Contributions to TV 3.0 using 5G-MAG Reference Tools

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Abstract— **The evolution of the evolved Multimedia Broadcast Multicast Service (eMBMS) to the Further evolved Multimedia Broadcast Multicast Service (FeMBMS) in Release 14 of 3GPP enabled broadcast transmission in a format 100% dedicated to user devices. As a result, the 5G standard for cellular networks expanded and began to be quoted in the broadcasting sector as 5G Broadcast. This standard is one of the quoted ones to integrate the TV 3.0 architecture in Brazil, being responsible for the physical layer. To be possible, this technology must meet some requirements, such as negative noise carrier ratio, MIMO antennas and channel bonding. To complement the tests conducted by the SBTVD Forum, this paper aims to evaluate and discuss the SNR and minimum signal level tests using an Open-Source receiver called 5G-MAG that is managed by the group of the same name. The tests were carried out using a Universal Software Radio Peripheral (USRP) Software Defined Radio (SDR) reproducing I/Q file with 5G Broadcast data with a bandwidth of 6MHz, the width of interest of the Forum, to transmit the signal via GNU Radio software and another USRP SDR as a receiver, having as interface the 5G-MAG.**

Index Terms—**5G-Broadcast, TV 3.0**

I. INTRODUCTION

Linear TV has a prominent role in Brazilian society. According to a study called "Inside Video 2022" conducted by Kantar IBOPE Media, a global leader in media intelligence, the reach of linear TV arrived 93% of the Brazilian population in 2021, with a dedication of 79% of the time in open TV stations. and 21% on video platforms [1]. These data are important, as they encourage interest in modern technologies around broadcasting in the country. Digital TV in Brazil is undergoing a process of evolution, which has been called TV 3.0. A disruptive evolution with improvements in image definition and processing, in addition to audio. 5G Broadcast was one of the standards evaluated at the physical layer and will be analyzed in this article. As the name suggests, the standard uses the fifth evolution of the mobile network for linear TV broadcasting. This feat is possible using a feature called Further evolved Multimedia Broadcast Multicast Service (FeMBMS) released in Release 14 of LTE and which allows up to 100% dedication to broadcast and multicast services. The proponents responsible for presenting this standard to the SBTVD Forum's Call for Proposals were Qualcomm, Rohde & Schwarz, and Katherin [2]. An open-source solution is managed by the 5G Media Action Group (5G-MAG) [3]. This group is an independent, non-profit association whose objective is to be a bridge between the media sectors and the ICT (information and communication technology) industries. They manage a range of tools called 5G-MAG Reference Tools that aim to receive 5G broadcast transmission in dedicated mode, as specified in Release 14 and 16 of 3GPP; combine transmission with mobile broadband, with the possibility of switching modes and developing interactive applications. The receiving system has three interfaces, the MBMS modem, middleware, and a web interface. The last two are optional unless the media content to be received is in HLS format. The system can be configured using two SDRs, one to transmit the content played by GNU Radio and the other to receive the content (see Fig. *1*).

Fig. 1. Representation of the test setup used in the laboratory.

This paper aims to discuss the results of SNR and minimum signal level tests and to evaluate the performance of the open-source receiver.

Based on the above, this paper will be organized as follows: Section II will present the theoretical framework that provides the basis for the investigation; Section III will describe the materials and methods involved in the tests; Section IV will present the performance evaluation and comparison with the SBTVD Forum test results for TV 3.0 and conclusions are drawn in Section V.

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II. TECHNOLOGY OVERVIEW

A. TV 3.0

TV 3.0 is the name given to the new open TV project, already in its final testing phase, which aims to replace the current model, SBTVD, which is currently in transition to TV 2.5. Its development is being led by the SBTVD Forum together with the Brazilian Ministry of Communications. TV 3.0 will bring new high-tech experiences to Brazilian homes. The SET's TV 3.0 Working Group [4] cites interactive services such as multi-angle camera service, which allows the viewer to watch a certain scene with a specific camera view; TV social service, which provides interactivity between people in a chat room; Emergency Warning Broadcast System (EWBS), as the name suggests, is an emergency information service that consists in making the viewer aware of the importance of the message and how to proceed; multi-language hidden language service, this service offers the possibility of inserting subtitles in another language via the internet; and sign language animation service that enables the insertion of other services for hearing and visually impaired people. The TV 3.0 architecture proposed by the SBTVD Forum is seen in Fig. *1*Fig. 2.

