

SEAS DTC Conference

Emergency Through-ground Mobile Communications System

CC016

July 2009



Presentation

- WFS
- History of through-ground and through water RF comms
- Technology
- Emergency Underground Comms System Project
- Applications
- Questions



About WFS

- Founded in 2003
 - Custom comms products
 - Military data links
- From late 2004
 - Underwater and Underground RF products & technology
 - >50 patent applications
 - First product launch Sept 2006
 - World's leading supplier
 - Emerging global industry
- Awards:
 - MoD (DDA) top innovation 2006/07
 - ISO9001, Dec 08
- Locations:
 - Edinburgh, Scotland
 - Belfast, N. Ireland
 - Houston TX
 - Washington DC,



Data link for Typhoon (Eurofighter)



World's first underwater RF modem



History of through-ground and through water RF comms

- Investigated in early days of radio
 - Morse developed first experiments in 1842
 - Through-ground comms used during WWI
 - Through-water research peaked 1950s-60s
 - U.S. & Russian /VLFELF submarine communications
 - Most recent DoD programs stopped late 90s
- Technology developments:
 - Digital Signal Processing (DSP)
 - Modelling capability
 - Antenna design
- Market need:
 - Machine to machine communications
 - Distributed networks; undersea vehicles
 - ISR; covert communications
 - Communication through water to air boundary
 - Harmless to sea life



Morse, 1842



History of through-ground and through-water RF comms

- Tesla (1892): presented a submarine comms concept to US Navy
- WW1 radio systems utilised through-ground paths
- VLF systems fitted to submarines from WWII
- Mid 1970s: Heyphone developed as amateur cave rescue system
- Late 90s: 1-way mine communications systems (pager)
- No 2-way systems



WW1 Trench Radio



WWII U-Boat VLF Antenna



Heyphone Cave Rescue



Mine Pager

Emergency Underground Comms System



Proprietary and Confidential

Emergency Underground Comms System

- In the aftermath of the 911 and the London bombings (Jul 05) identified a need for Emergency Services to enter bomb damaged buildings quickly.
- Fixed communications were damaged and traditional RF comms were problematic due to the environment
- WFS has been developing underwater RF communication systems and realised that the same techniques could be used to transmit data through solid materials
- Proposal to the SEAS DTC to develop a system to address the gap in emergency underground communications
- Contract CC016 was awarded in 2008.



Previous DTC Support

- This contract leveraged earlier SEAS DTC supported studies involving:
 - Phenomenological analysis of the propagation of H-field RF signals through seawater and other media
 - Analysis of dispersion and dispersion management techniques
 - Antenna modelling
 - Design of high performance, modular transmit and receive modules

Relevant WFS Work

- WFS has developed a proprietary modelling tool (Hades) to analyse near field RF propagation in a range of conductive media
- WFS has also developed a medium range RF data link to communicate at 100bps through water (Seatext[®])



