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Design and Simulation of Ground Station (GS) Television Channel (TV CH) Group

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Abstract: The Multiple Channel per Carrier (MCPC) is considered an efficient alternative when used in Ground Station (GS) TV channel stations as it accommodate multiple channel on a limited frequency range. The MCPC technique has been widely used worldwide due to its efficiency. The MCPC technique offers exemplary performance over the traditionally Single channel Per Carrier (SCPC) when considering system accuracy, time, and cost. In this study, the MCPC static mode technique has been investigated using MATLAB tool to simulate a four TV CH system. The GS transmitter and receiver components referenced to four explicit points representing the number of channels carried by the satellite. These components have been constructed and observed using Spectrum Analyzer.

Keywords: ground stations, satellites, path loss, MCR, CHTV.

INTRODUCTION

The Multiple Channel per Carrier (MCPC) communication technique offers an efficient alternative to be used in the Ground Station (GS) broadcasting TV channel stations. It has been widely used worldwide. The MCPC is a frequency division multiple access (FDMA) technique. It is considered a suitable alternative when stringent frequency budgets exist which is very typical situation in developing countries. The MCPC technique is advantageous when it comes to data rate flexibility to maintain broadcast quality [1].

In this study, the MCPC static mode technique has been investigated using MATLAB tool to simulate a four channel TV CH system. The GS transmitter and receiver components referenced to four explicit points representing the number of channels carried by the satellite. These components have been constructed and observed using Spectrum Analyzer.

Chavan and Jadhav[2] have reported on successful implementation and simulation of digital video broadcasting-satellite (DVB - S) channel coding and decoding using MATLAB. The implementation of channel coder and decoder and simulations results were in agreement with modulation error rates (MER). It was found that simulation errors were attributed to finite data length as opposed to continuous data streams in real digital television broadcast.

Colavolpe et. al. [3] have studied the achievable rates by single user in multi-beam satellite scenarios. The authors have addressed the problem of multiple user detection in the forward link of a multi-beam satellite system in the presence of strong interference in the common channel. An alternative technique for a single user discovery with strongest interference signal is treated. The authors reported that the technique can greatly increase the achievable rate but at the expense of higher computational complexity. S. Cioni et. al. [4] have studied 2nd generation satellite digital video broadcasting (DVB-S2) with a goal of improving spectral efficiency.

The authors have addressed the problem of optimizing user bandwidth taking into account realistic satellite broadcasting channel. On the receiver side two different demodulation techniques were compared. It was found that there was a slight independence from the selected roll-off value. The attainable gain in the spectrum efficiency was about 8% to 10% by optimizing user bandwidth and by choosing proper equalizer. Also, the impact of increased user bandwidth in terms of the output multiplexer OMUX dissipated power and found insignificant to the technology used in the study. The digital modulation (dvs2 (8QPSK)) and the area of the channels are included in the mathematical modeling, while transmitter and receiver aspects were not considered.

Moreover, the relocation strategy where the signals serving two user packages in implemented using the time division multiplexing (TDM) method. It was shown that this approach is effective at low signal-to-noise ratio. The resolution shape in the image and the number of the channel in the frequency space being higher or less were not considered.

The market for satellite communication within African countries has been investigated by multiple researchers. It has been reported by P. Galace [5] that all the indicators are pointing towards a vibrant market for satellite services for Africa. The risks for these markets are the danger of overcapacity and over regulation.

However, if the African region was left to normal market forces it should be a good market to invest in. Nevertheless, many African countries are struggling to catch up and fully utilize satellite communications to its fullest capacity. For example, the Sudan which is a sub-saharan country with a vast area over 1.8million square kilometers, and a population of 43million (2018 estimate) represent a good study case to investigate to highlight some of the issues and difficulties. The Sudan population is dispersed over the wide area of land that necessitate effective communication links to accomplish wide coverage while attain cost effectiveness. The Sudan has a satellite broadcast station directed to the satellite Arabsat with a MCPC system. The Sudan is reserving a transponder on the satellite that pack these channels together. However, the station operates less efficiently in the participation of national channels due to shortage of operating and supporting equipment. Moreover, personnel expertise often degrades due to infrequent freshen up and regular trainings and workshops. Also, the system lacks effective marketing skills and programs in hosting channels from outside the system.

1. GROUND STATION (GS) DESCRIPTIOPN

Ground station (GS) is a vital component of any space communication network. The function of a GS is to transmit and receive information through satellite network in the most cost-effective and reliable manner while maintaining the required signal quality. Depending on the terrestrial application, the GS may include both transmit and receive capabilities. Alternatively, GS may include either transmit or receive capability. Fig. 1 shows MCPC system with video, audio, and data channels that can be multiplexed into a digital stream and transmitted via satellite antenna to the receiving end. Fig. 2 shows detail of the MCPC transmitter side.

