Generic Interference Assessment Using a Wide-Range Propagation Model

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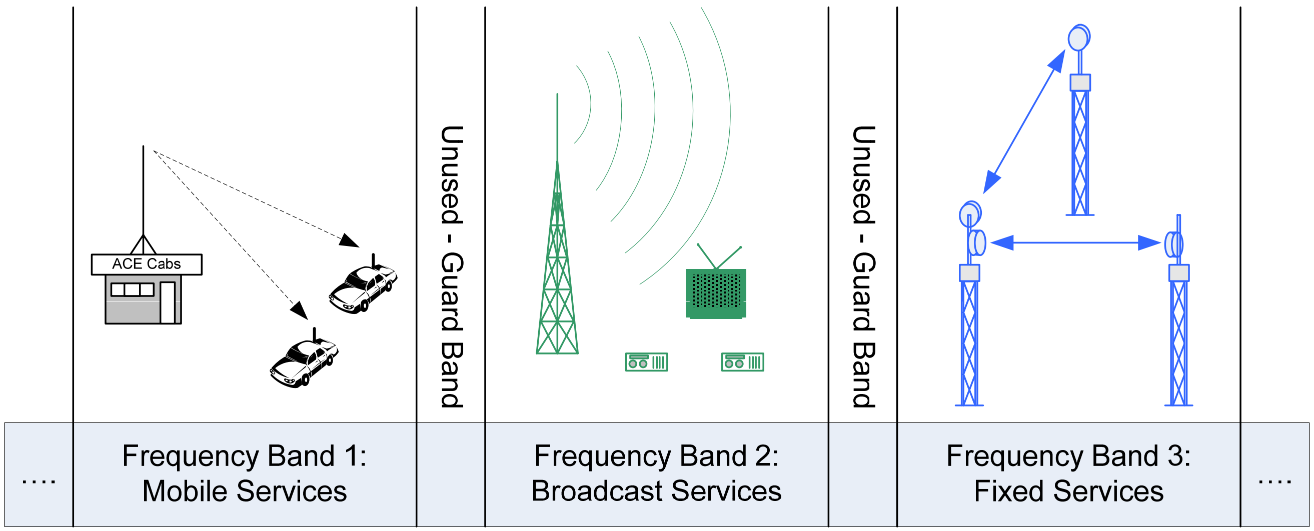
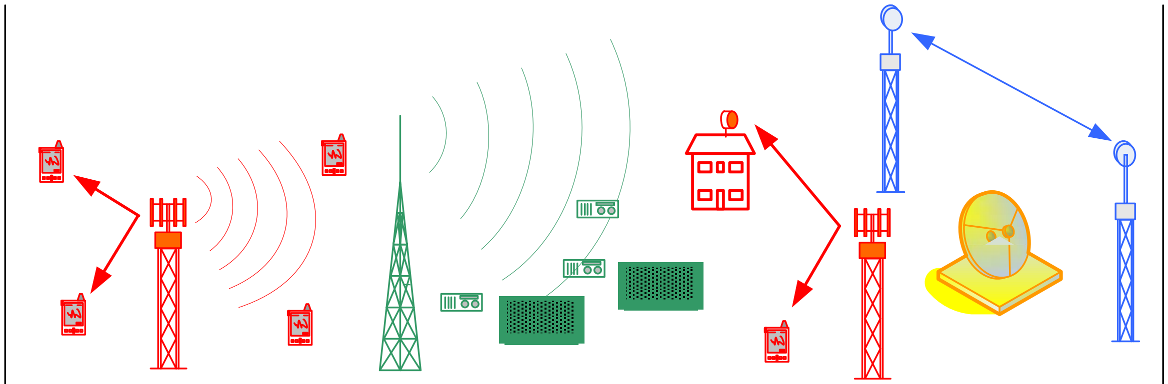
Standard Approach to Spectrum Licence Management



- Specific services selected by the regulator
- Services allocated to specific bands with size spectrum block determined by the regulator
- Empty spectrum (guard bands) between allocations
- Assignment done within each block

Liberalised Approach to Spectrum use



.... Multiple service types requiring technical coordination ....

Generic Radio Modelling Tool

Evaluate licence requests and "Change of Use" (CoU) proposals in a way that is:

- Transparent
- Technologically Neutral
- Evidence driven

A Generic Radio Modelling Tool (GRMT) – Technical Approach

Key problem to address:

- Want a technology neutral generic interference analysis tool with ability to analyse interference from any licence into any other

Proposed solution:

- Select a generic measure (“benchmark”) of spectrum quality – the SQB
- Define licence rights via a standard data format – GRMT’s Technology Neutral Radio Parameters (TNRPs)
- Develop the GRMT Algorithm which can calculate interference between any licences in this TNRP format and compare against the SQB

SQB Format Selected

- Propose following format:

  Interference at the receiver should not exceed X dBW for more than Y % of the time [at more than Z % of locations]
- Regulatory basis for this format:
  - *Interference is a generic, measurable, transparent, measure of spectrum quality*
  - *Licence applications should be judged on interference they generate not on how other systems are planned*
- Technical basis for this format:
  - *Interference levels can be derived from existing thresholds (e.g. in Ofcom Technical Frequency Assignment Criteria TFACs)*
  - *Interference can be used by system designers as input into planning process*
  - *Interference is computationally least intense*
- Single entry threshold (in-band or adjacent band) which can be derived from aggregate interference limits

