

**IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION**

EMPIRE TECHNOLOGY	)	
DEVELOPMENT LLC	)	
	)	
Plaintiff,	)	
	)	
v.	)	
	)	
SAMSUNG ELECTRONICS CO. LTD.,	)	
SAMSUNG ELECTRONICS AMERICA,	)	
INC.	)	
Defendant.	)	

C.A. No. 2:23-cv-00427

**PLAINTIFF EMPIRE TECHNOLOGY DEVELOPMENT LLC'S DISCLOSURE OF
ASSERTED CLAIMS AND INFRINGEMENT CONTENTIONS**

Pursuant to Rules of Practice for Patent Cases and the Court’s Order (Dkt. No. 11) entered on December 11, 2023, Plaintiff Empire Technology Development LLC (“Empire”) hereby submits the following infringement contentions to Defendant Samsung Electronics Co., Ltd.’s (“SEC”) and Defendant Samsung Electronics America, Inc.’s (“SEA” and collectively with SEC, “Defendants” or “Samsung”). These contentions are based on information currently known by and available to Empire. Empire does not waive any claim, contention, or argument regarding the factual and legal details of the following infringement contentions, and the following should not be construed as Empire’s preliminary construction of any asserted claim. Empire expressly reserves the right to supplement, amend, or modify its proposed construction of any claim, as well as the right to contend that the claims do not require construction, clarification, or interpretation. Further, these disclosures are made based on information ascertained to date and discovery has not yet begun. Empire’s investigation regarding the disclosed grounds of infringement is ongoing. Empire reserves the right to seek leave to further amend, modify, and/or supplement their contentions to the full extent permitted by the Federal Rules of Civil Procedure and the Rules of Practice for Patent Cases, including based on additional information obtained through discovery or other means concerning the Accused Instrumentalities.

I. THE INFRINGED CLAIMS

Empire provides the following contentions and disclosures regarding its claims of infringement of U.S. Patent No. 8,798,120 (the “’120 Patent”) and U.S. Patent No. 8,565,331 (the “’331 Patent”).

Pursuant to P.R. 3-1(a), Empire contends that Samsung has infringed and infringes at least claims 25 and 29 of the ’120 Patent under 35 U.S.C. § 271.

Pursuant to P.R. 3-1(a), Empire contends that Samsung has infringed and infringes at least claims 1, 5, 6, and 8 of the ’331 Patent under 35 U.S.C. § 271.

The infringed claims of the '120 Patent and the '331 Patent are collectively referred to as the "Asserted Claims".

II. THE ACCUSED INSTRUMENTALITIES

The Accused Instrumentalities with respect to the '120 Patent include Samsung apparatuses, products, systems, services, devices, processes, methods, acts, components (hardware and/or software), and/or other instrumentalities that include, e.g., transmitters with Smart Transmit™, Smart Transmit™ 2.0, or Smart Transmit™ 3.0, including, without limitation, the Galaxy S20 series; S21 series; S22 series; and S23 series phones; the Galaxy A 5G series phones; the Galaxy Z Flip series phones; the Galaxy Note series phones; the Galaxy Z Fold series phones; the Galaxy M 5G series phones; the Galaxy F 5G series phones; the Galaxy Xcover 6 Pro series phones; and the Galaxy Tab series tablets (the "'120 Patent Accused Instrumentalities"). The Accused Instrumentalities with respect to the '331 Patent include Samsung apparatuses, products, systems, services, devices, processes, methods, acts, components (hardware and/or software), and/or other instrumentalities that decode a signal transmitted over a 5G communications channel and that perform certain channel estimation in MIMO (the "'331 Patent Accused Instrumentalities," and together with the '120 Patent Accused Instrumentalities, the "Accused Instrumentalities"). More specifically, the '331 Patent Accused Instrumentalities include, without limitation, all instrumentalities with 5G-compatible modems and/or other components in the RF chain that perform certain channel estimation including, without limitation, the Galaxy S10 5G series phones; the Galaxy Note series phones; the Galaxy A 5G series phones; the Galaxy Z Fold series phones; the Galaxy S20 series, S21 series, S22 series, and S23 series phones; the Galaxy Z Flip series phones; the Galaxy M 5G series phones; the Galaxy F 5G series phones; the Galaxy Xcover 6 Pro series phones; and the Galaxy Tab series tablets.

A. THE '120 PATENT ACCUSED INSTRUMENTALITIES

The inventions claimed in the '120 Patent, entitled “Methods and Communication Systems Having Adaptive Mode Selection,” were invented by Gustavo de Veciana, Hongseok Kim, Chan-Byoung Chae, and Robert W. Health, Jr. The '120 Patent issued on August 5, 2014 from U.S. Patent Application No. 12/727,049, which was filed on March 18, 2010. The '120 Patent Accused Instrumentalities include Samsung apparatuses, products, systems, services, devices, processes, methods, acts, components (hardware and/or software), and/or other instrumentalities that include, e.g., transmitters with Smart Transmit™, Smart Transmit™ 2.0, or Smart Transmit™ 3.0, including, without limitation, the Galaxy S20 series; S21 series; S22 series; and S23 series phones; the Galaxy A 5G series phones; the Galaxy Z Flip series phones; the Galaxy Note series phones; the Galaxy Z Fold series phones; the Galaxy M 5G series phones; the Galaxy F 5G series phones; the Galaxy Xcover 6 Pro series phones; and the Galaxy Tab series tablets, and are further identified by series and model number below.

1. Samsung Galaxy S20 Series

Series	Model Number	Release Date
Galaxy S20	SM-G980	3/6/2020
Galaxy S20	SM-G980F	3/6/2020
Galaxy S20	SM-G980F/DS	3/6/2020
Galaxy S20+	SM-G985	3/6/2020
Galaxy S20+	SM-G985F	3/6/2020
Galaxy S20+	SM-G985F/DS	3/6/2020
Galaxy S20+	SM-G986	3/6/2020
Galaxy S20+	SM-G986F	3/6/2020
Galaxy S20+	SM-G986F/DS	3/6/2020
Galaxy S20+	SM-G986U	3/6/2020
Galaxy S20+	SM-G986U1	3/6/2020
Galaxy S20+	SM-G9860	3/6/2020
Galaxy S20+	SM-G986B/DS	3/6/2020
Galaxy S20+	SM-G986N	3/6/2020
Galaxy S20 5G	SM-G981	3/6/2020
Galaxy S20 5G	SM-G981F	3/6/2020
Galaxy S20 5G	SM-G981F/DS	3/6/2020

Galaxy S20 5G	SM-G981B/DS	3/6/2020
Galaxy S20 5G	SM-G981U	3/6/2020
Galaxy S20 5G	SM-G981U1	3/6/2020
Galaxy S20 5G	SM-G981N	3/6/2020
Galaxy S20 5G	SM-G981B	3/6/2020
Galaxy S20 5G	SM-G9810	3/6/2020
Galaxy S20 5G	SM-G981W	3/6/2020
Galaxy S20 5G	SC-51A	3/6/2020
Galaxy S20 5G	SCG01	3/6/2020
Galaxy S20 Ultra 5G	SM-G988	3/6/2020
Galaxy S20 Ultra 5G	SM-G988U	3/6/2020
Galaxy S20 Ultra 5G	SMG988U1	3/6/2020
Galaxy S20 Ultra 5G	SM-G9880	3/6/2020
Galaxy S20 Ultra 5G	SM-G988B/DS	3/6/2020
Galaxy S20 Ultra 5G	SM-G988N	3/6/2020
Galaxy S20 5G UW	SM-G981V	6/4/2020
Galaxy S20 FE	SM-G780F	10/2/2020
Galaxy S20 FE	SM-G780F/DSM	10/2/2020
Galaxy S20 FE	SM-G780G	10/2/2020
Galaxy S20 FE 5G	SM-G781B	10/2/2020
Galaxy S20 FE 5G	SM-G781B/DS	10/2/2020
Galaxy S20 FE 5G	SM-G781U	10/2/2020
Galaxy S20 FE 5G	SM-G781U1	10/2/2020
Galaxy S20 FE 5G	SM-G781W	10/2/2020
Galaxy S20 FE 5G	SM-G7810	10/2/2020
Galaxy S20 FE 5G	SM-G781N	10/2/2020
Galaxy S20 FE 5G	SM-G781V	10/2/2020
Galaxy S20 FE 2022	SM-G781NK	4/1/2022
Galaxy S20 FE 2022	SM-G781NK22	4/1/2022

2. Samsung Galaxy S21 Series

Series	Model Number	Release Date
Galaxy S21	SM-G991B	1/29/2021
Galaxy S21	SM-G991B/DS	1/29/2021
Galaxy S21	SM-G991U	1/29/2021
Galaxy S21	SM-G991U1	1/29/2021
Galaxy S21	SM-G991W	1/29/2021
Galaxy S21	SM-G991N	1/29/2021
Galaxy S21	SM-G9910	1/29/2021
Galaxy S21+	SM-G996B	1/29/2021
Galaxy S21+	SM-G996B/DS	1/29/2021
Galaxy S21+	SM-G996U	1/29/2021
Galaxy S21+	SM-G996U1	1/29/2021
Galaxy S21+	SM-G996W	1/29/2021

Galaxy S21+	SM-G996B	1/29/2021
Galaxy S21+	SM-G9960	1/29/2021
Galaxy S21 Ultra	SM-G998B	1/29/2021
Galaxy S21 Ultra	SM-G998B/DS	1/29/2021
Galaxy S21 Ultra	SM-G998U	1/29/2021
Galaxy S21 Ultra	SM-G998U1	1/29/2021
Galaxy S21 Ultra	SM-G998W	1/29/2021
Galaxy S21 Ultra	SM-G998B	1/29/2021
Galaxy S21 Ultra	SM-G9980	1/29/2021
Galaxy S21 FE	SM-G990B	1/7/2022
Galaxy S21 FE	SM-G990B/DS	1/7/2022
Galaxy S21 FE	SM-G990U	1/7/2022
Galaxy S21 FE	SM-G990U1	1/7/2022
Galaxy S21 FE	SM-G990W	1/7/2022
Galaxy S21 FE	SM-G990E	1/7/2022
Galaxy S21 FE	SM-G9900	1/7/2022
Galaxy S21 FE	SM-G990B2	1/7/2022
Galaxy S21 FE	SM-G990U2	1/7/2022
Galaxy S21 FE	SM-G990W2	1/7/2022

3. Samsung Galaxy S22 Series

Series	Model Number	Release Date
Galaxy S22	SM-S901B	2/25/2022
Galaxy S22	SM-S901B/DS	2/25/2022
Galaxy S22	SM-S901U	2/25/2022
Galaxy S22	SM-S901U1	2/25/2022
Galaxy S22	SM-S901W	2/25/2022
Galaxy S22	SM-S901N	2/25/2022
Galaxy S22	SM-S9010	2/25/2022
Galaxy S22	SM-S901E	2/25/2022
Galaxy S22+	SM-S906B	2/25/2022
Galaxy S22+	SM-S906B/DS	2/25/2022
Galaxy S22+	SM-S906U	2/25/2022
Galaxy S22+	SM-S906U1	2/25/2022
Galaxy S22+	SM-S906W	2/25/2022
Galaxy S22+	SM-S906N	2/25/2022
Galaxy S22+	SM-S9060	2/25/2022
Galaxy S22+	SM-S906E	2/25/2022
Galaxy S22 Ultra	SM-S908B	2/25/2022
Galaxy S22 Ultra	SM-S908B/DS	2/25/2022
Galaxy S22 Ultra	SM-S908U	2/25/2022
Galaxy S22 Ultra	SM-S908U1	2/25/2022
Galaxy S22 Ultra	SM-S908W	2/25/2022
Galaxy S22 Ultra	SM-S908N	2/25/2022

Galaxy S22 Ultra	SM-S9080	2/25/2022
Galaxy S22 Ultra	SM-S908E	2/25/2022

4. Samsung Galaxy S23 Series

Series	Model Number	Release Date
Galaxy S23	SM-S911B	2/17/2023
Galaxy S23	SM-S911B/DS	2/17/2023
Galaxy S23	SM-S911U	2/17/2023
Galaxy S23	SM-S911U1	2/17/2023
Galaxy S23	SM-S911W	2/17/2023
Galaxy S23	SM-S911N	2/17/2023
Galaxy S23	SM-S9110	2/17/2023
Galaxy S23	SM-S911E	2/17/2023
Galaxy S23	SM-S911E/DS	2/17/2023
Galaxy S23+	SM-S916B	2/17/2023
Galaxy S23+	SM-S916B/DS	2/17/2023
Galaxy S23+	SM-S916U	2/17/2023
Galaxy S23+	SM-S916U1	2/17/2023
Galaxy S23+	SM-S916W	2/17/2023
Galaxy S23+	SM-S916N	2/17/2023
Galaxy S23+	SM-S9160	2/17/2023
Galaxy S23+	SMS916E	2/17/2023
Galaxy S23 Ultra	SM-S918B	2/17/2023
Galaxy S23 Ultra	SM-S918B/DS	2/17/2023
Galaxy S23 Ultra	SM-S918U	2/17/2023
Galaxy S23 Ultra	SM-S918U1	2/17/2023
Galaxy S23 Ultra	SM-S918W	2/17/2023
Galaxy S23 Ultra	SM-S918N	2/17/2023
Galaxy S23 Ultra	SM-S9180	2/17/2023
Galaxy S23 Ultra	SM-S918E	2/17/2023
Galaxy S23 Ultra	SM-S918E/DS	2/17/2023
Galaxy S23 FE	SM-S711B	10/5/2023
Galaxy S23 FE	SM-S711B/DS	10/5/2023
Galaxy S23 FE	SM-S711U1	10/5/2023
Galaxy S23 FE	SM-S711U	10/5/2023
Galaxy S23 FE	SM-S711W	10/5/2023
Galaxy S23 FE	SM-S7110	10/5/2023

5. Samsung Galaxy A 5G Series

Series	Model Number	Release Date
Galaxy A71 5G UW	SM-A716V	7/16/2020
Galaxy A51 5G UW	SM-A516V	8/14/2020
Galaxy A42 5G	SM-A426B	11/11/2020

Galaxy A42 5G	SM-A426B/DS	11/11/2020
Galaxy A42 5G	SM-A4260	11/11/2020
Galaxy A42 5G	SM-A426U	11/11/2020
Galaxy A42 5G	SM-A426U1	11/11/2020
Galaxy A42 5G	SM-A426N	11/11/2020
Galaxy A52 5G	SM-A526B	3/19/2021
Galaxy A52 5G	SM-A526B/DS	3/19/2021
Galaxy A52 5G	SM-A5260	3/19/2021
Galaxy A52 5G	SM-A526W	3/19/2021
Galaxy A52 5G	SM-A526U	3/19/2021
Galaxy A52 5G	SM-A526U1	3/19/2021
Galaxy A52s 5G	SM-A528B	9/1/2021
Galaxy A52s 5G	SM-A528B/DS	9/1/2021
Galaxy A52s 5G	SM-A528N	9/1/2021
Galaxy A52s 5G	SM-A528B	9/1/2021
Galaxy A52s 5G	SM-A528B/DS	9/1/2021
Galaxy A52s 5G	SM-A528N	9/1/2021
Galaxy A73 5G	SM-A736B	4/22/2022
Galaxy A73 5G	SM-A736B/DS	4/22/2022
Galaxy A23 5G	SM-A236U	9/22/2022
Galaxy A23 5G	SM-A236U1	9/22/2022
Galaxy A23 5G	SM-A236B	9/22/2022
Galaxy A23 5G	SM-A236B/DS	9/22/2022
Galaxy A23 5G	SM-A236B/DSN	9/22/2022
Galaxy A23 5G	SM-A236E	9/22/2022

6. Samsung Galaxy Z Flip Series

Series	Model Number	Release Date
Galaxy Z Flip 5G	SM-F707B	8/7/2020
Galaxy Z Flip 5G	SM-F707N	8/7/2020
Galaxy Z Flip 5G	SM-F7070	8/7/2020
Galaxy Z Flip 5G	SM-F707U	8/7/2020
Galaxy Z Flip 5G	SM-F707U1	8/7/2020
Galaxy Z Flip 5G	SM-F707W	8/7/2020
Galaxy Z Flip 3	SM-F711B	8/11/2021
Galaxy Z Flip 3	SM-F711N	8/11/2021
Galaxy Z Flip 3	SM-F711U	8/11/2021
Galaxy Z Flip 3	SM-F711U1	8/11/2021
Galaxy Z Flip 3	SM-F711W	8/11/2021
Galaxy Z Flip 3	SM-F7110	8/11/2021
Galaxy Z Flip 4	SM-F721B	8/25/2022
Galaxy Z Flip 4	SM-F721B/DS	8/25/2022
Galaxy Z Flip 4	SM-F721N	8/25/2022
Galaxy Z Flip 4	SM-F721U	8/25/2022

Galaxy Z Flip 4	SM-F721U1	8/25/2022
Galaxy Z Flip 4	SM-F721W	8/25/2022
Galaxy Z Flip 4	SM-F7210	8/25/2022
Galaxy Z Flip 5	SM-F731B	8/11/2023
Galaxy Z Flip 5	SM-F731B/DS	8/11/2023
Galaxy Z Flip 5	SM-F731U	8/11/2023
Galaxy Z Flip 5	SM-F731U1	8/11/2023
Galaxy Z Flip 5	SM-F731W	8/11/2023
Galaxy Z Flip 5	SM-F731N	8/11/2023

7. Samsung Galaxy Note Series

Series	Model Number	Release Date
Galaxy Note 20	SM-N980F	8/21/2020
Galaxy Note 20	SM-N980F/DS	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986B	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986B/DS	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986U	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986U1	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986W	8/21/2020
Galaxy Note20 Ultra 5G	SM-N9860	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986N	8/21/2020
Galaxy Note20 Ultra 5G	SC-53A	8/21/2020

8. Samsung Galaxy Z Fold Series

Series	Model Number	Release Date
Galaxy Z Fold 2	SM-F916B	9/18/2020
Galaxy Z Fold 2	SM-F916U	9/18/2020
Galaxy Z Fold 2	SM-F916U1	9/18/2020
Galaxy Z Fold 2	SM-F916N	9/18/2020
Galaxy Z Fold 2	SM-F9160	9/18/2020
Galaxy Z Fold 2	SM-F916W	9/18/2020
Galaxy Z Fold 2	SCG05	9/18/2020
Galaxy Z Fold 3	SM-F926B	8/11/2021
Galaxy Z Fold 3	SM-F926B/DS	8/11/2021
Galaxy Z Fold 3	SM-F926U	8/11/2021
Galaxy Z Fold 3	SM-F926U1	8/11/2021
Galaxy Z Fold 3	SM-F926W	8/11/2021
Galaxy Z Fold 3	SM-F9260	8/11/2021
Galaxy Z Fold 3	SM-F926N	8/11/2021
Galaxy Z Fold 4	SM-F936B	8/25/2022
Galaxy Z Fold 4	SM-F936B/DS	8/25/2022
Galaxy Z Fold 4	SM-F936U	8/25/2022
Galaxy Z Fold 4	SM-F936U1	8/25/2022

Galaxy Z Fold 4	SM-F936N	8/25/2022
Galaxy Z Fold 4	SM-F936W	8/25/2022
Galaxy Z Fold 4	SM-F9360	8/25/2022
Galaxy Z Fold 5	SM-F946B	7/25/2023
Galaxy Z Fold 5	SM-F946B/DS	7/25/2023
Galaxy Z Fold 5	SM-F946U	7/25/2023
Galaxy Z Fold 5	SM-F946U1	7/25/2023
Galaxy Z Fold 5	SM-F946N	7/25/2023
Galaxy Z Fold 5	SM-F946W	7/25/2023
Galaxy Z Fold 5	SM-F9460	7/25/2023

9. Samsung Galaxy M 5G Series

Series	Model Number	Release Date
Galaxy M42 5G	SM-M426B	5/1/2021
Galaxy M42 5G	SM-M426B/DS	5/1/2021
Galaxy M52 5G	SM-M526BR	10/3/2021
Galaxy M52 5G	SM-M526BR/DS	10/3/2021
Galaxy M52 5G	SM-M526B	10/3/2021
Galaxy M52 5G	SM-M526B/DS	10/3/2021
Galaxy M23 5G	SM-M236B	3/4/2022
Galaxy M23 5G	SM-M236B/DS	3/4/2022

10. Samsung Galaxy F 5G Series

Series	Model Number	Release Date
Galaxy F52 5G	SM-E5260	5/20/2021
Galaxy F23 5G	SM-E236B	3/16/2022
Galaxy F23 5G	SM-E236B/DS	3/16/2022

11. Samsung Galaxy Xcover 6 Pro

Series	Model Number	Release Date
Galaxy Xcover 6 Pro	SM-G736U	7/13/2022
Galaxy Xcover 6 Pro	SM-G736U1	7/13/2022
Galaxy Xcover 6 Pro	SM-G736B	7/13/2022
Galaxy Xcover 6 Pro	SM-G736B/DS	7/13/2022

12. Galaxy Tab¹

Series	Model Number	Release Date
Samsung Galaxy Tab S7 5G	SM-T878U	8/21/2020
Samsung Galaxy Tab S7+ 5G	SM-T978U	8/21/2020
Samsung Galaxy Tab S7+ 5G	SM-T976B	8/21/2020

¹ For the avoidance of doubt, Empire does not intend to include as '120 Patent Accused Instrumentalities any tablets that are only Wi-Fi enabled (not cellular enabled) and utilize Smart Transmit or Smart Transmit 2.0.

Samsung Galaxy Tab S7 FE 5G	SM-T738U	6/18/2021
Samsung Galaxy Tab S7 FE 5G	SM-T736B	6/18/2021
Samsung Galaxy Tab S8 5G	SM-X706	3/22/2022
Samsung Galaxy Tab S8 5G	SM-X706B	3/22/2022
Samsung Galaxy Tab S8 5G	SM-X706U	3/22/2022
Samsung Galaxy Tab S8 5G	SM-X706N	3/22/2022
Samsung Galaxy Tab S8+ 5G	SM-X808U	4/14/2022
Samsung Galaxy Tab S8+ 5G	SM-X806	4/14/2022
Samsung Galaxy Tab S8+ 5G	SM-X806B	4/14/2022
Samsung Galaxy Tab S8+ 5G	SM-X806U	4/14/2022
Samsung Galaxy Tab S8+ 5G	SM-X806N	4/14/2022
Samsung Galaxy Tab S8 Ultra 5G	SM-X906	4/30/2022
Samsung Galaxy Tab S8 Ultra 5G	SM-X906B	4/30/2022
Samsung Galaxy Tab S8 Ultra 5G	SM-X906U	4/30/2022
Samsung Galaxy Tab S8 Ultra 5G	SM-X906N	4/30/2022
Samsung Galaxy Tab Active4 Pro	SM-T638U	9/13/2022
Samsung Galaxy Tab Active4 Pro	SM-T636B	9/13/2022
Samsung Galaxy Tab S9	SM-X710	8/11/2023
Samsung Galaxy Tab S9 5G	SM-X716B	8/11/2023
Samsung Galaxy Tab S9+	SM-X810	8/11/2023
Samsung Galaxy Tab S9+ 5G	SM-X816B	8/11/2023
Samsung Galaxy Tab S9+ 5G	SM-X818U	8/11/2023
Samsung Galaxy Tab S9 Ultra	SM-X910	8/11/2023
Samsung Galaxy Tab S9 Ultra	SM-X916B	8/11/2023
Samsung Galaxy Tab A9+	SM-X216B	10/17/2023

B. THE '331 PATENT ACCUSED INSTRUMENTALITIES

The inventions claimed in the '331 Patent, entitled "Inserting and Decoding Replicated Data Symbols in Wireless Communications," were invented by Ali Yazdan Panah and Robert W. Heath, Jr. The '331 Patent issued on October 22, 2013 from U.S. Patent Application No. 12/999,029, which was filed on August 20, 2010. The '331 Patent Accused Instrumentalities include Samsung apparatuses, products, systems, services, devices, processes, methods, acts, components (hardware

and/or software), and/or other instrumentalities that decode a signal transmitted over a 5G communications channel and that perform certain channel estimation in MIMO. More specifically, the '331 Patent Accused Instrumentalities include, without limitation, all instrumentalities with 5G-compatible modems and/or other components in the RF chain that perform certain channel estimation including, without limitation, the Galaxy S10 5G series phones; the Galaxy Note series phones; the Galaxy A 5G series phones; the Galaxy Z Fold series phones; the Galaxy S20 series, S21 series, S22 series, and S23 series phones; the Galaxy Z Flip series phones; the Galaxy M 5G series phones; the Galaxy F 5G series phones; the Galaxy Xcover 6 Pro series phones; and the Galaxy Tab series tablets, and are further identified by series and model number below.

