FUJITSU

DIGITAL DAYS

The change from essentially analogue switching of telephony traffic to digital switching in SPC exchanges commenced in the early 1980's was accompanied by a need for digital links between main exchanges, and eventually to all telephone exchanges. Commissioning of new analogue links was discontinued in 1984 apart from a handful of low-capacity links and some TV links. Planning and site works for new digital radio routes had been on-going since 1980.

Main trunkline routes

Radio was an early candidate with multi bearer systems using Fujitsu equipment being the technology of choice, with largely DM6G – 100H and DM7G – 100H systems, but with use of 4GHz and 11 GHz bands as required. Later models were the 1000H type. A frequency band generally had 8 RF channels which were used for one protection and up to 7 working bearers on a fully utilised route. Each bearer gave a 140 MBs capacity, the equivalent of around 1800 voice circuits with a route using a switched system for equipment protection.

However, fading and other propagation mechanisms had a greater effect on digital systems than on analogue systems. A combination of shorter path lengths (typically 50 km or less) and space diversity was typically used to maintain the required performance. A few short entrance links (Kaitaia, Whangarei, Dunedin, Tiritea Rd to Palmerston North for example) did not require space diversity.

A switched 140 Mb/s bearer for evaluation purposes was installed in December 1985 from Wright Hill to Jamies Knob, presumably to assess equaliser changes and other technical details.

New sites were often used for digital routes as the performance sought required somewhat shorter path lengths, and resilience considerations favoured new sites. In any event higher towers to provide for diversity reception would be necessary.

Notwithstanding, with each repeater site costing circa $1 million in dollars of the day, minimising repeaters was also a consideration. There was an understandable aversion to over water paths unless there was strong shielding from potential reflections. In the early installations new sites were constructed, firstly to give a diversity routing, and possible to eventually have two separate digital routes. With each bearer having space diversity on individual hops, and overall switch protection between terminals, the necessary low bit error rate and reliability was achieved. Degradation on analogue systems typically created transitory higher noise levels, but BER degradation on digital systems created data errors that could affect end user systems.

The switching bays at terminals were equipped with hitless switching so that there was no degradation to the bit-stream during changeovers.

The radio routes often covered more difficult country with fibre being used where urban ducts or easy country for cable laying existed.

The main routes included:

- Kaitaia to Whangarei Maunu) via repeaters at Maungataureia, Cooks Rd, Mt Hikurangi with spurs to Kaikohe and Taheke (via Rakautapu Rd);
- Whangarei to Auckland and Hamilton using some new sites and avoiding a single Auckland terminal. The sites included Maunu, Brynderwyn, Kraacks Hill, Torbay Radio, Manurewa Radio, Mt Puketutu, Glen Murray, Te Uku and Hamilton CAX. Auckland had fibre links to both Manurewa and Torbay;
- The two spare tubes on the Auckland – Hamilton coaxial were utilised for a 140 MB/s digital system with Telettra equipment while the two in-service tubes were expanded to 45 supergroups (with access added at Papakura) and;
- The Centre North Island (CNI - 1985) route (at least 1 for 6) from Hamilton (Pukekura by Cambridge) to Palmerston North (CAX) via the central plateau with repeaters at Ranginui, Pukepoto, Waimarino, Waipuna, Mt Maire and Tapuae. Fibre connected Hamilton CAX to Pukekura;
- Hamilton (Pukekura) to Palmerston Nth (CAX) (1 for 1 on most of the route) via repeaters at Kaimai, Mt Ngongataha, Whakapapataringa, Whakatau, Te Waka, Gwavas (Salisbury Rd), Takapau Radio, North Range Rd to Palmerston North CAX. DMR spurs from Te Waka to Meanee and from Gwavas via Kahuranaki to Napier (Shakespeare Rd[1], CAX) served Napier and Hastings. Meanee had fibre-optic cables to both Hastings and Napier;
- Palmerston North (CAX) to Wellington (Makara High) (1 for 7 by 1996) via repeaters at Arapaepae, Mt Field and Diggins. The system was initially (1986) a 1 for 3 from Wellington (Makara High) to Paraparaumu via Diggins and Mt Field and later altered to terminate at Palmerston CAX via Arapaepae, omitting Paraparaumu;
- Wellington (Makara High) to Canterbury (Ashley Forest near Rangiora) (1 for 7) via repeaters at Rahotia[2], Dashwood, Weld Cone, Puhi Peaks, Rileys Hill, Glenkens and Montserrat. There were fibre-optic cables to Makara High and again once the easier country of North Canterbury was reached. The system capacity was increased progressively from a 1 for 3 to a 1 for 7 system. Because the Nelson analogue system used 7 GHz the first hop from Makara High to Rahotia was in the 4 GHz band and had a 2 for 8 capability, shared with the Nelson system. The remainder of the Christchurch route was in the 6 GHz band;

[1] This probably used the original tall tower provided for the early analogue links.