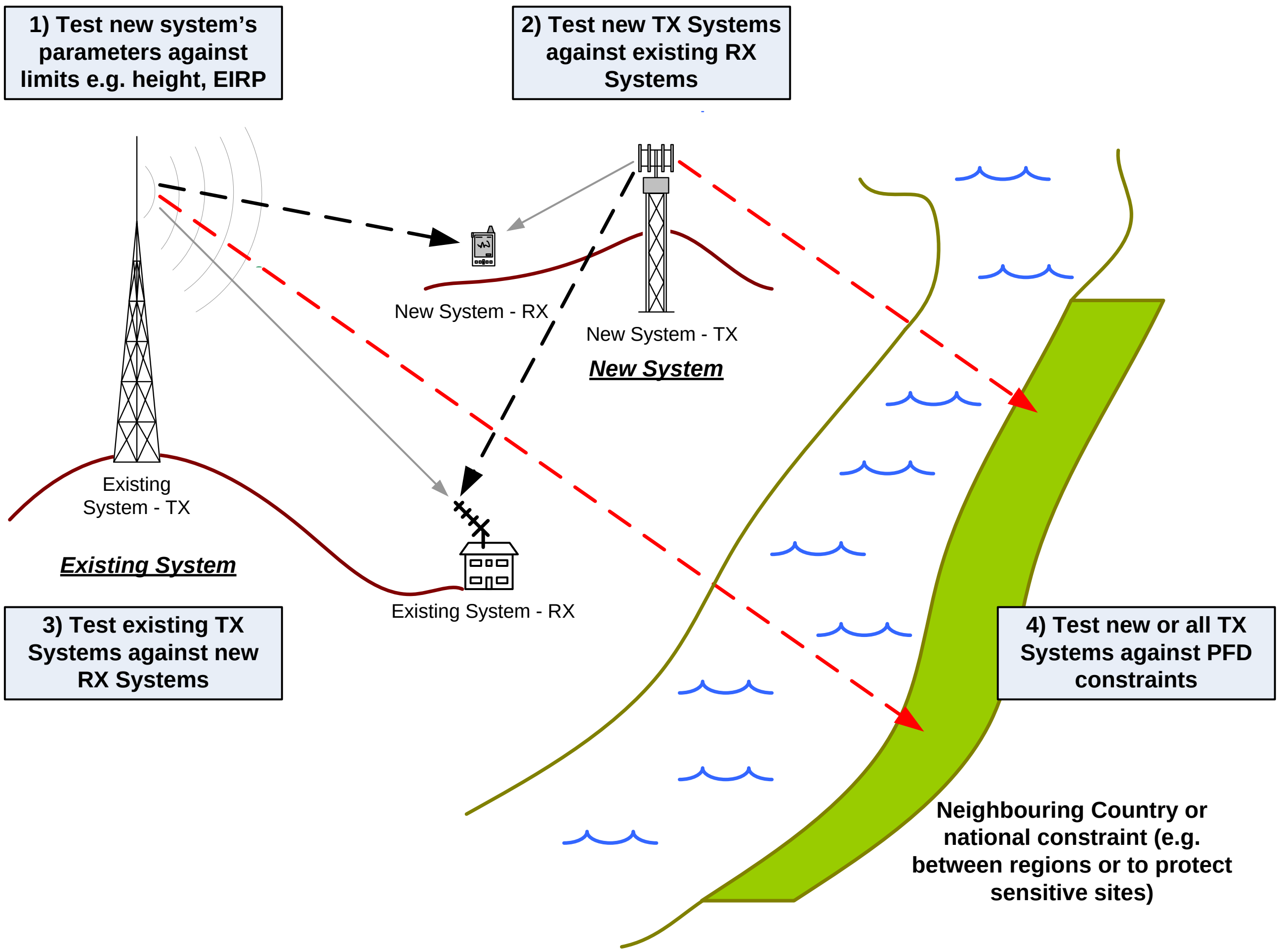
Using Templates to create Standard Spectrum Products

TNRPs are a rich data dictionary of radio parameters – standard products have much simpler requirements for parameters

GRMT includes the following *Templates* that map from standard spectrum products onto TNRP data format:

- Point to point single-direction FS
- Point to point bi-directional FS
- 3G-FDD cell single sector
- 3G-FDD cell three sectors
- 3G-TDD cell single sector
- GSM cell single sector
- GSM cell three sectors
- Land-mobile simplex
- Land-mobile duplex
- Land-mobile mobile to mobile
- DVB-T network
- T-DAB network
- DVB-H cell
- Transmit satellite earth station
- Receive satellite earth station
- Bi-directional satellite earth station
- Satellite RSA
- Radio astronomy site

