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A New RF Satellite Link Analyzing and Antenna Effect on Satellite Communication

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Abstract: Satellite communications (SatComs) recently, have admitted as a new technological advances that attracted and raised special investment and ventures. Space communication technology has found many application areas from costly, one-of-a-sort structures, to utilize again of technology on sequential tasks, to the progress of canonical protocols accepted by space agencies of lots of countries. Satellite communication has accepted as one of the important technologies for 5G backhauling, particularly on bandwidth request increased in 5G mobile broad band (eMBB) applications. This paper presents the efficiency of the satellite communication system using 16 QAM digital modulation technique for the X band. This digital modulation method presents high data rate in transmission without raising the bandwidth compared with other digital modulation methods. Applications are realized in Matlab environment and obtained conclusions are discussed such as power spectrum diagrams, constellation schemas and BER ratio for several bands such as 4, 8, 12, 16 GHz.

Keywords: antenna arrays; satellite communications; 5G

1 INTRODUCTION

Satellite Communications (SatComs) have applications such as media broadcasting, backhauling, news gathering etc. areas. Recently via advancing of Internet basis applications, SatComs are passing a conversion stage to make centre again the system model on data services, known as broadband SatComs [1-4]. While especially the number of Low Earth Orbit (LEO) satellites are growth rapidly, ground basis communication systems have also evolved. The transmitting and receiving antennas are at the forefront of these systems. To make better the parameters and to optimize the performances, many antenna configurations have tested and continue to test in cases where it is necessary to follow specific conditions to make receiving from the satellite. [5-8]. Arrays of antennas are combine of groups of antennas adjusted to get aimed directivity properties. An array can formed with any combination of radiant elements but, in application usually classified equivalent elements in organized geometries are used. With progressing of satellite, communications, in order to make receiving or transmitting the signals as close as feasible to the space where the signals have needed, via not to disturb other spaces, the radiation model have been more and more precise. So, antenna arrays in phased [5, 7] have been highly improved. These antennas can alter the radiation model in array with respect to the phase shift that occurred among the elements supply voltages. This paper has organized as channel modelling, antennas, UHTS systems, data collection, application, and obtained results of this paper has explained in the conclusion part, respectively.

1.1 Channel Modelling

Characteristics of channel and propagation have dictating act in the designing of system. These statuses have originally defined by the frequency of the process besides the system configuration. Because the satellite communication systems use a large interval of frequency, results with various channel models. Fixed satellite and Mobile satellite are channel models that came across in satellite communications. Since mobility means the existence of dispersed multipath constituents next to straight path, the channel characteristics of Mobile satellite systems are different from their Fixed Satellite equivalents. While following the satellite via the mobile station means the direct path, enhanced number of scatters in mobility caused variable environments, scattering from foliage, reflection from building defines the multipath term. In the literature, several of channel models such as narrowband and broadband have been suggested. In general, these models include a multiple condition Markov model, via every status defining the parameters and the character of the matching channel dispersion. As an example, a Markov model with 3 state narrowband interested state statistics have been presented by ITU Recommendation P.681 [9].

2 ANTENNAS

Antenna design is a necessary significant aspect to analyse. The principal properties of the passive and active antennas and highlight oncoming aspects in designing antenna for satellite communication systems will express in this section.

2.1 Passive Antennas

From radio transmission to broadband tasks signs a passing from contour ray coverage, which purposed serving a dedicated geographical area, to multi-beam antennas (MBAs) that by merit narrower ray makes possible both larger gains and use again of frequency, so spectral ability has maximized. GEO missions, which is the corresponding variation of conventional passive antenna structures, have directed the formed reflector antennas versus Multiple Feeds Per Beam (MFPB) MBAs [32] and Single Feed Per Beam (SFPB).

2.2 Active Antenna Arrays

Amplifiers of the active antennas integrate with the radiating elements. One of the differences between passive antennas and active antennas, the obtained signal is a distributed amplification of the spreading signal in passive antennas. Distribution of the power of spatial RF and the decreasing of peak RF power levels supply reliability advance in active arrays (inclusive decreasing multi-process brinks) and ensure an elegant corruption. Structures, where Active antennas can place, are Direct Radiating Array (DRA) or Array Fed Reflector (AFR) structures [32]. This selection and the incorporated trade-offs are potently related to the requirements of the system. When the wide area of sight joined with the decreased requests on gain preferred DRA solutions for LEO and MEO systems. The big electrical sizes necessary to reach the main aim of GEO HTS (High Throughput Satellite) missions are achieved preferentially with reflector basis structures that provide maintain an enlargement of the radiating interval, so there are still open questions about the best active array architecture [10-12].

