IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

AMERICAN PATENTS LLC, Plaintiff, v. SIERRA WIRELESS INC., Defendant.	CIVIL ACTION NO. 6:21-cv-637 ORIGINAL COMPLAINT FOR PATENT INFRINGEMENT **JURY TRIAL DEMANDED**

ORIGINAL COMPLAINT FOR PATENT INFRINGEMENT

Plaintiff American Patents LLC ("American Patents" or "Plaintiff") files this original complaint against Defendant Sierra Wireless Inc. ("Sierra"), alleging, based on its own knowledge as to itself and its own actions and based on information and belief as to all other matters, as follows:

PARTIES

1. American Patents is a limited liability company formed under the laws of the State of Texas, with its principal place of business at 2325 Oak Alley, Tyler, Texas, 75703.

2. Sierra Wireless Inc. is a corporation duly organized and existing under the laws of Canada having a place of business at 13811 Wireless Way, Richmond, BC, Canada.

3. Sierra and its affiliates are part of the same corporate structure and distribution chain for the making, importing, offering to sell, selling, and/or using of the accused devices in the United States, including in the State of Texas generally and this judicial district in particular.

4. Sierra and its affiliates share the same management, common ownership, advertising platforms, facilities, distribution chains and platforms, and accused product lines and products involving related technologies.

5. Thus, Sierra and its affiliates operate as a unitary business venture and are jointly and severally liable for the acts of patent infringement alleged herein.

JURISDICTION AND VENUE

6. This is an action for infringement of United States patents arising under 35 U.S.C. §§ 271, 281, and 284–85, among others. This Court has subject matter jurisdiction of the action under 28 U.S.C. § 1331 and § 1338(a).

7. This Court has personal jurisdiction over Sierra pursuant to due process and/or the Texas Long Arm Statute because, *inter alia*, (i) Sierra has done and continues to do business in Texas; and (ii) Sierra has committed and continues to commit acts of patent infringement in the State of Texas, including making, using, offering to sell, and/or selling accused products in Texas, and/or importing accused products into Texas, including by Internet sales and sales via retail and wholesale stores, inducing others to commit acts of patent infringement in Texas, and/or committing a least a portion of any other infringements alleged herein. In the alternative, Sierra Wireless Inc. is subject to this Court's specific personal jurisdiction consistent with the principles of due process and the Federal Long-Arm Statute of Fed. R. Civ. P. 4(k)(2) because: (1) it has substantial contacts with the United States and committed and/or induced acts of patent infringement in the United States; and (2) it is not subject to jurisdiction in any state's courts of general jurisdiction.

8. Venue is proper as to Sierra Wireless Inc., which is organized under the laws of Canada. 28 U.S.C. § 1391(c)(3) provides that "a defendant not resident in the United States may be sued in any judicial district, and the joinder of such a defendant shall be disregarded in determining where the action may be brought with respect to other defendants."

BACKGROUND

9. The patents-in-suit generally pertain to communications networks and other technology used in “smart” devices such as smartphones, smart TVs, and smart appliances. The technology disclosed by the patents was developed by personnel at Georgia Institute of Technology (“Georgia Tech”), and Nokia Corporation (“Nokia”).

10. Georgia Tech is a leading public research university located in Atlanta, Georgia. Founded in 1885, Georgia Tech is often ranked as one of the top ten public universities in the United States. The patents from Georgia Tech (“the Mody patents”) were developed by a professor and a graduate student in Georgia Tech’s Electrical and Computer Engineering department. The undergraduate and graduate programs of this department are often ranked in the top five of their respective categories.

11. The Mody patents are related to Multi-Input, Multi-Output (MIMO) technology. The inventors of the Mody patents were at the forefront of MIMO, developing, disclosing, and patenting a solution for achieving both time and frequency synchronization in MIMO systems. The Mody patents (or the applications leading to them) have been cited during patent prosecution hundreds of times, by numerous leading companies in the computing and communications industries, including AMD, Alcatel Lucent, Altair, AT&T, Atheros, Blackberry, Broadcom, Comcast, Ericsson, Facebook, HP, Hitachi, Huawei, Infineon, Intel, Interdigital, IBM, Kyocera, Marvell, Matsushita, Mediatek, Motorola, NEC, Nokia, Nortel Networks, NXP, Panasonic, Philips, Qualcomm, Realtek, Samsung, Sanyo, Sharp, Sony, STMicroelectronics, Texas Instruments, and Toshiba.

12. Nokia is a Finnish multinational telecommunications, IT, and consumer electronics company. Listed on both the Helsinki Stock Exchange and the New York Stock Exchange, Nokia regularly makes the Fortune Global 500. Nokia has been the largest worldwide

vendor of mobile phones and smartphones and has been a major contributor to the mobile phone industry.

13. The patent developed at Nokia ("the Rauhala patent") is related to reduction of interference in receivers with multiple antennas. The inventors of the Rauhala patent have a combined fifty plus years of experience at Nokia and were prolific inventors for Nokia. Inventor Jyri Rauhala spent over 25 years at Nokia. Mr. Rauhala obtained a Master of Science in Applied Electronics, Digital Electronics from Tampere University of Technology in Finland and is named as an inventor on 15 U.S. patents. Inventor Olli-Pekka Lunden spent over 8 years at Nokia. Dr. Lunden obtained a Doctor of Science in Technology, Radio Engineering from Aalto University and is named as an inventor on 5 U.S. patents. Currently, Dr. Lunden works as a university lecturer at Tampere University of Technology in Finland. Inventor Marko Erkkila spent over twenty years at Nokia. Mr. Erkkila obtained a Master of Science in Digital Signal Processing, Electronics, Computer Science from Tampere University of Technology in Finland and is named as an inventor on 6 U.S. patents.

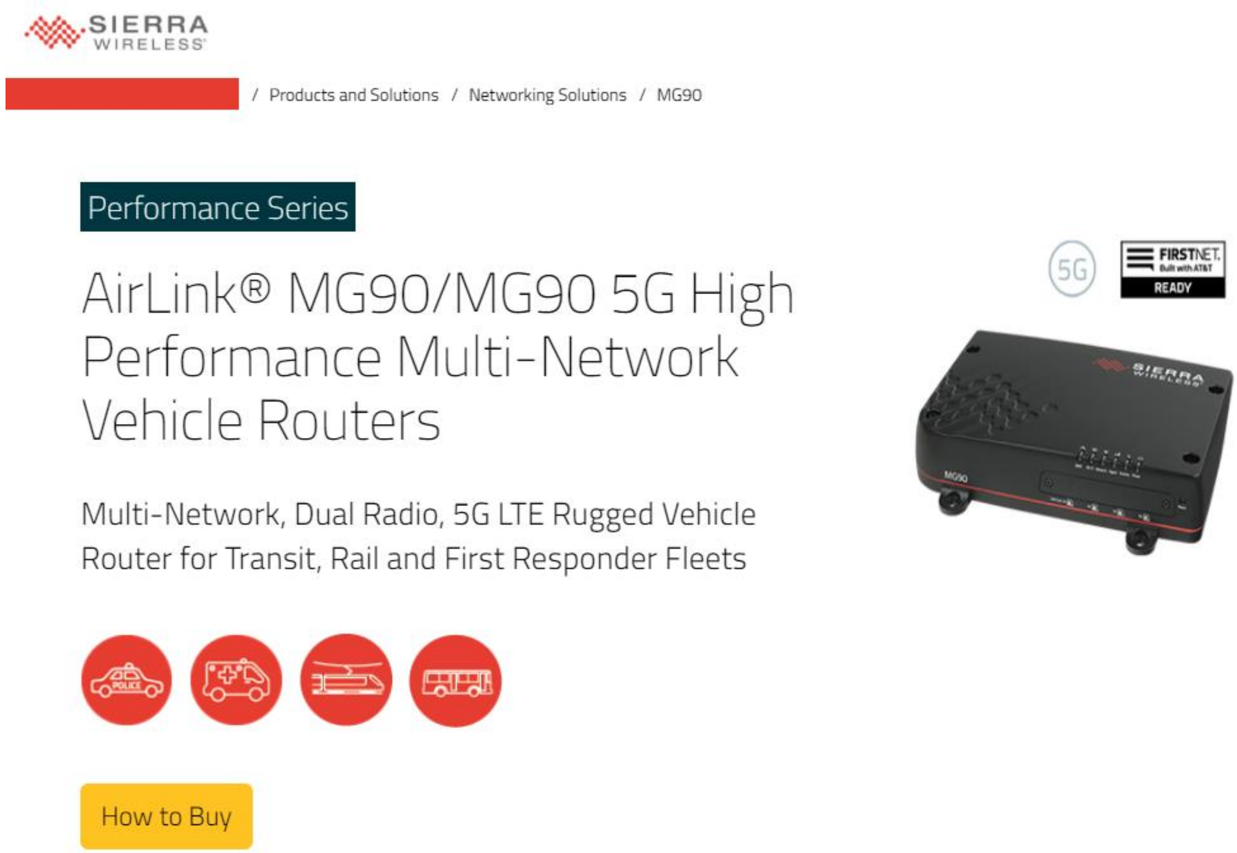
COUNT I

INFRINGEMENT OF U.S. PATENT NO. 7,088,782

14. On August 8, 2006, United States Patent No. 7,088,782 ("the '782 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Time And Frequency Synchronization In Multi-Input, Multi-Output (MIMO) Systems."

15. American Patents is the owner of the '782 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '782 Patent against infringers, and to collect damages for all relevant times.

16. Sierra used products and/or systems including, for example, its Sierra AirLink MG90, Sierra Airlink MP70, and EM LTE transceiver families of products, that include LTE and/or 802.11n and above capabilities ("accused products"):



(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MG90 5G	5G (2/1 Gbps), Dual Cellular radios (Option)
	MG90 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), Dual Cellular radios (Option)
	MG90 LTE	Cat 6 LTE (300/50 Mbps), Dual Cellular radios (Option)
Navigation	All	GNSS with inertial dead recognition and integrated vehicle telemetry.
Wi-Fi	All	Dual Radio, dual concurrent 3x3 MIMO 802.11 b/g/n/ac, Dual Band 2.4/5 GHz (each radio), Support for 128 clients. WWPA2 Enterprise.

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

SIERRA WIRELESS

/ Products and Solutions / Networking Solutions / MP70

Performance Series

AirLink® MP70: LTE Router

Multi-Port LTE-A Pro Rugged Vehicle Router for Public Safety Fleets and Industrial IoT

How to Buy

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MP70 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), FirstNet
	MP70 LTE-A	Cat 6 LTE (300/50 Mbps)
Navigation	All	GNSS with inertial dead reckoning and integrated vehicle telemetry.
Wi-Fi	All-Option	High-power, dual Band 2.4/5GHz 802.11ac Gigabit Wi-Fi (3 x 3 MIMO), 1.3 Gbps, up to 128 clients multiple SSIDs.

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

FUJITSU Notebook LIFEBOOK U7511

(Source : https://www.fujitsu.com/global/products/computing/pc/notebooks/lifebook-u7511/index.html)

Premium connectivity

Stay flexible and productive within a modern workplace environment

- Compact and versatile Intel® Thunderbolt™ 4 USB Type-C connector to charge your laptop, transfer files at fast speeds, connect external monitors and other peripherals
- Full set of interfaces with full-size LAN connector, full-size HDMI and USB Type-C
- Embedded 4G or 5G/LTE

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (cat.7) LTE Sierra Wireless EM9191 (5G)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

LTE Sierra Wireless EM7421 (Cat.7) (Downlink speed up to 300 Mbit/s, Uplink speed up to 150 Mbit/s)
LTE Sierra Wireless EM9191 (Downlink speed up to 4.5 Gbit/s MB/s, Uplink speed up to 660 Mbit/s)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

FUJITSU Tablet STYLISTIC Q7311

(Source : https://www.fujitsu.com/global/products/computing/pc/tablets/stylistic-q7311/index.html)

Wireless technologies	
Antennas	2x dual band for WLAN, 2x for LTE, Bluetooth shared with WLAN
Integrated WLAN	Intel WiFi 6 AX201 with integrated BT
WLAN encryption	WPA/WPA2/WPA3 (Wi-Fi Protected Access)
WLAN notes	Import and usage according to country-specific regulations.
Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (Cat. 7)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-STYLISTIC-Q7311.pdf)

17. By doing so, Sierra has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 30 of the '782 Patent. Sierra's infringement in this regard is ongoing.

18. Sierra has infringed the '782 Patent by using the accused products and thereby practicing a method for synchronizing a Multi-Input Multi-Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) system in time and frequency domains. For example, the accused products support the LTE standard and MIMO technology. According to the LTE standards, the physical layer performs various functions which include modulation and demodulation of physical channels as well as time and frequency synchronization.

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(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MP70 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), FirstNet
	MP70 LTE-A	Cat 6 LTE (300/50 Mbps)
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Wi-Fi	All-Option	High-power, dual Band 2.4/5GHz 802.11ac Gigabit Wi-Fi (3 x 3 MIMO), 1.3 Gbps, up to 128 clients multiple SSIDs.

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

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5.2 Overview of L1 functions

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Beamforming
- RF processing.

(Source: https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)

Synchronization Signals (PSS and SSS)

In LTE, there are two downlink synchronization signals which are used by the UE to obtain the cell identity and frame timing.

- Primary synchronization signal (PSS)
- Secondary synchronization signal (SSS)

The division into two signals is aimed to reduce the complexity of the cell search process.

(Source: https://in.mathworks.com/help/lte/ug/synchronization-signals-pss-and-sss.html)

19. The methods practiced by Sierra's use of the accused products include producing a frame of data comprising a training symbol that includes a synchronization component that aids in synchronization, a plurality of data symbols, and a plurality of cyclic prefixes. For example, the physical layer performs the modulation and demodulation of the physical channels. Further,

it uses OFDM in the downlink physical channel. Hence, there would be OFDM modulators present in transmitter of the apparatus (mobile devices such as the accused products) for modulating the data signals. The physical layer transmits downlink frames that include data symbols, pilot symbols such as PSS, SSS, reference symbols and cyclic prefixes for each symbol.

Synchronization signals are transmitted twice per 10 ms radio frame. The PSS is located in the last OFDM symbol of the first and 11th slot of each radio frame which allows the UE to acquire the slot boundary timing independent of the type of cyclic prefix length. The PSS signal is the same for any given cell in every subframe in which it is transmitted (the PSS uses a sequence known as Zadoff-Chu).

The location of the SSS immediately precedes the PSS – in the before to last symbol of the first and 11th slot of each radio frame. The UE would be able to determine the CP length by checking the absolute position of the SSS. The UE would also be able to determine the position of the 10 ms frame boundary as the SSS signal alternates in a specific manner between two transmissions (the SSS uses a sequence known as M-sequences).

In the frequency domain, the PSS and SSS occupy the central six resource blocks, irrespective of the system channel bandwidth, which allows the UE to synchronize to the network without a priori knowledge of the allocated bandwidth. The synchronization sequences use 62 sub-carriers in total, with 31 sub-carriers mapped on each side of the DC sub-carrier which is not used. This leaves 5 sub-carriers at each extremity of the 6 central RBs unused.

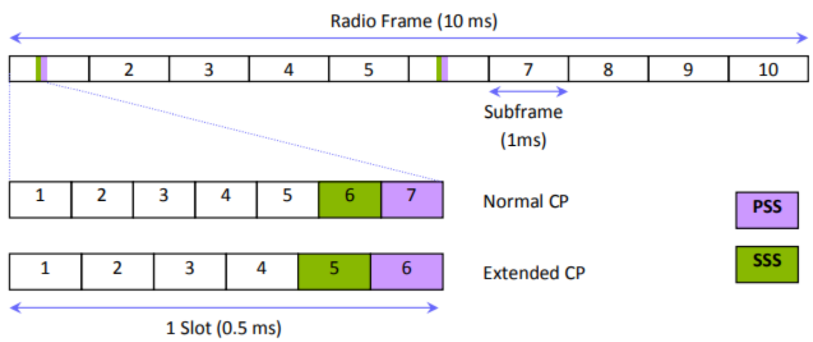

FIGURE 8 SYNCHRONIZATION SIGNAL FRAME AND SLOT STRUCTURE IN TIME DOMAIN.

(Source: https://home.zhaw.ch/kunr/NTM1/literatur/LTE%20in%20a%20Nutshell%20-%20Physical%20Layer.pdf)

4.2.1 Multiple Access

The multiple access scheme for the LTE physical layer is based on Orthogonal Frequency Division Multiplexing (OFDM) with a cyclic prefix (CP) in the downlink, and on Single-Carrier Frequency Division Multiple Access (SC-FDMA) with a cyclic prefix in the uplink. To support transmission in paired and unpaired spectrum, two duplex modes

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

6.11.1 Primary synchronization signal

6.11.1.1 Sequence generation

The sequence $d(n)$ used for the primary synchronization signal is generated from a frequency-domain Zadoff-Chu sequence according to

$$d_u(n) = \begin{cases} e^{-j\frac{\pi u n(n+1)}{63}} & n = 0,1,...,30 \\ e^{-j\frac{\pi u(n+1)(n+2)}{63}} & n = 31,32,...,61 \end{cases}$$

where the Zadoff-Chu root sequence index u is given by Table 6.11.1.1-1.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

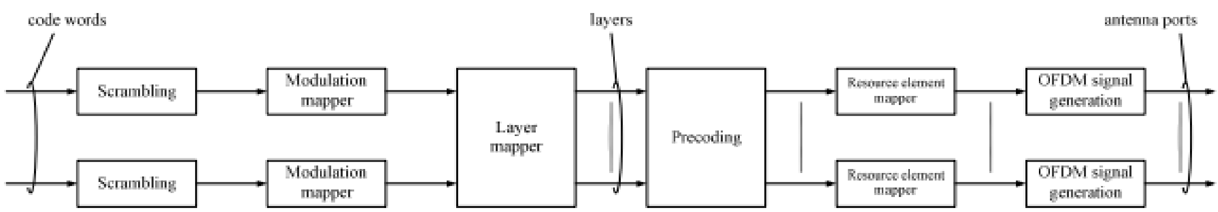

Figure 6.3-1: Overview of physical channel processing.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

Preamble and Pilot

There are two different ways to transmit training symbols: preamble or pilot tones. Preambles entail sending a certain number of training symbols prior to the user data symbols. In the case of OFDM, one or two preamble OFDM symbols are typical. Pilot tones involve inserting a few known pilot symbols among the subcarriers. Channel estimation in MIMO-OFDM systems can be performed in a variety of ways, but it is typical to use the preamble for synchronization[7] and initial channel estimation, and the pilot tones for tracking the time-varying channel in order to maintain accurate channel estimates.

In MIMO-OFDM, the received signal at each antenna is a superposition of the signals transmitted from the N_t transmit antennas. Thus, the training signals for each transmit antenna need to be transmitted without interfering with each other in order to accurately estimate the channel. Figure 5.18 shows three different patterns for MIMO-OFDM that avoid interfering with each other: independent, scattered, and orthogonal patterns [50].

(Source: Fundamentals of LTE, Ghosh et al.)

20. The methods practiced by Sierra's use of the accused products include transmitting the frame over a channel. The data frames having cyclic prefixes and other OFDM symbols are transmitted over a channel (e.g. PDCCH). Alternatively, on request from an accused product, an LTE base station can act as a transmitter and transmit the frame over a channel.

