RF in Motorway Tunnels
(Underground Down Under)

Exactly how do I get to hear the radio underground...
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- Based in Sydney, Australia
  - Electrical Engineer
  - Programmer

- This presentation describes work done in motorway tunnels
- The companies don’t mind me talking about this, but it will not be going onto YouTube
Motorway Tunnels

• Sydney, like many cities, has a number of road tunnels.

• M5east – 4km
• Lane Cove – 3.8km
• Eastern Distributor – 1.8km
• Cross City – 2.1km
• Epping – 600m
• WestConnex – 19km (under construction)
Radio Communications Underground

- Drivers want to listen to AM & FM radio whilst driving
- O&M Repeater needed for staff
- Government Radio Network for Police/Ambulance
AM & FM Radio

- Drivers need access to AM and FM broadcast underground
- Break-in audio in emergencies
AM Radio

- AM Radio Rebroadcast is simple
  - 12 HiFi AM Receivers about 2km from the tunnel
  - Audio goes on a 32 audio channel Fibre
  - Audio sent to two banks of 30W AM transmitters
    - One for eastbound and one for westbound
    - Announcements overridden as required
AM Radio

• Signals from 12 transmitters are combined
• They are then fed into a pair of 4km long wire antennas
• Since the wavelength of the tunnel is only about 15 wavelengths this works well.
FM Radio

• FM Radio is a LOT more complex
• Expect to learn something new
FM Antennas

- Twin 4km Tunnels
- Leaky LDF5-50 CoAx in each tunnel
- Too much loss in the CoAx for only one or two segments per tunnel
- Therefore each tunnel is split into five segments
- Getting RF to each segment is challenging
FM Antennas

• There is an equipment room for each segment, handling E and W tunnels

• These damp rooms contain the amplifiers for that segment

• Getting RF to these rooms is the fun bit
FM Radio – Simple Version
Diversion - Fibre Optics

• Fibre
  – Just like fast Morse Code. Right?

• WRONG!!!!
  – That is DIGITAL fibre
  – ANALOG fibre also exists
  – ANALOG fibre is cool!

• Question:
  – Who has ever operated at 400 THz?

• Answer
  – That is just red light
• Let's assume a laser carrier at 400 THz, and that we can modulate the laser linearly, either AM or FM

• If you have a detector that is fast enough, and the laser is fast enough you can get a large bandwidth of RF over fibre
Diversion – Fibre Optics

• Since fibre is Analog, there is no digital processing delay
• The four components emulate a piece of CoAx
  – RF to Fibre Converter
  – Fibre
  – Fibre to RF Converter
  – RF Amplifier
• It is important to have levels correct for it to work!
Underground

- 2 x Fibre to RF converters
- 2 x Broadband Amplifiers
- 1 x Uplink RF to Fibre converter
- Lots of soot and moisture
Underground
Underground
Uplink Antennas

- One per tunnel direction for segment
- Combined to a single Up-Link RF to Fibre converter
- Converted back to RF at the other end and combined
Maintenance

- 8:30PM Safety Briefing
  - “Toolbox”
- 10:00PM Road Closed
  - 10:30PM other direction
- 10:30PM Start Work
- 3:30AM Stop Work
  - 4:00AM other direction
- 4:30AM Road Opens
  - 5:00AM other direction

- One week a month
- 3 nights each direction, some shared
- 5 hours on doing actual work
- Assuming access to EWP’s which can take an hour to arrive
Maintenance

- Eight FM channels inside the tunnel
- Notice how uniform the levels are
- Levels change over time on the Fibre link so we need to periodically adjust levels
Work Practices

- No Ladders
- Testing hardware on wall (out of photo)
- We could walk on the ledge on the left, but the equipment was 1 foot too tall
- We brought in a knuckle boom!
- Notice two reflective stripes on pants too. Local requirement!
Transmission Chain

- FM Broadcast
  - Receiver
  - 30W Transmitter
  - Combiner
- FM Transmitter
  - For Voice Over
  - Combiner
- 30 dB PAD
- Switcher for source selection

- RF to Optical Converter each direction
- Optical Splitter to five outputs
- Underground
  - Optical to RF
  - RF Power Amp
  - Leaky CoAx Antenna

- PLUS Injection for GRN/O&M repeaters
Extending the Repeater

- A ventilation tunnel is about 700m long, and has LMR-550 bolted to the wall.
- Shotcrete and wind have caused the insulation to crack resulting in water getting in.
- This has required the replacement of about 700 KG of CoAx 50m below the surface where winds most of the time are 100 km/h and you can only work a few hours a month.
Extending the Repeater

• Major roadworks are also starting to extend the tunnel
• We have installed equipment by Kyros that allows us to extend to more transmit and receive sites via Ethernet with precision timing
Summary

- **AM**
  - Two Long Wire Antennas
- **FM and GRN (500 MHz)**
  - Five tunnel segments
  - Each with separate East and West bound leaky antennas
- **Uplink GRN**
  - Combined E & W antennas in 5 locations
Why doesn’t RDS work underground? Why are tunnels mono only?

- Tunnels normally go to audio and then back to RF so they can do audio break in
- RDS is encoded on the FM signal
- Therefore it needs to be added again, which adds cost

- Same goes for re-modulating AM stereo
- New receivers and transmitters are needed for each new channel, therefore adding channels is very expensive
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