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Specification of downlink-fixed reference channel DL-FRC for 5G new radio technology

Fatima Faydhe Al-Azzawi, Ruaa Ali Khamees, Zina Abdul Lateef, Batool Faydhe Al-Azzawi
Electronic technical department, Institute of Technology, Middle Technical University, Baghdad, Iraq

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ABSTRACT

The next generation for mobile communication is new radio (NR) that supporting air interface which referred to the fifth generation or 5G. Long term evolution (LTE), universal mobile telecommunications system (UMTS), and global system for mobile communication (GSM) are 5G NR predecessors, also referred to as fourth generation (4G), third generation (3G) and second generation (2G) technologies. Pseudo-noise (PN) code length and modulation technique used in the 5G technology affect the output spectrum and the payload of DL-FRC specification, in this paper quadrature phase shift keying (QPSK), 16 QAM modulation approaches tested under additive white Gaussian noise (AWGN) in term of bit error rate (BER) which used with 5G technology system implemented with MATLAB-Simulink and programing and, resulting of 1672, 12296 bit/slot payload at frequency range FR1 from 450 MHz-6 GHz and 4424, 20496 bit/slot payload at frequency range FR2 from 24.25 GHz-52.6 GHz, also determining subcarrier spacing, allocated source block, duplex mode, payload bit/slot, RBW (KHz), sampling rate (MHz), the gain and the bandwidth of main, side loop where illustrated.

Corresponding Author:

Fatima Faydhe Al-Azzawi
Head of Electronic Technical Department, Middle Technical University
Baghdad, Iraq
Email: fatima_faydy1981@mtu.edu.iq

1. INTRODUCTION

The next generation for mobile communication is new radio (NR) that supporting air interface which referred to the fifth generation (5G). Long term evolution (LTE), universal mobile telecommunications system (UMTS), and global system for mobile communication (GSM) are 5G NR predecessors, also referred to as fourth generation (4G), third generation (3G) and second generation (2G) technologies. Voice calls primarily enabled in GSM. LTE and UMTS interfaces redesigned gradually to improve and enabled the high efficiency and high data rates for mobile broadband connectivity [1], [2].

5G NR depend on LTE technology where enable the high rates of data and the higher efficiency in mobile broadband. Response to the society networking demands, going beyond connectivity of mobile broadband is the 5G NR scope. 5G NR main requirement is enabling everywhere the connectivity of wireless communication, for anything and to anyone at any time. Three main scenarios are classified by the 5G NR where a wide range of use cases [3]:

– Enhanced mobile broad band (EMBB): This approach communicate the addresses of human-centric. EMBB used by application with high challenges. Like hot spots where require high data rates, high density users so as needing higher capacity. Stressing of mobility in coverage of wide area can be constructed in experience of seamless user with low requirement of data rate and density of users [1], [2].

– Massive machine type communications (MMTC): Where based on machine-centric with pure addressing using characterized cases of large number of devices that connected. The requirement of data rate in MMTC applications is low. Cases that used demand a higher of connection locally, long battery life and low cost [2], [3].
– Ultra reliable and low latency communications (URLLC): Coverage that demand high availability, reliability and low latency for both critical machine-type communication (C-MTC) and human centric communication. URLLC use by application like self-driving cars, 3-D gaming, applications of mission-critical, remote medical surgery, and industrial equipment with wireless control. Depending on capabilities that mention, designing the interface of 5G NR is to easily adapting the unforeseen cases used with evolving and emerging over time [4]-[6].

Specification of 5G NR is developed by third generation partnership project (3GPP). The first standard was stopped in mid-2018 as 5G NR by 3GPP, releasing toolbox (15.5 G) provides subset design of the 5G NR specification of physical layer and channel model. Figure 1 is a 5G Toolbox stuck in terms of the addressing connectivity and their specifications [1], [2].