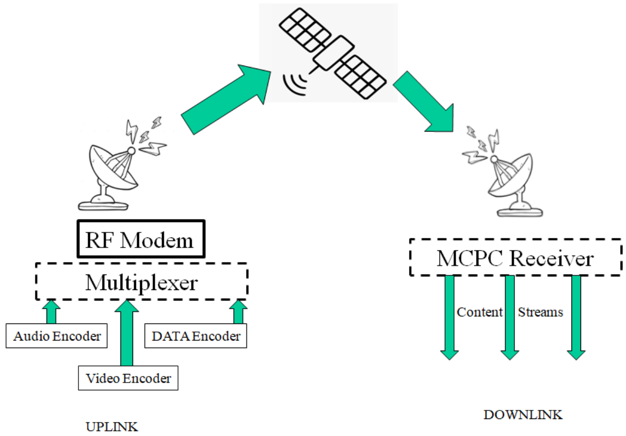

Fig .1. Multiple Channels per Carrier with 3 Channels.

Additional classification depends on the type of provided service, or on the operating frequency according to the signal path. This is determined by the International Telecommunication Union. The basic parameter that describes a GS performance is the carrier to noise ratio [6].

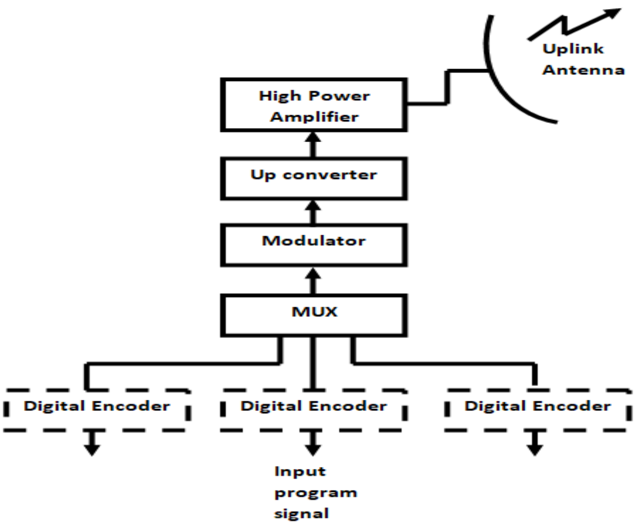

Fig .2. Multiple Channels per Carrier Transmitter Side

The design considerations of a GS depend on a number of factors such as[7]:

- Type of service:
  - fixed satellite service,
  - mobile satellite service or
  - broadcast satellite service
- Type of communication requirements: telephony, data, television etc.
- Required baseband signal quality at the destination.
- Traffic requirements:
  - number of channels,
  - type of traffic: continuous or bursty
- Cost
- Reliability

Any GS consists of four major subsystems:

- Transmitter,
- Receiver,
- Antenna,
- Tracking equipment

Two other important subsystems are [6]:

- Terrestrial interface equipment
- Power supply

The GS performance depends on several parameters which include transmitter power, choice of frequency, antenna gain, efficiency, pointing accuracy, noise temperature, polarization, propagation losses, and local conditions such as wind, weather, etc… conditions such as wind, weather etc.[7]

Digitally transmitted signals are usually represented in binary digits (0's and 1's). When the signal is received from terrestrial network it then enters the GS to be processed by the base band equipment. Initially, the GS encoder performs an error correction step to reduce error rate through introduction of inserting extra digits into the digital stream generated by the base band equipment. These extra digits carry additional information which is transmitted during modulation. The noise and non-ideality factors associated with the communication channel are evaluated and the resulting error rate is then recorded. Any information received above the recorded noise level is considered unstable.

The modulator function is to accept the symbol stream from the encoder and use it to modulate an intermediate frequency (IF) carrier. In satellite communication, the IFs are used rather than RF frequencies for three main reasons. At very high (gigahertz) frequencies, signal processing circuitry performs poorly. Active devices such as transistors cannot deliver much amplification. Ordinary circuits using capacitors and inductors must be replaced with cumbersome high frequency techniques such as striplines and waveguides [7]. The IF carrier frequency is chosen as follows:

- 70 MHz for communication using a 36 MHz transponder bandwidth
- 140 MHz for a transponder bandwidth of 54 or 72 MHz.