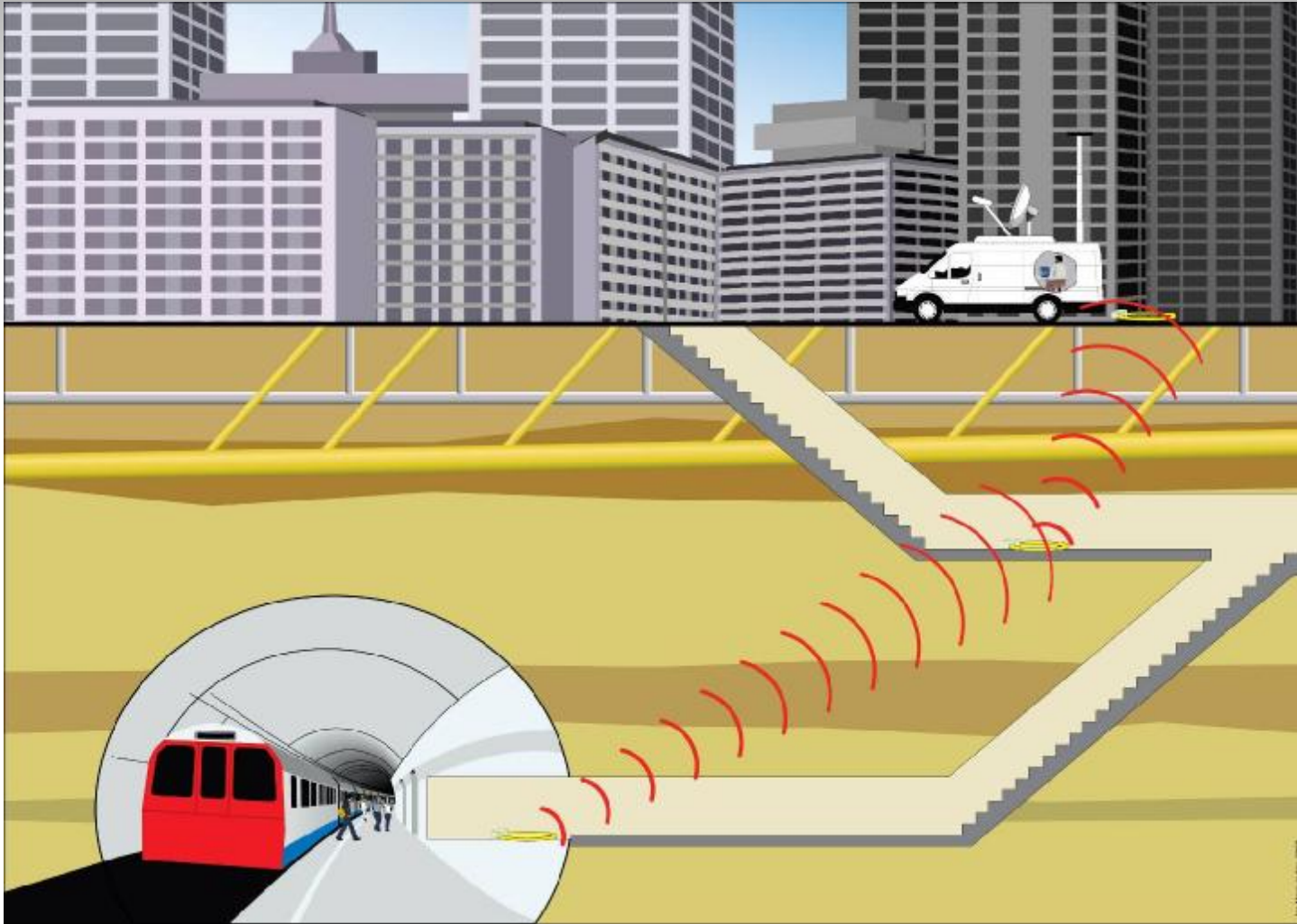
Seatext

Project Objectives

- Develop a model for RF communications through ground indicating the ranges that could be achieved
- Theoretical analysis to support through-ground communications
- Off-the-shelf through-water RF data link comms equipment modified to support texting through ground
- Trials and demonstration of 2 way communications through walls, ground and in typical underground transport locations such as the London Underground



Typical Scenario



Theory, Simulation and Analysis

- RF Propagation – using Maxwell's derived propagation equations
- Hades – simulates EM wave propagation through conductive media and media boundaries
- Calculates the fields produced by an arbitrary wire antenna in layered dielectric media and lends itself to modeling air/concrete/air boundaries.
- The underground can be represented by a layer of homogeneous media with any conductivity and permittivity. Material properties assumed were; Permittivity of $E_r = 25$ and Conductivity of $\sigma = 0.2 \text{ S.m}^{-1}$.
- Hades works by using numerical integration, taking into account effects such as reflection, refraction, diffraction and surface waves

