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High-performance Millimeter Wave Vector Network Analysis You Can Afford

Solution addresses the need for high-performance, affordable VNAs and creates new growth opportunities for high-frequency test equipment

A Frost & Sullivan White Paper

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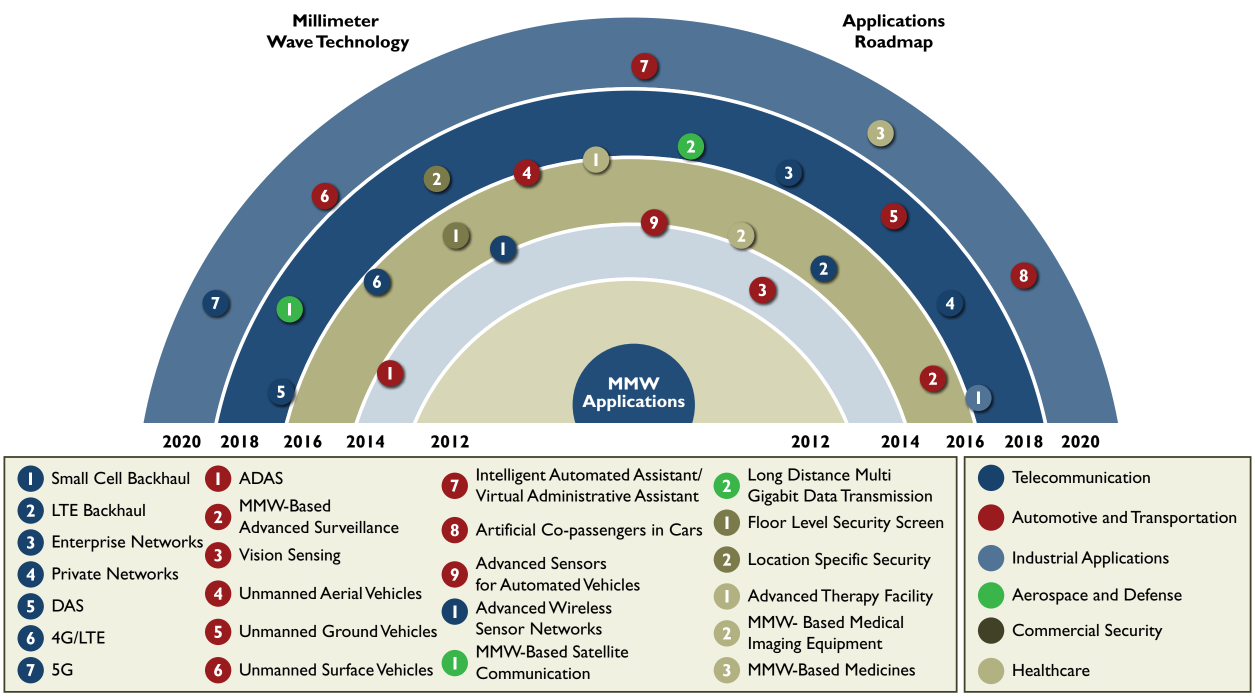
INTRODUCTION

Over time, there has been continued evolution of technologies toward higher frequencies across industries due to an increasing number of users at low frequencies in communications networks and the need for heightened security. While this trend is not new, the frequencies being considered today are significantly higher than in the past creating a need for new testing technologies that ensure precision in a variety of production settings.

Until recently, millimeter wave (mm-wave) frequencies, which commonly refer to the 30 to 300 GHz range, remained in limited use. However, the situation has changed in the past two years with the emergence of technologies with much higher frequencies. Requiring more capacity and bandwidth, original equipment manufacturers (OEM) across industries, including aerospace and defense, automotive, and wireless communications, have demonstrated an increasing interest in very high frequencies, driving the need for high-performance test and measurement (T&M) equipment.