The IF is needed to be at low frequency to avoid needing to design a modulator for the uplink frequency range of 6 GHz (or

14GHz). The modulated IF carrier is fed to an up-converter and frequency-translate it to the uplink RF frequency. This modulated RF carrier is then amplified by the high power amplifier (HPA) to a suitable level for transmission and radiation by the antenna to the satellite.

On the receive side, the GS antenna receives the low-level modulated RF carrier in the downlink frequency spectrum. The low noise amplifier (LNA) is used to amplify the weak received signals and improve the Signal-to-Noise ratio (SNR) where the error rate requirements can be met more easily. The RF signal is converted to the IF signal at 70MHz or 140MHz. The demodulation at IF frequencies can be achieved easily compared to operating at RF frequencies of 4GHz or 12GHz. The demodulator estimates which of the possible symbols were transmitted based on observing the received IF carrier. The decoder performs a reverse operation of the encoder. Since the sequence of symbols recovered by the demodulator may contain errors, the decoder must use the uniqueness of the redundant digits introduced by the encoder to correct the errors and recover information-bearing digits.

The information stream is fed to the base-band equipment for processing and delivery to the terrestrial network. The tracking equipment tracks the satellite and aligns the beam that is directed to it for communication facilitation.

2. MATLAB DESIGN OF GROUND STATION

In this work the MATLAB package is used to construct four source channels GS. The GS schematic modeled in MATLAB is shown in Fig. 3. The major blocks of the station are the Source CHs, the Transmitter, and the Receiver.

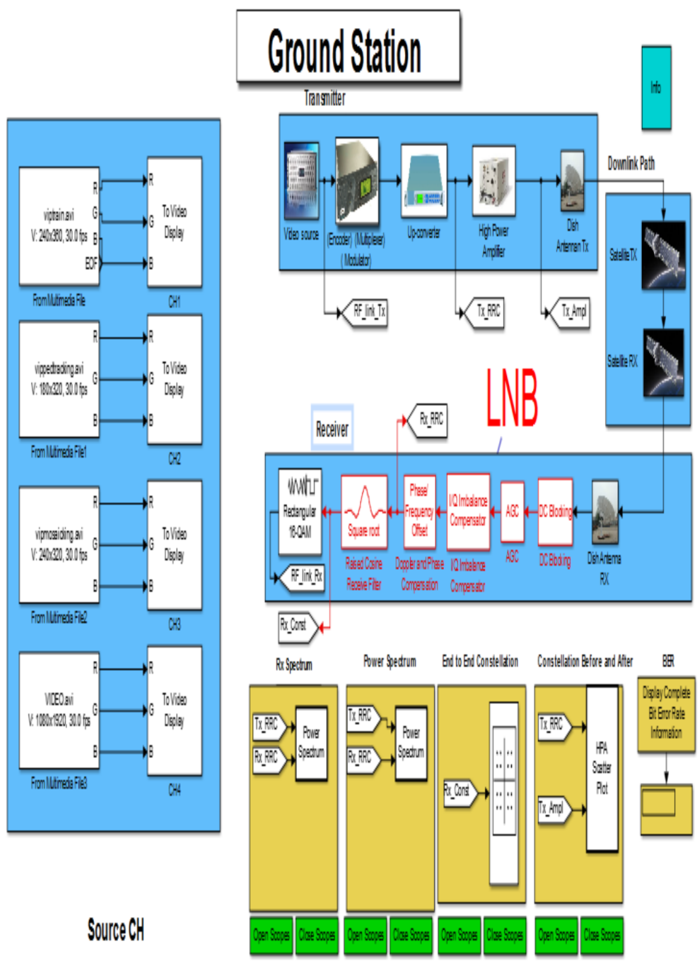

Fig .3. The Ground Station (GS) Schematic Modeled in MATLAB.

The following section provides setup details of each of the GS blocks.

A. GS Transmitter

The input to this section is a video signal that will be passed on to an encoder, modulator, and multiplexer unit which is modeled in MATLAB using Random Data Sources component from Input and Output toolbox. The encoder, modulator, and multiplexer unit compress video data using the 16-QAM technique and group all signals in one pass.

The output of the encoder is then passed to an up-converter to increase the frequency for transmission. The up-converter is modeled in MATLAB using Raised Cosine Transmit Filter component from Filtering toolbox. The up-converter up-samples and shapes the modulated signal using the square root raised cosine pulse shape.

