CONTENT
Vol. 6. No. 5-2020

Published bi-monthly since 2015.

ISSN 2664-066X (Print)
ISSN 2664-0678 (Online)

Publisher
Institute of Radio and Information Systems (IRIS), Vienna, Austria

Address:
1010 Wien, Austria, Ebendorferstrasse 10/6b
media-publisher.eu/synchroinfo-journal

REFLECTION OF ELECTROMAGNETIC WAVE FROM THE BORDER OF ELASTIC ENVIRONMENT FROM PIEZOACTIVE MATERIAL

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DOI: 10.36724/2664-066X-2020-6-5-2-5

ABSTRACT

A plane electromagnetic wave incident on the interface of a dielectric medium made of a piezoactive material leads to the excitation of elastic shear waves. Piezoelectric material is assumed to have 6mm class hexagonal symmetry. The case of a half-space and a finite layer is considered. Coefficients of reflection and refraction are determined. In the problem of an electromagnetic wave incidence on a half-space made of a piezoelectric material of hexagonal symmetry, class 6 mm, the nature of the piezoelectric effect influence on the transparency condition is established. In the case of reflection from a finite piezolayer, reflection coefficients are determined for different variants of boundary conditions.

KEYWORDS: *Electromagnetic wave, piezoelectric materia, electroelastic waves.*

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The influence of the electromagnetic field on the nature of the reflection and refraction of shear elastic waves in a quasi-static formulation was studied in [1-5]. Piezoelectric materials of cubic and hexagonal symmetry were considered. Particular problems of reflection of shear electroelastic waves without a quasi-static approximation for the equations of the electromagnetic field were solved in [6, 7].

Naturally, in problems of excitation of electroelastic waves by means of an electromagnetic wave incident on an elastic medium, it is necessary to use the exact equations of electrodynamics.

1. In a rectangular Cartesian coordinate system (x, y, z) half-space properties

$$-\infty < x < 0,\ -\infty < y < \infty, -\infty < z < \infty$$

are identified with the properties of vacuum. Half-space occupying an area

$$0 < x < \infty,\ -\infty < y < \infty,\ -\infty < z < \infty$$

is an elastic piezoelectric of hexagonal symmetry of class 6 mm. From half-space $-\infty < x < 0$ to the interface $x = 0$ falling transversely polarized flat $\left(\partial/\partial z = 0\right)$ electromagnetic wave with electric field components $E_1^{(1)}$, $E_2^{(2)}$ and magnetic field $H_3^{(1)}$. The electrodynamic equations for incident and reflected electromagnetic waves are conveniently used in the form

$$\Delta H_3^{(1)} = \varepsilon_0 \mu_0 \frac{\partial^2 H_3^{(1)}}{\partial t^2},$$
$$\frac{\partial E_1^{(1)}}{\partial t} = \frac{1}{\varepsilon_0}\frac{\partial H_3^{(1)}}{\partial y},\ \frac{\partial E_2^{(1)}}{\partial t} = -\frac{1}{\varepsilon_0}\frac{\partial H_3^{(1)}}{\partial x} \tag{1}$$

where

$$\Delta \equiv \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2},\ \varepsilon_0 \mu_0 = \frac{1}{c_0^2} \tag{2}$$

c_0 – speed of light propagation in a vacuum

Electroelasticity equations for piezoelectric medium $0 < x < \infty$, without quasi-static approximation, the following [7, 8]

$$\Delta w = \frac{1}{c_t^2}\frac{\partial^2 w}{\partial t^2},\ \Delta H_3 = \frac{1}{c^2}\frac{\partial^2 H_3}{\partial t^2}$$
$$\frac{\partial E_1}{\partial t} = \frac{1}{\varepsilon_1}\frac{\partial H_3}{\partial y} - \frac{e_{15}}{\varepsilon_1}\frac{\partial^2 w}{\partial x \partial t},\ \frac{\partial E_2}{\partial t} = -\frac{1}{\varepsilon_1}\frac{\partial H_3}{\partial x} - \frac{e_{15}}{\varepsilon_1}\frac{\partial^2 w}{\partial y \partial t} \tag{3}$$

Here

$$c_t^2 = \frac{c_{44}}{\rho}(1+\chi),\ c^2 = \frac{1}{\varepsilon_1 \mu},\ \chi = \frac{e_{15}^2}{\varepsilon_1 c_{44}} \tag{4}$$

w – elastic displacement perpendicular to the plane of wave propagation (x, y), c_{44} – shear modulus, ρ – medium material density, e_{15} – piezomodule, ε_1 and μ – dielectric and magnetic permeability of the medium, χ – electromechanical coupling coefficient.

As the main variant of the boundary conditions on the interface plane $x = 0$ the equality of tangential stress to zero and continuity of tangential components of electric vectors and magnetic fields are assumed

$$\sigma_{13} = 0,\ E_2^{(1)} = E_2,\ H_3^{(1)} = H_3 \quad \text{при } x = 0 \tag{5}$$

In the future, other variants of the boundary conditions will also be considered.

From the solutions of equations (1) for an electromagnetic wave incident on the interface, the following expressions are obtained

$$H_{3n}^{(1)} = A \exp i\left(\omega t - kx - k_2 y\right),\ k = \sqrt{\frac{\omega^2}{c_0^2} - k_2^2}$$
$$E_{1n}^{(1)} = -\frac{k_2}{\varepsilon_0 \omega} A \exp i\left(\omega t - kx - k_2 y\right), \tag{6}$$
$$E_{2n} = \frac{k}{\varepsilon_o \omega} A \exp i\left(\omega t - kx - k_2 y\right).$$

In accordance with (6), the electromagnetic wave reflected from the boundary will have the form

$$H_{30}^{(1)} = B \exp i\left(\omega t + kx - k_2 y\right)$$
$$E_{10}^{(1)} = -\frac{k_2}{\varepsilon_0 \omega} B \exp i\left(\omega t + kx - k_2 y\right), \tag{7}$$
$$E_{20}^{(1)} = -\frac{k_2}{\varepsilon_0 \omega} B \exp i\left(\omega t + kx - k_2 y\right)$$

Where is the amplitude B is the required quantity.

2. he fall of an electromagnetic wave on the boundary of a medium made of a piezoelectric material leads to the excitation of coupled elastic and electromagnetic waves in this medium. According to the first two equations of system (3), the magnetic field of the refracted electromagnetic wave and the excited elastic shear wave are determined as follows

$$H_3 = F \exp i\left(\omega t - p_2 x - k_2 y\right)$$
$$w = C \exp i\left(\omega t - p_1 x - k_2 y\right) \tag{8}$$

where

$$p_2 = \sqrt{\frac{\omega^2}{c^2} - k_2^2},\ p_1 = \sqrt{\frac{\omega^2}{c_t^2} - k_2^2},\ c^2 = \frac{1}{\varepsilon \mu} \tag{9}$$

Arbitrary constants F and C must be determined from the boundary conditions.

Substitution of (8) into the third and fourth equations of system (3) determines the components of the electric field

$$E_1 = -\frac{K_2}{\varepsilon_1\omega} F \exp i\left(\omega t - p_2 x - k_2 y\right) +$$
$$+ i\frac{p_1 e_{15}}{\varepsilon_1} C \exp i\left(\omega t - p_1 x - k_2 y\right) \tag{10}$$
$$E_2 = -\frac{p_2}{\varepsilon_1\omega} F \exp i\left(\omega t - p_2 x - k_2 y\right) +$$
$$+ i\frac{k_2 e_{15}}{\varepsilon_1} C \exp i\left(\omega t - p_1 x - k_2 y\right).$$

Satisfaction of boundary conditions (12) with the condition

$$E_2^{(1)} = E_{2h}^{(1)} + E_{2v}^{(1)},\ H_3^{(1)} = H_{3n}^{(1)} + H_{30}^{(1)} \tag{11}$$

Leads to a system of algebraic equations for the sought amplitudes B, F, C

$$A - B = \frac{\varepsilon_0\omega}{k}\left(\frac{p_2}{\varepsilon_1\omega} F + i\frac{e_{15}k_2}{\varepsilon_1} C\right)$$
$$A + B = F \tag{12}$$
$$ip_1 c_{44}\left(1+\chi\right) C - \frac{k_2 e_{15}}{\varepsilon_1\omega} F = 0$$

In particular, from system (12), the amplitude of the reflected magnetic field is determined as follows

$$B = \frac{\left(1-\chi\right) p_1\left(\varepsilon_1 k - \varepsilon_0 p_2\right) - \varepsilon_0\chi k_2^2}{\left(1+\chi\right)\left(p_1\right)\left(\varepsilon_1 k + \varepsilon_0 p_2\right) + \varepsilon_0\chi k_2^2} A \tag{13}$$

The equality to zero of numerator of expression (13) determines the conditions for the transparency of media relative to each other. By choosing the coefficient of electromechanical coupling χ you can control the degree of transparency

The condition of equality to zero of the denominator of expression (13) can be transformed to the form

$$\left(\varepsilon_1\sqrt{\theta_0\eta - 1} + \varepsilon\sqrt{\theta_\eta - 1}\right)\sqrt{\eta - 1} + \frac{\varepsilon\chi}{1+\chi} = 0 \tag{14}$$

where

$$\theta_0 = \frac{c_t^2}{c_i^2} << 1,\ \theta = \frac{c_t^2}{c^2} << 1,\ \eta = \frac{\omega^2}{k_2^2 c_t^2} \tag{15}$$

Assuming $\eta < 1$ (the angle of incident wave inclination with interface is small) equation (14) has a solution of the Gulyaev-Bluestein surface wave type. From (14) $\theta_0\eta << 1,\ \theta_\eta << 1$ we obtain a solution for the dimensionless parameter of the Gulyaev-Bluestein phase velocity [4]

$$\eta = 1 - \frac{\varepsilon^2\chi^2}{\left(\varepsilon_1 + \varepsilon\right)^2\left(1+\chi\right)^2} \tag{16}$$

From (14) and (13) it follows that at normal incidence of an electromagnetic wave $\left(k_2 = 0\right)$ the piezoelectric effect does not affect the reflected wave and does not excite an elastic wave.

Consideration of other variants of boundary conditions at $x = 0$ leads to the conclusion that there is no influence of piezoelectric effect. For boundary conditions

$$\sigma_{xz} = 0,\ E_2^{(1)} = 0 \text{ at } x = 0 \tag{17}$$

It turns out $B = A, F = C = 0$ if

$$\sigma_{xz} = 0,\ H_3^{(1)} = 0 \text{ at } x = 0 \tag{18}$$

It turns out $B = -A,\ F = C = 0$

Obviously, there will be no piezoelectric effect if one of the boundary conditions assumes zero elastic displacement $\left(w = 0\right)$.

