From: Sookyung Kim sk15.kim@samsung.com

Date: January 11, 2023 at 1:35:58 AM CST

To: Alison Richards <arichards@giplg.com>

Cc: Cheolwoo Ahn cw.ahn@samsung.com

Subject: [Samsung] Re: GenghisComm Holdings Patent Portfolio

Reply-To: sk15.kim@samsung.com

[redacted]

Dear Alison Richards,

I am writing this letter to inform you that Samsung receives a letter regarding GenghisComm Holdings Patent Portfolio including claim charts of US 11252005, US 11381285, and US 11424792. For your information, I've attahced PDF version of the scanned letter.

Furthermore, please be informed that I, Sookyung Kim, will be in charge of handling this case since the person in charge of this case has been changed to me. In this regard, would you please provide soft copies of the claim charts of US 11252005, US 11381285, and US 11424792 for our review?

Thank you.
Sookyung Kim

VIA EMAIL and PRIORITY MAIL

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December 21, 2022

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Re: *GenghisComm Holdings Patent Portfolio*

Dear Sirs:

This letter is a follow-up to GenghisComm's June 29, 2022 regarding the GenghisComm patent portfolio. Please find enclosed additional claim charts which provide further notice of Samsung's use of GenghisComm's patented technology. The new infringement charts include:

1. U.S. Patent 11,252,005 – Spreading and precoding in OFDM
2. U.S. Patent 11,381,285 – Transmit pre-coding
3. U.S. Patent 11,424,792 – Coordinated multipoint systems

We continue to offer Samsung a license to this patent portfolio.

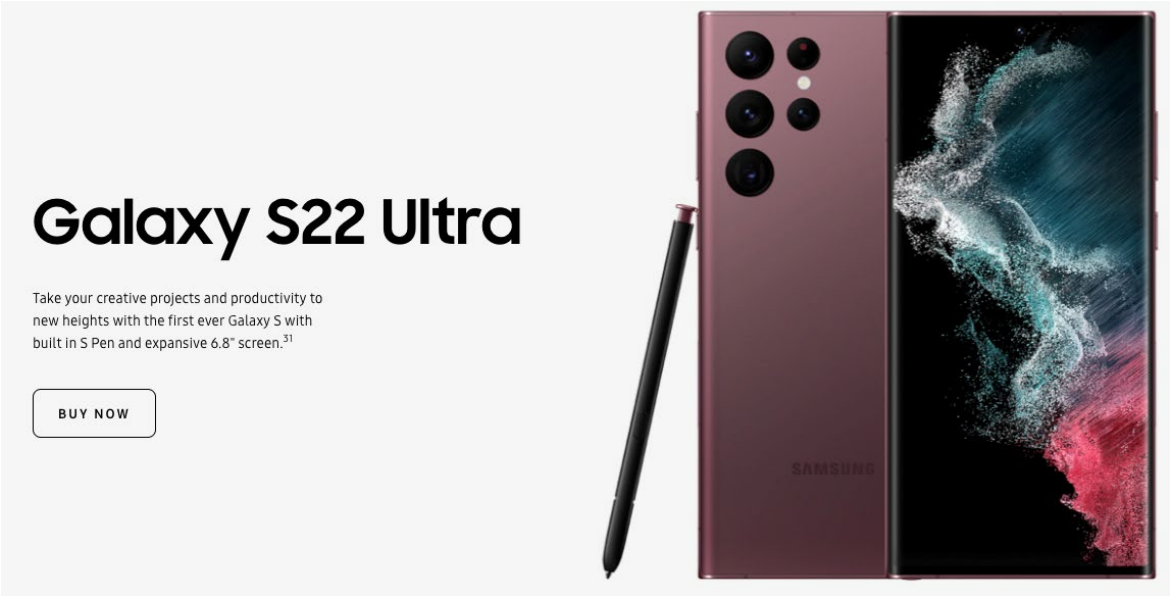
Very truly yours,

Enclosures

Notice

This letter shall not be construed to grant any express or implied license, authorization, covenant-not-to-sue, immunity, forbearance, indulgence, waiver, release or any other right with respect to these patents or otherwise. The owners reserve all rights with regard to its patents, including but not limited to: (1) the right to seek injunctive or other relief, including royalties or other damages going back at least as far as the last six years; (2) the right to change any royalty rates at any time; and (3) the right to change or withdraw any licensing offer at any time without notice. You should not rely on any communication, lack of communication, and/or any inactivity from Global IP Law Group or these owners as a relinquishment, acquiescence, waiver, or compromise of any of these owners' rights or as a change or withdrawal of any prior assertions stated. This letter and any subsequent related discussions do not create any obligation by the owners to proceed with any license or other contract with you. These owners reserve the right, in its sole discretion, to abandon or withdraw from at any time for any reason any discussions contemplated by this letter.

U.S. Patent No. 11,381,285: Samsung 5G Devices[1]

Claim 11	Analysis	Select Evidence
An apparatus for communication in a wireless network, comprising:	The Samsung Galaxy S22 Ultra ("Galaxy") is a non-limiting example of an apparatus for communication in a wireless communication network (e.g., 5G network). As shown to the right, the Galaxy is a 5G device, and adheres to the 5G specification.	 Source: https://www.samsung.com/us/smartphones/galaxy-s22-ultra/highlights/ Network & Connectivity: 5G 5G Non-Standalone (NSA), Standalone (SA), Sub6 / mmWave Source: https://www.samsung.com/global/galaxy/galaxy-s22-ultra/specs/

[1]This chart applies to all Samsung devices that include 5G compatibility.

Claim 11	Analysis	Select Evidence
a non-transitory computer-readable memory communicatively coupled to the at least one processor, the non-transitory computer-readable memory including a set of instructions stored thereon and executable by the at least one processor for:	The Galaxy includes a Qualcomm SM8450 processor. The Galaxy has at least one non-transitory computer-readable memory (e.g., LP-DDR5 memory) in communication with the processor. The memory stores executable instructions for using the 5G cellular network.	**PLATFORM** OS: Android 12, One UI 4.1 Chipset: Exynos 2200 (4 nm) - Europe Qualcomm SM8450 Snapdragon 8 Gen 1 (4 nm) - ROW CPU: Octa-core (1x2.8 GHz Cortex-X2 & 3x2.50 GHz Cortex-A710 & 4x1.8 GHz Cortex-A510) - Europe Octa-core (1x3.00 GHz Cortex-X2 & 3x2.40 GHz Cortex-A710 & 4x1.70 GHz Cortex-A510) - ROW Source: https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php **Memory** Support for LP-DDR5 memory up to 3200 MHz Memory Density: up to 16 GB Source: https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/snapdragon-8-gen-1-mobile-platform-product-brief.pdf **MEMORY** Card slot: No Internal: 128GB 8GB RAM, 256GB 12GB RAM, 512GB 12GB RAM, 1TB 12GB RAM UFS 3.1 Source: https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php

Claim 11	Analysis	Select Evidence
encoding a set of data symbols with a set of complex-valued codes, to produce a set of subcarrier values;	The Galaxy encodesdata symbols with complex-valued codes to produce a set of subcarrier values during the transform precoding step required by the 5G specification. The DFT used for transform precoding includes an exponential term that corresponds to complex-valued codes that are then multiplied by the data symbols.	6.3.1.4 Transform precoding If transform precoding is not enabled according to 6.1.3 of [6, TS38.214], $y^{(\lambda)}(i) = x^{(\lambda)}(i)$ for each layer $\lambda = 0,1,\ldots,\upsilon-1$. If transform precoding is enabled according to 6.1.3 of [6, TS38.214], $\upsilon = 1$ and $\tilde{x}^{(0)}(i)$ depends on the configuration of phase-tracking reference signals. If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are not being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$ for the single layer $\lambda = 0$ shall be divided into $M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one OFDM symbol and $\tilde{x}^{(0)}(i) = x^{(0)}(i)$. If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$ shall be divided into sets, each set corresponding to one OFDM symbol, and where set l contains $M_{\text{sc}}^{\text{PUSCH}} - \varepsilon_l N_{\text{samp}}^{\text{group}} N_{\text{group}}^{\text{PTRS}}$ symbols and is mapped to the complex-valued symbols $\tilde{x}^{(0)}(lM_{\text{sc}}^{\text{PUSCH}} + i')$ corresponding to OFDM symbol l prior to transform precoding, with $i' \in \{0,1,\ldots,M_{\text{sc}}^{\text{PUSCH}}-1\}$ and $i' \neq m$. The index m of PT-RS samples in set l, the number of samples per PT-RS group $N_{\text{samp}}^{\text{group}}$, and the number of PT-RS groups $N_{\text{group}}^{\text{PTRS}}$ are defined in clause 6.4.1.2.2.2. The quantity $\varepsilon_l = 1$ when OFDM symbol l contains one or more PT-RS samples, otherwise $\varepsilon_l = 0$. * * * * Transform precoding shall be applied according to $$y^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} \tilde{x}^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}}$$ $$k = 0,\ldots,M_{\text{sc}}^{\text{PUSCH}}-1$$ $$l = 0,\ldots,M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}-1$$ resulting in a block of complex-valued symbols $y^{(0)}(0),\ldots,y^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil $$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$$ where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers. Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf

Claim 11	Analysis	Select Evidence
modulating the set of subcarrier values onto a set of Orthogonal Frequency Division Multiplexing (OFDM) subcarriers assigned for use by the user device, to produce a plurality of modulated subcarriers; and	The Galaxy modulates subcarrier values on the subcarriers during OFDM baseband signal generation required by the 5G specification. Baseband signal generation converts frequency-domain values from transform precoding into time-domain values (waveforms) used during transmission.	5.3.1 OFDM baseband signal generation for all channels except PRACH The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p and subcarrier spacing configuration μ for OFDM symbol $l \in \{0,1,\ldots,N_{\text{slot}}^{\text{subframe},\mu} N_{\text{symb}}^{\text{slot}} - 1\}$ in a subframe for any physical channel or signal except PRACH is defined by $$s_l^{(p,\mu)}(t) = \sum_{k=0}^{N_{\text{grid}}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} - 1} a_{k,l}^{(p,\mu)} \cdot e^{j2\pi\left(k + k_0^{\mu} - N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}/2\right)\Delta f\left(t - N_{\text{CP},l}^{\mu} T_c - t_{\text{start},l}^{\mu}\right)}$$ $$k_0^{\mu} = \left(N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu}/2\right) N_{\text{sc}}^{\text{RB}} - \left(N_{\text{grid},x}^{\text{start},\mu_0} + N_{\text{grid},x}^{\text{size},\mu_0}/2\right) N_{\text{sc}}^{\text{RB}} 2^{\mu_0 - \mu}$$ where $t_{\text{start},l}^{\mu} \le t < t_{\text{start},l}^{\mu} + \left(N_{\text{u}}^{\mu} + N_{\text{CP},l}^{\mu}\right) T_c$ is the time within the subframe, $$N_{\text{u}}^{\mu} = 2048\kappa \cdot 2^{-\mu}$$ $$N_{\text{CP},l}^{\mu} = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^{\mu} \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \ne 0 \text{ and } l \ne 7 \cdot 2^{\mu} \end{cases}$$ Δf is given by clause 4.2, μ is the subcarrier spacing configuration, and μ_0 is the largest μ value among the subcarrier spacing configurations provided to the UE for this carrer. The starting position of OFDM symbol l for subcarrier spacing configuration μ in a subframe is given by Source: Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf

Claim 11	Analysis	Select Evidence
producing a time-domain waveform that comprises a superposition of the plurality of modulated subcarriers, the time-domain waveform to be transmitted in the wireless network by the user device;	A person of ordinary skill in the art at the time of the invention would understand that an OFDM signal is a superposition of subcarriers. The OFMD baseband generation step employed by the Galaxy usesan IFFT for transforming from the frequency-domain to the time-domain transformation. Each input symbol to an IFFT is modulated onto a particular subcarrier frequency, and the output of the IFFT is a discrete-time signal. If multiple symbols are input to the IFFT at the same time, the output discrete-time signal is a sum (i.e., superposition) of the subcarrier frequencies modulated with their corresponding symbols such that the signal resembles a single carrier.	5.3.1 OFDM baseband signal generation for all channels except PRACH The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p and subcarrier spacing configuration μ for OFDM symbol $l \in \{0,1,\ldots,N_{\text{slot}}^{\text{subframe},\mu} N_{\text{symb}}^{\text{slot}} - 1\}$ in a subframe for any physical channel or signal except PRACH is defined by $$s_l^{(p,\mu)}(t) = \sum_{k=0}^{N_{\text{grid}}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} - 1} a_{k,l}^{(p,\mu)} \cdot e^{j2\pi\left(k + k_0^{\mu} - N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}/2\right)\Delta f\left(t - N_{\text{CP},l}^{\mu} T_c - t_{\text{start},l}^{\mu}\right)}$$ $$k_0^{\mu} = \left(N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu}/2\right) N_{\text{sc}}^{\text{RB}} - \left(N_{\text{grid},x}^{\text{start},\mu_0} + N_{\text{grid},x}^{\text{size},\mu_0}/2\right) N_{\text{sc}}^{\text{RB}} 2^{\mu_0 - \mu}$$ where $t_{\text{start},l}^{\mu} \le t < t_{\text{start},l}^{\mu} + \left(N_{\text{u}}^{\mu} + N_{\text{CP},l}^{\mu}\right) T_c$ is the time within the subframe, $$N_{\text{u}}^{\mu} = 2048\kappa \cdot 2^{-\mu}$$ $$N_{\text{CP},l}^{\mu} = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^{\mu} \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \ne 0 \text{ and } l \ne 7 \cdot 2^{\mu} \end{cases}$$ Δf is given by clause 4.2, μ is the subcarrier spacing configuration, and μ_0 is the largest μ value among the subcarrier spacing configurations provided to the UE for this carrer. The starting position of OFDM symbol l for subcarrier spacing configuration μ in a subframe is given by Source: Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf A key enabler for OFDM is the use of the Inverse Fast Fourier Transform (IFFT) to efficiently create the time domain waveform from the array of modulated subcarriers. The resulting OFDM signal is in digital Source: https://www.5gtechnologyworld.com/the-basics-of-5gs-modulation-ofdm/

Claim 11	Analysis	Select Evidence
wherein the set of subcarrier values comprises a first polyphase code that encodes a first of the set of data symbols and at least a second polyphase code that encodes at least a second of the set of data symbols;	As shown to the right and as discussed above, transform precoding applies a DFT to generate subcarrier values. Application of the exponential term (which phase shifts inputs) of the DFT generates polyphase codes for each set of data symbols.	Transform precoding shall be applied according to $$y^{(0)}(l \cdot M_{sc}^{PUSCH} + k) = \frac{1}{\sqrt{M_{sc}^{PUSCH}}} \sum_{i=0}^{M_{sc}^{PUSCH}-1} \tilde{x}^{(0)}(l \cdot M_{sc}^{PUSCH} + i) e^{-j\frac{2\pi ik}{M_{sc}^{PUSCH}}}$$ $$k = 0, \ldots, M_{sc}^{PUSCH} - 1$$ $$l = 0, \ldots, M_{symb}^{layer} / M_{sc}^{PUSCH} - 1$$ resulting in a block of complex-valued symbols $y^{(0)}(0), \ldots, y^{(0)}(M_{symb}^{layer} - 1)$. The variable $M_{sc}^{PUSCH} = M_{RB}^{PUSCH} \cdot N_{sc}^{RB}$, where M_{RB}^{PUSCH} represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil $$M_{RB}^{PUSCH} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$$ where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers. Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf
wherein the first polyphase code causes constructive and	As is known in the art, the principle of superposition of waves states that when two or	The set of allowed values for N_{RB}^{DL} is given by 3GPP TS 36.104 [6]. The number of OFDM symbols in a slot depends on the cyclic prefix length and subcarrier spacing configured and is given in Table 6.2.3-1.

<table>
<tr><th>Claim 11</th><th>Analysis</th><th>Select Evidence</th></tr>
<tr>
<td>destructive interference between the plurality of modulated subcarriers to produce a first periodic pulse waveform having a peak value that is centered at a first time in an OFDM symbol interval, and the second polyphase code causes constructive and destructive interference between the plurality of modulated subcarriers to produce a second periodic pulse waveform having a peak value that is centered at a second time in the OFDM symbol interval, the second time different from the first time.</td>
<td>more propagating waves are incident on the same point, the resultant amplitude at that point is equal to the vector sum of the amplitudes of the individual waves. If a crest of a wave meets a crest of another wave at the same point, then the amplitude is the sum of the individual amplitudes—this is constructive interference. If a crest of one wave meets a trough of another wave, then the amplitude is equal to the difference in the individual amplitudes—this is destructive interference.