The output of the up-converted is passed through a high power amplifier (HPA) to amplify the signal power to enable successful transmission. This HPA is modeled in MATLAB using Memory less Nonlinearity component from Modeling and RF Impairments toolbox. The HPA uses the model of a traveling wave tube amplifier (TWTA) described by Saleh's model [8]. The output of the HPA is then passed on to the dish antenna for transmission. The dish antenna is modeled in MATLAB using Gain component from Math Operations toolbox. The transmitter dish antenna is modeled by the gain of the transmitter parabolic dish antenna on the satellite. This was modeled in MATLAB using Gain from the Math Operations tool box. The satellite downlink path attenuates the signal when traveling through free space path loss.

B. GS Receiver

The GS receiver performs the reverse operations compared to the transmitter section. This section consists of the Dish Antenna RX-Gain, the Low Noise Block down-converter (LNB), and the receiver perfection units.

The input to the receiver section is the signal received by the Dish Antenna RX-Gain of the receiver parabolic dish antenna at the GS. Then the signal passes through LNB unit which performs multi operations on the received signal described as follows:

1. Phase Noise - Introduces random phase perturbations that result from 1/f or phase flicker noise.
2. I/Q Imbalance - Introduces DC offset, amplitude imbalance, or phase imbalance to the signal.
3. DC Blocking - Estimates and removes the DC offset from the signal. Compensates for the DC offset in the I/Q Imbalance block.
4. Magnitude AGC I and Q AGC (Select AGC) - Automatic gain control compensates the gain of both in-phase and quadrature components of the signal, either jointly or independently.
5. I/Q Imbalance Compensator - Estimates and removes I/Q imbalance from the signal by a blind adaptive algorithm.
6. Phase/Frequency Offset (Doppler and Phase Compensation) - Rotates the signal to represent correction of phase and Doppler error on the link. This block is a static block that simply corrects using the same values as the Phase/Frequency Offset block.

The LNB unit is followed by receiver perfection unit which uses the following units:

1. Raised Cosine Receive Filter which applies a matched filter to the modulated signal using the square root raised cosine pulse shape.

2. Rectangular QAM Demodulator Baseband - The 16-QAM constellation has a video data stream.

3. SIMULATION RESULTS AND DISCUSSION

In this section simulation results obtained using the MATLAB modeling for GS using Simulink components is presented and discussed. The modeled system can be used in any of these two approaches:

1. starts from the Master Control Room (MCR), Or,
2. Starts from Simulink.

The following sections list details of using each approach.

4.1 DESIGN OF MASTER CONTROL ROOM

The setup parameters used in the experiment are listed in the master control room (MCR) of the GS design. Fig. 4 shows a snapshot of the MCR with parameters and their values being set. The GUI has three sections, the encoder, the modulator, and the Integrated receiver/decode and Switch (IRD) as shown in Fig. 4.

The encoder section enable user to select from the four encoders ENC1, ENC2, ENC3, or ENC4 where each can be set to state of "ON" or "OFF". When an encoder is selected and set to state of "ON" and details of encoder are entered and a "YES" checkbox is selected, then a picture will be shown to the program pane to view life broadcast as shown in Fig. 5.

The details of the encoder include:

- Name
- Service ID
- MB
- Type

When the state is set to "OFF", then a black screen will be shown in the preview pane indicating broadcast is discontinued as shown in Fig. 6.

The second section of the MCR GUI is the modulator section. In this section the mode, output frequency, output level, symbol, bit rate, and mod cod are fields that user will need to provide. The section will enable presentation of the carrier and message signals depending on user selection as shown in Fig. 7.

