E-Band wireless technology: a carrier-class solution for gigabit

by Adel Demian, Saab Grintek Technologies

E-Band is a relatively new addition to the spectrum allocated for fixed point-to-point wireless services. The E-Band normally covers the sub-bands 70, 80 and 90 GHz, and comprises a total of 10 GHz in the following frequency ranges: 71 – 76 GHz and 81 – 86 GHz plus 3 GHz in the 92 to 95 GHz band.

This large spectrum allocation far exceeds the allocations available for fixed wireless services at lower, more traditional microwave frequencies (6 – 38 GHz). This makes E-Band ideal for offering multi-gigabit connectivity; indeed radios operating in this band can easily provide over-the-air capacity of over 1000 Mbps.

Because E-Band is not in use for other applications, it has been consistently allocated to fixed wireless services worldwide, and the band is now open and is in use in most countries around the world.

Furthermore, because of the extremely narrow beam-width (<1˚), transmission in E-Band is exceptionally directional ("pencil beam"), and interference highly unlikely. For this reason, many countries dispense with full licensing of these links, and employ a "light-licence" scheme, which simply involves registration of the link, but no additional frequency coordination. The FCC ruling also presents a novel licensing scheme, allowing cheap and fast allocations to prospective users.

E-band transmission requires line-of-sight, and due to the very short wavelength, the Fresnel zone is significantly narrower than in traditional microwave frequencies. Adverse propagation phenomena for E-band are very similar for traditional microwave frequencies, although due to the "pencil-beam" characteristics of the transmission, multi-path (selective fading) is never an issue. Flat fading due to rain is the main limiting factor for link distances, practical link distances are normally up to about 4 km.

The case for E-Band

The demand for cost-effective solutions to high capacity connectivity are constantly on the rise. Both service providers and enterprises are looking for inexpensive, reliable solutions that are quick to deploy. Fixed point-to-point wireless systems are ideal because of their flexibility, speed of deployment, and lower overall life-cycle costs compared to leased-line services. This accounts for the widespread deployment and popularity of traditional microwave point-to-point system (6 – 38 GHz).

However, radios in traditional microwave frequencies are limited in the capacity they offer, and struggle to cross the 400 Mbps barrier. The maximum transmission capacity of any radio system is determined by the RF channel bandwidth permitted by the regulatory agency, and the type of modulation used. Because the 6 – 38 GHz point-to-point bands have a relatively small bandwidth (typically 5 – 28 MHz), and because they are generally heavily congested, the maximum channel bandwidth in these frequencies is 56 MHz. Even with 256 QAM, the highest practical modulation in common use, this limits the transmission capacity to under 400 Mbps. In most cases however, licences are granted on the basis of 28 MHz, which halves this capacity.

The Fig. 1 summarises the throughput capabilities of a typical high capacity, short-haul licensed radio, based on the RF channel bandwidth for a given modulation.

Therefore, while many solutions available on the market today include GigE interfaces, the reality is that because of their bandwidth and modulation constraints, they simply cannot provide full-rate gigabit data transport over a single RF channel.

In order to scale beyond the 400 Mbps single channel limit at these frequencies, it is necessary to combine two or more carriers over the same path. This is done either by utilising additional radio channels, whether at adjacent frequencies, or else using dual-polarisation transmission. However, regardless of the method, this involves:

- Doubling of hardware, leading to doubling of cost and footprint and increasing points of failure in the network.
- Requiring two frequency licences, increasing spectral congestion and licensing costs.

Fig. 1: Throughput based on RF channel bandwidth.
In comparison, in E-band, an unprecedented 10 GHz of bandwidth is available, far exceeding the spectrum allocations in any given lower licensed frequency band. This vast amount of bandwidth makes it practical to apportion the band into much larger channels, typically 250 MHz – 1500 MHz wide. It is easy to achieve GbE capacities with such wide channels, employing low-level modulations such as BPSK and QPSK. With such simple modulation schemes:

- The transmit amplifiers can be driven to their maximum power ratings, providing additional power compared to high-QAM modulations.
- The receiver sensitivity is improved with a low-level modulation.
- The hardware is simpler, more cost effective, and has a smaller footprint.

In summary, E-band radios offer a convenient, cost-effective alternative to traditional microwave spectrum. E-band offers plenty of bandwidth where gigabit, and even multi-gigabit, capacities can be transported in a single RF channel using one set of hardware, having a small footprint, and high system gain.

