Wide-band wireless LAN antenna for IEEE 802.11 a/b/g

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ABSTRACT: Wireless LAN (IEEE 802.11a/b/g standard) system has begun to be used as a kind of common communication tools recently. The category of 802.11a using the radio frequency (RF) range of 5 GHz is coming up especially, because one of the reason is that 5 GHz band is much clearer than 2 GHz band from the point of view of RF density, and the another reason is that the transfer rate of 802.11a is much faster than the one of 802.11b. However, we need to have the wide-band antenna covering different frequencies when using 802.11a. Because there are several frequencies in 5 GHz band which is used in several different countries like US, Europe and Asia. Now we've developed new wide-band antenna which has multi-resonance frequency such as 2.4 — 2.5 GHz for 802.11b and 4.8 — 6.2 GHz for 802.11a, it covers whole frequency described above, and the average gain is so high, around - 2 dBi over the full range even including the cable losses.

[1] INTRODUCTION

Wireless LAN (Local Area Network) system is used not only in the office but also in the home recently by users of the mobile terminal devices like lap-top computers or PDAs (Personal Digital Assistance). The specification used for the communication between the mobile terminal devices is defined as IEEE 802.11, which is classified broadly into 802.11b using 2.4 GHz and 802.11a using 5 GHz band.

The module for 802.11b specification has been developed early on, and now 802.11b system is standardized as a common in the world, and mounted on more than half of the current new-released computers. But 802.11b has following disadvantages basically; (1) the maximum transmission rate is up to 11 Mbps and (2) it's susceptible to the radiation from Bluetooth system or microwaves or the other mobile devices which use same frequency of 2.4 GHz.

On the other hand, 802.11a has high transmission rate up to 54 Mbps, which is stable because there is no major noise source around the frequency of 5 GHz. The 11a is expected to enable the high rate communication easily such as the transmission of moving pictures. However, the 11a has the following issues; (1) compatibility to 802.11b using 2.4 GHz and (2) it needs the wide band detection system, because the different frequencies shall be used in several countries such as U.S., Europe and Asia. For instance, the frequency of 5.2 GHz is restricted within indoor usage in every country, the following frequencies are given the permission of the outdoor usage at each country, 4.9 GHz in Japan, 5.7 GHz for U.S. and Europe, 6.0 GHz for South America and 6.1 GHz for China (undefined).

Every parts used for the mobile devices like laptop PC is limited the space for installation due to the downsizing of their devices. The antenna is also required to make it downsize, for instance, to install into the small space such as around the LCD (liquid crystal display) panel.

We have already developed the small size film-type antenna for wireless LAN which is made by copper alloy and laminating both side with poly-imide films[1]. And this antenna has been in mass-production state, actually we have more than 3 years experiences to deliver them to the domestic and foreign companies. Our film-type antenna is suitable for the one installed into the mobile devices because it has omni-directional radiation and radiates dual bands of both 2.4 GHz and 5 GHz bands[2)-4)]. The antenna is also possible to be installed into the narrow space because of its film-like shape, which is only 0.2 mm thick and flexible, and usually it's easily fixed to the chassis by a double-sided adhesive tape.

We developed the new dual wide-band antenna which is capable of being used in the whole world as the universal antenna. And we also developed another type of antenna which was fixed to the chassis by screws due to expanding the way of antenna installation for the customers.

[2] Wide-Band Antenna

2.1 Design of Wide-Band Antenna

Fig. 1 shows the photos of our current standard antenna and newly developed wide-band antenna. The dimension of both of

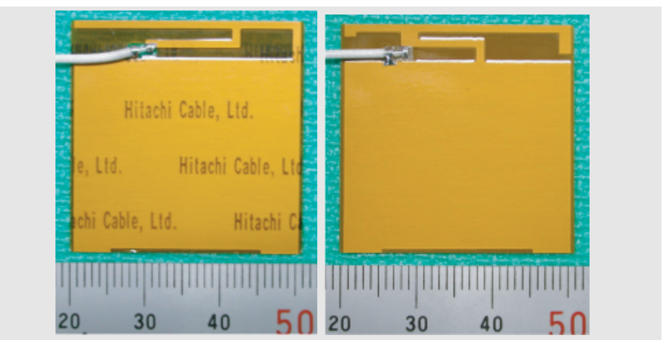

Fig. 1 – Photographs of the current standard antenna (Left) and the newly developed wide-band antenna (Right).

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two antennas are same, that is 31.0 (W) * 30.5 (H) * 0.2 (t) mm. The antenna properties of current antenna are composed by a mono-pole for 2.4 GHz and a loop antenna for 5.2 GHz. On the other hand, the properties of the new wide-band antenna are designed by one of L-shaped antenna for 2.4 GHz, and combined another L-shaped antenna and a loop antenna to achieve the wide bandwidth of 5 GHz. Both of these antennas work so stable because they have a ground plane in themselves. The resonance parts of the wide-band antenna are shown in **Fig. 2**. The frequency of 2.4 GHz is resonated by long L-shaped part which is indicated by red, and 5 GHz band is oscillated by the combination with short L-shaped part and the loop which is formed by feeding and grounding points through one short stab, indicated by blue color.

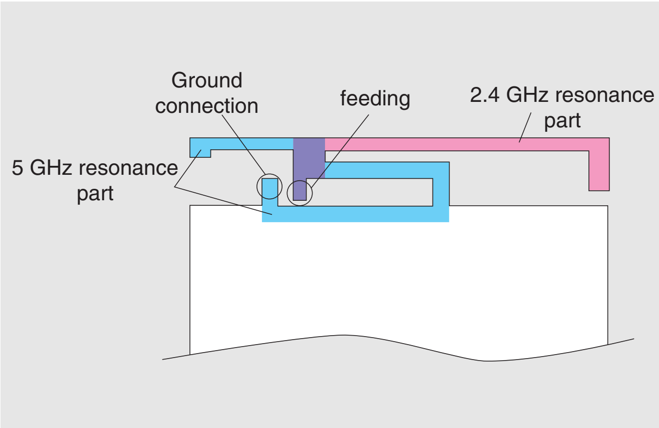


Fig. 2 – This indicates the resonance part of each frequency band of new wide-band antenna. The red part means the resonance part for 2.4 GHz, and the blue part means for 5 GHz.

2.2 Estimation

We measured the return loss and VSWR (voltage standing wave ratio) of the wide-band antenna. We installed the antenna into the dummy LCD chassis that we usually used for the basic estimation of our antenna. The dummy LCD chassis is made by a front cover, a frame, dummy LCD and a base. The material of each part is made by ABS plastic (both panel and frame), stainless alloy and aluminum, respectively. **Fig. 3** shows the installed condition of the antenna into the dummy LCD chassis. We used the cable of 1.13 mm outer diameter and 500 mm length made by Hitachi Cable, and a miniature coaxial connector for signal feeding. The results comparing to the current antenna are shown in **Fig. 4**. And the bandwidth of new antenna at 2.4 and 5 GHz are described in **Table 1**. From these results, this new antenna has enough bandwidth at 2.4 GHz and 5 GHz band. Especially at 5 GHz band, the bandwidth less than VSWR 2.0 is 2.68 GHz, which equals to 49% as normalized bandwidth (2.68 GHz/5.5 GHz). This value is more than twice compared to the current

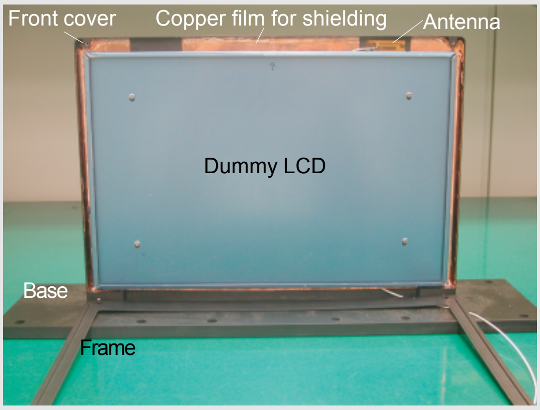


Fig. 3 –Photograph of the dummy LCD installed the wide-band antenna. Copper film (0.15 mm thickness) was attached on the front cover, excluding the antenna installation area. The window size for the antenna was 40 (W) by 10 (H) mm².

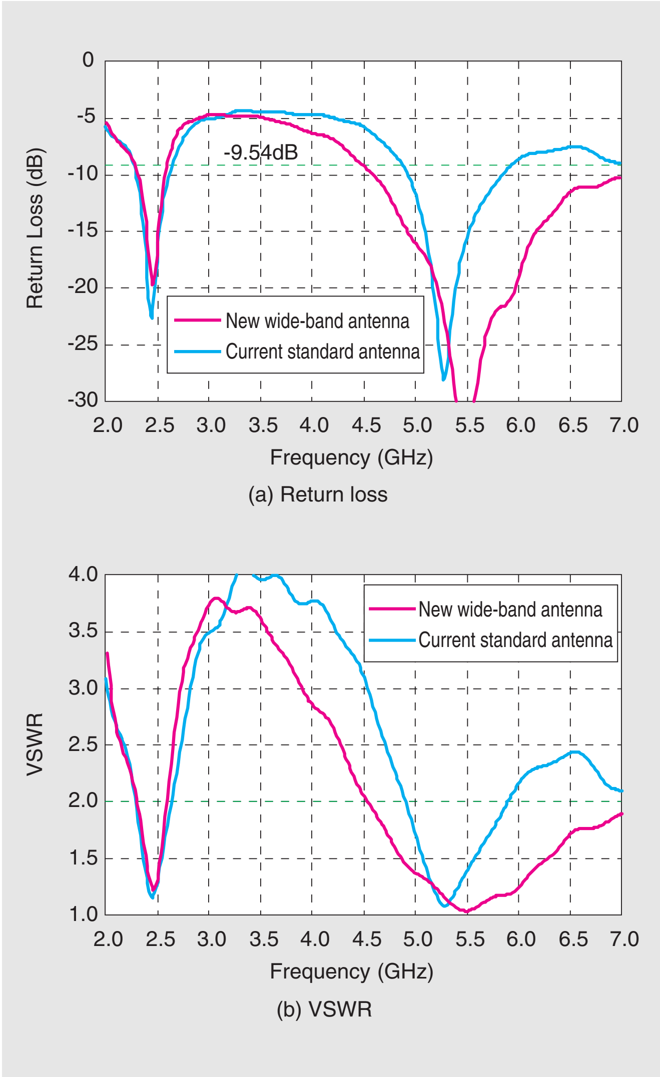


Fig. 4 – Return loss (a) and VSWR (b) of the new wide-band antenna and the current standard antenna. These results were measured by time gating method. The bandpass of the timing was from 4 ns to 7 ns. Coaxial cable of 1.13 mm outer diameter and 500 mm length was used.

Table 1 Bandwidth at each frequency range of the new wide-band antenna

Frequency range (GHz)	Bandwidth	Notice
2.4	280MHz	Values less than -9.54 dBi of return loss,or 2.0 of VSWR
5	2.68GHz	

antenna's one.

Next, we measured the radiation pattern and the average gain of new wide-band antenna. **Fig. 5** shows one of the results of the radiation pattern measurement at 2.45 and 5.25 GHz. These results show the vertical (in blue) and the horizontal (in red) polarized wave separately and also the combined radiation pattern (in purple). Each result of the combined pattern at 2.45 and 5.25 GHz shows almost omni-directional pattern without any null-point as defined by the value of less than - 30 dB. This omni-directional pattern is important for mobile devices such as laptop PC, because these devices must work normally when being put anywhere. The new antenna can achieve this required specification.

We calculated the average gain of each frequency by summing up the whole azimuth gain of the radiation pattern. We used the following equation to calculate the average gain,

$$\text{Average Gain(dBi)} = 10 \log \left(\frac{\sum_{i=0}^{N-1} (P_{Vi}+P_{Hi})}{N} \right) \quad \text{...........................(1)}$$

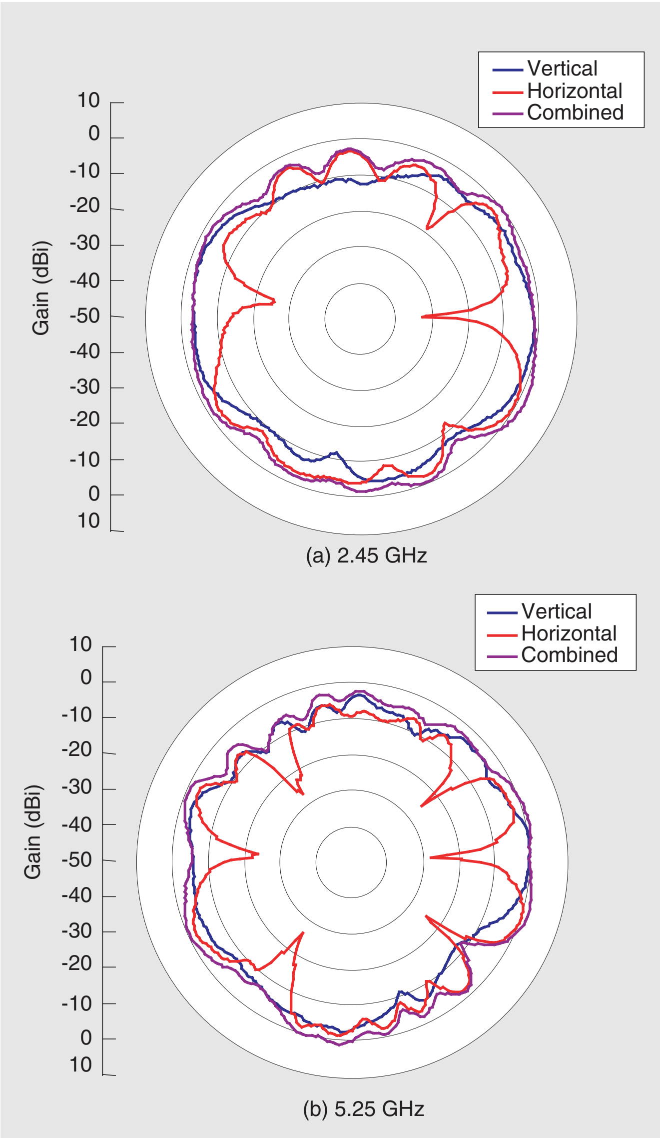


Fig. 5 – Radiation pattern of the wide-band antenna. Both of these results of combined one at 2.45 and 5.25 GHz showed nearly omni-directional pattern.

P_{Vi}, P_{Hi} are the gain values of the vertical and the horizontal polarized wave respectively, i is the number of azimuth angle (0, 1, 2, ---, 359) and N is the step counts of measurement (= 360). The comparison of the average gain between the current antenna and the new wide-band antenna is shown in **Fig. 6**. It's obvious that the performance of the gain properties and the bandwidth of the new antenna is superior to the current one at the frequency range of both 2 GHz and 5 GHz. The performance of 5 GHz band is especially improved regarding the flatness over the whole range which covers 1.4 GHz bandwidth and additionally achieves higher gain. And we assume that the average gain has still good performance at the out of the range which we have not measured at this time, because the result of VSWR measurement which still keeps VSWR low enough from 4.5 GHz to over 7 GHz.

From the above results, this new wide-band antenna can be applied to all systems using IEEE802.11 standard, covering the whole frequency range from 4.9 GHz (Japan) to over 6 GHz (China), and is suitable to be used as a universal antenna which is installed in the world-wide products.

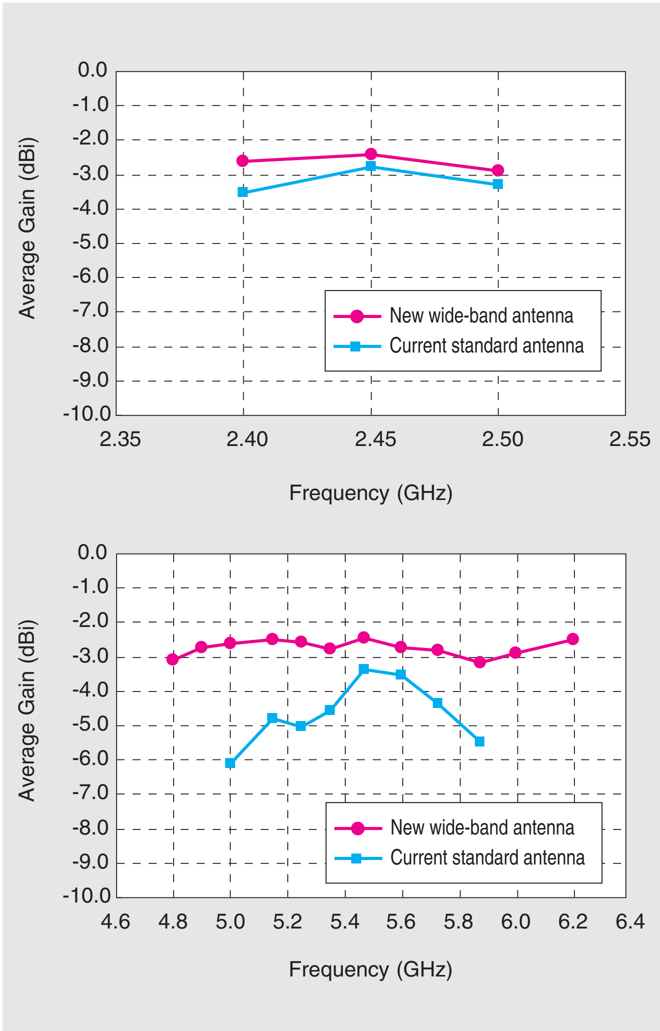


Fig. 6 – The average gain of the new wide-band antenna and the current standard antenna including the cable losses, 1.5 dB@2.4 GHz and 2.2 dB@5.4 GHz. Both gain at 2.4 GHz and 5 GHz ranges of the new wide-band antenna were superior to the current antenna's one. Especially at 5 GHz range, the average gain was almost flat over whole frequency, from 4.8 GHz to 6.2 GHz.

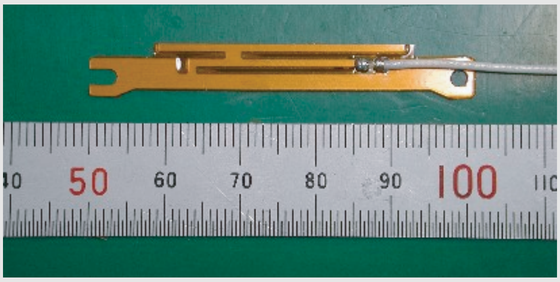
[3] Screw fixed bar-type antenna

30 mm square film type antenna described above is often used to be installed between the LCD and the front cover[1). However, looking at recent trends, it tends to be much thinner for lap-top PC itself, and much smaller for the space around the LCD. Therefore, we developed the lower height antenna which was suitable to be installed for the smaller space around the LCD.

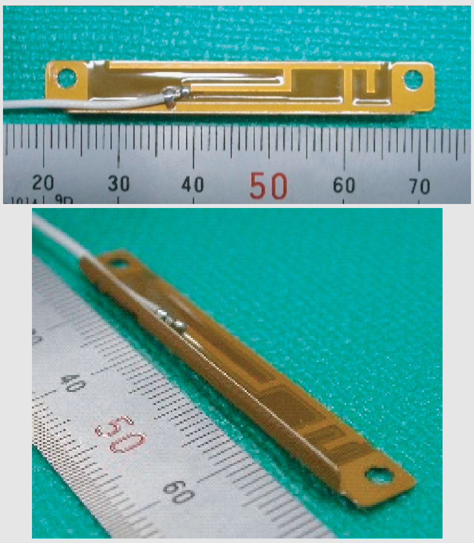
30 mm square antenna is currently fixed to the front cover by a double-sided adhesive tape. This has the advantage of easy installation which is no need to fix it using screws, only need of flat surface. On the other hand, if repair is needed in other mass-production process after assembling the antenna, it may happen to deform the antenna when removing the antenna from the front cover, which may cause the antenna nonrenewable.

Considering the above situation, we newly developed the screw fixed bar-type antenna which satisfies both the low height and good handling capability including renewable usage. This antenna was designed as bar-shaped to be able to fit the space around the LCD side, and has two screw holes at the both sides to be fixed on the chassis of lap-top PC by screws. **Fig. 7(a)** shows the antenna, which we design that the antenna can work when it is installed around the metal frame such as magnesium cover. This antenna uses the surrounding metal parts as self-grounding, so it can achieve small size, and high performance. The antenna shown in **Fig. 7(b)** is designed that it can work when installed into the plastic chassis without metal. This antenna has small bending ground (2 mm perpendicular bending), which provides enough self-grounding area and improvement of mechanical strength towards antenna deformation.

Fig. 8 and **9** show examples of the return loss and the average gain of screw fixed bar-type antenna indicated in **Fig. 7(a)**,



(a) For metal chassis
51(W) * 7(H) * 0.25(t)



(b) For non-metal chassis
52(W) * 7(H) * 2.5(D, L shaped)

Fig. 7 – Examples of our screw fixed bar-type antennas

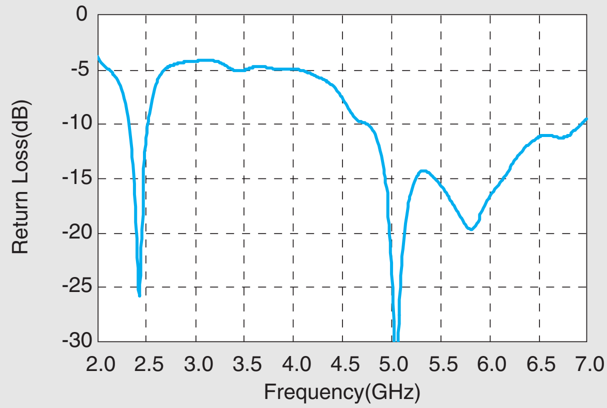
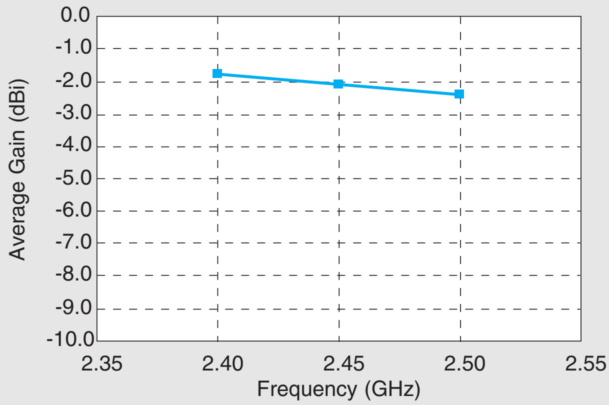
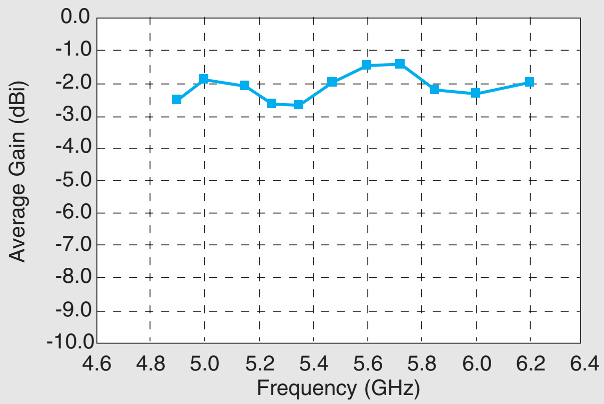


Fig. 8 – Return loss of the screw fixed bar-type antenna for metal chassis. This result was measured by time gating method. The bandpass of the timing was from 4 ns to 9 ns. Coaxial cable of 1.13 mm outer diameter and 600 mm length was used.



(a) 2.4 GHz range



(b) 5 GHz range

Fig. 9 – The average gain of the screw fixed bar-type antenna for metal chassis including the cable losses, 1.8 dB@2.4 GHz and 2.6 dB@5.4 GHz. This antenna also has high average gain and wide bandwidth at 5 GHz range.

respectively. We used the cable of 1.13 mm outer diameter and 600 mm length made by Hitachi Cable, and a miniature coaxial connector for signal feeding. This antenna also improves the bandwidth and the gain of 5 GHz band as well as above-mentioned 30 mm square wide-band antenna, and can correspond to the expansion of the frequency range of IEEE 802.11a standard.

[4] CONCLUSION

We have developed the new wide-band antenna which has dual mode at 2.4 GHz and 5 GHz, the bandwidth of 5 GHz is extremely large from 4.8 to 6.2 GHz, which can correspond to expanding the frequency range of IEEE 802.11a standard. We have also developed the screw fixed bar-type antenna which is achieved the compact size, easy handling and wide-band at 5 GHz range too. We try to make this antenna smaller as a next step.

We have a plan to expand our antenna products into the new field such as a digital home electronics and networking in the near future.

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