In OFDM, the subcarriers are uniformly spaced by frequency Δf, so the time-domain OFDM symbol is periodic with a symbol period of 1/f. Equivalently, in the digital domain, the N-point IDFT used in OFDM transmission produces a discrete-time OFDM signal with N samples and period N.</td>
<td>* * * *

Table 6.2.3-1: Physical resource blocks parameters

<table>
<tr><th colspan="2">Configuration</th><th>N_{sc}^{RB}</th><th>N_{symb}^{DL}</th></tr>
<tr><td rowspan="2">Normal cyclic prefix</td><td>$\Delta f = 15\,\text{kHz}$</td><td rowspan="2">12</td><td>7</td></tr>
<tr><td>$\Delta f = 15\,\text{kHz}$</td><td>6</td></tr>
<tr><td rowspan="2">Extended cyclic prefix</td><td>$\Delta f = 7.5\,\text{kHz}$</td><td>24</td><td>3</td></tr>
<tr><td>$\Delta f = 1.25\,\text{kHz}$</td><td>144</td><td>1</td></tr>
</table>

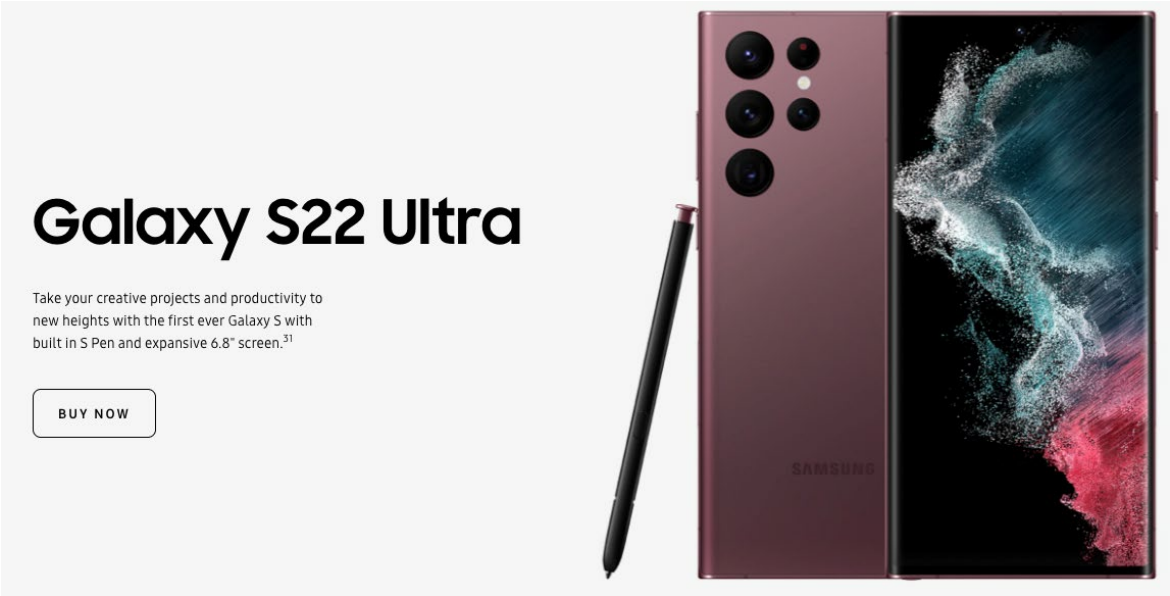
* * * *

Δf Subcarrier spacing

Source:
https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf</td>
</tr>
</table>

Claim 11	Analysis	Select Evidence
	If values of a first polyphase code are chosen properly, the codes provide phase offsets to the subcarriers that cause all of the subcarriers' phases to align at a particular time inside the symbol period, which causes constructive interference, resulting in a pulse waveform being centered at that time. If a second polyphase code also produces a pulse waveform, that pulse waveform is preferably centered at a different time in order for it to be distinguished from the first pulse waveform. This happens when the codes are chosen from the rows or columns of a DFT matrix. A person of ordinary skill in the art at the time of the invention would understand that the DFT used for transform precoding can be depicted as a complex matrix transform. Values are calculated by multiplying a matrix of complex-valued codes with a matrix of data symbols. In the equation at right, *x(N-1)* corresponds to the *x* variable in the 5G transform precoding equation shown above.	The DFT consists of inner products of the input signal $\underline{x}$ with sampled complex sinusoidal sections $\underline{s}_k$: $$X(\omega_k) \triangleq \langle \underline{x}, \underline{s}_k \rangle \triangleq \sum_{n=0}^{N-1} \underline{x}(n) e^{-j2\pi nk/N}, \quad k = 0, 1, 2, \ldots, N-1$$ By collecting the DFT output samples into a column vector, we have $$\underbrace{\begin{bmatrix} X(\omega_0) \\ X(\omega_1) \\ X(\omega_2) \\ \vdots \\ X(\omega_{N-1}) \end{bmatrix}}_{\underline{X}} = \underbrace{\begin{bmatrix} \overline{s_0(0)} & \overline{s_0(1)} & \cdots & \overline{s_0(N-1)} \\ \overline{s_1(0)} & \overline{s_1(1)} & \cdots & \overline{s_1(N-1)} \\ \overline{s_2(0)} & \overline{s_2(1)} & \cdots & \overline{s_2(N-1)} \\ \vdots & \vdots & \vdots & \vdots \\ \overline{s_{N-1}(0)} & \overline{s_{N-1}(1)} & \cdots & \overline{s_{N-1}(N-1)} \end{bmatrix}}_{\mathbf{S}_N^*} \underbrace{\begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ \vdots \\ x(N-1) \end{bmatrix}}_{\underline{x}}$$ * * * * where $\mathbf{S}_N^*$ denotes the *DFT matrix* $\mathbf{S}_N^*[k,n] \triangleq W_N^{-kn} \triangleq e^{-j2\pi kn/N}$, *i.e.*, $$\mathbf{S}_N^* \triangleq \begin{bmatrix} \underline{s}_0 & \underline{s}_1 & \cdots & \underline{s}_{N-1} \end{bmatrix}^*$$ $$\triangleq \begin{bmatrix} \overline{s_0(0)} & \overline{s_0(1)} & \cdots & \overline{s_0(N-1)} \\ \overline{s_1(0)} & \overline{s_1(1)} & \cdots & \overline{s_1(N-1)} \\ \overline{s_2(0)} & \overline{s_2(1)} & \cdots & \overline{s_2(N-1)} \\ \vdots & \vdots & \vdots & \vdots \\ \overline{s_{N-1}(0)} & \overline{s_{N-1}(1)} & \cdots & \overline{s_{N-1}(N-1)} \end{bmatrix}$$ $$\triangleq \begin{bmatrix} 1 & 1 & 1 & \cdots & 1 \\ 1 & e^{-j2\pi/N} & e^{-j4\pi/N} & \cdots & e^{-j2\pi(N-1)/N} \\ 1 & e^{-j4\pi/N} & e^{-j8\pi/N} & \cdots & e^{-j2\pi 2(N-1)/N} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & e^{-j2\pi(N-1)/N} & e^{-j2\pi 2(N-1)/N} & \cdots & e^{-j2\pi(N-1)(N-1)/N} \end{bmatrix}.$$ Source: https://ccrma.stanford.edu/~jos/st/Matrix_Formulation_DFT.html

U.S. Patent No. 11,252,005: Samsung 5G Devices[1]

Claim 13	Analysis	Select Evidence
An apparatus for communication in a wireless network, comprising:	The Samsung Galaxy S22 Ultra ("Galaxy") is a non-limiting example of an apparatus for communication in a wireless communication network (e.g., 5G network). As shown to the right, the Galaxy is a 5G device, and adheres to the 5G specification.	 Source: https://www.samsung.com/us/smartphones/galaxy-s22-ultra/highlights/ Network & Connectivity: 5G 5G Non-Standalone (NSA), Standalone (SA), Sub6 / mmWave Source: https://www.samsung.com/global/galaxy/galaxy-s22-ultra/specs/

[1]This chart applies to all Samsung devices that include 5G compatibility.

Claim 13	Analysis	Select Evidence
at least one processor; and at least one non-transitory computer-readable memory in electronic communication with the at least one processor, wherein instructions stored in the at least one non-transitory computer-readable memory are executable by the at least one processor for:	The Galaxy includes a Qualcomm SM8450 processor. The Galaxy has at least one non-transitory computer-readable memory (e.g., LP-DDR5 memory) in communication with the processor. The memory stores executable instructions for using the 5G cellular network.	**PLATFORM** OS: Android 12, One UI 4.1 Chipset: Exynos 2200 (4 nm) - Europe Qualcomm SM8450 Snapdragon 8 Gen 1 (4 nm) - ROW CPU: Octa-core (1x2.8 GHz Cortex-X2 & 3x2.50 GHz Cortex-A710 & 4x1.8 GHz Cortex-A510) - Europe Octa-core (1x3.00 GHz Cortex-X2 & 3x2.40 GHz Cortex-A710 & 4x1.70 GHz Cortex-A510) - ROW Source: https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php **Memory** Support for LP-DDR5 memory up to 3200 MHz Memory Density: up to 16 GB Source: https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/snapdragon-8-gen-1-mobile-platform-product-brief.pdf **MEMORY** Card slot: No Internal: 128GB 8GB RAM, 256GB 12GB RAM, 512GB 12GB RAM, 1TB 12GB RAM UFS 3.1 Source: https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php