3. Let an electromagnetic wave fall on a layer of piezoelectric material with a thickness h. Solution of the first two equations from system (3) for region $0 < x < h$ are presented as follows

$$w = f\left(x\right)\exp i\left(\omega t - k_2 y\right),$$
$$H_3 = g\left(x\right)\exp i\left(\omega t - k_2 y\right). \tag{19}$$

The requirement that (19) satisfies Eqs. (3) leads to the solutions

$$f\left(x\right) = C_1 \sin p_1 x + C_2 \cos p_1 x, g\left(x\right) =$$
$$= D_1 \sin p_2 x + D_2 \cos p_2 x \tag{20}$$

where $C_1, C_2,\ D_1, D_2$ – arbitrary constants.

The components of the electric field are determined from third and fourth equations of system (3), taking into account (19) and (20)

$$E_1 = -\frac{k_2}{\varepsilon_1\omega}\left(g + \frac{e_{15}\omega}{k_2} f'\right)\exp i\left(\omega t - k_2 y\right)$$
$$E_2 = -\frac{i}{\varepsilon_1\omega}\left(g' + e_{15}\omega k_2 f\right)\exp i\left(\omega t - k_2 y\right) \tag{21}$$

where the prime means differentiation with respect to x.

Substitution (8), (10), taking into account (11) and (19), (21), taking into account (20) into the boundary conditions (5) leads to a system of equations for the sought constants

$$\varepsilon_1 k\left(A - B\right) = \varepsilon\left(p_2 D_1 + e_{15}\omega k_2 c_2\right),\ A + B = D_2$$
$$C_{44}\left(1+\chi\right)\varepsilon_1\omega p_1 C_1 + k_2 e_{15} D_2 = 0 \tag{22}$$

On the second plane that bounds the layer, various variants of the boundary conditions are possible. The most general is the boundary conditions, when at $x = h$ the tangential stress is zero and the electromagnetic field is continuous.

Limit cases are considered here

$$w = 0,\ E_2 = 0 \text{ при } x = h \tag{23}$$

and

$$w = 0,\ H_3 = 0 \text{ при } x = h \tag{24}$$

In the case of boundary conditions (23), according to (19) - (21), we obtain

$$\begin{aligned} &C_1 \sin p_1 h + C_2 \cos p_1 h = 0 \\ &p_2 D_1 \cos p_2 h - p_2 D_2 \sin p_2 h = 0 \end{aligned} \tag{25}$$

The system of equations (22), (25) determines the constants B, C_1, C_2, D_1, D_2 through the amplitude of the incident wave A. From this system, in particular for amplitude of reflected wave, we obtain

$$\begin{aligned} &B = \left(\varepsilon_1 p_1 k - \varepsilon p_1 p_2 tgp_2 h - \chi\varepsilon k_2^2 tgp_1 h\right)\times \\ &\times\left(\varepsilon_1 p_1 k + \varepsilon p_1 p_2 tgp_2 h + \chi\varepsilon k_2^2 tgp_1 h\right)^{-1} A \end{aligned} \tag{26}$$

From (26) it follows that the numerator and denominator of expression for amplitude of the reflected electromagnetic wave vanishes at $p_1 = 0$ (and $k_2^2 = \omega^2 c_t^{-2}$). By dividing into p_1 and limiting the specified uncertainty is eliminated

$$\begin{aligned} &B = \left(\varepsilon_1 k - \varepsilon p_2 tgp_2 h - \chi\varepsilon k_2^2 h\right)\times \\ &\times\left(\varepsilon_1 k + \varepsilon p_2 tgp_2 h + \chi\varepsilon k_2^2 h\right)^{-1} A \end{aligned} \tag{27}$$

Equality of the expression numerator to zero gives the condition under which electromagnetic wave is not reflected. In the approximation of a thin layer $\left(p_2 h\right)^2 << 1$ this condition takes the form

$$\varepsilon_1 \sqrt{\frac{\omega^2}{c_0^2} - K_2^2} - \varepsilon h\left(\frac{\omega^2}{c^2} - k_2^2 + \chi K_2^2\right) = 0 \tag{28}$$

It follows from (28) that the electromechanical coupling coefficient χ can make the layer transparent to the electromagnetic wave.

If, provided $c_0^2 < c^2$ angle of incidence of the wave on the interface $x = 0$ choose $k_2^2 = \omega^2 c^{-2}$, the transparency condition will be

$$\frac{\omega}{c} = \frac{\varepsilon_1}{\chi\varepsilon h}\sqrt{\frac{c^2}{c_0^2} - 1} \tag{29}$$

In the case of boundary conditions (24), system of equations similar to equations (25) will be

$$\begin{aligned} &C_1 \sin p_1 h + C_2 \cos p_1 h = 0 \\ &D_1 \sin p_2 h + D_2 \cos p_2 h = 0 \end{aligned} \tag{30}$$

Equations (30) together with equations (22) constitute a system of five equations for determining the constants B, C_1, C_2, D_1, D_2 by the amplitude of the incident wave A, B. In particular, for the amplitude of reflected electromagnetic wave, we obtain

$$\begin{aligned} &B = \left[\left(1+\chi\right) p_1 \left(\varepsilon_1 k + \varepsilon p_2 ctgp_2 h\right) - \chi\varepsilon k_2^2 tgp_1 h\right]. \\ &\left[\left(1+\chi\right) p_1 \left(\varepsilon_1 k - \varepsilon p_2 ctgp_2 h\right) + \chi\varepsilon k_2^2 tgp_1 h\right]^{-1} A \end{aligned} \tag{31}$$

The numerator and denominator of expression (31), as well as formula (26), vanishes at $p_1 = 0$. After removing the uncertainty, it turns out

$$\begin{aligned} &B = \left[\left(1+\chi\right)\left(\varepsilon_1 k + \varepsilon p_2 ctgp_2 h\right) - \chi\varepsilon k_2^2 h\right]\cdot \\ &\cdot\left[\left(1+\chi\right)\left(\varepsilon_1 k - \varepsilon p_2 ctgp_2 h\right) + \chi\varepsilon k_2^2 h\right]^{-1} A \end{aligned} \tag{32}$$

CONCLUSION

In the problem of electromagnetic wave incidence on a half-space made of a piezoelectric material of hexagonal symmetry of class 6 mm, the nature of piezoelectric effect influence on transparency condition is established. In the case of reflection from a finite piezolayer, the reflection coefficients are determined for different variants of boundary conditions.

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ANALYSIS OF THE BRAIN COMPUTER TOMOGRAPHY RESULTS USING THE CONVENTIONAL NEURAL NETWORK

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DOI: 10.36724/2664-066X-2020-6-5-6-11

ABSTRACT

Advances in technology are making health research increasingly complex. Artificial intelligence is widely used in this research. Convolutional neural networks are one of the most common and optimal algorithms for working with images. Image recognition results are used to analyze the results of medical examinations of patients. The subject of the research – analysis of the human brain computed tomography results using a convolutional neural network based on the Keras library.

KEYWORDS: *Artificial intelligence, convolutional neural network, keras, convolutional layer, brain tomography.*

INTRODUCTION

Modern hospitals create a large number of medical images every day. These images are transferred to a special cloud center, which allows organizing their storage and processing. The main task in processing medical images is to extract various medical signs from them, which in the future are also accumulated and processed. Due to the significant progress made in the application of deep learning methods, some of them are successfully applied in the field of medical image analysis. One such method is a convolutional neural network (CNN).

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I. NEURAL NETWORKS

Neural networks are found used in various fields of science and technology [1,2]. If we talk about medicine, then the scope includes the analysis of images and video streams, data series, classification of signs and much more [3,4,5].

Keras

Keras is an extended open source neural network library written in Python that supports GPU and CPU as well as a highly modular library of neural networks themselves. Keras is currently used in the Theano and TensorFlow libraries. Keras provides APIs that allow users to focus on developing models and experiment with models faster.

The APIs integrate many small components from Tensorflow and Theano as modules, so a network built using those two can also be built with Keras, with no performance penalty. The main advantage of using the Keras infrastructure is that it can seriously save the developer's time when setting up the created network structure [6].

Convolutional neural network (CNN)

Convolutional Neural Network, CNN or ConvNet is a feedforward neural network [7,8]. It is usually formed from a convolutional layer, a convergence layer (activation and pooling) and a fully connected layer. Training is carried out on the basis of a backpropagation algorithm. When using a feed-forward neural network, a problem arises at the training stage related to the fact that there are too many parameters and it is difficult to extract local invariant functions. Convolutional neural networks have three structural features: local connections [9], weight distribution, and equal variation. These features make the convolutional neural network somewhat invariant to movement, scaling and rotation [10].

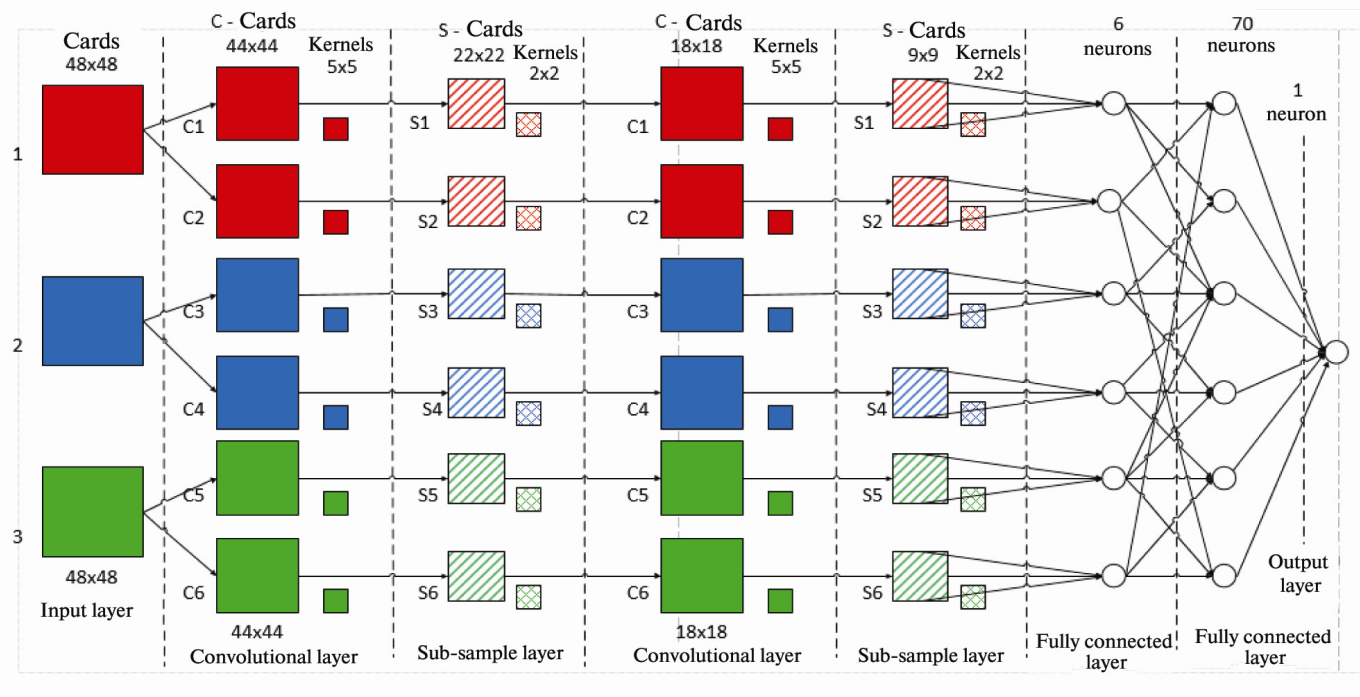

Figure 1. Convolutional neural network architecture

II. DATA SET

For work, we will use the prepared set of images created by Felipe Kitamura. These images are publicly available CT images of the brain from Google Images [11]:

https://www.kaggle.com/felipekitamura/head-ct-hemorrhage.