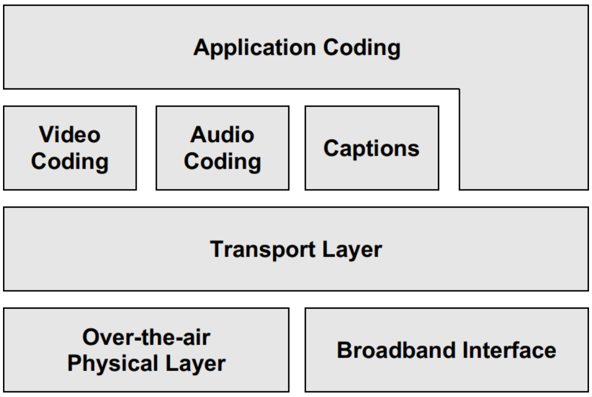

Fig. 2. TV 3.0 Architecture [2].

The system considers two complementary delivery methods: over-the-air and Internet. The physical Internet access interface (broadband interface) is outside the scope of the TV 3.0 system definitions and is considered any IP-based, bidirectional broadband access interface. From the architecture shown in Fig. 2, one can say:

The over-the-air physical layer comprises the unidirectional transmission modulation/ demodulation scheme and error correction. The transport layer comprises the multiplexing and transport of video, audio, subtitles, and applications, as well as all necessary metadata. The application coding in TV 3.0 includes, in addition to the interactivity and broadcast-band integration functions, handles the presentation of all audiovisual content. The audio, video, and subtitle encoding are self-evident and are responsible for the treatment of video, audio, and subtitles in transmission and reception. The intention of the third generation of Brazilian terrestrial television is to bring together the best of the current broadcasting technologies. Each block shown in the architecture of Fig. 2 was subject to proposals for evaluation by the SBTVD Forum. The over-the-air physical layer is the flagship of this work. For TV 3.0 this layer should, in principle, be deployed in the bands currently allocated to digital terrestrial TV in Brazil (VHF and UHF), using the 6 MHz channel bandwidth and should coexist with adjacent ISDB-T channels for a long time without mutual interference. Another specification is frequency-1 reuse, i.e., the use of the same RF channel by independent stations covering adjacent service areas. Such a feat would provide great flexibility for the transmission network, which could be freely expanded and subdivided using the same channel. It would also increase the resilience and robustness of the network. Transmission of the reuse frequency requires $C/N \leq 0$ dB. Taking advantage of this robustness, the new physical layer is also intended to target external mobile and fixed internal mobile reception with the same signal with a single modulation, coding and quality while maintaining the current network topology so as not to increase the cost of signal distribution. Another specification is the use of MIMO antennas, such antennas and Channel Bounding increase the channel capacity to compensate for $C/N \leq 0$ dB in a Rayleigh channel which implies a very limited channel capacity. Another feature needed for the TV 3.0 physical layer is to carry a "wake-up" signal (to turn receivers on stand-by) in case of an emergency warning. Finally, it should be noted that the physical layer must allow for future extensions.

B. 5G Broadcast

5G Broadcast is a candidate technology for the TV 3.0 physical layer. It enables broadcast, i.e., point-to-multipoint transmission, and can operate in receive-only mode without the need for SIM cards and network subscriptions. This system can operate in the same band used for terrestrial broadcasting services, it is important to note that 5G broadcast is different from 5G mobile, 5G defines two modes of broadcast communication, standalone and multicast in mixed mode. 5G broadcast is in standalone mode, while the other mode contemplates 5G New Radio (NR). The transmission of 5G Broadcast is conducted by broadcasters, the advantage is that cell phones with 5G can receive the 5G broadcast signal. With the 5G spectrum auction taking place in Brazil in 2021, 5G Broadcast would add value to traditional TV broadcasting, offering additional functionalities and applications and contributing to an efficient distribution of the TV signal to mobile users in the country.

5G Broadcast has been incorporated into Release-14 of 3GPP. The study of EnTV (Enhanced TV) has opened up the opportunity for broadcasters to offer all their services - linear and non-linear to 3GPP devices, enabling broadcast capabilities within the 3GPP system itself.

