PATENTING ACTIVATES IN GFDM TECHNOLOGIES: AN ANALYSIS

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Abstract
Mobile communication is considered as essential means of communication nowadays. It has huge impact on socio-economic condition of any country. 5G provides increase bandwidth and speed. Generalized Frequency Division Multiplexing (GFDM) is an upcoming modulation method for Fifth Generation (5G) wireless communication systems having many advantages over conventional Orthogonal Frequency Division Multiplexing (OFDM). GFDM is an emerging technology. It provide opportunity for dynamic spectrum allocation. Technology trends may be evaluated from patenting landscape as patent promotes technological innovation. The objective of the present work is to analyse patenting trends of GFDM technology. It is observed that GFDM is the promising technology in communication field. GFDM technology has been patented or applied for patent in the country like US, EP, China, Japan, and Korea. Patent portfolio of Vodafone, Germany and Huawei Technologies Co., Ltd, China prevails over other competitors.

Keywords: GFDM, 5G, communication, mobile, patent, family

1.0 INTRODUCTION

Over the last few decades, mobile communication has fundamentally changed the ways as to how human beings in the modern society access, exchange, and share information with each other thereby influencing the global economy and social development tremendously [1].

The primary objective of 5G standards includes; 1000-fold gain in network capacity, connection density of 1 Million Devices/km², peak data rate of 10 Gbps for stationary users and 1Gbps for mobile users, latency less than 1ms. Mobile Internet and Internet of Things are the two main market drivers for 5G. It is reported that fifth-generation (5G) wireless communication is expected to be a forthcoming revolution in the wireless world, achieving communications with a high peak rate, high spectral efficiency, multiple device connectivity, low end-to-end latency, and high reliability [2]. The fifth generation of mobile cellular systems require loose synchronization, low latency, reliable, robust and high throughput; high coverage, dynamic spectrum allocation with low out-of-band emission to deal with various types of usage scenarios.

In 2009, a transceiver architecture based on GFDM approach was proposed by Gerhard Fettweis et al. to exploit spectrum white spaces in the TV UHF bands. It is reported that it provides opportunity for dynamic
spectrum allocation [3]. Hence, demand for that specific technology has been increasing. Patents are one of the oldest forms of intellectual property protection that aims to encourage economic and technological development by rewarding an invention, which may be a product or a process. It has two important functions; a) it allows the patent holder to exclude others from commercially exploiting the invention covered by the patent in a certain country or region and for a specific period of time, generally not exceeding 20 years; and b) it gives the public access to information regarding new technologies in order to stimulate innovation and contribute to economic growth. Although the protection offered by a patent is territorial, covering only the jurisdiction in which the patent has been granted, the information contained in a patent document is global, allowing anyone to learn from and build on this knowledge. Thus the published patent applications and the granted patents provide both technical and legal information which benefit many areas of business.

The objective of the present work is to provide a comprehensive overview of the patenting activity in the GFDM technologies for the future generation of wireless network by analysing the published patent applications and the granted patents. The report aims at identifying the patent families that claim inventions related to the GFDM technology for the design of flexible PHY layer. It does not focus on aspects of validity of protection or freedom-to-operate. Claims have been primarily used to prepare the dataset using PATENTSCOPE database. The level of innovation of applications has been assessed for each patent family, by finding at least one publication of a granted patent in the patent family. The paper describes patterns or trends of patenting activities in this field by including a standard statistical analysis of the search results, e.g. with breakdown by main applicants, priority countries (i.e. offices of first filing, OFF), geographical distribution of patent family members (i.e. offices of subsequent filings/second filing, OSF), distribution of patenting activity by international patent classification (IPC).

2.0 SEARCH METHODOLOGY

This section provides the process of creating a collection of patent documents related to Generalized Frequency Division Multiplexing (GFDM) transmission scheme and corresponding devices and associated signal processing techniques for interference cancellation and data recovery. Patent search methodology, involves three fundamental steps: Selection of data sources and patent coverage, Understanding and selection of appropriate patent classifications, Understanding and selection of appropriate terminology related to the subject matter. This section of the report focuses on these three elements and describes the process undertaken for the creation of a collection of patent documents base don GFDM.

2.1 Data Sources

Many existing open source databases have been integrated into freely available search tools. The present work mainly focuses on the iterative search using three open source databases based on their ease of use, reliability of results and useful key features. These data sources include; PATENTSCOPE, Espacenet and Google Patents.

The PATENTSCOPE database provides access to international Patent Cooperation Treaty (PCT) applications in full text format on the day of publication, as well
as to patent documents of participating national and regional patent offices. PATENTSCOPE Search service provides 5 ways to conduct a search in 9 languages. The search interface includes; simple search, advanced search, field combination, cross-lingual information retrieval (CLIR) and chemical structure search. For the purpose of the present work, the advanced search and field combination have been used.

Espacenet is a patent database that allows doing full-text searches in English, French, or German and facilitates searching for published patent applications from over 95 patent granting authorities. Like all search tools, the EPO relies on the patent granting authorities for its data which is updated daily. However, the information related to legal status of patent application has been fetched from national registers for the present work.

Google Patents includes over 87 million patent publications from 17 patent offices around the world and also non patent literature available in Google Scholar, Google Books. In the present work only the patent family information has been extracted and the priority date and legal status of the family members and also non-English patent literature have been cross verified.

In addition to the above mentioned free patent search tools, other national patent office databases have been utilized for cross verification; such as USPTO, CNIPA, AusPat, KIPRIS, J-Plat Pat and inPASS.

2.2 Search String Creation and Formation of Dataset
The creation of the search strings was performed iteratively. The results of iteration was reviewed and evaluated to get the more accurate dataset. After creating a search string, the results obtained were sampled and reviewed for relevancy. Keywords and International Patent Classifications (IPC) were amended as appropriate. Further, the results of each string were data mined for further key terms of interest and synonyms, which were then incorporated in revised search strings. The final dataset was generated after careful observation of the subject matter (basically claims and description of the complete specification). Some of the search strings used to select the preliminary dataset for the present study is given below in table 1.

