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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY DOCKET NO	TOT CLAIMS	IND CLAIMS
62/462,258	02/22/2017		260	030284.14367/ 172845P2		

CONFIRMATION NO. 6237

FILING RECEIPT



0000000089621433

15142

Arent Fox, LLP and Qualcomm, Incorporated  
1717 K Street, NW  
Washington, DC 20006-5344

Date Mailed: 03/06/2017

Receipt is acknowledged of this provisional patent application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Hung LY, San Diego, CA;  
Tao LUO, San Diego, CA;  
Haitong SUN, San Diego, CA;

Applicant(s)

QUALCOMM Incorporated, San Diego, CA;

**Power of Attorney:** The patent practitioners associated with Customer Number 15142

**Permission to Access Application via Priority Document Exchange:** Yes

**Permission to Access Search Results:** Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

**If Required, Foreign Filing License Granted:** 03/02/2017

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/462,258**

**Projected Publication Date:** None, application is not eligible for pre-grant publication

**Non-Publication Request:** No

**Early Publication Request:** No

**Title****TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS****Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No****PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES**

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

**LICENSE FOR FOREIGN FILING UNDER****Title 35, United States Code, Section 184****Title 37, Code of Federal Regulations, 5.11 & 5.15****GRANTED**

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier

license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

#### **NOT GRANTED**

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

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### **SelectUSA**

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit <http://www.SelectUSA.gov> or call +1-202-482-6800.

## TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA/82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	To be assigned
Filing Date	Filed concurrently herewith
First Named Inventor	Hung LY
Title	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS
Art Unit	To be assigned
Examiner Name	To be assigned
Attorney Docket Number	030284.14367/ 172845P2

### SIGNATURE of Applicant or Patent Practitioner

Signature	/Lester J. Anderson, Reg. No. 45,833/	Date (Optional)	2017-02-22
Name	Lester J. Anderson	Registration Number	45833
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

**NOTE:** This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.



\*Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**POWER OF ATTORNEY BY APPLICANT**

I hereby revoke all previous powers of attorney given in the application identified in the attached transmittal letter.

- ☒ I hereby appoint Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A or equivalent):

15142

OR

- ☐ I hereby appoint Practitioner(s) named below as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A or equivalent):

Name Registration	Number	Name Registration	Number

Please recognize or change the correspondence address for the above-identified patent to:

- ☒ The address associated with the above-mentioned Customer Number.

OR

- ☐ The address associated with Customer Number:

OR

☐ Firm or Individual Name

Address

City

State

Zip

Country

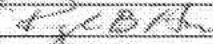
Telephone

Email

I am the Applicant:

- ☐ Inventor or Joint Inventor
- ☐ Legal Representative of a Deceased or Legally Incapacitated Inventor
- ☒ Assignee or Person to Whom the Inventor is Under an Obligation to Assign
- ☐ Person Who Otherwise Shows Sufficient *Proprietary* Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document)

**SIGNATURE of Applicant for Patent**

Signature		Date	9/26/2012
Name	Raymond B. Horn	Telephone	858-651-3679
Title and Company	Vice President, Patent Counsel and QUALCOMM Incorporated		

**NOTE:** Signature - This form must be signed by the applicant or applicant's representative in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms for more than one signature, see below \*.

- ☒ \*Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.31 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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<b>Application Data Sheet 37 CFR 1.76</b>		<b>Attorney Docket Number</b>	030284.14367/ 172845P2
		<b>Application Number</b>	
<b>Title of Invention</b>	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		
<p>The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.</p>			

**Secrecy Order 37 CFR 5.2:**

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

**Inventor Information:**

<b>Inventor</b>	1				<a href="#">Remove</a>
<b>Legal Name</b>					
<b>Prefix</b>	<b>Given Name</b>	<b>Middle Name</b>	<b>Family Name</b>	<b>Suffix</b>	
	Hung		LY		
<b>Residence Information (Select One)</b> <input checked="" type="radio"/> US Residency <input type="radio"/> Non US Residency <input type="radio"/> Active US Military Service					
<b>City</b>	San Diego	<b>State/Province</b>	CA	<b>Country of Residence</b>	US
<b>Mailing Address of Inventor:</b>					
<b>Address 1</b>	c/o QUALCOMM Incorporated				
<b>Address 2</b>	5775 Morehouse Drive				
<b>City</b>	San Diego	<b>State/Province</b>	CA		
<b>Postal Code</b>	92121-1714	<b>Country</b>	US		
<b>Inventor</b>	2				<a href="#">Remove</a>
<b>Legal Name</b>					
<b>Prefix</b>	<b>Given Name</b>	<b>Middle Name</b>	<b>Family Name</b>	<b>Suffix</b>	
	Tao		LUO		
<b>Residence Information (Select One)</b> <input checked="" type="radio"/> US Residency <input type="radio"/> Non US Residency <input type="radio"/> Active US Military Service					
<b>City</b>	San Diego	<b>State/Province</b>	CA	<b>Country of Residence</b>	US
<b>Mailing Address of Inventor:</b>					
<b>Address 1</b>	c/o QUALCOMM Incorporated				
<b>Address 2</b>	5775 Morehouse Drive				
<b>City</b>	San Diego	<b>State/Province</b>	CA		
<b>Postal Code</b>	92121-1714	<b>Country</b>	US		
<b>Inventor</b>	3				<a href="#">Remove</a>
<b>Legal Name</b>					
<b>Prefix</b>	<b>Given Name</b>	<b>Middle Name</b>	<b>Family Name</b>	<b>Suffix</b>	
	Haitong		SUN		
<b>Residence Information (Select One)</b> <input checked="" type="radio"/> US Residency <input type="radio"/> Non US Residency <input type="radio"/> Active US Military Service					



Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

<b>Application Data Sheet 37 CFR 1.76</b>		Attorney Docket Number		030284.14367/ 172845P2	
		Application Number			
Title of Invention	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS				
City	San Diego	State/Province	CA	Country of Residence	US
<b>Mailing Address of Inventor:</b>					
Address 1	c/o QUALCOMM Incorporated				
Address 2	5775 Morehouse Drive				
City	San Diego	State/Province	CA		
Postal Code	92121-1714	Country i	US		
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.					<input type="button" value="Add"/>

**Correspondence Information:**

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).		
<input type="checkbox"/> An Address is being provided for the correspondence information of this application.		
Customer Number	15142	
Email Address	patentdocket@arentfox.com	<input type="button" value="Add Email"/> <input type="button" value="Remove Email"/>

**Application Information:**

Title of the Invention	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		
Attorney Docket Number	030284.14367/ 172845P2	Small Entity Status Claimed	<input type="checkbox"/>
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	14	Suggested Figure for Publication (if any)	

**Filing By Reference:**

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

**Publication Information:**

<input type="checkbox"/> Request Early Publication (Fee required at time of Request 37 CFR 1.219)
<input type="checkbox"/> <b>Request Not to Publish.</b> I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application <b>has not and will not</b> be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

<b>Application Data Sheet 37 CFR 1.76</b>		Attorney Docket Number	030284.14367/ 172845P2
		Application Number	
Title of Invention	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		

## Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	<input checked="" type="radio"/> Customer Number	<input type="radio"/> US Patent Practitioner	<input type="radio"/> Limited Recognition (37 CFR 11.9)
Customer Number	15142		

## Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	<input type="text"/>	<input type="button" value="Remove"/>
Application Number	Continuity Type	Prior Application Number
<input type="text"/>	<input type="text"/>	<input type="text"/>
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the <b>Add</b> button.		<input type="button" value="Add"/>

## Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)<sup>i</sup> the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country <sup>i</sup>	Filing Date (YYYY-MM-DD)	<input type="button" value="Remove"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Additional Foreign Priority Data may be generated within this form by selecting the <b>Add</b> button.			<input type="button" value="Add"/>



<b>Application Data Sheet 37 CFR 1.76</b>		Attorney Docket Number	030284.14367/ 172845P2
		Application Number	
Title of Invention	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		

## Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

<p>This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.</p> <p><input type="checkbox"/> NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.</p>
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<b>Application Data Sheet 37 CFR 1.76</b>		Attorney Docket Number	030284.14367/ 172845P2
		Application Number	
Title of Invention	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		

## Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

**NOTE:** This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

### 1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

**A. Priority Document Exchange (PDX)** - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

**B. Search Results from U.S. Application to EPO** - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

### 2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

**NOTE:** Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

<b>Application Data Sheet 37 CFR 1.76</b>		Attorney Docket Number	030284.14367/ 172845P2
		Application Number	
Title of Invention	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		

## Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.			
<b>Applicant</b>	1	<input type="button" value="Remove"/>	
<p>If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.</p>			
		<input type="button" value="Clear"/>	
<input checked="" type="radio"/> Assignee	Legal Representative under 35 U.S.C. 117		Joint Inventor
Person to whom the inventor is obligated to assign.		Person who shows sufficient proprietary interest	
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:			
<div style="border: 1px solid black; height: 20px; width: 100%;"></div>			
Name of the Deceased or Legally Incapacitated Inventor: <div style="border: 1px solid black; height: 20px; width: 100%;"></div>			
If the Applicant is an Organization check here. <input checked="" type="checkbox"/>			
Organization Name	QUALCOMM Incorporated		
<b>Mailing Address Information For Applicant:</b>			
Address 1	5775 Morehouse Drive		
Address 2			
City	San Diego	State/Province	CA
Country	US	Postal Code	92121-1714
Phone Number		Fax Number	
Email Address			
Additional Applicant Data may be generated within this form by selecting the Add button.			<input type="button" value="Add"/>

## Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.



Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

<b>Application Data Sheet 37 CFR 1.76</b>		Attorney Docket Number	030284.14367/ 172845P2
		Application Number	
Title of Invention	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		

<b>Assignee</b>   1				
Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.				
				<a href="#">Remove</a>
If the Assignee or Non-Applicant Assignee is an Organization check here. <input type="checkbox"/>				
Prefix	Given Name	Middle Name	Family Name	Suffix
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<b>Mailing Address Information For Assignee including Non-Applicant Assignee:</b>				
Address 1		<input type="text"/>		
Address 2		<input type="text"/>		
City	<input type="text"/>	State/Province	<input type="text"/>	
Country <sup>i</sup>	<input type="text"/>	Postal Code	<input type="text"/>	
Phone Number	<input type="text"/>	Fax Number	<input type="text"/>	
Email Address	<input type="text"/>			
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<b>Application Data Sheet 37 CFR 1.76</b>		Attorney Docket Number	030284.14367/ 172845P2
		Application Number	
Title of Invention	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		

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**ABSTRACT**

For communication systems that include a PSS, a SSS, a TSS, and a PBCH, the TSS may be multiplexed with at least one of the PSS, the SSS, or the PBCH for transmission in an SS block. In one aspect, an apparatus may be configured to multiplex a TSS with at least one of a PSS, an SSS, or a physical broadcast channel (PBCH) for transmission in an SS block. The apparatus may be further configured to transmit the SS block including the TSS, the PSS, the SSS, and the PBCH. In another aspect, the apparatus may be configured to receive an SS block comprising a TSS multiplexed with at least one of a PSS, a SSS, or a physical broadcast channel (PBCH). The apparatus may be further configured to demultiplex the SS block to obtain the TSS, the PSS, the SSS, and the PBCH.

## CLAIMS

### WHAT IS CLAIMED IS:

1. A method of wireless communication in a base station, comprising:
  - multiplexing a tertiary synchronization signal (TSS) with at least one of a primary synchronization signal (PSS), a secondary synchronization signal (SSS), or a physical broadcast channel (PBCH) for transmission in a synchronization signal (SS) block; and
  - transmitting the SS block including the TSS, the PSS, the SSS, and the PBCH.
2. The method of claim 1, wherein the TSS comprises a first TSS and a second TSS, and the method further comprises:
  - generating a first tertiary synchronization sequence for the first TSS based on a first pseudo-noise (PN) sequence; and
  - generating a second tertiary synchronization sequence for the second TSS based on a second PN sequence.
3. The method of claim 2, further comprising:
  - cyclic shifting the first PN sequence based on a first cyclic shift to generate the first tertiary synchronization sequence; and
  - cyclic shifting the second PN sequence based on a second cyclic shift to generate the second tertiary synchronization sequence.
4. The method of claim 3, further comprising scrambling the second tertiary synchronization sequence using the first cyclic shift.
5. The method of claim 4, further comprising scrambling the first tertiary synchronization sequence and the second tertiary synchronization sequence based on a physical cell identifier (PCI) of the base station.
6. The method of claim 3, further comprising:
  - determining a block index for the SS block; and
  - determining the first cyclic shift and the second cyclic shift based on the block index.

7. The method of claim 1, wherein the TSS is frequency division multiplexed in a same Orthogonal Frequency Division Multiplexed (OFDM) symbol with the PSS.
8. The method of claim 7, wherein the TSS comprises a first TSS and a second TSS, and the first TSS, the second TSS, and the PSS are frequency division multiplexed in the same OFDM symbol.
9. The method of claim 8, wherein the PSS is between the first TSS and the second TSS in frequency.
10. The method of claim 8, where the PSS, the first TSS, and the second TSS together occupy a same number of resources blocks (RBs) in the SS block as the SSS.
11. The method of claim 10, wherein the same number of RBs is  $x$ , the PSS occupies  $x/2$  RBs, the first TSS occupies  $x/4$  RBs, and the second TSS occupies  $x/4$  RBs.
12. The method of claim 1, wherein the TSS is time division multiplexed with the PSS, the SSS, and the PBCH in a same set of subcarriers.
13. The method of claim 12, wherein the subcarrier spacing of the SSS and the PBCH is  $x$  kHz and the subcarrier spacing of the TSS and the PSS is  $2x$  kHz.
14. The method of claim 12, wherein the subcarrier spacing of the SSS, the PBCH, the TSS, and the PSS is the same.
15. The method of claim 13, wherein OFDM symbol time length for TSS and PSS are each  $1/2x$  ms, and OFDM symbol time length for SSS and PBCH are each  $1/x$  ms.
16. The method of claim 12, wherein the TSS comprises a first TSS and a second TSS, and the first TSS and the second TSS are frequency division multiplexed in a same OFDM symbol.



17. The method of claim 12, wherein the TSS and the PSS are transmitted with a first cyclic prefix, and the SSS and the PBCH are transmitted with a second cyclic prefix different from the first cyclic prefix.
18. The method of claim 1, wherein the TSS is frequency division multiplexed with at least one of the PSS, the SSS, or the PBCH in the same set of Orthogonal Frequency Division Multiplexed (OFDM) symbols.
19. The method of claim 18, wherein the TSS is frequency division multiplexed with the PSS, the SSS, and the PBCH in the same set of OFDM symbols.
20. The method of claim 18, wherein the TSS is frequency division multiplexed with the PSS and the SSS in the same set of OFDM symbols.
21. The method of claim 1, wherein the TSS is frequency division multiplexed with the PSS and the SSS in the same set of Orthogonal Frequency Division Multiplexed (OFDM) symbols.
22. The method of claim 21, wherein the TSS comprises a first TSS and a second TSS.
23. The method of claim 21, wherein the TSS, the PSS, and the SSS are time division multiplexed with the PBCH.
24. The method of claim 13, wherein OFDM symbol time length comprises five OFDM symbols.
25. A method of wireless communication in a user equipment (UE), comprising:  
    receiving a synchronization signal (SS) block comprising a tertiary synchronization signal (TSS) multiplexed with at least one of a primary synchronization signal (PSS), a secondary synchronization signal (SSS), or a physical broadcast channel (PBCH); and  
    demultiplexing the SS block to obtain the TSS, and the at least one of the PSS, the SSS, and the PBCH.

