Promoting deployment of 5G infrastructure

The best things come in small packages?

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The opinions expressed are solely my own.

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The best things come in small packages?

- Urban, rural, frequency and bandwidth
- Challenges to building out the 5G network
- Health effects of 5G (EMF)
- Concluding thoughts

URBAN, RURAL, FREQUENCY AND BANDWIDTH

Frequency bands for 5G mobile services

- Key radio spectrum bands identified at EU level as “pioneer bands” for 5G include:
  - the 700 MHz band,
  - the 3.6 GHz (3.4-3.8 GHz) band, and
  - the 26 GHz (24.25-27.5 GHz) band.
- Propagation is far greater in the lower bands.
- Available spectrum (thus speed) are greater in the higher bands – more spectrum re-use, but also more cells.
- Bands above 6 GHz will be slow to pick up – by 2025, we expect not more than 10% of cell sites to support 26 GHz.

Pujol, Lavender, Rudd and Marcus et al. (2019),
“Study on using millimetre waves bands for the deployment of the 5G ecosystem in the Union”.

Using 5G to support multiple use cases

- 5G is widely expected to enjoy rapid growth.
- The use of 5G for voice and for mobile broadband is clear, but its ability to support a wide range of additional *use cases* is thought to be a key element of the 5G value proposition in the medium term.
- These different use cases have needs that differ greatly from one another (consider automotive, the Internet of Things (IoT), and public safety), and some of these needs vary dynamically over time.
- For the next several years, however, most use in the EU can be expected to be for enhanced Mobile Broadband (eMBB).
- Fixed Wireless Access (FWA) will be important in the USA.

A wide range of use cases for 5G

Expected demand (subscription) for 5G use cases

Sector/Application	5G use cases	5G forecasts 2020/2025	5G forecasts 2025/2030
eMBB-mobile	Use of mm-wave bands in hot spots (indoor and outdoor small cells)	++	+++
eMBB-Fixed Wireless Access	Use of FWA to deliver HD video	-	+
Automotive	V2V, V2X	+ to ++	+++
Trains and buses	Access and backhauling	+	++
Medical applications	Tactile Internet, remote healthcare	+	++
Manufacturing / industrial automation	Robotics, Tactile Internet, localized real-time control, security, process automation	+	+++
Energy	Smart metering concentrator connection, smart grid	-	+
Smart cities	Digital signage, video surveillance	+	+++
Public safety	Real time video and high quality pictures	-	+
Satellite	Use for hybrid solutions	-	+
Backhauling	For in-band backhauling, for moving hot-spots	- to +	+ to ++

Legend: "+++": very strong demand, "++": important demand, "+": limited demand, "-": very limited demand