1. Samsung Galaxy S10 5G Series

Series	Model Number	Release Date
Galaxy S10 5G	SM-G977U	4/2019
Galaxy S10 5G	SM-G977N	4/2019
Galaxy S10 5G	SM-G977B	4/2019
Galaxy S10 5G	SM-G9770	4/2019
Galaxy S10 5G	SM-G977P	4/2019
Galaxy S10 5G	SM-G977T	4/2019

2. Samsung Galaxy Note Series

Series	Model Number	Release Date
Galaxy Note10 5G	SM-N971U	8/2019
Galaxy Note10 5G	SM-N971N	8/2019
Galaxy Note10+ 5G	SM-N976F	8/2019
Galaxy Note10+ 5G	SM-N976U	8/2019
Galaxy Note10+ 5G	SM-N976	8/2019
Galaxy Note10+ 5G	SM-N976B	8/2019
Galaxy Note10+ 5G	SM-N976N	8/2019
Galaxy Note10+ 5G	SM-N976V	8/2019
Galaxy Note10+ 5G	SM-N9760	8/2019
Galaxy Note10+ 5G	SM-N976Q	8/2019
Galaxy Note20 Ultra 5G	SM-N986B	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986B/DS	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986U	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986U1	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986W	8/21/2020

Galaxy Note20 Ultra 5G	SM-N9860	8/21/2020
Galaxy Note20 Ultra 5G	SM-N986N	8/21/2020
Galaxy Note20 Ultra 5G	SC-53A	8/21/2020

3. Samsung Galaxy A 5G Series

Series	Model Number	Release Date
Galaxy A90 5G	SM-A908B	9/2019
Galaxy A90 5G	SM-A908N	9/2019
Galaxy A90 5G	SM-A9080	9/2019
Galaxy A51 5G	SM-A516F	4/29/2020
Galaxy A51 5G	SM-A516F/DSN	4/29/2020
Galaxy A51 5G	SM-A516N	4/29/2020
Galaxy A51 5G	SM-A516B/DS	4/29/2020
Galaxy A51 5G	SM-A516B	4/29/2020
Galaxy A51 5G	SM-A516U	4/29/2020
Galaxy A51 5G	SC-54A	4/29/2020
Galaxy A51 5G	SM-A516U1	4/29/2020
Galaxy A51 5G	SCG07	4/29/2020
Galaxy A51 5G	SM-A5160	4/29/2020
Galaxy A Quantum	SM-A716N	5/22/2020
Galaxy A Quantum	SM-A716SS	5/22/2020
Galaxy A Quantum	SM-A716S	5/22/2020
Galaxy A71 5G	SM-A716F	6/15/2020
Galaxy A71 5G	SM-A716F/DS	6/15/2020
Galaxy A71 5G	SM-A716F/DSN	6/15/2020
Galaxy A71 5G	SM-A7160	6/15/2020
Galaxy A71 5G	SM-A716B/DS	6/15/2020
Galaxy A71 5G	SM-A716U	6/15/2020
Galaxy A71 5G	SM-A716B	6/15/2020
Galaxy A71 5G	SM-A716U1	6/15/2020
Galaxy A71 5G UW	SM-A716V	7/16/2020
Galaxy A51 5G UW	SM-A516V	8/14/2020
Galaxy A42 5G	SM-A426B	11/11/2020
Galaxy A42 5G	SM-A426B/DS	11/11/2020
Galaxy A42 5G	SM-A4260	11/11/2020
Galaxy A42 5G	SM-A426U	11/11/2020
Galaxy A42 5G	SM-A426U1	11/11/2020
Galaxy A42 5G	SM-A426N	11/11/2020
Galaxy A52 5G	SM-A526B	3/19/2021
Galaxy A52 5G	SM-A526B/DS	3/19/2021
Galaxy A52 5G	SM-A5260	3/19/2021
Galaxy A52 5G	SM-A526W	3/19/2021
Galaxy A52 5G	SM-A526U	3/19/2021
Galaxy A52 5G	SM-A526U1	3/19/2021

Galaxy A82 5G (Galaxy Quantum 2)	SM-A826S	4/13/2021
Galaxy A22 5G	SM-A226B	5/3/2021
Galaxy A22 5G	SM-A226B/DS	5/3/2021
Galaxy A22 5G	SM-A226B/DSN	5/3/2021
Galaxy A22 5G	SM-A226BR	5/3/2021
Galaxy A22 5G	SM-A226BR/N	5/3/2021
Galaxy A22 5G	SM-A226L, SC-56B	5/3/2021
Galaxy A52s 5G	SM-A528B	9/1/2021
Galaxy A52s 5G	SM-A528B/DS	9/1/2021
Galaxy A52s 5G	SM-A528N	9/1/2021
Galaxy A52s 5G	SM-A528B	9/1/2021
Galaxy A52s 5G	SM-A528B/DS	9/1/2021
Galaxy A52s 5G	SM-A528N	9/1/2021
Galaxy A13 5G	SM-A136U	12/3/2021
Galaxy A13 5G	SM-A136U1	12/3/2021
Galaxy A13 5G	SM-A136W	12/3/2021
Galaxy A13 5G	SM-A136B	12/3/2021
Galaxy A13 5G	SM-S136DL	12/3/2021
Galaxy A33 5G	SM-A336E	4/20/2022
Galaxy A33 5G	SM-A336B	4/20/2022
Galaxy A33 5G	SM-A336B/DS	4/20/2022
Galaxy A33 5G	SM-A336B/DSN	4/20/2022
Galaxy A33 5G	SM-A336E/DS	4/20/2022
Galaxy A33 5G	SM-A336M	4/20/2022
Galaxy A33 5G	SM-A3360	4/20/2022
Galaxy A73 5G	SM-A736B	4/22/2022
Galaxy A73 5G	SM-A736B/DS	4/22/2022
Galaxy A53 5G	SM-A536B	4/24/2022
Galaxy A53 5G	SM-A536B/DS	4/24/2022
Galaxy A53 5G	SM-A536U	4/24/2022
Galaxy A53 5G	SM-A536U1	4/24/2022
Galaxy A53 5G	SM-A5360	4/24/2022
Galaxy A53 5G	SM-A536E	4/24/2022
Galaxy A53 5G	SM-A536E/DS	4/24/2022
Galaxy A53 5G	SM-A536V	4/24/2022
Galaxy A53 5G	SM-A536W	4/24/2022
Galaxy A53 5G	SM-A536N	4/24/2022
Galaxy A53 5G	SM-S536DL	4/24/2022
Galaxy A23 5G	SM-A236U	9/22/2022
Galaxy A23 5G	SM-A236U1	9/22/2022
Galaxy A23 5G	SM-A236B	9/22/2022
Galaxy A23 5G	SM-A236B/DS	9/22/2022
Galaxy A23 5G	SM-A236B/DSN	9/22/2022
Galaxy A23 5G	SM-A236E	9/22/2022

Galaxy A34 5G	SM-A346E	3/24/2023
Galaxy A34 5G	SM-A346B	3/24/2023
Galaxy A34 5G	SM-A346B/DS	3/24/2023
Galaxy A34 5G	SM-A346B/DSN	3/24/2023
Galaxy A34 5G	SM-A346E/DS	3/24/2023
Galaxy A34 5G	SM-A346E/DSN	3/24/2023
Galaxy A34 5G	SM-A346M	3/24/2023
Galaxy A34 5G	SM-A346M/N	3/24/2023
Galaxy A34 5G	SM-A346M/DSN	3/24/2023
Galaxy A34 5G	SM-A3460	3/24/2023
Galaxy A54 5G	SM-A546V	3/24/2023
Galaxy A54 5G	SM-A546U	3/24/2023
Galaxy A54 5G	SM-A546U1	3/24/2023
Galaxy A54 5G	SM-A546B	3/24/2023
Galaxy A54 5G	SM-A546B/DS	3/24/2023
Galaxy A54 5G	SM-A546E	3/24/2023
Galaxy A54 5G	SM-A546E/DS	3/24/2023
Galaxy A54 5G	SM-A5460	3/24/2023

4. Samsung Galaxy Z Fold Series

Series	Model Number	Release Date
Galaxy Fold 5G	SM-F907F	9/2019
Galaxy Fold 5G	SM-F9007	9/2019
Galaxy Fold 5G	SM-F907W	9/2019
Galaxy Fold 5G	SM-F907U	9/2019
Galaxy Fold 5G	SM-F907B	9/2019
Galaxy Fold 5G	SM-F907N	9/2019
Galaxy Z Fold 2	SM-F916B	9/18/2020
Galaxy Z Fold 2	SM-F916U	9/18/2020
Galaxy Z Fold 2	SM-F916U1	9/18/2020
Galaxy Z Fold 2	SM-F916N	9/18/2020
Galaxy Z Fold 2	SM-F9160	9/18/2020
Galaxy Z Fold 2	SM-F916W	9/18/2020
Galaxy Z Fold 2	SCG05	9/18/2020
Galaxy Z Fold 3	SM-F926B	8/11/2021
Galaxy Z Fold 3	SM-F926B/DS	8/11/2021
Galaxy Z Fold 3	SM-F926U	8/11/2021
Galaxy Z Fold 3	SM-F926U1	8/11/2021
Galaxy Z Fold 3	SM-F926W	8/11/2021
Galaxy Z Fold 3	SM-F9260	8/11/2021
Galaxy Z Fold 3	SM-F926N	8/11/2021
Galaxy Z Fold 4	SM-F936B	8/25/2022
Galaxy Z Fold 4	SM-F936B/DS	8/25/2022
Galaxy Z Fold 4	SM-F936U	8/25/2022

Galaxy Z Fold 4	SM-F936U1	8/25/2022
Galaxy Z Fold 4	SM-F936N	8/25/2022
Galaxy Z Fold 4	SM-F936W	8/25/2022
Galaxy Z Fold 4	SM-F9360	8/25/2022
Galaxy Z Fold 5	SM-F946B	7/25/2023
Galaxy Z Fold 5	SM-F946B/DS	7/25/2023
Galaxy Z Fold 5	SM-F946U	7/25/2023
Galaxy Z Fold 5	SM-F946U1	7/25/2023
Galaxy Z Fold 5	SM-F946N	7/25/2023
Galaxy Z Fold 5	SM-F946W	7/25/2023
Galaxy Z Fold 5	SM-F9460	7/25/2023

5. Samsung Galaxy S20 Series

Series	Model Number	Release Date
Galaxy S20+	SM-G985	3/6/2020
Galaxy S20+	SM-G985F	3/6/2020
Galaxy S20+	SM-G985F/DS	3/6/2020
Galaxy S20+	SM-G986	3/6/2020
Galaxy S20+	SM-G986F	3/6/2020
Galaxy S20+	SM-G986F/DS	3/6/2020
Galaxy S20+	SM-G986U	3/6/2020
Galaxy S20+	SM-G986U1	3/6/2020
Galaxy S20+	SM-G9860	3/6/2020
Galaxy S20+	SM-G986B/DS	3/6/2020
Galaxy S20+	SM-G986N	3/6/2020
Galaxy S20 5G	SM-G981	3/6/2020
Galaxy S20 5G	SM-G981F	3/6/2020
Galaxy S20 5G	SM-G981F/DS	3/6/2020
Galaxy S20 5G	SM-G981B/DS	3/6/2020
Galaxy S20 5G	SM-G981U	3/6/2020
Galaxy S20 5G	SM-G981U1	3/6/2020
Galaxy S20 5G	SM-G981N	3/6/2020
Galaxy S20 5G	SM-G981B	3/6/2020
Galaxy S20 5G	SM-G9810	3/6/2020
Galaxy S20 5G	SM-G981W	3/6/2020
Galaxy S20 5G	SC-51A	3/6/2020
Galaxy S20 5G	SCG01	3/6/2020
Galaxy S20 Ultra 5G	SM-G988	3/6/2020
Galaxy S20 Ultra 5G	SM-G988U	3/6/2020
Galaxy S20 Ultra 5G	SMG988U1	3/6/2020
Galaxy S20 Ultra 5G	SM-G9880	3/6/2020
Galaxy S20 Ultra 5G	SM-G988B/DS	3/6/2020
Galaxy S20 Ultra 5G	SM-G988N	3/6/2020
Galaxy S20 5G UW	SM-G981V	6/4/2020

Galaxy S20 FE 5G	SM-G781B	10/2/2020
Galaxy S20 FE 5G	SM-G781B/DS	10/2/2020
Galaxy S20 FE 5G	SM-G781U	10/2/2020
Galaxy S20 FE 5G	SM-G781U1	10/2/2020
Galaxy S20 FE 5G	SM-G781W	10/2/2020
Galaxy S20 FE 5G	SM-G7810	10/2/2020
Galaxy S20 FE 5G	SM-G781N	10/2/2020
Galaxy S20 FE 5G	SM-G781V	10/2/2020
Galaxy S20 FE 2022	SM-G781NK	4/1/2022
Galaxy S20 FE 2022	SM-G781NK22	4/1/2022

6. Samsung Galaxy S21 Series

Series	Model Number	Release Date
Galaxy S21	SM-G991B	1/29/2021
Galaxy S21	SM-G991B/DS	1/29/2021
Galaxy S21	SM-G991U	1/29/2021
Galaxy S21	SM-G991U1	1/29/2021
Galaxy S21	SM-G991W	1/29/2021
Galaxy S21	SM-G991N	1/29/2021
Galaxy S21	SM-G9910	1/29/2021
Galaxy S21+	SM-G996B	1/29/2021
Galaxy S21+	SM-G996B/DS	1/29/2021
Galaxy S21+	SM-G996U	1/29/2021
Galaxy S21+	SM-G996U1	1/29/2021
Galaxy S21+	SM-G996W	1/29/2021
Galaxy S21+	SM-G996B	1/29/2021
Galaxy S21+	SM-G9960	1/29/2021
Galaxy S21 Ultra	SM-G998B	1/29/2021
Galaxy S21 Ultra	SM-G998B/DS	1/29/2021
Galaxy S21 Ultra	SM-G998U	1/29/2021
Galaxy S21 Ultra	SM-G998U1	1/29/2021
Galaxy S21 Ultra	SM-G998W	1/29/2021
Galaxy S21 Ultra	SM-G998B	1/29/2021
Galaxy S21 Ultra	SM-G9980	1/29/2021
Galaxy S21 FE	SM-G990B	1/7/2022
Galaxy S21 FE	SM-G990B/DS	1/7/2022
Galaxy S21 FE	SM-G990U	1/7/2022
Galaxy S21 FE	SM-G990U1	1/7/2022
Galaxy S21 FE	SM-G990W	1/7/2022
Galaxy S21 FE	SM-G990E	1/7/2022
Galaxy S21 FE	SM-G9900	1/7/2022
Galaxy S21 FE	SM-G990B2	1/7/2022
Galaxy S21 FE	SM-G990U2	1/7/2022
Galaxy S21 FE	SM-G990W2	1/7/2022

7. Samsung Galaxy S22 Series

Series	Model Number	Release Date
Galaxy S22	SM-S901B	2/25/2022
Galaxy S22	SM-S901B/DS	2/25/2022
Galaxy S22	SM-S901U	2/25/2022
Galaxy S22	SM-S901U1	2/25/2022
Galaxy S22	SM-S901W	2/25/2022
Galaxy S22	SM-S901N	2/25/2022
Galaxy S22	SM-S9010	2/25/2022
Galaxy S22	SM-S901E	2/25/2022
Galaxy S22+	SM-S906B	2/25/2022
Galaxy S22+	SM-S906B/DS	2/25/2022
Galaxy S22+	SM-S906U	2/25/2022
Galaxy S22+	SM-S906U1	2/25/2022
Galaxy S22+	SM-S906W	2/25/2022
Galaxy S22+	SM-S906N	2/25/2022
Galaxy S22+	SM-S9060	2/25/2022
Galaxy S22+	SM-S906E	2/25/2022
Galaxy S22 Ultra	SM-S908B	2/25/2022
Galaxy S22 Ultra	SM-S908B/DS	2/25/2022
Galaxy S22 Ultra	SM-S908U	2/25/2022
Galaxy S22 Ultra	SM-S908U1	2/25/2022
Galaxy S22 Ultra	SM-S908W	2/25/2022
Galaxy S22 Ultra	SM-S908N	2/25/2022
Galaxy S22 Ultra	SM-S9080	2/25/2022
Galaxy S22 Ultra	SM-S908E	2/25/2022

8. Samsung Galaxy S23 Series

Series	Model Number	Release Date
Galaxy S23	SM-S911B	2/17/2023
Galaxy S23	SM-S911B/DS	2/17/2023
Galaxy S23	SM-S911U	2/17/2023
Galaxy S23	SM-S911U1	2/17/2023
Galaxy S23	SM-S911W	2/17/2023
Galaxy S23	SM-S911N	2/17/2023
Galaxy S23	SM-S9110	2/17/2023
Galaxy S23	SM-S911E	2/17/2023
Galaxy S23	SM-S911E/DS	2/17/2023
Galaxy S23+	SM-S916B	2/17/2023
Galaxy S23+	SM-S916B/DS	2/17/2023
Galaxy S23+	SM-S916U	2/17/2023
Galaxy S23+	SM-S916U1	2/17/2023
Galaxy S23+	SM-S916W	2/17/2023

Galaxy S23+	SM-S916N	2/17/2023
Galaxy S23+	SM-S9160	2/17/2023
Galaxy S23+	SMS916E	2/17/2023
Galaxy S23 Ultra	SM-S918B	2/17/2023
Galaxy S23 Ultra	SM-S918B/DS	2/17/2023
Galaxy S23 Ultra	SM-S918U	2/17/2023
Galaxy S23 Ultra	SM-S918U1	2/17/2023
Galaxy S23 Ultra	SM-S918W	2/17/2023
Galaxy S23 Ultra	SM-S918N	2/17/2023
Galaxy S23 Ultra	SM-S9180	2/17/2023
Galaxy S23 Ultra	SM-S918E	2/17/2023
Galaxy S23 Ultra	SM-S918E/DS	2/17/2023
Galaxy S23 FE	SM-S711B	10/5/2023
Galaxy S23 FE	SM-S711B/DS	10/5/2023
Galaxy S23 FE	SM-S711U1	10/5/2023
Galaxy S23 FE	SM-S711U	10/5/2023
Galaxy S23 FE	SM-S711W	10/5/2023
Galaxy S23 FE	SM-S7110	10/5/2023

9. Samsung Galaxy Z Flip Series

Series	Model Number	Release Date
Galaxy Z Flip 5G	SM-F707B	8/7/2020
Galaxy Z Flip 5G	SM-F707N	8/7/2020
Galaxy Z Flip 5G	SM-F7070	8/7/2020
Galaxy Z Flip 5G	SM-F707U	8/7/2020
Galaxy Z Flip 5G	SM-F707U1	8/7/2020
Galaxy Z Flip 5G	SM-F707W	8/7/2020
Galaxy Z Flip 3	SM-F711B	8/11/2021
Galaxy Z Flip 3	SM-F711N	8/11/2021
Galaxy Z Flip 3	SM-F711U	8/11/2021
Galaxy Z Flip 3	SM-F711U1	8/11/2021
Galaxy Z Flip 3	SM-F711W	8/11/2021
Galaxy Z Flip 3	SM-F7110	8/11/2021
Galaxy Z Flip 4	SM-F721B	8/25/2022
Galaxy Z Flip 4	SM-F721B/DS	8/25/2022
Galaxy Z Flip 4	SM-F721N	8/25/2022
Galaxy Z Flip 4	SM-F721U	8/25/2022
Galaxy Z Flip 4	SM-F721U1	8/25/2022
Galaxy Z Flip 4	SM-F721W	8/25/2022
Galaxy Z Flip 4	SM-F7210	8/25/2022
Galaxy Z Flip 5	SM-F731B	8/11/2023
Galaxy Z Flip 5	SM-F731B/DS	8/11/2023
Galaxy Z Flip 5	SM-F731U	8/11/2023
Galaxy Z Flip 5	SM-F731U1	8/11/2023

Galaxy Z Flip 5	SM-F731W	8/11/2023
Galaxy Z Flip 5	SM-F731N	8/11/2023

10. Samsung Galaxy M 5G Series

Series	Model Number	Release Date
Galaxy M42 5G	SM-M426B	5/1/2021
Galaxy M42 5G	SM-M426B/DS	5/1/2021
Galaxy M32 5G	SM-M326B	9/2/2021
Galaxy M32 5G	SM-M326B/DS	9/2/2021
Galaxy M52 5G	SM-M526BR	10/3/2021
Galaxy M52 5G	SM-M526BR/DS	10/3/2021
Galaxy M52 5G	SM-M526B	10/3/2021
Galaxy M52 5G	SM-M526B/DS	10/3/2021
Galaxy M23 5G	SM-M236B	3/4/2022
Galaxy M23 5G	SM-M236B/DS	3/4/2022
Galaxy M33 5G	SM-M336B	4/8/2022
Galaxy M33 5G	SM-M336B/DS	4/8/2022
Galaxy M33 5G	SM-M336BU	4/8/2022
Galaxy M33 5G	SM-M336BU/DS	4/8/2022
Galaxy M33 5G	SM-M336K	4/8/2022
Galaxy M53 5G	SM-M536B	4/22/2022
Galaxy M53 5G	SM-M536B/DS	4/22/2022
Galaxy M53 5G	SM-M536B/DSN	4/22/2022
Galaxy M13 5G	SM-M136B	7/23/2022
Galaxy M13 5G	SM-M136B/DS	7/23/2022
Galaxy M14 5G	SM-M146B	3/8/2023
Galaxy M14 5G	SM-M146B/DS	3/8/2023
Galaxy M14 5G	SM-M146B/DSN	3/8/2023
Galaxy M54 5G	SM-M546B	4/11/2023
Galaxy M54 5G	SM-M546B/DS	4/11/2023
Galaxy M34 5G	SM-M346B	7/15/2023
Galaxy M34 5G	SM-M346B/DS	7/15/2023

11. Samsung Galaxy F 5G Series

Series	Model Number	Release Date
Galaxy F52 5G	SM-E5260	5/20/2021
Galaxy F42 5G	SM-E426B	9/29/2021
Galaxy F42 5G	SM-E426B/DS	9/29/2021
Galaxy F23 5G	SM-E236B	3/16/2022
Galaxy F23 5G	SM-E236B/DS	3/16/2022
Galaxy F14	SM-E146B	3/30/2023
Galaxy F14	SM-E146B/DS	3/30/2023
Galaxy F34	SM-E346B	8/12/2023

Galaxy F34	SM-E346B/DS	8/12/2023
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12. Samsung Galaxy Xcover 6 Pro

Series	Model Number	Release Date
Galaxy Xcover 6 Pro	SM-G736U	7/13/2022
Galaxy Xcover 6 Pro	SM-G736U1	7/13/2022
Galaxy Xcover 6 Pro	SM-G736B	7/13/2022
Galaxy Xcover 6 Pro	SM-G736B/DS	7/13/2022

13. Galaxy Tab²

Series	Model Number	Release Date
Samsung Galaxy Tab S6 5G	SM-T866N	1/30/2020
Samsung Galaxy Tab S7 5G	SM-T878U	8/21/2020
Samsung Galaxy Tab S7+ 5G	SM-T978U	8/21/2020
Samsung Galaxy Tab S7+ 5G	SM-T976B	8/21/2020
Samsung Galaxy Tab S7 FE 5G	SM-T738U	6/18/2021
Samsung Galaxy Tab S7 FE 5G	SM-T736B	6/18/2021
Samsung Galaxy Tab S8 5G	SM-X706	3/22/2022
Samsung Galaxy Tab S8 5G	SM-X706B	3/22/2022
Samsung Galaxy Tab S8 5G	SM-X706U	3/22/2022
Samsung Galaxy Tab S8 5G	SM-X706N	3/22/2022
Samsung Galaxy Tab S8+ 5G	SM-X808U	4/14/2022
Samsung Galaxy Tab S8+ 5G	SM-X806	4/14/2022
Samsung Galaxy Tab S8+ 5G	SM-X806B	4/14/2022
Samsung Galaxy Tab S8+ 5G	SM-X806U	4/14/2022
Samsung Galaxy Tab S8+ 5G	SM-X806N	4/14/2022
Samsung Galaxy Tab S8 Ultra 5G	SM-X906	4/30/2022
Samsung Galaxy Tab S8 Ultra 5G	SM-X906B	4/30/2022
Samsung Galaxy Tab S8 Ultra 5G	SM-X906U	4/30/2022
Samsung Galaxy Tab S8 Ultra 5G	SM-X906N	4/30/2022
Samsung Galaxy Tab Active4 Pro	SM-T638U	9/13/2022
Samsung Galaxy Tab Active4 Pro	SM-T636B	9/13/2022
Samsung Galaxy Tab S9 5G	SM-X716B	8/11/2023

² For the avoidance of doubt, Empire does not intend to include as '331 Patent Accused Instrumentalities any tablets that are only Wi-Fi enabled (not cellular enabled).

Samsung Galaxy Tab S9+ 5G	SM-X816B	8/11/2023
Samsung Galaxy Tab S9+ 5G	SM-X818U	8/11/2023
Samsung Galaxy Tab S9 Ultra	SM-X916B	8/11/2023
Samsung Galaxy Tab S9 FE 5G	SM-X518U	10/16/2023
Samsung Galaxy Tab S9 FE 5G	SM-X516B	10/16/2023
Samsung Galaxy Tab S9 FE+ 5G	SM-X616B	10/16/2023
Samsung Galaxy Tab A9+	SM-X216B	10/17/2023

III. CLAIM CHARTS

Exhibits A and B, attached hereto and incorporated by reference herein, are claim charts setting forth where each element of each of the Asserted Claims is found in the Accused Instrumentalities.

IV. PRESENCE OF ELEMENTS OF ASSERTED CLAIMS

A. THE '120 PATENT

Subject to ongoing discovery and investigation, Empire hereby contends that Samsung has infringed and continues to infringe the Asserted Claims of the '120 Patent under 35 U.S.C. § 271(a), literally, by making, using, offering to sell, selling within the United States, importing into and/or exporting from the United States, without authority or license, the Accused Instrumentalities. To the extent any element is not literally present, Empire contends that each element of the Asserted Claims of the '120 Patent is present in the Accused Instrumentalities under the doctrine of equivalents because any difference between such claim element and the accused element is insubstantial. In other words, the accused element performs substantially the same function, in substantially the same way, to achieve substantially the same result. The extent to which Empire will rely on the doctrine of equivalents with respect to the '120 Patent is not currently known because discovery has not yet

begun, the parties have not exchanged potentially disputed claim elements, and the Court has not construed any disputed claim terms.

Empire further contends that Samsung has infringed and continues to infringe the Asserted Claims of the '120 Patent under 35 U.S.C. § 271(b) by (among other things) and with specific intent or willful blindness, actively aiding and abetting infringement by others, such as Defendants' partners, customers, and end-users, in this District and elsewhere in the United States.

Empire contends that Samsung also indirectly infringes the Asserted Claims of the '120 Patent, pursuant to 35 U.S.C. § 271(c), by contributing to direct infringement committed by others, such as partners, customers, and end-users, in this District and elsewhere in the United States. Defendants' affirmative acts of selling and offering to sell, in this District and elsewhere in the United States, the '120 Patent Accused Instrumentalities and causing the '120 Patent Accused Instrumentalities to be manufactured, used, sold, and offered for sale, contribute to Defendants' partners', customers', and end-users' use of the '120 Patent Accused Instrumentalities, such that the Asserted Claims of the '120 Patent are directly infringed.

B. THE '331 PATENT

Subject to ongoing discovery and investigation, Empire hereby contends that Samsung has infringed and continues to infringe the Asserted Claims of the '331 Patent under 35 U.S.C. § 271(a), literally, by making, using, offering to sell, selling within the United States, importing into and/or exporting from the United States, without authority or license, the Accused Instrumentalities. To the extent any element is not literally present, Empire contends that each element of the Asserted Claims of the '331 Patent is present in the Accused Instrumentalities under the doctrine of equivalents because any difference between such claim element and the accused element is insubstantial. In other words, the accused element performs substantially the same function, in substantially the same way, to achieve substantially the same result. The extent to which Empire will rely on the doctrine of

equivalents with respect to the '331 Patent is not currently known because discovery has not yet begun, the parties have not exchanged potentially disputed claim elements, and the Court has not construed any disputed claim terms.

Empire further contends that Samsung has infringed and continues to infringe the Asserted Claims of the '331 Patent under 35 U.S.C. § 271(b) by (among other things) and with specific intent or willful blindness, actively aiding and abetting infringement by others, such as Defendants' partners, customers, and end-users, in this District and elsewhere in the United States.

Empire contends that Samsung also indirectly infringes the Asserted Claims of the '331 Patent, pursuant to 35 U.S.C. § 271(c), by contributing to direct infringement committed by others, such as partners, customers, and end-users, in this District and elsewhere in the United States. Defendants' affirmative acts of selling and offering to sell, in this District and elsewhere in the United States, the '331 Patent Accused Instrumentalities and causing the '331 Patent Accused Instrumentalities to be manufactured, used, sold, and offered for sale, contribute to Defendants' partners', customers', and end-users' use of the '331 Patent Accused Instrumentalities, such that the Asserted Claims of the '331 Patent are directly infringed.

V. PRIORITY OF PATENTS

A. '120 PATENT

The '120 Patent claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 61/161,166 (the "'166 provisional application"), filed on March 18, 2009. Empire contends that each Asserted Claim of the '120 Patent is supported by the disclosures in the '166 provisional application. Empire contends that each Asserted Claim of the '120 Patent was conceived as of October 1, 2007, was reduced to practice with reasonable diligence, and is entitled to a priority date of at least October 1, 2007.

B. '331 PATENT

Empire contends that each Asserted Claim of the '331 Patent is supported by the disclosures in International Application No. PCT/US2010/046106 filed on August 20, 2010. Empire contends that each Asserted Claim of the '331 Patent was conceived as of July 1, 2008, was reduced to practice with reasonable diligence, and is entitled to a priority date of at least July 1, 2008.

VI. IDENTIFICATION OF EMPIRE PRACTICING INSTRUMENTALITIES

Pursuant to P.R. 3-1(f), based upon the information currently known to Empire, Empire is not currently aware of any of its own apparatuses, products, devices, processes, methods, acts, or other instrumentalities that practice a claimed invention of the Asserted Patents.

VII. ACCOMPANYING DOCUMENT PRODUCTION

Pursuant to P.R. 3-2, Empire is producing documents evidencing conception and reduction to practice of the Asserted Claims (Bates Nos. Empire_0000491-525, Empire_0000838-1080), a certified copy of the file history for the '120 Patent (Bates Nos. Empire_0000001-490), and a certified copy of the file history for the '331 Patent (Bates Nos. Empire_0000526-837). Empire states that is not currently aware of any documents “sufficient to evidence each discussion with, disclosure to, or other manner of providing to a third party, or sale of or offer to sell, the claimed invention prior to the date of application” for each of the Asserted Patents pursuant to P.R. 3-2(a). Empire’s investigation is ongoing, and Empire reserves the right to identify, produce, and rely on additional documents and evidence, including without limitation evidence in the possession of Defendants or third parties, deposition testimony, and expert reports and testimony that are identified, discovered, obtained and developed during the course of this action.

Dated: January 4, 2024

/s/ Nathaniel Browand

Nathaniel Browand (admitted *pro hac vice*)

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Attorneys for Plaintiff

Empire Technology Development LLC

CERTIFICATE OF SERVICE

I hereby certify that, on January 4, 2024, all counsel of record are being served with a copy of the foregoing document.

/s/ Nathaniel Browand
Nathaniel Browand

EXHIBIT A

'120 Patent Accused Instrumentalities: The '120 Patent Accused Instrumentalities include Samsung apparatuses, products, systems, services, devices, processes, methods, acts, components (hardware and/or software), and/or other instrumentalities that include, e.g., transmitters with Smart Transmit™, Smart Transmit™ 2.0, or Smart Transmit™ 3.0, including, without limitation, the Galaxy S20 series; S21 series; S22 series; and S23 series phones; the Galaxy A 5G series phones; the Galaxy Z Flip series phones; the Galaxy Note series phones; the Galaxy Z Fold series phones; the Galaxy M 5G series phones; the Galaxy F 5G series phones; the Galaxy Xcover 6 Pro series phones; and the Galaxy Tab series tablets. The '120 Patent Accused Instrumentalities identified by model number above are hereby incorporated by reference. *See supra* Section II.A.

'120 Patent	The '120 Patent Accused Instrumentalities
[25] A mobile station for use in a communications system comprising:	The '120 Patent Accused Instrumentalities are examples of mobile stations for use in a cellular network communication system. For example, the Galaxy S20 Ultra 5G is a mobile station for use in a cellular network communication system. Specifically, below is a photograph of a Galaxy S20 Ultra 5G mobile station submitted by Samsung to the FCC.