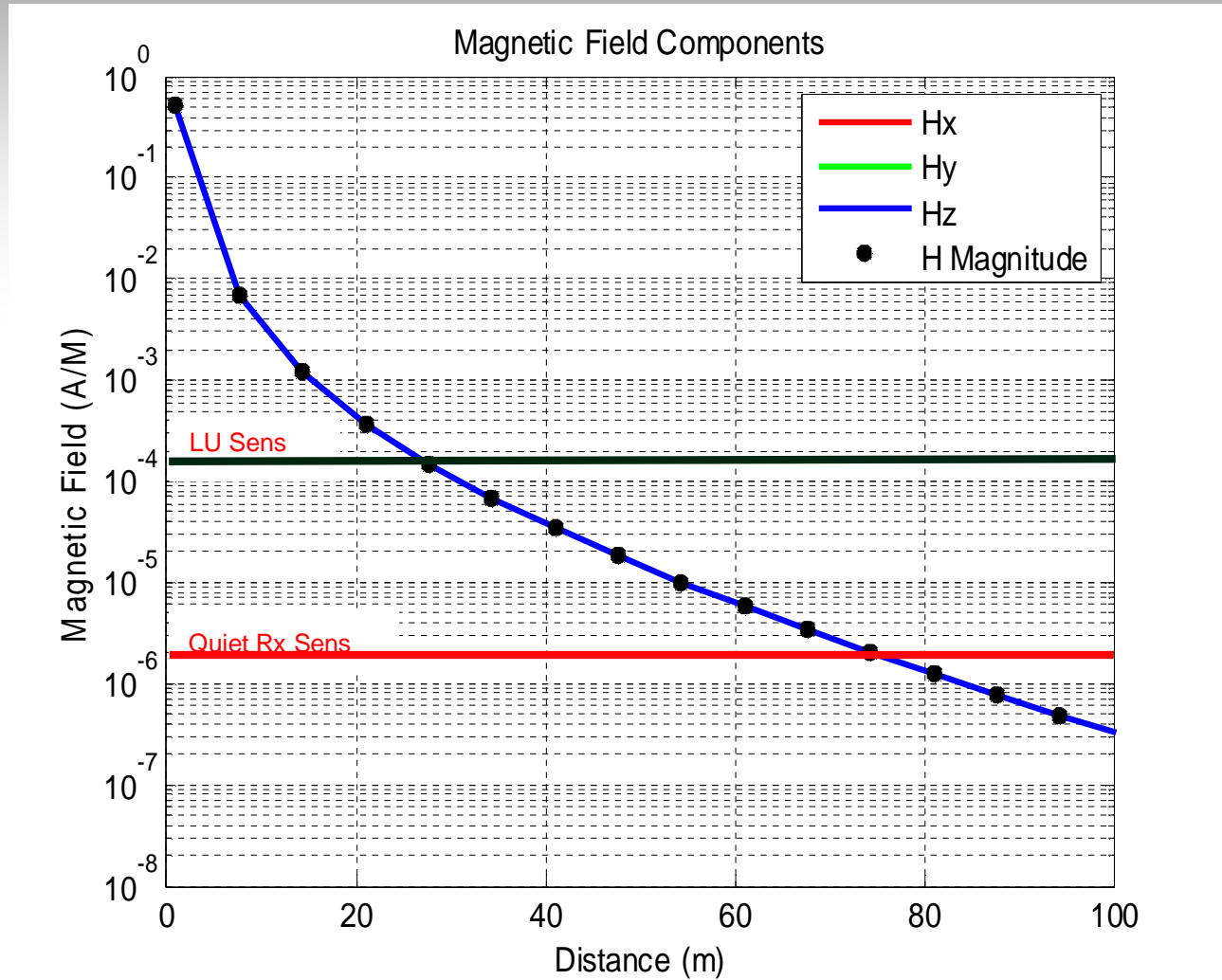


Published Material Properties

Material	Permittivity (ϵ_r)	Conductivity ($S.m^{-1}$)
Air	1	0
Saturated sand	20-30	0.01-0.00025
Clay	5-40	0.33-0.033
Concrete	6	0.01-0.0001
Dry sandy coastal land	10	0.005-0.001
Marsh or forested land	12	0.2-0.05



