OPPORTUNITIES IN 6G FOR WIRELESS DEVELOPERS

Customer-Oriented Solutions in 6G

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Executive Summary

6G is an excellent opportunity for wireless companies to gain competitive advantage and to drive business. In this paper, we present 6G enhancements that provide improved communication experience to users. The solutions detailed below are not subject to 3GPP standards because they can be implemented autonomously, as a proprietary performance-enhancing feature, in a wireless product. These are innovations that will become immensely profitable in the coming decade [1].

A major problem in 6G is the inevitably increasing fault rate, due to atmospheric attenuation at high frequencies and network crowding. Disclosed below are methods for a wireless receiver to correct faulted messages in real-time, without a retransmission, using logic and AI. Users will appreciate the increased communication reliability.

Another major problem is beam alignment. Messages in 6G are transmitted on focused beams to optimize signal clarity. Aligning those beams is currently a tedious and energy-intensive process. We developed procedures to align transmission and reception beams autonomously, resulting in better reception and better range.

All of these solutions are suitable for proprietary implementation. UltraLogic6G has obtained patent protection on each method, and is prepared to assist wireless companies in implementing them.

These solutions will propel forward the wireless leaders of tomorrow.

SECTION 1: AUTONOMOUS FAULT MITIGATION BY RECEIVER

This section details methods for wireless receivers to identify and correct message faults autonomously, resulting in improved reliability and lower latency for customers.

Fault Identification by Modulation Quality

The current response to a faulted message is to request a retransmission of the message itself, or the associated FEC (error-correction) data, which wastes precious time and often fails to correct the message.

We have developed a way to use the remaining information in the unfaulted message elements to cure the faults. The receiver first identifies the fault locations by measuring fault signatures of each message element, such as poor modulation or a noisy waveform, and then uses logic or AI to determine the most likely corrected version of the message.

Figure 1 shows an example of a "modulation deviation" indicating a faulted message element. The dots are the regular modulation states of the modulation scheme (QAM16 in this case, but it could be any modulation scheme) and the "o" is the modulation of a faulted message element. The modulation deviation is the amount that the received modulation differs from one of the calibrated states.

The modulation deviation is an excellent indicator of likely faulting because any noise or interference large enough to cause a demodulation error will leave it at some random location on the chart, whereas an unfaulted message element usually is quite close to the original state.

The receiver has direct access to the modulation properties of each message element, based on the signal waveform that 6G receivers acquire natively.

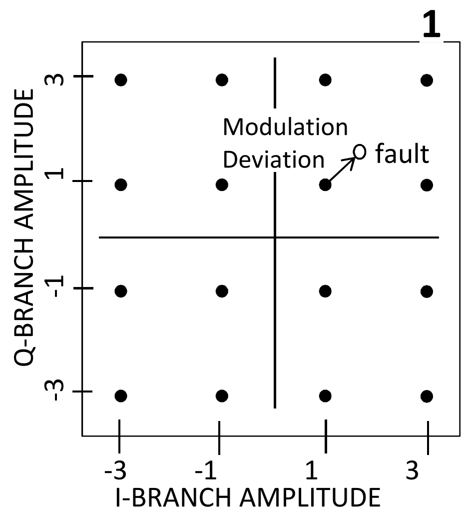

Fig. 1: <u>Modulation deviation</u> is the distance that the received signal differs from the calibrated modulation states.

<u>Fault Identification by Waveform Analysis</u>

The waveform of a faulted message element contains numerous other fault signatures besides the modulation deviation. The signal of each message element has a waveform amplitude and waveform phase. If the noise and interference are strong enough to cause a fault, the amplitude and phase of the signal are almost always distorted.

Figure 2 shows an example of amplitude variations in the received waveform. It is supposed to be flat and uniform (aside from the initial run-up, ignored herein). The variations clearly indicate the fault. The phase is distorted in a similar way, and can also be tested in the same procedure.

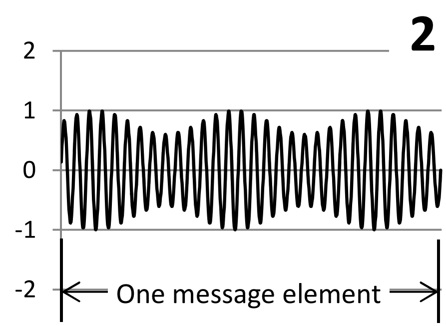

Fig. 2: <u>Amplitude variations</u> in a message element indicate noise or interference, and likely faulting.