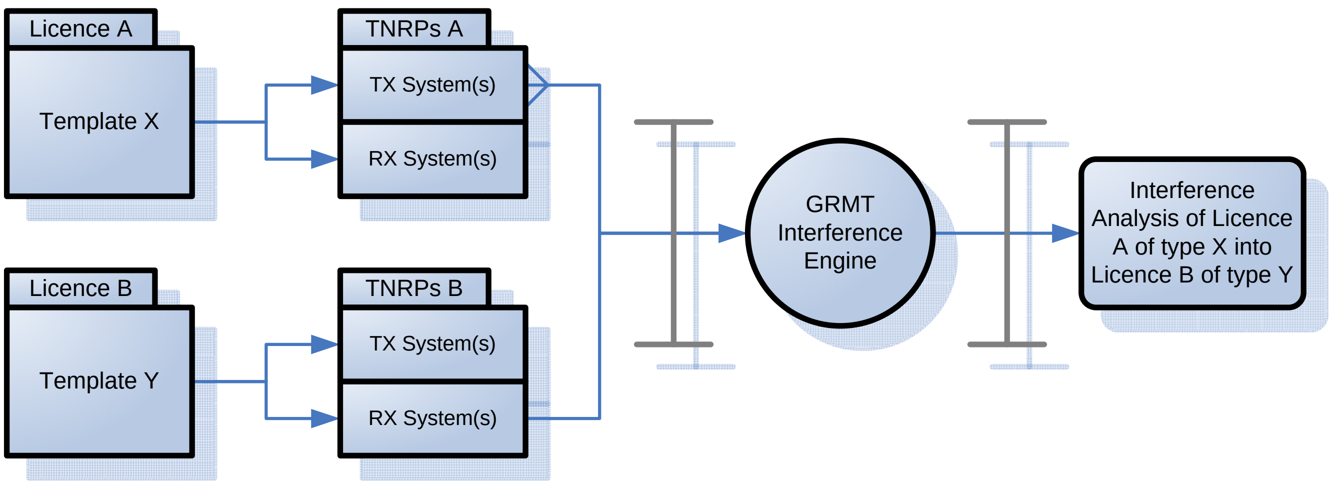
GRMT – Examination Tests



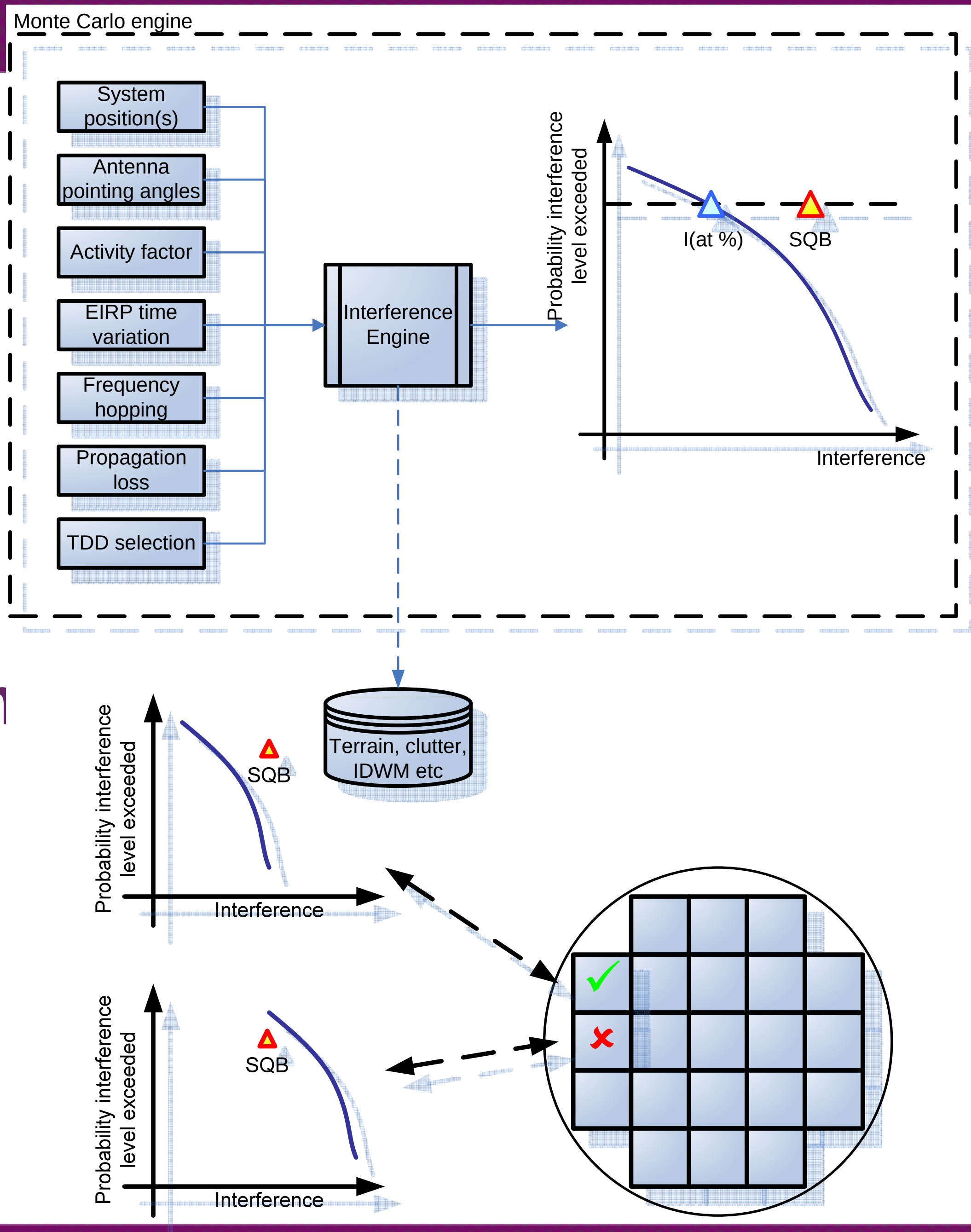
Ofcom

Templates, Tests & Jobs

- Map licence template to set of TNRP's TX & RX Systems
  - Test 1: Check parameters in range
- Search database to identify:
  - Test 2: Potentially affected licences
  - Test 3: Potentially affecting licences
- Break results of search into series of Jobs comprising:
  - One RX System e.g. Licence B $\{RX_i\}$
  - At least one TX System e.g. Licence A $\{TX_1, TX_2, \ldots\}$

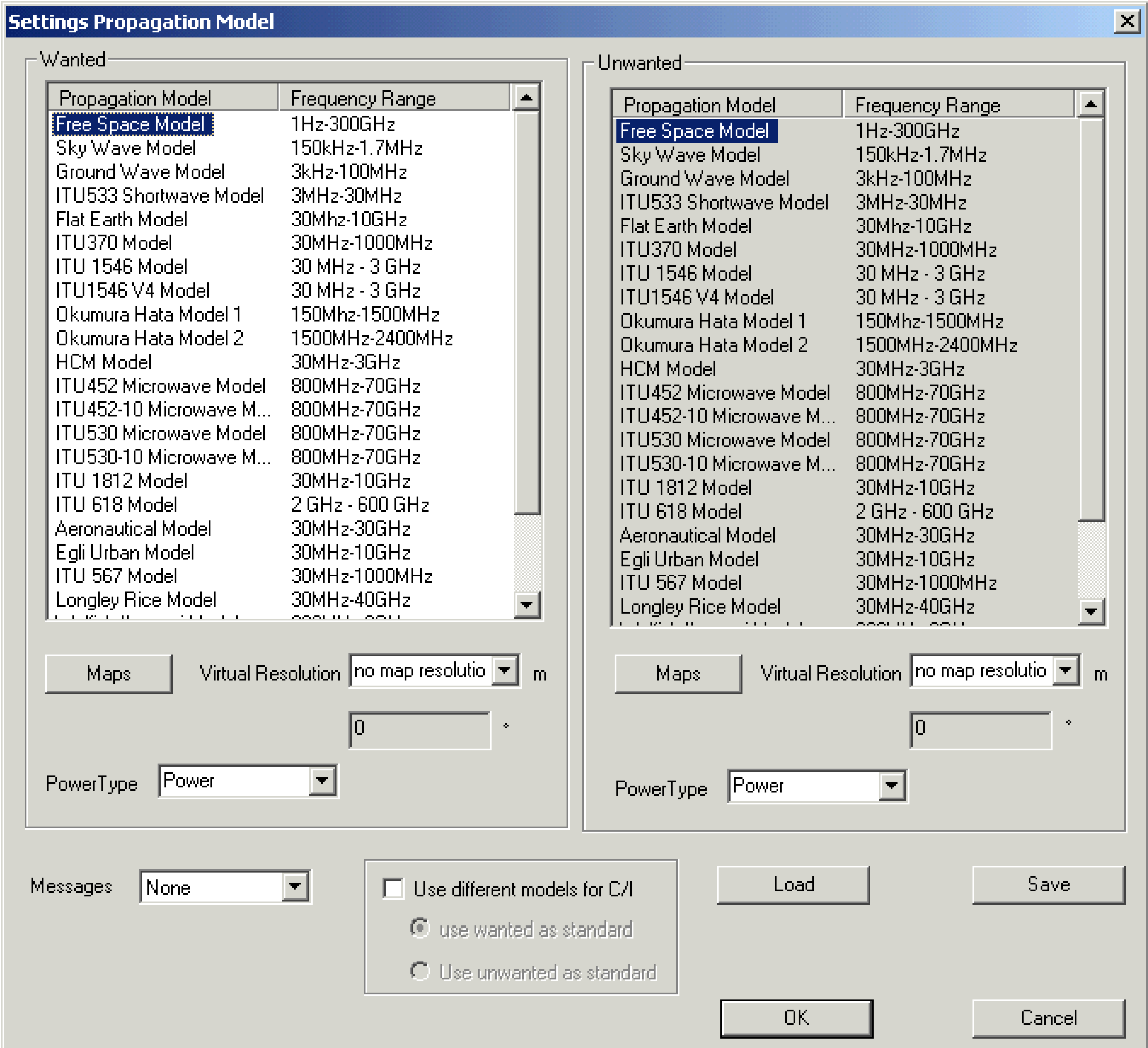


GRMT's Algorithm



But….how is the level of interference predicted?

- Plethora of propagation models exist giving users a bewildering choice
- Most models highly restrictive in applicability
- Users often invited to select different models depending on whether the prediction is of a wanted or unwanted signal
- A Generic Interference Prediction method must be consistent
- A need was identified for a more appropriate “wide-range” propagation model