Table 1: List of Search strings Used in PATENTSCOPE for Dataset Creation

<table>
<thead>
<tr>
<th>Search Strings</th>
<th>No. of Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL: (&quot;Generalized Frequency Division Multiplexing&quot;)</td>
<td>319</td>
</tr>
<tr>
<td>ALL: (GFDM)</td>
<td>487</td>
</tr>
<tr>
<td>ALL: (&quot;Generalized Frequency Division Multiplexing&quot; or GFDM)</td>
<td>544</td>
</tr>
<tr>
<td>ALL: (&quot;Generalized Frequency Division Multiplexing&quot; and GFDM)</td>
<td>262</td>
</tr>
<tr>
<td>ALL: (&quot;Generalized Frequency Division Multiplexing&quot; or GFDM) and IC:H04L27/26</td>
<td>211</td>
</tr>
<tr>
<td>ALL: (&quot;Generalized Frequency of Division Multiplexing&quot; and GFDM) and IC:H04L27/26</td>
<td>108</td>
</tr>
<tr>
<td>ALL: (&quot;Generalized Frequency of Division Multiplexing&quot; and GFDM) and IC:H04W72/04</td>
<td>108</td>
</tr>
<tr>
<td>ALL: (&quot;Generalized Frequency 61 Division Multiplexing&quot; and GFDM) and IC:H04W72/04</td>
<td>61</td>
</tr>
<tr>
<td>ALL: (&quot;Generalized Frequency 299 Division Multiplexing&quot; or GFDM)</td>
<td>299</td>
</tr>
</tbody>
</table>
RESULT AND DISCUSSION

3.1 Patent Families Based on GFDM Technology

Applicants often file patent applications in multiple jurisdictions, thus resulting in some inventions being recorded more than once. To take care of this factor, patent families have been developed. It is defined as a set of patent applications interlinked by a combination of; priority claim, PCT national phase entry, continuation, continuation-in-part, internal priority, addition or division. The patent family provides crucial information regarding the countries in which patent applications were filed and published, which in turn will enable to monitor the international market in line of business, keeping an eye on the worldwide situation and making aware of innovations and changes. It can also help to find another language version of a patent document.

For the present work based on GFDM technology, the required dataset is obtained from PATENTSCOPE. Figure 1 shows the timeline of activity of the collection of 24 patent families identified to be relevant through search. The bar graph is plotted between earliest first filing year (taken along X-axis) and count of corresponding patent families (taken along Y-axis). The first member of the first patent family based on GFDM technology was filed in the year 2008 at European Patent Office (EPO) by Vodafone Holding GmbH, Germany. There is a distinct peak in patenting activity in the year 2015, which records maximum number
(i.e. 8) of filing of first member corresponding to a patent family. Activity subsequently falls away to lower level (i.e. 5 and 1 for the years 2016 and 2017 respectively) with 2017 being the last year of complete information for this particular metric. The following sections provide information regarding the office of first filing (OFF), priority date, subsequent filing offices, applicant and subject matter of each patent family in ascending order based on first filing date.

Figure 1: Number of Patent Families per Year

Figure 2 illustrates the number of patent families corresponding to different numbers of family members from which the counts of subsequent filings can be noticed. Only 15 (62.5%) patent families have been filed in 2 locations the reason being the expense of filing in multiple jurisdictions and also the uncertainty about the commercial success. Out of these 15 families, 11 families have Patent Cooperation Treaty (PCT) as their second subsequent office of filing where the sources of family belong to United States (4), Japan (2), China (2), Korea (1), France (1) and Canada (1). The remaining 4 families with OFF at EPO have United States as their office of second filing through Paris Convention. In the figure, it is illustrated that 4 patent families (16.7%) have 3 members out of which 2 patent families have OFF at United States, 1 patent family at EPO and the rest is from PCT. The count of families with 4 and 5 members are found to be one for each with primary source at United States and France respectively. Two patent families with OFF at Japan and United States have 8 family members and there is only one family with source of origin from China has the highest number of family members i.e. 10.

3.1.1 Family list of EP2200244

European Patent Office (EPO) is the OFF for the patent application titled as “Method and apparatus for multi-carrier
frequency division multiplexing transmission”, which takes the priority of 18th December, 2008. The family contains three national applications; EP2200244 (A1), US2010189132 (A1) and US2015188654 (A1). The second domestic family includes a granted patent i.e. US8929352 (B2). The third application, which is a division of patent US8929352 (B2), is abandoned. The application of EP domestic family is under examination. For all family members, the applicant is Vodafone Holding GmbH.

The invention discloses a GFDM system comprising of transmitter and receiver which efficiently exploits white spaces in case of heavily fragmented spectrums. The transmitter detects vacant frequency ranges in a plurality of allocated transmission frequency band, defines a single central frequency for each of said detected vacant frequency ranges as a divisional multiplexer carrier frequency, and transmits information about said detected vacant frequency ranges with defined central frequencies to a receiver through an established communication channel. The claim tree of EP2200244 (A1) is illustrated in figure 3.

![Fig 3: Claims Tree of EP2200244 (A1)](image)

3.1.2 Family list of EP2608474

The second patent family titled as “Method and transmitter/receiver for data transmission with flexible exploitation of time and frequency diversity” which takes the priority of European Patent Office (EPO) dated 23rd December, 2011 contains two family members; EP2608474 (A1) and US20130163542 (A1). Although both the domestic family contains granted patents (EP2608474 (B1), US9167579 (B2), the US national application is being granted earlier in comparison to EPO. Vodafone Holding GmbH is the applicant for the patent family.

The invention relates to a method and corresponding transmitter and receiver for transmitting data using multi-dimensional fourier-processing in a non-orthogonal GFDM based multi-carrier communication system, in order to minimize the out-of-band leakage and to utilise the unused spectrum. The method of processing and transmitting information along with corresponding devices is claimed through sixteen claims whose representation is given below in figure 4.

![Fig 4: Claims Tree of EP2608474 (A1)](image)

3.1.3 Family list of FR3010267

The third patent family titled as “Method and device for the transmission of blocks of real data symbols, receiving method and device, and corresponding computer programs” contains two family members; FR3010267 (A1) and WO2015033052 (A1) with priority country France having priority date 3rd September 2013. The first domestic family has a granted patent FR3010267 (B1)
which is expired due to non-payment of fee. Orange, France is the applicant for the patent.

The prior art contains four main schemes for the implementation of multicarrier modulation: OFDM, Filter Bank Multi Carrier (FBMC) / Offset Quadrature Amplitude Modulation (OQAM), FBMC / Filtered Multi-Tone (FMT) and GFD modulation. However, regardless of the modulation chosen, there is always a compromise between two essential criteria; power spectral density (PSD) and orthogonality; considering varying channel conditions. In order to enhance the spectrum efficiency along with reduction in hardware complexity used for block processing to remove the interference generated from loss of orthogonality between multi-carriers, the present invention discloses a new technique for transmitting a multiplex of carriers OQAM type. The method comprises a step of forming at least one block of $M \times K$ real data symbols (where $M > 1$ and $K > 1$), implementing a step of cyclic convolution via a prototype filter $g[k]$ having a length $L = KM + b_1 = 2KN + b_1$ (where $b_1$ is a whole number such that $b_1 \geq 0$ and $N$ is an oversampling factor). The claims tree structure of FR3010267 (A1) is illustrated in Figure 5. Here, out of 11 dependent claims, claim 3 depends on anyone of claims 1 and 2; claim 9 depends on any one of claims 1 to 8 and claim 15 depends on either claim 1 or 12.

