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# MODELING OF ADS-B DATA TRANSMISSION VIA SATELLITE

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**Abstract.**For modelling of ADS-B messages transmissionvia low-orbit satellite constellation Іrіdіum the original model of a communication channel "Aircraft-to-Satellite-to-Ground Station" was built using MATLABSіmulіnk.The model comprises “Aircraft Uplink Transmitter” (Bernoulli Random Binary Generator, Convolutional Encoder, BPSK Baseband Modulator, High Power Amplifier with a memoryless nonlinearity, Transmitter Dish Antenna Gain), “Uplink Path” (Free Space Path Loss, Phase/Frequency Offset), “Satellite Transponder” (Receiver Dish Antenna Gain, Satellite Receiver System Temperature, Complex Baseband Amplifier, Phase Noise, Transmitter Dish Antenna Gain), “Downlink Path” (Free Space Path Loss, Phase/Frequency Offset), “Ground Station Downlink Receiver” (Receiver Dish Antenna Gain, Ground Receiver System Temperature, Viterbi Decoder), “Error Rate Calculation” block and “Display”.Modeling was realized without and with convolutional coding (r=3/4, K=7) at different noise temperatures and free space losses. Dependencies of a Bit Error Rate on free space path losses, antennas diameter, phase/frequency offsets, satellite transponder linear gain, aircraft and satellite transponder high power amplifier backoff level, and phase noise were received and analyzed.

**Key words**:ADS-B, BER,communication channel, aircraft, satellite transponder, ground station, convolutional encoder, BPSK, free space loss, phase/frequency offset, memoryless nonlinearity, phase noise, Viterbi decoder, amplifier backoff level, noise temperature, antenna diameter.

1. **Introduction**

Air-traffic control services in accordance with CNS/ATM (Communication, Navigation, Surveillance / Air Traffic Management) concept should be enhanced usingADS-B (Automatic Dependent Surveillance-Broadcast) function (Minimum…2002).

Global satellite communication service Iridium (Manual…2007) allows aviation users to send and receive voice, messaging and data regardless of their positions on or above the earth: air-to-land, land-to-air and air-to-air.

On 20 June 2012 satellite operator Iridium has decided that from 2015 they will be putting ADS-B receivers on its next-generation satellite constellation, aimed at bringing global, real-time aircraft surveillance for air navigation service providers (Iridium-Adds-ADS-B…2012). This new satellite system will enable continuous space-based monitoring and control of aircraft, using 1090 MHz Extended Squitter ADS-B receivers built into each of the 66 satellites in Iridium's second-generation satellite constellation.

ADS-B is a surveillance technology for tracking aircraft as part of the [Next Generation Air Transportation System](http://en.wikipedia.org/wiki/Next_Generation_Air_Transportation_System)(EUROCONTROL…2012).When using ADS-B system both pilots and controllers will see the same radar picture.

Telecommunications satellite systems are widely used in aviationdue toadvantagesof satellite communication whichis connected with possibility of operation with many airplanes at long distances and with independence of communication expenses on distances to airplanes (An Introduction…2009, Manual…Doc9880, Roddy…2006, Woolner…2003).

Operation of satellite communication link is very sensitive to its parameters and even small alterations of these parameters can cause changing of data rate and ground coverage of satellite system (Elbert…2012).For this reason it is important to develop models of real satellite communication channels and investigate methods of critical situations correction.

The Iridium systemincludes 66 low-orbit satellites at an altitude of 780 km and equally divided into 6 orbital planes (Iridium…2008).Each satellite can communicate with the Airborne Earth Station.Each satellite uses three phased-array antennas for the user links.These arrays are designed to provide user-link service by communicating within the 1616-1626.5 MHz band. The gateway serves as a gateway to the Aviation Telecommunication Network for forwarding messages from the aircraft to the required Air Traffic Command or Aircraft Operational Communication unit.

Channels are implemented in the Iridium Satellite Network using a hybrid Time Division Multiple Access/Frequency Division Multiple Access architecture based on Time Division Duplex using a 90 millisecond frame and a binary phase-shift keyed (BPSK) modulation scheme (or DE-QPSK differential encoding).

The aim of this paper is: 1) to design the model of communication channel "Aircraft-to-Satellite-to-Ground Station" with error-control coding for Iridium system using MATLAB Simulink software; 2) on the base of this model investigate a channel integrity and receive dependences of a bit-error rate (BER) on a free space path loss, a phase/frequency offset, a satellite transponder linear gain,an airborne and satellite transponderhigh power amplifiers backoff level, antennas diameters, a phase noise and a noise temperature; 3) to analyze the constellation before and after high power amplifiers.

**2. A model for “Aircraft-to-Satellite-to-Ground Station” link**

A model for satellite communication channel "Aircraft –to-Satellite-to-Ground Station" without error-control coding was built earlier using MATLAB Sіmulіnk software and demo model “RF Satellite Link” (Kharchenko…2012a, 2012b). The original model, shown in Fig. 1, comprises “Aircraft Uplink Transmitter” (Bernoulli Random Binary Generator, Convolutional Encoder, BPSK Baseband Modulator, High Power Amplifier(HPA) with a memoryless nonlinearity, Transmitter Dish Antenna Gain), “Uplink Path” (Free Space Path Loss, Phase/Frequency Offset), “Satellite Transponder” (Receiver Dish Antenna Gain, Satellite Receiver System Temperature, Complex Baseband Amplifier, Phase Noise, Transmitter Dish Antenna Gain), “Downlink Path” (Free Space Path Loss, Phase/Frequency Offset), “Ground Station Downlink Receiver”(Receiver Dish Antenna Gain,Ground Receiver System Temperature, Viterbi Decoder), “Error Rate Calculation block” and “Display”.

In the“Aircraft Uplink Transmitter”the Bernoulli Binary Generator block generates random binary numbers using a Bernoulli distribution with parameter p, produces “zero” with probability p and“one” with probability 1-p (the value p=0,5 is used). The output signal is a frame-based matrix.The Bernoulli Binary Generator block generates adiscrete signal and updates the signal at integer multiplesof a fixed time interval, called the sample time. The length ofthis time interval has the value 1. The output data type is “double”.

Iridium system employs aBPSK modulation and forward error correction coding in the form of convolutional encoding with Viterbi decoding (Viterbi…1971). Iridium uses a rate 3/4, constraint length 7, (r=3/4; K=7) convolutional code on both transmission and reception (Costello…1998).The Convolutional Encoder block is using the poly2trellis(7,[171 133],171)function with a constraint length of 7, code generator polynomials of 171 and 133 (in octal numbers), and a feedback connection of 171 (in octal). The puncture vector is [1; 1; 0; 1; 1; 0].

The BPSK Baseband Modulator block modulates a signal using the binary phase shift keying method. The output is a baseband representation of the modulated signal.

The High Power Amplifier block applies memoryless nonlinearity to complex baseband signal andprovides five different methods for modeling the nonlinearity. In this paper results only forSaleh model with standard AM/AM and AM/PM parameters are given(Saleh…1981). A HPA backoff level is used to determine how close the satellite high power amplifier is driven to saturation. The following selected backoff is used to set the input and output gain of the Memoryless Nonlinearity block: 30 dB - the average input power is 30 decibels below the input power that causes amplifier saturation(in this case AM/AM and AM/PM conversion is negligible); 7 dB - moderate nonlinearity; and 1 dB - severe nonlinearity (see MATLAB demo model “RF Satellite Link”).

