Generation of Signals Related to Different Cellular Generation Using GNU Radio

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***Abstract*—This study focuses on the generation of signals at frequencies associated with various cellular generations, accompanied by an analysis of their corresponding wavelengths. In this, GNU Radio Companion, an open-source software toolkit, is utilized as a primary tool for signal processing and analysis. The objective is to explore and comprehend the characteristics of signals pertaining to diverse cellular generations, including 1G, 2G, 3G, 4G, and 5G networks. The objective lies in creating signals representative of each cellular technology, enabling a detailed investigation into the respective wavelengths associated with these frequencies. The utilization of GNU Radio Companion facilitates efficient signal generation and robust wavelength analysis, providing valuable insights into the propagation characteristics and spectral properties of signals employed in different cellular communication standards. Through this exploration, the study aims to elucidate the relationship between frequency, wavelength, and cellular communication technologies, contributing to a deeper understanding of wireless communication systems and their evolving standards.**

Keywords*—Cellular Generations, Signal Generation, Wavelength Analysis, GNU Radio Companion, Wireless Communication, Signal Propagation.

I. INTRODUCTION

The research delves into a comprehensive exploration of signal generation and wavelength analysis across various cellular generations, encompassing 1G through 5G networks. Leveraging the capabilities of GNU Radio Companion—an open-source software toolkit—the study aims to dissect the unique characteristics of signals associated with each cellular technology. The primary objective revolves around creating representative signals for diverse cellular generations to facilitate an in-depth investigation into their corresponding wavelengths.

By harnessing GNU Radio Companion's functionalities for signal processing and analysis, the research endeavours to unravel critical insights into the propagation patterns and spectral attributes inherent in different cellular communication standards. This meticulous analysis is poised to shed light on the intricate relationship between frequency, wavelength, and the diverse landscape of cellular communication technologies.

The study's significance lies in its potential to offer a deeper understanding of wireless communication systems' evolving standards. Through a detailed examination of signal properties and wavelength variations across multiple generations, the research aims to contribute valuable knowledge that could enhance our comprehension of wireless communication systems and their evolving standards.

Radio frequency (RF) signals are characterized by two primary measurements: frequency and signal strength, both of which often comprise a blend of various frequencies and strengths. The depiction of the radio spectrum graphically employs a logarithmic scale, providing a clearer representation of the spectrum's vastness. The foundation of wireless communications is rooted in electromagnetic waves traversing through the air, generated by energized objects like antennas. Transmitters and receivers encode and decode information to and from these waves, forming the cornerstone of wireless signal transmission. The energy level utilized in transmitters significantly impacts the distance the waves can cover, demanding careful energy selection to avert interference. Receiver selections are equally crucial, necessitating optimal signal-to-noise ratios for enhanced reception performance.

Frequency is a pivotal property of these waves, dictating their oscillation speed within the entire range of the radio spectrum—spanning from 3kHz to 300 GHz. Traditionally, applications have operated within ranges from approximately 10 MHz to 5GHz. The primary industrial wireless devices predominantly inhabit the upper VHF and UHF frequencies. Another crucial aspect of these waves is their modulation, signifying variations in frequency and amplitude. Such variation renders signals from distinct devices incompatible—such as FM radio signals and Wi-Fi signals, preventing communication between disparate device types.

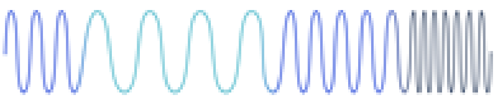

Fig 1 Visualization of frequency modulation

Light's wavelength and frequency share a direct correlation—the shorter the wavelength, the higher the frequency, establishing an inverse relationship between frequency and wavelength. As a consequence of light waves moving at a consistent speed in a vacuum, the wavelength determines the frequency, with shorter wavelengths boasting higher frequencies. The relationship between wavelength (λ), frequency (ν), and the speed of light (c) is expressed by the equation $\lambda\nu=c$. This equation forms the crux of analyzing signals pertinent to different cellular technologies in terms of their frequency and wavelength. Signal generators, a class of electronic devices, produce electrical signals featuring specific properties like amplitude, frequency, and wave shape. These signals are utilized for electronic measurements, aiding in designing, testing, and troubleshooting electronic devices. GNU Radio stands out as a premier open-source software-defined radio library, extending its utility beyond radio applications. It serves as a foundational library for various applications requiring signal processing and decoding libraries, transcending the realm of software-defined radio and communication systems.