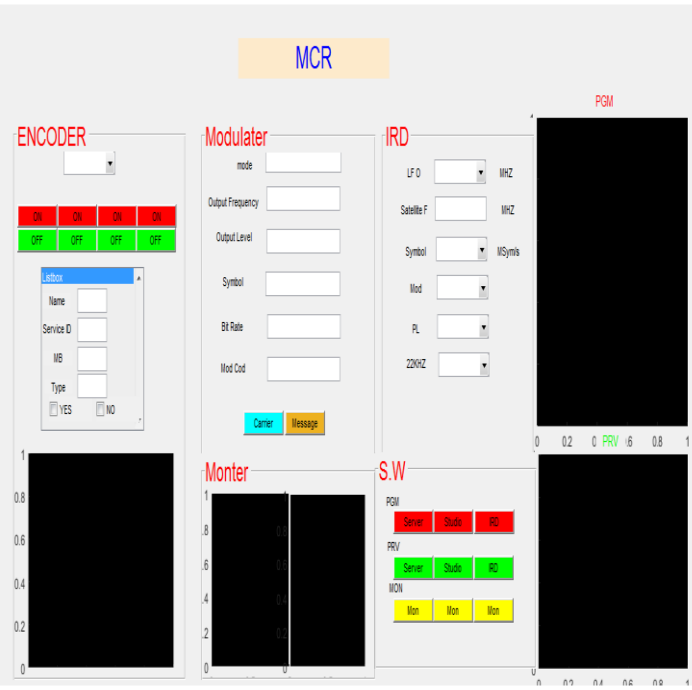

Fig .4. Master Control Room

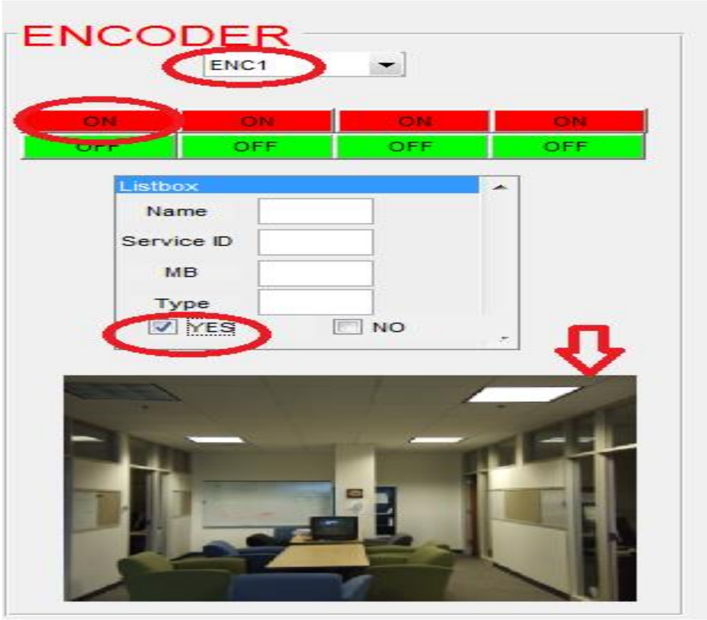

Fig .5. Encoder section of the MCR in state ON

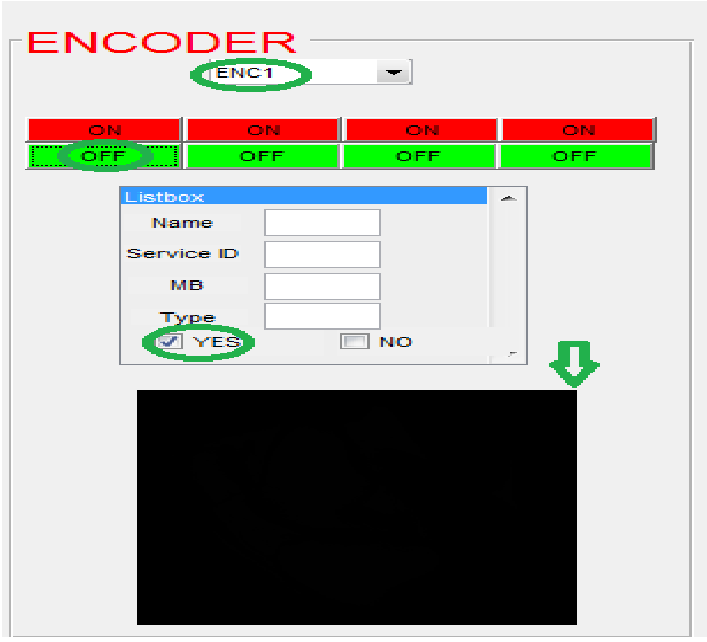

Fig .6. Encoder section of the MCR in state OFF

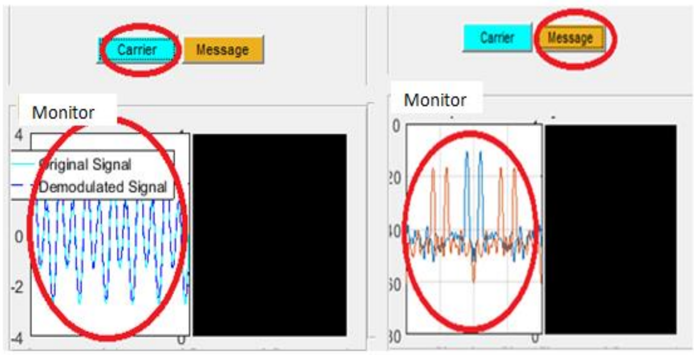

Fig .7. Modulator When Carrier/Message signals are selected

The third section of the MCR is the IRD where settings of the receiver can be implemented.

