
A MATERIAL
CASE
FOR TRUE
5G
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A material case for true 5G

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01 WHY 5G NETWORKS REPRESENT A QUANTUM LEAP IN MOBILE INTERNET CONNECTIVITY

Each new generation of wireless communication represents a leap in capability, connectivity and reliability. In less than 20 years, mobile internet connectivity moved from the 1G analog cellphone technology of the late 1980s to the 3G smartphone era of instant web browsing, video downloading and picture sharing. Users benefited further when 4G emerged in 2009, with greater speed and lower costs for voice and data services, multimedia and the internet.

Now the era of 5G is upon us. Whatever we do on our devices now, we will soon be able to do much better, quicker and smarter. Furthermore, 5G will enable a host of new capabilities that have simply not been possible until now.

'Welcome to the invention age,' declares chip manufacturer Qualcomm. 'An age of unprecedented creativity, when 5G speeds up not just your mobile devices, but your imagination.'[1]

1. www.qualcomm.com/invention-age

The fastest 4G mobile networks offer average real-world browsing and download speeds of about 45 Mbps (megabits per second), with a theoretical top speed of 300 Mbps under laboratory conditions.

Qualcomm predicts 5G could achieve speeds ten or even 20 times faster – and in the real world rather than a lab[2]. Average download speeds of around 1 Gbps (gigabits per second) could soon be the norm, with a theoretical top speed of 10 Gbps. That's the equivalent of downloading a two-hour movie not in 26 hours as with 3G, nor six minutes as with 4G, but in just 3.6 seconds.

As our world becomes ever more connected and driven by data, 5G is not just desirable but essential. According to the Alliance for Telecommunications Industry Solutions, 5G capability will be vital for 'citizen-centric functions, improving traffic flow, public safety and more'.

5G networks will bring about the infrastructure needed to carry massive volumes of data, accelerating the Internet of Things, enabling technologies as diverse as smart cities and remote surgery, and allowing autonomous vehicles to read live maps and interpret traffic.

At a personal level, wearable fitness devices will become capable of real-time health monitoring thanks to 5G.

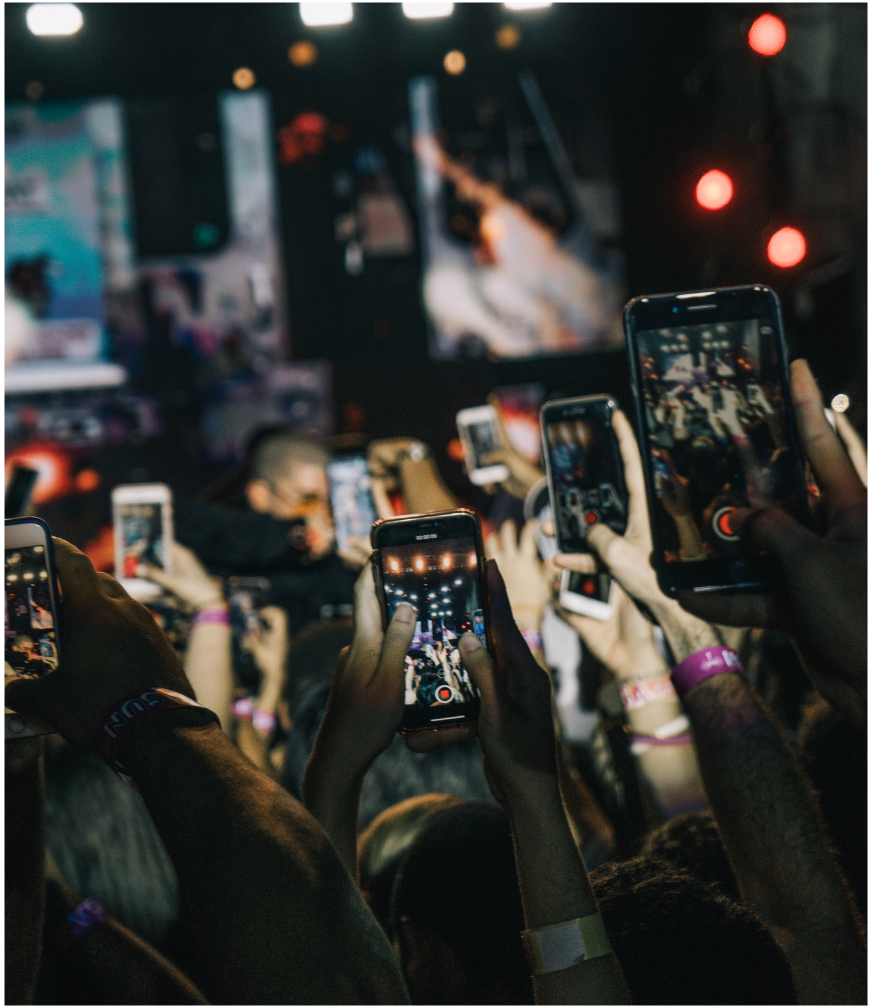
Gamers will no longer experience a frustrating delay between pressing a button on a controller and seeing the effect on screen.

For sports fans, 5G will transform fan engagement with live streaming, mixed reality experiences and real-time access to information both in a venue and remotely.

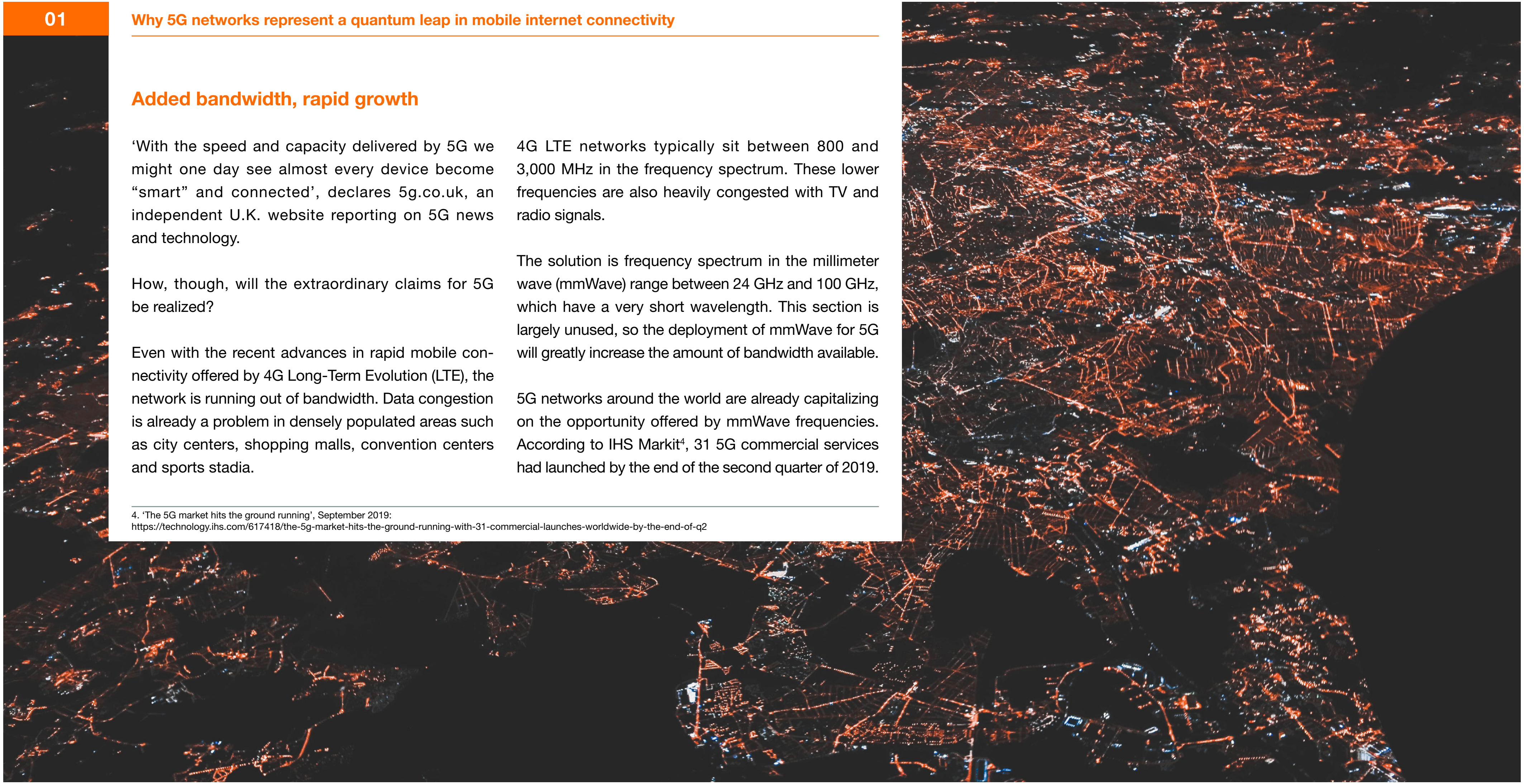
Critical for these developments will be 5G's much reduced latency – the time between a command being issued and a response being received. With 3G, latency is around 65 milliseconds (ms). 4G has cut that figure to around 40 ms. 5G will offer a potential target of 4 ms for mobile broadband services and a near-instantaneous 1 ms latency for mission-critical and Internet of Things applications.

