DVTEST

5G TECHNOLOGY PROPELS mmWAVE FREQUENCIES

DVTEST Portable RF Anechoic Test Enclosures DC-90 GHz

WHITE PAPER

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DVTEST Portable RF Anechoic Test Enclosures DC-90 GHz

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ABSTRACT

In order to meet the higher bandwidth requirements of 5G, the utilization of mmWave frequencies is deemed necessary. Bandwidth and data rates achievable using current technologies such as 4G LTE are not enough to satisfy a full 5G implementation. As a result, mmWave frequencies must be utilized in conjunction with LTE and all its variants to ensure seamless network operation and capacity expansion. This white paper identifies the test requirement complexities of 5G mmWave frequencies and the way a portable RF anechoic test enclosure from DC-90 GHz can provide an ideal test environment for OTA measurements.

INTRODUCTION

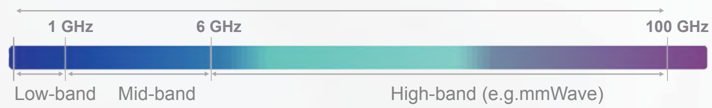
Fifth-generation wireless, or 5G, is the latest iteration of cellular technology engineered to bring extreme performance to wireless networks. With the increasing number of devices requiring high-speed connectivity, this network will need to support increased bandwidth and capacity while reducing the latency to as low as 1 ms. Currently, legacy networks operating below 6 GHz do not satisfy the demands of high gigabit data rates and network capacity, therefore the industry is investigating many options such as the application of higher frequency (up to 100 GHz, see Image 1) spectrum to satisfy these demands.

LTE-A and LTE-Advanced Pro (LTE-AP) networks provide up to 1 Gbps repeatable data rates which are insufficient for meeting all the 5G requirements. 5G developers plan to use lower frequencies below 6 GHz (5G-NR6) in parallel with higher frequency bands to improve network capacity and meet the mentioned higher data throughput expectations.

HetNet (Heterogeneous Networks) is one of the architectures proposed that will combine all LTE-A/LTE-AP, 5G-NR6 and 5G-mmWave technologies to provide an optimal user experience.

The 3rd Generation Partnership Project (3GPP™) recently released new standards that introduce 5G New Radio (5G-NR) as the air interface between mobile devices and base stations [1]. 5G-NR aims to effectively use low-, mid-, and high-frequency bands including shared, licensed, and unlicensed spectrum to achieve full 5G requirements.

Image 1 5G Spectrum



5G technology is expected to utilize mmWave spectrum to achieve wider bandwidths and higher data rates (nx10 Gbps).

DVTEST is a leader in portable RF anechoic test enclosures used by the industry to measure wireless devices. The dbSAFE mm (Image 2) introduced in this white paper provides a reliable and effective RF isolated test environment from DC-90 GHz for all 5G devices.

Image 2 DVTEST dbSAFE mm

CURRENT NETWORKS

LTE Advanced Pro Technology

LTE-AP technology incorporates advanced forms of LTE and LTE-A, implementing higher-order modulation and carrier aggregation for increasing bandwidth and reaching higher data rates.

With the release of LTE-U proposed by Qualcomm™ accessing the unlicensed 5 GHz frequency band and LAA (Licensed Assisted Access by 3GPP™ release 13[1], 14[2]) LTE-AP allows telecom providers to utilize carrier aggregation (via 32 carriers simultaneously with a carrier bandwidth of 20 MHz) and enhanced MIMO to reach data rates beyond 1 Gbps. MIMO technology in LTE-AP can incorporate more than 32 radiating elements to increase channel capacity and spectral efficiency.

Data rates achieved by LTE-AP alone will not be able to satisfy the full 5G requirement of +10 Gbps (20 Gbps in DL, 10 Gbps in UL as issued in 3GPP™ release 15 [1]). LTE-AP will be integrated into the network to work in parallel with 5G mmWave and 5G-NR technologies.