Claim 13	Analysis	Select Evidence
producing a set of subcarrier values that equals a product of a complex-valued code matrix with a matrix of data symbols;	The Galaxy produces subcarrier values during the transform precoding step required by the 5G specification.	6.3.1.4 Transform precoding If transform precoding is not enabled according to 6.1.3 of [6, TS38.214], $y^{(\lambda)}(i) = x^{(\lambda)}(i)$ for each layer $\lambda = 0,1,\ldots,\upsilon-1$. If transform precoding is enabled according to 6.1.3 of [6, TS38.214], $\upsilon = 1$ and $\tilde{x}^{(0)}(i)$ depends on the configuration of phase-tracking reference signals. If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are not being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$ for the single layer $\lambda = 0$ shall be divided into $M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one OFDM symbol and $\tilde{x}^{(0)}(i) = x^{(0)}(i)$. If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$ shall be divided into sets, each set corresponding to one OFDM symbol, and where set l contains $M_{\text{sc}}^{\text{PUSCH}} - \varepsilon_l N_{\text{samp}}^{\text{group}} N_{\text{group}}^{\text{PTRS}}$ symbols and is mapped to the complex-valued symbols $\tilde{x}^{(0)}(lM_{\text{sc}}^{\text{PUSCH}} + i')$ corresponding to OFDM symbol l prior to transform precoding, with $i' \in \{0,1,\ldots,M_{\text{sc}}^{\text{PUSCH}}-1\}$ and $i' \neq m$. The index m of PT-RS samples in set l, the number of samples per PT-RS group $N_{\text{samp}}^{\text{group}}$, and the number of PT-RS groups $N_{\text{group}}^{\text{PTRS}}$ are defined in clause 6.4.1.2.2.2. The quantity $\varepsilon_l = 1$ when OFDM symbol l contains one or more PT-RS samples, otherwise $\varepsilon_l = 0$. * * * * Transform precoding shall be applied according to $$y^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} \tilde{x}^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}}$$ $$k = 0,\ldots,M_{\text{sc}}^{\text{PUSCH}}-1$$ $$l = 0,\ldots,M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}-1$$ resulting in a block of complex-valued symbols $y^{(0)}(0),\ldots,y^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil $$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$$ where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers. Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf

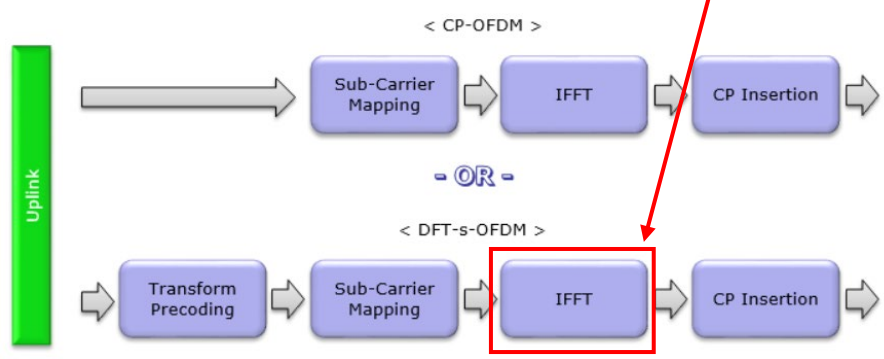
Claim 13	Analysis	Select Evidence
	A person of ordinary skill in the art at the time of the invention would understand that the DFT used for transform precoding can be depicted as a complex matrix transform. Values are calculated by multiplying a matrix of complex-valued codes with a matrix of data symbols. In the equation at right, *x(N-1)* corresponds to the *x* variable in the 5G transform precoding equation shown above.	The DFT consists of inner products of the input signal $\underline{x}$ with sampled complex sinusoidal sections $\underline{s}_k$: $$X(\omega_k) \triangleq \langle \underline{x}, \underline{s}_k \rangle \triangleq \sum_{n=0}^{N-1} \underline{x}(n) e^{-j2\pi nk/N}, \quad k = 0, 1, 2, \ldots, N-1$$ By collecting the DFT output samples into a column vector, we have $$\underbrace{\begin{bmatrix} X(\omega_0) \\ X(\omega_1) \\ X(\omega_2) \\ \vdots \\ X(\omega_{N-1}) \end{bmatrix}}_{\underline{X}} = \underbrace{\begin{bmatrix} \overline{s_0(0)} & \overline{s_0(1)} & \cdots & \overline{s_0(N-1)} \\ \overline{s_1(0)} & \overline{s_1(1)} & \cdots & \overline{s_1(N-1)} \\ \overline{s_2(0)} & \overline{s_2(1)} & \cdots & \overline{s_2(N-1)} \\ \vdots & \vdots & \vdots & \vdots \\ \overline{s_{N-1}(0)} & \overline{s_{N-1}(1)} & \cdots & \overline{s_{N-1}(N-1)} \end{bmatrix}}_{\mathbf{S}_N^*} \underbrace{\begin{bmatrix} x(0) \\ x(1) \\ x(2) \\ \vdots \\ x(N-1) \end{bmatrix}}_{\underline{x}}$$ * * * * where $\mathbf{S}_N^*$ denotes the *DFT matrix* $\mathbf{S}_N^*[k,n] \triangleq W_N^{-kn} \triangleq e^{-j2\pi kn/N}$, *i.e.*, $$\mathbf{S}_N^* \triangleq \begin{bmatrix} \underline{s}_0 & \underline{s}_1 & \cdots & \underline{s}_{N-1} \end{bmatrix}^*$$ $$\triangleq \begin{bmatrix} \overline{s_0(0)} & \overline{s_0(1)} & \cdots & \overline{s_0(N-1)} \\ \overline{s_1(0)} & \overline{s_1(1)} & \cdots & \overline{s_1(N-1)} \\ \overline{s_2(0)} & \overline{s_2(1)} & \cdots & \overline{s_2(N-1)} \\ \vdots & \vdots & \vdots & \vdots \\ \overline{s_{N-1}(0)} & \overline{s_{N-1}(1)} & \cdots & \overline{s_{N-1}(N-1)} \end{bmatrix}$$ $$\triangleq \begin{bmatrix} 1 & 1 & 1 & \cdots & 1 \\ 1 & e^{-j2\pi/N} & e^{-j4\pi/N} & \cdots & e^{-j2\pi(N-1)/N} \\ 1 & e^{-j4\pi/N} & e^{-j8\pi/N} & \cdots & e^{-j2\pi 2(N-1)/N} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & e^{-j2\pi(N-1)/N} & e^{-j2\pi 2(N-1)/N} & \cdots & e^{-j2\pi(N-1)(N-1)/N} \end{bmatrix}.$$ Source: https://ccrma.stanford.edu/~jos/st/Matrix_Formulation_DFT.html

Claim 13	Analysis	Select Evidence
selecting a set of subcarriers assigned for use by a user device; and	The Galaxy selects a set of subcarriers assigned for the device (e.g., 12 consecutive subcarriers per resource block).	**4.4.2 Resource grid** For each numerology and carrier, a resource grid of $N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}$ subcarriers and $N_{\text{symb}}^{\text{subframe},\mu}$ OFDM symbols is defined, starting at common resource block $N_{\text{grid}}^{\text{start},\mu}$ indicated by higher-layer signalling. There is one set of resource grids per transmission direction (uplink or downlink) with the subscript x set to DL and UL for downlink and uplink, respectively. When there is no risk for confusion, the subscript x may be dropped. There is one resource grid for a given antenna port p, subcarrier spacing configuration μ, and transmission direction (downlink or uplink). * * * * **4.4.4 Resource blocks** **4.4.4.1 General** A resource block is defined as $N_{\text{sc}}^{\text{RB}} = 12$ consecutive subcarriers in the frequency domain.
	As shown to the right, 5G introduced variable subcarrier spacing (numerology) to accommodate different usage scenarios. 5G allows for subcarrier spacings of 15, 30, 60, 120 and 240kHz.	**4.2 Numerologies** Multiple OFDM numerologies are supported as given by Table 4.2-1 where μ and the cyclic prefix for a bandwidth part are obtained from the higher-layer parameter *subcarrierSpacing* and *cyclicPrefix*, respectively. **Table 4.2-1: Supported transmission numerologies.** μ | $\Delta f = 2^{\mu} \cdot 15$[kHz] | **Cyclic prefix** 0 | 15 | Normal 1 | 30 | Normal 2 | 60 | Normal, Extended 3 | 120 | Normal 4 | 240 | Normal Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf The very simple defination of Numerology based on the usage of the term in 3GPP specification would be 'subcarrier spacing type', also often called as SCS. In LTE, we don't need any specific terminology to indicate the subcarrier spacing since there is only one subcarrier spacing, but in NR there are several different types of subcarrier spacing Source: https://www.sharetechnote.com/html/5G/5G_Phy_Numerology.html#:~:text=Numerology%20in%205G%2FNR%20refers,%2C%20480%2C%20960%20Khz)

