

INFRINGEMENT CONTENTIONS – CHART FOR U.S. PAT. NO. 7,593,492
EXHIBIT 5

'492 Claim Element	Accused Products
1[pre]: A hybrid Multi-User Detector System for processing received signals, comprising:	To the extent the preamble is found to be limiting, the Accused Instrumentalities include a hybrid Multi-User Detector System for processing received signals. Multiple data streams are received at the UE from an intracell SU-MIMO multi-layer transmission from the same serving cell sector, and from interfering (neighboring) cells. Multiuser detectors are used at the UE to separate the multiple data streams (layers) of SU-MIMO while cancelling interference data streams from the interfering cell(s). The multiuser detection systems may use a number of receiver types such as CodeWord IC (CWIC), Symbol Level IC (SLIC), Reduced complexity Maximum Likelihood (R-ML), LMSMSE-IRC, and variations of the CWIC, SLIC and R-ML with and without noise whitening. A specific multiuser detection such as the SU-MIMO detector, or an SU-MIMO in conjunction with intercell cancellation detector may use a hybrid of the available receiver types. MIMO in LTE: • <i>Downlink MIMO Technology</i> Single-User MIMO (SU-MIMO) was used for the downlink for LTE Rel. 8 to increase the peak data rate. The target data rates of over 100 Mbit/s were achieved by using a 20 MHz transmission bandwidth, 2×2 MIMO, and 64 Quadrature Amplitude Modulation (64QAM), and peak data rates of over 300 Mbit/s can be achieved using 4×4 SU-MIMO. The multi-antenna technology used for the downlink in LTE Rel. 8 is classified into the following three types. • Figure 1:

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	NTT DOCOMO Technical Journal Vol. 12 No. 2 Figure 1 Closed-loop SU-MIMO transmission using code-book-based precoding Via: 3g4g.blogspot.com

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	3GPP TS 36.211 V8.8.0: 6.3.3.2 Layer mapping for spatial multiplexing For spatial multiplexing, the layer mapping shall be done according to Table 6.3.3.2-1. The number of layers v is less than or equal to the number of antenna ports P used for transmission of the physical channel. The case of a single codeword mapped to two layers is only applicable when the number of antenna ports is 4. Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing <table><tr><th>Number of layers</th><th>Number of code words</th><th>Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$</th></tr><tr><td>1</td><td>1</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$</td></tr><tr><td>2</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$</td></tr><tr><td>2</td><td>1</td><td>$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$</td></tr><tr><td>3</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$</td></tr><tr><td>4</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$</td></tr></table>	Number of layers	Number of code words	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$	1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$	2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$	2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$	3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$	4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$
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'492 Claim Element	Accused Products
	Verizon Wireless Requirement Plan: 1.6.9.1 SU-MIMO IC RF Performance VZ_REQ_LTEB13NAC_39982 The device shall support and meet receiver maximum input level performance requirements for SU-MIMO IC (Enhanced Performance Requirements Type C), for all transmission modes that are supported on Verizon's network as specified in sections 8.2.1.3.1.B (FDD, TM3), 8.2.1.4.2.A (FDD, TM4), 8.3.1.2.A (TM9/TM10) of the Release 12 version of 3GPP TS 36.101: <i>Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment(UE) Radio Transmission and Reception</i>. 1.6.10 Blind Data IC VZ_REQ_LTEB13NAC_1238214 While operating in Blind Data IC mode, the UE shall meet enhanced receiver Type B performance requirements defined in TS 36.101 (Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception) requirements on the following channel operations: • PDSCH demodulation minimum performance using ○ CRS ▪ 8.2.1.2.5 Enhanced Performance Requirement Type B - 2 Tx Antenna Ports with TM2 interference model ▪ 8.2.1.4.1D Enhanced Performance Requirement Type B - Single-layer Spatial Multiplexing 2 Tx Antenna Port with TM4 interference model • PUCCH report of the channel quality (CQI) based on the receiver of the enhanced Type B using updated the updated fixed reference channel and interference models for enhanced performance requirements for Type-B receiver ○ 9.3.8 Additional requirements for enhanced receiver Type B ▪ 9.3.8.1.1 Minimum requirement PUCCH 1-1 (Cell-Specific Reference Symbols) – FDD Testing of these performance requirements will use GCF-based test cases w/o network-assisted configuration.

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	Verizon Wireless Requirements Plan: 1.3.2.20 LTE R10 eICIC and CRS IC w/o ABS (Enhanced Inter-Cell Interference Cancellation) VZ_REQ_LTEB13NAC_36948 Applicable scenarios: • Heterogeneous network that has both small/pico cells and macro cells deployed • R10 eICIC is used to enable network to perform necessary interference management by configuring ABS subframe dynamically. • Macro homogeneous network & Heterogeneous network • CRS IC is used in macro network in non-ABS scenario • Improve PDCCH and PDSCH performance in non-colliding CRS case (user throughput) • Improve RSRP accuracy and channel estimation in colliding CRS case (improved CRS SINR and as a result better performance on PBCH and PSS/SSS) TS 36.101 version 16.7.0: Enhanced performance requirements type A: This defines performance requirements assuming as baseline receiver reference symbol based linear minimum mean square error interference rejection combining. Enhanced performance requirements type B: This defines performance requirements assuming as baseline receiver using network assisted interference cancelation and suppression. Enhanced performance requirements type C: This defines performance requirements assuming as baseline receiver inter-stream interference cancellation.

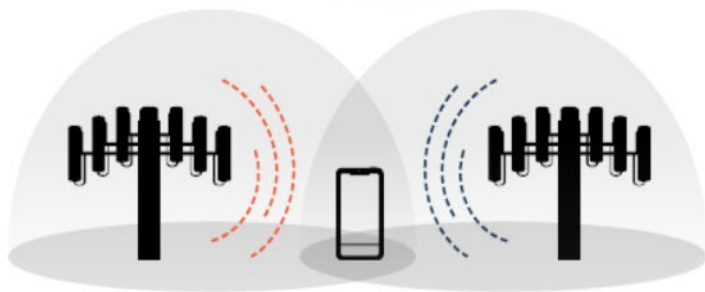
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	Sierra Wireless: Supported RF bands The modem, based on Qualcomm's MDM9250 baseband processor, supports data operation on LTE and UMTS networks over the bands described in Table 1-1, with LTE carrier aggregation (CA) as described in Table 1-2. Table 1-1: Supported RF Bands <table><tr><th rowspan="2">RAT</th><th colspan="26">Bands</th></tr><tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>12</th><th>13</th><th>18</th><th>19</th><th>20</th><th>26</th><th>28</th><th>29</th><th>30</th><th>32</th><th>41</th><th>42</th><th>43</th><th>46</th><th>48</th><th>66</th></tr><tr><td>LTE^a</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td></td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F^b</td><td>F</td><td>F^b</td><td>T</td><td>T</td><td>T</td><td>T^b</td><td>T^{b,c}</td><td>F</td></tr><tr><td>UMTS^d</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td></td><td>Y</td><td>Y</td><td></td><td></td><td></td><td>Y</td><td></td><td></td><td>N/A</td><td></td><td></td><td></td><td>N/A</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>GNSS</td><td colspan="26"> - GPS: 1575.42 MHz - GLONASS: 1602 MHz - BeiDou: 1561.098 MHz - Galileo: 1575.42 MHz - QZSS: 1575.42 MHz </td></tr><tr><td></td><td>•</td><td>•</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table> a. (LTE) Downlink MIMO support (2x2; 4x2) F=FDD; T=TDD Data rates: Downlink (Cat 12 with 3CA, 256QAM=600 Mbps; Cat 9 with 3CA, 64QAM=450 Mbps), Uplink (Cat 13 with 2CA contiguous, 64QAM=150 Mbps) b. Downlink only c. B48 support pending future release d. UMTS (DC-HSPA+, HSPA+, HSPA, UMTS) Diversity support Data rates: Downlink (Cat 24, up to 42 Mbps), Uplink (Cat 6, up to 11 Mbps)	RAT	Bands																										1	2	3	4	5	6	7	8	9	12	13	18	19	20	26	28	29	30	32	41	42	43	46	48	66	LTE ^a	F	F	F	F	F		F	F	F	F	F	F	F	F	F	F	F ^b	F	F ^b	T	T	T	T ^b	T ^{b,c}	F	UMTS ^d	Y	Y	Y	Y	Y	Y		Y	Y				Y			N/A				N/A						GNSS	- GPS: 1575.42 MHz - GLONASS: 1602 MHz - BeiDou: 1561.098 MHz - Galileo: 1575.42 MHz - QZSS: 1575.42 MHz																											•	•																							
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LTE ^a	F	F	F	F	F		F	F	F	F	F	F	F	F	F	F	F ^b	F	F ^b	T	T	T	T ^b	T ^{b,c}	F																																																																																																																																					
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	Qualcomm Snapdragon 5G Modem Features: <u>5G Modem-RF System</u> • <i>Snapdragon X60 5G Modem-RF System</i> • <i>5G mmWave and sub-6 GHz, standalone (SA) and non-standalone (NSA) modes, FDD, TDD</i> • <i>Dynamic Spectrum Sharing</i> • <i>mmWave: 800 MHz bandwidth, 8 carriers, 2x2 MIMO</i> • <i>Sub-6 GHz: 200 MHz bandwidth, 4x4 MIMO</i> • <i>Qualcomm® 5G PowerSave</i> • <i>Qualcomm® Smart Transmit™ technology</i> • <i>Qualcomm® Wideband Envelope Tracking</i> • <i>Qualcomm® AI-Enhanced Signal Boost</i> • <i>Global 5G multi-SIM</i> • <i>Downlink: Up to 7.5 Gbps</i> • <i>Uplink: Up to 3 Gbps</i> • <i>Multimode support: 5G NR, LTE including CBRS, WCDMA, HSPA, TD-SCDMA, CDMA 1x, EV-DO, GSM/EDGE</i>

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	Qualcomm LTE-Advanced Presentation: Enhanced receivers offer better user experience & more capacity Interference Cancellation  <table><thead><tr><th>Interference Cancellation</th><th>Rel. 10/11</th><th>Re. 12</th></tr></thead><tbody><tr><td>Sync ref. signal</td><td>✓</td><td>✓</td></tr><tr><td>Common ref. signal</td><td>✓</td><td>✓</td></tr><tr><td>Primary broadcast channel</td><td>✓</td><td>✓</td></tr><tr><td>Data channel</td><td></td><td>✓</td></tr></tbody></table> Better user experience - Higher data rates especially at cell-edges Higher network capacity - Higher users data rate increases overall network capacity Enhanced performance for HetNets - Even more beneficial in managing interference in small cell deployments 3GPP TR 36.866 V12.0.1: - Pages 11-12	Interference Cancellation	Rel. 10/11	Re. 12	Sync ref. signal	✓	✓	Common ref. signal	✓	✓	Primary broadcast channel	✓	✓	Data channel		✓
Interference Cancellation	Rel. 10/11	Re. 12														
Sync ref. signal	✓	✓														
Common ref. signal	✓	✓														
Primary broadcast channel	✓	✓														
Data channel		✓														

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	7.4 Interference Cancellation (IC) receivers IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - Linear Code word level SIC (L-CWIC): - receiver utilizing successive application of <i>linear detection</i> (e.g.: <i>LMMSE-IRC</i>), decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - ML-CWIC: - receiver utilizing successive application of <i>ML or reduced complexity ML detection</i>, decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (SLIC): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. 3GPP TR 36.829 V11.1.0: 4.3 MMSE IRC receiver For enhanced receiver, the MMSE-IRC receiver can suppress not only the inter-stream interference but also the inter-cell interference when the degrees of freedom at the receiver are sufficient, i.e., the number of receiver antennas is higher than that of the number of desired data streams, and MMSE IRC receiver weight matrix is expressed as follow:

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	$\mathbf{W}_{RX,l}(k,l) = \hat{\mathbf{H}}_1^H(k,l)\mathbf{R}^{-1}$ where $\hat{\mathbf{H}}_j(k,l)$ and $\mathbf{R}$ denote the estimated channel matrix and covariance matrix, respectively. To obtain the MMSE-IRC receiver weight matrix, the covariance matrix including the sources of inter-cell interference needs to be estimated. Various schemes can be considered for that purpose. • CRS based covariance matrix estimation scheme ▪ The covariance matrix is estimated at CRS REs by following equations $\mathbf{R} = P_1 \hat{\mathbf{H}}_1(k,l) \hat{\mathbf{H}}_1^H(k,l) + \frac{1}{N_{sp}} \sum_{k,l \in CRS} \tilde{\mathbf{r}}(k,l) \tilde{\mathbf{r}}(k,l)^H, \quad \tilde{\mathbf{r}}(k,l) = \mathbf{r}(k,l) - \hat{\mathbf{H}}_1(k,l) \mathbf{d}_1(k,l),$ where P_1 is the transmission power of the serving cell and is equal to $E[d_1(k,l) ^2]$ and N_{sp} is the number of sampling REs, respectively. • DM-RS based covariance matrix estimation scheme (applicable when DM-RS are configured) ▪ The covariance matrix is estimated at DM-RS REs by following equations: $\mathbf{R} = P_1 \hat{\mathbf{H}}_1(k,l) \hat{\mathbf{H}}_1^H(k,l) + \frac{1}{N_{sp}} \sum_{k,l \in DM-RS} \tilde{\mathbf{r}}(k,l) \tilde{\mathbf{r}}(k,l)^H, \quad \tilde{\mathbf{r}}(k,l) = \mathbf{r}(k,l) - \hat{\mathbf{H}}_1(k,l) \mathbf{d}_1(k,l)$ • Data signal based covariance matrix estimation scheme ▪ The covariance matrix is estimated at PDSCH REs by following equations: $\mathbf{R} = \frac{1}{N_{sp}} \sum_{k,l \in PDSCH, DM-RS} \mathbf{r}(k,l) \mathbf{r}(k,l)^H$
1[a]: a parameter estimator coupled to said received signals providing received data information;	The Accused Instrumentalities include a parameter estimator coupled to said received signals providing received data information. The Accused Instrumentalities use a channel estimator prior to symbol estimation, for interference mitigation, or for reconstructing decode symbols prior to interference cancellation. For example, channel estimates are needed in the LTE – SU-MIMO Products for symbol estimation, e.g., using an MMSE or its variations or maximum likelihood, prior to decoding a data stream, for intercell multiuser interference mitigation, or for reconstructing intracell or intercell interference signals prior to interference cancellation. MIMO in LTE:

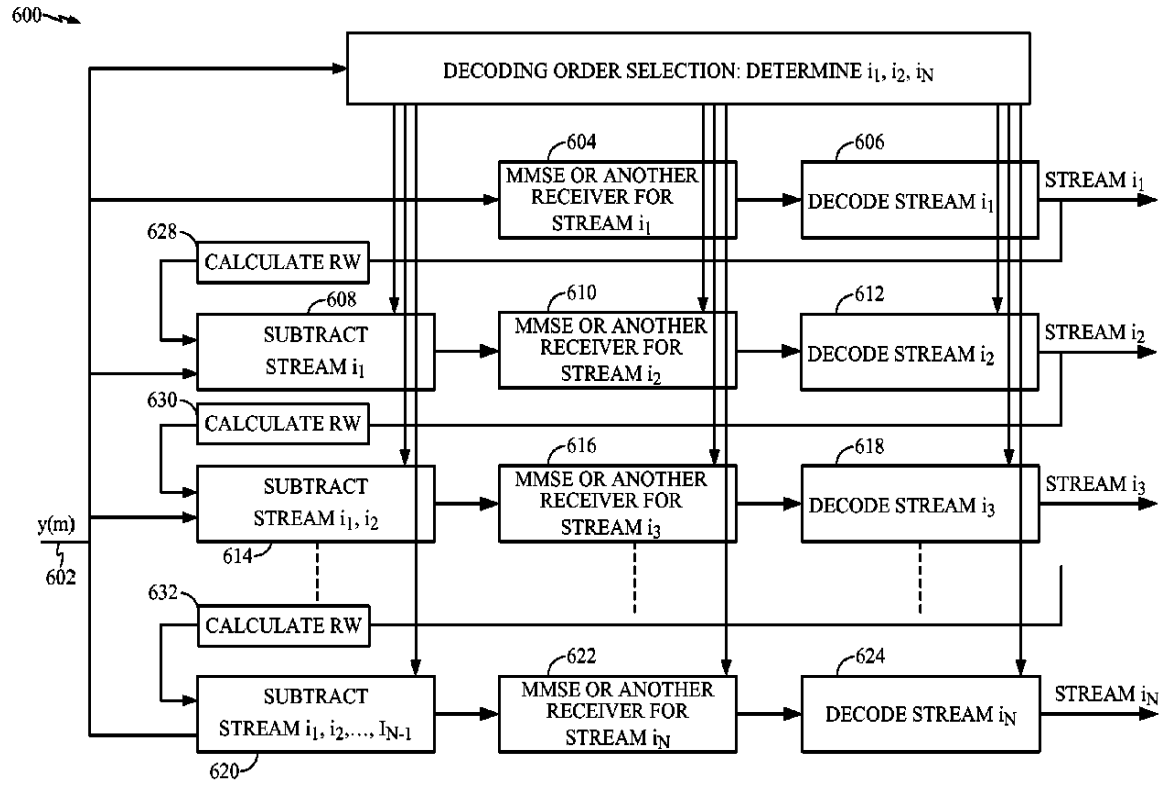
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	Downlink MIMO Technology Single-User MIMO (SU-MIMO) was used for the downlink for LTE Rel. 8 to increase the peak data rate. The target data rates of over 100 Mbit/s were achieved by using a 20 MHz transmission bandwidth, 2×2 MIMO, and 64 Quadrature Amplitude Modulation (64QAM), and peak data rates of over 300 Mbit/s can be achieved using 4×4 SU-MIMO. The multi-antenna technology used for the downlink in LTE Rel. 8 is classified into the following three types. - Figure 1: Figure 1 Closed-loop SU-MIMO transmission using code-book-based precoding Via: 3g4g.blogspot.com
	3GPP TR 36.866 V12.0.1: Pages 43-44: 9.1.1 Modelling methodologies for E-LMMSE-IRC Alternative 1 Assuming that a single dominant interferer is taken into account explicitly at the receiver, the following signal model is considered:

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	$ \begin{aligned} y &= H_0 x_0 + H_1 x_1 + \left(\sum_{i=2}^K H_i x_i \right) + n \\ &= H_0 x_0 + H_1 x_1 + z \\ &= H_0 x_0 + v \end{aligned} \tag{9.1} $ where z is the interference from non-dominant interferers and noise term, and v is the total interference and noise term. The E-LMMSE-IRC receiver is expressed as $ W = \hat{H}_0^H \left(\hat{H}_0 \hat{H}_0^H + \hat{H}_1 \hat{H}_1^H + \hat{R}_z \right)^{-1}, \tag{9.2} $ where $\hat{R}_z$ is the estimate of other cell interference and noise covariance, that is $R_z = E[zz^H]$. Therefore, the system level modelling of E-LMMSE-IRC consists of modelling the estimation of H_0, H_1, and R_z. The other cell interference and noise covariance estimate $\hat{R}_z$ may be modelled using the complex Wishart distribution, so that $ \hat{R}_z \sim CWishart(R_z, N_{eff}), \tag{9.3} $

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	Qualcomm's '994 patent:  The diagram illustrates a system 600 for decoding multiple streams. An input signal $y(m)$ (labeled 602) is fed into a series of processing blocks. At the top, a block labeled 'DECODING ORDER SELECTION: DETERMINE i_1, i_2, i_N' (labeled 600) receives the input and outputs control signals to a series of receiver and decoder blocks. The system processes the input signal through a series of subtraction and reception steps. For each stream i (from 1 to N), the input signal is subtracted by the previously decoded streams (e.g., 'SUBTRACT STREAM i_1' for stream 2, 'SUBTRACT STREAM i_1, i_2' for stream 3, and 'SUBTRACT STREAM $i_1, i_2, \dots, i_{N-1}$' for stream N). Each subtraction step is followed by a 'CALCULATE RW' block (e.g., 628, 630, 632) and an 'MMSE OR ANOTHER RECEIVER FOR STREAM i' block (e.g., 604, 610, 616, 622). The output of each receiver block is then passed to a 'DECODE STREAM i' block (e.g., 606, 612, 618, 624), which produces the final 'STREAM i' output. The diagram shows a parallel structure for each stream, with the input signal being processed sequentially for each stream in the order determined by the decoding order selection block. Figure 6:

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	9:25-43 (“As illustrated in FIG. 6, a composite received signal $y(m)$ 602 enters a SIC system 600 with decoding order selection and reconstruction weight calculation. The composite received signal $y(m)$ consists of a plurality of separately encoded streams of data. The decoding order selector 626 determines a decoding order for the N streams of data based on the received SNR of each and the required SNR at the input of each decoder. Based on the selected order, the streams are decoded and subtracted from the received signal. [¶] The received signal $y(m)$ passes through a receiver 604 for estimation and detection of the received symbols of a first stream of data. The receiver 604 may comprise a minimum mean square error (MMSE) or any general linear or nonlinear estimator/detector. The detected symbols of the first stream enter the channel decoder 606 for decoding. The decoded stream is re-encoded and re-modulated to reconstruct the first stream. The scale of this reconstructed stream may differ from the scale of the first transmitted stream or the scale of first stream in the received composite signal.”)
1[b]: a multi-user detector decision unit coupled to said parameter estimator and said received signals;	The Accused Instrumentalities include a multi-user detector decision unit coupled to said parameter estimator and said received signals. The Accused Instrumentalities may use several multi-user receiver types requiring a multi-user decision unit to choose a specific receiver type under different signal conditions. For example, UE receivers for intracell SU-MIMO multiple data stream detection and for intercell interference cancellation according to NAICS and/or CRS-IC features may use a receiver from among a set of receivers such as CWIC, SLIC, R-ML and LMMSE-IRC and may include a fallback mode to a different multi-user receiver. For instance, for intercell PDSCH interference cancellation, or for separating different layers of a SU-MIMO codeword SLIC or R-ML may be used. For separating different codewords of a SU-MIMO signal CWIC may be used. The CWIC or R-ML SU-MIMO receiver may further use noise whitening filter prior to aid separating the SU-MIMO data streams. 3GPP TR 36.866 V12.0.1: Pages 11-12

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	7.2 Interference Suppression (IS) receivers IS receivers refer to receivers that apply linear filtering to the received signal to suppress the interference, as opposed to explicitly cancel the interference. Three types of IS receivers are identified: - LMMSE-IRC: - It is baseline for Rel-11 MMSE-IRC study (refer to TR36.829). - No knowledge of interferer parameter(s) is required. - Enhanced LMMSE-IRC (E-LMMSE-IRC): - MMSE-IRC that explicitly considers interferer channel estimates and other interferer knowledge. - Interference parameters that can enable interferer channel estimation are needed, including, for example, its DMRS or CRS with PMI/RI. - Widely linear MMSE-IRC (WLMMSE-IRC): - WLMMSE-IRC exploits the additional degrees of freedom from the real and imaginary part of the received signal to enhance suppression of interference - Real-valued modulation may be used to increase performance of the WLMMSE-IRC receiver 7.3 Maximum Likelihood (ML) receivers ML-type of receivers are non-linear in nature. Three types of ML receivers are also identified: - ML: - Full-blown joint detection of useful and interference signals in accordance to the ML criterion - Interference parameters that can enable interferer channel estimation and interferer detection at symbol level (e.g., modulation) are needed. - Reduced complexity ML (R-ML): - Reduced complexity joint detection of useful and interference modulation symbols in accordance to the ML criterion (e.g. sphere decoding, QR-MLD, MLM, etc.) - Same interference knowledge as for ML - Iterative ML and Iterative R-ML: - Iterative MAP detection and decoding of useful and interference signals. Both successive and parallel processing implementations may be applied. - In addition to the interference knowledge needed for ML, interference knowledge that can enable code word demodulation and decoding is needed.