Figure 3 shows the distribution of amplitudes or phases received in a single message element. The wide distribution (solid line) is what the receiver would get with the noise depicted in Figure 2. The dashed line is an unfaulted message element, with a small amount of normal variation.

The increased width of the amplitude (or phase) distribution clearly indicates whether the message element is faulted or not.

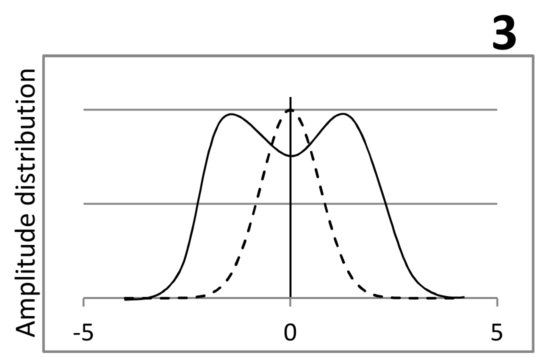

Fig. 3: <u>Distribution</u> of amplitude (or phase) variations in one message element, with noise as in Fig. 2 (solid line) and without noise (dashed).

The digitized data also provides other fault signatures. For example, interference often shifts the frequency offset from the subcarrier center. Also, the polarization angle of the received signal is often changed as well. The receiver can identify faults using all of these signatures in the digitized data.

Figure 4 shows another valuable fault identifier. Here the signal of each message element is compared to all the other message elements, instead of to the "nominal" value. Any outlier is likely faulted. Small deviations from the nominal values are normal, but any message element that deviates substantially from its neighbors is suspect.

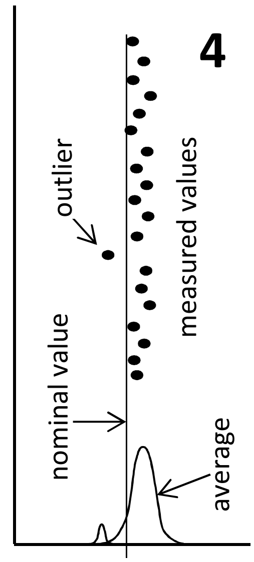

Fig. 4: Outlier fault is detected by deviation relative to the other message elements.

In Figure 4, the message elements are shown as dots, and the overall distribution is shown at the bottom. The calibrated or "nominal" level for that parameter is shown as a line. One of the message elements deviates significantly from the others, and this "outlier" is probably a fault, even though it is not far from the nominal value. Most standard diagnostic methods would miss this likely fault.

The receiver can detect even subtle changes by combining all of these diagnostics (and others not listed) in a statistical model. Or, for even greater fault detection, the data can be put into an AI model that compares the fault signatures and correlates them with faults. The AI model thereby achieves high certainty in identifying each fault in the message.

These fault localization methods can be implemented at extremely low cost, because wireless receivers in 6G are already capable of digitizing the waveform. The procedures can be provided as software, with no hardware changes necessary.

Autonomously Correcting Message Faults

Identifying the faulted message elements is just the first step. The real goal of fault mitigation is to correct the message without asking for a retransmission.

If the fault signatures indicate that there is only one faulted message element in the entire message, then correction is easy. All data messages in 6G include a short error-detection code, sort of like a parity check. So, the receiver can back-calculate the corrected value of that faulted message element using the error-detection code, and the task is done.

If there are multiple faults in the message, but not too many, the receiver can search for the correct version by altering each faulted message element sequentially in a grid-search, while checking the error-detection code. This takes some time, but not as much time as a retransmission.

If there are too many faults for the grid-search method, the best approach is to use artificial intelligence. AI excels at complex problems like message fault correction, but it requires a lot of input data. For example, the AI model can take, as input, the modulation deviation, the amplitude and phase variations, the polarization and frequency offsets, the outliers, and other waveform data described above (and others), for each message element, and generate a number of "candidate" message versions, along with the likelihood value of each candidate version.