4.2.1 Multiple Access

The multiple access scheme for the LTE physical layer is based on Orthogonal Frequency Division Multiplexing (OFDM) with a cyclic prefix (CP) in the downlink, and on Single-Carrier Frequency Division Multiple Access (SC-FDMA) with a cyclic prefix in the uplink. To support transmission in paired and unpaired spectrum, two duplex modes

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

6.7 Physical control format indicator channel

The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The set of OFDM symbols possible to use for PDCCH in a subframe is given by Table 6.7-1.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/11.05.00_60/ts_136211v110500p.pdf)

21. The methods practiced by Sierra's use of the accused products include receiving the transmitted frame. For example, the receiving antennas of the accused products can receive the transmitted frames for further processing.

Specifications

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	MG90 LTE	Cat 6 LTE (300/50 Mbps), Dual Cellular radios (Option)
Navigation	All	GNSS with inertial dead recognition and integrated vehicle telemetry.
Wi-Fi	All	Dual Radio, dual concurrent 3x3 MIMO 802.11 b/g/n/ac, Dual Band 2.4/5 GHz (each radio), Support for 128 clients. WWPA2 Enterprise.

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MP70 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), FirstNet
	MP70 LTE-A	Cat 6 LTE (300/50 Mbps)
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Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (cat.7) LTE Sierra Wireless EM9191 (5G)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

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LTE Sierra Wireless EM9191 (Downlink speed up to 4.5 Gbit/s MB/s, Uplink speed up to 660 Mbit/s)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

Wireless technologies	
Antennas	2x dual band for WLAN, 2x for LTE, Bluetooth shared with WLAN
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Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (Cat. 7)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-STYLISTIC-Q7311.pdf)

22. The methods practiced by Sierra's use of the accused products include demodulating the received frame. For example, according to the LTE standards, the physical

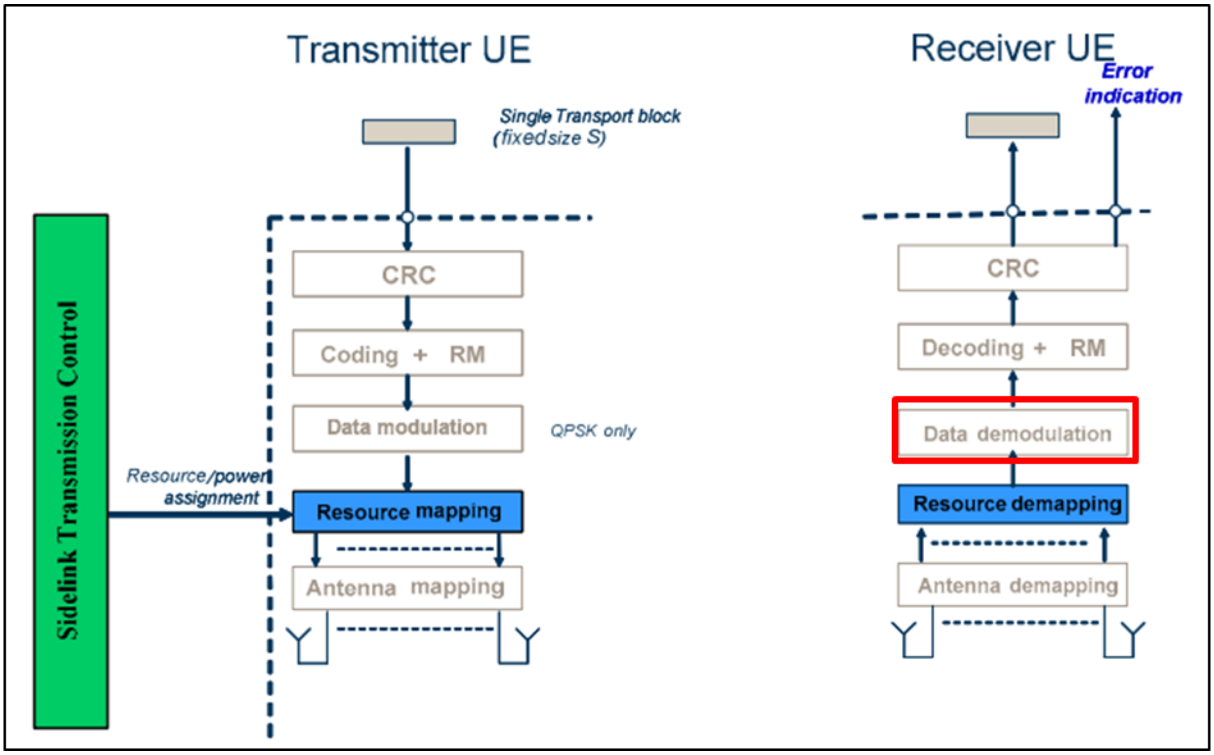
layer performs various functions which include modulation and demodulation of physical channels. Hence, the received frame will be demodulated for further processing.

5.2 Overview of L1 functions

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation

(Source: https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)



(Source: https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)

23. The methods practiced by Sierra's use of the accused products include synchronizing the received demodulated frame to the transmitted frame such that the data symbols are synchronized in the time domain and frequency domain. For example, according to the LTE standards, the physical layer performs various functions which include frequency and time synchronization. The procedure of achieving this time and frequency synchronizations is called 'Cell Search'.

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- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing

(Source:

https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

The following signals are transmitted in the downlink to facilitate cell search: the primary and secondary synchronization signals.

A UE may assume the antenna ports 0 – 3 and the antenna port for the primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136213/14.02.00_60/ts_136213v140200p.pdf)

24. The methods practiced by Sierra's use of the accused products include wherein the synchronizing in the time domain comprises coarse time synchronizing and fine time synchronizing. For example, the physical layer performs time and frequency synchronization on received frames using the cell search procedure. It uses primary and secondary synchronization signals for time and frequency synchronization. The time synchronization includes coarse and fine time synchronizations. The PSS and the SSS are and have been used for symbol timing and radio frame timing respectively providing coarse and fine timing synchronization.

The physical channels defined in the downlink are:

- the Physical Downlink Shared Channel (PDSCH),
- the Physical Multicast Channel (PMCH),
- the Physical Downlink Control Channel (PDCCH),
- the Relay Physical Downlink Control Channel (R-PDCCH),
- the Physical Broadcast Channel (PBCH),
- the Physical Control Format Indicator Channel (PCFICH)
- and the Physical Hybrid ARQ Indicator Channel (PHICH).

The physical channels defined in the uplink are:

- the Physical Random Access Channel (PRACH),
- the Physical Uplink Shared Channel (PUSCH),
- and the Physical Uplink Control Channel (PUCCH).

In addition, signals are defined as reference signals, primary and secondary synchronization signals.

The modulation schemes supported in the downlink and uplink are QPSK, 16QAM and 64QAM.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

The following signals are transmitted in the downlink to facilitate cell search: the primary and secondary synchronization signals.

A UE may assume the antenna ports 0 – 3 and the antenna port for the primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136213/14.02.00_60/ts_136213v140200p.pdf)

In time- and frequency-synchronous multi-carrier transmission the receiver at the base station needs to detect the start position of an OFDM symbol or frame and to estimate the channel state information from some known pilot symbols inserted in each OFDM symbol. If the coherence time of the channel exceeds an OFDM symbol, the channel estimation can estimate the time variation as well. This strategy, which will be considered in the following, simplifies a burst receiver.

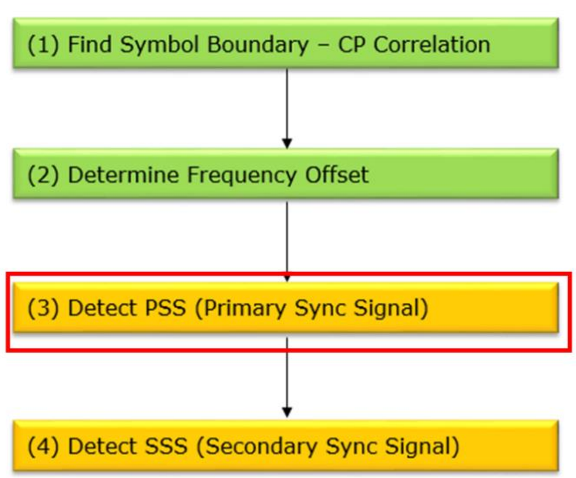
(Source: Multi-Carrier and Spread Spectrum Systems: From OFDM and MC-CDMA to LTE and WiMAX, Fazel et. Al (2008))

4.2.4.2 Fine Symbol Timing

For fine time synchronization, several methods based on transmitted reference symbols can be used [14]. One straightforward solution applies the estimation of the channel impulse response. The received signal without noise $r(t) = s(t) \otimes h(t)$ is the convolution of the transmit signal $s(t)$ and the channel impulse response $h(t)$. In the frequency domain after FFT processing we obtain $R(f) = S(f)H(f)$. By transmitting special reference symbols (e.g. CAZAC sequences [63]), $S(f)$ is *a priori* known by the receiver. Hence,

(Source: Multi-Carrier and Spread Spectrum Systems: From OFDM and MC-CDMA to LTE and WiMAX, Fazel et. Al (2008))

If you go into a little bit further details, you would need a couple of additional steps as follows (step (1) and step (2)). To detect PSS and SSS, you need to get the data with a sequence of specific resource elements accurately. To accurately extract the data from a specific resource elements, you need to know the exact symbol boundary (starting sample and ending sample of an OFDM symbol). Once you detect the exact symbol boundary, you can detect the frequency offset (a kind of frequency error) to further compenstate the signal. In some sense, these two steps are more difficult than PSS, SSS detection.



(Source: http://www.sharetechnote.com/html/BasicProcedure_LTE_TimeSync.html)

Determining Frame Synchronization and Cell Identification

The cell search involves two steps:

1. Perform running correlation with three possible PSS and detect a peak in any of the three correlators. The position of the peak provides frame timing with an uncertainty of five subframes, as the PSS is present in both subframe 0 and subframe 5.
2. Once a peak is detected, perform correlation with 31 possible SSS in subframes 0 and 5 to find one of 168 possible combinations of two SSS.

(Source: https://www.mathworks.com/company/newsletters/articles/understanding-and-demodulating-lte-signals.html)

15.1.1 DISCOVERY SIGNAL AND ASSOCIATED MEASUREMENTS

The *discovery reference signal* (DRS), although described as a new signal, actually consists of a combination already existing signals, namely

- synchronization signal (PSS and SSS) to assist in obtaining the cell identity and coarse frequency and time synchronization;
- cell-specific reference signals (CRS) to assist in obtaining fine frequency and time synchronization;
- CSI reference signals (optional) useful in determining the transmission point identity within the cell.

(Source: 4G, LTE-Advanced Pro and The Road to 5G, Dahlman et al. (2016))

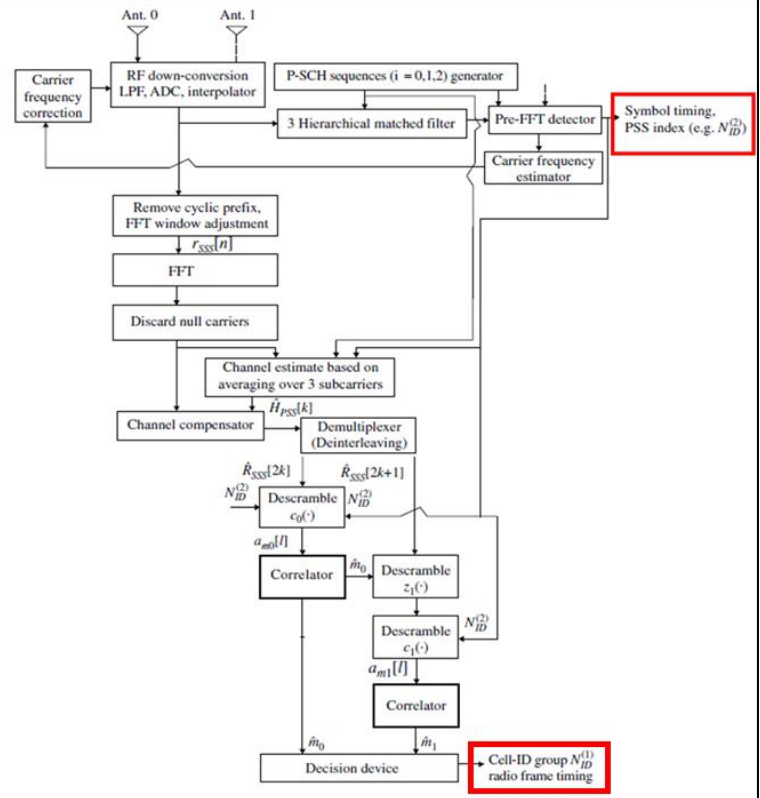


Figure 4.3 PSS and SSS detection blocks in UE receiver architecture

(Source: Mobile Terminal Receiver Design: LTE and LTE-Advanced, Das, Sajal Kumar (2017))

Step1: Symbol Timing, Frequency Offset and Physical Layer ID Detection using PSS

In this stage, the symbol timing, frequency offset, and physical-layer ID are detected using PSS. As discussed above, the PSS occupies a bandwidth of $62 \times 15\,\text{kHz}$ around the

(Source: Mobile Terminal Receiver Design: LTE and LTE-Advanced, Das, Sajal Kumar (2017))

Step-2: Radio Frame Timing and Cell Group ID Detection using SSS

Next, the radio-frame timing and cell group ID are detected using SSS in the frequency domain. As the SSS detection is generally performed in the frequency domain, FFT is

(Source: Mobile Terminal Receiver Design: LTE and LTE-Advanced, Das, Sajal Kumar (2017))

25. Sierra has had actual knowledge of the '782 Patent at least as of the date when it was notified of the filing of this action. By the time of trial, Sierra will have known and intended (since receiving such notice) that its continued actions would infringe and actively induce and contribute to the infringement of one or more claims of the '782 Patent.

26. Sierra has also indirectly and willfully infringed, and continues to indirectly and willfully infringe, the '782 Patent, as explained further below in the "Additional Allegations Regarding Infringement" section.

27. American Patents has been damaged as a result of the infringing conduct by Sierra alleged above. Thus, Sierra is liable to American Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

28. American Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the '782 Patent.

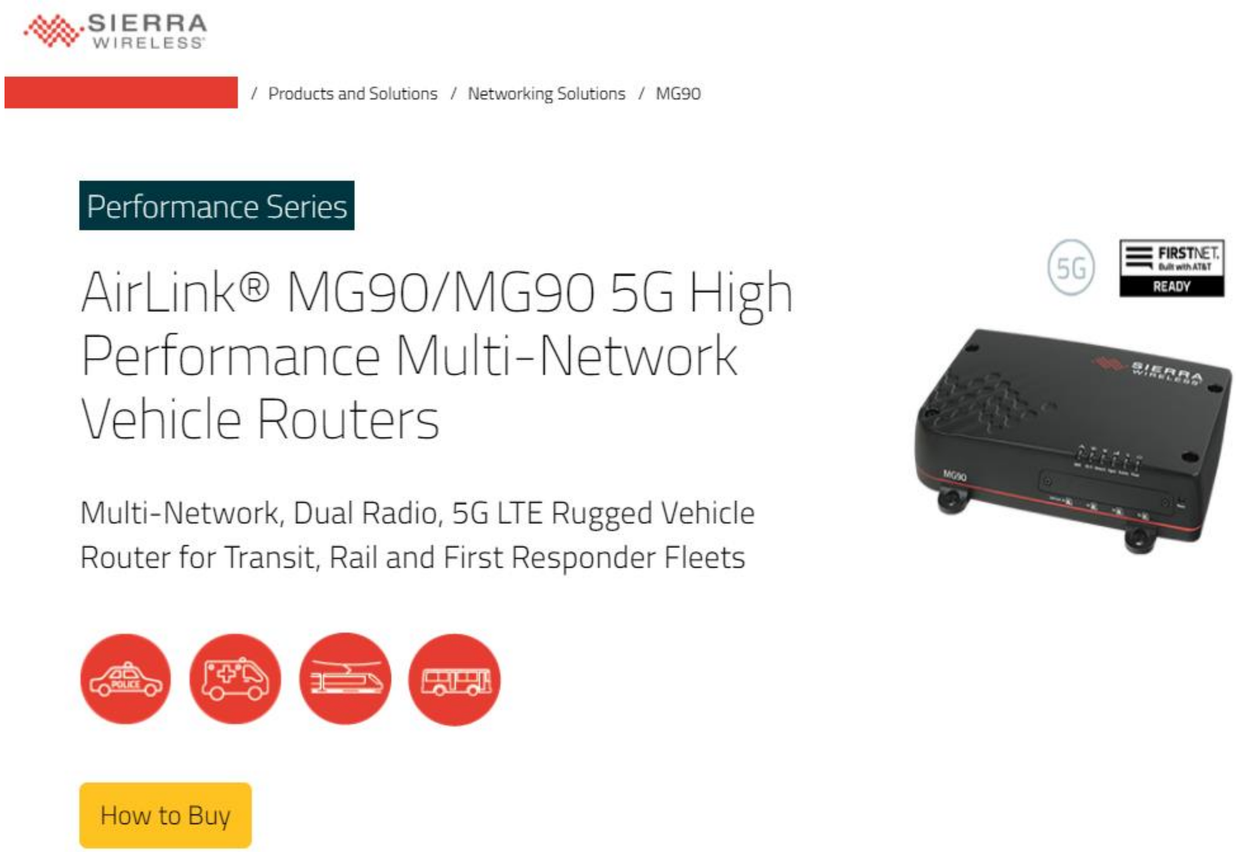
COUNT II

INFRINGEMENT OF U.S. PATENT NO. 7,310,304

29. On December 18, 2007, United States Patent No. 7,310,304 ("the '304 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Estimating Channel Parameters in Multi-Input, Multi-Output (MIMO) Systems."

30. American Patents is the owner of the '304 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '304 Patent against infringers, and to collect damages for all relevant times.

31. Sierra made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its Sierra AirLink MG90, Sierra Airlink MP70, and Sierra EM LTE transceiver families of products, that include LTE and/or 802.11n and above capabilities ("accused products"):



(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MG90 5G	5G (2/1 Gbps), Dual Cellular radios (Option)
	MG90 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), Dual Cellular radios (Option)
	MG90 LTE	Cat 6 LTE (300/50 Mbps), Dual Cellular radios (Option)
Navigation	All	GNSS with inertial dead recognition and integrated vehicle telemetry.
Wi-Fi	All	Dual Radio, dual concurrent 3x3 MIMO 802.11 b/g/n/ac, Dual Band 2.4/5 GHz (each radio), Support for 128 clients. WWPA2 Enterprise.

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

SIERRA WIRELESS

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(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MP70 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), FirstNet
	MP70 LTE-A	Cat 6 LTE (300/50 Mbps)
Navigation	All	GNSS with inertial dead reckoning and integrated vehicle telemetry.
Wi-Fi	All-Option	High-power, dual Band 2.4/5GHz 802.11ac Gigabit Wi-Fi (3 x 3 MIMO), 1.3 Gbps, up to 128 clients multiple SSIDs.

