9th INTERNATIONAL SYMPOSIUM ON POWER-LINE COMMUNICATIONS AND ITS APPLICATIONS

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Identifying Techno-Economic Criteria in PLC/BPL Applications & Commercialization
Panel Session 2 Thursday 7th April 2005 at 1630 hours:
Reviewing some techno-economic research and commercialization issues for PLC/BPL by way of a number of PC based spreadsheet modelling examples. The examples are aimed at illustrating the dependencies, interactivity and trends in a variety of related techno-economic data. The session will begin with a paper presentation which aims to illustrate examples of the modelling concepts and to stimulate debate. This will be followed by an open forum chaired by an independent R&D consultant with panel members from the FCC, IEEE, Industry, and Academic Research Leaders.

Panel: Professor Paul Brown (White Box Associates (chair)); Mr Jim Mollenkopf (IEEE Standards Liaison & SWG); Professor Han Vinck (University of Essen); Mr Bruce Romano (FCC); Mr Peter Biggs (OSMB Consulting); Professor Richard E. Newman (UF);
Identifying Some Criteria (micros and macros):

- **Dimensioning of Network** (transmission, distribution, underground, overhead, access, in-home)

- **Reach** (100’s of kilometres / miles, 10’s of kilometres/ miles 100’s of metres / yards, 10’s of metres / yards/ 100’s of centimetres / inches? - limited by network characteristics, launch PSD and Regulation)

- **Repeaters** (required to overcome losses, attenuation, delay spread, launch power spectral density, EMC requirements, etc)

- **Customers** (key--services required, service penetration, density, bandwidth available, traffic characteristics and statistics)

- **Bandwidth Provisioning** (customer densities and traffic statistics)

- **Return On Investment** (expenditure, revenue, profit, profit to investment ratio)
Network Infrastructure Theoretical (*Visual-but no Dimension*)

- LV transformer - substation
- Fiber Optic MANs
- MV EDNs
- LV EDNs
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North America - Typical Electricity Distribution Network - Medium Voltage (MV)

Substation

SC

Transformer

SC

Switch Cabinet

SC

Normally Open Point

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North American Distribution Substation
The North American Distribution Substation

Converts transmission level voltages (345 kV, 161 kV, etc.) to distribution level voltages (13.8 kV, etc.)

Average characteristics:

- 2,500 to 5,000 Customers
- 4 to 8 Feeders
- 500 to 1,000 Customers per Feeder

Typically serves a radius of about 2 miles, but can be significantly more.
Distribution Components

Switch Cabinet
Allows access to underground primary.

Pad Mount Transformer
Steps primary distribution voltages down to secondary distribution voltages.
Transformers and Secondary Distribution - Low Voltage (LV)
Typical Underground Service Entrance

Ringless Meter “Can” with Socket Meter Installed

Exterior Disconnect

Service Entrance

“Demarc” Box

Telephone

Cable Television

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Pad Mount Distribution Transformer
Customer Densities:

Europe / Asia

• Typically 250-300 customers per LV transformer

North America

• Typically 6-10 customers per LV transformer
Network Characteristics – PSD – Repeaters - EMC

\[ D_{\text{max}} = \frac{(\text{PSD tx} - \text{PSD noise} - \text{SNR min})}{\text{ATT dB/m}} = \frac{(-50 - (-120) - 15)m}{0.4} = 137.5 \text{ m} \tag{1} \]
Single PLC Substation Cell Topography

- Electricity
- Electricity & Telecomms
- PLT Basestation

nMbit/s (multiplexed)
Multiple PLC Substation Cells
Propagation Models

\[ P_R = \left( \frac{\lambda}{4\pi d} \right)^2 P_T G_T G_R \]  
(2)

\[ P_R = \frac{(H_T H_R)^2}{d^4} P_T G_T G_R \]  
(3)

\[ P_R = \left( \frac{40\text{MHz}}{f} \right)^2 \frac{(H_T H_R)^2}{d^4} P_T G_T G_R \]  
(4)

Where:

- \( P_R \) = Power Received (W)
- \( P_T \) = Power Transmitted (W)
- \( G_T \) = Transmitting (Tx) Antenna Gain
- \( G_R \) = Receiving (Rx) Antenna Gain
- \( H_T \) = Transmitting Antenna Height (m)
- \( d \) = Propagation Distance (m)
- \( H_R \) = Receiving Antenna Height (m)
Field Strength Regression (Measured @ 7 MHz)

12th October 2001 - Measured E Field Strength regression @ 7 MHz,
+10dBm injected signal power into CPCU, Dipole, EGLI Propagation Model (Dipole HT=6m HR=2m, and CPCU HT=1.5m HR=2m), and Free Space Model.
## Incremental Increase in Noise Floor

<table>
<thead>
<tr>
<th>Annulet No.</th>
<th>Annulet Radius (m)</th>
<th>No. of Substations</th>
<th>Field Strength from 1 Sub (dBuV/m)</th>
<th>Field Strength from all Subs in Annulet (dBuV/m)</th>
<th>Field Strength from all Subs so far (dBuV/m)</th>
<th>Taking into account overall Correction Factor of -19dB</th>
<th>Adding to Sensitive Receiving Site at -15dBuV/m Noise Floor in 9kHz</th>
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Service Penetration (SP) may be related to Service Cost (SC), including installation cost with the logarithm of the Data Transmission Rate (DTR) as follows:

$SP = \frac{(60-SC)+10\times(\log_2(DTR)-9)}{100}$

Probability of $k$ customers being connected at same time is given by:

$f_N(k) = \Pr\{N = k\} = \binom{n}{k}p^k(1-p)^{n-k}$
In 95% of cases less than 5 customers connected

Bandwidth Provision for 5 Customers
BPL Expenditure Revenue and Profit

- Total expenses per year
- Total revenue per year
- Profit per year

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