By the end of 2024, according to Ericsson, there will be 1.9 billion 5G subscriptions for enhanced mobile broadband, 35 percent of traffic will be carried by 5G networks and up to 65 percent of the global population could be covered by 5G technology.[3]

5G promises browsing and download speeds ten or even 20 times quicker than the current fastest 4G networks and will enable new digital capabilities that have not so far been possible. How will such advances be achieved?



2. 'Predicting real-world performance of 5G NR mobile networks and devices': www.qualcomm.com/news/onq/2018/03/07/predicting-real-world-5g-performance
3. Ericsson Mobility Report, June 2019: www.ericsson.com/en/mobility-report/reports/june-2019



Added bandwidth, rapid growth

‘With the speed and capacity delivered by 5G we might one day see almost every device become “smart” and connected’, declares 5g.co.uk, an independent U.K. website reporting on 5G news and technology.

How, though, will the extraordinary claims for 5G be realized?

Even with the recent advances in rapid mobile connectivity offered by 4G Long-Term Evolution (LTE), the network is running out of bandwidth. Data congestion is already a problem in densely populated areas such as city centers, shopping malls, convention centers and sports stadia.

4G LTE networks typically sit between 800 and 3,000 MHz in the frequency spectrum. These lower frequencies are also heavily congested with TV and radio signals.

The solution is frequency spectrum in the millimeter wave (mmWave) range between 24 GHz and 100 GHz, which have a very short wavelength. This section is largely unused, so the deployment of mmWave for 5G will greatly increase the amount of bandwidth available.

5G networks around the world are already capitalizing on the opportunity offered by mmWave frequencies. According to IHS Markit[4], 31 5G commercial services had launched by the end of the second quarter of 2019.

4. ‘The 5G market hits the ground running’, September 2019: https://technology.ihs.com/617418/the-5g-market-hits-the-ground-running-with-31-commercial-launches-worldwide-by-the-end-of-q2

Countries seeking to compete in the global economy and enhance the digital capabilities of their citizens are among the most enthusiastic advocates of 5G technology, providing services that will initially operate alongside existing 3G and 4G technology.

A key factor driving the rapid growth of 5G is the experience of the operators, who are drawing on lessons learned from 3G and 4G rollouts to ramp up their 5G services. A number of countries are emerging as leaders because multiple companies in these countries have deployed networks and are selling compatible devices, backed and facilitated by national agencies.

In the U.S., the Federal Communications Commission, the agency responsible for implementing and enforcing America's communications law and regulations, is pursuing a 5G FAST plan designed to push more spectrum into the marketplace, update infrastructure policy and modernize the regulatory framework.

In response, Verizon launched its 5G network in limited parts of Chicago and several other locations in April 2019. Tests obtained speeds of up to 1.4 Gbps, some 366 percent faster than 4G's theoretical top speed, although this entailed moving around the city's 5G masts[5]. By August 2019, AT&T had rolled out its 5G network to 19 U.S. cities.

Three operators in China – China Mobile, China Unicom and China Telecom – launched the world's largest 5G network across 50 cities in October 2019. Working together, the trio deployed nearly 86,000 5G base stations with plans to have over 130,000 by the end of 2019. According to Groupe Speciale Mobile (GSM)[6], which represents the interests of mobile operators worldwide, 36 percent of China's mobile users are expected to be using 5G by 2025, representing a total of 600 million subscribers.

Other key markets are:

- South Korea, where SK Telecom and Korea Telecom are the main competitors. It took only 69 days for one million customers to subscribe to 5G services following the initial network launch;
- The U.K., which saw EE, Vodafone UK, Three UK and O2 UK launch commercial deployments in several cities and towns during 2019; and
- Germany, where Vodafone launched 5G services in 20 cities and municipalities during 2019, including Cologne and Dusseldorf. Deutsche Telekom Germany launched in six, including Berlin and Munich.

5. '5G: everything you need to know': www.techradar.com/uk/news/what-is-5g-everything-you-need-to-know/1
6. 'The Mobile Economy China 2019': www.gsma.com/r/mobileeconomy/china/

01

Why 5G networks represent a quantum leap in mobile internet connectivity

In other parts of the world, Qatar's Ooredoo has launched a commercial service while Switzerland, Turkey, China and Japan all aim to have 5G technology available in 2020. In Australia, Telstra's 5G coverage went live in May 2019. An interesting example of trans-national cooperation is in the Nordic region, where Denmark, Finland, Iceland, Norway and Sweden began working together in 2018 to create an interconnected 5G network.

A high level of market readiness is also clear. During 4G's first year of launch, only three smartphones supporting the standard were available to consumers. In 2019 alone, at least 20 5G smartphone designs were available for release to the market.

Operators in countries around the world are deploying 5G networks and selling compatible devices to capitalize on the benefits of mmWave technology. What are the challenges relating to 5G connectivity that may need to be overcome in order to meet expectations?

02 THE CHALLENGES OF 5G CONNECTIVITY

The terms mmWave and 5G are sometimes used interchangeably, although mmWave technology is only one component of future 5G networks. The 5G standard will also develop to include ‘low-band’ frequencies, which transfer data over greater distances but at comparatively slower speeds.

It is, however, the mmWave frequency spectrum on which the most attention is focused. This has a limited range but transfers more data up to 20 times faster than 4G. This is why carriers are keen to publicize the impressive data speed figures it can deliver. In addition, 5G can support up to one million devices per square kilometer, while 4G supports only 4,000 devices per square kilometer.

Although 5G antennas will be able to handle more users and data, the fact that they only beam out over short distances requires new infrastructure to ensure coverage. This comprises ‘small cells’: miniature transmitters positioned about 250 m apart in densely populated areas and employing what is known as ‘massive MIMO (multiple-input multiple-output)’ – multiple 3D directional antennas on a single station.