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

FUJITSU Notebook LIFEBOOK U7511

(Source : https://www.fujitsu.com/global/products/computing/pc/notebooks/lifebook-u7511/index.html)

Premium connectivity

Stay flexible and productive within a modern workplace environment

- Compact and versatile Intel® Thunderbolt™ 4 USB Type-C connector to charge your laptop, transfer files at fast speeds, connect external monitors and other peripherals
- Full set of interfaces with full-size LAN connector, full-size HDMI and USB Type-C
- Embedded 4G or 5G/LTE

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (cat.7) LTE Sierra Wireless EM9191 (5G)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

LTE Sierra Wireless EM7421 (Cat.7) (Downlink speed up to 300 Mbit/s, Uplink speed up to 150 Mbit/s)
LTE Sierra Wireless EM9191 (Downlink speed up to 4.5 Gbit/s MB/s, Uplink speed up to 660 Mbit/s)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

FUJITSU Tablet STYLISTIC Q7311

(Source : https://www.fujitsu.com/global/products/computing/pc/tablets/stylistic-q7311/index.html)

Wireless technologies	
Antennas	2x dual band for WLAN, 2x for LTE, Bluetooth shared with WLAN
Integrated WLAN	Intel WiFi 6 AX201 with integrated BT
WLAN encryption	WPA/WPA2/WPA3 (Wi-Fi Protected Access)
WLAN notes	Import and usage according to country-specific regulations.
Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (Cat. 7)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-STYLISTIC-Q7311.pdf)

32. By doing so, Sierra has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 1 of the '304 Patent. Sierra's infringement in this regard is ongoing.

33. Sierra has infringed the '304 Patent by making, having made, using, importing, providing, supplying, distributing, selling or offering for sale products including an Orthogonal Frequency Division Multiplexing (OFDM) transmitter. For example, the accused products support LTE standards with MIMO technology.

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MG90 5G	5G (2/1 Gbps), Dual Cellular radios (Option)
	MG90 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), Dual Cellular radios (Option)
	MG90 LTE	Cat 6 LTE (300/50 Mbps), Dual Cellular radios (Option)
Navigation	All	GNSS with inertial dead recognition and integrated vehicle telemetry.
Wi-Fi	All	Dual Radio, dual concurrent 3x3 MIMO 802.11 b/g/n/ac, Dual Band 2.4/5 GHz (each radio), Support for 128 clients. WWPA2 Enterprise.

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

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	MP70 LTE-A	Cat 6 LTE (300/50 Mbps)
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Wi-Fi	All-Option	High-power, dual Band 2.4/5GHz 802.11ac Gigabit Wi-Fi (3 x 3 MIMO), 1.3 Gbps, up to 128 clients multiple SSIDs.

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (cat.7) LTE Sierra Wireless EM9191 (5G)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

LTE Sierra Wireless EM7421 (Cat.7) (Downlink speed up to 300 Mbit/s, Uplink speed up to 150 Mbit/s)
LTE Sierra Wireless EM9191 (Downlink speed up to 4.5 Gbit/s MB/s, Uplink speed up to 660 Mbit/s)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

Wireless technologies	
Antennas	2x dual band for WLAN, 2x for LTE, Bluetooth shared with WLAN
Integrated WLAN	Intel WiFi 6 AX201 with integrated BT
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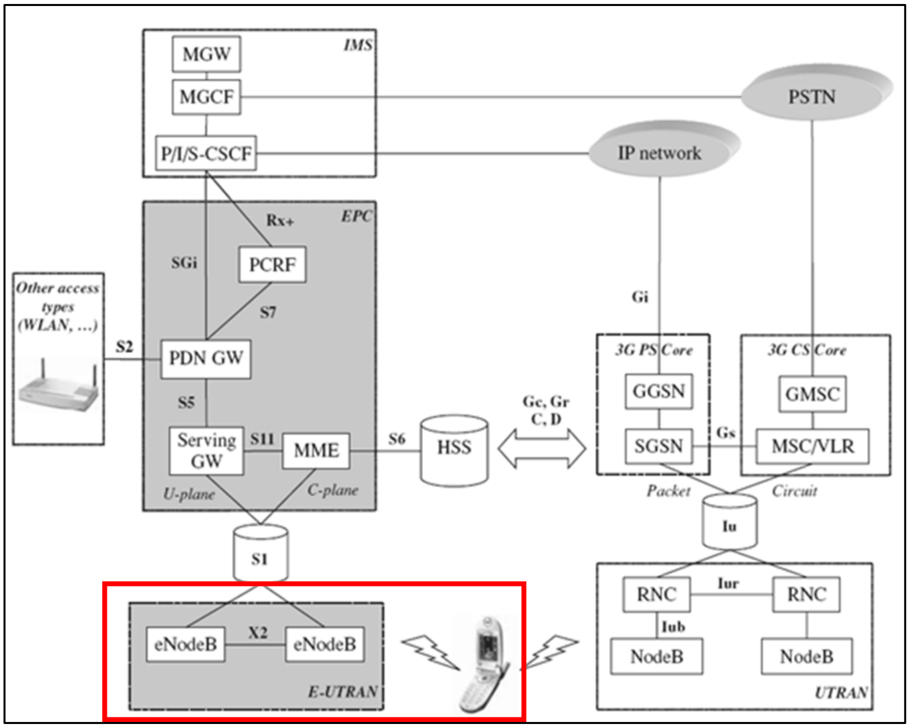
WLAN notes	Import and usage according to country-specific regulations.
Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (Cat. 7)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-STYLISTIC-Q7311.pdf)



(Source: https://sites.google.com/site/lteencyclopedia/lte-network-infrastructure-and-elements)

34. The accused products include an encoder configured to process data to be transmitted within an OFDM system, the encoder further configured to separate the data onto one or more transmit diversity branches (TDBs). Alternatively, on request from an accused product, an LTE base station includes a transmitter in an OFDM system with an encoder configured to process data to be transmitted within an OFDM system, the encoder further configured to separate the data onto one or more transmit diversity branches (TDBs). For example, according to the LTE standards, the physical layer performs FEC encoding on the transmitting data. Hence, there is an encoder block at the transmitter end; additionally, transmit diversity is performed at the transmitter end. The encoders output the data onto multiple transmit chains (i.e. transmit diversity branches) for further processing.

4.1.2 Service provided to higher layers

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Beamforming
- RF processing. (Note: RF processing aspects are specified in the TS 36.100 series)

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

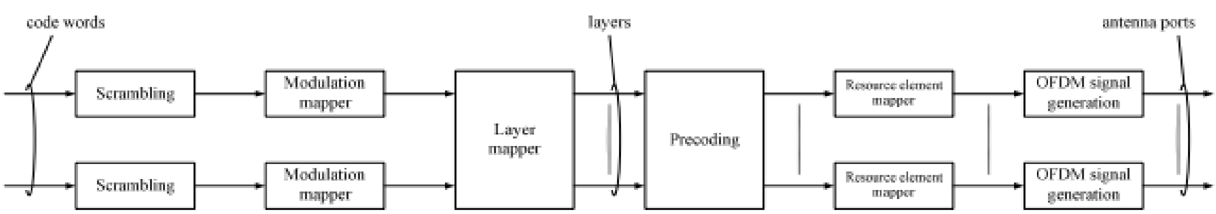


Figure 6.3-1: Overview of physical channel processing.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

35. The accused products include one or more OFDM modulators, each OFDM modulator connected to a respective TDB, each OFDM modulator configured to produce a frame

including a plurality of data symbols, a training structure, and cyclic prefixes inserted among the data symbols. For example, the physical layer performs the modulation and demodulation of the physical channels. Further, it uses OFDM in the downlink physical channel. Hence, there would be OFDM modulators for modulating the data signals. The physical layer transmits frames of data on the downlink that include cyclic prefixes, training symbols and other data groups.

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

4.2.1 Multiple Access

The multiple access scheme for the LTE physical layer is based on Orthogonal Frequency Division Multiplexing (OFDM) with a cyclic prefix (CP) in the downlink, and on Single-Carrier Frequency Division Multiple Access (SC-FDMA) with a cyclic prefix in the uplink. To support transmission in paired and unpaired spectrum, two duplex modes

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

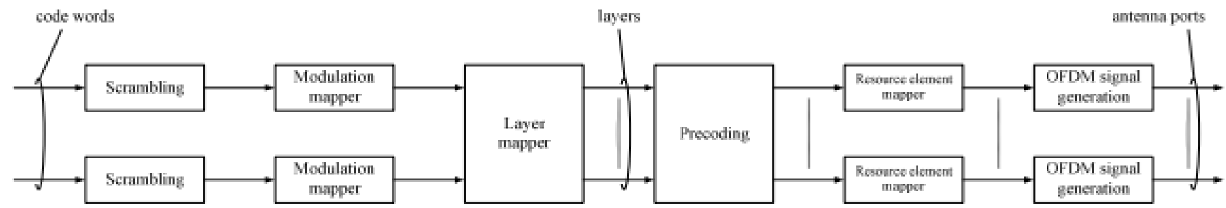


Figure 6.3-1: Overview of physical channel processing.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

Synchronization signals are transmitted twice per 10 ms radio frame. The PSS is located in the last OFDM symbol of the first and 11th slot of each radio frame which allows the UE to acquire the slot boundary timing independent of the type of cyclic prefix length. The PSS signal is the same for any given cell in every subframe in which it is transmitted (the PSS uses a sequence known as Zadoff-Chu).

The location of the SSS immediately precedes the PSS – in the before to last symbol of the first and 11th slot of each radio frame. The UE would be able to determine the CP length by checking the absolute position of the SSS. The UE would also be able to determine the position of the 10 ms frame boundary as the SSS signal alternates in a specific manner between two transmissions (the SSS uses a sequence known as M-sequences).

In the frequency domain, the PSS and SSS occupy the central six resource blocks, irrespective of the system channel bandwidth, which allows the UE to synchronize to the network without a priori knowledge of the allocated bandwidth. The synchronization sequences use 62 sub-carriers in total, with 31 sub-carriers mapped on each side of the DC sub-carrier which is not used. This leaves 5 sub-carriers at each extremity of the 6 central RBs unused.

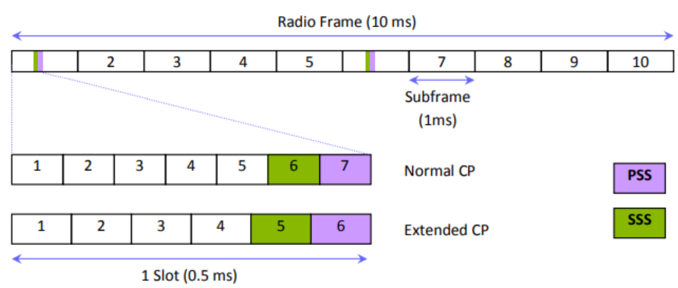


FIGURE 8 SYNCHRONIZATION SIGNAL FRAME AND SLOT STRUCTURE IN TIME DOMAIN.

(Source: https://home.zhaw.ch/kunr/NTM1/literatur/LTE%20in%20a%20Nutshell%20-%20Physical%20Layer.pdf)

36. The accused products include one or more transmitting antennas in communication with the one or more OFDM modulators, respectively, each transmitting antenna configured to transmit the respective frame over a channel. Alternatively, on request from an accused product, an LTE base station includes one or more transmitting antennas in

communication with the one or more OFDM modulators, respectively, each transmitting antenna configured to transmit the respective frame over a channel. The transmitting antennas in the base station are connected to the OFDM modulators to get the OFDM frames for further transmission.

> "Synchronization" refers to the technique applied to ensure the radios in the target LTE basestation are operating within the performance parameters defined by the appropriate 3rd Generation Partners Project (3GPP) standard. Synchronization is achieved by delivering a specifically formatted clock signal or signals to the basestation's radio circuitry. These signals in turn are used to generate the modulation method's RF air interface frequency/phase components.
>
> The RF or air interface requirements of LTE are determined by the 3GPP, a collaboration between groups of telecommunications associations, known as the Organizational Partners. The 3GPP's standardization encompasses radio, core network, and service architecture.

(Source: https://www.electronicdesign.com/communications/lte-requires-synchronization-and-standards-support)

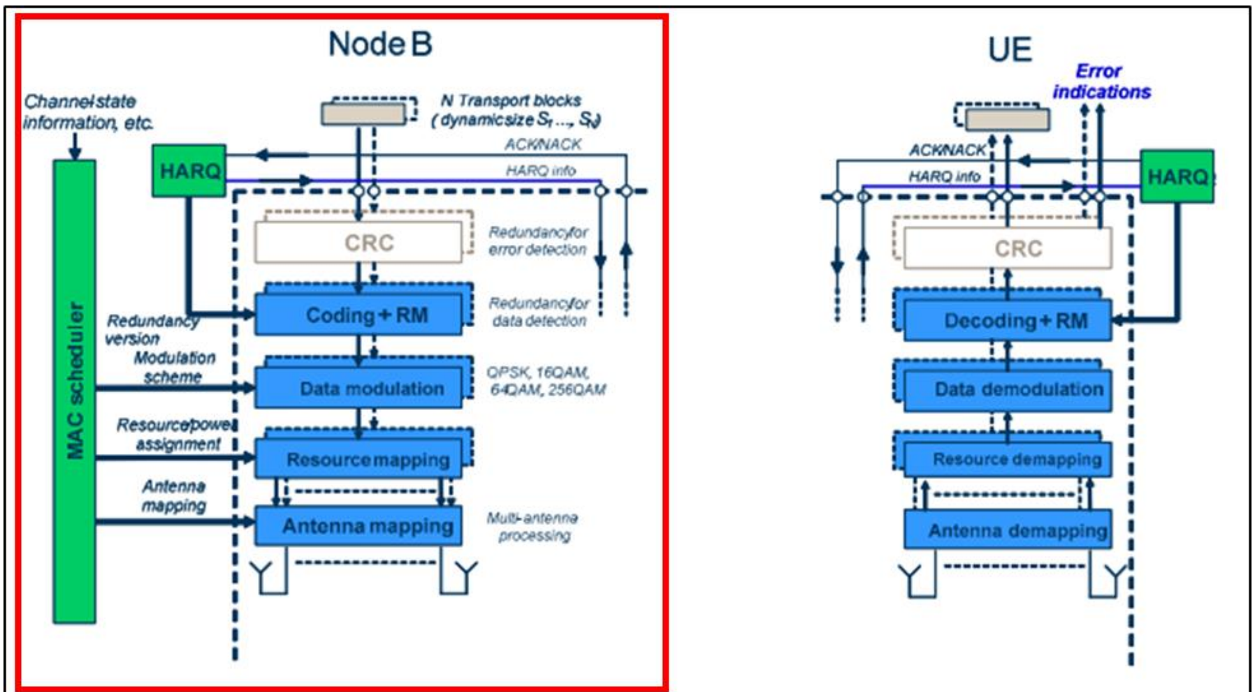


Figure 6.2.1-1: Physical-layer model for DL-SCH transmission

(Source :
https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)

6.7 Physical control format indicator channel

The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The set of OFDM symbols possible to use for PDCCH in a subframe is given by Table 6.7-1.

(Source:
https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/11.05.00_60/ts_136211v110500p.pdf)

37. The accused products include wherein the training structure of each frame includes a predetermined signal transmission matrix at a respective sub-channel, each training structure adjusted to have a substantially constant amplitude in a time domain, and the cyclic prefixes are further inserted within the training symbol, and wherein the cyclic prefixes within the training symbol are longer than the cyclic prefixes among the data symbols, thereby countering an extended channel impulse response and improving synchronization performance. Alternatively, on request from an accused product, an LTE base station includes a transmitter in an Orthogonal Frequency Division Multiplexing (OFDM) system, the transmitter comprising one or more OFDM modulators configured to produce a frame including a plurality of data symbols, a training structure, and cyclic prefixes inserted among the data symbols; wherein the training structure of each frame includes a predetermined signal transmission matrix at a respective sub-channel, each training structure adjusted to have a substantially constant amplitude in a time domain, and the cyclic prefixes are further inserted within the training symbol, and wherein the cyclic prefixes within the training symbol are longer than the cyclic prefixes among the data symbols, thereby countering an extended channel impulse response and improving

synchronization performance. For example, the physical layer performs precoding on both the downlink by generating a precoding matrix (i.e. signal transmission matrix) which is transmitted along with the data frames. Cyclic prefixes are added to the transmitting frames to help in frame synchronization at the receiver end. The evidence shows that a cell-specific reference signal acting as the training sequence are and have been used for channel estimation and are present in the first symbol of the slots in the frame. Also, the evidence shows that the cyclic prefix in the first symbol is longer than the cyclic prefix in the other data symbols. Thus, the cyclic prefix in the training strucuture reference signals are longer than the cyclic prefixes in the other data symbols. The primary synchronization signals and the cell specific reference signals are generated using Zadoff-Chu sequences which have a constant amplitude.

The scope of this specification is to establish the characteristics of the Layer-1 physical channels, generation of physical layer signals and modulation, and to specify:

- Definition of the uplink and downlink physical channels;
- The structure of the physical channels, frame format, physical resource elements, etc.;
- Modulation mapping (BPSK, QPSK, etc);
- Physical shared channel in uplink and downlink;
- Reference signal in uplink and downlink;
- Random access channel;
- Primary and secondary synchronization signals;
- OFDM signal generation in downlink;
- SC-FDMA signal generation in uplink;
- Scrambling, modulation and up conversion;
- Uplink-downlink timing relation;
- Layer mapping and precoding in downlink and uplink.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

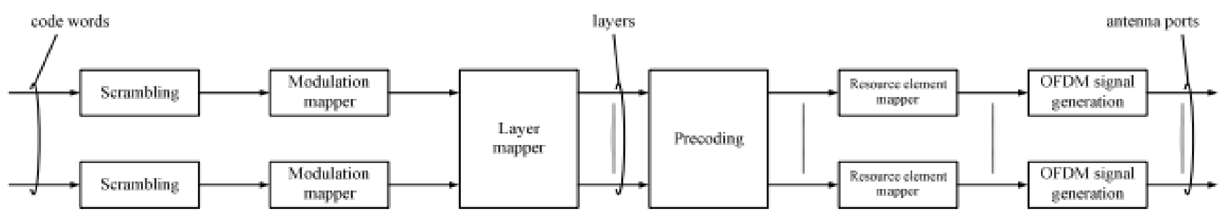


Figure 6.3-1: Overview of physical channel processing.

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

6.3.4 Precoding

The precoder takes as input a block of vectors $x(i) = \left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{layer}} - 1$ from the layer mapping and generates a block of vectors $y(i) = \left[... \quad y^{(p)}(i) \quad ...\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$ to be mapped onto resources on each of the antenna ports, where $y^{(p)}(i)$ represents the signal for antenna port p.

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

6.3.4.2.1 Precoding without CDD

Without cyclic delay diversity (CDD), precoding for spatial multiplexing is defined by

$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(P-1)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where the precoding matrix $W(i)$ is of size $P \times \upsilon$ and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

For spatial multiplexing, the values of $W(i)$ shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restrictions. The configured codebook shall be selected from Table 6.3.4.2.3-1 or 6.3.4.2.3-2.