Tx Range Simulation



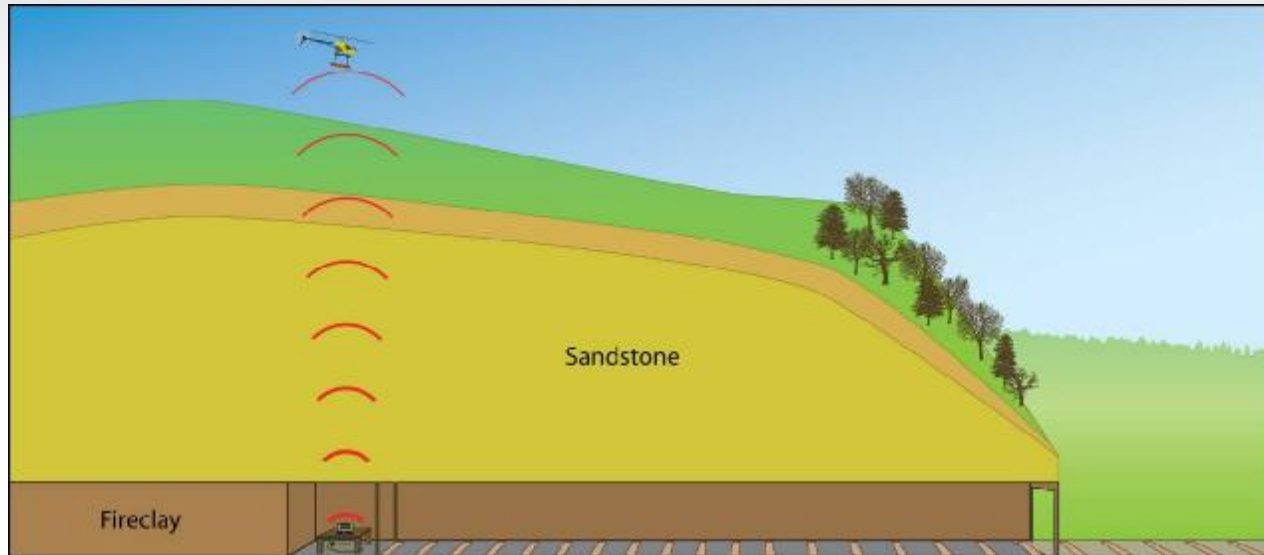
Rural Environment Trials



- At Birkhill Fireclay Mine, Bo'ness
- A data rate of 100 bits/s spread spectrum was used. The furthest distance available was 70 m through fireclay and clear, two way transmission was consistently achieved.

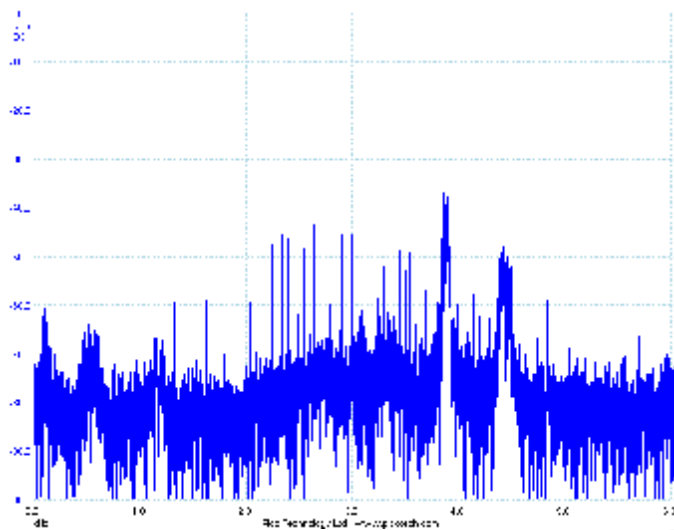
Flying Trials at Birkhill

- Successful trials were conducted from within the mine to a UAV (Minicopter) hovering overhead

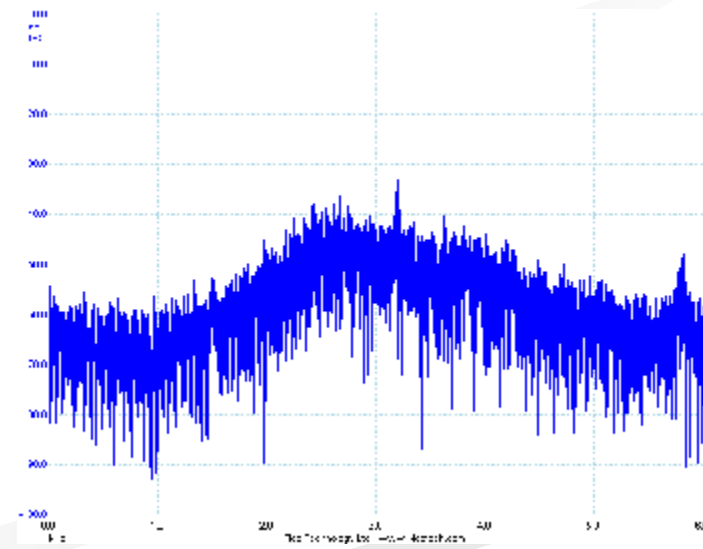


Noise Measurement

- Noise measurements taken at a number of stations at varying depth between 9 and 43m
- Tests at Monument, Pimlico, Bank and Elephant & Castle
- Noise level comparable at all depths
- Street level noise higher than anticipated

