White Paper: Antennas for Wi-Fi 6E

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Executive Summary

Compact and high-performance antennas are key to create a world where everything is connected wirelessly. The AN01-series embedded antenna, developed by JAE, offers industry-leading efficiency, a near-isotropic radiation pattern, robust performance in various deployment environments and supports automated mounting on PCBs. In this paper, the significance of the release of 6-GHz band for Wi-Fi devices is reviewed, and JAE's new tri-band (2.4, 5, and 6 GHz) Wi-Fi antenna for Wi-Fi 6E is introduced.

1. Wi-Fi 6E: overwhelming bandwidth availability by using 6-GHz band

High demand for wireless access with low deployment cost has rendered Wi-Fi as a primary means of connecting various devices for personal and enterprise use. When the IEEE 802.11 standard series, using 22-MHz bandwidth, was first released in 1997, data rate was limited to only 1 or 2 Mbit/s. As for the most-recent protocol, IEEE 802.11ax (draft 8.0), using 160-MHz bandwidth, specifies theoretical maximum data rate of 9.6 Gbit/s [1]. However, due to attenuation of radio signals, spectrum sharing with other users, and limited number of spatial streams in most deployment scenarios, actual data rate per user is typically less than 1 Gbit/s. Technologies such as advanced modulation and MIMO transmission have contributed to the increase in data rate; however, the bandwidth assignment in 5 GHz has been a critical factor in enhancing Wi-Fi capacity most in the last 20 years.

Current Wi-Fi in most countries uses unlicensed bands from 2.4 to 2.5 GHz and from 5.15 to 5.85 GHz. And the frequency range suitable for wireless local-area networks is limited to below 6 GHz, and an unlicensed band is a scarce resource. That unlicensed-band resource is so scarce because it is very difficult to reallocate frequency for different purposes. Once a range of frequencies is assigned as an unlicensed band, a vast number of devices start using it, and it becomes impossible to stop using that band. As a result, frequency regulators have been cautiously allocating unlicensed bands in the past.

In April 2020, the US FCC voted on and ratified a Report and Order to allocate 1.2 GHz of bandwidth (from 5.925 to 7.125 GHz) as an unlicensed band [2][3]. As shown in Figure 1, it was an epoch-making event that almost doubled the available bandwidth for Wi-Fi. The term "Wi-Fi 6E" was introduced by the Wi-Fi Alliance to identify and certify Wi-Fi devices that support this new 6-GHz band. The IEEE 802.11ax standard—including support of the 6-GHz band—was published in May 2021 [4]. Following the US FCC, in July 2020 Ofcom, in the UK decided to allow Wi-Fi operations in the lower 6-GHz band, namely, from 5.925 to 6.425 GHz [5], and the Ministry of Science and ICT in South Korea released the bandwidth from 5.925 to 7.125 GHz for unlicensed use [6][7] in October 2020. European countries are also preparing to release the bandwidth from 5.925 to 6.425 GHz for unlicensed devices [8], and Japan has started to discuss the technical specifications of shared use of the bandwidth from 5.925 to 7.125 GHz for Wi-Fi [9]. Wi-Fi 6E chipsets and devices are being developed, and some are already available in the market before the actual release of the 6-GHz spectrum globally [10]. Wi-Fi 6E-capable devices will be more common from 2021 onwards [17]. Furthermore, standardization of IEEE 802.11be, as a successor of IEEE 802.11ax, is taking place, and it is expected to be finalized in 2024 [3]. By utilizing 320-MHz bandwidth, devices compatible with IEEE 802.11be—to be called "Wi-Fi 7"—are expected to provide peak data rate of more than 10 Gb/s.