5G New Radio

While the initial aspects of 5G became available through a combination of LTE, LTE-A, and LTE-AP, significant infrastructure deployment is required to enable networks for 5G-NR. This technology is evolving to improve the performance, flexibility, scalability, and efficiency of current networks using licensed, shared, or unlicensed frequencies in the spectrum. 5G-NR utilizes several fundamental wireless technologies including: enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communication (URLLC), massive IoT, and massive Machine-Type Communication (mMTC).

eMBB provides data access across a wide coverage area in crowded locations, office areas, and high-speed public transport systems. Applications include multi-user interaction, augmented reality, and context recognition.

URLLC services require ultra-reliability, high availability, as well as latency sensitive services for applications such as factory automation, autonomous driving, and critical communications. These applications require sub-millisecond latency and error rates as low as 1 packet per million.

Massive IoT addresses the Low Power Wide Area (LPWA) need for low-cost devices, extended coverage, and long battery life.

Massive Machine-Type Communication (mMTC) covers narrow band internet access for sensing, metering, and monitoring devices.

5G-NR networks are classified as either Standalone (SA) or Non-Standalone (NSA) networks. NSA networks rely on a 4G core while SA networks are solely 5G. SA networks are more efficient and eliminate many of the challenges caused by dual 4G/5G connectivity. The bandwidth and data rates achievable by using sub-6 GHz 5G-NR are insufficient to satisfy the full 5G requirement. As a result, 5G mmWave frequencies must be utilized.

5G - mmWave

As 5G expands from sub-6 GHz frequencies to mmWave, the resulting network densification and massive MIMO will create ultra-high-speed access. Although mmWave technologies achieve higher bandwidth and data rates, one of the consequences is poor propagation resulting in lower coverage. Handheld devices such as next generation smartphones will require substantial antenna beamforming gain in order to mitigate this. On the other hand, antenna arrays, transceivers, filters, and similar devices, become so small that the entire circuit will be integrated into a very compact package. As an example, these front-end antenna arrays will have no RF measurement access, limiting the ability to characterize these devices. This constraint introduces Over-the-Air (OTA) radiated testing methodologies which measure antenna parameters without physical cable connections.

mmWave frequencies are ideal in short-range applications and densely populated areas that need high capacity. Global Mobile Suppliers Association (GMSA) lists new 5G-NR bands defined by 3GPP™ in Release 15[1] as shown in Table 1.

Frequency range designation by 3GPP™ [1] Table 1

Frequency Range Designation	Corresponding Frequency Range
FR1	450 MHz - 6000 MHz
FR2	24250 - 52600 MHz

The FR2 bands for 5G-NR mmWave are categorized in Table 2:

FR2 bands in mmWave frequency range Table 2

NR Operating Bands	Frequency Range
n257	26500 - 29500 MHz
n258	24250 - 27500 MHz
n260	37000 - 40000 MHz
n261	27500 - 28350 MHz

The most popular mmWave frequency ranges are bands 47.2 - 50 GHz, 50.4 - 52.6 GHz, and 59.3 - 72 GHz, the usage of which is specific to the region and country where the technology is deployed.

The characteristics of different frequency bands within this wide spectrum will be used to define their suitability for various applications such as high definition video, e-health, vehicle-to-vehicle (V2V) communication, augmented reality, and tactile internet.

Among 5G technologies that use mmWave, the WiGig IEEE 802.11ad standard aims to provide up to 7 Gbps data rates using the ISM band at 60 GHz. This technology and frequency reduce interference while providing high speed data. Microwave WiFi technology will be used in short-range, high volume data transfers such as HD video. Qualcomm's™ recent release of 5G WiFi chipsets operating in the 60 GHz band achieves more than 10 Gbps network speed with enhanced battery life as an industry low-power benchmark. Additionally, Qualcomm™ has also released a front-end mmWave antenna module that contains the 5G-NR transceiver and phased array antennas operating in 26.5-29.5 GHz, 27.5-28.35 GHz, and 37-40 GHz mmWave bands with 800 MHz of bandwidth. WLAN technology also uses frequencies in the 60 GHz unlicensed spectrum, depending on the country of operation, for example, in the US and Canada 57.05-64 GHz is used.