Frédéric Pujol, Tony Lavender, J. Scott Marcus et al. (2019),
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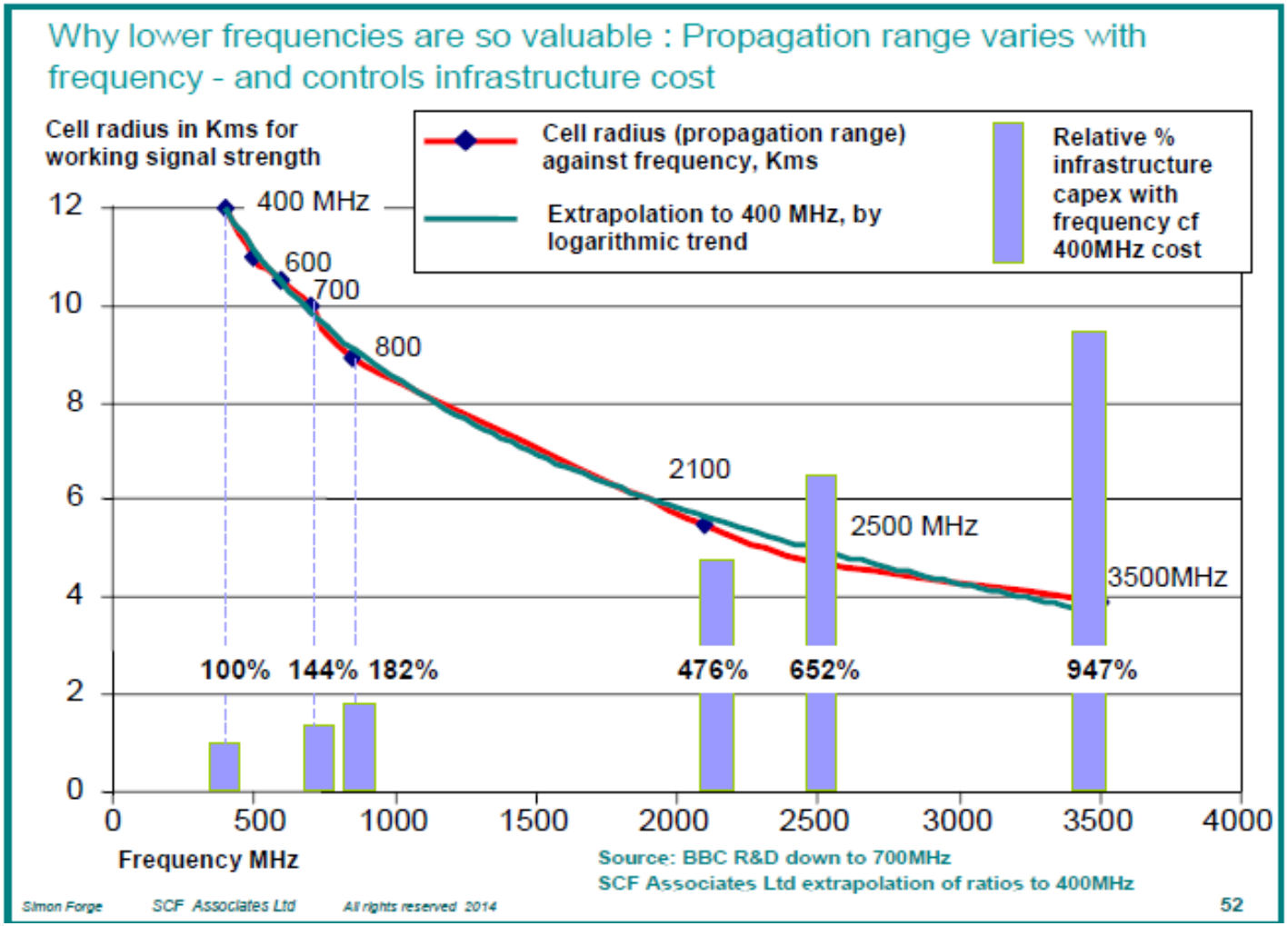
The role of frequency in achieving 5G coverage (historical and indicative)



Source: Simon Forge, Robert Horvitz and Colin Blackman (2014): Is Commercial Cellular Suitablefor Mission Critical Broadband?

Implications of frequency bands for deployment

- Real 5G deployments are sure to entail a mix of frequencies.
- For remote rural areas (where 5G offers little advantage over 4G), the 700 MHz band is likely to be crucial, enabling large distances and good building penetration.
- For dense urban areas where there are capacity challenges, the use of the 3400-3800 MHz band (i.e. 3.5 GHz) provides greater frequency re-use.
- The 26 GHz band provides far more effective capacity, but over short distances and thus at greater cost; consequently, large scale deployment in the 26 GHz band is unlikely in Europe until capacity in the 3.5 GHz band is exhausted.
- Building penetration at 26 GHz is poor.

CHALLENGES TO BUILDING OUT THE 5G NETWORK

Network densification and speed imply the need for substantial upgrades to the mobile network

- The shift to a denser network operating at higher frequencies, mainly in dense urban areas, implies the need to deploy a large number of new base stations.
- The higher speeds that 5G can support has important implications for the backhaul network as well – many sites that previously were served with copper will need to be served by fibre going forward.
- In the past, upgrading a mobile network to the next generation often consistently mainly of upgrading base stations and operational support systems.
- The 5G upgrade will, however, require far more changes to overall infrastructure (more base stations, faster backhaul).

Challenges in deploying new cell sites

- Deploying cells entails many challenges for the MNOs, with a highly decentralised delegation of public responsibility.
- Article 43 of the EECC requires that decisions on applications for access to public rights of way must be taken within six months.
- The granting of these rights does not necessarily mean that work can begin – there can be additional hurdles, such as:
  - Building permits;
  - Historic preservation; or
  - Electromagnetic Field (EMF) issues.
- The EECC has attempted to mitigate these somewhat.

Tools to mitigate the cost and complexity of deploying new cell sites and backhaul

- Article 57 of the new EECC exempts *small cells* from the need for local planning permits, except for “buildings or sites of architectural, historical or natural value protected in accordance with national law or where necessary for public safety reasons.”
  - Implementing Regulation (EU) 2020/1070 defines small cells and links to technical standards, such as the height above the walkway (typically 2.2 m).
- Article 58 EECC addresses EMF to a limited extent.
- The broadband Cost Reduction Direction (CRD) seeks to facilitate access to various kinds of infrastructure, and to set a time limit of four months for the granting of permits; however, the effectiveness is uncertain.