The Transmitter (Receiver) Dish Antenna Gainblock multiplies the input by a constant value (gain).Dependencies of a BER on transmitting and receivingantennas diameter were obtained using vectors [d1, d2] for each pair “transmitter-receiver”. The first element in the vector [d1, d2] represents the transmitting antenna diameter (in meters) and is used to calculate the gain in the Transmitter Dish Antenna Gain block. The second element represents the receiving antenna diameter and is used to calculate the gain in the Receiver Dish Antenna Gain block. The default setting is [1.0,1.0] (an antenna gain is 12,4) and diameters of all antennas (transmitting antenna on an aircraft, receiving and transmitting antennas on a satellite, receiving antenna on a ground station) were changed simultaneously.

In the “Uplink (Downlink) Path”the Free Space Path Lossblock simulates the loss of signal power due to the distance between theaircraft uplink transmitter and thesatellite transponder receiver. The block reduces the amplitude of the input signal by an amount that is determined by the Loss (dB) parameter.

The Phase/Frequency Offsetblock applies phase and frequency offsets to an incoming signal.

In the “Satellite Transponder”the Satellite Receiver System Temperatureblock simulates the effects of thermal noise on a complex, baseband signal. Modeling was provided for two values of effective satellite and ground station receiver systems noise temperatures20 K (very low noise level) and 290 K (typical noise level). These settings were changed simultaneously and the last setting was used to view how typical receivers operate.

The Complex Baseband Amplifierblock models an amplifier with noise (during simulations this setting was 0K). In addition to linear amplifier, this block has five different methods to model the nonlinear amplifier. In this paper results only for Saleh model with standard AM/AM and AM/PM parameters are given.

The Phase Noise block adds receiver phase noise to a complex baseband signal. The block applies the phase noise as follows: generates additive white Gaussian noise and filters it with a digital filter; adds the resulting noise to the angle component of the input signal. The level of the spectrum is specified by the noise power contained in a one hertz bandwidth offset from a carrier by a certain frequency. Modeling was provided for three levels: negligible (phase noise level: -100dBc/Hz, frequency offset: 100 Hz), low (-55 dBc/Hz, frequency offset: 100 Hz), high (-48 dBc/Hz, frequency offset: 100 Hz).

In the “Ground Station Downlink Receiver”the Viterbi Decoderblock decodes input symbols to produce binary output symbols. Unquantized decision type parameter was used.

Comparing scatter plots of the signal after BPSK modulation and before demodulation allows viewing the impact of all impairments on the received signal.

**3. Aeronautical satellite channel simulation**

For computer modeling a distance between the Iridium satellite and the ground station (satellite altitude) 780 km and an operational frequency 1616 MHzwere taken.Changing acarrier frequency of the link updates the Free Space Path Loss block.

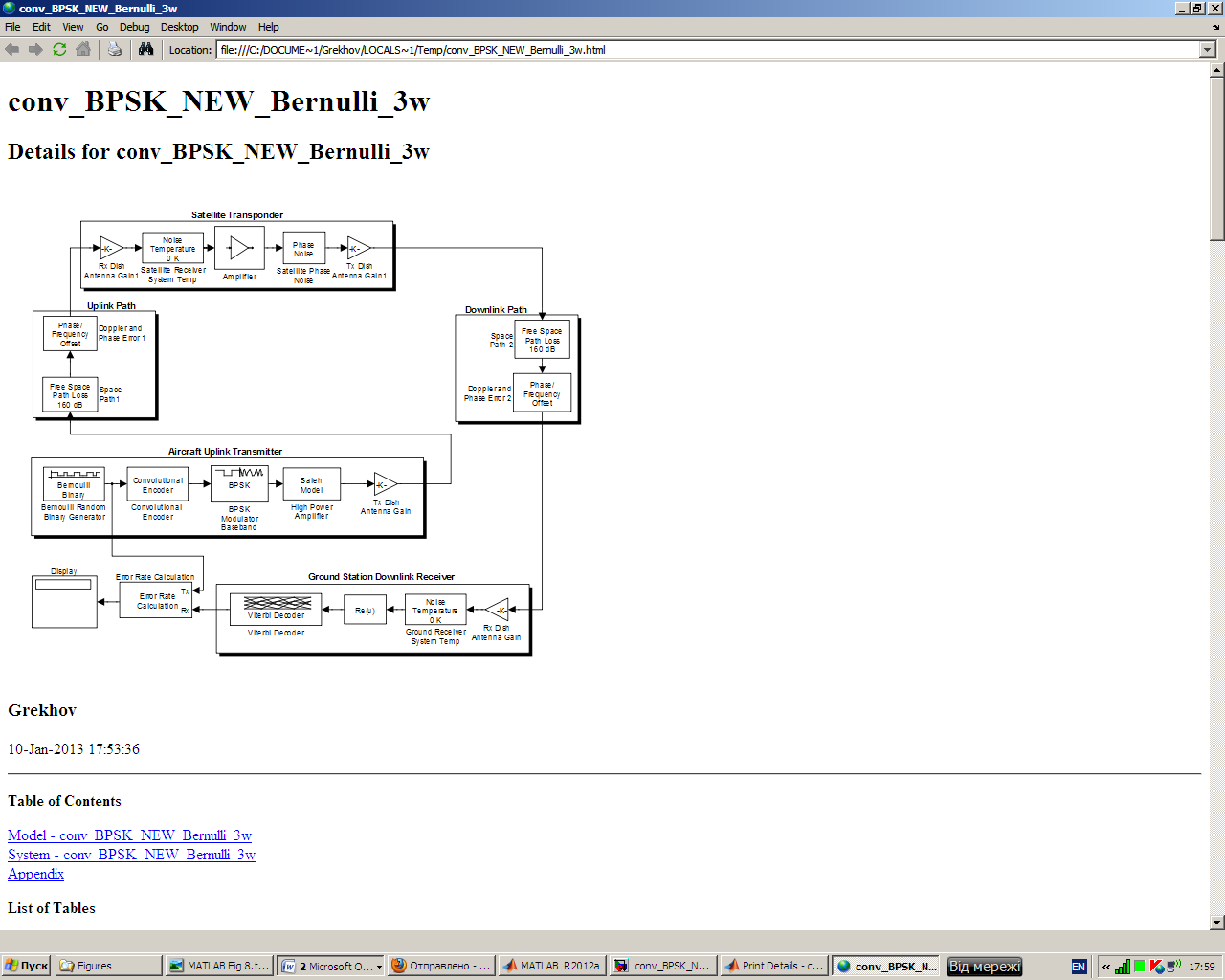
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Fig. 1. “Aircraft-to-Satellite-to-Ground Station” Link