Claim 13	Analysis	Select Evidence
	The actual number of subcarriers selected and used varies depending on the subcarrier spacing utilized, with a smaller subcarrier spacing	• In lower frequency bands, like **Sub-3GHz**, **Sub-6 GHz**, we don't have wider spectrum. So to get as many subcarriers as possible in these limited spectrum, we need to use subcarrier spacing as small as possible. That's why we use small subcarrier spacing like 15 Khz, **30 Khz**, **60 Khz** in lower bands • When operating in very high frequency like mmWave, as carrier frequency gets higher, the degree of frequency drift by moving transmitter or reciever gets higher i.e, **Doppler spread** gets wider as carrier frequency gets higher. To tolerate this kind of wide range of frequency drift (or shift), we need to use wider subcarrier spacing. So **3GPP** provided option to use very wide subcarrier spacing like **120 Khz** or **240 Khz** • As frequency goes higher, the **degree of phase noise** would increase. So we need to implement more sophisticated mechanism for **phase noise** estimation and correction. It is easier to implement this kind **mechanism** with wider subcarrier spacing Source: https://www.techplayon.com/5g-nr-numerology-subcarrier-spcaing-scs/

Claim 13	Analysis	Select Evidence
modulating the subcarrier values onto the set of subcarriers to produce a plurality of modulated subcarriers; and producing a time-domain waveform from a superposition of the plurality of modulated subcarriers, the time-domain waveform to be transmitted in the wireless network by the user device;	The Galaxy modulates subcarrier values on the subcarriers during OFDM baseband signal generation required by the 5G specification. Baseband signal generation converts frequency-domain values from transform precoding into time-domain values (waveforms) used during transmission. A person of ordinary skill in the art at the time of the invention would understand that an OFDM signal is a superposition of subcarriers. The OFMD baseband generation step uses an IFFT for transforming from the frequency-domain to the time-domain transformation. Each input symbol to an IFFT is modulated onto a particular subcarrier frequency, and the output of the IFFT is a discrete-time signal. If multiple symbols are input to the IFFT at the same time, the output discrete-time signal is a sum (i.e., superposition) of the subcarrier frequencies modulated with their corresponding symbols. Each subcarrier's amplitude varies in time according to its frequency, so the sum of the modulated subcarriers results in a combination of constructive and destructive interference. Thus, the transform precoding step shapes interference patterns.	5.3.1 OFDM baseband signal generation for all channels except PRACH The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p and subcarrier spacing configuration μ for OFDM symbol $l \in \{0,1,\ldots,N_{\text{slot}}^{\text{subframe},\mu} N_{\text{symb}}^{\text{slot}} - 1\}$ in a subframe for any physical channel or signal except PRACH is defined by $$s_l^{(p,\mu)}(t) = \sum_{k=0}^{N_{\text{grid}}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} - 1} a_{k,l}^{(p,\mu)} \cdot e^{j2\pi\left(k + k_0^{\mu} - N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}/2\right)\Delta f\left(t - N_{\text{CP},l}^{\mu} T_c - t_{\text{start},l}^{\mu}\right)}$$ $$k_0^{\mu} = \left(N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu}/2\right) N_{\text{sc}}^{\text{RB}} - \left(N_{\text{grid},x}^{\text{start},\mu_0} + N_{\text{grid},x}^{\text{size},\mu_0}/2\right) N_{\text{sc}}^{\text{RB}} 2^{\mu_0 - \mu}$$ where $t_{\text{start},l}^{\mu} \le t < t_{\text{start},l}^{\mu} + \left(N_{\text{u}}^{\mu} + N_{\text{CP},l}^{\mu}\right) T_c$ is the time within the subframe, $$N_{\text{u}}^{\mu} = 2048\kappa \cdot 2^{-\mu}$$ $$N_{\text{CP},l}^{\mu} = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^{\mu} \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \ne 0 \text{ and } l \ne 7 \cdot 2^{\mu} \end{cases}$$ Δf is given by clause 4.2, μ is the subcarrier spacing configuration, and μ_0 is the largest μ value among the subcarrier spacing configurations provided to the UE for this carrer. The starting position of OFDM symbol l for subcarrier spacing configuration μ in a subframe is given by Source: Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf A key enabler for OFDM is the use of the Inverse Fast Fourier Transform (IFFT) to efficiently create the time domain waveform from the array of modulated subcarriers. The resulting OFDM signal is in digital Source: https://www.5gtechnologyworld.com/the-basics-of-5gs-modulation-ofdm/

Claim 13	Analysis	Select Evidence
wherein producing the set of subcarrier values employs a plurality of complex-valued codes that shapes interference patterns of the superposition to produce a plurality of cyclic-shifted waveforms that each have one of the data symbols modulated thereon.	The set of subcarrier values is generated using a DFT during the transform precoding step. The DFT used for transform precoding includes an exponential term that corresponds to complex-valued codes that impart a cyclic shift to the encoded symbols and resulting waveforms. A person of ordinary skill in the art at the time of the invention would understand that an OFDM signal is a superposition of subcarriers. The 5G specification's SC-FDMA baseband generation step uses an IFFT for transforming from the frequency-domain to the time-domain transformation. Each input symbol to an IFFT is modulated onto a particular subcarrier frequency, and the output of the IFFT is a discrete-time signal. If multiple symbols are input to the IFFT at the same time, the output discrete-time signal is a sum (i.e., superposition) of the subcarrier frequencies modulated with their corresponding symbols. The amplitudes of the various subcarrier frequencies at a given time will not be the same; summing waveforms will result in either constructive or destructive interference. Thus, the transform precoding step shapes interference patterns.	6.3.1.4 Transform precoding If transform precoding is not enabled according to 6.1.3 of [6, TS38.214], $y^{(\lambda)}(i) = x^{(\lambda)}(i)$ for each layer $\lambda = 0,1,\ldots,\upsilon-1$. If transform precoding is enabled according to 6.1.3 of [6, TS38.214], $\upsilon = 1$ and $\tilde{x}^{(0)}(i)$ depends on the configuration of phase-tracking reference signals. If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are not being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$ for the single layer $\lambda = 0$ shall be divided into $M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one OFDM symbol and $\tilde{x}^{(0)}(i) = x^{(0)}(i)$. If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$ shall be divided into sets, each set corresponding to one OFDM symbol, and where set l contains $M_{\text{sc}}^{\text{PUSCH}} - \varepsilon_l N_{\text{samp}}^{\text{group}} N_{\text{group}}^{\text{PTRS}}$ symbols and is mapped to the complex-valued symbols $\tilde{x}^{(0)}(lM_{\text{sc}}^{\text{PUSCH}} + i')$ corresponding to OFDM symbol l prior to transform precoding, with $i' \in \{0,1,\ldots,M_{\text{sc}}^{\text{PUSCH}}-1\}$ and $i' \neq m$. The index m of PT-RS samples in set l, the number of samples per PT-RS group $N_{\text{samp}}^{\text{group}}$, and the number of PT-RS groups $N_{\text{group}}^{\text{PTRS}}$ are defined in clause 6.4.1.2.2.2. The quantity $\varepsilon_l = 1$ when OFDM symbol l contains one or more PT-RS samples, otherwise $\varepsilon_l = 0$. * * * * Transform precoding shall be applied according to $$y^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} \tilde{x}^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}}$$ $$k = 0,\ldots,M_{\text{sc}}^{\text{PUSCH}}-1$$ $$l = 0,\ldots,M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}} - 1$$ resulting in a block of complex-valued symbols $y^{(0)}(0),\ldots,y^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil $$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$$ where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers. Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf

Claim 18	Analysis	Select Evidence
The apparatus of claim 13, wherein modulating and producing the time-domain waveform is performed using an inverse discrete Fourier transform.	As discussed above, the Galaxy generates an OFDM baseband signal in accordance with the 5G specification. The baseband signal is generated using an inverse DFT.	5.3.1 OFDM baseband signal generation for all channels except PRACH The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p and subcarrier spacing configuration μ for OFDM symbol $l \in \{0,1,\ldots,N_{\text{slot}}^{\text{subframe},\mu} N_{\text{symb}}^{\text{slot}} - 1\}$ in a subframe for any physical channel or signal except PRACH is defined by $$s_l^{(p,\mu)}(t) = \sum_{k=0}^{N_{\text{grid}}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} - 1} a_{k,l}^{(p,\mu)} \cdot e^{j2\pi\left(k + k_0^{\mu} - N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}/2\right)\Delta f\left(t - N_{\text{CP},l}^{\mu} T_c - t_{\text{start},l}^{\mu}\right)}$$ $$k_0^{\mu} = \left(N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu}/2\right) N_{\text{sc}}^{\text{RB}} - \left(N_{\text{grid},x}^{\text{start},\mu_0} + N_{\text{grid},x}^{\text{size},\mu_0}/2\right) N_{\text{sc}}^{\text{RB}} 2^{\mu_0 - \mu}$$ where $t_{\text{start},l}^{\mu} \le t < t_{\text{start},l}^{\mu} + \left(N_{\text{u}}^{\mu} + N_{\text{CP},l}^{\mu}\right) T_c$ is the time within the subframe, $$N_{\text{u}}^{\mu} = 2048\kappa \cdot 2^{-\mu}$$ $$N_{\text{CP},l}^{\mu} = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^{\mu} \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \ne 0 \text{ and } l \ne 7 \cdot 2^{\mu} \end{cases}$$ Δf is given by clause 4.2, μ is the subcarrier spacing configuration, and μ_0 is the largest μ value among the subcarrier spacing configurations provided to the UE for this carrer. The starting position of OFDM symbol l for subcarrier spacing configuration μ in a subframe is given by Source: Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf  Source: https://www.sharetechnote.com/html/5G/5G_Waveform.html

<table>
<tr><th>Claim 19</th><th>Analysis</th><th>Select Evidence</th></tr>
<tr><td>The apparatus of claim 13, wherein selecting the set of subcarriers comprises selecting one of a plurality of selectable subcarrier spacings.</td><td>5G standard supports multiple OFDM numerologies, subcarrier spacings can be selected from 15kHz, 30kHz, 60kHz, 120kHz and 240kHz.</td><td>

4.2 Numerologies

Multiple OFDM numerologies are supported as given by Table 4.2-1 where μ and the cyclic prefix for a bandwidth part are obtained from the higher-layer parameter *subcarrierSpacing* and *cyclicPrefix*, respectively.