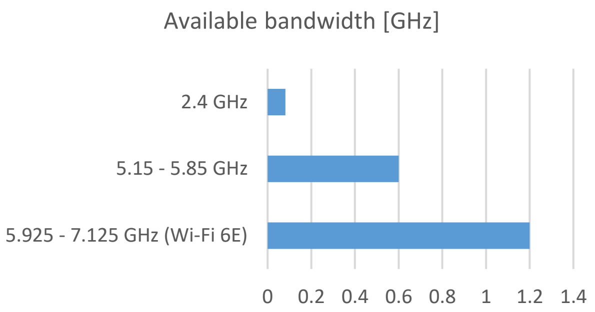


Figure 1: Available bandwidth with conventional Wi-Fi and Wi-Fi 6E (excluding 100 MHz from 5.35 GHz to 5.45 GHz)

2. Fundamental transformation of deployment of personal and enterprise networks

With availability of such abundant frequency bandwidth, deployment of networks in home and enterprise environments is expected to be fundamentally transformed.

1) No more need for wired networking by end users

A wireless connection of nearly 1 Gbit/s per user is usually more than enough to support almost all applications to date. Netflix UHD video streaming consumes less than 25 Mbit/s. And Cisco Webex requires up to 1.65 Mbit/s for transmitting data at 2.7 Mbit/s and for receiving data during web conferencing with five participants, and the software adapts the video quality according to whether the network is congested [11]. In the case of a Wi-Fi mesh (multi-hop) network, data rate decreases as number of hops increases; even so, the abundant bandwidth in the 6-GHz band will mitigate the degradation in throughput. Hence, the end user will be free from having to install Ethernet wired networking at home or in small offices.

2) Industrial IoT goes wireless without using dedicated standards

Wireless technology in factories (known as "Industrial IoT") has been expected to provide a flexible layout and high-level maintenance for production equipment. Conventionally, wired-network or factory-specific wireless communication standards were used for this purpose. By taking advantage of the large spectrum in Wi-Fi 6E, network administrators can partition the unlicensed spectrum into multiple parts, and one can be used for the production network and the other for the office network to avoid interference with each other. Unless wide-area transmission or ultra-low-latency communication is required, Wi-Fi is expected to play an active role in Industrial IoT.

3) Complementing LTE and 5G NR network in licensed bands

As for requirements such as wide-area transmission and ultra-low-latency communication, LTE and 5G NR in the licensed band are more suitable standard than Wi-Fi in the unlicensed band. In that case, Wi-Fi can complement LTE and 5G NR as a private extension of a wireless network without SIM.

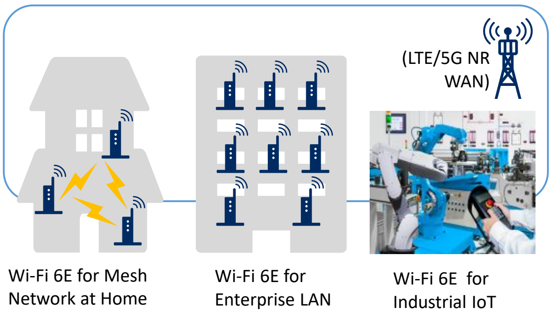


Figure 2: Scenarios for deployment of Wi-Fi 6E network

3. Technical challenges for Wi-Fi 6E antenna

The tradeoff between size and supportable bandwidth is a fundamental challenge concerning antennas of embedded systems. Because the size of a Wi-Fi device is limited, it is often difficult to add antennas only to support the 6-GHz bandwidth. In addition, commercial Wi-Fi-6E-capable chipsets must be configured as dual-band mode to transmit 5-GHz and 2.4-GHz signals simultaneously or tri-band mode to transmit 6-, 5-, and 2.4-GHz signals simultaneously [12]. Satisfying these requirements leads to the challenge for Wi-Fi 6E antenna that they must support large additional bandwidth (i.e., 1.2 GHz) in similar size without sacrificing radio performance.