5G antennas will be located on buildings and street furniture rather than standalone masts. They will support non-line of sight (NLOS) operation by using a technique known as ‘beamforming’. A base station computer continuously calculates the best route for radio waves to reach each wireless device, then organizes multiple antennas to work together as phased arrays to create beams of millimeter waves to reach the device.

Beamforming has the capability to direct waves off and around obstacles to a device, and to combine the data from multiple streams to strengthen the overall signal and increase the bandwidth. This works outdoors by reflecting signals off buildings, and indoors by reflecting signals off walls. However, many materials attenuate and reflect very high-frequency signals such as those in the millimeter wave spectrum, meaning that they are less able to travel easily through buildings or other solid objects.

A Sussex University report[7] showed that at a frequency of 60 GHz, this penetration loss was of ‘the order of some dBs for very thin plastic, wood or plaster partitions, -4 decibels (dB) for 0.7 cm thick single-panel tempered glass and -25 dB for a 9 cm indoor brick wall’.

What do the figures for loss of signal strength caused by different materials mean for a phone user?

Signal strength is measured in decibels (dBm), expressed as a negative number. A reading of -50 dBm is the strongest signal available, while a reading of -120 dBm would mean no effective signal. Although there is no definitive standard for the strength bars displayed on phones as each manufacturer uses their own algorithm to sense the level of available signal, the following Received Signal Strength Indication ranges[8] are indicative:

- -50 to -79 dBm: excellent signal (4 to 5 bars)
- -80 to -89 dBm: good signal (3 to 4 bars)
- -90 to -99 dBm: average signal (2 to 3 bars)
- -100 to -109 dBm: poor signal (1 to 2 bars)
- -110 to -120 dBm: very poor signal (0 to 1 bar)

The Sussex University findings equate to an approximate 5.7 percent reduction in signal strength for 0.7 cm thick single-panel tempered glass and a 35.7 percent reduction for a 9 cm indoor brick wall – the latter therefore turning an excellent signal into a poor one.

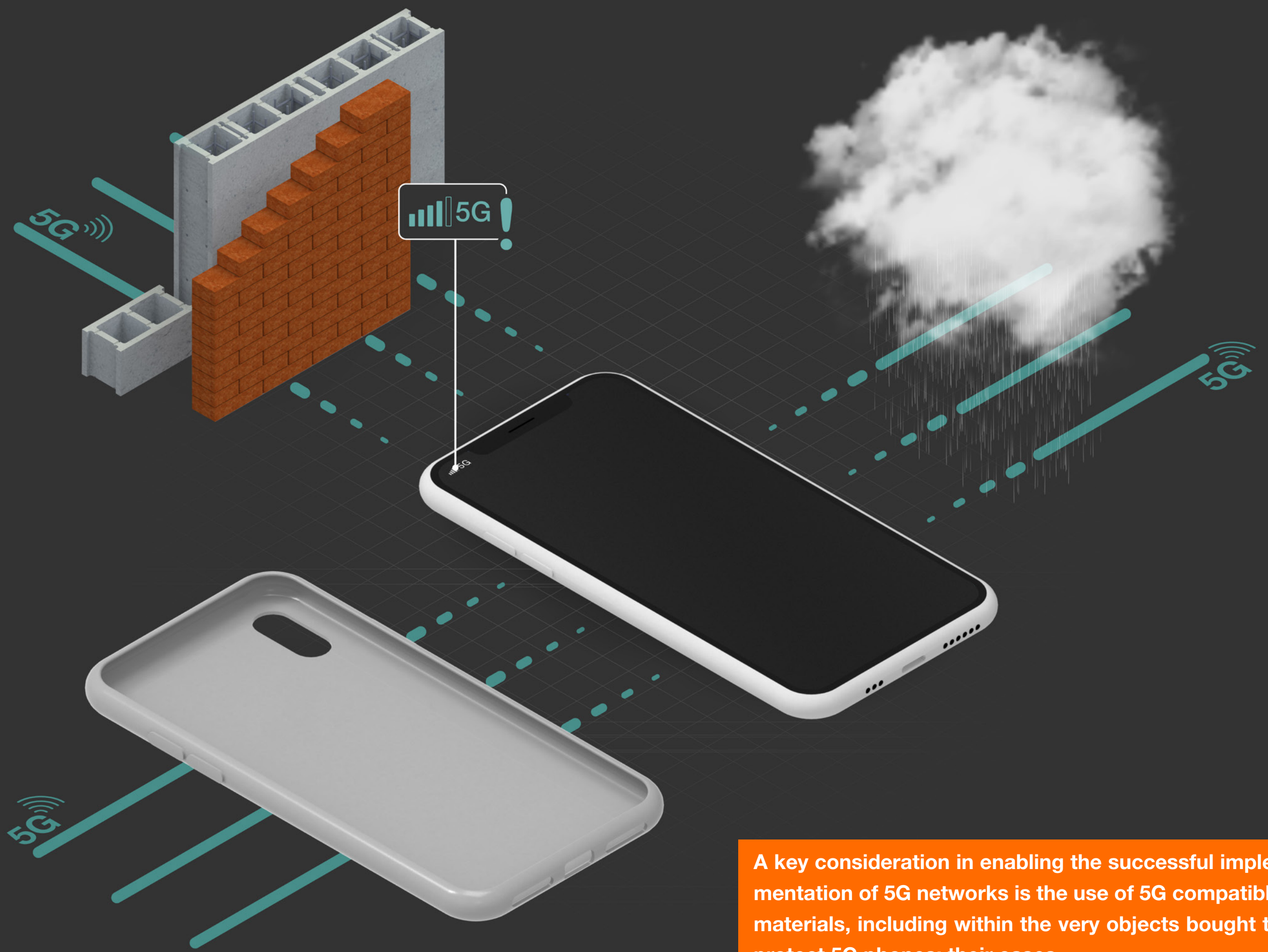
7. ‘Millimeter-wave Propagation Characterization and Modelling Towards 5G Systems’: http://sro.sussex.ac.uk/id/eprint/66812/4/20493.pdf
8. ‘How to Read Cell Phone Signal Strength the Right Way’: www.wilsonamplifiers.com/blog/how-to-read-cell-phone-signal-strength-the-right-way

Other materials can cause path loss for a 5G signal. Rain or falling snow add an extra level of density to the atmosphere, thereby attenuating signals as they travel. The Sussex University study cites a maximum attenuation of about 30 dB/km for very heavy (100 mm/hour) rainfall.

Glass and wood attenuate high-frequency signals to a lesser degree[9], so 5G mmWave will show signal loss of around -4 dB next to a closed window and approximately -9 dB through plywood, which is a significant material in many houses.

5G signal is even absorbed to some degree by air. Conventional frequencies can easily travel several kilometers whereas, even without any obstacles in the way, frequencies above 28 GHz may only have a workable maximum distance of around one kilometer.

As explained in a paper published by BMS College of Engineering, entitled 'Impact of atmospheric impairments on mmWave based outdoor communication'[10], 'the atmosphere is full of gases that…degrade the signal propagation along the propagation path'. However, cited research into atmospheric attenuation at different frequencies found that 'the frequencies ranging from 28 and 38 GHz encounter very small attenuation due to gas, providing feasibility of mmWave communication at such frequencies. It can be observed that negligible atmospheric absorption is encountered at 28 GHz and 38 GHz'.