Figure 1: Future Prospects- Application Roadmap

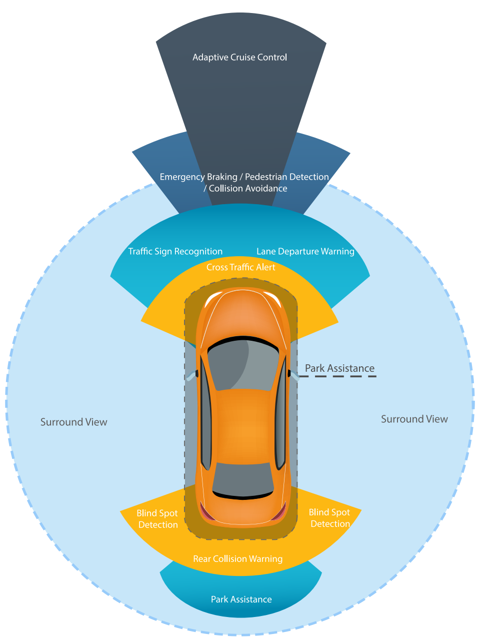


Source: Frost & Sullivan

HIGH FREQUENCIES APPLICATION TRENDS

Over the past few years, aerospace and defense markets, including homeland security, radar and imaging, have moved to mm-wave frequencies. For instance, more sophisticated imaging systems have been installed at airports to improve human traffic flow. In radar applications, the growing need to detect small targets has called for higher resolution, driving the need for wider bandwidth and triggering the move to higher frequencies. Similarly, in imaging applications, the need for higher-resolution images has led to the use of higher frequencies.

However, mm-wave frequencies have expanded beyond advanced applications in the space and military industries, and spread to others such as automotive, communications, and medical imaging. A key growth area in automotive for high frequencies has been radars for collision avoidance, driven by the automotive industry's transition to autonomous driving. Participants across the automotive supply chain are working to increase the range, resolution, and velocity of automotive radars. 2016 is expected to be a breakthrough year for autonomous driving, enabling technology and mm-wave frequencies to play a key role in the advent of 5G in cars. There has been increasing adoption of advanced sensor technologies to assist drivers and keep passengers informed, safer as well as more entertained and productive.



In communications, new technologies including Wi-Fi standard 802.11ad (WiGig) and 5G (the next generation of cellular technology) are expected to drive a significant shift in frequencies for antennas and communications systems, from less than 6 GHz to over 26.5 GHz. With the chipsets available, 802.11ad is now in the development phase and 5G will reach this milestone soon. With several service providers targeting 2020 for the first network deployments, there is significant research activity taking place at the moment with development activity expected to take off in the next few years. Today, almost all of cellular communication is constrained to a narrow spectrum below 3 GHz. The spectrum below 3 GHz is all allocated, and the spectrum below 6 GHz is becoming a scarce resource. The need for greater spectrum availability is a significant factor driving the industry to move cellular technology to higher frequency bands with interest in frequencies from 10 GHz to 80 GHz and particularly 15, 24, 28, 38, 60, and 71-76 GHz.

5G also represents a step up in complexity compared to previous generations of cellular standards. With 5G targets encompassing disparate requirements, the network will need to be highly flexible. Multiple radio access technologies (RAT) will be used and co-exist in the 5G network to accommodate various use cases. Candidate waveforms being investigated include Generalized Frequency Division Multiplex (GFDM), Filter Bank Multicarrier (FBMC), Universal Filtered Multicarrier (UFMC), Filtered OFDM (f-OFDM). With 5G, the industry will also transition from Multiple Input Multiple Output (MIMO) to Massive MIMO to enhance reliability and throughput. Massive MIMO achieves this objective by dramatically increasing the number of antennas in elements and spatial streams in a base transceiver station (BTS) compared to the configurations used in BTSs today. At millimeter-wave frequency bands, Massive MIMO allows for a significantly higher number of antennas to be fit in an antenna array as antenna size is inversely proportional to the frequency band. Thus, the size of an array featuring 64 antennas is 1176 cm^2 at 3.5 GHz but only 2.7 cm^2 at 73 GHz. Using controllable antennas, Massive MIMO enables communication with different users simultaneously. The narrow beams help direct the wireless energy to users efficiently but require beamforming to transmit the signal in the intended direction. Also called 3D MIMO, Massive MIMO allows base stations to beamform signals to vertically and horizontally.