Two categories of devices are defined when the 6-GHz band was opened as an unlicensed band by the FCC. The first category, called "standard-power access points and clients," is aimed at both outdoor and indoor deployment and can use two-thirds of the frequency band from 5.925 to 6.425 GHz and 6.525 to 6.875 GHz. Standard-power access points need to be controlled by automatic frequency coordination (AFC) systems to avoid interference with incumbent wireless systems. The second category, called "low-power access points and clients," is aimed only indoor deployment and can use the entire frequency band from 5.925 to 7.125 GHz, with 6-dB-lower transmitter power limit. Low-power devices are exempted from control by the AFC systems, so they are required to incorporate permanently attached integrated antennas. Requiring an integrated antenna makes it significantly more difficult to replace a device's antenna with a higher-gain antenna, which could increase a device's EIRP (equivalent isotropic radiated power) above the limit and thereby increase the potential for the device to cause harmful interference. On the contrary, standard-power devices are not under the restriction to attach a permanent antenna. It is expected that the vast majority of Wi-Fi 6E devices will be low-power types because of their easy deployment without requiring AFC systems, and the devices will have permanently attached integrated antennas. Maximum gain of the antenna should be less than 6 dBi, and if an antenna with a gain greater than 6 dBi is used, the power output of the device must be reduced by the amount greater than 6 dBi [3].

4. JAE's SMT antennas for Wi-Fi 6E

4.1. AN01 Series SMT Antenna for Wi-Fi

JAE offers AN01DL-series surface-mount-type (SMT) metal antennas for 2.4-/5-GHz Wi-Fi embedded products [15]. These antennas are compact (i.e., 13.0 × 8.8 × 2.0 mm) and highly efficient with near-isotropic radiation patterns. Supplied in an embossed reel package with 3,200 pieces, the AN01-DL series is automatically placed on printed circuit boards with component mounters.

4.2. AN01 series SMT Antenna for Wi-Fi 6E (New)

JAE has launched a tri-band SMT metal

antenna capable of operating in the bands from 5.925 to 7.125 GHz in addition to the 2.4-GHz and 5-GHz bands [16]. With dimensions of 13.0 × 10.15 × 2 mm, the Wi-Fi 6E antenna AN01ML27C00 has a similar shape to dual-band AN01DL25C00 antenna. As shown in Figure 3 and Figure 4, three ground terminals and two support terminals hold the AN01ML27C00 antenna component firmly in place. The RF signal is input and output from one of the inner terminals indicated as "FEED." The upper layer and lower layer of the AN01ML27C00 antenna form a split-ring structure, which—as a patent-pending technology—makes the antenna robust in various environments.

Figure 3: Shape of AN01ML27C00 antenna

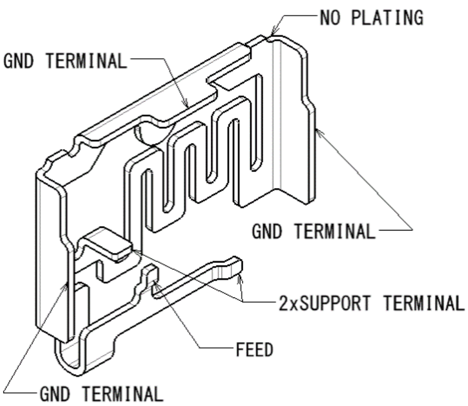


Figure 4: Structure of AN01ML27C00 antenna

The RF performance of the Wi-Fi 6E antenna AN01ML27C00 was evaluated as follows. An AN01ML27C00 antenna was mounted on standard 50 × 30-mm PCBs as shown in Figure 5. VSWR characteristics of the antenna are plotted in Figure 6. The AN01ML27C00 antenna showed VSWR < 2.0 in the 2.4-GHz band and from 5.15 GHz up to 7.125 GHz. The radiation efficiencies of the Wi-Fi 6E antenna (excluding cable and feeder loss) are shown in Figure 7. The antenna's efficiency is above 85% in the 2.4-GHz band and more than 70% in the 5.15-to-7.125-GHz band. Radiation patterns of the Wi-Fi 6E antenna in the 2.4-, 2.5-, 5.15-, 6.025-, and 7.125-GHz bands are shown in Figure 8. At all frequencies peak gain is less than 2.4 dBi, which is well below the FCC's assumption of 6 dBi [3]. And the radiation pattern is nearly isotropic, so the antenna is suitable for both consumer and enterprise use.