3.1.4 Family list of FR3010268

The patent application titled as “Method and apparatus for transmission of complex data symbol blocks, method and apparatus for reception and corresponding computer programs” takes the priority of France dated 3rd September, 2013. The five family members are FR3010268 (A1), CN105659551 (A), EP3042480 (A1), US2016197758 (A1) and WO2015033051 (A1). Only France and EP domestic families have granted members; FR3010268 (B1) and EP3042480 (B1) respectively. However, only EP domestic member is in active legal status and the US application is pending for the examination. The applicant is Orange for all the domestic families excluding China. The claim tree representation is provided in figure 6.
3.1.5 Family list of US2015071242

The patent application titled as “System and method for channel estimation for generalized frequency division multiplexing (GFDM)” contains two family members; US2015071242 (A1) and WO2015032313 (A2) with priority country US and priority date 9th September 2013. US domestic family has an active granted patent i.e. US9379917 (B2); applied by Huawei Technologies Co., Ltd.

Fig 7: Claims Tree of US2015071242 (A1)

Fig. 7 represents the claim tree structure of US2015071242 (A1).

3.1.6 Family list of EP2884709

The patent family having title “GFDM radio transmission using a pseudo circular preamble” takes the priority of European Patent Office (EPO) dated 12th December, 2013. It contains two family members; EP2884709 (A1) and US2015172010 (A1). US domestic family includes granted patent US9236981 (B2) which is being enforced whereas EP20130196934 is still pending for the examination. The applicant for the family is Vodafone GmbH.

Fig 8: Claims Tree of EP2884709 (A1)

GFDM system provides a fast, flexible scalable and content aware physical layer scheme for 5th generation cellular systems with opportunistic use of frequency spectrum. However, in contrast to OFDM, it uses a common preamble for a block of symbols allocated in the at least two sub-bands, which need proper synchronization procedure. The present invention relates to a pseudo circular preamble used in a GFDM system comprising a special data sequence either in a cyclic prefix (CP) and cyclic suffix (CS) in a single burst transmission to produce a pseudo circular preamble or in a suffix appended to each transmit block of a framed structure transmission. The said special data enables estimating the detection of the symbol time arrival, i.e. the symbol timing offset (STO) and the carrier frequency offset (CFO). From figure 8 it can be observed that the invention has 4 independent and 10 dependent claims.

3.1.7 Family list of EP2916506

the application corresponding to EP domestic family is pending for the examination. The applicant for the patent family is Vodafone GmbH.

Figure 9 illustrates the arrangement of claims of EP2916506 (A1) in a tree like structure.

![Claims Tree of EP2916506 (A1)](image)

3.1.8 Family list of CN106538011

The Office of First Filing (OFF) for the patent application titled as “Data transmission method and communications device” is China with priority date 10th March, 2014. The patent family has ten family members; CN106538011 (A), EP3119147 (A1), AU2015230528 (A1), JP2017513314 (A), KR20160129886 (A), RU2016139372 (A), SG11201607538Q (A), US2016381695 (A1), WO2015135107 (A1) and WO2015135430 (A1). The domestic families of Australia, Russia, Japan and Korea include following granted patents; AU2015230528 (B2), RU2650189 (C1), JP6343025 (B2), and KR101886548 (B1) respectively. The applicant for all the domestic families is Huawei Tech Co Ltd.

The claim tree of AU domestic member, illustrated in figure 10 shows 6 independent claims and 24 dependent claims.

![Claims Tree of AU2015230528 (A1)](image)

3.1.9 Family list of US2015282008

The Office of first filing for the patent application titled as “System and method for machine-type communications” is United States with priority date 27th March, 2014. The patent family has eight family members; US2015282008 (A1), US2017257727 (A1), EP3117684 (A1), BR112016022387 (A2), CN106453447 (A), JP2017511064 (A), KR20160135339 (A) and WO2015143991 (A1). The domestic families of United States and Korea have granted members; US9693172 (B2) and KR101880259 (B1) respectively. The corresponding applications are under examination process in China, Japan and EPO. The applicant for all the domestic families is Huawei Tech Co Ltd. excluding the first family member i.e. US20150282008 (A1) for which the applicant is FutureWei Technologies, Inc. Figure 11 represents the structure of claims in US2015282008 (A1).
3.1.10 Family list of EP3032790

The patent family titled as “Generalized frequency division multiplexing radio transmission using frequency domain offset-QAM” which takes the priority of European Patent Office (EPO) dated 8th December, 2014 contains two family members; EP3032790 (A1) and US2016164713 (A1). Although both the domestic family contains granted patents; EP3032790 (B1) and US9628317 (B2), the US national application is granted earlier in comparison to EPO. Vodafone GmbH is the applicant of these active granted patents.

The current LTE system utilise a frame structure having a transmission time interval (TTI) of 1 ms, and its data request latency time for a video application is 10 ms. However, due to the advent of new application, the future 5G technology requires data transmission of lower latency that requires a new TTI structure and new types of symbols. The present invention tries to solve the problem in prior art by providing a method for allocating resources to support plurality of wireless communication modes from a base station. The claimed method comprises allocating a first zone consisting of OFDM symbols and a second zone consisting of GFDM symbols on time and frequency domains by a frequency division multiplexing scheme; and allocating a predetermined number of guard subcarriers to a boundary between the first zone and the second zone. The calculation of predetermined number is based on the number of sub - symbols of the GFDM symbols. The number of sub - symbols of the GFDM symbols may be determined based on a number of resource blocks or subcarriers of the second zone. The invention includes two independent claims and ten dependent claims as shown in figure 16.

3.1.11 Family list of US2018083749

The patent family titled as “Method for allocating resources for supporting plurality of wireless communication modes in wireless communication system, and device for same” with priority date 19th March, 2015 contains two family members; WO2016148362 (A1) and US2018083749 (A1). The U.S. Application 15559223, which is a national stage entry of PCT/KR2015/010821(Parent number), is pending for the examination. LG Electronics Inc. is the applicant of the patent applications.
3.1.12 Family list of US2017064700

The patent family titled as “Frame structure for machine-type communications with adjustable pulse bandwidth” takes the priority of United States dated 26th August, 2015. It contains four family members; US2017064700 (A1), WO2017032299 (A1), CN107852676 (A) and EP3308581 (A1). The corresponding applications are pending for the examination. The applicant of these family members is Huawei Tech Co Ltd.