A key consideration in enabling the successful implementation of 5G networks is the use of 5G compatible materials, including within the very objects bought to protect 5G phones: their cases.

9. 'How Much and Which Building Materials Block Cellular and WiFi Signals?': www.signalbooster.com/blogs/news/how-much-which-building-materials-block-cellular-wifi-signals
10. 'Impact of atmospheric impairments on mmWave based outdoor communication': https://arxiv.org/ftp/arxiv/papers/1806/1806.05176.pdf

Overcoming battery drain

All smartphones are designed to operate at the minimum power level needed to maintain a link with a cell tower. If a mobile signal is weak, the device will switch to maximum transmit power to try to establish a reliable connection. Although the extent of any resulting battery drain will vary according to the device, a general principle is that the weaker the signal, the more a device will need to work to improve its strength and quality.

As new device technology emerges, users may be unable to tell the difference between a good and a bad signal in terms of the quality of a phone call. However, this difference in signal strength will certainly translate through to battery levels.

In the longer term, modern chip packages on 5G phones could, along with newer large batteries, actually lead to increased battery life once the 5G infrastructure expands, due to the greater number of towers and the reduced distances between them.

In the meantime, however, battery drain caused by insufficient signal is a real issue that can affect the speed at which 5G technology is adopted. Similar to electric vehicles, every obstacle to use removed will result in an increased likelihood of adoption.

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03 PROTECTING INVESTMENTS IN 5G

The exponential growth in mobile technology, particularly since the advent of the smartphone in 2007, has not only created an indispensable and defining element of our consumer lifestyle, it has enabled businesses to untether workers from their desks. People can now work from almost anywhere, using their devices to improve collaboration, flexibility and productivity. A report from the International Data Corporation[11], an IT market intelligence analyst, found that 86 percent of U.S. businesses were buying, deploying and managing smartphones for their employees with only slightly smaller numbers equipping staff with notebooks and tablets.

The arrival of 5G will further amplify these opportunities. With the right conditions, successful rollouts will be able to satisfy the clear demand for the exciting new capabilities offered by 5G technology.

Investment in 5G, while essential, is not just a matter of dollars spent on infrastructure. '5G is about much more than that,' states supply chain financier Greensill in its study, 'Financing the Future of 5G'[12]: 'This latest technological upgrade…is actually about upgrading everything from our cars, refrigerators and ovens to our buildings, factories and hospitals. Everything will be 5G once this generational project is complete.'

The report quantifies the financial outlay likely to be incurred by telecoms carriers as they upgrade vital infrastructure at somewhere between $500 billion and $1 trillion, with U.S. carriers estimated to invest $275 billion to deploy 5G networks.

According to Greensill: 'The most recent analysis of 5G spending…estimates the total bill for the 5G rollout throughout the global supply chain is likely to top $2.7 trillion by the end of 2020 alone.'

The value of such levels of investment is rooted both in the belief that 5G will deliver what has been dubbed the fourth industrial revolution, and in the quality of the end-to-end 5G user experience. These explain why network operators are also putting aside substantial sums to bid for slices of the higher frequency spectrum required to offer 5G services.

11. 'Pay Now, Save Later: The Business Case for Rugged Devices', November 2016: http://info.panasonic.com/rs/400-JUK-127/images/IDC-report_pay-now-save-later_the-business-case-for-rugged-devices.pdf

Why device protection matters

5G device users have an important role to play. The mobility benefit of handheld devices is countered by the fact that they are significantly more at risk of being damaged than traditional desktop computers. They can be dropped onto hard surfaces and into water, and subjected to rough handling and extreme weather conditions.

Devices provided by an employer are even more at risk than those purchased by individuals, who are most likely to bear the full cost of their investment. The International Data Corporation report cited earlier claimed an annual business smartphone failure rate of 13.9 percent. The screen or display accounted for 70 percent of component damage, with more than 35 percent of respondents citing battery damage and more than 25 percent the outer chassis. The main causes of damage were drops (almost 70 percent), liquid spills (more than 40 percent) and falling off a table while in use (40 percent).

Among non-business users, a 2018 survey, 'The annual cost of broken smartphones in America'[13], found that 66 percent of U.S. smartphone owners admitted to damaging their phones within the last year, with more than 50 million phone screens accidentally smashed.

The U.S. data platform Statista reported[14] that in 2018, the most common causes of accidental smartphone damage were dropping on the ground (74 percent), falling out of a pocket (49 percent), falling into water (39 percent) and being knocked off a table (38 percent). The damage resulting[15] included a cracked screen (29 percent), a scratched screen (27 percent) and non-working batteries (22 percent).

Owners spent an eye-watering $3.4 billion on damage repairs. Much of this cost could have been avoided had devices been properly protected with cases deploying impact resistant materials, such as those developed by impact protection specialist D3O.

The cost of damage repair could rise even further when more 5G devices enter the marketplace. Like most other new technology, 5G phone deals require significant investment. A highly-specified 5G handset from a reputable brand is likely to cost in excess of $2,000.

When extrapolating the costs of device failure to the business environment, other factors also need to be considered. Corporate buyers often have a fixed budget for mobile technology, which can be severely impacted by repair or replacement bills and associated insurance costs. Personnel whose devices are damaged or out of action may also experience a loss of productivity. Taken together, such issues can have a potentially significant negative effect on a company's bottom line.

13. 'The annual cost of broken smartphones in America': www.digitalinformationworld.com/2018/12/the-truth-is-out-there-uncovering-smartphone-myth-conceptions.html
14. 'Most common causes of accidental smartphone damages according to users the United States as of 2018': www.statista.com/statistics/959492/us-top-common-smartphone-damage-cause/
15. 'Most common smartphone damages according to users in the United States as of 2018': www.statista.com/statistics/959513/us-common-smartphone-damages/

04

BUILDING THE CASE FOR 5G PROTECTION

There is a clear justification for individual and business purchasers of 5G handsets to optimize their investment by protecting it against accidental damage. A key consideration is the material from which any protective casing is manufactured.

This needs to be addressed in conjunction with the placement of antennas within the phone. Optimal placement, and placement relative to each other, is critical to their performance.

‘Antenna design for mobile phones has always been a challenging topic for engineers,’ states a report by 3-Dimensional Data Systems[16]. The report notes that as 5G will be used alongside existing 4G, 3G and Wi-Fi communication channels, the number of antennas to be integrated in a phone will need to increase.

“Historically, antennas were mainly placed in the back panel of a phone,” says Kevin Fleer, Program Manager Team Lead for D3O. “With 5G phones also needing antennas for 4G, 3G and Wi-Fi, there will be a multiplicity of antennas and they will need to be placed around the edges of the case as well as the back panel.”

However, positioning changes of just a few millimeters can make the difference between a well performing and a poorly performing device if combined with a phone case that interferes with the 5G signal.

16. ‘5G Antenna Design for Mobile Phones’: https://3dds.gr/346-2/

There is a clear justification for individual and business purchasers of 5G handsets to optimize their investment by protecting it against accidental damage.

Adding a protective case to a phone can have a significant additional impact on the radiating performance of antennas. As previously outlined, the high frequencies employed in 5G networks have been shown to deliver what is called 'dielectric loss' when passing through even relatively low-density materials. The dielectric loss of a phone case material indicates how opaque to radio waves it is; the lower the loss, the stronger the signal. The materials used in many traditional phone cases for earlier-generation devices would, if used with a 5G device, attenuate and reflect millimeter waves to a detrimental extent.