### Interference in E-band

One of the key issues underlying frequency coordination is interference. At traditional microwave frequencies, beam-widths are quite wide, extending to up several degrees wide. This creates the possibility for receiving harmful interference from neighbouring links.

However, in E-band, even small antennas feature extremely narrow beams, on the order of one degree:

- The 3dB beam-width of 30 cm antenna is ±0.4º
- The 3dB beam-width of 60 cm antenna is ±0.2º

This is ten times narrower than the beam-widths created at 8 GHz with the same size antennas. Fig. 2 illustrates this concept:

The narrow beam-width at 80 GHz focuses the energy into a “pencil-beam” which creates a very directional transmission, greatly minimising the potential for interference. It also enhances link security by making it effectively impossible to intercept or jam the RF signal without physically blocking the intended RF path.

### Applications

The demand for ever larger capacity transmission is sharply rising in many industries. This includes the following:

**Mobile backhaul:** Backhaul and aggregation for mobile networks including 2G/3G migration as well as 4G next generation mobile service

**Fixed networks:** High-capacity business services, cellular/Wi-Fi/WiMAX backhaul, fiber backbone extensions, redundant fibre overlays, municipality mesh backbone and temporary connections

**Healthcare:** Secure (HIPAA-compliant) campus connectivity, off-site medical office and lab network access, real-time imaging application connectivity, redundant fibre overlay and disaster recovery.

**Education:** High-performance campus and off-site location connectivity, Wi-Fi and security camera backhaul and connectivity to service provider fibre

**Municipality:** Provide high-performance backbone connectivity for municipal private and public network deployments.

**Enterprises:** Inter-building LAN extensions, server centralisation, remote data storage and backup, redundant fiber overlays and disaster recovery.

**Government:** Highly secure inter-building connections, redundant fibre overlay, disaster recovery and short-term connections.

### Type of licensing

The current ETSI standard governing use of E-band is intended for self-coordinated, and as such does not stipulate a full set of receiver parameters. It recognises that due to the excellent spectral reuse characteristics of the band, minimal frequency coordination is required. Current feedback from carriers throughout Europe has indicated that they would prefer a more centrally coordinated/licensed approach in order to safeguard their mission-critical services. Therefore, ETSI TM4 are currently redrafting EN 302 217-2 to include 80 GHz, allowing regulators the choice of self-coordinated or fully-coordinated deployments in the future.

### Licensing costs in other countries

Most licensing schemes in traditional microwave frequencies use the occupied bandwidth as a linear component at

<table>
<thead>
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<th>Frequency (F)</th>
<th>Bandwidth (BW)</th>
<th>BW &lt; 3.5 MHz</th>
<th>3.5 MHz &lt; BW &lt; 20 MHz</th>
<th>20 MHz &lt; BW &lt; 40 MHz</th>
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<tr>
<td>17 GHz &lt; F &lt; 37 GHz</td>
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<td>€825</td>
<td>€900</td>
<td>€1125</td>
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<tr>
<td>F &gt; 39.5 GHz</td>
<td>€100</td>
<td>€110</td>
<td>€120</td>
<td>€150</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Annual fee (€) for a point-to-point radio link not being on a high usage path or in a congested area.

Fig. 2: A pencil-beam creates a very directional transmission.
determining the licence cost. For example, a licence for a 56 MHz channel will cost twice as much as a licence for a 28 MHz channel.

In E-band, however, the European Radio Communication Committee recommendations are written around low-level modulation schemes and very wide-bandwidths. Therefore, using the existing “formulas” for licensing costs can grossly overprice an 80 GHz 1 GHz wide channel in relation to a 23 GHz 56 MHz channel. Such algorithms have been adopted in some countries (e.g., Belgium), but have resulted in the de-facto sterilisation of the 80 GHz band, due to the exorbitant licence costs.

Fortunately, most countries have taken a more attractive approach of sensibly pricing licences in E-band, thus leading to a large utilisation of this still under-utilised spectrum. Some examples follow below.

Ireland has adopted a fully licensed approach, identical to the 6 – 55 GHz bands. However their licence costs have been dramatically reduced above 39,5 GHz, to promote the use of these resources in favour of the congested 23/38 GHz bands.

All bandwidths above 40 MHz are treated the same in terms of charges, irrespective of actual occupied bandwidth.