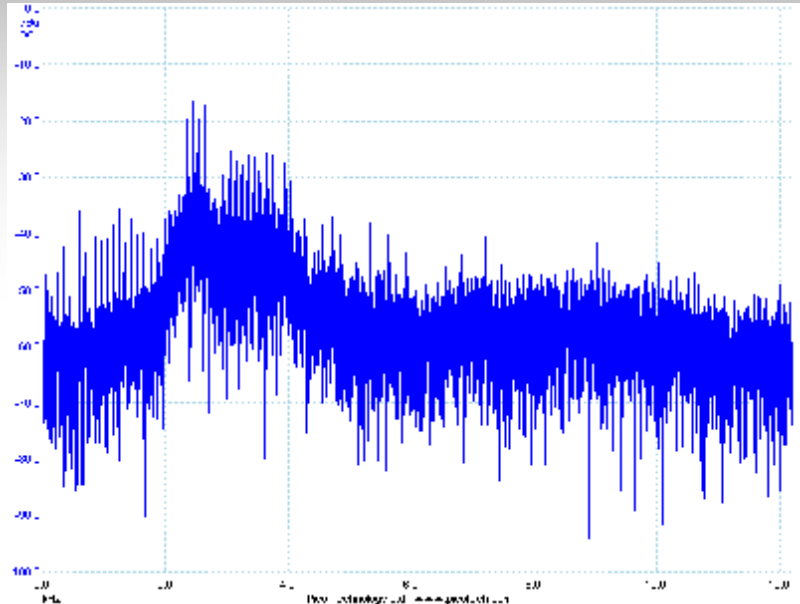


Noise on platform with no train

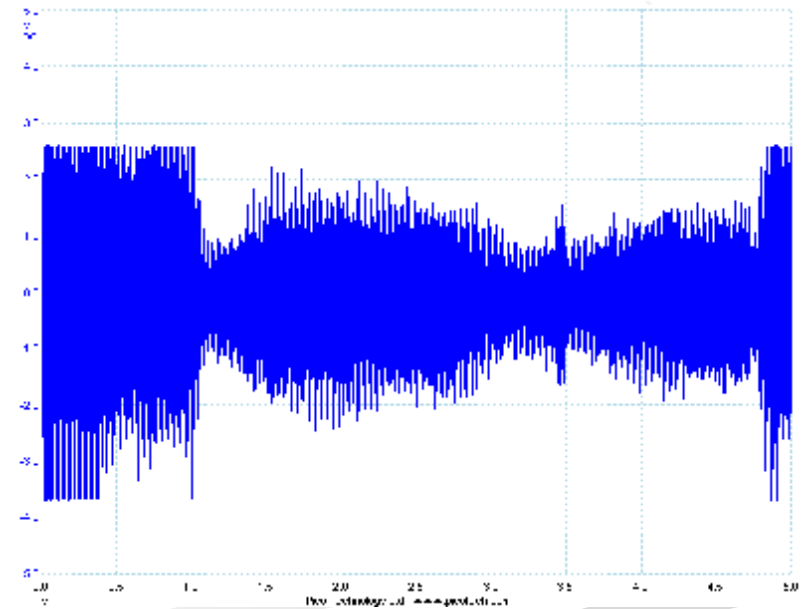


Noise on platform with train

Street Noise



Noise Spectrum at Street Entrance

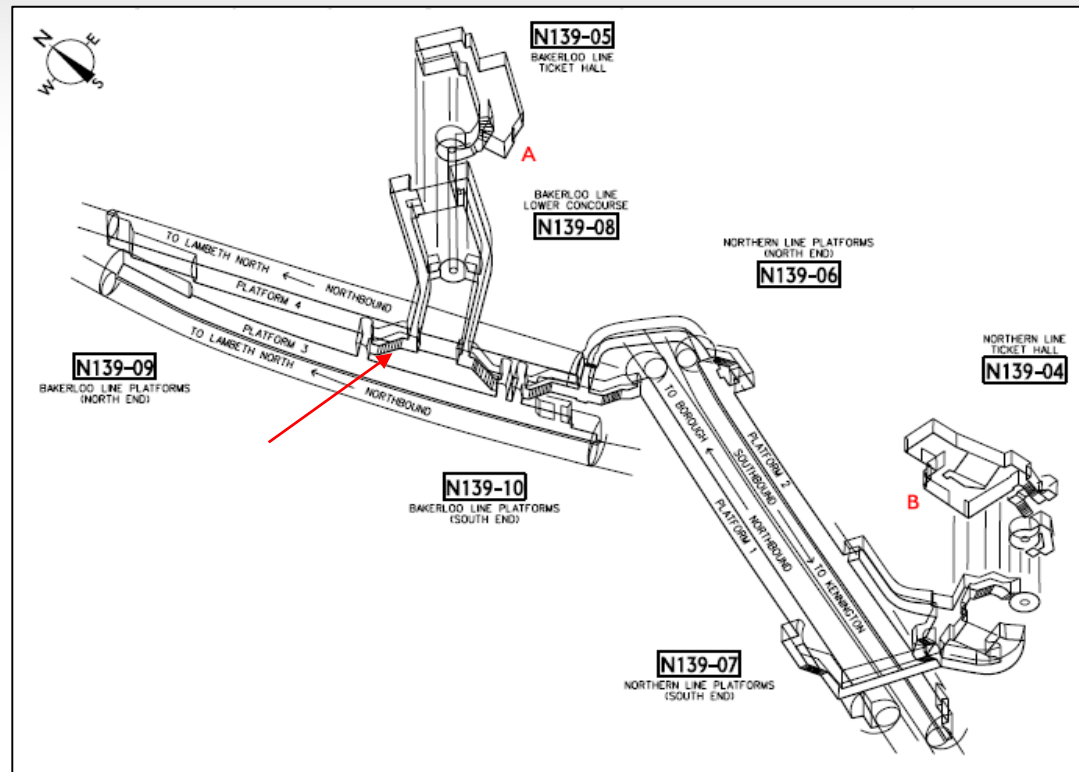


Noise Voltage at Street Entrance



Communications range tests at Elephant and Castle

- **Low Power System**
 - The first system trials used a low power system, comprising a 5A transmitter and 1m loop antenna.