According to Barquero [5] the European Broadcasting Union (EBU) has coordinated all activities regarding broadcasters' involvement in 3GPP. In Release-15 [6] the emphasis was on the possibility to dynamically switch between unicast, multicast and broadcast modes in order to respond to varying demands, for example as a consequence of varying user distributions and simultaneous service requests. Transmitter site-to-site distances, even beyond, must be considered to cater for very large coverage areas, as well as dedicated modes to support mobile MBMS services up to 250 km/h.

For [7] and [8] the main improvements to the eMBMS system architecture introduced in EnTV are:

- \- A receive-only device mode to allow the transmission of free-to-air content that can be received by all devices, including devices without uplink capabilities, SIM cards or 3GPP network subscriptions. A specific application of this mode is to allow the transmission of free-to-air content on eMBMS.

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- A transparent (transport/pass-only) delivery mode for using the eMBMS network as a content delivery platform that allows reuse of broadcast services without decoding, ensuring backward compatibility and minimal effort to migrate from legacy systems. It allows, for example, the use of MPEG-2 Transport Stream (TS) over IP. This mode has been added so as not to limit the supported TV formats to the standardized 3GPP media layer services.

The main enhancements to the eMBMS Radio Access Network introduced in EnTV are:

- Dedicated carriers with up to 100% allocation of broadcast content without any resources allocated for unicast and autonomous system information and synchronization signals.
- New subframe type without unicast control region to reduce signaling overhead in downlink-only eMBMS transmissions.
- Shared broadcast networks where different operators can aggregate their radio access networks and MBMS to create a common distribution platform, avoiding the transmission of the same broadcast content on multiple networks; and
- - Support for longer inter-site distances in SFN with a new OFDM numerology.

[5] discusses this topic in depth.

[9] presents two cases of open source 5G receivers using SDRs.

III. MATERIALS AND METHODS

A basic telecommunications system consists of something that transmits the message and something that receives it, and the medium that is the communication channel. The equipment used is shown in TABLE 1

Table 1. List of the equipment used.

1	PC Core i7, ninth generation, 16GB RAM (RX)
1	PC Core i7, 12th generation and 16GB RAM (TX)
1	USRP UHD Ettus B200 (TX)
1	USRP UHD Ettus B210 (RX)
1	Variable Attenuator Model 50DR-001
1	NOD 5200 Noise Generator - Micronetics
1	Anritsu MS8901A Spectrum Analyzer

The I/Q files for transmission are available on the 5G-MAG Github [10]. All files share the same characteristics of cyclic prefix (1.25 kHz), MCS16 (16QAM) and differ in bandwidth, with 3, 5, 6 MHz. From the tests performed by the SBTVD Forum [11] these configurations did not obtain negative C/N, which is one of the requirements for the new TV system in Brazil. This requirement was partially achieved with MCS3 and MCS2 values. Although TV 3.0 requires MIMO, 5G-MAG supports only SISO.

To transmit the RF signal on the SDR the open-source software GNU Radio that provides signal processing blocks for implementing radio and digital processing systems was used. Channel 37 which occupies the UHF band from 608 MHz to 614 MHz was used to transmit the data to the receiver. The 5G-MAG receiver consists of up to three interfaces depending on the payload to be received. If the payload contains DASH (Dynamic Adaptive Streaming over HTTP) or HLS (HTTP Live Streaming) content, then there is a need for MBMS Middleware, otherwise there is no need and the content can be viewed by another application, such as FFMPEG or VLC. The MBMS Modem is the head and can operate either automatically or manually via commands. The Webinterface is optional, but it shows the constellations and other data, such as the type of bandwidth used and the gain of the receiver. The transmit and receive setup has been validated and no errors have occurred. Fig. 6 shows the receiver interface, it displays the current SDR, synchronization and constellations settings of PDSCH, PMCH and services.

1) SDR: This field provides information about the interface device settings.