TEST REQUIREMENTS & CHALLENGES

5G mmWave devices need to be tested in an OTA environment because cost-effective deployment of Massive MIMO devices and base stations will not have accessible antenna ports. OTA testing for wireless devices is done in conventional large anechoic chambers providing suitable isolation from other devices and unwanted external signals. For OTA testing of 5G devices, a compact, low cost, and repeatable test method is necessary.

The Signal-to-Noise Ratio (SNR) value for cells defines maximum cell radius and coverage for each cell. In a HetNet architecture, the interference of adjacent cells and interference in the cell will determine the coverage. As the HetNets become more complex, the possibility to isolate and test the Remote Radio Heads (RRH) in an OTA environment will be a critical requirement.

Device manufacturers are mandated by standards to test their devices against multiple criteria in various test case scenarios before releasing their devices to the market. To achieve repeatable results, the test environment needs to be controllable and immune from any type of interference and noise. Therefore, device testing for 5G needs to be done within a shielded environment. Anechoic test enclosures suitable for mmWave frequencies have metallic walls covered with microwave absorbers (Image 3), to create a reflection-free environment. The impedance on the absorber surface is equal to the free space impedance of 377Ω, this impedance causes maximum absorption of electromagnetic waves and minimizes back reflections.

Conventional walk-in chambers used in OTA measurements eliminate unwanted RF signals from entering the test area. However, test time and the cost of walk-in chambers can be limiting factors as well as the phase shift and mismatching caused by large distances.

The three regions in front of a radiating antenna are Far Field (FF), Near Field (NF) including Radiating NF and Reactive NF. The FF zone is where the relative angular field distribution is independent of the distance from the antenna. The Radiating NF is a region between FF and Reactive NF; the shape of radiation pattern may vary with distance in this region. Reactive NF is in the immediate vicinity of a radiating antenna, and unlike the other two regions, the E and H radiating fields are 90° out of phase.

Image 3 DVTEST dbSAFE mmWAVE microwave absorbers

Conventionally, antenna measurements are performed in the FF as parameters are more predictable in this region. When walk-in anechoic chambers are used for lower frequency testing, for example below 1 GHz, the DUT can be placed within the FF region of the test antenna. These chambers provide a larger area where electromagnetic waves reflected from the walls are below a calculated level. This is defined as the Quiet Zone.

As the frequency of interest increases, the FF distance increases respectively. This results in the need for larger measurement facilities, requiring more complicated mechanical systems contributing to measurement complexity.

For example, a radiating device approximately the size of a mobile phone, has a FF distance of more than 6 m when operating at 60 GHz. A walk-in chamber suitable for this measurement is a significant investment in both cost and floor space. 5G engineers can test the same device in the NF region using a portable anechoic test enclosure.

In certain 5G applications, multiple scanning antennas are required to measure the DUT. Phase shifts, mismatch errors as well as losses due to physical cable length create real challenges for test engineers at mmWave frequencies. New 5G mmWave devices, with improved sensitivity, require accurate and repeatable measurements. Testing in compact, portable anechoic test enclosures guarantees repeatable results with less complexity and cost when compared to similar testing performed in walk-in chambers.

According to 3GPP™ Release 15[1], antennas can be measured in both the FF and NF regions. NF measurement results are transformed into extrapolated FF results using various mathematical methods. As 5G frequencies increase to higher bands, the FF space becomes too large to make these measurements feasible and the industry is trending toward small, portable anechoic test enclosures to reduce measurement cost, time, and space. As 5G testing in mmWave and sub 6 GHz bands expand, OTA testing of 5G devices in the NF becomes more prevalent.

mmWAVE DEVICE TESTING

Testing highly sensitive devices for parameters such as Effective Isotropic Radiated Power (EIRP) requires a high level of isolation. DVTEST offers portable mmWave anechoic test enclosures as an alternative to large walk-in chambers when measuring 5G antennas in a reflection-free environment. The walls of the test enclosure are lined with pyramidal absorbers to create impedance of free space against incident electromagnetic waves. The dbSAFEmm provides a test environment for OTA measurements with a frequency range of DC-90 GHz. These test enclosures, constructed from lightweight aluminum, have multiple attachment points for antenna measurement equipment. In 5G-NR and mmWave applications, antennas can be measured using planar, cylindrical, and spherical methods.