While the technologies used in 5G are not all new, some are very new and disruptive especially to the commercial world that has not dealt with high frequencies yet. The multiple radio technologies, devices and materials that will be used in 5G call for individual as well as in-system characterization. Testing MIMO and over the air (OTA) are top challenges lying ahead especially as the technology progresses down the lifecycle to production.

In medical imaging, the use of mm-wave technology has expanded to enable medical personnel to look at the human body's response to millimeter waves for diagnostic and treatment purposes. The capability of mm-wave frequencies to capture the image of the whole human body is used in various imaging and scanning equipment. They also find application in therapy and other healthcare facilities.

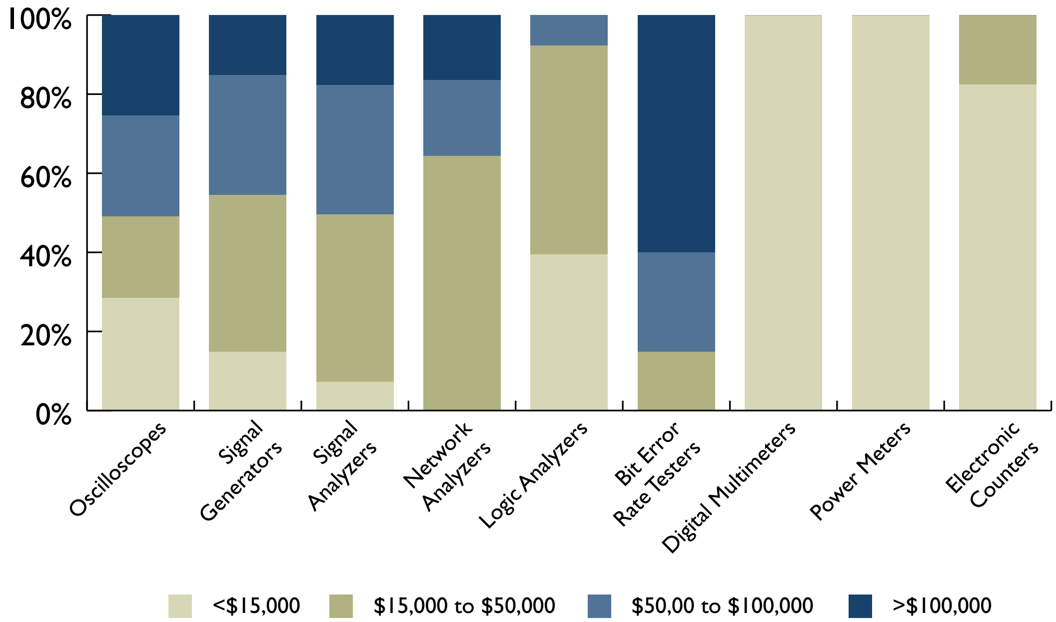
Overall, numerous systems now operate in the 80-90 GHz range, and along these systems there is mass development and production of related components. This is only expected to grow further with the deployment of 5G and the Internet of Things (IoT). Wider spectrum is needed to achieve faster data rates, and 5G is expecting to be 100 times faster than 4G. 5G also has to provide a backdrop for the billions of devices expected to be connected to the Internet in the future with the advent of IoT. **However, technical implications aside, the market's evolution to high frequencies poses a significant challenge to manufacturers due to cost pressure.**

CUSTOMER CHALLENGES

The mm-wave frequencies provide significant technical challenges to design and test engineers. At these frequencies, the device and circuit parasitics are far more difficult to measure and model when compared to lower frequencies. The test setup is a burden to the engineers who can also struggle with interconnecting devices and viable measurement techniques. Path loss and attenuation are also more significant at high frequencies making accuracy and reliability of measurement more difficult to achieve. With all these issues in mind, engineers have to be able to perform accurate measurements and characterization of devices. Proper, precise measurements are more critical than ever.