[2] The original small timber framed building used for the Nelson analogue system was replaced by a larger permanent building when DMR was implemented.

- Wellington (Makara High) to Nelson (Grampians), (1 for 1 using 4 GHz) via Rahotia, Takorika and Maungatapu Saddle, overlaying the analogue system. but with an extra repeater at Takorika, and a spur to Blenheim (Riverlands). The hop across Cook Strait was combined with the Christchurch system;
- Oamaru (Big Hill) to Dunedin (CAX) via repeaters at Razorback and Mt Cargill (a fibre cable connected from Christchurch to Oamaru). Some capacity was fed north from Big Hill to Mt Ellen (near the analogue site Waimate (Mt John), and by cable to Waimate.

The main Auckland to Christchurch routes (via the CNI) were typically installed with an initial capacity of 1 for 1 or up to 1 for 3. Expansion soon occurred to a full route deployment of 1 for 6 or 1 for 7. A two bearer system used a single rack and, with an adjacent rack, would use a waveguide filter system for 4 RF channels on both polarisations of an antenna for transmission and reception. Further expansion would add up to four receivers on the original transmit waveguide, and another four transmitters on the original receive waveguide. Space diversity reception used a second antenna with an extra receiver alongside each main receiver.

The DMR systems used switched bearers and could therefore more readily incorporate a bearer for local use. The capacity on various hops varied as required to accommodate both spur and local requirements.

As well as 140 MB/s bearers, there were also many smaller capacity systems at 2, 8 or 32 MB/s. These were typically Fujitsu 100H or 1000H series and operated in the 1.8, Lower 6, Upper 6, 7 and 11 GHz frequency bands. These typically gave digital capacity to outlying exchanges as they were upgraded to digital switching.

Where new towers were required at an existing site, a new waveguide entry was typically used. The larger tower base was generally connected to lateral rock anchors in the foundation, before concrete placement. New towers had a splayed lower section which allowed a small equipment building to be placed within the footprint, but this was not always utilised.

Digital radio transmissions used a standard RF channel, but did have the problem of affecting other channels on a fully utilised route. On the Wellington – Christchurch system the initial system used RF channels 2, 4. 6 and 8 with transmission and reception on separate waveguides on the main antenna. Expansion using RF channels 1, 3, 5 and 7 was by adding the new receivers to the original transmit waveguide and the new transmitters to the original receive waveguide. This meant that there was no disruption during the expansion process, but did place transmitting and receiving RF channels on frequencies on either side of the centre band gap on a common waveguide, with the transmitters affecting the receivers. Special band elimination filters and compensating equalisers were used in these circumstances.

DMR CNI REPEATER – Tapuae site with a 1 for 3 configuration

The main and diversity antenna for the main trunk bearers are at the top and bottom of the tower. The middle antenna were installed for a lower capacity local system.

The four racks show a 1 for 3 system with two racks facing each direction. There are two RF channels in each rack. The upper shelf has two receivers (main and space diversity) and a transmitter power amplifier for one channel, alongside a similar set for a second channel. The second shelf has two transmitter modules with the lower shelves containing modems and equalisers. Note that there are pre-installed circulators for connecting expansion racks for additional RF channels.

However, even with 7 radio bearers each providing 140 MB/s capacity, the transmission needs soon grew and this made the use of fibre cables increasingly attractive from a capacity and economic perspective. A single wavelength on a fibre pair could readily provide 10 GB or more, dependent upon the circuit length. In addition, a cable would typically provide 24 or more fibres. A fibre cable was quite physically small, the main elements being strength elements and fibre protection layers. Depending on the fibre used, technology could allow multiple wavelengths to be accommodated by adding terminal equipment, with 24 or more wavelengths being possible. This was generally only used on submarine cable such as crossing Cook Strait.

