SOLUTIONS TO 6G WIRELESS ROADBLOCKS

Achieving the Ultimate Network Performance

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Executive Summary

Major roadblocks need immediate attention for 6G to become a successful business reality. Developers are under great competitive pressure to deliver large improvements over 5G. And simply recycling 5G modalities will not be sufficient to achieve the desired success. Therefore, without new and truly creative innovative solutions, 6G faces serious shortfalls and unsatisfactory compromises that will negatively affect adoption and the hoped-for increases in revenue.

Those roadblocks are:

(a) beam control to maintain focus on the intended recipient without wasting energy;
(b) inevitable increase in message faulting due to network crowding and attenuation;
(c) need for improved methods for high-throughput communications.

In this whitepaper, we offer winning solutions to these roadblocks. Each 6G solution can be implemented by allowing base stations and user devices to select the desired new procedures.

It is universally understood that time is of the essence for major business victories. We therefore recognize that developers should be made aware of creatively significant, practical solutions as soon as possible, and certainly before the next Standards Release is published.

Herein, we propose a mutually successful business outcome: UltraLogic6G seeks a 3GPP Member company to acquire our protected IP [1], incorporate it in the Standards, and enjoy substantial licensing revenue thereafter.

SECTION 1: PROPOSED STANDARDS FOR BEAM CONTROL

The conflicting goals of high throughput and low energy consumption present a real challenge in 6G. In this section, methods are outlined for improved beam alignment without beam scanning, improved power control without power scanning, and improved feedback at low cost.

Earliest Possible Disclosure of Base Station Location

Beamforming is essential for meeting the rising demand. Currently, beam alignment involves a tedious and energy-intensive beam scan procedure with multiple back-and-forth messages. We propose a simpler alignment method that enables the user to aim its beam toward the base station upon first contact.

Before making contact with the base station, new user devices receive a system information message (the SSB message) on the broadcast channel. We propose that the base station's location be added to the SSB message. A prospective user device can then read the location with the SSB message, calculate the angle relative to its own location, and align its beams immediately - without a beam scan.

In addition:

1. The user device can use its directed reception beam to receive other system information data, such as the SIB1 message, and other messages.

2. The user device can use a directed transmission beam to transmit the initial entry request (the random-access preamble), and other access messages, to the base station.

3. The user device can calculate the distance to the base station according to the location data, and thereby adjust its transmission power for proper reception, without a power scan.

Figure 1 shows how the modified SSB message would look to new user devices. The user device first synchronizes with the base station's clock using the PSS and SSS portions, and receives the BPCH data as usual. The user device then reads the location data from the fifth symbol-time, containing the latitude, longitude, and elevation of the base station's antenna. The user device can then align its own beam toward the base station, without a beam scan, in time to receive the SIB1 message, thereby obtaining far greater signal clarity. Then, using the calculated power level and the calculated alignment angle, the user can transmit a random-access preamble to the base station, thereby initiating the process of joining the network.

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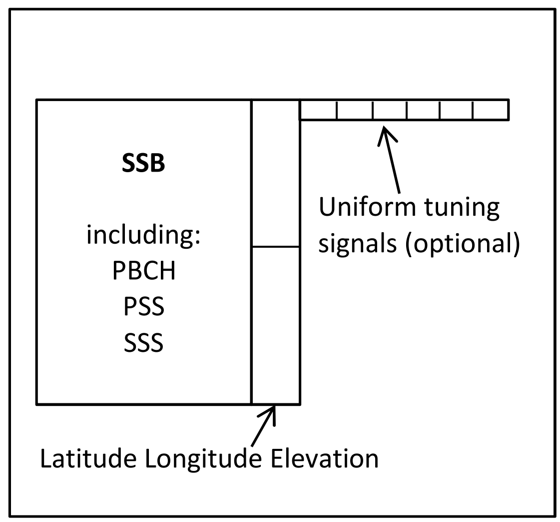


Fig. 1: The first system information message (SSB), followed by the latitude and longitude of the base station's antenna, and a series of uniform tuning signals.

By avoiding a beam scan and a power scan, the user saves time, resources, and energy. The cost is extremely low, just a single symbol-time added to the regular SSB message.

The figure also shows a string of "uniform tuning signals" after the location data. These are unmodulated signals, all the same, that the user can use to fine-tune its reception beam, if desired.

The user device can also inform the base station of its location early in the initial access procedure. For example, the user can use a selected code for the RACH signal, or it can append its location data to the Msg3 of a four-step access procedure, or the MsgA of a two-step procedure, or in a subsequent message. The base station could then begin using directed beams and appropriate power for subsequent communications with the user device.

A 3GPP Member company can add these valuable features to the 6G standards. UltraLogic6G is prepared to assist that Member company in doing so.

Value-Chain Analysis for Early Location Disclosure

For users:

For greatly improved signal clarity, users should begin using aligned reception and transmission beams as early in the initial-access procedure as possible. Beam alignment requires that the user device know the direction toward the base station antenna. In addition, if the user knows the distance, then the user can apply the correct transmission power to its RACH entry message, thereby avoiding a time-consuming and non-deterministic power scan.