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

6.3.4.2.2 Precoding for large delay CDD

For large-delay CDD, precoding for spatial multiplexing is defined by

$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(P-1)}(i) \end{bmatrix} = W(i)D(i)U \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where the precoding matrix $W(i)$ is of size $P \times \upsilon$ and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$. The diagonal size-$\upsilon \times \upsilon$ matrix $D(i)$ supporting cyclic delay diversity and the size-$\upsilon \times \upsilon$ matrix U are both given by Table 6.3.4.2.2-1 for different numbers of layers υ.

The values of the precoding matrix $W(i)$ shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restriction. The configured codebook shall be selected from Table 6.3.4.2.3-1 or 6.3.4.2.3-2.

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

The spatial correlation matrix for the complete system can be calculated using equation (1) above and forming the individual spatial correlation matrices at the eNB and the UE. For example, given a 2x2 MIMO system, assume the factors α and β represent the correlation coefficients, calculated using (1), for the eNB and UE antenna pairs, respectively. The correlation matrices for eNB and the UE are represented as

$$R_{BS} = \begin{pmatrix} 1 & \alpha \\ \alpha^* & 1 \end{pmatrix}, \qquad (2)$$

$$R_{MS} = \begin{pmatrix} 1 & \beta \\ \beta^* & 1 \end{pmatrix}. \qquad (3)$$

The system spatial correlation matrix for the downlink channel can be calculated using the Kronecker product

$$R_S = R_{BS} \otimes R_{MS}, \qquad (4)$$

$$R_S = \begin{pmatrix} 1 & \beta & \alpha & \alpha\beta \\ \beta^* & 1 & \alpha\beta^* & \alpha \\ \alpha^* & \alpha^*\beta & 1 & \beta \\ \alpha^*\beta^* & \alpha^* & \beta^* & 1 \end{pmatrix}. \qquad (5)$$

These expressions are needed to determine the parameters for the user interface of a fading emulator.

(Source: LTE and the Evolution to 4G Wireless: Design and Measurement Challenges, Wiley (2013))

> The useful symbol time is $T_u = 2048 \cdot T_s \approx 66.7\ \mu s$. For the normal mode, the first symbol has a cyclic prefix of length $T_{CP} = 160 \cdot T_s \approx 5.2\ \mu s$. The remaining six symbols have a cyclic prefix of length $T_{CP} = 144 \cdot T_s \approx 4.7\ \mu s$. The reason for different CP length of the first symbol is to make the overall slot length in terms of time units divisible by 15360. For the extended mode, the cyclic prefix is $T_{CP\text{-}e} = 512 \cdot T_s \approx 16.7\ \mu s$. The CP is longer than the typical delay spread of a few microseconds typically encountered in practice as shown in Figure 4. The normal cyclic prefix is used in urban cells and high data rate applications while the extended cyclic prefix is used in special cases like multi-cell broadcast and in very large cells (e.g. rural areas, low data rate applications).

(Source: https://home.zhaw.ch/kunr/NTM1/literatur/LTE%20in%20a%20Nutshell%20-%20Physical%20Layer.pdf)

> According to Chapter 4, a subcarrier spacing $\Delta f = 15$ kHz corresponds to a useful symbol time $T_u = 1/\Delta f \approx 66.7\ \mu s$ $(2048 \cdot T_s)$. The overall OFDM symbol time is then the sum of the useful symbol time and the cyclic-prefix length T_{CP}. As illustrated in Figure 16.5, LTE defines two cyclic-prefix lengths, the normal cyclic prefix and an *extended* cyclic prefix, corresponding to seven and six OFDM symbols per slot, respectively. The exact cyclic-prefix lengths, expressed in the basic time unit T_s, are given in Figure 16.5. It should be noted that, in case of the normal cyclic prefix, the cyclic-prefix length for the first OFDM symbol of a slot is somewhat larger, compared to the remaining OFDM symbols. The reason for this is simply to fill the entire 0.5 ms slot as the number of time units T_s per slot (15360) is not dividable by seven.

(Source: 3G Evolution: HSPA and LTE for Mobile Broadband, Dahlman, et al. (2010))

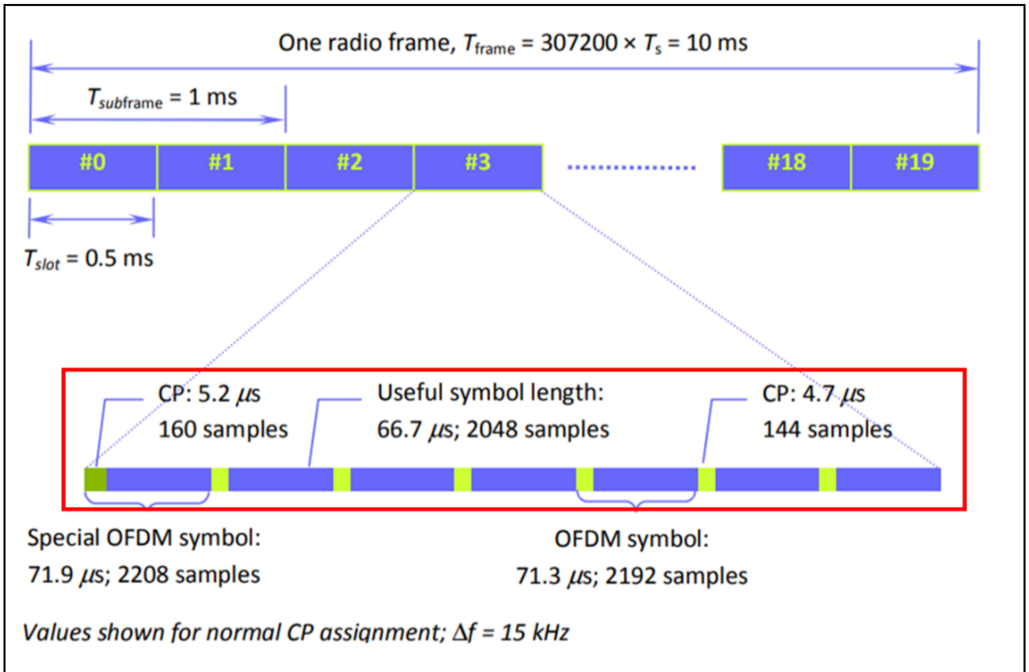


FIGURE 3 FRAME STRUCTURE TYPE 1 (FDD FRAME).

(Source: https://home.zhaw.ch/kunr/NTM1/literatur/LTE%20in%20a%20Nutshell%20-%20Physical%20Layer.pdf)

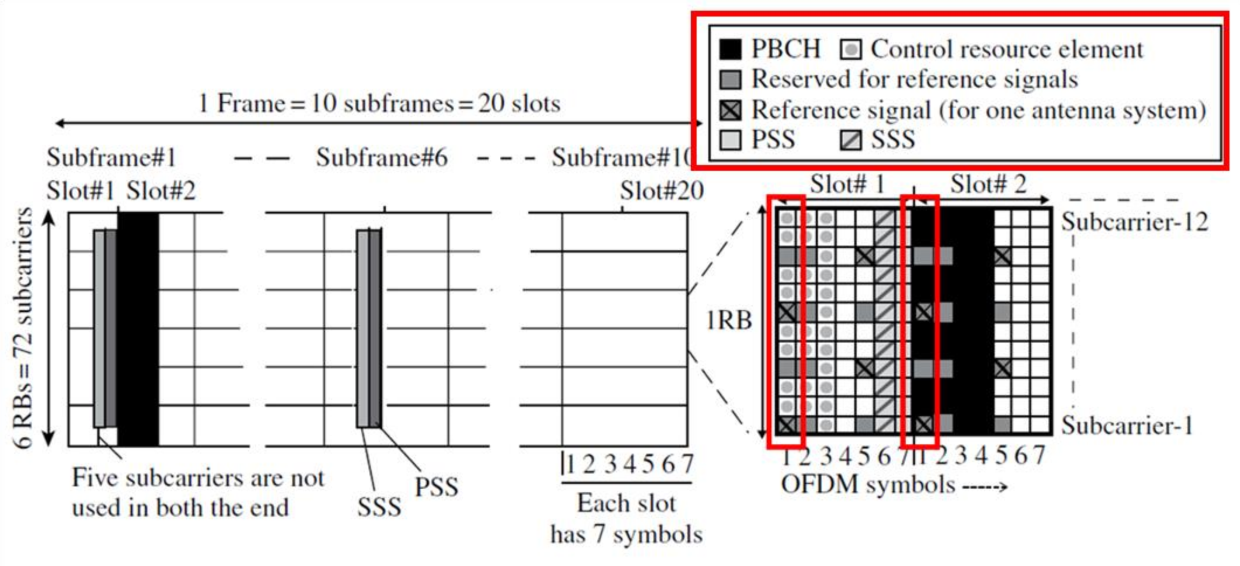


Figure 4.5 Appearance of PSS, SSS and PBCH in LTE DL frame structure

(Source: Mobile Terminal Receiver Design: LTE and LTE-Advanced, Das, Sajal Kumar (2017))

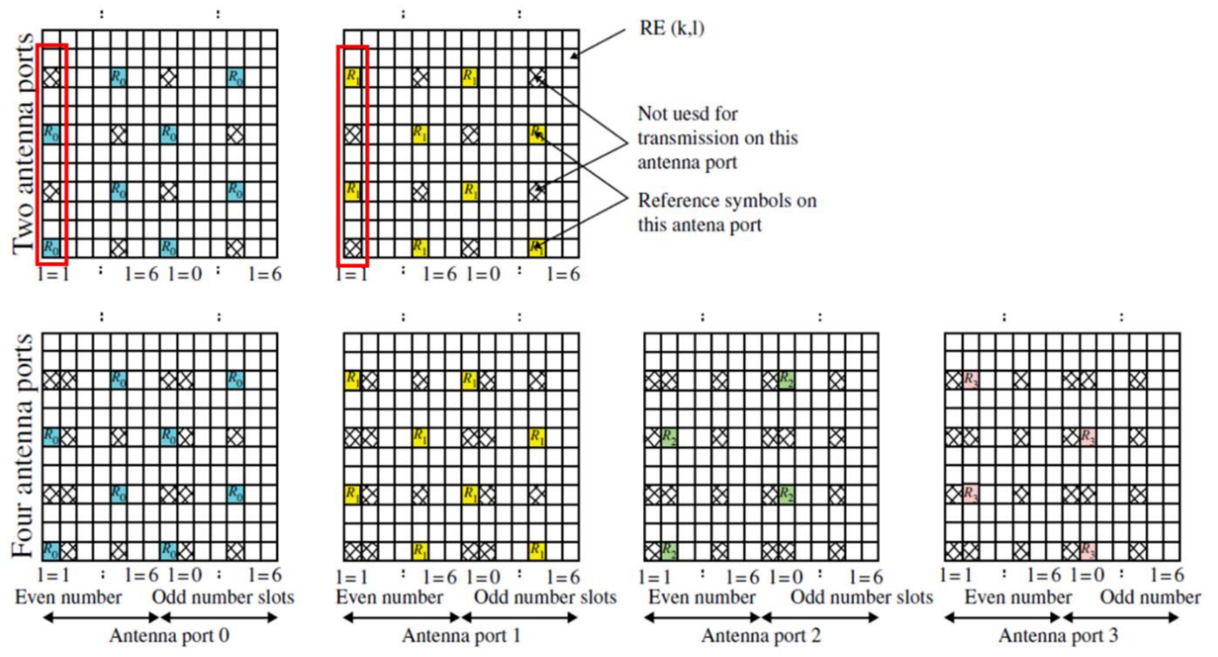


Figure 3.16 Mapping of downlink reference signals for different antenna ports (normal cyclic prefix)

(Source: Mobile Terminal Receiver Design: LTE and LTE-Advanced, Das, Sajal Kumar (2017))

6.11.1 Primary synchronization signal

6.11.1.1 Sequence generation

The sequence $d(n)$ used for the primary synchronization signal is generated from a frequency-domain Zadoff-Chu sequence according to

$$d_u(n) = \begin{cases} e^{-j\frac{\pi u n(n+1)}{63}} & n = 0,1,\ldots,30 \\ e^{-j\frac{\pi u(n+1)(n+2)}{63}} & n = 31,32,\ldots,61 \end{cases}$$

where the Zadoff-Chu root sequence index u is given by Table 6.11.1.1-1.

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

Zadoff chu sequence properties:

-It has constant amplitude.

-It has zero circular auto correlation.

-It has flat frequency domain response.

-circular cross correlation between two zadoff chu sequence is low.

-It has constant amplitude provided, L is a prime number.

LTE physical signals/channels where Zadoff chu is used

P-SS: Primary synchronization signal,Zadoff chu sequence is used for this signal.

RS: Reference Signal, used both in uplink and downlink, Zadoff chu sequence is used.

PUCCH: Physical Uplink Control Channel, Zadoff chu sequence is used.

(Source: http://www.rfwireless-world.com/Terminology/Zadoff-chu-sequence-LTE.html)

38. Sierra has had actual knowledge of the '304 Patent at least as of the date when it was notified of the filing of this action. By the time of trial, Sierra will have known and intended (since receiving such notice) that its continued actions would infringe and actively induce and contribute to the infringement of one or more claims of the '304 Patent.

39. Sierra has also indirectly and willfully infringed, and continues to indirectly and willfully infringe, the '304 Patent, as explained further below in the "Additional Allegations Regarding Infringement" section.

40. American Patents has been damaged as a result of the infringing conduct by Sierra alleged above. Thus, Sierra is liable to American Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

41. American Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the '304 Patent.

COUNT III

INFRINGEMENT OF U.S. PATENT NO. 7,706,458

42. On April 27, 2010, United States Patent No. 7,706,458 ("the '458 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Time And Frequency Synchronization In Multi-Input, Multi-Output (MIMO) Systems."

43. American Patents is the owner of the '458 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '458 Patent against infringers, and to collect damages for all relevant times.

44. Sierra made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its Sierra AirLink MG90, Sierra Airlink MP70, and Sierra EM LTE transceiver families of products, that include LTE and/or 802.11n and above capabilities ("accused products"):

SIERRA WIRELESS

/ Products and Solutions / Networking Solutions / MG90

Performance Series

AirLink® MG90/MG90 5G High Performance Multi-Network Vehicle Routers

5G FIRSTNET. Built with AT&T READY

Multi-Network, Dual Radio, 5G LTE Rugged Vehicle Router for Transit, Rail and First Responder Fleets

How to Buy

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MG90 5G	5G (2/1 Gbps), Dual Cellular radios (Option)
	MG90 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), Dual Cellular radios (Option)
	MG90 LTE	Cat 6 LTE (300/50 Mbps), Dual Cellular radios (Option)
Navigation	All	GNSS with inertial dead recognition and integrated vehicle telemetry.
Wi-Fi	All	Dual Radio, dual concurrent 3x3 MIMO 802.11 b/g/n/ac, Dual Band 2.4/5 GHz (each radio), Support for 128 clients. WWPA2 Enterprise.

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

SIERRA WIRELESS

/ Products and Solutions / Networking Solutions / MP70

Performance Series

AirLink® MP70: LTE Router

Multi-Port LTE-A Pro Rugged Vehicle Router for Public Safety Fleets and Industrial IoT

How to Buy

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MP70 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), FirstNet
	MP70 LTE-A	Cat 6 LTE (300/50 Mbps)
Navigation	All	GNSS with inertial dead reckoning and integrated vehicle telemetry.
Wi-Fi	All-Option	High-power, dual Band 2.4/5GHz 802.11ac Gigabit Wi-Fi (3 x 3 MIMO), 1.3 Gbps, up to 128 clients multiple SSIDs.

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

FUJITSU Notebook LIFEBOOK U7511

(Source : https://www.fujitsu.com/global/products/computing/pc/notebooks/lifebook-u7511/index.html)

Premium connectivity

Stay flexible and productive within a modern workplace environment

- Compact and versatile Intel® Thunderbolt™ 4 USB Type-C connector to charge your laptop, transfer files at fast speeds, connect external monitors and other peripherals
- Full set of interfaces with full-size LAN connector, full-size HDMI and USB Type-C
- Embedded 4G or 5G/LTE

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (cat.7) LTE Sierra Wireless EM9191 (5G)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

LTE Sierra Wireless EM7421 (Cat.7) (Downlink speed up to 300 Mbit/s, Uplink speed up to 150 Mbit/s)
LTE Sierra Wireless EM9191 (Downlink speed up to 4.5 Gbit/s MB/s, Uplink speed up to 660 Mbit/s)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

FUJITSU Tablet STYLISTIC Q7311

(Source : https://www.fujitsu.com/global/products/computing/pc/tablets/stylistic-q7311/index.html)

Wireless technologies	
Antennas	2x dual band for WLAN, 2x for LTE, Bluetooth shared with WLAN
Integrated WLAN	Intel WiFi 6 AX201 with integrated BT
WLAN encryption	WPA/WPA2/WPA3 (Wi-Fi Protected Access)
WLAN notes	Import and usage according to country-specific regulations.
Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (Cat. 7)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-STYLISTIC-Q7311.pdf)

45. By doing so, Sierra has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 1 of the '458 Patent. Sierra's infringement in this regard is ongoing.

46. Sierra has infringed the '458 Patent by making, having made, using, importing, providing, supplying, distributing, selling or offering for sale products including an apparatus for synchronizing a communication system. The accused product is a receiver in an apparatus for synchronizing a communication system. An LTE compliant base station that is communicating with an accused product can be part of the apparatus, acting as a transmitter. For example, according to the LTE standards, the physical layer performs various functions which include modulation and demodulation of physical channels, as well as time and frequency synchronization.

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MG90 5G	5G (2/1 Gbps), Dual Cellular radios (Option)
	MG90 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), Dual Cellular radios (Option)
	MG90 LTE	Cat 6 LTE (300/50 Mbps), Dual Cellular radios (Option)
Navigation	All	GNSS with inertial dead recognition and integrated vehicle telemetry.
Wi-Fi	All	Dual Radio, dual concurrent 3x3 MIMO 802.11 b/g/n/ac, Dual Band 2.4/5 GHz (each radio), Support for 128 clients. WWPA2 Enterprise.

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MP70 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), FirstNet
	MP70 LTE-A	Cat 6 LTE (300/50 Mbps)
Navigation	All	GNSS with inertial dead reckoning and integrated vehicle telemetry.
Wi-Fi	All-Option	High-power, dual Band 2.4/5GHz 802.11ac Gigabit Wi-Fi (3 x 3 MIMO), 1.3 Gbps, up to 128 clients multiple SSIDs.