As a result, adding a phone case made of non-5G compatible materials to a 5G device could interfere with the 5G network signal and significantly affect performance. This in turn could lead to the frustrations of dropped calls and slow data transmission. An additional consequence would be poor battery life, with the device being required to work harder in order to find and maintain a good connection, thus depleting the battery more quickly.

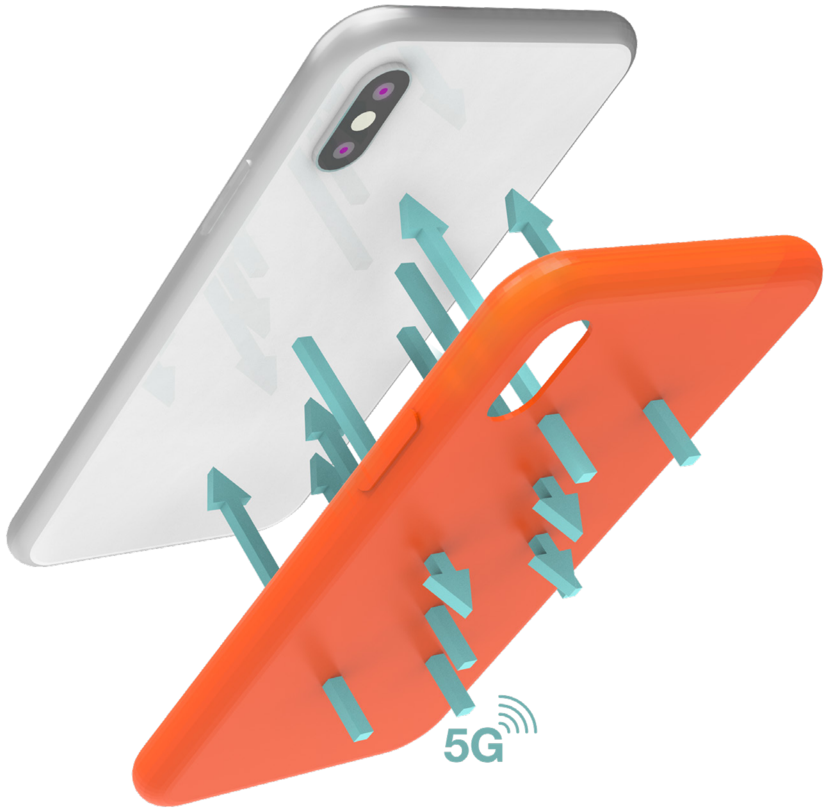
"Because there has never been an issue with consumers putting a protective case on a 4G phone and losing signal strength," says Fleer, "there is a lack of awareness that the situation is different with a 5G phone. Consumers will need to know what they should buy and have confidence that a product they choose will be reliable."

This view supports the findings in a 2018 report by PwC, 'The promise of 5G'[17], which states that reliability is the foundation on which 5G must be built. Consumers surveyed for the PwC Consumer Intelligence Series placed reliability at the top of their 'must have' list when using a mobile device, ahead of unlimited data, security, cost and speed.

Should cases advertised as 5G compatible prove not to be the case, the potentially negative consequences could damage consumer trust at a critical point in 5G roll-out. This could then have a knock-on effect, impinging on the sustained investment required to maximize the benefits of the technology.

The approach to resolving this issue without resorting to short-cuts or the need to lean heavily on lower frequency bandwidths is a deep dive into materials science to address the root cause of dielectric loss leading in turn to signal loss, with the aim of developing a material solution that is genuinely 5G compatible.

By using case materials that act as a lens for 5G signal to pass through, consumers will be able to protect their investment and truly benefit from the faster connections and data transmission speeds offered by the new technology.



17. 'The promise of 5G': www.pwc.com/us/en/services/consulting/library/consumer-intelligence-series/promise-5g.html

05 RESPONDING TO THE CHALLENGE OF OPTIMIZING 5G PROTECTION

Permittivity is defined as a measure of the response of a substance to an electric field. It indicates how easily electric lines of force can pass through a material. By definition, a perfect vacuum has a permittivity of exactly 1.

In the example of a phone case, the lower the permittivity of its materials, the stronger the signal that can pass through it.

'External cases create distortions in 5G mmWave antenna radiation pattern; peak gain [a measure of input power concentration in the main beam direction] and spherical coverage [the range of solid angles that a piece of user equipment can cover] profiles are altered,' confirms Samsung. 'This negative impact can be reduced by using thinner cases (less than 3 mm) with low permittivity materials.'

Measurement

D3O worked with an independent laboratory, specifically to obtain external measurements for dielectric permittivity and signal loss that could then be used for analysis. The outcomes were twofold:

- First, to obtain the permittivity of various materials at different frequencies; and
- Second, to measure any loss of signal from these materials.

The materials under review included those used in existing phone protection products, together with D3O® with 5G Signal Plus™ Technology. This material employs micro voids to increase the air content of a phone case. As explained in section 2, air enables a 5G signal to pass through with minimal loss in terms of both strength and quality.

"D3O has been developing different thermoplastic elastomers (TPEs) for phone cases since 2015," says Richard Holman, Material Development Team Leader at D3O. "Once it became apparent that 5G would experience some technical challenges around signal loss, and that these could be exacerbated by adding a non-5G compatible material to a case, D3O saw this as a unique opportunity for its materials development specialists."

"Permittivity is an established property of a material," Holman explains. "Measuring permittivity using plaques [small slabs] of different materials is a factual check and is repeatable. If anyone else were to mold plaques of the materials tested and carry out the same measurements, they would get the same results."

"Permittivity is mentioned in the 5G specs issued by major operators," adds Holman, "so it was the first port of call to see if various materials, including D3O® with 5G Signal Plus™ Technology, were meeting these specifications. All the measurements were done on plaques of materials so any design element was disregarded. It was purely and simply a test to demonstrate which was the most appropriate material."

"The second test, measurement of signal strength, took almost two months to set up and establish the parameters," says Fleer, who managed the Signal Plus™ development project. "Then the measurement process took another month with technicians in a temperature controlled, radio frequency, fully anechoic chamber taking readings. The objective was to obtain independent data from a specialist lab."

Beating the permittivity benchmark

The benchmark originally set by Samsung was a permittivity at 5G frequencies of less than 2.5, allowing phone case manufacturers to have a level to work to in order to claim true 5G compatibility. Techniques to determine material permittivity vary according to the frequency of the signal.