26. The method of claim 25, wherein:

the TSS comprises a first TSS corresponding to a first tertiary synchronization sequence and a second TSS corresponding to a second tertiary synchronization sequence,

the first tertiary synchronization sequence is based on a first pseudo-noise (PN) sequence, and

the second tertiary synchronization sequence is based on a second PN sequence.

27. The method of claim 26, wherein:

the first tertiary synchronization sequence is a first cyclic shift of the first PN sequence, and

the second tertiary synchronization sequence is a second cyclic shift of the second PN sequence.

28. The method of claim 27, further comprising descrambling the second tertiary synchronization sequence based on the first cyclic shift.

29. The method of claim 28, further comprising descrambling the first tertiary synchronization sequence and the second tertiary synchronization sequence based on a physical cell identifier (PCI) received from a base station.

30. The method of claim 27, further comprising:

determining the first cyclic shift and the second cyclic shift; and

determining a block index of the SS block based on the determined first cyclic shift and the determined second cyclic shift.

31. The method of claim 25, wherein the TSS is frequency division multiplexed in a same Orthogonal Frequency Division Multiplexed (OFDM) symbol with the PSS.

32. The method of claim 31, wherein the TSS comprises a first TSS and a second TSS, and the first TSS, the second TSS, and the PSS are frequency division multiplexed in the same OFDM symbol.

33. The method of claim 32, wherein the PSS is between the first TSS and the second TSS in frequency.
34. The method of claim 32, where the PSS, the first TSS, and the second TSS together occupy a same number of resources blocks (RBs) in the SS block as the SSS.
35. The method of claim 34, wherein the same number of RBs is  $x$ , the PSS occupies  $x/2$  RBs, the first TSS occupies  $x/4$  RBs, and the second TSS occupies  $x/4$  RBs.
36. The method of claim 25, wherein the TSS is time division multiplexed with the PSS, the SSS, and the PBCH in a same set of subcarriers.
37. The method of claim 36, wherein the subcarrier spacing of the SSS and the PBCH is  $x$  kHz and the subcarrier spacing of the TSS and the PSS is  $2x$  kHz.
38. The method of claim 36, wherein the subcarrier spacing of the SSS, the PBCH, the TSS, and the PSS is the same.
39. The method of claim 37, wherein OFDM symbol time length for TSS and PSS are each  $1/2x$  ms, and OFDM symbol time length for SSS and PBCH are each  $1/x$  ms.
40. The method of claim 36, wherein the TSS comprises a first TSS and a second TSS, and the first TSS and the second TSS are frequency division multiplexed in a same OFDM symbol.
41. The method of claim 36, wherein the TSS and the PSS have a first cyclic prefix, and the SSS and the PBCH have a second cyclic prefix different from the first cyclic prefix.
42. The method of claim 25, wherein the TSS is frequency division multiplexed with at least one of the PSS, the SSS, or the PBCH in the same set of Orthogonal Frequency Division Multiplexed (OFDM) symbols.
43. The method of claim 42, wherein the TSS is frequency division multiplexed with the PSS, the SSS, and the PBCH in the same set of OFDM symbols.



44. The method of claim 42, wherein the TSS is frequency division multiplexed with the PSS and the SSS in the same set of OFDM symbols.

45. The method of claim 42, wherein the TSS is frequency division multiplexed with the PSS and the SSS in the same set of Orthogonal Frequency Division Multiplexed (OFDM) symbols.

46. The method of claim 45, wherein the TSS comprises a first TSS and a second TSS.

47. The method of claim 45, wherein the TSS, the PSS, and the SSS are time division multiplexed with the PBCH.

48. The method of claim 37, wherein OFDM symbol time length comprises five OFDM symbols.

**TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS****BACKGROUND****Field**

- [0001] The present disclosure relates generally to communication systems, and more particularly, to a tertiary synchronization signal (TSS).

**Background**

- [0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources. Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.
- [0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is Long Term Evolution (LTE). LTE is a set of enhancements to the Universal Mobile Telecommunications System (UMTS) mobile standard promulgated by Third Generation Partnership Project (3GPP). LTE is designed to support mobile broadband access through improved spectral efficiency, lowered costs, and improved services using OFDMA on the downlink, SC-FDMA on the uplink, and multiple-input multiple-output (MIMO) antenna technology. However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in LTE technology. These improvements may also be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.
- [0004] Synchronization between devices within wireless communication systems may be provided by synchronization signals (SS) such as a primary synchronization signal

(PSS) and a secondary synchronization signal (SSS), as in LTE systems. Some systems may also include a tertiary synchronization signal (TSS). The TSS may need to be transmitted, e.g., from a base station to a user equipment (UE).

### SUMMARY

- [0005]** The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.
- [0006]** As discussed above, synchronization between devices within wireless communication systems may be provided by SS such as a PSS and a SSS, as in LTE systems. Some systems may also include a TSS. The TSS may need to be transmitted, e.g., from a base station to a user equipment (UE). The TSS may be multiplexed with at least one of the PSS, the SSS, or the PBCH for transmission in an SS block.
- [0007]** In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided. The apparatus may be configured to multiplex a TSS with at least one of a PSS, an SSS, or a physical broadcast channel (PBCH) for transmission in an SS block. The apparatus may be further configured to transmit the SS block including the TSS, the PSS, the SSS, and the PBCH.
- [0008]** In another aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided. The apparatus may be configured to receive an SS block comprising a TSS multiplexed with at least one of a PSS, a SSS, or a physical broadcast channel (PBCH). The apparatus may be further configured to demultiplex the SS block to obtain the TSS, the PSS, the SSS, and the PBCH.
- [0009]** To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

### BRIEF DESCRIPTION OF THE DRAWINGS

- [0010]** FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network.
- [0011]** FIGs. 2A, 2B, 2C, and 2D are diagrams illustrating LTE examples of a DL frame structure, DL channels within the DL frame structure, an UL frame structure, and UL channels within the UL frame structure, respectively.
- [0012]** FIG. 3 is a diagram illustrating an example of an evolved Node B (eNB)(LTE) or a gNodeB (gNB)(NR/5G) and UE in an access network.
- [0013]** FIGs. 4A through 4G are diagrams illustrating an example of the transmission of beamformed signals between a base station and a UE.
- [0014]** FIG. 5 is a diagram illustrating an example SS burst set.
- [0015]** FIG. 6 is a diagram illustrating an example of frequency-division multiplexing of a TSS with a PSS in an SS block in accordance with the systems and methods described herein.
- [0016]** FIG. 7 is a diagram illustrating an example of time-division multiplexing of a TSS with other SS in an SS block in accordance with the systems and methods described herein.
- [0017]** FIG. 8 is a diagram illustrating an example of frequency-division multiplexing of a TSS with other SS in an SS block in accordance with the systems and methods described herein.
- [0018]** FIG. 9 is a diagram illustrating another example of frequency-division multiplexing of a TSS with other SS in an SS block in accordance with the systems and methods described herein.
- [0019]** FIG. 10 is a diagram illustrating another example of frequency-division multiplexing of a TSS with other SS in an SS block in accordance with the systems and methods described herein.
- [0020]** FIG. 11 is a diagram illustrating another example of frequency-division multiplexing of a TSS with other SS in an SS block in accordance with the systems and methods described herein.
- [0021]** FIG. 12 is a flowchart of a method of wireless communication in accordance with the systems and methods described herein.

**[0022]** FIG. 13 is a flowchart of a method of wireless communication in accordance with the systems and methods described herein.

#### **DETAILED DESCRIPTION**

**[0023]** The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

**[0024]** Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

**[0025]** By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a “processing system” that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads



of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

**[0026]** Accordingly, in one or more example embodiments, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

**[0027]** FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network 100. The wireless communications system (also referred to as a wireless wide area network (WWAN)) includes base stations 102, UEs 104, and an Evolved Packet Core (EPC) 160. The base stations 102 may include macro cells (high power cellular base station) and/or small cells (low power cellular base station). The macro cells include eNBs/gNBs. The small cells include femtocells, picocells, and microcells.

**[0028]** In LTE/LTE-A networks, including such networks described herein, the term evolved node B (eNB) may be generally used to describe the base stations. The wireless communications system or systems described herein may include a heterogeneous LTE/LTE-A or NR network in which different types of evolved node B (eNBs) provide coverage for various geographical regions. For example, each eNB, gNB or base station may provide communication coverage for a macro cell, a small cell, or other types of cell. The term “cell” may be used to describe a base station, a carrier or component carrier associated with a base station, or a coverage area (*e.g.*, sector, *etc.*) of a carrier or base station, depending on context.

**[0029]** Base stations may include or may be referred to by those skilled in the art as a base transceiver station, a radio base station, an access point, a radio transceiver, a NodeB, eNodeB (eNB), next generation NodeB (gNB), Home NodeB, a Home eNodeB, or some other suitable terminology. The geographic coverage area for a base station may

be divided into sectors making up only a portion of the coverage area. The wireless communications system or systems described herein may include base stations of different types (*e.g.*, macro or small cell base stations). The UEs described herein may be able to communicate with various types of base stations and network equipment including macro eNBs, small cell eNBs, gNBs, relay base stations, and the like. There may be overlapping geographic coverage areas for different technologies.

**[0030]** The base stations 102 (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN)) interface with the EPC 160 through backhaul links 132 (*e.g.*, S1 interface). In addition to other functions, the base stations 102 may perform one or more of the following functions: transfer of user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (*e.g.*, handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, radio access network (RAN) sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate directly or indirectly (*e.g.*, through the EPC 160) with each other over backhaul links 134 (*e.g.*, X2 interface). The backhaul links 134 may be wired or wireless.

**[0031]** The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. There may be overlapping geographic coverage areas 110. For example, the small cell 102' may have a coverage area 110' that overlaps the coverage area 110 of one or more macro base stations 102. A network that includes both small cell and macro cells may be known as a heterogeneous network. A heterogeneous network may also include Home Evolved Node Bs (eNBs) (HeNBs) (gNB), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links 120 between the base stations 102 and the UEs 104 may include uplink (UL) (also referred to as reverse link) transmissions from a UE 104 to a base station 102 and/or downlink (DL) (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use MIMO antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links may be through one or more

carriers. The base stations 102 / UEs 104 may use spectrum up to  $Y$  MHz (e.g., 5, 10, 15, 20 MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of  $Yx$  MHz ( $x$  component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or less carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

- [0032] The wireless communications system may further include a Wi-Fi access point (AP) 150 in communication with Wi-Fi stations (STAs) 152 via communication links 154 in a 5 GHz unlicensed frequency spectrum. When communicating in an unlicensed frequency spectrum, the STAs 152 / AP 150 may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.
- [0033] The small cell 102' may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell 102' may employ LTE and use the same 5 GHz unlicensed frequency spectrum as used by the Wi-Fi AP 150. The small cell 102', employing LTE in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network. LTE in an unlicensed spectrum may be referred to as LTE-unlicensed (LTE-U), licensed assisted access (LAA), or MuLTEfire.
- [0034] The millimeter wave (mmW) base station 180 may operate in mmW frequencies and/or near mmW frequencies in communication with the UE 182. Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW / near mmW radio frequency band has extremely high path loss and a short range. The mmW base station 180 may utilize beamforming 184 with the UE 182 to compensate for the extremely high path loss and short range.
- [0035] The EPC 160 may include a Mobility Management Entity (MME) 162, other MMEs 164, a Serving Gateway 166, a Multimedia Broadcast Multicast Service (MBMS)

Gateway 168, a Broadcast Multicast Service Center (BM-SC) 170, and a Packet Data Network (PDN) Gateway 172. The MME 162 may be in communication with a Home Subscriber Server (HSS) 174. The MME 162 is the control node that processes the signaling between the UEs 104 and the EPC 160. Generally, the MME 162 provides bearer and connection management. All user Internet protocol (IP) packets are transferred through the Serving Gateway 166, which itself is connected to the PDN Gateway 172. The PDN Gateway 172 provides UE IP address allocation as well as other functions. The PDN Gateway 172 and the BM-SC 170 are connected to the IP Services 176. The IP Services 176 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service (PSS), and/or other IP services. The BM-SC 170 may provide functions for MBMS user service provisioning and delivery. The BM-SC 170 may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a public land mobile network (PLMN), and may be used to schedule MBMS transmissions. The MBMS Gateway 168 may be used to distribute MBMS traffic to the base stations 102 belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting eMBMS related charging information.

**[0036]** The base station may also be referred to as a Node B, evolved Node B (eNB), a next generation Node B (gNB), an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), or some other suitable terminology. The base station 102 provides an access point to the EPC 160 for a UE 104. Examples of UEs 104 include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, or any other similar functioning device. The UE 104 may also be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

- [0037]** Referring again to FIG. 1, in certain aspects, the eNB/gNB 102 may be configured to multiplex a TSS with at least one of a PSS, a SSS, or a PBCH for transmission in a SS block, and transmitting the SS block including the TSS, the PSS, the SSS, and the PBCH (196).
- [0038]** Additionally, in certain aspects, the UE 104 may be configured to receive a SS block comprising a TSS multiplexed with at least one of a PSS, a SSS, or a PBCH, and demultiplexing the SS block to obtain the TSS, the PSS, the SSS, and the PBCH (198). The procedure described with respect to (198) may provide a cell search procedure by which the UE 104 acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. The TSS may be utilized in connection with beamforming. Beamforming is discussed below with respect to FIGS. 4A through 4G. The TSS may provide a block index that may be used to determine a beam direction.
- [0039]** FIG. 2A is a diagram 200 illustrating an example of a DL frame structure in LTE. FIG. 2B is a diagram 230 illustrating an example of channels within the DL frame structure in LTE. FIG. 2C is a diagram 250 illustrating an example of an UL frame structure in LTE. FIG. 2D is a diagram 280 illustrating an example of channels within the UL frame structure in LTE. Other wireless communication technologies may have a different frame structure and/or different channels. In LTE, a frame (10 ms) may be divided into 10 equally sized subframes. Each subframe may include two consecutive time slots. A resource grid may be used to represent the two time slots, each time slot including one or more time concurrent resource blocks (RBs) (also referred to as physical RBs (PRBs)). The resource grid is divided into multiple resource elements (REs). In LTE, for a normal cyclic prefix, an RB contains 12 consecutive subcarriers in the frequency domain and 7 consecutive symbols (for DL, OFDM symbols; for UL, SC-FDMA symbols) in the time domain, for a total of 84 REs. For an extended cyclic prefix, an RB contains 12 consecutive subcarriers in the frequency domain and 6 consecutive symbols in the time domain, for a total of 72 REs. The number of bits carried by each RE depends on the modulation scheme.
- [0040]** As illustrated in FIG. 2A, some of the REs carry DL reference (pilot) signals (DL-RS) for channel estimation at the UE. The DL-RS may include cell-specific reference signals (CRS) (also sometimes called common RS), UE-specific reference signals (UE-RS), and channel state information reference signals (CSI-RS). FIG. 2A illustrates CRS for antenna ports 0, 1, 2, and 3 (indicated as  $R_0$ ,  $R_1$ ,  $R_2$ , and  $R_3$ ,



respectively), UE-RS for antenna port 5 (indicated as  $R_5$ ), and CSI-RS for antenna port 15 (indicated as  $R$ ). FIG. 2B illustrates an example of various channels within a DL subframe of a frame. The physical control format indicator channel (PCFICH) is within symbol 0 of slot 0, and carries a control format indicator (CFI) that indicates whether the physical downlink control channel (PDCCH) occupies 1, 2, or 3 symbols (FIG. 2B illustrates a PDCCH that occupies 3 symbols). The PDCCH carries downlink control information (DCI) within one or more control channel elements (CCEs), each CCE including nine RE groups (REGs), each REG including four consecutive REs in an OFDM symbol. A UE may be configured with a UE-specific enhanced PDCCH (ePDCCH) that also carries DCI. The ePDCCH may have 2, 4, or 8 RB pairs (FIG. 2B shows two RB pairs, each subset including one RB pair). The physical hybrid automatic repeat request (ARQ) (HARQ) indicator channel (PHICH) is also within symbol 0 of slot 0 and carries the HARQ indicator (HI) that indicates HARQ acknowledgement (ACK) / negative ACK (NACK) feedback based on the physical uplink shared channel (PUSCH).