Settings Propagation Model
Wanted
Propagation Model Frequency Range
Free Space Model 1Hz-300GHz
Sky Wave Model 150kHz-1.7MHz
Ground Wave Model 3kHz-100MHz
ITU533 Shortwave Model 3MHz-30MHz
Flat Earth Model 30Mhz-10GHz
ITU370 Model 30MHz-1000MHz
ITU 1546 Model 30 MHz - 3 GHz
ITU1546 V4 Model 30 MHz - 3 GHz
Okumura Hata Model 1 150Mhz-1500MHz
Okumura Hata Model 2 1500MHz-2400MHz
HCM Model 30MHz-3GHz
ITU452 Microwave Model 800MHz-70GHz
ITU452-10 Microwave M... 800MHz-70GHz
ITU530 Microwave Model 800MHz-70GHz
ITU530-10 Microwave M... 800MHz-70GHz
ITU 1812 Model 30MHz-10GHz
ITU 618 Model 2 GHz - 600 GHz
Aeronautical Model 30MHz-30GHz
Egli Urban Model 30MHz-10GHz
ITU 567 Model 30MHz-1000MHz
Longley Rice Model 30MHz-40GHz
Maps
Virtual Resolution
no map resolutio
m
0
PowerType
Power
Unwanted
Propagation Model Frequency Range
Free Space Model 1Hz-300GHz
Sky Wave Model 150kHz-1.7MHz
Ground Wave Model 3kHz-100MHz
ITU533 Shortwave Model 3MHz-30MHz
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ITU 1546 Model 30 MHz - 3 GHz
ITU1546 V4 Model 30 MHz - 3 GHz
Okumura Hata Model 1 150Mhz-1500MHz
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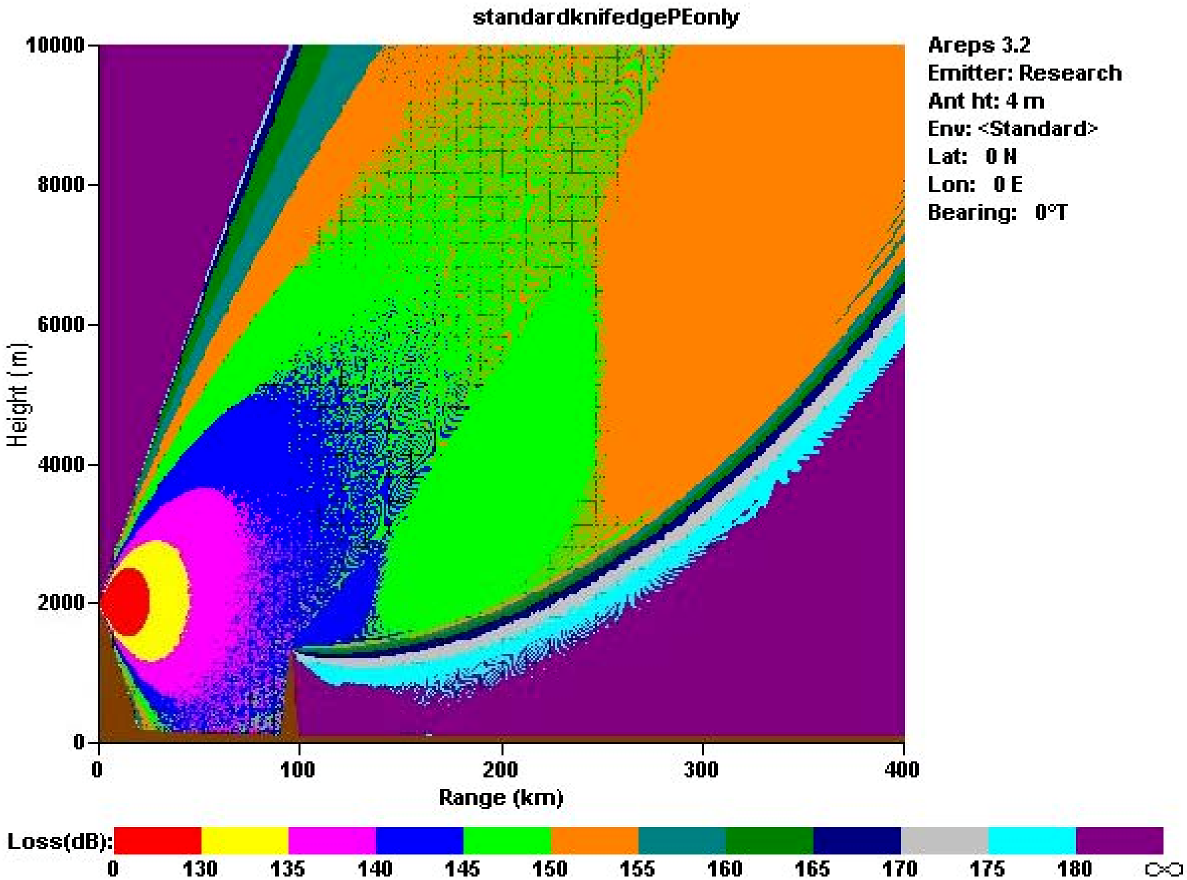
ITU452 Microwave Model 800MHz-70GHz
ITU452-10 Microwave M... 800MHz-70GHz
ITU530 Microwave Model 800MHz-70GHz
ITU530-10 Microwave M... 800MHz-70GHz
ITU 1812 Model 30MHz-10GHz
ITU 618 Model 2 GHz - 600 GHz
Aeronautical Model 30MHz-30GHz
Egli Urban Model 30MHz-10GHz
ITU 567 Model 30MHz-1000MHz
Longley Rice Model 30MHz-40GHz
Maps
Virtual Resolution
no map resolutio
m
0
PowerType
Power
Messages
None
Use different models for C/I
use wanted as standard
Use unwanted as standard
Load
Save
OK
Cancel

Propagation model wish list

- Wide frequency range (30 MHz to 50 GHz is present objective)
- Large range of distances (to be determined but at least up to 1000 km)
- Outputs c.d.f. of path loss between any two points against time over a wide range of time percentages (“0% to 100%”)
- Will use a general path profile together with geographic characteristics (e.g. rain rate) as inputs
- Free of discontinuities and non-monotonic behaviour
- Software implementable
- Efficient to run on a computer

An aside: the parabolic equation method (Craig and Levy)



Step 1: Identify relevant propagation mechanisms ("sub-models")

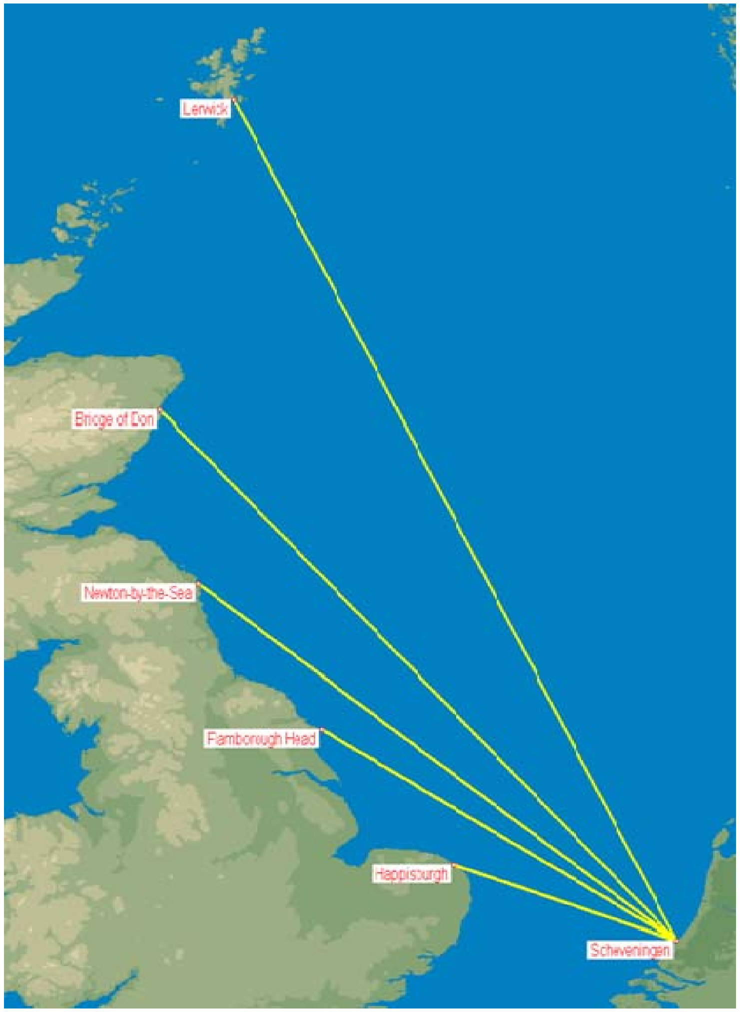
- Line-of-sight: clear air enhancements and fading
- Diffraction
- Ducting
- Tropospheric scatter
- Rain attenuation
- Gaseous absorption
- Sporadic – E

