



RF in Motorway Tunnels (Underground Down Under)

Exactly how do I get to hear the radio
underground...

www.redshiftwireless.c

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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

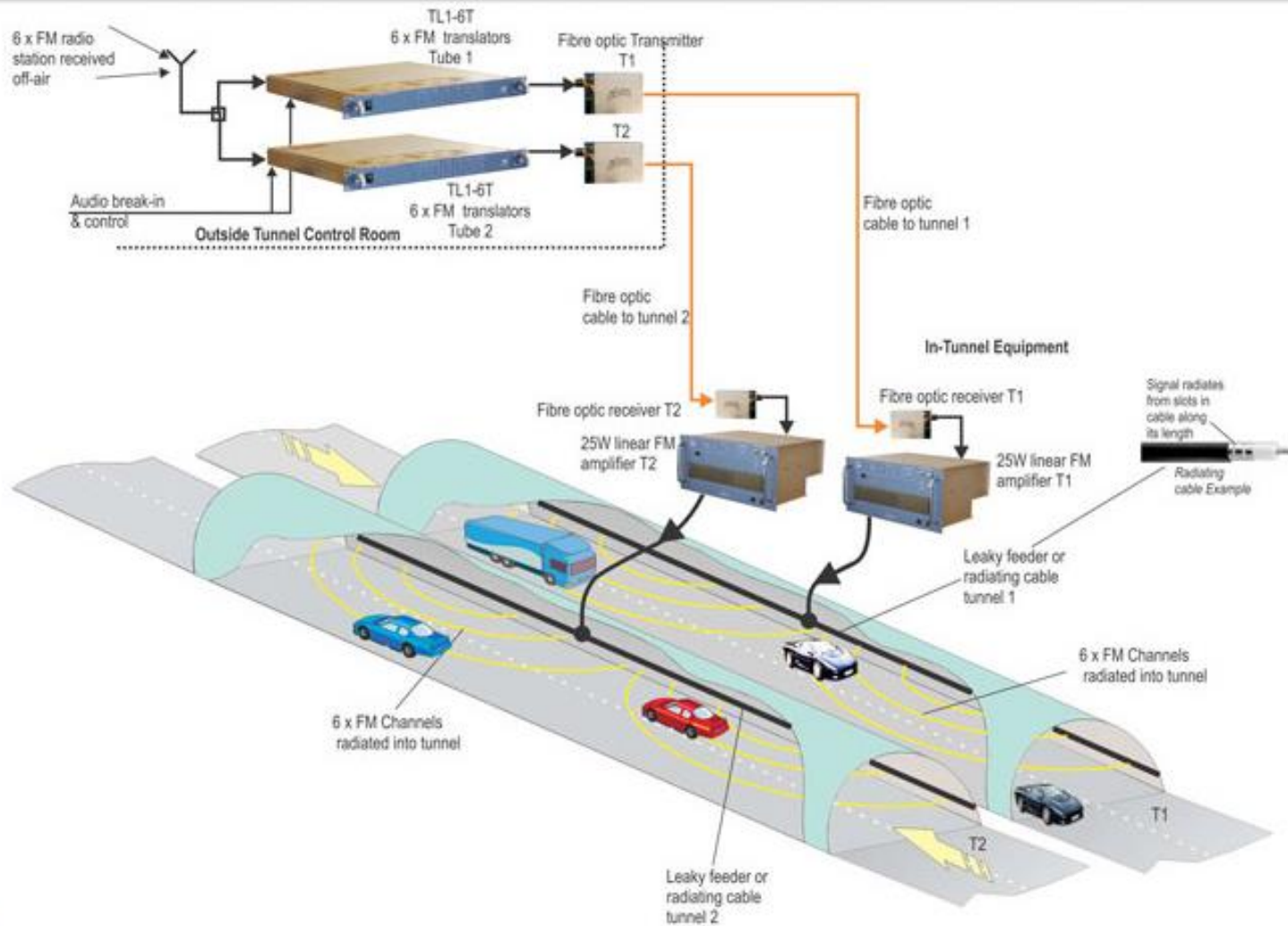


FM Antennas

- 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

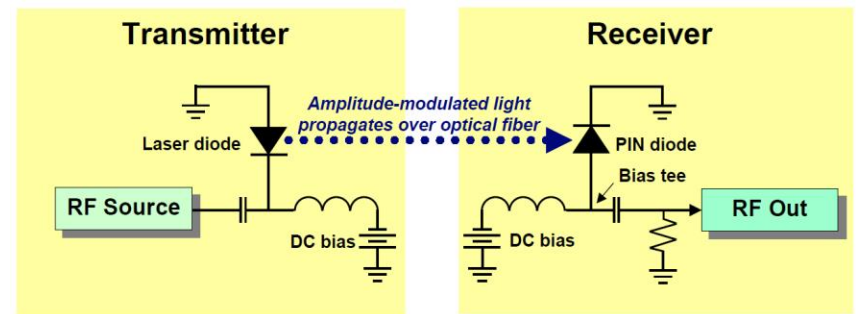