The AI can also compare the faulted message to numerous unfaulted messages that the receiver or the application has received in the past. The AI can search for characteristic bit sequences or symbol sequences that indicate how the faulted message elements should (or should not) look. The AI can also check the form and format of the faulted message, comparing to the rules and standards for this type of message, and find whether similar messages have appeared in the past.

For even greater power and versatility, the AI can figure out the meaning or intent of the message, based on the unfaulted message elements and prior received message types. The AI can inductively determine whether the message "makes sense" in the application. The meaning or intent often leads to a valid correction in a single step. AI is extremely fast at this type of problem (after training).

These fault-correcting procedures are virtually instantaneous, zero cost, zero energy consumption (other than the negligible calculation), and readily performed by regular receivers. They are implemented in software alone, without hardware changes.

Message faults cause problems that users really hate. Dropped calls, message errors, poor signal quality -- users will not tolerate much of this. Any company that includes our autonomous fault-correction technologies, directly in the receiver, will gain the immediate appreciation of its customers.

SECTION 2: AUTONOMOUS BEAM OPTIMIZATION BY TRANSMITTER

In this section, methods are presented for controlling beams autonomously. Directed beams are essential in 6G, but they must be carefully aligned. Our solutions avoid the burdensome beam-scanning procedures of the past. Users will benefit from better signal quality, fewer delays, and an improved communication experience overall.

Location-Based Beam Control by Base Station

Messages in 6G are carried on finely-directed transmission and reception beams, but they need to be aimed correctly at the other communicating entity. Currently, beam control procedures require multiple energy-intensive beam-scan sequences with back-and-forth messaging, repeated for each user in the network, and repeated again when the user moves.

We propose a simpler way to align beams by the base station, without burdening the user. Base stations know their own location (latitude and longitude), and can determine the user device location by various means. The base station can then calculate the angle toward the user device, and aim its antenna toward that location. The user then gets optimal communication quality, without beam scanning. UltraLogic6G holds broad patent protection on this method.

For vehicles, we propose an additional solution enabling the base station to efficiently track the users in real-time. Currently, the base station transmits location requests to mobile users frequently, a significant burden. Instead, we propose a digital map (Figures 6A, 6B) maintained by the base station, covering all the territory reachable from the base station's antennas. The base station can track each mobile user in real-time, thereby autonomously maintaining a beam lock.

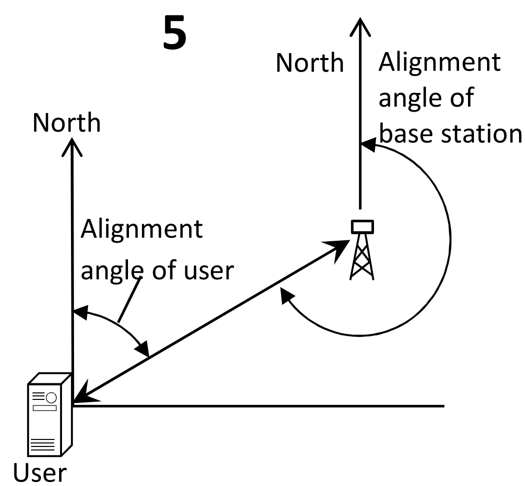

Fig. 5: Antenna alignment. User and base station can calculate the initial antenna alignment angle from the location of the user and location of the base station, avoiding beam scan.