In the current LTE system, the frame structure is based on a fixed transition time interval (TTI) length. However, machine to machine systems need configurable signal pulse bandwidth design where the bandwidth and pulse length can vary to enable an acceptable trade-off between throughput, energy efficiency, and the number of connected MTC devices (MTCD). Therefore, there is a need for a frame structure for MTC that can support diverse applications and different coverage levels of MTCDs. The present invention discloses methods and systems for a frame structure with adjustable pulse bandwidth for MTC. This represents an uplink frame structure which illustrates a plurality of coverage levels. The coverage levels depend on the coverage range of a base station. Each coverage level is associated with corresponding sub-frames, and each sub-frame within a coverage level has the same sub-frame length and bandwidth. The US domestic member has 5 independent claims and 18 dependents claims as shown in figure 17.

3.1.13 Family list of KR1020170030847

The office of first filing for the patent application titled as “Apparatus and method for transmitting/receiving signals in multi-carrier system” is Korea with priority date 10th September, 2015. The patent family has two family members; KR20170030847 (A) and WO2017043866. The applicant of the domestic families is Samsung Electronics Co Ltd.

The present invention relates to a 5th-generation or pre-5G communication system, which would support a higher data transmission rate after the 4th-generation communication system, such as long term evolution (LTE). The present invention provides a method for receiving a signal in a
multi-carrier system, which involves waveform pre-processing operation, with respect to an input signal, on the basis of at least one of an equalizing operation. The filtering operation is carried out to check whether the waveform pre-processed signal is a Gaussian proximity signal. The method also includes performing soft-de-mapping with respect to the waveform pre-processed signal. The claims of the invention are organized as illustrated in figure 18.

3.1.14 Family list of JPWO2017056796

Japan is the office of first filing for the patent application titled as “Device, method, and program” with priority date 1st October 2015. The family includes eight applications: JPWO2017056796 (A1), CN107005333 (A), EP3358765 (A1), MX2017006753 (A), SG12101703106P (A), TW201724791 (A), US2017374664 (A1), and WO2017056796 (A1) applied by SONY CORP.

Fig 19: Claims Tree of EP3358765 (A1)

The present invention provides a mechanism capable of accommodating legacy terminals not supporting GFDM along with terminals supporting GFDM when GFDM is introduced. The device includes; a setting unit configured to variably set at least one of an interval between subcarriers and a time length of a sub-symbol included in a unit resource constituted by one or more subcarriers or one or more sub-symbols; and a transmission processing unit configured to perform filtering for every predetermined number of sub-carriers. The invented program makes the computer to function as: a setting unit to variably set an interval between subcarriers and a time length of a sub-symbol included in a unit resource constituted by one or more subcarriers; and a transmission processing unit configured to perform filtering for every predetermined number of subcarriers. A bit sequence from an upper layer is processed, and a radio frequency signal is output. The bit sequence undergoes forward error correction (FEC) coding, rate matching, scrambling, interleaving, and mapping bit sequences to symbols (which may be a complex symbol or are also referred to as "signal points") and then undergoes one of the modulation; such as BPSK, QPSK, 8PSK, 16QAM, 64QAM, 256QAM, or the like may be used for mapping the bit sequence to symbols. In the modulation, first, serial to parallel conversion is performed, resource element mapping, oversampling, and pulse shaping are performed on each of a plurality of divided signals. The resulting divided signals are combined into one signal in a time domain by IDFT or IFFT which is subsequently performed. After the modulation, cyclic prefix addition, analog processing, and RF processing are performed. The claims tree of EP3358765 (A1) is presented in figure 19.

3.1.15 Family list of CN106612163

The patent family titled as “Pilot signal transmission method and apparatus, and transmitting terminal” which takes the priority of China dated 23rd October, 2015 contains two family members; CN106612163 (A) and WO2017067349 (A1), applied by ZTE CORP.
The method of improving channel estimation performance by the use of null data symbols, pilot spaced symbols and data symbols in some FBMC-OQAM system may not be so effective in case of multiple antennas due to large pilot signal overhead. Another method of using an auxiliary pilot to the interference cancelling data also doesn’t perform well due to large PAPR value. The present invention proposes a pilot signal transmission method and apparatus, as well as transmitter, to reduce pilot overhead and to improve the channel estimation. The method comprises: setting a first pilot signal, a second pilot signal, and a third pilot signal on a same subcarrier; and separately transmitting each of these pilot signals on three continuous symbols on the same subcarrier. Here, the pilot signals are all nonzero data and the phase difference between the two consecutive pilot signals is 90 degrees, the phase difference between the first pilot signal and the third pilot signal is 180 degrees. The technical solution saves resources for interference separation and pilot overheads to improve channel estimation performance. Figure 20 illustrates two independent claims and seventeen dependent claims of the published application.

3.1.16 Family list of CN106685612

China is the office of first filing for the patent application titled as “Pilot signal transmission method and pilot signal transmission device in multi-carrier system” with priority date 6th November, 2015. The family includes two applications; CN106685612 (A) and WO2017076326 (A1) applied by ZTE CORP.

The present invention provides a transmission method and device for pilot signals in a multicarrier system. The method comprises; a transmitting node transmits pilot data on three symbols with continuous time domains on the same subcarrier m, wherein the pilot data is: \(X(m,n-1), X(m,n), \) and \(X(m,n+1)\). Here, \(m\) represents a sequence number of subcarriers, precisely the subcarrier index, and \(n\) is a sequence number of symbols. The phase difference between \(X(m,n-1)\) and \(X(m,n)\) is \(\pi/2\), for \(X(m,n+1)\) and \(X(m,n)\) is \(\pi/2\), the difference \(\pi\) between the phases of \(X(m,n-1)\) and \(X(m,n+1)\) is met, and \(X(m,n-1)\) and \(X(m,n+1)\) are equal in modulus. \(X(m,n)\) is a pure imaginary number. The claims are organized in the following manner as indicated by figure 21.

Fig 20: Claims Tree of WO2017067349

Fig 21: Claims Tree of WO2017076326 (A1)
3.1.17 Family list of JPWO2017085971
The office of first filing for the patent application titled as “Apparatus, Method and Program” is Japan which bears the priority date of 19th November, 2015. The family includes two applications; JPWO2017085971 (A1) and WO2017085971 (A1) applied by Sony Corp.

The present invention discloses a mechanism to suppress out-of-band frequency distortion components that can occur in GFDM, efficiently. The device consists of a processing unit which performs filtering on data having a predetermined value and mapped to a sub-symbol at an end in a time direction of a unit resource comprising one or more sub-carriers and a plurality of sub-symbols, and on transmission data mapped to the other sub-symbols in the unit resource every predetermined number of subcarriers. The processing unit controls the data length of the transmission data. The data length is set to a length equal to the number of subcarriers of the unit resources. The filtering is carried out by any one of the following filters: Raised Cosine filter, Root Raised Cosine filter, or Isotropic Orthogonal Transfer Algorithm filter. The disclosure has 4 independent claims and 8 dependent claims as given in figure 22.