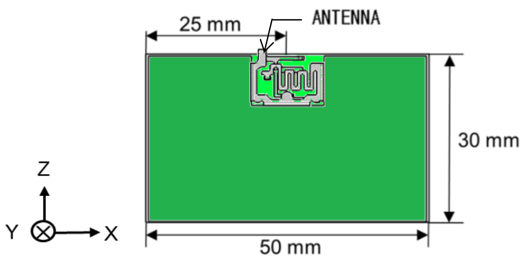


Figure 5: Reference board

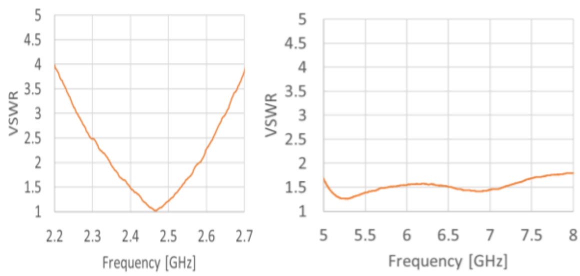


Figure 6: VSWR characteristics

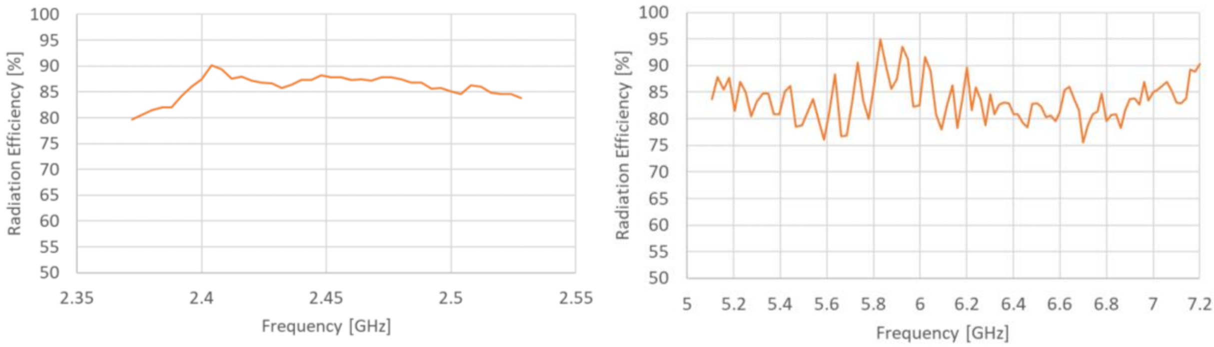
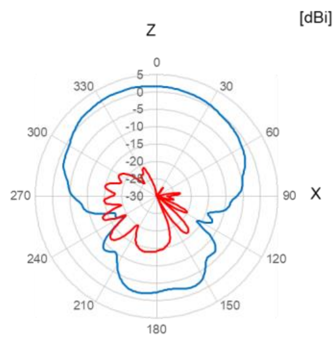
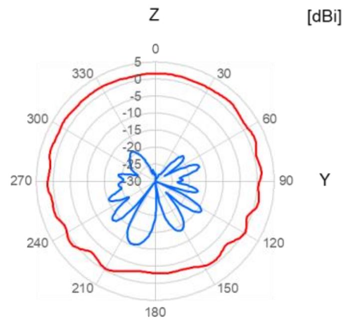