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	- Additionally, assumptions on network coordination may be necessary. 7.4 Interference Cancellation (IC) receivers IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - Linear Code word level SIC (L-CWIC): - receiver utilizing successive application of <i>linear detection</i> (e.g.: <i>LMMSE-IRC</i>), decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - ML-CWIC: - receiver utilizing successive application of <i>ML or reduced complexity ML detection</i>, decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (SLIC): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. • Pages 43-44: 9.1.1 Modelling methodologies for E-LMMSE-IRC Alternative 1

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	Assuming that a single dominant interferer is taken into account explicitly at the receiver, the following signal model is considered: $ \begin{aligned} y &= H_0 x_0 + H_1 x_1 + \left(\sum_{i=2}^K H_i x_i \right) + n \quad , \\ &= H_0 x_0 + H_1 x_1 + z \\ &= H_0 x_0 + v \end{aligned} \tag{9.1} $ where z is the interference from non-dominant interferers and noise term, and v is the total interference and noise term. The E-LMMSE-IRC receiver is expressed as $W = \hat{H}_0^H \left(\hat{H}_0 \hat{H}_0^H + \hat{H}_1 \hat{H}_1^H + \hat{R}_z \right)^{-1} , \tag{9.2}$ where $\hat{R}_z$ is the estimate of other cell interference and noise covariance, that is $R_z = E[zz^H]$. Therefore, the system level modelling of E-LMMSE-IRC consists of modelling the estimation of H_0, H_1, and R_z. The other cell interference and noise covariance estimate $\hat{R}_z$ may be modelled using the complex Wishart distribution, so that $\hat{R}_z \sim CWishart(R_z, N_{eff}). \tag{9.3}$ TSG-RAN WG4, Contribution # R4-150991: Title: On UE Demodulation Test Setup for NAICS : : In this paper, we present our views for defining UE demodulation requirements in RAN4. • Receiver Selection • Fallback Operation

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	• Blind Detection Granularity • Transmission Modes • 2.4 Receiver Selection Proposal 3: Target a single unified UE demodulation performance requirement based on SLIC and R-ML receivers in the Rel-12 NAICS UE demodulation requirements. • As observed previously, NAICS gains from SLIC and R-ML receivers are greater than EMMSE-IRC receivers in multiple scenarios [2]. Therefore, in order to being maximum gains via NAICS processing, unified requirements should be set based on SLIC/R-ML receivers. TSG-RAN WG4, Contribution # R4-146945: Title: Discussion and simulation result for NAICS demodulation performance • 2. Discussion on Test Scenario Based on WID [1] of NAICS, considerations to define performance requirement for NAICS receiver are as follows: ▪ Define unified performance requirement for NAICS receiver ▪ Ensure no performance loss compared to LMMSE-IRC receiver in all interference PDSCH scenarios In this section, we discuss two points of verification for NAICS receiver gain and robustness. 2.1 Performance Gain for NAICS Receiver In general, NAICS performance gain can be achieved in high interference power condition, and can easily distinguish performance of NAICS and baseline receiver in most test scenarios. When high interference power is configured, since PDCCH decoding performance of serving cell is affected by control channel of

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	interfering cell, PDSCH performance of NAICS receivers seriously degraded. However, for PDSCH performance requirement, PDCCH decoding impact can be minimized by using low loading control channel of interfering cell as the proposal of [4]. Therefore, to define performance gain for NAICS receiver, high interference power can be configured. - <i>Proposal 1:</i> Use high interference profile for verification of NAICS performance gain. Targeted network deployment scenarios for NAICS are homogeneous and heterogeneous networks. In general, dominant interfering cell has non-colliding CRS with serving cell in homogeneous network, and in heterogeneous network, dominant interfering cell could have colliding CRS with serving cell. NAICS receiver can achieve reasonable performance gain for colliding and non-colliding CRS scenarios under CRS based transmission mode in high INR [3]. Therefore, considering both network scenarios, colliding and non-colliding CRS scenarios should be considered for verification of NAICS performance gain. - <i>Proposal 2:</i> Both colliding and non-colliding CRS network scenarios should be considered for NAICS performance requirement. NAICS receiver blindly detects various TMs for interference PDSCH, and for NAICS performance requirement, TMs need to be narrowed for typical case such as TM4 and TM9 represented by CRS and DMRS base TM and TM2 used as fallback mode. Although the number of effective layer is four in TM2-TM2 case and current RAN4 agreement is violated which is to limit total layer (serving + interfering) up to 3, total 3 layers can be handled by NAICS receiver among 4 layers, and NAICS performance gain for TM2-TM2 case can be achieved [3][5]. - <i>Proposal 3:</i> TM2 should be used for fallback TM for all TMs, and TM4 and TM9 can be used as representative of CRS and DMRS based TM for performance requirement. RAN4 agreed that R-ML and SLIC receivers are used for NAICS performance requirement for 2 CRS ports, and FFS is for 4 CRS ports. To unify performance requirement for NAICS receivers, two options to define unified performance requirement with multiple reference receivers can be considered as follows: ▪ Option 1: Take average performance of both R-ML and SLIC receiver ▪ Option 2: Take minimum performance between R-ML and SLIC receivers similar to SU-MIMO case

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	Between the two options, if performance difference between R-ML and SLIC receiver is not large, these are reasonable approaches to unify performance requirement. If noticeable performance gap between receivers is observed, option 2 is reasonable since it is difficult to satisfy both R-ML and SLIC receivers by option 1 based performance requirement. - <i>Proposal 4:</i> For unified performance requirement, it should take minimum performance between R-ML and SLIC receivers. 2.2 Robustness for NAICS Receiver To ensure no performance loss compared to LMMSE-IRC receiver, NAICS receiver should consider fallback operation. In some interference scenarios such as low INR and high rank, NAICS receiver has no performance gain in comparison with baseline receiver. Dual decoding capability has been proposed as one possible approach for robust NAICS operations. However, additional decoding process can introduce increased power consumption and complexity in UE implementation perspective. Considering implementation complexity and receiver structures, various approaches for fallback operation to verify robustness NAICS receiver are available. Therefore, to verify the robustness of a NAICS receiver, it is not necessary to mandate specific fallback operation, and NAICS fallback operation should be a UE implementation issue. Then, one worst test case such as non-colliding CRS or low INR condition can be utilized to verify no performance loss compared to LMMSE-IRC receiver. Detail test scenario for robustness needs more investigation for various tests which both R-ML and SLIC receivers have performance loss in comparison with baseline receiver. - <i>Observation 1:</i> For verification of robustness for NAICS receivers, one worst case such as non-colliding CRS, high MCS level, or low INR condition can be used. - <i>Observation 2:</i> Need more investigation to find common test case which both R-ML and SLIC receivers have performance loss compared to baseline receiver. - <i>Proposal 5:</i> NAICS fallback operation should be UE implementation issue. In some worst test scenario which blind detection reliability cannot be guaranteed, the performance of NAICS receiver ensures no loss compared to baseline IRC receiver. However, if higher-layer signaling from eNB is incorrect, NAICS receiver may introduce performance loss due to wrong parameter detection

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	by incorrect high-layer signaling. Therefore, NAICS performance requirement should be defined under correct higher-layer signaling. - <i>Proposal 6:</i> NAICS performance requirement should be defined under correct higher-layer signaling from eNB. TSG-RAN WG4, Contribution # R4-150484: Title: Simulation results for multi-cell whitening verification : : 1. Introduction In RAN4#73, WF [1] for multi-cell whitening verification test was agreed. In this contribution, we provide simulation results for multi-cell whitening verification test based on agreed WF. : : 3. Conclusion In this contribution, we provide simulation results for multi-cell whitening verification test for alignment. For discrimination between receiver w/ and w/o whitening function, high INR setting is more suitable than medium INR setting since performance difference between w/ and w/o whitening function in high INR is larger than that in medium INR. TSG-RAN WG4, Contribution # R4-143876: Way forward for SU-MIMO WI in Rel-12 • RAN4 consider to take both R-ML and CWIC receiver as the candidate receiver for SU-MIMO. • RAN4 consider to define demodulation test of SU-MIMO based on the minimum performance of the above candidate receivers.

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	– For each demodulation test there will be a single requirement which is based on R-ML receiver. – If the performance of CWIC is found to be worse than R-ML, then requirement will be based on CWIC receiver for the agreed test cases.
1[c]: at least two multi-user detectors coupled to said parameter estimator and said multi-user detector decision unit, said multi-user detector decision unit using decision criteria to determine a selected multi-user detector, wherein said selected multi-user detector outputs a plurality of information streams, one stream corresponding to each of said received signals; and	The Accused Instrumentalities include at least two multi-user detectors coupled to said parameter estimator and said multi-user detector decision unit, said multi-user detector decision unit using decision criteria to determine a selected multi-user detector, wherein said selected multi-user detector outputs a plurality of information streams, one stream corresponding to each of said received signals. The Accused Instrumentalities use at least two multi-user detectors, a multi-user detector using decision criteria to select a multi-user detector and detecting the symbols of each data stream (“layers”). For example, SU-MIMO multi-user detector module may choose from at least two multi-user detectors depending on the number of data streams (“layers”), on intercell reference symbol conditions, signal and intracell and intercell interference levels and complexity considerations. For instance: (1) in a multi-cell environment, the SU-MIMO detector may use a multi-user detector such as R-ML with noise whitening for higher other cell INR (Interference to Noise Ratio) to mitigate interference from an interfering cell or without noise whitening for low INR conditions; (2) alternatively, in a multi-cell environment, the SU-MIMO detector may use a detector such a R-ML or CWIC for separating the SU-MIMO data streams while concurrently using a NAICS interference cancellation detector such as SLIC or R-ML to cancel or mitigate interference from an interfering cell; (3) the multiuser detector for cancelling/mitigating the interfering cell interference for SU-MIMO, in a multicell environment, that uses R-ML or SLIC, may fallback to the LMMSE-IRC or other multi-user detector to avoid loss of performance under certain signal and interference conditions; (4) the SU-MIMO receiver may also implement interfering cell CRS/DMRS symbol interference mitigation, where the CRS/DMRS interference mitigation receiver structure depends on whether or not the CRS/DMRS symbols are colliding, where the multi-user detector unit determine an appropriate CRS/DMRS interference mitigation receiver type; (5) the SU-MIMO comprising 3 or 4 layers in LTE uses two codewords and 2 layers within the codeword for at least one of the codewords. When there are 2 or more data streams (“layers”) layers within a codeword then the different layers within a codeword need to be separated using a detector such as SLIC or R-ML while a CWIC detector may be used for separating the two codewords. Therefore, the multiuser detector decision unit may choose a

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	different combination of multiuser detector depending on the number of data streams of the SU-MIMO mode. To the extent that the Court construes the “multi-user detection decision unit” as means-plus-function language, the scenarios above contemplate situations where the decision unit is covered by structure in the specification. These scenarios use a one or a combination of the following for the decision unit: number of users, correlation matrix/structure, SINR or expected SINR, expected BER, and eigenvalues. TSG-RAN WG4, Contribution # R4-150991: Title: On UE Demodulation Test Setup for NAICS ⋮ In this paper, we present our views for defining UE demodulation requirements in RAN4. • Receiver Selection • Fallback Operation • Blind Detection Granularity • Transmission Modes ⋮ 2.4 Receiver Selection Proposal 3: Target a single unified UE demodulation performance requirement based on SLIC and R-ML receivers in the Rel-12 NAICS UE demodulation requirements. • As observed previously, NAICS gains from SLIC and R-ML receivers are greater than EMMSE-IRC receivers in multiple scenarios [2]. Therefore, in order to being maximum gains via NAICS processing, unified requirements should be set based on SLIC/R-ML receivers. TSG-RAN WG4, Contribution # R4-146945: Title: Discussion and simulation result for NAICS demodulation performance .

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	DMRS base TM and TM2 used as fallback mode. Although the number of effective layer is four in TM2-TM2 case and current RAN4 agreement is violated which is to limit total layer (serving + interfering) up to 3, total 3 layers can be handled by NAICS receiver among 4 layers, and NAICS performance gain for TM2-TM2 case can be achieved [3][5]. - <i>Proposal 3:</i> TM2 should be used for fallback TM for all TMs, and TM4 and TM9 can be used as representative of CRS and DMRS based TM for performance requirement. RAN4 agreed that R-ML and SLIC receivers are used for NAICS performance requirement for 2 CRS ports, and FFS is for 4 CRS ports. To unify performance requirement for NAICS receivers, two options to define unified performance requirement with multiple reference receivers can be considered as follows: ▪ Option 1: Take average performance of both R-ML and SLIC receiver ▪ Option 2: Take minimum performance between R-ML and SLIC receivers similar to SU-MIMO case Between the two options, if performance difference between R-ML and SLIC receiver is not large, these are reasonable approaches to unify performance requirement. If noticeable performance gap between receivers is observed, option 2 is reasonable since it is difficult to satisfy both R-ML and SLIC receivers by option 1 based performance requirement. - <i>Proposal 4:</i> For unified performance requirement, it should take minimum performance between R-ML and SLIC receivers. 2.2 Robustness for NAICS Receiver To ensure no performance loss compared to LMMSE-IRC receiver, NAICS receiver should consider fallback operation. In some interference scenarios such as low INR and high rank, NAICS receiver has no performance gain in comparison with baseline receiver. Dual decoding capability has been proposed as one possible approach for robust NAICS operations. However, additional decoding process can introduce increased power consumption and complexity in UE implementation perspective. Considering implementation complexity and receiver structures, various approaches for fallback operation to verify robustness NAICS receiver are available. Therefore, to verify the robustness of a NAICS receiver, it is not necessary to mandate specific fallback operation, and NAICS fallback operation should be a UE implementation issue. Then, one worst test case such as non-colliding CRS or low INR condition can be

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	utilized to verify no performance loss compared to LMMSE-IRC receiver. Detail test scenario for robustness needs more investigation for various tests which both R-ML and SLIC receivers have performance loss in comparison with baseline receiver. - <i>Observation 1:</i> For verification of robustness for NAICS receivers, one worst case such as non-colliding CRS, high MCS level, or low INR condition can be used. - <i>Observation 2:</i> Need more investigation to find common test case which both R-ML and SLIC receivers have performance loss compared to baseline receiver. - <i>Proposal 5:</i> NAICS fallback operation should be UE implementation issue. In some worst test scenario which blind detection reliability cannot be guaranteed, the performance of NAICS receiver ensures no loss compared to baseline IRC receiver. However, if higher-layer signaling from eNB is incorrect, NAICS receiver may introduce performance loss due to wrong parameter detection by incorrect high-layer signaling. Therefore, NAICS performance requirement should be defined under correct higher-layer signaling. - <i>Proposal 6:</i> NAICS performance requirement should be defined under correct higher-layer signaling from eNB. TSG-RAN WG4, Contribution # R4-150484: Title: Simulation results for multi-cell whitening verification ⋮ 2. Introduction In RAN4#73, WF [1] for multi-cell whitening verification test was agreed. In this contribution, we provide simulation results for multi-cell whitening verification test based on agreed WF. ⋮ 4. Conclusion In this contribution, we provide simulation results for multi-cell whitening verification test for alignment.

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	For discrimination between receiver w/ and w/o whitening function, high INR setting is more suitable than medium INR setting since performance difference between w/ and w/o whitening function in high INR is larger than that in medium INR. TSG-RAN WG4, Contribution # R4-143876: Way forward for SU-MIMO WI in Rel-12 • RAN4 consider to take both R-ML and CWIC receiver as the candidate receiver for SU-MIMO. • RAN4 consider to define demodulation test of SU-MIMO based on the minimum performance of the above candidate receivers. – For each demodulation test there will be a single requirement which is based on R-ML receiver. – If the performance of CWIC is found to be worse than R-ML, then requirement will be based on CWIC receiver for the agreed test cases. TSG-RAN WG4, Contribution # R4-125318: Title: Demod and CSI reporting requirements for FeICIC Proposal 1: For demod and CSI requirements/test, the number of aggressors to be explicitly modelled and whose CRS interference to be handled by UE should be N=2. Unlike eICIC, FeICIC capable UEs should be able to handle both non-colliding and colliding CRS aggressors under both non-MBSFN and MBSFN ABS. On the other hand, it is important to be conscious of the number of test cases, as the combinations of colliding and non-colliding CRS settings for N=2 interferers in combination with non-MBSFN and MBSFN ABS setting can easily blow up the number of test cases and the UE test complexity. For eICIC, the impact of CRS interference from non-colliding CRS non-MBSFN ABS and colliding CRS MBSFN ABS were very different, as the former impacts the control/data REs while the latter impacts the channel estimation. In contrast, FeICIC UEs are capable of CRS handling, and with proper handling of CRS interference, the difference from the impact of residual CRS interference between non-MBSFN ABS and MBSFN-ABS should be small. In fact, our previous

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	simulations [3][4] show that it is sufficient to define test cases only for non-MBSFN ABS, as the performance under MBSFN ABS is either equal or marginally better than that under non-MBSFN ABS. 3GPP TS 36.211 V8.8.0: 6.3.3.2 Layer mapping for spatial multiplexing For spatial multiplexing, the layer mapping shall be done according to Table 6.3.3.2-1. The number of layers v is less than or equal to the number of antenna ports P used for transmission of the physical channel. The case of a single codeword mapped to two layers is only applicable when the number of antenna ports is 4. Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing <table><tr><th>Number of layers</th><th>Number of code words</th><th>Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$</th></tr><tr><td>1</td><td>1</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$</td></tr><tr><td>2</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$</td></tr><tr><td>2</td><td>1</td><td>$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$</td></tr><tr><td>3</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$</td></tr><tr><td>4</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$</td></tr></table>	Number of layers	Number of code words	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$	1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$	2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$	2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$	3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$	4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$
Number of layers	Number of code words	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$																	
1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$																	
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$																	
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$																	
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4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$																	

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	Qualcomm's '994 patent: 9:24-10:("2 As illustrated in FIG. 6, a composite received signal $y(m)$ 602 enters a SIC system 600 with decoding order selection and reconstruction weight calculation. The composite received signal $y(m)$ consists of a plurality of separately encoded streams of data. The decoding order selector 626 determines a decoding order for the N streams of data based on the received SNR of each and the required SNR at the input of each decoder. Based on the selected order, the streams are decoded and subtracted from the received signal. The received signal $y(m)$ passes through a receiver 604 for estimation and detection of the received symbols of a first stream of data. The receiver 604 may comprise a minimum mean square error (MMSE) or any general linear or non linear estimator/detector. The detected symbols of the first stream enter the channel decoder 606 for decoding. The decoded stream is re-encoded and re-modulated to reconstruct the first stream. The scale of this reconstructed stream may differ from the scale of the first transmitted stream or the scale of first stream in the received composite signal. A reconstruction weight vector is calculated at 628 for the reconstructed stream. Blocks 628, 630 and 632 may calculate reconstruction weights for each decoded stream to cancel the interference of the decoded stream from the composite received signal as efficiently as possible. Weight reconstruction, in accordance with certain aspects, is described in greater detail below. In 608, the reconstructed stream is multiplied with the reconstruction weight vector and subtracted from the received signal. The resulting signal passes through a second receiver 610 and a second decoder 612 to detect and decode the second stream, respectively. After decoding, effects of both of the first and second streams of data are subtracted at 614 from the received signal to cancel the interference and condition the received signal to enter the third decoding block 618 for decoding the third stream. The process continues with subtraction 620, receiver operation 622 and decoding 624 until all the streams are decoded. The decoders 606, 612 and 618 may use any kind of error correcting code such as turbo codes. The decoders 606, 612 and 618 may decode a plurality of encoded streams with a plurality of types and code rates. The Subtraction operation may not be performed if the decoding operation fails at any step. The decoding order selector may update the decoding order of the remaining streams after each Successful decode and subtract operation (i.e., each SIC iteration).")

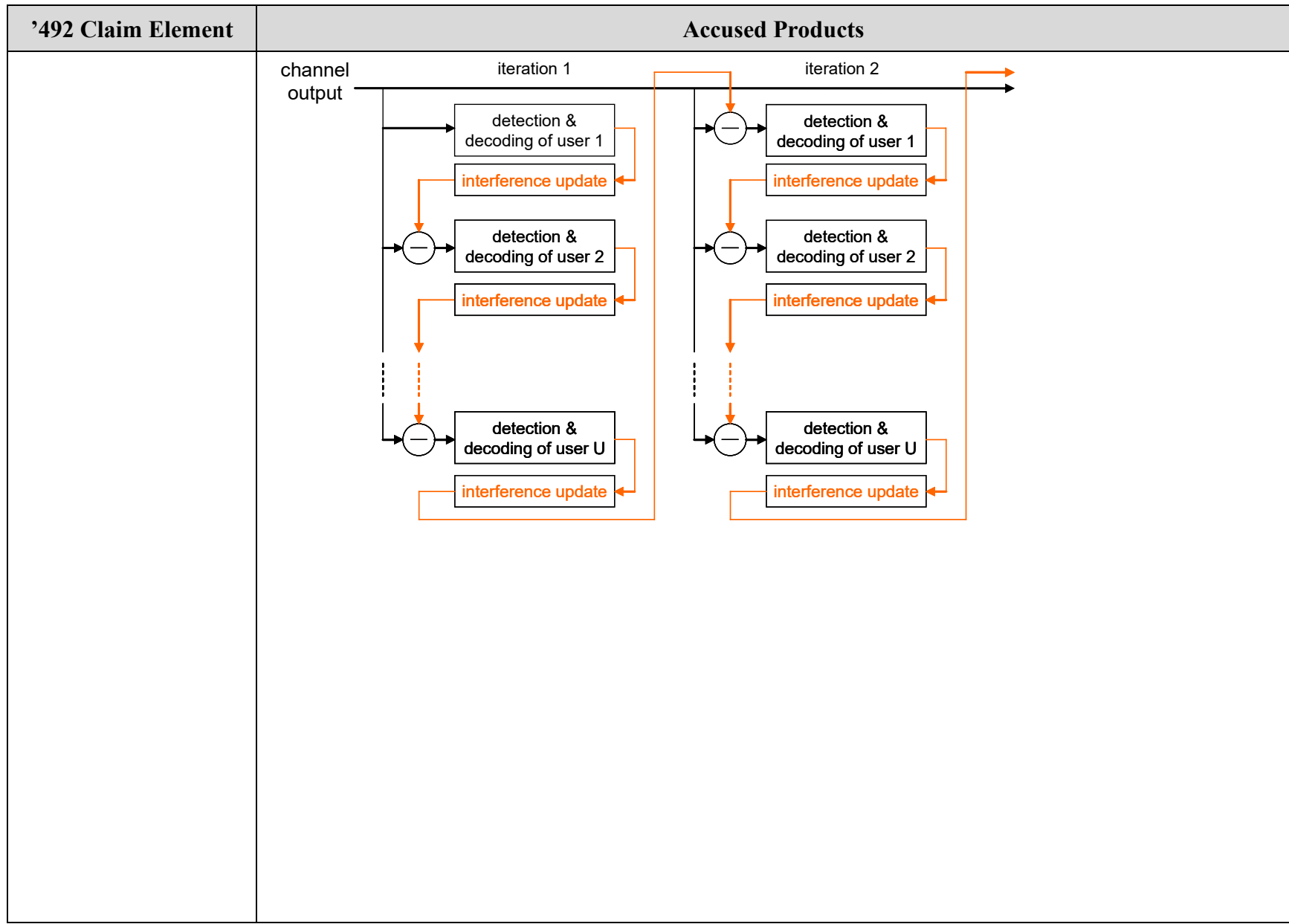
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'492 Claim Element	Accused Products
	• Figure 6: FIG. 6

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'492 Claim Element	Accused Products
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
1[d]: a bank of decoders coupled to said plurality of information streams, wherein said decoders output a plurality of improved information streams.	The Accused Instrumentalities include a bank of decoders coupled to said plurality of information streams, wherein said decoders output a plurality of improved information streams. The Accused Instrumentalities use a bank of decoders coupled to said symbol estimator, producing a plurality of symbol likelihood estimates for each data stream. TSG-RAN WG1, Contribution # R1-090919: Receiver Turbo-SIC strategy After proper noise filtering and sampling of the channel output at the receiver side, the turbo-SIC detection strategy in a multi-user context consists in an iterative linear filtering with Successive Interference Cancellation (SIC) of the users, as depicted in Fig. 3.