The Netherlands too is promoting the use of E-band by pricing licences very reasonably. There is the initial fee of €618, followed by an annual fee of €82 for transmission of 1 Gbps, or €75 for transmission of 100 Mbps. This is very similar to more traditional microwave bands, where the once-off cost is the same, and the annual fee is somewhat higher:

- At 23 GHz: €192 for a 28 MHz, and €219 for a 56 MHz channel
- At 38 GHz: €151 for a 28 MHz, and €178 for a 56 MHz channel.

Switzerland has a higher licence cost model. As an example, 1 GHz of FDD spectrum will cost 3368 SFR per annum. This compares with 4480 SFR for a 23 GHz 28 MHz channel, so 80 GHz has been made cost effective when compared to 23/38 GHz, again in an attempt to promote usage of the band. Switzerland did not want to change its basic algorithm, as it was written into law. Their algorithm uses a bandwidth multiplexer, but also has a frequency band multiplexer, so to promote growth of 80 GHz, they have adopted a frequency band multiple of 0,02 for 70 GHz and above. Compare this to 23 GHz where same multiplier is 1, and at 38 GHz it is 0,8. This is done to counteract the bandwidth multiplexer, resulting in 1 GHz of spectrum at 80 GHz, costing about 75% as much as a 28 MHz channel at 23 GHz, and being significantly cheaper than a 23 GHz 56 MHz channel.

In the United States, the FCC issues a nationwide 70/80/90 GHz licence (for $895) and maintains a database of point-to-point links. For $75, you have to register each link in their database and it’s a pretty quick go/no-go licence. The only caveat is if you’re near a radio astronomy site, there is additional paperwork you have to submit and the approval process can take up to 30 days (compared to a day or so in the normal process). The $75 gives you a ten-year licence.

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In the United Kingdom: the process is similar. Here is an excerpt from the OFCOM (UK) website:

The licence for the 70/80 GHz band is a non-exclusive national licence which authorises licensees to register point to point fixed wireless links in the UK, through a link registration process administered by OFCOM.

A licence does not authorise operation until a link is registered. To operate a link in 70/80 GHz band, a licensee must register their link through the OFCOM link registration process and that link must have a valid entry on the 70/80 GHz section of OFCOM’s wireless telegraphy register (the “Register”).

The licence fee is £50 which includes the charge for registration of the first link for the first year of the licence. This fee £50 must be enclosed with the licence application.

In Australia, it’s about $AU$195 per year for the licence fee, and the process is similar to the US and UK with registering links with a national database.

In Canada, the regulator (Industry Canada) has finally decided on a set of technical specs, but as of yet, has not opened the band, as they’re still debating what if any licence fees should apply to the spectrum. We understand that this decision is supposed to come in 2H 2012.

Brazil: Not opened yet and no one that we know of is pushing.

Russia: Operators do not need to get permission for installing 80 GHz radios.

The main thing is that equipment should correspond with the Radio Frequency Committee decision. But operators need to register equipment after installation, which is made in the notification order via mail to the supervision authority. Afterwards, the operators receive the certificate of registration. There are fees which operators should pay for using these frequencies. Payments are made quarterly. Each link is calculated by the supervision authority individually. Prices range from $65 – $325 per link.

India: NFAP2011 (National Frequency Allocation Plan) was approved on 30 September 2011 which allows for both FDD and TDD systems to operate in the 70/80 GHz spectrum.

Conclusion

The significance of the E-band frequencies cannot be overstated. The 10 GHz of spectrum available in the 70 and 80 GHz bands represents by far the most ever allocated by the Federal Communications Commission at any one time, representing 50-times the bandwidth of the entire cellular spectrum. With 5 GHz of bandwidth available per channel, gigabit and greater data rates can easily be accommodated with reasonably simple radio architectures. With propagation characteristics comparable to those at the widely used microwave bands, and well characterised weather characteristics allowing rain fade to be understood, link distances of several kilometres can confidently be realised.

Commercially available equipment can provide fibre-like performance at a fraction of the cost of laying fibre or leased capacity. These tried and tested equipment provide full duplex data rates in excess of 1 Gbps in a cost effective, reliable architectures, with carrier-class 99,999% availability at a distance of few kilometres. Although several other technologies (such as microwave equipment, fibre, 60 GHz radio and free space optics) exist to provide gigabit services, yet E-band wireless can provide cost effective solutions that can transform backhaul and access business models.

Saab Grintek Technologies, in collaboration with a couple of first tier network operators in South Africa, has conducted successful field trials for E-band equipment. Unfortunately the lack of formal licensing regulations for E-band equipment has caused delays in the deployment of this technology.

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