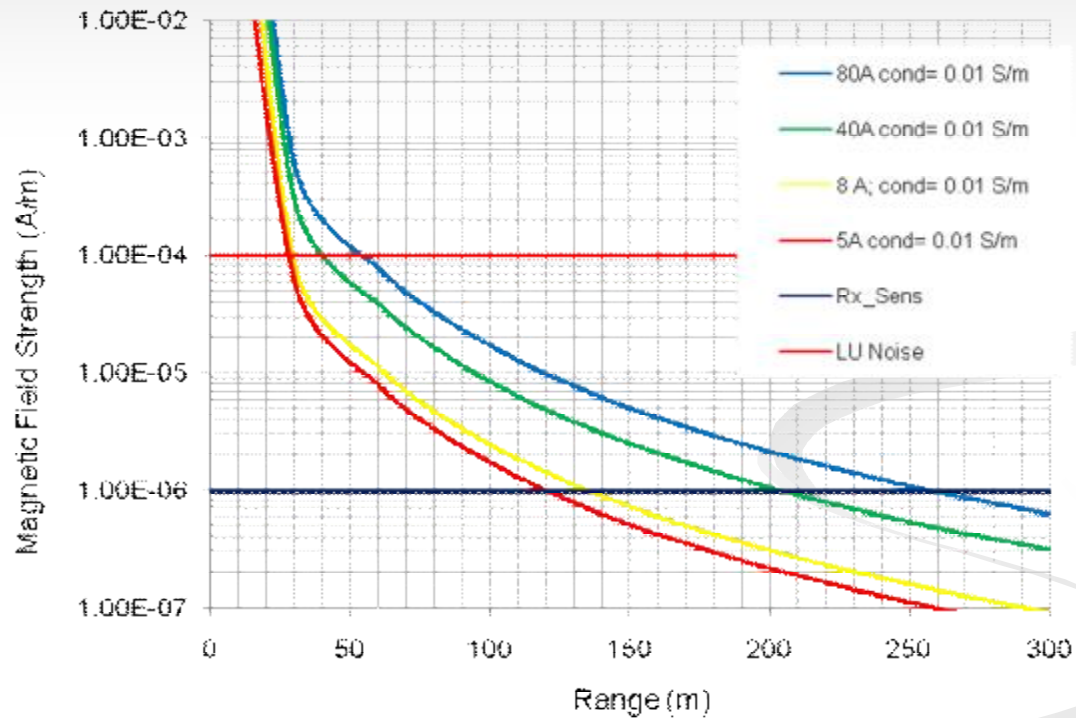
High-Power Transmitter



Transmitter Board

- High power, transmitter developed to extend range and performance.
- Though designed for peak output of 80A, the version available for these trials generated a peak current of 40A.

Range Simulation



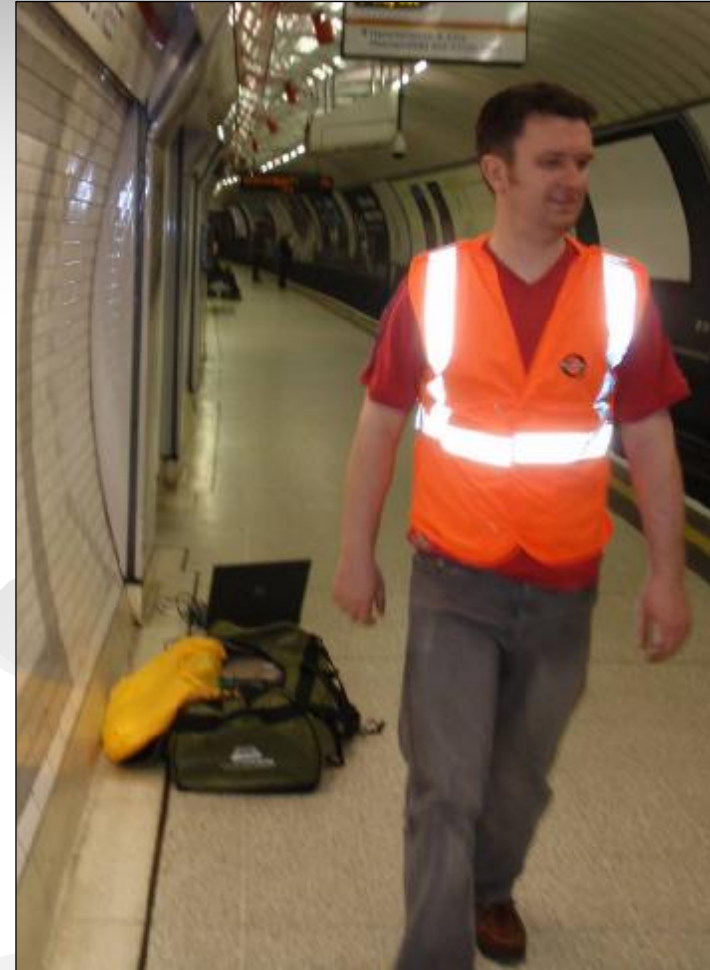
5A, 8A, 40A & 80A; 40cm TX System Range Simulation