'120 Patent	The '120 Patent Accused Instrumentalities
	FCC ID: A3LSMG988U External Photographs 

'120 Patent	The '120 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=s3p85PbIvL3JWmQHP6peg%3D%3D&fcc_id=A3LSMG988U (external photos). As another example, the Galaxy S20 5G is a mobile station for use in a cellular network communication system. Specifically, below is a photograph of a Galaxy S20 5G mobile station submitted by Samsung to the FCC.

'120 Patent	The '120 Patent Accused Instrumentalities
	FCC ID: A3LSMG981U, IC: 649E-SMG981U, HVIN: SM-G981W External Photographs 

'120 Patent	The '120 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=8Twxpjxm25uB8pCHfwZLA%3D%3D&fcc_id=A3LSMG981U (external photos).
[25a] a first antenna and a second antenna	The '120 Patent Accused Instrumentalities include at least a first antenna and a second antenna. For example, Galaxy S20 series smartphones include at least a first antenna and a second antenna. Below is an image from Samsung's submission to the FCC for a Galaxy S20 Ultra 5G model showing antenna locations:



Note: Exact antenna dimensions and separation distances are shown in the Technical Descriptions in the FCC Filing.

Figure E-1
DUT Antenna Locations

FCC ID: A3LSMG988U	PCTEST	SAR EVALUATION REPORT	SAMSUNG	Approved by: Quality Manager
Test Dates: 11/18/19 – 01/23/20	DUT Type: Portable Handset			APPENDIX E: Page 2 of 14

'120 Patent	The '120 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=s3p85PbIvL3JW/mQHP6peg%3D%3D&fcc_id=A3LSMG988U (SAR Test Setup Photos). As another example, below is an image from Samsung's submission to the FCC for a Galaxy S20 5G model showing antenna locations:

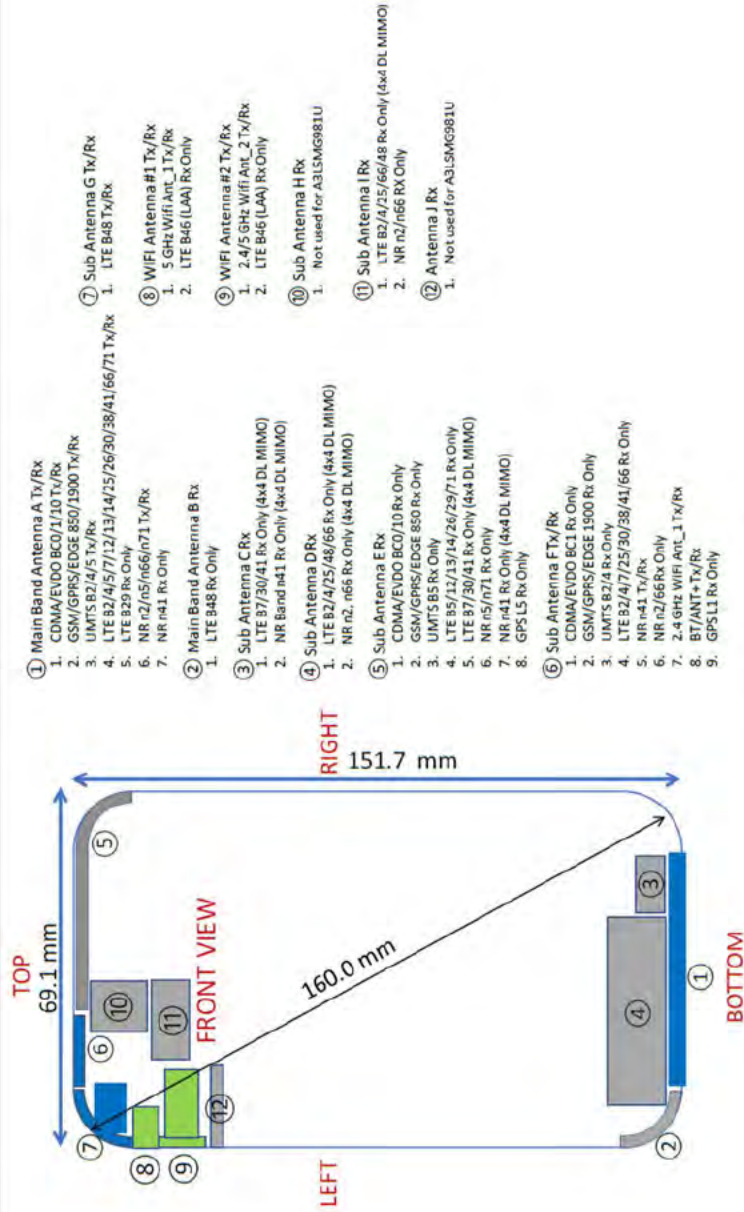
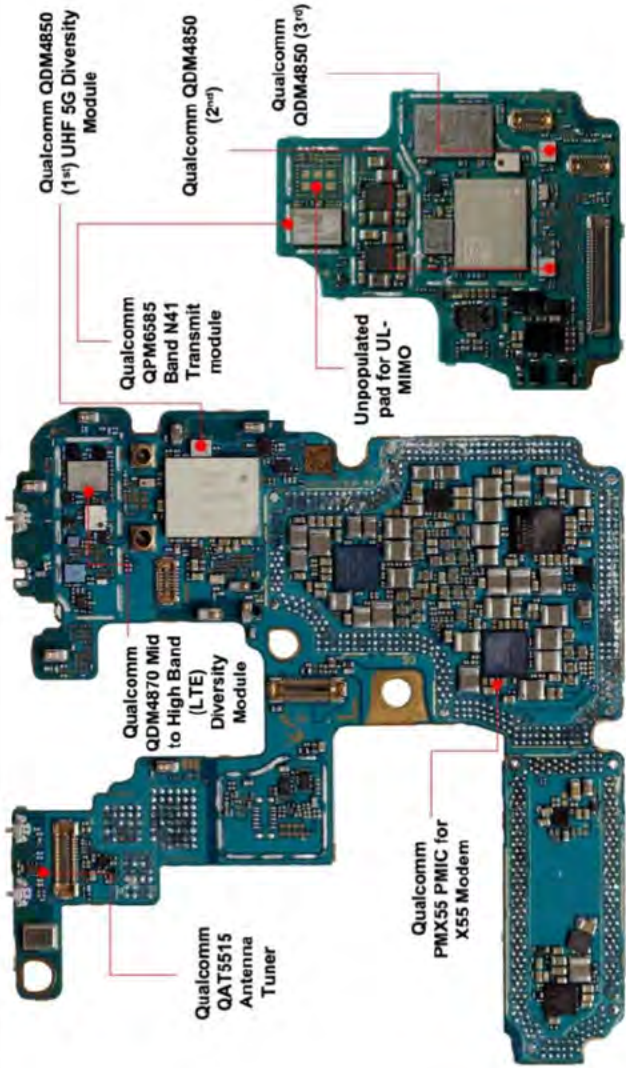


Figure E-1
DUT Antenna Locations

FCC ID: A3LSMG981U	PCTEST	SAR EVALUATION REPORT	SAMSUNG	Approved by: Quality Manager
Test Dates: 10/23/19 - 12/18/19	DUT Type: Portable Handset			APPENDIX E: Page 2 of 14

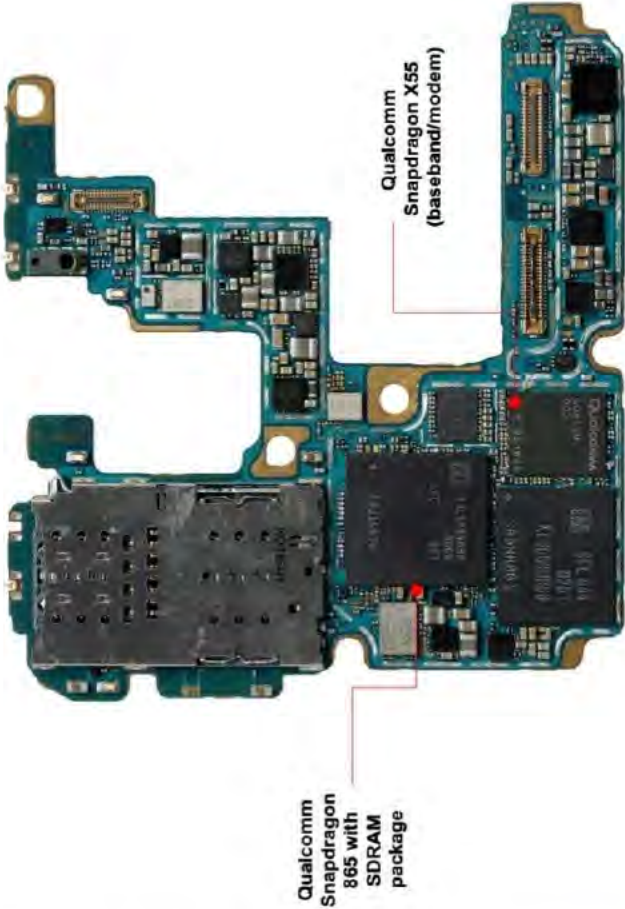
'120 Patent	The '120 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=8Twxpjxm25uB8pCHfvZLA%3D%3D&fcc_id=A3LSMG981U (Test Setup Photos).
[25b] first circuitry coupled to the first antenna and configured to process signals for transmission by the first antenna; second circuitry coupled to the second antenna and configured to process signals for transmission by the second antenna; and	The '120 Patent Accused Instrumentalities include first circuitry coupled to the first antenna and configured to process signals for transmission by the first antenna and second circuitry coupled to the second antenna and configured to process signals for transmission by the second antenna. For example, the Galaxy S20 Ultra 5G includes first circuitry coupled to the first antenna and configured to process signals for transmission by the first antenna and second circuitry coupled to the second antenna and configured to process signals for transmission by the second antenna. More specifically, e.g., the three annotated images below show modules and circuitry for processing signals in the Galaxy S20 Ultra 5G (Model Number SM-G988U1):

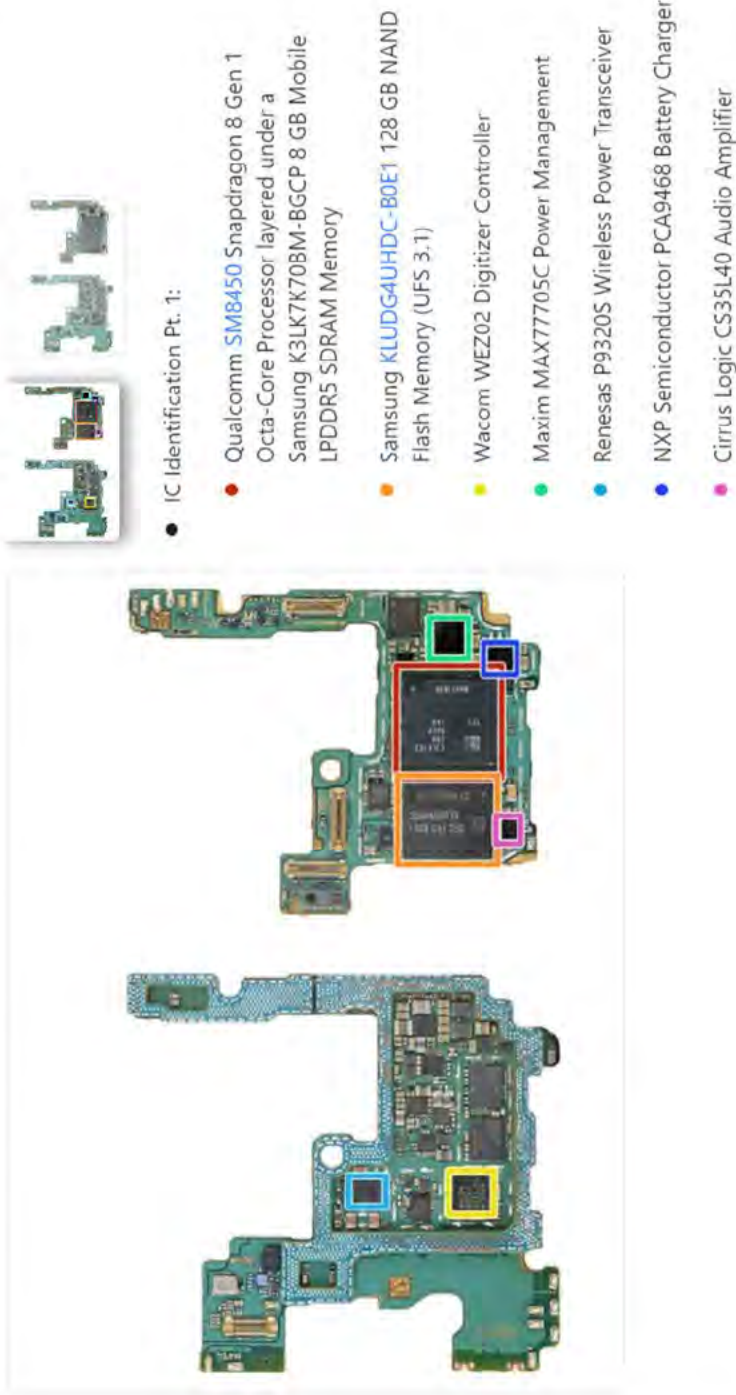
'120 Patent	The '120 Patent Accused Instrumentalities
	Qualcomm QPM5677 5G PAM or Transmit Module for band N78 Qualcomm SDR865 RF Transceiver 5G/4G/3G Qualcomm QDM4820 Low Band (LTE & 5G) Diversity Module Qualcomm QDM5872 Mid to High 5G Front End or Diversity Module Qualcomm SMR526 RF / IF integrated circuit (mmWave IF)

'120 Patent	The '120 Patent Accused Instrumentalities
	

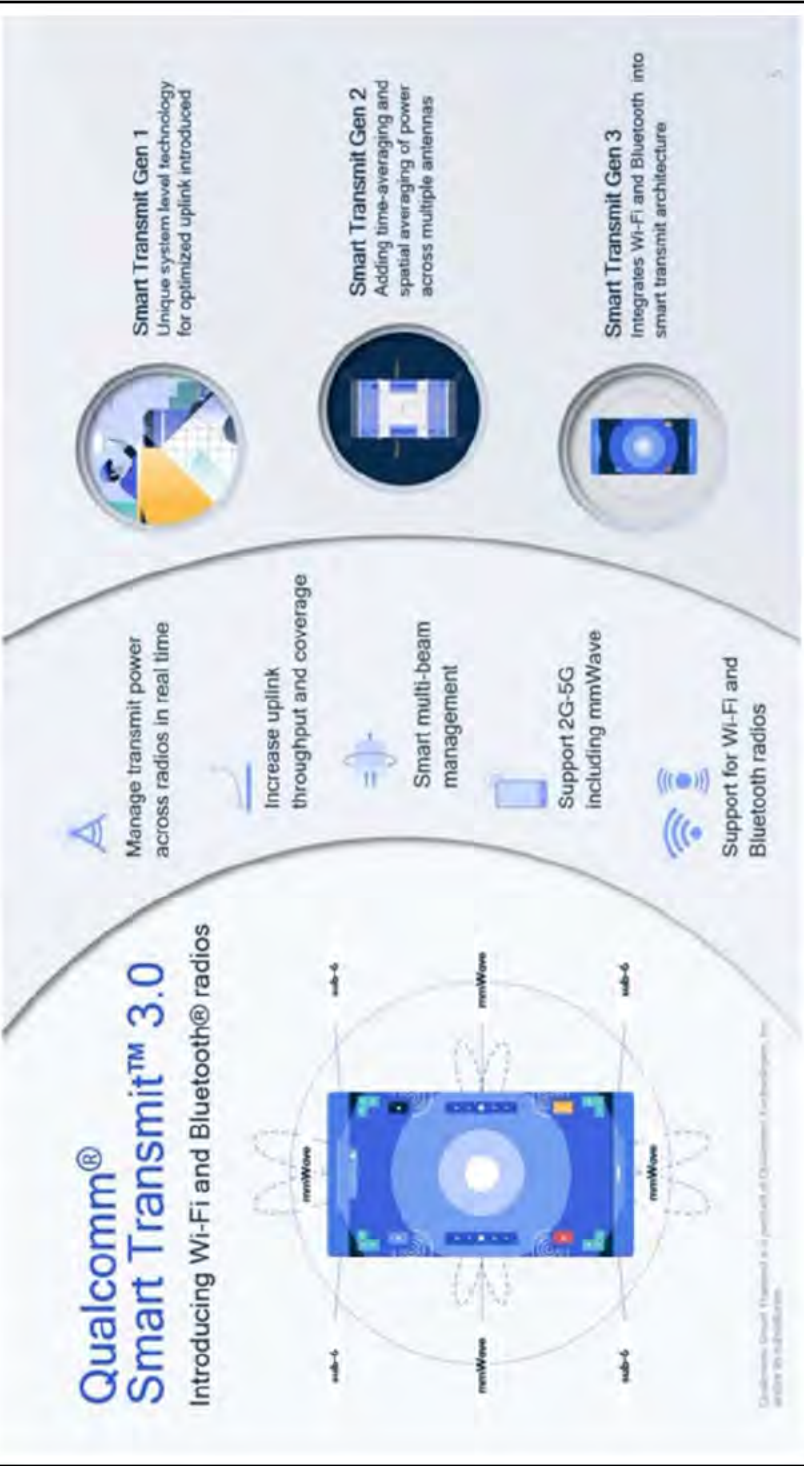
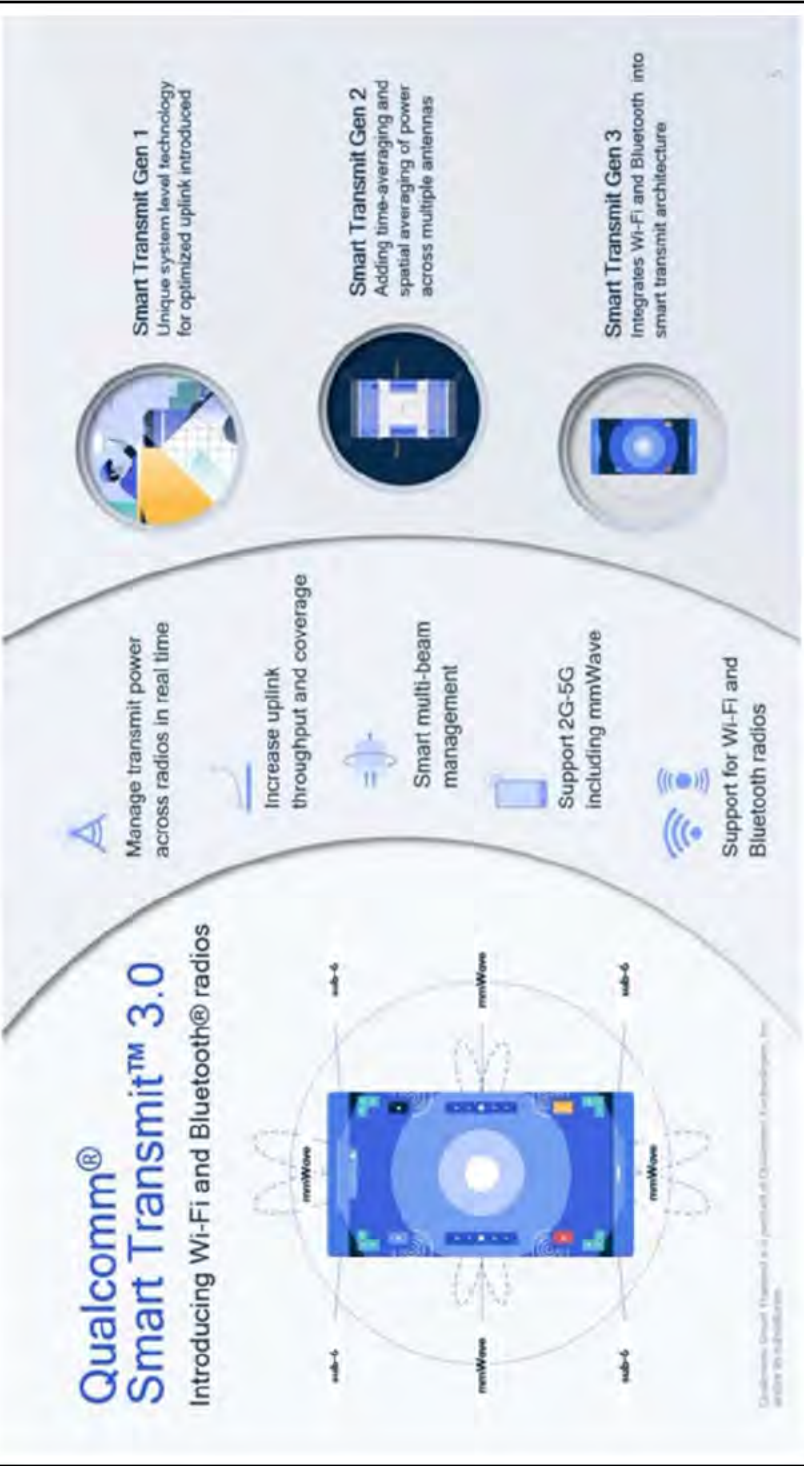
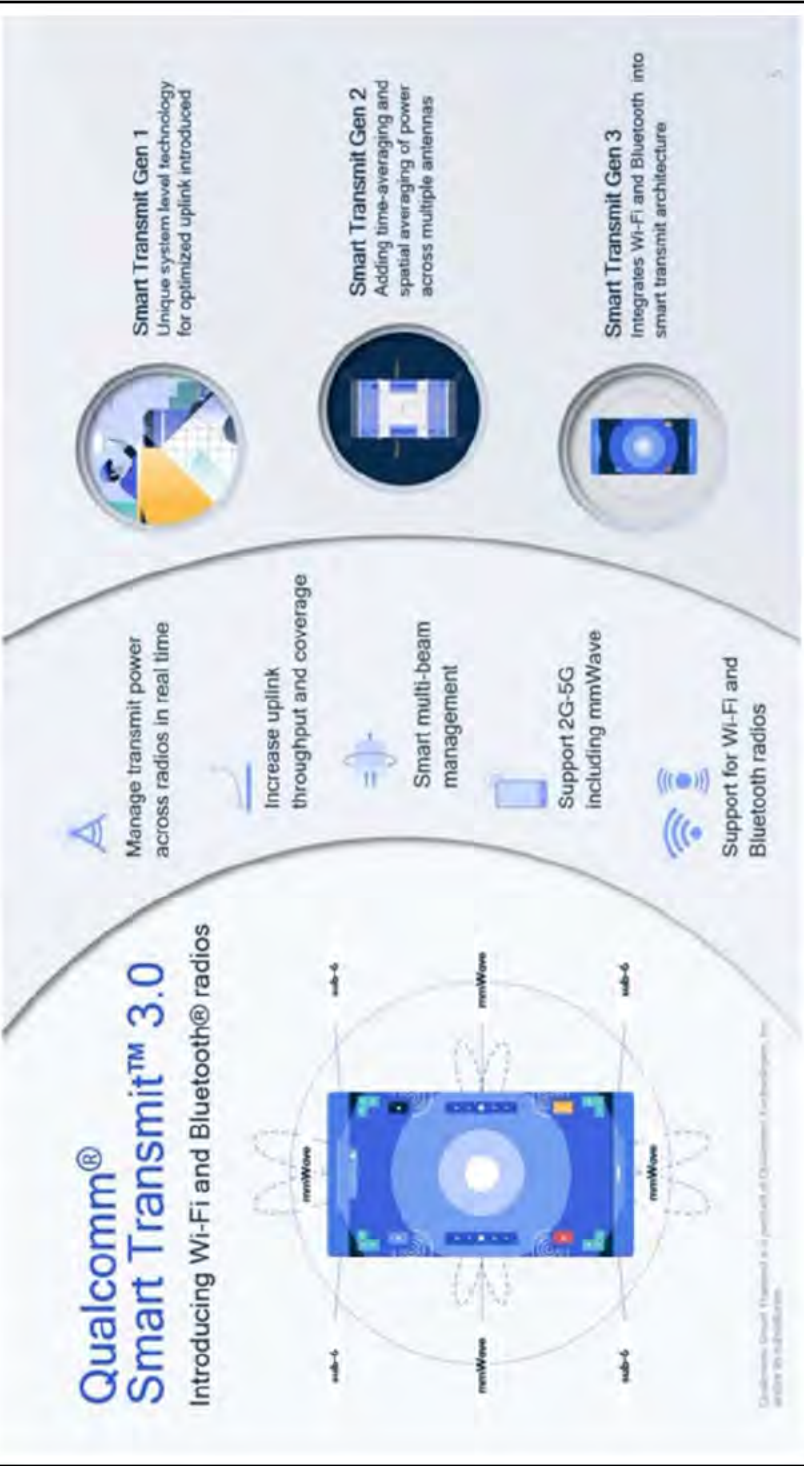
'120 Patent	The '120 Patent Accused Instrumentalities https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra#c66138ec-595f-4a26-a02a-3e0acbf3e83e. One of Defendants' suppliers, Qualcomm, states that its "second-generation RF front-end (RFFE) solutions for 5G multi-mode mobile devices ... represent a comprehensive RF solution designed to work with the new Qualcomm® Snapdragon™ X55 5G modem, delivering a comprehensive modem-to-antenna system for high-performance 5G mobile devices supporting both sub-6 GHz and millimeter wave (mmWave) bands." These RFFE solutions comprise power amplifiers and diversity modules that include the following:
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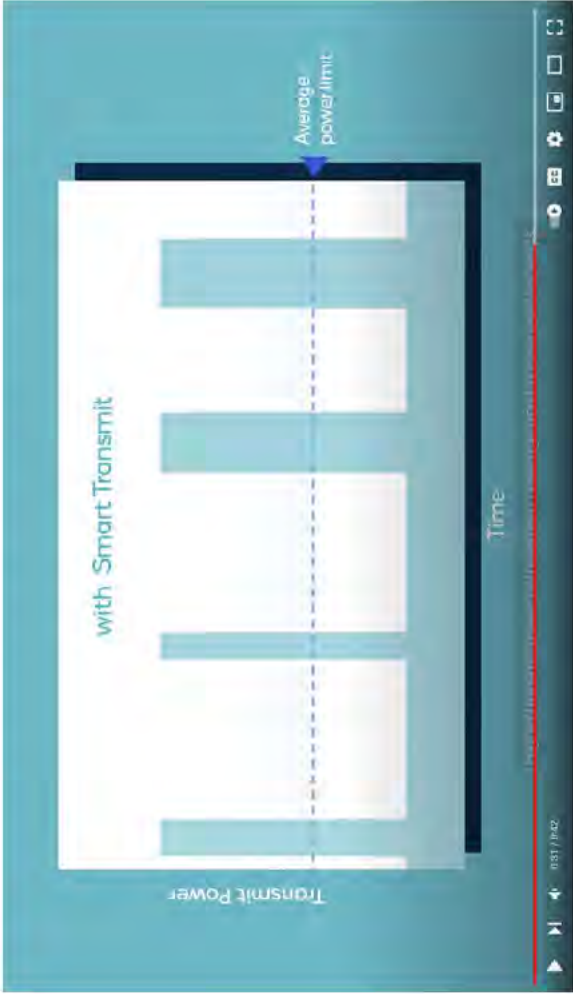
'120 Patent	The '120 Patent Accused Instrumentalities
	• PA modules which pair with QET6100 to support 100 MHz 5G envelope tracking. QPM6585, QPM5677 and QPM5679 for bands n41, n77/78 and n79 respectively. • Mid/High-band 5G/4G PA module QPM5670 features integrated LNA, switch, filters and 5G hexaplexer. • Low-band 5G/4G PA module QPM5621 with integrated LNA, switch and filters, and support for low-band/low-band carrier aggregation and dual connectivity. • Diversity module family QDM58xx, featuring integrated 5G/4G LNA, switch and filters for receive diversity and MIMO support for sub-6 GHz bands. https://www.qualcomm.com/news/releases/2019/02/qualcomm-announces-second-generation-5g-rf-front-end-solutions-sleeper-more.
[25c] a controller coupled to the first and second circuitry, wherein the controller is configured to receive a control signal and, in accordance with the control signal, to select between a multiple-input multiple-output (MIMO) mode wherein both the	The '120 Patent Accused Instrumentalities include a controller coupled to the first and second circuitry, wherein the controller is configured to receive a control signal and, in accordance with the control signal, to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a SIMO mode wherein only one of the first and second antennas transmit data over a communications channel. For example, the Galaxy S20 models include a controller coupled to the first and second circuitry and configured to receive a control signal and, in accordance with the control signal, to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a SIMO mode wherein only one of the first and second antennas transmit data over a communications channel. Specifically, the annotated image below shows a Snapdragon 865 5G chipset and Snapdragon X55 modem in the Galaxy S20 Ultra 5G (Model Number SM-G988U1):

'120 Patent	The '120 Patent Accused Instrumentalities
first and second antennas transmit data over a communications channel and a single-input multiple-output (SIMO) mode wherein only one of the first and second antennas transmit data over a communications channel	 https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra#c66138ec-595f-4a26-a02a-3e0acbf3e83e. Similarly, the Samsung Galaxy S22 Ultra includes the “Snapdragon 8 Gen 1” chipset, which includes a Snapdragon X65 5G modem, and includes a controller coupled to the first and second circuitry and configured to receive a control signal and, in accordance with the control signal, to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a SIMO mode wherein only one of the first and second antennas transmit data over a communications channel.