3 ULTRA HIGH THROUGHPUT SATELLITES (UHTS)

In addition to numerical payloads, fore-coding techniques, and non-orthogonal multiple reach the main servers of the UHTS system are accession to the PHY layer view. Satellite communications have been obligated to satisfy the increment demands for the trustworthy and elastic links at higher yields due to the diversity of markets. The payload has accepted as a piece of the head on channel constantly and its attitude should measure continuously. In Orbit Test (IOT) process of the satellite payloads includes a specially modelled testing signal for the evaluation and subtracting of several important payload factors such as on board responses of filter answer of high power amplifier. The IOT is basic process throughout used the lifetime of the satellite to confirm and track the success and structural necessities of the satellite payload [13].

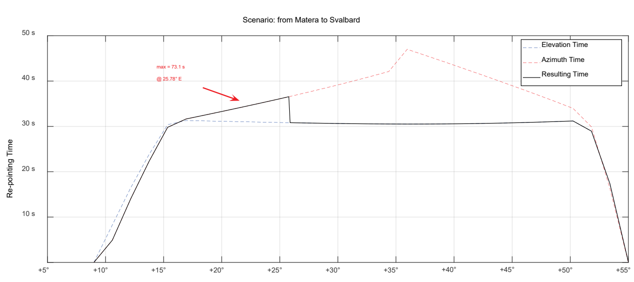

Figure 1 Re-pointing Time to Pass-break Longitude for Scenario: Svalbard to Matera

3.1 Data Collection

Collecting data from Earth or from space is also a significant subject worthy of taking into account. Satellite communication in commercial applications, such as observation and LEO satellites, stand on exceedingly available great rates in data along a short transition of the satellite. Thus, new station modems talented of the efficient process are developed at much great symbol rates recently. If the whole *Ka* band is used, the main challenge for the designing modem, outcomes from a much wide signal spectrum that can raise up to 1.5 GHz. These days, the proposed terminal modems for commercial high data rates support up to 500 MHz [14-16].

Elevation and azimuth time are important parameters in antenna design. In our application there is two scenario to be evaluated. In Fig. 1 for pass break longitude is between +5 to +55 degree, maximum re-pointing time 73.1 s is obtained at 25.78 degree. For pass-break longitude is between +170 to 145 degree, maximum re-pointing time 84. s is obtained at 163.62 degree in Fig. 2.

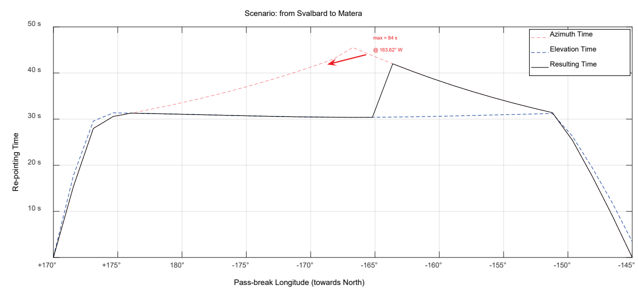

Figure 2 Re-pointing Time to Pass-break Longitude for Scenario: Matera to Svalbard

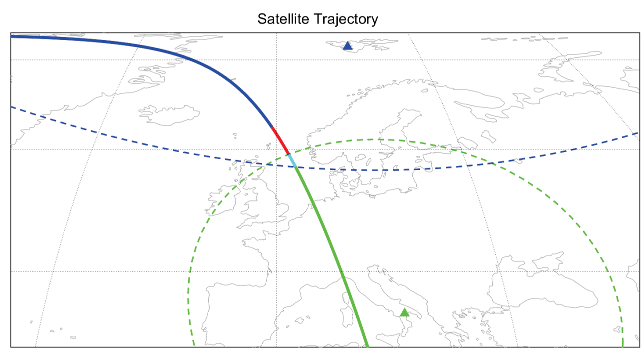

Figure 3 Satellite trajectory for Scenario: Svalbard to Matera

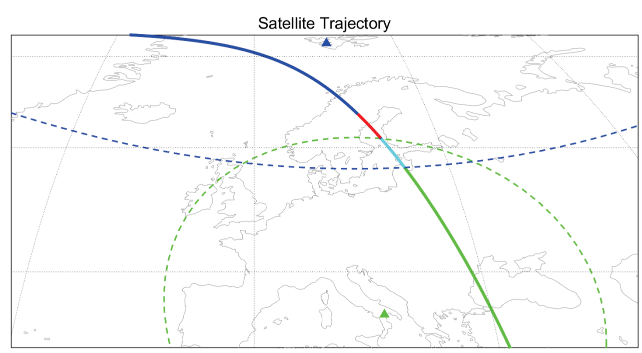

Figure 4 Satellite trajectory for Scenario: Matera to Svalbard

3.2 5G Networks

5G has purposed more than alteration of the former norms, to make please significant department of the market, such as the automotive and transporting lines, broadcasting and demonstration, industry. For 2020 and beyond, ITU-R International Mobile Telecommunications has defined several great structures for the enhancement of 5G [8]. Thus, the role of satellites that is crucial in the 5G ecosystem has largely acknowledged.

Satellite trajectory plotting for Scenario: Svalbard to Matera has given with Fig. 3. Satellite trajectory plotting for Scenario: Matera to Svalbard has given with Fig. 4.

Recently, mid-layers of transmissions systems have emerged between terrestrial and conventional satellite slices via the technological progress of the air and miniature satellite structures. According to their operation elevation, these new structures can categorized into three major groups have allocated High Altitude Platforms (HAPs) satellites, Low Altitude Platforms (LAPs) satellites and Very Low Earth Orbit (VLEO) satellites [33]. Elevation sets are admitted [17, 18] 100-450 km for VLEO satellites, 15-25 km for HAP satellites, and 0-4 km for LAP satellites respectively. A recent multi-floor transmissions structure [19] with multiple inter-floor linkages able to cope with the toughest scripts has enabled by the ad-vent of these new structures. The schematic approximation of this new multi-layer transmissions system has shown in Fig. 5.

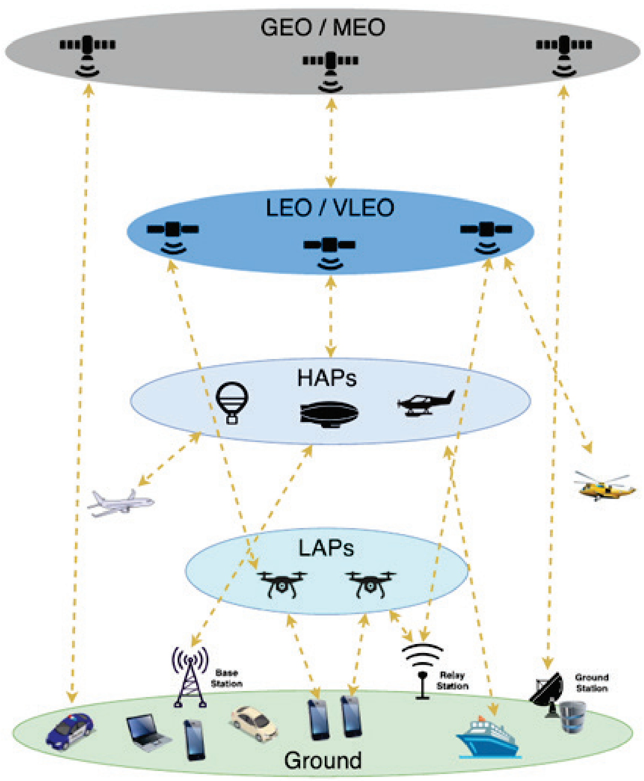

Figure 5 Multi-layer communications architecture

LEO satellites work more intimately with the Earth according to LEO satellites. For this reason, VLEO satellites are simple, small and cheap according to LEO satellites [17]. However, lower altitudes like VLEO cover a more intense section of the atmosphere, and so, larger aerodynamical powers. Although this has seen as a tough, but this can also point out a chance in check of trajectory and height [20]. In addition, in VLO satellites the raised dragging indicates a shortening of the trajectory life span, which means a denser shipping exchange of smaller and cheaper space craft. At the end of this situation, VLO satellites become appropriate more sensitive to technology and changes in the bazaar [21]. Varied particular firms such as Telesat, SpaceX and OneWeb are purposing to initiate their Mobile Satellite Services (MSS) at VLEO. HAPs have features to supplement traditional satellite networks. In fact, they also acknowledged as High Altitude Pseudo Satellites [22, 23]. HAPs have the ability to supply telecommunications duties at a local scale be-cause of their working altitude. The most evident example of LAPs is Unmanned Aerial Vehicles (UAVs). A significant component of the immediate future wire-less networks is expected to be UAVs which can make ease wireless broadcast and assist high rate transfer potentially [24, 25]. UAVs (LAPs) have similarities to the HAPs ones in terms of the main advantages, but on the cellular plane: LAPs have fast and elastic propagation specifications, powerful line-of-sight (LoS) link, and independence in design with the tested mobility and autonomous. In addition, atmospheric base stations working with UAV can install, improve, and rescue coverage of cellular as real time for consumers in far away, crowded and catastrophic regions.

Satellite communications utilize the Extremely High Frequency (EHF) band, in particular among 1-50 GHz. In varied air circumstance, service and users types operate on different frequency bands. The frequency bands utilized for satellites defined by straightforward characters for ease. For example lower frequencies are determined as *L*, *S*, *X* and *C*, and larger frequencies are determined as *Ku*, *K*, *Ka*, *Q*/*V*. A diagrammatic demonstration spectrum of the satellite is shown in Fig. 6.

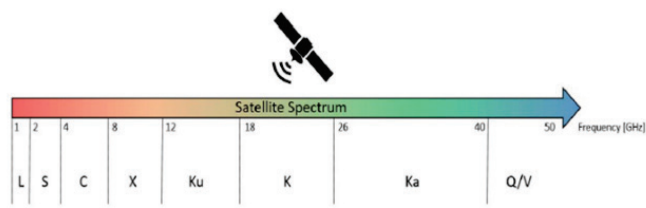

Figure 6 Satellite spectrum

In the *L*-band, navigation systems of radio, like GPS or Galileo work. Radar of weather and surface ship, and several satellites, and particularly satellites of NASA for transmission with the International Space Station (ISS) and the Space Shuttle [26, 33] use the *S*-band. In addition, *L* and S bands have utilized for Telemetry, Tracking and Control (TT&C). Especially, the space search, space process, and EO satellite services share the frequency bands among 2-2.3 GHz equivalently [27]. Since in the lower bands, there is not much bandwidth available so it has become costly work. Spatial variation of the traffic over the satellite orbit is practiced in MEO and LEO satellites. Therefore, there is a requirement for a reconfigurable antenna to make equal the coverage of satellite with the spatial spreading of the receiving and transmitting traffic. Telesat, Starlink and Akash have a compatible approach with the LEO constellations [28]. O3B admits a controllable beam approximation for the MEO constellation [29]. For small satellite structures such as CubeSats a review of antenna solutions can be found in [30].

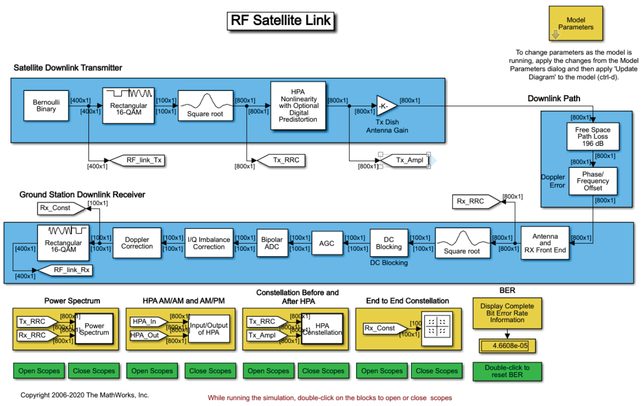

Figure 7 RF Satellite Link Scheme [32]

4 SIMULATION RESULTS

The model in Fig. 7 shows a satellite link to simulate several impairments such as nonlinearity of memoryless, path loss of free space, error of Doppler, thermal noise of receiver, noise in phase, instability in-phase and quadrature, and DC offsets [32]. The satellite connection sample and its signal areas have shown by the model, which includes Satellite Downlink Transmitter, Downlink Path, and Ground Station Downlink Receiver. This architecture models the gains and losses on the connection and calculates link budget to define bit error rate (BER). The Free Space Path Loss block and the Receiver Thermal Noise that named as the gain and loss blocks, specify to be supported data rate in an additive white Gaussian noise channel. In block named as Satellite Downlink Transmitter; Bernoulli Binary Generator forms binary data flow randomly, Rectangular QAM Modulator Baseband plans the constellation diagram of 16-QAM data stream. The signal modulated utilization the SRRC (Square Root Raised Cosine) pulse shape is up-sampled and developed by Transmit Filter of Raised Cosine. A mobile wave tube amplifier utilization the Saleh pattern choice of the Memoryless Nonlinearity is modelled by HPA (High Power Amplifier) Nonlinearity with Optional Digital Predistortion and selectively the AM to AM and AM to PM are corrected with a Digital Predistortion block. Tx Dish Antenna Gain known as gain block utilize gain of the parabolic dish antenna in the transmitter. Free space path loss reduces the signal by the free space path loss in Downlink Path. The signal is rotated by Phase/Frequency Offset (Doppler Error) to define Doppler error on the connection. Rx Dish Antenna Gain known as Gain block performs gain of the receiver parabolic dish antenna In Ground Station Downlink Receiver. White Gaussian noise that indicates the active temperature of the system in the receiver is added using the Receiver Thermal Noise block. Random phase corruption that outcomes from 1/f or phase chills noise is presented using Phase Noise. The block of I/Q Imbalance Correction brings to the signal several impairments such as DC offset, amplitude or phase non-stabilization. In short known as LNA, Low Noise Amplifier supplies low noise amplifier gain. A corresponding filter to the modulated signal has obtained using Raised Cosine Receive Filter. DC Blocking block eliminates the DC offset in I/Q Imbalance block. AGC block has used to adjust the desired level signal power. I/Q Imbalance Compensator has used for prediction and eliminating I/Q imbalance from the signal using an algorithm that presents solutions adaptively. Doppler Correction block and Carrier Synchronizer blocks together are using to eliminate the carrier frequency offset emerging due to Doppler Effect. Rectangular 16-QAM block is using to remap the data stream from constellation space.