I. *Frequency: is the system's operating frequency.*
II. *Gain: indicates the receiver gain.*
III. *Antenna: indicates which input of the SDR is being used.*
IV. *Sample rate: indicates the sample rate.*
V. *Filter BW: indicates the size of the bandpass filter; and*
VI. *Buffer Level: indicates the System buffer level.*

2) SYNC: Displays data regarding system synchronization. The features are:

I. *Status: indicates the synchronization status.*
II. *CFO (Carrier Frequency Offset): indicates the size of the frequency offset to achieve synchronism.*
III. *Cell ID: Cell ID.*
IV. *PRB (Physical Resource Block): is the smallest provisioning unit in an LTE frame and differs with bandwidths.*
V. *Width: indicates the bandwidth used.*
VI. *Subcarrier Spacing: indicates the spacing between the carriers; and*
VII. *CINR (Carrier to Interference Noise Ratio): is a measure of signal effectiveness, the higher the level, the better.*

3) PDSCH (Physical Downlink Shared Channel): This is the downlink data channel for the users. The more concentrated the points are, the better the reception of the

4) PMCH (Physical Multicast Channel) (MCCH, Multicast Control Channel): Control channel, does not need high rates, so MCS2.

5) PMCH (MCH 0): Transport channel, MSC16, constellation 16QAM.

6) Services: shows the information regarding the transmitted services.

All constellations show bit error rates and block errors.

B. Least Signal Level test versus Gain of the 5G-MAG Receiver

The minimum signal level test is intended to evaluate the reception sensitivity of the 5G-MAG. The transmitter signal level was set at -30 dBm, and the receiver gain varied from 10 to 50 dB, with a 5 dB interval. The I/Q files used were 3, 5, 6 MHz. The TOV (Threshold of Visibility) was taken as the 1 dB level above the point where artifacts occur in the image, observed on the TV. The setup used is shown in Fig. 3. For the transmission setup a GNU Radio flow Graph was used, to which the channel, TX gain and I/Q file was set. The attenuator 50DR-001 has an accuracy of 1dB, the spectrum analyzer was used to check the signal level when the video

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started to show artifacts on the screen. The video time to validate the configuration was 1 minute. The receiver was configured in manual mode, i.e., controlled via commands in the Ubuntu terminal.

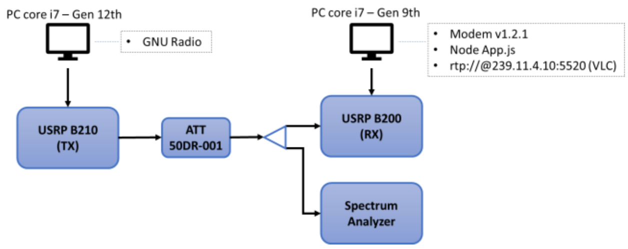

Fig. 3. Setup of the minimum signal level test.

C. *C/N test*

In addition to the minimum signal level test, the C/N test is important, because digital TV depends on other factors to work without interruptions, the signal level alone is not enough. The current SBTVD system uses a carrier/noise threshold of 19dB [12]. The purpose of this test is to find out this threshold for TV 3.0.

The transmitter signal level was set to -30 dBm, and the receiver gain to 20 dB. The I/Q files used were 3, 5, 6 MHz. The TOV was considered to be the level 0.1 dB above the point where artifacts occur in the image, observed on the TV. The setup used is shown in Fig. 4. In the transmission setup a GNU Radio flow Graph was used, to which the channel, TX gain and I/Q file was set. The NOD 5200 noise generator has an accuracy of 0.1dB, and has three levels of accuracy, tens, units, and hundredths. The control was made to change the values in the higher levels and taper off as the transmission image presented artifacts. The spectrum analyzer was used to fix the signal level. The video time to validate the configuration was 1 minute. The receiver was configured in manual mode, i.e., controlled via commands in the Ubuntu terminal.

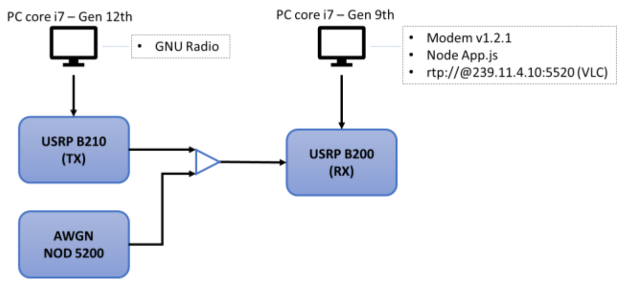

Fig. 4. Setup for the C/N test.