This dataset contains 100 images of normal sections and 100 images of signs of cerebral stroke. However, there is no difference between different types of strokes [12].

Tags are in the CSV file. Each image belongs to a unique person. The main idea behind using such a small dataset is to develop a method that can predict the presence of signs of stroke even with a small amount of baseline data.

Figure 2 shows 20 CT images of the brain in the dataset.

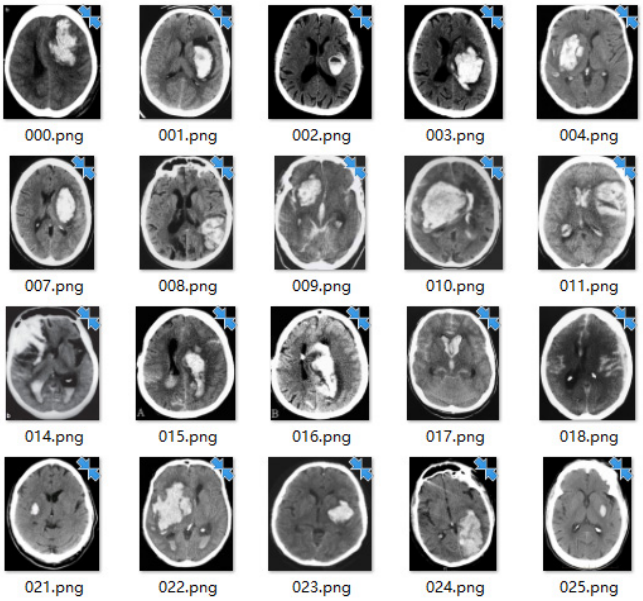

Figure 2. Images of the brain computed tomography results

III. DATA PREPARATION

Before performing any operations with the data, we need to pre-process images in order to improve the estimation of forecast accuracy [13].

In order to obtain higher image fidelity in subsequent training, we examine images length and width to obtain statistics over the set.

Figure 3 shows images distribution in a set by length and width.

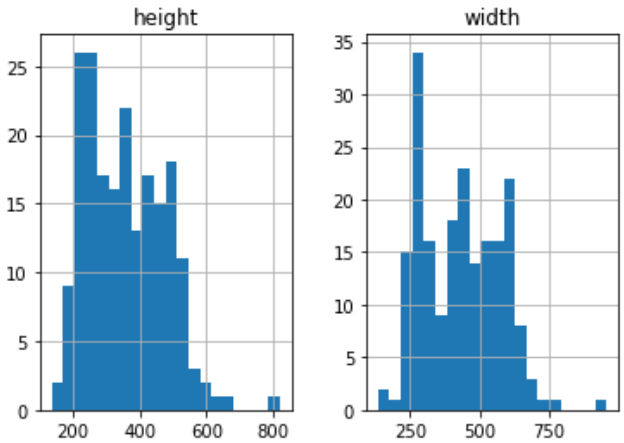

Figure 3. Images distribution by length and width

The description () function is used to display statistics. Results include object counts, means, standard deviations, minimums, maximums, bottom 50 percentile, bottom 25 percentile. 75.50 is both the percentile and median.

Figure 4 shows the results of statistical analysis for length and width.

	height	width
count	200.000000	200.000000
mean	355.505000	433.720000
std	116.785247	142.059481
min	134.000000	135.000000
25%	252.000000	298.750000
50%	345.000000	435.500000
75%	447.250000	554.000000
max	821.000000	957.000000

Figure 4. Results of set analysis in terms of length and width

Before training the model, you should make all images the same size 128 * 128. A simple principle is applied here: the smaller the image size, the faster the training will take place, more objects will be processed, the less likely it is to retrain, but all this is associated with an obvious loss of information.

```
images = np.array([cv2.resize(image, (128, 128)) for
image in images])
```

If the error is large, then you should use larger images and either stretch the small images (and lose significantly in quality), or discard them completely and expose network to the risk of overfitting.

Figure 5 shows images with a size of 128 * 128 after processing.

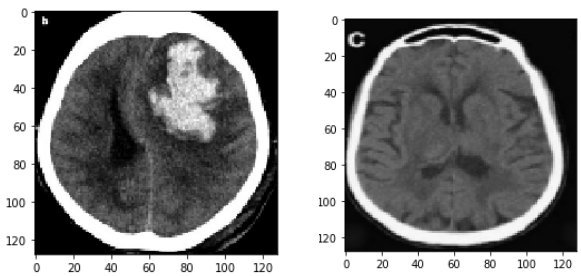

Figure 5. Images 128 * 128

IV. WORKING WITH INVERTED IMAGES

We can also improve the model by adding the ability to work with inverted images. It does not matter how computed tomography is viewed, cerebral hemorrhage can and should be diagnosed in any case. Combined with small capacity of dataset, by adding inverted images to it, we can significantly improve the model accuracy.

Figure 6 shows the results of set images rotating by 90 degrees.

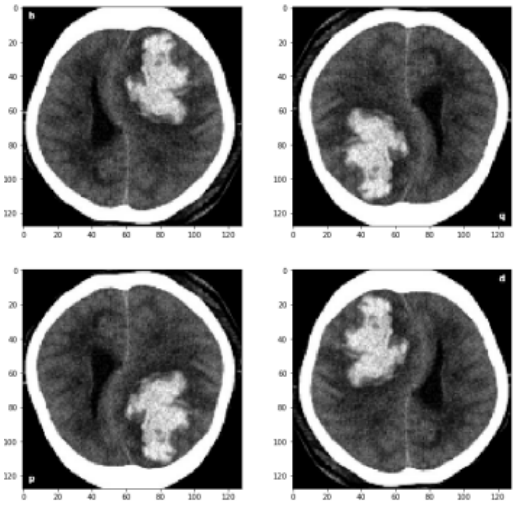

Figure 6. Images are rotated 90°

Using three functions from the library, figure, enumerate and subplot, all preprocessed images are processed and the results are added to the set.

```
plt.figure(figsize=(12, 12))
for i, flip in enumerate([None, -1, 0, 1]):
plt.subplot(221 + i)
if flip is None:
plt.imshow(images[0])
else:
plt.imshow(cv2.flip(images[0], flip)
```

V. IMPROVING IMAGES

Image enhancement [14,15] is implemented using the ImageDataGenerator function, which supports real-time data enhancement. During training, the function will generate data indefinitely until it reaches the specified number of epochs. We improved the image by increasing horizontal vertical deflection by 90° and 180°, horizontal and vertical offset by 0.05 logical values when lifting data, increasing rejection ratio and fixing the image channel size position (128, 128, 3).

```
train_image_data = ImageDataGenerator(
    rescale=1./255,
    shear_range=0.,
    zoom_range=0.05,
    rotation_range=180,
    width_shift_range=0.05,
    height_shift_range=0.05,
    horizontal_flip=True,
    vertical_flip=True,
    fill_mode='constant',
    cval=0)
validation_image_data = ImageDataGenerator(
   rescale=1./255,
   shear_range=0.,
   zoom_range=0.05,
   rotation_range=90,
   width_shift_range=0.05,
   height_shift_range=0.05,
   horizontal_flip=True,
   vertical_flip=True,
   fill_mode='constant',
       cval=0)
```

Figure 7 shows the results of enhancing the images of a set using built-in functions.

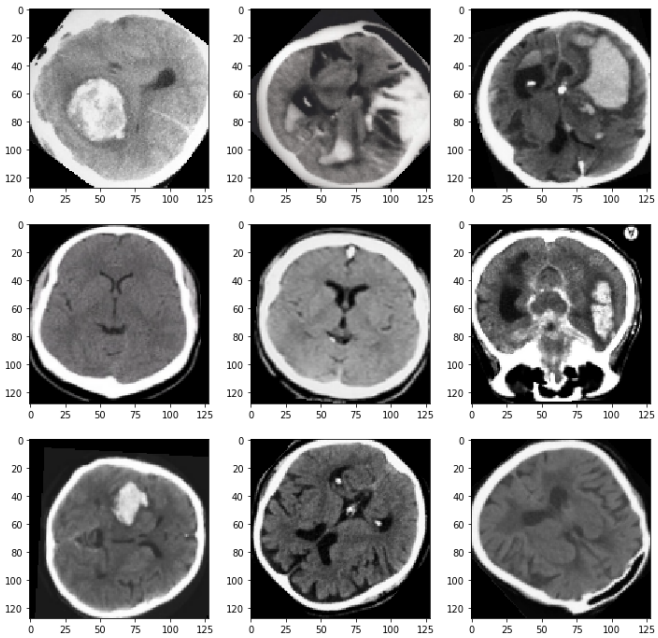

Figure 7. Improved set images

VI. MODEL BUILDING

The SNN model uses a small fixed-size convolution kernel (3 * 3). Convolution pool structure of three convolution layers with two pooling layers. The Sigmoid activation function is used on the output of the convolution layer. Simplified calculation and added Drop layer to prevent model overlap.

Using the summary () function, you can see the complete structure of the network convolutional layer model. The results are shown in Figure 8.