6A

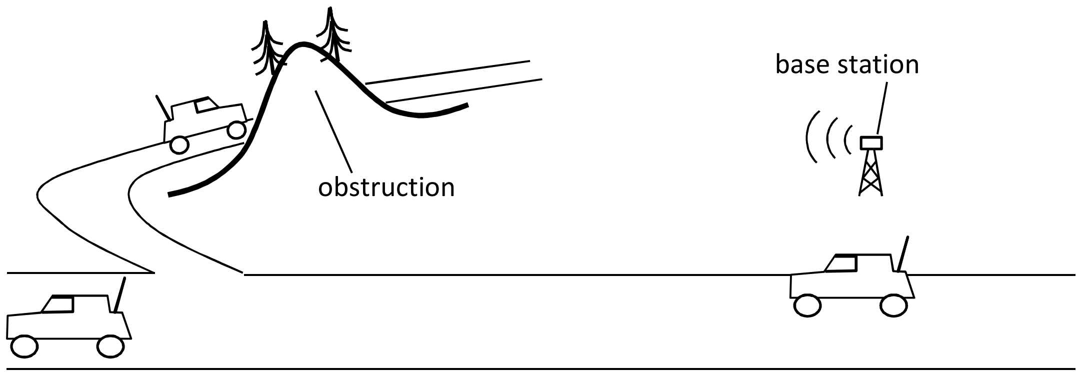

Fig. 6A: Mobile users know their location and the location of base station. They calculate the alignment angle toward the base station for both transmission and reception beams, updating as they move relative to the base station. However, the vehicle passing behind the obstruction has lower receptivity and a weak signal.

6B

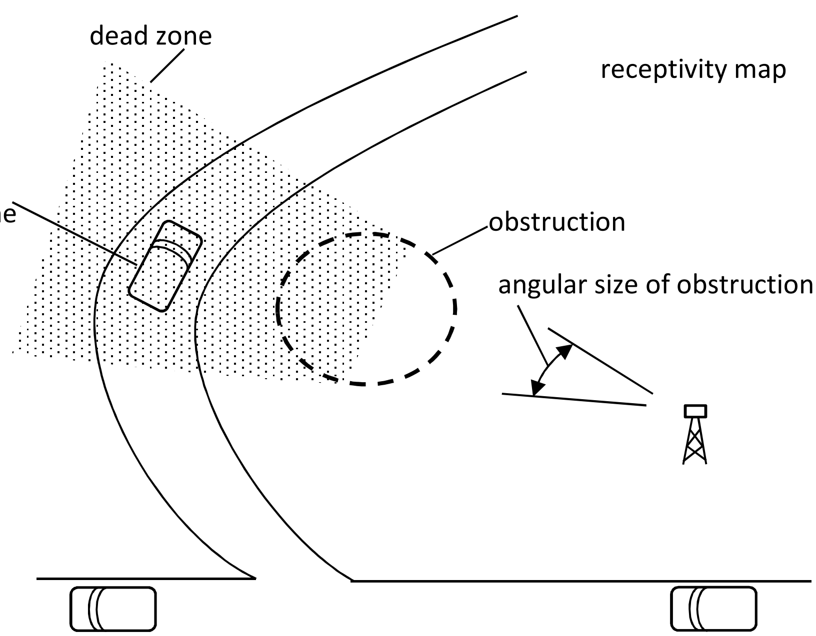

Fig. 6B: Digital map of the area, including receptivity. The base station knows the roads in its area and thus can calculate where each user device is located in time, based on traffic patterns. The base station also knows the receptivity distribution. Then the base station can automatically increase transmitted power to a user when it enters a dead zone, and reduce power again when the user exits the dead zone, thereby maintaining good communication everywhere.

For example, the base station can place each user on the map, upon entry into the network, and then calculate the user's future locations based on the speed of traffic, redirecting the beam accordingly.

The base station can also control the transmission power according to the changing distance to the mobile user device, autonomously and without a tedious power scan.

The base station can also eliminate the dreaded "dead zones" that users are all too familiar with. The base station has measured the receptivity at each point on the map, and can then adjust the transmission power whenever a user enters one.

For even greater beam control, the base station can use an artificial intelligence model to optimize its transmission and reception beams according to the user location, the signal quality received by the base station, the receptivity map, current noise conditions, proximity of other cells, and many other input values. The AI program can then provide optimal choices for the beam direction, width, and power level to keep the user device well-served, while avoiding interference with other users or other networks.

Location-Based Beam Control by User Device

Each user device also aligns its beam toward the base station. In our method, the user device first determines its own location using, for example, satellite signals. It also determines the base station location by any means. The user device then calculates the angle toward the base station, and transmits uplink messages using beams aligned in the direction defined by that angle, without a beam scan. It can also adjust the power based on the distance, autonomously and without a power scan. This will be a boon for battery-constrained users. UltraLogic6G has broad patent coverage on these methods as well.

The receptivity varies with location, due to the changing distance as well as any obstructions. The user device can use a digital map of its environs, including the receptivity, to control the uplink power level. The user's map may be the same as the base station's receptivity map. Compensating power autonomously in real-time, without a power scan, saves time and battery power.

