The terahertz frequencies that are expected in the 6G era offer both opportunities and challenges

July 2021

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Each new generation of mobile technology generally takes up to a decade to define and standardise, so while 5G roll-outs are still ongoing, early-stage research is already underway into what might become the next generation of mobile connectivity, that is, a sixth generation (6G).

There is a vision that 6G connectivity may deliver peak data rates of the order of terabits per second together with sub-millisecond latency. These peak rates are unlikely to be delivered over wide areas, but might be useful for some use cases in localised areas. As such, there is interest in the potential use of frequencies in the sub-terahertz and terahertz ranges to provide the bandwidth to deliver these peak data rates and to enable the intensive use of spectrum within localised areas.[1] However, the characteristics of sub-terahertz/terahertz frequencies are very different to those of the bands used for wide-area, contiguous coverage in mobile networks today. Potential use of sub-terahertz frequencies in 6G therefore raises fundamental questions in terms of usage environments, use cases, network topologies and devices.

Networks must evolve beyond 5G

The vision for 5G is based on three vertices: enhanced mobile broadband, ultra-reliable, low-latency communications and massive machine-type connections. To deliver these, spectrum for use in 5G networks is defined across three frequency ranges: low bands (below 1GHz), mid bands (typically around 3.5GHz) and high bands (currently standardised 5G millimetre-wave spectrum with a frequency of 26GHz).

The ability to map the 5G radio expansion onto existing grids of network sites (which were laid out to efficiently use low frequency bands) has been an important practical aspect of rolling out 5G for mobile operators. The deployment of 5G millimetre-wave bands (such as the 26GHz band) represents a shift in focus away from the traditional lower-frequency bands. The limited propagation of the 26GHz band compared to that of lower-frequency bands means that it is ideally suited to the delivery of very high capacity in localised areas. These characteristics (high capacity and high spatial reuse) will be even more pronounced if frequencies in the sub-terahertz and terahertz bands are used in the 6G era. However, the characteristics of these frequencies mean that new technologies and materials are needed; extensive research is still required to understand the capabilities and limitations of these frequencies in terms of bandwidth and range.

The commercial viability of using sub-terahertz spectrum remains unclear

The opening up of sub-terahertz and terahertz spectrum is one area of 6G research that is attracting interest due to the potential for these frequencies to provide very wide bandwidths that could support terabits-per-second

[1] The sub-terahertz and terahertz ranges encompass spectrum between 90GHz and 300GHz, which is between millimetre-wave and infrared. For more information, see Brave Research Project, *Sub-THz frequencies*. Available at: http://www.brave-beyond5g.com/index.php/sub-thz/.

transmission. The FCC has already opened up terahertz spectrum (above 95GHz) in the USA. It has chosen to offer relatively long-term (10-year) experimental licences (issued on a locally licensed, first come, first served basis), but has designated several portions (116–123GHz, 174.8–182GHz, 185–190GHz and 244–246GHz) specifically for unlicensed use. The regulator in the UK, Ofcom, also consulted on making frequencies above 100GHz available. It decided not to include unlicensed use, but instead introduced a flexible access (shared use) licence in several bands (116–122 GHz, 174.8–182 GHz and 185–190 GHz). We can see, therefore, that the frequency bands released in the USA are similar to those in the UK, but the licensing approach is different.

However, it remains unknown how sub-terahertz frequencies might be deployed together with the spectrum and architecture used in today's mobile networks. This will be the subject of further research, industry debate and standardisation over the coming years. The significant differences between these frequencies and those used by mobile networks today mean that 6G is unlikely to be defined entirely by its ability to use the sub-terahertz/terahertz ranges, so as to ensure an ordered evolution from 4G/5G.

A key consideration for 6G lies in how the network architecture used in mobile networks today might evolve to address future traffic volumes generated by today's mobile consumers, while also catering for the new use cases that might emerge with 6G, which the sub-terahertz frequencies might accommodate. It will be challenging to integrate terahertz frequencies into existing mobile network architecture since terahertz communication only occurs over short ranges (of the order of 100m) and therefore communications will be limited to 'line of sight'. The use of denser infrastructure itself will also bring about several key challenges, largely relating to mobility management, cost and coverage. Such dense infrastructure, or even a move to user-centric, 'no cell' architecture, does not appear to be commercially viable for providing contiguous coverage given the level investment required, and hence would be limited to localised deployments.

As such, networks that incorporate 6G radio will also need access to lower frequencies (such as those used for 4G and 5G today) if they are to provide population and geographic coverage levels that are similar to those of the current generations of mobile networks. The 5G mid bands (around 3.5GHz currently, and potentially expanding into 7GHz, 10GHz or beyond, depending on the outcome of international discussions) will be essential to ensure that the high volumes of mobile data that are expected in the future can be accommodated using evolved 5G architecture. Alternatively, if 5G evolutions do not support traffic growth indefinitely, 6G will need to support the low and mid bands natively.

Analysys Mason has already started to look into 6G, particularly how one might achieve very high data rates and sub-millisecond latency. Details of how to authorise use of new bands, the characteristics of use and the bands to be used are likely to form part of national regulatory authorities' future spectrum roadmaps over the next few years. Analysys Mason's spectrum consulting team is experienced in advising regulators and operators on market and technology trends in the wireless market, spectrum strategy and spectrum roadmap formation. For further advice, please contact Janette Stewart.