Table 4.2-1: Supported transmission numerologies.

μ	$\Delta f = 2^{\mu} \cdot 15$ [kHz]	Cyclic prefix
0	15	Normal
1	30	Normal
2	60	Normal, Extended
3	120	Normal
4	240	Normal

* * * *

Δf Subcarrier spacing

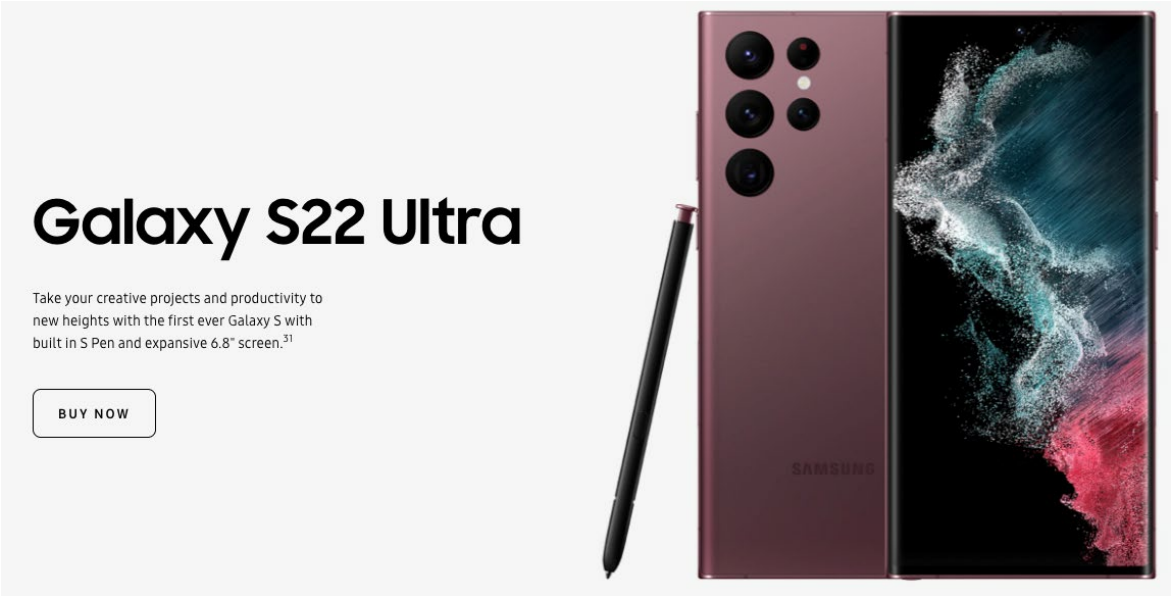
* * * *

μ Subcarrier spacing configuration, $\Delta f = 2^{\mu} \cdot 15$ [kHz]

Source:
https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf

</td></tr>
</table>

U.S. Patent No. 11,424,792: Samsung 5G Devices[1]

Claim 8	Analysis	Select Evidence
An apparatus for providing flexible channel bandwidth in mobile radio communications, comprising: at least one processor; and	The Samsung Galaxy S22 Ultra ("Galaxy") is a non-limiting example of an apparatus that uses 5G cellular communications. The Galaxy includes a Qualcomm SM8450 processor.	 Source: https://www.samsung.com/us/smartphones/galaxy-s22-ultra/highlights/ Network & Connectivity: 5G 5G Non-Standalone (NSA), Standalone (SA), Sub6 / mmWave Source: https://www.samsung.com/global/galaxy/galaxy-s22-ultra/specs/ PLATFORM — OS: Android 12, One UI 4.1 Chipset: Exynos 2200 (4 nm) - Europe Qualcomm SM8450 Snapdragon 8 Gen 1 (4 nm) - ROW CPU: Octa-core (1x2.8 GHz Cortex-X2 & 3x2.50 GHz Cortex-A710 & 4x1.8 GHz Cortex-A510) - Europe Octa-core (1x3.00 GHz Cortex-X2 & 3x2.40 GHz Cortex-A710 & 4x1.70 GHz Cortex-A510) - ROW Source: https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php

[1] This chart applies to all Samsung devices that include 5G compatibility.

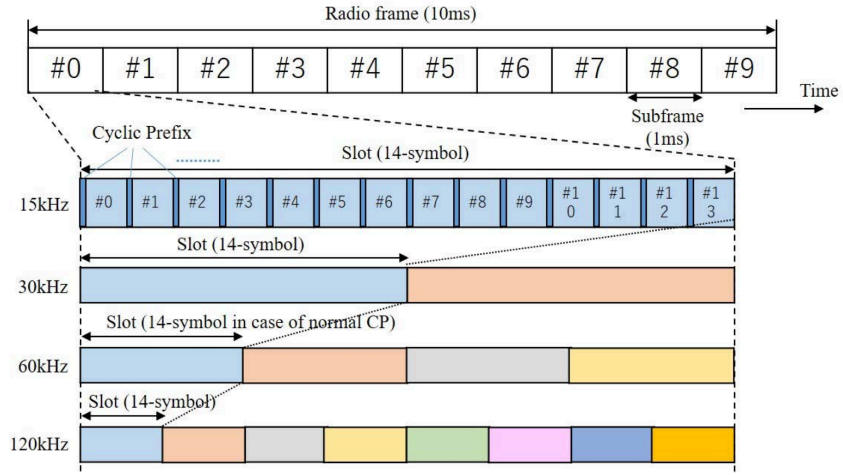
Claim 8	Analysis	Select Evidence
	Devices that use 5G adhere to the 5G specification. The 5G specification allows for different subcarrier spacings and bandwidth depending on the scenario.	The very simple defination of Numerology based on the usage of the term in 3GPP specification would be 'subcarrier spacing type', also often called as SCS. In LTE, we don't need any specific terminology to indicate the subcarrier spacing since there is only one subcarrier spacing, but in NR there are several different types of subcarrier spacing * * * * • In OFDM, number of subcarrier that can be packed into a specific frequency range is directly related to spectrum efficiency (how many bits can be transmitter per Hz per second). The more subcarriers you can pack into a frequency range (i.e, the narrow subcarrier spacing you use), the more data you can transmit (or recieve). • Based on Physics(anti-proportional relationship between subcarrier spacing and OFDM symbo length), Narrow subcarrier spacing means longer OFDM symbol length. With longer OFDM symbol, we can assign more room for CP(Cyclick Prefic). With longer CP, we can make the signal more tolerable to fading channel(Ref [33]). • In lower frequency (like sub 3Ghz, sub 6 Ghz), we don't have much wide band spectrum left for this new technology. In order to pack as many subcarriers as possible in these limited spectrum, we need to get subcarrier spacing as small as possible. That's why we use small subcarrier spacing like 15 Khz, 30 Khz, 60 Khz in NR numerology. • Then, why we don't use even smaller subcarrier like 10 Khz, 5 Khz etc ? As you know, in OFDM maintaining orthogonolity between subcarriers is critical (See Overview section of OFDM page). The transmitted signal would go through various fading channel causing the drift of each subcarrier and the degree of the drift gets even more serious when the transmitter or reciever moves faster. So the narrower of subcarrier spacing you use, the tolerance to fading gets weaker. • Then we need very wide subcarrier spacing like 120 Khz or 240 Khz ? It is for the operation in very high frequency like mmWave. As carrier frequency gets higher, the degree of frequency drift by moving transmitter or reciever gets higher (i.e, Doppler spread gets wider as carrier frequency gets higher). To tolerate this kind of wide range of frequency drift (or shift), we need to use wider subcarrier spacing. • There is another reason for wider subcarrier spacing in mmWave. For the reason as explained here, we would use beamforming (Massive MIMO based beamforming), for the implementaion of beamforming controlling the phase of the signal is critical and it is difficult to control the phase of the signal with narrow subcarrier spacing (Ref [33]). • As frequency goes higher, the degree of phase noise would increase. So we need to implement more sophisticated mechanism for phase noise estimation and correction. It is easier to implement this kind mechanism with wider subcarrier spacing(Ref [33]). Source: https://www.sharetechnote.com/html/5G/5G_Phy_Numerology.html#:~:text=Numerology%20in%205G%2FNR%20refers,%2C%20480%2C%20960%20Khz) • In lower frequency bands, like **Sub-3GHz**, **Sub-6 GHz**, we don't have wider spectrum. So to get as many subcarriers as possible in these limited spectrum, we need to use subcarrier spacing as small as possible. That's why we use small subcarrier spacing like 15 Khz, **30 Khz**, **60 Khz** in lower bands • When operating in very high frequency like mmWave, as carrier frequency gets higher, the degree of frequency drift by moving transmitter or reciever gets higher i.e, **Doppler spread** gets wider as carrier frequency gets higher. To tolerate this kind of wide range of frequency drift (or shift), we need to use wider subcarrier spacing. So **3GPP** provided option to use very wide subcarrier spacing like **120 Khz** or **240 Khz** • As frequency goes higher, the **degree of phase noise** would increase. So we need to implement more sophisticated mechanism for **phase noise** estimation and correction. It is easier to implement this kind **mechanism** with wider subcarrier spacing Source: https://www.techplayon.com/5g-nr-numerology-subcarrier-spcaing-scs/