The mobile user device can also correct its transmission and reception frequencies autonomously to compensate for the changing Doppler shift. The Doppler correction is based on the current direction and distance of the base station, and the user's speed and direction of travel.

Like the base station, the user device can also use an AI program to calculate the optimal beam direction, power, width, and frequency shift in real-time as the vehicle moves, turns, changes speed, and travels relative to the base station. The AI program could also adjust the transmission power based on current noise and interference levels to maintain a satisfactory signal quality at the base station, while avoiding excess power transmission. These autonomous real-time adjustments avoid wasting time with legacy downlink power control messages and the like, thereby minimizing the user's power cost.

Autonomous beam control is an enabling factor for our ambitious 6G goals, specifically the goals in throughput, energy efficiency, and message reliability.

Conclusions

UltraLogic6G has developed solutions to some of 6G's most pressing problems. Autonomous correction of faulted messages by the receiver avoids loss of latency, wasted battery energy, and generation of backgrounds. Users can obtain high signal quality even when conditions are poor due to long range or weak signal or network crowding, for example. User communications will be uninterrupted, even when there is frequent faulting, with our real-time message correction. Our solutions provide automatic beam control and fault mitigation, completely transparently to the user, thus enabling the user to enjoy an uninterrupted communication experience of consistently high quality.

The solutions described in this paper - solo fault mitigation and solo beam control - can be implemented in a single company's product operating autonomously, and therefore are not the subject of Standards. Instead, these methods are ideally suited to proprietary implementation by a wireless equipment or software provider. Our solutions provide enhanced communication success, including fast recovery of corrupted messages, better reception despite weak signals and high backgrounds, and substantial energy savings especially for battery-constrained users. In addition, the methods are simpler than the legacy procedures they replace, enabling lower-cost devices to enter the market.

Companies implementing these solutions will greatly profit from increased customer satisfaction due to the improved communication experience. UltraLogic6G has received patent protection on the procedures disclosed herein. We are prepared to work with system developers and wireless equipment producers to implement these improvements in 6G.

UltraLogic6G invites enquiries from wireless stakeholders. For more information, contact:

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Glossary

"Base station", as used herein, includes all network assets communicating with users, including access points, access relay stations, roadside monitors, satellite relays, and the like. The term also includes the core network, backhaul, and other internal systems of the network assets, unless otherwise called out.

"User device", as used herein, refers to the radio portion of user equipment, specifically the transmitter, receiver, antenna, signal processing electronics, and demodulation processor. The term also includes AI models for fault mitigation and message interpretation and the like, when present.

3GPP (Third Generation Partnership Program) is the primary organization for wireless technical specifications, and with seven "Partner" organizations, promulgates universal wireless standards.

OFDM (Orthogonal Frequency-Division Multiplexing) means transmitting message data in multiple frequencies (subcarriers) at the same time. The receiver then measures the subcarrier signals to separate and demodulate the message elements.

IoT (Internet of Things) devices are low-cost, reduced-capability wireless sensors and actuators.

SNR (Signal-to-Noise Ratio), as used herein, includes interference, stochastic noise, clock drift, and all other effects causing message faults, unless specifically indicated.

FR1 and FR2 are frequency ranges. FR1 is 7.125 GHz and below (and up to 8.4 GHz in 6G). FR2 is 24.25 GHz and up. FR2 is often called mmWave, although a wavelength of 1 mm actually corresponds to a frequency of 300 GHz.

BPSK (binary phase-shift keying) is phase modulation at constant amplitude with 2 states separated by 180 degrees, carrying 1 bit per symbol.

QPSK (quadrature phase-shift keying) is phase modulation at constant amplitude with 4 states separated by 90 degrees, carrying 2 bits per symbol

QAM (Quadrature Amplitude Modulation) is a modulation scheme in which the message data is encoded in the amplitudes of two orthogonal signal components, termed I and Q branches.

A resource grid is an array of resource elements, arranged by symbol-times in time and subcarriers in frequency.

A message element is a single modulated resource element of a wireless message.

A "symbol-time" is the time duration of a single message element.