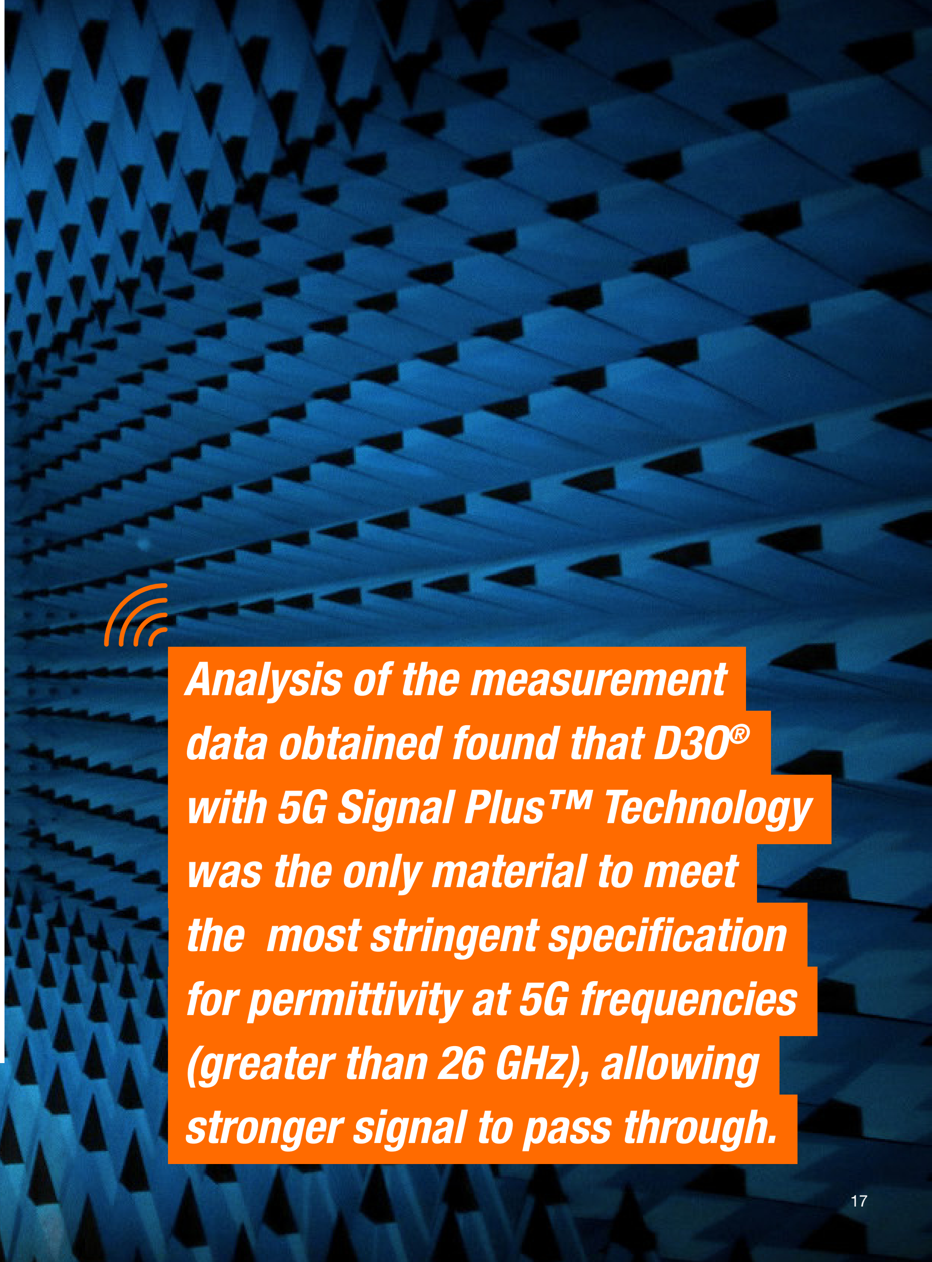
The measurement methodologies for material permittivity were as follows:

- 4G and sub-10 GHz 5G frequencies were tested using a split post dielectric resonator (SPDR). This device is widely used to measure the permittivity of dielectric laminar specimens in the 1-10 GHz frequency range. D3O tested at 1.8 GHz and 10.2 GHz.
- For targeted 5G frequencies in the 26-39 GHz range, no equipment is currently available to test low loss materials at these frequencies. The closest result is obtained using Lynch’s formula, which allows the calculation of any change in permittivity for a given change in frequency using dielectric constant and loss values from 1.8 GHz and 10.2 GHz.
- For longer term 5G frequencies (50 GHz), testing equipment is available. However, permittivity decreases with higher frequencies. This means that any material failing to pass the benchmark figure at 50 GHz will fail at 26-39 GHz.

Demonstrating improved signal strength

A number of existing phone protection materials, including D3O® with 5G Signal Plus™ Technology, were also tested to measure any loss in signal. This is another essential element in optimizing 5G protection because, as Holman explains, it shows what the actual effect would be of wrapping a material around a phone.

As explained in section 2, the only reliable way to determine the absolute strength of a signal is to take a reading in decibels (dBm). In order to achieve completely accurate data, the tests conducted used a mmWave 5G software defined radio, a vector network analyzer (VNA) and the temperature controlled, radio frequency, fully anechoic chamber mentioned earlier.



Analysis of the measurement data obtained found that D3O® with 5G Signal Plus™ Technology was the only material to meet the most stringent specification for permittivity at 5G frequencies (greater than 26 GHz), allowing stronger signal to pass through.

The distance between transmitting and receiving antennas was set at 0.5 m to reduce the edge fringing effect on the transmission loss measurement due to the size of the material sample, which was itself positioned at different distances from the front face of the receiving antenna. The transmission loss between transmitter and receiver was then measured by using continuous wave signals and the VNA.

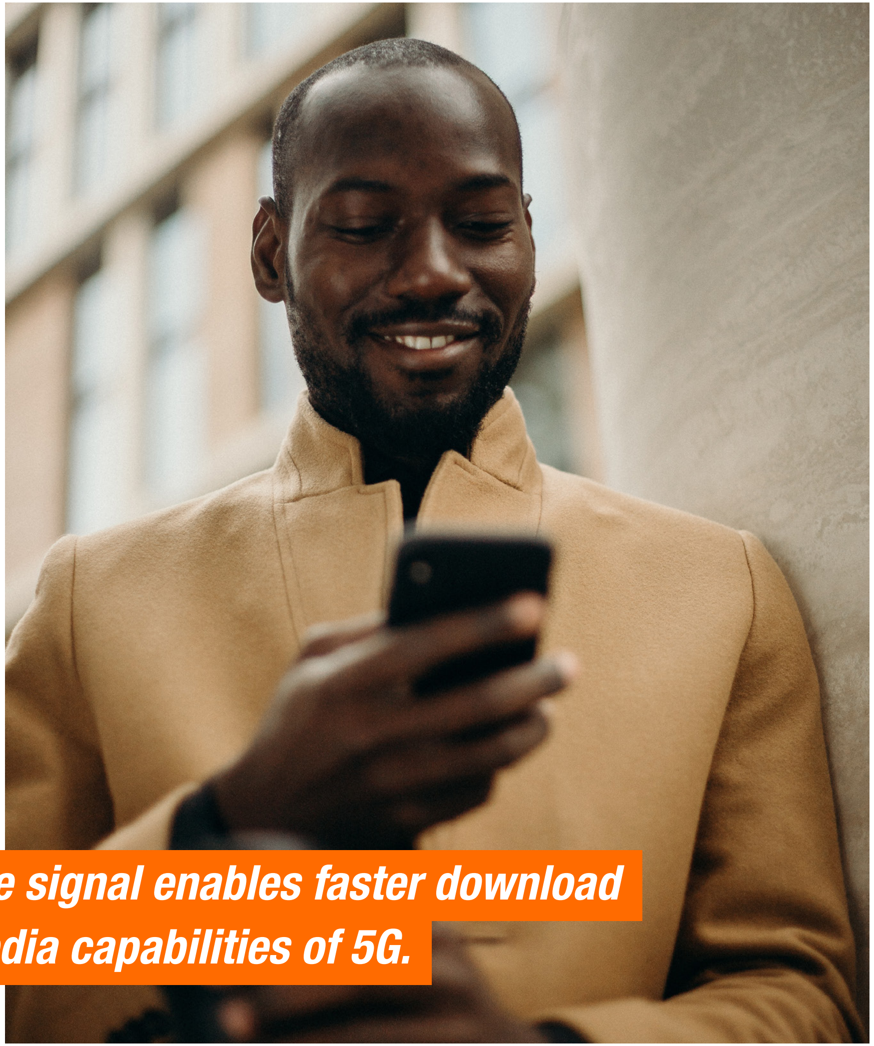
“As frequency increases, permittivity decreases in an almost linear path,” Holman explains. “Signal loss, on the other hand, can go up and down. What we were checking was that there was no peak in the loss at the frequencies we were testing – that is, the 26-39 GHz 5G frequencies.