Proprietary and Confidential

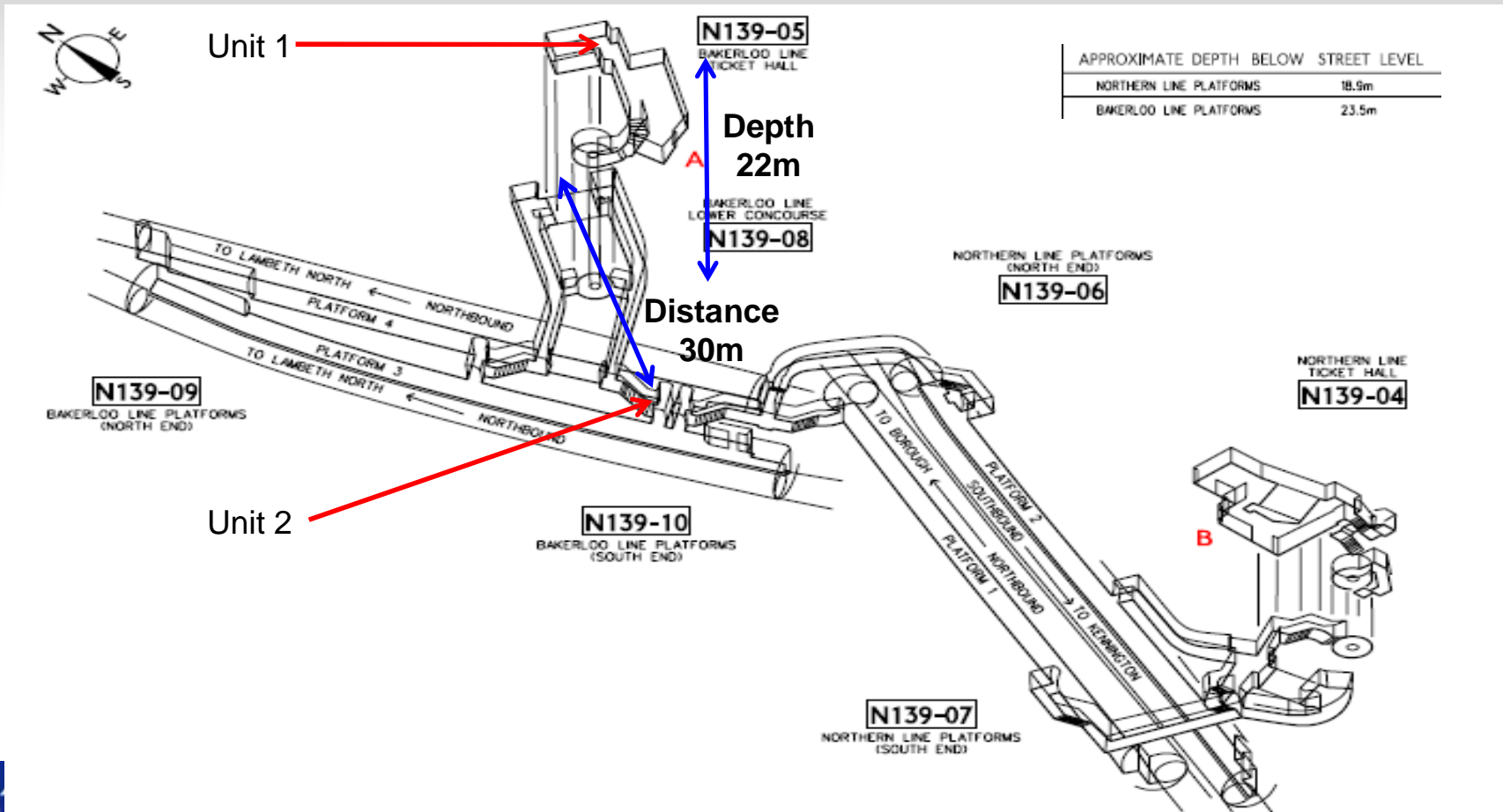


Final Trial and Demonstration

- Equipment in rucksack
- Communicated directly between the ticket office and the platform level
 - 23m deep
 - 30m to platform entrance
- Comms between street level and deepest platform level demonstrated and operated reliably



Tests at Elephant and Castle



Conclusion

- A theoretical analysis underpinning the propagation of RF through solid, conductive media.
- A theoretical model utilising WFS's custom tool, Hades, to predict the performance of RF communications in a range of through-ground scenarios.
- WFS's off-the-shelf RF communications equipment designed for through-water communications was successfully modified to support low bandwidth text communications through ground in complex and challenging environments.
- A successful demonstration of video streaming through a dense wall was provided to an MoD audience at the Cabinet War Rooms in London during April. WFS's system was integrated with in-service 3eTi WiFi video streaming equipment.



Recommendations (1)

- Conduct trials in environmentally quiet locations such as caves, culverts and basements to measure performance, calibrate of the simulation model and increase experience of the deployment and operation of this equipment
- Modify the RF equipment used in this programme to support voice and/or data communications and conduct field trials.
- Undertake research into DSP techniques to improve performance in high noise environments



Recommendations (2)

- Undertake research into antenna technology to improve launch efficiency
- Reduce the size, weight and power the RF system to make more readily man-portable
- Integrate low bandwidth RF equipment with in-service RF equipment such as Bowman with a view to supporting UoRs
- Run trials to determine the practicality in the field of hybrid RF Communications systems for cave clearances
- Run trials to determine the practicality of commanding and controlling autonomous vehicles underground for cave and building exploration and clearance.