For Networks:

The base station also benefits from early beam alignment, with improved signal strength and background avoidance while receiving uplink messages, and by saving power on downlink messages to each user. The base station can proactively adjust its transmission power to each user according to the distance, if known, thereby avoiding the time and cost of multiple power adjustment messages.

Angle-Dependent Alignment Pulse

An entirely different beam alignment option is shown in Figure 2. Here the base station transmits an "angle-dependent alignment pulse", which is a single pulse tailored to have a different phase in each direction all around the base station. A user device can determine its alignment angle by detecting the pulse and measuring the phase. All of the user devices can align their beams simultaneously, with just one pulse from the base station.

The angle-dependent alignment pulse has many advantages. It enables simultaneous alignment of all the users at low cost. It eliminates the time-consuming and energy-consuming beam scan for each user device. And it is easy – every wireless user device can measure the phase of a pulse.

The base station can also transmit a "calibration" pulse, which has the same phase all around. User devices can compare the two pulses and get better accuracy.

The base station can also transmit a "vernier" pulse with a much higher phase gradient, such as varying a full 360 degrees of phase in just 90 degrees of angle. This enables the users to determine their alignment angle with better precision.

The user device can then inform the base station of the alignment angle, so both entities can use directed beams.

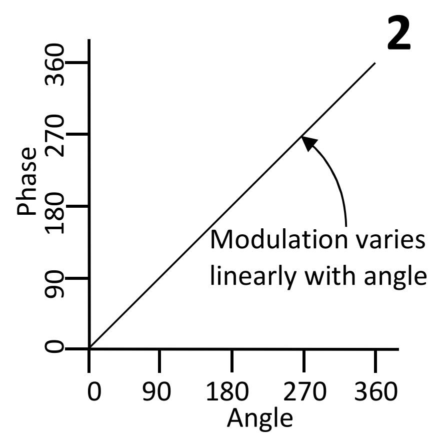


Fig. 2: Base station transmits a single pulse modulated to have a different phase (or amplitude) at each angle.

In an alternate version, the base station can transmit 3 or 4 pulses, simultaneously in subcarriers, each pulse having different amplitudes in different directions. The user device can then compare the amplitudes received and unambiguously determine the alignment angle. In this version, a reduced-capability IoT device, which may be unable to quantify the phase explicitly, can still obtain instantaneous alignment using amplitude measurements alone. As a further option, the base station could transmit the angle-dependent phase pulses and the angle-dependent amplitude pulses simultaneously in a single OFDM symbol, and each user could analyze whichever pulse type it prefers, or both.

We propose that a 3GPP Member company add the angle-dependent alignment pulse as an option to the 6G standards. This will enable fast and easy beam alignment without a beam scan, saving substantial energy and avoiding background generation.

Value-Chain Analysis for Angle-Dependent Pulse

For users:

The angle-dependent alignment pulse(s) can be placed before the SSB message on the broadcast channel, thereby enabling all users to align their beams before receiving the SSB message, and hence to receive the SSB with greater clarity and fewer (or none) costly misreads of the critical PBCH information.

For Networks:

Transmitting the few angle-dependent pulses requires negligible extra power, but saves a huge amount of transmission power and beam scanning overhead for the network. Both analog and hybrid antenna transmissions are possible.

SECTION 2: PROPOSED STANDARDS FOR FAULT MITIGATION

Solutions for reducing message faulting at high frequencies are presented in this section. Message faulting in 6G is a serious limitation, especially at high frequencies. We propose a versatile modulation scheme with wider phase margins, and the versatility needed to optimize reception.

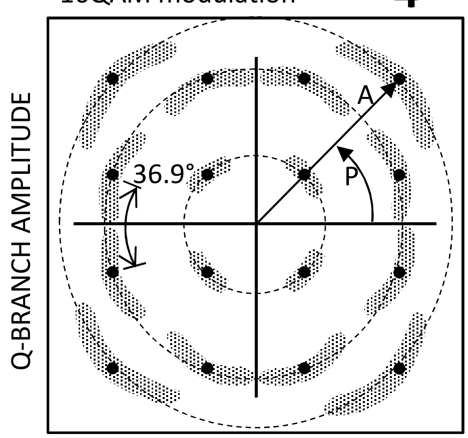
Amplitude-Phase Modulation and Phase Noise Mitigation

Most data messages are modulated in QAM (quadrature amplitude modulation) in which the signal is composed of two orthogonal "branches" termed I and Q. Receivers naturally process the received signal in orthogonal components, so 6G uses QAM as a default.

Figure 4 shows a constellation chart for 16QAM. The dots are states of the modulation scheme, and the gray blobs represent the expected phase noise at the frequencies of 6G.

The amplitude (A) and phase (P) of the overall waveform are also indicated. It is easy to calculate A and P from I and Q, and vice versa.