“The measurements carried out provided levels for permittivity and also for loss. So, if your aim is a material that is 5G compatible, even if you get good permittivity you don’t want to see a spike in loss at the frequency you’re interested in.”

Analysis of the measurement data obtained found that D3O® with 5G Signal Plus™ Technology achieved on average 37 percent less signal loss than its nearest market competitor and outperformed all benchmark materials. This equates to a 10 percent stronger received signal output for consumers, enabling the fastest download and upload speeds.

Analysis of Variance (ANOVA), a statistical method used to test differences between two or more means, verified a meaningful difference in mean transmission loss for 5G Signal Plus™ Technology compared to market competitors across all the measurement distances and materials tested.

A stronger and more reliable signal enables faster download speeds and the full multimedia capabilities of 5G, delivering optimal browsing and multimedia viewing. A stronger and more reliable signal also means that a phone needs to use less power to find and retain a signal, giving a positive impact on battery life.



A stronger and more reliable signal enables faster download speeds and the full multimedia capabilities of 5G.

Confirming improved battery life

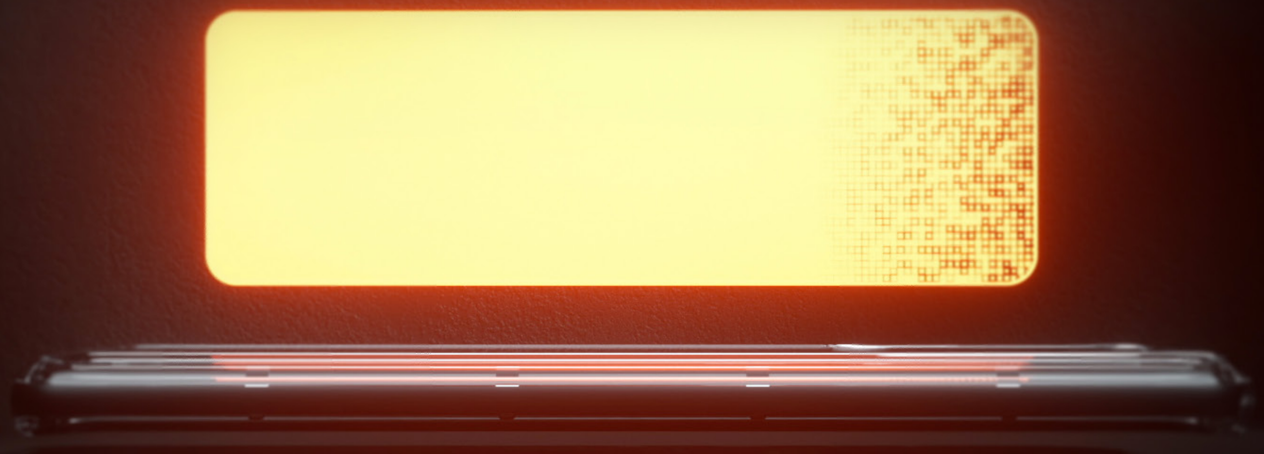
A 2013 Cambridge University research paper, 'Characterizing and Modeling the Impact of Wireless Signal Strength on Smartphone Battery Drain'[18], was the first measurement study of 3G and WiFi signal strength experienced by a large number of smartphone users over a long period of daily usage.

The paper took as its proposition: 'Poor wireless signal strength not only affects network performance, but also – in the context of energy constrained mobile devices perhaps more importantly – can significantly inflate the actual energy consumption by the wireless interface to be much higher than under good signal strength, while transferring the same amount of network traffic'.

The users that were studied carried out an average of 43 percent and 21 percent of their foreground data transfers during periods of poor 3G and WiFi signal strength. A sample finding was that in order to complete a 100 kB download using 3G at a signal frequency of -85 dBm to -95 dBm, energy consumption increased mildly by 6.6 percent. With a much weaker signal of -105 dBm, energy consumption to complete the download increased by a massive 52 percent compared to consumption at -85 dBm.

This finding is corroborated by other research, including a 2015 Purdue University study[19] which noted that the power needed to transmit and receive data 'generally increases with weaker signal strength'.

Given D3O® with 5G Signal Plus™ Technology suffers less average signal loss and delivers a stronger signal output, it follows that a 5G phone placed inside a case made from this type of material needs to use less power to find and retain a signal. This positive impact on battery life plays its part in delivering the high-quality user experience one would expect from a 5G device.



18. 'Characterizing and Modeling the Impact of Wireless Signal Strength on Smartphone Battery Drain': www.cl.cam.ac.uk/~acr31/pubs/ding-signalstrength.pdf
19. 'Smartphone Energy Drain in the Wild: Analysis and Implications': https://engineering.purdue.edu/~ychu/publications/TR-ECE-15-03.pd