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'492 Claim Element	Accused Products
	Fig. 1 - SIC process assuming natural ordering of the users Qualcomm's '994 patent: 9:24-10:2 ("As illustrated in FIG. 6, a composite received signal $y(m)$ 602 enters a SIC system 600 with decoding order selection and reconstruction weight calculation. The composite received signal $y(m)$ consists of a plurality of separately encoded streams of data. The decoding order selector 626 determines a decoding order for the N streams of data based on the received SNR of each and the required SNR at the input of each decoder. Based on the selected order, the streams are decoded and subtracted from the received signal. The received signal $y(m)$ passes through a receiver 604 for estimation and detection of the received symbols of a first stream of data. The receiver 604 may comprise a minimum mean square error (MMSE) or any general linear or non linear estimator/detector. The detected symbols of the first stream enter the channel decoder 606 for decoding. The decoded stream is re-encoded and re-modulated to reconstruct the first stream. The scale of this reconstructed stream may differ from the scale of the first transmitted stream or the scale of first stream in the received composite signal. A reconstruction weight vector is calculated at 628 for the reconstructed stream. Blocks 628, 630 and 632 may calculate reconstruction weights for each decoded stream to cancel the interference of the decoded stream from the composite received signal as efficiently as possible. Weight reconstruction, in accordance with certain aspects, is described in greater detail below. In 608, the reconstructed stream is multiplied with the reconstruction weight vector and subtracted from the received signal. The resulting signal passes through a second receiver 610 and a second decoder 612 to detect and decode the second stream, respectively. After decoding, effects of both of the first and second streams of data are subtracted at 614 from the received signal to cancel the interference and condition the received signal to enter the third decoding block 618 for decoding the third stream. The process continues with subtraction 620, receiver operation 622 and decoding 624 until all the streams are decoded. The decoders 606, 612 and 618 may use any kind of error correcting code such as turbo codes. The decoders 606, 612 and 618 may decode a plurality of encoded streams with a plurality of types and code rates. The Subtraction operation may not be performed

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'492 Claim Element	Accused Products
	if the decoding operation fails at any step. The decoding order selector may update the decoding order of the remaining streams after each Successful decode and subtract operation (i.e., each SIC iteration).”) Figure 6: FIG. 6

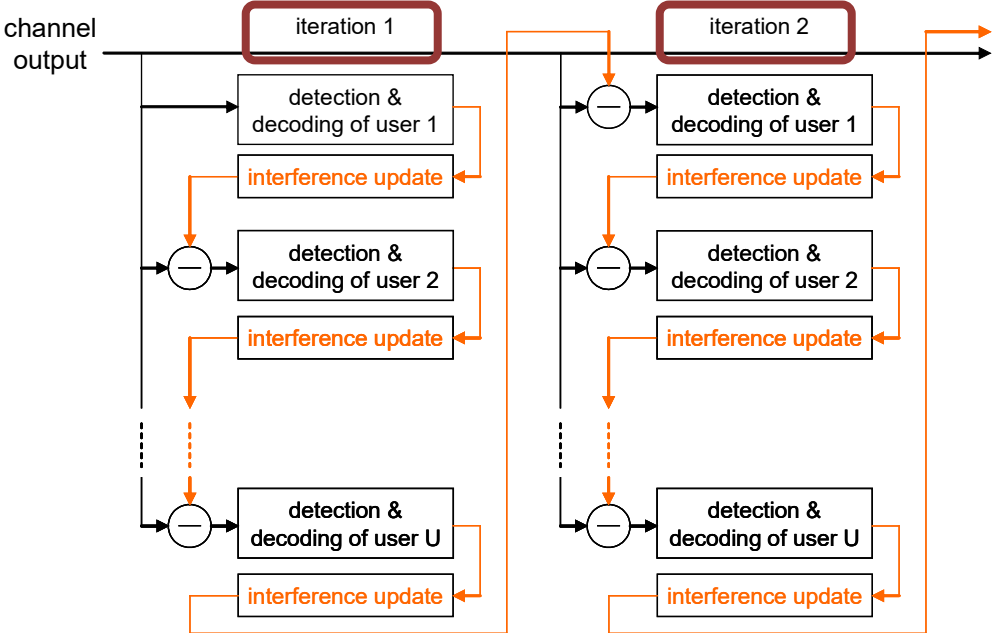
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'492 Claim 2 Element	<u>Accused Products (UE)</u>
The system according to claim 1 wherein said plurality of improved information streams are fed back to said multi user detector decision unit until a final condition is reached and said bank of decoders output a final data stream.	The Accused Instrumentalities include the system according to claim 1, <i>see</i> Claim 1, wherein said plurality of improved information streams are fed back to said multiuser detector decision unit until a final condition is reached and said bank of decoders output a final data stream. For example, successive interference cancellation schemes feed back the decoder output (“improved information stream”) to the multiuser detector in an iterative manner until a condition is met. <u>Qualcomm’s ’994 patent:</u> Figure 6: FIG. 6

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'492 Claim 2 Element	<u>Accused Products (UE)</u>
	9:44-55 (“A reconstruction weight vector is calculated at 628 for the reconstructed stream. Blocks 628, 630 and 632 may calculate reconstruction weights for each decoded stream to cancel the interference of the decoded stream from the composite received signal as efficiently as possible. Weight reconstruction, in accordance with certain aspects, is described in greater detail below. In 608, the reconstructed stream is multiplied with the reconstruction weight vector and subtracted from the received signal. The resulting signal passes through a second receiver 610 and a second decoder 612 to detect and decode the second stream, respectively.”) 7:66-8:19 (“The process may continue with subtraction, at 420, utilizing receiver 422 and decoder 424 until all the N streams are decoded. The decoders 406, 412 and 418 may decode any kind of error correcting code. Such as turbo or convolutional codes. The decoders 406, 412 and 418 may decode a plurality of encoded streams with a plurality of types and code rates. The subtraction operation may not be performed if the decoding operation fails at any step. <i>Each Successful decode and subtract operation of the SIC system is referred to herein as one “iteration.”</i> <i>For certain embodiments of the present disclosure, at the end of some of the SIC iterations, decoding of some streams may be unsuccessful. Therefore, the process may continue with a subset of streams that have yet to be correctly decoded, by modifying the decoding order in a recursive manner. This process may continue until a maximum allowable time passes or convergence happens. The process may converge if either of the following conditions satisfies: i) all streams are decoded successfully ii) size of the subset of streams to be decoded and their decoding order is identical in two consecutive iterations.”)</i> <u>TSG-RAN WG1, Contribution # R1-090919:</u> Receiver Turbo-SIC strategy After proper noise filtering and sampling of the channel output at the receiver side, the turbo-SIC detection strategy in a multi-user context consists in an iterative linear filtering with Successive Interference Cancellation (SIC) of the users, as depicted in Fig. 3.

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'492 Claim 2 Element	<u>Accused Products (UE)</u>
	 Fig. 2 - SIC process assuming natural ordering of the users If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

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'492 Claim 3 Element	<u>Accused Products (UE)</u>
The system according to claim 1 wherein said design criteria is based <u>upon at least one threshold selected from at least one of the group consisting of number of symbols, correlation matrix between users, expected bit error rate, eigen decomposition of correlation matrix, signal to interference plus noise ratio, and expected SINR.</u>	The Accused Instrumentalities include the system according to claim 1, <i>see</i> Claim 1, wherein said design criteria is based upon at least one threshold selected from at least one of the group consisting of number of symbols, correlation matrix between users, expected bit error rate, eigen decomposition of correlation matrix, signal to interference plus noise ratio, and expected SINR. For example, an interference cancellation receiver may use noise whitening depending the value of Interference to Noise Ratio (INR), where interference is received from other cells. High INR has higher out of cell interference which results in a lower Signal to Interference plus Noise (SINR) at the UE. The multiuser detection decision unit may use a multiuser detector w or w/o noise whitening based on a threshold on SINR or some other received signal statistics. TSG-RAN WG4, Contribution # R4-150484: Title: Simulation results for multi-cell whitening verification : : 3. Introduction In RAN4#73, WF [1] for multi-cell whitening verification test was agreed. In this contribution, we provide simulation results for multi-cell whitening verification test based on agreed WF. : : 5. Conclusion In this contribution, we provide simulation results for multi-cell whitening verification test for alignment. <u>For discrimination between receiver w/ and w/o whitening function, high INR setting is more suitable than medium INR setting since performance difference between w/ and w/o whitening function in high INR is larger than that in medium INR.</u>

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'492 Claim 3 Element	<u>Accused Products (UE)</u>
	TSG-RAN WG4, Contribution # R4-150991 Fallback Operation General Aspects of NAICS Fallback Operation On fallback, the WID states the following: “<i>Ensure no performance loss compared to LMMSE-IRC receivers in all interference PDSCH scenarios including different transmission modes than that of desired PDSCH, per PRB or PRB-pair based resource allocation for interference PDSCH, and/or lack of higher-layer signaling</i>”. <u>The exact test cases to fallback to Rel-11 MMSE-IRC performance need to be discussed further</u>, we would like confirm that covering <i>incorrect NAICS signaling</i> is not part of the WID scope. <u>Proposal 4: The fallback performance of Rel-12 advanced receiver should be no worse than the Rel-11 MMSE-IRC performance, an aspect that needs to be tested by RAN4.</u> • <u>Proposal 4.1: Reliability of NAICS processing:</u> As observed during the study item and work item phase, there could be some scenarios in which NAICS receiver processing may not be reliable both in terms of blind detection and demodulation. Exact scenarios need further discussion → Propose to have RAN4 demodulation test cases to ensure this behaviour. • <u>Proposal 4.2: Lack of NAICS Signaling:</u> In the absence of NAICS signaling, the NAICS UE is expected to perform no worse than the Rel-11 MMSE-IRC receiver → Not needed to test this behavior, it is automatically implied by Rel-11 tests. • <u>Proposal 4.3: Incorrect Signaling:</u> If the NAICS signaling is incorrect, i.e., eNB does not follow the signaled parameters in its transmission, there should be no performance requirement on the NAICS UE. Incorrect information from the eNB may mislead the UE into false detections. If the eNB cannot guarantee accurate signaling, the signaling could be skipped, hence not requiring the UE to meet NAICS requirements. → Not needed to test this behavior. TSG-RAN WG4, Contribution # R4-150091:

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'492 Claim 3 Element	<u>Accused Products (UE)</u>
	NAICS fallback operation assumptions So far, many companies have provided simulation results to show variable NAICS gains for different test cases, so there has a question that which test cases would be suitable for NAICS gain requirement, and which one is better for robustness. In our opinion, RAN4 shall reach a general principle how to define the UE fallback operation for the purpose of clarifying which test cases are suitable for NAICS gain tests or nor. For example, a general principle could be: - If the practical performance gain of NAICS receiver over MMSE-IRC receiver is below x.x dB (e.g. 1.0dB @70% maximum throughput), the NAICS UE could fallback to MMSE-IRC receiver. Proposal 4: <u><i>The NAICS UE could fallback to MMSE-IRC receiver as long as the practical performance gain of NAICS receiver over MMSE-IRC receiver is below x.x dB (e.g. 1.0dB @70% maximum throughput).</i></u> Another issue of NAICS fallback operation assumptions is that whether NAICS UE needed to check the truth of NAICS signalling. In another words, whether NAICS UE should be required no-performance loss if the interference condition is not aligned with NAICS high-layer signalling. In our opinion, checking the consistency of NAICS high signalling and interference condition would greatly increase implement complexity and beyond the UE's responsibility. So, we think the inconsistency of NAICS high signalling and interference condition is not a valid fallback scenarios. Proposal 5: <i>The inconsistence of NAICS high signalling and interference condition is not a valid fallback scenario. In another words, NAICS UE would not guarantee no-performance-loss over MMSR-IRC when the signalling and interference condition are not aligned.</i>

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'492 Claim 5 Element	<u>Accused Products (UE)</u>
The system according to claim 1 <u>wherein said at least two multiuser detectors are selected from the group consisting of M-algorithm, sphere decoder, T-algorithm, FANO, reduced state Viterbi, Maximum Likelihood, matched filter, minimum mean squared error (MMSE), decorrelator, and combinations thereof.</u>	The Accused Instrumentalities include the system according to claim 1, <i>see</i> Claim 1, wherein said at least two multiuser detectors are selected from the group consisting of M-algorithm, sphere decoder, T-algorithm, FANO, reduced state Viterbi, Maximum Likelihood, matched filter, minimum mean squared error (MMSE), decorrelator, and combinations thereof. For example, advanced 4G/5G receivers utilize interference cancellation or mitigation techniques such as MMSE, or variants of MMSE, Successive Interference Cancellation (SIC), Maximum Likelihood (ML) or Reduced complexity variations of R-ML. <u>3GPP TR 36.866 V12.0.1:</u> • Pages 53-54 <u>9.1.5.2 Alternative 2</u> Generally, the system level modelling methodology for SLIC is carried out by two steps. The first step is to derive the post-processing SINR per subcarrier. After that, the simulator predicts the instantaneous BLER for each transmission block by a link quality model (such as MIESM, EESM etc.) based on the input SINRs. Here, we will only focus on how to obtaining of post-processing SINRs. For simplicity, we assume the target UE eliminates the strongest interference, and only one layer is transmitted for both target UE and interfering UE. The received downlink signal for each subcarrier can be written as

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$$y = H_s x_s + H_1 x_1 + \sum_{k=2}^{N-1} H_k x_k + n \quad (9.47)$$

Where H_1 denotes the effective channel from the strongest interfering cell to the target UE and x_1 denotes the strongest interfering symbol.

In the first place, the strongest interference signal is detected with its corresponding post-processed SINR, take MMSE receiver as an example,

$$\gamma_{MMSE-1st-inf} = w_{MMSE-1st-inf} \cdot \tilde{H}_1 / (1 - w_{MMSE-1st-inf} \cdot \tilde{H}_1) \quad (9.48)$$

where

$$w_{MMSE-1st-inf} = \tilde{H}_1^H \left(\tilde{H}_1 \tilde{H}_1^H + \text{diag} \left(\tilde{H}_s \tilde{H}_s^H + \sum_{k=2}^{N-1} \tilde{H}_k \tilde{H}_k^H + \sigma_N^2 \cdot I \right) \right)^{-1} \quad (9.49)$$

Once the strongest interference signal is detected, it could be removed from the received signal. However, the strongest interference signal cannot be completely removed in practical system. Let e denotes the residual error and $\bar{\sigma}$ be the variance of demodulated symbols residual error,

$$e = \tilde{H}_1 x_1 - \tilde{H}_1 \tilde{x}_1 = \tilde{H}_1 (x_1 - \tilde{x}_1), \quad \bar{\sigma} = \frac{1}{L} \sum_{l=1}^L \|x_{1,l} - \tilde{x}_{1,l}\|^2, \quad (9.50)$$

where L is the number of trials.

Considering the remaining interference after SLIC, the post-processed SINR of the desired signal could be expressed as

$$\gamma_{SLIC} = w_{SLIC} \cdot \tilde{H}_s / (1 - w_{SLIC} \cdot \tilde{H}_s) \quad (9.51)$$

where

$$w_{SLIC} = \tilde{H}_s^H \left(\tilde{H}_s \tilde{H}_s^H + \text{diag} \left(\bar{\sigma} \cdot \tilde{H}_1 \tilde{H}_1^H + \sum_{k=2}^{N-1} \tilde{H}_k \tilde{H}_k^H + \sigma_N^2 \cdot I \right) \right)^{-1} \quad (9.52)$$

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'492 Claim 5 Element	<u>Accused Products (UE)</u>
	$\bar{\sigma}$ can be obtained by looking up a predefined SNR-to-variance mapping table. Here e a simple link level simulation is proposed to estimate $\bar{\sigma}$. The link simulation process is illustrated in Figure 6.  <pre> graph LR A[RandomBit] --> B[Modulate] B --> C[AWGN] C --> D[Demodulation] D --> E[variance] </pre> Figure6: Link simulation structure for variance calculation Assuming the transmitted complex symbol is x, x belongs to a certain modulation constellation A_j, $j=1, \dots, M$, M is the modulation order. The received signal in an AWGN channel is given by $y = x + n, n \sim CN(0, \sigma_N^2). \quad (9.53)$ <u>3GPP TR 36.866 V12.0.1:</u> • Pages 11-12 7.4 Interference Cancellation (IC) receivers IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - <u>Linear Code word level SIC (L-CWIC):</u> - <u>receiver utilizing successive application of linear detection (e.g.: LMMSE-IRC), decoding, re-encoding, and cancellation</u> - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - <u>ML-CWIC:</u> - receiver utilizing successive application of <u>ML or reduced complexity ML detection, decoding, re-encoding, and cancellation</u>

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'492 Claim 5 Element	<u>Accused Products (UE)</u>
	- May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (SLIC): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. <u>Qualcomm's '503 patent:</u> The effective MIMO channel response $\underline{H}$ includes the actual MIMO channel response H, and the spatial mapping matrix P used by the transmitter. The effective MIMO channel response matrix may be given as: $\underline{H} = \begin{bmatrix} h_{1,1} & \dots & h_{1,M} \\ \vdots & \ddots & \vdots \\ h_{R,1} & \dots & h_{R,M} \end{bmatrix}, \quad \text{Eq (3)}$ where entry $h_{r,m}$, for $r = 1, \dots, R$ and $m = 1, \dots, M$, denotes the complex channel gain observed by data stream m at receive antenna r. For simplicity, the MIMO channel is assumed to be flat fading with no frequency selectivity. The receiver typically derives $\hat{H}$, which is an estimate of H, and uses $\hat{H}$, for detection. For simplicity, the description herein assumes no channel estimation error, so that $\hat{H} = H$. H is also referred to as a MIMO channel response matrix. For a MIMO transmission on a single subcarrier, the receiver obtains a received symbol vector y in each symbol period used for transmission. For a MIMO transmission on multiple subcarriers, the receiver obtains a received symbol vector y for each subcarrier in each symbol period used for transmission. In one or more embodiments, the receiver performs detection separately for each received symbol vector y.

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'492 Claim 5 Element	<u>Accused Products (UE)</u>
	In other embodiments, the receiver performs detection jointly for multiple received symbol vectors. The receiver may perform detection in various manners. <u>The receiver may perform maximum likelihood (ML) detection on the received symbols to obtain the detected symbols.</u> For ML detection, the receiver evaluates each of 2^K hypothesized symbol vectors that might have been transmitted for data symbol vectors. For each hypothesized symbol vector, the receiver computes a distance metric that may be given as: $D(\tilde{S}) = \ y - H \cdot \tilde{S}\ ^2 \quad \text{Eq (4)}$ Where $\tilde{S}$ is a symbol vector hypothesized to have been transmitted for vectors; and $D(\tilde{S})$ is the distance for hypothesized symbol vector $\tilde{S}$. Equation (4) may also be referred to as a cost function, an error function, and so on. $D(\tilde{S})$ may also be referred to as a cost value or an error value for vector $\tilde{S}$. For ML detection, the receiver obtains 2^K distances for the 2^K hypothesized symbol vectors $\tilde{S}$. The receiver may then derive the detected symbols as follows: $\hat{\underline{s}} = \arg\left\{\min_{\underline{\tilde{s}}} \ \underline{y} - \underline{H} \cdot \underline{\tilde{s}}\ ^2\right\}, \quad \text{Eq (5)}$ where $\hat{\underline{s}} = [\hat{s}_1 \ \hat{s}_2 \ \dots \ \hat{s}_M]^T$ is an $M \times 1$ vector with M detected symbols. In equation (5), the minimum distance among the 2^K distances for the 2^K hypothesized symbol vectors is identified. The hypothesized symbol vector with the minimum distance is provided as the detected symbol vector $\tilde{S}$, which is an estimate of the transmitted data symbol vector S. For ML detection, an exhaustive search is performed over all possible combinations of data symbols that might have been transmitted for data symbol vectors. The exhaustive search considers all 2^K possible hypotheses for the data symbol vectors. Hence, the complexity of ML detection is exponential in the number of bits (K) used to form the data symbol vectors. ML detection can provide good performance. However, the exhaustive search is computationally intensive and may be prohibitive for many

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'492 Claim 5 Element	<u>Accused Products (UE)</u>
	applications. For example, if four data streams are sent using QPSK for all streams, then K=8 and 256 hypotheses are evaluated for each received symbol vector y. However, if 16-QAM is used for the four streams, then K=16 and 65,536 hypotheses are evaluated for each received symbol vector y, which is much more complex. If the four data streams are sent using QPSK, 16-QAM, 64-QAM, and 256-QAM, then K=20 and over one million hypotheses are evaluated for each received symbol vector y, which may be impractical. This example illustrates the rapid growth in the number of hypotheses for larger signal constellation sizes. The number of hypotheses to consider may be reduced by performing sphere detection (SD), which is also referred to as list sphere detection, sphere decoding, spherical decoding, and so on. Sphere detection seeks to reduce the search space of ML detection by performing a search for candidate hypotheses and discarding less likely hypotheses. If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

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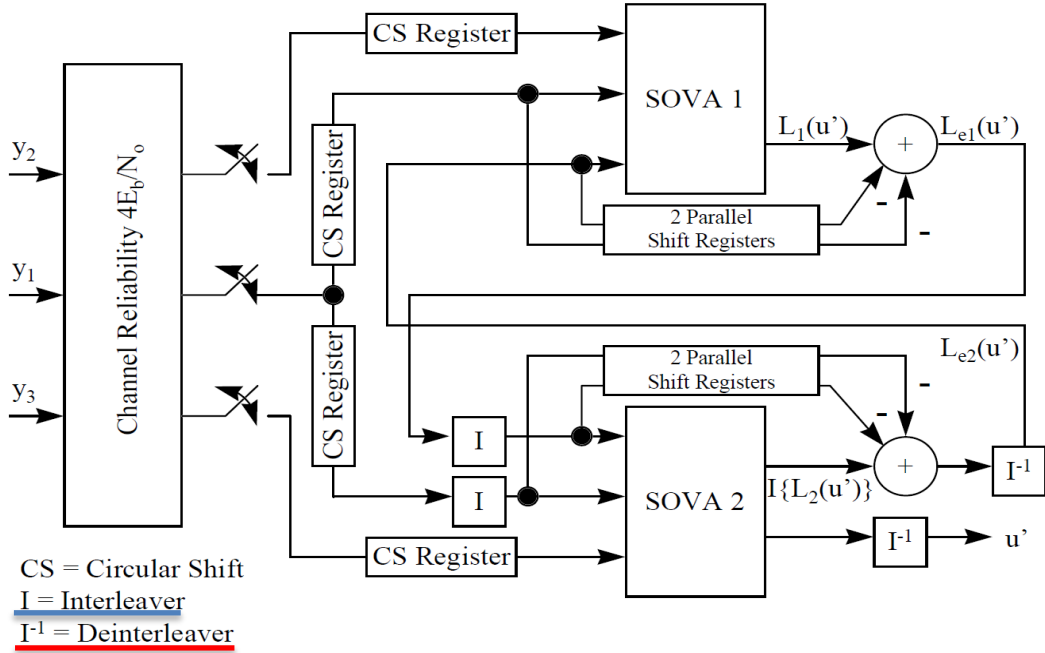
'492 Claim 6 Element	<u>Accused Products (UE)</u>
The system according to claim 1, further comprising <u>an interleaver unit</u> and <u>a deinterleaver unit</u> coupled between said bank of decoders and said multi-user detectors.	The Accused Instrumentalities include the system according to claim 1, <i>see</i> Claim 1, and an interleaver unit and a deinterleaver unit coupled between said bank of decoders and said multi-user detectors. For example, successive interference cancellation receivers decode a data stream and then reconstruct the decoded data stream and cancel the reconstructed data stream from the received signal to reduce inter-stream interference. The output of the decoder is a deinterleaved version of the encoded data. Encoders include an interleaver and therefore the decoded data stream must be interleaved, encoded and then reconstructed to prior to cancellation. <u>Decoder:</u>  CS = Circular Shift <u>I = Interleaver</u> <u>I⁻¹ = Deinterleaver</u>

Figure 4.12: SOVA iterative turbo code decoder.