The fourth section has three modes of operation, program (PGM), preview (PRV), and monitor (MON). Each mode enables us to show server output, studio, or the receiver (IRD). The GUI provides three monitors to show results labeled as MON with MON1, MON2, and MON3.

Table 1. List of Simulink components used to construct GS.

MATLAB		Physical device
Toolbox	**Name**	**Name**
Communications System Toolbox Communications Modeling Input and Output	Random Data Sources	Video source
Communications System Toolbox System Design Digital Baseband Modulation AM Modulation	Rectangular QAM Modulator Baseband	(Encoder) (Multiplexer) (Modulator)
Communications System Toolbox System Design Filtering	Raised Cosine Transmit Filter	Up-converter
Communications System Toolbox Channel Modeling and RF Impairments	Memoryless Nonlinearity	High Power Amplifier
Simulink Modeling Block Libraries Math Operations	Gain	Dish Antenna Tx
Phased Array System Toolbox Signal Propagation and Environment	SatelliteTX	SatelliteTX
Communications System Toolbox Channel Modeling and RF Impairments	Satellite RX	Satellite RX
Simulink Modeling Block Libraries Math Operations	Gain	Dish Antenna Tx
Communications System Toolbox Channel Modeling and RF Impairments Communications System Toolbox System Design Synchronization and Receiver Design	Receiver Thermal Noise Phase Noise I/Q Imbalance Compensator	LNB
DSP System Toolbox DSP Modeling Signal Operations Communications System Toolbox System Design Synchronization and Receiver Design Communications System Toolbox Channel Modeling and RF Impairments	DC Blocker AGC I/Q Imbalance Compensator Phase/Frequency Offset	LNB
HDL Coder HDL Code Generation from Simulink Model and Architecture Design Supported Blocks Communications System Toolbox	Raised Cosine Receive Filter	Receive
Communications System ToolboxSystem Design Digital Baseband ModulationAM Modulation	Rectangular QAM Demodulator Baseband	

4.2 DESIGN USING SIMULINK

In this section simulation results obtained using the Simulink from MATLAB is described. Table 1. Provides a complete list of all MATLAB Simulink components used to construct the GS system investigated in this study.

5.0 EXAMPLE OF GS MATLAB SIMULATIONS

In this section, simulations obtained from the MATLAB modeled GS system when the MCR approach is presented. Figs. 8 and 9 illustrate the TX and RX signals with the IF range highlighted.

Figs. 10 to 13 demonstrate results from CH1, CH2, CH3, and CH4 channels respectively.

Fig. 14 illustrates setting of the encoder ENC1 and data received when used in programming case. Fig. 15 illustrates setting and data received of the encoder ENC1 when used in preview case.

Fig. 16 illustrates setting of the encoder ENC2 and data received when used in programming case. Fig. 17 illustrates setting and data received of the encoder ENC2 when used in preview case.

Fig. 18 illustrates setting of the encoder ENC3 and data received when used in programming case. Fig. 19 illustrates setting and data received of the encoder ENC3 when used in preview case.

Fig. 20 illustrates setting of the encoder ENC4 and data received when used in programming case. Fig. 21 illustrates setting and data received of the encoder ENC4 when used in preview case.

Fig. 23 illustrates the monitored message signal component on the carrier signal.

The setting of the IRD with symbol values is shown in Fig. 24.

The setting of IRD with MOD values is shown in Fig. 25.

The setting of IRD LFO values is shown in Fig. 26.

Results of DATA message is depicted in Fig. 27.

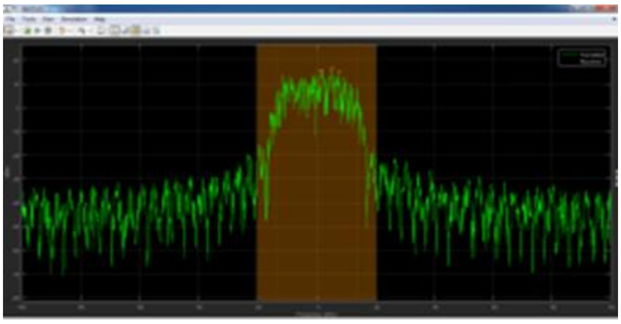

Fig .8. Results of signal TX

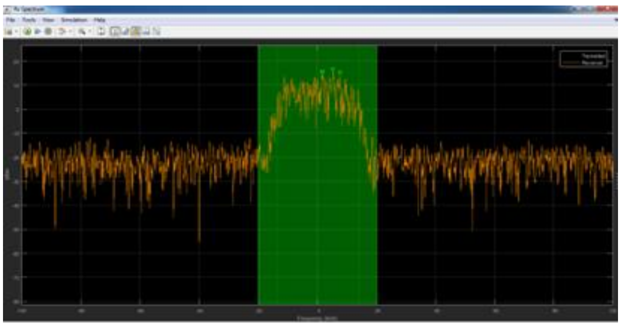

Fig .9. Results of signal RX

Fig .10. Results of CH1

Fig .11. Results of CH2.