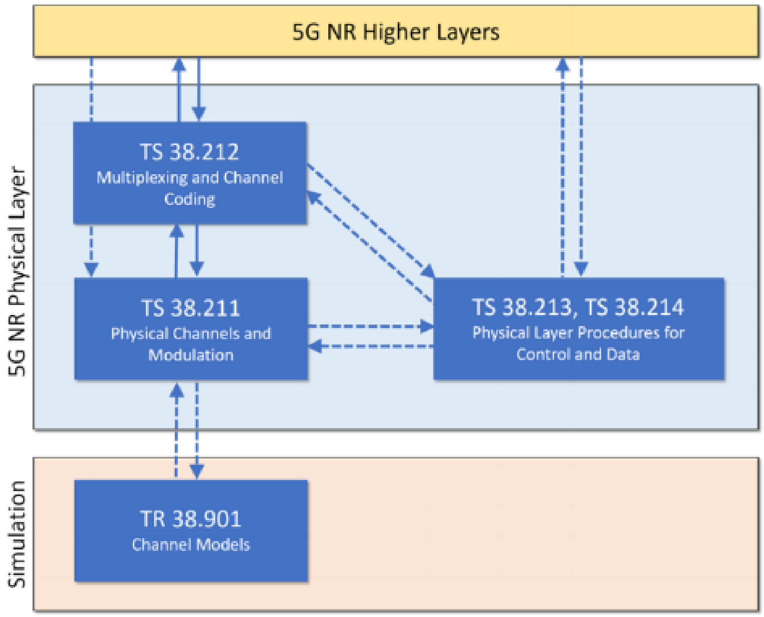

Figure 1. Diagram of 5G toolbox in terms of the addressing connectivity and their specifications

Where TSG is technical specification produced by the 3GPP. The 5G-NR standard uses the orthogonal modulation (OFDM) on both the downlink and uplink. Specification of NR are designed with higher flexibility degree for covering a diverse applications set. Spacing of the carrier with flexibility of doubling with up to 3300 subcarriers. The subcarrier modulation can be quadrature phase shift keying (QPSK), 16 QAM, 64 QAM or 256 QAM. In this paper PN9, PN15 message payload size and QPSK, 16 QAM modulation approaches used in downlink fixed reference channel of 5G-NR technology with tow frequency ranges applied [6]-[8].

2. DL-FRC SPECIFICATION

The physical downlink shared channel (PDSCH) fixed reference channel (FRC) for FR1 and FR2 They are used in a number of user equipment user equipment (UE) tests, including UE receiver requirements and maximum UE input level testing, they are used in a number of base station reception tests, including: reference sensitivity, adjacent channel selectivity (ACS), in-band and out-of-band blocking, receiver intermodulation, in-channel selectivity, dynamic range, performance requirements new radio-test models (NR-TMs) and FRCs are defined across a standardized set of transmission bandwidth configurations for a valid range of channel bandwidth and subcarrier spacing combinations. Each PDSCH reference waveform is defined by a combination of: NR-TM or FRC name, Duplexing mode, channel bandwidth, and subcarrier spacing [9]-[11].

Different NR-TMs are defined for FR1 and FR2. Depending on the test model purposes, NR-TMs have varying PDSCH characteristics. For example: Full band, single modulation scheme, or full band, multiple modulation schemes with varying power boosting/de-boosting or single, varying PRB allocation. Common features to all NR-TMs are: no SS burst, PDSCH mapping type A with one (FR2) or two (FR1) DM-RS positions per slot transmission, and a single PDCCH across two symbols with NCCE=1. There is no transport or downlink control information (DCI) coding used and the input to the PDSCH and PDCCH is all 0's. frequency division duplexing (FDD) NR-TM waveforms are 10 ms in length and time division duplex (TDD) cases are 20 ms. Phase tracking reference signals (PT-RS) are specified for FR2 NR-TM [12]-[14].

By comparison, downlink FRC waveforms contain transport coded PDSCH using RV=0. The reference PDSCH are not defined in slots which overlap the SS burst (slot 0 or slots 0 and 1). They use front loaded PDSCH mapping type A with 2 additional demodulation reference signal (DM-RS) positions. There is no frequency division multiplexing (FDM) between the PDSCH and the DM-RS. The full-band PDSCH start at symbol 2 and the first 2 symbols in a slot contain a full occupied CotrolResourceSet (CORESET). The FRC waveforms generated in this example do not contain additional OCNG. Power levels for all resource elements are uniform. The transport block data source is International Telecommunication Union Pseudo-Noise 9 (ITU PN9) [15]. Bandwidth of the channel and spacing of subcarrier combination have to be a valid pair from the associated FR bandwidth configuration table. The standard only defines FR2 NR-TM and FRC for TDD but with this example you can also create FDD waveforms [16]-[18].