Fig 22: Claims Tree of WO 2017085971 (A1)

3.1.18 Family list of JPWO2017094153
Japan is the office of first filing for the patent application titled as “Radio communication apparatus and radio signal processing method” with priority date 2nd December, 2015. The family includes two applications; JPWO2017094153 (A1) and WO2017094153 (A1) applied by Fujitsu Ltd.

The present invention aims to provide a radio communication apparatus and a wireless signal processing method capable of enabling narrowband communication without providing a dedicated band for narrowband communication. A radio communication apparatus comprises a multiplexing unit, an analog conversion unit, a high power amplifier and a transmission antenna. The claims of the patent family are represented in a tree like structure as given in figure 23.

Fig 23: Claims Tree of WO2017094153 (A1)

3.1.19 Family list of WO2017126206
The Patent Cooperation Treaty (PCT) application titled as “Device, Method and Program” has the priority date of 21st January, 2016. The family includes three applications; WO2017126206 (A1), AU2016387773 (A1) and CN108476191 (A) applied by Sony Corp, Japan.
In GFDM system, the number of sub-symbols in the unit resources and the number of sub-carriers is flexibly set. However, for successful demodulation at the receiving side, there is a case when the resource configuration is restricted. Therefore, it is desirable that a mechanism capable of also to release the restriction of the resource set to successfully demodulate at the receiving side without degrading the bit error rate. The present invention tries to solve the aforementioned technical problem by providing a device with a processing unit which sets the number of subcarriers and/or the number of sub-symbols contained in a unit resource. A filter coefficient to be applied for processing is set in accordance with rules that differ depending on whether the number of sub-symbols contained in the unit resource is an even number or an odd number. The claims tree of one of the family member is provided in figure 24.

Fig 24: Claims Tree of WO2017043866

3.1.20 Family list of CA3009729

The present invention provides a mechanism capable of improving frequency use efficiency even though part of a carrier frequency band is not used in GFDM. The claimed device provided with a processing unit variably sets the bandwidth of a subcarrier and/or the time length of a sub-symbol. The subcarrier or the sub-symbol is being included in a unit resource comprising one or more subcarriers or one or more sub-symbols. The device also defines, the subcarrier to be used, at least part of a frequency band, which corresponds to an unused subcarrier in a first resource, in a second resource comprising the unit resource having a narrower subcarrier bandwidth than the first resource. The invention has five independent claims and thirteen dependent claims as shown in figure 25.

Fig 25: Claims Tree of CA3009729

3.1.21 Family list of US2017331663

United States is the office of first filing for the patent application titled as “Systems, devices and methods for communicating data over circularly pulse-shaped waveforms” with priority date 13th May, 2016. The family includes two applications; US2017331663 (A1) and WO2017197270 (A1) applied by Battelle Energy Alliance Llc[Us].
The present invention discloses a communication system comprising a transmitter and a receiver and the method for communicating data over circularly pulse-shaped waveforms including a single carrier modulation. Figure 26 illustrates the published application has four independent claims and seventeen dependent claims.

Figure 26: Claims Tree of US2017331663

3.1.22 Family list of US20180152330

The patent family titled as “Wireless Devices and Systems Including Examples of Mixing Input Data with Coefficient Data” which takes the priority of United States dated 30th November, 2016 contains four family members; US20180152330 (A1) and WO2018101997 (A1), applied by Micron Technology Inc. US domestic family includes a granted patent; US10027523 (B2).

Digital signal processing for wireless communications, such as digital baseband processing or digital front – end implementations, can be implemented using some hardware computing platforms. Figure 27 indicates that the US domestic family member has six independent claims and twenty dependent claims.

Figure 27: Claims Tree of US2018152330 (A1)

3.1.23 Family list of US9942074

The patent family titled as “Wireless Devices And Systems Including Examples of Mixing Coefficient Data Specific to A Processing Mode Selection” which takes the priority of United States dated 30th November, 2016 contains three family members; US9942074 (B1), which is being enforced, US2018227158 (A1), which is a continuation application of the granted patent US9942074 (B1), and WO2018101994 (A1). Micron Technology Inc. is the applicant for all the applications.

The present invention discloses a system comprising one processing unit and non-transitory computer readable media encoded with executable instructions, when executed, cause the system to perform certain specific operations. Figure 28 is an illustrative of claims structure; i.e. five independent claims and twenty one dependent claims, of US domestic family member.
Fig 28: Claims Tree of US9942074 (B1)

3.1.24 Family list of US2018255546

The office of first filing for the patent application titled as “Wireless Devices and Systems Including Examples of Configuration Modes for Baseband Units and Remote Radio Heads” is United States with priority date 2nd March, 2017. The patent family has three family members; US2018255546 (A1), WO2018160753 (A1) and US2018255552 (A1), which is continuation in part of US10070432 (B1). The applicant of the patent family is Micron Technology Inc.

The present invention includes wireless devices and systems which may implement wireless processing stages using baseband units (BBUS) and remote radio heads (RRHs Figure 29 represents the US domestic family member has 3 independent claims and 17 dependent claims.

Fig 29: Claims Tree of US2018255546 (A1)

3.2 Patent Family Analysis based on OFF

Figure 30 illustrates the distribution statistics of 24 patent families related to GFDM technology across different jurisdictions based on Office of First Filing (OFF). From the pie chart, it can be observed that United States tops the list with highest percentage (i.e. 33%) of earliest filings followed by EPO (21%), China (13%), Japan (13%), France (8%), Korea (4%), Canada (4%) and PCT (4%) respectively. The applicants who have chosen United States as their OFF are; Micron Technology Inc, Battelle Energy Alliance Llc, LG Electronics Inc, and Huawei Technologies Co., Ltd. However, Vodafone Holding GmbH is the only applicant who takes the priority date from EPO for its five patent applications. Huawei Technologies Co., Ltd and ZTE Corp have preferred China as their OFF. Sony Corp and Fujitsu Ltd are the two applicants to file in Japan considering the priority date. Samsung Electronics Co Ltd and Sony Corp are the applicants in Korea and Canada respectively from first filing point of view. In addition, there is only one PCT application which is filed by Sony Corp, Japan with China and Australia chosen for subsequent filing.
Figure 31: Comparative Analysis of Activity of First Filing in US and EPO

Figure 31 provides a comparative visualization of first filing activity related to GFDM technology at United States and EPO. The blue curve and the green curve correspond to the activity of United States and EPO respectively. Here, the timeframe of activity is taken along X-axis which extends from 2008 to 2017 and the counts of patent families of two OFFs are taken along Y-axis. The first filing process at EPO started in the year 2008, and irregularly continued up to 2014 with discontinuity in the years 2009, 2010 and 2012. The counts of patent families first filed in EPO is found to be 1, 1, 1 and 2 in the years 2008, 2011, 2013 and 2014 respectively. In contrast, the filing activity in United States started in 2014 and continues up to 2016 with the number of patent families recorded as 1, 1, 2, 3 and 1 within one year interval between two consecutive years. Thus considering the continuity factor of first filing (figure 31) as well as the patent families counts (figure 30), it can be inferred that US is the leading OFF for the applicants in the field of GFDM technology followed by EPO, the reason being the faster processing of applications for grant.

Summary:

The United States is the pre-eminent source of activity (fig 29 and 30), making up a significantly large proportion of all activity. However, Europe becomes the secondary source where the activity is on decline after the year 2014 (fig 29 and 30). China and Japan occupy the third position each contributing 13% to the global activity.
3.3 Patent Family Analysis based on Subsequent Filing Locations

Figure 32 provides the full list of offices of subsequent filing within the dataset and corresponding number of families. The PCT (Patent Cooperation Treaty) is the top office by far with a count of 15 patent families. The reason of such subsequent filing may be to protect the invention in multiple jurisdictions via PCT route. The second position in the list is occupied by United States with 11 patent families which indicate the significant market for the GFDM technology in US. This is then followed by EPO and China having the equal number of patent families i.e. 5, making them the second preferred markets next to US. Singapore, Australia, Korea and Japan have recorded 2 patent families followed by Taiwan, Mexico, Russia and Brazil with only 1 patent family. From the dataset, it is found that all the patent families with OFF at EPO have second subsequent filing at United States through Paris Convention. In contrast, families originating from US, China, Japan, France, Korea, and Canada have PCT as second subsequent filing for protection of invention in multiple jurisdictions.

3.4 Patent Family Analysis based on Legal Status of Family Member

Data related to legal status are used to determine whether; the examination of a patent application is still pending; the application has been withdrawn or was rejected; a patent has been granted and is still valid; or a granted patent has expired, lapsed or been revoked. As such, they play an essential role in, e.g., technology transfer since they answer the question which technology is still protected and where or whether it will soon become freely available to the public. Figure 33 represents the number of families corresponding to the legal status of the family members. From the figure, it can be observed that most of the patent applications based on GFDM technology are still pending for the
examination at different national offices which is approximately 79.2% of total families. Nearly 54.2% of total families have at least one granted patent as the family member whereas only 50% continue to be alive and 8.3% have been lapsed due to non-payment of fee. The family with at least one abandoned application has been considered for the counting purpose, which is found to be 4.2% of total families.

### 3.4.1 Analysis based on Pending Patent Applications

Figure 34 indicates the number of pending applications at different national offices including office of first filing along with the subsequent filing. A normalization variable can be evaluated by taking the ratio of number of pending applications to the total no. of applications corresponding to a specific jurisdiction. This normalized factor can be used to analyse the comparative processing activity of various offices. From figure, it can be observed that the counts of pending applications based on GFDM is highest i.e. 9 in United States followed by China (8), EPO (7), Japan (4), Singapore (2), Korea (1), Australia (1), Brazil (1), Mexico (1), Taiwan (1) and Canada (1) in descending order. However, if we calculate the normalized factor of each jurisdiction, the order will be different compared to the previous one. The countries such as; Canada, Taiwan, Mexico, Brazil, Singapore and China have normalized factor of 1 indicating that all the filed applications are under examination process. The values of normalized factor for the offices such as; Japan, EPO, Australia, United States and Korea are found to be 0.8, 0.7, 0.5, 0.45 and 0.33 respectively. Thus Korea has the least number of pending applications compared to its total filings.

![Fig 34: Comparative Analysis based on Pending Applications at Different National Offices](image)

### 3.4.2 Analysis based on Granted Patents

Figure 35 illustrates the list of the national offices where the patent applications based on GFDM technology have been granted along with the number of total applications filed. United States has the highest number of granted patents i.e. 10 followed by EPO. Two patents have been granted in Korea and France followed by Japan, Australia and Russia each having 1 granted patent. The grant success rate of the national offices can be compared based on the normalized value which can be evaluated...
by taking ratio of counts of granted patents to the total number of applications filed. For Russia and France, the normalized values are found to be 1 which is highest, indicating that all the filed applications are being granted. However, in Korea, Australia, US, EPO and Japan the values are 0.67, 0.5, 0.5, 0.3 and 0.2 respectively.

3.5 Analysis based on International Patent Classification

![Fig 36: Top 9 IPC Classifications with the Total Number Patent Applications]

**Fig 35: Comparative Analysis based on Granted Patents at Different National Offices**
Table 2: List of Significant IPC Codes Based on Filed Applications & Granted Patents

<table>
<thead>
<tr>
<th>IPC Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H04L27/26</td>
<td>Systems using multi-frequency codes</td>
</tr>
<tr>
<td>H04W72/04</td>
<td>Wireless resource allocation</td>
</tr>
<tr>
<td>H04L5/00</td>
<td>Arrangements affording multiple use of the transmission path</td>
</tr>
<tr>
<td>H04J11/00</td>
<td>Orthogonal multiplex systems</td>
</tr>
<tr>
<td>H04B7/04</td>
<td>Radio transmission systems, i.e. using radiation field, using two or more spaced independent antennas</td>
</tr>
<tr>
<td>H04J1/00</td>
<td>Frequency-division multiplex systems</td>
</tr>
<tr>
<td>H04L25/03</td>
<td>Shaping networks in transmitter or receiver, e.g. adaptive shaping networks</td>
</tr>
<tr>
<td>H04W4/00</td>
<td>Services specially adapted for wireless communication networks; Facilities therefor</td>
</tr>
<tr>
<td>H04L27/01</td>
<td>Equalizers</td>
</tr>
<tr>
<td>H04W4/00</td>
<td>Services specially adapted for wireless communication networks; Facilities therefor</td>
</tr>
<tr>
<td>H04L25/02</td>
<td>Details</td>
</tr>
<tr>
<td>H04L27/12</td>
<td>Modulator circuits; Transmitter circuits</td>
</tr>
<tr>
<td>H04L27/14</td>
<td>Demodulator circuits; Receiver circuits</td>
</tr>
<tr>
<td>H04L27/34</td>
<td>Amplitude- and phase-modulated carrier systems, e.g. quadrature-amplitude modulated carrier systems</td>
</tr>
<tr>
<td>H04J13/00</td>
<td></td>
</tr>
</tbody>
</table>