Claim 8	Analysis	Select Evidence
at least one non-transitory computer-readable memory in electronic communication with the at least one processor, and instructions stored in the at least one memory, the instructions executable by the at least one processor for:	The Galaxy has at least one non-transitory computer-readable memory (e.g., LP-DDR5 memory) in communication with the processor. The memory stores executable instructions for using the 5G cellular network.	**Memory** Support for LP-DDR5 memory up to 3200 MHz Memory Density: up to 16 GB Source: https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/snapdragon-8-gen-1-mobile-platform-product-brief.pdf **MEMORY** Card slot: No Internal: 128GB 8GB RAM, 256GB 12GB RAM, 512GB 12GB RAM, 1TB 12GB RAM UFS 3.1 Source: https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php

Claim 8	Analysis	Select Evidence
provisioning a set of Orthogonal Frequency Division Multiplexing (OFDM) subcarriers for mobile radio communications;	The Galaxy provisions a consecutive series of OFDM subcarriers for uplink or downlink, as specified by the 5G standard. Similar to LTE, 3GPP defines one 5G resource block to consist of 12 consecutive OFDM subcarriers.	4.4.2 Resource grid For each numerology and carrier, a resource grid of $N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}$ subcarriers and $N_{\text{symb}}^{\text{subframe},\mu}$ OFDM symbols is defined, starting at common resource block $N_{\text{grid}}^{\text{start},\mu}$ indicated by higher-layer signalling. There is one set of resource grids per transmission direction (uplink or downlink) with the subscript x set to DL and UL for downlink and uplink, respectively. When there is no risk for confusion, the subscript x may be dropped. There is one resource grid for a given antenna port p, subcarrier spacing configuration μ, and transmission direction (downlink or uplink). The carrier bandwidth $N_{\text{grid}}^{\text{size},\mu}$ for subcarrier spacing configuration μ is given by the higher-layer parameter *carrierBandwidth* in the *SCS-SpecificCarrier* IE. The starting position $N_{\text{grid}}^{\text{start},\mu}$ for subcarrier spacing configuration μ is given by the higher-layer parameter *offsetToCarrier* in the *SCS-SpecificCarrier* IE. The frequency location of a subcarrier refers to the center frequency of that subcarrier. * * * * 4.4.4 Resource blocks 4.4.4.1 General A resource block is defined as $N_{\text{sc}}^{\text{RB}} = 12$ consecutive subcarriers in the frequency domain. Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf

Claim 8	Analysis	Select Evidence
encoding data symbols with polyphase codes derived from a discrete Fourier transform to produce encoded data symbols; and	The Galaxy encodes data symbols with polyphase codes generated from a discrete Fourier transform, resulting in encoded data symbols. The 5G specification requires a transform precoding step, which encodes data symbols ("complex-valued symbols x….") with polyphase codes using a DFT to generate encoded data symbols ("complex-valued symbols y…."). The exponential used in the DFT employs polyphase codes.	6.3.1.4 Transform precoding If transform precoding is not enabled according to 6.1.3 of [6, TS38.214], $y^{(\lambda)}(i) = x^{(\lambda)}(i)$ for each layer $\lambda = 0,1,\ldots,\upsilon-1$. If transform precoding is enabled according to 6.1.3 of [6, TS38.214], $\upsilon = 1$ and $\tilde{x}^{(0)}(i)$ depends on the configuration of phase-tracking reference signals. If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are not being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$ for the single layer $\lambda = 0$ shall be divided into $M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one OFDM symbol and $\tilde{x}^{(0)}(i) = x^{(0)}(i)$. If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used, the block of complex-valued symbols $x^{(0)}(0),\ldots,x^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$ shall be divided into sets, each set corresponding to one OFDM symbol, and where set l contains $M_{\text{sc}}^{\text{PUSCH}} - \varepsilon_l N_{\text{samp}}^{\text{group}} N_{\text{group}}^{\text{PTRS}}$ symbols and is mapped to the complex-valued symbols $\tilde{x}^{(0)}(lM_{\text{sc}}^{\text{PUSCH}} + i')$ corresponding to OFDM symbol l prior to transform precoding, with $i' \in \{0,1,\ldots,M_{\text{sc}}^{\text{PUSCH}}-1\}$ and $i' \neq m$. The index m of PT-RS samples in set l, the number of samples per PT-RS group $N_{\text{samp}}^{\text{group}}$, and the number of PT-RS groups $N_{\text{group}}^{\text{PTRS}}$ are defined in clause 6.4.1.2.2.2. The quantity $\varepsilon_l = 1$ when OFDM symbol l contains one or more PT-RS samples, otherwise $\varepsilon_l = 0$. * * * * Transform precoding shall be applied according to $$y^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} \tilde{x}^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}}$$ $$k = 0,\ldots,M_{\text{sc}}^{\text{PUSCH}}-1$$ $$l = 0,\ldots,M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}-1$$ resulting in a block of complex-valued symbols $y^{(0)}(0),\ldots,y^{(0)}(M_{\text{symb}}^{\text{layer}}-1)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil $$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$$ where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers. Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf

Claim 8	Analysis	Select Evidence
modulating the encoded data symbols onto the OFDM subcarriers to produce a superposition signal that resembles a single-carrier signal	The Galaxy modulates the encoded data symbols onto OFDM subcarriers during the OFDM baseband signal generation step required by the 5G specification. A person of ordinary skill in the art at the time of the invention would understand that an OFDM signal is a superposition of subcarriers. The OFDM baseband generation step uses an IFFT for transforming from the frequency-domain to the time-domain transformation. Each input symbol to an IFFT is modulated onto a particular subcarrier frequency, and the output of the IFFT is a discrete-time signal. If multiple symbols are input to the IFFT at the same time, the output discrete-time signal is a sum (i.e., superposition) of the subcarrier frequencies modulated with their corresponding symbols such that the signal resembles a single carrier.	5.3.1 OFDM baseband signal generation for all channels except PRACH The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p and subcarrier spacing configuration μ for OFDM symbol $l \in \{0,1,\ldots,N_{\text{slot}}^{\text{subframe},\mu} N_{\text{symb}}^{\text{slot}} - 1\}$ in a subframe for any physical channel or signal except PRACH is defined by $$s_l^{(p,\mu)}(t) = \sum_{k=0}^{N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} - 1} a_{k,l}^{(p,\mu)} \cdot e^{j2\pi\left(k + k_0^{\mu} - N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}/2\right)\Delta f\left(t - N_{\text{CP},l}^{\mu} T_c - t_{\text{start},l}^{\mu}\right)}$$ $$k_0^{\mu} = \left(N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu}/2\right) N_{\text{sc}}^{\text{RB}} - \left(N_{\text{grid},x}^{\text{start},\mu_0} + N_{\text{grid},x}^{\text{size},\mu_0}/2\right) N_{\text{sc}}^{\text{RB}} 2^{\mu_0 - \mu}$$ where $t_{\text{start},l}^{\mu} \le t < t_{\text{start},l}^{\mu} + \left(N_{\text{u}}^{\mu} + N_{\text{CP},l}^{\mu}\right) T_c$ is the time within the subframe, $$N_{\text{u}}^{\mu} = 2048\kappa \cdot 2^{-\mu}$$ $$N_{\text{CP},l}^{\mu} = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^{\mu} \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \ne 0 \text{ and } l \ne 7 \cdot 2^{\mu} \end{cases}$$ Δf is given by clause 4.2, μ is the subcarrier spacing configuration, and μ_0 is the largest μ value among the subcarrier spacing configurations provided to the UE for this carrier. The starting position of OFDM symbol l for subcarrier spacing configuration μ in a subframe is given by Source: Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf For 5G NR, as specified in 3GPP Release 15, the standardization organization decided to use cyclic prefix based orthogonal frequency division multiplex (CP-OFDM) as the access scheme. Unlike LTE, 5G NR also supports CP-OFDM in the uplink direction. But LTE's discrete Fourier transform spread OFDM (DFT-s-OFDM) uplink scheme, better known as single carrier frequency division multiplex (SC-FDMA), is still a valid access scheme and support is mandatory for any 5G terminal. The network decides which of the two schemes is used in the uplink. Source: https://www.rohde-schwarz.com/us/solutions/test-and-measurement/wireless-communication/cellular-standards/5g-test-and-measurement/embb/5g-waveforms/5g-waveforms_230224.html