- [0041]** To aid in frequency and timing acquisition, a primary synchronization signal (PSS), secondary synchronization signal (SSS) and, in some systems, a tertiary synchronization signal may be utilized. In LTE systems, the PSS is within symbol 6 of slot 0 within subframes 0 and 5 of a frame and is used by a UE to determine subframe timing and a physical layer identity. The secondary synchronization signal (SSS) is within symbol 5 of slot 0 within subframes 0 and 5 of a frame and is used by a UE to determine a physical layer cell identity group number and radio frame timing. With NR systems, synchronization signals (SS) may be sent in bursts with pre-defined periodicity. Each SS burst may include a number of SS blocks, and each SS block can include PSS, TSS, TSS, and PBCH elements. In NR systems, the TSS may be used to SS block indices to facilitate beams, mmWave commination. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the aforementioned DL-RS. The physical broadcast channel (PBCH) is within symbols 0, 1, 2, 3 of slot 1 of subframe 0 of a frame, and carries a master information block (MIB). The MIB provides a number of RBs in the DL system bandwidth, a PHICH configuration, and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information

not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.

**[0042]** As illustrated in FIG. 2C, some of the REs carry demodulation reference signals (DM-RS) for channel estimation at the eNB/gNB. The UE may additionally transmit sounding reference signals (SRS) in the last symbol of a subframe. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. The SRS may be used by an eNB/gNB for channel quality estimation to enable frequency-dependent scheduling on the UL. FIG. 2D illustrates an example of various channels within an UL subframe of a frame. A physical random access channel (PRACH) may be within one or more subframes within a frame based on the PRACH configuration. The PRACH may include six consecutive RB pairs within a subframe. The PRACH allows the UE to perform initial system access and achieve UL synchronization. A physical uplink control channel (PUCCH) may be located on edges of the UL system bandwidth. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The PUSCH carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

**[0043]** FIG. 3 is a block diagram of an eNB/gNB 310 in communication with a UE 350 in an access network. In the DL, IP packets from the EPC 160 may be provided to a controller/processor 375. The controller/processor 375 implements layer 3 and layer 2 functionality. Layer 3 includes a radio resource control (RRC) layer, and layer 2 includes a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor 375 provides RRC layer functionality associated with broadcasting of system information (e.g., MIB, SIBs), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression / decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC

data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

**[0044]** The transmit (TX) processor 316 and the receive (RX) processor 370 implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor 316 handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator 374 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 350. Each spatial stream may then be provided to a different antenna 320 via a separate transmitter 318TX. Each transmitter 318TX may modulate an RF carrier with a respective spatial stream for transmission.

**[0045]** In an aspect, one or more of the TX processor 316 and the controller/processor 375 may generate SS blocks. The one or more processors (e.g., the TX processor 316 and/or the controller/processor 375) may cause the SS blocks to be transmitted, e.g., by one or more transmitters transmitter 318TX.

**[0046]** At the UE 350, each receiver 354RX receives a signal through its respective antenna 352. Each receiver 354RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor 356. The TX processor 368 and the RX processor 356 implement layer 1 functionality associated with various signal processing functions. The RX processor 356 may perform spatial processing

on the information to recover any spatial streams destined for the UE 350. If multiple spatial streams are destined for the UE 350, they may be combined by the RX processor 356 into a single OFDM symbol stream. The RX processor 356 then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the eNB/gNB 310. These soft decisions may be based on channel estimates computed by the channel estimator 358. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the eNB/gNB 310 on the physical channel. The data and control signals are then provided to the controller/processor 359, which implements layer 3 and layer 2 functionality.

**[0047]** In an aspect, the receiver 354RX may receive SS blocks. One or more of the RX processor 356 and the controller/processor 359 may process the SS blocks to acquiring frequency/time synchronization, e.g., using one or more of the PSS, SSS, and TSS. The UE 350 may perform an initial acquisition based on the SS block. Accordingly, as described herein, the SS signals (the PSS, the SSS, and/or the TSS) may be used to perform synchronization and/or cell identification in a communication system. Furthermore, scrambling in different ways as described herein may provide for better separation. How TSS is multiplexed may impact detection complexity, timing resolution, range of index values, etc.

**[0048]** The controller/processor 359 can be associated with a memory 360 that stores program codes and data. The memory 360 may be referred to as a computer-readable medium. In the UL, the controller/processor 359 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the EPC 160. The controller/processor 359 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

**[0049]** Similar to the functionality described in connection with the DL transmission by the eNB/gNB 310, the controller/processor 359 provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression / decompression, and security (ciphering, deciphering, integrity

protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

- [0050] Channel estimates derived by a channel estimator 358 from a reference signal or feedback transmitted by the eNB/gNB 310 may be used by the TX processor 368 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 368 may be provided to different antenna 352 via separate transmitters 354TX. Each transmitter 354TX may modulate an RF carrier with a respective spatial stream for transmission.
- [0051] The UL transmission is processed at the eNB/gNB 310 in a manner similar to that described in connection with the receiver function at the UE 350. Each receiver 318RX receives a signal through its respective antenna 320. Each receiver 318RX recovers information modulated onto an RF carrier and provides the information to a RX processor 370.
- [0052] The controller/processor 375 can be associated with a memory 376 that stores program codes and data. The memory 376 may be referred to as a computer-readable medium. In the UL, the controller/processor 375 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 350. IP packets from the controller/processor 375 may be provided to the EPC 160. The controller/processor 375 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.
- [0053] FIGS. 4A through 4G are diagrams illustrating an example of the transmission of beamformed signals between a base station and a UE. The base station 402 may be embodied as a base station in a mmW system (mmW base station), such as a gNB or the mmW base station 180. In one aspect, the base station 402 may be collocated with another base station, such as an eNB/gNB, a cellular base station, or other base station (e.g., a base station configured to communicate in a sub-6 GHz band). While some beams are illustrated as adjacent to one another, such an arrangement may be different in different aspects (e.g., beams transmitted during a same symbol may not be adjacent



to one another). Additionally, the number of illustrated beams is to be regarded as illustrative.

**[0054]** Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters (the super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave). While the disclosure herein refers to mmWs, it should be understood that the disclosure also applies to near mmWs. Further, while the disclosure herein refers to mmW base stations, it should be understood that the disclosure also applies to near-mmW base stations.

**[0055]** In order to build a useful communication network in the millimeter wavelength spectrum, a beamforming technique may be used to compensate for path loss. Beamforming technique focuses the RF energy into a narrow direction to allow the RF beam to propagate farther in that direction. Using the beamforming technique, non-line of sight (NLOS) RF communication in the millimeter wavelength spectrum may rely on reflection and/or diffraction of the beams to reach the UE. If the direction becomes blocked, either because of UE movement or changes in the environment (e.g., obstacles, humidity, rain, etc.), the beam may not be able to reach the UE. Thus, in order to ensure that the UE has continuous, seamless coverage, multiple beams in as many different direction as possible may be available. In an aspect, the beamforming technique may require that the mmW base stations and the UEs transmit and receive in a direction that allows the most RF energy to be collected.

**[0056]** The base station 402 may include hardware for performing analog and/or digital beamforming. For example, the base station 402 may transmit a TSS. The TSS may be utilized in connection with beamforming. The TSS may include a block index. The block index may be decoded and used to determine a beam direction. If the base station 402 is equipped with analog beamforming, at any one time, the base station 402 may transmit or receive a signal in only one direction. If the base station 402 is equipped with digital beamforming, the base station 402 may concurrently transmit multiple signals in multiple directions or may receive multiple signals concurrently in multiple directions.

**[0057]** Further, the UE 404, for example, may include hardware for performing analog and/or digital beamforming. If the UE 404 is equipped with analog beamforming, at any one

time, the UE 404 may transmit or receive a signal in only one direction. If the UE 404 is equipped with digital beamforming, the UE 404 may concurrently transmit multiple signals in multiple directions or may concurrently receive multiple signals in multiple directions.

**[0058]** In the mmW network, UEs may perform beam sweeps with mmW base stations within range. For example, the base station 402 may transmit  $m$  beams in a plurality of different spatial directions. The UE 404 may listen/scan for the beam transmissions from the base station 402 in  $n$  different receive spatial directions. When listening/scanning for the beam transmissions, the UE 404 may listen/scan for the beam sweep transmission from the base station 402  $m$  times in each of the  $n$  different receive spatial directions (a total of  $m*n$  scans). In another aspect, in a beam sweep, the UE 404 may transmit  $n$  beams in a plurality of different spatial directions. The base station 402 listens/scans for the beam transmissions from the UE 404 in  $m$  different receive spatial directions. When listening/scanning for the beam transmissions, the base station 402 may listen/scan for the beam sweep transmission from the UE 404  $n$  times in each of the  $m$  different receive spatial directions (a total of  $m*n$  scans).

**[0059]** Based on the performed beam sweeps, the UEs and/or the mmW base stations may determine a channel quality associated with the performed beam sweeps. For example, the UE 404 may determine the channel quality associated with the performed beam sweeps. Alternatively, the base station 402 may determine the channel quality associated with the performed beam sweeps. If the UE 404 determines a channel quality associated with the performed beam sweeps, the UE 404 may send the channel quality information (also referred to as beam sweep result information) to the base station 402. The UE 404 may send the beam sweep result information to the base station 402. If the base station 402 determines a channel quality associated with the performed beam sweeps, the base station 402 may send the beam sweep result information to the UE 404. In an aspect, the channel quality may be affected by a variety of factors. The factors include movement of the UE 404 along a path or due to rotation (e.g., a user holding and/or rotating the UE 404), movement along a path behind obstacles, and/or movement within particular environmental conditions (e.g., obstacles, rain, humidity). The UE 404 and the base station 402 may also exchange other information, for example, associated with for

beamforming (e.g., analog or digital beamforming capabilities, beamforming type, timing information, configuration information, etc.).

- [0060]** Based on the received information, the base station 402 and/or the UE 404 may determine various configuration information, such as mmW network access configuration information, information for adjusting beam sweeping periodicity, information regarding overlapping coverage for predicting a handoff to another base station, such as a mmW base station.
- [0061]** In an aspect, a beam set may contain eight different beams. For example, FIG. 4A illustrates eight beams 421, 422, 423, 424, 425, 426, 427, 428 for eight directions. In aspects, the base station 402 may be configured to beamform for transmission of at least one of the beams 421, 422, 423, 424, 425, 426, 427, 428 toward the UE 404. In one aspect, the base station 402 can sweep/transmit directions using eight ports during a subframe (e.g., synchronization subframe).
- [0062]** In an aspect, a base station may transmit a signal, such as a beam reference signal (BRS), in a plurality of directions, for example, during a synchronization subframe. In one aspect, this transmission may be cell-specific. Referring to FIG. 4B, the base station 402 may transmit a first set of beams 421, 423, 425, 427 in four directions. For example, the base station 402 may transmit a BRS in a synchronization subframe of each of the transmit beams 421, 423, 425, 427. For example, the synchronization subframe may be a TSS. The TSS may provide a block index. The block index may be used to determine a beam direction.
- [0063]** In an aspect, these beams 421, 423, 425, 427 transmitted in the four directions may be odd-indexed beams 421, 423, 425, 427 for the four directions out of a possible eight for the beam set. For example, the base station 402 may be capable of transmitting beams 421, 423, 425, 427 in directions adjacent to other beams 422, 424, 426, 428 that the base station 402 is configured to transmit. In an aspect, this configuration in which the base station 402 transmits beams 421, 423, 425, 427 for the four directions may be considered a “coarse” beam set.
- [0064]** The UE 404 may determine a respective beam index (sometimes abbreviated as “BI”) corresponding to a respective beam. In various aspects, the beam index may be indicate at least a direction for communicating through a corresponding beam toward the UE 404 (e.g., a beamforming direction). For example, the beam index may be a logical beam index associated with an antenna port, OFDM symbol index, and/or BRS transmission period, which may be indicated by one or more bits (e.g., 9 bits). For

example, the UE 404 may be configured to determine a beam index corresponding to a beam based on a time at which a BRS is received – e.g., a symbol or slot during which a BRS is received may indicate a beam index corresponding to a beam.

- [0065]** In FIG. 4C, the UE 404 may determine or select a beam index (sometimes abbreviated as “BI”) that is strongest or preferable. In one example, the UE 404 may determine a beam index from a TSS. The TSS may provide a beam index that may be used to determine a beam direction. In another example, the UE 404 may determine that the beam 425 carrying a BRS is strongest or preferable. The UE 404 may select a beam by measuring values for a received power or received quality associated with each of the first set of beams 421, 423, 425, 427. In one aspect, the received power may be referred to as a BRS received power (BRSRP).
- [0066]** The UE 404 may compare respective values to one another. The UE 404 may select a “best” beam. In an aspect, the best beam may be a beam that corresponds to the greatest or highest value (e.g., the best beam may be a beam with the highest BRSRP). The selected beam may correspond to a beam index, which may be a beam index with respect to the base station 402. For example, the UE 404 may determine that the BRSRP corresponding to the fifth beam 425 is the highest, and therefore the fifth beam 425 is the best beam as determined by the UE 404.
- [0067]** The UE 404 may transmit a first indication 460 of the fifth beam 425 to the base station 402. In an aspect, the first indication 460 may include a request to transmit a beam refinement reference signal (BRRS). The BRRS may be UE-specific. One of ordinary skill would appreciate that the BRRS may be referred to by different terminology without departing from the present disclosure, such as a beam refinement signal, a beam tracking signal, or another term.
- [0068]** In one aspect, the base station 402 may trigger transmission of the first indication 460. For example, the base station 402 may trigger transmission of the first indication 460 by a DCI message.
- [0069]** The base station 402 may receive the first indication 460. In one aspect, the first indication 460 may include a beam adjustment request (BAR). (e.g., a request for beam tracking, a request for a BRRS, a request for the base station to start transmitting on an indicated beam index without any further beam tracking, and the like). In one aspect, the first indication 460 may be indicated by a scheduling request. Based on the first indication 460, the base station 402 may determine the beam index corresponding to the fifth beam 425.