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'492 Claim 6 Element	Accused Products (UE)
	Qualcomm '994 Patent: Figure 6: <pre> graph TD 600[DECODING ORDER SELECTION: DETERMINE i1, i2, iN] 602[y(m)] 604[MMSE OR ANOTHER RECEIVER FOR STREAM i1] 606[DECODE STREAM i1] 608[608 CALCULATE RW] 610[MMSE OR ANOTHER RECEIVER FOR STREAM i2] 612[DECODE STREAM i2] 616[MMSE OR ANOTHER RECEIVER FOR STREAM i3] 618[DECODE STREAM i3] 620[620 SUBTRACT STREAM i1, i2, ..., iN-1] 622[MMSE OR ANOTHER RECEIVER FOR STREAM iN] 624[DECODE STREAM iN] 630[630 CALCULATE RW] 632[632 CALCULATE RW] 614[614] 616[616] 618[618] 620[620] 622[622] 624[624] 602 --> 608 602 --> 610 602 --> 616 602 --> 620 600 --> 604 600 --> 610 600 --> 616 600 --> 622 608 --> 606 608 --> 610 608 --> 616 608 --> 620 610 --> 612 616 --> 618 620 --> 622 622 --> 624 606 --> 610 612 --> 616 618 --> 622 624 --> 624 630 --> 608 632 --> 620 614 -.- 616 616 -.- 618 618 -.- 622 </pre>

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'492 Claim 6 Element	<u>Accused Products (UE)</u>
	The following model at the data symbol level for a MIMO system is considered for a received signal. It should be noted that all quantities in the following equation have complex values and may be indexed by time t, $0 \leq t < T$ to represent a stream of data of length T. $y = H \cdot s + n$ where $y = [y_1 \dots y_N]^T$ may be an N-dimensional received vector of samples, H may represent a symbol-level $N \times N$ matrix that models the effects of the pre-coder such as beam-forming matrix in WCDMA, power scaling, channel, and a complete front-end receiver processing, such as Rake receiver and equalizer on transmitted modulated symbols. In the equation above, $s = [s_1 \dots s_N]^T$ may represent the N-dimensional vector of coded and modulated symbols transmitted on each stream s_i, and n is an additive N-dimensional noise vector that is independent for each s. When the i^{th} stream is decoded, $\hat{s}_i$ may represent the reconstructed (i.e., re-encoded, rate-matched and re-modulated) complex symbols, with a similar scaling convention as s_i. If the block of data in stream s_i is decoded successfully (i.e., a valid cyclic redundancy check (CRC)), values of the $\hat{s}_i$ may be equal to the values of stream s_i. Otherwise, if the SNR is not very low, values of s_i may be a close approximation of s_i. The SIC technique removes the interference of i^{th} stream from the received signal. Therefore, the signal after each iteration of SIC may be written as follows: $y' = y - W_i \hat{s}_i$ where W_i is the reconstruction weight vector. Note that in each iteration of interference cancellation, y' is updated to remove the interference of each stream from the received signal (for $N > 2$).

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'492 Claim 6 Element	<u>Accused Products (UE)</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

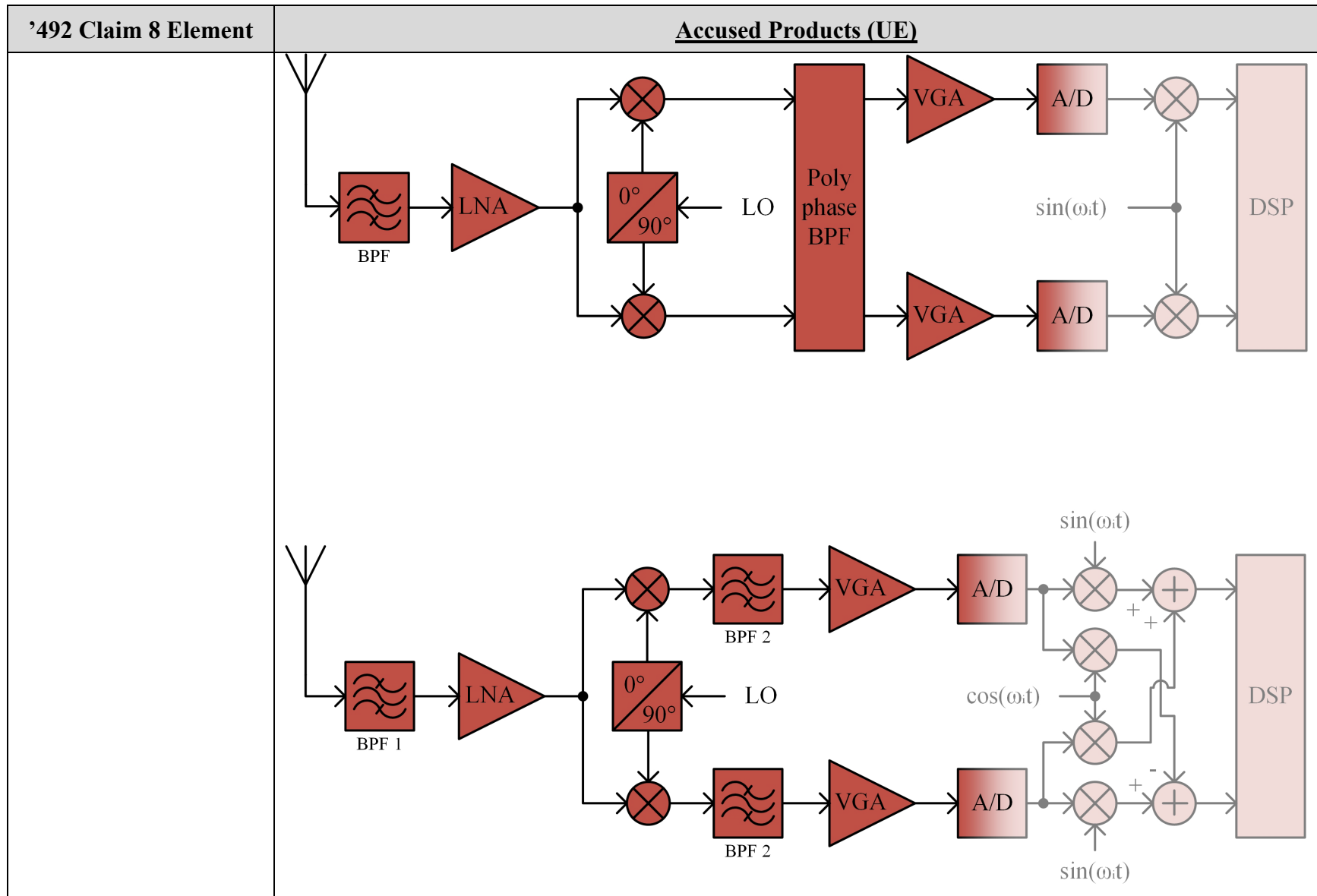
**INFRINGEMENT CONTENTIONS – CHART FOR U.S. PAT. NO. 7,593,492
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'492 Claim 7 Element	<u>Accused Products (UE)</u>
The system according to claim 2, <u>wherein said final condition is determined by one of a fixed number of iterations and an allowable performance level.</u>	The Accused Instrumentalities include the system according to claim 2, <i>see</i> claim 2, wherein said final condition is selected from at least one of the group consisting of bit error rate metric level and fixed number of iterations. For example, interference cancellation receivers iterate the process of interference cancellation until a maximum number of iterations are reached or a convergence criteria such as a bit error rate is reached. <u>Qualcomm's '994 patent:</u> • 9:44-55 (“A reconstruction weight vector is calculated at 628 for the reconstructed stream. Blocks 628, 630 and 632 may calculate reconstruction weights for each decoded stream to cancel the interference of the decoded stream from the composite received signal as efficiently as possible. Weight reconstruction, in accordance with certain aspects, is described in greater detail below. In 608, the reconstructed stream is multiplied with the reconstruction weight vector and subtracted from the received signal. The resulting signal passes through a second receiver 610 and a second decoder 612 to detect and decode the second stream, respectively.”) • 7:66-8:19 (“The process may continue with subtraction, at 420, utilizing receiver 422 and decoder 424 until all the N streams are decoded. The decoders 406, 412 and 418 may decode any kind of error correcting code. Such as turbo or convolutional codes. The decoders 406, 412 and 418 may decode a plurality of encoded streams with a plurality of types and code rates. The subtraction operation may not be performed if the decoding operation fails at any step. <u>Each Successful decode and subtract operation of the SIC system is referred to herein as one “iteration.”</u> <u>For certain embodiments of the present disclosure, at the end of some of the SIC iterations, decoding of some streams may be unsuccessful. Therefore, the process may continue with a subset of streams that have yet to be correctly decoded, by modifying the decoding order in a recursive manner. This process may continue until a maximum allowable time passes or convergence happens. The process may converge if either of the following conditions satisfies: i) all streams are decoded successfully ii) size of the subset of streams to be decoded and their decoding order is identical in two consecutive iterations.”)</u>

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'492 Claim 8 Element	<u>Accused Products (UE)</u>
The system according to claim 1, <u>further comprising a filter unit coupled to said received signals, wherein said filter unit is coupled to said multi-user detector decision unit.</u>	The Accused Instrumentalities include the system according to claim 1, <i>see</i> claim 1, and a filter unit coupled to said received signals, wherein said filter unit is coupled to said multi-user detector decision unit. For example, a multiuser detector is coupled to a downconversion circuitry which includes a filter. The received signals are filtered and converted into digital samples to be processed by the multiuser detector. Receiver Filter: In a homodyne receiver, the signal is directly downconverted to baseband, without using an IF. Thus, since $f_i = 0$, the mirror frequency is equal to the desired signal's frequency. Nevertheless, a problem with the mirror frequency still exists: the wanted signal is mirrored in the negative frequency range, resulting in the top end of the signal band from the positive frequencies overlapping with the low end of the signal band from the negative frequencies after downconversion, and vice versa. Therefore, a quadrature downconversion is needed [3], as illustrated in Fig. 4. Since, in theory, quadrature downconversion is equivalent to complex mixing [6], [7], the desired signal can be obtained by the DSP. As shown in Fig. 4, in most homodyne receivers the signal from the antenna is filtered and amplified before mixing. The former serves to prevent desensitization due to blockers, while the latter serves to decrease the receiver's NF. <u>After mixing, the desired signal is at baseband, and thus channel selection can be performed by low-pass filters (LPF).</u> The signal is then brought in range of the ADC's by VGA's and converted to the digital domain where it is demodulated using a DSP.

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'492 Claim 8 Element	<u>Accused Products (UE)</u>
	Fig. 5. Block diagram of (a) low-IF receiver which uses a complex BPF (diagram based on [6], [10], [13]) and (b) low-IF receiver which uses real filters (diagram based on [6], [7], [24], [27]). Elements in the analog domain are outlined in black, while elements in the digital domain are outlined in grey. <i>Source: Wireless Receiver Architectures Towards 5G: Where Are We?</i> If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
'492 Claim 9 Element	<u>Accused Products (UE)</u>
The system according to claim 1, <u>further comprising a hard decision unit coupled to said bank of decoders and producing a final data stream.</u>	The Accused Instrumentalities include the system according to claim 1, <i>see</i> Claim 1, and further includes a hard decision unit coupled to said bank of decoders and producing a final data stream. For example, a multiuser detector includes a decoder which uses hard decision to determine the transmitted symbol, and to reconstruct the received symbols before cancelling the decode stream from the received signal.

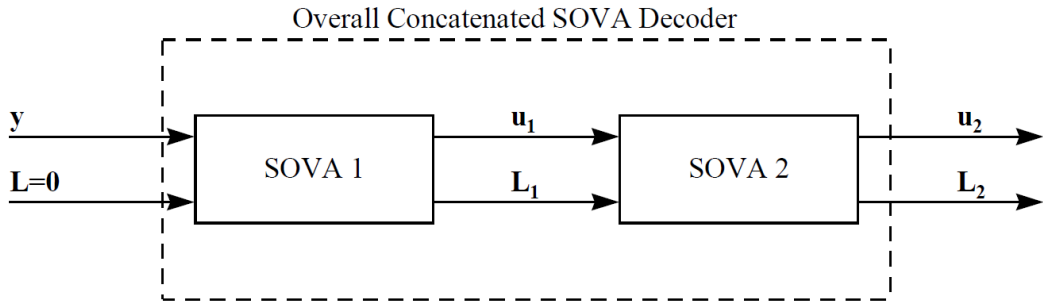
**INFRINGEMENT CONTENTIONS – CHART FOR U.S. PAT. NO. 7,593,492
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'492 Claim 9 Element	Accused Products (UE)
	Qualcomm's '994 patent: Figure 6: <pre> graph TD 600[DECODING ORDER SELECTION: DETERMINE i1, i2, iN] 602[y(m)] 604[MMSE OR ANOTHER RECEIVER FOR STREAM i1] 606[DECODE STREAM i1] 608[608] 610[MMSE OR ANOTHER RECEIVER FOR STREAM i2] 612[DECODE STREAM i2] 614[614] 616[MMSE OR ANOTHER RECEIVER FOR STREAM i3] 618[DECODE STREAM i3] 620[620] 622[MMSE OR ANOTHER RECEIVER FOR STREAM iN] 624[DECODE STREAM iN] 630[630] 632[632] 600 --> 604 600 --> 610 600 --> 616 600 --> 622 602 --> 608 602 --> 630 602 --> 614 602 --> 632 602 --> 620 608 --> 604 608 --> 610 608 --> 616 608 --> 622 630 --> 604 630 --> 610 630 --> 616 630 --> 622 614 --> 604 614 --> 610 614 --> 616 614 --> 622 632 --> 604 632 --> 610 632 --> 616 632 --> 622 620 --> 604 620 --> 610 620 --> 616 620 --> 622 604 --> 606 610 --> 612 616 --> 618 622 --> 624 606 --> 608 612 --> 610 618 --> 616 624 --> 622 </pre>

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'492 Claim 9 Element	<u>Accused Products (UE)</u>
	The following model at the data symbol level for a MIMO system is considered for a received signal. It should be noted that all quantities in the following equation have complex values and may be indexed by time t, $0 \leq t < T$ to represent a stream of data of length T. $y = H \cdot s + n$ where $y = [y_1 \dots y_N]^T$ may be an N-dimensional received vector of samples, H may represent a symbol-level $N \times N$ matrix that models the effects of the pre-coder such as beam-forming matrix in WCDMA, power scaling, channel, and a complete front-end receiver processing, such as Rake receiver and equalizer on transmitted modulated symbols. In the equation above, $s = [s_1 \dots s_N]^T$ may represent the N-dimensional vector of coded and modulated symbols transmitted on each stream s_i, and n is an additive N-dimensional noise vector that is independent for each s. When the i^{th} stream is decoded, $\hat{s}_i$ may represent the reconstructed (i.e., re-encoded, rate-matched and re-modulated) complex symbols, with a similar scaling convention as s_i. If the block of data in stream s_i is decoded successfully (i.e., a valid cyclic redundancy check (CRC)), values of the $\hat{s}_i$ may be equal to the values of stream s_i. Otherwise, if the SNR is not very low, values of $\hat{s}_i$ may be a close approximation of s_i. The SIC technique removes the interference of i^{th} stream from the received signal. Therefore, the signal after each iteration of SIC may be written as follows: $y' = y - W_i \cdot \hat{s}_i$ where W_i is the reconstruction weight vector. Note that in each iteration of interference cancellation, y' is updated to remove the interference of each stream from the received signal (for $N > 2$).

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'492 Claim 9 Element	<u>Accused Products (UE)</u>
	Decoder: 4.1 Principle of the General Soft-Output Viterbi Decoder The Viterbi algorithm produces the ML output sequence for convolutional codes. This algorithm provides optimal sequence estimation for one stage convolutional codes. For concatenated (multistage) convolutional codes, there are two main drawbacks to conventional Viterbi decoders. First, the inner Viterbi decoder produces bursts of bit errors which degrades the performance of the outer Viterbi decoders [Hag89]. Second, the inner Viterbi decoder produces hard decision outputs which prohibits the outer Viterbi decoders from deriving the benefits of soft decisions [Hag89]. Both of these drawbacks can be reduced and the performance of the overall concatenated decoder can be significantly improved if the Viterbi decoders are able to produce reliability (soft-output) values [Ber93a]. The reliability values are passed on to subsequent Viterbi decoders as a-priori information to improve decoding performance. This modified Viterbi decoder is referred to as the soft-output Viterbi algorithm (SOVA) decoder. Figure 4.1 shows a concatenated SOVA decoder.  <pre> graph LR subgraph "Overall Concatenated SOVA Decoder" SOVA1[SOVA 1] SOVA2[SOVA 2] SOVA1 -- u1 --> SOVA2 SOVA1 -- L1 --> SOVA2 end y --> SOVA1 L0["L=0"] --> SOVA1 SOVA2 -- u2 --> out_u2 SOVA2 -- L2 --> out_L2 </pre> Figure 4.1: <u>A concatenated SOVA decoder where y represents the received channel values, u represents the hard decision output values, and L represents the associated reliability values.</u>

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'492 Claim 9 Element	<u>Accused Products (UE)</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'492 Claim 10 Element	<u>Accused Products (UE)</u>
10[pre] A hybrid receiver for processing a plurality of received signals, said receiver comprising:	To the extent the preamble is found to be limiting, the Accused Instrumentalities include a hybrid receiver for processing a plurality of received signals. Multiple data streams are received at the UE from an intracell SU-MIMO multi-layer transmission from the same serving cell sector, and from interfering (neighboring) cells. Multiuser detectors are used at the UE to separate the multiple data streams (layers) of SU-MIMO while cancelling interference data streams from the interfering cell(s). The multiuser detection systems may use a number of receiver types such as CodeWord IC (CWIC), Symbol Level IC (SLIC), Reduced complexity Maximum Likelihood (R-ML), LMSMSE-IRC, and variations of the CWIC, SLIC and R-ML with and without noise whitening. A specific multiuser detection such as the SU-MIMO detector, or an SU-MIMO in conjunction with intercell cancellation detector may use a hybrid of the available receiver types. MIMO in LTE: • <i>Downlink MIMO Technology</i> Single-User MIMO (SU-MIMO) was used for the downlink for LTE Rel. 8 to increase the peak data rate. The target data rates of over 100 Mbit/s were achieved by using a 20 MHz transmission bandwidth, 2×2 MIMO, and 64 Quadrature Amplitude Modulation (64QAM), and peak data rates of over 300 Mbit/s can be achieved using 4×4 SU-MIMO. The multi-antenna technology used for the downlink in LTE Rel. 8 is classified into the following three types. • Figure 1:

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	NTT DOCOMO Technical Journal Vol. 12 No. 2 When transmitting 4×4 MIMO rank 2 (example) Figure 1 Closed-loop SU-MIMO transmission using code-book-based precoding Via: 3g4g.blogspot.com

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'492 Claim 10 Element	<u>Accused Products (UE)</u>																		
	3GPP TS 36.211 V8.8.0: 6.3.3.2 Layer mapping for spatial multiplexing For spatial multiplexing, the layer mapping shall be done according to Table 6.3.3.2-1. The number of layers ν is less than or equal to the number of antenna ports P used for transmission of the physical channel. The case of a single codeword mapped to two layers is only applicable when the number of antenna ports is 4. Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing <table><tr><th>Number of layers</th><th>Number of code words</th><th>Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$</th></tr><tr><td>1</td><td>1</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$</td></tr><tr><td>2</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$</td></tr><tr><td>2</td><td>1</td><td>$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$</td></tr><tr><td>3</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$</td></tr><tr><td>4</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$</td></tr></table>	Number of layers	Number of code words	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$	1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$	2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$	2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$	3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$	4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$
Number of layers	Number of code words	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$																	
1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$																	
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$																	
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$																	
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$																	
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$																	

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	Verizon Wireless Requirement Plan: 1.6.9.1 SU-MIMO IC RF Performance VZ_REQ_LTEB13NAC_39982 The device shall support and meet receiver maximum input level performance requirements for SU-MIMO IC (Enhanced Performance Requirements Type C), for all transmission modes that are supported on Verizon's network as specified in sections 8.2.1.3.1.B (FDD, TM3), 8.2.1.4.2.A (FDD, TM4), 8.3.1.2.A (TM9/TM10) of the Release 12 version of 3GPP TS 36.101: <i>Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment(UE) Radio Transmission and Reception</i>. 1.6.10 Blind Data IC VZ_REQ_LTEB13NAC_1238214 While operating in Blind Data IC mode, the UE shall meet enhanced receiver Type B performance requirements defined in TS 36.101 (Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception) requirements on the following channel operations: • PDSCH demodulation minimum performance using ○ CRS ▪ 8.2.1.2.5 Enhanced Performance Requirement Type B - 2 Tx Antenna Ports with TM2 interference model ▪ 8.2.1.4.1D Enhanced Performance Requirement Type B - Single-layer Spatial Multiplexing 2 Tx Antenna Port with TM4 interference model • PUCCH report of the channel quality (CQI) based on the receiver of the enhanced Type B using updated the updated fixed reference channel and interference models for enhanced performance requirements for Type-B receiver ○ 9.3.8 Additional requirements for enhanced receiver Type B ▪ 9.3.8.1.1 Minimum requirement PUCCH 1-1 (Cell-Specific Reference Symbols) – FDD Testing of these performance requirements will use GCF-based test cases w/o network-assisted configuration.

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	Verizon Wireless Requirements Plan: 1.3.2.20 LTE R10 eICIC and CRS IC w/o ABS (Enhanced Inter-Cell Interference Cancellation) VZ_REQ_LTEB13NAC_36948 Applicable scenarios: • Heterogeneous network that has both small/pico cells and macro cells deployed • R10 eICIC is used to enable network to perform necessary interference management by configuring ABS subframe dynamically. • Macro homogeneous network & Heterogeneous network • CRS IC is used in macro network in non-ABS scenario • Improve PDCCH and PDSCH performance in non-colliding CRS case (user throughput) • Improve RSRP accuracy and channel estimation in colliding CRS case (improved CRS SINR and as a result better performance on PBCH and PSS/SSS) TS 36.101 version 16.7.0: Enhanced performance requirements type A: This defines performance requirements assuming as baseline receiver reference symbol based linear minimum mean square error interference rejection combining. Enhanced performance requirements type B: This defines performance requirements assuming as baseline receiver using network assisted interference cancellation and suppression. Enhanced performance requirements type C: This defines performance requirements assuming as baseline receiver inter-stream interference cancellation.