'120 Patent	The '120 Patent Accused Instrumentalities https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php; https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/snapdragon-8-gen-1-mobile-platform-product-brief.pdf. Specifically, the annotated image below shows a Snapdragon 8 Gen 1 chipset, outlined in red, in the Galaxy S22 Ultra:  IC Identification Pt. 1: - Qualcomm SM8450 Snapdragon 8 Gen 1 Octa-Core Processor layered under a Samsung K3LK7K708M-BGCP 8 GB Mobile LPDDR5 SDRAM Memory - Samsung KLUDG4UHD-C-B0E1 128 GB NAND Flash Memory (UFS 3.1) - Wacom WEZ02 Digitizer Controller - Maxim MAX77705C Power Management - Renesas P93205 Wireless Power Transceiver - NXP Semiconductor PCA9468 Battery Charger - Cirrus Logic CS35L40 Audio Amplifier
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'120 Patent	https://www.ifixit.com/Guide/Samsung+Galaxy+S22+Ultra+Chip+ID/148073. Qualcomm describes Snapdragon X65 as designed to “[b]reak through the 10 Gbps barrier in both 5G non-standalone (NSA) and standalone (SA) modes. This modem-to-antenna solution features an all-new Qualcomm 545 mmWave Antenna Module, next-gen Qualcomm Wideband Envelope Tracking and Qualcomm AI-Enhanced Signal Boost to help achieve unmatched data speeds and coverage.” https://www.qualcomm.com/products/technology/modems/snapdragon-x65-5g-modem-rf-system. For example, the '120 Patent Accused Instrumentalities include a controller that is configured to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a SIMO mode wherein only one of the first and second antennas transmit data over a communications channel at least because they are compatible with LTE Release 12: SIMO Mode MIMO Mode <table><caption>Uplink Transmission modes in LTE Release 12</caption><thead><tr><th>Transmission modes</th><th>Description</th><th>DCI (Main)</th><th>Comment</th></tr></thead><tbody><tr><td>1</td><td>Single transmit antenna</td><td>0</td><td>single antenna port (port 10)</td></tr><tr><td>2</td><td>Closed-loop spatial multiplexing</td><td>4</td><td>2 or 4 antennas (ports 20 and 21) (ports 40,41,42,43)</td></tr></tbody></table> Table 6: The two uplink transmission modes in LTE Release 12. https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_application/application_notes/1ma186/1MA186_2e_LTE_TMs_and_beamforming.pdf (annotated).	Transmission modes	Description	DCI (Main)	Comment	1	Single transmit antenna	0	single antenna port (port 10)	2	Closed-loop spatial multiplexing	4	2 or 4 antennas (ports 20 and 21) (ports 40,41,42,43)
Transmission modes	Description	DCI (Main)	Comment										
1	Single transmit antenna	0	single antenna port (port 10)										
2	Closed-loop spatial multiplexing	4	2 or 4 antennas (ports 20 and 21) (ports 40,41,42,43)										
[25d] wherein the control signal is based, at least in	The '120 Patent Accused Instrumentalities include a control signal based, at least in part, on a power consumption of the first and second circuitry. For example, Smart Transmit technology incorporated into the '120 Patent												

'120 Patent	<table><tr><td data-bbox="191 609 289 1646"> The '120 Patent Accused Instrumentalities </td><td data-bbox="289 189 1380 1646"> Accused Instrumentalities, including the Galaxy S20 series, includes a control signal based, at least in part, on a power consumption of the first and second circuitry. See <i>supra</i> claim element [25c], which is incorporated by reference. The features of SmartTransmit are described as follows:  Qualcomm® Smart Transmit™ 3.0 Introducing Wi-Fi and Bluetooth® radios Manage transmit power across radios in real time Increase uplink throughput and coverage Smart multi-beam management Support 2G-5G including mmWave Support for Wi-Fi and Bluetooth radios Smart Transmit Gen 1 Unique system level technology for optimized uplink introduced Smart Transmit Gen 2 Adding time-averaging and spatial averaging of power across multiple antennas Smart Transmit Gen 3 Integrates Wi-Fi and Bluetooth into smart transmit architecture </td></tr></table>	The '120 Patent Accused Instrumentalities	Accused Instrumentalities, including the Galaxy S20 series, includes a control signal based, at least in part, on a power consumption of the first and second circuitry. See <i>supra</i> claim element [25c], which is incorporated by reference. The features of SmartTransmit are described as follows:  Qualcomm® Smart Transmit™ 3.0 Introducing Wi-Fi and Bluetooth® radios Manage transmit power across radios in real time Increase uplink throughput and coverage Smart multi-beam management Support 2G-5G including mmWave Support for Wi-Fi and Bluetooth radios Smart Transmit Gen 1 Unique system level technology for optimized uplink introduced Smart Transmit Gen 2 Adding time-averaging and spatial averaging of power across multiple antennas Smart Transmit Gen 3 Integrates Wi-Fi and Bluetooth into smart transmit architecture
The '120 Patent Accused Instrumentalities	Accused Instrumentalities, including the Galaxy S20 series, includes a control signal based, at least in part, on a power consumption of the first and second circuitry. See <i>supra</i> claim element [25c], which is incorporated by reference. The features of SmartTransmit are described as follows:  Qualcomm® Smart Transmit™ 3.0 Introducing Wi-Fi and Bluetooth® radios Manage transmit power across radios in real time Increase uplink throughput and coverage Smart multi-beam management Support 2G-5G including mmWave Support for Wi-Fi and Bluetooth radios Smart Transmit Gen 1 Unique system level technology for optimized uplink introduced Smart Transmit Gen 2 Adding time-averaging and spatial averaging of power across multiple antennas Smart Transmit Gen 3 Integrates Wi-Fi and Bluetooth into smart transmit architecture		

'120 Patent	The '120 Patent Accused Instrumentalities https://www.youtube.com/watch?v=nrlicMdlak. For example, with Smart Transmit technology, transmit power may exceed the average power limit at certain times and transmit power may be less than the average power limit at other times, as shown below.  https://www.youtube.com/watch?v=KUh7NlpSZw. Qualcomm states that “Smart Transmit technology takes advantage of modem-to-antenna system awareness to optimize uplink speeds while complying with RF transmitter power limits. Higher transmit power helps extend coverage and improve uplink speeds.” https://www.youtube.com/watch?v=KUh7NlpSZw. As another example, a Samsung submission to the FCC describes Smart Transmit as follows:
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'120 Patent	The '120 Patent Accused Instrumentalities
	The Smart Transmit algorithm controls and manages the instantaneous transmit power (Tx) to maintain the time-averaged Tx power (in turn, time-averaged RF exposure) in compliance with FCC limits.... If time-averaged transmit power approaches the P_{limit}, then the modem needs to limit instantaneous transmit power to ensure the time-averaged transmit power does not exceed the P_{limit}... The wireless device can instantaneously transmit at high transmit powers and exceed the P_{limit} ... level for a short duration before limiting the power to maintain the time-averaged transmit power under P_{limit}.” https://fccid.io/A3LSMN976V/RF-Exposure-Info/Smart-Transmit-Summary-Report-4354628. As a further example, Qualcomm stated as follows: Smart Transmit uses advanced techniques to intelligently manage transmit power across multiple antenna groups, enabling significantly extended coverage, improved uplink speeds, and lower latency — especially important to meet the high expectations for today’s 5G devices and networks, all while ensuring devices remain compliant with regulatory requirements. https://www.qualcomm.com/news/onq/2022/02/meet-inventor-behind-qualcomm-smart-transmit-breakthrough-technology-optimizes.
[25e] wherein the control signal is based, at least in part, on an idle power consumption of the mobile station.	The '120 Patent Accused Instrumentalities include a control signal based, at least in part, on an idle power consumption of the mobile station. For example, Smart Transmit technology incorporated into the '120 Patent Accused Instrumentalities, including the Galaxy S20 series, includes a control signal based, at least in part, on a transmission power of the transceiver during an idle time. See <i>supra</i> claim elements [25c] and [25d], which are incorporated by reference. For example, a Samsung submission to the FCC describes Smart Transmit as follows:

'120 Patent	The '120 Patent Accused Instrumentalities To avoid dropping the radio link, Smart Transmit algorithm starts the power limiting enforcement earlier in time to back off the Tx power to a reserve level (denoted as $P_{reserve}$), so the wireless device can maintain the radio link at a minimum reserve power level for as long as needed, and at the same time ensure the time-averaged Tx power over any defined time window is less than P_{limit} at all times (see Figure [3.2]). Figure 3-2 Transmit with reserve power to support continuous transmission at a minimum power level ($P_{reserve}$) https://fccid.io/A3LSMN976V/RF-Exposure-Info/Smart-Transmit-Summary-Report-4354628. As another example, Samsung submitted a “RF Exposure Evaluation Report” to the FCC in connection with its Galaxy S20 smartphone, i.e., one of the '120 Patent Accused Instrumentalities. This report includes the results of a “Call Drop Test Case” in which “the transmitting power kept the same Preserve level” greater than zero dBm as shown in the plot below “after the call was re-established”:
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'120 Patent	The '120 Patent Accused Instrumentalities 9.2 Call Drop Test Case This test was measured LTE Band 48, Antenna F, DSI=3, and with callbox requesting maximum power. The call drop was manually performed when the DUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black region). The measurement setup is shown in Figure 6-1. The detailed test procedure is described in Section 4.3.2. <u>Call drop test result:</u> Plot 1: Measured Tx power (dBm) versus time shows that the transmitting power kept the same $P_{reserve}$ level of LTE Band 48 after the call was re-established: https://fcc.report/FCC-ID/A3LSMG981V/4728830.
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'120 Patent	The '120 Patent Accused Instrumentalities
	FCC ID: A3L SMG988U External Photographs 

'120 Patent	The '120 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=s3p85PbIvL3JWmQHP6peg%3D%3D&fcc_id=A3LSMG988U (external photos). As another example, the Galaxy S20 5G is a mobile station for use in a cellular network communication system. Specifically, below is a photograph of a Galaxy S20 5G mobile station submitted by Samsung to the FCC.

'120 Patent	The '120 Patent Accused Instrumentalities
	FCC ID: A3LSMG981U, IC: 649E-SMG981U, HVIN: SM-G981W External Photographs 

'120 Patent	The '120 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=8Twxpjxm25uB8pCHfwZLA%3D%3D&fcc_id=A3LSMG981U (external photos).
[29a] a first antenna and a second antenna	The '120 Patent Accused Instrumentalities include at least a first antenna and a second antenna. For example, Galaxy S20 series smartphones include at least a first antenna and a second antenna. Below is an image from Samsung's submission to the FCC for a Galaxy S20 Ultra 5G model showing antenna locations:



Note: Exact antenna dimensions and separation distances are shown in the Technical Descriptions in the FCC Filing.

Figure E-1
DUT Antenna Locations

FCC ID: A3LSMG988U	SAR EVALUATION REPORT		Approved by: Quality Manager
Test Dates: 11/18/19 – 01/23/20	DUT Type: Portable Handset		APPENDIX E: Page 2 of 14

'120 Patent	The '120 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=s3p85PbIvL3JWmQHP6peg%3D%3D&fcc_id=A3LSMG988U (SAR Test Setup Photos). As another example, below is an image from Samsung's submission to the FCC for a Galaxy S20 5G model showing antenna locations:

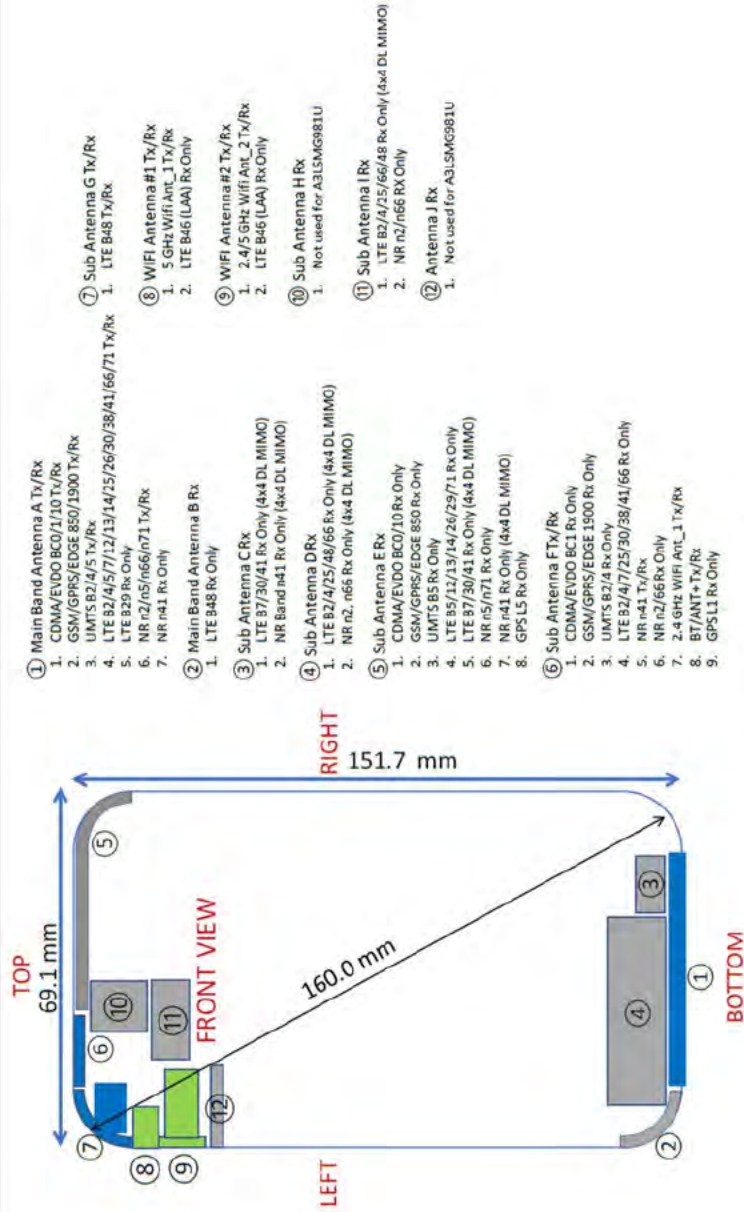
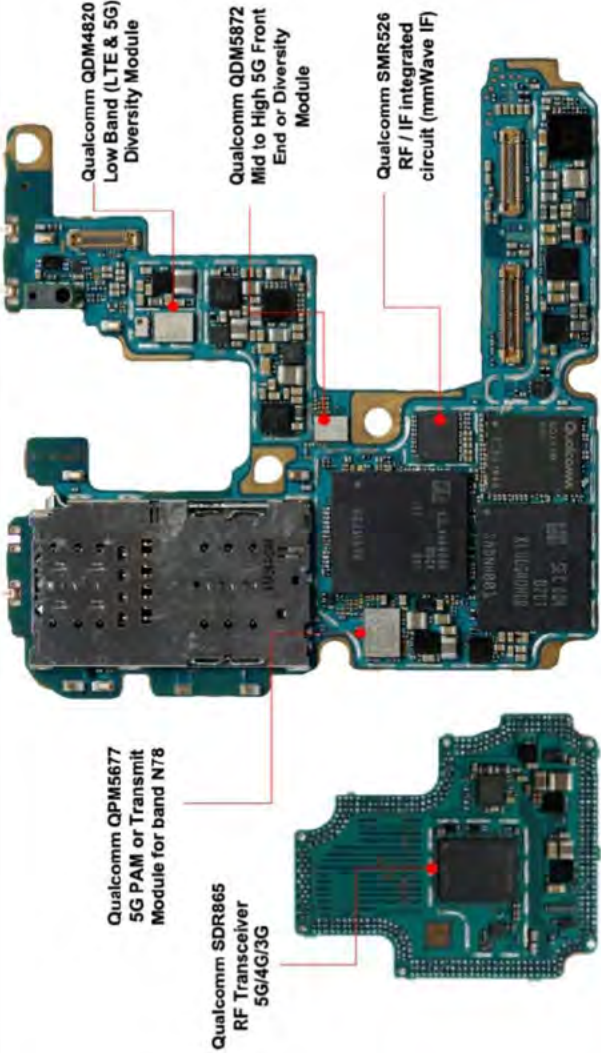


Figure E-1
DUT Antenna Locations

FCC ID: A3LSMG981U	PCTEST	SAR EVALUATION REPORT	SAMSUNG	Approved by: Quality Manager
Test Dates: 10/23/19 - 12/18/19	DUT Type: Portable Handset			APPENDIX E: Page 2 of 14

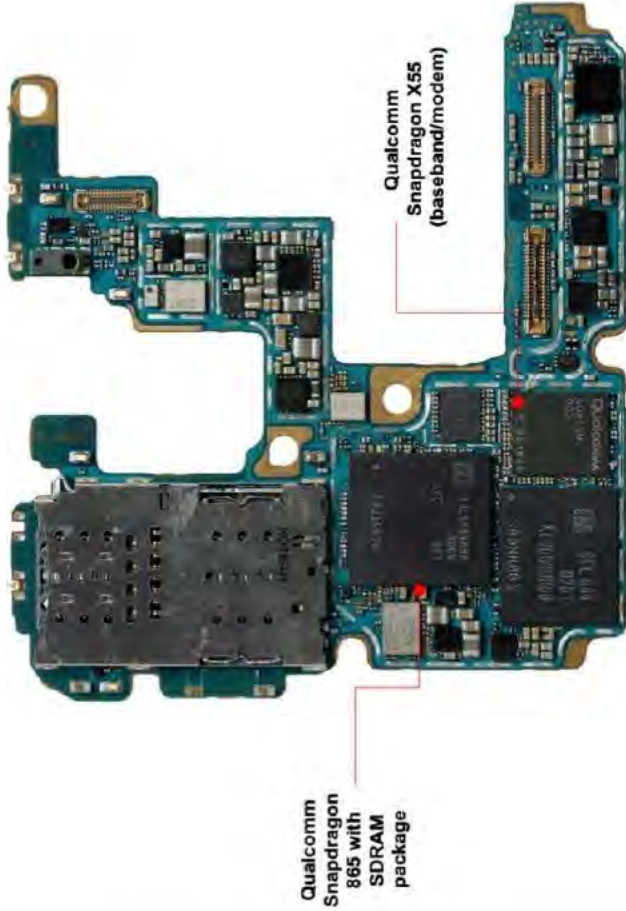
'120 Patent	The '120 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=8Twxpjxm25uB8pCHfvZLA%3D%3D&fcc_id=A3LSMG981U (Test Setup Photos).
[29b] first circuitry coupled to the first antenna and configured to process signals for transmission by the first antenna; second circuitry coupled to the second antenna and configured to process signals for transmission by the second antenna; and	The '120 Patent Accused Instrumentalities include first circuitry coupled to the first antenna and configured to process signals for transmission by the first antenna and second circuitry coupled to the second antenna and configured to process signals for transmission by the second antenna. For example, the Galaxy S20 Ultra 5G includes first circuitry coupled to the first antenna and configured to process signals for transmission by the first antenna and second circuitry coupled to the second antenna and configured to process signals for transmission by the second antenna. More specifically, e.g., the three annotated images below show modules and circuitry for processing signals in the Galaxy S20 Ultra 5G (Model Number SM-G988U1):

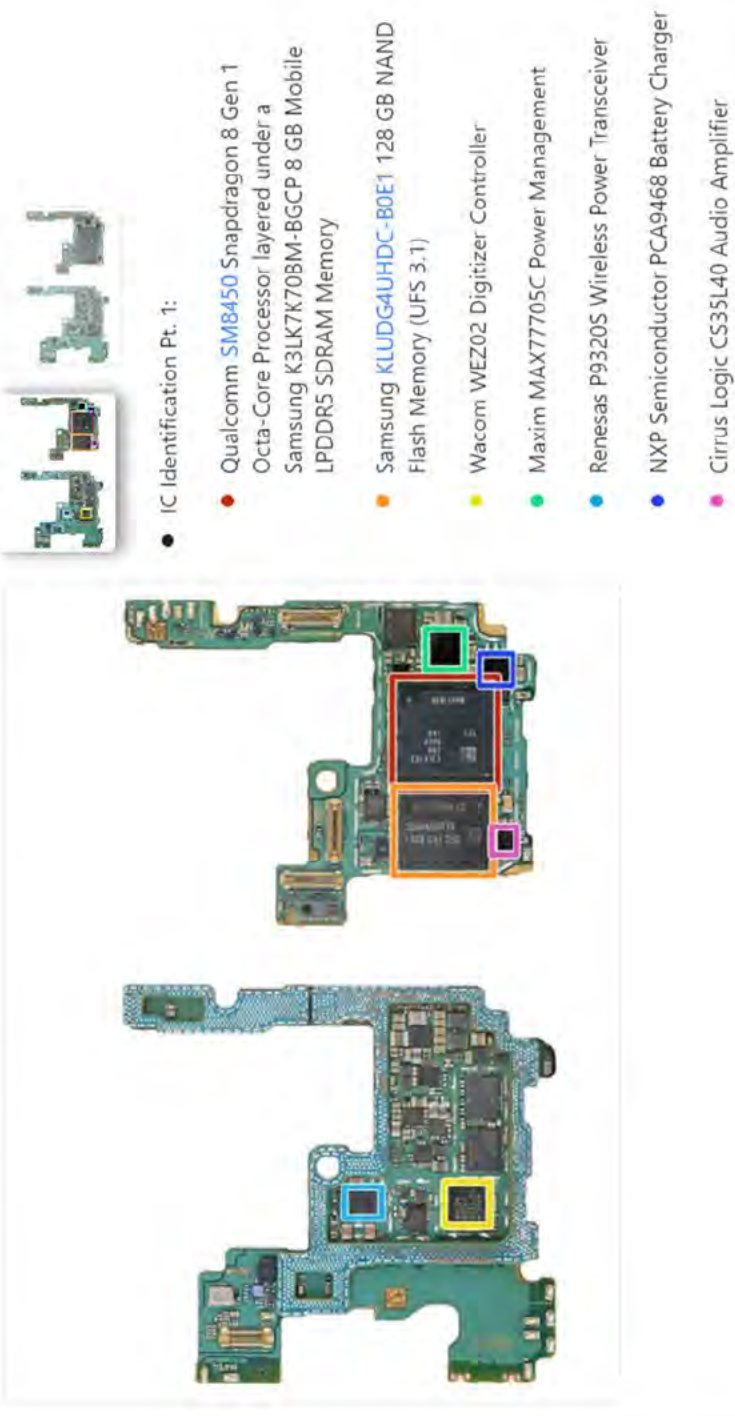
'120 Patent	The '120 Patent Accused Instrumentalities
	

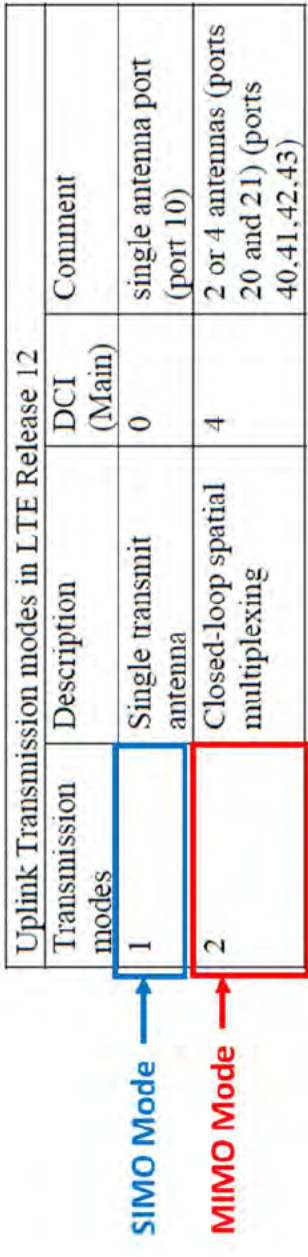
'120 Patent	The '120 Patent Accused Instrumentalities
	Qualcomm QAT5515 Antenna Tuner Qualcomm QDM4870 Mid to High Band (LTE) Diversity Module Qualcomm QPM6585 Band N41 Transmit module Qualcomm QDM4850 (1st) UHF 5G Diversity Module Qualcomm QDM4850 (2nd) Qualcomm QDM4850 (3rd) Unpopulated pad for UL-MIMO Qualcomm PMX55 PMIC for X55 Modem