16QAM modulation **4**



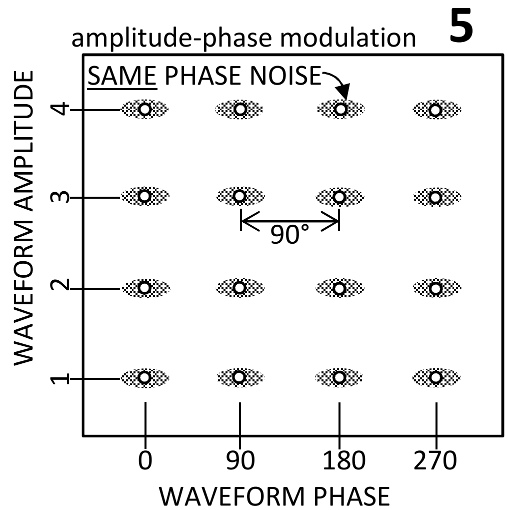
Some of the QAM states are so close together, the phase noise distributions almost overlap, and this causes message faults. In 16QAM, the minimum phase separation of 36.9 degrees is far too small for 6G. This is the source of most phase-noise faulting in 6G.

Dotted circles also indicate the waveform amplitudes of the states. Although the branches are modulated in four amplitude levels, there are actually only three waveform amplitudes in 16QAM, as you can see. This results in crowding of the states in the phase direction.

To solve the problem of message faulting, we propose an alternative modulation scheme, "waveform amplitude-phase modulation" (related to Polar and APSK, among others) in which the amplitude and phase of the overall waveform are modulated according to the message data. Figure 5 is a chart of its states. There are 16 states, same as 16QAM, but they are more widely spaced apart.

In fact, every state in Figure 5 has a full 90 degrees of phase margin, which greatly reduces message faulting. The gray blobs in Figure 5 represent EXACTLY THE SAME PHASE NOISE as in Figure 4. They look smaller because the phase margins are much larger in amplitude-phase modulation. Consequently, phase faulting will be much less problematic in 6G if we use amplitude-phase modulation instead of QAM.

Also note that in Figure 5 there are four amplitude levels instead of three, and they are equally spaced. Waveform amplitude-phase modulation makes maximum use of the available modulation space for information encoding. Thus the benefit of reduced phase faulting does not result in less throughput - it provides exactly the same information density as QAM of the same order.



Waveform amplitude-phase modulation is easy to implement, with regular hardware and regular signal processing. The receiver calculates the waveform A and P values from the I and Q branch values, and demodulates with A and P. No changes are needed in the transmitter or receiver hardware.

More specifically: The transmitter modulates the message using amplitude-phase modulation of the waveform and transmits it. The receiver receives the net signal, and separates it into I and Q branches as usual, and measures the branch amplitudes as usual. Then, the receiver calculates the waveform amplitude and waveform phase as follows: $A=\sqrt{(I^2+Q^2)}$ and $P=\arctan(Q/I)$. The receiver then demodulates in A and P. And that's all there is to it! Amplitude-phase modulation provides wider phase margins and greatly reduced phase faulting in 6G messages, at zero cost.

We propose that a 3GPP Member company include, as an option, waveform amplitude-phase modulation in 6G, especially at high frequencies where phase faulting is otherwise a limiting factor.

Value-Chain Analysis for Phase Noise Mitigation

For users:

For users, the primary benefit of waveform modulation is the greatly reduced incidence of phase faulting, due to the larger and uniform phase margins on each state. Advantageously, the receiver can use standard signal processing, with only the addition of two software commands to convert the branch amplitude values into the waveform values before demodulating.

For Networks:

Due to the larger phase margins provided by waveform modulation, phase faulting is greatly reduced, even at high FR2 frequencies. Networks implementing waveform modulation can access much higher frequencies than legacy modulation schemes such as QAM of any order, thereby obtaining the large bandwidths needed for the projected demands of 6G users. The cost is zero, other than the small software update to implement demodulation, as mentioned.

Asymmetric Modulation

Another big advantage of amplitude-phase modulation is that it enables asymmetric modulation, in which the number of amplitude levels is different from the number of phase levels. This allows the base station to select a modulation scheme specifically optimized to combat the current noise environment. QAM has nothing comparable.

For example, in Figure 6 there are 8 amplitude levels and 2 phase levels, 16 states in all, each state with a full 180 degrees of phase margin. This would be ideal at very high frequencies where phase noise is limiting. At low frequencies, where amplitude faults prevail, the network could use asymmetric modulation with more phase levels and fewer, spread-apart amplitude levels.

Asymmetric modulation is a valuable feature because it enables the base station to shape the modulation scheme to mitigate current fault types effectively. QAM has no such capability because the I and Q branches are logically equivalent.

