WHITEPAPER

How to accelerate the mmWave market

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Introduction

Ever since the inception of 5G, millimetre-wave (mmWave) spectrum has always been integral to the overarching vision of next-generation cellular communications. It was well understood that 5G would need more spectrum to live up to its three-point promise of ultrafast broadband speeds, ultra-reliable low latencies and massive machine-to-machine communications. And mmWave spectrum was identified early on as a key and mostly available resource to enable it, particularly the 24.25-29.5 GHz band.

However, five years after the first commercial 5G services were launched, mmWave 5G has been the exception to the rule. Most 5G deployments have concentrated on using sub-6 GHz spectrum, largely for practical reasons. To be clear, mmWave remains an essential element to fulfilling 5G's true potential in the longer term. But for now, most operators have put it on the back burner.

That said, some operators have moved forward with mmWave 5G deployments to some degree or other. Meanwhile, there are still viable use cases to be found outside of the classic cellular model of consumer mobility, particularly private 5G and fixed wireless access (FWA).

There is growing demand for mmWave solutions for both use cases. The primary challenge is that developing mmWave solutions is an expensive undertaking due to the expensive cost of key components like chipsets and beamforming antenna modules. There are relatively few manufacturers pursuing mmWave because cost is a key barrier to entry for new players, especially for a technology that has yet to really take off at scale.

A key solution to this dilemma lies in making mmWave beamforming antenna components easier and more cost-effective to integrate.

By streamlining the process for integration and testing of beamforming antenna modules, OEMs can experiment with mmWave and develop solutions more quickly at lower cost. This in turn presents an opportunity to accelerate the mmWave market by targeting those early market opportunities in private 5G, FWA and mmWave DAS ahead of the larger-scale adoption of mmWave by mobile operators that will come further down the road.

mmWave market status

5G deployments have been progressing steadily across the globe since the first commercial networks were launched in South Korea in April 2019. According to GSMA Intelligence, as of January 2024, 261 operators in 101 markets have launched commercial 5G services, while another 90 operators have committed to launching 5G in the coming years. The Global mobile Suppliers Association (GSA) puts that figure at 299 operators in 117 markets as of May 2024, including soft launches.

However, most of these deployments have focused on sub-6 GHz bands, particularly 3.5 GHz, 3.7 GHz and 2.5 GHz, as well as refarming of 3G spectrum in the 2.1 GHz band. This is partly because some regulators where 5G has been launched have not yet licenced mmWave spectrum. GSA figures from 2022 indicate that just 24 countries had issued mmWave licences to 140 mobile operators – but only 28 of those operators in 16 countries had deployed 5G using those bands.

There are several practical reasons for this, starting with simple economics. Millimetre-wave radio signals don't propagate very far – around a few hundred metres. This means operators have to deploy a lot of mmWave cell sites to get the same coverage as one site using mid-range bands like 3.5 GHz, which naturally means higher upfront capex investments.

The cost issue also extends to devices. According to a recent report from Ookla, devices that support mmWave connectivity typically cost more. For example, the mmWave version of the Google Pixel 6 in the US cost US$599 in 2023, versus US$599 without it. The gap is narrowing, according to a 2023 report from Counterpoint Research, which said that the price delta between sub-6 GHz and mmWave smartphones was narrowing down to US$10-20. Even so, the fact remains that OEMs have little incentive to produce mmWave compatible devices when only a relative handful of networks currently offer mmWave connectivity. Little wonder the GSA estimates that less than 10% of announced 5G devices support mmWave.

Millimetre-wave also comes with the limitation of poor indoor coverage. Technologies like massive MIMO and beamforming can help mmWave 5G get around the requirement for strict line-of-sight, but sub 6 GHz 5G and LTE signals are much easier and cost-effective solutions to this problem.

mmWave market opportunities

While the operator community has put mmWave on the back burner in terms of their immediate and near-term 5G plans, that doesn't mean there are no meaningful commercial use cases for mmWave technology.

One key use case is private 5G for enterprises. The telecoms sector has long touted the possibilities of using 5G as a wireless alternative or complement to Wi-Fi in Industry 4.0 scenarios. For example, 5G can be used to connect robotics, cameras and other machines on a factory assembly line. In such scenarios, mmWave's limited range is not an issue, not least because Wi-Fi access points in similar scenarios require similar density to achieve sufficient coverage.

Another use case for mmWave is fixed wireless access (FWA). Quite a few operators initially saw FWA as a major revenue opportunity for 5G outside of the obvious mobile broadband applications. The GSA says that 153 operators in 71 countries and territories have launched or soft-launched 5G FWA services as of May 2024. Not all of them use mmWave bands, but that's changing, as operators find that mmWave 5G is far better than sub-6 GHz 5G at delivering connectivity speeds comparable with fibre connectivity.

A related development for FWA involves integrating Wi-Fi 7, which converts Wi-Fi 7 to mmWave frequencies. Recently, several OEMs have announced FWA CPEs that combine Wi-Fi 7 and mmWave technology, enabling ultrafast broadband signals to be distributed more evenly indoors and outdoors. Consequently, both 5G and Wi-Fi 7 can leverage mmWave for certain FWA applications.