- [0070]** In FIG. 4D, the base station 402 may transmit a second set of beams based on the first indication 460 (e.g., based on a beam index indicated by the first indication 460). For example, the UE 404 may indicate that a fifth beam 425 is the best beam and, in response, the base station 402 may transmit a second set of beams 424, 425, 426 to the UE 404 based on the indicated beam index. In an aspect, the beams 424, 425, 426 transmitted based on the first indication 460 may be closer (e.g., spatially and/or directionally) to the fifth beam 425 than those other beams 421, 423, 427 of the first set of beams.
- [0071]** In an aspect, the beams 424, 425, 426 transmitted based on the first indication 460 may be considered a “fine” beam set. In an aspect, the base station 402 may transmit a BRRS through each of the beams 424, 425, 426 of the fine beam set. In an aspect, the beams 424, 425, 426 of the fine beam set may be adjacent. In an aspect, BRRS transmission can span 1, 2, 5 or 10 OFDM symbols and may be associated with a BRRS resource allocation, BRRS process indication, and/or a beam refinement process configuration.
- [0072]** Based on the BRRS transmission through the beams 424, 425, 426 of the fine beam set, the UE 404 may transmit a second indication 465 to the base station 402 to indicate a “best” beam. In an aspect, the second indication 465 may use two (2) bits to indicate the selected beam. For example, the UE 404 may transmit the second indication 465 that indicates a beam index corresponding to the selected beam 425. In one aspect, the second indication 465 may report beam refinement information (BRI). In one aspect, the second indication 465 may include a resource index (e.g., a BRRS-RI) and/or a reference power (RP) associated with the reception of the BRRS as measured by the UE 404 (e.g., a BRRS-RP). The base station 402 may then communicate with the UE 404 through the selected beam 425. As described herein, knowing a beam index from a synchronization procedure, e.g., from the TSS, may be useful for beam selection.
- [0073]** Referring to FIG. 4E, the base station 402 may transmit a BRS in a plurality of directions during a synchronization subframe. In an aspect, the base station 402 may transmit the BRS continuously, e.g., even after the UE 404 has communicated the second indication 465. For example, the base station 402 may transmit beams 421, 423, 425, 427 that each include a BRS (e.g., a “coarse” beam set).
- [0074]** Referring to FIG. 4F, the quality of a selected beam 425 may deteriorate so that the UE 404. For example, when the base station 402 and the UE 404 are communicating



through the selected beam 425, the selected beam 425 may become occluded or otherwise unsatisfactory such that the base station 402 and the UE 404 may prefer to communicate through another beam. Based on the BRS (e.g., transmitted during a synchronization subframe), the UE 404 may determine a new beam 423 through which to communicate. For example, the UE 404 may determine that the third beam 423 through which a BRS is communicated may be the best beam. The UE 404 may select a beam based by measuring values for a received power (e.g., BRSRP) or received quality associated with each of the set of beams 421, 423, 425, 427, comparing respective values to one another, and selecting the beam that corresponds to the highest value. The selected beam may correspond to a beam index at the base station 402. The UE 404 may transmit a third indication 470 indicating this beam index to the base station 402. In an aspect, the third indication 470 may include a request to transmit a BRRS. The BRRS may be UE-specific. In one aspect, a BAR may be used to request the base station 402 to transmit a BRRS. In one aspect, the third indication 470 may be triggered by the base station 402, such as by a DCI message. Similar to the first indication 460, the third indication 470 may be included in a scheduling request.

- [0075] With respect to FIG. 4G, the base station 402 may receive the third indication 470 from the UE 404. The base station 402 may be configured to determine a beam index based on at least the third indication 470. The base station 402 and the UE 404 may perform a beam refinement procedure, such as illustrated with respect to FIG. 4E (e.g., in order to select a new beam through which to communicate).
- [0076] FIG. 5 is a diagram illustrating an example SS burst set 500. The example SS burst set 500 includes a number of burst sets, B. As illustrated in FIG. 5, the SS burst set 500 includes the following, SSburst0 502, SSburst1 504, and SSburst(B-1) 506. Each of the SSbursts (SSburst0 502, SSburst1 504, and SSburst(B-1) 506) include a series of SS blocks 508, 510, 512. For example, FIG. 5 illustrates that SSburst0 502 includes a number, b, SS blocks. An SS block contains synchronization signals and PBCH. The b SS blocks are numbered 0 to  $(b_{ss}^{max} - 1)$  and include SSblock0 508, SSblock1 510, and SSblock  $(b_{ss}^{max} - 1)$  512.
- [0077] The SS block may include one or more of a PSS, an SSS, a TSS, or a PBCH. In an example, the PSS may be used to signal symbol timing. The signaling of symbol timing may be used to send timing information that may be used for synchronization of a UE in a communication system. In an example, the SSS may be used to signal a

PCI and radio frame timing. The PCI may be used to identify base stations in a communication network. The frame timing is timing information that may be used to synchronize the communication system. In an example, the TSS may be used to signal SS block indices. For example, TSS can be constructed based on pseudo-noise (PN) sequences and cyclic shifts of pseudo-noise (PN) sequences may be used to signal SS block indices. In an example, the PBCH may be used to signal minimum system information to support a UE in initial access procedures.

- [0078]** In an aspect, the TSS signal may convey index information that relates to beams, e.g., the beam index or indices of SS block repetitions within a beam. The SS blocks may be repeated within a beam for improved link budget. In some aspects, the TSS may be used to provide the beam index and/or SS block repetition index to a UE. Decoding the TSS may provide the beam index and/or SS block repetition index to the UE. For example, a base station may transmit a TSS. The TSS may include a block index that may be used to determine a beam direction.
- [0079]** FIG. 6 is a diagram illustrating an example of frequency-division multiplexing 600 of a TSS with a PSS in an SS block 610 in accordance with the systems and methods described herein. The diagram, illustrating an example of frequency-division multiplexing 600, is a time/frequency diagram. The time/frequency diagram illustrates an example placement of the PSS, the SSS, the TSS (TSS1, TSS2), and the PBCH (two PBCHs) in time and frequency. The PSS, the SSS, the TSS (TSS1, TSS2), the PSS, and the PBCH (two PBCHs) may be transmitted as part of an SS block 610.
- [0080]** In the example of FIG. 6, the TSS is frequency-division multiplexed with the PSS. In frequency-division multiplexing, the bandwidth available for synchronization 602 in a communication medium may be divided into a series of non-overlapping frequency sub-bands 604. Each of the non-overlapping frequency sub-bands 604 may be used to carry a separate signal. In the illustrated example of FIG. 6, TSS1, TSS2, and PSS may each use one of the non-overlapping frequency sub-bands 604.
- [0081]** In an aspect, the TSS may be multiplexed with other SS in the SS block 610 such as the PSS. The PSS and SSS may be mapped around the synchronization signal frequency. The TSS may be split into two TSS, e.g., TSS1, TSS2. Thus, the TSS may be mapped into two neighbor sub-bands of the PSS such that the bandwidth of PSS and TSS (TSS1 + TSS2) is equal to the bandwidth of the SSS. Mapping of the TSS sequences may be defined such that a UE 104 may identify a sequence and

perform a look up in order to arrive at an SS block index. The SS block index may be decoded and used to determine a beam direction.

**[0082]** The frequency-division multiplexed PSS and TSS may be time division multiplexed with one or more of the SSS and the PBCHs. In time-division multiplexing, the available time for transmission may be divided into a series of non-overlapping periods 606. In the illustrated example, in a first period 606, a first PBCH is transmitted using the bandwidth available for synchronization 602. In a second period 606, the frequency-division multiplexed PSS and TSS is transmitted using the non-overlapping frequency sub-bands 604. One non-overlapping frequency sub-band 604 may be used for each of the TSS1, the PSS, and the TSS2. In a third period 606, an SSS is transmitted using the bandwidth available for synchronization 602. In a fourth period 606, a second PBCH is transmitted using the bandwidth available for synchronization 602. Such an FDM approach to locating the TSS may reduce the number of timing hypotheses to test and thereby facilitate lower PSS detection complexity.

**[0083]** In the diagram, time may increase along the time-axis in the direction of the arrow on the time-axis. Accordingly, the first PBCH may be transmitted, followed by the PSS, the TSS1, and the TSS2, at the same time using frequency multiplexing. The SSS may follow the PSS, the TSS1, and the TSS2. The second PBCH may follow the SSS. However, the diagram illustrates only one example of possible time/frequency resource allocation for frequency-division multiplexing of the TSS and the PSS. Other orderings, other than the ordering illustrated in the diagram may also be used. Additionally, in the diagram, frequency may increase along the frequency-axis in the direction of the arrow.

**[0084]** In an example, the TSS sequence design may be constructed based on PN sequences. Example PN sequences include, but are not limited to M-sequences and Zadoff-Chu sequences. The M-sequence may be a maximum length sequence (MLS). The MLS is a type of pseudorandom binary sequence, the bits of which may be generated using maximal linear feedback shift registers. The Zadoff-Chu sequence is an example of a complex-valued mathematical sequence.

**[0085]** In an example, the TSS1 and the TSS2 may be cyclic shifts of base PN sequences. A cyclic shift is the operation of rearranging entries in a sequence. Thus, the TSS1 and the TSS2 may be a rearranged (shifted) version of base PN sequences.

- [0086] Furthermore, in an aspect, the TSS2 may be scrambled by the cyclic shift of TSS1. The TSS2 may be scrambled by the cyclic shift of TSS1 to differentiate different SS indices from the same cell.
- [0087] In another aspect, the TSS1 and the TSS2 may be scrambled by the PCI. Scrambling the TSS1 and the TSS2 using the PCI may allow for differentiating the same SS index from different cells.
- [0088] In another aspect, the SS block index may be signaled by a combination of cyclic shifts of the TSS1 and the TSS2.
- [0089] In an aspect, a determination of a block index based on an identity/root of a PN sequence may be used in a communication system in connection with the PSS and the SSS. A device may recognize a sequence (or an offset to a sequence, or a combination of sequences) and map the recognized sequence identifier to an index value as part of a larger synchronization procedure that includes cell identification and beam information.
- [0090] The example of FIG. 6 may be less complex than the example of FIG. 7 discussed below because the PSS detection may use a lower sampling rate which may lead to fewer timing hypotheses to test needing to be performed.
- [0091] In an aspect, having both TSS1 and TSS2 may provide a larger sequence space than a case having a long TSS sequence. A sequence space may be a vector space of real or complex numbers.
- [0092] FIG. 7 is a diagram illustrating an example of time-division multiplexing 700 of a TSS with other SS in an SS block 710 in accordance with the systems and methods described herein. The diagram, illustrating an example of time-division multiplexing 700, is a time/frequency diagram. The time/frequency diagram illustrates an example placement of the PSS, the SSS, the TSS, and the two PBCH in time and frequency. Additionally, the PSS, the SSS, the TSS, and the two PBCH may be transmitted as part of an SS block 710.
- [0093] In the example of FIG. 7, the TSS may be time-multiplexed with other SS in SS block 710 such as the PSS, the SSS, the TSS, and the two PBCHs. In time-division multiplexing, the available time for transmission may be divided into a series of non-overlapping periods 706, 708. In the illustrated example, in a first period 706, a first PBCH is transmitted using the bandwidth available for synchronization 702. In a second period 708, the PSS is transmitted using the bandwidth available for synchronization 702. If the first time period 706 is a time period,  $t$ , the second period

708 may be a time period,  $t/2$ . In a third period 708, the TSS is transmitted using the bandwidth available for synchronization 702. In a fourth period 706, an SSS is transmitted using the bandwidth available for synchronization 702. In a fifth period 706, a second PBCH is transmitted using the bandwidth available for synchronization 702. In the example of FIG. 7, four OFDM symbols (4T) may be used.

- [0094] In another example, five OFDM symbols (5T) may be used. For example, the first PBCH, SSS, TSS, PSS, and the second PBCH may all span a period, T. In other words, TSS and PSS may span the same period as PBCH and SSS.
- [0095] In the diagram, time may increase along the time-axis in the direction of the arrow on the time-axis. Accordingly, the first PBCH may be transmitted, followed by the PSS and then the TSS. The SSS may follow the TSS. The second PBCH may follow the SSS. However, the diagram illustrates only one example of a possible time/frequency resource allocation for time-division multiplexing. Other orderings, other than the ordering illustrated in the diagram may also be used. Additionally, in the diagram, frequency may increase along the frequency-axis in the direction of the arrow.
- [0096] In an aspect, the TSS and the PSS may be time-division multiplexed in a split symbol. The TSS may be multiplexed with other SS in the SS block 710. The TSS and the PSS may be time-division multiplexed so that the TSS and the PSS have the same numerology. In other words, the TSS and the PSS may have the same subcarrier spacing and cyclic prefix. The TSS and the PSS may include a scaled numerology of other SS symbols (e.g., SSS and PBCH) in the SS block 710. For example, the subcarrier spacing and cyclic prefix may be scaled from other SS symbols. In an example, a subcarrier spacing of the TSS and the PSS may be 60 kHz while the subcarrier spacing of the SSS and the PBCH may be 30 kHz. . While potentially increasing SS detection complexity, the split symbol approach may support better timing resolution than the FDM approach shown in FIG. 6 due to the wider bandwidth of PSS and correspondingly higher sampling rate.
- [0097] In an aspect, the TSS may be constructed based on cyclic shifts of PN sequences e.g., M-sequence or Zadoff-Chu sequences. Accordingly, the SS block index may be signaled by cyclic shifts.
- [0098] In an aspect, the TSS may be a frequency division multiplexed version of the TSS1 and the TSS2. In frequency-division multiplexing, the available bandwidth 702 in a communication medium may be divided into a series of non-overlapping frequency sub-bands 704. Each of the non-overlapping frequency sub-bands 704 may be used

to carry a separate signal. For example, in the illustrated example of FIG. 7, TSS1 and TSS2 may each use one of the non-overlapping frequency sub-bands 704. In an aspect, the TSS1 and TSS2 design may be similar to the TSS1 and TSS2 designs described with respect to FIG. 7.

- [0099]** In an aspect, the TSS may be scrambled by a PCI. The TSS may be scrambled by the PCI to differentiate the same SS index from different cells.
- [00100]** In an aspect, the example may use one OFDM symbol for each of the PSS, the SSS, the TSS and each of the two PBCH that are time-division multiplexed. The subcarrier spacing of TSS and PSS may be double of the subcarrier spacing of the SSS and the PBCH. In another aspect, all of the PSS, the SSS, the TSS and both of the PBCHs may have the same numerology and may use 5 OFDM symbols.
- [00101]** In an aspect, the cyclic shifts of the PN sequences may be used to signal SS block indices. For example, FIG. 7 illustrates two short sequences TSS1 and TSS2. Assuming that the TSS1 is associated with a first base sequence of length N and TSS2 is associated with a second base sequence of length N, theoretically there may be  $N^2$  combinations to be used for signaling the SS block indices.
- [00102]** The design of FIG. 7 may have a higher PSS detection complexity. However, the design of FIG. 7 may provide improved timing resolution relative to the design of FIG. 6. Additionally, the design of FIG. 7 may provide improved timing resolution due to a higher sampling rate. The PSS used in the design of FIG. 7 may have a wider bandwidth than the PSS used in the design of FIG. 6. For example, the PSS illustrated in FIG. 6 may be 1/3 the width of the PSS illustrated in FIG. 7 (assuming a case when each example uses the same total bandwidth).
- [00103]** FIG. 8 is a diagram illustrating an example of frequency-division multiplexing 800 of a TSS with other SS in an SS block 810 in accordance with the systems and methods described herein. The diagram, illustrating an example of frequency-division multiplexing 800, is a time/frequency diagram. The time/frequency diagram illustrates an example placement of the PSS, the SSS, the TSS, the PSS, and the PBCH (two PBCHs) in time and frequency. The PSS, the SSS, the TSS, the PSS, and the PBCH (two PBCHs) may be transmitted as part of an SS block 810.
- [00104]** In the example of FIG. 8, the TSS is frequency-division multiplexed with both of the PBCHs, the PSS, and the SSS. In frequency-division multiplexing, the bandwidth available for synchronization signals in a communication medium 802 may be divided into a series of non-overlapping frequency sub-bands 804, 812. Each of the non-

overlapping frequency sub-bands 804, 806 may be used to carry a separate signal. For example, in the illustrated example of FIG. 8, the non-overlapping frequency sub-band 804 may be used to transmit the PSS, the SSS, and both PBCHs. The non-overlapping frequency sub-band 804 may be used to transmit the PSS, the SSS, and both PBCHs. The non-overlapping frequency sub-band 806 may be used to transmit the TSS. The TSS may be frequency-multiplexed with each of the other SS in an SS block 810.