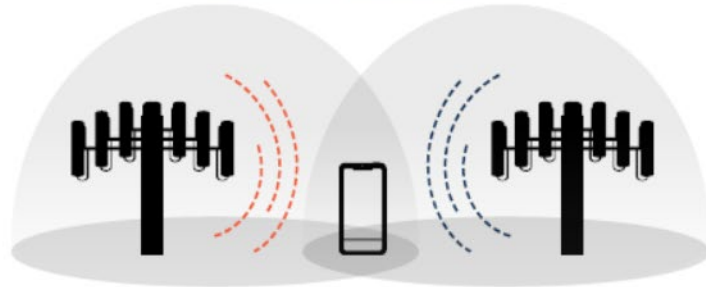
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'492 Claim 10 Element	Accused Products (UE)																																																																																																																																																													
	Sierra Wireless: Supported RF bands The modem, based on Qualcomm's MDM9250 baseband processor, supports data operation on LTE and UMTS networks over the bands described in Table 1-1, with LTE carrier aggregation (CA) as described in Table 1-2. Table 1-1: Supported RF Bands <table><tr><th rowspan="2">RAT</th><th colspan="26">Bands</th></tr><tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>12</th><th>13</th><th>18</th><th>19</th><th>20</th><th>26</th><th>28</th><th>29</th><th>30</th><th>32</th><th>41</th><th>42</th><th>43</th><th>46</th><th>48</th><th>66</th></tr><tr><td>LTE^a</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td></td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F^b</td><td>F</td><td>F^b</td><td>T</td><td>T</td><td>T</td><td>T^b</td><td>T^{b,c}</td><td>F</td></tr><tr><td>UMTS^d</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td></td><td>Y</td><td>Y</td><td></td><td></td><td></td><td>Y</td><td></td><td></td><td>N/A</td><td></td><td></td><td></td><td>N/A</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>GNSS</td><td colspan="26"> - GPS: 1575.42 MHz - GLONASS: 1602 MHz - BeiDou: 1561.098 MHz - Galileo: 1575.42 MHz - QZSS: 1575.42 MHz </td></tr><tr><td></td><td>•</td><td>•</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table> a. (LTE) Downlink MIMO support (2x2; 4x2) F=FDD; T=TDD Data rates: Downlink (Cat 12 with 3CA, 256QAM=600 Mbps; Cat 9 with 3CA, 64QAM=450 Mbps), Uplink (Cat 13 with 2CA contiguous, 64QAM=150 Mbps) b. Downlink only c. B48 support pending future release d. UMTS (DC-HSPA+, HSPA+, HSPA, UMTS) Diversity support Data rates: Downlink (Cat 24, up to 42 Mbps), Uplink (Cat 6, up to 11 Mbps)	RAT	Bands																										1	2	3	4	5	6	7	8	9	12	13	18	19	20	26	28	29	30	32	41	42	43	46	48	66	LTE ^a	F	F	F	F	F		F	F	F	F	F	F	F	F	F	F	F ^b	F	F ^b	T	T	T	T ^b	T ^{b,c}	F	UMTS ^d	Y	Y	Y	Y	Y	Y		Y	Y				Y			N/A				N/A						GNSS	- GPS: 1575.42 MHz - GLONASS: 1602 MHz - BeiDou: 1561.098 MHz - Galileo: 1575.42 MHz - QZSS: 1575.42 MHz																											•	•																							
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LTE ^a	F	F	F	F	F		F	F	F	F	F	F	F	F	F	F	F ^b	F	F ^b	T	T	T	T ^b	T ^{b,c}	F																																																																																																																																					
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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	Qualcomm Snapdragon 5G Modem Features: <u>5G Modem-RF System</u> • <i>Snapdragon X60 5G Modem-RF System</i> • <i>5G mmWave and sub-6 GHz, standalone (SA) and non-standalone (NSA) modes, FDD, TDD</i> • <i>Dynamic Spectrum Sharing</i> • <i>mmWave: 800 MHz bandwidth, 8 carriers, 2x2 MIMO</i> • <i>Sub-6 GHz: 200 MHz bandwidth, 4x4 MIMO</i> • <i>Qualcomm® 5G PowerSave</i> • <i>Qualcomm® Smart Transmit™ technology</i> • <i>Qualcomm® Wideband Envelope Tracking</i> • <i>Qualcomm® AI-Enhanced Signal Boost</i> • <i>Global 5G multi-SIM</i> • <i>Downlink: Up to 7.5 Gbps</i> • <i>Uplink: Up to 3 Gbps</i> • <i>Multimode support: 5G NR, LTE including CBRS, WCDMA, HSPA, TD-SCDMA, CDMA 1x, EV-DO, GSM/EDGE</i>

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'492 Claim 10 Element	Accused Products (UE)															
	Qualcomm LTE-Advanced Presentation: Enhanced receivers offer better user experience & more capacity Interference Cancellation  <table><tr><th>Interference Cancellation</th><th>Rel. 10/11</th><th>Re. 12</th></tr><tr><td>Sync ref. signal</td><td>✓</td><td>✓</td></tr><tr><td>Common ref. signal</td><td>✓</td><td>✓</td></tr><tr><td>Primary broadcast channel</td><td>✓</td><td>✓</td></tr><tr><td>Data channel</td><td></td><td>✓</td></tr></table> Better user experience - Higher data rates especially at cell-edges Higher network capacity - Higher users data rate increases overall network capacity Enhanced performance for HetNets - Even more beneficial in managing interference in small cell deployments	Interference Cancellation	Rel. 10/11	Re. 12	Sync ref. signal	✓	✓	Common ref. signal	✓	✓	Primary broadcast channel	✓	✓	Data channel		✓
Interference Cancellation	Rel. 10/11	Re. 12														
Sync ref. signal	✓	✓														
Common ref. signal	✓	✓														
Primary broadcast channel	✓	✓														
Data channel		✓														

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	3GPP TR 36.866 V12.0.1: • Pages 11-12 7.4 Interference Cancellation (IC) receivers IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - Linear Code word level SIC (L-CWIC): - receiver utilizing successive application of <i>linear detection</i> (e.g.: <i>LMMSE-IRC</i>), decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - ML-CWIC: - receiver utilizing successive application of <i>ML or reduced complexity ML detection</i>, decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (SLIC): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. 3GPP TR 36.829 V11.1.0:

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	4.3 MMSE IRC receiver For enhanced receiver, the MMSE-IRC receiver can suppress not only the inter-stream interference but also the inter-cell interference when the degrees of freedom at the receiver are sufficient, i.e., the number of receiver antennas is higher than that of the number of desired data streams, and MMSE IRC receiver weight matrix is expressed as follow: $\mathbf{W}_{RX,1}(k,l) = \hat{\mathbf{H}}_1^H(k,l)\mathbf{R}^{-1}$ where $\hat{\mathbf{H}}_j(k,l)$ and $\mathbf{R}$ denote the estimated channel matrix and covariance matrix, respectively. To obtain the MMSE-IRC receiver weight matrix, the covariance matrix including the sources of inter-cell interference needs to be estimated. Various schemes can be considered for that purpose. • CRS based covariance matrix estimation scheme ▪ The covariance matrix is estimated at CRS REs by following equations $\mathbf{R} = P_1 \hat{\mathbf{H}}_1(k,l) \hat{\mathbf{H}}_1^H(k,l) + \frac{1}{N_{sp}} \sum_{k,l \in CRS} \tilde{\mathbf{r}}(k,l) \tilde{\mathbf{r}}(k,l)^H, \quad \tilde{\mathbf{r}}(k,l) = \mathbf{r}(k,l) - \hat{\mathbf{H}}_1(k,l) \mathbf{d}_1(k,l),$ where P_1 is the transmission power of the serving cell and is equal to $E[d_1(k,l) ^2]$ and N_{sp} is the number of sampling REs, respectively. • DM-RS based covariance matrix estimation scheme (applicable when DM-RS are configured) ▪ The covariance matrix is estimated at DM-RS REs by following equations: $\mathbf{R} = P_1 \hat{\mathbf{H}}_1(k,l) \hat{\mathbf{H}}_1^H(k,l) + \frac{1}{N_{sp}} \sum_{k,l \in DM-RS} \tilde{\mathbf{r}}(k,l) \tilde{\mathbf{r}}(k,l)^H, \quad \tilde{\mathbf{r}}(k,l) = \mathbf{r}(k,l) - \hat{\mathbf{H}}_1(k,l) \mathbf{d}_1(k,l)$ • Data signal based covariance matrix estimation scheme ▪ The covariance matrix is estimated at PDSCH REs by following equations: $\mathbf{R} = \frac{1}{N_{sp}} \sum_{k,l \in PDSCH, DM-RS} \mathbf{r}(k,l) \mathbf{r}(k,l)^H$
10[a]: a parameter estimation unit coupled to said received signals,	The Accused Instrumentalities include a parameter estimation unit coupled to said received signals, wherein said parameter estimation unit extracts received signal information.

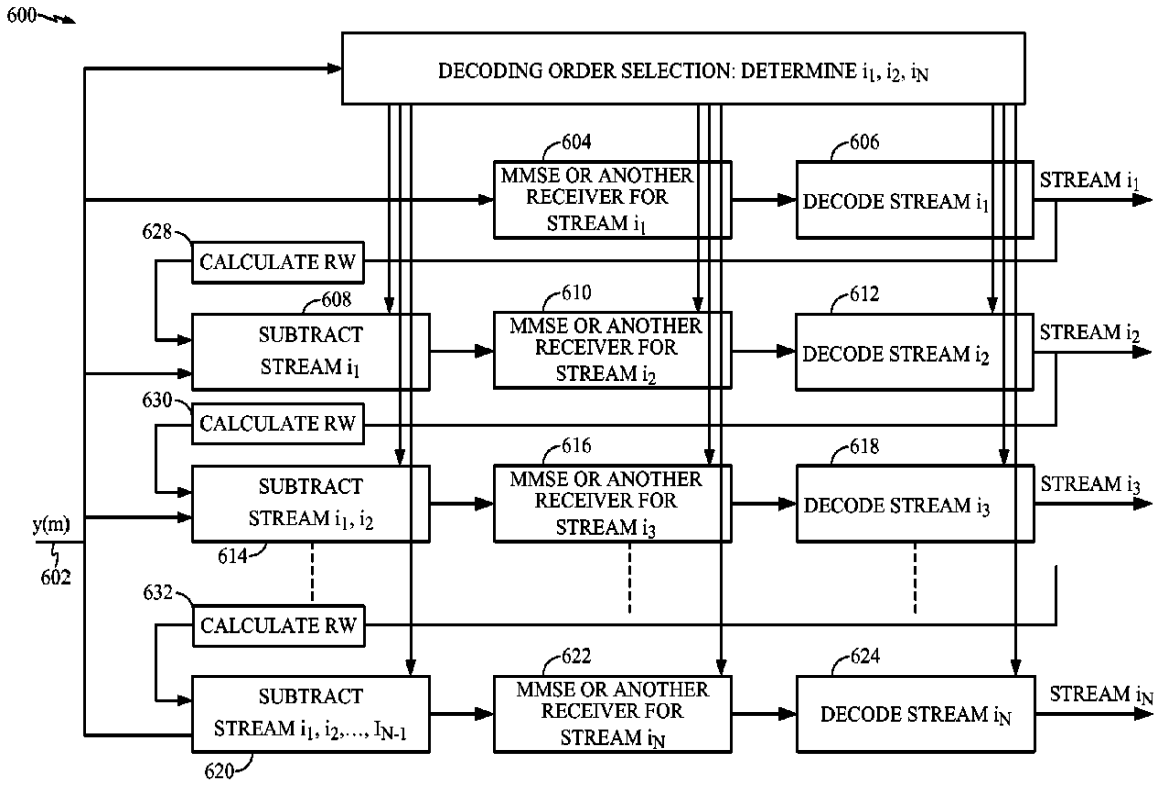
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wherein said parameter estimation unit extracts received signal information;	For example, channel estimates are needed in the LTE – SU-MIMO Products for symbol estimation, e.g., using an MMSE or its variations or maximum likelihood, for decoding a data stream, for intercell multiuser interference mitigation, or for reconstruing intracell or intercell interference signals prior to interference cancellation. MIMO in LTE: Downlink MIMO Technology Single-User MIMO (SU-MIMO) was used for the downlink for LTE Rel. 8 to increase the peak data rate. The target data rates of over 100 Mbit/s were achieved by using a 20 MHz transmission bandwidth, 2×2 MIMO, and 64 Quadrature Amplitude Modulation (64QAM), and peak data rates of over 300 Mbit/s can be achieved using 4×4 SU-MIMO. The multi-antenna technology used for the downlink in LTE Rel. 8 is classified into the following three types. - Figure 1: Received Data Stream Channel Estimation NTT DOCOMO Technical Journal Vol. 12 No. 2 When transmitting 4×4 MIMO rank 2 (example) Figure 1 Closed-loop SU-MIMO transmission using code-book-based precoding Via: 3g4g.blogspot.com 3GPP TR 36.866 V12.0.1:

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	Pages 43-44: 9.1.1 Modelling methodologies for E-LMMSE-IRC Alternative 1 Assuming that a single dominant interferer is taken into account explicitly at the receiver, the following signal model is considered: $ \begin{aligned} y &= H_0 x_0 + H_1 x_1 + \left(\sum_{i=2}^K H_i x_i \right) + n \\ &= H_0 x_0 + H_1 x_1 + z \\ &= H_0 x_0 + v \end{aligned} \tag{9.1} $ where z is the interference from non-dominant interferers and noise term, and v is the total interference and noise term. The E-LMMSE-IRC receiver is expressed as $ W = \hat{H}_0^H \left(\hat{H}_0 \hat{H}_0^H + \hat{H}_1 \hat{H}_1^H + \hat{R}_z \right)^{-1}, \tag{9.2} $ where $\hat{R}_z$ is the estimate of other cell interference and noise covariance, that is $R_z = E[zz^H]$. Therefore, the system level modelling of E-LMMSE-IRC consists of modelling the estimation of H_0, H_1, and R_z. The other cell interference and noise covariance estimate $\hat{R}_z$ may be modelled using the complex Wishart distribution, so that $ \hat{R}_z \sim CWishart(R_z, N_{eff}), \tag{9.3} $

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	Qualcomm's '994 patent:  Figure 6: 9:25-43 (“As illustrated in FIG. 6, a composite received signal $y(m)$ 602 enters a SIC system 600 with decoding order selection and reconstruction weight calculation. The composite received signal $y(m)$ consists of a plurality of separately encoded streams of data. The decoding order selector 626 determines a decoding order for the N streams of data based on the received SNR of each and the

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	required SNR at the input of each decoder. Based on the selected order, the streams are decoded and subtracted from the received signal. [¶] The received signal y(m) passes through a receiver 604 for estimation and detection of the received symbols of a first stream of data. The receiver 604 may comprise a minimum mean square error (MMSE) or any general linear or nonlinear estimator/detector. The detected symbols of the first stream enter the channel decoder 606 for decoding. The decoded stream is re-encoded and re-modulated to reconstruct the first stream. The scale of this reconstructed stream may differ from the scale of the first transmitted stream or the scale of first stream in the received composite signal.”)
10[b] a multi-user detector decision unit coupled to said parameter estimator and said received signals, wherein said multi-user detector decision unit selects a multi-user detector based upon at least one threshold;	The Accused Instrumentalities include a multi-user detector decision unit coupled to said parameter estimator and said received signals, wherein said multi-user detector decision unit selects a multi-user detector based upon at least one threshold. For example, UE receivers for intracell SU-MIMO multiple data stream detection and for intercell interference cancellation according to NAICS and/or CRS-IC features may use a receiver from among a set of receivers such as CWIC, SLIC, R-ML and LMMSE-IRC and may include a fallback mode to a different multi-user receiver. For instance, for intercell PDSCH interference cancellation, or for separating different layers of a SU-MIMO codeword SLIC or R-ML may be used. For separating different codewords of a SU-MIMO signal CWIC may be used. The CWIC or R-ML SU-MIMO receiver may further use noise whitening filter prior to aid separating the SU-MIMO data streams. For example, an interference cancellation receiver may use noise whitening depending the value of Interference to Noise Ratio (INR), where interference is what is received from other cells. High INR has higher out of cell interference which results in a lower Signal to Interference plus Noise (SINR) at the UE. The multiuser detection decision unit may use a multiuser detector w or w/o noise whitening based on a threshold on SINR or some other received signal statistics. 3GPP TR 36.866 V12.0.1: • Pages 11-12

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7.2 Interference Suppression (IS) receivers

IS receivers refer to receivers that apply linear filtering to the received signal to suppress the interference, as opposed to explicitly cancel the interference. Three types of IS receivers are identified:

- LMMSE-IRC:
 - It is baseline for Rel-11 MMSE-IRC study (refer to TR36.829).
 - No knowledge of interferer parameter(s) is required.
- Enhanced LMMSE-IRC (E-LMMSE-IRC):
 - MMSE-IRC that explicitly considers interferer channel estimates and other interferer knowledge.
 - Interference parameters that can enable interferer channel estimation are needed, including, for example, its DMRS or CRS with PMI/RI.
- Widely linear MMSE-IRC (WLMMSE-IRC):
 - WLMMSE-IRC exploits the additional degrees of freedom from the real and imaginary part of the received signal to enhance suppression of interference
 - Real-valued modulation may be used to increase performance of the WLMMSE-IRC receiver

7.3 Maximum Likelihood (ML) receivers

ML-type of receivers are non-linear in nature. Three types of ML receivers are also identified:

- ML:
 - Full-blown joint detection of useful and interference signals in accordance to the ML criterion
 - Interference parameters that can enable interferer channel estimation and interferer detection at symbol level (e.g., modulation) are needed.
- Reduced complexity ML (R-ML):
 - Reduced complexity joint detection of useful and interference modulation symbols in accordance to the ML criterion (e.g. sphere decoding, QR-MLD, MLM, etc.)
 - Same interference knowledge as for ML
- Iterative ML and Iterative R-ML:
 - Iterative MAP detection and decoding of useful and interference signals. Both successive and parallel processing implementations may be applied.
 - In addition to the interference knowledge needed for ML, interference knowledge that can enable code word demodulation and decoding is needed.
 - Additionally, assumptions on network coordination may be necessary.

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	7.4 Interference Cancellation (IC) receivers IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - Linear Code word level SIC (L-CWIC): - receiver utilizing successive application of <i>linear detection</i> (e.g.: <i>LMMSE-IRC</i>), decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - ML-CWIC: - receiver utilizing successive application of <i>ML or reduced complexity ML detection</i>, decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (SLIC): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. • Pages 43-44: 9.1.1 Modelling methodologies for E-LMMSE-IRC Alternative 1

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	Assuming that a single dominant interferer is taken into account explicitly at the receiver, the following signal model is considered: $ \begin{aligned} y &= H_0 x_0 + H_1 x_1 + \left(\sum_{i=2}^K H_i x_i \right) + n \quad , \\ &= H_0 x_0 + H_1 x_1 + z \\ &= H_0 x_0 + v \end{aligned} \tag{9.1} $ where z is the interference from non-dominant interferers and noise term, and v is the total interference and noise term. The E-LMMSE-IRC receiver is expressed as $W = \hat{H}_0^H \left(\hat{H}_0 \hat{H}_0^H + \hat{H}_1 \hat{H}_1^H + \hat{R}_z \right)^{-1}, \tag{9.2}$ where $\hat{R}_z$ is the estimate of other cell interference and noise covariance, that is $R_z = E[zz^H]$. Therefore, the system level modelling of E-LMMSE-IRC consists of modelling the estimation of H_0, H_1, and R_z. The other cell interference and noise covariance estimate $\hat{R}_z$ may be modelled using the complex Wishart distribution, so that $\hat{R}_z \sim CWishart(R_z, N_{eff}). \tag{9.3}$ TSG-RAN WG4, Contribution # R4-150991: Title: On UE Demodulation Test Setup for NAICS ⋮ ⋮ In this paper, we present our views for defining UE demodulation requirements in RAN4. • Receiver Selection • Fallback Operation

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	• Blind Detection Granularity • Transmission Modes • 2.4 Receiver Selection Proposal 3: Target a single unified UE demodulation performance requirement based on SLIC and R-ML receivers in the Rel-12 NAICS UE demodulation requirements. • As observed previously, NAICS gains from SLIC and R-ML receivers are greater than EMMSE-IRC receivers in multiple scenarios [2]. Therefore, in order to being maximum gains via NAICS processing, unified requirements should be set based on SLIC/R-ML receivers. TSG-RAN WG4, Contribution # R4-146945: Title: Discussion and simulation result for NAICS demodulation performance • 2. Discussion on Test Scenario Based on WID [1] of NAICS, considerations to define performance requirement for NAICS receiver are as follows: ▪ Define unified performance requirement for NAICS receiver ▪ Ensure no performance loss compared to LMMSE-IRC receiver in all interference PDSCH scenarios In this section, we discuss two points of verification for NAICS receiver gain and robustness. 2.1 Performance Gain for NAICS Receiver In general, NAICS performance gain can be achieved in high interference power condition, and can easily distinguish performance of NAICS and baseline receiver in most test scenarios. When high interference power is configured, since PDCCH decoding performance of serving cell is affected by control channel

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	of interfering cell, PDSCH performance of NAICS receivers seriously degraded. However, for PDSCH performance requirement, PDCCH decoding impact can be minimized by using low loading control channel of interfering cell as the proposal of [4]. Therefore, to define performance gain for NAICS receiver, high interference power can be configured. - <i>Proposal 1:</i> Use high interference profile for verification of NAICS performance gain. Targeted network deployment scenarios for NAICS are homogeneous and heterogeneous networks. In general, dominant interfering cell has non-colliding CRS with serving cell in homogeneous network, and in heterogeneous network, dominant interfering cell could have colliding CRS with serving cell. NAICS receiver can achieve reasonable performance gain for colliding and non-colliding CRS scenarios under CRS based transmission mode in high INR [3]. Therefore, considering both network scenarios, colliding and non-colliding CRS scenarios should be considered for verification of NAICS performance gain. - <i>Proposal 2:</i> Both colliding and non-colliding CRS network scenarios should be considered for NAICS performance requirement. NAICS receiver blindly detects various TMs for interference PDSCH, and for NAICS performance requirement, TMs need to be narrowed for typical case such as TM4 and TM9 represented by CRS and DMRS base TM and TM2 used as fallback mode. Although the number of effective layer is four in TM2-TM2 case and current RAN4 agreement is violated which is to limit total layer (serving + interfering) up to 3, total 3 layers can be handled by NAICS receiver among 4 layers, and NAICS performance gain for TM2-TM2 case can be achieved [3][5]. - <i>Proposal 3:</i> TM2 should be used for fallback TM for all TMs, and TM4 and TM9 can be used as representative of CRS and DMRS based TM for performance requirement. RAN4 agreed that R-ML and SLIC receivers are used for NAICS performance requirement for 2 CRS ports, and FFS is for 4 CRS ports. To unify performance requirement for NAICS receivers, two options to define unified performance requirement with multiple reference receivers can be considered as follows: ▪ Option 1: Take average performance of both R-ML and SLIC receiver ▪ Option 2: Take minimum performance between R-ML and SLIC receivers similar to SU-MIMO case

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	Between the two options, if performance difference between R-ML and SLIC receiver is not large, these are reasonable approaches to unify performance requirement. If noticeable performance gap between receivers is observed, option 2 is reasonable since it is difficult to satisfy both R-ML and SLIC receivers by option 1 based performance requirement. - <i>Proposal 4:</i> For unified performance requirement, it should take minimum performance between R-ML and SLIC receivers. 2.2 Robustness for NAICS Receiver To ensure no performance loss compared to LMMSE-IRC receiver, NAICS receiver should consider fallback operation. In some interference scenarios such as low INR and high rank, NAICS receiver has no performance gain in comparison with baseline receiver. Dual decoding capability has been proposed as one possible approach for robust NAICS operations. However, additional decoding process can introduce increased power consumption and complexity in UE implementation perspective. Considering implementation complexity and receiver structures, various approaches for fallback operation to verify robustness NAICS receiver are available. Therefore, to verify the robustness of a NAICS receiver, it is not necessary to mandate specific fallback operation, and NAICS fallback operation should be a UE implementation issue. Then, one worst test case such as non-colliding CRS or low INR condition can be utilized to verify no performance loss compared to LMMSE-IRC receiver. Detail test scenario for robustness needs more investigation for various tests which both R-ML and SLIC receivers have performance loss in comparison with baseline receiver. - <i>Observation 1:</i> For verification of robustness for NAICS receivers, one worst case such as non-colliding CRS, high MCS level, or low INR condition can be used. - <i>Observation 2:</i> Need more investigation to find common test case which both R-ML and SLIC receivers have performance loss compared to baseline receiver. - <i>Proposal 5:</i> NAICS fallback operation should be UE implementation issue. In some worst test scenario which blind detection reliability cannot be guaranteed, the performance of NAICS receiver ensures no loss compared to baseline IRC receiver. However, if higher-layer signaling from eNB is incorrect, NAICS receiver may introduce performance loss due to wrong parameter detection

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	by incorrect high-layer signaling. Therefore, NAICS performance requirement should be defined under correct higher-layer signaling. - <i>Proposal 6:</i> NAICS performance requirement should be defined under correct higher-layer signaling from eNB. TSG-RAN WG4, Contribution # R4-150484: Title: Simulation results for multi-cell whitening verification : : 4. Introduction In RAN4#73, WF [1] for multi-cell whitening verification test was agreed. In this contribution, we provide simulation results for multi-cell whitening verification test based on agreed WF. : : 6. Conclusion In this contribution, we provide simulation results for multi-cell whitening verification test for alignment. For discrimination between receiver w/ and w/o whitening function, high INR setting is more suitable than medium INR setting since performance difference between w/ and w/o whitening function in high INR is larger than that in medium INR. TSG-RAN WG4, Contribution # R4-143876: Way forward for SU-MIMO WI in Rel-12 • RAN4 consider to take both R-ML and CWIC receiver as the candidate receiver for SU-MIMO. • RAN4 consider to define demodulation test of SU-MIMO based on the minimum performance of the above candidate receivers. – For each demodulation test there will be a single requirement which is based on R-ML receiver.