The dbSAFEmm test enclosures are designed to house multiple IO panels to accommodate data, RF, and power. requirements. Panels designated for RF connectivity typically utilize waveguide channels such as WR-12, 15, 19. Separate panels are dedicated for data bus and power filtering. Ventilation is achieved using DVTEST's proprietary Waveguide Technology.

ISOLATION TESTING

The isolation of the dbSAFEmm test enclosure was measured using two 50 – 75 GHz WR15 high gain horn antennas[4]. First, a reference point was established with the radiating boresight of each antenna. This reference point is denoted by "d".

Second, the isolation was measured from within the test enclosure. The goal of this test was to measure the isolation of the test enclosure once mmWave vent modules and sample I/O panels were mounted.

The VNA was first calibrated for 50-75 GHz with frequency extenders connected at ports 1 and 2 using 12"/6" transitions. This calibration is recommended since each waveguide transition or bend can introduce insertion loss to the RF path.

A full 2 port calibration was performed to the head of WR-15 flange and then the calibration was evaluated by connecting a 50Ω broadband load. After this step, both antennas were mounted and spaced 2" of each other. The S21 (dB) value was recorded.

Equipment Used in Isolation Measurement

Enclosure: mmWave portable enclosure PN:301001

VNA: Copper Mountain COBALTFx with frequency extender FEV-15

Waveguide ports: 50Ω WR-15

Antenna Tx: WR-15 Horn Antenna, 24 dBi Gain (Directive)

Antenna Rx: WR-15 Horn Antenna, 24 dBi Gain (Directive)

RF cables: VNA test cables (phase stable)

Waveguides: WR-15 panel mount, WR-15 transitions

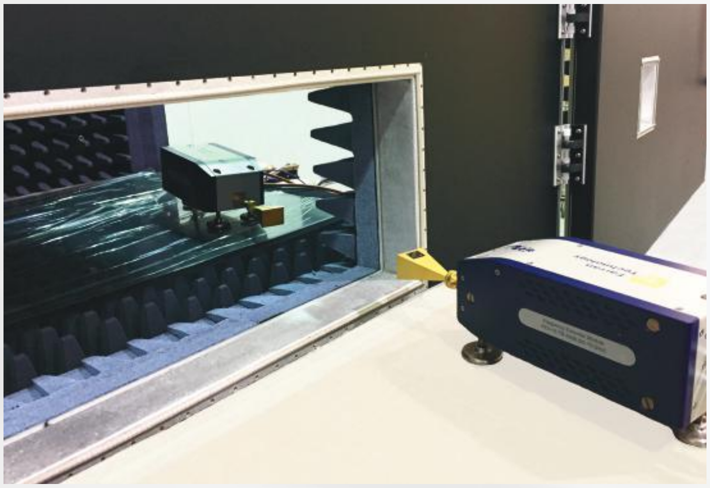


Image 4 Reference point measurement: Opening of the I/O panel on the test enclosure