New fibre cables were added to main centres and the need for DMR reduced accordingly.

In some cases it was possible to utilise shared cable capacity such as the Transpower Cook Strait fibre cables and via Molesworth to Christchurch. Vodafone also installed a “multi-stop” undersea cable from Auckland to Christchurch (with some land sections). FX networks also invested in fibre cables to various centres.

Around 2000 Telecom provided a new cable to the South Island from Levin (Hokio Beach to Nelson (Cable Bay), with 24 fibres, and a capacity of 32 wavelengths (each 10 GB) per fibre. Technology has likely increased the capacity since installation. The cable continued from Nelson to Murchison, Reefton, Greymouth and Christchurch. This placed Wellington, and the Wellington – Christchurch DMR system away from the main north – south route.

DMR RACK LAYOUT

The Fujitsu rack layout in a 1 for 1 arrangement has 2 RF transmitters (and power amplifiers) and 4 receivers (inc 2 for Space diversity) in a single rack (S1A and S11). Waveguide filters were spaced across the upper section, feeding down to the relevant RF modules. Three waveguides would be used, initially one each for transmit (say H) and receive (say V) on a single antenna, with a third on a separate antenna for space diversity reception (if used). In a given repeater rack, the waveguides were such that the incoming receivers and the ongoing next-hop transmitters were in the same rack, simplifying interconnection.

A second rack alongside would expand the basic 1 for 1 arrangement to a 1 for 3 capacity (S12 and S13), completing four non-adjacent channels on a route. These would be coupled into the existing waveguides by circulators. A similar arrangement would be provided for the other transmission path, with racks typically alongside each other.

Circulators were provided to connect further racks, typically located opposite the first racks, allowing up to a further 4 RF channels in an overall 1 for 7 arrangement. The transmitters on this second group of 4 channels would couple into the receive waveguide on the first channel group. Similarly, the second receiver group would couple into the first transmitter group.

UNUSUAL INSTALLATIONS

A novel development was the use of so-called RF repeaters. These took an RF signal, filtered and amplified it, and then retransmitted it on the same frequency but at an increased power level. An obvious difficulty is gaining adequate isolation between the receive and transmit antenna, necessarily needing to be greater than the gain of the amplifier. A further difficulty is that with a similar arrangement for the other direction of transmission the opportunity for unwanted antenna interaction increases.

Around 1976 Lenkurt developed a 700F1 RF repeater that operated in the 2 GHz bands. The design was based on a single oppositely polarised antenna in each direction, with circulators, filters, and redundant common amplifiers giving 45 dB gain, to allow a single set of cabinet mounted equipment to be used for both directions of transmission. The design used 4 watts of DC power and gave full

active redundancy. It was promoted as suitable for 32 analogue voice circuits. Two such repeaters were used in 1985 for digital links on the West Coast, at Ianthe Ridge (Seaview[3], to Harihari link) and at Mt Hercules (Harihari to Whataroa link). The systems used OKI 2GP 8 MB/s terminal equipment.

A further unusual installation was a Telettra digital 8 MB/s system from Kapuka to Waimahaka, east of Invercargill. The system used PCM on cable to link back to Invercargill and was presumably to automate an exchange, although this is the only recorded use of Telettra radio equipment.

SUPERVISORY

The introduction of new routes with multiple bearers meant there were more monitored points requiring greater ASR transmission capacity and a more sophisticated central monitoring system. The majority of analogue systems, and therefore sites, were typically monitored locally with bespoke systems.

Computer monitored systems were becoming available and a decision was made to use a system marketed by Granger Associates in the United States. Unfortunately, before systems could be installed, or possibly before all the equipment and documentation was even delivered, the company went into liquidation. Without assured manufacturer support the installation ceased and alternatives were sought.

The needs were largely met by use of the system developed at the Palmerston North Radio Depot. These allowed for at least 2 banks of 16 alarms on a single tone. A DMR repeater could typically have 5 banks of 16 tones to monitor the 8 transmit and receive bearers in each direction, as well as common station alarms.

Order wires were provided by service panel telephones and monitors. The overall supervisory was then added to the digital stream.

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[3] Seaview was adjacent to Hokitka Airport.