- [00105]** In the diagram, time may increase along the time-axis in the direction of the arrow on the time-axis. Accordingly, the first PBCH may be transmitted, followed by the PSS, the SSS, and the second PBCH. At the same time as each of the first PBCH, the PSS, the SSS, and the second PBCH, on the non-overlapping frequency sub-band 806, the TSS may be transmitted. In other words, the TSS may be transmitted on a separate frequency from the first PBCH, the PSS, the SSS, and the second PBCH over a period of time that includes the transmissions of the first PBCH, the PSS, the SSS, and the second PBCH. The diagram illustrates only one example of a possible time/frequency resource allocation for frequency-division multiplexing of the TSS and the other SS, however. Other orderings, other than the ordering illustrated in the diagram may also be used.
- [00106]** In an aspect, the TSS and other SS may be frequency-division multiplexed. For example, the TSS may be frequency-division multiplexed with other SS in the SS block 810. The TSS may be frequency-division multiplexed with all or a subset of the PSS, the SSS and both of the PBCH symbols within an SS block 810. The TSS may include one or multiple OFDM symbols.
- [00107]** In an aspect, the TSS may be constructed based on cyclic shifts of PN sequences e.g., M-sequence or Zadoff-Chu sequences, as discussed above. When the TSS uses multiple OFDM symbols, the TSS sequences in different symbols may be identical or different. In an aspect, when the TSS sequences are different in different symbols, the combination of cyclic shifts associated with the TSS sequences may be used to signal the SS block index.
- [00108]** In an aspect, the TSS may be scrambled by the PCI. The TSS may be scrambled by PCI to differentiate the same SS index from different cells.
- [00109]** FIG. 9 is a diagram illustrating another example of frequency-division multiplexing 900 of a TSS with other SS in an SS block 910 in accordance with the systems and methods described herein. The diagram of FIG. 9 is generally similar to the diagram

of FIG. 8. Unlike the diagram of FIG. 8, however, which illustrates frequency-division multiplexing of the TSS with each of the first PBCH, the PSS, the SSS, and the second PBCH, the diagram of FIG. 9, illustrates that the TSS may be frequency multiplexed with fewer than all of the other SS. More specifically, the diagram of FIG. 9 illustrates frequency-division multiplexing of the TSS with the PSS and the SSS (and not the PBCHs). Furthermore, unlike FIG. 6, in the diagram of FIG. 9, the bandwidth of the frequency-division multiplexed PSS and SSS is the same as the bandwidth of the PBCHs, which are not frequency-division multiplexed.

**[00110]** FIG. 10 is a diagram illustrating another example of frequency-division multiplexing of a TSS with other SS in an SS block in accordance with the systems and methods described herein. As shown, TSS1 and TSS2 can be separate, short PN sequences or parts of a larger PN sequence. The diagram, illustrating an example of frequency-division multiplexing 1000, is a time/frequency diagram. The time/frequency diagram illustrates an example placement of the PSS, the SSS, the TSS (TSS1, TSS2), and the PBCH (two PBCHs) in time and frequency. The PSS, the SSS, the TSS, and the PBCH (two PBCHs) may be transmitted as part of an SS block 1010. In an example of short sequence design: TSS1 and TSS2 may be constructed from PN sequences of length 31 (e.g., assuming TSS can occupy 62 REs).

**[00111]** In the example of FIG. 10, TSS1 and TSS2 are frequency-division multiplexed with both of the PSS, and the SSS. In frequency-division multiplexing, the bandwidth available for synchronization signals in a communication medium 1002 may be divided into a series of non-overlapping frequency sub-bands 1004, 1012. Each of the non-overlapping frequency sub-bands 1004, 1012 may be used to carry a separate signal. For example, in the illustrated example of FIG. 10, the non-overlapping frequency sub-bands 1012 may be used to transmit the PSS, the SSS. The bandwidth available for synchronization 1002 may be used to transmit both PBCHs. The non-overlapping frequency sub-band 1004 may be used to transmit TSS1 and TSS2. PBCH, PSS, and SSS may be time multiplexed in periods 1006, while TSS1 and TSS2 may span two periods 1006 for a total period 1008. Thus, in the illustrated example, PSS and SSS are time division multiplexed with each other; PSS and SSS are frequency division multiplexed with TSS1 and TSS2; and PBCH is time division multiplexed with TSS1/TSS2/PSS/SSS.

**[00112]** In the diagram, time may increase along the time-axis in the direction of the arrow on the time-axis. Accordingly, the first PBCH may be transmitted, followed by the PSS



and then SSS, and then the second PBCH (in the illustrated example). At the same time as the PSS and then SSS, the non-overlapping frequency sub-band 1004 may be used to transmit TSS1 and TSS2. In other words, TSS1 and TSS2 may be transmitted on a separate frequency from the PSS and the SSS at the same period of time. The diagram illustrates only one example of a possible time/frequency resource allocation for frequency-division multiplexing of the TSS and the other SS, however. Other orderings, other than the ordering illustrated in the diagram may also be used.

- [00113]** In an aspect, the PSS and the SSS may have the same bandwidth. The PBCH may have a wider bandwidth than the PSS and the SSS.
- [00114]** In an aspect, the TSS may be frequency division multiplexed with the PSS and/or the SSS. The TSS may be frequency division multiplexed with the PSS and/or the SSS such that bandwidth of (TSS + PSS) is equal to bandwidth of PBCH.
- [00115]** In an aspect, the bandwidth of (TSS + SSS) is equal to bandwidth of PBCH.
- [00116]** In an aspect, the TSS may include two short PN sequences, TSS1 and TSS 2, or TSS may be a long PN sequence (which may be an upper neighbor subband or a lower neighbor subband of the PSS and the SSS).
- [00117]** In an aspect, a numerology of the TSS may be identical to the numerology of the PSS and/or the SSS.
- [00118]** In an aspect, both the TSS and the SSS may be used as demodulation RS (DMRS) for PBCH.
- [00119]** In an aspect, the TSS is frequency division multiplexed with the PSS and the SSS in the same set of OFDM symbols.
- [00120]** In an aspect, the TSS comprises a first TSS and a second TSS. For example, the TSS may be made up of two short sequences. In another aspect, the TSS may be a single long sequence.
- [00121]** In an aspect, the TSS, the PSS, and the SSS are time division multiplexed with the PBCH.
- [00122]** FIG. 11 is a diagram illustrating another example of frequency-division multiplexing of a TSS with other SS in an SS block in accordance with the systems and methods described herein. As shown, TSS may be part of a larger PN sequence or may be separate, short PN sequences. The diagram, illustrating an example of frequency-division multiplexing 1100, is a time/frequency diagram. The time/frequency diagram illustrates an example placement of the PSS, the SSS, the TSS, the PSS, and the PBCH (two PBCHs) in time and frequency. The PSS, the SSS, the TSS, and the

PBCH (two PBCHs) may be transmitted as part of an SS block 1110. In an example of a long sequence design TSS may be constructed from PN sequences of length 61 (e.g., assuming TSS can occupy 62 REs, e.g., with one tone zero RE).

- [00123]** In the example of FIG. 11, TSS is frequency-division multiplexed with both of the PSS, and the SSS. In frequency-division multiplexing, the bandwidth available for synchronization signals in a communication medium 1102 may be divided into a series of non-overlapping frequency sub-bands 1104, 1112. Each of the non-overlapping frequency sub-bands 1104, 1112 may be used to carry a separate signal. For example, in the illustrated example of FIG. 11, the non-overlapping frequency sub-band 1104 may be used to transmit the TSS. The non-overlapping frequency sub-band 1112 may be used to transmit both PSS and SSS. The bandwidth available for synchronization 1102 may be used to transmit the PBCHs (time division multiplexed). The PBCHs may be time division multiplexed with the TSS/PSS/SSS over time periods 1106. The TSS may use two time periods 1106 (a time 1108).
- [00124]** In the diagram, time may increase along the time-axis in the direction of the arrow on the time-axis. Accordingly, the first PBCH may be transmitted, followed by the PSS and then SSS, and the second PBCH. At the same time as the PSS and then SSS, the non-overlapping frequency sub-band 1104 may be used to transmit TSS across time periods used by PSS and SSS in the other frequency sub-band 1112. In other words, TSS may be transmitted on a separate frequency from the PSS and the SSS during the same two periods of time (with PSS and SSS each using one time period 1106). The diagram illustrates only one example of a possible time/frequency resource allocation for frequency-division multiplexing of the TSS and the other SS, however. Other orderings, other than the ordering illustrated in the diagram may also be used.
- [00125]** In an aspect, the TSS is frequency division multiplexed with the PSS and the SSS in the same set of OFDM symbols.
- [00126]** In an aspect, the TSS comprises a first TSS and a second TSS. For example, the TSS may be made up of two short sequences. In another aspect, the TSS may be a single long sequence.
- [00127]** In an aspect, the TSS, the PSS, and the SSS are time division multiplexed with the PBCH.
- [00128]** FIGS. 6-11 illustrate specific examples of multiplexing a TSS with at least one of a PSS, an SSS, or a PBCH for transmission in an SS block. It will be understood,

however, that other combinations of multiplexing a TSS with at least one of a PSS, an SSS, or a PBCH for transmission in an SS block are also possible.

- [00129]** FIG. 12 is a flowchart 1200 of a method of wireless communication in accordance with the systems and methods described herein. The method may be performed by an eNB/gNB (e.g., the eNB/gNB 102, 310, 402). At block 1202, the eNB/gNB multiplexes a TSS with at least one of a PSS, an SSS, or a PBCH for transmission in an SS block. For example, the eNB/gNB (102, 310, 402) multiplexes a TSS (“TSS” FIGS. 6-11) with at least one of a PSS (“PSS” FIGS. 6-11), an SSS (“SSS” FIGS. 6-11), or a PBCH (“PBCH” FIGS. 6-11) for transmission in an SS block (610, 710, 810, 910, 1010, 1110).
- [00130]** At block 1204, the eNB/gNB transmits the SS block including the TSS, the PSS, the SSS, and the PBCH. For example, the eNB/gNB (102, 310, 402) transmits the SS block (610, 710, 810, 910, 1010, 1110) including the TSS (“TSS” FIGS. 6-11), the PSS (“PSS” FIGS. 6-11), the SSS (“SSS” FIGS. 6-11), and the PBCH (“PBCH” FIGS. 6-11).
- [00131]** In an aspect, the TSS may include a first TSS (“TSS1” FIG. 6, FIG. 10) and a second TSS (“TSS2” FIG. 6, FIG. 10). Additionally, the TSS of FIG. 7 may also be split in to multiple TSS.
- [00132]** In an aspect, the eNB/gNB may generate a first tertiary synchronization sequence for the first TSS based on a first PN sequence. For example, the eNB/gNB (102, 310, 402) generates a first tertiary synchronization sequence (e.g., a series of bits) for the first TSS (e.g., “TSS1” FIG. 6, FIG. 10) and a first portion of “TSS” FIG. 7, FIG. 11) based on a first PN sequence.
- [00133]** In an aspect, the eNB/gNB may generate a second tertiary synchronization sequence for the second TSS based on a second PN sequence. For example, the eNB/gNB (102, 310, 402) generates a second tertiary synchronization sequence (e.g., a series of bits) for the second TSS (“TSS2” FIG. 6, FIG. 10) and a second portion of “TSS” FIG. 7, FIG. 11) based on a first PN sequence.
- [00134]** In an aspect, the eNB/gNB may cyclic shift the first PN sequence based on a first cyclic shift to generate the first tertiary synchronization sequence. For example, the eNB/gNB (102, 310, 402) cyclic shifts the first PN sequence based on a first cyclic shift to generate the first tertiary synchronization sequence.
- [00135]** In an aspect, the eNB/gNB may cyclic shift the second PN sequence based on a second cyclic shift to generate the second tertiary synchronization sequence. For example,

the eNB/gNB (102, 310, 402) cyclic shifts the second PN sequence based on a second cyclic shift to generate the second tertiary synchronization sequence.

- [00136] In an aspect, the TSS2 can be scrambled by the cyclic shift of TSS1. Alternatively, in another aspect the TSS may be a single, long sequence which may be chopped into two parts for TSS1 and TSS2.
- [00137] Accordingly, some examples may have one PN sequence (long). Other examples may use two PN sequences (short). For an example including a second PN sequence, the second PN sequence may be separately be scrambled by a cyclic shift of TSS1 to enhance orthogonality.
- [00138] In an aspect, the eNB may scramble the second tertiary synchronization sequence using the first cyclic shift. For example, the eNB/gNB (102, 310, 402) scrambles the second tertiary synchronization sequence using the first cyclic shift.
- [00139] In an aspect, the eNB/gNB may scramble the first tertiary synchronization sequence and the second tertiary synchronization sequence based on a PCI of the base station. For example, the eNB/gNB (102, 310, 402) scrambles the first tertiary synchronization sequence and the second tertiary synchronization sequence based on the PCI of the base station (e.g., eNB/gNB).
- [00140] In an aspect, the eNB/gNB may determine a block index for the SS block. For example, the eNB/gNB (102, 310, 402) determines a block index for the SS block (610, 710, 810, 910, 1010, 1110).
- [00141] In an aspect, the eNB/gNB may determine the first cyclic shift and the second cyclic shift based on the block index. For example, the eNB/gNB (102, 310, 402) determines the first cyclic shift and the second cyclic shift based on the block index.
- [00142] In an aspect, the TSS may be frequency division multiplexed in a same OFDM symbol with the PSS.
- [00143] In an aspect, the TSS may include a first TSS and a second TSS, and the first TSS, the second TSS, and the PSS are frequency division multiplexed in the same OFDM symbol.
- [00144] In an aspect, the PSS may be between the first TSS and the second TSS in frequency.
- [00145] In an aspect, the PSS, the first TSS, and the second TSS together may occupy a same number of RBs in the SS block as the SSS.
- [00146] In an aspect, the same number of RBs is  $x$ , the PSS occupies  $x/2$  RBs, the first TSS occupies  $x/4$  RBs, and the second TSS occupies  $x/4$  RBs.

- [00147] In an aspect, the TSS may be time division multiplexed with the PSS, the SSS, and the PBCH in a same set of subcarriers.
- [00148] In an aspect, the subcarrier spacing of the SSS and the PBCH is  $x$  kHz and the subcarrier spacing of the TSS and the PSS is  $2x$  kHz.
- [00149] In an aspect, the subcarrier spacing of the SSS, the PBCH, the TSS, and the PSS may be the same.
- [00150] In an aspect, OFDM symbol time length for TSS and PSS are each  $1/2x$  ms, and OFDM symbol time length for SSS and PBCH are each  $1/x$  ms.
- [00151] In an aspect, the TSS may include a first TSS and a second TSS, and the first TSS and the second TSS are frequency division multiplexed in a same OFDM symbol.
- [00152] In an aspect, the TSS and the PSS may be transmitted with a first cyclic prefix, and the SSS and the PBCH are transmitted with a second cyclic prefix different from the first cyclic prefix.
- [00153] In an aspect, the TSS may be frequency division multiplexed with at least one of the PSS, the SSS, or the PBCH in the same set of OFDM symbols.
- [00154] In an aspect, the TSS is frequency division multiplexed with the PSS, the SSS, and the PBCH in the same set of OFDM symbols.
- [00155] In an aspect, the TSS may be frequency division multiplexed with the PSS and the SSS in the same set of OFDM symbols.
- [00156] In an aspect, the TSS is frequency division multiplexed with the PSS and the SSS in the same set of OFDM symbols.
- [00157] In an aspect, the TSS frequency division multiplexed with the PSS and the SSS includes a first TSS and a second TSS.
- [00158] In an aspect, the TSS, the PSS, and the SSS are time division multiplexed with the PCCH.
- [00159] FIG. 13 is a flowchart 1300 of a method of wireless communication in accordance with the systems and methods described herein. The method may be performed by a UE (e.g., the UE 104, 350, 404) such as part of an initial acquisition procedure in which the UE performs cell identification, acquires frame timing, etc. At block 1302, the UE receives a SS block comprising a TSS multiplexed with at least one of a PSS, an SSS, or a PBCH. For example, the UE 104, 350, 404 receives an SS block (610, 710, 810, 910, 1010, 1110) comprising a TSS ("TSS" FIGS. 6-11) multiplexed with at least one of a PSS ("PSS" FIGS. 6-11), an SSS ("SSS" FIGS. 6-11), or a PBCH ("PBCH" FIGS. 6-11).

- [00160]** At block 1304, the UE demultiplexes the SS block to obtain the at least one of the TSS, the PSS, the SSS, and the PBCH. For example, the UE (104, 350, 404) demultiplexes the SS block (610, 710, 810, 910, 1010, 1110) to obtain the at least one of the TSS (“TSS” FIGS. 6-11), the PSS (“PSS” FIGS. 6-11), the SSS (“SSS” FIGS. 6-11), and the PBCH (“PBCH” FIGS. 6-11).
- [00161]** In an aspect, the TSS may include a first TSS corresponding to a first tertiary synchronization sequence and a second TSS corresponding to a second tertiary synchronization sequence.
- [00162]** In an aspect, the first tertiary synchronization sequence may be based on a first pseudo-noise (PN) sequence, and
- [00163]** In an aspect, the second tertiary synchronization sequence may be based on a second PN sequence.
- [00164]** In an aspect, the first tertiary synchronization sequence may be a first cyclic shift of the first PN sequence.
- [00165]** In an aspect, the second tertiary synchronization sequence may be a second cyclic shift of the second PN sequence.
- [00166]** In an aspect, a UE may descramble the second tertiary synchronization sequence based on the first cyclic shift.
- [00167]** In an aspect, a UE may descramble the first tertiary synchronization sequence and the second tertiary synchronization sequence based on a physical cell identifier (PCI) received from a base station.
- [00168]** In an aspect, a UE may determine the first cyclic shift and the second cyclic shift.
- [00169]** In an aspect, a UE may determine a block index of the SS block based on the determined first cyclic shift and the determined second cyclic shift.
- [00170]** In an aspect, the TSS may be frequency division multiplexed in a same OFDM symbol with the PSS.
- [00171]** In an aspect, the TSS may include a first TSS and a second TSS, and the first TSS, the second TSS, and the PSS are frequency division multiplexed in the same OFDM symbol.
- [00172]** In an aspect, the PSS may be between the first TSS and the second TSS in frequency.
- [00173]** In an aspect, the PSS, the first TSS, and the second TSS together may occupy a same number of resources blocks (RBs) in the SS block as the SSS.
- [00174]** In an aspect, the same number of RBs is  $x$ , the PSS occupies  $x/2$  RBs, the first TSS occupies  $x/4$  RBs, and the second TSS occupies  $x/4$  RBs .

- [00175]** In an aspect, the TSS may be time division multiplexed with the PSS, the SSS, and the PBCH in a same set of subcarriers.
- [00176]** In an aspect, the subcarrier spacing of the SSS and the PBCH is  $x$  kHz and the subcarrier spacing of the TSS and the PSS is  $2x$  kHz.
- [00177]** In an aspect, the subcarrier spacing of the SSS, the PBCH, the TSS, and the PSS may be the same.
- [00178]** In an aspect, OFDM symbol time length for TSS and PSS are each  $1/2x$  ms, and OFDM symbol time length for SSS and PBCH are each  $1/x$  ms.
- [00179]** In an aspect, the TSS may include a first TSS and a second TSS, and the first TSS and the second TSS are frequency division multiplexed in a same OFDM symbol.
- [00180]** In an aspect, the TSS and the PSS have a first cyclic prefix, and the SSS and the PBCH have a second cyclic prefix different from the first cyclic prefix.
- [00181]** In an aspect, the TSS may be frequency division multiplexed with at least one of the PSS, the SSS, or the PBCH in the same set of OFDM symbols.
- [00182]** In an aspect, the TSS may be frequency division multiplexed with the PSS, the SSS, and the PBCH in the same set of OFDM symbols.
- [00183]** In an aspect, the TSS may be frequency division multiplexed with the PSS and the SSS in the same set of OFDM symbols.
- [00184]** In an aspect, the cyclic shifts of PN sequences may be used to signal SS block indices. The example discussed with respect to FIG. 6 may include two short sequences TSS1 and TSS2. Assuming TSS1 is associated with base sequence 1 of length  $N$  and TSS2 is associated with base sequence 2 of length  $N$ , there may be  $N*N$  combinations that may be used for signaling SS block indices.
- [00185]** Mapping of TSS sequences may be defined in a standard such that a UE may identify the sequence and may perform a lookup in order to arrive at the SS block index, (e.g., determining a slot index value based on a sequence, shift, of the TSS).
- [00186]** In an aspect, NR/5G PSS/SSS may have the same roles as LTE PSS/SSS. A UE may first detect PSS/SSS and then decode TSS to obtain SS block index.
- [00187]** The example described with respect to FIG. 7 may have a higher PSS detection complexity. However, the example described with respect to FIG. 7 may provide better timing resolution due to higher sampling rate (PSS has wider bandwidth than PSS in the example described with respect to FIG. 6).

- [00188]** The example described with respect to FIG. 6 may be less complex than the example described with respect to FIG. 7 in PSS detection due to lower sampling rate which may lead to a lower number of timing hypotheses to test.
- [00189]** Having TSS1 and TSS2 may provide larger sequence space (e.g.,  $N*N$  example above) than the case having a long TSS sequence.
- [00190]** The example discussed with respect to FIG. 6 may be a more attractive options than the examples described with respect to FIGS. 7-9.
- [00191]** In an aspect, the TSS is frequency division multiplexed with the PSS and the SSS in the same set of OFDM symbols.
- [00192]** In an aspect, the TSS frequency division multiplexed with the PSS and the SSS includes a first TSS and a second TSS.
- [00193]** In an aspect, the TSS, the PSS, and the SSS are time division multiplexed with the PCH.
- [00194]** Further disclosure is included in the Appendix.
- [00195]** It is understood that the specific order or hierarchy of blocks in the processes / flowcharts disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes / flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not meant to be limited to the specific order or hierarchy presented.
- [00196]** The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term "some" refers to one or more. Combinations such as "at least one of A, B, or C," "one or more of A, B, or C," "at least one of A, B, and C," "one or more of A, B, and C," and "A, B, C, or any combination thereof" include any



combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words “module,” “mechanism,” “element,” “device,” and the like may not be a substitute for the word “means.” As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase “means for.”

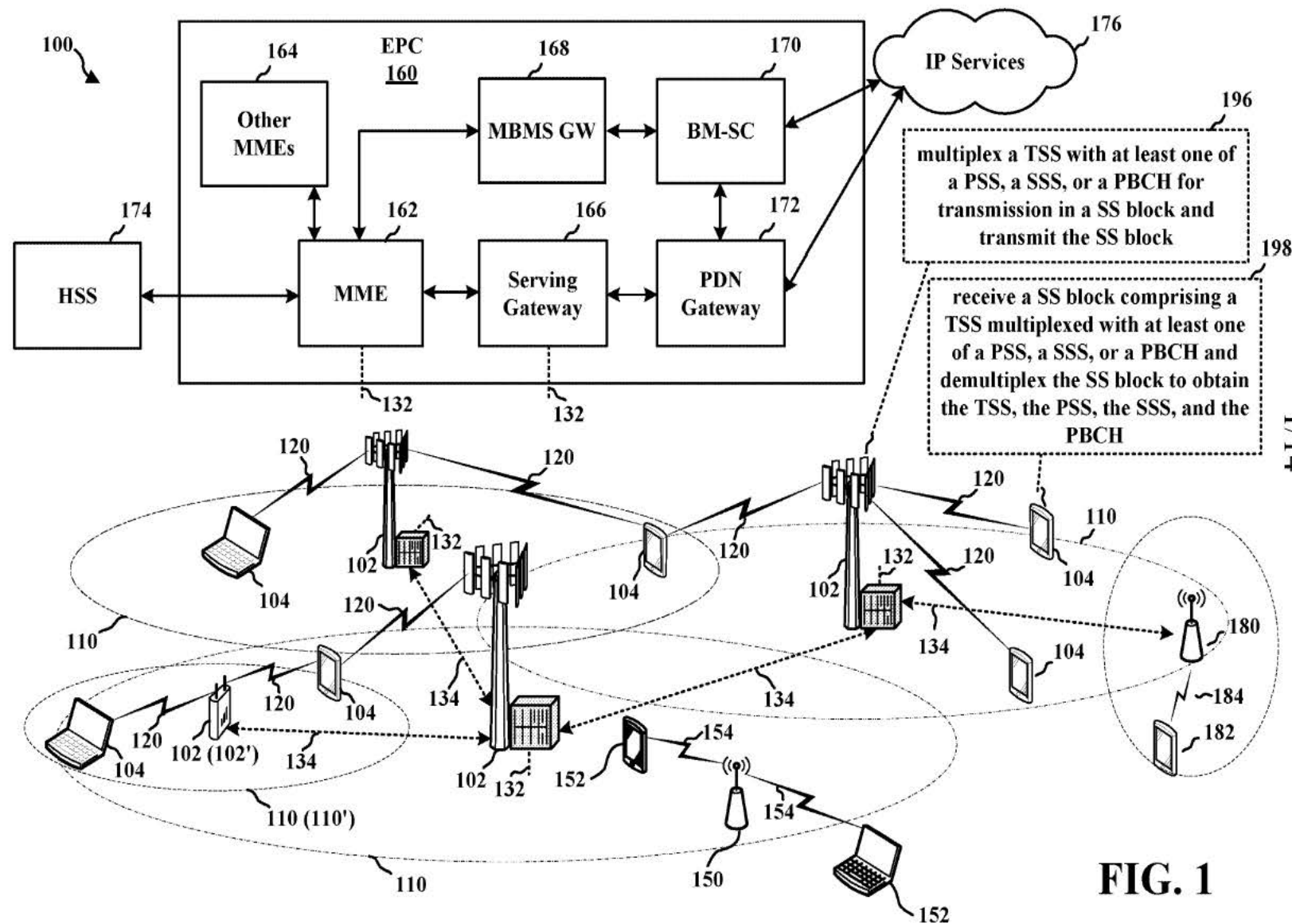


FIG. 1

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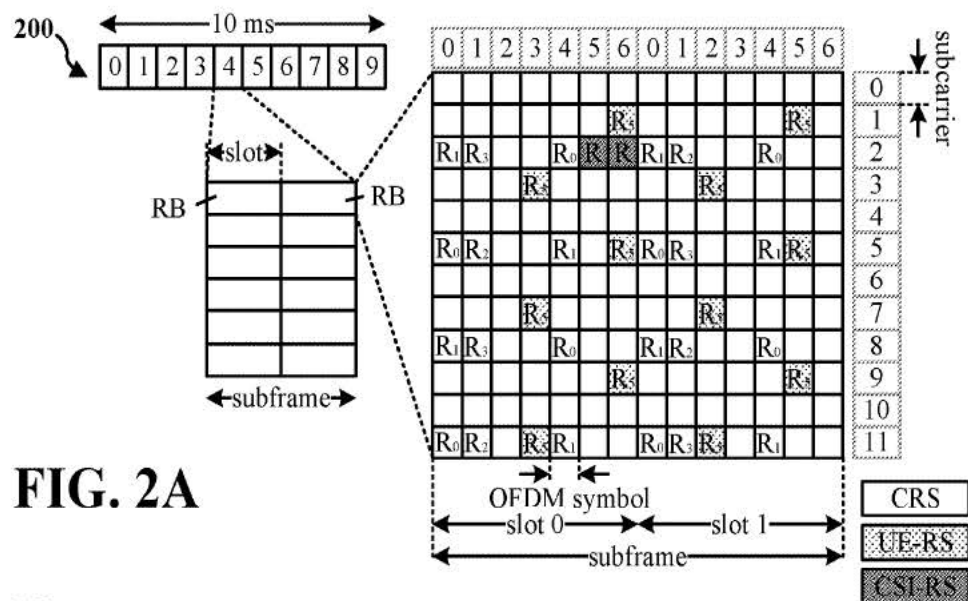


FIG. 2A

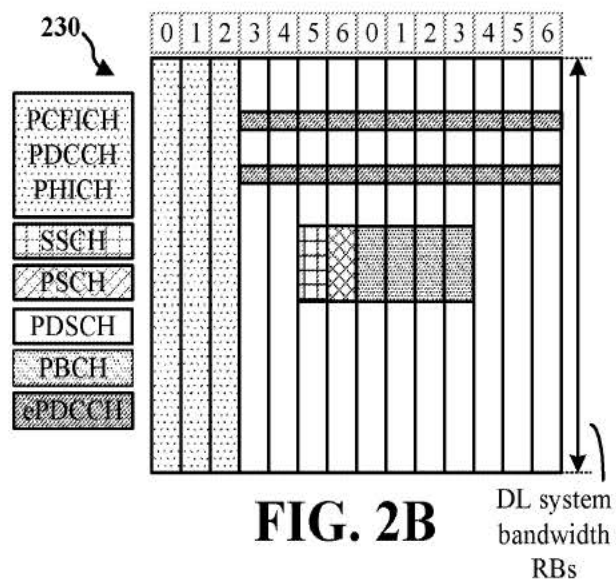


FIG. 2B

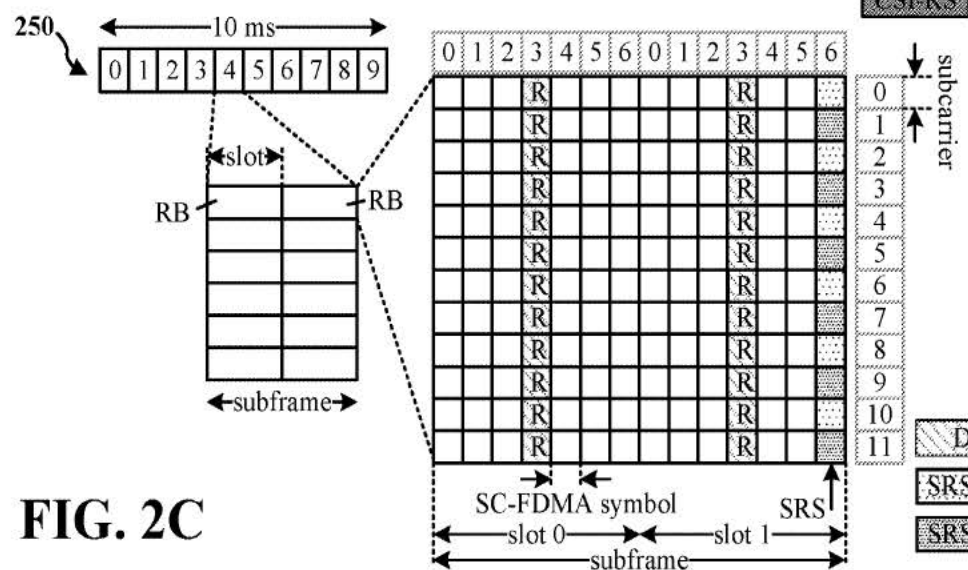


FIG. 2C

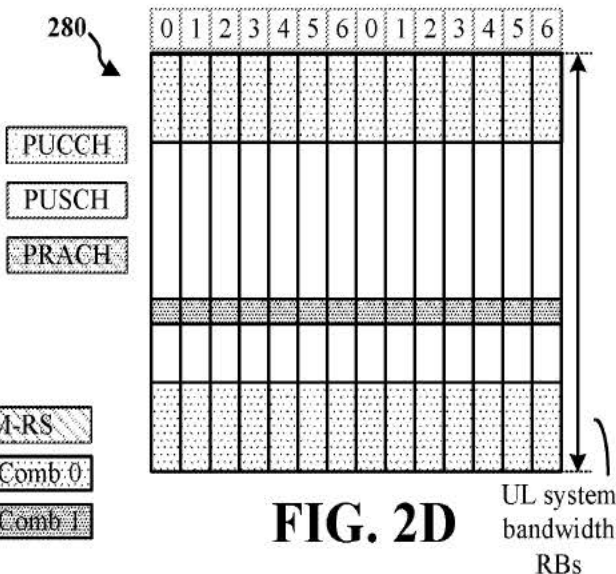


FIG. 2D

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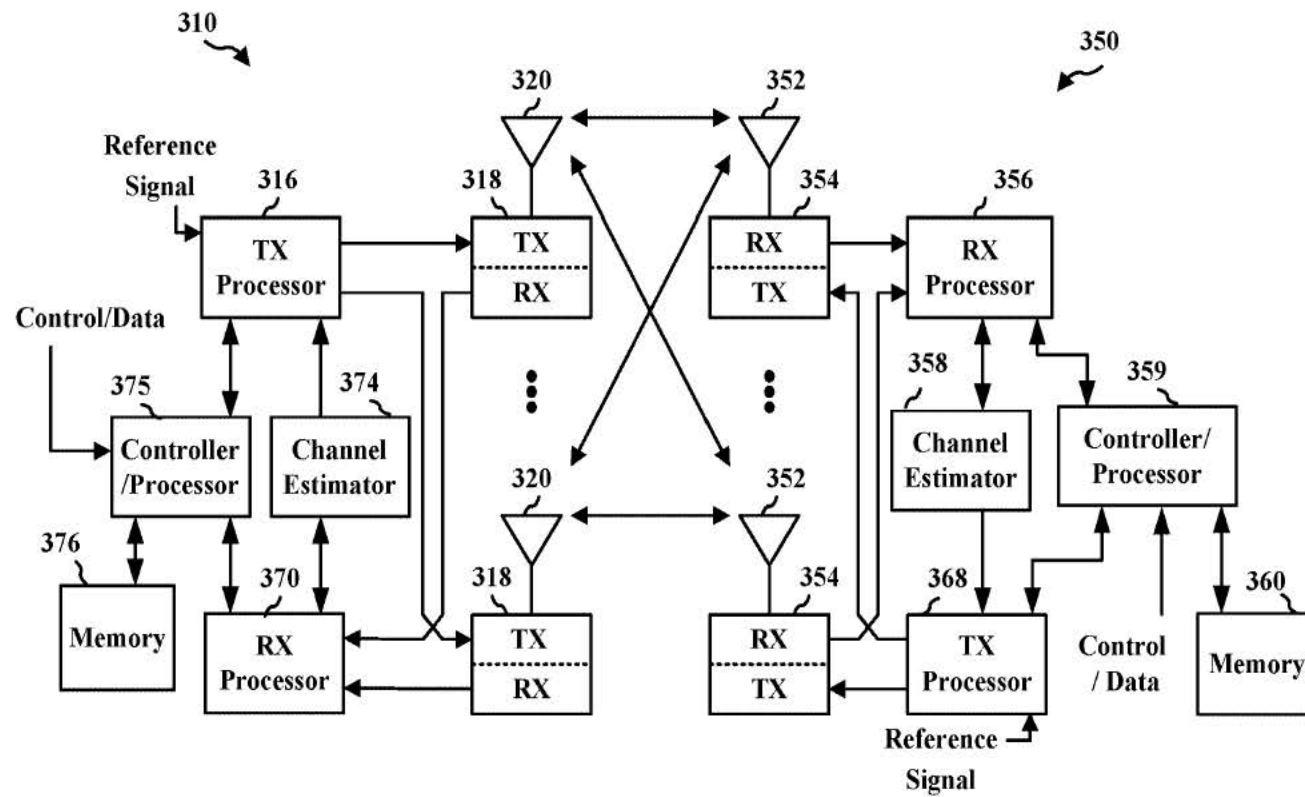


FIG. 3

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400

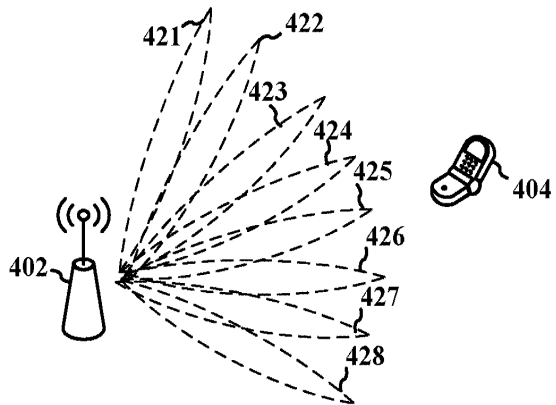


FIG. 4A

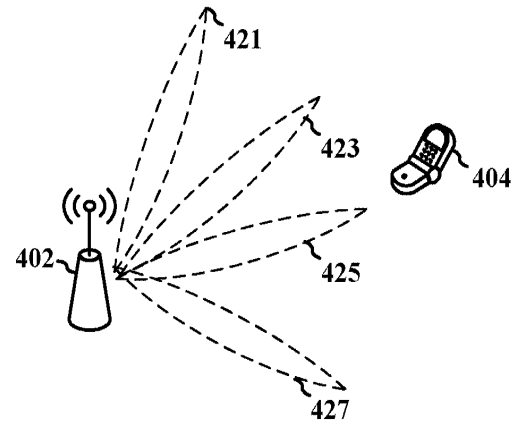


FIG. 4B

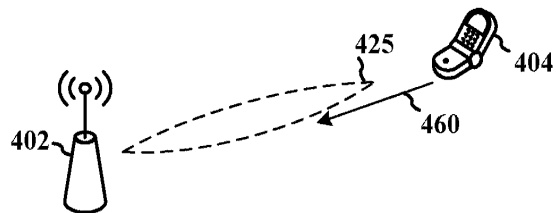


FIG. 4C

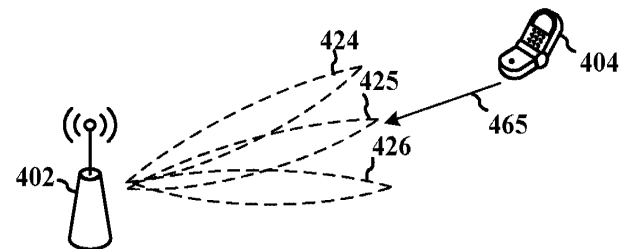
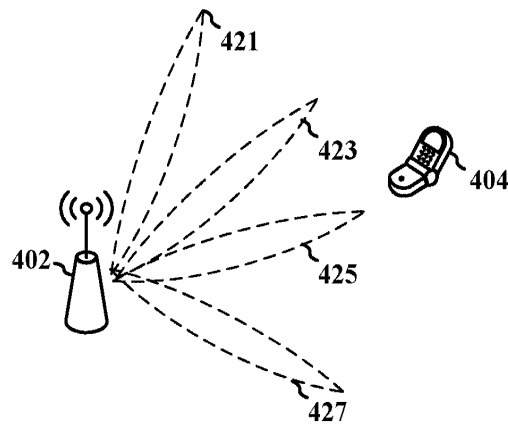
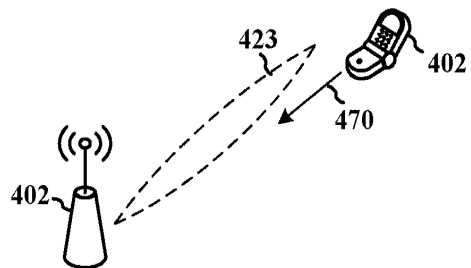


FIG. 4D

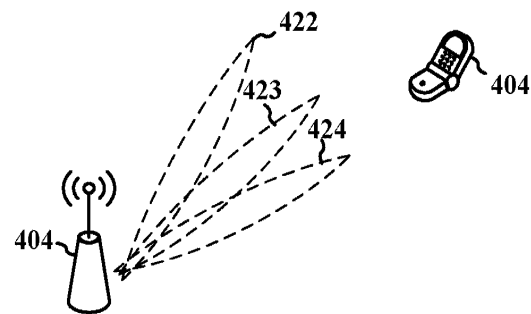
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**FIG. 4E**