II. LITERATURE REVIEW

Ref paper [1] outlines the evolution of wireless technology from 1G to 5G, emphasizing its profound impact on various aspects of human life. It highlights the continuous advancements and the ever-growing ambition to find innovative solutions to problems. The focus is on discussing the technologies integral to 4G and 5G communication, along with a review of their implementation in mobile networks. Both 4G and 5G have seen significant improvements, particularly in terms of customer experience, data speeds, coverage, and other facets, with a primary emphasis on enhancing the mobile consumer's experience. The primary objective of this paper is to offer a comprehensive analysis of the fundamental technologies driving 4G and 5G while highlighting their differences in terms of flexibility and connectivity.

Ref paper [2] highlights the evolution of 5G standardization and commercial deployment since 2016, emphasizing the transition to 5G-Advanced, an extension of 3GPP Releases 15, 16, and 17. Beginning with 3GPP Release 18, 5G-Advanced introduces diverse features focusing on device and network evolution. These advancements aim to evolve mobile broadband services, expand vertical applications, and meet immediate and long-term commercial needs. 5G-Advanced is expected to significantly enhance 5G capabilities, address various use cases, transform connectivity experiences, and play a pivotal role in advancing towards 6G mobile communications. The paper aims to provide an inclusive overview of 3GPP's 5G-Advanced development, showcasing leading-edge technologies under exploration and outlining future research and standardization directions.

Ref paper [3] provides an overview of the evolution of cellular communication technologies across multiple generations, from 1G to the current advancements in 5G and the potential developments in 6G. It highlights the progress made in terms of data rate, performance, quality of service (QoS), and efficiency in each generation. The paper compares network architectures, technological standards, multiplexing techniques, frequencies, and challenges faced in each generation, emphasizing the advancements that have led to more reliable systems. The study aims to illustrate the continuous improvements in communication systems, addressing their features and enhancements while overcoming limitations of previous generations.

Ref paper [4] outlines the evolution of mobile wireless communication from 1G to 5G, highlighting the transition from voice-only services to the integration of voice, data, and internet capabilities. The paper emphasizes the significance of 5G technology in enabling remote access and the proliferation of the Internet of Things (IoT) to connect numerous devices. It underscores the improved communication achieved by 4th and 5th generation technologies, offering fast data transmission and efficient services. The future scope aims for a completely wireless world, demanding seamless access to high-quality, high-speed information at reduced costs and increased capacity.

Ref paper [5] discusses the evolution of wireless localization from an auxiliary feature to a fundamental aspect of cellular networks, especially in the context of sixth-generation (6G) networks. The paper focuses on the role of radio localization across all cellular generations from 1G to 6G, exploring the concept of holographic localization facilitated by advanced intelligent surfaces constructed from metamaterials. It provides insights into the current technological landscape while highlighting the challenges and prospects associated with this emerging technology.

III. METHODOLOGY

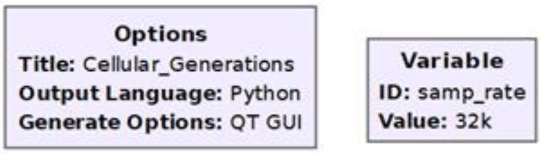

Fig 2 Options and Variable Block Diagram

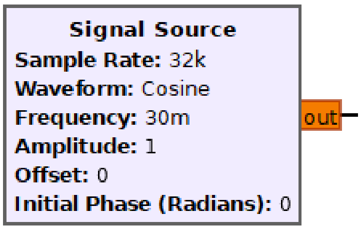

Fig 3 Signal Source Block Diagram

In GNU Radio, the Options and Variable blocks serve distinct purposes, allowing for flexibility and customization within the signal processing flowgraph.

Options Block: This block is used to expose parameters that can be set or configured when running the GNU Radio flowgraph. It allows users to define various options or settings that affect the behaviour of the flowgraph. These settings could include sampling rates, frequencies, gains, modulation schemes, and more. Users can configure these parameters from the GNU Radio Companion (GRC) interface or by accessing them programmatically.

Variable Block: The Variable block enables the dynamic manipulation of parameters during the execution of the flowgraph. It permits changing specific parameters or settings in real-time, allowing for flexibility and adaptability in signal processing. This block is particularly useful for altering values like frequencies, thresholds, or any other adjustable parameters while the flowgraph is running. Users can either modify these variables manually or use external control mechanisms like sliders, buttons, or scripts to change the values dynamically.

