Meeting the challenge of long-distance mobile backhaul

White Paper

John Yaldwyn
Chief Technical Officer
4RF Communications Ltd
New Zealand
www.4rf.com

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Introduction

Engineering mobile backhaul networks in today’s market is a challenge, as the ever-increasing demands for more coverage must be met as free spectrum becomes ever more limited. As operators move to address emerging opportunities for service delivery in low-revenue and often low-subscriber-density markets, implementation costs are under pressure as never before.

Whether it is to meet licence coverage obligations or to expand the subscriber base, many mobile operators need to roll out coverage in remote and often hard-to-reach areas.

Microwave links – particularly low-cost, millimetre-wave systems – are the most popular backhaul solutions for new operators, while incumbent operators tend to prefer fibre. While fibre is usually readily available in metropolitan and urban areas, even established operators struggle to provide backhaul in rural and remote regions.

In rural areas, the distance between mobile Base Transceiver Stations (BTSs) may be up to 35 kilometres, or more with extended cells. These distances present a challenge to microwave backhaul planning and rule out low-cost, millimetre wave products.

The traditional solution is to engineer longer remote links in the 7–15GHz bands. Such links are much more costly than millimetre wave systems, however. Apart from the additional capital cost of the radios, larger solid dish antenna systems are required. Furthermore, these antennas require more robust mechanical mounting and may require special consideration of tower strength and stiffness.

Radios operating in the 7–15GHz bands often have far more capacity than is actually needed for a BTS link. The capital costs of these over-specified radios, combined with their installation costs, contribute to a significant increase in overall backhaul costs in rural areas.

Spread spectrum links

Many operators are tempted by unlicensed spread spectrum links as a low-cost alternative to conventional digital microwave radio links. Although spread spectrum equipment does have a number of useful advantages in certain circumstances, it is most often proposed simply as a means to save money and avoid formal licensing procedures.

In theory, the interference rejection capabilities of spread spectrum systems allow for unco-ordinated use in the Industrial Scientific and Medical (ISM) frequency allocations around 2,450MHz and 5,760MHz. However operation in the ISM bands is in practice a free-for-all, with cordless phones, wireless LANs and microwave ovens all vying for the same frequencies.

The problem for the operator relying on a spread spectrum link is that, although the level of interference may be acceptable at the time of installation, there is no protection against interference that might be encountered a year, a month, or even a day after installation. By contrast, a licensed frequency allocation from a competent licensing authority provides the applicant with continuing protection against current and future allocations.

Although the freedom from formal licensing procedures and the lower initial capital cost may make unlicensed links attractive, the long-term costs and risk of interference limits applications to those of a temporary nature. The potential for interference can only be mitigated by engineering links with very high fade margins, resulting in ranges considerably shorter than manufacturers' typical claims and limiting rural applications.

Long-distance alternatives

The distance potential or reach of low microwave and upper UHF frequency bands is often overlooked by network planners. There is a general misapprehension that the low frequencies are 'gone' or that mobile services have taken all available spectrum. While large chunks of the 400MHz, 800MHz, 900MHz and 1500–2200MHz spectrum are predominately assigned to mobile services, there are numerous spectrum opportunities for narrowband, high-efficiency links with adequate capacity for rural BTS linking.

Recent advances in RF design, electronic integration and the implementation of high performance QAM (Quadrature Amplitude Modulation) techniques have resulted in a new breed of integrated low-capacity, point-to-point digital radio systems developed to provide highly efficient, reliable and cost-effective transmission solutions.

High-performance 64 QAM modulation has been made practical using techniques of feed-forward, decision-feedback adaptive equalizers and forward error correction, enabling economic systems to be designed for low-cost cellular and other mobile radio linking. These equalization techniques help minimize potential transmission degradation due to multi-path and other interference sources. Selectable modulation, high system gain, and the choice of operation in the UHF or low microwave frequency bands offer working ranges of 70 kilometres. Depending on terrain and antenna height, distances of more than 100 kilometres can reliably be covered. The use of 64 QAM provides considerable spectrum efficiencies, making the best use of the valuable low-frequency microwave bands most suitable for long-distance rural backhaul.

Cost-efficiencies

Grid-type dish antennas are usually employed for the low-frequency microwave bands at 1.4GHz and 2GHz. At 400MHz and 800/900MHz, low-cost Yagi types can be used, but grids are preferred for their better front-to-back ratio performance. Most administrations require the use of relatively high-performance antenna for fixed links in these bands to optimize frequency reuse.

Grid antennas are cheaper than the solid types required at 7GHz and above and the use of grids reduces tower wind loads. Antennas operating at the low-frequency bands have wider beam widths than at higher microwave bands, reducing the requirements for tower stiffness – a further cost saving. Feeder costs are reduced as coaxial cable can be used instead of more expensive elliptical waveguide. As all the RF equipment may be mounted indoors, further savings are possible – both in capital cost and in ongoing maintenance – when compared with split-mount implementations common above 7GHz.

Bandwidth efficiency

Spectrum in the lower microwave bands is valuable and needs to be used judiciously. At 32 QAM, a full E1 bearer can be accommodated in 500kHz of spectrum while still meeting the ETSI 1.4GHz mask. However, not every BTS needs a full 2Mbit/s E1 connection and a lower capacity fractional E1 connection will often suffice. As long as the BTS equipment is presented with the standard framed E1 connection, small sites might be served with just five to ten timeslots at 64kbit/s. This type of fractional E1 link can be accommodated in a bandwidth of 75kHz and 150kHz. The integrated cross-connect feature of these new radio products enables grooming of circuits to make best use of bearer capacity.

In-band linking

While cellular spectrum is congested in major markets, this congestion is usually limited to metro and urban areas. In rural areas operators may often have considerable unused spectrum available. Under these circumstances, it is possible to operate backhaul links within the spectrum managed by the operator. Not all regulatory administrations will permit this mixed but efficient use of spectrum. Where possible, the idea is a useful addition to the backhaul toolbox.

GSM channels are 200kHz wide and easily accommodate fractional E1 links with capacities of up to ten 64kbit/s timeslots. Such links are best implemented between a BTS site and a point-of-presence that does not have a BTS co-sited. It is relatively straightforward to operate the microwave link in a non-conflicting manner where the link’s transmit carrier is in the BTS downlink band, and receive carrier is in the uplink band. If the other end of the link is also located at a BTS site, the transmit and receive frequencies conflict and require considerable engineering to prevent interference between the BTS and the microwave radio.

Conclusion

To connect rural BTS sites, cellular operators need ‘easy to engineer, easy to deploy’ connections that help keep capital expenditure as low as possible. Fibre, millimetre wave and unlicensed linking products are unsuitable for these long-haul applications.

High-performance digital radio systems that use low microwave and UHF bands are now available that can transport E1 and fractional E1 payloads economically and with new levels of bandwidth efficiency. As rural BTS sites do not often require a full E1 connection, fractional links may be employed to conserve spectrum with the integrated cross-connect feature of the new radios used to provide grooming.

Such links now meet mobile operators’ needs to deliver high-quality long-distance connections to rural and remote locations more cost-effectively than traditional methods.

John Yaldwyn is the *Chief Technical Officer* and founder of 4RF Communications Ltd. 4RF provides carriers throughout the world with high-performance Aprisa™ digital UHF and microwave wireless access solutions for the transmission of voice and data in remote broadband applications. www.4rf.com