Layer (type)	Output Shape	Param #
conv2d_1 (Conv2D)	(None, 64, 64, 32)	896
max_pooling2d_1 (MaxPooling2	(None, 32, 32, 32)	0
conv2d_2 (Conv2D)	(None, 16, 16, 32)	9248
max_pooling2d_2 (MaxPooling2	(None, 8, 8, 32)	0
conv2d_3 (Conv2D)	(None, 4, 4, 64)	18496
global_average_pooling2d_1 (	(None, 64)	0
dropout_1 (Dropout)	(None, 64)	0
dense_1 (Dense)	(None, 32)	2080
dropout_2 (Dropout)	(None, 32)	0
dense_2 (Dense)	(None, 1)	33

Total params: 30,753
Trainable params: 30,753
Non-trainable params: 0

Figure 8. Structure of network convolutional layer

The first segment of a convolutional network consists of a convolutional layer and a maximum pooling layer. The size of the convolution kernels of these two convolutional layers is 3 * 3, and the number of convolution kernels is 32. The size of the image at the input of the first layer is 128 * 128 * 3, and the size of the output is 64 * 64 * 32. After passing the maximum pooling layer 2 * 2, the output size becomes 32 * 32 * 32, because the step size is 2. Then the result is fed to the second, similar segment of the convolutional network. The sizes of the convolutional kernel of the two convolutional layers are also 3 * 3, but the number of links after the convolutional layer changes, and the final output size becomes 4 * 4 * 64. After processing by the GAP layer to change the data from multidimensional to one-dimensional, and Dropout regularization to prevent overfitting, the generalization of the model is improved, and then the Sigmoid activation function is applied.

The experiment was carried out on a personal computer with Windows 10 operating system; Python programming language was used as an environment for neural network training. Keras library was used for feature extraction, model creation and training.

The set size is 128. After 16 steps, trained model was tested on a set of computed tomograms of brain. The highest accuracy that was achieved is 91.89% at step 16. The results of model testing are shown in Figure 9.

```
def simple_conv_model(input_shape):
 model = Sequential()
    model.add(Conv2D(32, kernel_size=3, strides=2, padding='same', activation='relu', input_shape=input_shape))
    model.add(MaxPooling2D(pool_size=2))
 model.add(Conv2D(32, kernel_size=3, strides=2, padding='same', activation='relu'))
    model.add(MaxPooling2D(pool_size=2))
    model.add(Conv2D(64, kernel_size=3, strides=2, padding='same', activation='relu'))
    model.add(GlobalAveragePooling2D())
    model.add(Dropout(0.4))
    model.add(Dense(32, activation='relu'))
 model.add(Dropout(0.4))
    model.add(Dense(1, activation='sigmoid'))
return model
```

The accuracy and likelihood of retraining the model in the process of working with CT images of the brain change depending on the number of training steps and are presented using Tensorboard visualization in the form of curves of changes in accuracy and loss factor in Figure 10.

```
128/128 [==============================] - 47s 364ms/step - loss: 0.4569 - accuracy: 0.7807 - val_loss: 0.0726 - val_accuracy: 0.7989
Epoch 6/24
128/128 [==============================] - 47s 367ms/step - loss: 0.4236 - accuracy: 0.8070 - val_loss: 0.2790 - val_accuracy: 0.8278
Epoch 7/24
128/128 [==============================] - 47s 365ms/step - loss: 0.3845 - accuracy: 0.8309 - val_loss: 0.0702 - val_accuracy: 0.6722
Epoch 8/24
128/128 [==============================] - 47s 364ms/step - loss: 0.3714 - accuracy: 0.8475 - val_loss: 0.4140 - val_accuracy: 0.8022
Epoch 9/24
128/128 [==============================] - 47s 365ms/step - loss: 0.3250 - accuracy: 0.8674 - val_loss: 0.1843 - val_accuracy: 0.8633
Epoch 10/24
128/128 [==============================] - 47s 366ms/step - loss: 0.2873 - accuracy: 0.8826 - val_loss: 0.6402 - val_accuracy: 0.8444
Epoch 11/24
128/128 [==============================] - 47s 367ms/step - loss: 0.2711 - accuracy: 0.8931 - val_loss: 0.1948 - val_accuracy: 0.8811
Epoch 12/24
128/128 [==============================] - 47s 367ms/step - loss: 0.2410 - accuracy: 0.9079 - val_loss: 0.0430 - val_accuracy: 0.8689
Epoch 13/24
128/128 [==============================] - 47s 368ms/step - loss: 0.2182 - accuracy: 0.9160 - val_loss: 1.2892e-04 - val_accuracy: 0.9011
Epoch 14/24
128/128 [==============================] - 47s 366ms/step - loss: 0.2026 - accuracy: 0.9236 - val_loss: 0.0218 - val_accuracy: 0.8833
Epoch 15/24
128/128 [==============================] - 47s 364ms/step - loss: 0.1930 - accuracy: 0.9289 - val_loss: 0.0669 - val_accuracy: 0.8622
Epoch 16/24
128/128 [==============================] - 47s 365ms/step - loss: 0.1727 - accuracy: 0.9360 - val_loss: 0.0104 - val_accuracy: 0.8422
Epoch 17/24
128/128 [==============================] - 47s 365ms/step - loss: 0.1778 - accuracy: 0.9360 - val_loss: 0.1257 - val_accuracy: 0.9267
Epoch 18/24
128/128 [==============================] - 47s 365ms/step - loss: 0.1543 - accuracy: 0.9436 - val_loss: 0.0052 - val_accuracy: 0.8856
Epoch 19/24
128/128 [==============================] - 47s 364ms/step - loss: 0.1531 - accuracy: 0.9438 - val_loss: 0.2364 - val_accuracy: 0.9200
Epoch 20/24
128/128 [==============================] - 47s 365ms/step - loss: 0.1320 - accuracy: 0.9537 - val_loss: 0.0091 - val_accuracy: 0.8956
Epoch 21/24
128/128 [==============================] - 47s 364ms/step - loss: 0.1265 - accuracy: 0.9525 - val_loss: 0.5809 - val_accuracy: 0.8689
Epoch 22/24
128/128 [==============================] - 47s 364ms/step - loss: 0.1197 - accuracy: 0.9551 - val_loss: 0.0222 - val_accuracy: 0.8978
Epoch 23/24
128/128 [==============================] - 47s 364ms/step - loss: 0.1174 - accuracy: 0.9586 - val_loss: 2.0594e-05 - val_accuracy: 0.9222
Epoch 24/24
128/128 [==============================] - 47s 364ms/step - loss: 0.1100 - accuracy: 0.9618 - val_loss: 0.2535 - val_accuracy: 0.8989
```

Figure 9. Model test results

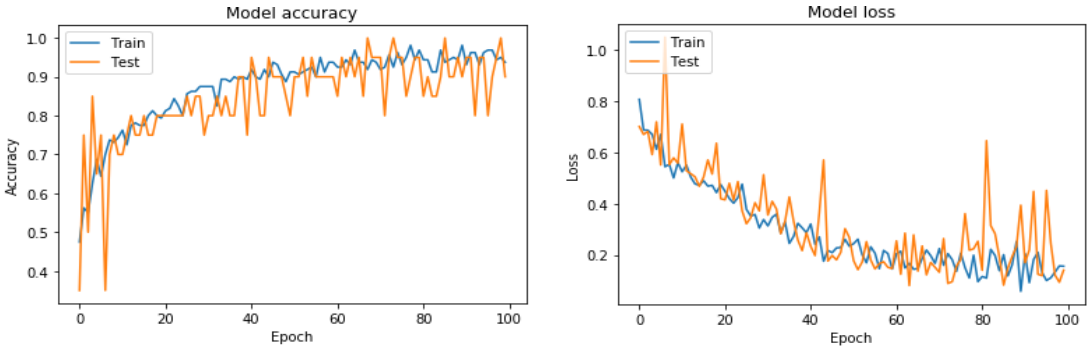

Figure 10. Graphs of changes in the values of accuracy and loss factor

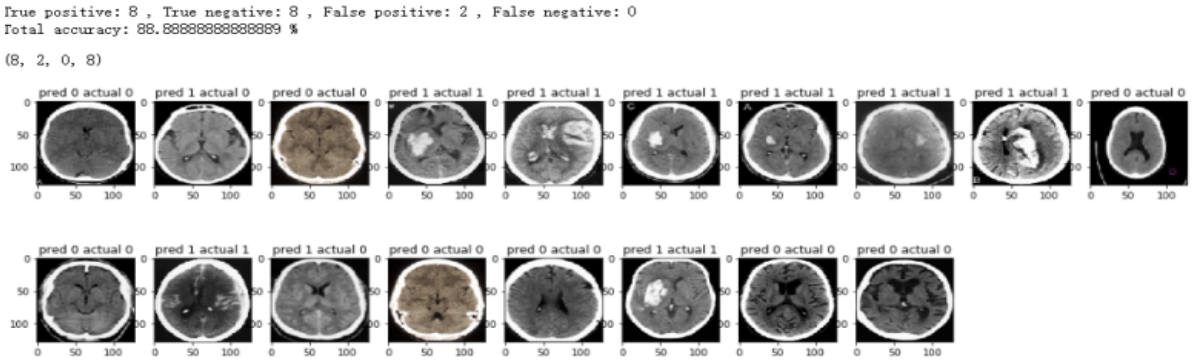

Figure 11. Model results

VII. LTS

The model showed 89% accuracy on the test set. The results obtained indicate full applicability of created model for predicting presence of stroke signs in the brain from computed tomography images. Figure 11 shows the results of created model applying to the test set of images.

CONCLUSION

A predictive model for the presence of signs of cerebral stroke on computed tomography images using a convolutional neural network is proposed and designed. Dataset contained images of normal brains and brains of stroke patients. Prediction accuracy using the model reaches 90%. It is shown that software image enhancement leads to certain effects.

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VECTOR SIGNAL ANALYSIS AND SYNTHESIS SOLUTIONS OVERVIEW

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DOI: 10.36724/2664-066X-2020-6-5-12-20

ABSTRACT

Modern signals with a complex structure require technological equipment capable of evaluating many parameters that determine the signal quality. Therefore, in order to systematize the solutions existing on the market and their capabilities, a review was made of the solutions existing on the market for the synthesis and analysis of complex signals. The main parameters for assessing the quality of complex signals are considered, the characteristics of generators and analyzers of complex signals existing on the market are presented and their comparison is made according to the main consumer qualities. The article also describes the basic principles of generation and analysis of vector signals. The direction of increasing the significance of the software complex in systems for generating and analyzing signals and the advantages determined by this trend, such as an increase in the time of possible operation of equipment and an increase in versatility, which makes it possible to increase the economic efficiency of the used control and measuring equipment, are shown.