Challenges of developing mmWave solutions

However, while market opportunities exist for mmWave beyond mobile 5G connectivity for consumers, solution vendors aren't rushing to capitalize on them.

Again, the problem is primarily about the economics. Demand for private 5G is still low compared to the broader 5G market, and the current cost of developing mmWave radios is high.

Part of the cost issue is because so few players are actively developing mmWave radio components, such as Qualcomm, NXP and Metanoia. Additionally, some of the licensing models make it an expensive option, making the price of 5G mmWave deployment unattractive for potential customers.

The other cost issue is related to test equipment. Plenty of manufacturers worldwide have sub-6 GHz test gear in their manufacturing plant. However, those testers don't support mmWave bands. Consequently, manufacturers would have to invest in new test equipment capable of supporting mmWave frequencies.

To summarize, the solution to this stalemate is two-fold. First, manufacturers need a modular mmWave antenna solution that's easy to integrate without trading off high performance, thus streamlining the production process and providing a cost-effective alternative to expensive licensing options. And second, they need a proven test solution that can not only be integrated with existing test instruments, but also leverage up/down converter kits to enable legacy instruments to test mmWave bands.

Such solutions could help accelerate the mmWave market so that solutions vendors can take advantage of the early market opportunities for mmWave in private 5G and FWA.

And, as it happens, this is precisely the solution being proposed and implemented by Taiwan-based Aethertek Technology.

Aethertek's AiMs

Aethertek develops highly integrated beamforming antenna in modules (AiMs) with a user-friendly GUI with the aim of accelerating the mmWave market by making it cost-effective for laboratories, academic institutions, and production facilities to invest more in mmWave solution development. The company has also established partnerships with leading chip vendors and test instrument providers. Its beamforming antenna modules have been successfully integrated with baseband chip FR2 reference designs from Metanoia and NXP, as well as customers' FPGA-based FR2 O-RUs. This collaborative approach enables Aethertek to streamline the development process, and provide comprehensive solutions to customers.

Aethertek currently has three highly integrated beamforming AiM products, dubbed Unicorn, Iris and Gelato. Each beamforming module has an up/down converter embedded inside. Gelato supports the n258 band and Iris the n257 and n261 bands, while the Unicorn AiM supports all three bands.

Unicorn

The design concept of the Unicorn AiM is to allow customers to integrate it more freely by letting them choose antenna combinations to achieve their desired power output. For example, they can put two antenna modules together to achieve an EIRP of 56 dBm (Maximum), or four antenna modules to achieve up to 62 dBm (Maximum).

All antennas are equipped with a scanning function so the angles of Aethertek products can scan vertically and horizontally, with scanning angles of +60º and -60º. This allows for beam tracking so the antenna can track the device as it moves.

Gelato and Iris

The Gelato and Iris AiMs come with an evaluation board (EVB) "Hoya" that customers can use to integrate the antenna modules with their baseband platform.

Aethertek's EVB is FPGA-based and has software control. It also features 64 predefined beamforming IDs that customers can choose from in terms of their application. For the Unicorn EVB, for example, customers can integrate four antenna modules together with the baseband platform to perform hybrid beamforming.

Testing and compliance

To ensure 3GPP compliance, Aethertek has also invested in Rodhe & Schwarz's compact antenna test range (CATR) ATS 1800C solution. Aethertek develops its products within a CATR test chamber, which supports extreme temperature testing from -40°C to +85°C. It then tests the solution for all 3GPP requirements, which is documented and presented to customers.

Aethertek's antenna module production setup for calibration and testing includes a shielding chamber, horn antennas, a UDC kit and automatic test software. The UDCs convert sub-6 GHz bands to mmWave bands for testing. This is key because Aethertek develops its own UDC kits, which its customers can then integrate into their existing sub-6 GHz testers in their manufacturing plant. This eliminates the need to invest in new test equipment – manufacturers can quickly integrate the UDC with their existing instrument to conduct phase calibration and RF testing.

AiM integration

Aethertek's AiM EVBs are designed to be integrated easily into platforms from the only Taiwan-based 5G baseband chip provider Metanoia, as well as NXP.

Case studies

The following two case studies illustrate the fruits of Aethertek's partnership model in developing mmWave antenna modules that are easy to integrate quickly and seamlessly.

1. Amarisoft Callbox Extreme

France-based Amarisoft provides gNodeB and eNodeB emulators. Aethertek recently conducted a field trial with Amarisoft using its AiM to evaluate connectivity speed using Amarisoft's Callbox Extreme gNodeB test equipment.

The test was performed in an indoor setting in its office using four carriers of 100 MHz in the 5G FR2 band. The test achieved a maximum throughput of around 2.4 Gbps in the n257 and n261 bands with an iPhone 13, and in the n258 band with a Samsung S22.