Diversion - Fibre Optics

- 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

Diversion - Fibre Optics

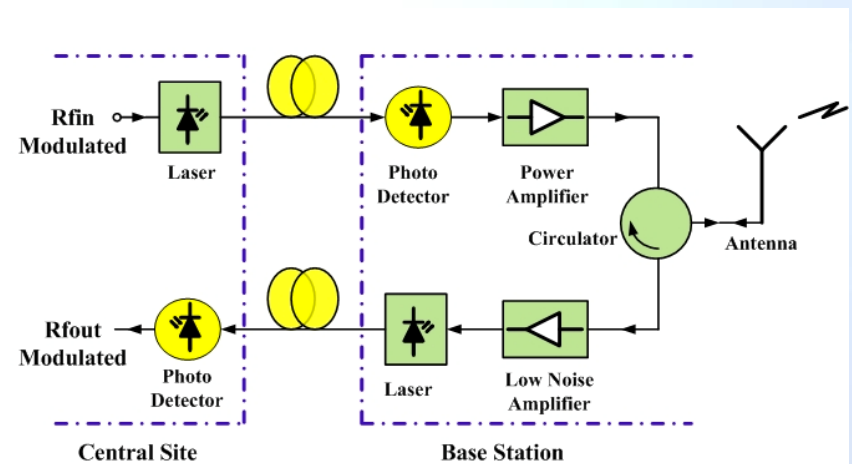
- Lets assume a laser carrier at 400 THz, and that we can modulate the laser linearly, either AM or FM
- If you have a detector that is fast enough, and the laser is fast enough you can get a large bandwidth of RF over fibre