HEALTH EFFECTS OF 5G (EMF)

EMF arrangements in place today

- There have been long-standing public concerns over possible health effects due to exposure to electromagnetic fields (EMF).
- These concerns have led to general advisory limits on permissible EMF levels throughout the EU (Council Recommendation of 1999).
- In Europe, limits for non-ionising radiation are set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and were recently updated.
- ICNIRP protects *only* against thermal effects. Other health effects have not been conclusively demonstrated, but risks cannot be ruled out.

Pujol, Lavender, Rudd and Marcus et al. (2019),
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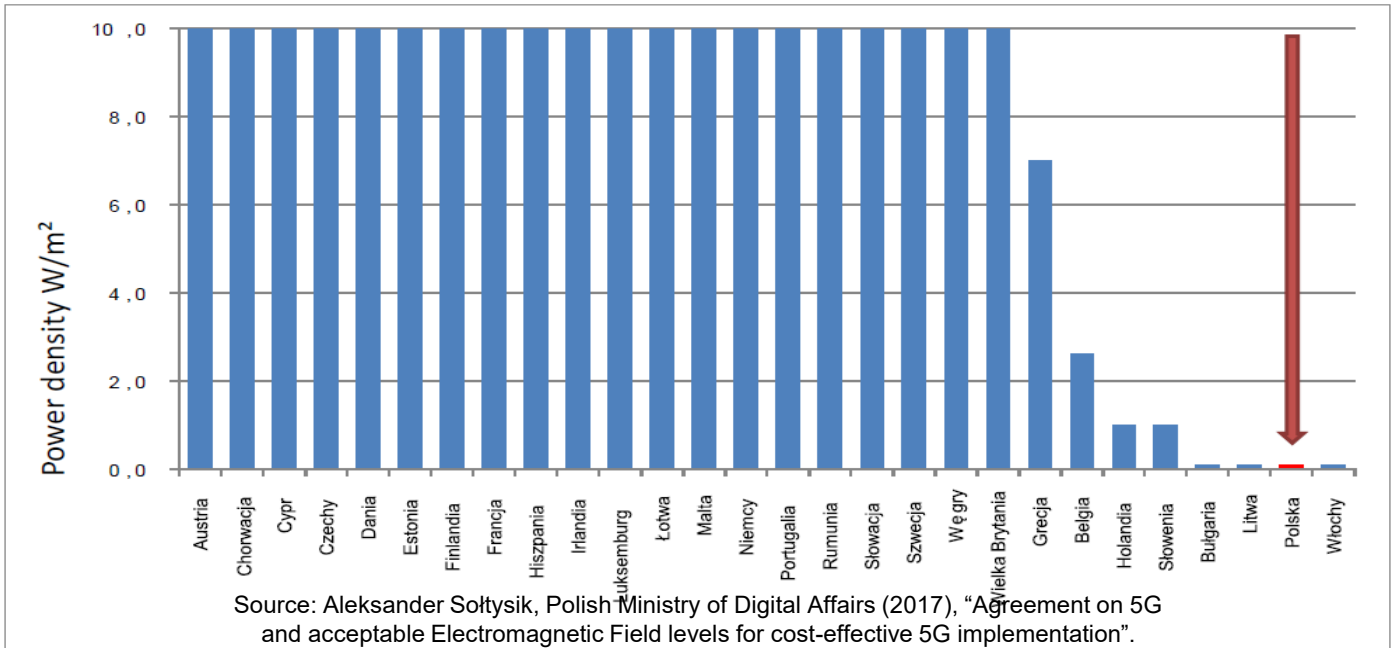
Some Member States or municipalities impose restrictive EMF limits

- In those Member States that impose EMF limits substantially more restrictive than ICNIRP, deployment of 5G is likely to face severe challenges.



Source: Aleksander Sołtysik, Polish Ministry of Digital Affairs (2017), "Agreement on 5G and acceptable Electromagnetic Field levels for cost-effective 5G implementation".

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5G and mm-wave

- Transmitters in mm-wave bands will be much closer to the public in light of the much shorter propagation distance of higher frequency waves (which implies advantages in terms of frequency re-use and capacity, but also disadvantages in terms of the cost of coverage).
- As previously noted, in dense urban areas, large numbers of cells smaller than those in use today are to be expected.
- At the same time, the small cells will necessarily operate at much lower power levels than those of the macro-cells of today, and at higher frequencies.
- EMF health effects at higher frequencies are different from those of waves in current cellular bands.
- Beam-forming adds additional complexity.