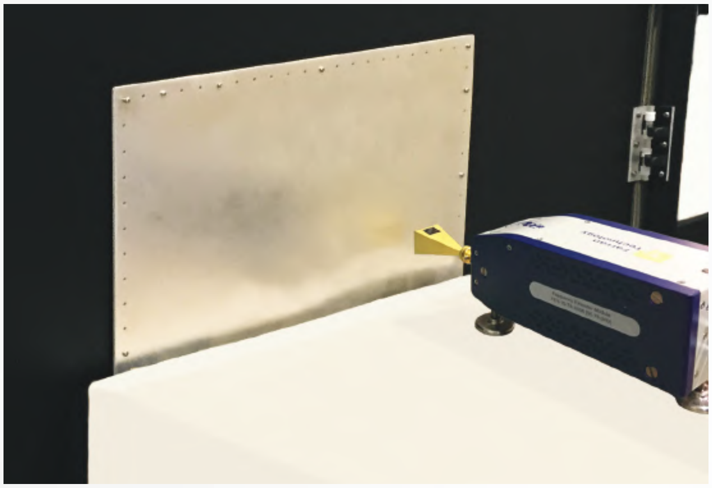


Image 5 Isolation measurement: Blank I/O panel installed

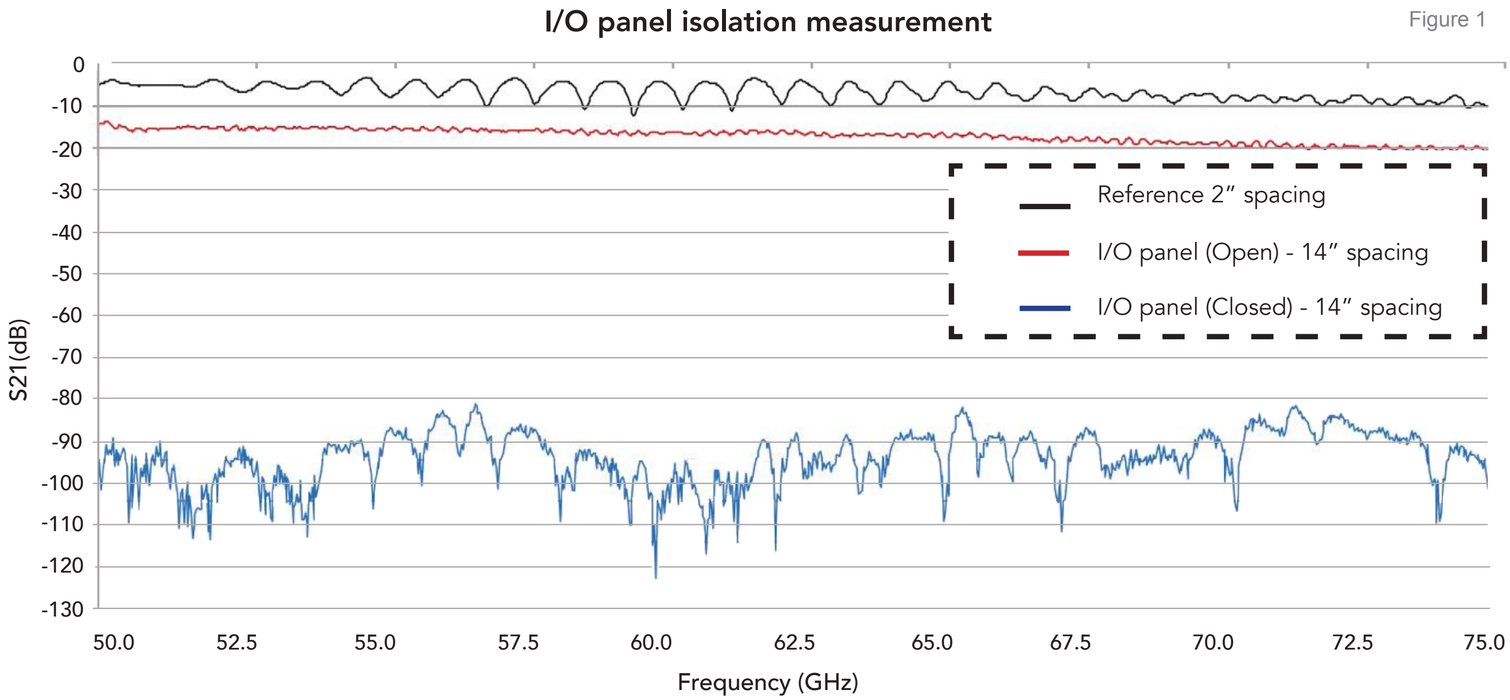


Figure 1

In Figure 1, the reference level when both antennas are located at (d=2”) is measured and shown in blue. This measurement excludes the test enclosure and only shows signal path when both antennas are directed at each other.

The same measurement was performed on the test enclosure; however, the limit created by test cable length and size of the enclosure forced the measurement to be taken in 14” spacing (spacing between transmit TX and receive antennas RX). Firstly, the I/O panel on the test enclosure was opened and the reference value was measured – data in blue shows average 14 dB signal amplitude. Then, the TX antenna was placed inside the enclosure and the RX antenna outside (see Image 5). The isolation was measured and it is shown in Figure 1. The blue data shows that the mmWave enclosure provides a minimum of 80 dB of isolation, with the majority of the spectrum falling below -90 dB.