2.1. Modulation scheme in 5G technology

The standard format of modulation for 5G NR is orthogonal frequency-division multiplexing OFDM which is used in modern communication wireless systems including 5G as efficient format of modulation. OFDM is a hybrid of quadrature amplitude modulation (QAM) and FDM to produce communication system with a high-data-rate. QAM refers to a modulation types like: binary phase shift keying (BPSK), QPSK, 16 QAM, and 64 QAM [19]. Bit error rate (BER) of modulation approaches used in 5G-NR technology have been plotted using MATLAB BER tool as shown in Figure 2 based on the following equation, where BER equation of QAM in additive white Gaussian noise (AWGN) channel are illustrated below: Equation of QAM BER with AWGN channel [20], [21].

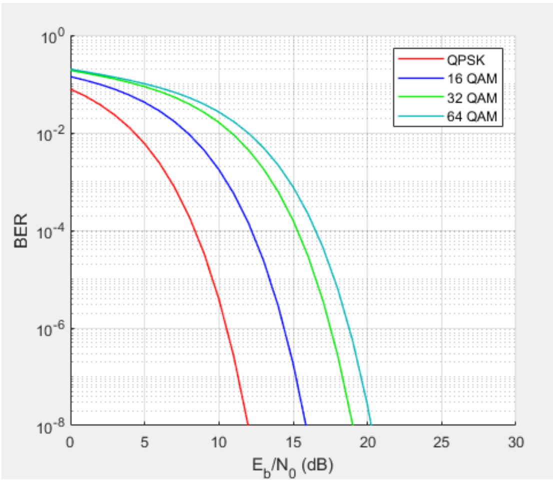

Figure 2. BER of modulation approaches in AWGN used in 5G-NR technology

$$P_b = \frac{2}{\sqrt{M}\log_2\sqrt{M}} \times \sum_{k=1}^{\log_2\sqrt{M}} \sum_{i=0}^{(1-2^{k})\sqrt{M}-1} \left\{ (-1)^{\left\lfloor \frac{i2^{k-1}}{\sqrt{M}} \right\rfloor} \left(2^{k-1} - \left\lfloor \frac{i2^{k-1}}{\sqrt{M}} + \frac{1}{2} \right\rfloor \right) Q\left((2i+1)\sqrt{\frac{6\log_2 M E_b}{2(M-1)N_0}} \right) \right\}$$

Where P_b is BER, M is modulation constellation Size, K is bits per symbol number → $k=\log_2 M$, $\frac{E_b}{E_0}$ is ratio of energy per bit-to-noise power-spectral-density. Equation of M-PSK in AWGN is [20], [21]:

$$iP_s = \frac{1}{\pi}\int_0^{(Mi-1)\pi/Mi} \text{expi}\,(-\frac{kiE_b}{N_o}\frac{sin^2 i[\pi/Mi]}{isin^2\theta})d\theta$$
$$iP_b = \frac{1}{k}\left(\sum_{i=i1}^{iM/2}(w_i')P_i\right)$$

where $w_i' = iw_i + iw_{M-i}, iw_{M/2}' = w_{M/i2}$, w_i is the hamming weight of bit assigned to symbol i, and

$$P_i = \frac{1i}{2\pi}\int_0^{\pi i(1-(2i-1)i/Mi)} \exp\left(-\frac{kE_b}{N_o}\frac{sin^2\left[\frac{(2i-i1)\pi}{Mi}\right]}{sin^2\theta}\right)d\theta$$
$$-\frac{1}{2\pi}\int_0^{\pi i(1-(2i-i1)/iM)} \exp\left(-\frac{kE_b}{N_o}\frac{sin^2\left[\frac{(i2i+i1)\pi}{Mi}\right]}{sin^2\theta}\right)d\theta$$

Expressions of convolutional code: d_{free} is a code free distance, and the number of distance paths di which from the all-zero path that merge with the all-zero path [20], [21]:

$$P_b < \sum_{d=d_{free}}^{\infty} ia_d f(id) iP_2(idi)$$

where

$$iP_2(d) = \sum_{ki=(di+1)/i2}^{di}\binom{di}{ki} iP^k(i1-iP)^{d-ik}$$

when di is odd, and

$$P_2(di) = \sum_{k=(id+1)/2}^{di}\binom{di}{ki}P^k(1-Pi)^{d-ki} + \frac{1i}{2i}\binom{di}{di/2}P^{d/2}(i1-p)^{id/2}$$

when di is even (Pi is the BER in an uncooked AWGN channel).

2.2. PN sequence generation

PN data sequence is an M-sequence that is generated with the use of linear feedback shift-register circuit, as shown in Figure 3. M is the number of shift registers. D(M) is the m^{th} shift register, and $\{c_1, c_2, ..., c_M\}$ are the coefficients of them. At each clock pulse, the data in the registers will right shift once and one PN datum is output from register D(M) [22], [23].

Mathematically, the procedure can be defined by a generator polynomial. $\{c_1, c_2, ..., c_M\}$ becomes the coefficients of the generator polynomial. For instance, the polynomial for PN9 is x^9+x^5+1, therefore, M=9 and c9=1, c5=1, ci∈{1~9}, and i≠9, i≠5=0. The PN sequence, $\{a_n\}$, $0 \le n < 2^M$, is generated by the equation [24], [25].

$$a_n = \{^{initial\ state\ in\ D^{M-n}, 0\le n<M}_{C_M a_{n-M} + C_{M-1} a_{n-(M-1)} + \cdots + C_2 a_{n-2} + C_1 a_{n-1}, M\le n<2^M}$$

Where, the initial state of registers $\{D^1, D^2..., D^M\}$ is the seed. D(M) stores the LSB of the seed, and D1 stores the MSB of the seed. For example, if the seed is 10 (binary form 1010), the initial state in register $\{D^1, D^2..., D^M\}$ is {0 0 0 0 0 1 0 1 0}.

Figure 4 shows the initial state of each register for PN9. It's obvious that LSB of the seed comes out first. Afterwards, the registers store previously generated data, $D^m=a_{n-m}$, m∈(1,M). The generator polynomial for PN15 is $x^{15}+x^{14}+1$, therefore M=15 and c_{15}=1, c14=1, ci∈{1~15}, and i≠15, i≠14=0.

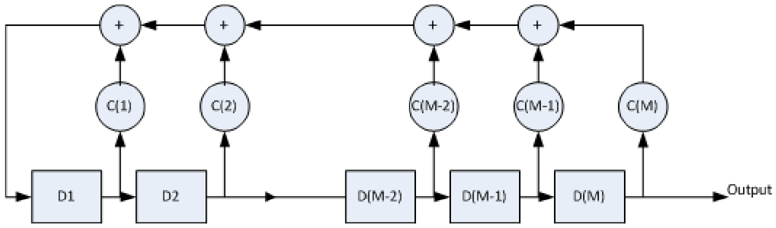

Figure 3. A PN data sequence generator

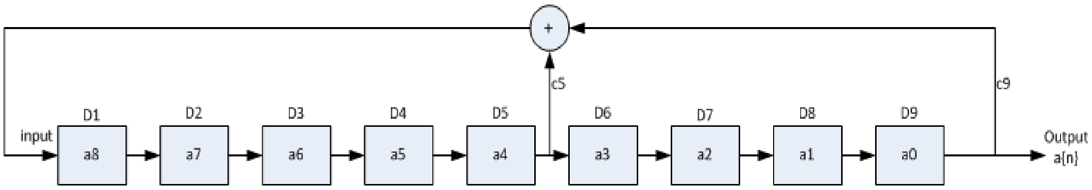

Figure 4. The initial state of each register for PN9

3. RESULTS

The physical downlink shared channel (PDSCH) implemented in MATLAB-Simulink with FRC specification illustrated in Table 1, where PN9 and PN15 source code used in FR1 and FR2 with QPSK and 16 QAM modulation schemes, determining subcarrier spacing, Allocated source block, duplex mode, payload bit/slot, RBW (KHz), sampling rate (MHz). Comparison of systems with coverage-limited at the same frequency band, TDD system required more base stations by 31% than FDD when using a 1:1 TDD system and more base stations by 65% when using a 2:1 TDD system. Higher frequency bands required even more base stations. So TDD is used with FR2 and FDD used with FR1 as shown in Table 1, payload increased with 16 QAM over QPSK in both FR1 and FR2 because information modulated for both phase and amplitude in QAM. Using source length of PN9 and PN15 for both FR1 and FR2 effecting on the spectrum pf DL-5G NR technology as shown in Figure 5. Where spectrum analyzer in QPSK illustrate the spectrum with 15 MHz and 44 MHz main loop width in FR1 and FR2 respectively, side loop in QPSK with FR1 reach to -170 dBm and -175 dBm for PN15 and PN9 respectively, while reaching to -90 to -75 dBm in FR2.

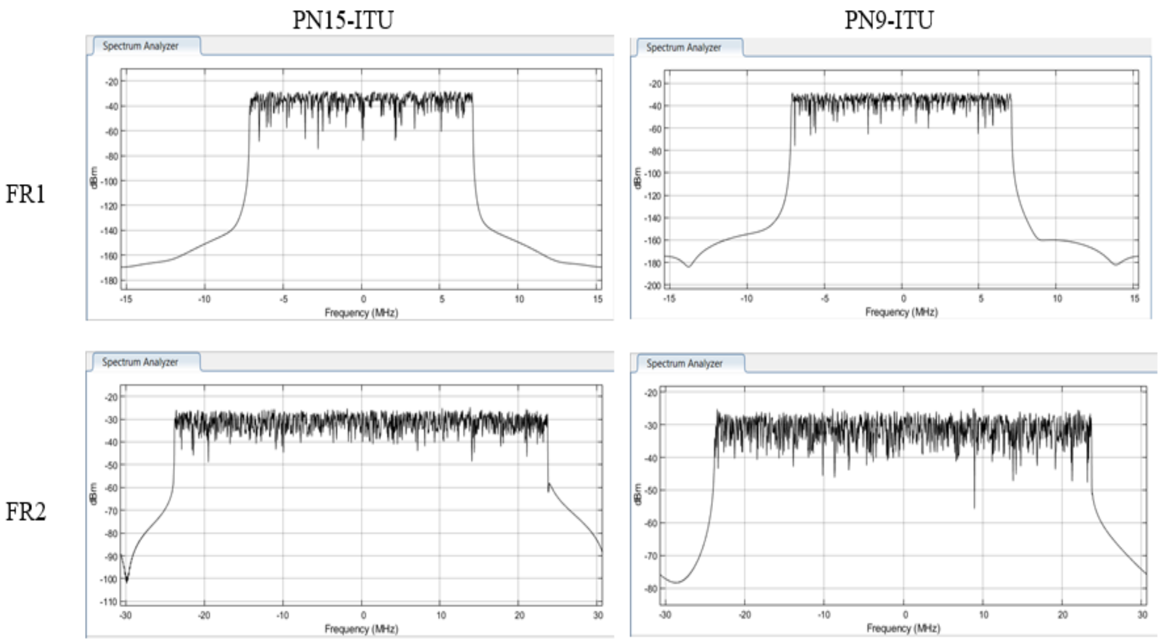

Figure 5. Downlink FRC using PN15, 9-ITU FR1 vs FR2 with QPSK modulation

Table 1. Downlink FRC specification

Source code length	PN9-ITU				PN15-ITU			
Frequency range	450 MHz-6 GHz		24.25 GHz-52.6 GHz		450 MHz-6 GHz		24.25 GHz-52.6 GHz	
Modulation type	QPSK	16 QAM	QPSK	16 QAM	QPSK	16 QAM	QPSK	16 QAM
Subcarrier spacing	15	15	60	60	15	15	60	60
Allocated source block	79	79	66	66	79	79	66	66
Duplex mode	FDD	FDD	TDD	TDD	FDD	FDD	TDD	TDD
Payload bit/slot	5120	38936	4224	20496	5120	38936	4224	20496
RBW (KHz)	30 KHz	30 KHz	60	60	30 KHz	30 KHz	60	60
Sampling rate (MHz)	30.72	30.72 MHz	61.44	61.44	30.72	30.72 MHz	61.44	61.44

From Figure 6, spectrum analyzer in 16 QAM illustrate the spectrum with the same main loop width in QPSK with FR1 and FR2, side loop in 16 QAM with FR1 reach to -185 dBm and -175 dBm for PN15 and PN9 respectively, while reaching to -73 to -83 dBm in FR2. The gain which is the difference between the amplitude of main loop and side loop in dBm illustrated in Table 2, so the bandwidth of main, side loop where illustrated. Downlink FRC using PN15 -ITU FR1 vs FR2 with QPSK modulation. Using PN15, 9 -ITU FR1 vs FR2 with 16 QAM modulation.

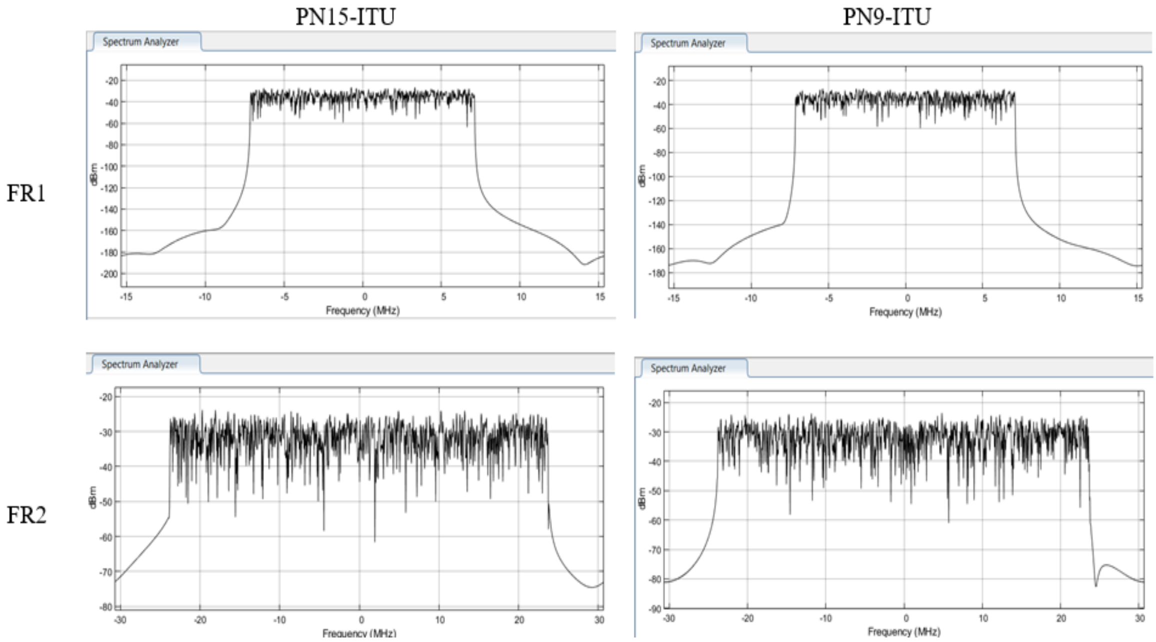

Figure 6. Downlink FRC using PN15, 9-ITU FR1 vs FR2 with 16 QAM modulation

Table 2. The gain in dBm

Source Code Length	PN9-ITU				PN15-ITU			
Frequency Range	450 MHz-6 GHz		24.25 GHz-52.6 GHz		450 MHz-6 GHz		24.25 GHz-52.6 GHz	
Modulation Type	QPSK	16 QAM	QPSK	16 QAM	QPSK	16 QAM	QPSK	16 QAM
Main Loop MHz	15	15	44	46	15	15	44	46
Side Loop MHz	15	15	16	14	15	15	16	14
Gain in dBm	155	48	50	55	135	155	65	140

4. CONCLUSION

The PDSCH implemented in MATLAB-Simulink with FRC specification of determining subcarrier spacing, Allocated source block, duplex mode, payload bit/slot, RBW (KHz), sampling rate (MHz), the gain and the bandwidth of main, side loop where illustrated, PN9 and PN15 source code used in FR1 and FR2 with QPSK and 16 QAM modulation schemes, determining subcarrier spacing, allocated source block, duplex mode, payload bit/slot, RBW (KHz), sampling rate (MHz), modulation approaches tested under AWGN in term of BER which used with 5G technology system, resulting of 1672, 12296 bit/slot payload at frequency range 1 from 450 MHz-6 GHz and 4424, 20496 bit/slot payload at frequency range 2 from 24.25 GHz-52.6 GHz, also determining subcarrier spacing, allocated source block, duplex mode, payload bit/slot, RBW (KHz), sampling rate (MHz), the gain and the bandwidth of main, side loop where illustrated. Specification of 5G-NR technology that have been determined in proposed paper approved that 5G NR main specification is enabling everywhere the connectivity of wireless communication, for anything and to anyone at any time.

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