References

[1] The following patents cover the methods discussed in the text, and can be found at: www.UltraLogic6G.com.

US Patent	Title
FAULT MITIGATION:	
11,387,935	Error Detection and Correction by Modulation Quality in 5G/6G
11,398,876	Error Detection and Correction in 5G/6G Pulse-Amplitude Modulation
11,405,131	AI-Based Error Detection and Correction in 5G/6G Messaging
11,411,795	Artificial-Intelligence Error Mitigation in 5G/6G Messaging
11,418,281	Error Correction by Merging Copies of 5G/6G Messages
11,456,821	Retransmission of Selected PAM-Modulated Message Portions in 5G/6G
11,463,296	Error Correction by Merging Copies of PAM-Modulated 5G/6G Messages
11,469,856	Retransmission of Selected Message Portions in 5G/6G
11,516,065	Identifying Specific Faults in 5G/6G Messages by Modulation Quality
11,522,636	Modulation Quality and Fault Mitigation in 5G/6G
11,522,637	Selection of Faulted Message Elements by Modulation Quality in 5G/6G
11,522,638	Artificial Intelligence Fault Localization in 5G and 6G Messages
11,522,745	Identification and Mitigation of Message Faults in 5G and 6G Communications
11,546,201	Selection of Message Elements based on Modulation Quality in 5G and 6G
11,563,515	Fault Recovery by Selection based on Modulation Quality in 5G/6G
11,616,679	Detection and Mitigation of 5G/6G Message Faults
11,695,612	Method to Locate Faulted Message Elements Using AI in 5G and 6G
11,736,332	Enhanced Fault Correction and Noise Avoidance in 5G/6G Networking
11,770,207	Method for Mitigating Branch-Amplitude Faults in 5G and 6G Messages
11,770,209	Signal Quality Input for Error-Detection Codes in 5G and 6G
11,784,764	Artificial Intelligence for Fault Localization and Mitigation in 5G/6G
11,799,585	Error Correction in 5G and 6G using AI-Based Analog-Digital Correlations
11,811,579	Recovery of Corrupted 5G/6G Messages by Modulation Quality
11,817,950	AI Means for Mitigating Faulted Message Elements in 5G/6G
11,824,667	Waveform Indicators for Fault Localization in 5G and 6G Messages
11,843,468	Fault Detection, Localization, and Correction by 5G/6G Signal Quality
11,848,774	AI-Based Analog-Digital Fault Detection and Localization in 5G/6G
11,848,788	AI-Based Waveform Analysis for Fault Localization in 5G and 6G
11,849,349	Fault Mitigation Using Signal Quality and Error-Detection Codes in 5G/6G
BEAM CONTROL:	
11,398,850	Rapid Doppler Correction for Mobile V2X Communication in 5G/6G
11,411,612	Location-Based Beamforming for Rapid 5G and 6G Directional Messaging
11,424,787	AI-Based Power Allocation for Efficient 5G/6G Communications
11,438,033	Location-Based Power for High Reliability and Low Latency in 5G/6G
11,509,381	Resource-Efficient Beam Selection in 5G and 6G
11,533,084	Automatic Adjustment of Transmission Power for 5G/6G Messaging
11,581,919	Transmission Power Compensation by Attenuation Mapping in 5G and 6G
11,611,375	Location-Based System Information and Doppler Correction in 5G/6G
11,644,522	Triangular Beam Configurations for Rapid Beam Alignment in 5G and 6G
11,652,533	Rapid Alignment of User Directional Beams in 5G/6G Networks
11,689,249	Geographical Localization of 5G/6G Network Users and Base Stations

11,782,119 Phased Beam-Alignment Pulse for Rapid Localization in 5G and 6G
2023/0100826 Throughput Enhancement by Location-Based Power Adjustment in 5G and 6G
2023/0179261 Automatic Condition-Based Adjustment of Transmission Power in 5G and 6G
2023/0246699 Low-Complexity Procedure for 5G/6G Beam Alignment
2023/0283322 Beamforming Communication Method for Wireless Devices in 5G and 6G
2023/0408622 Low-Complexity Beam Alignment by Directional Phase in 5G and 6G
2024/0045013 Deterministic Low-Complexity Beam Alignment for 5G and 6G Users