Sub-model example 1: ducting at VHF

- Required frequency range is 30 MHz – 50 GHz
- P.452 has a ducting model valid above 700 MHz
- P.1812 has a lower frequency bound of 30 MHz with predictions of signal strength exceeded for only 1% of time.
  - Accuracy of low time percentages at low frequencies has been questioned
  - Investigation involved re-examination of previous measurement campaigns

Sub-model example 1: ducting at VHF

- Bulk of measurements come from a single campaign
- Five links at four different frequencies (94 MHz, 187 MHz, 560 MHz, 774 MHz)



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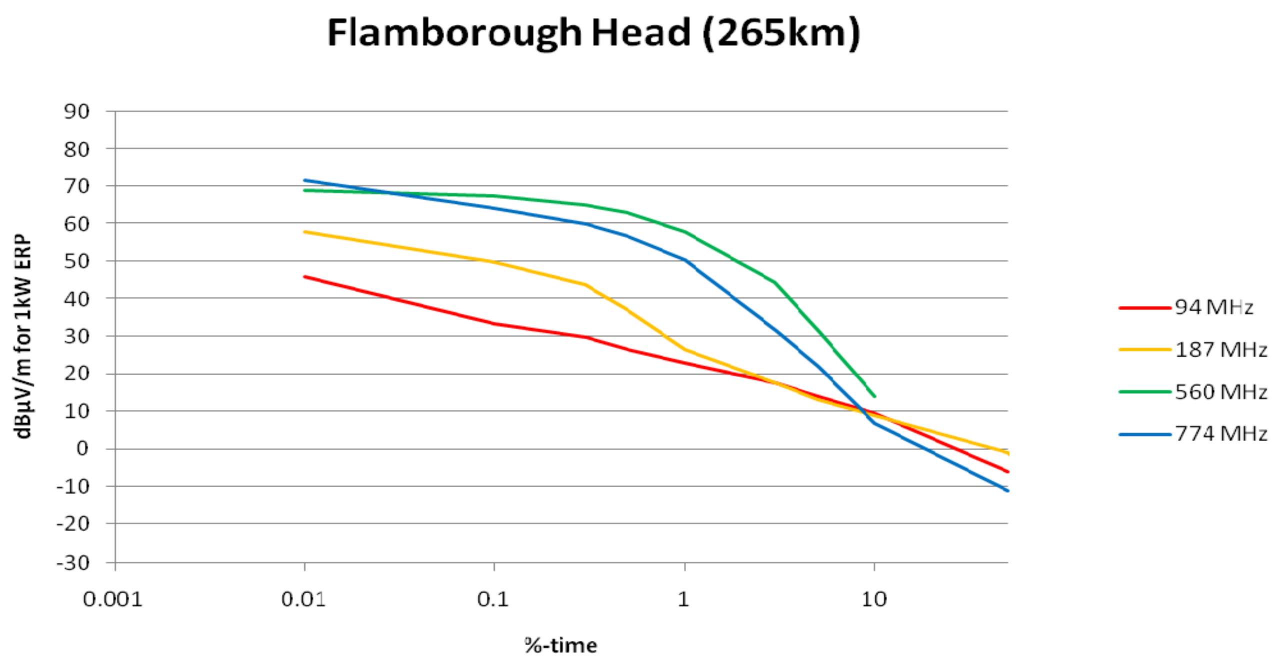
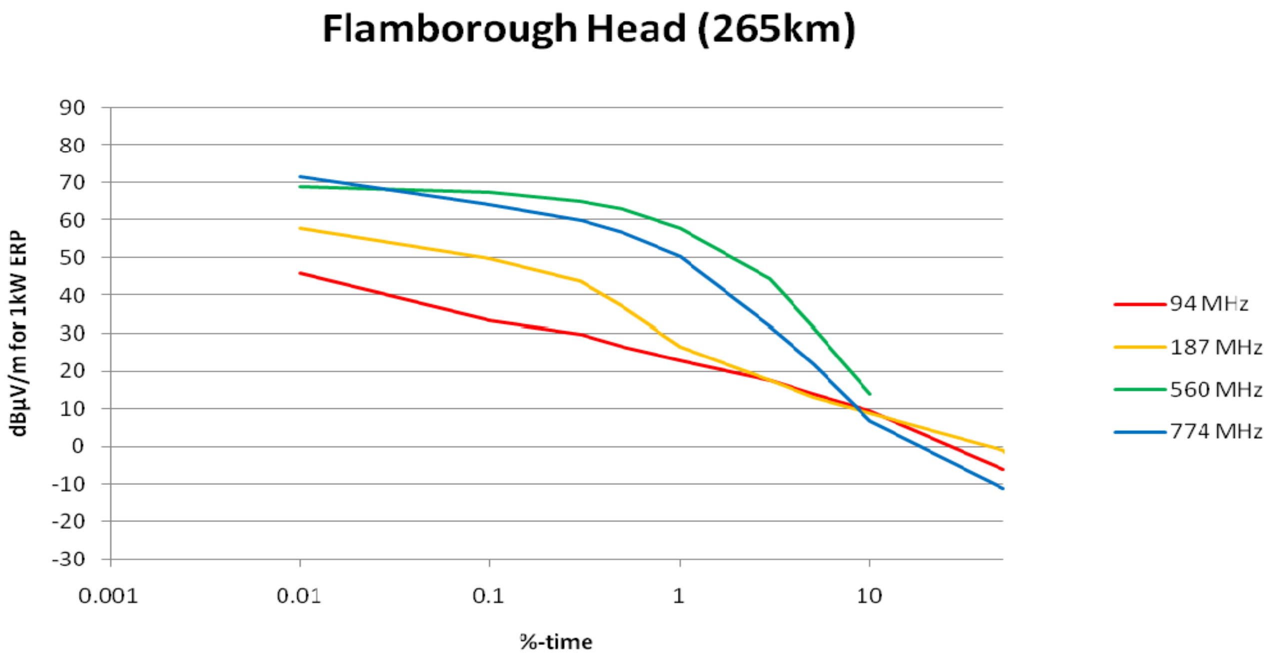
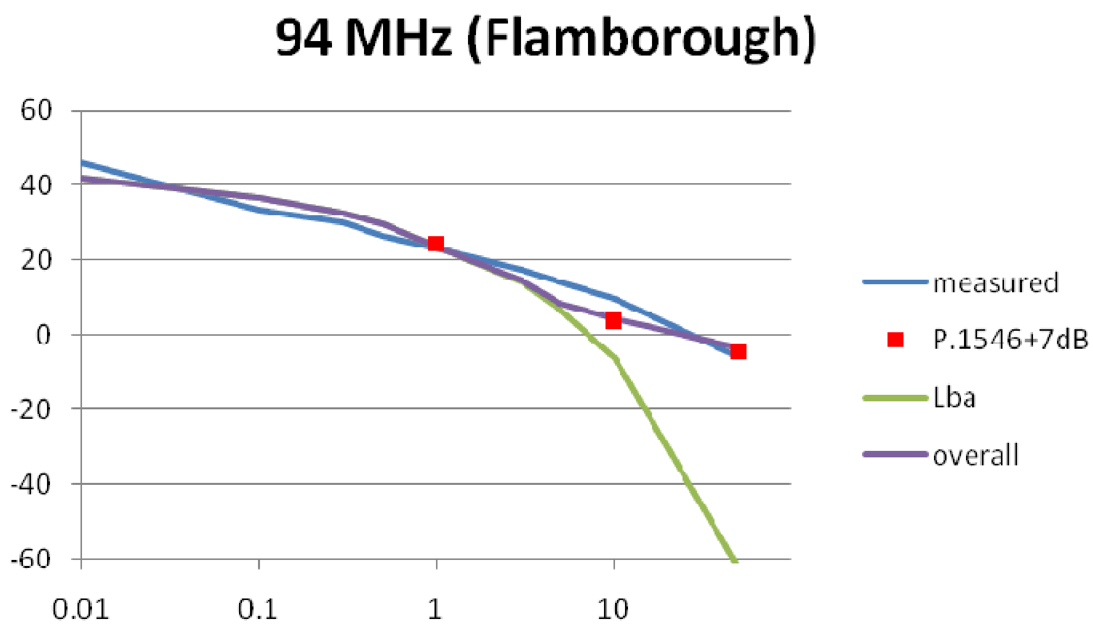