Fig . 12. Results of CH3

Fig .13. Results of CH4

Fig .14. Results of ENC1 PRG

Fig .15. Results of ENC1 PRV

Fig .16. Results of ENC2 PRG

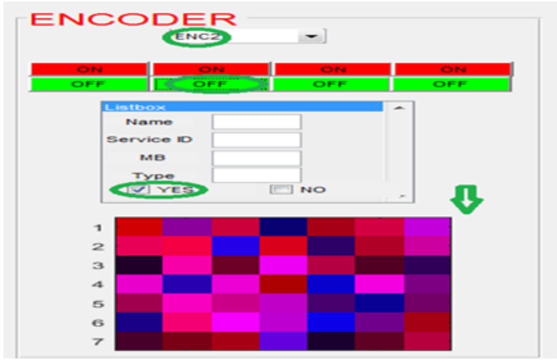

Fig .17. Results of ENC2 PRV

Fig .18. Results of ENC3 PRG

Fig .19. Results of ENC3 PRV

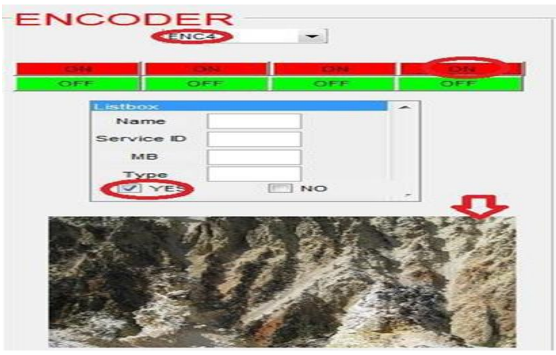

Fig .20. Results of ENC4PRG

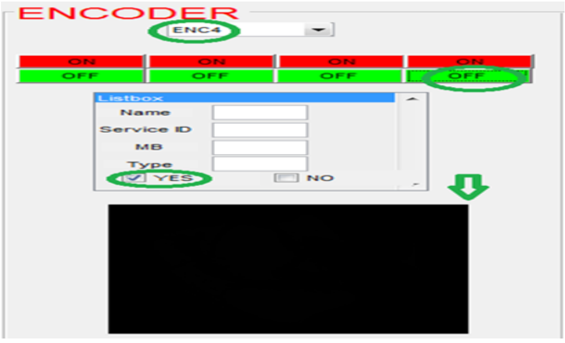

Fig .21. Results of ENC4 PRV

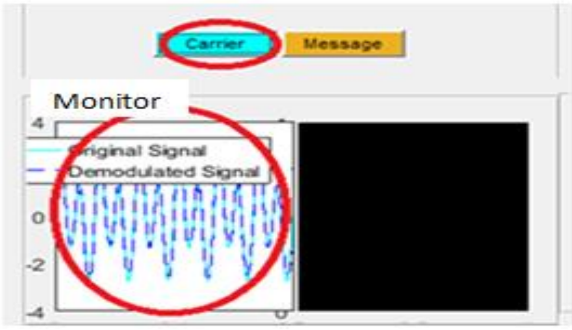

Fig .22. Signal of Monitor Carrier

Fig .23. Signal of Monitor Message

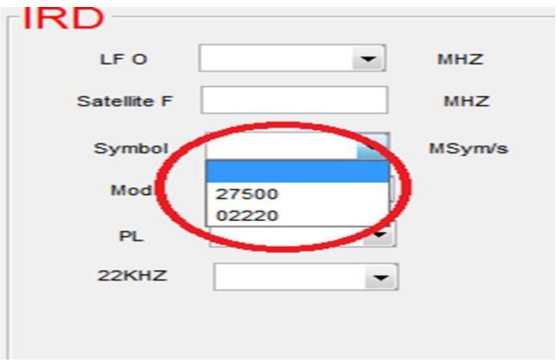

Fig .24. Results of IRD Symbol

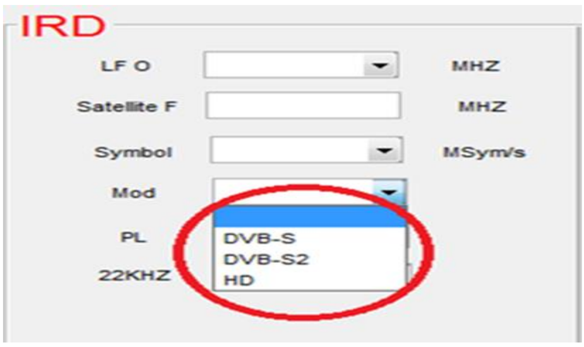

Fig .25. Results of IRD MOD

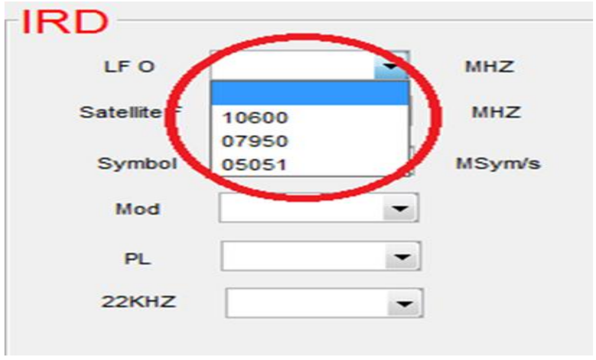

Fig .26. Results of IRD LFO

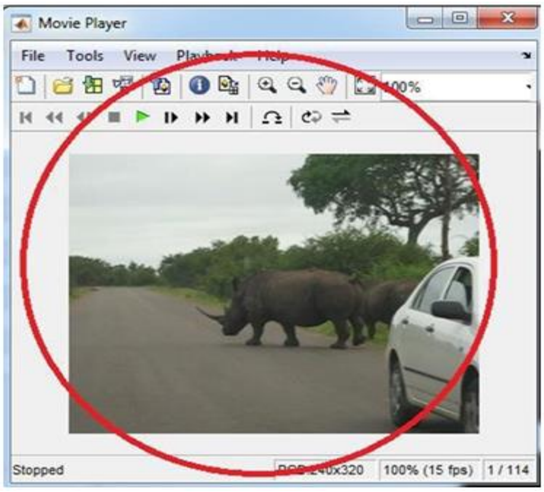

Fig .27. Results of DATA Message

6.0 CONCLUSIONS

In this paper, a description of GS and all of its involved components is presented. The MATLAB Simulink representation of GS is detailed and can be used to run simulation of transmitter and receiver link performances. Additionally, a master control room (MC) graphical user interface is designed in MATLAB to provide an easier and alternate method of supplying system settings. Both methods were used to simulate performance of GS in MCPC protocol. The tests used a source of four video channels to assess the utility of the proposed controllers. Results of test simulation were presented and discussed. The achieved results confirmed the ability to transmit multiple channels on one frequency.