The dataset consisting of 24 patent families includes 77 patent applications (including PCT application) which fall under 35 International Patent Classifications (IPC) categories. Figure 36 represents top nine IPCs based on the count of patent applications filed in different national offices (including OFF and subsequent offices of filing). The IPC H04L27/26 is applied in 34
patent applications which form 44% of total. This is then followed by IPCs H04W72/04, H04L5/00, H04J11/00, H04B7/04, H04J1/00, H04L25/03, H04W4/00 and H04L 27/01 contributing 17%, 14%, 13%, 9%, 8%, 8%, 7% and 5% of total respectively. However, all the above mentioned IPC codes don’t belong to the granted patents of the families. From the dataset, it is observed the granted patents fall under 19 different IPC codes; among which the IPC H04L27/26 is associated with highest number of granted patents i.e.10, followed by the IPC H04W72/04, H04L25/03, H04W4/00 and H04L5/00 with 6, 3, 2, and 2 numbers of granted patents respectively. IPC codes are significant from technical subject matter point of view. Table 2 lists the description of the IPC codes represented in figure 36 and also the 5 most important ones included in granted patents.

3.6 Patent Family Analysis based on Applicant

<table>
<thead>
<tr>
<th>Applicant</th>
<th>Total No. of Granted Patents</th>
<th>No. of Patent Families</th>
</tr>
</thead>
<tbody>
<tr>
<td>VODAFONE, Germany</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Huawei Technologies...</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Sony Corp, Japan</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Micron Technology Inc, US</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>ORANGE, France</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>ZTE CORP, China</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>BATTELLE ENERGY...</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fujitsu Ltd, Japan</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Samsung Electronics Co...</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LG Electronics Inc, Korea</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 37 provides the list of ten major market players in the GFDM technology who have filed the patent applications across 13 different jurisdictions for the protection of their invention. Vodafone, Germany (including both Vodafone Holding GmbH and Vodafone GmbH) has the highest number of patent families (5) contributing 21% to total no. of families, followed by Huawei Technologies Co., Ltd, China and Sony Corp, Japan consisting of 17% approximately. The third position in the list is occupied by Micron Technology Inc, US with 3 patent families. This is then followed by Orange, France and ZTE CORP, China which hold 8.3% of total families individually. In addition, Battelle Energy Alliance LLC, Us, Fujitsu Ltd, Japan, Samsung Electronics Co Ltd. Korea and LG Electronics Inc, Korea, each have 1 patent family. The number of protected inventions by each applicant given in figure 37 illustrates, Vodafone, Germany and Huawei Technologies Co., Ltd, China are the two leading companies to invest in research and development based on GFDM.

3.6.1 Patent Family Analysis of Vodafone Germany

Vodafone Germany is the largest subsidiary of the Vodafone Group, one of the largest telecommunications companies in the world. The Group operates its own mobile networks in 25 countries and maintains partner networks in another 46 nations.

In the present work, it is found that Vodafone Holding GmbH and Vodafone GmbH hold 2 and 3 patent families (discussed in subsections 3.1.1, 3.1.2, 3.1.6, 3.1.7 and 3.1.10) respectively. As a whole, Vodafone Germany has 11 patent
applications across 2 Jurisdictions (EPO, United States), tops among the group of applicants. The inventions include various digital signal processing methods and channel encoding techniques to construct GFDM based transmitter and receiver for future generation of wireless communication. From the dataset it is observed that for all the patent families the office of first filing is located at EPO and United States is the subsequent filing office being the potential market for GFDM technology. Out of 11 filings, 7 applications have been granted and enforced, 3 applications are pending for examination and 1 US application is abandoned (division application of granted US patent) because of failure to respond the office action. The numbers of granted patents in United States and EPO are 5 and 2 respectively, whereas all the pending applications belong to EPO. Though the OFF for all the patent families is EPO, but the number of grants is higher in US (which is office of second filing). Hence, it can be inferred that, the examination procedure is faster in case of US as compared to EPO.

3.6.2 Patent Family Analysis of Huawei Technologies Co., Ltd

Huawei Technologies Co., Ltd. is a Chinese multinational networking, telecommunications equipment, and Services Company headquartered in Shenzhen, Guangdong, founded in 1987. It is the largest telecommunications equipment manufacturer in the world, having overtaken Ericsson in 2012. As of 2018, Huawei is the second largest smartphone manufacturer in the world behind Samsung. In the present work, it is found that Huawei Technologies Co., Ltd occupies the second position in the list of applicants with 4 patent families (discussed in subsections 3.1.5, 3.1.8, 3.1.9, and 3.1.12) consisting of 24 patent applications (including 5 PCT applications). The inventions include digital signal processing techniques for cancellation of interference, dynamic wireless traffic scheduling, wireless resource allocation methods and negotiation of wireless communication parameters for machine-type communication. From the dataset it is observed that three patent families have office of first filing at United States and only one patent family has OFF at China. The subsequent filings pertaining to patent families with US OFF cover PCT, United States (for continuation application), EPO, China, Korea, Japan and Brazil. Out of 14 (including 3 PCT) applications, only three have been granted and being enforced in US (2) and Korea. The patent family having source of activity in China has the highest number of family members (10) with subsequent filings at PCT (2), United States, EPO, Japan, Korea, Singapore, Russia and Australia. However, the invention is protected in only four jurisdictions; i.e. Japan, Korea, Russia and Australia. Thus, Huawei Technologies Co., Ltd has 7 granted patents across 6 jurisdictions and 12 applications are pending for examination at 6 patent offices.

3.6.3 Patent Family Analysis of Sony Corporation

Sony Corporation is a Japanese multinational conglomerate corporation headquartered in Tokyo, Japan. It is the electronics business unit and the parent company of the Sony Group. Sony Corporation primarily conducts strategic business planning of the group, research and development (R&D), planning, designing and marketing for electronics products.

In the present study, it is found from the patent family dataset, Sony Corporation, Japan is the applicant for 4 patent families
(discussed in subsections 3.1.14, 3.1.17, 3.1.19, and 3.1.20) having 15 patent applications (including 4 PCT applications) filed across 9 jurisdictions. The inventions are based on signal processing techniques to suppress out of band emission, improved data recovery techniques at receiver, adaptive bandwidth allocation, device which facilitates backward compatibility with respect to GFDM. Out of 4 families, two patent families have OFF at Japan and subsequent filings at China, EPO, United States, Mexico, Singapore, Taiwan and PCT. One patent family has Canada as the OFF and subsequently has PCT publication. The first member of the remaining family is PCT with subsequent members from China and Australia. However, eleven patent applications are still pending for the examination and the patent families don’t possess any granted patents.