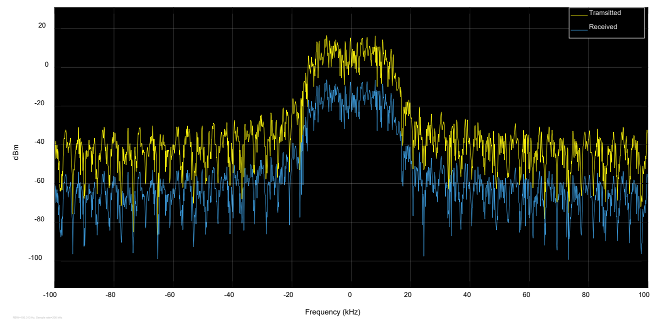

Figure 8 Power spectral density of transmitted (yellow) and received (blue) signal for RF Satellite Link [32]

Referring to Fig. 8 the main difference of the noise level among power spectral density of transmitted and received signals observed at 20 kHz is –6 dB approximately.

When compare the two spectrum the impact of the some RF corruptions are encountered such as regrowth in spectrum emerged due to HPA non-stabilities raised by the Memoryless Nonlinearity block, thermal noise occurred by the Receiver Thermal Noise block and Phase chills occurred by the Phase Noise block. In Fig. 8 the value of Thermal Noise is selected 20 that is low noise.

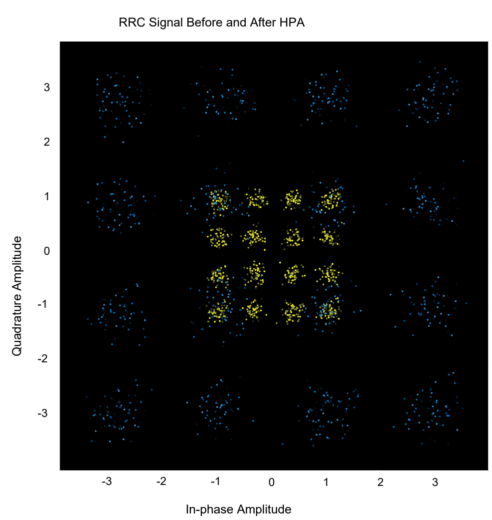

Figure 9 Modulated (yellow) and received (blue) signal for RF Satellite Link

Fig. 9 allows us to check the constellation diagram of the transmitter signal with yellow and after the HPA with blue. Output signal of the HPA is larger than input signal of the HPA due to the amplifier gain. This figure facilitates us to observe the united impact of both non-stability and digital pre-defect of the HPA. As seen in the constellation diagram in Fig. 9 the received signal has affected by noise compared to the transmitted signal.

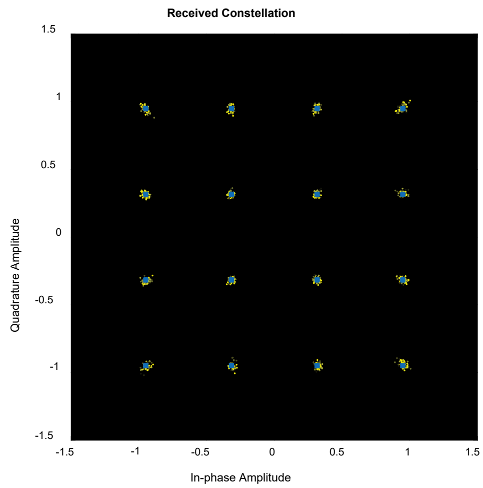

Figure 10 Received constellation diagram

Fig. 10 allows us to compare the 16-QAM reference constellation diagram (blue) with the received QAM constellation before demodulation (yellow). The effect over all the RF corruptions on the received signal and the influence of the compensations have observed by using these constellation diagrams. Satellite height (km) has defined as the margin among the satellite and the ground station. Modification of this parameter renovates the Free Space Path Loss block, which the default value has selected as 35600 [31]. Frequency defines the link carrier frequency, changing of this parameter renovates the Free Space Path Loss block, which the default value has chosen as 4000 kHz. Diameters of transmit and receive antenna are the first elements in the vector and are utilized to compute the gain of a block of the Tx Dish Antenna Gain. The other component expresses the receive antenna and is utilized to compute the gain in block of the Rx Dish Antenna Gain. Noise temperature lets us to choose from noise temperatures in four active receiver systems. The chosen temperature of noise alters the Noise Temperature of the Receiver Thermal Noise block.

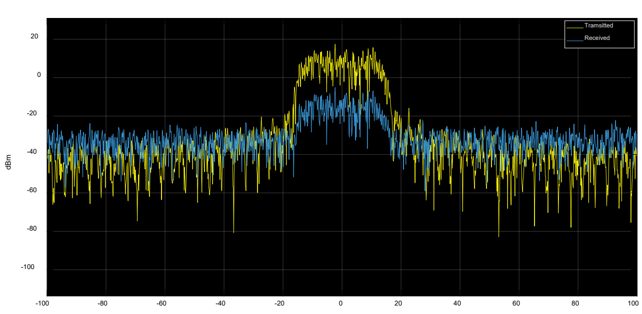

Figure 11 Power spectral density for Noise Temperature 290 K

The effect of chosen temperature noise 290 K is shown by Fig. 11, 12 and 13 for power spectral density, RRC signal before and after HPA and received constellation. In addition, Fig. 14, 15 and 16 present the effect of chosen temperature noise 500 K for power spectral density, RRC signal before and after HPA and received constellation.