REFERENCES

[1] Bruce R. Elbert, "Introduction to Satellite Communication", Third Edition, ISBN: 978-1-59693-210-4, 2008.

[2] Tejas S. Chavan, V. S. Jadhav," MATLAB Simulation of the DVB-S Channel Coding and Decoding", International Journal of Engineering Research & Technology (IJERT), Vol. 1, Issue 9, November 2012, pp.1-5.

[3] G. Colavolpe, A. Modenini, A. Piemontese, A. Ugolini," On the Application of Multiuser Detection in Multibeam Satellite Systems",2015 IEEE International Conference on Communications (ICC), London, 2015, pp. 898-902.

[4] S. Cioni, E. Ernst, A. Ginesi, G. Colavolpe" Bandwidth Optimization for Satellite Digital Broadcasting",Proceeding of Commuications Satellite Systems Conference, October 14-17, 2013

[5] Peter Galace, "Prospects in the African Satellite Market", Satellite Markets and Research, EMEA,

http://www.satellitemarkets.com , accessed October 28, 2020

[6] Jonathan Higgins, "Introduction to SNG and ENG Microwave", 1st Edition, ISBN: 978-1138141278, April 14, 2016.

[7] Rembovsky, A.M., Ashikhmin, A.V., Kozmin, V.A., Smolskiy, S.M, "Radio Monitoring: Problems, Methods and Equipment." 1st Edition, ISBN: 978-1-4614-2937-1, 2009.

[8] A. A. M. Saleh, "Frequency-Independent and Frequency-Dependent Nonlinear Models of TWT Amplifiers," in *IEEE* Transactions on Communications, vol. 29, no. 11, pp. 1715-1720, November 1981.