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

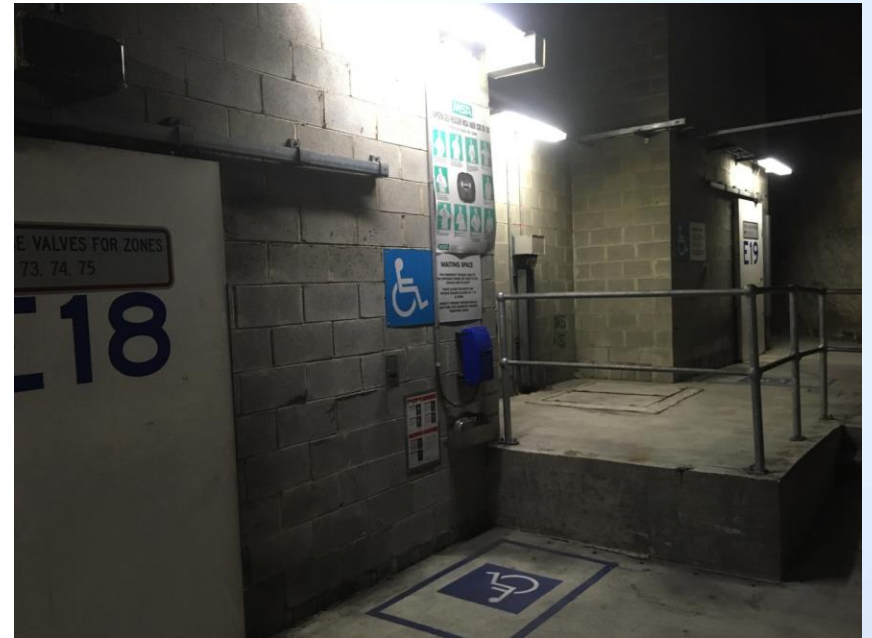
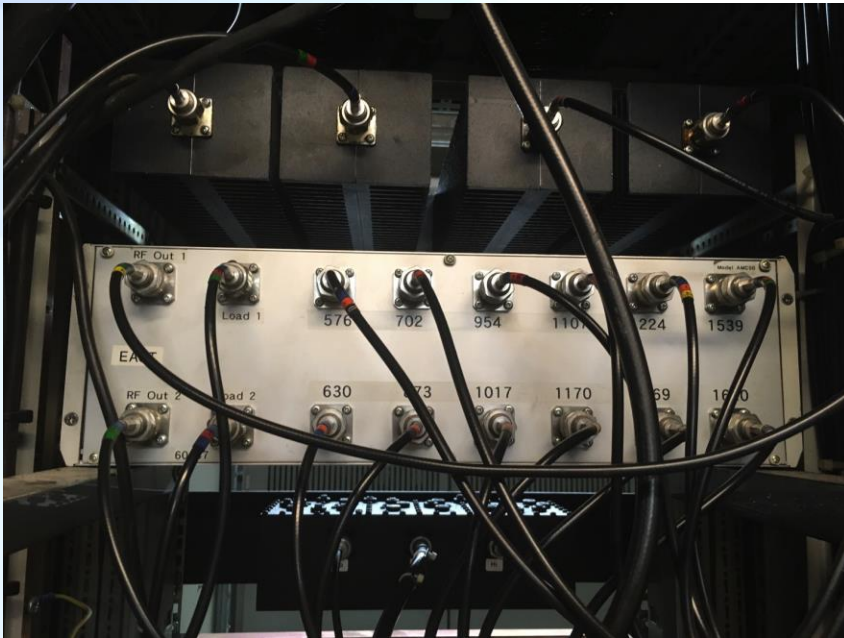
- 2 x Fibre to RF converters
- 2 x Broadband Amplifiers
- 1 x Uplink RF to Fibre converter
- Lots of soot and moisture