Sub-model example 1: ducting at VHF

- P.1812 is a first attempt at converting curve based predictions at VHF to equations, adopting a similar approach to P.452.
- Improvement is required in performance at low VHF in particular.

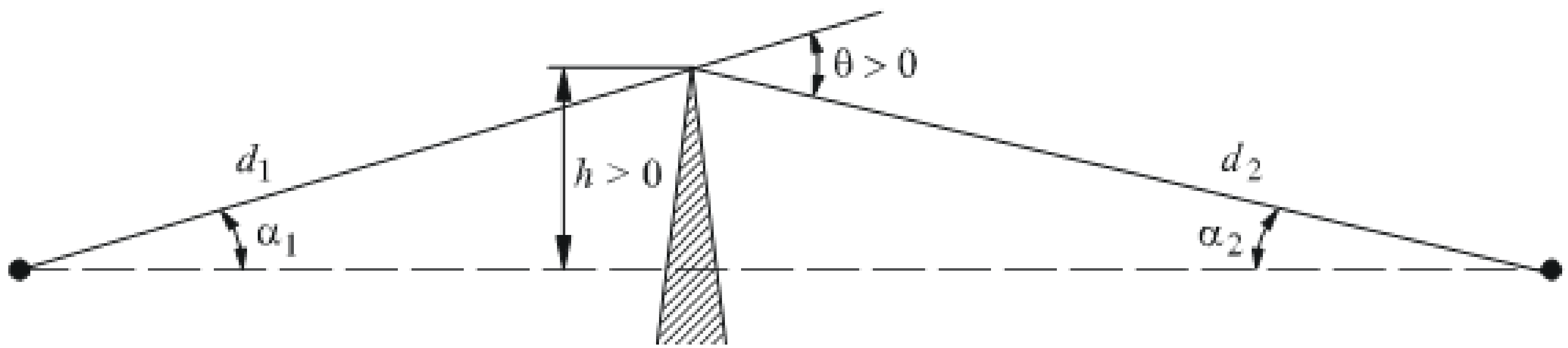


Sub-model example 1: ducting at VHF



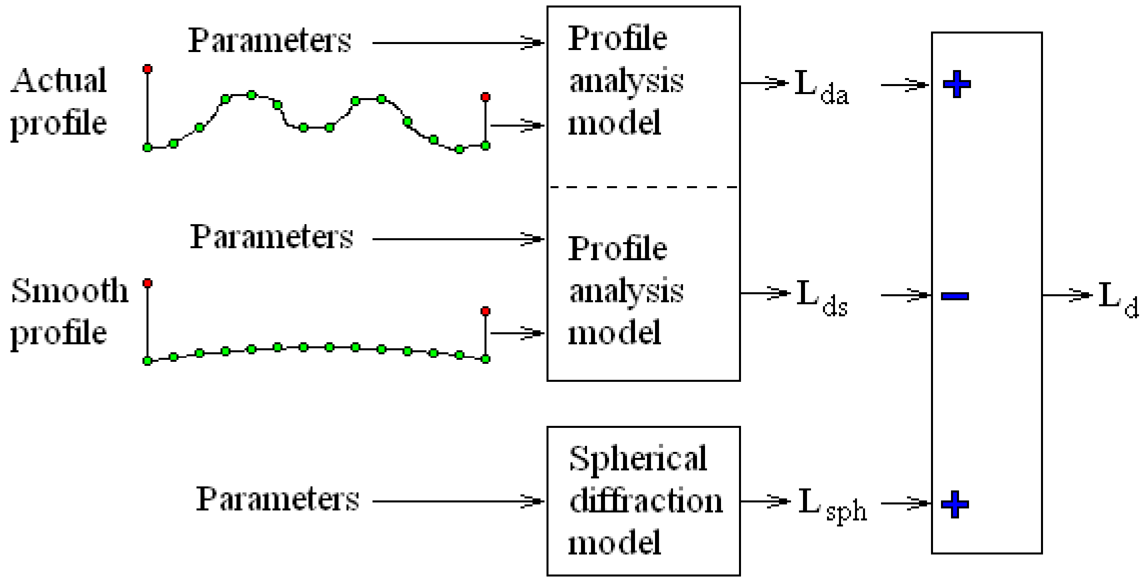
- A frequency-based empirical correction factor produces a close fit to measurements.