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	– If the performance of CWIC is found to be worse than R-ML, then requirement will be based on CWIC receiver for the agreed test cases.
10[c] <u>a low complexity multi-user detector switchably coupled by said multi-user detector decision unit, wherein said low complexity multi-user detector outputs a plurality of low complexity processed information streams;</u>	The Accused Instrumentalities include a low complexity multi-user detector switchably coupled by said multi-user detector decision unit, wherein said low complexity multi-user detector outputs a plurality of low complexity processed information streams. For example, a number of receivers such as LMMSE-IRC, or other variations of MMSE, CWIC, SLIC, R-ML, and ML-CWIC may be available for separating and decoding multiple data streams. Depending on certain received signal statistics, such as received SINR, the receiver may use a low complexity LMMSE-IRC or other variations of MMSE receiver. 3GPP TR 36.866 V12.0.1: • Pages 11-12 7.2 Interference Suppression (IS) receivers IS receivers refer to receivers that apply linear filtering to the received signal to suppress the interference, as opposed to explicitly cancel the interference. Three types of IS receivers are identified: - <u>LMMSE-IRC</u>: - It is baseline for Rel-11 MMSE-IRC study (refer to TR36.829). - No knowledge of interferer parameter(s) is required. - <u>Enhanced LMMSE-IRC (E-LMMSE-IRC)</u>: - MMSE-IRC that explicitly considers interferer channel estimates and other interferer knowledge. - Interference parameters that can enable interferer channel estimation are needed, including, for example, its DMRS or CRS with PMI/RI. - Widely linear MMSE-IRC (WLMMSE-IRC): - WLMMSE-IRC exploits the additional degrees of freedom from the real and imaginary part of the received signal to enhance suppression of interference - Real-valued modulation may be used to increase performance of the WLMMSE-IRC receiver

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	Assuming that a single dominant interferer is taken into account explicitly at the receiver, the following signal model is considered: $ \begin{aligned} y &= H_0 x_0 + H_1 x_1 + \left(\sum_{i=2}^K H_i x_i \right) + n \\ &= H_0 x_0 + H_1 x_1 + z \\ &= H_0 x_0 + v \end{aligned} \tag{9.1} $ where z is the interference from non-dominant interferers and noise term, and v is the total interference and noise term. The E-LMMSE-IRC receiver is expressed as $ W = \hat{H}_0^H \left(\hat{H}_0 \hat{H}_0^H + \hat{H}_1 \hat{H}_1^H + \hat{R}_z \right)^{-1}, \tag{9.2} $ where $\hat{R}_z$ is the estimate of other cell interference and noise covariance, that is $R_z = E[zz^H]$. Therefore, the system level modelling of E-LMMSE-IRC consists of modelling the estimation of H_0, H_1, and R_z. The other cell interference and noise covariance estimate $\hat{R}_z$ may be modelled using the complex Wishart distribution, so that $ \hat{R}_z \sim CWishart(R_z, N_{eff}), \tag{9.3} $ 3GPP TR 36.829 V11.1.0: 4.3 MMSE IRC receiver For enhanced receiver, the MMSE-IRC receiver can suppress not only the inter-stream interference but also the inter-cell interference when the degrees of freedom at the receiver are sufficient, i.e., the number of receiver antennas is higher than that of the number of desired data streams, and MMSE IRC receiver weight matrix is expressed as follow: $ \mathbf{W}_{RX,1}(k, l) = \hat{\mathbf{H}}_1^H(k, l) \mathbf{R}^{-1} $

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	where $\hat{\mathbf{H}}_j(k, l)$ and $\mathbf{R}$ denote the estimated channel matrix and covariance matrix, respectively. To obtain the MMSE-IRC receiver weight matrix, the covariance matrix including the sources of inter-cell interference needs to be estimated. Various schemes can be considered for that purpose. • CRS based covariance matrix estimation scheme ▪ The covariance matrix is estimated at CRS REs by following equations $\mathbf{R} = P_1 \hat{\mathbf{H}}_1(k, l) \hat{\mathbf{H}}_1^H(k, l) + \frac{1}{N_{sp}} \sum_{k, l \in CRS} \tilde{\mathbf{r}}(k, l) \tilde{\mathbf{r}}(k, l)^H, \quad \tilde{\mathbf{r}}(k, l) = \mathbf{r}(k, l) - \hat{\mathbf{H}}_1(k, l) \mathbf{d}_1(k, l),$ where P_1 is the transmission power of the serving cell and is equal to $E[d_1(k, l) ^2]$ and N_{sp} is the number of sampling REs, respectively. • DM-RS based covariance matrix estimation scheme (applicable when DM-RS are configured) ▪ The covariance matrix is estimated at DM-RS REs by following equations: $\mathbf{R} = P_1 \hat{\mathbf{H}}_1(k, l) \hat{\mathbf{H}}_1^H(k, l) + \frac{1}{N_{sp}} \sum_{k, l \in DM-RS} \tilde{\mathbf{r}}(k, l) \tilde{\mathbf{r}}(k, l)^H, \quad \tilde{\mathbf{r}}(k, l) = \mathbf{r}(k, l) - \hat{\mathbf{H}}_1(k, l) \mathbf{d}_1(k, l)$ • Data signal based covariance matrix estimation scheme ▪ The covariance matrix is estimated at PDSCH REs by following equations: $\mathbf{R} = \frac{1}{N_{sp}} \sum_{k, l \in PDSCH, DM-RS} \mathbf{r}(k, l) \mathbf{r}(k, l)^H$
10[d] <u>a medium complexity multi-user detector switchably coupled by said multi-user detector decision unit, wherein said medium complexity multi-user detector outputs a plurality of medium complexity</u>	The Accused Instrumentalities include a medium complexity multi-user detector switchably coupled by said multi-user detector decision unit, wherein said medium complexity multi-user detector outputs a plurality of medium complexity processed information streams. For example, a number of receivers with different degree of complexity such as LMMSE-IRC, or other variations of MMSE, SLIC, R-ML, CWIC, and ML-CWIC may be available for separating and decoding multiple data streams. Depending on certain receiver signal statistics, such as received SINR, the receiver may use a receiver such as SLIC or R-ML. For example, in inter-cell interference cancellation, the UE may use a medium complexity SLIC receiver, and in SU-MIMO detection the receiver may use an R-ML versus CWIC or ML-CWIC.

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
processed information streams;	TSG-RAN WG4, Contribution # R4-150991: Title: On UE Demodulation Test Setup for NAICS : : In this paper, we present our views for defining UE demodulation requirements in RAN4. • Receiver Selection • Fallback Operation • Blind Detection Granularity • Transmission Modes : : 2.4 Receiver Selection Proposal 3: Target a single unified UE demodulation performance requirement based on SLIC and R-ML receivers in the Rel-12 NAICS UE demodulation requirements. • As observed previously, NAICS gains from SLIC and R-ML receivers are greater than ELMMSE-IRC receivers in multiple scenarios [2]. Therefore, in order to being maximum gains via NAICS processing, unified requirements should be set based on SLIC/R-ML receivers. TSG-RAN WG4, Contribution # R4-146945: Title: Discussion and simulation result for NAICS demodulation performance : : : 2. Discussion on Test Scenario Based on WID [1] of NAICS, considerations to define performance requirement for NAICS receiver are as follows: ▪ Define unified performance requirement for NAICS receiver

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	▪ Ensure no performance loss compared to LMMSE-IRC receiver in all interference PDSCH scenarios In this section, we discuss two points of verification for NAICS receiver gain and robustness. 2.1 Performance Gain for NAICS Receiver In general, NAICS performance gain can be achieved in high interference power condition, and can easily distinguish performance of NAICS and baseline receiver in most test scenarios. When high interference power is configured, since PDCCH decoding performance of serving cell is affected by control channel of interfering cell, PDSCH performance of NAICS receivers seriously degraded. However, for PDSCH performance requirement, PDCCH decoding impact can be minimized by using low loading control channel of interfering cell as the proposal of [4]. Therefore, to define performance gain for NAICS receiver, high interference power can be configured. - <i>Proposal 1:</i> Use high interference profile for verification of NAICS performance gain. Targeted network deployment scenarios for NAICS are homogeneous and heterogeneous networks. In general, dominant interfering cell has non-colliding CRS with serving cell in homogeneous network, and in heterogeneous network, dominant interfering cell could have colliding CRS with serving cell. NAICS receiver can achieve reasonable performance gain for colliding and non-colliding CRS scenarios under CRS based transmission mode in high INR [3]. Therefore, considering both network scenarios, colliding and non-colliding CRS scenarios should be considered for verification of NAICS performance gain. - <i>Proposal 2:</i> Both colliding and non-colliding CRS network scenarios should be considered for NAICS performance requirement. NAICS receiver blindly detects various TMs for interference PDSCH, and for NAICS performance requirement, TMs need to be narrowed for typical case such as TM4 and TM9 represented by CRS and DMRS base TM and TM2 used as fallback mode. Although the number of effective layer is four in TM2-TM2 case and current RAN4 agreement is violated which is to limit total layer (serving + interfering) up to 3, total 3 layers can be handled by NAICS receiver among 4 layers, and NAICS performance gain for TM2-TM2 case can be achieved [3][5]. - <i>Proposal 3:</i> TM2 should be used for fallback TM for all TMs, and TM4 and TM9 can be used as representative of CRS and DMRS based TM for performance requirement.

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	RAN4 agreed that R-ML and SLIC receivers are used for NAICS performance requirement for 2 CRS ports, and FFS is for 4 CRS ports. To unify performance requirement for NAICS receivers, two options to define unified performance requirement with multiple reference receivers can be considered as follows: ▪ Option 1: Take average performance of both R-ML and SLIC receiver ▪ Option 2: <u>Take minimum performance between R-ML and SLIC receivers similar to SU-MIMO case</u> If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
10[e] <u>a high complexity multi-user detector switchably coupled by said multi-user detector decision unit, wherein said high complexity multi-user detector outputs a plurality of high complexity processed information streams; and</u>	The Accused Instrumentalities include a high complexity multi-user detector switchably coupled by said multi-user detector decision unit, wherein said high complexity multi-user detector outputs a plurality of high complexity processed information streams. For example, a number of receivers with different degree of complexity such as LMMSE-IRC, or other variations of MMSE, SLIC, R-ML, CWIC, and ML-CWIC may be available for separating and decoding multiple data streams. Depending on certain receiver signal statistics, such as received SINR, the receiver may use a higher complexity receiver such as CWIC or ML-CWIC. For example, in inter-cell interference cancellation, the UE may use an R-ML receiver vs SLIC, and in SU-MIMO detection the receiver may use a CWIC or ML-CWIC receiver versus R-ML or SLIC. 3GPP TR 36.866 V12.0.1: • Pages 11-12 7.4 Interference Cancellation (IC) receivers IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	- Linear Code word level SIC (<u>L-CWIC</u>): - receiver utilizing successive application of <i>linear detection</i> (e.g.: <i>LMMSE-IRC</i>), decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - <u>ML-CWIC</u>: - receiver utilizing successive application of <i>ML or reduced complexity ML detection</i>, decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (SLIC): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. TSG-RAN WG4, Contribution # R4-143876: Way forward for SU-MIMO WI in Rel-12 • RAN4 consider to take both <u>R-ML</u> and <u>CWIC</u> receiver as the candidate receiver for SU-MIMO. • RAN4 consider to define demodulation test of SU-MIMO based on the minimum performance of the above candidate receivers. – For each demodulation test there will be a single requirement which is based on R-ML receiver.

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'492 Claim 10 Element	<u>Accused Products (UE)</u>
	– If the performance of CWIC is found to be worse than R-ML, then requirement will be based on CWIC receiver for the agreed test cases.
10[f] a bank of decoders coupled to said plurality of low complexity processed information streams, said plurality of medium complexity processed information streams, and said plurality of high complexity processed information streams, wherein said decoders output a plurality of refined information streams.	The Accused Instrumentalities include a bank of decoders coupled to said plurality of low complexity processed information streams, said plurality of medium complexity processed information streams, and said plurality of high complexity processed information streams, wherein said decoders output a plurality of refined information streams. TSG-RAN WG1, Contribution # R1-090919: Receiver Turbo-SIC strategy After proper noise filtering and sampling of the channel output at the receiver side, the turbo-SIC detection strategy in a multi-user context consists in an iterative linear filtering with Successive Interference Cancellation (SIC) of the users, as depicted in Fig. 3.

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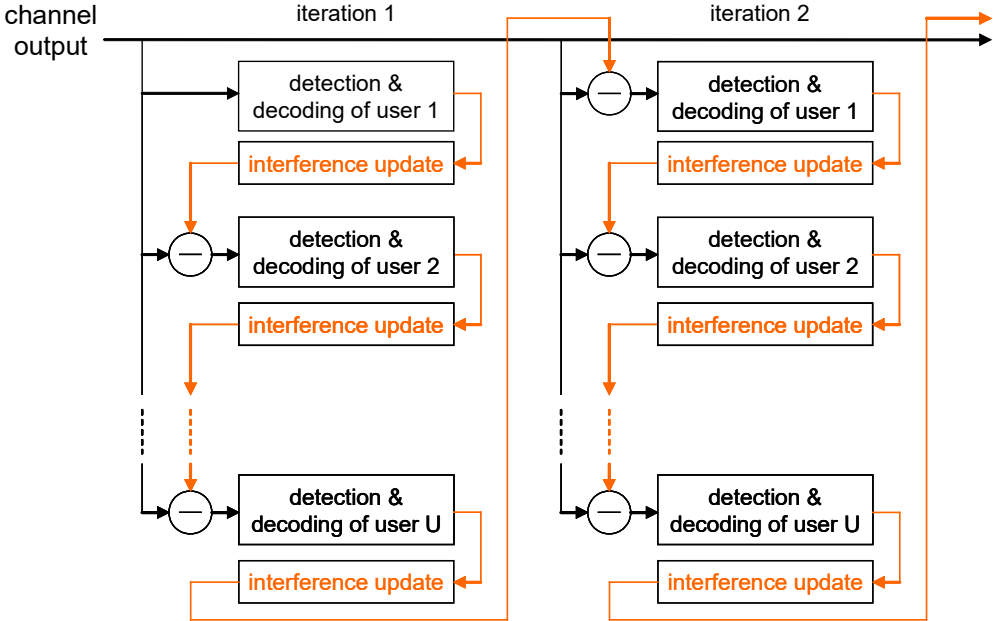
'492 Claim 10 Element	<u>Accused Products (UE)</u>
	 The diagram illustrates the Successive Interference Cancellation (SIC) process for multiple users. It starts with a 'channel output' signal. This signal enters a series of blocks for 'iteration 1' and 'iteration 2'. Each iteration contains blocks for 'detection & decoding of user 1', 'interference update', 'detection & decoding of user 2', 'interference update', and 'detection & decoding of user U'. The process involves subtracting the detected signals from the channel output to isolate the next user's signal. Orange arrows indicate the flow of interference updates between iterations.

Fig. 3 - SIC process assuming natural ordering of the users

Qualcomm's '994 patent:

9:24-10:2 ("As illustrated in FIG. 6, a composite received signal $y(m)$ 602 enters a SIC system 600 with decoding order selection and reconstruction weight calculation. The composite received signal $y(m)$ consists of a plurality of separately encoded streams of data. The decoding order selector 626 determines a decoding order for the N streams of data based on the received SNR of each and the required SNR at the input of each decoder. Based on the selected order, the streams are decoded and subtracted from the received signal.

The received signal $y(m)$ passes through a receiver 604 for estimation and detection of the received symbols of a first stream of data. The receiver 604 may comprise a minimum mean square error (MMSE) or any general linear or non linear estimator/detector. The detected symbols of the first stream enter the channel decoder 606 for decoding. The decoded stream is re-encoded and re-modulated to

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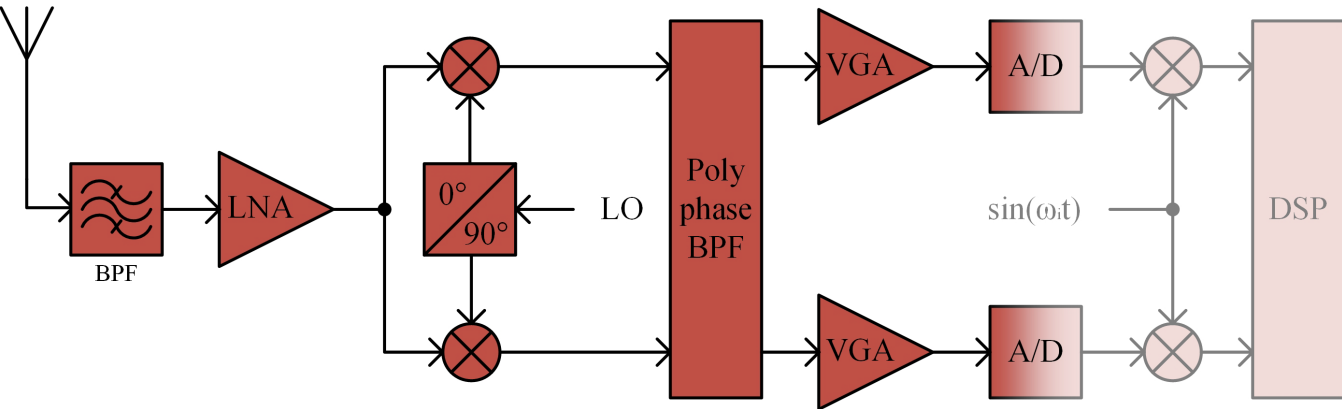
'492 Claim 10 Element	<u>Accused Products (UE)</u>
	recon struct the first stream. The scale of this reconstructed stream may differ from the scale of the first transmitted stream or the scale of first stream in the received composite signal. A reconstruction weight vector is calculated at 628 for the reconstructed stream. Blocks 628,630 and 632 may calculate reconstruction weights for each decoded stream to cancel the interference of the decoded stream from the composite received signal as efficiently as possible. Weight reconstruction, in accordance with certain aspects, is described in greater detail below. In 608, the reconstructed stream is multiplied with the reconstruction weight vector and subtracted from the received signal. The resulting signal passes through a second receiver 610 and a second decoder 612 to detect and decode the second stream, respectively. After decoding, effects of both of the first and second streams of data are subtracted at 614 from the received signal to cancel the interference and condition the received signal to enter the third decoding block 618 for decoding the third stream. The process continues with subtraction 620, receiver operation 622 and decoding 624 until all the streams are decoded. The decoders 606, 612 and 618 may use any kind of error correcting code such as turbo codes. The decoders 606, 612 and 618 may decode a plurality of encoded streams with a plurality of types and code rates. The Subtraction operation may not be performed if the decoding operation fails at any step. The decoding order selector may update the decoding order of the remaining streams after each Successful decode and subtract operation (i.e., each SIC iteration).”) • Figure 6:

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'492 Claim 10 Element	Accused Products (UE)
	FIG. 6 If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'492 Claim 11 Element	Accused Products (UE)
<u>The hybrid receiver according to claim 10, further comprising a</u>	The Accused Instrumentalities include the hybrid receiver according to claim 10, <i>see</i> Claim 10, and further include a front end section coupled to said received signals and to said received signal information which filters said received signals.

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'492 Claim 11 Element	Accused Products (UE)
<u>front end section coupled to said received signals and to said received signal information which filters said received signals.</u>	For example, a multiuser detector is coupled to a downconversion circuitry which includes a filter. The received signals are filtered and converted into digital samples to be processed by the multiuser detector. Receiver Filter: In a homodyne receiver, the signal is directly downconverted to baseband, without using an IF. Thus, since $f_i = 0$, the mirror frequency is equal to the desired signal's frequency. Nevertheless, a problem with the mirror frequency still exists: the wanted signal is mirrored in the negative frequency range, resulting in the top end of the signal band from the positive frequencies overlapping with the low end of the signal band from the negative frequencies after downconversion, and vice versa. Therefore, a quadrature downconversion is needed [3], as illustrated in Fig. 4. Since, in theory, quadrature downconversion is equivalent to complex mixing [6], [7], the desired signal can be obtained by the DSP. As shown in Fig. 4, in most homodyne receivers the signal from the antenna is filtered and amplified before mixing. The former serves to prevent desensitization due to blockers, while the latter serves to decrease the receiver's NF. <u>After mixing, the desired signal is at baseband, and thus channel selection can be performed by low-pass filters (LPF).</u> The signal is then brought in range of the ADC's by VGA's and converted to the digital domain where it is demodulated using a DSP. 

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'492 Claim 11 Element	<u>Accused Products (UE)</u>
	• <i>Source: Wireless Receiver Architectures Towards 5G: Where Are We?</i> If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'492 Claim 12 Element	<u>Accused Products (UE)</u>
The hybrid receiver according to claim 10, wherein said plurality of refined information streams are fed back to said multi-user detector decision unit for iterative processing until a final condition is reached and said bank of error correction decoders output a final plurality of bit streams.	The Accused Instrumentalities include the hybrid receiver according to claim 10, <i>see</i> Claim 10, wherein the plurality of refined information streams are fed back to said multi-user detector decision unit for iterative processing until a final condition is reached and said bank of error correction decoders output a final plurality of bit streams. For example, successive interference cancellation schemes feedback the decoder output (“improved information stream”) to the multiuser detector in an iterative manner until a condition is met.

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'492 Claim 12 Element	Accused Products (UE)
	Qualcomm's '994 patent: Figure 6: FIG. 6 <i>For certain embodiments of the present disclosure, at the end of some of the SIC iterations, decoding of some streams may be unsuccessful. Therefore, the process may continue with a subset of streams that have yet to be correctly decoded, by modifying the decoding order in a recursive manner. This process may continue until a maximum allowable time passes or convergence happens. The process may converge if either of the following conditions satisfies: i) all streams are decoded successfully ii) size of the subset of streams to be decoded and their decoding order is identical in two consecutive iterations.”)</i>

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TSG-RAN WG1, Contribution # R1-090919:

Receiver

Turbo-SIC strategy

After proper noise filtering and sampling of the channel output at the receiver side, the turbo-SIC detection strategy in a multi-user context consists in an iterative linear filtering with Successive Interference Cancellation (SIC) of the users, as depicted in Fig. 3.

