White Paper

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The Need for High Frequency Connectors in 5G Communications

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THE NEED FOR HIGH FREQUENCY CONNECTORS IN 5G COMMUNICATIONS

5G is almost here, with many operators announcing plans to trial or even launch service in late 2018 and full 5G network roll-outs scheduled to begin in 2020. The industry is gearing up for this launch with device manufacturers such as Qualcomm releasing 5G modems, (Snapdragon), test equipment manufacturers updating their portfolios and a number of companies such as Huawei, Nokia and Ericsson working on antenna and the beam-forming technology that will be required to enable the MIMO functionality of 5G. Within the various areas of 5G technology, RF connectors are omnipresent and the demands of mmWave frequencies place critical requirements on the precision of their manufacture. The ubiquitous nature of cellular networks is also placing downward pressure on the cost of these connectors, whose use was historically limited to military and aerospace applications. Johnson connectors have been at the forefront of RF applications for over 50 years and have supported previous generations of wireless networks. In this article, we look at 5G, the demands it is placing on connector technology and how Johnson is responding with new product launches.

The deployment of 5G is being driven by the growing number of devices requiring high bandwidth internet access, putting pressure on existing networks. 5G will address this by using frequencies that range from sub-1GHz to, eventually, the 26GHz band and beyond. The total bandwidth used by 5G will be vastly greater than the amount of frequency spectrum used by 4G and previous wireless network technologies.

Spectrum allocations are decided by the World Radiocommunication Conference, which meets every three to four years. WRC-19 will take place in Sharm el-Sheikh, Egypt between 29 October and 22 November 2019, but in the meantime work is ongoing to agree the spectrum for 5G, with carrier frequencies such as 24, 28 and 38 GHz anticipated. At these frequencies, latencies will also be extremely low, less than 1m sec being targeted by the ITU-R specification, M.2083 [16], **(Figure 1).**

From the specification, it can be seen that 5G broadband connections are expected to offer downlink speeds of up to 20 Gbps and latencies as low as 1 ms. 5G will also enable a step-change increase in the amount of data transmitted over wireless systems due to the availability of more bandwidth at the higher frequencies earmarked for 5G.

REQUIREMENT		VALUE
Data rate	Peak	Downlink: 20Gb/s Uplink: 10Gb/s
	User experienced	Downlink: 100Mb/s Uplink: 50Mb/s
Spectral efficiency	Peak	Downlink: 30 bit/s/Hz Uplink: 15 bit/s/Hz
	5th percentile user	Downlink: 0.12 ~ 0.3 bit/s/Hz Uplink: 0.045 ~ 0.21 bit/s/Hz
	Average	Downlink: 3.3 ~ 9 bit/s/Hz Uplink: 1.6 ~ 6.75 bit/s/Hz
Area traffic capacity		10 Mbit/s/m^2
Latency	User plane	1ms ~ 4ms
	Control plane	20ms

REQUIREMENT	VALUE
Connection density	1,000,000 devices per km^2
Energy efficiency	Loaded: see average spectral efficiency No data: Sleep ratio[1]
Reliability	1-10^{-5} success probability of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1ms
Mobility	0km/hr ~ 500km/hr
Mobility interruption time	0ms
Bandwidth	**100MHz**

[1] The fraction of unoccupied time resources (for the network) or sleeping time (for the device) in a period of time corresponding to the cycle of the control signalling (for the network) or the cycle of discontinuous reception (for the device) when no user data transfer takes place.

Figure 1: 5G Technical Requirements (source GSMA)

Source: https://www.gsma.com/futurenetworks/wp-content/uploads/2018/04/Road-to-5G-Introduction-and-Migration_FINAL.pdf

THE NEED FOR HIGH FREQUENCY CONNECTORS IN 5G COMMUNICATIONS

The telecommunications industry has started to refer to this as the Massive Internet of Thing, or MIoT, while the ITU-R IMT-2020 (5G) includes three major use case classes: Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC) and Ultra-Reliable and Low Latency Communications (URLLC). Spectrum allocated to 5G networks will fall into 3 bands, aligning with the use case classes, as illustrated in **Figure 2.**

Applications within each use case class will have different requirements and the enhanced network management features of 5G, including network slicing, will enable operators to offer services tailored to the application. Self-driving cars, for example, will require extremely fast, low latency connections to support real-time navigation. On the other hand, many IoT sensors transmit data in periodic bursts and don't require high speeds, so a lower class of service would be suitable.