KEYWORDS: *vector analysis; vector synthesis.*

INTRODUCTION

Signals used in modern digital communication systems, often, have a complex structure. It is not possible to detect violations of the "fine" structure of complex signals using traditional methods of exploring the signal in the time and spectral regions. Due to the random nature and variability inherent in such a signal, both the temporal and spectral form of presentation of complex signals do not allow assessing the quality of the generated modulated signal, determining the degree of signal distortion arising from the passage of RF paths. It is known from practice that even a slight violation of the "fine" structure of a complex signal in RF paths leads to a noticeable deterioration in the quality of the communication system as a whole. To reveal such damage to the structure of modulated signals, using more accurate, sensitive instruments, such as a number of relatively new parameters and characteristics, including statistical ones, allows vector signal analysis. It is of fundamental importance that vector analysis and synthesis of signals is carried out in digital form – for this, digital data and corresponding mathematical algorithms are used. Vector analyzers allow you to use new, more accurate, sensitive modulated signal analysis tools and relatively new quality indicators (EVM, CCDF). Hardware and software tools for vector synthesis (generation) of signals (Vector Signal Generator) allow you to generate modulated signals used in the most common standa*rds and communication technologies: multi-tone, GMSK, 8-PSK; EDGE, QAM (4, 8, 16, 32, 64, 128, 256-QAM), 16-PSK, 64-PSK, etc. [1].*

I. VECTOR ANALYSIS AND SYNTHESIS CONCEPT

A. IQ radio signal presentation

Quadrature signals are the mapping of the original signal to the real and imaginary axes. As is known, frequency transfer of signals is used to transmit information over long distances. As a result, high frequency signals are generated. These signals are narrowband signals in a broad sense. This means that in such signals the ratio of the upper spectrum frequency to the lower one is close to unity. A narrowband signal can be represented as a sine wave modulated by a low frequency signal. It can be written as:

$$S(t) = A(t)\sin(2\pi ft + \varphi(t)) \qquad (1)$$

where A – signal amplitude, f – frequency; φ – phase.

Mathematically, a sinusoidal signal with an arbitrary phase can be represented as a complex exponent. The same signal according to the Euler formula can be represented in the Cartesian coordinate system, which will correspond to the quadrature signals. A narrowband signal in complex form and its decomposition into quadrature components is described by:

$$\begin{aligned} S(t) &= A(t)e^{j2\pi ft+\phi(t)} = \\ &= I(t)\cos(2\pi ft) + jQ(t)\sin(2\pi ft) \end{aligned} \qquad (2)$$

The mapping of a complex exponential signal to the real and imaginary axes is called I (in-phase) and Q (quadrature) quadratures. The I signal is a projection onto the real (cosine) axis. A graphic representation of the signal in I and Q coordinates is shown in Fig. 1 [2].

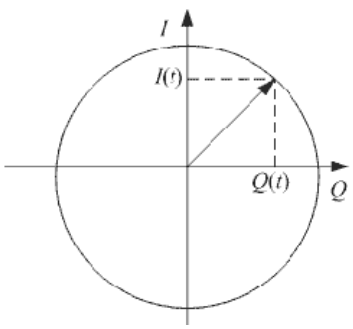

Figure 1. Graphical representation of a quadrature signal in the I and Q axes [2]

B. Signal Representation as a Samples

Systems that use digital processing and signal generation use a sample representation of the signal. Sample – signal values at a certain point in time (at the moment of polling). Time interval between samples – polling (sampling) period; if it is constant – regular sampling, otherwise – Iregular. The sampling rate, according to the Nyquist frequency, determines the maximum frequency of a signal that can be processed by the device without distortion.

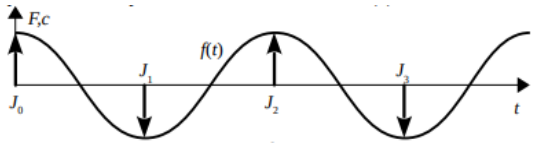

Figure 2. Classic graphical representation of analog signal and its samples [3]

II. PARAMETERS DERIVED FROM VECTOR ANALYSIS

A. Error Vector Magnitude

Unfortunately, the temporal shape of complex signals used in modern communication systems does not allow determining the degree of distortion of the modulated signal due to its inherent random nature and variability. To extract useful information from such a noise-like signal, it is necessary to use a statistical description of the power levels in this signal, to obtain the error vector magnitude (EVM) magnitude (EVM), which is widely used today for evaluating the quality of modulated signals, and the graph of the integral distribution function of the CCDF signal levels (complementary-cumulative-distribution-function) [5].

One of the most widely used quantitative indicators of modulation quality in digital communication systems is the magnitude of the EVM error vector. This parameter is used in almost all modern digital information transmission systems as an indicator of signal quality and, accordingly, is reflected in the standards for them (IEEE 802.11 family of standards, LTE system (ETSI TS 136 141 testing standard), IEEE 802.15.1 (bluetooth), etc.).

In general, the error vector EV is the vector difference between an ideal reference signal and a measured signal, as illustrated in Fig. 3.

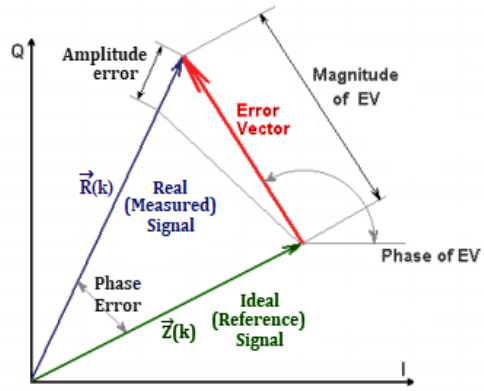

Figure 3. Graphical representation of the EVM error vector

The error vector magnitude (EVM) is the Euclidean distance between the coordinates of the ideal and actually measured symbols. In general, the EVM is averaged over an ensemble of symbol paths and is described by the following expression:

$$EVM = \sqrt{\frac{\sum_{k=1}^{M} |Z(k) - R(k)|^2}{\sum_{k=1}^{M} |R(k)|^2}} \qquad (3)$$

Thus, the EVM parameter is a measure of the ratio of the error vector to the reference vector. In a perfect system, in which there are no noise and nonlinearities that can distort the signal, the measured and reference vectors would coincide, and the EVM would be zero [4].

The magnitude of the EVM error vector is sensitive to any degradation in signal quality that affects the magnitude and phase trajectory of the signal vector. There are regular constellation distortions, figuratively speaking, visible to the eye: DC offset, amplitude and phase imbalance, etc. All of them should not be taken into account when measuring the EVM value; they must be pre-compensated. Those. all errors that can be easily eliminated must be eliminated. As a result, noise, discrete interference in the path of the reference and received signal and phase distortions remain on the signal constellation. Before measuring EVM, it is necessary to normalize the measured signal [5].

B. Complementary Cumulative Distribution Function (CCDF)

It should be noted that the magnitude of the error vector only gives a quantitative assessment of the quality of the modulated signal, but does not reflect the type of integrity violation, does not make it possible to determine the source and nature of this violation. A more "fine" mechanism for analyzing the quality of a modulated signal is the cumulative distribution function of the CCDF signal levels, which is widely used in most modern standards. This statistic shows how long the signal is equal to or exceeds a certain power level and displays, in fact, the dynamics of the signal envelope

The CCDF function has a strictly individual form for each type of modulation, which makes it possible to use it to assess the quality of the generated signal. Any damage to the integrity of the signal results in a change in the appearance of the function.

In contrast to using the magnitude of the EVM vector, analysis of the CCDF type allows not only to estimate the degree of signal damage, but also to indicate the nature and source of this damage. The type of CCDF function depends on the payload of the signal, so it can be used for complex testing of paths and channels. For this, it is necessary to know the canonical form of the function for the tested channel, to fix and correctly interpret the differences of the obtained CCDF function from the canonical form [5].

CCDF curves can be used to identify a number of important characteristics in the design and testing of RF devices. For example, signal compression (clipping) can be easily detected by comparing the CCDF of the input signal and the amplified output signal, as illustrated in Fig. 4. As you can see, the effect of the limitation is manifested in the "cutting" of signal trajectory outliers at the corners of the vector diagram.

This method of detecting distortions is still less visual and effective in comparison with CCDF, which makes it possible to immediately detect very subtle violations in the structure of the modulated signal.

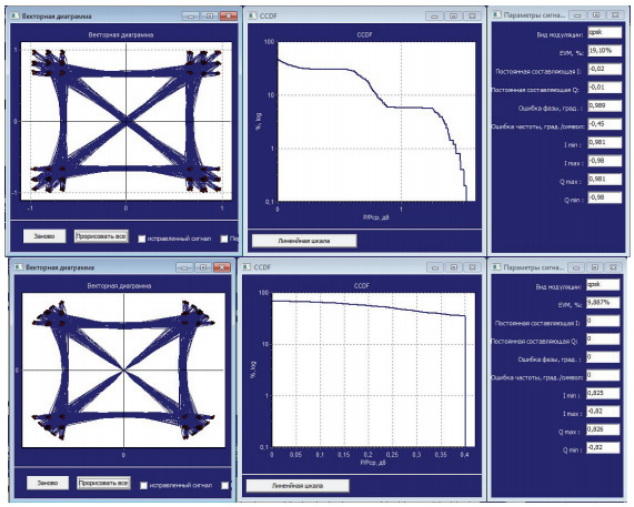

Figure 4. CCDF for QPSK signal with pre-modulation filtering and signal with limitation (bottom figure) [5]

This effect makes the CCDF a good indicator of the degree of linearity of the transmission path, in particular the level of compression of the signal in the PA [5].

III. Software systems for vector signal generation

Today's wideband, time-varying vector modulation signals (also called complex or digital modulation) are very convenient to investigate using Fast Fourier Transform (FFT) and other digital signal processing (DSP) techniques. Vector signal analysis enables fast, high-resolution spectral measurements as well as demodulation and advanced time domain analysis. It is especially useful for measuring the characteristics of multiplexed or modulated signals used in communications, video recording, television broadcasting, radar and ultrasonic research [16].

A. Vector VSG (MTUCI)

The vector signal generation (synthesis) program "Vector-VSG" is designed to generate samples of the quadrature components of modulated signals used in the most common communication standards and technologies: multi-tone, GMSK, 8-PSK; EDGE, QAM (4, 8, 16, 32, 64, 128, 256-QAM), 16-PSK, 64-PSK with the ability to write them to files of popular formats – ASCII, binary.

Vector signal generation software allows you to introduce into the generated signal a number of the most common distortions inherent in RF paths. At the moment, additional service capabilities are being introduced into the signal generation program, in particular, distortions of the generated signals of various kinds: noise of the signal generation path and the reference signal path, DC offset (DC offset), phase error (Phase error); imbalance of amplitudes and phases (IQ imbalance); frequency shift (Frequency deviation). You can introduce the necessary distortions into the generated signal on the corresponding distortion panel, which appears when you select the Distortion item in the Main Menu.