This not only illustrates the performance capabilities of the AiM, but also the power of Aethertek's embedded UDC. The test was conducted using Amarisoft's Callbox Extreme, which supports up to ten carriers in the 5G NR FR2 bands (100 MHz 2x2) and up to six cells over a bandwidth of 100 MHz with a 4x4 MIMO configuration in sub-6 GHz bands.

2. Metanoia and Pegatron 5G

Aethertek recently partnered with Metanoia to promote its FR2 Open RAN Radio Unit (O-RU) semi-turnkey solution, which combines Aethertek's Iris and Gelato AiMs with Metanoia's 5G SoC. The objective of this collaboration is to offers a streamlined solution for customers seeking to develop mmWave O-RUs for the n257, n258, and n261 bands.

The FR2 O-RU – which is designed for both semi-outdoor and outdoor applications – is integrated on Aethertek's "Hoya" 5G mmWave RF Board. The combined solution features 64 pre-defined beam IDs that are also customizable, and supports option 7.2x, which is based on the O-RAN standard. (Note: The Hoya board can also integrate with solutions from other vendors such as NXP.)

Aethertek and Metanoia recently announced a partnership with Taiwanese firm Pegatron 5G to develop Pegatron's FR2 product line supporting various frequency bands. Under that collaboration, Pegatron will leverage Aethertek's and Metanoia's antenna array design and 5G O-RU SoC solution, including a complete software stack, system-level integration and thermal management.

At the Mobile World Congress 2024 event in Barcelona, the three companies showcased a Proof of Concept using the n258 band, 100 MHz bandwidth, and 256QAM modulation.

Conclusion

Despite being a centrepiece of the 5G paradigm, millimetre-wave radio technology has not played a major role in 5G rollouts to date, mainly for practical reasons revolving around costs that affect the entire 5G ecosystem.

Telecoms players correctly assert that mmWave will still fulfil its role in 5G networks over time – however, that's not to say mmWave adoption will ramp up in the distant future. As we have seen, market drivers for mmWave 5G exist today for use cases such as private 5G and FWA. What's needed is a way to streamline integration of components into mmWave beamforming antenna systems in a way that makes the process both faster and more cost-effective.

Aethertek's achievements and collaborations with its highly integrated beamforming AiMs showcase how this can be done. Streamlining the process for integration and testing of beamforming antenna modules can provide network infrastructures, laboratories, and academic institutions, a cost-effective way to pursue mmWave solution development, which can also help to not only accelerate the mmWave market, but also pave the way for mmWave technology to evolve faster and unlock new innovative possibilities for evolving the capabilities of 5G and even 6G.

Inside the AiM

Aethertek's highly integrated beamforming antenna in modules (AiMs) have currently been developed into three products: Unicorn, Iris and Gelato. Gelato supports the n258 band and Iris the n257 and n261 bands, while the Unicorn AiM supports all three bands. Here's a quick look under the hood at Unicorn, which gives an idea of a what AiMs can deliver.

Aethertek's AiM product line is an active phased array antenna module based on the 3GPP Release 15 standard that can be controlled by any processor supporting the SPI interface. Additionally, users can easily configure key parameters to customize their experience.

The intent of the module design is to create flexible antenna configuration, such as 8×8, 16×8, and 16×16, to accommodate various application scenarios.

Unicorn supports the n257, n258, and n261 FR2 bands in TDD mode, enabling high-speed wireless communication in these specific frequency ranges. The performance of the module are tested under 256QAM modulation within 3.5% EVM. The device supports a maximum channel bandwidth of 400 MHz for both downlink and uplink, providing substantial capacity for data transmission.

Unicorn is also an ideal solution for mmWave Remote Radio Units due to its power consumption advantages. This matters because heat can degrade the performance of circuits, affecting signal integrity, transmission quality, and overall system reliability – consequently, thermal management in mmWave products is crucial. Unicorn achieves 47 dBm EiRP@3.5% with a 100% duty cycle power consumption of 43W. The next generation improves this to 50 dBm EiRP@3.5% with a reduced power consumption of 42W.

Aethertek's AiM product line consists of (beamformer chips, up-down converter chips, physical circuitry, antenna element array, memory, etc.), offering seamless integration with a radio transceiver and baseband platform to create remote radio heads for wireless networks.

Aethertek has developed an EVB for Unicorn (as well as Iris and Gelato) designed for integration with Metanoia or NXP platforms, which simplifies and expedites the development process for customers. Additionally, Aethertek is continuing to develop next-generation beamforming modules that meet customer requirements for power consumption, EIRP, and beam design, while maintaining a market-acceptable price.

Aethertek Technology is a leading provider of high-frequency connectivity and production test solutions, playing a crucial role in the 5G networks supply chain as a major supplier of mmWave Antennas- in-Modules. Leveraging cutting-edge technology and superior integration capabilities, the company accelerates mmWave deployment by lowering the threshold for introducing mmWave technology and enabling high-powered 5G networks for enterprises— strives to empower everyone with maximal 5G capacity and throughput.

Find out more at www.aether-tek.com

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