Known health effects

- A quite huge literature exists on the analysis of overall health effects of EMF associated with mobile services.
- A number of rigorous studies have been conducted, including epidemiological cohort and incidence time trend studies and animal studies.
- There are diverging views on the interpretation of the results of this research.
- Existing literature seems to indicate that current scientific evidence has not conclusively demonstrated that wireless and mobile communications cause harmful health effects in humans when operated within established limits; however, risks cannot be excluded.

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How to interpret even the best results?

- Even the best studies leave many questions unanswered.
- A study using rats and mice that was just concluded by the US National Toxicology Program (NTP) is considered by many to be the best conducted to date.
- Per the press release for the study, “High exposure to radiofrequency radiation (RFR) in rodents resulted in tumors in tissues surrounding nerves in the hearts of male rats, but not female rats or any mice …
- The incidence of tumors, called malignant schwannomas, that were observed in the heart increased in male rats as they were exposed to increasing levels of [EMF] beyond the allowable cell phone emissions. …
- Overall, there was little indication of health problems in mice related to [EMF].”

How to interpret even the best results?

- “A seemingly paradoxical finding that has also puzzled the researchers is that the rats exposed to the cellphone radiation actually lived longer than the controls.
- One possible explanation, Dr. Bucher said, is that the radiation may ease inflammation, and lessen the severity of a chronic kidney disorder that is common in aging rats and can kill them.”

New York Times (2018), “Cellphones Are Still Safe for Humans, Researchers Say”, 2 February 2018.

Known EMF health effects of mm waves

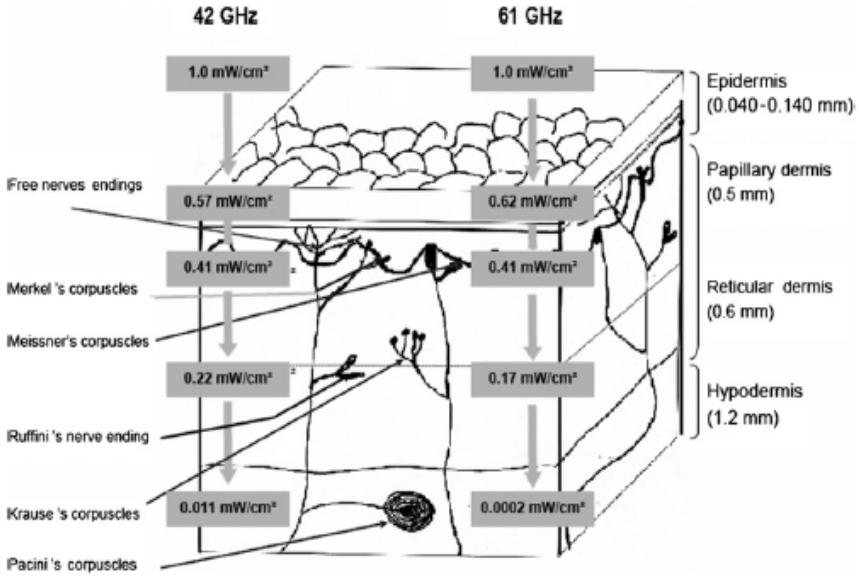
- The ability of mm-waves to penetrate the skin is extremely limited.
- Penetration “is of the order of a few tenths of millimetres to several millimetres, depending on frequency and tissues, indicating that the skin or near-surface zones of the tissues are the main targets for [mm-wave]radiations”.

(Le Dréan et al., 2013)

- Shown here is remaining power for every mW/cm^2 that is incident at the surface of the skin at 42 GHz and at 61 GHz.
- Many assume that health effects would be limited to the skin and eyes; however, use of mm-waves in Eastern Europe for pain relief suggests that there might also be effects that are transmitted in other ways.