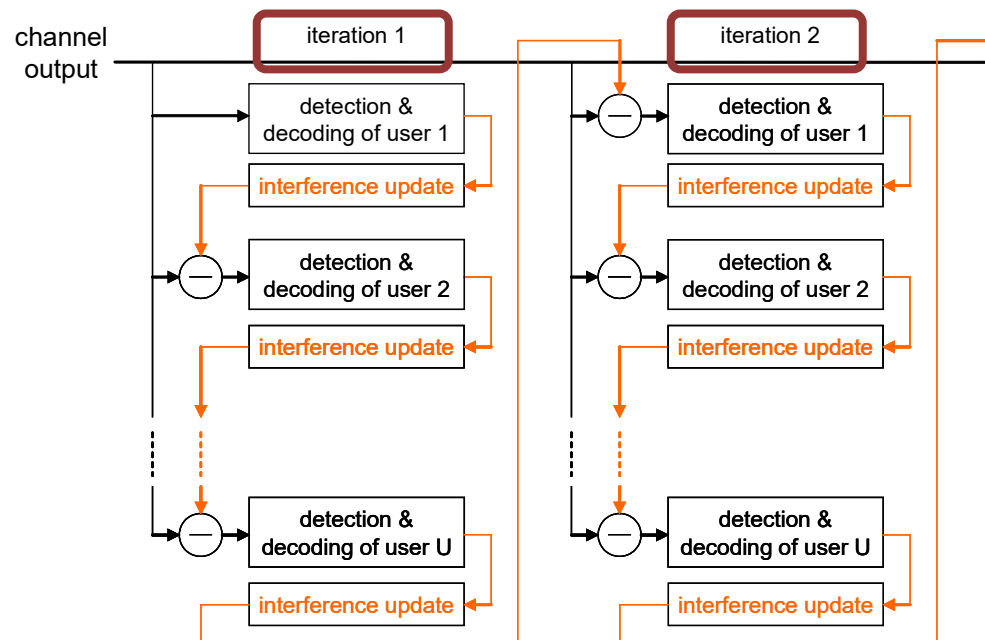


Fig. 4 – SIC process assuming natural ordering of the users

If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

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'492 Claim 13 Element	<u>Accused Products (UE)</u>
The hybrid receiver according to claim 10, <u>wherein said multi-user detector decision unit makes a selection determined by design criteria based upon at least one threshold selected from at least one of the group consisting of number of symbols, correlation matrix between users, expected bit error rate, eigen decomposition of correlation matrix, signal to interference plus noise ratio, and expected SINR.</u>	The Accused Instrumentalities include the hybrid receiver according to claim 10, <i>see</i> Claim 10, wherein wherein said design criteria is based upon at least one threshold selected from at least one of the group consisting of number of symbols, correlation matrix between users, expected bit error rate, eigen decomposition of correlation matrix, signal to interference plus noise ratio, and expected SINR. For example, an interference cancellation receiver may use noise whitening depending the value of Interference to Noise Ratio (INR), where interference is what is received from other cells. High INR has higher out of cell interference which results in a lower Signal to Interference plus Noise (SINR) at the UE. The multiuser detection decision unit may use a multiuser detector w or w/o noise whitening based on a threshold on SINR or some other received signal statistics. TSG-RAN WG4, Contribution # R4-150484: Title: Simulation results for multi-cell whitening verification : : 5. Introduction In RAN4#73, WF [1] for multi-cell whitening verification test was agreed. In this contribution, we provide simulation results for multi-cell whitening verification test based on agreed WF. : : 7. Conclusion In this contribution, we provide simulation results for multi-cell whitening verification test for alignment. <u>For discrimination between receiver w/ and w/o whitening function, high INR setting is more suitable than medium INR setting since performance difference between w/ and w/o whitening function in high INR is larger than that in medium INR.</u>

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'492 Claim 13 Element	<u>Accused Products (UE)</u>
	TSG-RAN WG4, Contribution # R4-150991 Fallback Operation General Aspects of NAICS Fallback Operation On fallback, the WID states the following: “<i>Ensure no performance loss compared to LMMSE-IRC receivers in all interference PDSCH scenarios including different transmission modes than that of desired PDSCH, per PRB or PRB-pair based resource allocation for interference PDSCH, and/or lack of higher-layer signaling</i>”. <u>The exact test cases to fallback to Rel-11 MMSE-IRC performance need to be discussed further</u>, we would like confirm that covering <i>incorrect NAICS signaling</i> is not part of the WID scope. <u>Proposal 4: The fallback performance of Rel-12 advanced receiver should be no worse than the Rel-11 MMSE-IRC performance, an aspect that needs to be tested by RAN4.</u> • <u>Proposal 4.1:</u> Reliability of NAICS processing: As observed during the study item and work item phase, there could be some scenarios in which NAICS receiver processing may not be reliable both in terms of blind detection and demodulation. Exact scenarios need further discussion → Propose to have RAN4 demodulation test cases to ensure this behaviour. • <u>Proposal 4.2:</u> Lack of NAICS Signaling: In the absence of NAICS signaling, the NAICS UE is expected to perform no worse than the Rel-11 MMSE-IRC receiver → Not needed to test this behavior, it is automatically implied by Rel-11 tests. • <u>Proposal 4.3:</u> Incorrect Signaling: If the NAICS signaling is incorrect, i.e., eNB does not follow the signaled parameters in its transmission, there should be no performance requirement on the NAICS UE. Incorrect information from the eNB may mislead the UE into false detections. If the eNB cannot guarantee accurate signaling, the signaling could be skipped, hence not requiring the UE to meet NAICS requirements. → Not needed to test this behavior. TSG-RAN WG4, Contribution # R4-150091:

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'492 Claim 13 Element	<u>Accused Products (UE)</u>
	NAICS fallback operation assumptions So far, many companies have provided simulation results to show variable NAICS gains for different test cases, so there has a question that which test cases would be suitable for NAICS gain requirement, and which one is better for robustness. In our opinion, RAN4 shall reach a general principle how to define the UE fallback operation for the purpose of clarifying which test cases are suitable for NAICS gain tests or nor. For example, a general principle could be: - If the practical performance gain of NAICS receiver over MMSE-IRC receiver is below x.x dB (e.g. 1.0dB @70% maximum throughput), the NAICS UE could fallback to MMSE-IRC receiver. Proposal 4: <u><i>The NAICS UE could fallback to MMSE-IRC receiver as long as the practical performance gain of NAICS receiver over MMSE-IRC receiver is below x.x dB (e.g. 1.0dB @70% maximum throughput).</i></u> Another issue of NAICS fallback operation assumptions is that whether NAICS UE needed to check the truth of NAICS signalling. In another words, whether NAICS UE should be required no-performance loss if the interference condition is not aligned with NAICS high-layer signalling. In our opinion, checking the consistency of NAICS high signalling and interference condition would greatly increase implement complexity and beyond the UE's responsibility. So, we think the inconsistency of NAICS high signalling and interference condition is not a valid fallback scenarios. Proposal 5: <i>The inconsistence of NAICS high signalling and interference condition is not a valid fallback scenario. In another words, NAICS UE would not guarantee no-performance-loss over MMSR-IRC when the signalling and interference condition are not aligned.</i> If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

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'492 Claim 15 Element	<u>Accused Products (UE)</u>
The hybrid receiver according to claim 12, <u>wherein said final condition is one of a fixed number of iterations and an allowable performance level.</u>	The Accused Instrumentalities include the hybrid receiver according to claim 12, <i>see</i> Claim 12, wherein said final condition is one of a fixed number of iterations and an allowable performance level. For example, interference cancellation receivers iterate the process of interference cancellation until a maximum number of iterations are reached or a convergence criteria such as a bit error rate is reached. <u>Qualcomm's '994 patent:</u> • 9:44-55 (“A reconstruction weight vector is calculated at 628 for the reconstructed stream. Blocks 628, 630 and 632 may calculate reconstruction weights for each decoded stream to cancel the interference of the decoded stream from the composite received signal as efficiently as possible. Weight reconstruction, in accordance with certain aspects, is described in greater detail below. In 608, the reconstructed stream is multiplied with the reconstruction weight vector and subtracted from the received signal. The resulting signal passes through a second receiver 610 and a second decoder 612 to detect and decode the second stream, respectively.”) • 7:66-8:19 (“The process may continue with subtraction, at 420, utilizing receiver 422 and decoder 424 until all the N streams are decoded. The decoders 406, 412 and 418 may decode any kind of error correcting code. Such as turbo or convolutional codes. The decoders 406, 412 and 418 may decode a plurality of encoded streams with a plurality of types and code rates. The subtraction operation may not be performed if the decoding operation fails at any step. <u>Each Successful decode and subtract operation of the SIC system is referred to herein as one “iteration.”</u> <u>For certain embodiments of the present disclosure, at the end of some of the SIC iterations, decoding of some streams may be unsuccessful. Therefore, the process may continue with a subset of streams that have yet to be correctly decoded, by modifying the decoding order in a recursive manner. This process may continue until a maximum allowable time passes or convergence happens. The process may converge if either of the following conditions satisfies: i) all streams are decoded successfully ii) size of the subset of streams to be decoded and their decoding order is identical in two consecutive iterations.”)</u>

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'492 Claim 15 Element	<u>Accused Products (UE)</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

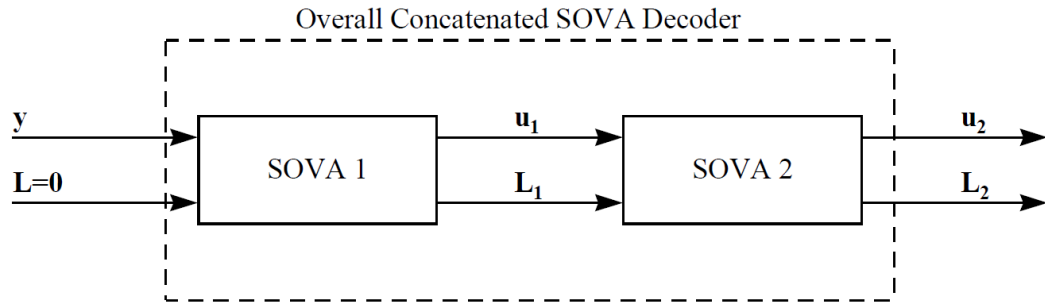
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'492 Claim 16 Element	Accused Products (UE)
The hybrid receiver according to claim 10, <u>further comprising a hard decision unit coupled to said bank of decoders and producing a final data stream.</u>	The Accused Instrumentalities include the hybrid receiver according to claim 10, <i>see</i> Claim 10, further comprising a hard decision unit coupled to said bank of decoders and producing a final data stream. For example, a multiuser detector includes a decoder which uses hard decision to determine the transmitted symbol, and to reconstruct the received symbols before cancelling the decode stream from the received signal. Qualcomm's '994 patent: Figure 6: <pre> graph TD 600[DECODING ORDER SELECTION: DETERMINE i1, i2, iN] 602[y(m)] 604[MMSE OR ANOTHER RECEIVER FOR STREAM i1] 606[DECODE STREAM i1] 608[608] 610[MMSE OR ANOTHER RECEIVER FOR STREAM i2] 612[DECODE STREAM i2] 614[614] 616[MMSE OR ANOTHER RECEIVER FOR STREAM i3] 618[DECODE STREAM i3] 620[620] 622[MMSE OR ANOTHER RECEIVER FOR STREAM iN] 624[DECODE STREAM iN] 630[630] 632[632] 602 --> 608 608 --> 604 604 --> 606 606 --> 608 608 --> 610 610 --> 612 612 --> 610 610 --> 614 614 --> 616 616 --> 618 618 --> 614 614 --> 620 620 --> 622 622 --> 624 624 --> 620 620 --> 630 630 --> 632 632 --> 622 632 --> 624 624 --> 630 630 --> 600 600 --> 604 600 --> 610 600 --> 616 600 --> 622 600 --> 606 600 --> 612 600 --> 618 600 --> 624 606 --> 608 612 --> 610 618 --> 616 624 --> 622 </pre>

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'492 Claim 16 Element	<u>Accused Products (UE)</u>
	The following model at the data symbol level for a MIMO system is considered for a received signal. It should be noted that all quantities in the following equation have complex values and may be indexed by time t, $0 \leq t < T$ to represent a stream of data of length T. $y = H \cdot s + n$ where $y = [y_1 \dots y_N]^T$ may be an N-dimensional received vector of samples, H may represent a symbol-level $N \times N$ matrix that models the effects of the pre-coder such as beam-forming matrix in WCDMA, power scaling, channel, and a complete front-end receiver processing, such as Rake receiver and equalizer on transmitted modulated symbols. In the equation above, $s = [s_1 \dots s_N]^T$ may represent the N-dimensional vector of coded and modulated symbols transmitted on each stream s_i, and n is an additive N-dimensional noise vector that is independent for each s. When the i^{th} stream is decoded, $\hat{s}_i$ may represent the reconstructed (i.e., re-encoded, rate-matched and re-modulated) complex symbols, with a similar scaling convention as s_i. If the block of data in stream s_i is decoded successfully (i.e., a valid cyclic redundancy check (CRC)), values of the $\hat{s}_i$ may be equal to the values of stream s_i. Otherwise, if the SNR is not very low, values of $\hat{s}_i$ may be a close approximation of s_i. The SIC technique removes the interference of i^{th} stream from the received signal. Therefore, the signal after each iteration of SIC may be written as follows: $y' = y - W_i \cdot \hat{s}_i$ where W_i is the reconstruction weight vector. Note that in each iteration of interference cancellation, y' is updated to remove the interference of each stream from the received signal (for $N > 2$).

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'492 Claim 16 Element	<u>Accused Products (UE)</u>
	<u>Decoder:</u> 4.1 Principle of the General Soft-Output Viterbi Decoder The Viterbi algorithm produces the ML output sequence for convolutional codes. This algorithm provides optimal sequence estimation for one stage convolutional codes. For concatenated (multistage) convolutional codes, there are two main drawbacks to conventional Viterbi decoders. First, the inner Viterbi decoder produces bursts of bit errors which degrades the performance of the outer Viterbi decoders [Hag89]. Second, the inner Viterbi decoder produces hard decision outputs which prohibits the outer Viterbi decoders from deriving the benefits of soft decisions [Hag89]. Both of these drawbacks can be reduced and the performance of the overall concatenated decoder can be significantly improved if the Viterbi decoders are able to produce reliability (soft-output) values [Ber93a]. The reliability values are passed on to subsequent Viterbi decoders as a-priori information to improve decoding performance. This modified Viterbi decoder is referred to as the soft-output Viterbi algorithm (SOVA) decoder. Figure 4.1 shows a concatenated SOVA decoder.  Figure 4.1: <u>A concatenated SOVA decoder where v represents the received channel values, u represents the hard decision output values, and L represents the associated reliability values.</u>

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'492 Claim 16 Element	<u>Accused Products (UE)</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'492 Claim 17 Element	<u>Accused Products (UE)</u>
17[pre]A method for processing signals from multiple users with raw digitized data, comprising:	To the extent the preamble is found to be limiting, the Accused Instrumentalities include a method for processing signals from multiple users with raw digitized data. For example, multiple data streams are received at the UE from an intracell SU-MIMO multi-layer transmission from the same serving cell sector, and from interfering (neighboring) cells. Multiuser detectors are used at the UE to separate the multiple data streams (layers) of SU-MIMO while cancelling interfering data streams from the interfering cell(s). The multiuser detection systems may use a number of receiver types such as CodeWord IC (CWIC), Symbol Level IC (SLIC), Reduced complexity Maximum Likelihood (R-ML), LMSMSE-IRC, and variations of the CWIC, SLIC and R-ML. A specific multiuser detection for the SU-MIMO detector in conjunction with intercell cancellation may use a hybrid of the available receiver types. For example, wireless receivers include a downconverter circuitry that downconverts the received signal from the carrier frequency to baseband, samples the signal and digitizes (quantizes) the samples into a stream of bits ("raw digitized bits") for further processing by the receiver. MIMO in LTE: • <i>Downlink MIMO Technology</i> Single-User MIMO (SU-MIMO) was used for the downlink for LTE Rel. 8 to increase the peak data rate. The target data rates of over 100 Mbit/s were achieved by using a 20 MHz transmission bandwidth, 2×2 MIMO, and 64 Quadrature Amplitude Modulation (64QAM), and peak data rates of over 300 Mbit/s can be achieved using 4×4 SU-MIMO. The multi-antenna technology used for the downlink in LTE Rel. 8 is classified into the following three types. • Figure 1:

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'492 Claim 17 Element	Accused Products (UE)
	NTT DOCOMO Technical Journal Vol. 12 No. 2 When transmitting 4×4 MIMO rank 2 (example) Figure 1 Closed-loop SU-MIMO transmission using code-book-based precoding Via: 3g4g.blogspot.com

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'492 Claim 17 Element	<u>Accused Products (UE)</u>																		
	3GPP TS 36.211 V8.8.0: 6.3.3.2 Layer mapping for spatial multiplexing For spatial multiplexing, the layer mapping shall be done according to Table 6.3.3.2-1. The number of layers v is less than or equal to the number of antenna ports P used for transmission of the physical channel. The case of a single codeword mapped to two layers is only applicable when the number of antenna ports is 4. Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing <table><tr><th>Number of layers</th><th>Number of code words</th><th>Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$</th></tr><tr><td>1</td><td>1</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$</td></tr><tr><td>2</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$</td></tr><tr><td>2</td><td>1</td><td>$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$</td></tr><tr><td>3</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$</td></tr><tr><td>4</td><td>2</td><td>$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$</td></tr></table>	Number of layers	Number of code words	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$	1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$	2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$	2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$	3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$	4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$
Number of layers	Number of code words	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$																	
1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$																	
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$																	
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$																	
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$																	
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$																	

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	Verizon Wireless Requirement Plan: 1.6.9.1 SU-MIMO IC RF Performance VZ_REQ_LTEB13NAC_39982 The device shall support and meet receiver maximum input level performance requirements for SU-MIMO IC (Enhanced Performance Requirements Type C), for all transmission modes that are supported on Verizon's network as specified in sections 8.2.1.3.1.B (FDD, TM3), 8.2.1.4.2.A (FDD, TM4), 8.3.1.2.A (TM9/TM10) of the Release 12 version of 3GPP TS 36.101: <i>Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment(UE) Radio Transmission and Reception</i>. 1.6.10 Blind Data IC VZ_REQ_LTEB13NAC_1238214 While operating in Blind Data IC mode, the UE shall meet enhanced receiver Type B performance requirements defined in TS 36.101 (Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception) requirements on the following channel operations: • PDSCH demodulation minimum performance using ○ CRS ▪ 8.2.1.2.5 Enhanced Performance Requirement Type B - 2 Tx Antenna Ports with TM2 interference model ▪ 8.2.1.4.1D Enhanced Performance Requirement Type B - Single-layer Spatial Multiplexing 2 Tx Antenna Port with TM4 interference model • PUCCH report of the channel quality (CQI) based on the receiver of the enhanced Type B using updated the updated fixed reference channel and interference models for enhanced performance requirements for Type-B receiver ○ 9.3.8 Additional requirements for enhanced receiver Type B ▪ 9.3.8.1.1 Minimum requirement PUCCH 1-1 (Cell-Specific Reference Symbols) – FDD Testing of these performance requirements will use GCF-based test cases w/o network-assisted configuration.

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	Verizon Wireless Requirements Plan: 1.3.2.20 LTE R10 eICIC and CRS IC w/o ABS (Enhanced Inter-Cell Interference Cancellation) VZ_REQ_LTEB13NAC_36948 Applicable scenarios: • Heterogeneous network that has both small/pico cells and macro cells deployed • R10 eICIC is used to enable network to perform necessary interference management by configuring ABS subframe dynamically. • Macro homogeneous network & Heterogeneous network • CRS IC is used in macro network in non-ABS scenario • Improve PDCCH and PDSCH performance in non-colliding CRS case (user throughput) • Improve RSRP accuracy and channel estimation in colliding CRS case (improved CRS SINR and as a result better performance on PBCH and PSS/SSS) TS 36.101 version 16.7.0: Enhanced performance requirements type A: This defines performance requirements assuming as baseline receiver reference symbol based linear minimum mean square error interference rejection combining. Enhanced performance requirements type B: This defines performance requirements assuming as baseline receiver using network assisted interference cancelation and suppression. Enhanced performance requirements type C: This defines performance requirements assuming as baseline receiver inter-stream interference cancellation.

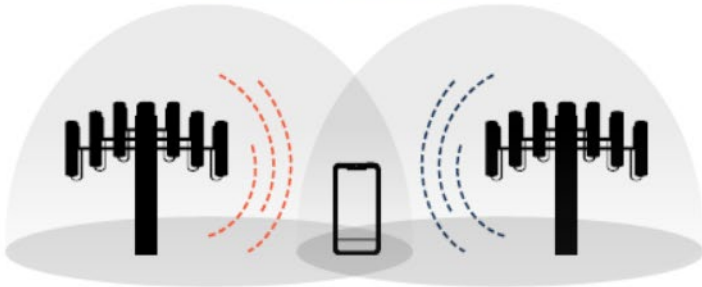
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'492 Claim 17 Element	Accused Products (UE)																																																																																																																																																													
	Sierra Wireless: Supported RF bands The modem, based on Qualcomm's MDM9250 baseband processor, supports data operation on LTE and UMTS networks over the bands described in Table 1-1, with LTE carrier aggregation (CA) as described in Table 1-2. Table 1-1: Supported RF Bands <table><tr><th rowspan="2">RAT</th><th colspan="26">Bands</th></tr><tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>12</th><th>13</th><th>18</th><th>19</th><th>20</th><th>26</th><th>28</th><th>29</th><th>30</th><th>32</th><th>41</th><th>42</th><th>43</th><th>46</th><th>48</th><th>66</th></tr><tr><td>LTE^a</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td></td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F</td><td>F^b</td><td>F</td><td>F^b</td><td>T</td><td>T</td><td>T</td><td>T^b</td><td>T^{b,c}</td><td>F</td></tr><tr><td>UMTS^d</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td></td><td>Y</td><td>Y</td><td></td><td></td><td></td><td>Y</td><td></td><td></td><td>N/A</td><td></td><td></td><td>N/A</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>GNSS</td><td colspan="26"> • GPS: 1575.42 MHz • GLONASS: 1602 MHz • BeiDou: 1561.098 MHz • Galileo: 1575.42 MHz • QZSS: 1575.42 MHz </td></tr><tr><td></td><td>•</td><td>•</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table> a. (LTE) Downlink MIMO support (2x2; 4x2) F=FDD; T=TDD Data rates: Downlink (Cat 12 with 3CA, 256QAM=600 Mbps; Cat 9 with 3CA, 64QAM=450 Mbps), Uplink (Cat 13 with 2CA contiguous, 64QAM=150 Mbps) b. Downlink only c. B48 support pending future release d. UMTS (DC-HSPA+, HSPA+, HSPA, UMTS) Diversity support Data rates: Downlink (Cat 24, up to 42 Mbps), Uplink (Cat 6, up to 11 Mbps)	RAT	Bands																										1	2	3	4	5	6	7	8	9	12	13	18	19	20	26	28	29	30	32	41	42	43	46	48	66	LTE ^a	F	F	F	F	F		F	F	F	F	F	F	F	F	F	F	F ^b	F	F ^b	T	T	T	T ^b	T ^{b,c}	F	UMTS ^d	Y	Y	Y	Y	Y	Y		Y	Y				Y			N/A			N/A							GNSS	• GPS: 1575.42 MHz • GLONASS: 1602 MHz • BeiDou: 1561.098 MHz • Galileo: 1575.42 MHz • QZSS: 1575.42 MHz																											•	•																							
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LTE ^a	F	F	F	F	F		F	F	F	F	F	F	F	F	F	F	F ^b	F	F ^b	T	T	T	T ^b	T ^{b,c}	F																																																																																																																																					
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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	Qualcomm Snapdragon 5G Modem Features: <u>5G Modem-RF System</u> • <i>Snapdragon X60 5G Modem-RF System</i> • <i>5G mmWave and sub-6 GHz, standalone (SA) and non-standalone (NSA) modes, FDD, TDD</i> • <i>Dynamic Spectrum Sharing</i> • <i>mmWave: 800 MHz bandwidth, 8 carriers, 2x2 MIMO</i> • <i>Sub-6 GHz: 200 MHz bandwidth, 4x4 MIMO</i> • <i>Qualcomm® 5G PowerSave</i> • <i>Qualcomm® Smart Transmit™ technology</i> • <i>Qualcomm® Wideband Envelope Tracking</i> • <i>Qualcomm® AI-Enhanced Signal Boost</i> • <i>Global 5G multi-SIM</i> • <i>Downlink: Up to 7.5 Gbps</i> • <i>Uplink: Up to 3 Gbps</i> • <i>Multimode support: 5G NR, LTE including CBRS, WCDMA, HSPA, TD-SCDMA, CDMA 1x, EV-DO, GSM/EDGE</i>

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'492 Claim 17 Element	Accused Products (UE)															
	Qualcomm LTE-Advanced Presentation: Enhanced receivers offer better user experience & more capacity Interference Cancellation  <table><tr><th>Interference Cancellation</th><th>Rel. 10/11</th><th>Re. 12</th></tr><tr><td>Sync ref. signal</td><td>☑</td><td>☑</td></tr><tr><td>Common ref. signal</td><td>☑</td><td>☑</td></tr><tr><td>Primary broadcast channel</td><td>☑</td><td>☑</td></tr><tr><td>Data channel</td><td></td><td>☑</td></tr></table> Better user experience - Higher data rates especially at cell-edges Higher network capacity - Higher users data rate increases overall network capacity Enhanced performance for HetNets - Even more beneficial in managing interference in small cell deployments	Interference Cancellation	Rel. 10/11	Re. 12	Sync ref. signal	☑	☑	Common ref. signal	☑	☑	Primary broadcast channel	☑	☑	Data channel		☑
Interference Cancellation	Rel. 10/11	Re. 12														
Sync ref. signal	☑	☑														
Common ref. signal	☑	☑														
Primary broadcast channel	☑	☑														
Data channel		☑														

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	3GPP TR 36.866 V12.0.1: • Pages 11-12 7.4 Interference Cancellation (IC) receivers IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - Linear Code word level SIC (L-CWIC): - receiver utilizing successive application of <i>linear detection</i> (e.g.: <i>LMMSE-IRC</i>), decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - ML-CWIC: - receiver utilizing successive application of <i>ML or reduced complexity ML detection</i>, decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (SLIC): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML.