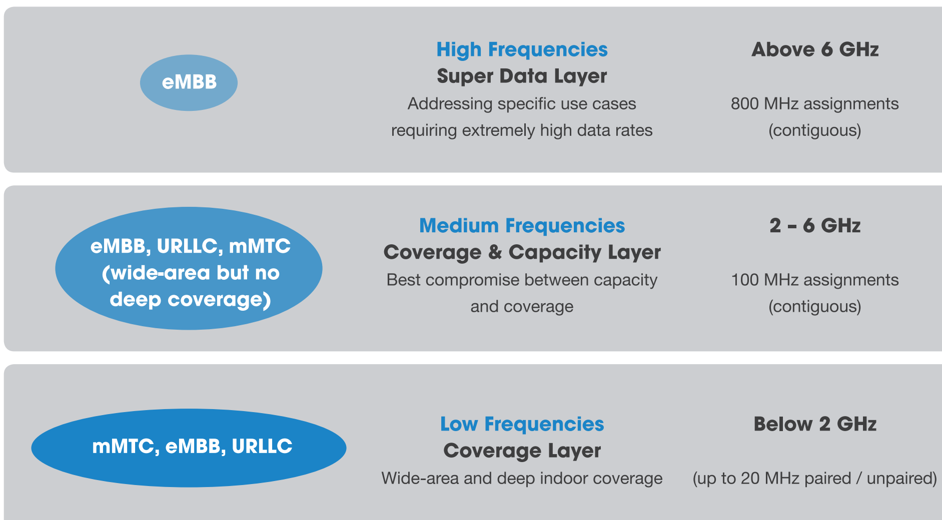

Figure 2: 5G Spectrum Bands allocated to 5G use cases (Source Huawei)
Source: http://www-file.huawei.com/-/media/CORPORATE/PDF/public-policy/public_policy_position_5g_spectrum.pdf?la=en

The higher frequencies allocated to 5G, with their correspondingly short wavelengths, will enable the use of smaller antenna, allowing massive MIMO techniques to be used to multiply the capacity of a wireless connection without requiring more spectrum. While this will mean more 5G base stations will be needed to provide the coverage expected, they will utilize multiple antennas within each base station, enabling 5G to support over 1,000 more devices per meter than 4G. Correspondingly, 5G networks will be able to beam ultra-fast data to a lot more users, with high precision and little latency – addressing the growing requirement for high-speed data, driven by emerging wireless applications such as the MIoT.

Designing RF devices for the mmWave region of the spectrum brings a number of opportunities and challenges. As discussed above, higher frequencies enable smaller antenna which enables more per base station. Technology developments such as nanometer CMOS is enabling drastic reductions in the size of many of the devices that will connect to 5G networks (for example, IoT sensors), as well as delivering increased antenna density. This is leading to a corresponding reduction in the size of base station components. These trends of higher speeds, increased bandwidth, greater density and smaller sizes create specific demands on connector technology which, at mmWave frequencies, becomes critical to any electronic device or system.

THE NEED FOR HIGH FREQUENCY CONNECTORS IN 5G COMMUNICATIONS

RF connectors must transfer electromagnetic energy from one transmission line to another while ensuring minimum losses and reflections, so the precision of their design is critical.

With the push towards higher frequencies, smaller footprints, unique interfaces and better performance, RF connector design must meet constraints based on geometry, size and transmission characteristics while ensuring that the connector impedance matches that of the rest of the transmission line. As the frequency increases, maintaining the impedance becomes more complex; the electrical, mechanical and environmental characteristics of RF connectors all have a vital role to play in ensuring their performance.

Key electrical characteristics include impedance (normally 50 ohms), VSWR, PIM, (Passive Intermodulation Distortion) and maximum frequency. VSWR is of particular importance, determining how much of an electro-magnetic wave will be reflected by the connector – leading to signal loss. VSWR will vary with frequency but may be kept to a flat line value over a given frequency range, e.g. 1.3:1 up to 40 GHz.