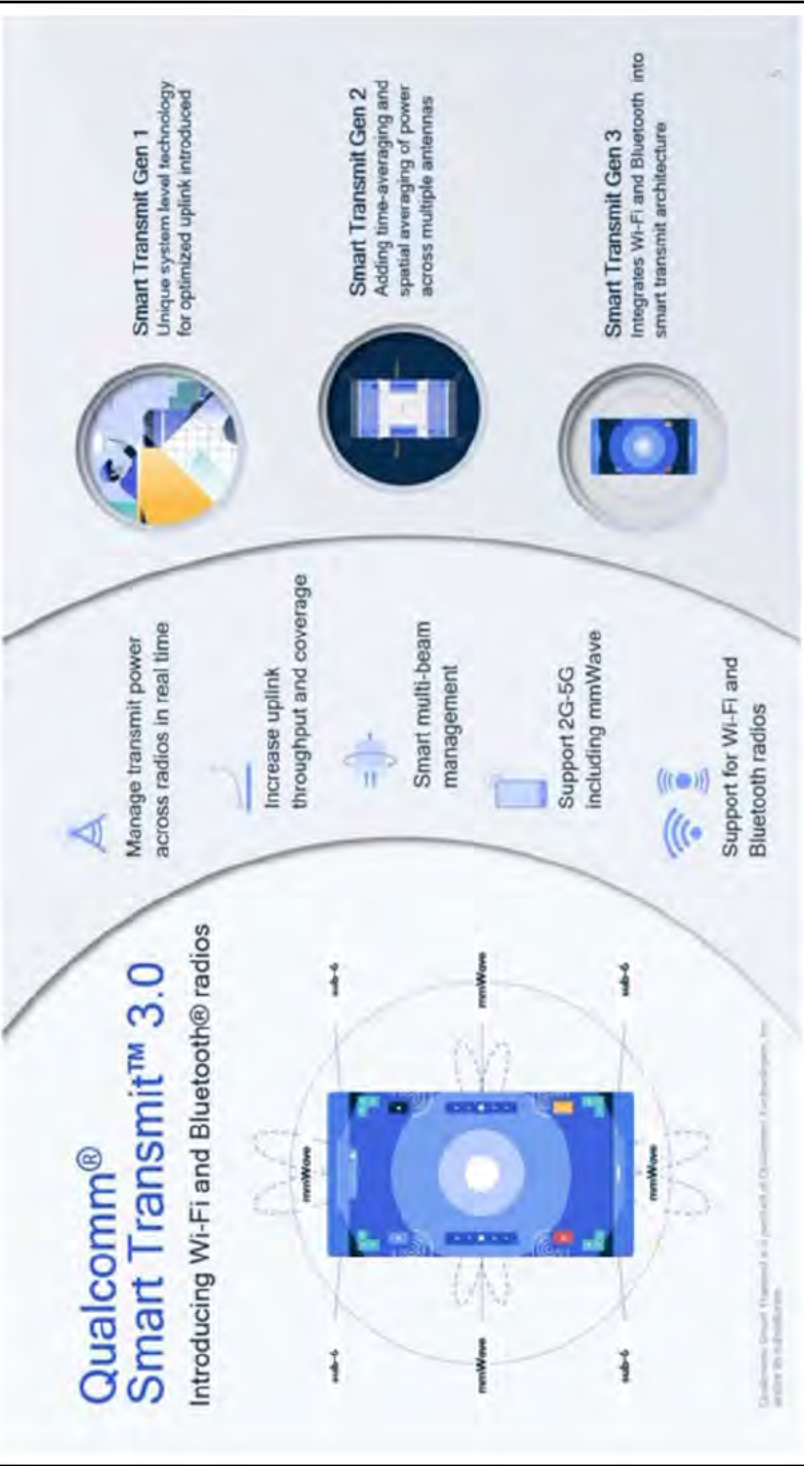
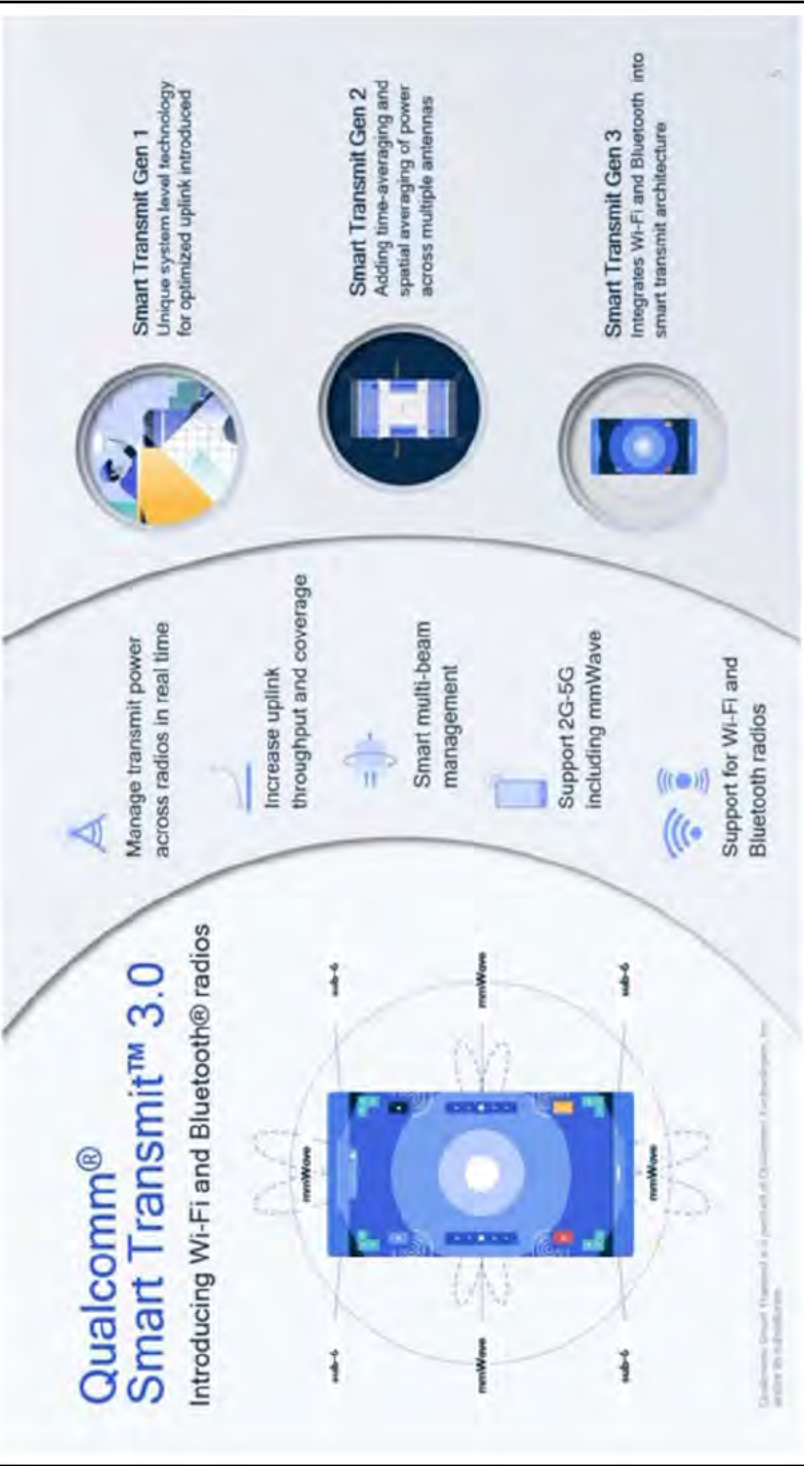
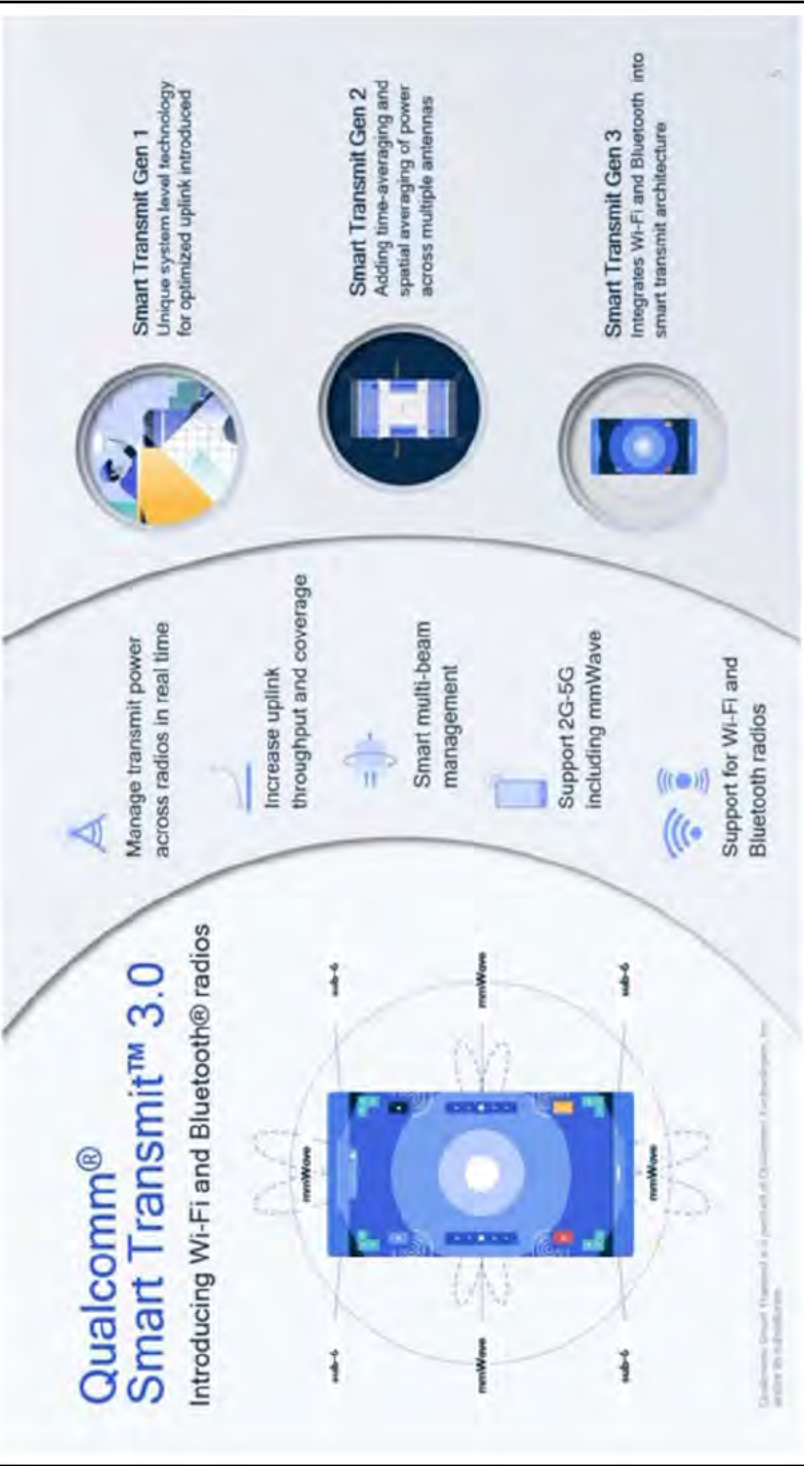
'120 Patent	The '120 Patent Accused Instrumentalities https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra#c66138ec-595f-4a26-a02a-3e0acbf3e83e. One of Defendants' suppliers, Qualcomm, states that its "second-generation RF front-end (RFFE) solutions for 5G multi-mode mobile devices ... represent a comprehensive RF solution designed to work with the new Qualcomm® Snapdragon™ X55 5G modem, delivering a comprehensive modem-to-antenna system for high-performance 5G mobile devices supporting both sub-6 GHz and millimeter wave (mmWave) bands." These RFFE solutions comprise power amplifiers and diversity modules that include the following:
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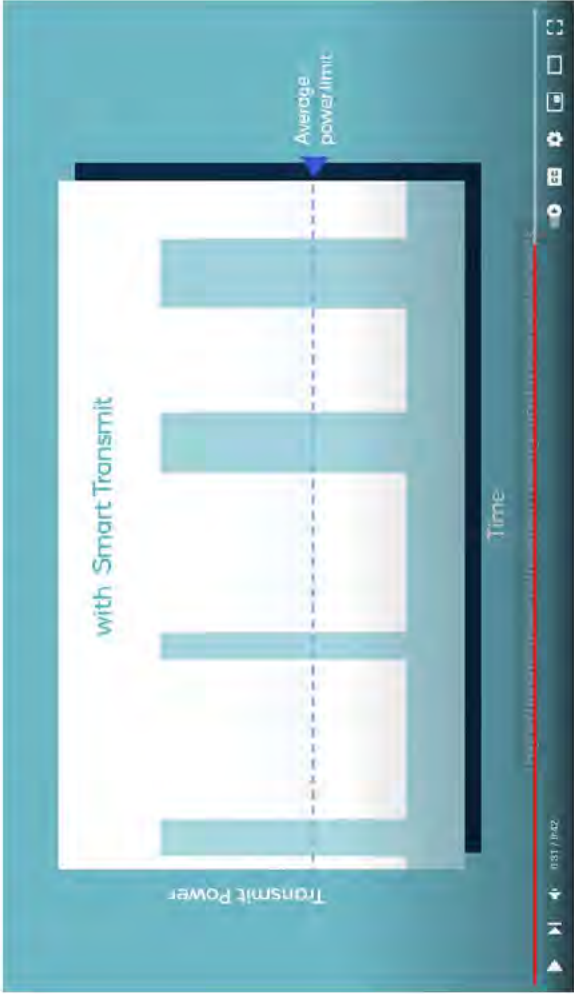
'120 Patent	The '120 Patent Accused Instrumentalities
	• PA modules which pair with QET6100 to support 100 MHz 5G envelope tracking. QPM6585, QPM5677 and QPM5679 for bands n41, n77/78 and n79 respectively. • Mid/High-band 5G/4G PA module QPM5670 features integrated LNA, switch, filters and 5G hexaplexer. • Low-band 5G/4G PA module QPM5621 with integrated LNA, switch and filters, and support for low-band/low-band carrier aggregation and dual connectivity. • Diversity module family QDM58xx, featuring integrated 5G/4G LNA, switch and filters for receive diversity and MIMO support for sub-6 GHz bands. https://www.qualcomm.com/news/releases/2019/02/qualcomm-announces-second-generation-5g-rf-front-end-solutions-sleeper-more.
[29c] a controller coupled to the first and second circuitry, wherein the controller is configured to receive a control signal and, in accordance with the control signal, to select between a multiple-input multiple-output (MIMO) mode wherein both the	The '120 Patent Accused Instrumentalities include a controller coupled to the first and second circuitry, wherein the controller is configured to receive a control signal and, in accordance with the control signal, to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a SIMO mode wherein only one of the first and second antennas transmit data over a communications channel. For example, the Galaxy S20 models includes a controller coupled to the first and second circuitry and configured to receive a control signal and, in accordance with the control signal, to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a SIMO mode wherein only one of the first and second antennas transmit data over a communications channel. Specifically, the annotated image below shows a Snapdragon 865 5G chipset and Snapdragon X55 modem in the Galaxy S20 Ultra 5G (Model Number SM-G988U1):

The '120 Patent Accused Instrumentalities	'120 Patent first and second antennas transmit data over a communications channel and a single-input multiple-output (SIMO) mode wherein only one of the first and second antennas transmit data over a communications channel  https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra#c66138ec-595f-4a26-a02a-3e0acbf3e83e. Similarly, the Samsung Galaxy S22 Ultra includes the “Snapdragon 8 Gen 1” chipset, which includes a Snapdragon X65 5G modem, and includes a controller coupled to the first and second circuitry and configured to receive a control signal and, in accordance with the control signal, to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a SIMO mode wherein only one of the first and second antennas transmit data over a communications channel.
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'120 Patent	The '120 Patent Accused Instrumentalities https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php; https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/snapdragon-8-gen-1-mobile-platform-product-brief.pdf. Specifically, the annotated image below shows a Snapdragon 8 Gen 1 chipset, outlined in red, in the Galaxy S22 Ultra: 
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'120 Patent	https://www.ifixit.com/Guide/Samsung+Galaxy+S22+Ultra+Chip+ID/148073. Qualcomm describes Snapdragon X65 as designed to “[b]reak through the 10 Gbps barrier in both 5G non-standalone (NSA) and standalone (SA) modes. This modem-to-antenna solution features an all-new Qualcomm 545 mmWave Antenna Module, next-gen Qualcomm Wideband Envelope Tracking and Qualcomm AI-Enhanced Signal Boost to help achieve unmatched data speeds and coverage.” https://www.qualcomm.com/products/technology/modems/snapdragon-x65-5g-modem-rf-system. For example, the '120 Patent Accused Instrumentalities include a controller that is configured to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a SIMO mode wherein only one of the first and second antennas transmit data over a communications channel at least because they are compatible with LTE Release 12: <table><tr><th colspan="4">Uplink Transmission modes in LTE Release 12</th></tr><tr><th>Transmission modes</th><th>Description</th><th>DCI (Main)</th><th>Comment</th></tr><tr><td>1</td><td>Single transmit antenna</td><td>0</td><td>single antenna port (port 10)</td></tr><tr><td>2</td><td>Closed-loop spatial multiplexing</td><td>4</td><td>2 or 4 antennas (ports 20 and 21) (ports 40,41,42,43)</td></tr></table> SIMO Mode → MIMO Mode → Table 6: The two uplink transmission modes in LTE Release 12. https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_application/application_notes/1ma186/1MA186_2e_LTE_TMs_and_beamforming.pdf (annotated).	Uplink Transmission modes in LTE Release 12				Transmission modes	Description	DCI (Main)	Comment	1	Single transmit antenna	0	single antenna port (port 10)	2	Closed-loop spatial multiplexing	4	2 or 4 antennas (ports 20 and 21) (ports 40,41,42,43)
Uplink Transmission modes in LTE Release 12																	
Transmission modes	Description	DCI (Main)	Comment														
1	Single transmit antenna	0	single antenna port (port 10)														
2	Closed-loop spatial multiplexing	4	2 or 4 antennas (ports 20 and 21) (ports 40,41,42,43)														
[29d] wherein the control signal is based, at least in	The '120 Patent Accused Instrumentalities include a control signal based, at least in part, on a power consumption of the first and second circuitry. For example, Smart Transmit technology incorporated into the '120 Patent																

'120 Patent	<table><tr><td data-bbox="191 609 289 1646"> The '120 Patent Accused Instrumentalities </td><td data-bbox="289 189 1380 1646"> Accused Instrumentalities, including the Galaxy S20 series, includes a control signal based, at least in part, on a power consumption of the first and second circuitry. See <i>supra</i> claim element [29c], which is incorporated by reference. The features of SmartTransmit are described as follows:  The advertisement for Qualcomm Smart Transmit™ 3.0 features a central image of a smartphone with concentric circles representing signal range, labeled 'mmWave' and 'sub-6'. To the right, three circular icons represent 'Smart Transmit Gen 1', 'Gen 2', and 'Gen 3'. Gen 1 is described as 'Unique system level technology for optimized uplink introduced'. Gen 2 is 'Adding time-averaging and spatial averaging of power across multiple antennas'. Gen 3 is 'Integrates Wi-Fi and Bluetooth into smart transmit architecture'. Below the smartphone image, several features are listed: 'Manage transmit power across radios in real time', 'Increase uplink throughput and coverage', 'Smart multi-beam management', 'Support 2G-5G including mmWave', and 'Support for Wi-Fi and Bluetooth radios'. The text 'Qualcomm Smart Transmit™ 3.0 Introducing Wi-Fi and Bluetooth® radios' is prominently displayed. </td></tr></table>	The '120 Patent Accused Instrumentalities	Accused Instrumentalities, including the Galaxy S20 series, includes a control signal based, at least in part, on a power consumption of the first and second circuitry. See <i>supra</i> claim element [29c], which is incorporated by reference. The features of SmartTransmit are described as follows:  The advertisement for Qualcomm Smart Transmit™ 3.0 features a central image of a smartphone with concentric circles representing signal range, labeled 'mmWave' and 'sub-6'. To the right, three circular icons represent 'Smart Transmit Gen 1', 'Gen 2', and 'Gen 3'. Gen 1 is described as 'Unique system level technology for optimized uplink introduced'. Gen 2 is 'Adding time-averaging and spatial averaging of power across multiple antennas'. Gen 3 is 'Integrates Wi-Fi and Bluetooth into smart transmit architecture'. Below the smartphone image, several features are listed: 'Manage transmit power across radios in real time', 'Increase uplink throughput and coverage', 'Smart multi-beam management', 'Support 2G-5G including mmWave', and 'Support for Wi-Fi and Bluetooth radios'. The text 'Qualcomm Smart Transmit™ 3.0 Introducing Wi-Fi and Bluetooth® radios' is prominently displayed.
The '120 Patent Accused Instrumentalities	Accused Instrumentalities, including the Galaxy S20 series, includes a control signal based, at least in part, on a power consumption of the first and second circuitry. See <i>supra</i> claim element [29c], which is incorporated by reference. The features of SmartTransmit are described as follows:  The advertisement for Qualcomm Smart Transmit™ 3.0 features a central image of a smartphone with concentric circles representing signal range, labeled 'mmWave' and 'sub-6'. To the right, three circular icons represent 'Smart Transmit Gen 1', 'Gen 2', and 'Gen 3'. Gen 1 is described as 'Unique system level technology for optimized uplink introduced'. Gen 2 is 'Adding time-averaging and spatial averaging of power across multiple antennas'. Gen 3 is 'Integrates Wi-Fi and Bluetooth into smart transmit architecture'. Below the smartphone image, several features are listed: 'Manage transmit power across radios in real time', 'Increase uplink throughput and coverage', 'Smart multi-beam management', 'Support 2G-5G including mmWave', and 'Support for Wi-Fi and Bluetooth radios'. The text 'Qualcomm Smart Transmit™ 3.0 Introducing Wi-Fi and Bluetooth® radios' is prominently displayed.		

'120 Patent	The '120 Patent Accused Instrumentalities
	https://www.youtube.com/watch?v=nrlicMdlak. For example, with Smart Transmit technology, transmit power may exceed the average power limit at certain times and transmit power may be less than the average power limit at other times, as shown below.  https://www.youtube.com/watch?v=KUh7NlpSZw. Qualcomm states that “Smart Transmit technology takes advantage of modem-to-antenna system awareness to optimize uplink speeds while complying with RF transmitter power limits. Higher transmit power helps extend coverage and improve uplink speeds.” https://www.youtube.com/watch?v=KUh7NlpSZw. As another example, a Samsung submission to the FCC describes Smart Transmit as follows:

'120 Patent	The '120 Patent Accused Instrumentalities
	The Smart Transmit algorithm controls and manages the instantaneous transmit power (Tx) to maintain the time-averaged Tx power (in turn, time-averaged RF exposure) in compliance with FCC limits.... If time-averaged transmit power approaches the P_{limit}, then the modem needs to limit instantaneous transmit power to ensure the time-averaged transmit power does not exceed the P_{limit}... The wireless device can instantaneously transmit at high transmit powers and exceed the P_{limit} ... level for a short duration before limiting the power to maintain the time-averaged transmit power under P_{limit}.” https://fccid.io/A3LSMN976V/RF-Exposure-Info/Smart-Transmit-Summary-Report-4354628. As a further example, Qualcomm stated as follows: Smart Transmit uses advanced techniques to intelligently manage transmit power across multiple antenna groups, enabling significantly extended coverage, improved uplink speeds, and lower latency — especially important to meet the high expectations for today’s 5G devices and networks, all while ensuring devices remain compliant with regulatory requirements. https://www.qualcomm.com/news/onq/2022/02/meet-inventor-behind-qualcomm-smart-transmit-breakthrough-technology-optimizes.
[29e] wherein the control signal is based, at least in part, on a number of users of the communications system.	The '120 Patent Accused Instrumentalities include a control signal based, at least in part, on a number of users of the communications system. For example, Smart Transmit technology incorporated into the '120 Patent Accused Instrumentalities, including the Galaxy S20 series, includes a control signal based, at least in part, on a number of users of the communications system. See <i>supra</i> claim elements [29c] and [29d], which are incorporated by reference. For example, the '120 Patent Accused Instrumentalities include a controller that is configured to select between a MIMO mode wherein both the first and second antennas transmit data over a communications channel and a

'120 Patent	The '120 Patent Accused Instrumentalities
	SIMO mode wherein only one of the first and second antennas transmit data over a communications channel at least because they are compatible with LTE Release 12:

'120 Patent	The '120 Patent Accused Instrumentalities
	The number of component carriers that can be used in a wireless communication system depends on the available spectrum and the technology used. In LTE, a maximum of five component carriers can be used, while in NR, up to 16 component carriers can be used. ... The use of Component Carrier provides several benefits in wireless communication systems, including... flexibility in terms of allocating frequency bands to different services and users, depending on the traffic demands and available spectrum.” https://www.telecomtrainer.com/cc-component-carrier-2/#:~:text=Component%20Carrier%20(CC)%20is%20a,a%20specific%20user%20or%20service. Thus, when the controller in the '120 Patent Accused Instrumentalities selects between a MIMO mode or a SIMO mode depends, at least in part, on the number of supported uplink CCs needed, which in turn depends on “allocating frequency bands to different services and users, depending on the traffic demands and available spectrum.” https://www.telecomtrainer.com/cc-component-carrier-2/#:~:text=Component%20Carrier%20(CC)%20is%20a,a%20specific%20user%20or%20service.

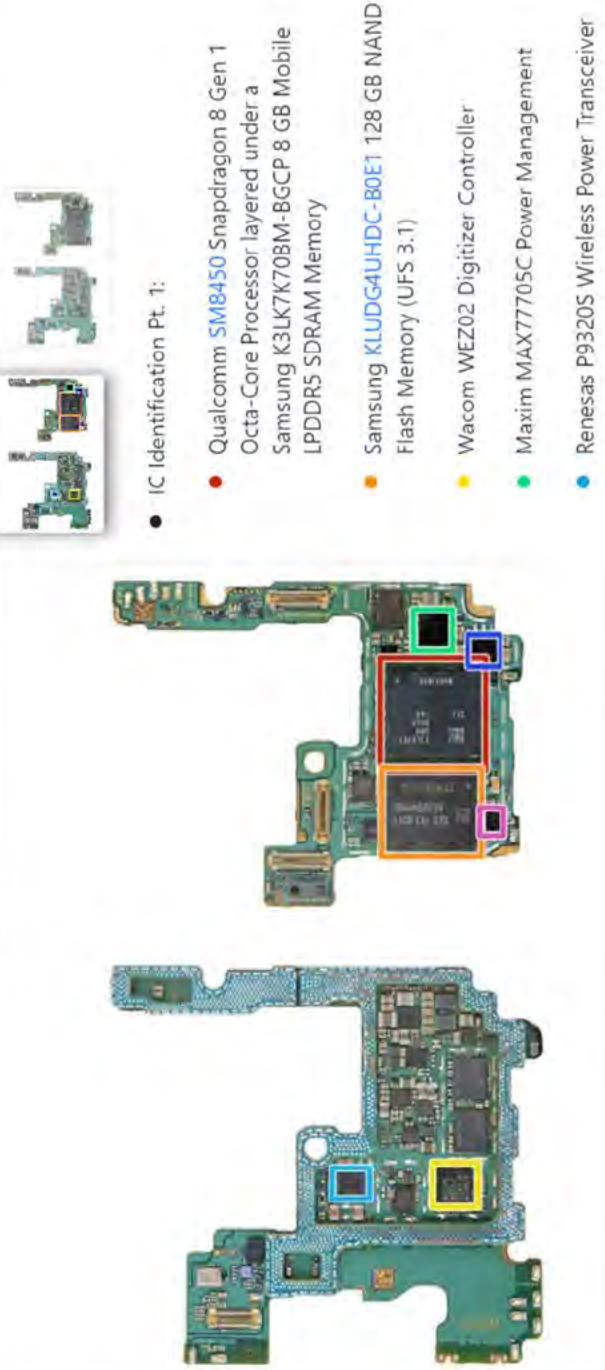
EXHIBIT B

'331 Patent Accused Instrumentalities: The '331 Patent Accused Instrumentalities include Samsung apparatuses, products, systems, services, devices, processes, methods, acts, components (hardware and/or software), and/or other instrumentalities that decode a signal transmitted over a 5G communications channel and that perform certain channel estimation in MIMO. More specifically, the '331 Patent Accused Instrumentalities include, without limitation, all instrumentalities with 5G-compatible modems and/or other components in the RF chain that perform certain channel estimation including, without limitation, the Galaxy S10 5G series phones; the Galaxy Note series phones; the Galaxy A 5G series phones; the Galaxy Z Fold series phones; the Galaxy S20 series, S21 series, S22 series, and S23 series phones; the Galaxy Z Flip series phones; the Galaxy M 5G series phones; the Galaxy F 5G series phones; the Galaxy Xcover 6 Pro series phones; and the Galaxy Tab series tablets. The '331 Patent Accused Instrumentalities identified by model number above are hereby incorporated by reference. *See supra* Section II.B.