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	3GPP TR 36.829 V11.1.0: 4.3 MMSE IRC receiver For enhanced receiver, the MMSE-IRC receiver can suppress not only the inter-stream interference but also the inter-cell interference when the degrees of freedom at the receiver are sufficient, i.e., the number of receiver antennas is higher than that of the number of desired data streams, and MMSE IRC receiver weight matrix is expressed as follow: $\mathbf{W}_{RX,1}(k,l) = \hat{\mathbf{H}}_1^H(k,l) \mathbf{R}^{-1}$ where $\hat{\mathbf{H}}_j(k,l)$ and $\mathbf{R}$ denote the estimated channel matrix and covariance matrix, respectively. To obtain the MMSE-IRC receiver weight matrix, the covariance matrix including the sources of inter-cell interference needs to be estimated. Various schemes can be considered for that purpose. • CRS based covariance matrix estimation scheme ▪ The covariance matrix is estimated at CRS REs by following equations $\mathbf{R} = P_1 \hat{\mathbf{H}}_1(k,l) \hat{\mathbf{H}}_1^H(k,l) + \frac{1}{N_{sp}} \sum_{k,l \in CRS} \tilde{\mathbf{r}}(k,l) \tilde{\mathbf{r}}(k,l)^H, \quad \tilde{\mathbf{r}}(k,l) = \mathbf{r}(k,l) - \hat{\mathbf{H}}_1(k,l) \mathbf{d}_1(k,l),$ where P_1 is the transmission power of the serving cell and is equal to $E[d_1(k,l) ^2]$ and N_{sp} is the number of sampling REs, respectively. • DM-RS based covariance matrix estimation scheme (applicable when DM-RS are configured) ▪ The covariance matrix is estimated at DM-RS REs by following equations: $\mathbf{R} = P_1 \hat{\mathbf{H}}_1(k,l) \hat{\mathbf{H}}_1^H(k,l) + \frac{1}{N_{sp}} \sum_{k,l \in DM-RS} \tilde{\mathbf{r}}(k,l) \tilde{\mathbf{r}}(k,l)^H, \quad \tilde{\mathbf{r}}(k,l) = \mathbf{r}(k,l) - \hat{\mathbf{H}}_1(k,l) \mathbf{d}_1(k,l)$ • Data signal based covariance matrix estimation scheme ▪ The covariance matrix is estimated at PDSCH REs by following equations: $\mathbf{R} = \frac{1}{N_{sp}} \sum_{k,l \in PDSCH, DM-RS} \mathbf{r}(k,l) \mathbf{r}(k,l)^H$

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
17[a] <u>performing parameter estimation of said raw digitized data</u>	The Accused Instrumentalities include performing parameter estimation using the raw digitized data. For example, 4G and 5G base stations transmit reference symbols, such as CRS, DRS and DMRS, which the UE uses to estimate propagation channel parameters, and then uses the channel estimates to estimate data stream symbols and interference values. 3GPP TR 36.866 V12.0.1: • Pages 11-12 7.2 Interference Suppression (IS) receivers IS receivers refer to receivers that apply linear filtering to the received signal to suppress the interference, as opposed to explicitly cancel the interference. Three types of IS receivers are identified: - LMMSE-IRC: - It is baseline for Rel-11 MMSE-IRC study (refer to TR36.829). - No knowledge of interferer parameter(s) is required. - Enhanced LMMSE-IRC (E-LMMSE-IRC): - <u>MMSE-IRC that explicitly considers interferer channel estimates and other interferer knowledge.</u> - <u>Interference parameters that can enable interferer channel estimation are needed, including, for example, its DMRS or CRS with PMI/RI.</u> - Widely linear MMSE-IRC (WLMMS-IRC): - WLMMS-IRC exploits the additional degrees of freedom from the real and imaginary part of the received signal to enhance suppression of interference

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	- Real-valued modulation may be used to increase performance of the WMMSE-IRC receiver 7.3 Maximum Likelihood (ML) receivers ML-type of receivers are non-linear in nature. Three types of ML receivers are also identified: - ML: - Full-blown joint detection of useful and interference signals in accordance to the ML criterion - <u>Interference parameters that can enable interferer channel estimation and interferer detection at symbol level (e.g., modulation) are needed.</u> - Reduced complexity ML (R-ML): - Reduced complexity joint detection of useful and interference modulation symbols in accordance to the ML criterion (e.g. sphere decoding, QR-MLD, MLM, etc.) - Same interference knowledge as for ML - Iterative ML and Iterative R-ML: - Iterative MAP detection and decoding of useful and interference signals. Both successive and parallel processing implementations may be applied. - In addition to the interference knowledge needed for ML, interference knowledge that can enable code word demodulation and decoding is needed. - Additionally, assumptions on network coordination may be necessary. 3GPP TR 36.866 V12.0.1: Pages 43-44: 9.1.1 Modelling methodologies for E-LMMSE-IRC Alternative 1 Assuming that a single dominant interferer is taken into account explicitly at the receiver, the following signal model is considered:

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	$ \begin{aligned} y &= H_0 x_0 + H_1 x_1 + \left(\sum_{i=2}^K H_i x_i \right) + n \\ &= H_0 x_0 + H_1 x_1 + z \\ &= H_0 x_0 + v \end{aligned} \tag{9.1} $ where z is the interference from non-dominant interferers and noise term, and v is the total interference and noise term. The E-LMMSE-IRC receiver is expressed as $ W = \hat{H}_0^H \left(\hat{H}_0 \hat{H}_0^H + \hat{H}_1 \hat{H}_1^H + \hat{R}_z \right)^{-1} , \tag{9.2} $ where $\hat{R}_z$ is the estimate of other cell interference and noise covariance, that is $R_z = E[zz^H]$. Therefore, the system level modelling of E-LMMSE-IRC consists of modelling the estimation of H_0, H_1, and R_z. The other cell interference and noise covariance estimate $\hat{R}_z$ may be modelled using the complex Wishart distribution, so that $ \hat{R}_z \sim CWishart(R_z, N_{eff}), \tag{9.3} $ If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
17[b] <u>grabbing a window of bits from said raw digitized data; subtracting any known bits from said window of bits:</u>	The Accused Instrumentalities include grabbing a window of bits from said raw digitized data; subtracting any known bits from said window of bits. For example, in the case of SU-MIMO transmission mode the multiuser detector may subtract estimated interference symbols from an interfering data stream received from another transmitter/cell in the network, which is referred to as Network Assisted Interference Cancellation and Suppression (NAICS) in 3GPP, and then choose a multiuser detector such as CWIC, R-ML, or ML-CWIC to detect and decode the different data streams/layers of the SU-MIMO transmission mode. 3GPP TR 36.866 v12.0.1: • Pages 11-12 7.3 Maximum Likelihood (ML) receivers ML-type of receivers are non-linear in nature. Three types of ML receivers are also identified: - ML: - Full-blown joint detection of useful and interference signals in accordance to the ML criterion - Interference parameters that can enable interferer channel estimation and interferer detection at symbol level (e.g., modulation) are needed. - Reduced complexity ML (R-ML): - <u>Reduced complexity joint detection of useful and interference modulation symbols in accordance to the ML criterion (e.g. sphere decoding, OR-MLD, MLM, etc.)</u> - Same interference knowledge as for ML - Iterative ML and Iterative R-ML: - Iterative MAP detection and decoding of useful and interference signals. Both successive and parallel processing implementations may be applied. - In addition to the interference knowledge needed for ML, interference knowledge that can enable code word demodulation and decoding is needed. - Additionally, assumptions on network coordination may be necessary.

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	7.4 Interference Cancellation (IC) receivers IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - Linear Code word level SIC (L-CWIC): - receiver utilizing successive application of <i>linear detection</i> (e.g.: <i>LMMSE-IRC</i>), decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - ML-CWIC: - receiver utilizing successive application of <i>ML or reduced complexity ML detection</i>, decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - <u>Symbol level IC (SLIC)</u>: - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. TSG-RAN WG4, Contribution # R4-146945: Title: Discussion and simulation result for NAICS demodulation performance ⋮

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2. Discussion on Test Scenario

Based on WID [1] of NAICS, considerations to define performance requirement for NAICS receiver are as follows:

- Define unified performance requirement for NAICS receiver
- Ensure no performance loss compared to LMMSE-IRC receiver in all interference PDSCH scenarios

In this section, we discuss two points of verification for NAICS receiver gain and robustness.

2.1 Performance Gain for NAICS Receiver

In general, NAICS performance gain can be achieved in high interference power condition, and can easily distinguish performance of NAICS and baseline receiver in most test scenarios. When high interference power is configured, since PDCCH decoding performance of serving cell is affected by control channel of interfering cell, PDSCH performance of NAICS receivers seriously degraded. However, for PDSCH performance requirement, PDCCH decoding impact can be minimized by using low loading control channel of interfering cell as the proposal of [4]. Therefore, to define performance gain for NAICS receiver, high interference power can be configured.

- *Proposal 1:* Use high interference profile for verification of NAICS performance gain.

Targeted network deployment scenarios for NAICS are homogeneous and heterogeneous networks. In general, dominant interfering cell has non-colliding CRS with serving cell in homogeneous network, and in heterogeneous network, dominant interfering cell could have colliding CRS with serving cell. NAICS receiver can achieve reasonable performance gain for colliding and non-colliding CRS scenarios under CRS based transmission mode in high INR [3]. Therefore, considering both network scenarios, colliding and non-colliding CRS scenarios should be considered for verification of NAICS performance gain.

- *Proposal 2:* Both colliding and non-colliding CRS network scenarios should be considered for NAICS performance requirement.

NAICS receiver blindly detects various TMs for interference PDSCH, and for NAICS performance requirement, TMs need to be narrowed for typical case such as TM4 and TM9 represented by CRS and DMRS base TM and TM2 used as fallback mode. Although the number of effective layer is four in TM2-TM2 case and current RAN4 agreement is violated which is to limit total layer (serving + interfering) up

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	to 3, total 3 layers can be handled by NAICS receiver among 4 layers, and NAICS performance gain for TM2-TM2 case can be achieved [3][5]. - <i>Proposal 3</i>: TM2 should be used for fallback TM for all TMs, and TM4 and TM9 can be used as representative of CRS and DMRS based TM for performance requirement. <u>RAN4 agreed that R-ML and SLIC receivers are used for NAICS performance requirement for 2 CRS ports, and FFS is for 4 CRS ports. To unify performance requirement for NAICS receivers, two options to define unified performance requirement with multiple reference receivers can be considered as follows:</u> ▪ Option 1: Take average performance of both R-ML and SLIC receiver ▪ Option 2: Take minimum performance between R-ML and SLIC receivers similar to SU-MIMO case If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
17[c] <u>selecting a multi-user detector; estimating unknown bits from said window of bits using said multi-user detector, incrementing to a next window of bits:</u>	The Accused Instrumentalities include selecting a multi-user detector; estimating unknown bits from said window of bits using said multi-user detector, incrementing to a next window of bits. For example, to detect and decode the data streams of the SU-MIMO transmission mode, the UE may choose from one of CWIC, SLIC, R-ML, ML-CWIC or other decoders from a pool of available multiuser decoders. The data transmitted on a transmission layer in SU-MIMO is divided into transport blocks, where each transport block is transmitted on scheduled time and frequency resources. The receiver downconverts, samples and digitizes each transport block into a sequence of symbols (“window of bits”), and uses the resulting symbols to detect and decode the data streams. Once one transport block is processed, the receiver starts processing the next set of sampled and digitized symbols (“next window of bits”) corresponding to the next transport block. 3GPP TR 36.866 V12.0.1:

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	• Pages 11-12 7.2 <u>Interference Suppression (IS) receivers</u> IS receivers refer to receivers that apply linear filtering to the received signal to suppress the interference, as opposed to explicitly cancel the interference. Three types of IS receivers are identified: - LMMSE-IRC: - It is baseline for Rel-11 MMSE-IRC study (refer to TR36.829). - No knowledge of interferer parameter(s) is required. - Enhanced LMMSE-IRC (E-LMMSE-IRC): - MMSE-IRC that explicitly considers interferer channel estimates and other interferer knowledge. - Interference parameters that can enable interferer channel estimation are needed, including, for example, its DMRS or CRS with PMI/RI. - Widely linear MMSE-IRC (WLMMSE-IRC): - WLMMSE-IRC exploits the additional degrees of freedom from the real and imaginary part of the received signal to enhance suppression of interference - Real-valued modulation may be used to increase performance of the WLMMSE-IRC receiver 7.3 <u>Maximum Likelihood (ML) receivers</u> ML-type of receivers are non-linear in nature. Three types of ML receivers are also identified: - ML: - Full-blown joint detection of useful and interference signals in accordance to the ML criterion - Interference parameters that can enable interferer channel estimation and interferer detection at symbol level (e.g., modulation) are needed. - Reduced complexity ML (R-ML): - Reduced complexity joint detection of useful and interference modulation symbols in accordance to the ML criterion (e.g. sphere decoding, QR-MLD, MLM, etc.) - Same interference knowledge as for ML - Iterative ML and Iterative R-ML: - Iterative MAP detection and decoding of useful and interference signals. Both successive and parallel processing implementations may be applied.

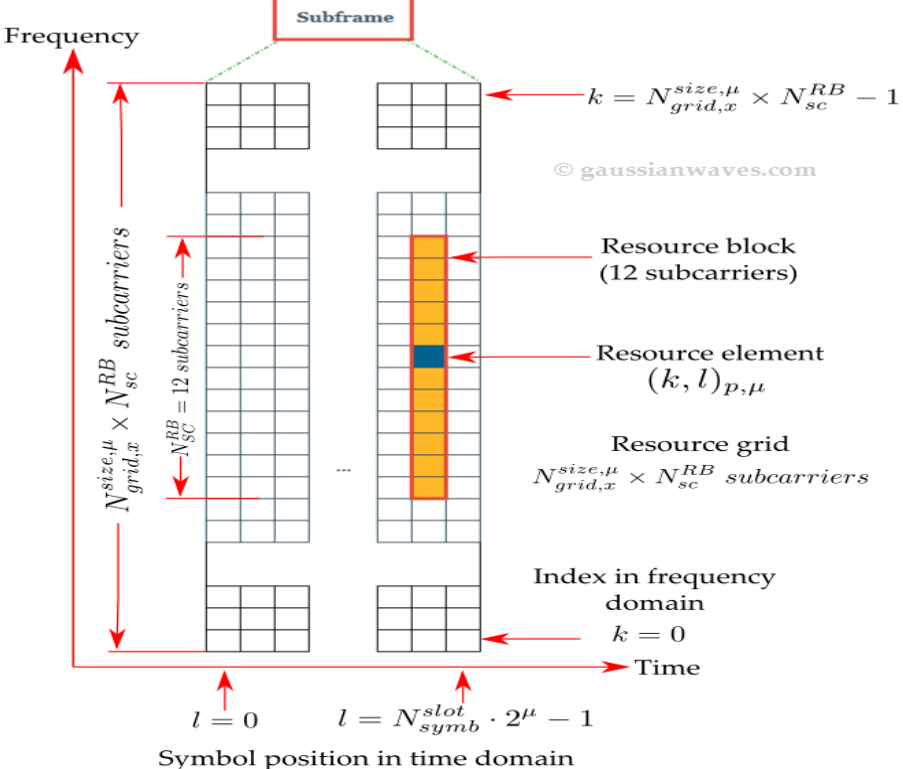
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	- In addition to the interference knowledge needed for ML, interference knowledge that can enable code word demodulation and decoding is needed. - Additionally, assumptions on network coordination may be necessary. 7.4 <u>Interference Cancellation (IC) receivers</u> IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - Linear Code word level SIC (L-CWIC): - receiver utilizing successive application of <i>linear detection</i> (e.g.: <i>LMMSE-IRC</i>), decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo L-CWIC) - May utilize CRC check (e.g., hard L-CWIC) - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - ML-CWIC: - receiver utilizing successive application of <i>ML or reduced complexity ML detection</i>, decoding, re-encoding, and cancellation - May have iteration (e.g., Turbo ML-CWIC) - May utilize CRC check (e.g., hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (SLIC): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. <u>5G NR Transport Block Size (TBS) Calculation (Techplayon Article)</u> <u>August 16, 2020</u>Author3GPP Specification, 5G MAC Layer, 5G NR, 5G Physical Layer

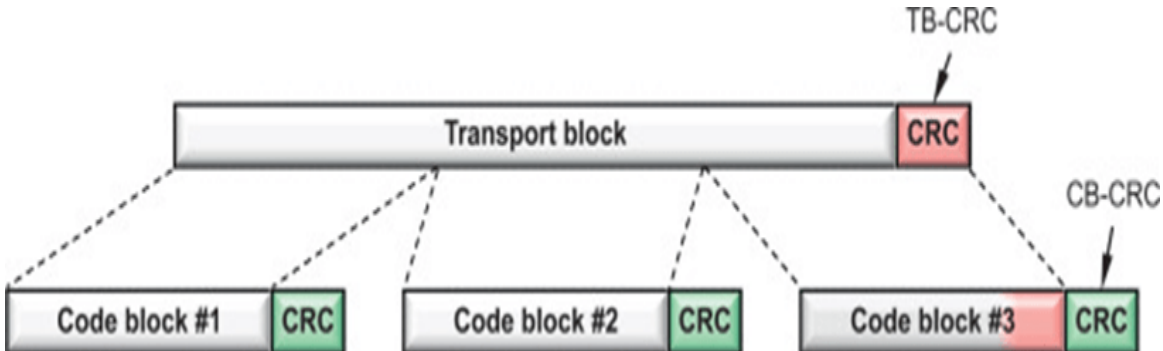
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	<u>Transport Block in 5G NR, is nothing but the payload, which is passed between the MAC and Phy Layers, specifically for the shared data channel such as PDSCH and PUSCH. A Transport Block undergoes Phy layer processing at the transmitter before being mapped onto the PDSCH for transmission over the air interface. A Transport block is added with CRC and segmented into code blocks as shown as below. The transport block consists of up to million bits and the code block consists of up to 8448 bits.</u> The diagram illustrates the segmentation of a Transport Block. At the top, a long horizontal bar represents the 'Transport block'. To its right is a red box labeled 'CRC', with an arrow pointing to it from the label 'TB-CRC'. Below the Transport block, three dashed lines branch out to three separate blocks labeled 'Code block #1', 'Code block #2', and 'Code block #3'. Each code block has a green box labeled 'CRC' to its right, with an arrow pointing to it from the label 'CB-CRC'. <u>Time-Frequency resource (GaussianWaves Article)</u> A <i>resource element</i> is the smallest time-frequency resource over one subcarrier of a single OFDM symbol. It is identified as $(k,l)_{p,\mu}$ where k is the index of the subcarrier in the frequency domain, l is the OFDM symbol position in time domain, p is the antenna port and μ is the subcarrier spacing configuration defined in Table 1 above. <u>A <i>resource block</i> (a.k.a <i>physical resource block – PRB</i>) is a block of $N_{sc}^{RB} = 12$ subcarriers over which the transmissions are scheduled. 5G NR physical layer uses time-frequency resource (<i>physical resource block</i>) for transmission.</u> <u>A resource grid consists of $N_{grid,x}^{size,\mu}$ subcarriers and $N_{subframe,\mu}^{subframe,\mu}$ number of OFDM symbols (<i>Table 2 and 3</i>).</u>

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	 Figure 3: Resource element, Resource block, Resource grid in 5G NR If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
17[d] <u>repeating said steps of subtracting, selecting, estimating</u>	The Accused Instrumentalities include repeating the steps of subtracting, selecting, estimating and incrementing until there are no more windows and outputting a set of symbol estimates

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<u>and incrementing until there are no more windows and outputting a set of symbol estimates.</u>	For example, the data transmitted on a transmission layer in SU-MIMO is divided into transport blocks, where each transport block is transmitted on scheduled time and frequency resources. The receiver downconverts, samples and digitizes each transport block into a sequence of symbols (“window of bits”), and uses the resulting symbols to detect and decode the data streams. Once one transport block is processed, the receiver starts processing the next set of sampled and digitized symbols (“next window of bits”) corresponding to the next transport block. <u>5G NR Transport Block Size (TBS) Calculation (Techplayon Article)</u> <u>August 16, 2020 Author 3GPP Specification, 5G MAC Layer, 5G NR, 5G Physical Layer</u> <u>Transport Block in 5G NR, is nothing but the payload, which is passed between the MAC and Phy Layers, specifically for the shared data channel such as PDSCH and PUSCH. A Transport Block undergoes Phy layer processing at the transmitter before being mapped onto the PDSCH for transmission over the air interface. A Transport block is added with CRC and segmented into code blocks as shown as below. The transport block consists of up to million bits and the code block consists of up to 8448 bits.</u>  <pre> graph TD TB[Transport block] --> CB1[Code block #1] TB --> CB2[Code block #2] TB --> CB3[Code block #3] TB --- TB_CRC[TB-CRC] CB1 --- CB1_CRC[CB-CRC] CB2 --- CB2_CRC[CB-CRC] CB3 --- CB3_CRC[CB-CRC] style TB_CRC fill:#f00 style CB1_CRC fill:#0f0 style CB2_CRC fill:#0f0 style CB3_CRC fill:#0f0 style TB_CRC stroke:#f00 style CB1_CRC stroke:#0f0 style CB2_CRC stroke:#0f0 style CB3_CRC stroke:#0f0 </pre>

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Time-Frequency resource (GaussianWaves Article)

A *resource element* is the smallest time-frequency resource over one subcarrier of a single OFDM symbol. It is identified as $(k, l)_{p, \mu}$ where k is the index of the subcarrier in the frequency domain, l is the OFDM symbol position in time domain, p is the antenna port and μ is the subcarrier spacing configuration defined in Table 1 above.

A *resource block* (a.k.a *physical resource block – PRB*) is a block of $N_{sc}^{RB} = 12$ subcarriers over which the transmissions are scheduled. 5G NR physical layer uses time-frequency resource (*physical resource block*) for transmission.

A resource grid consists of $N_{grid,x}^{size, \mu}$ subcarriers and $N_{subframe, \mu}^{subframe, \mu}$ number of OFDM symbols (*Table 2 and 3*).

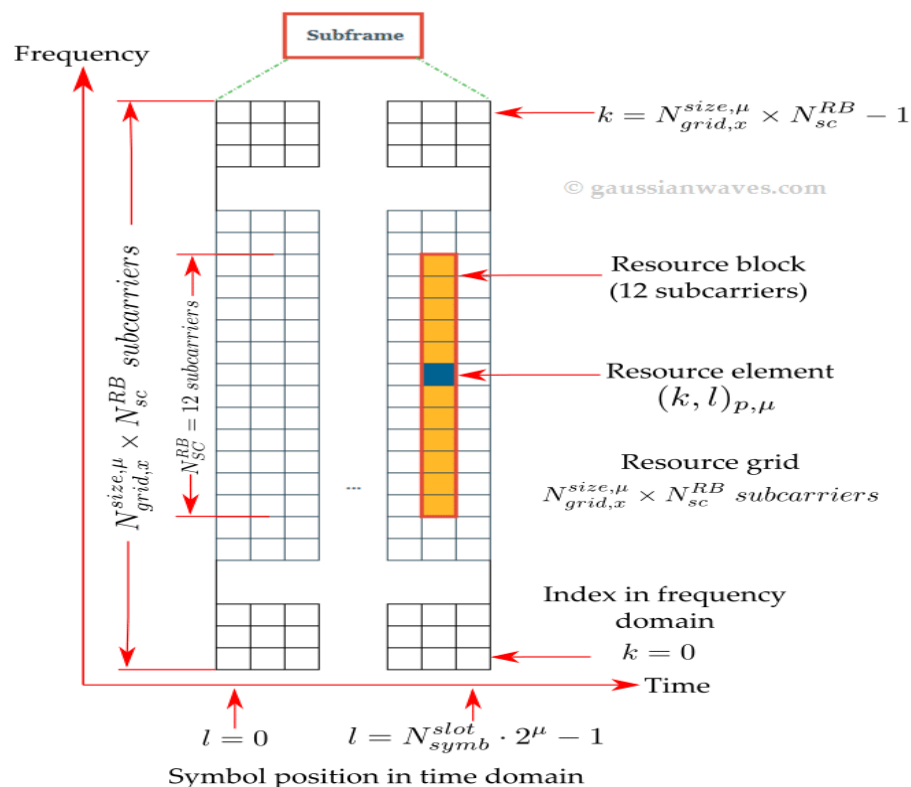


Figure 3: Resource element, Resource block, Resource grid in 5G NR

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'492 Claim 17 Element	<u>Accused Products (UE)</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

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