Referring to Fig. 11 the key difference of the noise level among power spectral density of transmitted and received signals monitored at 20 kHz is approximately –6 dB.

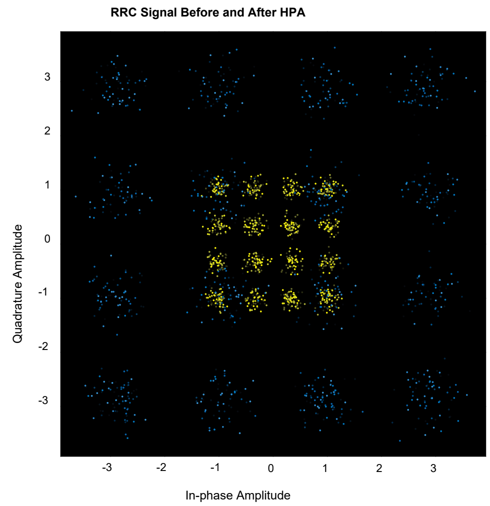

Figure 12 RRC signal for Noise Temperature 290 K

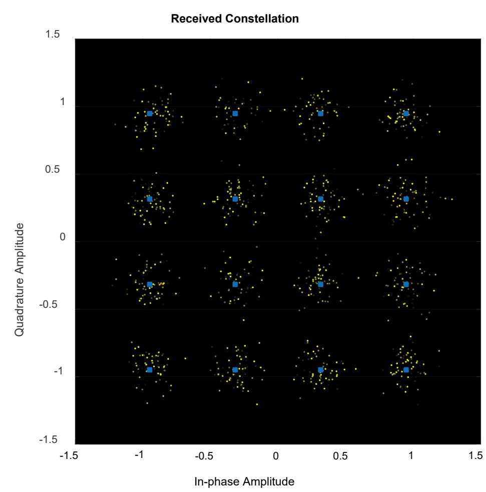

Figure 13 Received constellation for Noise Temperature 290 K

As seen in the constellation diagram in Fig. 12 the received signal has effected by noise compared to the transmitted signal.

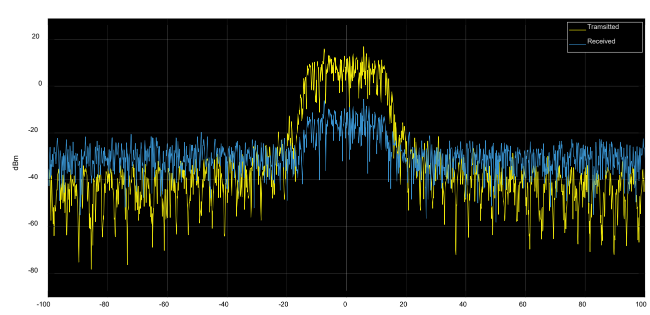

Figure 14 Power spectral density for Noise Temperature 500 K

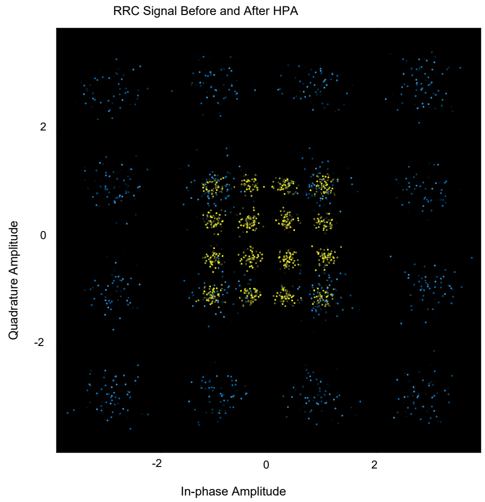

Figure 15 RRC signal for Noise Temperature 500 K

When the noise performance is compared, the constellation diagram of the signal at the output of the HPA is better than at the input of HPA.

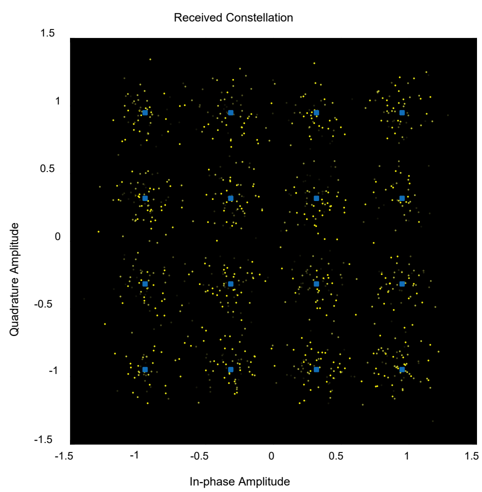

Figure 16 Received constellation for Noise Temperature 500 K

In Tab. 1 Variation of BER according to Carrier Frequency is reported. From this table, it is seen obvious the value of BER increases as the carrier frequency increase.

Table 1 Variation of BER according to Carrier Frequency

Frequency Band	BER
4 GHz	1.39e-6
8 GHz	2.99e-6
12 GHz	5.98e-6
16 GHz	2.98e-5

In this article, the ultimate technical progress in academic, industrial, and standardization investigations in the satellite communications domain have been examined. Particularly, the titles of channel modelling of satellite communication, active and passive antennas, UHTS systems, data collection, and layers of communications systems that have emerged between terrestrial and conventional satellites are explained in detail. After all the explanations, applications realized and results have given with figures. Especially RF satellite link transmitter and receiver blocks have expressed separately.

In this paper, an RF satellite system using 16 QAM digital modulation technology is proposed, and the performance of the satellite system is explored and examined. The purposed model was implemented for various noise temperatures and obtained results such as power spectral density, constellation diagram. In addition, it was seen that the value of BER increases as the carrier frequency increase obtained as a result of simulations.

One of the future applications is named delay-tolerant networking (DTN) which should get knowledge from one area of the Solar System to another one. The DTN structure enables uniform communications over extended distances and delays in time. In fact here that there is the Bundle Protocol (BP), which has similarities to the Internet Protocol (IP) that is known as the base of the Internet on Earth [33]. Some researchers have been now studying to improve a recent link-floor structure for the Space Internet but have not observed applicable improvement yet.

Notice

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5 REFERENCES

[1] Sturza, M. (1995). The teledesic satellite system: overview and design trades. *Teledesic Corp.*, Kirkland, WA, USA.
[2] https://en.wikipedia.org/wiki/SpaceX_Starlink, accessed 2021/11/12.
[3] Antipolis, S. (2019). Technical specification group radio access network; study on new radio (NR) to support non-terrestrial networks; (release 15), version 15.2.0, 3GPP, France, Rep. 38.811.
[4] Antipolis, S. (2019). Technical specification group radio access network solutions for NR to support non-terrestrial networks; (release 16), version 0.9.0, 3GPP, Sophia Antipolis, France, Rep. 38.821.
[5] Bruninga, B. (2019). Antennas for APRS satellite Igates, http://www.aprs.org/aprs-satellite-igate-antennas.html
[6] Done, A.: Contributions to the development of ground stations for satellite reception. PhD Thesis, "Ştefan cel Mare" University of Suceava, Suceava.
[7] Lesanu, C. E., Done, A., Cailean, A. M., & Graur, A. (2018). Vertical polarized antennas for low VHF radio meteor detection. *14th International Conference on Development and Applications Systems*, Suceava, Romania. https://doi.org/10.1109/DAAS.2018.8396078
[8] Stutzman, W. L. & Thiele, G. A. (2013). Antenna theory and design. 3rd New York: Wiley.
[9] ITU. (2003). Propagation data required for the design of earth space land mobile telecommunication systems. ITU, Geneva, Switzerland, ITU Recommendation P. 681-6.
[10] Rao, S. K. (2015). Advanced antenna technologies for satellite communications payloads. *IEEE Transactions Antennas Propagation*, *63*(4), 1205-1217. https://doi.org/10.1109/TAP.2015.2391283

[11] Palacin, B. et al. (2017). Multibeam antennas for very high throughput satellites in Europe: Technologies and trends. *11th Eur. Conf. Antennas Propag, (EUCAP),* 2413-2417. https://doi.org/10.23919/EuCAP.2017.7928493

[12] Fenech, H., Amos, S., & Waterfield, T. (2016). The role of array antennas in commercial telecommunication satellites. *Proc. 10th Europe Conference Antennas Propagation*, *(EuCAP),* 1-4. https://doi.org/10.1109/EuCAP.2016.7481857

[13] Perez-Neira, A. I., Vazquez, M. A., Shankar, M. R. B., Maleki, S., & Chatzinotas S. (2019). Signal processing for high-throughput satellites: Challenges in new interference-limited scenarios. *IEEE Signal Processing Magazine*, *36*(4), 112-131. https://doi.org/10.1109/MSP.2019.2894391

[14] Kodheli, O., Andrenacci, S., Maturo, N., Chatzinotas, S., & Zimmer, F. (2018). Resource allocation approach for differential Doppler reduction in NBIoT over LEO satellite. *9th Advanced Satellite Multimedia Systems Conference, 15th Signal Processing Space Communication Workshop*, *(ASMS/SPSC)*, 1-8. https://doi.org/10.1109/ASMS-SPSC.2018.8510724

[15] Hofmann, C. A. & Knopp, A. (2019). Direct access to satellites: An Internet of remote things technology, *IEEE 2nd 5G World Forum (5GWF),* 578-583. https://doi.org/10.1109/5GWF.2019.8911640

[16] Hofmann, C. A. & Knopp, A. (2019). Ultra narrowband waveform for IoT direct random multiple access to satellites. *IEEE Internet Things Journal, 6*(6), 10134-10149. https://doi.org/10.1109/JIOT.2019.2935909

[17] Llop, J. V., Roberts, P. K., Hao, Z., Tomas, L., & Beauplet, V. (2014). Very low earth orbit mission concepts for earth observation: Benefits and challenges. *Reinventing Space Conference*, 1441-1444.