'331 Patent	The '331 Patent Accused Instrumentalities
[1] A method of decoding a signal transmitted over a communications channel, the method comprising:	The '331 Patent Accused Instrumentalities perform a method of decoding a signal transmitted over a communications channel. For example, the Galaxy S20 Ultra 5G includes, and Samsung's specifications identify, the "Snapdragon 865 5G" chipset, which includes the Snapdragon X55 modem, and decodes a signal transmitted over a communication channel. https://www.gsmarena.com/samsung_galaxy_s20_ultra_5g-10040.php;https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/prod_brief_qcom_sd865_5g.pdf. Specifically, the annotated image below shows a Snapdragon 865 5G chipset and Snapdragon X55 modem in the Galaxy S20 Ultra 5G (Model Number SM-G988U1):

'331 Patent	The '331 Patent Accused Instrumentalities https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra#c66138ec-595f-4a26-a02a-3e0acbf3e83e. More specifically, as a non-limiting example, “Snapdragon X55 is designed to provide comprehensive support for 5G NR TDD and FDD.... While driving 5G forward, we also continue to innovate and push 4G LTE boundaries. Snapdragon X55 features cutting-edge LTE features, including 24 spatial streams, 4x4 MIMO, and 1024-QAM.” https://www.qualcomm.com/news/onq/2019/02/meet-snapdragon-x55-worlds-most-advanced-commercial-5g-modem; see also https://www.qualcomm.com/content/dam/qcomm-martech/dm-
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'331 Patent	The '331 Patent Accused Instrumentalities
	assets/documents/x55_9_final.pdf (“World’s most advanced commercial 5G modem,” with 4G/LTE “FD-MIMO”). As another example, the Samsung Galaxy S22 Ultra includes the “Snapdragon 8 Gen 1” chipset, which includes a Snapdragon X65 5G modem, and decodes a signal transmitted over a communication channel. https://www.gsmarena.com/samsung_galaxy_s22_ultra_5g-11251.php; https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/snapdragon-8-gen-1-mobile-platform-product-brief.pdf. Specifically, the annotated image below shows a Snapdragon 8 Gen 1 chipset, outlined in red, in the Galaxy S22 Ultra:

'331 Patent	The '331 Patent Accused Instrumentalities  ● IC Identification Pt. 1: ● Qualcomm SM8450 Snapdragon 8 Gen 1 Octa-Core Processor layered under a Samsung K3LK7K70BM-BGCP 8 GB Mobile LPDDR5 SDRAM Memory ● Samsung KLUDG4UHDG-B0E1 128 GB NAND Flash Memory (UFS 3.1) ● Wacom WEZ02 Digitizer Controller ● Maxim MAX77705C Power Management ● Renesas P93205 Wireless Power Transceiver ● NXP Semiconductor PCA9468 Battery Charger ● Cirrus Logic CS35L40 Audio Amplifier https://www.ifixit.com/Guide/Samsung+Galaxy+S22+Ultra+Chip+ID/148073. More specifically, as a non-limiting example, Snapdragon X65 is designed to “[b]reak through the 10 Gbps barrier in both 5G non-standalone (NSA) and standalone (SA) modes. This modem-to-antenna solution features an all-new Qualcomm 545 mmWave Antenna Module, next-gen Qualcomm Wideband Envelope Tracking and Qualcomm AI-Enhanced Signal Boost to help achieve unmatched data speeds and coverage.” https://www.qualcomm.com/products/technology/modems/snapdragon-x65-5g-modem-rf-system.
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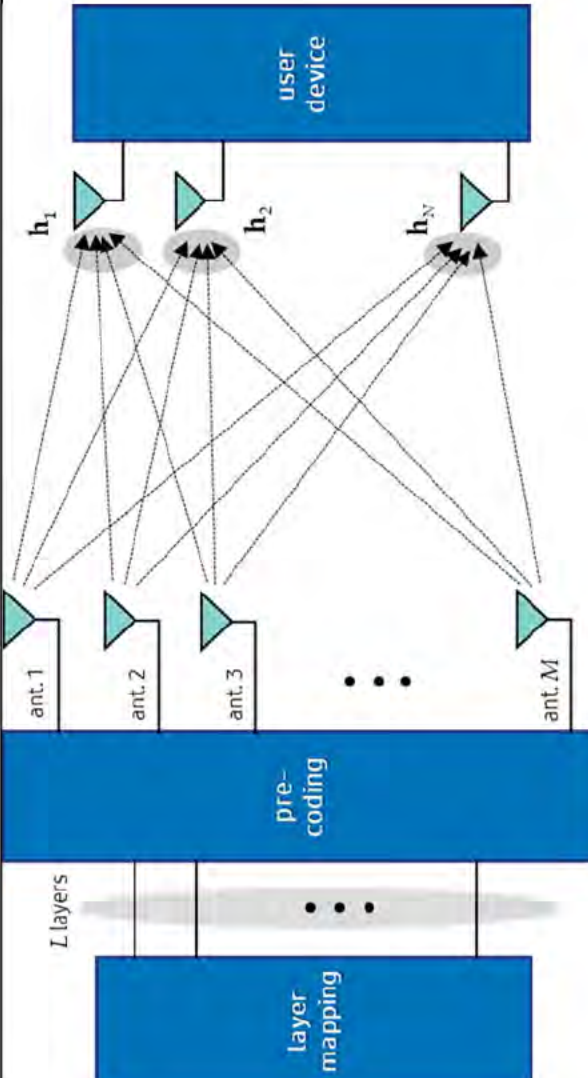
'331 Patent	The '331 Patent Accused Instrumentalities
[1a] receiving a pilot symbol over the communications channel	The '331 Patent Accused Instrumentalities perform the step of receiving a pilot symbol over the communications channel. For example, the Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain perform the step of receiving a pilot symbol over the communications channel. https://www.qualcomm.com/news/onq/2022/09/how-qualcomm-inventor-dr--kiran-mukavilli-helped-hash-out-the-f ("In this project, we developed a systematic methodology and provided solutions to several fundamental challenges of using OFDM in a mobile wireless system. For example, I started with designing pilot signals for figuring out the wireless link characteristics, including the number of paths the signal takes and the strength of each of the paths, which is referred to as channel estimation. A good, up-to-date channel estimate is essential to supporting high data rates on wireless channels, and pilot signals are used to estimate that wireless channel, which varies with time. <i>I came up with a pilot design based on periodic placement and staggering of pilot symbols both in frequency and over time, which became a fundamental structure in OFDM-based cellular systems in 4G and 5G. We then further expanded this pilot design in 5G to dynamically adapt the pilot pattern depending on a user's environment and mobility conditions....</i>") (emphasis added). A demodulation reference signal (DMRS) is a form of pilot used for channel estimation, e.g. "5G NR Reference signals DMRS, PT-RS, CSI-RS, SRS This page mentions 5G NR Reference signals viz. DMRS, PT-RS, CSI-RS, SRS. These 5G NR reference signals are used in the downlink and uplink. ... 5G NR DMRS • DMRS refers to Demodulation Reference Signal. • It is used by 5G NR receiver to produce channel estimates for demodulation of associated physical channel."

'331 Patent	The '331 Patent Accused Instrumentalities
	https://www.rfwireless-world.com/5G/5G-NR-Reference-Signals-DMRS-vs-PTRS-vs-CSI-RS-vs-SRS.html#:~:text=DMRS%20refers%20to%20Demodulation%20Reference%20Signal.&text=It%20is%20used%20by%205G.demodulation%20of%20associated%20physical%20channel.&text=The%20design%20and%20mapping%20of,%20C%20PDSCH%2C%20PUSCH%20and%20PUCCH Furthermore, numerous patents related to wireless communications reference cell phones, receiving a pilot signal. <i>See, e.g.,</i> U.S. Patent No. 9,985,802 at 1:38-39, Figure 12 (“whereby a UE that receives the pilot reference signal...”); U.S. Patent No. 9,967,070 at 9:15-17, Figure 5 (“In block 510 at least one frame with at least one pilot structure is received and processed by a UE”); U.S. Patent No. 10,868,650 at Figure 11 (“The pilot symbol is received...”).
[1b] estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol.	The '331 Patent Accused Instrumentalities perform the step of estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol. <i>See</i> [1a] above, which is incorporated by reference. For example, the Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain perform the step of estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol. Samsung describes 5G (New Radio), MIMO, and pilot-aided channel estimation as follows, for example: Another method of DL SU-MIMO is for a user to report a set of CSI measurement results consisting of channel quality indicator (CQI), PMI, and rank indicator (RI) to the base station. In this method, <i>the user device continuously monitors a set of M port reference signals at every receive antennas and constructs $(N \times M)$ MIMO channel matrix.</i> Samsung Technical White Paper, <i>Massive MIMO for New Radio</i>, December 2020 (emphasis added); <i>see also</i> https://www.qualcomm.com/news/onq/2022/09/how-qualcomm-inventor-dr--kiran-mukavilli-helped-hash-out-the-f (“A good, up-to-date channel estimate is essential to supporting high data rates on wireless

'331 Patent	The '331 Patent Accused Instrumentalities <i>channels, and pilot signals are used to estimate that wireless channel, which varies with time. I came up with a pilot design based on periodic placement and staggering of pilot symbols both in frequency and over time, which became a fundamental structure in OFDM-based cellular systems in 4G and 5G. We then further expanded this pilot design in 5G to dynamically adapt the pilot pattern depending on a user's environment and mobility conditions...."</i> (emphasis added). Moreover, as another example, 5G channel matrix estimation is based, at least in part, on a pilot symbol, e.g., see below: https://www.youtube.com/watch?v=TZzTsPQJDRo&t=562s (2:30-3:08 – PDSCH signal contains <i>data</i> and DMRS resource elements (REs) contain one or more <i>pilots</i>, as outlined in the 3GPP standard). As yet another example, U.S. Patent No. 9,985,802 entitled "Channel Estimation Enhancements" states that a user equipment "apparatus generates a channel estimate based on the received pilot." U.S. Patent No. 9,985,802 at 20:12-13, Fig. 12. Similarly, U.S. Patent No. 9,967,070 entitled "Pilot Reconfiguration and Retransmission
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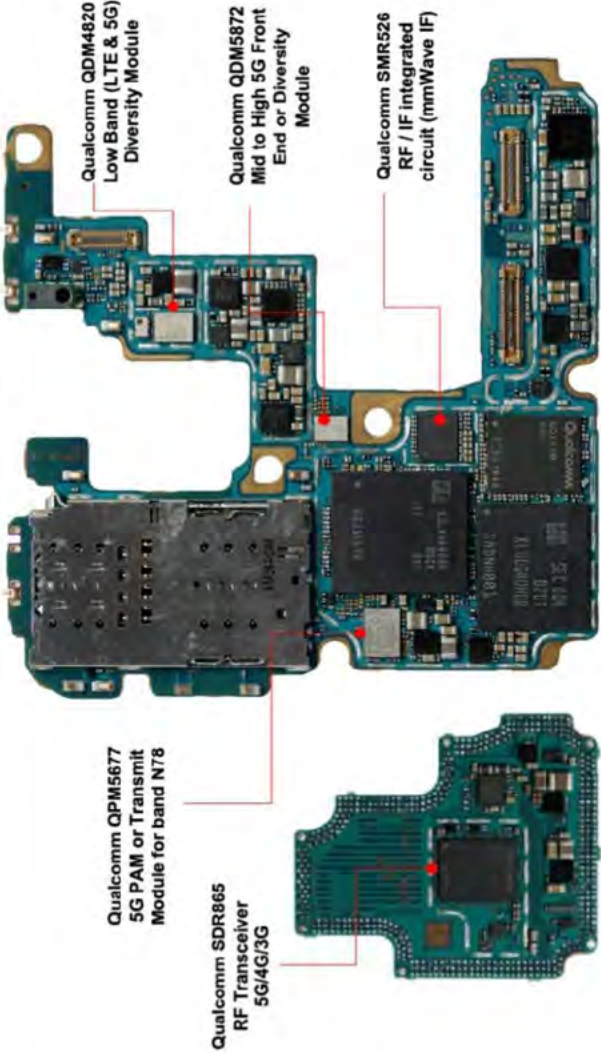
'331 Patent	The '331 Patent Accused Instrumentalities
	in Wireless Networks” states that “pilot data is typically a known data pattern that is processed in a known manner and may be used at the receiver system to estimate the channel response or other channel parameters. Pilot data may be formatted into pilot symbols.” U.S. Patent No. 9,967,070 at 4:22-26, Fig. 5.
[1c] receiving replicated data from multiple data streams transmitted over the communications channel	The '331 Patent Accused Instrumentalities perform the step of receiving replicated data from multiple data streams transmitted over the communications channel. For example, the Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain perform the step of receiving replicated data from multiple data streams transmitted over the communications channel. The Snapdragon 865 5G chipset and/or Snapdragon X55 modem employ spatial diversity, which is one transmission technique available in multiple-input multiple-output (MIMO) antenna systems utilized in 5G data networks. “Snapdragon X55 is designed to provide comprehensive support for 5G NR TDD and FDD..... While driving 5G forward, we also continue to innovate and push 4G LTE boundaries. Snapdragon X55 features cutting-edge LTE features, including 24 spatial streams, 4x4 MIMO, and 1024-QAM.” (https://www.qualcomm.com/news/onq/2019/02/meet-snapdragon-x55-worlds-most-advanced-commercial-5g-modem; see also https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/x55_9_final.pdf (“World’s most advanced commercial 5G modem,” with 4G/LTE “FD-MIMO”). Samsung describes 5G (New Radio), MIMO, and spatial diversity as follow, for example: Massive multi-input multi-output (MIMO) is a major breakthrough technology that improves the capacity and user experience of 5G eMBB. Instead of broadcasting data throughout the entire coverage area, the massive MIMO system concentrates the signal energy to a specific user, resulting in significant improvement of throughput and efficiency. This characteristic not only increases the downlink (DL) and uplink (UL) signal strength but also enhances the cell throughput <i>by allocating multiple beams to one or multiple users</i>. The spatially optimized signal can minimize its interference toward other users and/or

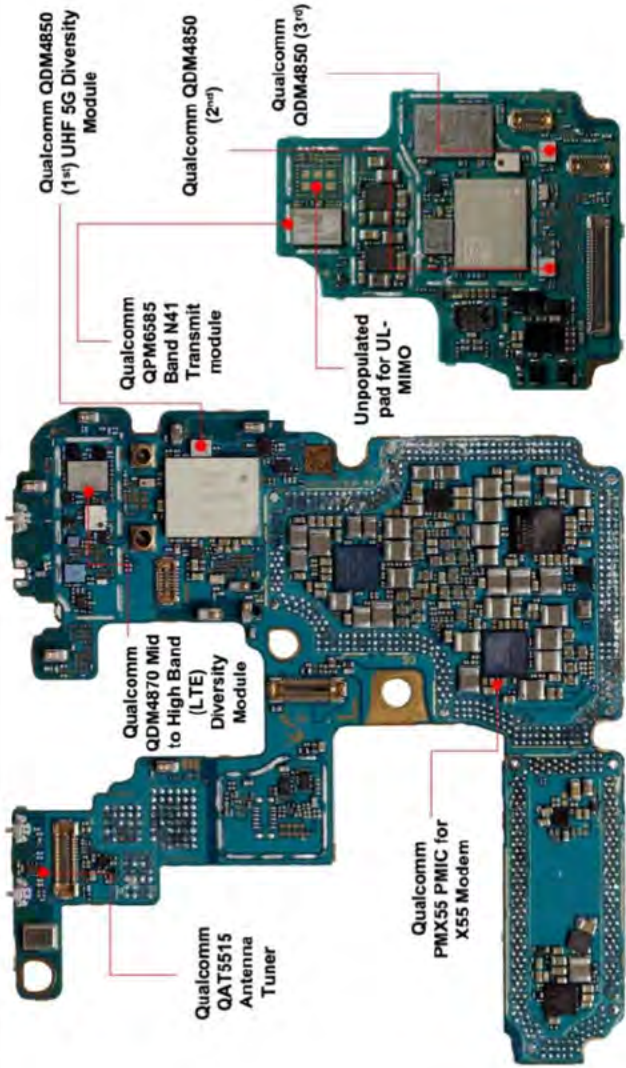
'331 Patent	The '331 Patent Accused Instrumentalities
	adjacent cells and reduces interference levels of the entire network, especially in interference limited cell deployments [1-2]. ... Allocation of multiple beams to different receive antennas of a single user increases the number of layers for single user (SU-) MIMO. The intensified signal power and increased number of layers contribute to better user throughput. ... Figure 5 depicts the MIMO channel model between M transmit antennas of massive MIMO base station and N receive antennas of the user device. ...

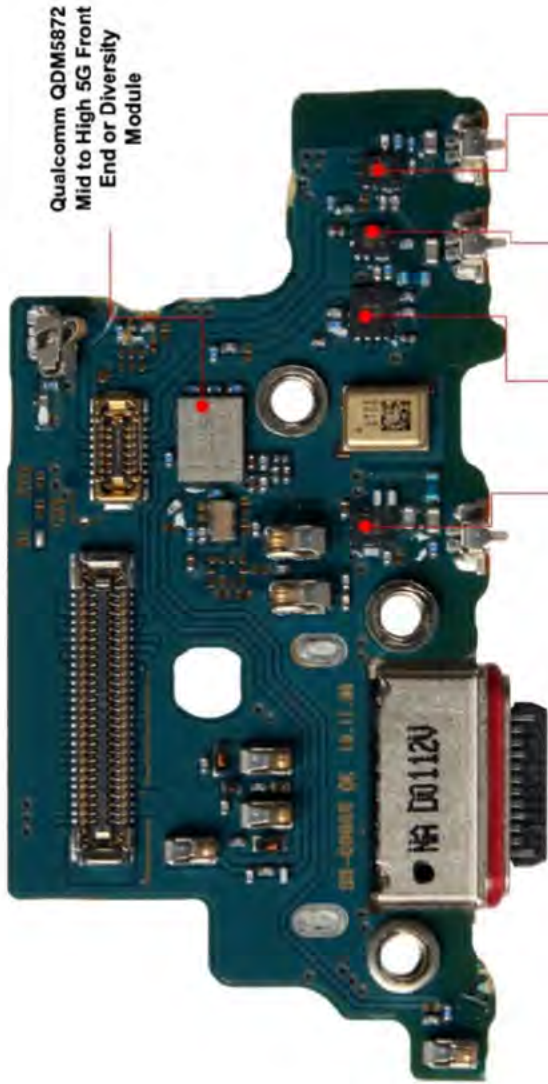
'331 Patent	The '331 Patent Accused Instrumentalities
	 Figure 5. Downlink Channel model for single user MIMO Samsung Technical White Paper, <i>Massive MIMO for New Radio</i>, December 2020 (emphasis added). Qualcomm describes 5G, MIMO, and spatial diversity as follows, as another example: “How 5G massive MIMO transforms your mobile experiences Qualcomm Technologies breakthroughs help enable 5G networks to serve more users, with dramatically improved capacity, coverage, and quality ...

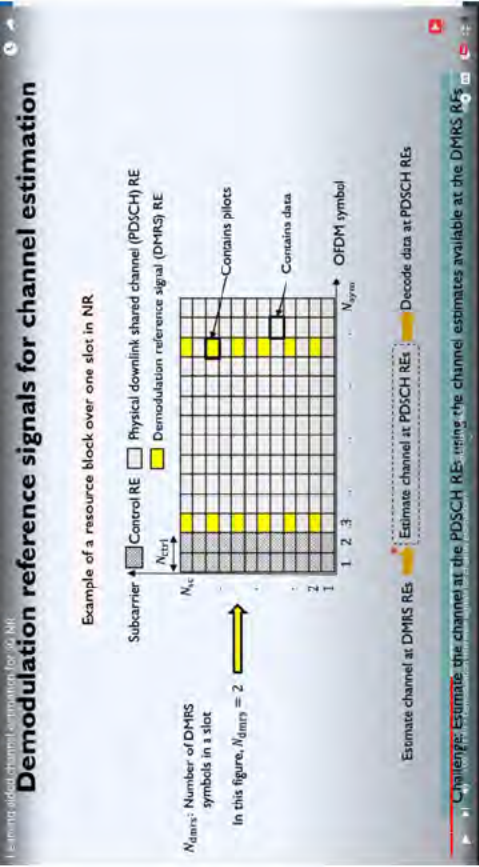
'331 Patent	The '331 Patent Accused Instrumentalities
	5G NR (New Radio) massive MIMO (Multiple Input Multiple Output) technology is one of the major keys to unlocking these 5G user experiences. ... Demystifying massive MIMO technology Let's dive deeper into the building blocks of MIMO systems. They capitalize on three key concepts, which are spatial diversity, spatial multiplexing, and beamforming: Spatial diversity and spatial multiplexing Spatial diversity is one of the fundamental benefits of MIMO technology. In brief, diversity aims at improving the reliability of the system by sending the same data across different propagation, or spatial, paths. https://www.qualcomm.com/news/onq/2019/06/how-5g-massive-mimo-transforms-your-mobile-experiences (emphasis added); see also https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/5g_research_on_waveform_and_multiple_access_techniques.pdf. More generally, literature in the wireless communications field further explains that when MIMO spatial diversity is employed, “the transmitting device creates multiple data streams of the same data and transmits the multiple streams over the same channel using different antennas. Consequently, a recipient device (also referred to herein simply as a recipient) receives two or more copies of the same data:” Next generation wireless systems make use of multiple transmitters and receivers (i.e., multiple antenna systems) in a mobile device and in a base station. Multiple antenna systems are also known as Multiple Input, Multiple Output (MIMO) systems. The availability of multiple transmitters and receivers provides for <i>communicating data over multiple paths or streams</i> in the uplink and downlink directions. For example, in a MIMO system, spatial diversity can be used to make data transmission more robust or reliable. More specifically, using spatial diversity, robustness or reliability is increased by transmitting the same data

'331 Patent	The '331 Patent Accused Instrumentalities
	redundantly over the same channel using multiple antennas. In other words, the transmitting device creates multiple data streams of the same data and transmits the multiple streams over the same channel using different antennas. Consequently, a recipient device (also referred to herein simply as a recipient) receives two or more copies of the same data. U.S. Patent No. 9,813,262 at 1:13-30 (emphasis added). Furthermore, the three annotated images below of the Samsung Galaxy S20 Ultra 5G (Model Number SM-G988U1) show several “diversity modules” for processing signals. Qualcomm describes diversity receive modules as “combin[ing] switches, filters and low-noise amplifiers into a module, providing a highly integrated, user-friendly solution for implementing high-order diversity receive paths for advanced 5G multimode architectures.” https://www.qualcomm.com/products/technology/modems/rf#overview. A third-party website explains that “Within the Galaxy S20 Ultra, multiple Qualcomm QDM5872 diversity modules are used to support the downlink MIMO for band n41...with 3 additional Qualcomm QDM4850s <i>diversity modules to capture the additional 3 spatial streams</i> to achieve 4x4 MIMO on this particular 5G frequency.” https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra. Thus, these diversity modules receive replicated data that is sent using spatial diversity.

'331 Patent	The '331 Patent Accused Instrumentalities
	 Qualcomm QPM5677 5G PAM or Transmit Module for band N78 Qualcomm SDR865 RF Transceiver 5G/4G/3G Qualcomm QDM4820 Low Band (LTE & 5G) Diversity Module Qualcomm QDM5872 Mid to High 5G Front End or Diversity Module Qualcomm SMR526 RF / IF integrated circuit (mmWave IF)

'331 Patent	The '331 Patent Accused Instrumentalities
	

'331 Patent	The '331 Patent Accused Instrumentalities  Qualcomm QDM5872 Mid to High 5G Front End or Diversity Module Qualcomm Antenna Tuners: QAT3516 QAT3555 QAT5515 QAT3516 https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra#c66138ec-595f-4a26-a02a-3e0acb3e83e
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'331 Patent	The '331 Patent Accused Instrumentalities
[1d] decoding the replicated data using the estimated channel matrix	The '331 Patent Accused Instrumentalities perform the step of decoding the replicated data using the estimated channel matrix. For example, in 5G, the estimated channel matrix is used in decoding data, <i>e.g.</i>, see below: Demodulation reference signals for channel estimation  https://www.youtube.com/watch?v=TZzTsPQJDRo&t=562s. “In 5G NR, PDSCH is the physical downlink channel that carries user data.” https://mathworks.com/help/5g/ug/nr-pdsch-resource-allocation-and-dmrs-and-pters-reference-signals.html. The “DMRS [demodulation reference signal] is a special type of physical layer signal which functions as a reference signal for decoding PDSCH [physical downlink shared channel].” https://www.sharetechnote.com/html/5G/5G_PDSCH_DMRS.html. “PDSCH DMRS is a special type of physical layer signal which functions as a reference signal for decoding PDSCH.” Sharetechnote.com/html/5G/5G_PDSCH_DMRS.html.

'331 Patent	The '331 Patent Accused Instrumentalities
	As another example, U.S. Patent No. 9,985,802 states that user equipment “decode[s] (e.g., demodulate[s]) received data based on the channel estimate.” U.S. Patent No. 9,985,802 at 10:61-63. Once a channel matrix is estimated, the Samsung Galaxy S20 Ultra 5G’s Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain decode the replicated data using the estimated channel matrix, e.g., decoding incoming streams of a MIMO transmission after the channel has been estimated using one or more pilots in a DMRS RE of a resource block (RB). <i>See supra</i> claim element [1c], which is incorporated by reference; <i>see also</i> https://www.qualcomm.com/news/onq/2022/09/how-qualcomm-inventor-dr--kiran-mukhavilli-helped-hash-out-the-f (interview of Dr. Kiran Mukhavilli: “A good, up-to-date channel estimate is essential to supporting high data rates on wireless channels....”).
[1e] generating an updated estimate of the channel matrix based, at least in part, on the replicated data; and	The '331 Patent Accused Instrumentalities perform the step of generating an updated estimate of the channel matrix based, at least in part, on the replicated data. The 5G modems and/or additional components in the RF chain found in the '331 Patent Accused Instrumentalities generate an updated estimate of the channel matrix based, at least in part, on the replicated data. For example, (i) DMRS resource elements (REs) include pilots used for channel estimation, (ii) PT-RS REs are replicated across streams, are decoded, and are used at least in part for channel estimation, and (iii) non-pilot data are replicated across streams, are decoded, and are used at least in part for channel estimation. Each PDSCCH resource block (RB) contains both a pilot and data. A pilot is found in a DM-RS resource element (RE) of a particular RB. Examples of non-pilot information in a PDSCCH resource block are, e.g., (i) PT-RS, and (ii) data within an RB also used to separate or identify the location(s) of pilots. Those types of non-pilot information may be used, at least in part, to estimate the channel. The PDSCCH RB is replicated across two streams in a MIMO transmission.

'331 Patent	The '331 Patent Accused Instrumentalities
	“Introduction In 5G NR, PDSCH is the physical downlink channel that carries user data. DM-RS and PT-RS are the reference signals associated with PDSCH. These signals are generated within the PDSCH allocation, as defined in TS 38.211 Sections 7.4.1.1 and 7.4.1.2 [1]. DM-RS is used for channel estimation as part of coherent demodulation of PDSCH. To compensate for the common phase error (CPE), 3GPP 5G NR introduced PT-RS. Phase noise produced in local oscillators introduces a significant degradation at mmWave frequencies. It produces CPE and inter-carrier interference (ICI). CPE leads to an identical rotation of a received symbol in each subcarrier. ICI leads to loss of orthogonality between the subcarriers. PT-RS is used mainly to estimate and minimize the effect of CPE on system performance. ... PDSCH PDSCH is the physical channel that carries the user data. The resources allocated for PDSCH are within the bandwidth part (BWP) of the carrier, as defined in TS 38.214 Section 5.1.2 [2]. ... DM-RS DM-RS is used to estimate the radio channel. The signal is present only in the RBs allocated for the PDSCH. ... The DM-RS is present in each RB allocated for PDSCH. Parameters That Control Time Domain Resources The parameters that control DM-RS OFDM symbol locations are: • PDSCH symbol allocation • Mapping type • DM-RS type A position • DM-RS length

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	DM-RS additional position The symbol allocation of PDSCH indicates the OFDM symbol locations used by the PDSCH transmission in a slot. DM-RS symbol locations lie within the PDSCH symbol allocation. The positions of DM-RS OFDM symbols depend on the mapping type. The mapping type of PDSCH is either slot-wise (type A) or non-slot-wise (type B). The positions of any additional DM-RS symbols are defined by a set of tables, as specified in TS 38.211 Section 7.4.1.1.2 [1]. For the purpose of indexing the tables, the specification defines the term l_d indicating the duration of OFDM symbols to be accounted for, depending on the mapping type. For mapping type A, the DM-RS OFDM symbol locations are defined relative to the first OFDM symbol of the slot (symbol #0). The location of first DM-RS OFDM symbol (l_0) is provided by the DM-RS type A position, which is either 2 or 3. For any additional DM-RS, the duration of OFDM symbols (l_d) is the number of OFDM symbols between the first OFDM symbol of the slot (symbol #0) and the last OFDM symbol of the allocated PDSCH resources. Note that l_d may differ from the number of OFDM symbols allocated for PDSCH, when the first OFDM symbol of PDSCH is other than symbol #0. For mapping type B, the DM-RS OFDM symbol locations are defined relative to the first OFDM symbol of allocated PDSCH resources. The location of first DM-RS OFDM symbol (l_0) is always 0, meaning that the first DM-RS OFDM symbol location is the first OFDM symbol location of the allocated PDSCH resources. For any additional DM-RS, the duration of OFDM symbols (l_d) is the duration of the allocated PDSCH resources. Figure 1 illustrates the DM-RS symbol locations depending on the mapping type for an RB within a slot, having single-symbol DM-RS. The figure shows a configuration with PDSCH occupying the OFDM symbols from 1 to 10 (0-based) with l_d equal to 11 for mapping type A, and from 3 to 9 (0-based) with l_d equal to 7 for mapping type B respectively.

'331 Patent	The '331 Patent Accused Instrumentalities
	a) Mapping Type A, $l_0 = 2$ b) Mapping Type A, $l_0 = 3$ c) Mapping Type B, $l_0 = 0$ Figure 1: DM-RS Symbol Locations Based on Mapping Type The maximum number of DM-RS OFDM symbols used by a UE is configured by RRC signaling (<i>dmrs-AdditionalPosition</i> and <i>maxLength</i>). The <i>maxLength</i> RRC parameter configures the length of DM-RS symbol, single symbol DM-RS or double symbol DM-RS. For double-symbol DM-RS, the actual selection is signaled in the DCI format 1_1 message. Figure 2 illustrates the single-symbol and double-symbol DM-RS locations.

'331 Patent	The '331 Patent Accused Instrumentalities
	Subcarriers in a Resource Block OFDM Symbols in a Slot l_0 l_d a) Single-Symbol DM-RS b) Double-Symbol DM-RS Legend: Data (Blue), DM-RS (Green) Figure 2: DM-RS Symbol Locations Based on Number of Front-Loaded DM-RS Symbols The higher-layer parameter <i>dmrs-AdditionalPosition</i> defines the maximum number of additional single- or double-symbol DM-RS transmitted. The number of additional positions is in the range of 0 to 3 and depends on the mapping type, DM-RS length, and PDSCH symbol allocation. The DM-RS symbol locations are given by TS 38.211 Tables 7.4.1.1.2-3, and 7.4.1.1.2-4. Figure 3 illustrates the DM-RS additional positions in combination with single-symbol and double-symbol DM-RS.