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IV. EXPERIMENTAL SETUP

A. *Step-by-step procedure followed to generate signals at various frequencies.*

- Identify the list of hardware and software utilized for signal generation and analysis.
- GNU Radio Setup and Configuration
- Signal Generation for different cellular generations
- Details of the experimental scenarios designed to analyze cellular signals.
- Implementation of GNU Radio for Analysis

In GNU Radio, a "signal source" block is a fundamental component used to generate digital signals for further processing within a flowgraph. It acts as a source of data that can simulate various types of signals or provide real-time data from hardware sources. It generates basic waveform signals like sine, square, triangle, or noise for simulation purposes

Integration within Flow graphs: Signal sources are connected to other blocks (like filters, modulators, demodulators, etc.) within GNU Radio flowgraphs to create signal processing chains.

Parameter Configuration: Signal sources typically allow configuration of parameters such as frequency, amplitude, sample rate, and waveform type to generate the desired signal.

Real-Time Data Processing: Hardware interface signal sources (e.g., USRP, RTL-SDR) enable real-time data acquisition from physical devices, allowing for live signal processing.

Signal Simulation: Signal sources for simulation aid in testing and developing signal processing algorithms without the need for physical hardware by generating synthetic signals.

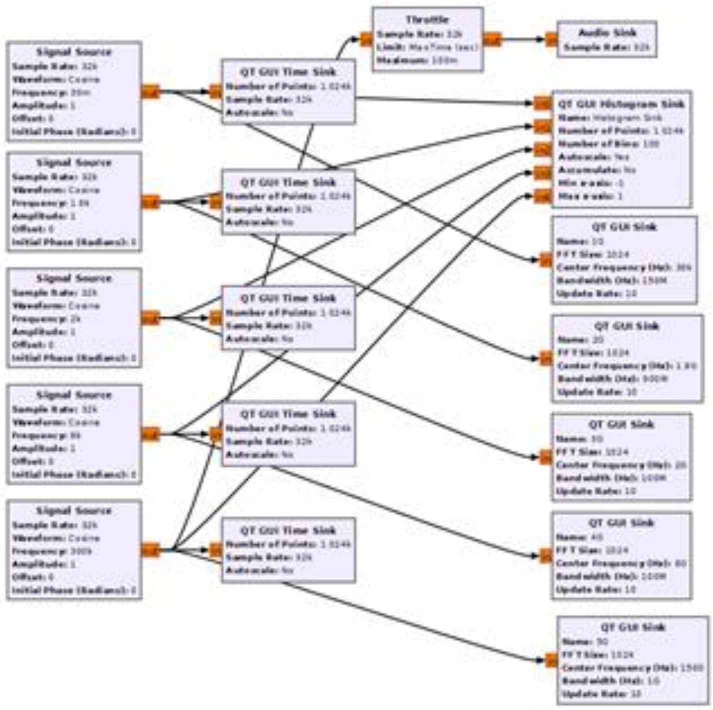


Fig 4 Visualization of Main Block Diagram with Source & Sink

B. *Components of the Block Diagram:*

Signal Source Block: This block generates modulated signals simulating different cellular generations—1G, 2G, 3G, 4G, and 5G. Each signal corresponds to the characteristics and modulation schemes of its respective generation.

QT GUI Time Sink: This sink block displays the time-domain representation of the generated signals. It allows visualization of signal characteristics such as amplitude, frequency, and modulation in the time domain.

QT GUI Histogram Sink: This block represents signal statistics or characteristics using a histogram, providing insights into various signal parameters such as power distribution, symbol distribution, or frequency distribution for each cellular generation.

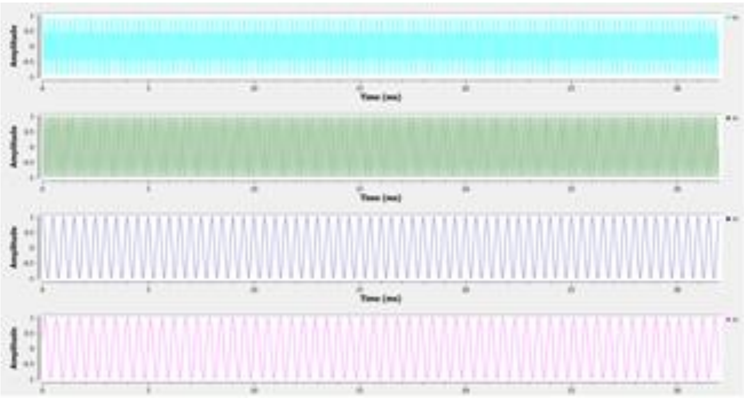
QT GUI Sink: This block visualizes the signals in the frequency domain, displaying their spectral characteristics. It helps in observing the frequency components and bandwidth allocation specific to each cellular generation.