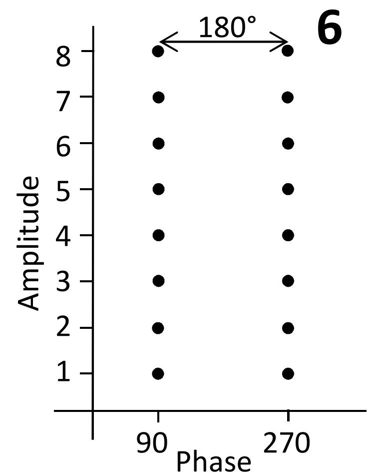


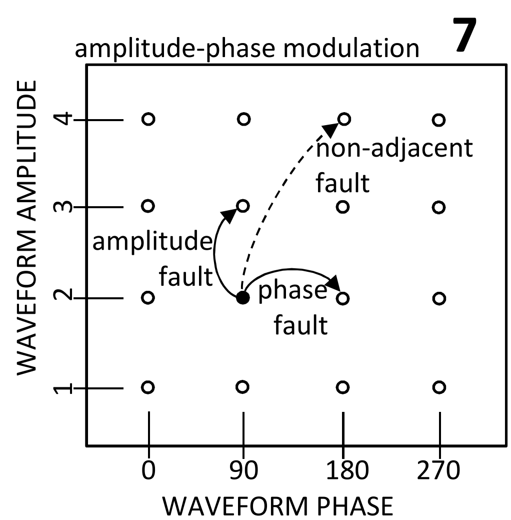
Fig. 6: Asymmetric modulation. Namp=8, Nphase=2, Nstates=16

Another big advantage of amplitude-phase modulation is that message faults can be diagnosed as due to phase noise or amplitude interference, or some other cause, leading to a rational mitigation.

Figure 7 shows the difference. The black dot is the transmitted state. A phase fault is a distortion of one phase level, and an amplitude fault is a distortion of one amplitude level. A non-adjacent fault is off by multiple A and P levels.

Each type of faulting requires a different type of mitigation strategy. By determining the current fault types, the base station can intelligently select a better modulation scheme.

Fault-type analysis is difficult in QAM because noise scrambles the I and Q branches, which conceals the source of the problem. In QAM, faults are just faults, so the standard response is to reduce the modulation order, which reduces throughout.



Due to the many advantages of waveform amplitude-phase modulation, and the zero cost of using it, we propose that a 3GPP Member company present this option in the next standards Release.

Value-Chain Analysis for Asymmetric Modulation

For users:

Waveform modulation greatly simplifies fault diagnosis, readily separating sources of amplitude noise, phase noise, and interference, which require different mitigations. When a user measures an excessive rate of faults of one type, it can request a suitable change of modulation scheme.

For Networks:

Asymmetric modulation enables the base station to choose from a wide range of constellation charts, thereby enabling an effective mitigation of each type of message fault. Such flexibility is essential for network performance optimization in 6G.

SECTION 3: PROPOSED STANDARDS FOR NETWORKING

In this section, multiple innovations are disclosed enabling networks to save time and energy while achieving higher message reliability and higher throughput in 6G.

Demarcations to Identify Downlink Messages

For battery-constrained users, a major hurdle is simply recognizing their downlink control messages (DCI) on the downlink control channel (PDCCH). The user does not know when their DCI messages will occur, nor at which frequency, nor the length. So the user has to check every possible combination, and must do so rapidly during a single symbol-time of transmission to keep from missing its messages. This is a monumental task.

Another problem is that the user's identification is scrambled with the embedded error-detection code. This forces the user to demodulate and decrypt and unscramble each one of those myriad combinations of time, frequency, and length. Low-cost processors cannot possibly keep up.

A third problem is that scrambling the ID makes it impossible for users to correct a faulted message, or even to recognize that a faulted message was intended for that user. As a result, numerous retransmissions are requested until finally a perfect version is finally received - a time waster.

Networks have tried to solve the DCI problem by restricting user messages to certain "search spaces". This provides only minimal relief, while increasing latency, and does nothing to recover faulted-messages.

Figure 8 shows a low-cost solution. The base station can "demark" each downlink control message with easily-recognized signals. In this case, the demarcation is a blank resource element with no transmission in it. The user device can easily recognize the blanks, thereby extracting each message without searching. This alone would greatly reduce the user's computation burden.

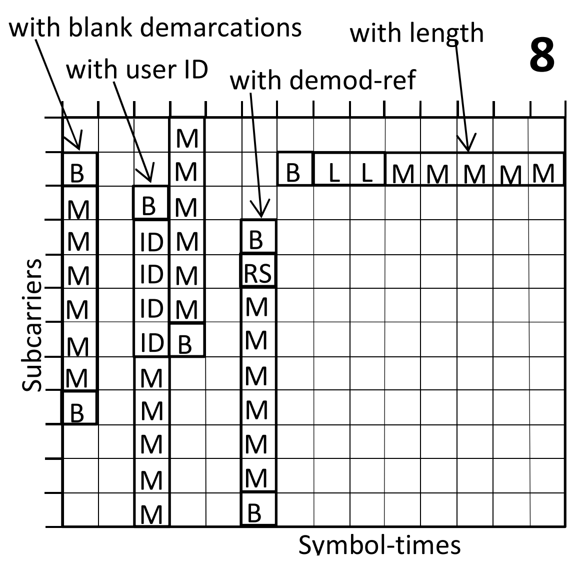


Fig. 8: DCI messages (M) can be demarked by a blank (B) resource element at start and end. They can also include the recipient's identification (ID), a demodulation reference signal (RS), and the message overall length (LL), to assist the user device.

In addition, the user's identification can be provided in an encrypted form for privacy, but NOT scrambled with the error-detection code, as shown in the figure. This would assist the user even further in recognizing its messages. It would also enable the user device to correct faulted messages, which is otherwise not possible. The extra resources are partially compensated by reducing the CRC back to 16 bits, an 8-bit savings.

As a further option, the network could demark the user's data messages as well as the control messages. In that case, the user can easily find its data messages. The user no longer needs DCI messages for downlink scheduling, and the network can stop transmitting them for that purpose. This would result in lower latency, lower energy consumption, lower background generation, and vastly simpler reception for user devices.

Therefore, we propose that a 3GPP Member company add the option of demarking downlink control and/or data messages with a recognizable signal (such as blank), and also an option that the user ID not be masked by the error-detection code.

Value-Chain Analysis for DCI Demarcations

For users:

DCI demarcations enable user devices to find their downlink messages without the monumental amount of computation currently required. Additionally, including the recipient's ID not masked by the error-detection code would enable the recipient to recognize its messages even when faulted, thereby enabling the recipient to correct the faults instead of wastefully requesting a retransmission. Although consuming a few resource elements, many users would opt for these features if available.

For Networks:

Demarcations would reduce the false positive rate sufficiently that the network could return to the original CDC length of 16 bits instead of 24, as mentioned. In addition, eliminating user search spaces would greatly simplify the downlink scheduling task. As an option, the network could eliminate DCI messages for downlink scheduling entirely, by demarking the PDSCH messages instead, and including the recipient's ID in the data message, thereby greatly relieving the downlink control channel, reducing overall latency, and enabling in-receiver fault correction - a major enhancement to network operations.

Temporary QoS Elevation

Message priority is determined by the QoS (quality of service) requested by the user. Emergency responders request high QoS for priority communication, whereas a simple IoT device, such as a temperature sensor, would use a low QoS to save money.

However, there are times when a high-QoS user wishes to transmit a low-priority message such as a routine confirmation. There are also times when a low-QoS user suddenly needs fast service, for example the temperature sensor reporting a fire. Currently, users can only change their default QoS. Transmitting a single message with a different priority involves multiple steps, and changing back requires more messages, a costly delay.

What's needed is a "temporary QoS" option in which the user device can specify an increase or decrease in the QoS handling of a single message, without changing the default. For example, the user device can append a brief code to its scheduling request or its BSR (size) message, indicating whether a temporary increase or decrease in QoS is needed.

Therefore, we propose that a 3GPP Member company should add an option in 6G (or sooner) enabling user devices to request a QoS elevation or reduction for a single uplink message. Users will appreciate the added flexibility.

Value-Chain Analysis for Temporary QoS

For users:

The option of quickly sending an alarm message could be life-saving. Temporary QoS avoids the time-wasting requirement to change the default QoS before, and then after, transmitting the alarm message.

For Networks:

Enabling temporary QoS options may help the network demonstrate the required level of emergency preparedness. In the unlikely event that the Temporary QoS service is abused by a user, the network can temporarily or permanently withhold the service from that user.

Short-Form Demodulation Reference

A demodulation reference is a short transmission indicating the amplitude or phase modulation levels of the current modulation scheme. The receiver can then compare the modulation levels of a message with those of the demodulation reference, and thereby negate the effects of noise (assuming the demodulation reference is close enough to the message).

Currently, demodulation reference signals are multi-symbol constructs encoding various information other than the predetermined modulation levels.

Therefore, we propose a shorter, simpler, non-encoded "short-form" demodulation reference that exhibits a subset of the modulation levels, but enough levels that the receiver can easily fill in the missing levels by interpolation.

The short-form demodulation reference may occupy just a single resource element. The short-form demodulation may display the maximum amplitude level in the I branch and the minimum (most negative) level in the Q branch, from which the receiver can fill in the intermediate levels. For waveform amplitude-phase modulation, the maximum amplitude and phase levels may be provided. In each case, the receiver can determine the remaining levels. Such a brief signal can be placed in closer proximity to the message, and even embedded within the message, thereby providing highly localized noise cancellation.

An advantage of short-form demodulation references is that they are small enough to be added to each message, at negligible cost, thereby avoiding dependency on the regular scheduled references which are often too distant from the message to provide an accurate amplitude calibration. For additive noise (which most wireless noise is), it is sufficient to specify just one or two levels, such as the maximum and minimum amplitudes, and the receiver can calculate the rest.

Therefore, we propose that a 3GPP Member company add short-form demodulation references as an option to the 6G standards, to provide an extremely granular noise cancellation option.

Value-Chain Analysis for Short-Form References

For users:

Recipients can demodulate messages that contain short-form calibrations, included in or adjacent to the message, more reliably than with distant scheduled demodulation references which are typically found elsewhere in the resource grid, too far from the message (or part of the message) to provide a precise noise cancellation.

For Networks:

Since the short-form demodulation references occupy only a single resource element, they conserve resource space and minimize transmission energy. Short-form demodulation references could also be embedded in uplink messages, greatly facilitating the base station in receiving weak messages from users, at negligible cost.

<u>Guard-Space Demodulation Reference</u>

As an alternative demodulation reference option, the guard-space between symbols could be re-purposed as a demodulation reference. This would provide a fresh calibration in each symbol-time of the message. The guard-space is a short region just before the message data, and serves to prevent inter-symbol interference. Currently, the last portion of the message data of each message element is copied into the guard-space, but this is not absolutely required.

Instead, we propose that a demodulation reference be placed in the guard-space of a single subcarrier, or alternatively the guard-space of a complete OFDM symbol. (The OFDM symbol is a sum of hundreds of subcarrier signals, and has a much larger bandwidth.) In either case, the guard-space demodulation reference could then provide local noise cancellation at no extra cost in terms of resource area, transmitted power, and energy consumed.

Therefore, we propose that a 3GPP Member company promote an option of putting a short-form demodulation reference in each guard-space of each message, for enhanced noise cancellation.

Value-Chain Analysis for Guard-Space Demodulation Reference

For users:

Messages with guard-space demodulation references have the advantage of modulation calibration as close as possible to the message data, an extremely localized calibration. As an option, the guard-space demodulation reference could be applied only to the resource elements of messages addressed to users that have requested this option, while other users' messages, and the OFDM symbol as a whole, would remain unaffected.

For Networks:

Inserting the demodulation references in the guard-space conserves resource area and transmission power, while continuing to prevent inter-symbol interference. When applied by user devices in uplink messages, the guard-space demodulation references would provide enhanced localized noise cancellation at zero resource cost.

Zero-Power States

The high throughput goal of 6G requires packing as much information into each message element as possible. Currently, the modulation schemes planned for 6G include QPSK and various orders of QAM.

We propose to add new modulation states, termed "zero-power" states, which the receiver can easily and unambiguously recognize.

Figure 9 shows the four states of QPSK as dots. They are equally-spaced phases at constant amplitude. The new state (circle at the center) has zero power transmitted, that is, a blank message element. The fifth state enables shorter messages due to the higher information content. Any signal received during the zero-power state can be used as a quantitative measure of the noise including phase, leading to more effective mitigation.

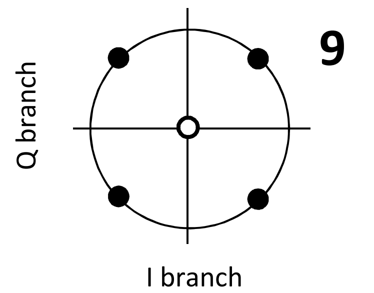


Fig. 9: A fifth zero-power state in QPSK is easily discriminated, and results in higher throughput.

Figure 10 shows 16QAM, slightly adjusted, plus eight new states in which one of the I or Q branches has zero power, and a central new state with zero power in both branches, that is, nine new states in total.

In these and other cases, the information density is increased with zero-power modulation states, resulting in shorter messages and hence higher throughput, at no cost.

As an option, one of the zero-power states could be reserved for special functions, such as demarking the start and end of messages, among many other possible uses.

Therefore, we propose that a 3GPP Member company should introduce modulation schemes including zero-power states as an option in 6G, for higher throughput and thus lower transmission energy expended.

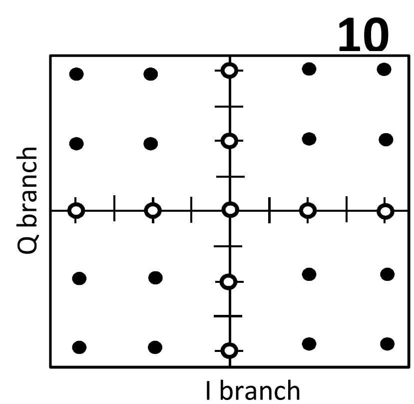


Fig. 10: 16QAM has 16 states in I and Q branches. Here 9 additional states are added, having zero power in one or both branches.

Value-Chain Analysis for Zero-Power States

For users:

Zero-power states enable users to transmit shorter messages, thus saving transmitter power at zero incremental cost, and without increasing the fault rate. Users can quantify the background by measuring the noise amplitude and phase during a zero-power state.

For Networks:

Networks can use the zero-power states as flags indicating something other than message data, such as DCI demarcations, or separators between a message and its demodulation reference.

Synchronization and Timing

High-speed wireless is critically dependent on precise time synchronization between the transmitting and receiving entities. Any deviation results in message faults, among other problems.

Currently, each wireless user is expected to synchronize with the base station using a time-consuming, message-heavy legacy procedure.

Therefore, we propose a simpler, low-complexity synchronization procedure, sufficient to enable proper uplink and downlink communication with a base station. Specifically, the new procedure enables the user device to (a) adjust its clock rate to match the base station, including a Doppler shift if any, (b) determine an arrival time of downlink messages, accurate to a fraction of a symbol-time including the one-way propagation time, and (c) determine a timing advance, sufficient to cause its uplink messages to arrive at the base station aligned with the base station's resource grid, including the one-way propagation time (Figure 11).

The new procedure satisfies all those requirements, is quite simple, and occupies just a few resource elements.