'331 Patent	The '331 Patent Accused Instrumentalities
	Subcarriers in a Resource Block OFDM Symbols in a Slot OFDM Symbols in a Slot b) 1 Additional Position for Double-Symbol a) 3 Additional Positions for Single-Symbol Figure 3: DM-RS Symbol Locations Based on Number of Additional DM-RS Positions DM-RS Data l_0 l_d l_0 l_d

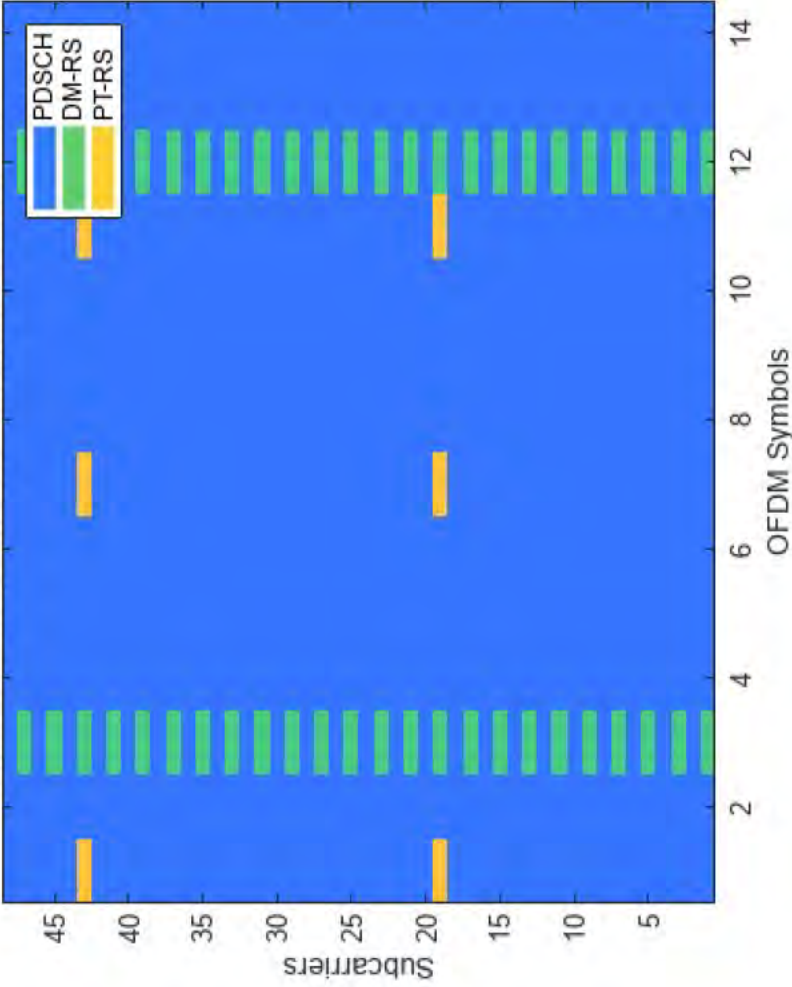
	Parameters That Control Frequency Domain Resources The parameters that control the subcarrier locations of DM-RS are: • DM-RS configuration type • DM-RS antenna ports The configuration type indicates the frequency density of DM-RS and is signaled by RRC message <i>dmrs-Type</i>. Configuration type 1 defines six subcarriers per physical resource block (PRB) per antenna port, comprising alternate subcarriers. Configuration type 2 defines four subcarriers per PRB per antenna port, consisting of two groups of two consecutive subcarriers. Figure 4 indicates the DM-RS subcarrier locations based on configuration type.
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'331 Patent	The '331 Patent Accused Instrumentalities
	Subcarriers in a Resource Block OFDM Symbols in a Slot l_0 l_d Data DM-RS a) Configuration Type 1 b) Configuration Type 2 Figure 4: DM-RS Subcarrier Locations Based on DM-RS Configuration Type ...

'331 Patent	The '331 Patent Accused Instrumentalities PT-RS PT-RS is the phase tracking reference signal. PT-RS is used mainly to estimate and minimize the effect of CPE on system performance. Due to the phase noise properties, PT-RS signal has a low density in the frequency domain and a high density in the time domain. PT-RS always occurs in combination with DM-RS and only when the network has configured PT-RS to be present. Parameters That Control Time Domain Resources PT-RS is configured through the higher layer parameter <i>DMRS-DownlinkConfig</i> for downlink. The parameters that control the time resources of PT-RS are: • DM-RS symbol locations • Time density of PT-RS (<i>LPT-RS</i>) <i>LPT-RS</i> depends on the scheduled modulation and coding scheme. Value of <i>LPT-RS</i> must be from the set {1, 2, 4}. For the parameters that control DM-RS symbol locations, refer to Parameters that Control DM-RS Time Resources. The PT-RS symbol locations in a slot start from the first OFDM symbol in the shared channel allocation and hop every <i>LPT-RS</i> symbols, if no DM-RS symbol is present in this interval. In the case where a DM-RS symbol or symbols are present in between or at the hop interval, the hop starts from the last DM-RS symbol location to provide the next PT-RS symbol. Figure 7 shows the PT-RS symbol locations in an RB for single slot with time-density set to 4 and DM-RS symbol locations set to 2 and 11 (0-based).
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'331 Patent	The '331 Patent Accused Instrumentalities ... Parameters That Control Frequency Domain Resources PT-RS occupies only one subcarrier in an RB for one OFDM symbol. The parameters that control the frequency resources of PT-RS are: • PRB allocation • DM-RS configuration type • Frequency density of PT-RS (K_{PT-RS}) • Radio network temporary identifier (n_{RNTI}) • Resource element offset • PT-RS antenna port K_{PT-RS} depends on the scheduled bandwidth. The value of K_{PT-RS} is either 2 or 4, which indicates whether PT-RS is present in every two RBs or every four RBs.
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'331 Patent	The '331 Patent Accused Instrumentalities
	The starting RB at which PT-RS is present (k_{RBref}), depends on K_{PT-RS}, M_{RNTI}, and the number of RBs (N_{RB}) allocated for PDSCH. For the purpose of mapping PT-RS, all the RBs of PDSCH are numbered in increasing order from 0 to $M_{RB}-1$. The subcarrier location of PT-RS (k_{REref}) within a resource block depends on the DM-RS configuration type, resource element (RE) offset, and PT-RS antenna port. The PT-RS antenna port must be a subset of DM-RS antenna ports. The PT-RS subcarrier location always aligns with one of the DM-RS subcarrier locations in an RB. PT-RS in an RB occupies the same subcarrier locations in all the OFDM symbols where PT-RS is present. ...

'331 Patent	The '331 Patent Accused Instrumentalities
	Carrier Grid Containing PDSCH, DM-RS and PT-RS  In the preceding figure, PT-RS is located at the start of the OFDM symbol in the PDSCH allocation. The symbols are present at every L_{PT-RS} hop interval from each other or from DM-RS symbols. PT-RS symbols in the frequency domain are located at subcarrier 19 (first RB) and at subcarrier 43 (third RB) of each OFDM

'331 Patent	The '331 Patent Accused Instrumentalities
	symbol where PT-RS is present. The difference in consecutive subcarrier locations of PT-RS is 24, which is the number of subcarriers in an RB (12) times the frequency density of PT-RS (2).” https://www.mathworks.com/help/5g/ug/nr-pdsch-resource-allocation-and-dmrs-and-pt-rs-reference-signals.html. PT-RS is distinct from DMRS and is not a pilot. “Reference Signals Mapping with associated with different physical channel is depicted in following figure.

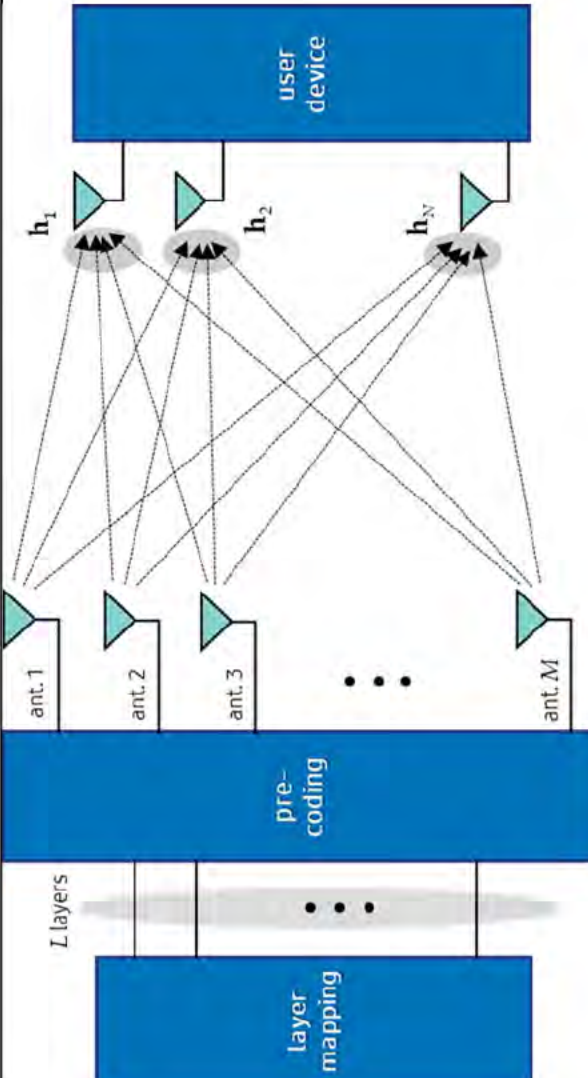
- In NR, there is not Cell specific Reference Signal (C-RS)
- New Reference Signal PTRS has been introduced for Time/Frequency tracking
- DMRS has been introduced for both downlink and uplink channels
- In NR, reference signals are transmitted only when it is necessary where as in LTE constantly exchanging reference signals to manage the link.”

<https://www.techplavon.com/5g-nr-reference-signals-dmrs-ptssrs-and-csirs/>

'331 Patent	The '331 Patent Accused Instrumentalities
	In addition, as shown above, data REs separate DMRS signals from one another for a particular RB in which multiple DMRS REs are found at a particular subcarrier. Those data REs are replicated across streams and thus those data REs, at least in part, contribute to generation of the channel matrix. As a further example, the Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain perform the step of generating an updated estimate of the channel matrix based, at least in part, on the replicated data. U.S. Patent No. 10,868,650 indicates that the channel estimate/matrix is constantly updated by the receiving device (i.e., the '331 Patent Accused Instrumentalities) based on the data frames that are received. <i>See</i> U.S. Patent No. 10,868,650 at 8:12-19 ("In action 420, the [user equipment] UE 120 receives the frames and computes CSI based at least in part on the received frames.... The CSI may incorporate historical CSI data based on past frames, so the CSI may be based on more than just the most recently transmitted frame or frames"). Thus, if the transmitter chose to transmit using spatial diversity, then the replicated data received by the receiver device would update the channel matrix using the received replicated data. <i>See supra</i> claim elements [1c] and [1d], which are incorporated by reference. Furthermore, literature in the wireless communications field explains that received data, not just pilot symbols, update the channel matrix through a process called "data aided channel estimation." Inaamullah Khan et al., Data Aided Channel Estimation for MIMO-OFDM Wireless Systems Using Reliable Carriers, 11 IEEE Access 47836, 47838 (2023).
[1f] decoding subsequently received signals over the communications channel using the updated estimate	The '331 Patent Accused Instrumentalities perform the step of decoding subsequently received signals over the communications channel using the updated estimate of the channel matrix. For example, and as explained above with reference to initial decoding based on an initial estimate of the channel matrix, the Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain perform the step of decoding subsequently received signals over the communications channel using the updated estimate of the channel matrix.

'331 Patent	The '331 Patent Accused Instrumentalities
of the channel matrix.	As another example, U.S. Patent No. 9,985,802 states that user equipment “decode[s] (e.g., demodulate[s]) received data based on the channel estimate.” U.S. Patent No. 9,985,802 at 10:61-63. The Galaxy S20 Ultra 5G’s Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain decode signals received over a MIMO communications channel using the updated estimate of the channel matrix. See <i>supra</i> claim elements [1c], [1d], and [1e], which are incorporated by reference.
[5] The method of claim 1, wherein the replicated data includes same data symbols in multiple data streams.	The '331 Patent Accused Instrumentalities perform the step of receiving replicated data that includes the same data symbols in multiple data streams. See <i>supra</i> claim 1, which is incorporated by reference. For example, the Galaxy S20 Ultra 5G’s Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain perform the step of receiving replicated data that includes the same data symbols in multiple data streams. The Snapdragon 865 5G chipset and/or Snapdragon X55 modem employ spatial diversity, which is one transmission technique available in multiple-input multiple-output (MIMO) antenna systems utilized in 5G data networks. “Snapdragon X55 is designed to provide comprehensive support for 5G NR TDD and FDD While driving 5G forward, we also continue to innovate and push 4G LTE boundaries. Snapdragon X55 features cutting-edge LTE features, including 24 spatial streams, 4x4 MIMO, and 1024-QAM.” (https://www.qualcomm.com/news/onq/2019/02/meet-snapdragon-x55-worlds-most-advanced-commercial-5g-modem; see also https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/x55_9_final.pdf (“World’s most advanced commercial 5G modem,” with 4G/LTE “FD-MIMO”). Samsung describes 5G (New Radio), MIMO, and spatial diversity as follow, for example:

'331 Patent	The '331 Patent Accused Instrumentalities
	Massive multi-input multi-output (MIMO) is a major breakthrough technology that improves the capacity and user experience of 5G eMBB. Instead of broadcasting data throughout the entire coverage area, the massive MIMO system concentrates the signal energy to a specific user, resulting in significant improvement of throughput and efficiency. This characteristic not only increases the downlink (DL) and uplink (UL) signal strength but also enhances the cell throughput <i>by allocating multiple beams to one or multiple users</i>. The spatially optimized signal can minimize its interference toward other users and/or adjacent cells and reduces interference levels of the entire network, especially in interference limited cell deployments [1-2]. ... Allocation of multiple beams to different receive antennas of a single user increases the number of layers for single user (SU-) MIMO. The intensified signal power and increased number of layers contribute to better user throughput. ... Figure 5 depicts the MIMO channel model between M transmit antennas of massive MIMO base station and N receive antennas of the user device. ...

'331 Patent	The '331 Patent Accused Instrumentalities
	 Figure 5. Downlink Channel model for single user MIMO Samsung Technical White Paper, <i>Massive MIMO for New Radio</i>, December 2020 (emphasis added). Qualcomm describes 5G, MIMO, and spatial diversity as follows, as another example: “How 5G massive MIMO transforms your mobile experiences Qualcomm Technologies breakthroughs help enable 5G networks to serve more users, with dramatically improved capacity, coverage, and quality ...

'331 Patent	The '331 Patent Accused Instrumentalities
	5G NR (New Radio) massive MIMO (Multiple Input Multiple Output) technology is one of the major keys to unlocking these 5G user experiences. ... Demystifying massive MIMO technology Let's dive deeper into the building blocks of MIMO systems. They capitalize on three key concepts, which are spatial diversity, spatial multiplexing, and beamforming: Spatial diversity and spatial multiplexing Spatial diversity is one of the fundamental benefits of MIMO technology. In brief, diversity aims at improving the reliability of the system by sending the same data across different propagation, or spatial, paths. https://www.qualcomm.com/news/onq/2019/06/how-5g-massive-mimo-transforms-your-mobile-experiences (emphasis added); see also https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/5g_research_on_waveform_and_multiple_access_techniques.pdf. More generally, literature in the wireless communications field further explains that when MIMO spatial diversity is employed, “the transmitting device creates multiple data streams of the same data and transmits the multiple streams over the same channel using different antennas. Consequently, a recipient device (also referred to herein simply as a recipient) receives two or more copies of the same data:” Next generation wireless systems make use of multiple transmitters and receivers (i.e., multiple antenna systems) in a mobile device and in a base station. Multiple antenna systems are also known as Multiple Input, Multiple Output (MIMO) systems. The availability of multiple transmitters and receivers provides for <i>communicating data over multiple paths or streams</i> in the uplink and downlink directions. For example, in a MIMO system, spatial diversity can be used to make data transmission more robust or reliable. More specifically, using spatial diversity, robustness or reliability is increased by transmitting the same data

'331 Patent	The '331 Patent Accused Instrumentalities
	redundantly over the same channel using multiple antennas. In other words, the transmitting device creates multiple data streams of the same data and transmits the multiple streams over the same channel using different antennas. Consequently, a recipient device (also referred to herein simply as a recipient) receives two or more copies of the same data. U.S. Patent No. 9,813,262 at 1:13-30 (emphasis added).
[6] A communication device comprising:	The '331 Patent Accused Instrumentalities are communication devices. For example, Samsung's "IT & Mobile Communications" webpage describes its "Mobile Communications" business as including its Galaxy 5G products. https://www.samsung.com/us/about-us/our-business/it-and-mobile-communications/. The Galaxy S20 Ultra 5G is an example of a communication device; below is an external photograph of a Galaxy S20 Ultra 5G submitted by Samsung to the FCC.

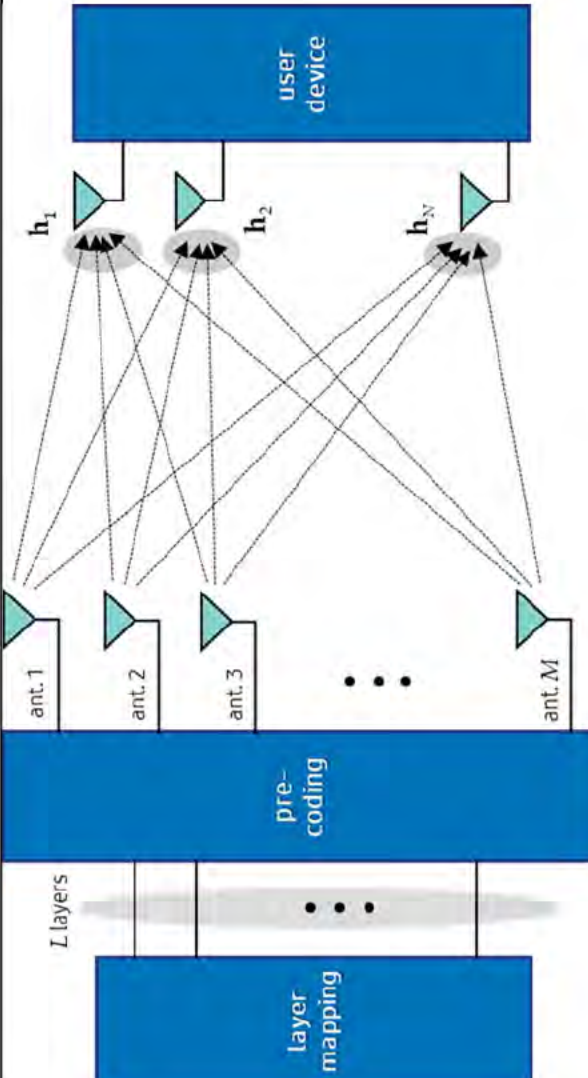
'331 Patent	The '331 Patent Accused Instrumentalities
	FCC ID: A3L SMG988U External Photographs 

'331 Patent	The '331 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=s3p85PbIvL3JWmQHP6peg%3D%3D&fcc_id=A3LSMG988U (external photos). The Galaxy S20 5G is another example of a communication device; below is an external photograph of a Galaxy S20 5G submitted by Samsung to the FCC.

'331 Patent	The '331 Patent Accused Instrumentalities
	FCC ID: A3LSMG981U, IC: 649E-SMG981U, HVIN: SM-G981W External Photographs 

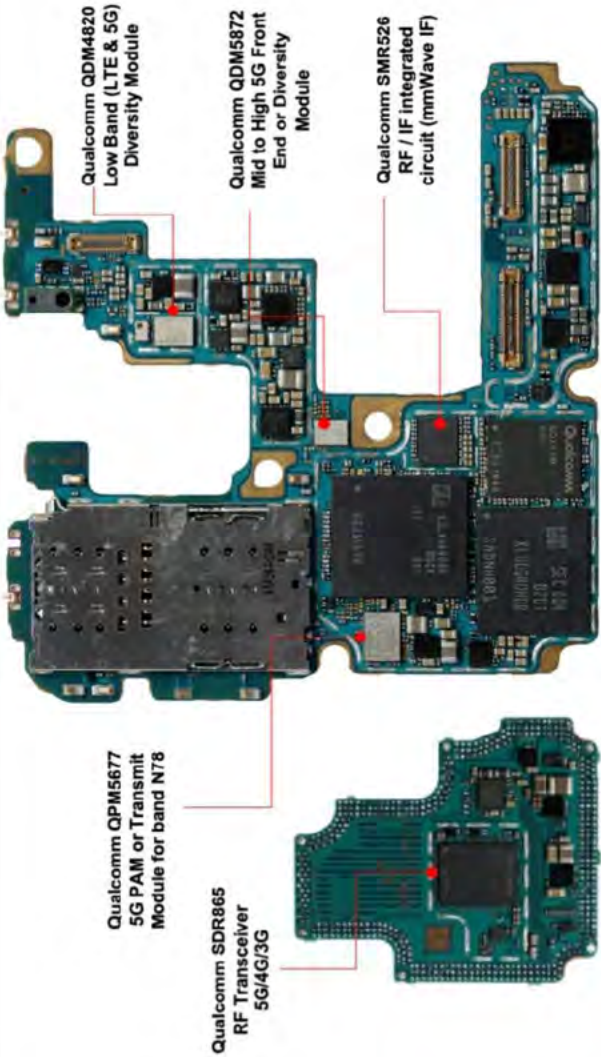
'331 Patent	The '331 Patent Accused Instrumentalities
	Available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=8Twpxjxm25uB8pCHfwZLA%3D%3D&fcc_id=A3LSMG981U (external photos).
[6a] a receiver configured to receive signals over a communications channel, wherein the signals are based at least in part on first and second data streams transmitted over a communications channel, and wherein the second data stream includes at least one data symbol replicated from the first data stream;	The '331 Patent Accused Instrumentalities include a receiver that is configured to receive signals over a communications channel, wherein the signals are based at least in part on first and second data streams transmitted over a communications channel, and wherein the second data stream includes at least one data symbol replicated from the first data stream. For example, the Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain include a receiver configured to receive signals over a communications channel, wherein the signals are based at least in part on first and second data streams transmitted over a communications channel, and wherein the second data stream includes at least one data symbol replicated from the first data stream. The Snapdragon 865 5G chipset and/or Snapdragon X55 modem employ spatial diversity, which is one transmission technique available in multiple-input multiple-output (MIMO) antenna systems utilized in 5G data networks. "Snapdragon X55 is designed to provide comprehensive support for 5G NR TDD and FDD While driving 5G forward, we also continue to innovate and push 4G LTE boundaries. Snapdragon X55 features cutting-edge LTE features, including 24 spatial streams, 4x4 MIMO, and 1024-QAM." (https://www.qualcomm.com/news/onq/2019/02/meet-snapdragon-x55-worlds-most-advanced-commercial-5g-modem; see also https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/x55_9_final.pdf ("World's most advanced commercial 5G modem," with 4G/LTE "FD-MIMO"). Samsung describes 5G (New Radio), MIMO, and spatial diversity as follow, for example: Massive multi-input multi-output (MIMO) is a major breakthrough technology that improves the capacity and user experience of 5G eMBB. Instead of broadcasting data throughout the entire coverage area, the massive MIMO system concentrates the signal energy to a specific user, resulting in significant

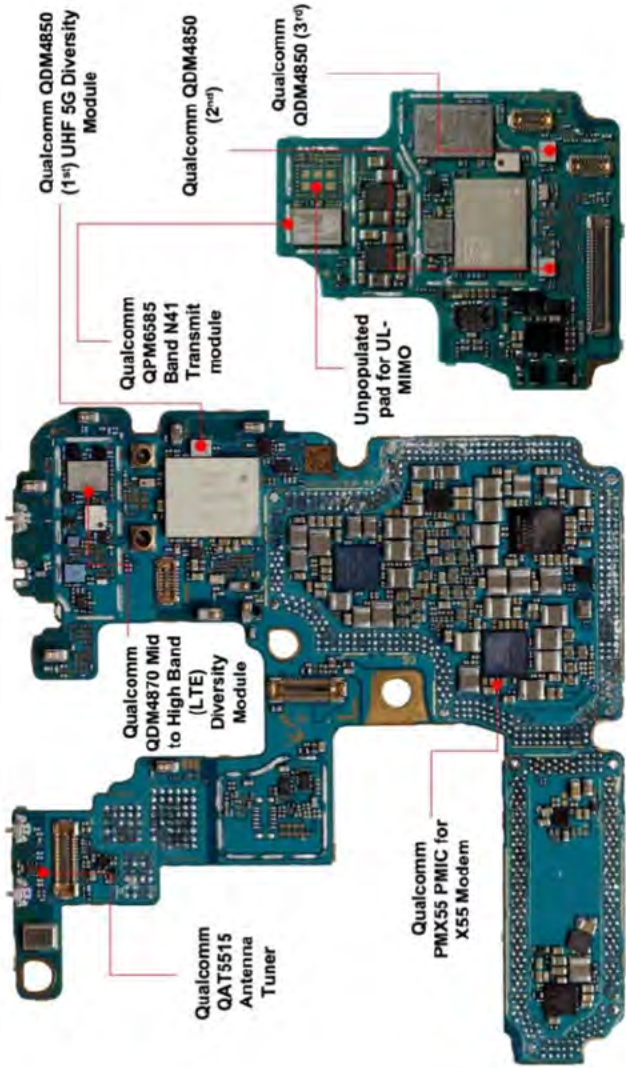
'331 Patent	The '331 Patent Accused Instrumentalities
	improvement of throughput and efficiency. This characteristic not only increases the downlink (DL) and uplink (UL) signal strength but also enhances the cell throughput <i>by allocating multiple beams to one or multiple users</i>. The spatially optimized signal can minimize its interference toward other users and/or adjacent cells and reduces interference levels of the entire network, especially in interference limited cell deployments [1-2]. ... Allocation of multiple beams to different receive antennas of a single user increases the number of layers for single user (SU-) MIMO. The intensified signal power and increased number of layers contribute to better user throughput. ... Figure 5 depicts the MIMO channel model between M transmit antennas of massive MIMO base station and N receive antennas of the user device. ...

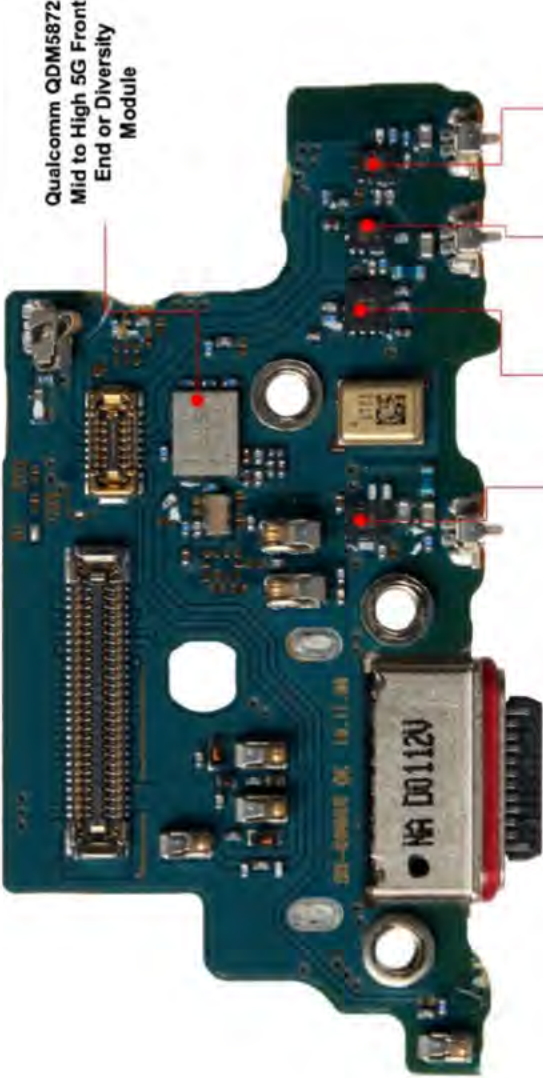
'331 Patent	The '331 Patent Accused Instrumentalities
	 Figure 5. Downlink Channel model for single user MIMO Samsung Technical White Paper, <i>Massive MIMO for New Radio</i>, December 2020 (emphasis added). Qualcomm describes 5G, MIMO, and spatial diversity as follows, as another example: “How 5G massive MIMO transforms your mobile experiences Qualcomm Technologies breakthroughs help enable 5G networks to serve more users, with dramatically improved capacity, coverage, and quality ...