Underground

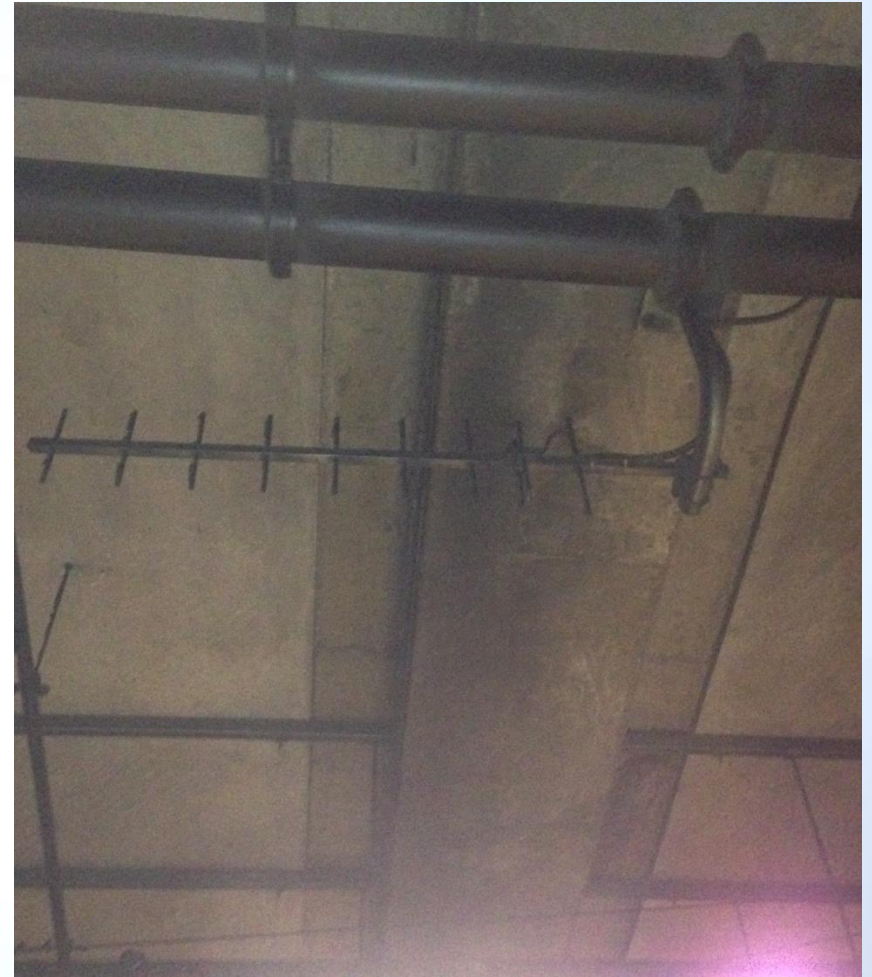


Underground



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

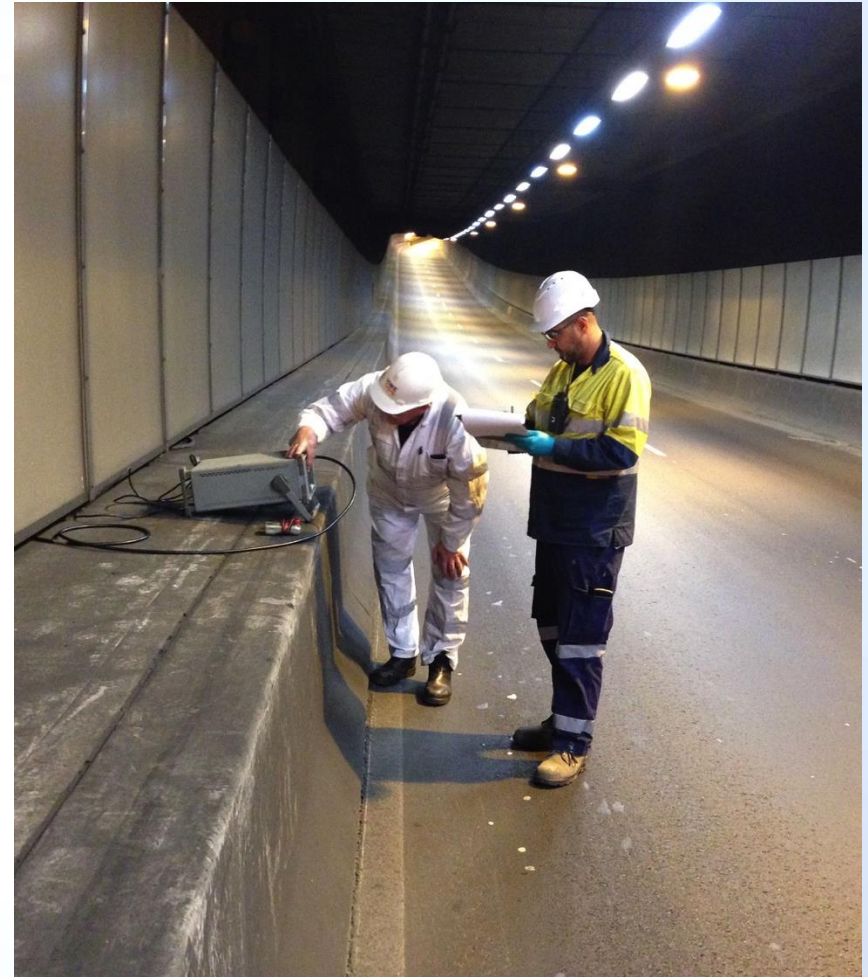
Maintenance



- 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.
- Shot-crete 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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