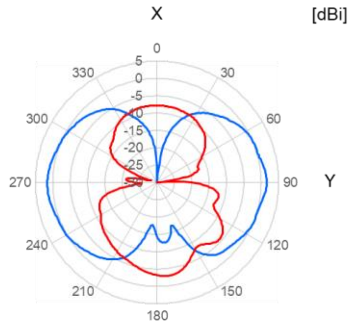
Figure 7: Radiation efficiency



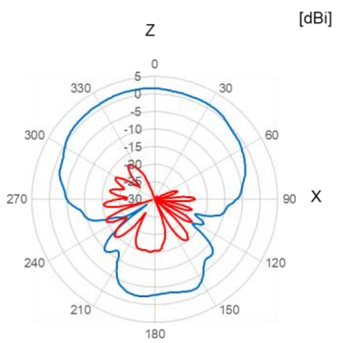
(a) 2.4 GHz Z-X plane



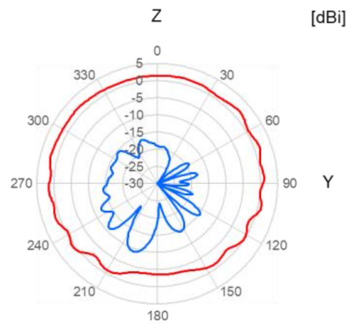
(b) 2.4 GHz Z-Y plane



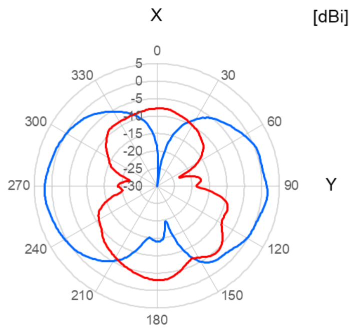
(c) 2.4 GHz X-Y plane



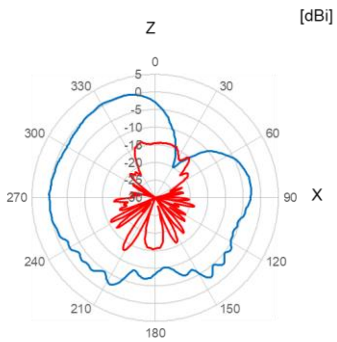
(d) 2.5 GHz Z-X plane



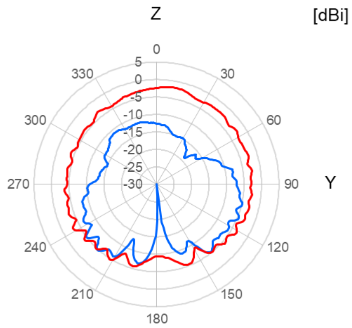
(e) 2.5 GHz Z-Y plane



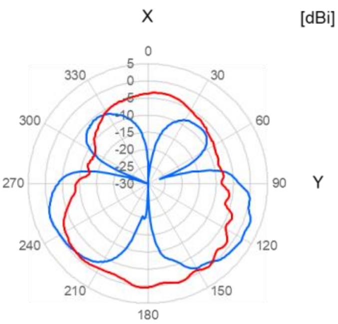
(f) 2.4 GHz X-Y plane



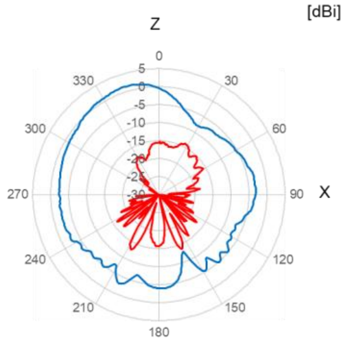
(g) 5.15 GHz Z-X plane



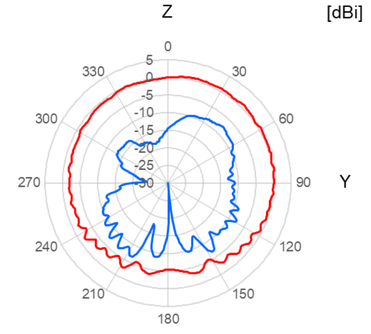
(h) 5.15 GHz Z-Y plane



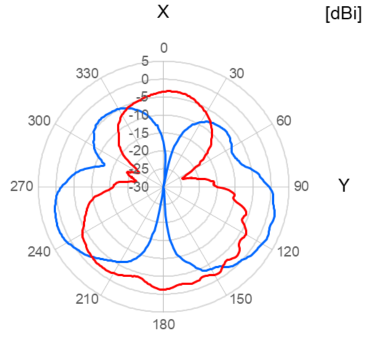
(i) 5.15 GHz X-Y plane



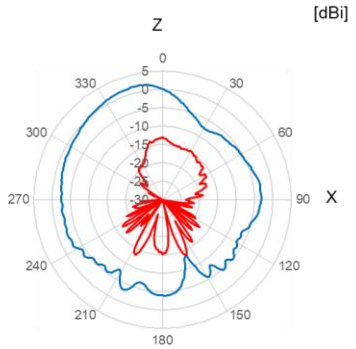
(j) 5.85 GHz Z-X plane



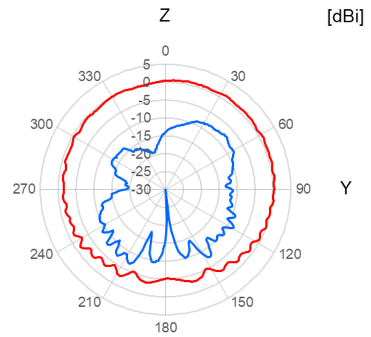
(k) 5.85 GHz Z-Y plane



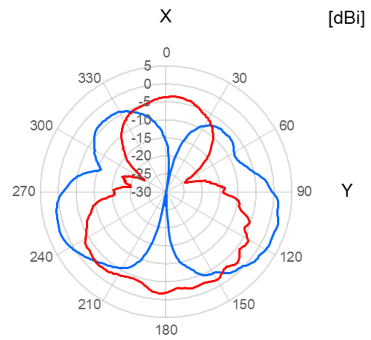
(l) 5.15 GHz X-Y plane



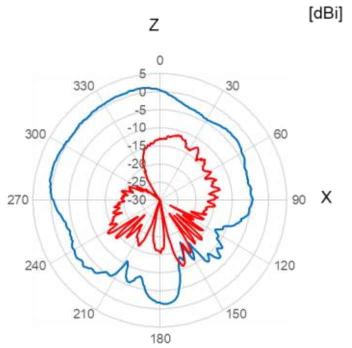
(m) 5.925 GHz Z-X plane



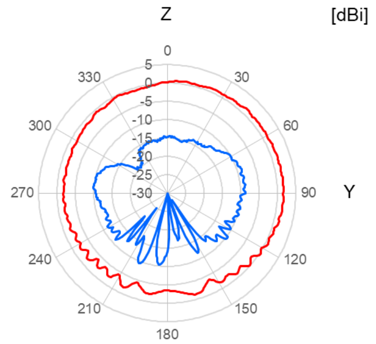
(n) 5.925 GHz Z-Y plane



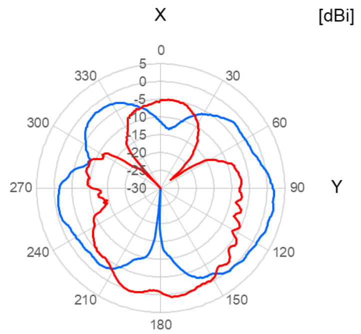
(o) 5.925 GHz X-Y plane



(p) 7.125 GHz Z-X plane



(q) 5.925 GHz Z-Y plane



(r) 5.925 GHz X-Y plane

Figure 8: Radiation pattern of Wi-Fi 6E antenna

(red Line: horizontal polarization; blue line: vertical polarization)

5. Conclusions

The release of 6-GHz band for Wi-Fi and other unlicensed devices will have a significant impact on personal and enterprise networks in the coming years. The major challenge facing Wi-Fi 6E antennas is to support 1.2 GHz of additional bandwidth while keeping performance at the same size. As a leading electric component supplier, JAE has successfully developed a SMT metal antenna for Wi-Fi 6E, and we have confirmed its superior performance up to the 7.125-GHz band.

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Acronyms

5G NR	5^{th} Generation New Radio
AFC	Automatic Frequency Coordination
EIRP	Equivalent Isotropic Radiated Power
FCC	Federal Communications Commission
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
LTE	Long Term Evolution
MIMO	Multiple-Input and Multiple-Output
Ofcom	Office of Communications
PCB	Printed Circuit Board
RF	Radio Frequency
SMT	Surface Mount Technology
UHD	Ultra High Definition

Note: Wi-Fi is a registered trademark of Wi-Fi Alliance.