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (cat.7) LTE Sierra Wireless EM9191 (5G)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

LTE Sierra Wireless EM7421 (Cat.7) (Downlink speed up to 300 Mbit/s, Uplink speed up to 150 Mbit/s)
LTE Sierra Wireless EM9191 (Downlink speed up to 4.5 Gbit/s MB/s, Uplink speed up to 660 Mbit/s)

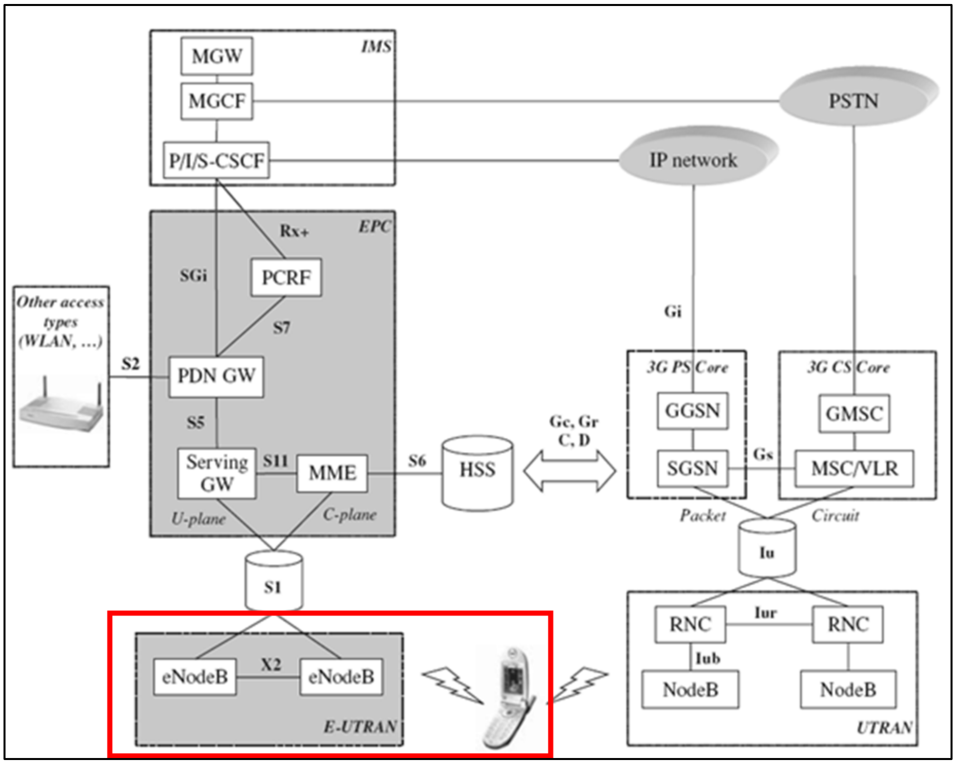
(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

Wireless technologies	
Antennas	2x dual band for WLAN, 2x for LTE, Bluetooth shared with WLAN
Integrated WLAN	Intel WiFi 6 AX201 with integrated BT
WLAN encryption	WPA/WPA2/WPA3 (Wi-Fi Protected Access)
WLAN notes	Import and usage according to country-specific regulations.
Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (Cat. 7)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-STYLISTIC-Q7311.pdf)

> "Synchronization" refers to the technique applied to ensure the radios in the target LTE basestation are operating within the performance parameters defined by the appropriate 3rd Generation Partners Project (3GPP) standard. Synchronization is achieved by delivering a specifically formatted clock signal or signals to the basestation's radio circuitry. These signals in turn are used to generate the modulation method's RF air interface frequency/phase components.
>
> The RF or air interface requirements of LTE are determined by the 3GPP, a collaboration between groups of telecommunications associations, known as the Organizational Partners. The 3GPP's standardization encompasses radio, core network, and service architecture.

(Source: https://www.electronicdesign.com/communications/lte-requires-synchronization-and-standards-support)



(Source: https://sites.google.com/site/lteencyclopedia/lte-network-infrastructure-and-elements)

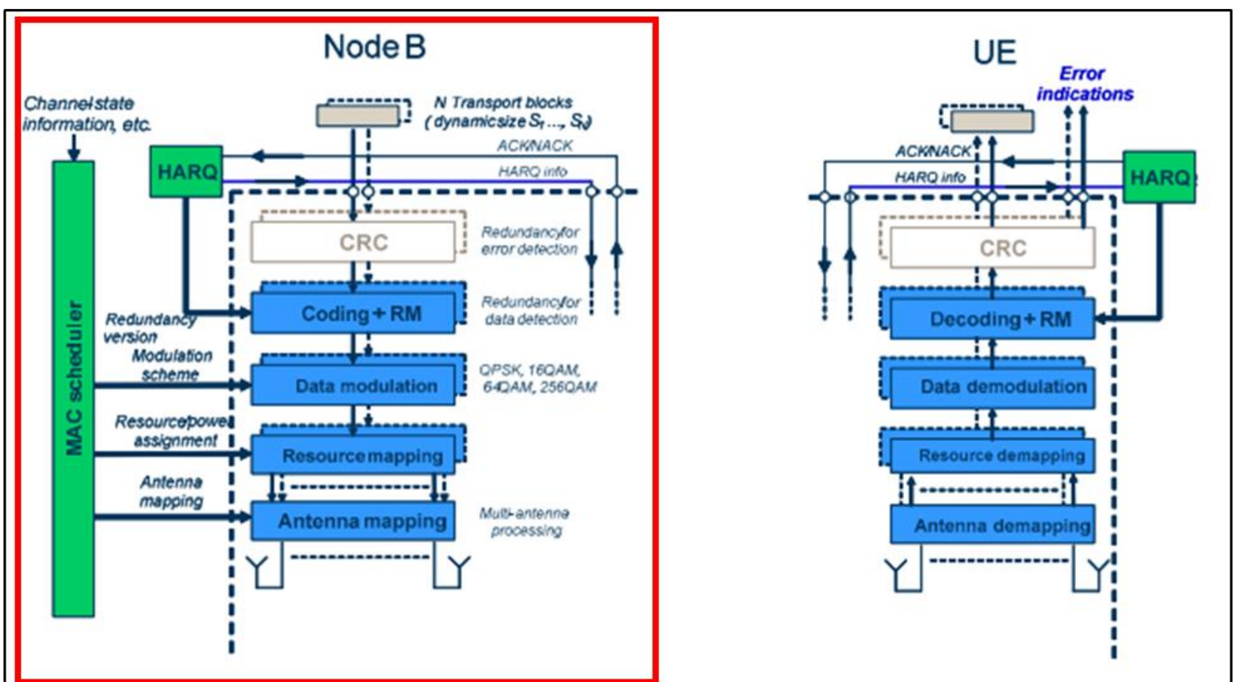


Figure 6.2.1-1: Physical-layer model for DL-SCH transmission

(Source:

https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

47. The accused products include a number (Q) of Orthogonal Frequency Division Multiplexing (OFDM) modulators, each OFDM modulator producing a frame having at least one inserted symbol, a plurality of data symbols, and cyclic prefixes. Alternatively, on being requested by an accused product, an LTE base station acts as a transmitter and includes a number (Q) of Orthogonal Frequency Division Multiplexing (OFDM) modulators, each OFDM modulator producing a frame having at least one inserted symbol, a plurality of data symbols, and cyclic prefixes. The LTE base station eNodeB acts as the transmitter for the OFDM frames. The physical layer performs the modulation and demodulation of the physical channels. Further, it uses OFDM in the downlink physical channel. Hence, there would be OFDM modulators for

modulating the data signals at the base station. The physical layer transmits frames of data on the downlink, that includes data symbols, synchronization symbols such as PSS, SSS and cyclic prefixes.

> The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:
>
> - Error detection on the transport channel and indication to higher layers
> - FEC encoding/decoding of the transport channel
> - Hybrid ARQ soft-combining
> - Rate matching of the coded transport channel to physical channels
> - Mapping of the coded transport channel onto physical channels
> - Power weighting of physical channels
> - Modulation and demodulation of physical channels
> - Frequency and time synchronisation
> - Radio characteristics measurements and indication to higher layers

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

> **4.2.1 Multiple Access**
>
> The multiple access scheme for the LTE physical layer is based on Orthogonal Frequency Division Multiplexing (OFDM) with a cyclic prefix (CP) in the downlink, and on Single-Carrier Frequency Division Multiple Access (SC-FDMA) with a cyclic prefix in the uplink. To support transmission in paired and unpaired spectrum, two duplex modes

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

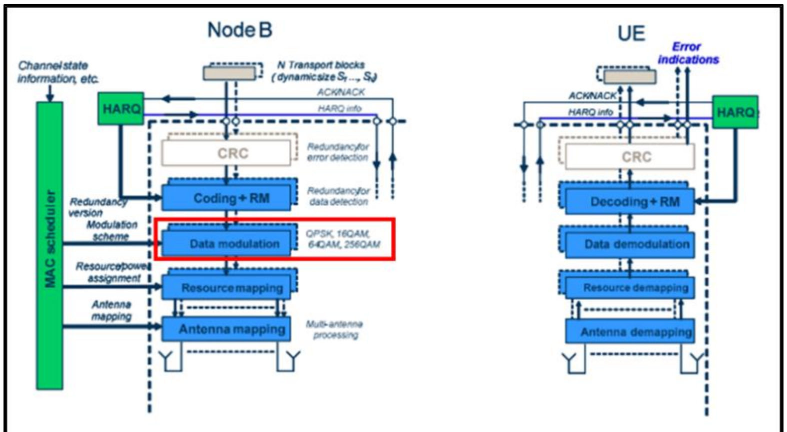


Figure 6.2.1-1: Physical-layer model for DL-SCH transmission

(Source:

https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)

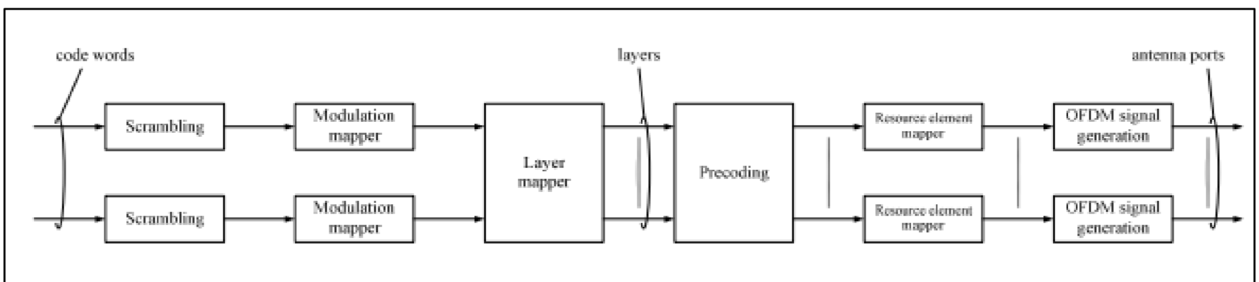


Figure 6.3-1: Overview of physical channel processing.

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.06.00_60/ts_136211v080600p.pdf)

Synchronization signals are transmitted twice per 10 ms radio frame. The PSS is located in the last OFDM symbol of the first and 11th slot of each radio frame which allows the UE to acquire the slot boundary timing independent of the type of cyclic prefix length. The PSS signal is the same for any given cell in every subframe in which it is transmitted (the PSS uses a sequence known as Zadoff-Chu).

The location of the SSS immediately precedes the PSS – in the before to last symbol of the first and 11th slot of each radio frame. The UE would be able to determine the CP length by checking the absolute position of the SSS. The UE would also be able to determine the position of the 10 ms frame boundary as the SSS signal alternates in a specific manner between two transmissions (the SSS uses a sequence known as M-sequences).

In the frequency domain, the PSS and SSS occupy the central six resource blocks, irrespective of the system channel bandwidth, which allows the UE to synchronize to the network without a priori knowledge of the allocated bandwidth. The synchronization sequences use 62 sub-carriers in total, with 31 sub-carriers mapped on each side of the DC sub-carrier which is not used. This leaves 5 sub-carriers at each extremity of the 6 central RBs unused.

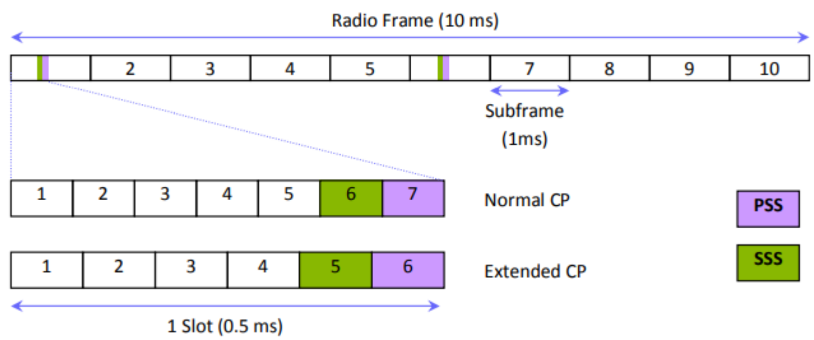


FIGURE 8 SYNCHRONIZATION SIGNAL FRAME AND SLOT STRUCTURE IN TIME DOMAIN.

(Source: https://home.zhaw.ch/kunr/NTM1/literatur/LTE%20in%20a%20Nutshell%20-%20Physical%20Layer.pdf)

48. The accused products include Q transmitting antennas, each transmitting antenna connected to a respective OFDM modulator, the transmitting antennas configured to transmit a respective frame over a channel. Alternatively, on being requested by an accused product, the LTE base station can act as a transmitter and include Q transmitting antennas, each transmitting antenna connected to a respective OFDM modulator, the transmitting antennas configured to transmit a respective frame over a channel. The LTE base station eNodeB acts as the transmitter for the data frames. The data frames having cyclic prefixes and other OFDM symbols are transmitted over a channel (PDCCH, etc.). The transmitting antennas of a base station would transmit multiple OFDM frames over a channel. Thus, these transmitting antennas would be connected to OFDM modulators to get the OFDM frames for further transmission.

6.7 Physical control format indicator channel

The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The set of OFDM symbols possible to use for PDCCH in a subframe is given by Table 6.7-1.

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/11.05.00_60/ts_136211v110500p.pdf)

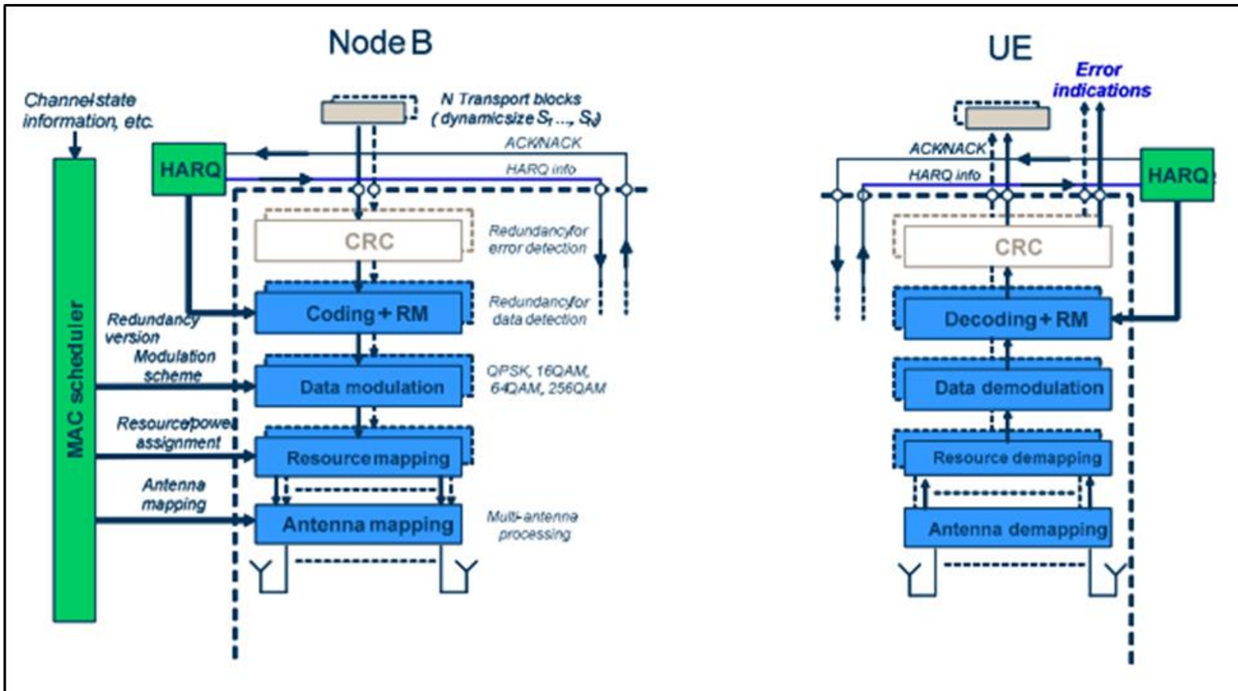


Figure 6.2.1-1: Physical-layer model for DL-SCH transmission

(Source :

https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)

49. The accused products include a number (L) of receiving antennas for receiving the transmitted frames. For example, the accused products comply with LTE standards and uses

MIMO antenna system. These receiving antennas would receive the frames transmitted by the base station.

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MG90 5G	5G (2/1 Gbps), Dual Cellular radios (Option)
	MG90 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), Dual Cellular radios (Option)
	MG90 LTE	Cat 6 LTE (300/50 Mbps), Dual Cellular radios (Option)
Navigation	All	GNSS with inertial dead recognition and integrated vehicle telemetry.
Wi-Fi	All	Dual Radio, dual concurrent 3x3 MIMO 802.11 b/g/n/ac, Dual Band 2.4/5 GHz (each radio), Support for 128 clients. WWPA2 Enterprise.

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MP70 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), FirstNet
	MP70 LTE-A	Cat 6 LTE (300/50 Mbps)
Navigation	All	GNSS with inertial dead reckoning and integrated vehicle telemetry.
Wi-Fi	All-Option	High-power, dual Band 2.4/5GHz 802.11ac Gigabit Wi-Fi (3 x 3 MIMO), 1.3 Gbps, up to 128 clients multiple SSIDs.

(Source: https://www.sierrawireless.com/products-and-solutions/routers-gateways/mp70/)

Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (cat.7) LTE Sierra Wireless EM9191 (5G)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

LTE Sierra Wireless EM7421 (Cat.7) (Downlink speed up to 300 Mbit/s, Uplink speed up to 150 Mbit/s)
LTE Sierra Wireless EM9191 (Downlink speed up to 4.5 Gbit/s MB/s, Uplink speed up to 660 Mbit/s)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-LIFEBOOK_U7511.pdf)

Wireless technologies	
Antennas	2x dual band for WLAN, 2x for LTE, Bluetooth shared with WLAN
Integrated WLAN	Intel WiFi 6 AX201 with integrated BT
WLAN encryption	WPA/WPA2/WPA3 (Wi-Fi Protected Access)
WLAN notes	Import and usage according to country-specific regulations.
Integrated LTE or UMTS	LTE Sierra Wireless EM7421 (Cat. 7)

(Source : https://sp.ts.fujitsu.com/dmsp/Publications/public/ds-STYLISTIC-Q7311.pdf)

50. The accused products include L OFDM demodulators, each OFDM demodulator corresponding to a respective receiving antenna, the L OFDM demodulators including a synchronization circuit that processes the received frame in order to synchronize the received frame in both time domain and frequency domain. For example, according to the LTE standards, the physical layer performs various functions which include modulation and demodulation, as well as frequency and time synchronization. Hence, there would be demodulator blocks and synchronization circuits for performing these functions. The procedure of achieving time and frequency synchronizations is called 'Cell Search'.

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

The following signals are transmitted in the downlink to facilitate cell search: the primary and secondary synchronization signals.

