUM MONITORING AND MIMO DIVERSITY

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1. UWB CHANNEL MODELS, AND TOWARDS MORE PRECISE MODELING

1.1. Channel Models for UWB Signal Propagation in Indoor Environments Including Multipath Effects

1.1.1. Channel Models for UWB Signal Propagation in Office and Laboratory Environments Including Multipath Effects

- M.Z. Win's experimental and analytical studies (about 1995-1998)

  Number of dominant multipath components and mitigation of fading effects by using a selective Rake receiver
- Hall's report (*circa 2000)* at TDC to improve on 2 aspects of Win's work, and noted a large range in path loss exponent, from less than 2 to 7.
- Withington (*circa 1995)* at TDC did independent analyses of the same data as Win's.

- Zhu, Wu and Nassar (2000): general Markov model for fading channels of which all fading channel models were claimed to be a special case
- Cramer studied beamforming and array processing, and introduced various algorithms to obtain more accurate estimates of TOA and AOA.
- Kunisch (2002) analyzed measured data statistically and obtained plots of averaged power profiles, delay dependent power decay, amplitude statistics and much more.
- Band-divided ray tracing method was introduced (2004) by Sugahara, *et al.* to solve the problem of frequency dependence of materials. Estimated path losses and delay profiles were found, and UWB coverage and interference into UWB estimated.

1.1.2 Path Loss Models for UWB Signal Propagation in Office, Laboratory and Residential Environments

- Regression models for path loss: many variations, with and without a shadowing term, with extra terms for losses due to propagation through floors, ceilings.
- Exponent n may has been found to vary form 0.86 to 7.60 in Hall's study.

- General equation used and adapted for path loss models based on regression.
- The path loss model used to fit the data obtained from measurement campaigns by regression is expressed as
- $$PL(d) = PL(d_0) + 10 \cdot n \cdot log\left(\frac{d}{d_0}\right) + X_\sigma$$
- which has a zero mean lognormally distributed random variable, sigma, with a standard deviation of to account for shadowing. The reference distance is usually taken as 1 metre.

1.1.3. Indoor Generalized UWB Channel Models

- Hovinen *et al.* propose a concatenation of deterministic model (DM), and an independent Rician fading part, i.e., a statistical model (SM).
- Zhang *et al.* derive the POCA-NAZU and NAZU distributions for the characterization of a finite number of scatterers, and show that the Rayleigh and Rician distributions are obtained in the limit as the number of scatterers become large.

1.2. Channel Models for UWB Signal Propagation in Outdoor Environments

1.2.1. Channel Model for UWB Signal Propagation in an Outdoor Rural Environment

- Win *et al.* (1997):

$PL(r) = PL(r_0) - 10\log_{10} (r^{-\alpha})$

1.2.2. Generalized Outdoor UWB Path Loss Models

- Numerous studies on the effects of interference of UWB into the GPS. In these studies the free space path loss model with path loss exponent = 2 was used for shorter distances up to and including a breakpoint distance of , and a two-ray, flat earth multipath model was used for distances greater than a break point distance, resulting in the well known fourth power law path loss formula.
- In 2003 researchers from Finland proposed a two ray path model (see additional material with my poster) for short distances up to 10 metres.
- Other path specialized path loss models, without the shadowing term, for different frequencies (such as up to about 3 and 15 GHz are given)

1.3. Proposed Comparisons of Path Loss Models for Different Environments on a Unified Basis

- See the additional material to my poster, especially the ITU document, UWB Path Loss Models, contributed by Switzerland.

1.4. A Proposed New Method for More Precise Modeling of UWB Channels

- Adapt the state-space model and a formulation using a Hidden Gaussian Markov Model (HGMM) used successfully in the narrowband case to obtain a new dynamic model that yields an ARMA model as a special case, to model UWB channels more precisely. (See W. Turin's 2005 book and paper with R. Jana at the 2005 IEEE VTC conference in Stockholm). This is a Kalman filtering approach, and involves, e.g., solving a Riccati equation.

1.5. UWB Channel Modeling Based on Electromagnetic Theory Using Ray Tracing

- Wave-based system based on geometric and uniform theories of diffraction
- Three-ray model for the received signal (R. Qui) consists of the direct LOS pulse, a reflected pulse and a diffracted pulse
- Is the precision sufficient with just a few rays?
- One may dream of a future accurate UWB channel model based on electromagnetic theory and ray tracing methods in which the environment is extracted by a computer from photographs and a list of dimensions, material properties, and then use many emitted rays that are received and analyzed to obtain the desired model information! This would be a large challenge in programming and may require a supercomputer!

2. Interference Problems and their Mitigation

- Until about 2002, for mitigating interference by UWB signals the main methods were: pulse shaping, modulation, representing a bit by many low amplitude pulses, randomization using PN and related sequences, PSD shaping and whitening, choice of design parameters such as pulse repetition frequency.
- For mitigating interference into UWB channels, choice of pulse shapes, modulation methods and a wavelet-based method for decomposition into subbands, eliminating the subbands where there is interference and reconstructing the pulse from the remaining subbands
- Mitigating multipath effects by using a RAKE receiver
- Multi-band
- Avoidance methods
- Adaptive methods vs. complexity

- Given aggregate interference considerations to what extent can satellite and TV, as well as other services, be guaranteed freedom from interference by UWB signals?
- Measurement campaigns probably not sufficient.
- More sophisticated theoretical models that will use measured data.

3. UWB Minimum Detectable Signal Levels

- Monitoring the presence of LPD UWB signals is of interest to governments and the military
- Elizabeth C. Kisenwether, in 1992, published some fundamental work on this (see my poster for a summary).
- What has been done since 1992?
- Can correlation methods (N. Weiner & Y.W. Lee at MIT) be used?
- Singularity detection using wavelet theory, and time-frequency methods.

• MIMO UWB Systems

- Preliminary investigations indicate considerable promise for MIMOO UWB systems, but much investigation is needed
- Characteristics of the channel dramatically influence the diversity gain and led to poor results due to time and angular dispersion, due to deficiency of the synchronization scheme
- Beam switching worked well.
- What are the issues regarding performance of broadband antenna arrays for MIMO? Dispersionless antennas are very difficult to design for UWB.