[18] Reynaud L. & Rasheed, T. (2012). Deployable aerial communication networks: Challenges for futuristic applications. *9th ACM Symposium Performance Evaluation Wireless and Hoc Sensor Ubiquitous Networking (PE-WASUN),* 9-16. https://doi.org/10.1145/2387027.2387030

[19] Li, Y., Wei, H., Li, L., Han, Y., Zhou, J., & Zhou, W. (2019). An extensible multi-layer architecture model based on LEO MSS and performance analysis. *IEEE 90th Vehicular Technology Conference* (VTC-Fall), 1-6. https://doi.org/10.1109/VTCFall.2019.8891397

[20] Virgili-Llop, J., Polat, H. C., & Romano, M.: Attitude stabilization of spacecraft in very low earth orbit by center of mass shifting. *Front. Robot. AI, 6*(7). https://doi.org/10.3389/frobt.2019.00007

[21] Dakka, S. M. (2018). VLEO satellites a new earth observation space systems commercial and business model. *36th Int. Communication Satellite System Conference (ICSSC),* 1-11. https://doi.org/10.1049/cp.2018.1718

[22] Iskandar, M. A., Wibisono, S., Priatna, T. & Rachmana, N. (2017). On the design and development of flying BTS system using balloon for remote area communication. *The 11th International Conference Telecommunication System Services Applications*, 1-5. https://doi.org/10.1109/TSSA.2017.8272902

[23] Qiantori, A., Sutiono, A. B., Hariyanto, H., Suwa H. & Ohta, T. (2010). An emergency medical communications system by low altitude platform at the early stages of a Natural Disaster in Indonesia. *Journal of Medical Systems*, *36*, 41-52. https://doi.org/10.1007/s10916-010-9444-9

[24] Li, B., Fei, Z., & Zhang, Y. (2019). UAV communications for 5G and beyond: Recent advances and future trends. *IEEE Internet Things Journal, 6*(2), 2241-2263. https://doi.org/10.1109/JIOT.2018.2887086

[25] 5G-SKY: Interconnecting the Sky in 5G and Beyond a Joint Communication and Control Approach (2019), https://wwwfr.uni.lu/snt/research/sigcom/projects/5g_sky_interconneting_the_sky_in_5g_and_beyond_a_joint_communication_and_control_approach, accessed 2021/11/30.

[26] ESOA-EMEA Satellite Operator Association. Satellite Spectrum. https://www.esoa.net/spectrum/satellite-spectrum.asp, accessed 2022/01/01

[27] Li, Y., Wang, Z., & Tan, W. (2013). The frequency spectrum management for aerospace TT &C system. *5th IEEE International Symposium Microwave Antenna Propagation EMC Technology Wireless Communication,* 595-600. https://doi.org/10.1109/MAPE.2013.6689909

[28] Tubau, S., Vidal, F., Legay, H., Palacin, B., & Goussetis, G. (2019). Novel multiple beam antenna farms for megaconstellations. *40th ESA Antenna Workshop (ESA-ESTEC)*, Nordwijk, The Netherlands, 2-31.

[29] https://www.itu.int/dms_pub/itu-r/md/12/iturka.band/c/R12-ITURKA.BAND-C-0010!!PDF-E.pdf, accessed 2021/11/25.

[30] Gao, S., Rahmat Samii, Y., Hodges, R. E., & Yang, X. (2018). Advanced antennas for small satellites. *IEEE, 106(3),* 391-403. https://doi.org/10.1109/JPROC.2018.2804664

[31] Alshepane S. H., Alhaddar K. F., & Bishi H. (2021). Investigation the Performance of RF Satellite Link Model Using 32 QAM. *2021 IEEE 1st International Maghreb Meeting of the Conference on Sciences a Techniques of Automatic Control and Computer Engineering MISTA*. https://doi.org/10.1109/MI-STA52233.2021.9464443

[32] MathWorks, UK. (2022). RF Satellite Link - MATLAB & Simulink - MathWorks, United Kingdom. https://uk.mathworks.com/help/comm/ug/rf-satellite-link.html

[33] Kodheli, O. et al. (2021*).* Satellite Communications in the New Space Era: A Survey and Future Challenges. *IEEE Communications Surveys & Tutorials*, 23(1), 70-109. https://doi.org/10.1109/COMST.2020.3028247

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