D. *C/N test versus Gain of the 5G-MAG Receiver*

The test setup is like the C/N test (see Fig. 4), the band chosen was 3MHz, as it was the configuration that was currently running. The transmitter signal level was set at -30 dBm, and the receiver gain varied from 10 to 50 dB, with a 5 dB interval. The TOV was considered to be the level 0.1 dB above the point where artifacts occur in the image, observed on the TV. The video time to validate the configuration was 1 minute. The receiver was configured in manual mode, that is, it was controlled via commands in the Ubuntu terminal.

IV. RESULTS AND COMMENTS

The C/N versus receiver gain test was performed first to have a basis for the other tests. Although Fig. 5 shows an increasing trend, there was inconsistency of values. The best receiver setting was G = 20 dB. In this setting the signal synchronized quickly. The gain set at 50 dB did not get a good response, with the image freezing even without noise.

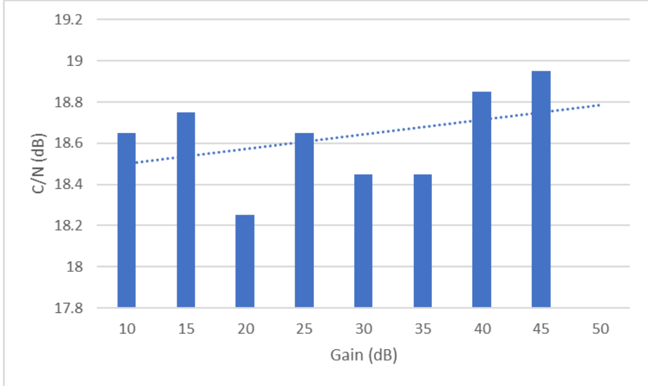

Fig. 5. C/N with different gain values in the 3MHz band receiver.

For the minimum signal level test (see Table 2) the average system margin was -80.5 dBm for the 3MHz band, -75.7 for the 5MHz band, and -65.8 for the 6MHz band. The best sensitivity occurred with the 45 dB gain.

Table 2. Result of the minimum signal level test.

	BW (MHz)		
Gain (dB)	3	5	6
10	-59,87 dBm	-61,9 dBm	-63,0 dBm
15	-67,17 dBm	-64,08 dBm	-63,2 dBm
20	-67,32 dBm	-64,40 dBm	-63,71 dBm
25	-67,25 dBm	-65,96 dBm	-65,81 dBm
30	-68,79 dBm	-67,06 dBm	-68,62 dBm
35	-77,58 dBm	-73,18 dBm	-72,19 dBm
40	-79,63 dBm	-76,50 dBm	-73,08 dBm
45	-80,5 dBm	-78,38 dBm	-78,08 dBm
50	-	-75,66 dBm	-75,70 dBm

The C/N test showed that the carrier-to-noise ratio was very close to the threshold in effect in the current transmission system which is 19dB. Figures Fig. 6 and Fig. 7 show the receiver interface without and with AWGN noise, respectively. The CINR value depicts what is seen in the constellations. Fig. 7 shows no BLER and BER errors in any of the constellations. However, it is important to note that the C/N≤0 condition was not observed in any of the tests, indicating that the system does not match the SBTVD Forum requirements for TV 3.0.

Table 3. Results of the C/N test.

BW (MHz)	C/N (dB)
3	18,25
5	19,24
6	18,60

Table 4 and Table 5 present the results obtained by the SBTVD Forum during the second phase of tests using the 5MHz band. Table 4 brings the results of the C/N test for VHF channels 7 and 10 and UHF channels 14, 33 and 51 with signal level of -28dBm. Analyzing the data in Table 4 with the tests performed in this paper, it is evident that the bit rate of the MCSs has an impacting factor on the C/N, the higher the modulation order, the more susceptible to errors the

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system becomes, this demonstrates that 5G Broadcast is not a robust system. Table 5 presents the minimum signal level values for the 5MHz band. The tests done by the SBTVD Forum for the 5MHz band resulted in -83.9 dB for the field tests [13] and -98.5 dB [11] for the laboratory tests.

Compared to the test in this paper the receiver used by the Forum had a sensitivity of more than superior to the 5G-MAG used in this paper, this indicates that both receivers are sensitive to signal variations, with the receiver used by the Forum being more sensitive than the 5G-MAG. The sensitivity of the receiver is important, since the medium used by radio transmitters is air, and air is susceptible to various sources of noise, which degrade the signal.