'331 Patent	The '331 Patent Accused Instrumentalities 5G NR (New Radio) massive MIMO (Multiple Input Multiple Output) technology is one of the major keys to unlocking these 5G user experiences. ... Demystifying massive MIMO technology Let's dive deeper into the building blocks of MIMO systems. They capitalize on three key concepts, which are spatial diversity, spatial multiplexing, and beamforming: Spatial diversity and spatial multiplexing Spatial diversity is one of the fundamental benefits of MIMO technology. In brief, diversity aims at improving the reliability of the system by sending the same data across different propagation, or spatial, paths. https://www.qualcomm.com/news/onq/2019/06/how-5g-massive-mimo-transforms-your-mobile-experiences (emphasis added); see also https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/5g_research_on_waveform_and_multiple_access_techniques.pdf. More generally, literature in the wireless communications field further explains that when MIMO spatial diversity is employed, “the transmitting device creates multiple data streams of the same data and transmits the multiple streams over the same channel using different antennas. Consequently, a recipient device (also referred to herein simply as a recipient) receives two or more copies of the same data:” Next generation wireless systems make use of multiple transmitters and receivers (i.e., multiple antenna systems) in a mobile device and in a base station. Multiple antenna systems are also known as Multiple Input, Multiple Output (MIMO) systems. The availability of multiple transmitters and receivers provides for <i>communicating data over multiple paths or streams</i> in the uplink and downlink directions. For example, in a MIMO system, spatial diversity can be used to make data transmission more robust or reliable. More specifically, using spatial diversity, robustness or reliability is increased by transmitting the same data
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'331 Patent	The '331 Patent Accused Instrumentalities
	redundantly over the same channel using multiple antennas. In other words, the transmitting device creates multiple data streams of the same data and transmits the multiple streams over the same channel using different antennas. Consequently, a recipient device (also referred to herein simply as a recipient) receives two or more copies of the same data. U.S. Patent No. 9,813,262 at 1:13-30 (emphasis added). Furthermore, the three annotated images below of the Samsung Galaxy S20 Ultra 5G (Model Number SM-G988U1) show several “diversity modules” for processing signals. Qualcomm describes diversity receive modules as “combin[ing] switches, filters and low-noise amplifiers into a module, providing a highly integrated, user-friendly solution for implementing high-order diversity receive paths for advanced 5G multimode architectures.” https://www.qualcomm.com/products/technology/modems/rf#overview. A third-party website explains that “Within the Galaxy S20 Ultra, multiple Qualcomm QDM5872 diversity modules are used to support the downlink MIMO for band n41...with 3 additional Qualcomm QDM4850s <i>diversity modules to capture the additional 3 spatial streams</i> to achieve 4x4 MIMO on this particular 5G frequency.” https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra. Thus, these diversity modules receive replicated data that is sent using spatial diversity.

'331 Patent	The '331 Patent Accused Instrumentalities
	 Qualcomm QPM5677 5G PAM or Transmit Module for band N78 Qualcomm SDR865 RF Transceiver 5G/4G/3G Qualcomm QDM4820 Low Band (LTE & 5G) Diversity Module Qualcomm QDM5872 Mid to High 5G Front End or Diversity Module Qualcomm SMR526 RF / IF integrated circuit (mmWave IF)

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'331 Patent	The '331 Patent Accused Instrumentalities  Qualcomm QDM5872 Mid to High 5G Front End or Diversity Module Qualcomm Antenna Tuners: QAT3516 QAT3555 QAT5515 QAT3516 https://omdia.tech.informa.com/OM006104/Criticality-of-5G-Modem-to-RF-Integration-A-look-inside-Samsung-Galaxy-S20-Ultra#c66138ec-595f-4a26-a02a-3e0acbf3e83e
[6b] a decoder coupled to the receiver and the channel estimator, wherein the decoder is	The '331 Patent Accused Instrumentalities include a decoder coupled to the receiver and the channel estimator, wherein the decoder is configured to receive the received signals and decode the at least one data symbol replicated from the first data stream. For example, in 5G, the estimated channel matrix is used in decoding data, <i>e.g.</i>, see below:

'331 Patent	The '331 Patent Accused Instrumentalities Coming soon channel estimation for 5G NR Demodulation reference signals for channel estimation Example of a resource block over one slot in NR Challenge: Estimate the channel at the PDSCH REs using the channel estimates available at the DMRS REs Decode data at PDSCH REs https://www.youtube.com/watch?v=TZzTsPQJDRo&t=562s. “In 5G NR, PDSCH is the physical downlink channel that carries user data.” https://mathworks.com/help/5g/ug/nr-pdsch-resource-allocation-and-dmrs-and-pters-reference-signals.html. The “DMRS [demodulation reference signal] is a special type of physical layer signal which functions as a reference signal for decoding PDSCH [physical downlink shared channel].” https://www.sharetechnote.com/html/5G/5G_PDSCH_DMRS.html. “PDSCH DMRS is a special type of physical layer signal which functions as a reference signal for decoding PDSCH.” Sharetechnote.com/html/5G/5G_PDSCH_DMRS.html. As another example, U.S. Patent No. 9,985,802 states that user equipment “decode[s] (e.g., demodulate[s]) received data based on the channel estimate.” U.S. Patent No. 9,985,802 at 10:61-63.
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configured to receive the received signals and decode the at least one data symbol replicated from the first data stream;

'331 Patent	The '331 Patent Accused Instrumentalities
	The Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain are configured to receive the received signals and decode the at least one data symbol replicated from the first data stream. See <i>supra</i> claim element [6a], which is incorporated by reference; see <i>also</i> https://www.qualcomm.com/news/onq/2022/09/how-qualcomm-inventor-dr--kiran-mukavilli-helped-hash-out-the-f (interview of Dr. Kiran Mukavilli: "A good, up-to-date channel estimate is essential to supporting high data rates on wireless channels....").
[6c] a channel estimator coupled to the decoder and the receiver, wherein the channel estimator is configured to receive the received signals and the decoded at least one data symbol, wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded	wherein the channel estimator coupled to the decoder and the receiver, wherein the channel estimator is configured to receive the received signals and the decoded at least one data symbol, wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol. The chipsets, 5G modems, and/or additional components in the RF chain found in the '331 Patent Accused Instrumentalities include a channel estimator coupled to the decoder and the receiver, wherein the channel estimator is configured to receive the received signals and the decoded at least one data symbol, wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol. For example, (i) DMRS resource elements (REs) include pilots used for channel estimation, (ii) PT-RS REs are replicated across streams, are decoded, and are used at least in part for channel estimation, and (iii) non-pilot data are replicated across streams, are decoded, and are used at least in part for channel estimation. Each PDSCCH resource block (RB) contains both a pilot and data. A pilot is found in a DM-RS resource element (RE) of a particular RB. Examples of non-pilot information in a PDSCCH resource block are, e.g., (i) PT-RS, and (ii) data within an RB also used to separate or identify the location(s) of pilots. Those types of non-pilot information may be used, at least in part, to estimate the channel. The PDSCCH RB is replicated across two streams in a MIMO transmission.

'331 Patent	The '331 Patent Accused Instrumentalities
the decoded at least one data symbol; and	“Introduction In 5G NR, PDSCH is the physical downlink channel that carries user data. DM-RS and PT-RS are the reference signals associated with PDSCH. These signals are generated within the PDSCH allocation, as defined in TS 38.211 Sections 7.4.1.1 and 7.4.1.2 [1]. DM-RS is used for channel estimation as part of coherent demodulation of PDSCH. To compensate for the common phase error (CPE), 3GPP 5G NR introduced PT-RS. Phase noise produced in local oscillators introduces a significant degradation at mmWave frequencies. It produces CPE and inter-carrier interference (ICI). CPE leads to an identical rotation of a received symbol in each subcarrier. ICI leads to loss of orthogonality between the subcarriers. PT-RS is used mainly to estimate and minimize the effect of CPE on system performance. ... PDSCH PDSCH is the physical channel that carries the user data. The resources allocated for PDSCH are within the bandwidth part (BWP) of the carrier, as defined in TS 38.214 Section 5.1.2 [2]. ... DM-RS DM-RS is used to estimate the radio channel. The signal is present only in the RBs allocated for the PDSCH. ... The DM-RS is present in each RB allocated for PDSCH. Parameters That Control Time Domain Resources The parameters that control DM-RS OFDM symbol locations are: • PDSCH symbol allocation • Mapping type • DM-RS type A position • DM-RS length

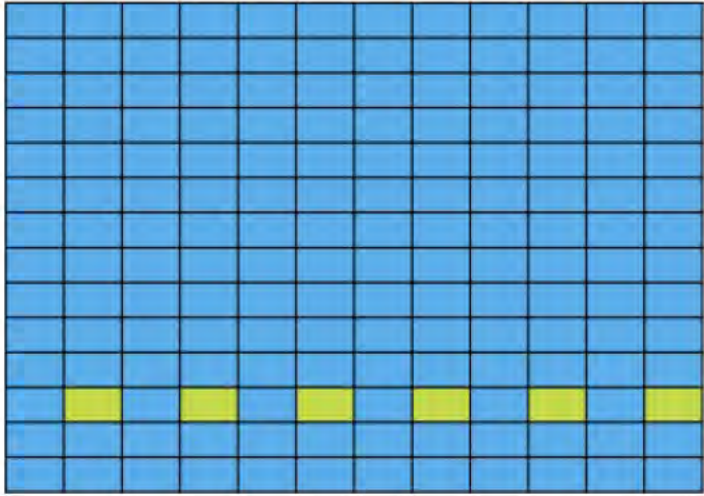
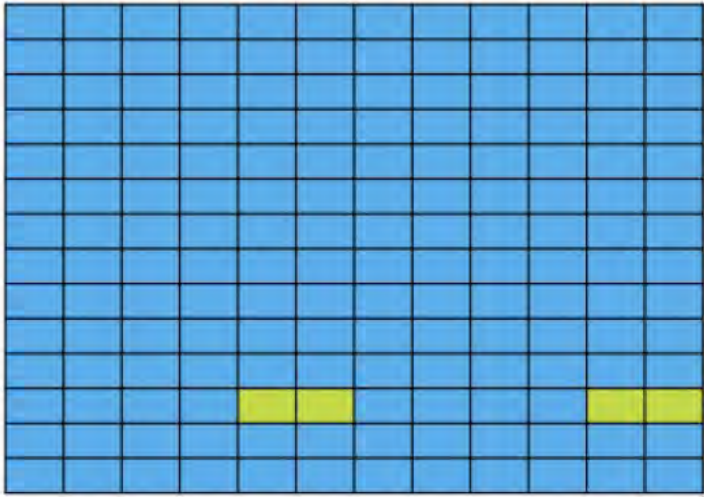
'331 Patent	The '331 Patent Accused Instrumentalities
	DM-RS additional position The symbol allocation of PDSCH indicates the OFDM symbol locations used by the PDSCH transmission in a slot. DM-RS symbol locations lie within the PDSCH symbol allocation. The positions of DM-RS OFDM symbols depend on the mapping type. The mapping type of PDSCH is either slot-wise (type A) or non-slot-wise (type B). The positions of any additional DM-RS symbols are defined by a set of tables, as specified in TS 38.211 Section 7.4.1.1.2 [1]. For the purpose of indexing the tables, the specification defines the term l_d indicating the duration of OFDM symbols to be accounted for, depending on the mapping type. For mapping type A, the DM-RS OFDM symbol locations are defined relative to the first OFDM symbol of the slot (symbol #0). The location of first DM-RS OFDM symbol (l_0) is provided by the DM-RS type A position, which is either 2 or 3. For any additional DM-RS, the duration of OFDM symbols (l_d) is the number of OFDM symbols between the first OFDM symbol of the slot (symbol #0) and the last OFDM symbol of the allocated PDSCH resources. Note that l_d may differ from the number of OFDM symbols allocated for PDSCH, when the first OFDM symbol of PDSCH is other than symbol #0. For mapping type B, the DM-RS OFDM symbol locations are defined relative to the first OFDM symbol of allocated PDSCH resources. The location of first DM-RS OFDM symbol (l_0) is always 0, meaning that the first DM-RS OFDM symbol location is the first OFDM symbol location of the allocated PDSCH resources. For any additional DM-RS, the duration of OFDM symbols (l_d) is the duration of the allocated PDSCH resources. Figure 1 illustrates the DM-RS symbol locations depending on the mapping type for an RB within a slot, having single-symbol DM-RS. The figure shows a configuration with PDSCH occupying the OFDM symbols from 1 to 10 (0-based) with l_d equal to 11 for mapping type A, and from 3 to 9 (0-based) with l_d equal to 7 for mapping type B respectively.

'331 Patent	The '331 Patent Accused Instrumentalities
	a) Mapping Type A, $l_0 = 2$ b) Mapping Type A, $l_0 = 3$ c) Mapping Type B, $l_0 = 0$ Figure 1: DM-RS Symbol Locations Based on Mapping Type The maximum number of DM-RS OFDM symbols used by a UE is configured by RRC signaling (<i>dmrs-AdditionalPosition</i> and <i>maxLength</i>). The <i>maxLength</i> RRC parameter configures the length of DM-RS symbol, single symbol DM-RS or double symbol DM-RS. For double-symbol DM-RS, the actual selection is signaled in the DCI format 1_1 message. Figure 2 illustrates the single-symbol and double-symbol DM-RS locations.

'331 Patent	The '331 Patent Accused Instrumentalities
	Figure 2: DM-RS Symbol Locations Based on Number of Front-Loaded DM-RS Symbols a) Single-Symbol DM-RS b) Double-Symbol DM-RS The higher-layer parameter <i>dmrs-AdditionalPosition</i> defines the maximum number of additional single- or double-symbol DM-RS transmitted. The number of additional positions is in the range of 0 to 3 and depends on the mapping type, DM-RS length, and PDSCH symbol allocation. The DM-RS symbol locations are given by TS 38.211 Tables 7.4.1.1.2-3, and 7.4.1.1.2-4. Figure 3 illustrates the DM-RS additional positions in combination with single-symbol and double-symbol DM-RS.

'331 Patent	The '331 Patent Accused Instrumentalities
	Subcarriers in a Resource Block DM-RS Data a) 3 Additional Positions for Single-Symbol b) 1 Additional Position for Double-Symbol OFDM Symbols in a Slot OFDM Symbols in a Slot Figure 3: DM-RS Symbol Locations Based on Number of Additional DM-RS Positions

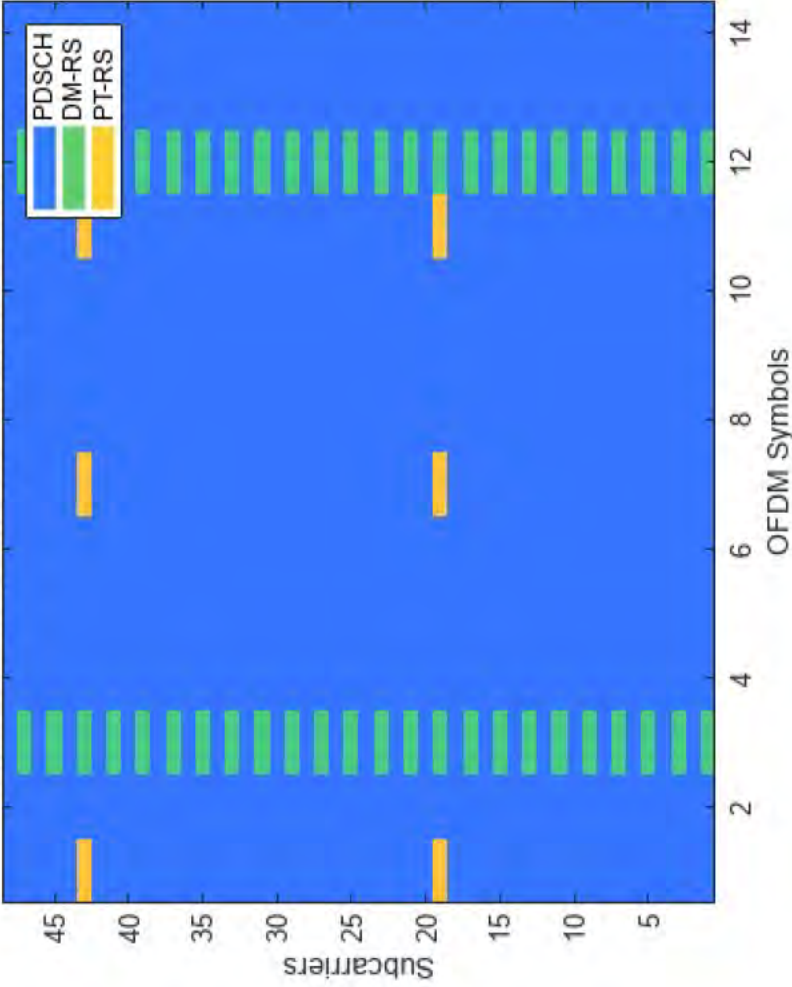
	Parameters That Control Frequency Domain Resources The parameters that control the subcarrier locations of DM-RS are: • DM-RS configuration type • DM-RS antenna ports The configuration type indicates the frequency density of DM-RS and is signaled by RRC message <i>dmrs-Type</i>. Configuration type 1 defines six subcarriers per physical resource block (PRB) per antenna port, comprising alternate subcarriers. Configuration type 2 defines four subcarriers per PRB per antenna port, consisting of two groups of two consecutive subcarriers. Figure 4 indicates the DM-RS subcarrier locations based on configuration type.
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'331 Patent	The '331 Patent Accused Instrumentalities
	Subcarriers in a Resource Block  OFDM Symbols in a Slot l_d l_o a) Configuration Type 1 Subcarriers in a Resource Block  OFDM Symbols in a Slot l_d l_o b) Configuration Type 2 Data DM-RS ... Figure 4: DM-RS Subcarrier Locations Based on DM-RS Configuration Type

'331 Patent	The '331 Patent Accused Instrumentalities
	PT-RS PT-RS is the phase tracking reference signal. PT-RS is used mainly to estimate and minimize the effect of CPE on system performance. Due to the phase noise properties, PT-RS signal has a low density in the frequency domain and a high density in the time domain. PT-RS always occurs in combination with DM-RS and only when the network has configured PT-RS to be present. Parameters That Control Time Domain Resources PT-RS is configured through the higher layer parameter <i>DMRS-DownlinkConfig</i> for downlink. The parameters that control the time resources of PT-RS are: • DM-RS symbol locations • Time density of PT-RS (<i>LPT-RS</i>) <i>LPT-RS</i> depends on the scheduled modulation and coding scheme. Value of <i>LPT-RS</i> must be from the set {1, 2, 4}. For the parameters that control DM-RS symbol locations, refer to Parameters that Control DM-RS Time Resources. The PT-RS symbol locations in a slot start from the first OFDM symbol in the shared channel allocation and hop every <i>LPT-RS</i> symbols, if no DM-RS symbol is present in this interval. In the case where a DM-RS symbol or symbols are present in between or at the hop interval, the hop starts from the last DM-RS symbol location to provide the next PT-RS symbol. Figure 7 shows the PT-RS symbol locations in an RB for single slot with time-density set to 4 and DM-RS symbol locations set to 2 and 11 (0-based).

'331 Patent	The '331 Patent Accused Instrumentalities Parameters That Control Frequency Domain Resources PT-RS occupies only one subcarrier in an RB for one OFDM symbol. The parameters that control the frequency resources of PT-RS are: • PRB allocation • DM-RS configuration type • Frequency density of PT-RS (K_{PT-RS}) • Radio network temporary identifier (n_{RNTI}) • Resource element offset • PT-RS antenna port K_{PT-RS} depends on the scheduled bandwidth. The value of K_{PT-RS} is either 2 or 4, which indicates whether PT-RS is present in every two RBs or every four RBs.
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'331 Patent	The '331 Patent Accused Instrumentalities
	The starting RB at which PT-RS is present (k_{RBref}), depends on K_{PT-RS}, N_{RNTL}, and the number of RBs (N_{RB}) allocated for PDSCH. For the purpose of mapping PT-RS, all the RBs of PDSCH are numbered in increasing order from 0 to $N_{RB}-1$. The subcarrier location of PT-RS (k_{REref}) within a resource block depends on the DM-RS configuration type, resource element (RE) offset, and PT-RS antenna port. The PT-RS antenna port must be a subset of DM-RS antenna ports. The PT-RS subcarrier location always aligns with one of the DM-RS subcarrier locations in an RB. PT-RS in an RB occupies the same subcarrier locations in all the OFDM symbols where PT-RS is present. ...

'331 Patent	The '331 Patent Accused Instrumentalities
	Carrier Grid Containing PDSCH, DM-RS and PT-RS  In the preceding figure, PT-RS is located at the start of the OFDM symbol in the PDSCH allocation. The symbols are present at every L_{PT-RS} hop interval from each other or from DM-RS symbols. PT-RS symbols in the frequency domain are located at subcarrier 19 (first RB) and at subcarrier 43 (third RB) of each OFDM

'331 Patent	The '331 Patent Accused Instrumentalities
	symbol where PT-RS is present. The difference in consecutive subcarrier locations of PT-RS is 24, which is the number of subcarriers in an RB (12) times the frequency density of PT-RS (2).” https://www.mathworks.com/help/5g/ug/nr-pdsch-resource-allocation-and-dmrs-and-pt-rs-reference-signals.html. PT-RS is distinct from DMRS and is not a pilot. “Reference Signals Mapping with associated with different physical channel is depicted in following figure.

- In NR, there is not Cell specific Reference Signal (C-RS)
- New Reference Signal PTRS has been introduced for Time/Frequency tracking
- DMRS has been introduced for both downlink and uplink channels
- In NR, reference signals are transmitted only when it is necessary where as in LTE constantly exchanging reference signals to manage the link.”

<https://www.techplayon.com/5g-nr-reference-signals-dmrs-ptssrs-and-csi-rs/>.

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	In addition, as shown above, data REs separate DMRS signals from one another for a particular RB in which multiple DMRS REs are found at a particular subcarrier. Those data REs are replicated across streams and thus those data REs, at least in part, contribute to generation of the channel matrix. As a further example, the Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain include a channel estimator coupled to the decoder and the receiver, wherein the channel estimator is configured to receive the received signals and the decoded at least one data symbol, wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol. U.S. Patent No. 10,868,650 indicates that the channel estimate/matrix is constantly updated by the receiving device (i.e., the '331 Patent Accused Instrumentalities) based on the data frames that are received. <i>See</i> U.S. Patent No. 10,868,650 at 8:12-19 ("In action 420, the [user equipment] UE 120 receives the frames and computes CSI based at least in part on the received frames.... The CSI may incorporate historical CSI data based on past frames, so the CSI may be based on more than just the most recently transmitted frame or frames"). Thus, if the transmitter chose to transmit using spatial diversity, then the replicated data received by the receiver device would update the channel matrix using the received replicated data. <i>See supra</i> claim elements [6a] and [6b], which are incorporated by reference. Furthermore, literature in the wireless communications field explains that received data, not just pilot symbols, update the channel matrix through a process called "data aided channel estimation." Inaamullah Khan et al., Data Aided Channel Estimation for MIMO-OFDM Wireless Systems Using Reliable Carriers, 11 IEEE Access 47836, 47838 (2023).
[6d] wherein the decoder is further configured to decode subsequent received signals based, at least in part, on the	The '331 Patent Accused Instrumentalities include a decoder that is further configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix. For example, and as explained above with reference to initial decoding based on an initial estimate of the channel matrix, the Galaxy S20 Ultra 5G's Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain include a decoder that is further configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix.

'331 Patent	The '331 Patent Accused Instrumentalities
estimate of the channel matrix.	As another example, U.S. Patent No. 9,985,802 states that user equipment “decode[s] (e.g., demodulate[s]) received data based on the channel estimate.” U.S. Patent No. 9,985,802 at 10:61-63. The Galaxy S20 Ultra 5G’s Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain decode signals received over a MIMO communications channel using the updated estimate of the channel matrix. See <i>supra</i> claim elements [6a] and [6b], which are incorporated by reference.
[8] The communication device of claim 6 wherein the first and second data streams each further include at least one pilot symbol, and wherein the channel estimator is configured to receive the at least one pilot symbol and generate an initial estimate of the channel matrix based, at least in part on the at	The channel estimator of the '331 Patent Accused Instrumentalities is configured to receive the at least one pilot symbol included in each of the first and second data streams and generate an initial estimate of the channel matrix based, at least in part on the at least one pilot symbol. See <i>supra</i> claim 6, which is incorporated by reference. For example, the Galaxy S20 Ultra 5G’s Snapdragon 865 5G chipset, including the Snapdragon X55 modem, and/or additional components in the RF chain includes a channel estimator that is configured to receive the at least one pilot symbol included in each of the first and second data streams and generate an initial estimate of the channel matrix based, at least in part on the at least one pilot symbol. https://www.qualcomm.com/news/onq/2022/09/how-qualcomm-inventor-dr-kiran-mukavilli-helped-hash-out-the-f (“In this project, we developed a systematic methodology and provided solutions to several fundamental challenges of using OFDM in a mobile wireless system. For example, I started with designing pilot signals for figuring out the wireless link characteristics, including the number of paths the signal takes and the strength of each of the paths, which is referred to as channel estimation. A good, up-to-date channel estimate is essential to supporting high data rates on wireless channels, and pilot signals are used to estimate that wireless channel, which varies with time. <i>I came up with a pilot design based on periodic placement and staggering of pilot symbols both in frequency and over time, which became a fundamental structure in OFDM-based cellular systems in 4G and 5G. We then further expanded this pilot design in 5G to</i>

'331 Patent	The '331 Patent Accused Instrumentalities <i>dynamically adapt the pilot pattern</i> depending on a user's environment and mobility conditions....") (emphasis added). A demodulation reference signal (DMRS) is a form of pilot used for channel estimation, e.g. "5G NR Reference signals DMRS, PT-RS, CSI-RS, SRS This page mentions 5G NR Reference signals viz. DMRS, PT-RS, CSI-RS, SRS. These 5G NR reference signals are used in the downlink and uplink. ... 5G NR DMRS • DMRS refers to Demodulation Reference Signal. • It is used by 5G NR receiver to produce channel estimates for demodulation of associated physical channel." https://www.rfwireless-world.com/5G/5G-NR-Reference-Signals-DMRS-vs-PTRS-vs-CSI-RS-vs-SRS.html#:~:text=DMRS%20refers%20to%20Demodulation%20Reference%20Signal.&text=It%20is%20used%20by%205G,demodulation%20of%20associated%20physical%20channel.&text=The%20design%20and%20mapping%20of,%2C%20PDSCH%2C%20PUSCH%20and%20PUCCH Furthermore, numerous patents related to wireless communications reference cell phones, receiving a pilot signal. <i>See, e.g.</i>, U.S. Patent No. 9,985,802 at 1:38-39, Figure 12 ("whereby a UE that receives the pilot reference signal..."); U.S. Patent No. 9,967,070 at 9:15-17, Figure 5 ("In block 510 at least one frame with at least one pilot structure is received and processed by a UE"); U.S. Patent No. 10,868,650 at Figure 11 ("The pilot symbol is received..."). Samsung describes 5G (New Radio), MIMO, and pilot-aided channel estimation as follows, for example: Another method of DL SU-MIMO is for a user to report a set of CSI measurement results consisting of channel quality indicator (CQI), PMI, and rank indicator (RI) to the base station. In this method, <i>the user</i>
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'331 Patent	The '331 Patent Accused Instrumentalities device continuously monitors a set of M port reference signals at every receive antennas and constructs $(N \times M)$ MIMO channel matrix. Samsung Technical White Paper, <i>Massive MIMO for New Radio</i>, December 2020 (emphasis added); see also https://www.qualcomm.com/news/onq/2022/09/how-qualcomm-inventor-dr--kiran-mukavilli-helped-hash-out-the-f (“A good, up-to-date channel estimate is essential to supporting high data rates on wireless channels, and pilot signals are used to estimate that wireless channel, which varies with time. I came up with a pilot design based on periodic placement and staggering of pilot symbols both in frequency and over time, which became a fundamental structure in OFDM-based cellular systems in 4G and 5G. We then further expanded this pilot design in 5G to dynamically adapt the pilot pattern depending on a user’s environment and mobility conditions...” (emphasis added). Moreover, as another example, 5G channel matrix estimation is based, at least in part, on a pilot symbol, e.g., see below:
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'331 Patent	The '331 Patent Accused Instrumentalities
	https://www.youtube.com/watch?v=TZzTsPQJDRo&t=562s (2:30-3:08 – PDSCH signal contains <i>data</i> and DMRS resource elements (REs) contain one or more <i>pilots</i>, as outlined in the 3GPP standard). As yet another example, U.S. Patent No. 9,985,802 entitled “Channel Estimation Enhancements” states that a user equipment “apparatus generates a channel estimate based on the received pilot.” U.S. Patent No. 9,985,802 at 20:12-13, Fig. 12. Similarly, U.S. Patent No. 9,967,070 entitled “Pilot Reconfiguration and Retransmission in Wireless Networks” states that “pilot data is typically a known data pattern that is processed in a known manner and may be used at the receiver system to estimate the channel response or other channel parameters. Pilot data may be formatted into pilot symbols.” U.S. Patent No. 9,967,070 at 4:22-26, Fig. 5.