3.6.4 Patent Family Analysis of Micron Technology Inc

Micron Technology, Inc. is an American global corporation based in Boise, Idaho. The company produces many forms of semiconductor devices, including dynamic random-access memory, flash memory, and solid-state drives. Its consumer products are marketed under the brands Crucial and Ballistix. Micron and Intel together created IM Flash Technologies, which produces NAND flash memory. From building the world’s first 256K DRAM facility in 1984 to introducing the revolutionary 3D XPoint technology in 2015, Micron Technology has become one of the leading companies to provide innovative memory solutions.

From the dataset, it is found that Micron Technology Inc has three patent families with OFF at United States and subsequent filings in United States (Continuation application) and PCT. The inventions are associated with Inverse Fourier transform modulators, and wireless resource allocation techniques involving control information exchange between nodes between access point and access point controlling device. Out of 8 patent applications (including 3 PCT applications), three patents have been granted by USPTO (United States Patent and Trademark Office) and two applications are pending for examination.

3.6.5 Patent Family Analysis of Orange

Orange S.A. (formerly known as France Télécom S.A.), is a French multinational telecommunications corporation. The company’s head office is located in the 15th arrondissement of Paris. Orange S.A. holds two patent families (discussed in subsections 3.1.3 and 3.1.4) with OFF at France and subsequent filings at PCT, United States, China and EPO. The inventions are based on the signal processing methods in modulators for oversampling for transmission of multicarrier signal. Out of 7 patent applications (including 2 PCT applications), only three have been granted (in France 2 patents and in EPO 1 patent); the remaining are pending for examination. However, only one patent is in active legal status (EP) out of 3 granted patents. The two patents granted in France have been expired due to non-payment of renewal fee.

3.6.6 Patent Family Analysis of ZTE CORP

ZTE Corporation is a Chinese multinational telecommunications equipment and systems company headquartered in Shenzhen, Guangdong, China. It is one of China’s leading telecom equipment manufacturers. From the dataset, it is found that ZTE Corporation is the applicant for two
patent families (discussed in subsections 3.1.15 and 3.1.16) with OFF at home country China, and subsequently files PCT applications. The inventions are based on pilot signal transmission method in multicarrier environment. All the patent applications of ZTE Corporation based on the GFDM technology are pending and thus the families don’t have at least one granted patent.

3.6.7 Patent Family Analysis of Battelle Energy Alliance, LLC

Battelle Energy Alliance, LLC manages and operates a science-based applied engineering national laboratory. It provides its services to establish Idaho National Laboratory that offers nuclear energy research, development, demonstration, and education services. In the present work it is found that, Battelle Energy Alliance, LLC has only 1 patent family (discussed in subsection 3.1.21) with OFF at United States and subsequent PCT filing. The invention is related to pulse shaping techniques for amplitude- and phase- modulated carrier systems. The application is pending for the examination at USPTO. Battelle Energy Alliance, LLC hasn’t applied for the protection of IP in other jurisdictions.

3.6.8 Patent Family Analysis of Fujitsu Ltd

Fujitsu Limited is Japanese multinational information technology equipment and Services Company headquartered in Tokyo, Japan, founded in 1923. It operates as an information and communication technology (ICT) company worldwide. The company operates in three segments: Technology Solutions, Ubiquitous Solutions, and Device Solutions.

The dataset reveals that, Fujitsu Ltd. has only one patent family (discussed in subsection 3.1.18) with OFF at home country Japan and one PCT publication. The application is pending for the examination at JPO. The invention is related to signal processing method in wireless communication using WALSH codes. Fujitsu Ltd. hasn’t subsequent filings in any other jurisdictions. This family doesn’t contain any granted patent.

3.6.9 Patent Family Analysis of Samsung Electronics Co Ltd

Samsung Electronics Co., Ltd., founded in 1938, is a South Korean multinational electronics company headquartered in Suwon, South Korea. Together with its subsidiaries, it is engaged in the consumer electronics, information technology and mobile communications, and device solutions businesses worldwide. From the dataset, it is observed that only one patent family (discussed in subsection 3.1.13) belongs to Samsung Electronics Co Ltd. The application was first filed in home country Korea with subsequent PCT filing. The invention is related to signal processing techniques in receiver side to provide signals with specified spectral properties in non-orthogonal multi-carrier systems. This family doesn’t contain any granted patent and the filed application is pending for examination.

3.6.10 Patent Family Analysis of LG Electronics Inc

LG Electronics Inc. is a South Korean multinational electronics company headquartered in Yeouido-dong, Seoul, South Korea, and is part of LG Corporation, founded in 1958.

In the present work, it is found LG Electronics Inc is the applicant for only 1 patent family (discussed in subsection 3.1.11) which is related to method of resource
allocation in a cooperative multipoint environment. The OFF for the family is United States and the subsequent filing is PCT. However, the application is pending for examination at USPTO.

4.0 CONCLUSION
It can be concluded Generalized Frequency Division Multiplexing (GFDM) is an upcoming modulation method for Fifth Generation (5G) wireless communication systems having many advantages over conventional Orthogonal Frequency Division Multiplexing (OFDM). GFDM is an emerging technology. It has more commercialization value in near future. It is observed that

- United States tops the list with highest percentage of earliest filings followed by EPO, China, Japan, France, Korea, Canada and PCT respectively. From the offices of subsequent filing, the PCT (Patent Cooperation Treaty) is the top office by far with a count of 18 patent families. The reason of such subsequent filing may be to protect the invention in multiple jurisdictions via PCT route. Families originating from US, China, Japan, France, Korea, and Canada choose PCT as second subsequent filing for protection of invention in multiple jurisdictions.

- Though the first filing process at EPO started in the year 2008 but filing activity is on decline after the year 2014, on the other hand the filing activity in United States started in 2014 and continues up to 2016. China and Japan occupy the third position each contributing 13% to the global activity. It can be inferred that US is the leading OFF for the applicants in the field of GFDM technology followed by EPO, the reason being the faster processing of applications for grant and significant market in the US.

- It can be observed that most of the patent applications based on GFDM technology are still pending for the examination at different national offices. From the pending application in different jurisdiction, it is found that, Korea has the least number of pending applications compared to its total filings. US has the highest numbers of granted patent in this technology.

- IPC H04L27/26 is associated with highest number of granted patents i.e.10, followed by the IPC H4W72/04, H04L25/03, H04W4/00 and H04L5/00. IPC H04L27/26 associated with Systems using multi-frequency codes which is relevant with core technology of GFDM

- Vodafone, Germany and Huawei Technologies Co., Ltd, China are the two leading companies that have invested substantially in GFDM technology.

- Patenting trends indicate GFDM as prospective technology for mobile communication.

5.0 References: