Weather forecasting and fade mitigation

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Orbit attenuation due to rain exceeded for 1 % at 50 GHz

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Introduction

Why bother to forecast propagation conditions …
- Better performance than “closed-loop” FMT systems?
- what can a priori knowledge of fades do for us?
- Proactive rather than reactive fade countermeasures
- What if the time-of-flight becomes too long?

Our approach: use meteorological information to determine propagation conditions – can be done in real-time
Background to our work

- Fade mitigation technique simulation …
  - Design of FMT systems e.g. **power-control, variable rate coding**
  - Requirement for synthetic attenuation time-series

- Our approach …
  - recreate the meteorology …
  - …rather than to attempt to model the statistical and dynamic behaviour of attenuation …
  - …and then estimate the resulting propagation conditions
Generation of historical time-series

▶ Estimate attenuation from combination of
  ▷ archived numerical weather prediction model data (UK Met Office’s so-called Unified Model)
  ▷ UK Met Office’s weather radar network (15 C-band radars)

▶ Have the complete “picture” - fade estimates for entire networks that have …
  ▷ correct spatial and temporal statistics (e.g. cdf)
  ▷ correct dynamic characteristics (e.g. fade slope)
  ▷ correct spectral characteristics (e.g. psd)
University of Bath model

Image of a diagram showing the University of Bath model for radar downscaling and attenuation modeling.
Example time-coincident time series for multiple sites

- Data from 22/6/2003
- Fade Level experienced from 50 GHz Downlink
- Geo satellite at 2W
ITU-R verification – Bath, UK 50 GHz
The thin line represents the VDK theoretical model, the thick line represents the analysis from the output time series.
Example model output

- Data from UM (5 minute intervals)
- 1st April 1998
- Fade Level (dB) experienced from 50 GHz Downlink
- Geo satellite at 2W
Forecasting for resource management

- If run in real-time the model can provide forecasts of network availability – *can be used for network control*
- The components that model stochastic small scale structures are disabled – *you can’t predict the actual scintillation*
Advantages of employing forecasting techniques

- Can take time to get **accurate signal quality measurements** (BER, PER etc), or the coding used may be so strong that the PER dynamic range is insufficient.

- Allows “proactive” resource management systems such as time diversity techniques to **create service availabilities that exceed link availabilities**.

- Can be used when time-of-flight is longer than the channel can be considered stationary.
Errors – what if it goes wrong?

▶ Suppose the forecast is wrong – what effect does that have on the network performance?
▶ can we make things worse?

▶ How can the forecast go wrong?
▶ Temporal errors - e.g. a fade is correctly predicted - but occurs earlier/later than forecast
▶ Spatial errors - e.g. rain cells occur that the forecast does not predict
▶ Fade depth errors - e.g. fade is deeper than predicted – variability in raindrop size distribution
Temporal error results

- If we sum all the terminal error performances, we can get a measure of the overall network performance.
- From a network point of view we get an improvement over the temporal error ranges:
  - Terminal set 1:
    - -10.17 to 10.24 mins,
  - Terminal set 2:
    - -9.92 to 10.04 mins.
20.7 GHz GBS (23W) Beacon
Chilbolton & Sparsholt

- Currently the only live Ku / Ka / V band beacon measurements in the UK
- US military satellite – ephemeris is not precisely known
- We have taken an example week 13-20th October 2004 of beacon measurements, filtered to remove most of the scintillation component
- The model outputs were taken for a 3x3 0.11 degree grid around the relevant receiver
20.7 GHz GBS (23W) Beacon
Chilbolton & Sparsholt
20.7 GHz GBS (23W) Beacon
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- Simulating operational ‘tactical’ deployment
- Measure the ability to predict an attenuation threshold being exceeded
  - Fade warning or suggested data rate change etc
- Measure forecasting skill as a Extreme Dependency Score (EDS)
  - More appropriate than Equitable Threat Score (ETS) for rare events, EDS is not explicitly dependent on bias or base rate
- Initial investigations showed that the greatest skill was demonstrated with an umbrella point of 1
Example ETS measures for 24 precipitation forecasts at 10mm/hr threshold - compared to NIMROD radar system:

- HIRLAM (Finnish Met. Inst.) (22km) 0.45
- ALADIN (Meteo France) (10km) 0.55
- Lokal Modell LM (DWD, Germany) (7km) 0.60
- UM (UK Met Office) (12km) 0.70
The Future

► NWP model development …
  ▶ Smaller grid lengths – improves resolution and accuracy
  ▶ Improvements in the modelling of convection

► UK Met Office has operational European domain model – *encompasses all of Europe on a 12 km grid*

► Future work …
  ▶ more experimental beacon data – increase confidence
  ▶ does it work for other climate zones – tropical regions?
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