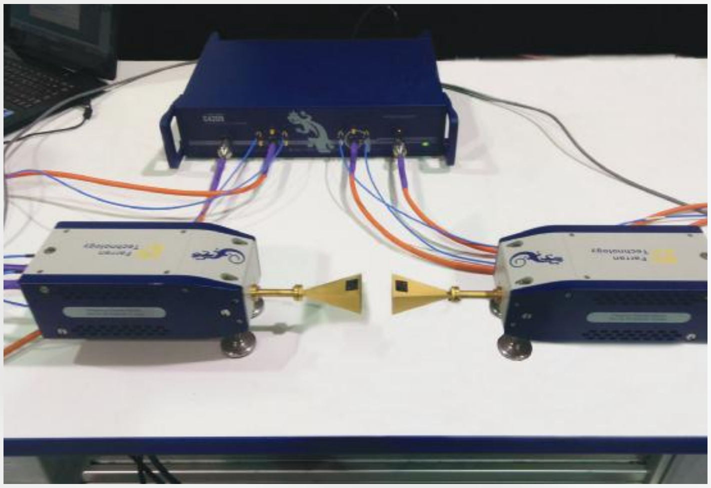


Image 6 Measurements being taken at 2” spacing

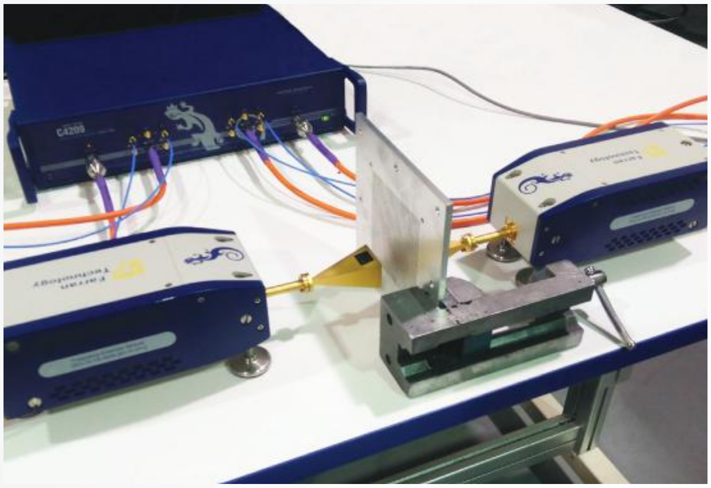
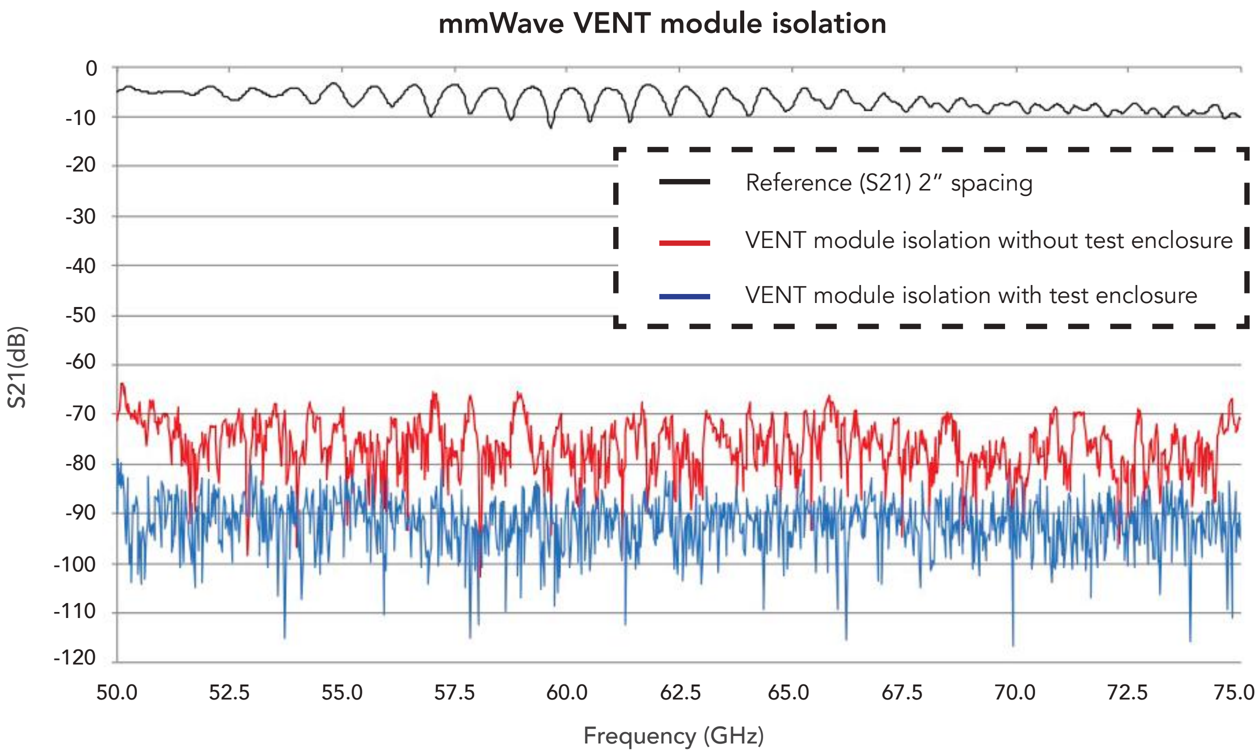