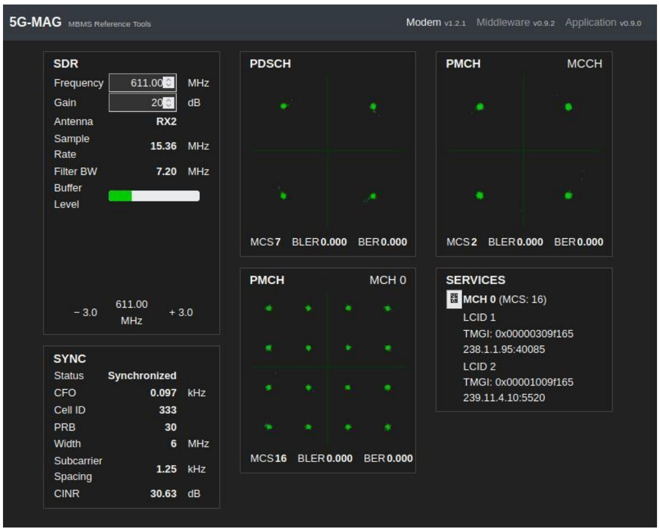

Fig. 6. Signal reception in the absence of noise for BW = 6MHz.

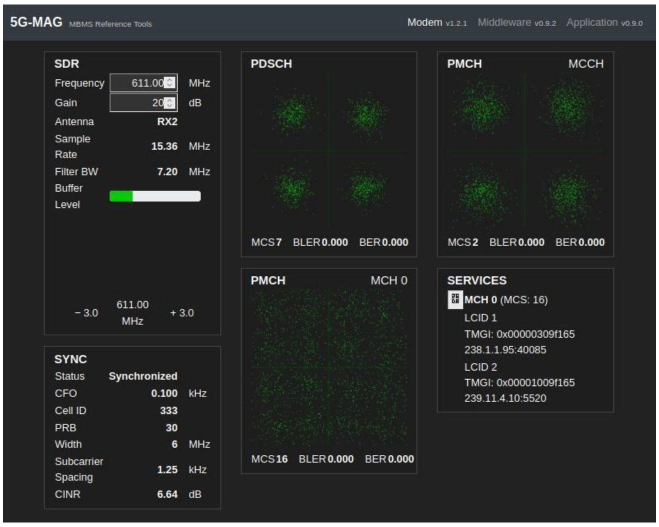

Fig. 7. C/N test at the reception threshold for BW = 6MHz.

Table 4. C/N test done by the SBTVD Forum using BW = 5MHz.

CH	C/N			
	MCS2	MCS3	MCS4	MCS9
7	0,1	0,00	0,10	4,50
10	0,2	-0,10	0,10	4,60
14	-0,1	0,00	0,00	4,70
33	0,2	-0,20	0,10	4,80
51	0,1	-0,10	0,30	4,60

Table 5. Receiver Minimum Level for SISO Configuration done by SBTVD Forum using BW = 5MHz.

CH	Min. Level Signal (dBm)
7	-98,7
13	-99,0
14	-98,2
33	-98,3
51	-98,6

V. CONCLUSIONS

The receiver does not have an automatic gain control, and although the webinterface presents a method for varying this characteristic, it does not work, because when changed the modem abruptly stops. This could be a point of improvement to the system. Another feature to be improved is the synchronization, sometimes the receiver cannot synchronize and locate the channel, being necessary to run the application several times for this to happen. Considering that TV 3.0 is a disruptive system, the fact that the 5G-MAG receiver is open-source contributes to the easy adhesion by the industry, which will have to change devices when this new system starts to be implemented in 2024. In 2023 phase 3 of the TV 3.0 trials will begin, and if 5G Broadcast can meet the requirements of TV 3.0 it is expected that this system will enter commercial operation in 2025. The fact that this receiver can operate in other bands is a positive point, and this feature is provided for in the Forum requirements, however, more importantly, the negative C/N and operability using MIMO have not been met, even for low MCS numbers. The use of MIMO is not contemplated by 5G-MAG/ 5G Broadcast. Further testing can be done, provided there is a configuration that meets the negative C/N.

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