Vector network analysis has been the method for thorough device characterization for decades. For this type of measurement, customers mainly have two options at their disposal to address mm-wave frequencies – broadband VNAs and combinations of VNAs with frequency extenders. With a frequency range starting from kHz to tens of GHz, broadband VNAs are very complex instruments as they need to measure a broad range of frequencies accurately. Hence, these instruments are scarce and extremely expensive. Moreover, most customers working in the mm-wave space do not actually need the lower frequency capabilities of these instruments as they typically focus on specific bandwidths of interest. Hence, the acquisition price of a broadband VNA is prohibitive to many customers, especially since only a few organizations use the equipment to their full extent.

Figure 2: Electronic Test and Measurement Equipment in Research and Development Applications



Source: Frost & Sullivan

Alternatively, customers can use a lower frequency VNA, typically a 20 GHz model, and extend its frequency by using frequency extension modules. The VNA is connected to frequency multipliers and up and down converters. This enables customers to measure at higher frequencies without having to invest in a broadband VNA. While more affordable, this solution poses a major challenge to customers due to the frequency conversion process, which contributes noise. Customers are also extremely concerned about the ability of the frequency extenders to preserve the dynamic range from the VNA over temperature and time for measurement accuracy. Here again, due to the level of difficulty of this challenge, only a handful of companies provide these solutions. While less expensive than broadband VNAs, these solutions remain relatively expensive as a special version of the VNA is required for proper frequency up and down conversion and access to the VNA's IF and local oscillator. Such VNAs range in price between $80,000 and $150,000, which results in a total price ranging between $150,000 and $200,000 for the full mm-wave VNA solution when combined with the frequency extenders.

While a number of solutions for vector network analysis are available in the market to address mm-wave frequencies, these solutions remain expensive. Such prices are prohibitive to many customers, especially new, emerging companies and those that need multiple systems. **Test has become a bottleneck for innovation and business growth.**

Another key challenge faced by design and test engineers with existing mm-wave VNA solutions is their size and portability. Space continues to be an issue especially in manufacturing environments. Striving to boost their throughput, customers are trying to fit more equipment on the production floor. They are also striving to reduce equipment footprint to reduce costs. This is a significant challenge for the customers who require multiple such systems for their production and quality control (QC) departments. The current size of available mm-wave VNA systems is also not conducive to high portability, preventing customers from taking the solutions in certain places while the need to perform testing at the test point is increasing.

The evolution of computer technology poses yet another significant challenge to customers of leading VNAs as the computers inside these instruments become outdated quickly due to their long development cycles –typically 2 years. Processor, display and other PC technologies evolve at a much faster pace. Users also face issues with the hard drive, display and memory. The hard drive may die, the display might be too small and fall apart over time, and there may not be enough memory for the customer's application. Furthermore, customers often have to transfer data from the built-in computer to another computer and overcome challenges associated with this process. The inclusion of computers in VNAs also generates other challenges from a maintenance perspective. Customer operations may be disrupted as the replacement of the computers is only performed by the OEM or an authorized partner. This is a significant challenge as the built-computer is one of the components of a VNA that fail the most besides displays and knobs and buttons.

SOLUTION SPOTLIGHT: CobaltFx

CobaltFx is a high-performance, affordable and intuitive solution for millimeter wave vector network measurements that addresses the market need for cost-effective solutions. Combining Copper Mountain Technologies (CMT)' VNA and high-frequency extensions from Farran Technology (FTL), CobaltFx help customers reach high frequencies at a fraction of the price of available solutions in the market. The solution is as precise as traditional lab-grade equipment, yet much more practical and cost-efficient.