Image 7 Measurement of the isolation level of the mmWave VENT module placed between the antennas

Figure 2



- The vent module (mmWave VENT) is also tested for isolation mmWave test enclosure is equipped with vent modules on the test enclosure door and its back wall. In this report, the isolation was measured for the vent module on the test enclosure door only.

- In Figure 2, the reference measurement is taken at 2” spacing. The isolation level of the vent module is measured by placing it between both antennas when both antennas directed towards each other, see Image 7. The data points in red showed an average 75 dB isolation for the vent module itself. Then the vent module was mounted on the door of the enclosure and the measurement was repeated. The data points in blue indicated that the vent module installed on the enclosure provides a minimum 80 dB of isolation with the majority of the spectrum falling below -90 dB.

CONCLUSION

5G research and development is ever expanding within the telecom industry and 5G devices are expected to take over the market in the next 5 years. In the short term, this new technology will not replace existing networks, but enhance them with the addition of 5G and upgraded LTE infrastructure. Using technologies such as carrier aggregation and MIMO, the expectation is that they will eventually combine into one single 5G network.

The test procedure and standards for 5G devices are still under investigation by the governing bodies and consortia. Based on the published 3GPP article release 15, FR1 bands are below 6 GHz and FR2 bands cover frequencies from 24 - 52 GHz. Sub-6 GHz is the primary technology behind 5G-NR and it will merge with new technologies operating at mmWave bands to cover full 5G requirements.

The product/network development requires 5G devices to be tested in a controlled, noise-free environment to achieve reproducible data. The telecomm industry trend for testing is to minimize mechanical and measurement complexity due to large chambers and utilize portable anechoic test enclosures to measure DUT in NF.

The dbSAFEmm RF Portable Anechoic Test Enclosure is designed to meet the high demands of testing this next generation of technology, providing 90 dB of isolation over DC - 90 GHz. This wide frequency coverage and high isolation level enables testing of various 5G applications such as low frequency devices (below 1 GHz), LTE-AP, 5G-NR, and mmWave.

These test enclosures allow waveguide connections through I/O connectivity panels and provide high data rate signal filters (Ethernet, USB) to eliminate radiated or conducted noise from the measurement environment.

Device testing requiring antenna characterization using spherical, cylindrical, or planar measurement platforms can be integrated into the above mentioned test enclosures. The positioning mechanism can be manual or fully automated with a user-friendly interface. The antenna measurement software measures the DUT in NF or FF regions and it constructs the antenna patterns. dbSAFE test enclosures are compatible with all test instrumentation available on the market.

REFERENCES

[1] Flynn, K. (2018). Release 15. Retrieved from http://www.3gpp.org/release-15

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[3] Flynn, K. (2018). Release 14. Retrieved from http://www.3gpp.org/release-14

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