Sub-model example 2: diffraction



- Diffraction is still a “thorn in the side” of propagation scientists
  - It’s just not as straightforward as you think it should be

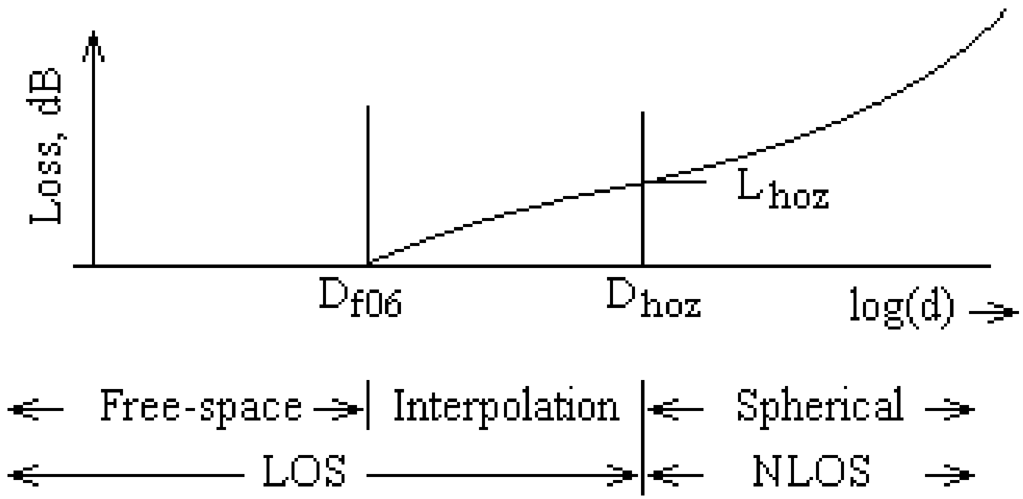
Sub-model example 2: diffraction



$$L_d = L_{da} - L_{ds} + L_{sph}$$

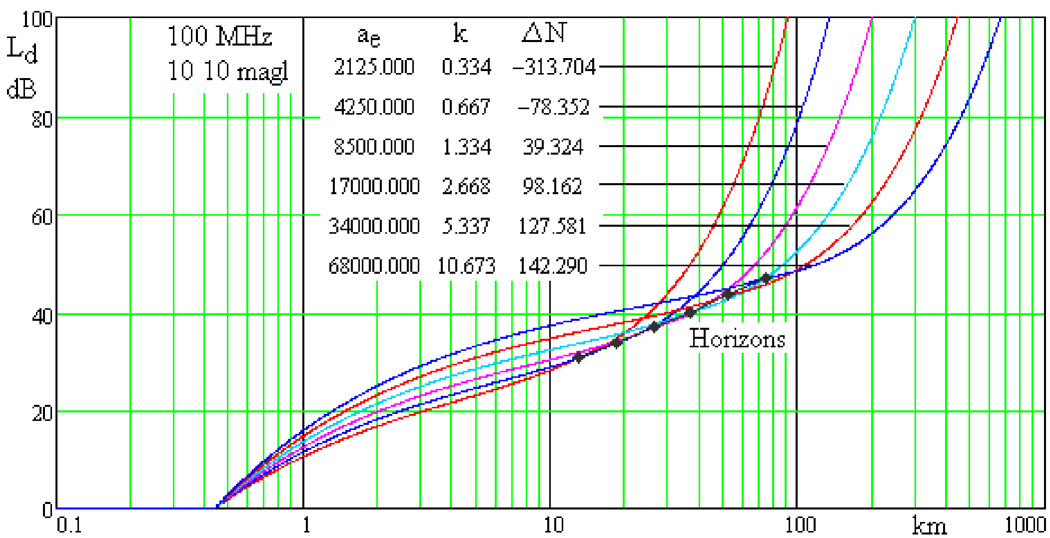
- A novel “delta method” eliminates the need for an empirical correction.

Sub-model example 2: diffraction



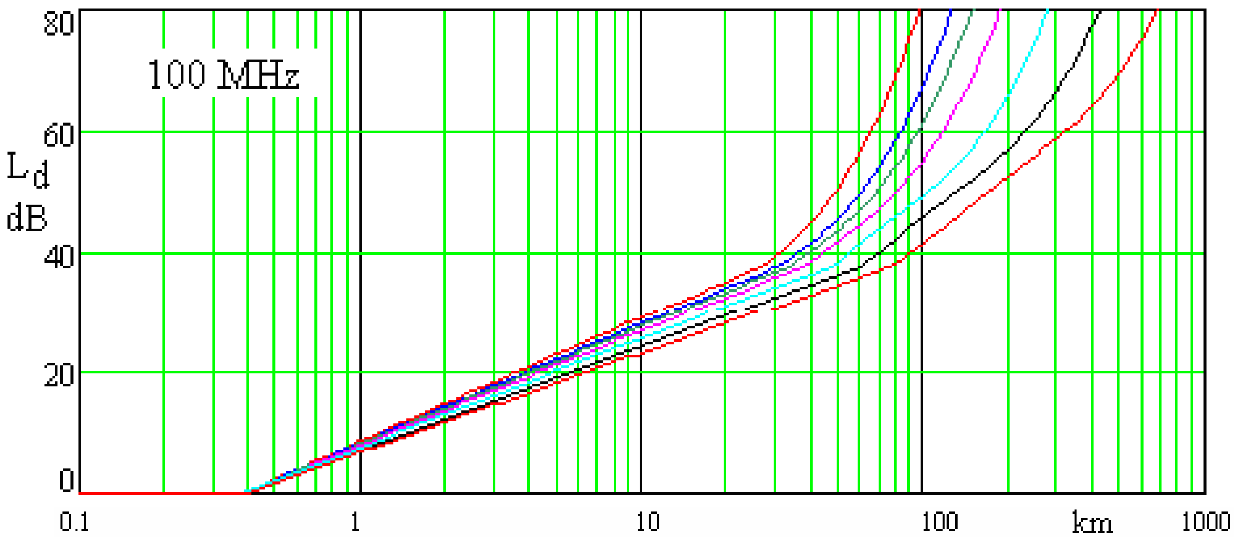
- This new method has a strong reliance on the semi-deterministic Spherical Diffraction model within P.526-10