A UE may assume the antenna ports 0 – 3 and the antenna port for the primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

(Source:

https://www.etsi.org/deliver/etsi_ts/136200_136299/136213/14.02.00_60/ts_136213v140200p.pdf)

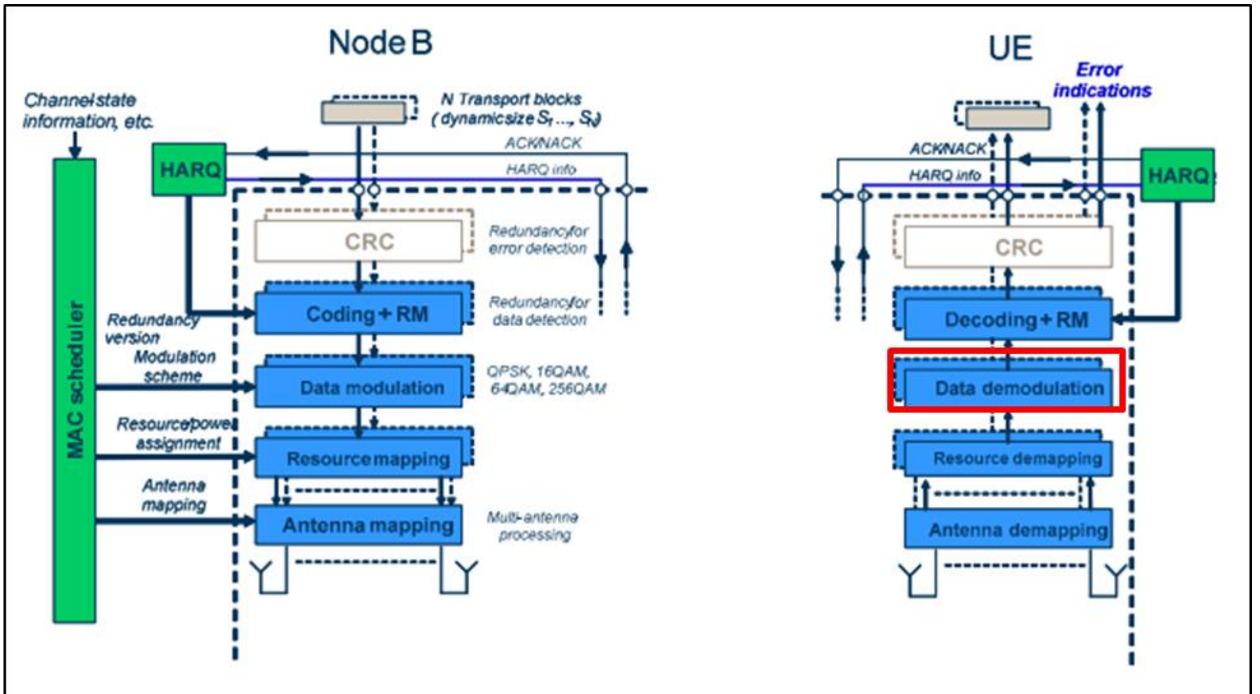


Figure 6.2.1-1: Physical-layer model for DL-SCH transmission

(Source: https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/15.00.00_60/ts_136302v150000p.pdf)

51. The accused products include wherein each of the L OFDM demodulators comprises a pre-amplifier, a local oscillator, a mixer having a first input and a second input, the first input connected to an output of the pre-amplifier, the second input connected to an output of the local oscillator, an analog-to-digital converter (ADC) connected to an output of the mixer. LTE devices generally include RF Front-end Modules. After the data is transmitted by the base station, the data is received by a receiving antenna of the accused product for further processing. To prevent the demodulator from demodulating the noise associated with the received signal, an RF front end circuit is implemented to increase the SNR of demodulated signal. The RF front end circuit generally consists of amplifiers, local oscillator, filters and mixers. The output from

the mixer is generally fed to an analog-to-digital converter (ADC). This RF front end circuit generally lies at the start of the demodulation process.

> The technique to combat a low SNR_{demod_in} is by adding a front end block, which processes (conditions) the received signal/AWGN/interference before admitting it to the demodulator. This processing can be done in several ways:

(Source: VLSI for Wireless Communication)

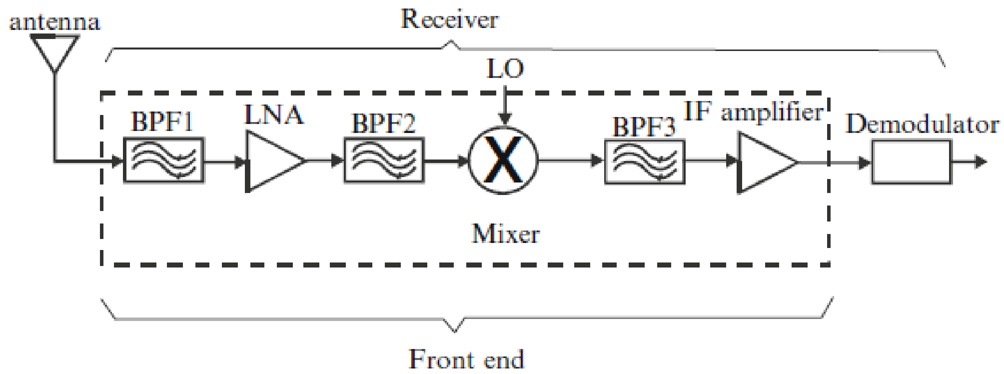
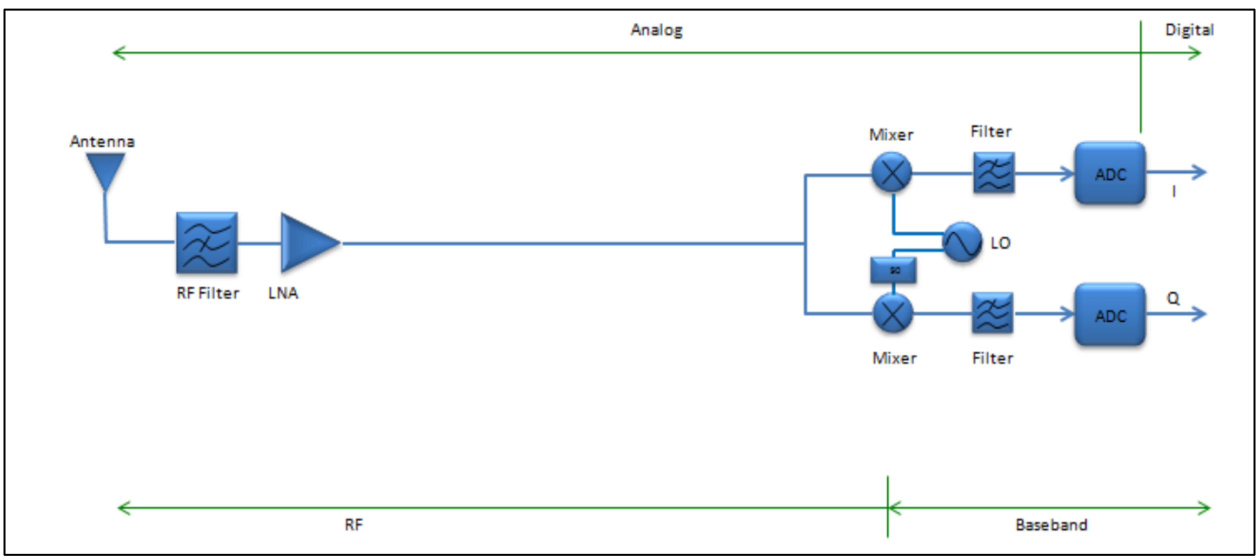


Fig. 2.2 RF receiver using a heterodyne architecture

(Source: VLSI for Wireless Communication)



(Source: http://www.sharetechnote.com/html/RF_Introduction.html)

2.4 Rest of Receiver Front End: Nonidealities and Design Parameters

Now that we have talked about the design of filters in the receiver front, we turn our attention to the design of the rest of the components. Normally these components consist of circuits such as LNA, mixer, IF amplifier, and analog/digital (A/D) converter. Unlike filters, their relevant design parameters are different. Hence our first task is to discuss these design parameters.

(Source: VLSI for Wireless Communication)

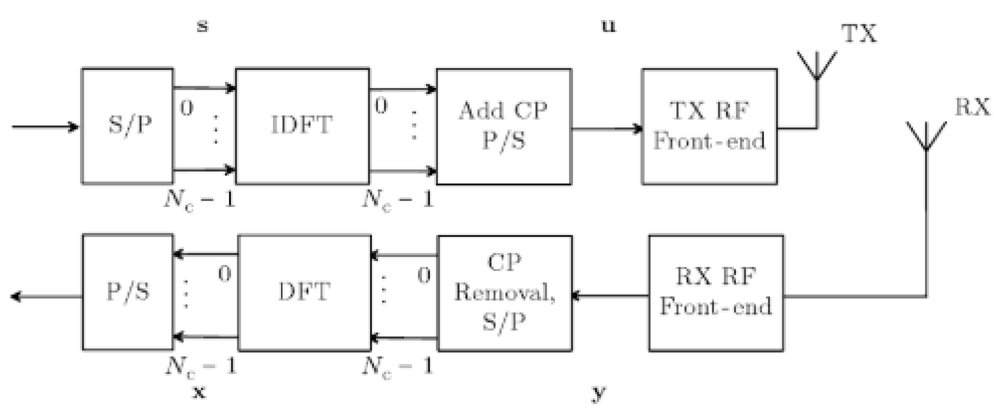


Figure 2.7. OFDM system model.

(Source: RF Imperfections in High-rate Wireless Systems: Impact and Digital Compensation, Schenk (2008))

The RF front end is generally defined as everything between the antenna and the digital baseband system. For a receiver, this "between" area includes all the filters, low-noise amplifiers (LNAs), and down-conversion mixer(s) needed to process the modulated signals received at the antenna into signals suitable for input into the baseband analog-to-digital converter (ADC). For this reason, the RF front end is often called the analog-to-digital or RF-to-baseband portion of a receiver.

(Source: https://www.eetimes.com/document.asp?doc_id=1276331)

52. The accused products include the synchronization circuit having one input connected to an output of the ADC. According to the LTE standards, the physical layer performs various functions which include frequency and time synchronization. The procedure of achieving this time and frequency synchronizations is called 'Cell Search'. Hence, there are synchronization circuits for performing these functions. The synchronization circuit is connected to an ADC.

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136201/10.00.00_60/ts_136201v100000p.pdf)

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

The following signals are transmitted in the downlink to facilitate cell search: the primary and secondary synchronization signals.

A UE may assume the antenna ports 0 – 3 and the antenna port for the primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

(Source: https://www.etsi.org/deliver/etsi_ts/136200_136299/136213/14.02.00_60/ts_136213v140200p.pdf)

53. The accused products include a cyclic-prefix remover connected to an output of the synchronization circuit, a serial-to-parallel converter connected to an output of the cyclic prefix remover, and a discrete Fournier transform (DFT) stage connected to an output of the serial-to-parallel converter, an output of the DFT stage connected to another input to the synchronization circuit. Cyclic prefixes are added in the preamble for each transmitted frame. In a general OFDM system, a cyclic prefix remover circuit would be present at the receiver end. The output from the cyclic prefix remover circuit is fed to a serial-to-parallel converter for performing a DFT operation on its output.

Synchronization signals are transmitted twice per 10 ms radio frame. The PSS is located in the last OFDM symbol of the first and 11th slot of each radio frame which allows the UE to acquire the slot boundary timing independent of the type of cyclic prefix length. The PSS signal is the same for any given cell in every subframe in which it is transmitted (the PSS uses a sequence known as Zadoff-Chu).

The location of the SSS immediately precedes the PSS – in the before to last symbol of the first and 11th slot of each radio frame. The UE would be able to determine the CP length by checking the absolute position of the SSS. The UE would also be able to determine the position of the 10 ms frame boundary as the SSS signal alternates in a specific manner between two transmissions (the SSS uses a sequence known as M-sequences).

In the frequency domain, the PSS and SSS occupy the central six resource blocks, irrespective of the system channel bandwidth, which allows the UE to synchronize to the network without a priori knowledge of the allocated bandwidth. The synchronization sequences use 62 sub-carriers in total, with 31 sub-carriers mapped on each side of the DC sub-carrier which is not used. This leaves 5 sub-carriers at each extremity of the 6 central RBs unused.

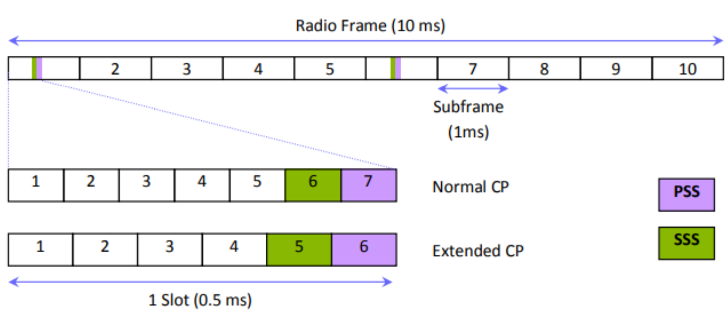


FIGURE 8 SYNCHRONIZATION SIGNAL FRAME AND SLOT STRUCTURE IN TIME DOMAIN.

(Source: https://home.zhaw.ch/kunr/NTM1/literatur/LTE%20in%20a%20Nutshell%20-%20Physical%20Layer.pdf)

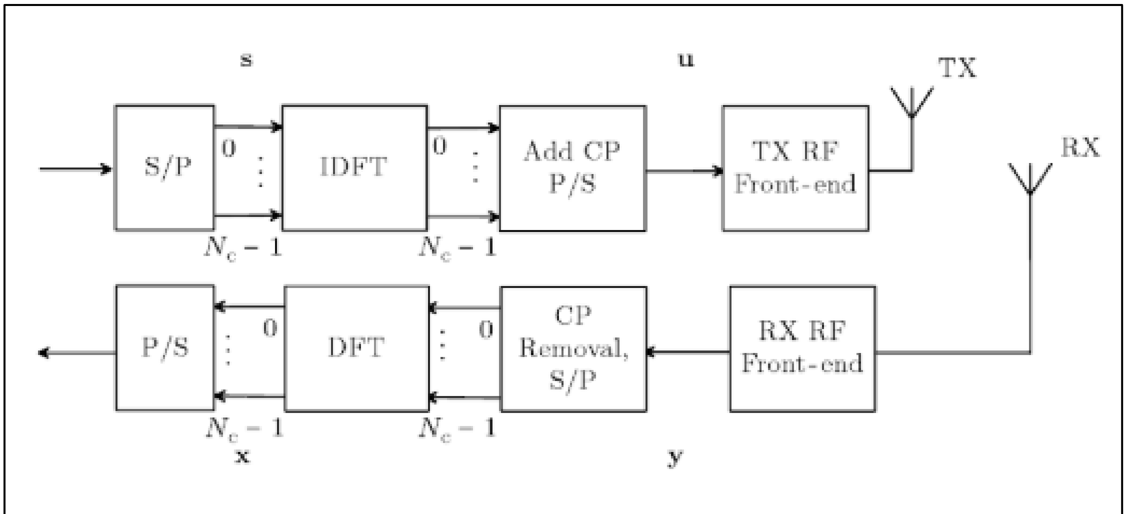


Figure 2.7. OFDM system model.

(Source: RF Imperfections in High-rate Wireless Systems: Impact and Digital Compression, Schenk, Tim)

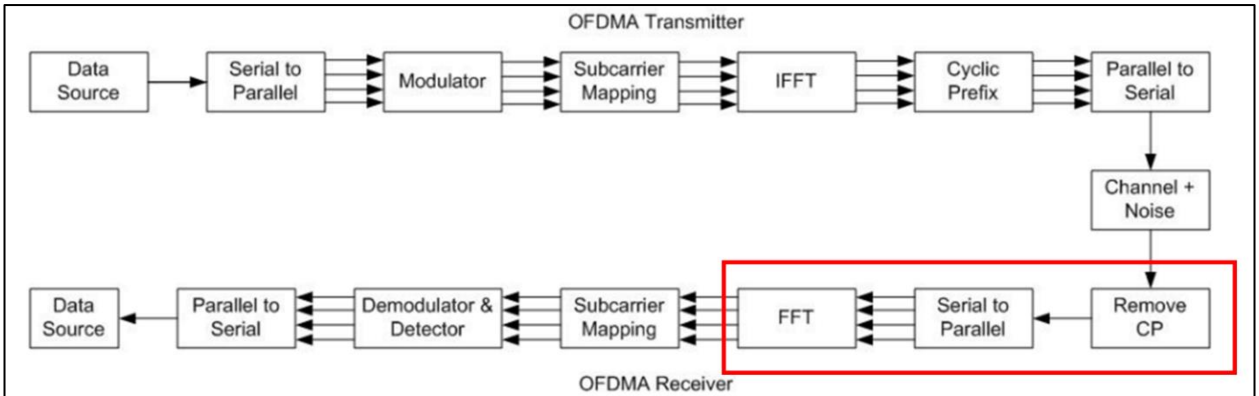


Fig 13: Block diagram of an OFDMA system.

(Source: http://ijettjournal.org/volume-12/number-2/IJETT-V12P214.pdf)

54. Sierra has had actual knowledge of the '458 Patent at least as of the date when it was notified of the filing of this action. By the time of trial, Sierra will have known and intended (since receiving such notice) that its continued actions would infringe and actively induce and contribute to the infringement of one or more claims of the '458 Patent.

55. Sierra has also indirectly and willfully infringed, and continues to indirectly and willfully infringe, the '458 Patent, as explained further below in the "Additional Allegations Regarding Infringement" section.

56. American Patents has been damaged as a result of the infringing conduct by Sierra alleged above. Thus, Sierra is liable to American Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

57. American Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the '458 Patent.

COUNT IV

INFRINGEMENT OF U.S. PATENT NO. 6,847,803

58. On January 25, 2005, United States Patent No. 6,847,803 ("the '803 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Method for Reducing Interference in a Receiver."

59. American Patents is the owner of the '803 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '803 Patent against infringers, and to collect damages for all relevant times.

60. Sierra made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its Sierra AirLink MG90 family of products, that include 802.11ac beamforming capabilities ("accused products"):

SIERRA WIRELESS

/ Products and Solutions / Networking Solutions / MG90

Performance Series

AirLink® MG90/MG90 5G High Performance Multi-Network Vehicle Routers

5G

FIRSTNET. Built with AT&T READY

Multi-Network, Dual Radio, 5G LTE Rugged Vehicle Router for Transit, Rail and First Responder Fleets

How to Buy

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

Specifications

Top Features	Device Variant	Specifications
LTE Supported	MG90 5G	5G (2/1 Gbps), Dual Cellular radios (Option)
	MG90 LTE-A Pro	Cat 12 LTE-A Pro (600/150 Mbps), Dual Cellular radios (Option)
	MG90 LTE	Cat 6 LTE (300/50 Mbps), Dual Cellular radios (Option)
Navigation	All	GNSS with inertial dead recognition and integrated vehicle telemetry.
Wi-Fi	All	Dual Radio, dual concurrent 3x3 MIMO 802.11 b/g/n/ac, Dual Band 2.4/5 GHz (each radio), Support for 128 clients. WWPA2 Enterprise.

(Source : https://www.sierrawireless.com/products-and-solutions/routers-gateways/mg90/)

WIFI SPECIFICATION

Chipset		Antennas	6
MU-MIMO		Max. Clients	128
Roaming		Radios	2
Max. Throughput		Beamforming	

BAND	MAX. RADIOS	TECHNOLOGY	MIMO
2.4 GHz	1	802.11n	3x3 MIMO
5 GHz	1	802.11ac Wave 1	3x3 MIMO
2.4 GHz	1	BLE 4.2	1x1 SISO

(Source : https://r-spectrum.com.au/equipment/modems/sierra-wireless-mg90-industrial-5g-modem-2-gbs)

Beamforming and MU-MIMO

Beamforming is key for the support of multiuser MIMO, or MU-MIMO, which is becoming more popular as 802.11ax routers roll out. As the name implies, MU-MIMO involves multiple users that can each communicate to multiple antennas on the router. MU-MIMO uses beamforming to make sure communication from the router is efficiently targeted to each connected client.

(Source: https://www.networkworld.com/article/3445039/beamforming-explained-how-it-makes-wireless-communication-faster.html)

61. By doing so, Sierra has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 1 of the '803 Patent. Sierra's infringement in this regard is ongoing.

62. Sierra has infringed the '803 Patent by using the accused products and thereby practicing a method for reducing interference in a receiver for receiving information in receiving time slots, in which receiver signals are received with at least a first antenna (ANT1) and a second antenna (ANT2). For example, the accused products are and have been used by Sierra to implement the IEEE 802.11-2016 Standard, whose requirements were in effect five years before the Complaint. Devices that can communicate using 802.11 protocol are known as Stations (STAs). Multiple Input Multiple Output (MIMO) and Beamforming techniques are and have been used by a STA with multiple antennas for steering the signals to each STA ("receiver") for reception. In such MIMO transmissions, the space-time streams in the transmitted signal would be intended for reception by each STA in its corresponding time slots. These time slots at which the STA receives the space-time streams with actual data information can be construed as receiving time slots. Since, there are multiple antennas, when they transmit simultaneously, the signal appears as interference at each of the receive antennas. Further, a STA will also be able to identify the space-time streams intended for other STAs that act as interference. STA uses and

has used the channel state information that is obtained by estimating a channel to reduce the interference caused by other space time streams. The beamforming calibration procedures ("method for reducing interference") involves channel estimation and matrix calculations which help in reducing the interference in a receiver. Indeed, the IEEE 802.11-2016 Standard shows MIMO systems with two STAs (i.e., STA A and STA B) using multiple antennas ("a first antenna (ANT1) and a second antenna (ANT2)") for receiving transmitted signals.

21.3.11.1 General

SU-MIMO and DL-MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming all space-time streams in the transmitted signal are intended for reception at a single STA. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs.

(Source : IEEE 802.11-2016 Standard, p. 2578)

19.3.12 Beamforming

19.3.12.1 General

Beamforming is a technique in which the beamformer utilizes the knowledge of the MIMO channel to generate a steering matrix Q_k that improves reception in the beamformee.

(Source : IEEE 802.11-2016 Standard, p. 2392)

A STA is also able to identify the space-time streams intended for other STAs that act as interference. VHT-LTF symbols in the VHT MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, the STA may use the channel state information for all space-time streams to reduce the effect of interfering space-time streams.

(Source : IEEE 802.11-2016 Standard, p. 2580)

(2) (**STA**tion) A client device in an 802.11 (Wi-Fi) wireless network such as a computer, laptop or smartphone. The term STA is sometimes used for the access point (AP) as well, in which case a STA is any device communicating via the 802.11 protocol. See wireless LAN and access point.

(Source : https://www.pcmag.com/encyclopedia/term/sta)

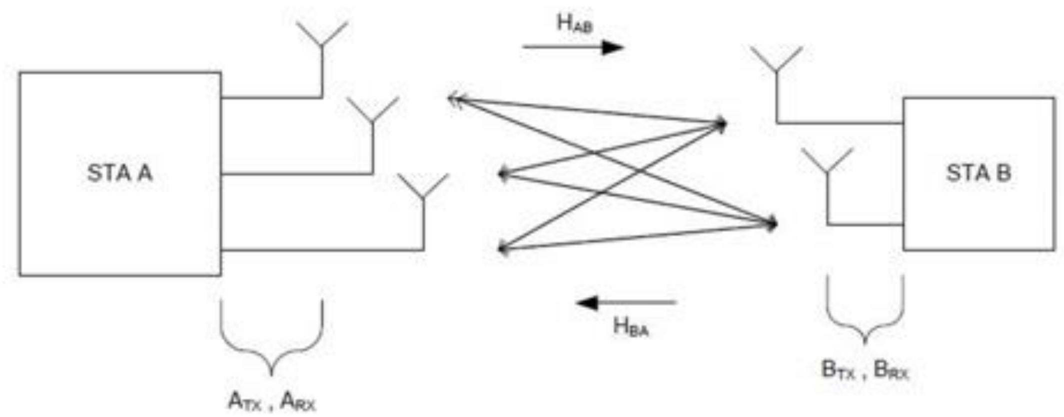


Figure 19-14—Beamforming MIMO channel model (3x2 example)

(Source : IEEE 802.11-2016 Standard, p. 2393)

63. The methods practiced by Sierra's use of the accused products include methods where signals are received with said first antenna (ANT1) and second antenna (ANT2) at moments of time other than in said receiving time slot, when no information is being received. For example, the accused products are and have been used by Sierra to implement the IEEE 802.11-2016 Standard, whose requirements were in effect five years before the Complaint. A STA in that Standard transmits data in PHY Protocol Data Units (PPDUs). PPDUs can be transmitted in High Throughput (HT) mode and Very High Throughput (VHT) mode. A Null Data Packet (NDP) can be transmitted in both HT and VHT Modes. Training Fields (TFs) inside the NDP carry no data related information and can be used as sounding PPDUs in beamforming calibration procedures. Sounding PPDUs would help in channel estimation at the STA. Certain TFs include the interference information which is and has been used as reference during calibration procedures. The NDPs ("signals received") in HT-PPDU and VHT PPDU format includes several TFs which are and have been used as a reference for the receiver to perform calibration/tuning. Thus, there is no actual data information that is received during the

beamforming calibration procedures ("at moments of time other than in said receiving time slots").

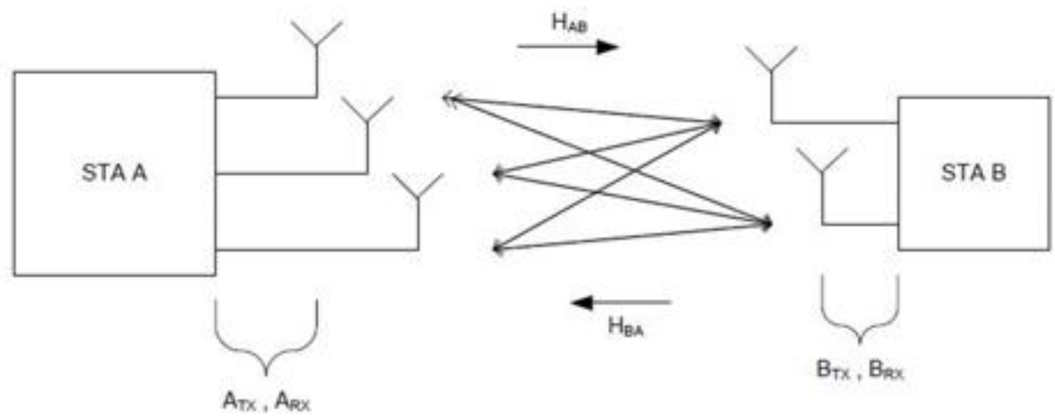


Figure 19-14—Beamforming MIMO channel model (3x2 example)

(Source : IEEE 802.11-2016 Standard, p. 2393)

Table 19-5—Elements of the HT PPDU

Element	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
HT-SIG	HT SIGNAL field
HT-STF	HT Short Training field
HT-GF-STF	HT-Greenfield Short Training field
HT-LTF1	First HT Long Training field (Data)
HT-LTFs	Additional HT Long Training fields (Data and Extension)
Data	The Data field includes the PSDU

(Source : IEEE 802.11-2016 Standard, p. 2347)

Table 21-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carrying the PSDU(s)

The VHT-SIG-A, VHT-STF, VHT-LTF, and VHT-SIG-B fields exist only in VHT PPDUs. In a VHT NDP the Data field is not present. The number of symbols in the VHT-LTF field, N_{VHTLTF}, can be either 1, 2, 4, 6, or 8 and is determined by the total number of space-time streams across all users being transmitted in the VHT PPDU (see Table 21-13).

(Source : IEEE 802.11-2016 Standard, p. 2514)

In both HT-mixed format and HT-greenfield format frames, there are two types of HT-LTFs: Data HT-LTFs (HT-DLTFs) and Extension HT-LTFs (HT-ELTFs). HT-DLTFs are always included in HT PPDUs to provide the necessary reference for the receiver to form a channel estimate that allows it to demodulate the data

(Source : IEEE 802.11-2016 Standard, p. 2347)

null data packet (NDP): A physical layer (PHY) protocol data unit (PPDU) that carries no Data field.

off-channel: A channel used by a tunneled direct link setup (TDLS) station (STA) that does not overlap the channel(s) used by the access point (AP) with which the TDLS STA is associated.

(Source : IEEE 802.11-2016 Standard, p. 157)

sounding physical layer (PHY) protocol data unit (PPDU): A PPDU that is intended by the transmitting station (STA) to enable the receiving STA to estimate the channel between the transmitting STA and the receiving STA. The Not Sounding field in the High Throughput SIGNAL field (HT-SIG) is equal to 0 in sounding PPDUs.

(Source : IEEE 802.11-2016 Standard, p. 163)

21.3.12 VHT preamble format for sounding PPDUs

NDP is the only VHT sounding format.

The format of a VHT NDP PPDU is shown in Figure 21-28.

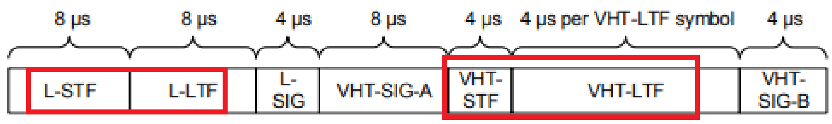


Figure 21-28—VHT NDP format

NOTE—The number of VHT-LTF symbols in the NDP is determined by the SU NSTS field in VHT-SIG-A.

The VHT NDP PPDU has the following properties:

— Uses the VHT PPDU format but without the Data field.
— Is a VHT SU PPDU as indicated by the VHT-SIG-A field.
— Has the data bits of the VHT-SIG-B field set to a fixed bit pattern (see 21.3.8.3.6).

(Source : IEEE 802.11-2016 Standard, p. 2580)

10.34 Null data packet (NDP) sounding

10.34.1 HT NDP sounding protocol

Sounding may be accomplished using either staggered sounding PPDU or HT NDP, as described in 19.3.13. The MAC rules associated with sounding using HT NDP are described in 10.34.1 to 10.34.4.

(Source : IEEE 802.11-2016 Standard, p. 1485)

64. The methods practiced by Sierra's use of the accused products include methods in which a reference signal representing interference in said other time slot is formed and used for the tuning of the receiver in said receiving time slots. For example, the accused products are and have been used by Sierra to implement the IEEE 802.11-2016 Standard, whose requirements were in effect five years before the Complaint. In that Standard, beamforming techniques are used to improve the reception at a receiver STA. These techniques use the channel state information and generate steering matrices for the transmission of data. There are two types of beamforming methods described in the standard, Implicit feedback beamforming and Explicit feedback beamforming. A steering matrix, Q_k, is calculated in both beamforming methods. Explicit feedback beamforming enables a beamformee i.e., receiving STA to calculate

beamforming feedback matrix based on the received sounding packets/PPDUs. NDPs can be used as sounding PPDUs and hence, no data/information is received during the beamforming procedures. The Standard shows a scenario wherein STA A (transmit STA) transmits a sounding packet (which can be NDP PPDU) that is used by STA B (receiving STA) to calculate a beamforming feedback matrix V_k ("reference signal"). The feedback matrix is later sent to STA A for determining a steering matrix which is used to tune and re-calibrate the receiver STA in order to demodulate the transmitted signal. Implicit feedback beamforming enables STA to estimate a MIMO channel and calculate channel matrices, based on a received sounding PPDU. NDPs can be used as sounding PPDUs and hence, no data/information is received during the beamforming procedures. The Standard shows a scenario wherein STA A and STA B (receiving STA) follow beamforming calibration procedures using sounding PPDUs. STA A and STA B will exchange sounding PPDUs (which can be NDP PPDUs), using which each of the STAs will estimate respective channel matrices. Quantized estimates of the channel matrices ("reference signal") are sent from STA B to STA A. Later, STA A uses its local estimates and the received quantized estimates from STA B to calculate set of correction matrices. These correction matrices that are formed using the received quantized estimates, are applied at transmit side of a STA to correct/tune the amplitude and phase differences in transmit and receive chains. All the above discussed steps are performed as a part of beamforming calibration procedures using sounding PPDUs. The Standard also shows equations for the received signal with beamforming. The channel estimates and beamforming steering matrix are and have been used to tune and re-calibrate the receiver in order to demodulate the transmitted signal.

19.3.12 Beamforming

19.3.12.1 General

Beamforming is a technique in which the beamformer utilizes the knowledge of the MIMO channel to generate a steering matrix Q_k that improves reception in the beamformee.

The equivalent complex baseband MIMO channel model is one in which, when a vector $\mathbf{x}_k = [x_1, x_2, \ldots x_{N_{TX}}]^T$ is transmitted in subcarrier k, the received vector $\mathbf{y}_k = [y_1, y_2, \ldots y_{N_{RX}}]^T$ is modeled as shown in Equation (19-62).

$$\mathbf{y}_k = H_k \mathbf{x}_k + \mathbf{n} \quad (19\text{-}62)$$

where

H_k is channel matrix of dimensions $N_{RX} \times N_{TX}$

$\mathbf{n}$ is white (spatially and temporally) Gaussian noise as illustrated in Figure 19-14

(Source : IEEE 802.11-2016 Standard, p. 2392-2393)

When beamforming is used, the beamformer replaces $\mathbf{x}_k$, which in this case has $N_{STS} \leq N_{TX}$ elements, with $Q_k \mathbf{x}_k$, where Q_k has N_{TX} rows and N_{STS} columns, so that the received vector is as shown in Equation (19-63).

$$\mathbf{y}_k = H_k Q_k \mathbf{x}_k + \mathbf{n} \quad (19\text{-}63)$$

The beamforming steering matrix that is computed (or updated) from a new channel measurement replaces the existing Q_k for the next beamformed data transmission. There are several methods of beamforming, differing in the way the beamformer acquires the knowledge of the channel matrices H_k and on whether the beamformer generates Q_k or the beamformee provides feedback information for the beamformer to generate Q_k.

(Source : IEEE 802.11-2016 Standard, p. 2393)

19.3.12.3 Explicit feedback beamforming

19.3.12.3.1 General

In explicit beamforming, in order for STA A to transmit a beamformed packet to STA B, STA B measures the channel matrices and sends STA A either the effective channel, $H_{eff,k}$, or the beamforming feedback matrix, V_k, for STA A to determine a steering matrix, $Q_{steer,k} = Q_k V_k$, with V_k found from $H_k Q_k$, where Q_k is the orthonormal spatial mapping matrix that was used to transmit the sounding packet that elicited the V_k feedback. The effective channel, $H_{eff,k} = H_k Q_k$, is the product of the spatial mapping matrix used on transmit with the channel matrix. When new steering matrix $Q_{steer,k}$ is found, $Q_{steer,k}$ may replace Q_k for the next beamformed data transmission.

NOTE—$Q_{steer,k}$ is a mathematical term to update a new steering matrix for Q_k in the next beamformed data transmission.

(Source : IEEE 802.11-2016 Standard, p. 1477)

10.32.3 Explicit feedback beamforming

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

In this subclause, the terms *HT beamformer* and *HT beamformee* refer to STAs that are involved in explicit feedback beamforming.

An HT beamformer uses the feedback response that it receives from the HT beamformee to calculate a beamforming feedback matrix for transmit beamforming. This feedback response may have one of three formats:

— *CSI*: The HT beamformee sends the MIMO channel coefficients to the HT beamformer.

— *Noncompressed beamforming*: The HT beamformee sends calculated beamforming feedback matrices to the HT beamformer.

— *Compressed beamforming*: The HT beamformee sends compressed beamforming feedback matrices to the HT beamformer.

(Source : IEEE 802.11-2016 Standard, p. 1477)

10.34 Null data packet (NDP) sounding

10.34.1 HT NDP sounding protocol

Sounding may be accomplished using either staggered sounding PPDU or HT NDP, as described in 19.3.13. The MAC rules associated with sounding using HT NDP are described in 10.34.1 to 10.34.4.

(Source : IEEE 802.11-2016 Standard, p. 1477)

10.34.5 VHT sounding protocol

10.34.5.1 General

Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the *VHT beamformer*, and a STA for which reception is optimized is called a *VHT beamformee*. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.

(Source : IEEE 802.11-2016 Standard, p. 1477)

21.3.12 VHT preamble format for sounding PPDUs

NDP is the only VHT sounding format.

The format of a VHT NDP PPDU is shown in Figure 21-28.

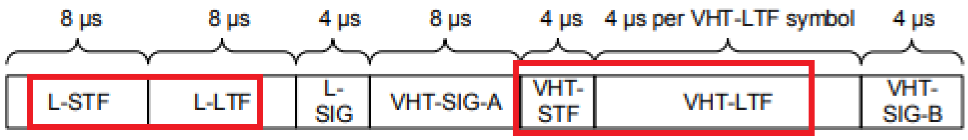


Figure 21-28—VHT NDP format

NOTE—The number of VHT-LTF symbols in the NDP is determined by the SU NSTS field in VHT-SIG-A.

The VHT NDP PPDU has the following properties:

- Uses the VHT PPDU format but without the Data field.
- Is a VHT SU PPDU as indicated by the VHT-SIG-A field.
- Has the data bits of the VHT-SIG-B field set to a fixed bit pattern (see 21.3.8.3.6).