Claim 8	Analysis	Select Evidence
and has one of a plurality of different symbol durations;	As described above 5G standard specifies the subcarrier spacing to be selected from 15kHz, 30kHz, 60kHz, 120kHz and 240 kHz. The 5G standard specifies the duration of one subframe to be 1ms and Number of OFDM symbols per slot to be 14 (except when having extended CP at 60kHz SCS). When the subcarrier spacing changes, the number of slots in one subframe changes. For example, OFDM symbol duration is approximately 66.6 μs for 15kHz SCS, and the OFDM symbol duration is halved when SCS is doubled (see below).	 **Figure 5.5.4.1-1: Frame structure in NR** In turn, each subframe consists of 1/2/4/8/16 slots -shown in different colors- depending on the selected SCS/numerology. The figure shows the cases of SCS values of 15; 30; 60 and 120 KHz, while the table below provides the full list of possible numerologies in NR. As shown in the figure for the 15 kHz case, each slot consists of 14 OFDM symbols (independently of the SCS) preceded by a cyclic prefix (CP). * * * * **Table 5.5.4.1-2: Multiple numerologies in NR** **Cyclic Prefix** | **subcarrier spacing (SCS) [kHz]** | **Number of subframes per radio frame** | **Number of slots per subframe** | **Number of OFDM symbols per slot** | **Applicable frequency range** normal | 15 | 10 | 1 | 14 | FR1 normal | 30 | 10 | 2 | 14 | FR1 normal | 60 | 10 | 4 | 14 | FR1 and FR2 extended | 60 | 10 | 4 | 12 | FR1 and FR2 normal | 120 | 10 | 8 | 14 | FR2 normal | 240 | 10 | 16 | 14 | FR2 Note: Additional specific numerologies are defined for PRACH, as described in Section 5.5.4.3. Note that, for the 60 kHz SCS, an extended CP is possible. The extended CP is approximately four times longer than the normal CP and is used for cells having large delay spread. In this case, one slot consists of only 12 OFDM symbols. The OFDM symbol duration and CP length are inversely proportional of the SCS. E.g. for 15 kHz SCS, the OFDM symbol duration is approximately 66.6 μs and the CP length is approximately 4.7 μs. When the SCS is doubled, i.e. 30 kHz, the OFDM and CP lengths are approximately devided by two compared to the 15kHz SCS. Source: https://www.etsi.org/deliver/etsi_tr/121900_121999/121915/15.00.00_60/tr_121915v150000p.pdf

Claim 8	Analysis	Select Evidence
wherein provisioning comprises selecting one of a plurality of different selectable subcarrier spacings, to provide for the one of the plurality of different symbol durations.	5G standard supports multiple OFDM numerologies, subcarrier spacings can be selected from 15kHz, 30kHz, 60kHz, 120kHz and 240kHz.	4.2 Numerologies Multiple OFDM numerologies are supported as given by Table 4.2-1 where μ and the cyclic prefix for a bandwidth part are obtained from the higher-layer parameter *subcarrierSpacing* and *cyclicPrefix*, respectively. **Table 4.2-1: Supported transmission numerologies.** μ | $\Delta f = 2^{\mu} \cdot 15$[kHz] | **Cyclic prefix** 0 | 15 | Normal 1 | 30 | Normal 2 | 60 | Normal, Extended 3 | 120 | Normal 4 | 240 | Normal * * * * Δf Subcarrier spacing * * * * μ Subcarrier spacing configuration, $\Delta f = 2^{\mu} \cdot 15$[kHz] Source: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf **OFDM Symbol Duration** Parameter / Numerlogy (u) | 0 | 1 | 2 | 3 | 4 Subcarrier Spacing (Khz) | 15 | 30 | 60 | 120 | 240 OFDM Symbol Duration (us) | 66.67 | 33.33 | 16.67 | 8.33 | 4.17 Cyclic Prefix Duration (us) | 4.69 | 2.34 | 1.17 | 0.57 | 0.29 OFDM Symbol including CP (us) | 71.35 | 35.68 | 17.84 | 8.92 | 4.46 Source: https://www.sharetechnote.com/html/5G/5G_FrameStructure.html

<table>
<tr><th>Claim 9</th><th>Analysis</th><th>Select Evidence</th></tr>
<tr>
<td>The apparatus of claim 8, wherein at least one of the plurality of different selectable subcarrier spacings equals at least one other of the plurality of different selectable subcarrier spacings multiplied by a scaling factor that is a power of two.</td>
<td>As described above 5G standard specifies the subcarrier spacing to be selected from 15kHz, 30kHz, 60kHz, 120kHz and 240 kHz.

As shown to the right, subcarrier spacing $\Delta f = 2^{\mu} \cdot 15[\mathrm{kHz}]$ wherein the scaling factor is the subcarrier spacing configuration μ.</td>
<td>

4.2 Numerologies

Multiple OFDM numerologies are supported as given by Table 4.2-1 where μ and the cyclic prefix for a bandwidth part are obtained from the higher-layer parameter *subcarrierSpacing* and *cyclicPrefix*, respectively.

Table 4.2-1: Supported transmission numerologies.

μ	$\Delta f = 2^{\mu} \cdot 15[\mathrm{kHz}]$	**Cyclic prefix**
0	15	Normal
1	30	Normal
2	60	Normal, Extended
3	120	Normal
4	240	Normal

* * * *

Δf Subcarrier spacing

* * * *

μ Subcarrier spacing configuration, $\Delta f = 2^{\mu} \cdot 15[\mathrm{kHz}]$

Source:
https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/15.02.00_60/ts_138211v150200p.pdf
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Claim 10	Analysis	Select Evidence
The apparatus of claim 8, further comprising instructions stored in the at least one non-transitory computer-readable memory, the instructions executable by the at least one processor for adding a cyclic prefix to the superposition signal.	The Galaxy is further configured to add a cyclic prefix to the SC-FDMA signal prior to transmit. As shown to the right, a cyclic prefix of length $N_{CP,l}^{\mu}$ is added when converting the SC-FDMA frequency domain signal into time domain signal.	$N_{\mathrm{CP},l}^{\mu}$ Cyclic prefix length; see clause 5.3.1 * * * * **5.3 OFDM baseband signal generation** **5.3.1 OFDM baseband signal generation for all channels except PRACH** The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p and subcarrier spacing configuration μ for OFDM symbol $l \in \{0,1,\ldots,N_{\mathrm{slot}}^{\mathrm{subframe},\mu} N_{\mathrm{symb}}^{\mathrm{slot}} - 1\}$ in a subframe for any physical channel or signal except PRACH is defined by $s_l^{(p,\mu)}(t) = \sum_{k=0}^{N_{\mathrm{grid}}^{\mathrm{size},\mu} N_{\mathrm{sc}}^{\mathrm{RB}}-1} a_{k,l}^{(p,\mu)} \cdot e^{j2\pi\left(k+k_0^{\mu}-N_{\mathrm{grid},x}^{\mathrm{size},\mu} N_{\mathrm{sc}}^{\mathrm{RB}}/2\right)\Delta f\left(t-N_{\mathrm{CP},l}^{\mu} T_{\mathrm{c}}-t_{\mathrm{start},l}^{\mu}\right)}$ $k_0^{\mu} = \left(N_{\mathrm{grid},x}^{\mathrm{start},\mu} + N_{\mathrm{grid},x}^{\mathrm{size},\mu}/2\right) N_{\mathrm{sc}}^{\mathrm{RB}} - \left(N_{\mathrm{grid},x}^{\mathrm{start},\mu_0} + N_{\mathrm{grid},x}^{\mathrm{size},\mu_0}/2\right) N_{\mathrm{sc}}^{\mathrm{RB}} 2^{\mu_0-\mu}$ where $t_{\mathrm{start},l}^{\mu} \le t < t_{\mathrm{start},l}^{\mu} + \left(N_{\mathrm{u}}^{\mu} + N_{\mathrm{CP},l}^{\mu}\right) T_{\mathrm{c}}$ is the time within the subframe, $N_{\mathrm{u}}^{\mu} = 2048\kappa \cdot 2^{-\mu}$ $N_{\mathrm{CP},l}^{\mu} = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^{\mu} \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \ne 0 \text{ and } l \ne 7 \cdot 2^{\mu} \end{cases}$ Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf