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Analysis of BER , FER in the coexistence scenario of 4G LTE and 5G NR

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***Abstract*— The technology trend is progressing towards the sharing of the same spectrum by 4G and 5G mobile. The co-existance of 5G eMBB and 4G MBB spectrum needs to be placed cognitively to avoid Self Interference and side by side improving spectral efficiency. Dynamic spectrum Sharing DSS is useful (CR). The coexistence of 4G LTE and 5G New Radio (NR) gives a great opportunity in the real world. During the coexistence of these two signals, there will be chance of Interference of the signal. As a result, the reliability of the signal will be reduced due to interference. So in order to reduce the interference of the signal, the frequency of 4G LTE is kept fixed and that of 5G NR should be variable. It has been realized that when the frequencies of 4G LTE and 5G NR are equal, similar or same approximation value, then there will be BER and FER. Hence in order to reduce BER or FER, the frequency of 5G NR should be changed and kept in such a situation where there will be no BER or FER. Analysis of BER and FER indicates the reliability of the signal.**

Keywords*— *DRiVE, DSS, RAT, BER, FER, ESS

I. Introduction

The mobile communication technology for the next Generation is 5G Technology. In comparison to 4G, 5G technology provides huge capacity, faster data speeds having low latency, high reliability enabling for the smartness of industries, cities, vehicles etc. Pre 5G commercial products are already launched in few countries. In 2021, 5G products are to be spread globally. Both existing 4G mobile technology and new Radio Technologies (5G New Radio) are included in the future target.

Now days, Wireless technology has rapid development and its impact is much broader. It has the confirmation of both societal and individual benefits. The radio spectrums have much more increasing demand. But due to the smaller fixed range, there is a very limited range of spectrum which is not accessible for vast applications in wireless technology. Hence in order to make it accessible Spectrum Sharing is one such method which is being used to share the limited range of spectrum between different users. As result, the spectral efficiency of the wireless networks are increased. Dynamic spectrum access is one such method in which spectrum should be shared by two users' i.e. primary and secondary user.

Dynamic Spectrum Sharing (DSS) [1] is a technology in which both 4G LTE and 5G NR in the same frequency are deployed and allocation of spectrum resources between the two technologies based on user demand in a dynamic manner. Categorization of Dynamic Spectrum Access can be made under three models i.e. Exclusive use Model, Open Sharing model and Hierarchical access model. In the dynamic exclusive model, the spectrum bands are licensed to services for exclusive as in the current spectrum regulation policy but flexibility is introduced to improve spectrum efficiency. There are two approaches i.e. Spectrum property rights, dynamic spectrum allocation. In the spectrum property rights, licensees can able to sell and trade spectrum and choose the technology. The dynamic spectrum was brought forth by the DRiVE [3] (Dynamic Radio for Internet protocol services in Vehicular Environments) project located in Europe.

In the Dynamic Spectrum Allocation [4], allocation, the improvement of spectrum efficiency through the assignment of dynamic spectrum by exploiting the spatial and temporal traffic statistics of different services. In the Open sharing model, sharing among peer users for spectrum management is employed for the management of the spectral region. Users involved in this model draw support from the phenomenal success of wireless services operating in the unlicensed Industrial, Scientific and Medical (ISM) radio band (Wi-Fi). Under this spectrum management model, the centralized distributed spectrum sharing has been investigated. In the hierarchical access model, the hierarchical access structure with primary and secondary users are represented. There is an opportunity for the secondary users to use the licensed spectrum without interfering the primary users (licensees).

For the spectrum sharing between primary users and the secondary users, two approaches should be considered viz spectrum underlay and spectrum overlay[2]. The underlay approach imposes severe constraints on the transmission power of secondary users, so the operation below the noise floor of primary users. By spreading transmitted signals over a Ultra Wide Band (UWB) [5] frequency, secondary users can achieve short range high data rate with extremely low power. Spectrum overlay does not impose severe restrictions on the transmission power of secondary users but rather on when and where they may transmit. Spectrum overlay targets at spatial and temporal spectrum white space by allowing secondary users to identify and exploit local and instantaneous spectrum availability in non intrusive manner.

In the future 5G technologies, the user expectation is high. The expectation includes excellent performance from smart phones, improved performance levels from remote areas, usage of spectrum assets, utilization of each band's performance for business purposes etc. The new frequency bands specified for 5G are in mid and high bands. For wide area New Radio (NR) coverage, it is necessary to operate NR in lower frequency bands. Ericsson Spectrum Sharing (ESS) [6] provides the operators to execute LTE and NR simultaneously on the same carrier frequencies. The assignment of the time frequency resources at the millisecond level to the devices is done by the ESS. Here LTE devices experience a LTE cell and NR devices experience a 5G NR cell. ESS software allows dynamic spectrum allocation to 4G and 5G on the same band. Migration from 4G to 5G takes place by minimizing the impact on 4G as 5G which is being introduced in the same band. For 5G NR deployments, mid band (3.5 GHz) and high band (28 GHz -40 GHz) . The capacity loss takes place if the LTE and NR device does not match the fixed spectrum. ESS solves the problem by providing the devices of both Radio Access Technologies (RAT) to the entire carrier bandwidth which will superb the entire capacity of the system. With the help of ESS, migration from 4G LTE to 5G NR is becoming simpler, efficient and faster. Deployment of ESS makes the network more efficient. ESS is unique and game changing. ESS is easy and cost effective, make the best possible use of radio spectrum. In the future, ESS will bring 5G to everyone, everywhere and much faster.

In 3GPP, a decision has been taken that it is not necessary to remove LTE V2X when NR V2X will be launched. Hence there will be the coexistence of LTE V2X with NR V2X [7]. The basic safety mechanism is already applied in LTE V2X but the advanced driving mechanism which includes high connectivity and process of automation is applied in NR V2X. Selection of Radio Access Technology (RAT) is based upon V2X applications. The communication between two vehicles is possible with the help of LTE or New Radio (NR). In Release 16, there is a facility during the coexistence of NR V2X and LTE V2X. It is basically In Device coexistence for the management of Side Link resources. In this coexistence, there is a cooperation between two Radio Access Technologies (RAT) and it is said to be cross Radio Access Technologies. When two radio access technologies are integrated, the number of in-device coexistence challenges is created. In 3GPP,there arises a new term called Co-channel coexistence in which the two Radio Access Technologies i.e.NR V2X and LTE V2X are used concurrently in the same time or frequency. Due to this, the signal interference takes place. Release 16 does not support Co-channel coexistence. The cause of interference is due to the simultaneous transmission of signals over both LTE V2X and NR V2X. The interference is done by two Radio Access Technologies. Basically there is an occurrence of interference when both RATs are at same or nearly frequencies. There is a simultaneous utilization of two RATs. Due to the interference, vehicle cannot able to receive the data through Radio Access Technologies.

Organization of the paper and novelty of the research work

The authors have established as a contributory work. Here the total work has been done in software platform using SystemVue software simulation. Initially the circuit design has been established using SystemVue software given Article 2. The Article 2 specifies the circuit design using SystemVue software and the experimental procedure along with System requirements given in Table I. In the experimental procedure, the frequency of 4G LTE is fixed and the frequency of 5G NR is variable. The experimental results are mentioned in Article 3. After the execution, the spectrum is displayed which can be seen with the help of spectrum analyzer given in Article 3. Side by side, in Article 3, the values of BER (BER_BER), FER (BER_FER) are mentioned in Table II. Here two graphs are obtained by varying frequency with Bit Error Rate (BER) and Frame Error Rate (FER) given in Fig. 6 and Fig. 7. which indicates the analysis of BER and FER. In future, researcher can dedicate upon this analysis. Finally the summary and conclusion is mentioned in Article 4.

II. Design and Development of the Coexistence of 4G LTE and 5G NR

A. Circuit Diagram using Software Simulation:

The SystemVue software is utilized for simulation purpose. With the help of this software, coexistence of 4G LTE and 5G NR is designed. Fig. 1 show the coexistence of 4G LTE and 5G NR in which two spectrum analyzers are connected where the spectrum can be analyzed for both in 4G LTE and 5G NR.

Here there is a combination of both 4G and 5G . Here the frequency of 4G is kept fixed whereas the frequency of 5G should be changed.

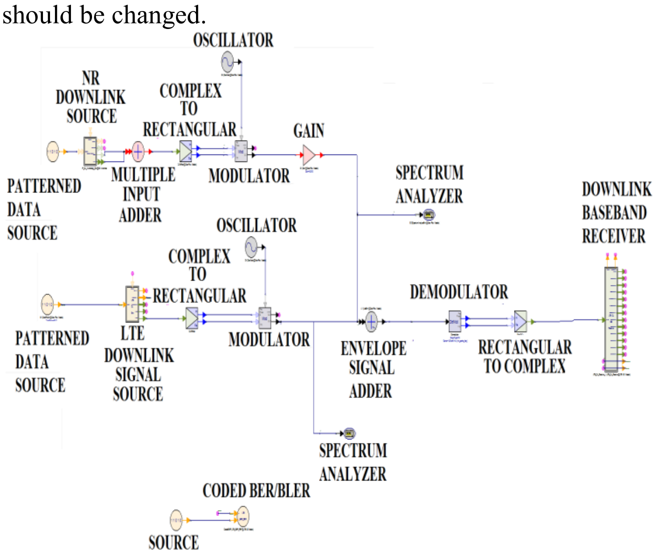

Fig. 1. Experimental Diagram for the coexistence of 4G LTE and 5G NR

B. Experimental Procedure:

The patterned data sources are required both for 4G LTE and 5G NR.

4G LTE: In case of 4G, the pattern data source is connected to LTE downlink signal source. From the source, the signals are being transferred to Complex to Rectangular where the signals are divided into two parts i.e. Real and Imaginary part. The real part is connected to In Phase and the Imaginary part is connected to Quadrature. Both In Phase and Quadrature are present in the Modulator. The carrier frequency of the modulator is set to 1.901 GHz. The oscillator frequency is also set to 1.901 GHz and it will be fixed. The oscillator is connected to the modulator. From the modulator, the modulated signal is emitted. The modulated signal is connected to the spectrum analyzer. In the spectrum analyzer, the spectrum analyzer, the spectrum signal is displayed. (Marked with Red color).

5G NR: The pattern data source is connected to New Radio (NR) downlink source. From the source, the signals are being divided. The divided signals are added with the help of Multiple Input Adder. These signals are being transferred to Complex to Rectangular where the signals are divided into two parts i.e. Real and Imaginary part. The real part is connected to In Phase and the Imaginary part is connected to Quadrature. Both In Phase and Quadrature are present in the Modulator. The carrier frequency of the modulator is set to 1.901 GHz. The oscillator frequency is ranging from 1.8950 GHz to 1.9068 GHz. The oscillator is connected to the modulator. From the modulator, the modulated signal is emitted. The modulated signal is connected to the constant gain having the value of 0.0012. This gain is connected to the spectrum analyzer. In the spectrum analyzer, the spectrum signal is displayed. (Marked with blue color).

In case of 4G and 5G, the requirements may be similar or different. Few parameters are mentioned in Table I.

TABLE I. 4G VS 5G

Serial No.	Requirements for 4G and 5G		
	Parameters	***4G***	***5G***
1	Source	LTE Downlink Signal Source	NR Downlink Source
2	Multiple Input Adder	NA	Applicable
3	Carrier Frequency	1.901 GHz	1.901 GHz
4	Bandwidth	5 MHz	50 MHz
5	Power in oscillator	-41 dBm	-41 dBm
6	Sampling Rate	15.36 MHz	15.36 MHz
7	Modulator Input Type	I/Q	I/Q
8	Cyclic Prefix	Normal	Normal
9	Constant Gain	NA	0.0012
10	Oscillator Frequency	Fixed	Variable

III. EXPERIMENTAL RESULTS

When the frequencies of both 4G and 5G are equal, similar or same approximation value, there will be the occurrence errors. These errors are both Bit Error Rate (BER) and Frame Error Rate (FER). So in order to reduce errors, the frequency difference between 4G and 5G should be large. It has been experimented and the different values for BER and FER are obtained with the change in frequencies given in Table II. Side by side, by the changing the frequencies in 5G, the different graphs for spectrum are obtained out of which four graphs are given in Fig.2, Fig. 3, Fig. 4 and Fig. 5. The Oscillator Frequency (f_1) for 4G LTE is set to 1.901 GHz and it is kept fixed. On the other hand the Oscillator Frequency for 5G New Radio (f_2) should be changed.

Case 1, If f_1=1.901 GHz, f_2=1.9102 GHz, then BER= 0 and FER=0

It is seen that when 5G New Radio (Blue in colour) and 4G LTE (Red in colour) have a large frequency difference between them, then there will be no signal interference as shown in Fig. 2. Due to the absence of signal interference, there will be no errors. As a result, in this stage the reliability of the signal will be increased.

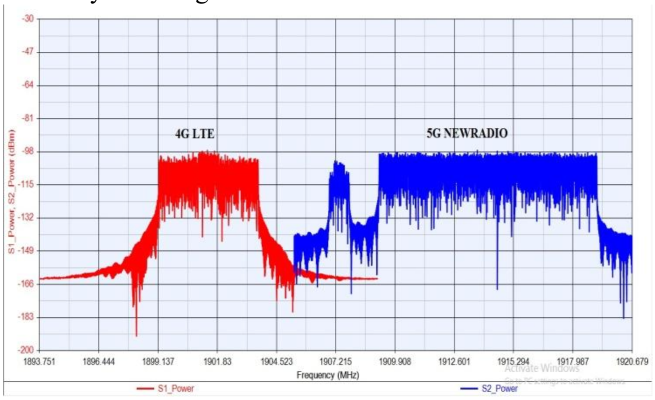

Fig. 2. Spectrum Analysis for the coexistence of 4G and 5G (f_1=1.901 GHz, f_2=1.9102 GHz)

Case 2, If f_1=1.901 GHz, f_2=1.892 GHz, then BER= 0 and FER=0

There will be the same effect as in previous case, hence there will be no errors as shown in Fig. 3. As a result, in this stage the reliability of the signal will be increased.

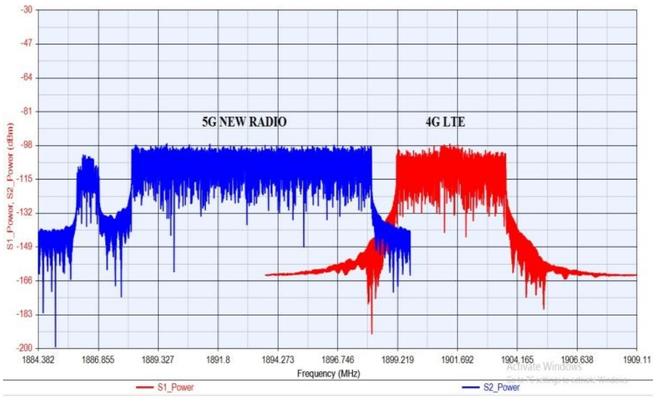

Fig. 3. Spectrum Analysis for the coexistence of 4G and 5G (f_1=1.901 GHz, f_2=1.892 GHz)

Case 3, If f_1=1.901 GHz, f_2=1.9 GHz, then BER= 0.202 and FER=1

It is seen that when 5G New Radio (Blue in color) and 4G LTE (Red in color) have similar frequency, and then there will be signal interference as shown in Fig. 4. Due to the presence of signal interference, there will be errors. As a result, in this stage the reliability of the signal will be decreased.

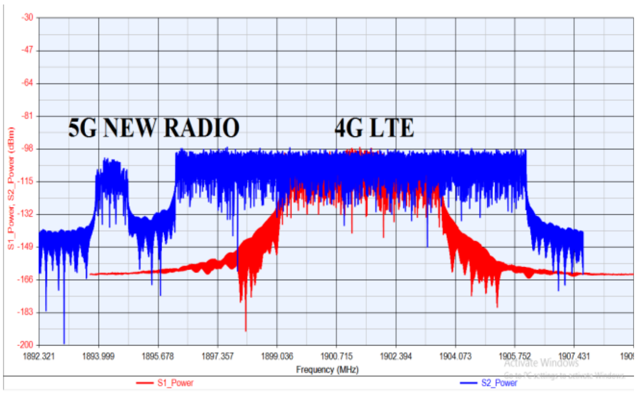

Fig. 4. Spectrum Analysis for the coexistence of 4G and 5G (f_1=1.901 GHz, f_2=1.9 GHz)

Case 4, If f_1=1.901 GHz, f_2=1.9034 GHz, then BER= 0.166 and FER=1

There will be the same effect as in previous last case, hence there will be errors. As a result, in this stage the reliability of the signal will be decreased.

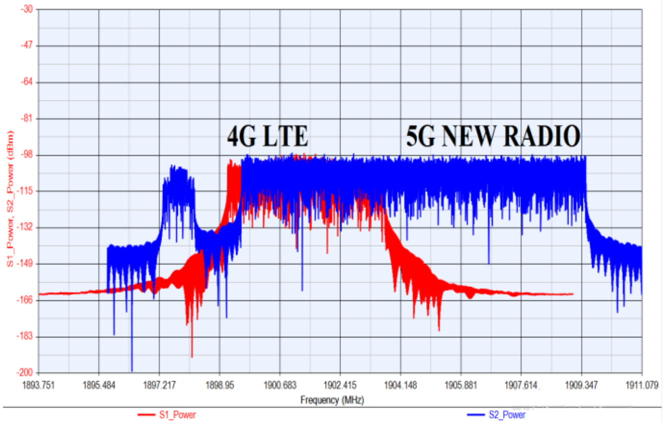

Fig. 5. Spectrum Analysis for the coexistence of 4G and 5G (f_1=1.901 GHz, f_2=1.9034 GHz)

From the above cases, it is clear that every researcher can able to estimate at which frequency, the reliability of the signals can be achieved during the coexistence of 4G LTE and 5G New Radio (NR). It is possible when Bit Error Rate (BER) and Frame Error Rate (FER) can be calculated by changing the frequency values in 5G New Radio (NR).

TABLE II. VARIATION OF FREQUENCY WITH BER(BER_BER) AND FER (BER_FER)

Serial No.	Frequency vs BER vs FER		
	Frequency(GHz)	*BER_BER*	*BER_FER*
1	1.8950	0	0
2	1.8952	0	0
3	1.8954	0	0
4	1.8956	0	0
5	1.8958	0.0002759	0.04
6	1.8960	0.005482	0.22
7	1.8962	0.014	0.32
8	1.8964	0.038	0.82
9	1.8966	0.071	0.88
10	1.8968	0.118	1
11	1.8970	0.143	1
12	1.8972	0.163	1
13	1.8974	0.185	1
14	1.8976	0.203	1
15	1.8978	0.202	1
16	1.8980	0.201	1
17	1.8982	0.197	1
18	1.8984	0.2	1
19	1.8986	0.2	1
20	1.8988	0.204	1
21	1.8990	0.198	1
22	1.8992	0.201	1
23	1.8994	0.199	1
24	1.8996	0.2	1
25	1.8998	0.203	1
26	1.9000	0.205	1
27	1.9002	0.201	1
28	1.9004	0.204	1
29	1.9006	0.202	1
30	1.9008	0.202	1
31	1.9010	0.207	1
32	1.9012	0.203	1
33	1.9014	0.207	1
34	1.9016	0.201	1
35	1.9018	0.2	1
36	1.9020	0.204	1
37	1.9022	0.201	1
38	1.9024	0.206	1
39	1.9026	0.199	1
40	1.9028	0.202	1
41	1.9030	0.204	1
42	1.9032	0.186	1
43	1.9034	0.166	1
44	1.9036	0.149	1
45	1.9038	0.123	0.98
46	1.9040	0.079	0.88
47	1.9042	0.055	0.74
48	1.9044	0.00963900	0.44
49	1.9046	0.00409300	0.2
50	1.9048	0.0029800	0.18
51	1.9050	0.0045440000	0.2
52	1.9052	0.0001380000	0.04
53	1.9054	0.0000919800	0.02

Serial No.	Frequency vs BER vs FER		
	Frequency(GHz)	*BER_BER*	*BER_FER*
54	1.9056	0	0
55	1.9058	0	0
56	1.9060	0	0
57	1.9062	0	0
58	1.9064	0	0
59	1.9066	0	0
60	1.9068	0	0

From the above table (Table II) , it is clear that the reliability of the signal can be achieved at which frequencies of the 5G New Radio (NR). Side by side, with the help of the table given above, two graphs are being drawn. In these two graphs of Fig. 6 and Fig. 7, used part and unused parts are highlighted. The used part mentioned with blue color box present in Fig. 6 and Fig. 7 denotes the part free of error and the unused part mentioned with red color box present in Fig. 6 and Fig. 7 denotes the part full of error. These highlighted part shows that where the reliability of the signal can be achieved. Hence in future, every researcher can able to estimate which part can be utilized. Side by side, these two figures show that the in the used part, there are no BER (BER_BER) or FER (BER_FER). But in the unused part, at a specific stage, when the frequency of 5G NR reaches near the frequency of 4G LTE, there will be the serial increase in BER and FER. After a certain stage, when the frequency of 5G NR comes more nearer the frequency of 4G LTE, the BER and FER will reach the maximum value. The value of BER becomes approximately 0.2 and the value of FER becomes 1 and it will remain fixed until the frequency value of 5G NR is nearer to 4G LTE. In this stage, the unreliability of the signal is indicated. When the difference between their frequencies will increase, the value of BER and FER will start to decrease. As a result, the reliability of the signal will increase. After a certain stage, when the difference between 4G LTE and 5G NR becomes large, then there will be no BER and FER. As a result, the reliability of the signal will increase. Hence the graph given in Fig. 6 and Fig. 7 , the used part is indicated.