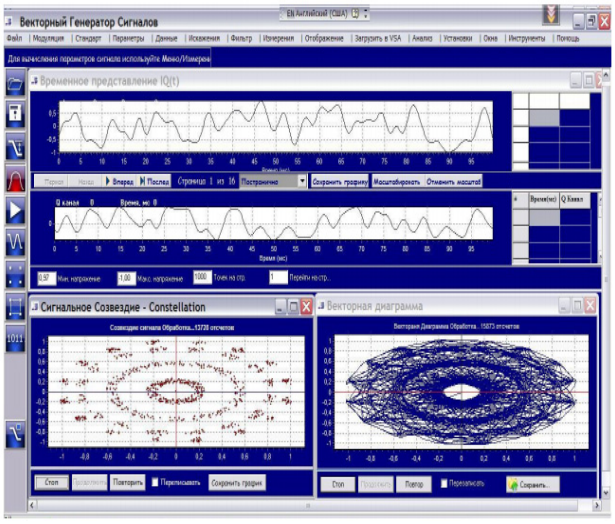

Figure 5. Example of Vector VSG program interface [6]

The program uses a pre-modulation signal filtering module. Currently, it is possible to use several types of filters. When generating modulated signals of various kinds, adjustable filters can be used: Gaussian filter with variable BT parameter, RRC and RC filters with variable Alpha parameter. The user can apply a number of standard filters with parameters corresponding to the regulatory documents of several communication standards: GSM, EDGE, WCDMA WCDMA RC. The program provides for the use of custom filters.

Selecting the Settings item in the Main Menu allows you to go to the selection of the parameters of the channels of the actual modulated signal formation (Transmitter, Tx), reception (1 ^ x) and the Communication channel). This makes it possible to introduce into the generated signal various types of distortions characteristic of real RF devices [6].

B. WinIQSIM (Rohde & Schwarz)

The R&S WinIQSIM ™ software is specially designed for the generation of digitally modulated signals. The graphical user interface, together with the context-sensitive help system, makes operation intuitive.

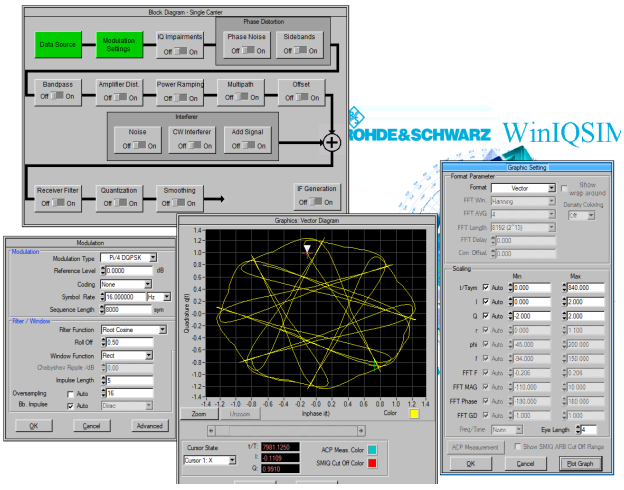

Figure 6. Example of WinIQSIM program interface

A convenient way to generate signals of all supported standards, the generation of multi-carrier and multi-segment signals make the R & S®WinIQSIM ™ a convenient tool for a wide range of tasks.

Program features:

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary;
- User-generated digital pulses generate digital arbitrary waveforms with freely selectable modulation parameters;
- Generation of CW signal with multiple carriers;
- Multi-carrier signal generation allows you to combine multiple digital signals and generate a single signal with different frequency offsets;
- The multi-segment waveform function allows the arbitrary waveform generator to store several different waveforms in the memory and ensures the shortest switching times between them, while still allowing smooth transitions;
- Generation of additive white Gaussian noise AWGN and its superposition on the signal;
- The import function allows I / Q samples to be transferred via a server connection to the R & S®WinIQSIM ™ signal generator circuit for filtering and overlaying with AWGN noise [7].

IV. VECTOR SIGNAL GENERATORS AND THEIR COMPARISON

A. SMW200A (Rohde & Schwarz)

The R & S®SMW 200A is ideal for generating digitally modulated signals for the development of new broadband communications systems, testing 3G and 4G base stations, or in the aerospace and defense sector.

Figure 7. Exterior of the vector signal generator R&S SMW200A [8]

Main parameters:

- One or two RF outputs, each with a range from 100 kHz to 3/6 / 12.75 / 20 / 31.8 / 40 GHz, with different frequency combinations;
- High output power without additional options (at least 18dBm up to 6 GHz);
- IQ generator bandwidth up to 160 MHz, IQ modulator bandwidth up to 2 GHz with modulation from an external generator;
- Memory of ARB generator up to 1 mld. counts;

- Support for all major wireless standards (including LTE Advanced and WLAN 802.11ac). Digital standard signals can be configured and generated directly in the R & S®SMW 200A;
- Support for higher order MIMO, including 3x3,4x4 and 8x2.
- Additional features:
- Optional integrated fading simulators (up to 8 modulating oscillators, 16 signal paths and 20 fading paths per channel);
- Built-in digital summation of baseband signals, even with frequency and level offset;
- Test Case Wizard for LTE and 3GPP simplifies verification of base station compliance with 3GPP TS 25.141 or 3GPP TS 36.141;
- Supports complex standards such as dual carrier HSPA, carrier aggregation LTE and LTE multi-user. Allows connection of external SGS100A generators to create four RF paths. Has a phase coherence option used, for example, to beamform antennas.

Characteristics:

- Ability to equip the generator with additional options required for specific applications;
- Generator capacity exceeds that of two combined conventional generators;
- Multi-carrier signal generation and signal combinations of different standards;
- Only one two-channel generator is required to form the sum of the wanted signal and interference, often required for testing receivers;
- Built-in ability to simulate fading [8].

B. E8267D (Keysight)

Figure 8. Exterior of the vector signal generator E8267D [9]

Key features:

- The ability to test modern receivers using realistic broadband signals from radar systems, electronic warfare and satellite communication systems due to metrological-grade characteristics and wide functional capabilities;
- Simulate complex electromagnetic environments with up to 4 GHz modulation bandwidth;
- Reduce the time required to create complex signals through the use of Keysight Signal Studio software: pulse sequencing, setting the relative noise power (NPR), creating multi-tone signals, wireless signals, etc.;
- Create the most complex signals with industry-leading single sideband phase noise: –143 dBc / Hz (typ.) At 1 GHz at 10 kHz offset;
- Compatible with industry standard software packages such as MATLAB and Excel [9].

Specifications:

- Frequency range from 100 kHz to 44 GHz;
- Frequency switching time 9ms;
- Output power -130 to +22 dBm;
- SSB phase noise (10 GHz; 10 kHz carrier offset) - -126 dBc / Hz;
- Harmonics (10 GHz) -55 dBc;
- Non-harmonic components (1 GHz) -88 dBc;
- AM frequency from 0 to 100 kHz;
- FM deviation (max.) 1 to 128 MHz;
- FM phase deviation (max. In normal mode) from 1 to 800 rad;
- Minimum pulse width 20 ns;
- Error vector amplitude (LTE) 0.8%;
- Adjacent Channel Power Level Relative (16QAM, 10 GHz) -64 dBc;
- Built-in 80 MHz baseband generator bandwidth;
- External I / Q modulator bandwidth up to 4 GHz;
- 64 Msample waveform playback memory;
- Built-in modulation types: BPSK, QPSK, 8-PSK, QAM-16, QAM-64, OOK, ASK-2, ASK-4, ASK-8, FSK-2, FSK-4, MSK, GMSK, pulse, frequency hopping, Chirp, arbitrary baseband signal specified by the user [9].

Features:

- Built-in arbitrary waveform generator and baseband generator;
- Output power level 22dBm;
- Functional completeness of vector microwave signal generators operating in the range up to 44 GHz;
- The modulation bandwidth of the internal LF generator reaches 80MHz [10].

C. TSG4106A (Tektronix)

The generator has built-in support for the most common vector modulation schemes: ASK, QPSK, DQPSK, π / 4 DQPSK, 8PSK, FSK, CPM, QAM (4 to 256), 8VSB and 16VSB [11].

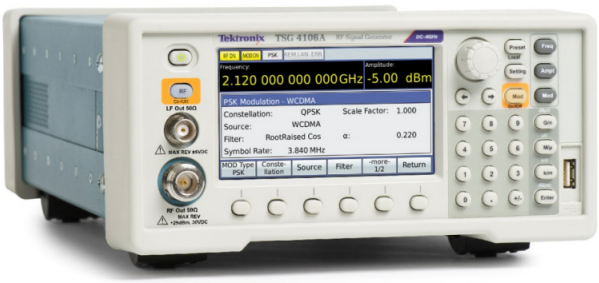

Figure 9. External view of the TSG4106A vector signal generator [11]

Main characteristics:

- Generation of analog and vector / digital signals in the frequency range from 0 to 6 GHz;
- Typical amplitude uncertainty ≤ ± 0.30 dB (for 0 dBm CW at 22 ºC) from 10 MHz to 6 GHz;
- Baseband I / Q inputs (400 MHz bandwidth);
- Modulation ASK, FSK, MSK, PSK, QAM, VSB and special I / Q signals;

- Low phase noise (-113 dBc / Hz @ 20 kHz offset from 1 GHz carrier);
- 1 μHz resolution at any frequency.

Benefits:

- The TSG4100A Series Vector Signal Generator offers mid-range performance with modulation bandwidths up to 200 MHz, but is offered at an entry-level RF generator price ($ 17,500).

D. G7M-06 (Mikran)

Signal generator G7M-06 is designed to generate continuous harmonic signals, as well as signals with analog and digital modes of modulation. The areas of application of the signal generator are research, tuning, control and testing in the production of HF and microwave devices and equipment used in communications, radar, instrumentation and measurement technology.

The G7M-06 signal generator is controlled from an external personal computer with the VEGA software installed through universal commands of the SCPI standard, which allows the device to be integrated into automated control and measuring complexes.

Figure 10. External view of the vector signal generator G7M-06 [12]

Characteristics:

- Frequency range 10 MHz to 6 GHz;
- Wide range of output power adjustment from -90 to +12 dBm;
- Low phase noise of −132 dBc / Hz at 20 kHz offset from 1 GHz carrier;
- Analog modulation capabilities: AM, FM, FM, IM, as well as digital (PSK, FSK, MSK, QAM, VSB);
- Custom digital modulation capabilities;
- Built-in baseband generator;
- HF modulated bandwidth 100 MHz.
- Key features:
- Continuous generation of harmonic signal with fixed frequency and power;
- Scanning by frequency, power or arbitrary list of frequencies / powers;
- Continuous generation of modulated signal;
- Continuous generation of baseband signals (I and Q).
- Benefits:
- Low price (about $ 12,500) [12].

E. MWT-160U (Microwave Electronics LLC)

Figure 11. External view of the vector signal generator MWT-160U [13]

Main characteristics:

- Operating frequency range 8 kHz – 6/10/16 GHz;
- Output power up to 33 dBm matched load;
- Rubidium reference generator (optional) with temperature instability up to ± 1 * 10-10;
- Frequency hopping time up to 560 MHz <4 ns;
- Ultra-low phase noise (-140 dBc / Hz typ. @ 10 kHz offset from 1 GHz carrier);
- Ultra-low distortion <-81 dBc;
- Generation of arbitrary modulation signals with bandwidth up to 560 MHz from the built-in baseband generator, from the built-in sample memory or Ethernet data stream;
- Built-in memory of samples with a volume of 67 million samples;
- Symbol rate up to 600 Msps;
- DAC 16 bit 1.2 GHz;
- Generate signals from an external analog IQ source with bandwidth up to 1.8 GHz;
- Pulse modulation with pulse duration from 4 ns;
- Generation of chirp, frequency hopping, multitone and other types of signals;
- 10 Gb / s I / O interface (Ethernet) allows real-time data transmission over a radio channel at speeds> 5 Gb / s;
- FPGA programming is available to the user (Kintex-7) [13].

F. SG396 (SRS)

Based on a new frequency synthesis technique called Rational Approximation Frequency Synthesis (RAFS).

Figure 12. External view of the vector signal generator SG396 [14]

Main characteristics:

- Frequency range from 400MHz to 6 GHz;
- Dual baseband generators;
- Vector and analog modulation;
- Modulation I / Q inputs (300 MHz RF BW);
- ASK, FSK, MSK, PSK, QAM, VSB, and custom I / Q;
- Presets for GSM, EDGE, W-CDMA, APCO-25, DECT, NADC, PDC, ATSC-DTV & TETRA;
- GPIB, RS-232 and Ethernet interfaces;
- 1 μHz frequency resolution at any frequency;
- Switching speed <8ms;
- Output power -110dBm to + 16.5dBm.
- Features:
- Based on a new frequency synthesis technique called Rational Approximation Synthesis (RAFS);
- High frequency of phase comparison (usually 25 MHz);
- There are no excitations in the synthesis of fractional frequencies;
- There are no costs for the spheres of yttrium iron garnet to provide almost infinite frequency resolution, respectively, the price is about $ 5000 [14].

G. Comparison

The SMW200A is the only generator on the list that can work with MIMO systems, but it comes at a huge cost.

E8267D has the lowest single sideband phase noise, has a wide output power range, and is capable of generating arbitrary baseband signal specified by the user.

The TSG4106A offers mid-range performance with modulation bandwidths up to 200 MHz, but is offered at an entry-level RF generator price ($ 17,500).

G7M-06 – relatively wide, compared to other generators, range of output signal power adjustment, small dimensions, low price.

MWT-160U – the highest output power up to 33 dBm, has one of the lowest phase noise levels, the largest onboard sample memory, built-in FPGA programmability, the fastest sweep time.

The SG396 is based on a new frequency synthesis technique called Rational Approximation Synthesis (RAFS), which reduced the price of $ 5000.

V. Vector Signal Analyzers Parameters

One of the main parameters of a vector analyzer is the parallel processing bandwidth, which depends on the speed of the ADC and the performance of the DSP. Analyzing and demodulating high-speed radio interface and spread spectrum signals requires parallel analysis bandwidths of the order of a few MHz. However, widening the parallel analysis bandwidth and using an ADC with a higher sampling rate can negatively affect the dynamic range and frequency resolution of the analyzer. Real-time bandwidth reflects the instrument's ability to analyze continuous stationary signals in real time. For broadband analyzers, this bandwidth can be significantly less than the parallel processing bandwidth. The duration of the recorded realizations is related only to the amount of DSP memory and determines the capabilities of the device for recording and detecting pulse and single-shot signals.

The rest of the analyzer's parameters: operating frequency range, sensitivity, range of measured levels and dynamic range at the input are entirely determined by the type of used frequency converter. Measuring signal levels and frequencies requires calibration of its gain, as well as the use of frequency synthesizers with the required stability and phase noise level.

VI. Software Systems for Vector Signal Analyzers

A. Vector VSA (MTUCI)

The vector signal analysis program "Vector-VSA" allows for a comprehensive analysis of signals, calculation of their various parameters and characteristics. Work with the program is carried out using a number of windows. In this case, various forms of signal display can be selected: signal constellation or vector diagram, temporal display of the signal in the form of graphs, amplitude and phase spectra, etc.

In the process of analyzing signals, if necessary, they are demodulated, clock sequences are restored, a copy of the original message is obtained, etc. The program allows calculating a number of signal characteristics, the most interesting and informative of which is the EVM error signal vector. Requirements for the value of this parameter are included in all modern standards for digital communication systems. Algorithms for calculating EVM for signals with GMSK modulation (GSM standard) and signals used in EDGE technology are currently implemented in software. Samples of the analyzed signals can be specified in the form of files of various formats (pcm, txt) and, if necessary, converted by software.

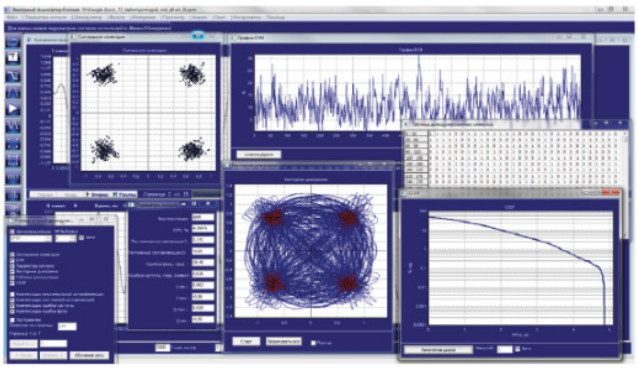

Figure 13. Vector VSA program interface example [15]

Main features and functions of the VSA program:

- Analysis of the input signal in the time domain;
- Spectral analysis of the signal;
- Analysis of input signal parameters: voltage, power;
- Display of signals in the time domain;
- Display of I / Q quadrature components;
- Installation of markers in the time and spectral regions with display of marker parameters;
- Finding extreme values of the studied signals;

- Measurements of modulation parameters: signal shift (DC offset), phase error (Phase error); amplitude imbalance (IQ imbalance); frequency shift (Frequency deviation); the amplitude of the error vector EVM (Error vector magnitude);
- Digital demodulation of signals (Digital demodulation) GMSK, EDGE, 3GPP, 16QAM.
- Filtering signals according to the used standard [16].

B. 89600 VSA (Keysight Technologies)

The 89600 VSA software is a digital system that analyzes signals using raw data and mathematical algorithms. To do this, it is enough to have discrete data samples coming from a measuring device, program or digital bus. With the increasing use of digital technology in today's wireless communications systems, the 89600 VSA's value for analyzing these complex signals is steadily increasing.

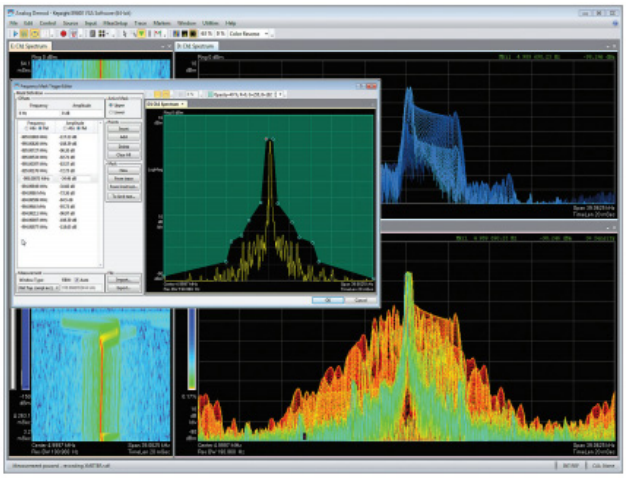

Figure 14. Example program interface 89600 VSA [17]

Main features and functions of the program:

- Measurement and analysis of frequency, time and modulation characteristics of the signal;
- Analyze data from over 40 supported devices or use with simulators to validate design devices;
- Characterization of power amplifiers based on complex stimulus / response measurements;
- Simultaneous or sequential configuration, execution and display of results of several measurements with an unlimited number of traces and markers;
- Recording and playback of signals for advanced analysis;
- Test automation using .NET language (full support) or SCPI (partial support) [17].

VII. VECTOR SIGNAL ANALYZERS AND THEIR COMPARISON

A. M9393A (Keysight)

The Keysight M9393A PXIe Vector Signal Analyzer consists of four separate modules: the M9365A PXIe Downconverter, the M9308A PXIe Synthesizer, the M9214A Digitizer, and the M9300A PXIe Reference Clock. The M9300A Reference Generator Module can be used simultaneously by several different modular instruments. It is also recommended to use the M9169E PXI-H PXI-H Switching Input Programmable Step Attenuator Module when connecting the FRX option to extend the frequency range to 50 GHz.

Figure 15. External view of the vector signal analyzer M9393A [18]

Functionality:

- Frequency range: 9 kHz to 8.4 GHz, 14 GHz, 18 GHz or 27 GHz;
- Extending the frequency range to 50 GHz (minimum frequency 3.6 GHz) using the FRX option;
- Demodulation bandwidth: 40 MHz (standard), 100 MHz or 160 MHz (optional); broadband IF output (option WB1);
- Up to four synchronized channels.
- Main characteristics:
- Amplitude measurement absolute error: ± 0.13 dB;
- Average Noise Level (DANL): –168 dBm / Hz with preamplifier and noise correction;
- Intermodulation distortion (3rd order intercept, TOI): +31 dBm;
- Frequency switching speed: less than 135 µs [18].

B. FSW (Rohde & Schwarz)

The R&S®FSW has an analysis bandwidth of up to 5 GHz, providing measurement of broadband modulated or frequency hopping signals like those found in the new 5G New Radio standard or in automotive and pulse radars.

800 MHz real-time analysis bandwidth allows you to monitor any events occurring in a wide spectral bandwidth and trigger on short signals.

Figure 16. Exterior view of FSW vector spectrum and signal analyzer [19]

Main characteristics:

- Frequency range 2 Hz to 90 GHz (up to 500 GHz with external harmonic mixers from Rohde & Schwarz);
- Low phase noise: –140 dBc (1 Hz) @ 10 kHz offset (1 GHz carrier), –143 dBc (1 Hz) @ 100 kHz offset (1 GHz carrier);
- Spurious free dynamic range (SFDR) 60 dBc for 2 GHz analysis bandwidth with built-in ADC;
- Analysis bandwidth up to 5 GHz (2 GHz bandwidth with integrated ADC, 5 GHz bandwidth when using the R & S®RTO oscilloscope as external ADC);
- Real-time analysis with bandwidth up to 800 MHz, 2.4M FFT / s, POI (100% detection probability) 0.46 μs, and 500 MHz real-time I / Q streaming interface;
- SCPI command recorder for easy instrument remote control code generation;
- New design and Windows 10 operating system with support for multi-touch gestures;
- Possibility of parallel launch and display of several measurement applications [19].