Mechanical characteristics such as engagement/disengagement force, coupling nut torque, contact captivation and durability, (number of mating cycles) are equally important in guaranteeing the stability of a connection. Unintended gaps in the connection due to misalignments can lead to drastic changes in the electrical characteristics of the connection **(Figure 3).**

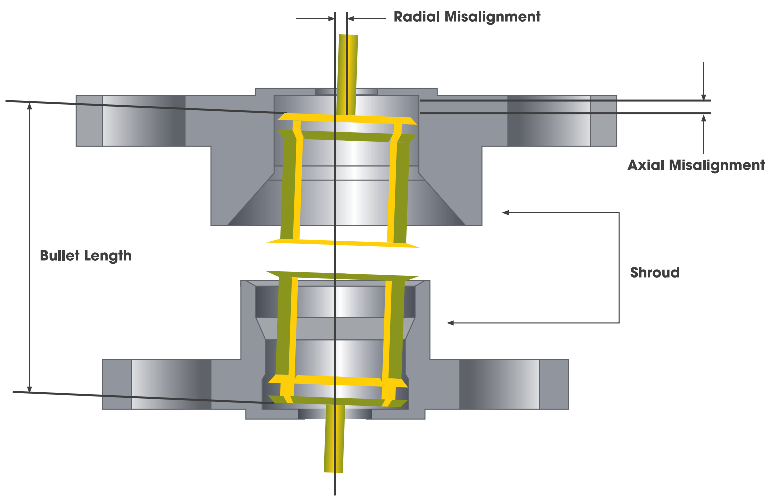

Figure 3: RF Connector alignment

Finally, environmental characteristics such as operating temperature range, moisture and corrosion resistance must match the condition within which the connectors will be deployed.

Connector size is an over-arching parameter given the trend towards density in 5G networks. The 4.2 mm SMA connector is well established in RF implementations, and now sub-miniature variants are becoming more common as frequencies increase and modules shrink in size. Table 1 shows some of the main connector types in current use. Designs for 5G applications will require a variety of high frequency connector and adaptor types, extending to adaptors, multi-port ganged solutions and cable assemblies.

THE NEED FOR HIGH FREQUENCY CONNECTORS IN 5G COMMUNICATIONS

With over 50 years' experience in the industry, Johnson offers one of the most comprehensive ranges of RF connectors on the global market and has been leveraging its experience and resources to develop and extend its product range to meet the evolving demands of the 5G market. Johnson's extensive range of 50-Ohm SMA connectors are rated up to 26.5 GHz and are available in brass or stainless steel, with support for a number of configurations including P.C. board mount (thru-hole and surface mount), End Launch, Bulkhead Flan ge Mount and Cable.

In response to the changing market needs, driven by the 5G roll-out, Johnson have been actively launching a number of new products to support higher frequencies and smaller sizes, including:

- 2.92mm family up to 40 GHz
- 2.4mm family up to 50 GHz
- 1.85mm family up to 67 GHz
- SMP family expansion up to 40 GHz
- SMPM family expansion up to 65 GHz
- Ganged SMP 4 Port up to 40 GHz

With sales, design and manufacturing centers in the United States and China, Johnson is ideally placed to support the requirements of the emerging 5G market and will continue to invest in their product portfolio to support the emerging needs of 5G networks.

TYPE	DESCRITION	SIZE	FREQUENCY	TIGHTENING METHOD
SMA	Semi-precision sub-miniature RF and microwave connector that extensively used for frequencies up to 18 GHz and sometimes more. Comes in a variety formats, male, female, straight, right-angled, bulkhead fitting to meet most requirements.	4.2mm	DC – 18 GHz (26.5 GHz)	Screw thread
2.92mm K type	Smaller-size Variant on SMA, operating up to a higher frequency	2.92mm	DC – 46 GHz	Screw thread
2.4mm	Smaller-size Variant on SMA, operating up to a higher frequency	2.4mm	DC – 50 GHz	Screw thread
1.85mm V type	Smaller-size Variant on SMA, operating up to a higher frequency	1.85mm	DC – 67 Ghz	Screw thread
SMP	Miniature push-on connectors, with inner female-to-female component, called a bullet, and two outer panel, circuit or cable-mounted receptacles called shrouds. Unlike threaded connectors, allows a small amount of radial misalignment during mating, Applications include antennas, broadband and Instrumentation	3.0mm	DC – 40 GHz	Push-on
SMPM	30% smaller than SMP, designed for very high frequency applications where space and package density are a necessity. Applications include Next generation phase arrays, high speed semiconductor test, customer specific development	2.4mm	DC – 65 GHz	Push-on and snap-on mating styles

Table 1: Sample of RF Connector Types and Characteristics

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