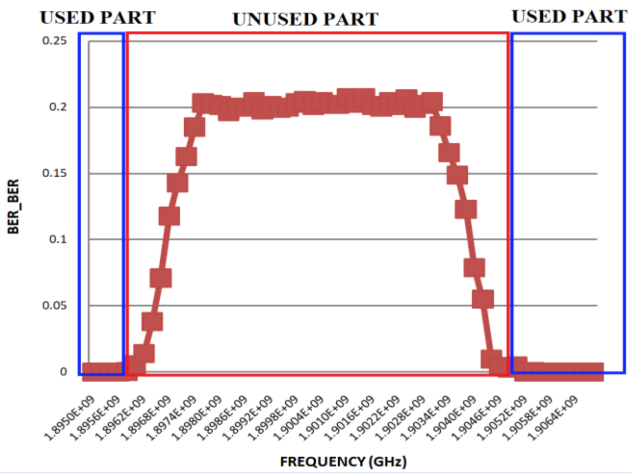

Fig. 6. Frequency vs BER (BER_BER)

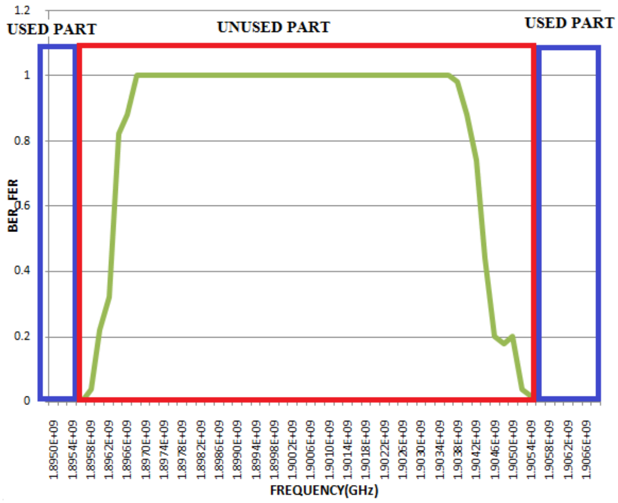

Fig. 7. Frequency vs FER (BER_FER)

IV. SUMMARY AND CONCLUSION

The coexistence of 4G LTE and 5G NR shapes a new area or opportunity. SystemVue software is one of the reliable software with the help of which the circuit design is possible. Now days, the real world is dedicated upon the problem of interference and the researchers want to solve it. Many organizations in the world had invested huge expenses for the construction of 4G LTE technologies. In 2020, the 5G technologies already launched. It has been imagined that while launching 5G technologies, if 4G technologies will be totally removed, then the organizations will face a great loss in their business strategy. So in order maintain the business strategy, 5G technologies will be constructed by keeping the existing 4G technologies. Hence the concept of the coexistence of 4G LTE and 5G NR is existing in the world. The problem of interference is due to the coexistence of 4G LTE and 5G NR. Side by side, the researchers also think about the launching of 5G technologies without removing 4G. So to fulfill these, a circuit has been developed using SystemVue software where the presence of both 4G LTE and 5G NR has been illustrated. Side by side, the requirements for 4G and 5G should be followed to establish the design. The frequency of 4G LTE is kept fixed at 1.901 GHz whereas the frequency of 5G NR is always changing and it is ranging from 1.895 GHz to 1.9068 GHz. The spectrum analysis diagram is mentioned where both 4G LTE spectrum (red in color) and 5G NR spectrum (blue in color) are present. It has achieved that how the Bit Error Rate (BER) and Frame Error Rate (FER) have been obtained by varying the frequency of 5G NR. Hence the reliability or unreliability of the signal can be estimated by varying the frequencies in 5G NR. The values of BER and FER are possible with the help of data analysis. The variation of frequency with BER and FER is specified in the Table II and illustrated in the two graphs given in Fig.6 and Fig. 7. This experiment denotes the reliability and unreliability of the signal at different frequencies in 5G NR. In these two graphs, the used part and unused part are specified so that researchers can proceed for their future work. As a result, the coexistence scenario of 4G LTE and 5G NR will be successful. Side by side, this graphical diagram also is helpful which shows clear illustration. The change in frequency present in 5G NR is done in manual mode. In future, this experiment should be done in hardware platform in which more accurate results should be obtained. Side by side, this operation will be done by following the process of automation. Our future work is dedicated upon the Dynamic Spectrum Sharing (DSS).

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