Free-space path loss is the loss in [signal strength](http://en.wikipedia.org/wiki/Signal_strength) that results from a [line-of-sight](http://en.wikipedia.org/wiki/Line-of-sight_propagation) path through free space, does not include the [gain](http://en.wikipedia.org/wiki/Antenna_gain) of the [antennas](http://en.wikipedia.org/wiki/Antenna_%28radio%29) used at the [transmitter](http://en.wikipedia.org/wiki/Transmitter) and [receiver](http://en.wikipedia.org/wiki/Receiver_%28radio%29), is [proportional](http://en.wikipedia.org/wiki/Proportionality_%28mathematics%29) to the [square](http://en.wikipedia.org/wiki/Square_%28algebra%29) of the distance between the transmitter and receiver, and also proportional to the square of Iridiumoperational [frequency](http://en.wikipedia.org/wiki/Frequency). A dependence of a BER on free space path loss for different noise temperatures without coding and with convolutional coding is shown in Fig. 2. Loss values were changed simultaneously inuplink and downlink channelsfor equal antennas diameter d1 = d2 =d3 =d4 = 1,0 m, moderate HPAs nonlinearity (backoff level 7 dB), satellite transponder gain - 0 dB. Convolutional coding considerably decreases errors probability and a BER is vanishingfor free space path loss in the range from 0 dB to 161 dB (in case of very low noise temperature 20 K) and from 0 dB to 155 dB (in case of typical noise temperature 290 K). For low-orbital satellites such losses are realistic and for geostationary satellites they can achieve 200 dB (Osborne…1999, Sclar…2001).

Changing of all antennas diameter has significant influence on errors probability shown in Fig. 3 – the more antennas diameter, the less is an error probability. In this simulation free space path loss was fixed (160 dB), HPAs nonlinearity – moderate (backoff level 7 dB), and two noise temperatures were considered (20 K and 290 K).

Convolutional coding essentially reduces the error probability that leads to a BER vanishing for antennas with diameter more than 1,2 m. Iridium satellite has three Main Mission Antennas (each of 0,86 m wide and 1,86 m high) (Iridium…2008). The same area has a circle with diameter ≈1,4 m. Apparently, results of our modeling are in the good consent with these data.

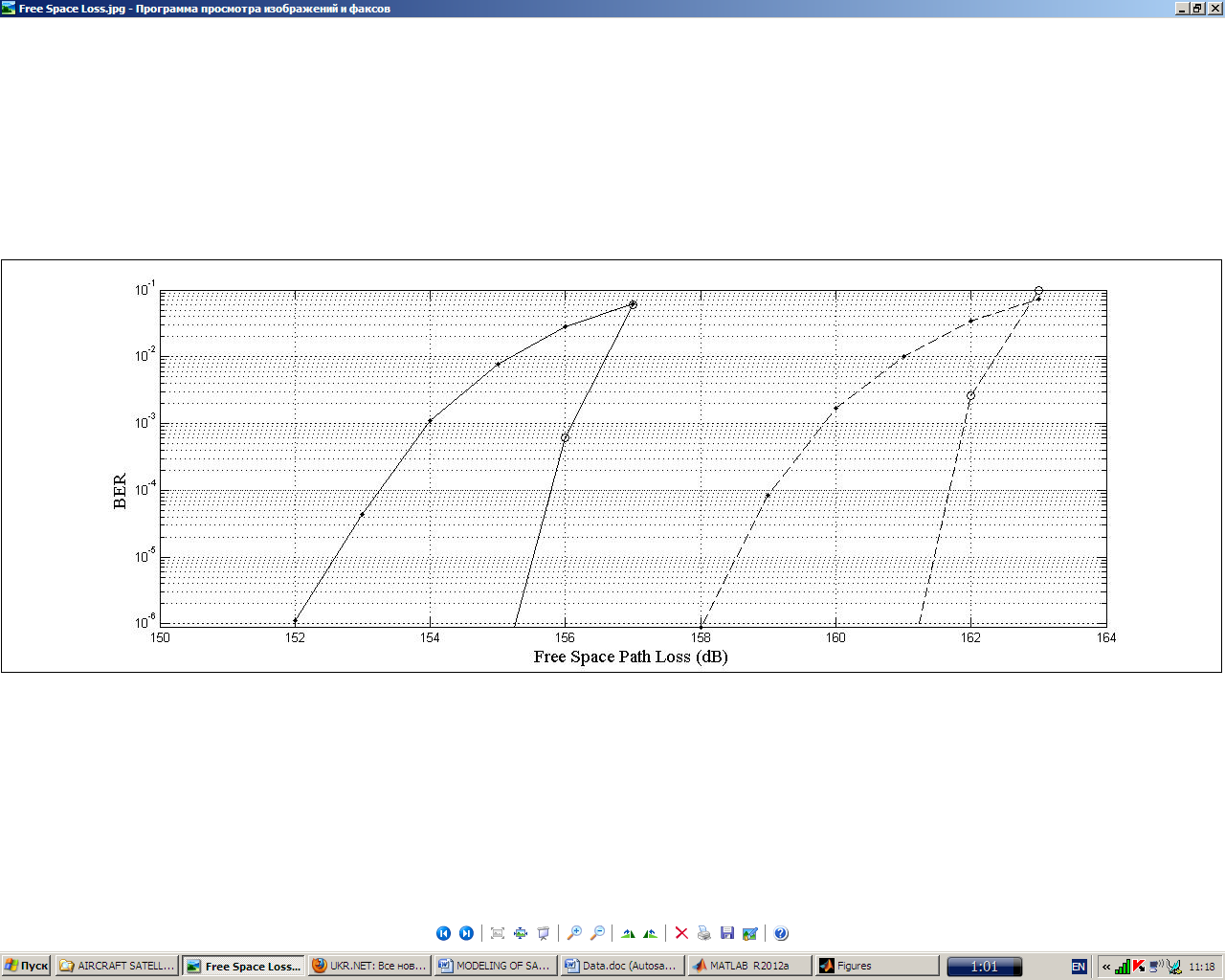
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Fig. 2. Dependence of an error probability for a BPSK modulation scheme on free space path loss inthe uplink andthe downlink:

dots – without coding, circles – with convolutional coding (rate ¾, constraint length K=7);satellite and ground receivers noise temperatures are 20 K (dashed lines) and 290 K (solid lines), HPAs backoff level is 7 dB, phase and frequency offsets are equal to zero, d1 = d2 = d3 =d4 = 1,0 m; satellite transponder phase noise is negligible.