(Source : IEEE 802.11-2016 Standard, p. 2580)

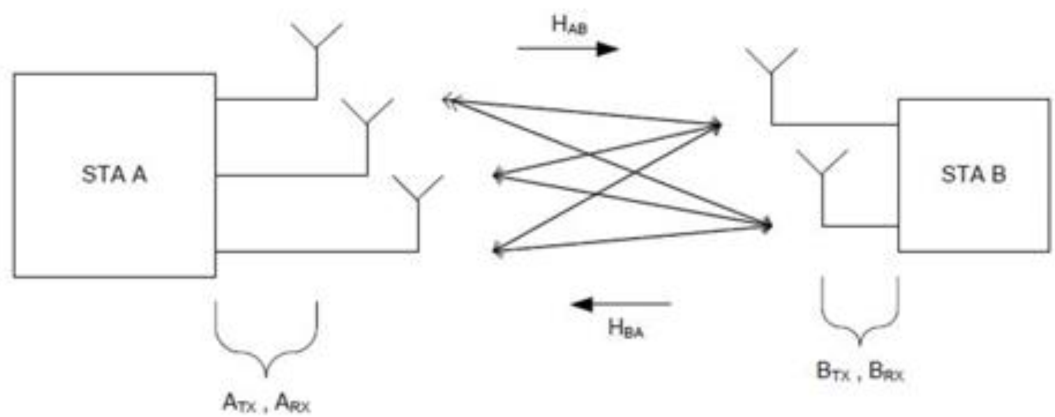


Figure 19-14—Beamforming MIMO channel model (3x2 example)

(Source : IEEE 802.11-2016 Standard, p. 2393)

Focusing on STA A, the procedure for estimating $K_{A,k}$ is as follows:

a) STA A sends STA B a sounding PPDU, the reception of which allows STA B to estimate the channel matrices $\tilde{H}_{AB,k}$.

b) STA B sends STA A a sounding PPDU, the reception of which allows STA A to estimate the channel matrices $\tilde{H}_{BA,k}$.

c) STA B sends the quantized estimates of $\tilde{H}_{AB,k}$ to STA A.

d) STA A uses its local estimates of $\tilde{H}_{BA,k}$ and the quantized estimates of $\tilde{H}_{AB,k}$ received from STA B to compute the correction matrices $K_{A,k}$.

(Source : IEEE 802.11-2016 Standard, p. 2395)

Figure 10-48 and Figure 10-49 illustrate the calibration PPDU exchange using NDPs.

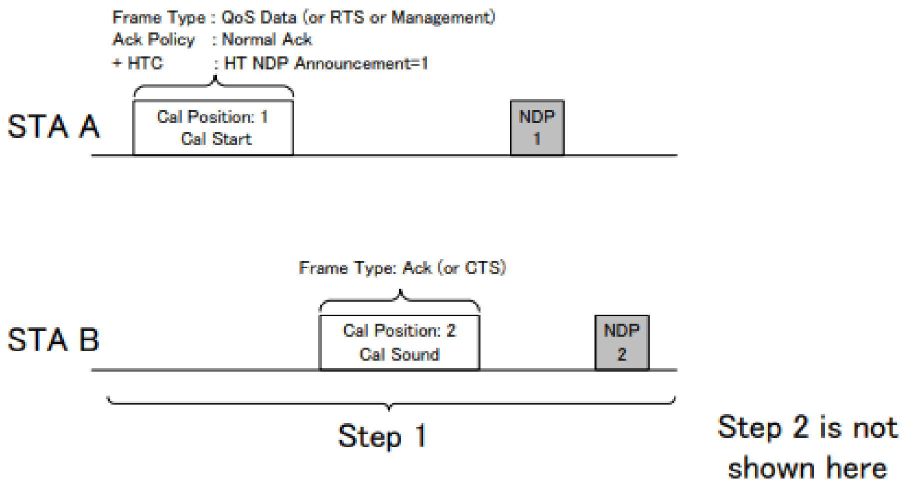


Figure 10-48—Calibration procedure with NDP

(Source : IEEE 802.11-2016 Standard, p. 1475)

21.3.12 VHT preamble format for sounding PPDUs

NDP is the only VHT sounding format.

The format of a VHT NDP PPDU is shown in Figure 21-28.

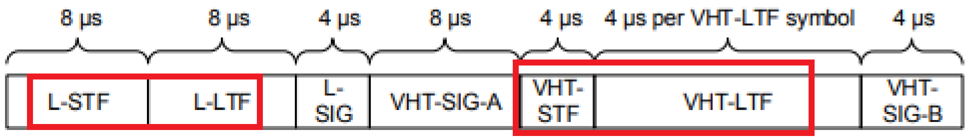


Figure 21-28—VHT NDP format

NOTE—The number of VHT-LTF symbols in the NDP is determined by the SU NSTS field in VHT-SIG-A.

The VHT NDP PPDU has the following properties:

— Uses the VHT PPDU format but without the Data field.

— Is a VHT SU PPDU as indicated by the VHT-SIG-A field.

— Has the data bits of the VHT-SIG-B field set to a fixed bit pattern (see 21.3.8.3.6).

(Source : IEEE 802.11-2016 Standard, p. 2580)

> While the over-the-air channel between the antenna(s) at one STA and the antenna(s) at a second STA is reciprocal, the observed baseband-to-baseband channel used for communication might not be, as it includes the transmit and receive chains of the STAs. Differences in the amplitude and phase characteristics of the transmit and receive chains associated with individual antennas degrade the reciprocity of the over-the-air channel and cause degradation of performance of implicit beamforming techniques. The over-the-air calibration procedure described in 10.32.2.4 may be used to restore reciprocity. The procedure provides the means for calculating a set of correction matrices that can be applied at the transmit side of a STA to correct the amplitude and phase differences between the transmit and receive chains in the STA. If this correction is done at least at the STA that serves as the beamformer, there is sufficient reciprocity for implicit feedback in the baseband-to-baseband response of the forward link and reverse channel.

(Source : IEEE 802.11-2016 Standard, p. 2394)

> **19.3.13.3 Sounding PPDU for calibration**
>
> In the case of a bidirectional calibration exchange, two STAs exchange sounding PPDUs, the exchange of which enables the receiving STA to compute an estimate of the MIMO channel matrix H_k for each subcarrier k. In general, in an exchange of calibration messages, the number of spatial streams is less than the number of transmit antennas. In such cases, HT-ELTFs are used. In the case of sounding PPDUs for calibration, the antenna mapping matrix shall be as shown in Equation (19-86).

(Source : IEEE 802.11-2016 Standard, p. 2401)

> Two preamble formats are defined. For HT-mixed format operation, the preamble has a non-HT portion and an HT portion. The non-HT portion of the HT-mixed format preamble enables detection of the PPDU and acquisition of carrier frequency and timing by both HT STAs and STAs that are compliant with Clause 17 and/or Clause 18. The non-HT portion of the HT-mixed format preamble also consists of the SIGNAL field defined in Clause 17 and is thus decodable by STAs compliant with Clause 17 and Clause 18 as well as HT STAs.
>
> The HT portion of the HT-mixed format preamble enables estimation of the MIMO channel to support demodulation of the HT data by HT STAs. The HT portion of the HT-mixed format preamble also includes the HT-SIG field, which supports HT operation. The SERVICE field is prepended to the PSDU.

(Source : IEEE 802.11-2016 Standard, p. 2346)

19.3.12 Beamforming

19.3.12.1 General

Beamforming is a technique in which the beamformer utilizes the knowledge of the MIMO channel to generate a steering matrix Q_k that improves reception in the beamformee.

The equivalent complex baseband MIMO channel model is one in which, when a vector $\mathbf{x}_k = [x_1, x_2, \ldots x_{N_{TX}}]^T$ is transmitted in subcarrier k, the received vector $\mathbf{y}_k = [y_1, y_2, \ldots y_{N_{RX}}]^T$ is modeled as shown in Equation (19-62).

$$\mathbf{y}_k = H_k \mathbf{x}_k + \mathbf{n} \quad (19\text{-}62)$$

where

H_k is channel matrix of dimensions $N_{RX} \times N_{TX}$
n is white (spatially and temporally) Gaussian noise as illustrated in Figure 19-14

(Source : IEEE 802.11-2016 Standard, p. 2392-2393)

When beamforming is used, the beamformer replaces $\mathbf{x}_k$, which in this case has $N_{STS} \le N_{TX}$ elements, with $Q_k \mathbf{x}_k$, where Q_k has N_{TX} rows and N_{STS} columns, so that the received vector is as shown in Equation (19-63).

$$\mathbf{y}_k = H_k Q_k \mathbf{x}_k + \mathbf{n} \quad (19\text{-}63)$$

The beamforming steering matrix that is computed (or updated) from a new channel measurement replaces the existing Q_k for the next beamformed data transmission. There are several methods of beamforming, differing in the way the beamformer acquires the knowledge of the channel matrices H_k and on whether the beamformer generates Q_k or the beamformee provides feedback information for the beamformer to generate Q_k.

(Source : IEEE 802.11-2016 Standard, p. 2393)

65. American Patents only asserts method claims from the ‘803 Patent.

66. American Patents has been damaged as a result of the infringing conduct by Sierra alleged above. Thus, Sierra is liable to American Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

67. American Patents and/or its predecessors-in-interest have satisfied all statutory obligations required to collect pre-filing damages for the full period allowed by law for infringement of the '803 Patent.

ADDITIONAL ALLEGATIONS REGARDING INFRINGEMENT

68. In addition to any specific products mentioned above, the accused products also include at least Sierra AirLink oMG2000, Sierra AirLink oMG500, Sierra AirLink ES450, Sierra AirLink GL7x00, Sierra AirLink LX40 LTE, Sierra AirLink LX40 LTE-M, Sierra AirLink LX60 LTE, Sierra AirLink LX60 LTE-M, Sierra AirLink MG90 LTE, Sierra AirLink MG90 LTE-A Pro, Sierra AirLink MP70 LTE-A, Sierra AirLink MP70 LTE-A Pro, Sierra AirLink RV50X, Sierra AirLink RV55 LPWA, Sierra AirLink RV55 LTE, Sierra AirLink RV55 LTE-A Pro, Sierra AirLink XR80, Sierra AirLink XR90, Sierra AirPrime AR7550, Sierra AirPrime AR7552, Sierra AirPrime AR7558, Sierra AirPrime AR7582, Sierra AirPrime AR7584, Sierra AirPrime AR7592, Sierra AirPrime AR7594, Sierra AirPrime BX3100, Sierra AirPrime BX3105, Sierra AirPrime BX3210, Sierra AirPrime EM7305, Sierra AirPrime EM7345, Sierra AirPrime EM7355, Sierra AirPrime EM7411, Sierra AirPrime EM7421, Sierra AirPrime EM7430, Sierra AirPrime EM7431, Sierra AirPrime EM7455, Sierra AirPrime EM7511, Sierra AirPrime EM7565, Sierra AirPrime EM7690, Sierra AirPrime EM9190, Sierra AirPrime EM9191, Sierra AirPrime HL7518, Sierra AirPrime HL7519, Sierra AirPrime HL7548, Sierra AirPrime HL7588, Sierra AirPrime HL7618, Sierra AirPrime HL7648, Sierra AirPrime HL7650, Sierra AirPrime HL7688, Sierra AirPrime HL7692, Sierra AirPrime HL7718, Sierra AirPrime HL7748, Sierra AirPrime MC7304, Sierra AirPrime MC7350, Sierra AirPrime MC7350L, Sierra AirPrime MC7354, Sierra AirPrime MC7411, Sierra AirPrime MC7421, Sierra AirPrime MC7430, Sierra AirPrime MC7455, Sierra AirPrime MC7475, Sierra AirPrime RC7611, Sierra AirPrime RC7611-1, Sierra AirPrime RC7620, Sierra AirPrime RC7620-1, Sierra AirPrime

RC7630, Sierra AirPrime RC7630-1, Sierra AirPrime WP7502, Sierra AirPrime WP7504, Sierra AirPrime WP7504-1, Sierra AirPrime WP7601, Sierra AirPrime WP7601-1, Sierra AirPrime WP7603, Sierra AirPrime WP7603-1, Sierra AirPrime WP7605, Sierra AirPrime WP7607, Sierra AirPrime WP7607-1, Sierra AirPrime WP7609, Sierra AirPrime WP7609-1, Sierra AirPrime WP7610, Sierra AirPrime WP7611, Sierra AirPrime WP7611-1 , Sierra AirPrime WP7700, Sierra AirPrime WP7702, Sierra BX3105 development kit, Sierra FX30 LTE, Sierra FX30 LTE-M, Sierra FX30S LTE, Sierra FX30S LTE-M, Sierra GL7500, Sierra GL7600, Sierra GNX-5P LTE, Sierra GNX-5P LTE-M1, Sierra GNX-6 LTE, Sierra GNX-6 LTE-M1, Sierra HL7800 LPWA, Sierra HL7800-M LPWA, Sierra HL7802 LPWA, Sierra mangOH Red - WP7601-1, Sierra mangOH Red - WP7601-4, Sierra mangOH Red - WP7603-1, Sierra mangOH Red - WP7603-4, Sierra mangOH Red - WP7607, Sierra mangOH Red - WP7608, Sierra mangOH Red - WP7700, Sierra mangOH Red - WP7700 AT&T, Sierra mangOH Red - WP7702, Sierra mangOH Red - WP7702 - Octave, Sierra mangOH Red - WP8548, Sierra mangOH Yellow - WP7702_Soldered, Sierra OM500, Sierra Uplink 5500 LTE, Sierra Uplink LTE30EX.

69. Sierra has also indirectly infringed the ‘782 Patent, the ‘304 Patent, and the ‘458 Patent by inducing others to directly infringe the ‘782 Patent, the ‘304 Patent, and the ‘458 Patent. Sierra has induced the end-users, Sierra’s customers, to directly infringe (literally and/or under the doctrine of equivalents) the ‘782 Patent, the ‘304 Patent, and the ‘458 Patent by using the accused products.

70. Sierra took active steps, directly and/or through contractual relationships with others, with the specific intent to cause them to use the accused products in a manner that infringes one or more claims of the patents-in-suit, including, for example, Claim 30 of the ‘782 Patent, Claim 1 of the ‘304 Patent, and Claim 1 of the ‘458 Patent.

71. Such steps by Sierra included, among other things, advising or directing customers and end-users to use the accused products in an infringing manner; advertising and promoting the use of the accused products in an infringing manner; and/or distributing instructions that guide users to use the accused products in an infringing manner.

72. Sierra has performed these steps, which constitute induced infringement, with the knowledge of the ‘782 Patent, the ‘304 Patent, and the ‘458 Patent and with the knowledge that the induced acts constitute infringement.

73. Sierra was and is aware that the normal and customary use of the accused products by Sierra’s customers would infringe the ‘782 Patent, the ‘304 Patent, and the ‘458 Patent. Sierra’s inducement is ongoing.

74. Sierra has also induced its affiliates, or third-party manufacturers, shippers, distributors, retailers, or other persons acting on its or its affiliates’ behalf, to directly infringe (literally and/or under the doctrine of equivalents) the ‘782 Patent, the ‘304 Patent, and the ‘458 Patent by importing, selling or offering to sell the accused products.

75. Sierra has at least a significant role in placing the accused products in the stream of commerce in Texas and elsewhere in the United States.

76. Sierra directs or controls the making of accused products and their shipment to the United States, using established distribution channels, for sale in Texas and elsewhere within the United States.

77. Sierra directs or controls the sale of the accused products into established United States distribution channels, including sales to nationwide retailers.

78. Sierra’s established United States distribution channels include one or more United States based affiliates (e.g., at least Sierra Wireless America Inc.).

79. Sierra directs or controls the sale of the accused products nationwide through its own websites as well as in nationwide retailers, including for sale in Texas and elsewhere in the United States, and expects and intends that the accused products will be so sold.

80. Sierra took active steps, directly and/or through contractual relationships with others, with the specific intent to cause such persons to import, sell, or offer to sell the accused products in a manner that infringes one or more claims of the patents-in-suit, including, for example, Claim 30 of the '782 Patent, Claim 1 of the '304 Patent, and Claim 1 of the '458 Patent.

81. Such steps by Sierra included, among other things, making or selling the accused products outside of the United States for importation into or sale in the United States, or knowing that such importation or sale would occur; and directing, facilitating, or influencing its affiliates, or third-party manufacturers, shippers, distributors, retailers, or other persons acting on their behalf or on behalf of Sierra, to import, sell, or offer to sell the accused products in an infringing manner.

82. Sierra performed these steps, which constitute induced infringement, with the knowledge of the '782 Patent, the '304 Patent, and the '458 Patent and with the knowledge that the induced acts would constitute infringement.

83. Sierra performed such steps in order to profit from the eventual sale of the accused products in the United States.

84. Sierra's inducement is ongoing.

85. Sierra has also indirectly infringed by contributing to the infringement of the '782 Patent, the '304 Patent, and the '458 Patent. Sierra has contributed to the direct infringement of the '782 Patent, the '304 Patent, and the '458 Patent by the end-user of the accused products.

86. The accused products have special features that are specially designed to be used in an infringing way and that have no substantial uses other than ones that infringe the '782 Patent, the '304 Patent, and the '458 Patent, including, for example, Claim 30 of the '782 Patent, Claim 1 of the '304 Patent, and Claim 1 of the '458 Patent.

87. The special features include improved wireless communication capabilities and initiation and/or control of Internet streamed content used in a manner that infringes the '782 Patent, the '304 Patent, and the '458 Patent.

88. The special features constitute a material part of the invention of one or more of the claims of the '782 Patent, the '304 Patent, and the '458 Patent and are not staple articles of commerce suitable for substantial non-infringing use.

89. Sierra's contributory infringement is ongoing.

90. Furthermore, Sierra has a policy or practice of not reviewing the patents of others (including instructing its employees to not review the patents of others), and thus has been willfully blind of American Patents' patent rights. *See, e.g.*, M. Lemley, "Ignoring Patents," 2008 Mich. St. L. Rev. 19 (2008).

91. Sierra's actions are at least objectively reckless as to the risk of infringing valid patents and this objective risk was either known or should have been known by Sierra.

92. Sierra has knowledge of the '782 Patent, the '304 Patent, and the '458 Patent.

93. Sierra's customers have infringed the '782 Patent, the '304 Patent, and the '458 Patent.

94. Sierra encouraged its customers' infringement.

95. Sierra's direct and indirect infringement of the '782 Patent, the '304 Patent, and the '458 Patent is, has been, and/or continues to be willful, intentional, deliberate, and/or in conscious disregard of American Patents' rights under the patents.

96. American Patents has been damaged as a result of the infringing conduct by Sierra alleged above. Thus, Sierra is liable to American Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

CLARIFICATION REGARDING PATENT EXPIRATION

97. For the avoidance of doubt, American Patents does not seek relief under any asserted patent for acts occurring after the expiration of that patent.

JURY DEMAND

American Patents hereby requests a trial by jury on all issues so triable by right.

PRAYER FOR RELIEF

American Patents requests that the Court find in its favor and against Sierra, and that the Court grant American Patents the following relief:

a. Judgment that one or more claims of the '782 Patent, the '304 Patent, the '458 Patent, and the '803 Patent have been infringed, either literally and/or under the doctrine of equivalents, by Sierra and/or all others acting in concert therewith;

b. A permanent injunction enjoining Sierra and its officers, directors, agents, servants, affiliates, employees, divisions, branches, subsidiaries, parents, and all others acting in concert therewith from infringement of the '782 Patent, the '304 Patent, and the '458 Patent; or, in the alternative, an award of a reasonable ongoing royalty for future infringement of the '782 Patent, the '304 Patent, and the '458 Patent by such entities;

c. Judgment that Sierra account for and pay to American Patents all damages to and costs incurred by American Patents because of Sierra's infringing activities and other conduct complained of herein, including an award of all increased damages to which American Patents is entitled under 35 U.S.C. § 284;

d. That American Patents be granted pre-judgment and post-judgment interest on the damages caused by Sierra's infringing activities and other conduct complained of herein;

e. That this Court declare this an exceptional case and award American Patents its reasonable attorney's fees and costs in accordance with 35 U.S.C. § 285; and

f. That American Patents be granted such other and further relief as the Court may deem just and proper under the circumstances.

Dated: June 21, 2021

Respectfully submitted,

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