(Le Dréan et al., 2013)

Schematic representation of the skin’s structure

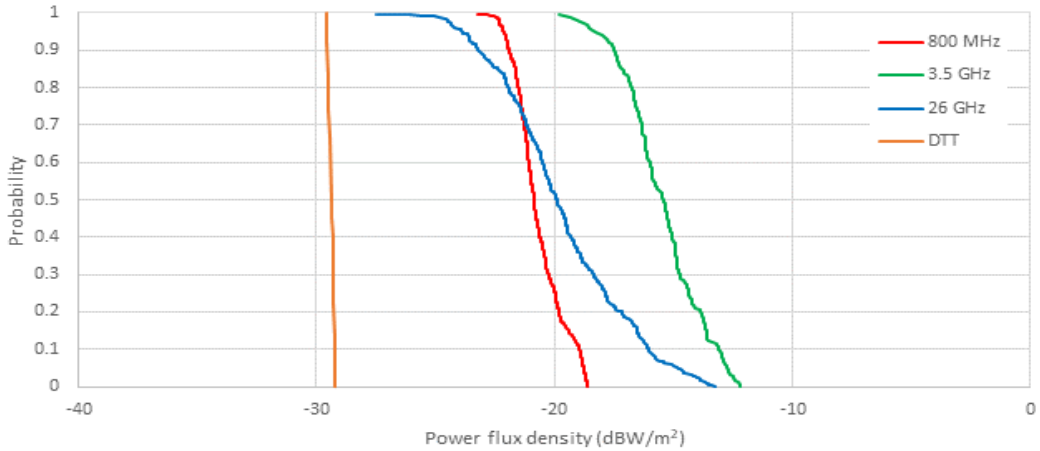


Source: Le Dréan et al., 2013

Results of static modelling

- Static modelling under worst case assumptions suggests that 5G EMF is not likely to be a problem.
- Distance from the transmitter at which PFD is exceeded are:
  - 0.72m to exceed the relevant ICNIRP limit of 10 W/m2.
  - 2.3m to exceed 1W/m2.

Cumulative Power Flux Density (PFD) for a sample deployment



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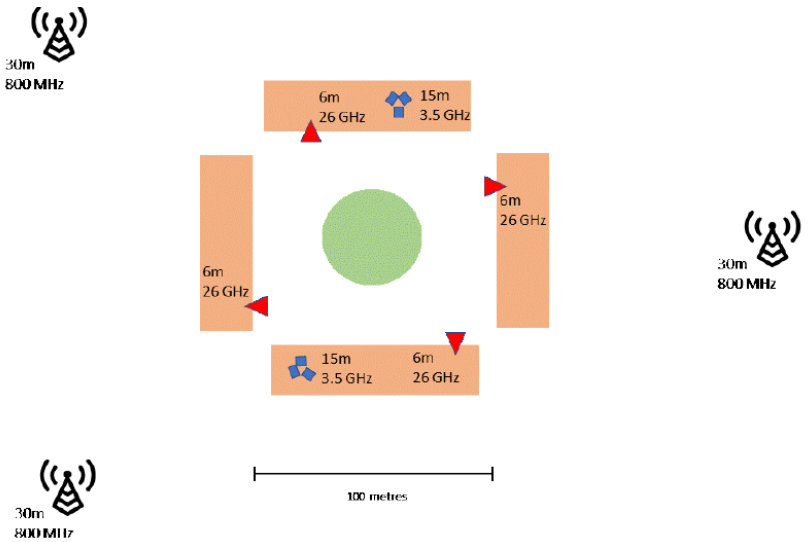
Results of probabilistic modelling

- My colleagues developed a simple, ray-tracing model using Monte Carlo methods in order to take reflection, scattering and active (beamforming) antennas into account.
- Even in the worst case, the EMF values lie more than 20dB below the ICNIRP limits.



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Key recommendations from the study

- We encouraged the Commission to fill in a few gaps in technical standards, which has now been done.
- We urged the Commission to put in place a process for periodic objective review of relevant portions of standards with EMF implications by independent experts with relevant health expertise, rather than by telecommunications experts. The Commission already has suitable expert panels in place.

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Concluding thoughts

- Greater need for build-out of infrastructure for 5G should be expected than for previous mobile generational transitions.
- There are numerous long-standing practical challenges to infrastructure deployment for electronic communications.
- The EECC that comes into place this month includes a number of practical tools that should help – perhaps a lot!
- EMF is one deployment challenge out of many.
  - There is no proven risk with mobile technology today.
  - There are however opportunities for further research.
  - The shift with 5G to small cells and millimetre wave makes things better in many important ways, not worse.

References

- Frédéric Pujol, Carole Manero, Samuel Ropert, Ariane Enjalbal, Tony Lavender, Val Jervis, Richard Rudd and J. Scott Marcus (2019), “Study on using millimetre waves bands for the deployment of the 5G ecosystem in the Union”.
- Yves Le Dréan, Yonis Soubere Mahamoud, Yann Le Page, Denis Habauzit, Catherine Le Quément, Maxim Zhadobov, and Ronan Sauleau (2013), Electromagnetic fields: from dosimetry to human health: State of knowledge on biological effects at 40–60 GHz.