Sub-model example 2: diffraction



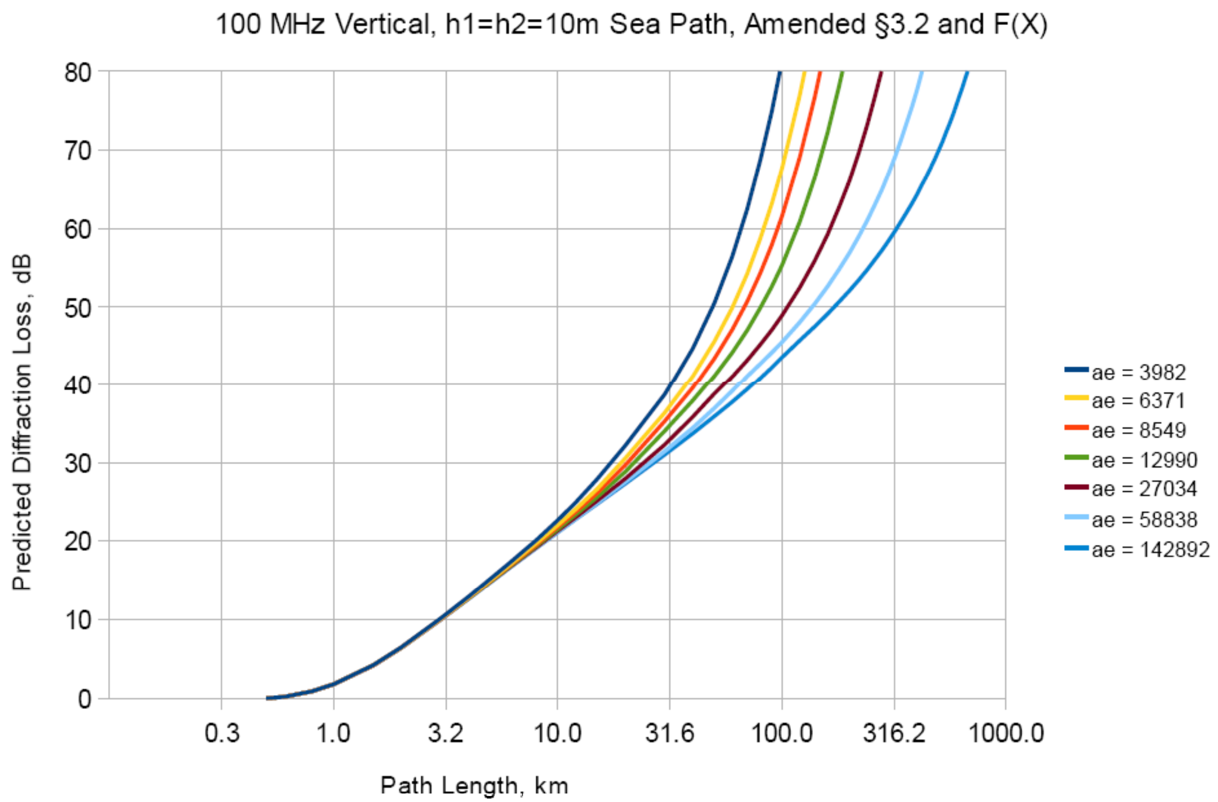
- “Logical” method of interpolating between free space and the radio horizon produces an anomaly when variation against time is considered.

Sub-model example 2: diffraction



- A new method of interpolating has been proposed to rectify this anomaly.
- This makes the delta method a realistic way of predicting diffraction loss.
- The question of what method to use to analyse the profile remains open.

Benefits of international peer review and collaboration

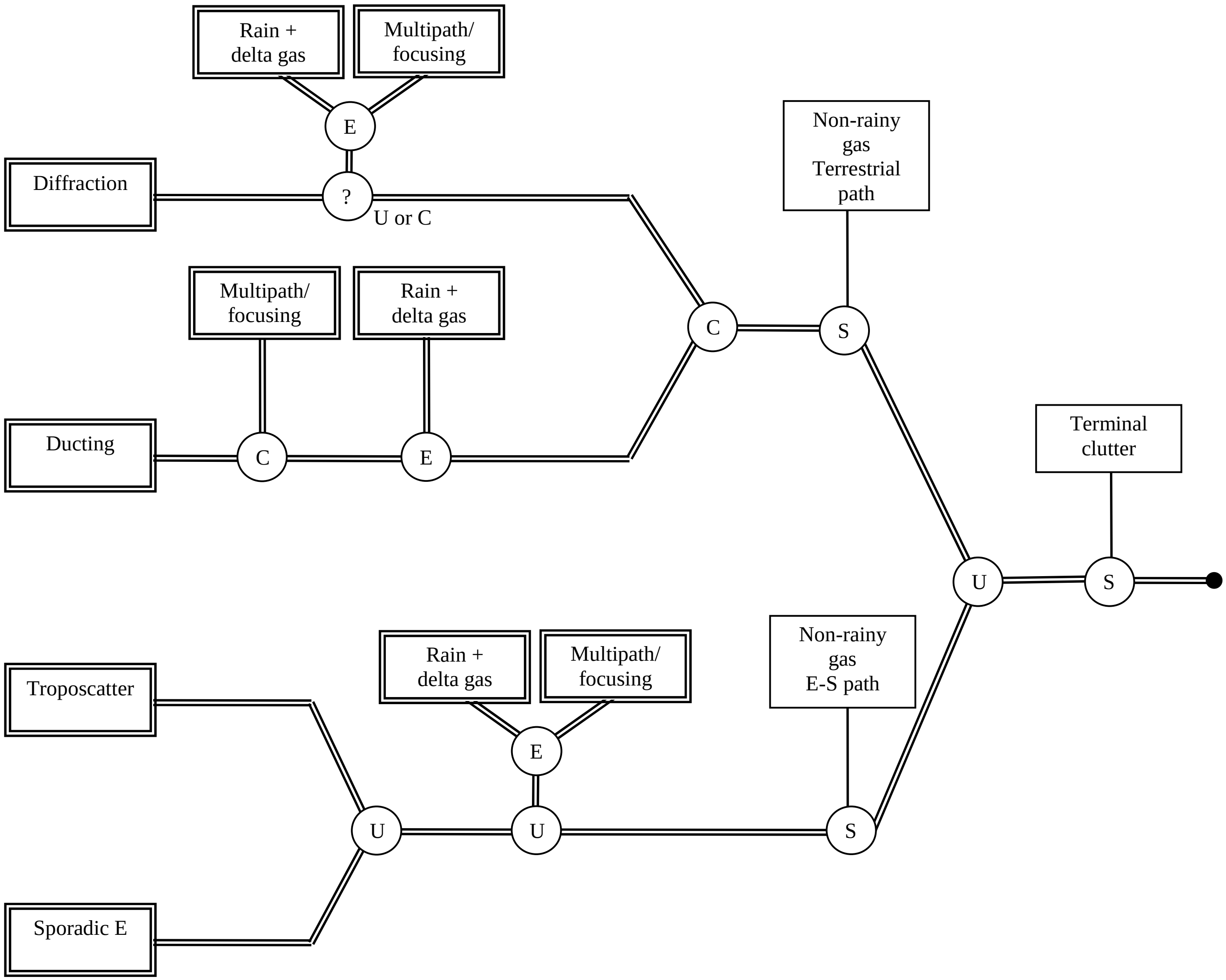


- A more elegant interpolation method developed by the Australian administration

Combination of sub-models:

- **Correlated losses:** losses can be combined by power-summation. E.g. ducting, diffraction, tropospheric scatter.
- **Losses due to mutually exclusive mechanisms:** This is more complicated, because in general it requires the models to be iterated towards the loss for which the separate values of *p*% sum to the required value. E.g. rain and clear air fading.
- **Statistically-independent losses:** The most complicated situation. This requires the separate loss probability distributions to be combined. One solution is to use a Monte-Carlo method. Closed form solution a possibility.
- **Interaction of mechanisms:** correlated losses act such as the one giving the lowest transmission loss will dominate; but mechanisms such as rain fading and gaseous absorption cause additional attenuation.

Combination of sub-models:



Conclusions and further work

- A Generic Assessment engine has been demonstrated as capable of assessing interference between different services
- The evident need for an improved propagation model has been addressed
- Description of new model to be input to ITU-R Study Group 3 before November 2010
- Further study into improved urban "end-correction" model is ongoing
- Acknowledgments: Ken Craig (Signal Science), Richard Rudd (Aegis Systems), David Bacon (dBSpectrum Services), Mike Willis (Rutherford-Appleton Laboratory), John Pahl (Transfinite), Alastair Taylor (Transfinite)