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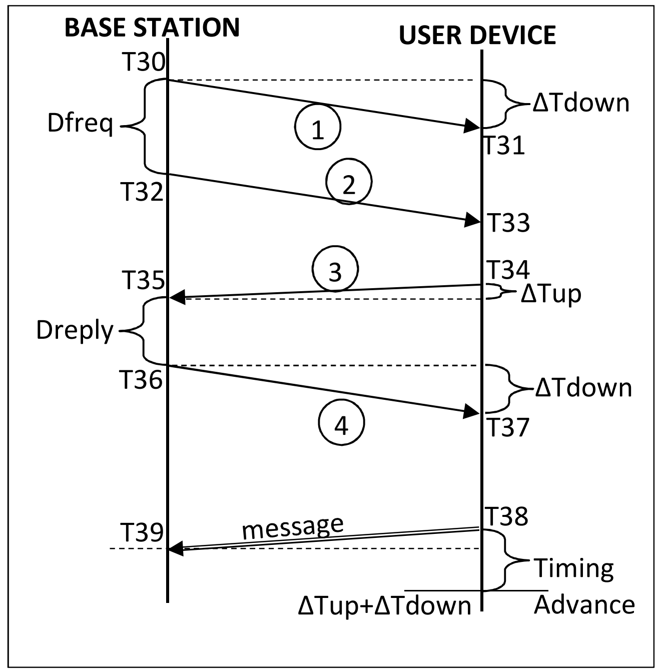

Fig. 11: Base station aligns user device using only 4 transmissions at scheduled times.

First, the base station sends out two signals (1,2). Each is a single-resource-element pulse at a predetermined time and frequency. The user device receives those two pulses and adjusts its clock setting according to the scheduled transmission time (T30) of the first pulse, and then adjusts its reception clock rate according to the predetermined interval between the two pulses (T32-T30), thereby matching the base station's clock rate. Then the user device transmits a third pulse (3), uplink, again occupying a single resource element at a predetermined time according to the user's now-corrected clock. The base station receives the third pulse and, after a predetermined delay (T36-T35), transmits a fourth pulse (4) back to the user. The user then subtracts the predetermined delay from the time interval between sending the third pulse and receiving the fourth pulse (T37-T34), and uses that remainder as the timing advance, relative to the user's resource clock, for transmitting uplink messages.

With this simple and economical procedure, the user device has matched the base station clock, arranged to receive downlink messages aligned with its reception clock, and arranged to set the timing advance of its transmission clock so that uplink messages will arrive correctly timed with the base station's resource grid, thereby fulfilling all of the requirements, with just four brief pulses.

If the user device is in motion, the same procedure can be used to account for the Doppler shift as well. The absolute time, according to the base station, can also be calculated by subtraction.

Therefore, we propose that a 3GPP Member company should add the simplified synchronization procedure as an option for user devices in 6G standards.

Value-Chain Analysis for Lean Synchronization

For users:

Lean synchronization enables cost-constrained use-cases, such as IoT devices controlled by a basic microcontroller. The procedure consumes far less user transmission power than legacy synchronization procedures.

For networks:

Lean synchronization occupies far less resource space and far less transmission energy than the legacy procedure. Enabling all users to maintain close agreement with the base station's resource grid (frame boundaries and subcarrier frequencies) greatly reduces uplink message faulting, a particular problem due to the weak signals of many user devices.

Conclusions

The current 6G plans continue to require legacy procedures that often are costly in terms of time, resource area, and energy consumption, as well as being overly complex. In this paper, we have outlined numerous solutions for providing faster, simpler, cheaper procedures that accomplish the same objectives while conserving resources and avoiding annoying the user.

The solutions mitigate important problems for high-performance wireless. **Beam control** is central to delivering sufficient signal to the intended recipient; **fault mitigation** is crucial for maintaining the high reliability and low latency promised; and **communication enhancements related to access, synchronization, and modulation** will provide significant gains in throughput and reliability.

UltraLogic6G is deeply committed to making 6G successful. Therefore, we submit that one of the 3GPP Member companies should advance this project forward by introducing the compelling solutions herein to peer Members – and placing these game-winning advances as options in the coming 6G Standards. The revenue generated for the Member company, by licensing these solutions to other developers and providers, will far exceed the expense.

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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.

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.

APSK (amplitude phase shift keying) is a modulation scheme that provides separate modulation of the waveform amplitude and phase, but not necessarily uniform separation of the phase levels.

References
[1] The following patents detail the solutions presented above, and can be found at: www.UltraLogic6G.com.