Audio Sink: This sink block facilitates the audio playback of the generated signals. This might aid in auditory identification or differentiation of the signals representing each cellular generation.

C. *Execution of the Block Diagram:*

Signal Generation: The Signal Source block generates signals representing different cellular generations with their respective modulation schemes and characteristics.

Time-Domain Visualization: The QT GUI Time Sink displays the time-domain waveform of the generated signals, showing variations in amplitude, frequency, and modulation patterns.



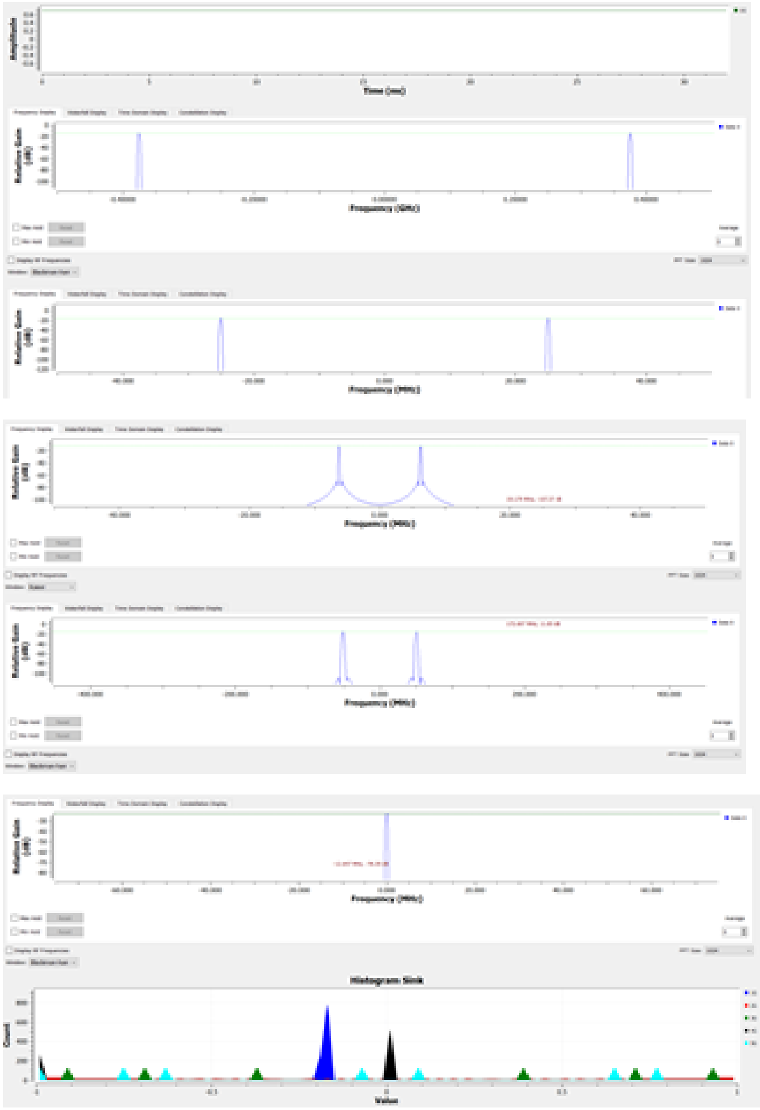


Fig 5 Visualization of GUI Sink for each Cellular Generation

Histogram Representation: The QT GUI Histogram Sink presents histograms that depict statistical characteristics or distributions of signal parameters for each cellular generation, offering insights into their unique properties.

Frequency-Domain Visualization: The QT GUI Sink showcases the frequency spectra of the signals, allowing observation of frequency allocations, bandwidths, and spectral characteristics specific to each generation.

Audio Playback: The Audio Sink enables the auditory representation of the signals, potentially aiding in the identification or differentiation of cellular generations based on their sound representations.

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V. RESULTS AND DISCUSSIONS

1G (First Generation): The time-domain representation might exhibit analog modulated signals with basic amplitude and frequency variations. It might showcase a simple analog waveform with lower frequencies and consistent amplitudes.

2G (Second Generation): The visualization could display digitally modulated signals, perhaps showing more complex patterns compared to 1G. It might exhibit time-division multiple access (TDMA) or code-division multiple access (CDMA) signals with improved modulation schemes.

3G (Third Generation): The time sink may portray signals that display enhanced complexity and modulation techniques. The waveform might demonstrate the use of higher data rates and more sophisticated modulation like wideband code division multiple access (WCDMA) or similar technologies.

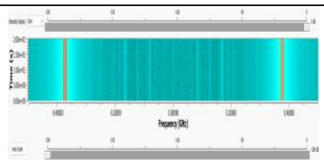
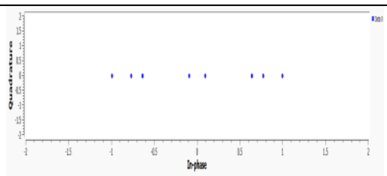
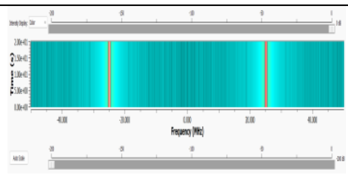
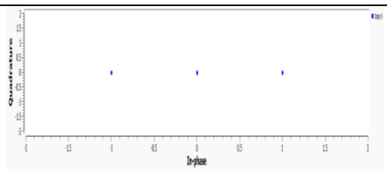
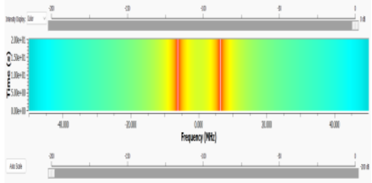
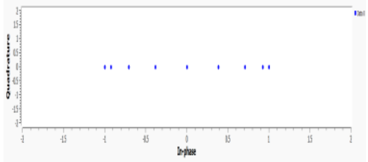
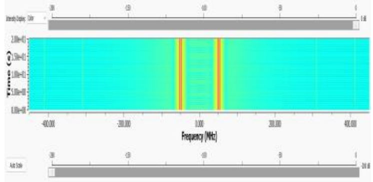
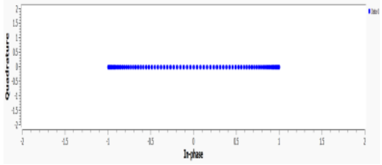
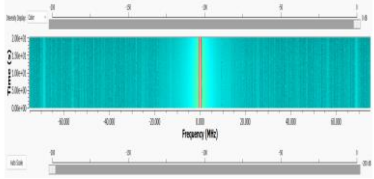
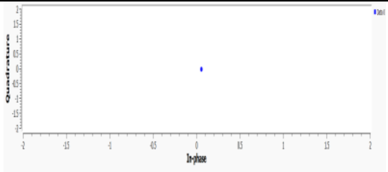
Cellular Generations	Waterfall Display	Constellation Display
1G		
2G		
3G		
4G		
5G		

Fig 6 Visualization of Waterfall Display and Constellation Display for each Cellular Generation

4G (Fourth Generation): The time-domain visualization could showcase signals with even more advanced modulation schemes such as Orthogonal Frequency Division Multiplexing (OFDM). The waveform might exhibit higher data rates, improved spectral efficiency, and better performance in terms of speed and latency. 5G (Fifth Generation): The visualization might indicate signals with extremely complex waveforms due to the utilization of technologies like millimeter waves, massive MIMO (Multiple Input Multiple Output), and beamforming. The waveform could show distinctive patterns demonstrating the advanced features and high-speed data rates of 5G.

REFERENCES

1. Mishra, Ranjan. "An overview of backbone technology behind the latest advanced gadgets in use: 4G & 5G." Spatial Information Research 31, no. 1 (2023): 15-26.
2. Chen, Wanshi, Xingqin Lin, Juho Lee, Antti Toskala, Shu Sun, Carla Fabiana Chiasserini, and Lingjia Liu. "5G-Advanced Toward 6G: Past, Present, and Future." IEEE Journal on Selected Areas in Communications 41, no. 6 (2023): 1592-1619.
3. Ratul, Rashed Hasan, and Hwang-Cheng Wang. "Cellular communication network evolution and the reliability of system design from 1g to 6g." In International Conference on Wireless Intelligent and Distributed Environment for Communication, pp. 165-187. Cham: Springer International Publishing, 2023.
4. Sharma, Sunil, Shambhoo Prasad, and Alok Semwal. "Technological Aspect to Heal the Social Communication Gap by Evolution in Mobile Networks from 1G to 5G." Journal for ReAttach Therapy and Developmental Diversities 6, no. 2s (2023): 136-139.
5. Elzanaty, Ahmed, Anna Guerra, Francesco Guidi, Davide Dardari, and Mohamed-Slim Alouini. "Towards 6G holographic localization: Enabling technologies and perspectives." IEEE Internet of Things Magazine (2023).