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"Enhancing Wireless Network Performance by Addressing Human Body Effects in AAS Systems"

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Abstract: *While it is true that wireless networks are now central to our everyday life, linking devices and enabling seamless interaction among humans, the presence of a human body can significantly affect the performance of a wireless network such as Antenna Array Systems (AAS). In this article, we will examine how human bodies may interfere with AAS technology in relation to wireless networks. We propose means of minimizing these impacts and optimizing overall network performance. To realize reliable and efficient communication through AAS systems, we have to address problems like signal attenuation, interference and path loss due to user influence. Our discoveries also help in designing and deploying wireless networks that factor in human body effects so as to enhance connectivity and user experience.*

Key Words: *Wireless Network, Wi-Fi, signals, AAS Systems.*

1. INTRODUCTION :

Wireless connectivity has 100 percent changed the way we communicate, talk, and write. Wi-Fi networks are everywhere, from our smartphones to smart home devices. However, there is one regularly overlooked factor that greatly affects their overall performance: the human body. Imagine yourself running down the road, engaged in a cell phone call. Your phone communicates wirelessly with nearby antennas, ensuring a seamless connection. But did you already know that your body—in fact, those organs of flesh and bone—can change its response to that symptom? It's like a serene dance between biology and technology. In this issue, we explore the complex interaction between wireless networks and the human body, focusing on Antenna Array Systems (AAS). These systems, which use more than one simultaneous antenna, hold great promise for increasing network performance. But how do we our bodies fit into this equation? Let's see. Antenna Array Systems (AAS) in Mobile Phones Role of Antenna Technology: Single Antenna Systems: Traditional mobile phones had almost unmarried antennas and they performed reasonably well but there were limitations in coverage and number of accounts. Multiple antenna systems: Modern smartphones incorporate more than one antenna system. These systems use MIMO (Multiple-Input Multiple-Output) and other techniques to improve throughput and reduce interference. Antenna Arrays: AAS phase up. Suppose a set of antennas operates in sync. By varying the phase and size of each antenna, AAS can steer the signal, increase coverage and reduce interference. Human Body Impact: When you hold your phone, your hands and head are near the antenna. Guess what? Your body absorbs it.

2. HUMAN BODY EFFECT ON AAS ANTENNA SYSTEM IN FREQUENCY RANGE :

A. Single antenna system

In the context of 5G communication, the frequency range (FR1) spans from **410 MHz to 7125 MHz** . Similar to previous mobile network generations, the human body affects a single antenna system in two primary ways:

- Antenna Mismatch Loss: The presence of the human body can lead to impedance mismatch, causing detuning of the antenna.
- Power Absorption Loss: The human body absorbs some of the radiated energy, reducing the antenna's radiation efficiency.

Consequently, key RF parameters like total radiated power (TRP) and total isotropic sensitivity (TIS) are adversely impacted. <u>Measurements on commercial phones have shown that TRP losses can exceed </u>15 dB<u> due to the presence of body phantoms</u>

Fig. 1. The illustration of the Human body effect on the antenna impedance matching (left) and the power absorption (right).

B. Multiple antenna system with antenna diversity

Antenna switching [19] and combining [20], commonly referred to as antenna diversity, are common techniques to enhance RF performance, particularly for modern mobile phone reception. This is partly attributed to the widespread adoption of various antenna systems. Table I shows the total TIS of a prototype mobile phone with total TIS when there are numerous antennas in free space in addition to the head and hand (BHH) being listed. It is noticed that doubling the number of reception antennas can enhance TIS by nearly 3db It's also beneficial to design the mobile antenna so that it is naturally resistant to body bodily affects. This is especially important for the antenna.

TABLE-I. MEASURED TIS OF A MOBILE HANDSET WITH MULTIPLE ANTENNA SYSTEM

Number of antennas	**TIS in free space (dBm)**	**TIS in BHH (dBm)**
4	-100.4	-9
6	-101.7	-94.4

C. Multiple antenna system with spatial multiplexing

The antenna diversity technologies mentioned above are typically used to improve the wireless system's signal-to-noise ratio. As an alternative, multiple antennas with parallel data streams (spatial multiplexing or multiple-input multiple-output (MIMO)) to increase channel throughput have been deployed in LTE networks and will be expanded in 5G NR networks. In recent years, researchers have investigated the effects of user bodies on MIMO performance [8]-[10]. A mobile handset's MIMO performance is typically measured by channel throughput. The test setup of MIMO performance for 5G new radio (NR) in 3GPP is currently under discussion [23]. Nonetheless, as with the LTE test setup, channel throughput will be measured using an emulated channel model. Nonetheless, such

Where represents the total efficiency of the ith antenna, and R denotes antenna correlation matrix. The MUX provides a direct link from antenna parameters to MIMO channel capacity, allowing us to easily see how the user body influences MIMO performance. Figure 2 depicts the MUX of a two-port MIMO antenna design for a mobile handset in free space using a hand phantom. The MUX dropped dramatically when the user's hand was presented, with the antennas' total efficiency loss accounting for the majority of the losses.

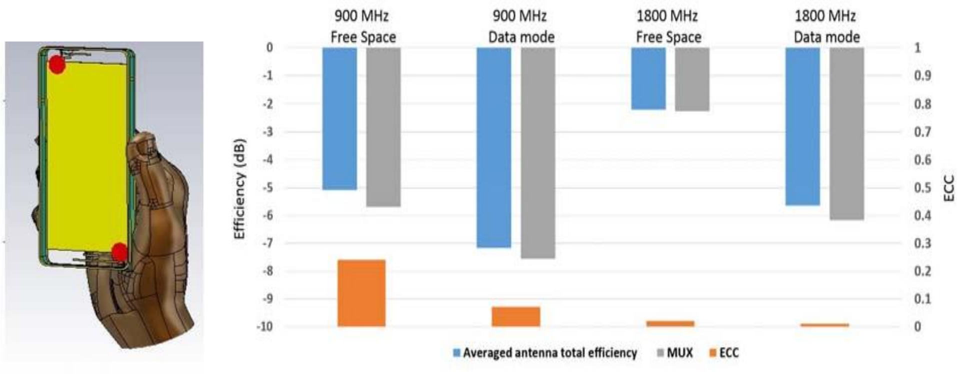


Fig. 2. The simulation model in the data mode, and the MIMO antenna performance variation due to the hand effect.

3. HUMAN BODY EFFECT ON CELLULAR ANTENNA SYSTEM IN FREQUENCY RANG 2

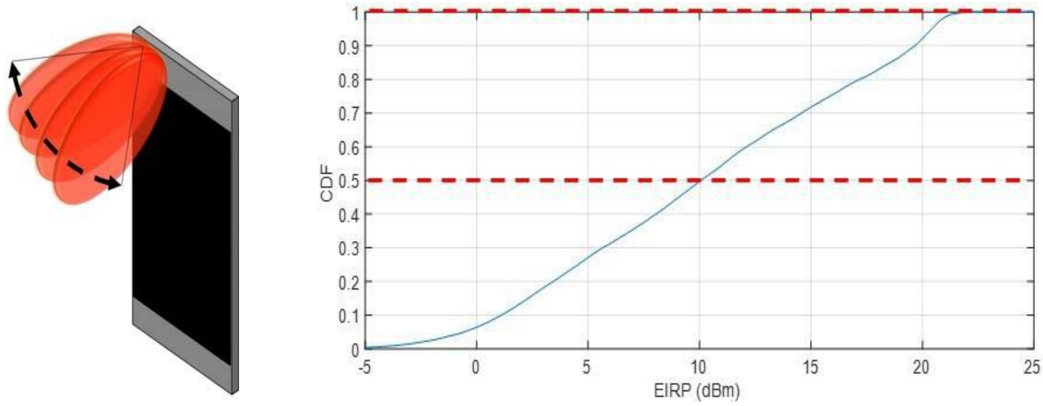
The previous section focuses on human physiological effects on FR1 of 5G NR, which are similar to the physiological effects of previous 4G, 3G, and 2G mobile networks due to adjacent frequency band For a complete analysis is needed to understand what it is So far, four FR2 lines are defined in the 3GPP NR specification [11], as shown in Table II. A new group, n259, is currently under consideration.

TABLE II. NR OPERATING BANDS IN FR2

Operating band	Frequency
n257	26500 MHz - 29500 MHz
n258	24250 MHz - 27500 MHz
n259	39500 MHz - 43500 MHz
n260	37000 MHz - 40000 MHz
n261	27500 MHz - 28350 MHz

In FR1, the user induces a change in the impedance of the antenna by distorting the antenna near the field. In addition, a lot of electrical energy enters and is absorbed by the body. However, due to the relatively short wavelength and depth gradient in FR2, the mismatch loss and absorption loss have been greatly reduced [25]-[27 when shadow loss or the operator the inhibitory body has been the main effect [12] [14].

The shading effect is rarely mentioned in FR1 as the propagation path is assumed to be more dispersed: signals arriving at the mobile handset from many directions, so radiation direction is less important but channel more in multipath components in FR2 due to propagation environment due to the use of beamforming Spherical coverage of mobile handsets is a very basic RF requirement because the antenna system in a UE, especially mobile handsets, needs to be able to receive signals in the desired direction on the sphere by isotopically radiated energy a it is equal (EIRP) and works well on isotropic susceptibility (EIS), respectively.



(a) (b)

Fig. 3. (a) The illustration of mobile handset spherical coverage with beamforming array. (b) The illustration of CDF of EIRP for a mobile handset.

An illustration of the spherical coverage of a handheld mobile device with beam steering capability is shown in Fig. 3(a), and the CDF of EIRP is shown in Fig. 3(b). The mobile handset is categorized as power class (PC) 3 UE in 3GPP, where the uplink spherical coverage requirement in FR2 is listed in Table II.

TABLE III. UE MINIMUM PEAK EIRP AND SPHERICAL COVERAGE FOR POWER CLASS 3 (FREE SPACE)

Operating band	Min peak EIRP (dBm)	Min EIRP at 50 %- tile CDF (dBm)
n257	22.4	11.5
n258	22.4	11.5
n259	18.7	5.8
n260	20.6	8
n261	22.4	11.5

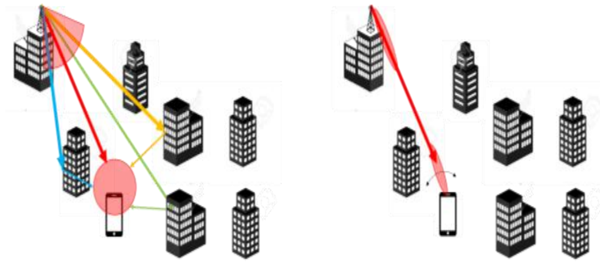


Fig 4. Illustration of the cellular propagation channel (a) in a sub-6 GHz frequency band with an omnidirectional antenna in the UE and (b) in a mmWave frequency band with a beam steering antenna system in the UE.

Though the 3GPP requirement only applies to the free space scenario, the shadowing loss from the user body place a degradation on the spherical coverage and impact on the real-life performance of 5G mobile handset. Therefore, a good understanding of the UE spherical coverage degradation due to the user body effect in FR2 is necessary.

In addition to antenna layout, the characteristics of UE coverage of a circle is also a major challenge for 5G networks, as the demand calculations used for 3G and 4G networks cannot be done for this purpose Traditionally, network operators are over the air (OTA).) UEs in sub-6 GHz cellular bands. Minimum performance information is specified, including total radiated power (TRP) and total isotropic sensitivity (TIS) but neither TRP nor TIS is relevant for the beam-steering capability characteristics of a UE. Characterizing the spherical coverage of a UE requires parameters that can measure radiated power in a particular way.

*In [16], the overall coverage efficiency and scan scheme are described to measure the spherical coverage of beam-steering antenna systems. The entire scan pattern can be obtained from all possible beam steering radiation patterns by obtaining the best possible gain per solid square All covered solid parts of the antenna system can be obtained from its scan the system as a whole will have a threshold gain value sufficient to support the wireless communication link budget The coverage efficiency can be defined as the ratio of the total covered cubic corners to the total sphere surrounding it ie. 4π (see Fig. 2) Recent publications in [8]9*Shading loss due to fuselage and head effects: When we talk about user body effects in FR1, fuselage effects are rarely considered. But its shadow effect has been neglected in FR2 due to its physical size, which can be seen from the actual user intercept measurements at 28 GHz (see Figure 5): far-field radiation patterns of an antenna element are measured between Three use cases with real their users (free space). , data mode, and talk mode) : the antenna element is placed on top of the device and out of reach of the user so hand effects can be excluded based on our analysis in the previous section. Although a clear user body shape shadow region can be observed in the data mode, and the shadow loss in the shadow region is about 25-30 dB The CDF of the EIRP is also plotted in Figure 6: about 2 dB,000. 5 dB and 10 dB at CDF = 100%, 50%, 10 % respectively Decay can be seen. We can see that the user's head is strongly shaped by the radiation pattern of the antenna element because the antenna is effectively closed to the user's head in the speech condition The studies in [13], [28] show that different elements have the same spherical coverage performance in data walk mode with real users, which means solving the problem of body shadows properly by making the element separately for the antenna array Cannot be done In 29], the shadow area of the body can be reduced by combining several systems mounted at the four corners of the