US Patent	Title
12,166,619	Procedures for Efficiently Defaulting QAM Messages in 5G and 6G
12,149,985	Artificial Intelligence for Optimizing 5G/6G Wireless Network Performance
12,143,189	Low-Complexity Procedure for 5G/6G Beam Alignment
12,126,477	Noise Mitigation by Guard-Space Reference Calibration in 5G and 6G
12,047,220	AI-Based Correction of Corrupted 5G/6G Messages
11,153,780	Selecting a Modulation Table to Mitigate 5G Message Faults
11,202,198	Managed Database of Recipient Addresses for Fast 5G Message Delivery
11,206,092	Artificial Intelligence for Predicting 5G Network Performance
11,206,169	Asymmetric Modulation for High-Reliability 5G Communications
11,297,643	Temporary QoS Elevation for High-Priority 5G Messages
11,387,960	Downlink Demarcations for Rapid, Reliable 5G/6G Messaging
11,387,961	Short-Form Demodulation Reference for Improved Reception in 5G and 6G
11,398,876	Error Detection and Correction in 5G/6G Pulse-Amplitude Modulation
11,411,795	Artificial-Intelligence Error Mitigation in 5G/6G Messaging
11,418,372	Low-Complexity Demodulation of 5G and 6G Messages
11,438,834	Searchable Database of 5G/6G Network Access Information
11,451,429	Modulation Including Zero-Power States in 5G and 6G
11,502,893	Short-Form 5G/6G Pulse-Amplitude Demodulation References
11,509,381	Resource-Efficient Beam Selection in 5G and 6G
11,510,096	Selecting a Modulation Table to Mitigate 5G Message Faults
11,516,065	Identifying Specific Faults in 5G/6G Messages by Modulation Quality
11,522,745	Identification and Mitigation of Message Faults in 5G and 6G Communications
11,523,334	Network Database for Rapid, Low-Complexity 5G/6G Network Access
11,528,178	Zero-Power Modulation for Resource-Efficient 5G/6G Messaging
11,546,111	Demarking the Start and End of 5G/6G Downlink Messages
11,558,236	Single-Branch Reference for High-Frequency Phase Tracking in 5G and 6G
11,601,150	Demodulation for Phase-Noise Mitigation in 5G and 6G
11,601,320	Single-Point Demodulation Reference for Noise Mitigation in 5G and 6G
11,616,668	Fault-Tolerant Method for Demodulating 5G or 6G Messages
11,616,679	Detection and Mitigation of 5G/6G Message Faults
11,626,955	Resource-Efficient Demodulation Reference for 5G/6G Networking
11,637,649	Phase-Noise Mitigation at High Frequencies in 5G and 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
11,671,305	Extremely Compact Phase-Tracking 5G/6G Reference Signal
11,695,612	Method to Locate Faulted Message Elements Using AI in 5G and 6G
11,722,980	Guard-Space Timestamp Point for Precision Synchronization in 5G and 6G
11,736,320	Multiplexed Amplitude-Phase Modulation for 5G/6G Noise Mitigation
11,736,333	Information Content in Zero-Power Modulation States in 5G and 6G
11,737,044	Mid-Symbol Timestamp Point for Precision Synchronization in 5G and 6G
11,777,547	Phase-Tracking Demodulation Reference and Procedure for 5G and 6G
11,777,639	How to Maximize Phase-Noise Margins in 5G and 6G
11,782,119	Phased Beam-Alignment Pulse for Rapid Localization in 5G and 6G
11,799,608	Low-Complexity Method for Identifying Downlink Messages in 5G and 6G
11,799,707	Guard-Space Phase-Tracking Reference Signal for 5G and 6G Networking

11,800,480	Ultra-Lean Timing Signal for Precision Synchronization in 5G and 6G
11,805,491	Compact Timing Signal for Low-Complexity 5G/6G Synchronization
11,811,565	Demodulation Using Two Modulation Schemes in 5G and 6G
11,824,667	Waveform Indicators for Fault Localization in 5G and 6G Messages
11,832,128	Fault Detection and Mitigation Based on Fault Types in 5G/6G
11,832,204	Ultra-Lean Synchronization Procedure for 5G and 6G Networking
11,843,468	Fault Detection, Localization, and Correction by 5G/6G Signal Quality
11,943,160	Resource-Efficient Demarcations for Downlink Messages in 5G and 6G
11,950,197	Precision Timing for Low-Complexity User Devices in 5G/6G Networks
11,956,746	Precision Synchronization Using Amplitude Measurements in 5G and 6G
11,996,971	Enhanced Throughput and Reliability with Zero-Power States in 5G and 6G
11,996,973	Scheduling Single-Branch Phase-Tracking References in 5G and 6G
12,034,571	Modulation and Demodulation for Enhanced Noise Margins in 5G and 6G
12,038,519	Low-Complexity Beam Alignment by Directional Phase in 5G and 6G
12,040,891	How to Maximize Throughput and Phase Margin in 5G/6G Communications
12,047,219	Fault Detection and Correction by Sum-Signal Modulation in 5G or 6G
12,047,894	Rapid Low-Complexity Synchronization and Doppler Correction in 5G/6G
12,052,129	Ultra-Compact Phase-Tracking Demodulation Reference for 5G/6G
12,074,741	Identifying Faulted Message Elements by Modulation Consistency in 5G/6G

2023/0231685	AI-Assisted Selection of Demodulation Reference Type in 5G and 6G
2023/0254198	Low-Complexity Resource-Efficient Demodulation Reference for 5G and 6G
2023/0262595	Automatic Base Station Discovery, Selection, and Registration in 5G/6G
2023/0387952	Selecting a Modulation Scheme to Mitigate Specific Fault Types in 5G and 6G
2024/0045013	Deterministic Low-Complexity Beam Alignment for 5G and 6G Users
2024/0080144	Enhanced Reliability by Waveform Analysis in 5G/6G Communications
2024/0196354	Phase-Shift Guard-Space Timestamp Point for 5G/6G Synchronization
2024/0205857	Fast, Resource-Efficient Timestamp Generation and Measurement in 5G/6G
2024/0214961	Simultaneous Timing Synchronization of User Devices in a 5G/6G Wireless Network