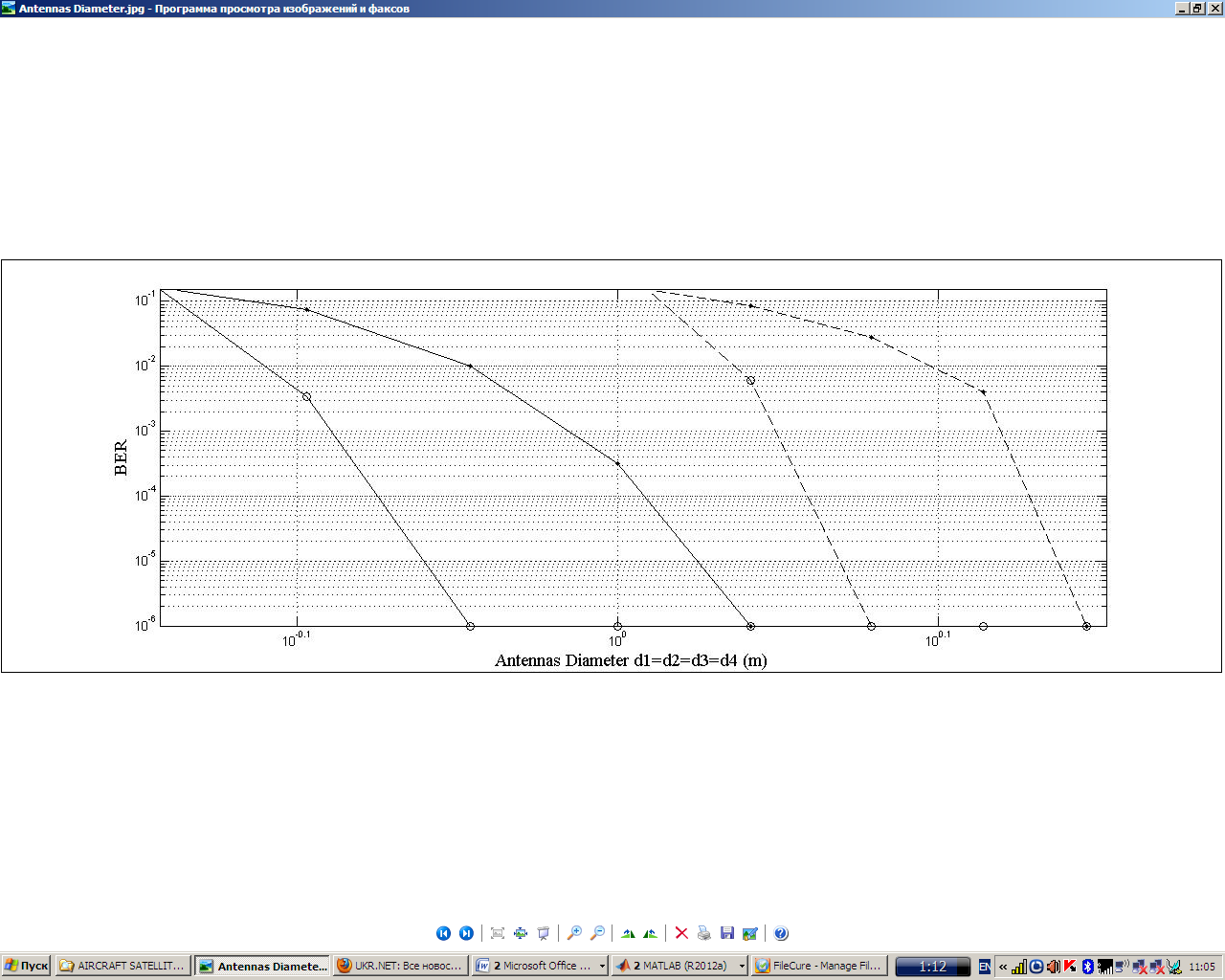


Fig. 3. Dependence of error probability for a BPSK modulation scheme on satellite and aircraft antennas diameter:

dots – without coding, circles – with convolutional coding (rate ¾, constraint length K=7);satellite and ground receiversnoise temperatures are 20 K (solid lines) and 290 K (dashed lines), phase and frequency offsets are equal to zero, HPAs backoff level is

7 dB, free space path loss is 160 dB;satellite transponder phase noise is negligible.

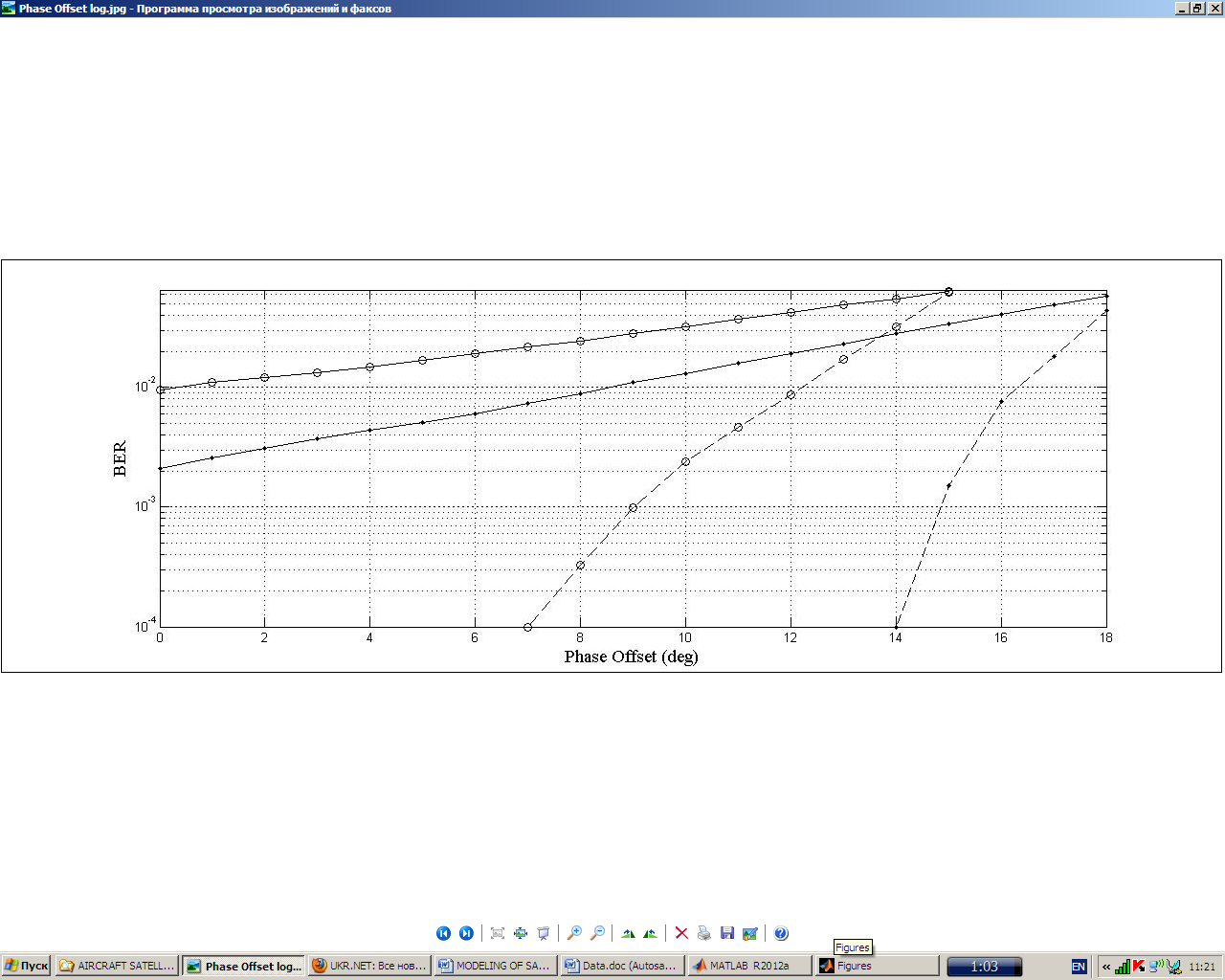
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Fig. 4. Dependence of error probability for BPSK modulation scheme on phase offset in the uplink and the downlink:

solid lines – without coding, dashed lines – with convolutional coding (rate ¾, constraint length K=7);satellite and ground receivers

noise temperatures 20 K (dots, free space path loss 162 dB) and 290 K (circles, free space path loss 157 dB); HPAs backoff level

7 dB; frequency offset is equaled to zero; d1 = d2 = d3 = d4 = 1,0 m; satellite transponder phase noise is negligible.

In the presence of an arbitrary phase offset introduced by the uplink and the downlink, the demodulator is unable to tell which constellation point is which. A dependence of a BER on phase offset in the uplink and the downlink is shown in Fig. 4 for two noise temperatures without convolutional coding and with it.At usingconvolutional coding a BER is vanishing for phase shifts up to 7oat uplink and downlink losses in free space 157 dB and a noise temperature of a satellite transponder and a ground receiver 290 K.Signal constellations for BPSK modulation scheme at the phase offset 20oin theuplink and thedownlink is shown in Fig. 5, and for the frequency offset in the uplink and the downlink 2 Hz – in Fig. 6.

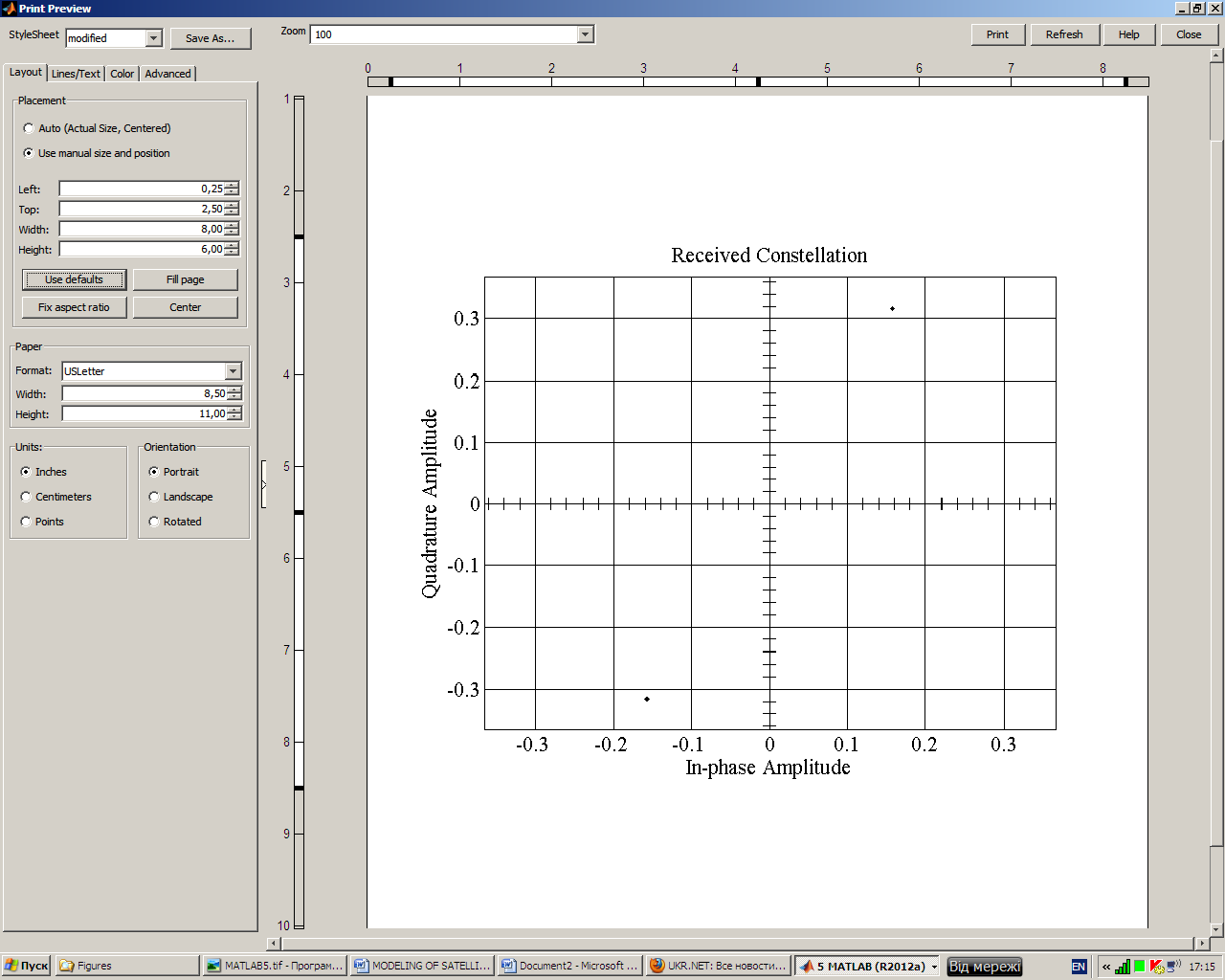
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Fig. 5. End signal constellation for BPSK modulation scheme for phase offset 20oin the uplink and the downlink:

with convolutional coding (rate ¾, constraint length K=7); satellite and ground receivers noise temperatures 0 K;

free space path loss 157 dB; HPAs backoff level 7 dB; frequency offset is equal to zero; d1 = d2 = d3 = d4 = 1,0 m;

satellite transponder phase noise is negligible.

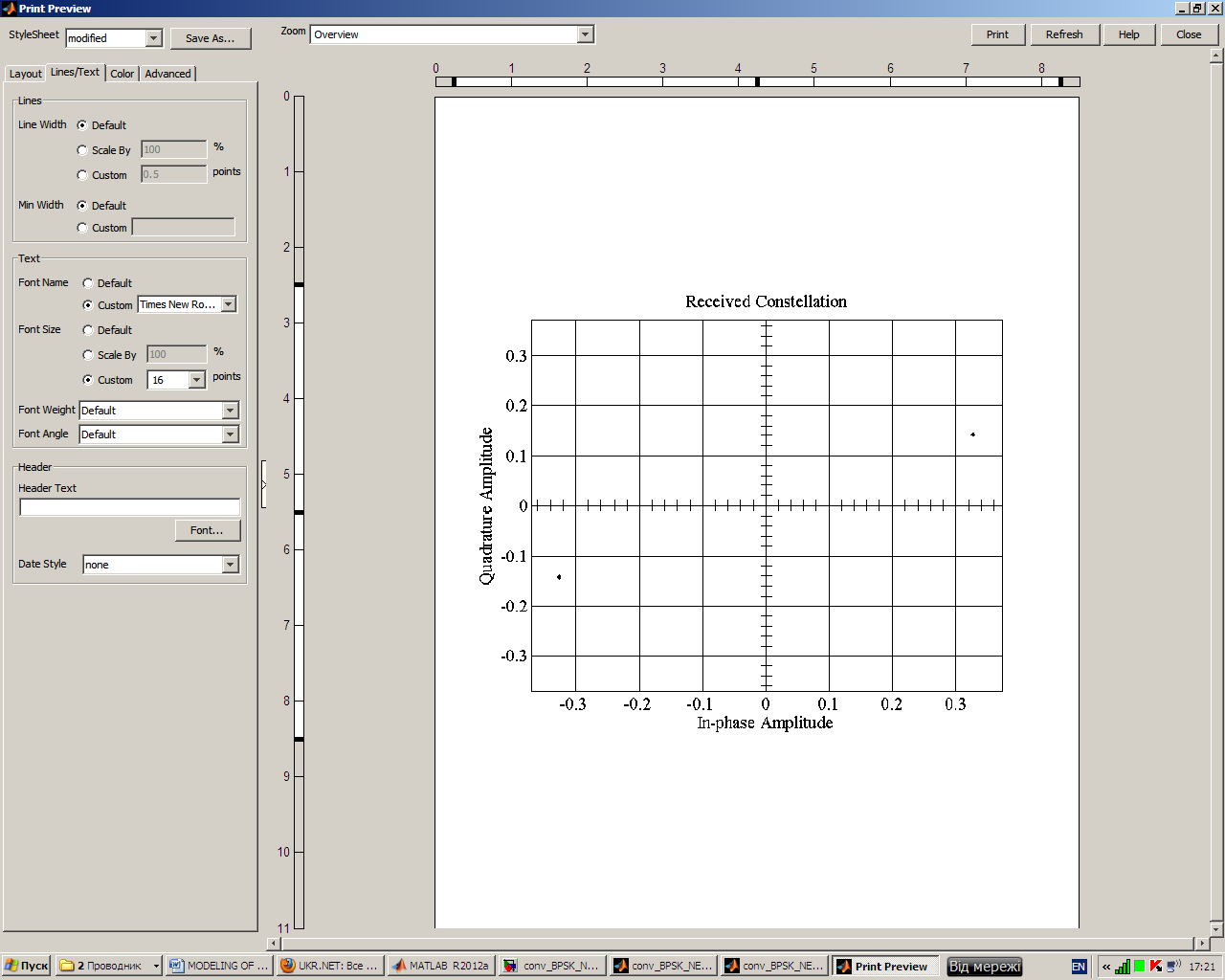
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Fig. 6. End signal constellation for BPSK modulation scheme for frequency offset 2 Hz in the uplink and the downlink:

with convolutional coding (rate ¾, constraint length K=7);satellite and ground receivers noise temperatures 0 K;

free space path loss 157 dB; HPAs backoff level 7 dB;phase offset is equal tozero;d1 = d2 = d3 = d4 = 1,0 m;

satellite transponder phase noise is negligible.

Our model allows exploring the end-to-end simulation of "Aircraft–to-Satellite-to-Ground Station” communications links using original model of a satellite transponder. The Complex Baseband Amplifier block can model a linear amplifier in which the linear method is implemented by a Gain block. A dependence of a BER on satellite transponder gain is shown in Fig. 7 for two noise temperatures without coding and with convolutional coding. Convolutional coding essentially reduces the error probability that leads to a BER vanishing for satellite amplifier linear gain more than 8 dB.

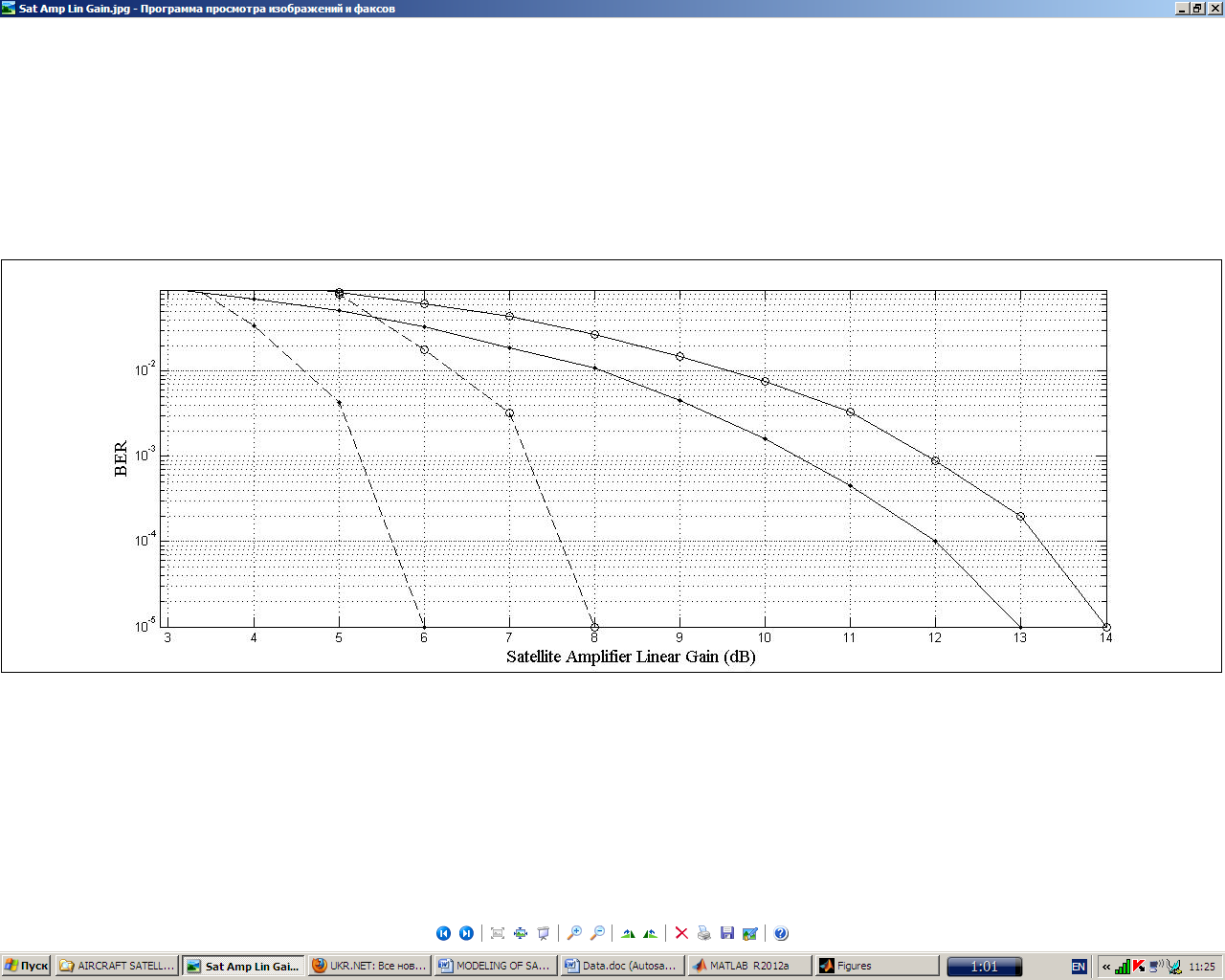


Fig. 7. Dependence of error probability for BPSK modulation scheme on satellite transponder linear gain:

solid lines – without coding, dashed lines – with convolutional coding (rate ¾, constraint length K=7);satellite and ground receivers noise temperatures 20 K (dots, free space path loss – 160 dB) and 290 K (circles, free space path loss – 157 dB), phase and frequency offsets are equal to zero; HPAs nonlinearity is negligible; d1 = d2 = d3 = d4 = 1,0 m;satellite transponder phase noise is negligible.

Table 1. Dependence of Error Probability for BPSK Modulation Scheme on Amplifiers Nonlinearity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| HPA backoff level  (Aircraft and Satellite) | BER  (Satellite and Ground Receivers  Noise Temperatures T=20K) | | | BER  (Satellite and Ground Receivers  Noise Temperatures T=290K) | | |
| Free Space Path Loss | | | Free Space Path Loss | | |
| 107 dB | 116 dB | 120 dB | 110 dB | 112 dB | 115 dB |
| 1. Aircraft HPA – 30 dB  Satellite HPA – 30 dB | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 2. Aircraft HPA – 7 dB  Satellite HPA – 30 dB | 0,0 | 0,0 | 1,7·10-3 | 0,0 | 0,0 | 4,8·10-2 |
| 3. Aircraft HPA – 1 dB  Satellite HPA – 30 dB | 0,0 | 2,3·10-2 | 4,9·10-1 | 8,3·10-3 | 4,4·10-1 | 5,0·10-1 |
| 4. Aircraft HPA – 30 dB  Satellite HPA – 7 dB | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 5. Aircraft HPA – 7 dB  Satellite HPA – 7 dB | 0,0 | 0,0 | 1,7·10-3 | 0,0 | 0,0 | 4,8·10-2 |
| 6. Aircraft HPA – 1 dB  Satellite HPA – 7 dB | 0,0 | 2,3·10-2 | 4,9·10-1 | 0,0 | 4,4·10-1 | 5,0·10-1 |
| 7. Aircraft HPA – 30 dB  Satellite HPA – 1 dB | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 8. Aircraft HPA – 7 dB  Satellite HPA – 1 dB | 0,0 | 0,0 | 1,7·10-3 | 0,0 | 0,0 | 4,8·10-2 |
| 9. Aircraft HPA – 1 dB  Satellite HPA – 1 dB | 0,0 | 2,3·10-2 | 4,9·10-1 | 8,3·10-3 | 4,4·10-1 | 5,0·10-1 |
| *Note:* All antennas gain G≈1; with convolutional coding (rate ¾, constraint length K=7). | | | | | | |

In proposed model aircraft uplink transmitter amplifier andthe satellite transponder are amplifyinga signal on the uplink and the downlink sides of Iridium communications satelliteby themodel of a traveling wave tube amplifier (TWTA) using the Saleh model.For an input sine wave of frequency *f* and amplitude *r*, the TWTA is characterized by the relationship (Elbert…2003):

,

wherethe empirical relations

describe *A(r)* and *φ(r)*. The first term is called AM/AM conversion, and the second is AM/PM conversion (the four constants:   .

Nonlinear method options in the block apply a memoryless nonlinearity to the complex baseband input signal in the following manner: multiplies the signal by a gain factor; splits the complex signal into its magnitude and angle components; applies an AM/AM conversion to the magnitude of the signal, according to the Saleh nonlinearity method, to produce the magnitude of the output signal; applies an AM/PM conversion to the phase of the signal, according to the Saleh nonlinearity method, and adds the result to the angle of the signal to produce the angle of the output signal; combines the new magnitude and angle components into a complex signal and multiplies the result by a gain factor, which is controlled by the Linear gain parameter. A dependence of a BER onnonlinearities of satellite transponder and aircraft uplink transmitter amplifiers is shown in Table 1.

Setting the Phase Noise parameter to thehigh level (-48 dBc/Hz, frequency offset: 100 Hz) leads to the increased variance in the tangential direction in the received signal scatter plot shown in Fig. 8. Setting the Phase Noise to the low level (-55 dBc/Hz, frequency offset: 100 Hz)leads to a situation when the variance in the tangential direction has decreased somewhat. This level of phase noise is not sufficient to cause errors.

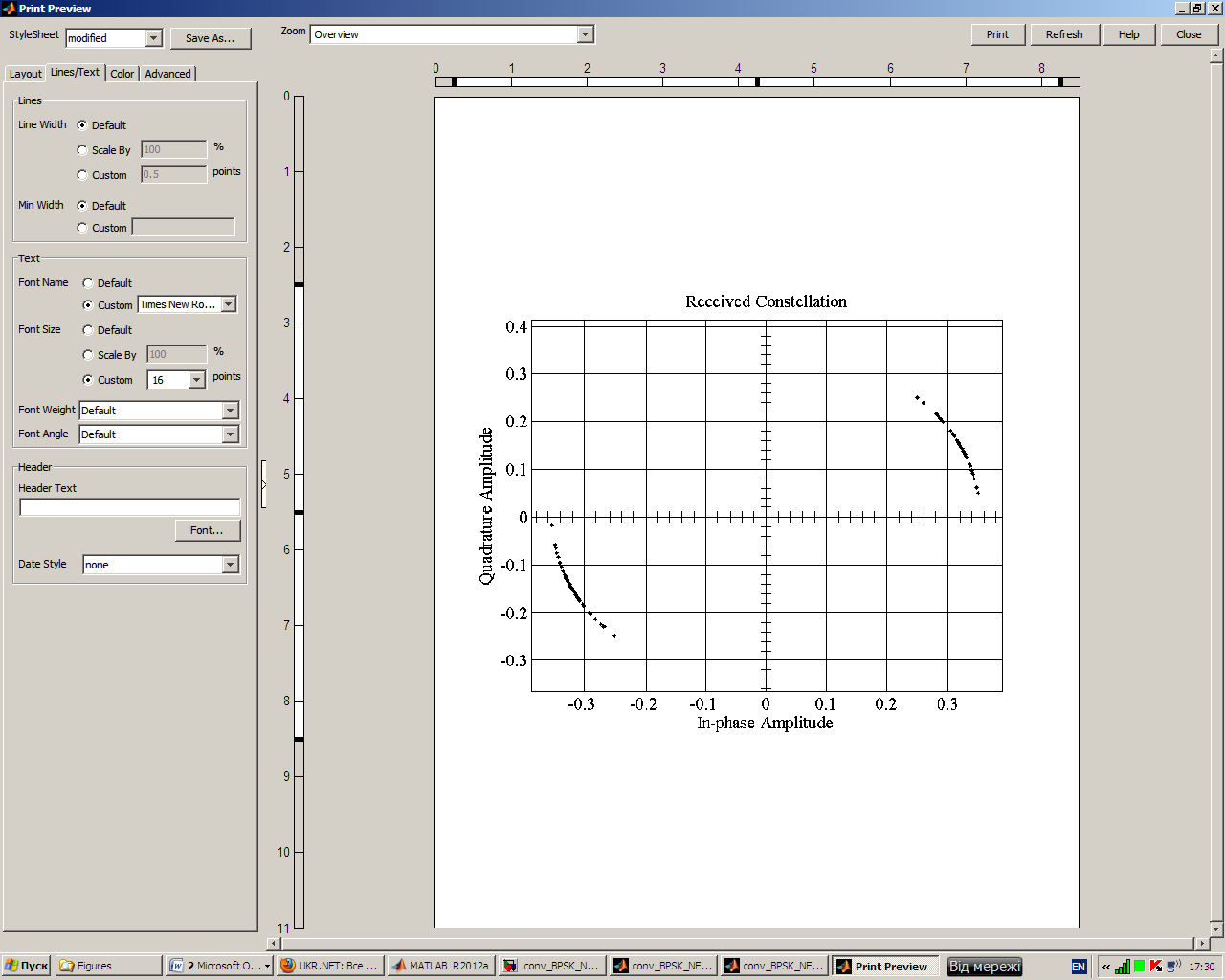


Fig. 8. Signal constellation for BPSK modulation scheme for the high level ofphase noise (-48 dBc/Hz, frequency offset: 100 Hz):with convolutional coding (rate ¾, constraint length K=7);satellite and ground receivers noise temperatures 0 K; free space path loss 157 dB; HPAs backoff level 7 dB;phase offset is equal tozero; d1 = d2 = d3 = d4 = 1,0 m.

**4. Conclusions**

For modelling of ADS-B messages transmitting on the base of low-orbit satellite constellation Іrіdіum the original model of a communication channel "Aircraft–to-Satellite-to-Ground Station" with error-control codingwas built using MATLAB Sіmulіnk software.

For studying of a signal transmission through a communication channel without coding and with convolutional coding the following parameters were changed: losses in a free space simultaneously in the uplink and the downlink from 0 dB to 250 dB in each channel (Fig. 2); noise temperature of a satellite transponder and a ground receiver (20 K, 290 K); symmetrically and asymmetrically diameters of all four antennas that increased or reduced a power of the received signal (Fig. 3); phase and frequency (due to Doppler’s effect) offsets simultaneously in the uplink and the downlink from 0o to 20o (from 0 Hz to 10 Hz) in each channel (Fig. 4-6); satellite transponder linear gain from 0 dB to 15 dB (Fig. 7); nonlinearity of HPAs on an airplane and a satellite (Table 1); and satellite transponder phase noise (Fig. 8).

Signal changes were analyzed by means of active windows-indicators which allowed defining a BER and constellations of the transmitted and received signals Fig. 5, 6).

Dependencies shown in Fig. 2-8 were obtained for “standard parameters”: without coding and with convolutional coding (rate ¾, constraint length K=7); satellite and ground receivers noise temperatures 20 K and 290 K; without phase and frequency offsets; negligible HPAs; d1 = d2 = d3 = d4 = 1,0 m; negligible satellite transponder phase noise. Values of free space path losses,phase and frequency offsets, antennas diameter were specified in each special case.

For “standard parameters” a BER is vanishing for free space path losses changing from 0 dB to 163 dB at use of convolutional coding and a noise temperature 20К.

Diameters of antennas essentially influence on a BERwhat is shown in (Fig. 3).The probability of errors for “standard parameters” is vanishing for diameters of all antennas more than 1,2 m. This result is in good agreement with the size of Iridium satellite antennas (Iridium…2008). At the same time calculations with a diameter ofaircraft transmitting antennad1=0,3 m, a diameter ofsatellite receiving antennad2=1 m, a diameter of satellite transmitting antenna d3 = 1 m and a diameter of ground station receiving antenna d4 = 2 m (for the noise temperature 0 K) gives BERvanishing for losses in free space up to 220 dB. This result is in good agreement with a satellite communication channel budget (Sklar…2001).

Influence of convolutional coding on dependence of a BER on phase offsets in the uplink and the downlink is critical and changes character of this dependence (Fig. 4), essentially reducing a level of errors. Under "standard parameters" and noise temperature 20 Ka BER is vanishing at phase shifts up to 14o. The signal constellation (Fig. 5) shows a presence of strong distortions during signal transmission. Frequency offsets caused by the Doppler's effect (Fig. 6) also bring essential distortions.

Satellite transponder is the central element of a considered communication channel and transponder linear gain along with a choice of a working point (level of TWTA nonlinearity)make strong impact on quantity of errors at data transmission. Under “standard parameters”, noise temperature 290 K and free spacelosses 157 dB in the uplink and 157 dB in the downlink a BER vanishes when transponder linear gain is not less than 8 dB (Fig. 7). At a noise temperature 20 K and free spacelosses 160 dB in the uplink and 160 dB in the downlink a BER vanish when transponder linear gain is not less than 6 dB.

Influence of HPA backoff parameter on a BER was studied for different free space losses and noise temperatures (Table 1). In this case a gain of all four antennaswas equal to unit to exclude effect of preamplifying in front of satellitetransponder HPA. Nevertheless, results of modelling have shown that defining influence on a BER has backoff parameterof the aircraft (compare cases 2, 5, 8 and 3,6, 9 in Table 1). It is possible to explain this by entering ofpredistortions byaircraft HPA which then are partially compensated by the transponder HPA.

The impact of phase noise on a transmitted signal is shown in Fig. 8.

Proposed model can be used as basic model for investigation of communication between two airplanes and ground stations using several satellites.

Developed model can also be used for finding optimal methods of error-correcting coding.

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**MODELIAVIMAS ADS-B DUOMENŲ PERDAVIMASPER PALYDOVĄ**

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**Abstrakti.**Modeliavimo ADS-Bpranešimų perdavimoperžemosorbitospalydovųІrіdіumOriginalus modelisryšio kanalo"Orlaivių palydovųįžemėsStation"buvopastatytas naudojantMATLABSіmulіnk. ModelissudaroAircraftuplinksiųstuvo(Bernulio AtsitiktinisDvejetainisgeneratorius,ConvolutionalEncoder, BPSKBasebandmoduliatorius, Didelės galios stiprintuvassuatmintiesnetiesiškumosiųstuvasIndųantenospelnas) uplinkKelias (Free Space kelio nuostolių,etapas/dažnio poslinkis), palydovinėTransponder(imtuvasIndųantenospelnas, Palydoviniai imtuvaisistemos temperatūra, kompleksas Basebandstiprintuvas, fazinis triukšmas,siųstuvasIndųantenospelnas), DownlinkKelias(Free Space kelio nuostolių,etapas/dažnio poslinkis), antžeminių stočiųDownlinkimtuvas (imtuvo Indųantenos stiprinimo,žemėsimtuvas sistematemperatūra,Viterbiegodekoderis), Klaida normos skaičiavimasblokasir ekranas. Modeliavimasbuvo realizuotasbe ir suskirtingaistriukšmotemperatūra irLaisvaerdvionuostoliusconvolutionalkodavimas. Gavo ir išnagrinėjopriklausomybėsBit Error RateapieLaisvaerdviotrajektorijainuostolių, antenos skersmuofazės /dažnisnukrypimais, palydovinėsatsakiklislinijiniupelnas, orlaivių irpalydovinėatsakikliodidelės galiosstiprintuvobackofflygio, irfazinis triukšmas.

**Reikšminiai žodžiai**: ADS-B, BIR, komunikacijos kanalas, lėktuvai, palydovinėatsakiklis,antžeminių stočių, convolutionalencoder, BPSK,Nuostoliai laisvoje erdvėje, fazė /dažnio poslinkis, atmintiesnetiesiškumas, fazinis triukšmas, Viterbidekoderis, stiprintuvas backofflygis, triukšmas, temperatūra, antenosskersmens.