MIMO antenna performance variation due to hand effect

MIMO antenna performance variation due to hand effect

Fig. 5. MIMO antenna performance variation due to hand effect

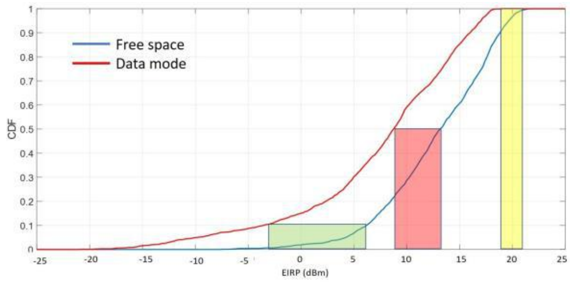
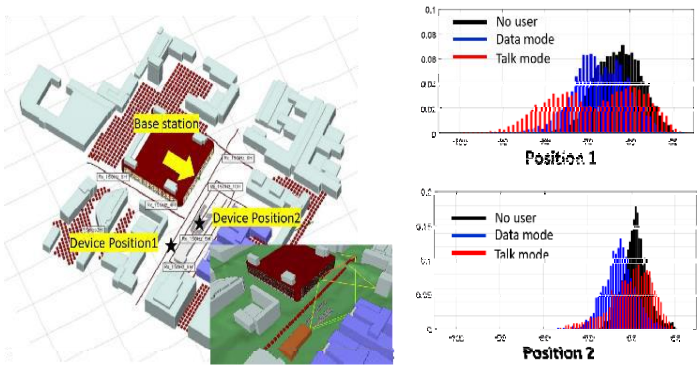


Fig. 6. The CDF of EIRP fin data mode with a real user.



(a) (b)

Fig. 7. (a) The 3D raytracing simulation model at 28 GHz and (b) the RSS PDF of the mobile handset at device position 1 and position 2 with the rotated orientation.

Different with the efficiency loss in FR1, the shadowing effect from a user in FR2 is a directional dependent loss, and thus its impact on a cellular network also depends on the spatial parameters of the wireless channel, e.g., angle of arrival (AoA) and angle of depart (AoD) of the downlink signals. To exam the user body effect on a 5G mmWave wireless link, a 3D raytracing simulation has been carried out at 28 GHz in an urban environment, where multiple buildings with 8-10 m are included (see Fig. 7(a)). The detail of the simulation model can be found in [27].

The probability density function (PDF) of the received signal strength (RSS) of a mobile handset with and without a user is shown in Fig. 7(b). The RSS is simulated at two positions in the environment with the device/user randomly orientated over the horizontal plane. In position 1, the incoming signal is limited to a few directions with a small angle spread (AS) due to the urban canyon effect. As can be observed, the mean value of the RSS does not change dramatically with different use cases, but the standard deviation

has been increased with a broader shadowing region. This behavior is substantially different from user body effect in FR1, and it implies that a considerable uncertainty of the cellular network performance can be expected in the FR2 network, especially if signals of the base station can only come from a single direction.
In contrast, the AS of the incoming signal distributed more uniformly over the horizontal plane when the device is placed in position 2: Several cars are around the user, and they create a rich scattering environment. Consequently, it can be observed that the PDF of RSS in all three use cases become comparable, and the standard deviation has been reduced in all use cases. This result indicates a possible mitigation method of the user body effect in FR2 from the network deployment aspect: Multiple BSs or transmission points (TPs) are desired to be deployed over different angles to illumine the covered area in order to create an angular diversity system which could be more robust against the shadowing loss of user body (see Fig. 8).

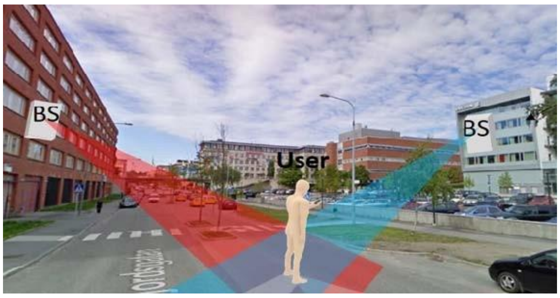


Fig. 8. Deployment multiple BSs to mitigate the user body blockage.

4. CONCLUSION :

The paper "Enhancing Wireless Network Performance Through Addressing Human Body Effects in AAS Systems" highlights the human body effects on wi-fi networks in a different edition and the main takeaways are: Frequency (FR1 and FR2): 1.1. The physiological effects of the user in FR1 are similar to those in LTE systems, resulting in both photovoltaic (TRP) and radiation sensitivity (TRS) losses in mobile phones Designing complex antennas with different antennas is a practical solution. In FR2, the effects of customer physiology lead to blockade losses, especially in spherical antenna arrays. Circular coverage and beam-tracing simulations: Although the 3GPP defines requirements for circular insurance in the free zone, the overall operation itself can add up from consumers to individuals. Beam tracing simulations reveal a significant lack of shadows due to the user's body, especially at high frequencies. 5G networks (FR2) require more than one system and network quality in mobile phones to overcome the physical influence of the individual. Future Directions: Investigate the effect of the user frame in a heavy MIMO antenna configuration in FR1, especially at high frequencies. For FR2 and above, in-depth information on the effect of individual shadows on wi-fi networks is needed. Real-time measurement of consumer's physiological output provides valuable insight. Consider using an extended body phantom at mmWave frequencies for more stable results. In summary, addressing the physical ramifications of gain is essential to improving the overall performance of wi-fi networks, especially as we transition from higher frequency bands to 5G and beyond

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