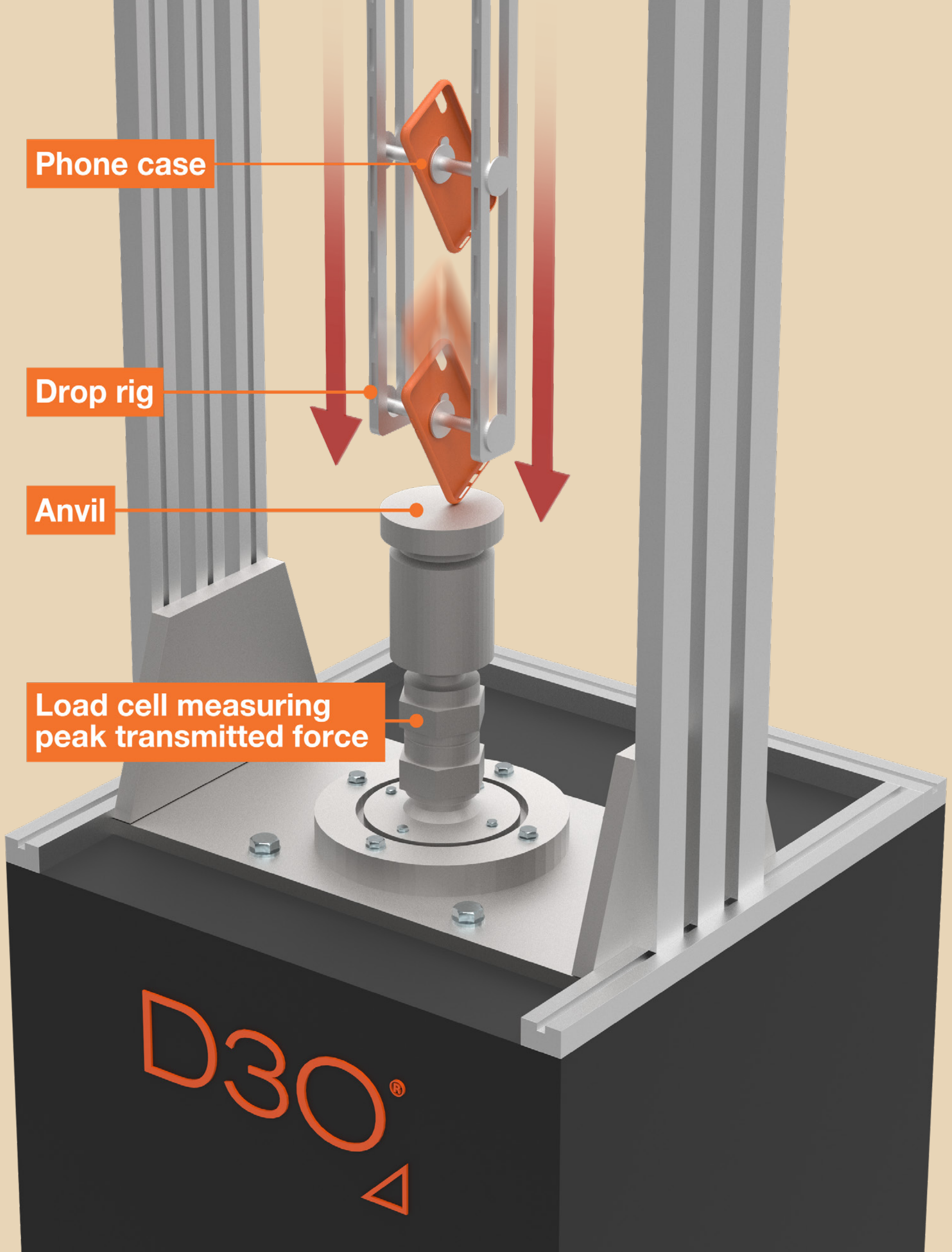
06 PROVIDING TRUSTED PROTECTION

At this point, the primary function of a phone case needs to be remembered – that is, to protect the device from the drops and other accidental impacts outlined in section 3.

D3O® with 5G Signal Plus™ Technology leverages the micro voids introduced into it in order to meet the most stringent specification for permittivity at 5G frequencies while being engineered to provide superior impact absorption.

"We have been developing thermoplastic elastomer (TPE) for phone cases since 2015," says D3O's Holman. "Our objective with this material was to match the impact performance of our current best-performing TPE.

"In fact, when analyzed using a standardized drop test on a phone case, the results showed that D3O® with 5G Signal Plus™ Technology exceeded the performance of D3O's existing, market-leading materials."



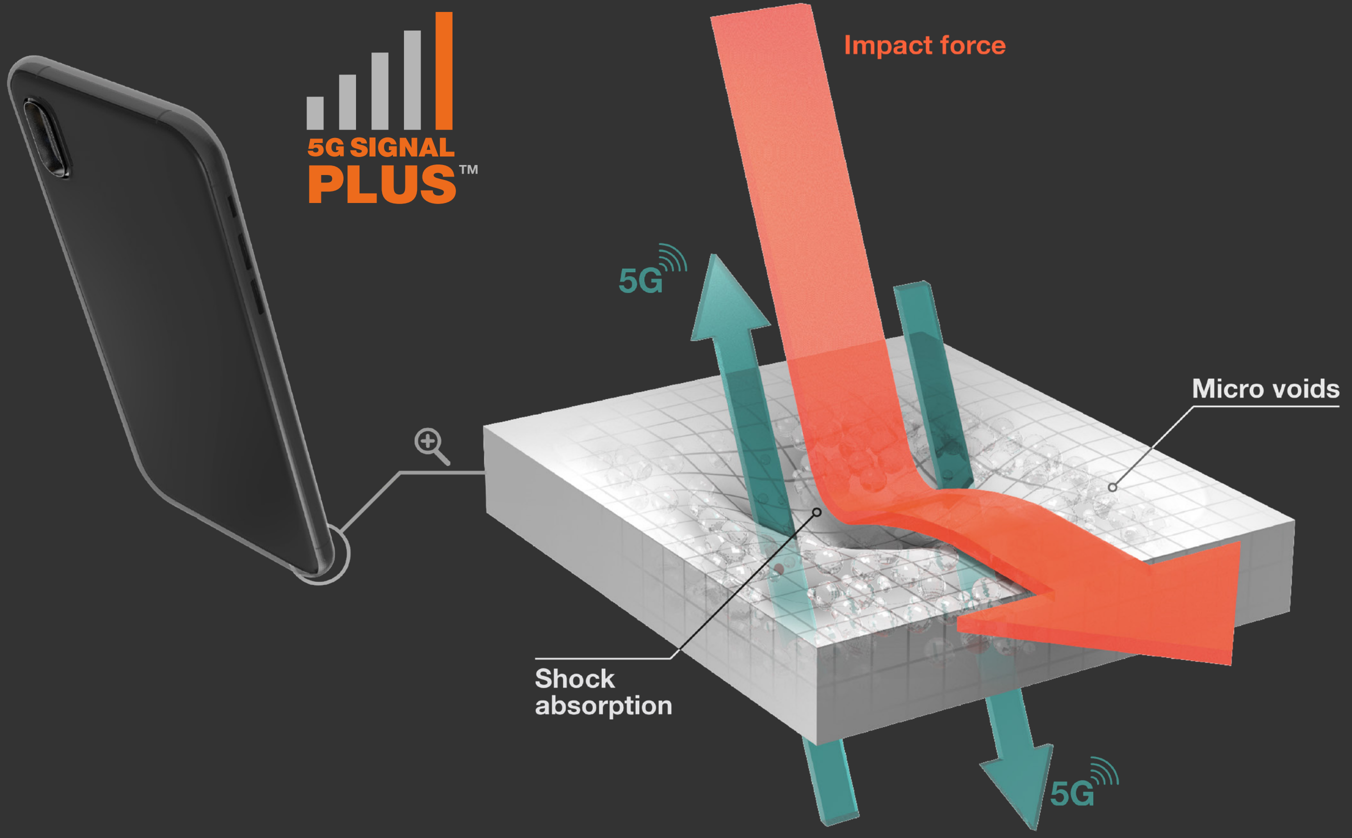
07 DELIVERING THE SOLUTION

For anyone seeking to reap the benefits of 5G, choosing the right phone case, made from the right material, is paramount. "A 5G compatible material that delivers better reception, faster connections and better battery life is a compelling proposition,' says D3O's Holman.

In contrast, an unreliable signal caused by an incompatible case can lead to the frustration of dropped calls, slow data and poor battery life, as a result of the phone having to work harder to track down and sustain a good connection. A user might well end up questioning why they bothered to invest in 5G in the first place.

Tests have shown that a material providing maximum void volume while retaining maximum strength is best able to deliver the necessary dielectric effects for optimal 5G signal reception.

D3O® with 5G Signal Plus™ Technology has been proven to meet the most stringent specification for permittivity at 5G frequencies. Using the lowest permittivity protective material enables design of the most 5G compatible case.



WITH AN IMPROVED SIGNAL, FASTER DOWNLOAD SPEEDS, ENHANCED BATTERY LIFE AND THE BEST EVER IMPACT PROTECTION, USERS ARE EQUIPPED TO CAPITALIZE ON THE FULL POTENTIAL OF 5G TECHNOLOGY TO DELIVER THE PROMISED QUANTUM LEAP IN MOBILE COMMUNICATION.

This white paper was commissioned by D3O, world experts in impact protection and shock absorption.

D3O provides guidance and advice on impact protection to many of the world's leading regulatory bodies for personal protection, and its technology is widely used in the defence, sports, motorcycle, electronics and workwear industries.

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