One of the key reasons for the lower cost of the solution is the use of CMT's VNA. While high-performance, CMT VNAs are much less expensive than others of similar performance available in the market. This has been achieved by removing the on-board computer that is inside traditional VNAs combined with the smaller size of the units. CMT's Cobalt line of VNAs includes two models, the C1209 and the C1220. With a frequency range of up to 9 or 20 GHz depending on the model, a dynamic range of 145 dB typical, and measurement speed of 15 or 10 μs, these models are an innovative combination of fast measurement time, wide dynamic range, and small size yet are priced at $20,995 and $39,995 (US price), respectively.

The CobaltFx system uses the CMT's C4209 model, which is based on C1209. C4209 is 9 GHz VNA with a dynamic range of 162 dB and sweep speed down to 10 μs and has all of the functionality needed for use with frequency extensions. CobaltFx works seamlessly and exclusively with frequency extensions developed by FTL – FEV series. FTL's extenders offer high dynamic range, output power and excellent directivity ensuring accurate and repeatable mm-wave measurements. The modules are enclosed in compact and versatile enclosures that allow for various bench-top configurations as well as custom mounting at antenna ranges. Due to the level of technical expertise required to develop high-performance mm-wave frequency extenders, FTL is one of only a handful of companies in the world specialized in this domain. The company has a long history of providing high-frequency products spanning over 3 decades for the test and measurement and imaging industries among others. For CobaltFx, FTL engineers went out of their way to innovate their technology and develop frequency extension modules that could operate from 9 GHz while maintaining the level of performance required for the customer. The use of a 9 GHz VNA instead of the typical 20 GHz model helped further reduce the price of the CobaltFx system.

Aiming to make high precision test equipment more widely available and accessible to customers than it has traditionally been, CMT and FTL have succeeded with CobaltFx, which sells for approximately $75,000, saving customers about $100,000 compared to existing solutions. Solutions are currently available for 3 bands - 50 to 75 GHz (CobaltFx 15), 60 to 90 GHz (CobaltFx 12), and 75 to 110 GHz (CobaltFx 10). Pricing for the CobaltFx 15 system is $74,825, $75,575 for CobaltFx 12 and $76,325 for CobaltFx 10. The system includes the C4209 VNA, a pair of frequency extenders, all the necessary cables and a precision waveguide calibration kit containing flush short, offset piece and broadband load and allows for full 12-term port calibration. As a whole, the systems are capable of 110 or 120 dB dynamic range.

The companies also kept practicality and cost of ownership as top considerations while developing CobaltFx. CMT's VNAs are PC-driven USB-based instruments smaller than available solutions in the market making them highly portable. While most frequency extenders are bulky, FTL's FEV extension modules adopt a sleek design. Encompassing the VNA, frequency extenders and all of the cables necessary to run the system, CobaltFx is a full solution that is easy to setup as it only requires the connection of a few radio frequency (RF) cables, alleviating the burden of the test setup on customers.

CONCLUSION

Once thought exotic or impractical for many applications, mm-wave frequencies are becoming the norm. Their use has expanded significantly over the past few years and now spans A&D, automotive, communications, medical imaging and others. New technologies on the horizon are expected to continue to drive manufacturers to higher and higher frequencies in the future. While this drives the need for higher-performance test equipment, the heavier dependence on consumer-related applications make current prices for such equipment unsustainable. CMT and Farran Technology have understood the impasse customers are at and addressed it through CobaltFx. CobaltFx is an exciting product for customers who need a more affordable, high-performance VNA solution.

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SILICON VALLEY
331 E. Evelyn Ave., Suite 100
Mountain View, CA 94041
Tel 650.475.4500
Fax 650.475.1570

SAN ANTONIO
7550 West Interstate 10,
Suite 400
San Antonio, TX 78229
Tel 210.348.1000
Fax 210.348.1003

LONDON
4 Grosvenor Gardens
London SWIW 0DH
Tel +44 (0)20 7343 8383
Fax +44 (0)20 7730 3343

877.GoFrost
myfrost@frost.com
www.frost.com