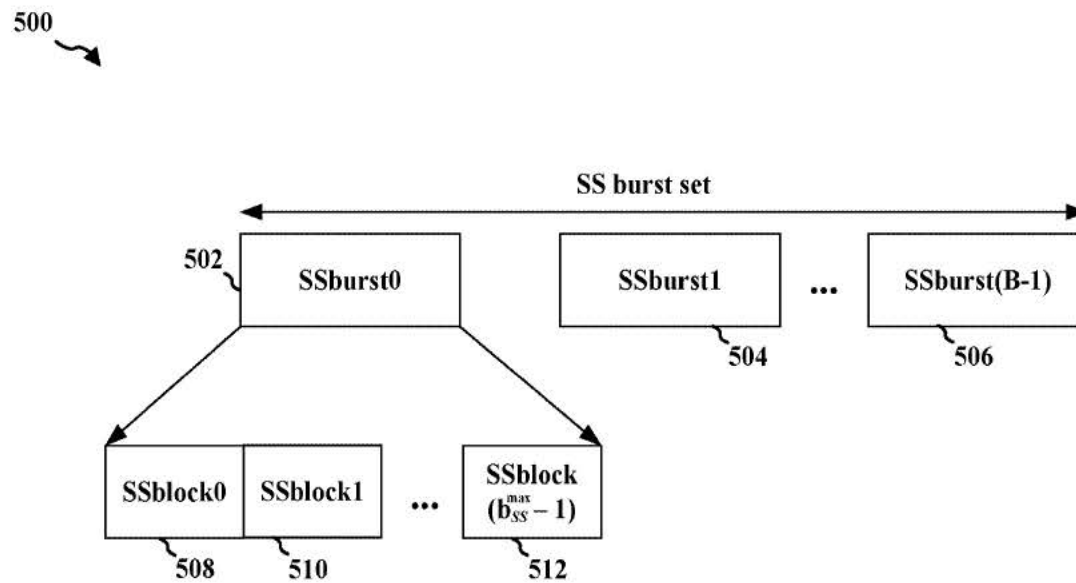


**FIG. 4F**



**FIG. 4G**

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**FIG. 5**

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600 ↗

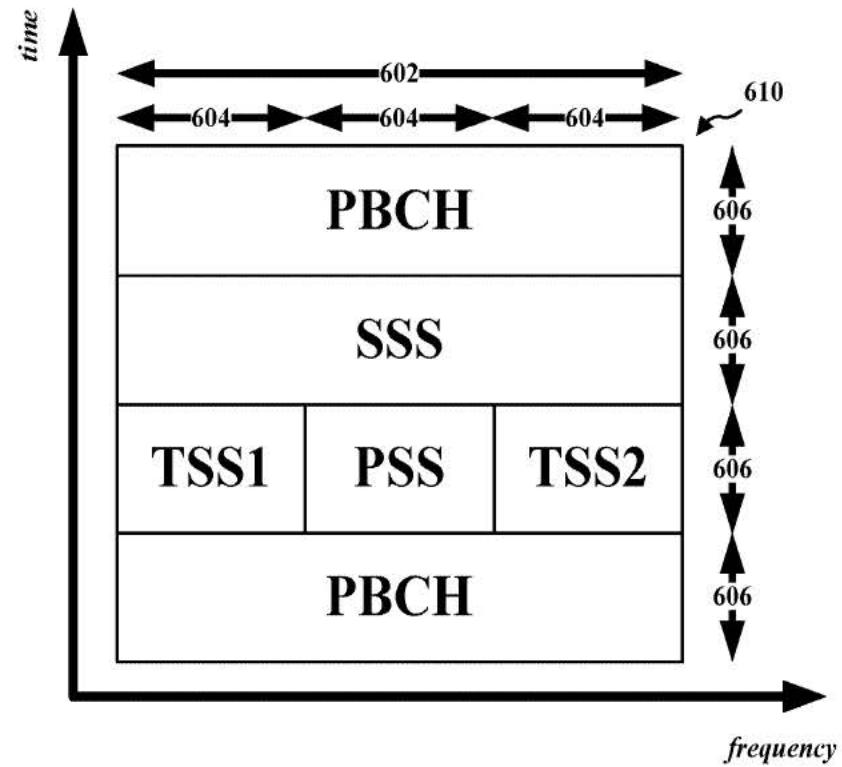


FIG. 6

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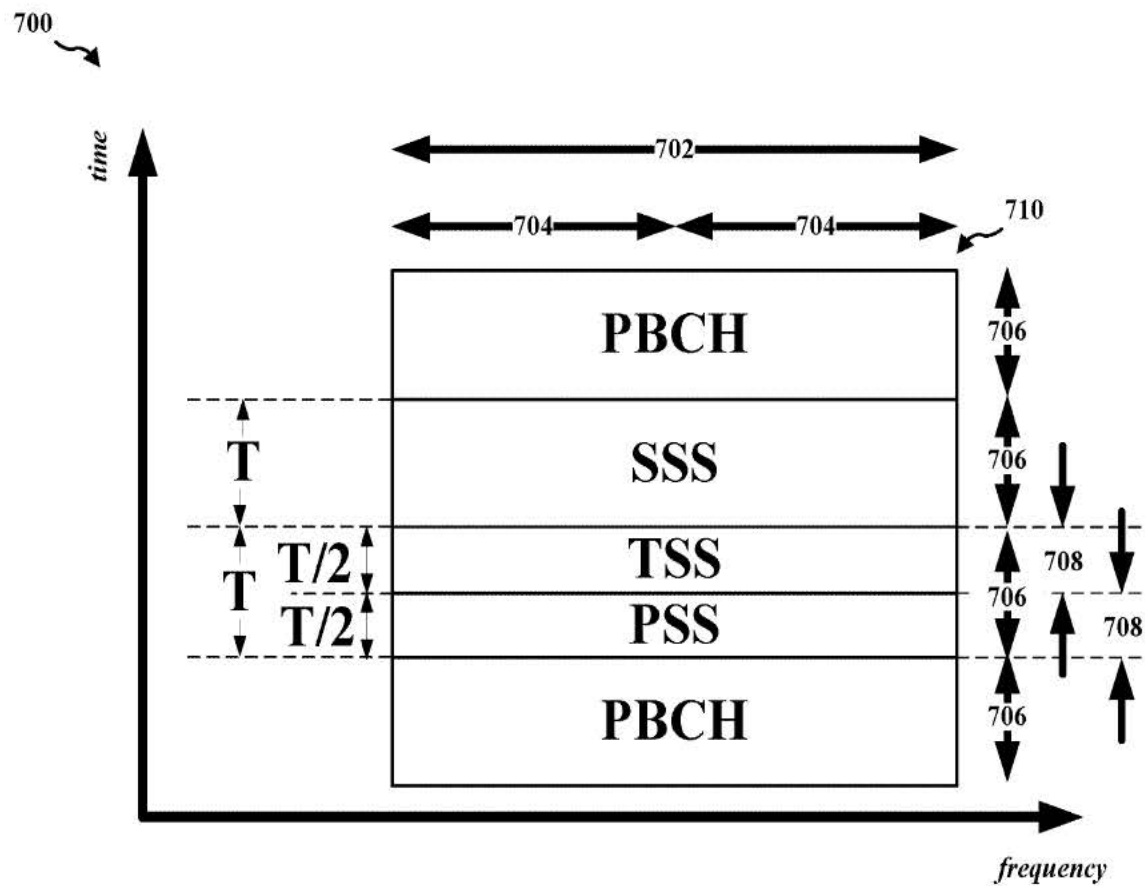
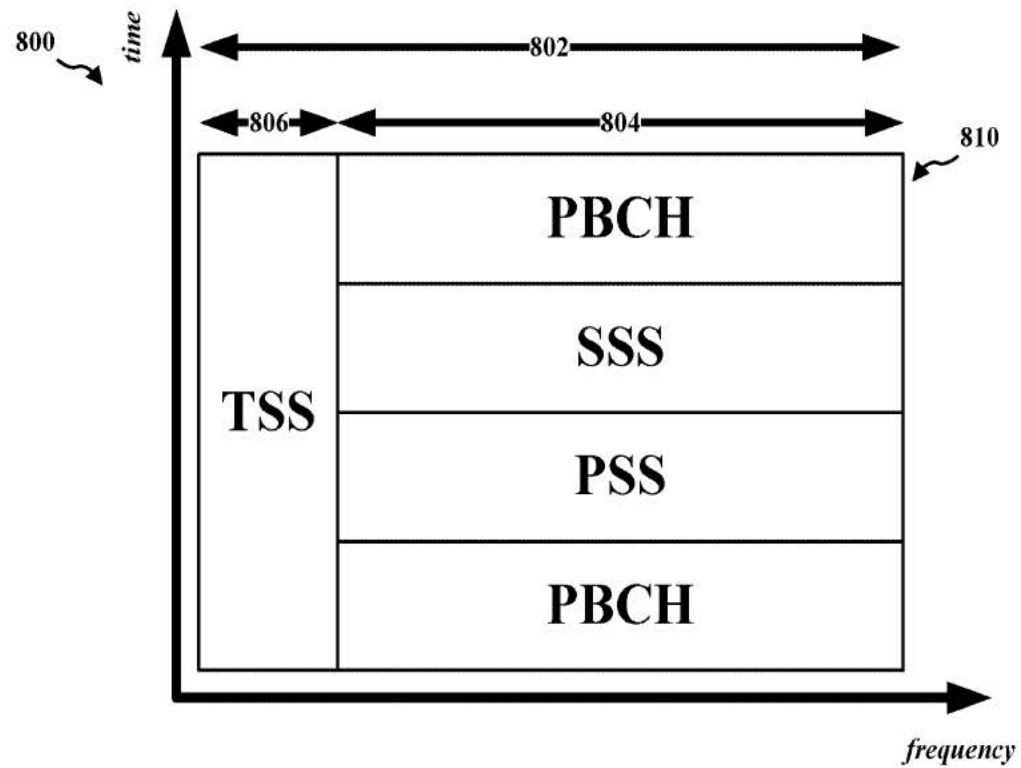


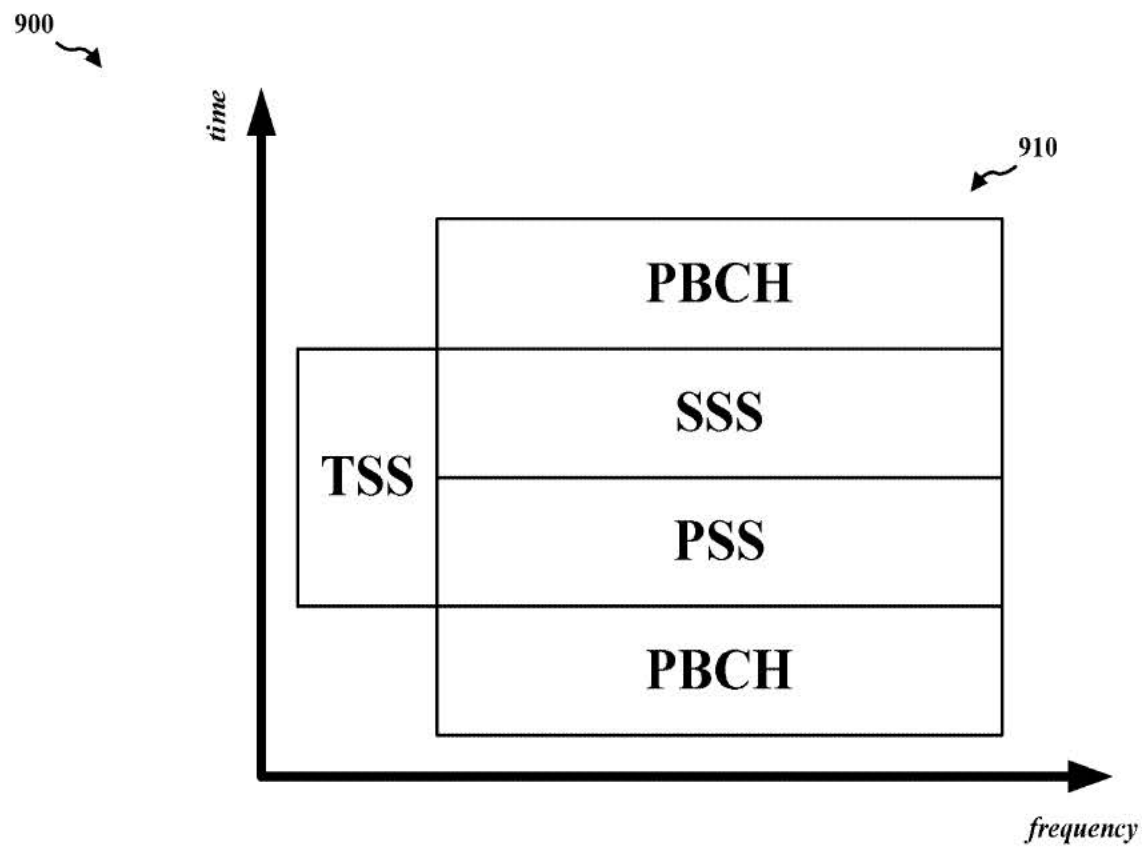
FIG. 7

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**FIG. 8**

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**FIG.9**

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1000 ↗

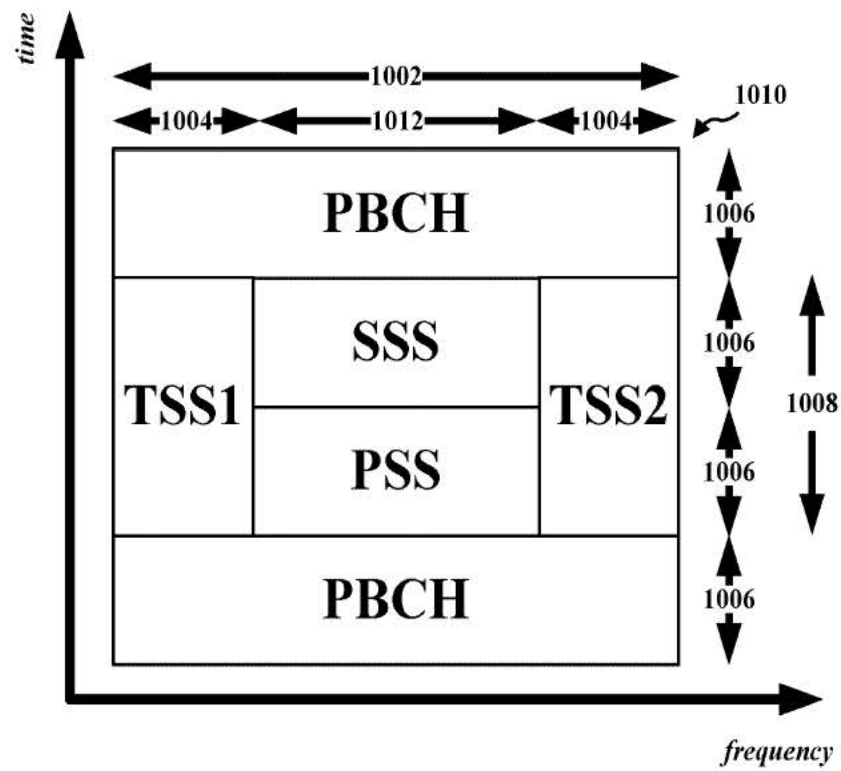


FIG. 10

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1100 ↘

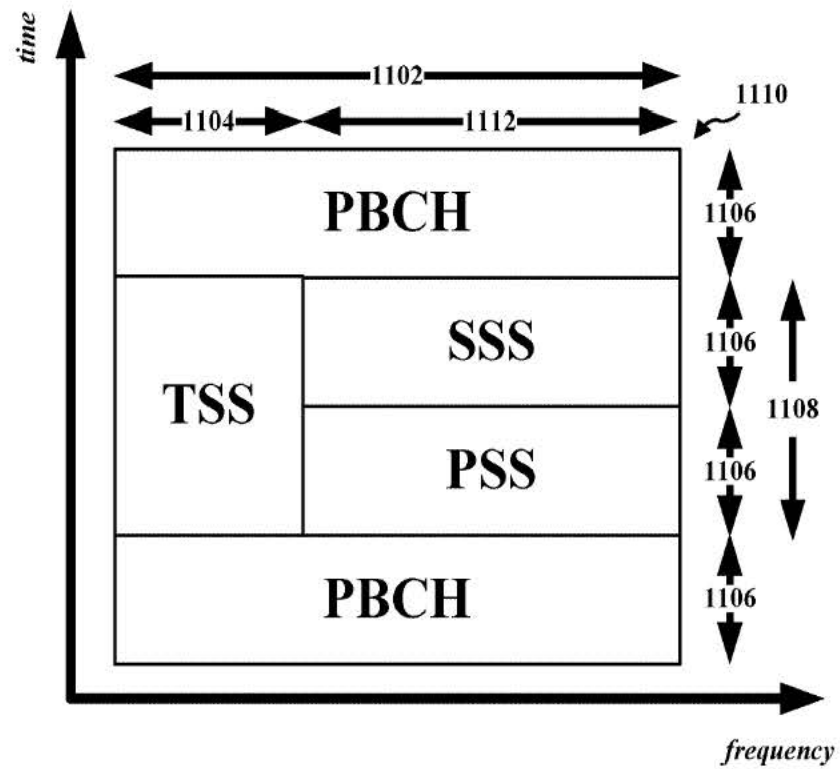
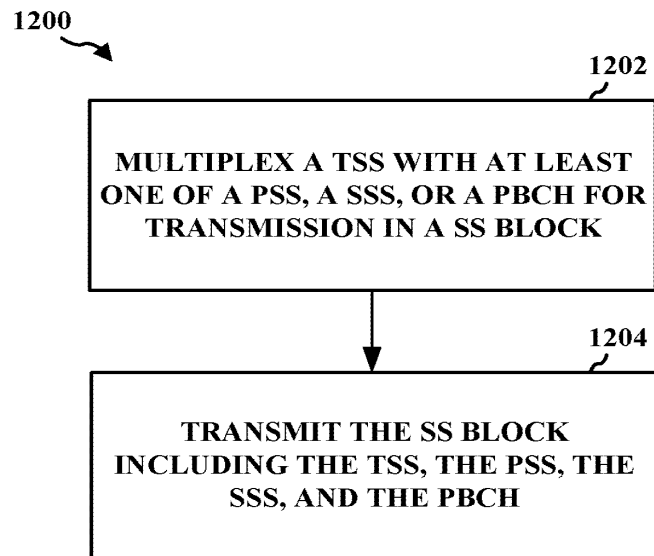
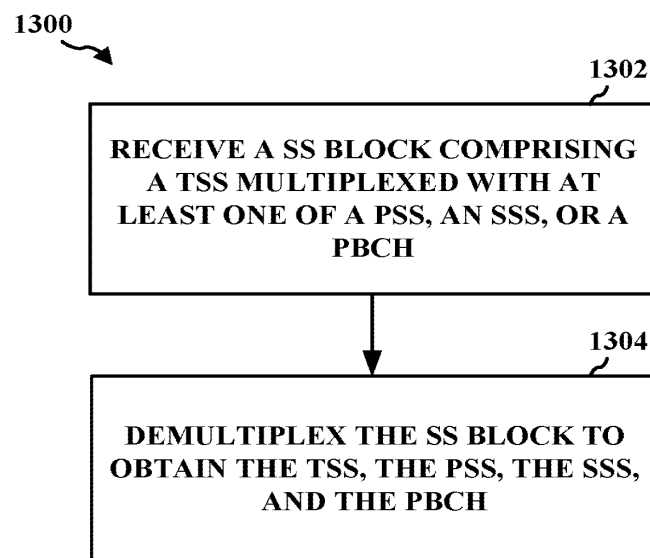


FIG. 11

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**FIG. 12**



**FIG. 13**

Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS		
First Named Inventor/Applicant Name:		Hung LY		
Filer:		Jonas J. Hodges/rebecca golden		
Attorney Docket Number:		030284.14367/ 172845P2		
Filed as Large Entity				
Filing Fees for Provisional				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
PROVISIONAL APPLICATION FILING	1005	1	260	260
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				



Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				260

Electronic Acknowledgement Receipt	
<b>EFS ID:</b>	28434850
<b>Application Number:</b>	62462258
<b>International Application Number:</b>	
<b>Confirmation Number:</b>	6237
<b>Title of Invention:</b>	TERTIARY SYNCHRONIZATION SIGNAL DESIGN CONSIDERATIONS
<b>First Named Inventor/Applicant Name:</b>	Hung LY
<b>Customer Number:</b>	15142
<b>Filer:</b>	Jonas J. Hodges/rebecca golden
<b>Filer Authorized By:</b>	Jonas J. Hodges
<b>Attorney Docket Number:</b>	030284.14367/ 172845P2
<b>Receipt Date:</b>	22-FEB-2017
<b>Filing Date:</b>	
<b>Time Stamp:</b>	19:23:50
<b>Application Type:</b>	Provisional

### Payment information:

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Payment Type	CARD
Payment was successfully received in RAM	\$260
RAM confirmation Number	022317INTEFSW19251200
Deposit Account	012300
Authorized User	Rebecca Golden
<p>The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:</p> <p>37 CFR 1.16 (National application filing, search, and examination fees)</p> <p>37 CFR 1.17 (Patent application and reexamination processing fees)</p>	

**File Listing:**

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	172845P2_POA.PDF	1112279	no	2
			58710c4f7df4f4f8131ebf61e22a50ca41a4094f		
Warnings:					
Information:					
2	Application Data Sheet	172845P2_ADS.PDF	1833148	no	9
			824cab1ac39ff70ed1274cc9b41d4ca32643a449		
Warnings:					
Information:					
3		172845P2_Specification.pdf	334117	yes	43
			9e4f75596a31419f8f0ae1f255a83befef2acca31		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Abstract		43	43	
	Claims		37	42	
	Specification		1	36	
Warnings:					
Information:					
4	Drawings-only black and white line drawings	172845P2_Drawings.pdf	863462	no	14
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5	Fee Worksheet (SB06)	fee-info.pdf	29803	no	2
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<b>Warnings:</b>	
<b>Information:</b>	
<b>Total Files Size (in bytes):</b>	4172809
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