C. Comparison

FSW has a wider frequency range, built-in spectrum analyzer, has its own interface, but M9393A has a lower noise floor.

VIII. Conclusion

The article describes the basic principles of vector generation and vector analysis of telecommunication signals used in assessing the quality of the signal conversion paths. The main hardware and software vector generators and analyzers, their parameters and features are considered, their characteristics are compared.

Modern VSA and VSG have high parameters allowing to analyze/generate signals of existing telecommunication systems.

It is shown that almost all modern VSA and VSG allow adding new advanced telecommunication standards and protocols to the software being developed, which gives users greater flexibility in investing in the areas of development they need. It also increases the life cycle of equipment, due to the ability to implement the generation of signals of more modern signals, by modifying the software, allowing you to reduce the cost of instrumentation and, in general, the cost of developing a radio frequency path.

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CLUSTERING METHODS IN LARGE-SCALE SYSTEMS

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DOI: 10.36724/2664-066X-2020-6-5-21-24

ABSTRACT

Interactions between people, groups, organizations, and biological cells have a relationship character that can be represented as a network. The system properties of such networks, regardless of their physical nature, but clearly determining the performance of networks, create the totality of the real world. Complex networks – are naturally existing networks (graphs) that have complex topological properties. The researchers who participate and also make discoveries in this field come from various Sciences such as mathematics, computer science, physics, sociology, and engineering. Therefore, the results of research carry both theoretical knowledge and practical applications in these Sciences. This paper discusses the definition of complex networks. The main characteristics of complex networks, such as clustering and congestion, are considered. A popular social network is considered as a complex network. The calculation of nodes and links of the considered social network is made. The main types of AI development and training are highlighted.

KEYWORDS: *complex networks, network implementation, technology, node, communication, network, artificial intelligence, algorithm, characteristics, clustering, workload, training, algorithm, analysis, solution, problem*

INTRODUCTION

Often in practice, the interaction between different objects and/or subjects is expressed in the form of established relationships or associations that show how the relationships of system elements relate or interact. Any of these interactions can be represented as a "Question-Answer" bundle, which is defined as binary relationships in which each object represents a specific point that is connected to another object using a line or arc. Another factor also comes up here – the inheritance Paradigm, which is based on distributed axioms of biosphere unity: fuzziness – clarity (1D and 2D) of continuous nature and is built on three clusters of inseparability. Two incompatible universal laws of nature are valid -Transformation and Conservation, for the closeness of the basis the third dogma is inevitable – Inheritance 3D [1].

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I. Connections and distances between nodes

Every day, the relationship between a person and their personal digital devices becomes stronger and stronger. Along with this, the degree of immersion of people in the virtual world – in the world of the Internet, applications and social networks is also growing. Virtuality is absorbing more and more, drawing people deeper and deeper into its networks, and making people separate nodes of this network. Gadgets are constantly expanding their capabilities and connecting people in one digital, large-scale and complex social network.

A social network is a resource, a platform that provides relationships between people. Your profile is used to communicate and create an offline connection or a connection based on common interests. People upload their photos and information about themselves to their social network profiles and thus personal information becomes public, and the intensive development of information technologies has significantly increased interest and attention to the problem of privacy and security of personal data, including during their automated processing [2]. Thus, personal data may be used by other users, including for unfavorable purposes.

Each of the network nodes has a certain number of connections, combining with other nodes of the same type. If the connection between nodes has a direction, then the network is oriented, and if the connection is symmetric for all nodes connected by it, then the network obtained by such connections is called undirected. For example, if we assume that a connection exists if two people are close friends, then the network will be undirected. If we assume that there is a connection, if one person considers himself a friend of another, then the formed network will be oriented. The number of links of a node is determined by its degree. In oriented networks, there is an outgoing and incoming node degree. The degree distribution of nodes is an important characteristic of a complex network. The main part of all complex networks is close to the power law distribution of degrees of nodes with an exponent between 2 and 3. the Distance between nodes is the minimum number of connections that must be overcome in order to get from one node to another. For all network pairs, there is an average distance between them when moving from one node to another. This distance is called the average distance between nodes – d. For most complex networks, $d \approx \log N$, where N is the number of nodes in the network [3].

Determining the distance between nodes is closely related to clustering, which is one of the local characteristics of the network. It represents a characteristic of the level of interaction between the nearest neighbors of a node. The clustering task is to fragment objects from the Y-set into several subsets (clusters), in which the objects are more similar to each other than objects from other clusters. There are several main known clustering methods. In most cases, to choose the correct method, you need to determine the type of connection between network objects.

II. The method of nearest-neighbor or single link

In this method, the distance between two clusters (Figure 1) is determined by the smallest distance between two close objects in different clusters (1).

$$R^{\delta}(W,S) = \min_{w \in W, s \in S} \rho(w,s) \tag{1}$$

$$\alpha_U = \alpha_V = \frac{1}{2}, \beta = 0, \gamma = -\frac{1}{2}$$

where W , S – clusters.

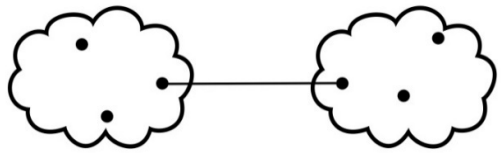

Figure 1. The method of nearest-neighbor or single link

If different parts of such clusters are connected by chains of elements that are close to each other, this method allows you to select clusters of arbitrarily complex shapes. The result of this method is clusters represented by long "chains" that are "linked together" only by individual elements that happen to be closest to each other.

III. Most distant neighbor method or full connection

In this method, the distance between clusters (Fig. 2) is determined by the largest distance between any two objects in different clusters (2).

$$R^{Д}(W,S) = \max_{w \in W, s \in S} \rho(w,s) \tag{2}$$

$$\alpha_U = \alpha_V = \frac{1}{2}, \beta = 0, \gamma = \frac{1}{2}$$

where W , S – clusters.

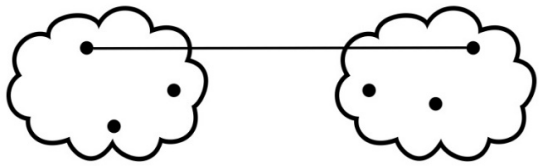

Figure 2. Most distant neighbor method or full connection

This method is good to use when objects actually come from different structures.

IV. Ward's method

One of the main clustering methods is the Ward's method, which is constructed in such a way as to optimize the minimum variance within clusters. This objective function is known as the intragroup sum of squares or sum of squared deviations (3).

$$CKO = x_j^2 - \frac{1}{n \bullet (-x_j)^2} \tag{3}$$

where x_j is the value of the attribute of the j-th object. In the first step, the sum of squared deviations is 0. This method is aimed at combining closely located clusters and tends to create small clusters.

V. UNWEIGHTED PAIR GROUP METHOD USING ARITHMETIC AVERAGES (UPGMA)

The distance between two clusters (Figure 3) is the average distance between all pairs of objects in them. The distance between these clusters is determined by (4).

$$D\left(\left(u,\upsilon\right),\omega\right)=\frac{T_u D_{u,\omega}+T_\upsilon D_{\upsilon,\omega}}{T_u+T_\upsilon} \quad (4)$$

where u, ω are clusters containing T_u, T_ω objects, respectively.

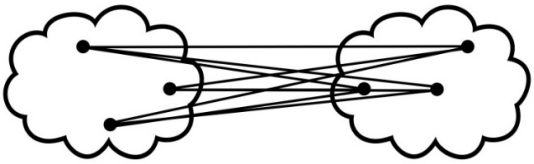

Figure 3. Unweighted pair group method using arithmetic averages (UPGMA)

This method should be used if the objects actually come from different structures. In cases where there are clusters of the "chain" type, assuming unequal cluster sizes.

VI. WEIGHTED PAIR GROUP METHOD WITH ARITHMETIC MEAN (WPGMA)

This method uses the cluster size (the number of objects contained in the cluster) as the weighting factor. The distance between clusters is determined according to the (5).

$$D\left(\left(u,\upsilon\right),\omega\right)=\frac{D_{u,\omega}+D_{\upsilon,\omega}}{2} \quad (5)$$

This method should be used only if there is an assumption about clusters of different sizes.

VII. UNWEIGHTED PAIR GROUP METHOD WITH CENTROID AVERAGE (UPGMC)

In this method, the distance between two clusters (Figure 4) is taken as the distance between their centers of gravity. The distance between the centers of gravity is determined by (6).

$$R^{U}\left(W,S\right)=\rho^2\left(\sum_{w\in W}\frac{w}{|W|},\sum_{s\in S}\frac{s}{|S|}\right) \quad (6)$$

$$\alpha_U=\frac{|U|}{|W|},\alpha_V=\frac{|V|}{|W|},\beta=-\alpha_U\alpha_V,\gamma=0$$

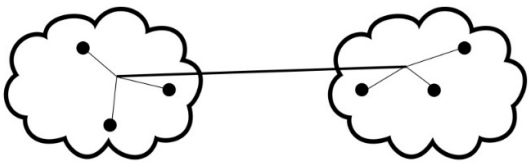

Figure 4. Unweighted Pair Group Method with Centroid average (UPGMC)

VIII. WEIGHTED PAIR-GROUP METHOD USING THE CENTROID AVERAGE (WPGMC)

This method is similar to the UPGMC method, the only difference is that weights are used to account for the difference between cluster sizes (the number of objects in them). This method is preferable if there are assumptions about significant differences in cluster sizes.

The clustering coefficient of a node is the probability that the two nearest neighbors of that node are themselves nearest neighbors. For example, as we are friends with our friend, so we are friends with his friends. The concept of friends of friends can also be found in social networks. Connection through friends of friends or friends at ambiguous numbers may be submitted to the original node. That is, going through a huge amount of links, we can return to the starting point at the source node, as all nodes in the network are interconnected. Each node must be processed and analyzed, which is very time-consuming work.

Using the example of one of the most popular social networks, such as Vk.com, which has been included in the top 10 most popular sites in Russia for several years, let's look at the task that the network has to face. The monthly audience of this site is 71 million people, this is the number of nodes involved in the social network. There are many more connections between these nodes. Let's assume that the text information about one participant corresponds to the volume that fits on a standard A4 sheet.
On average, a sheet contains 25 lines, each line containing 75 characters of 8 bits each, i.e. the size of a single page is approximately 1.5 KB, and the amount of information for active users is about 105 GB. Based on the fact that this information is presented in the form of typewritten text and contains certain items (full name, address, place of study, etc.), it is structured and the easiest to analyze. In addition to text information, there is also information in various graphic and multimedia formats (drawings, photos, videos, audio), which is more difficult to structure and is not considered in this work. We can assume that if we consider a social network as an information network consisting of nodes and communication channels, it contains 71 million nodes. Communication channels determine the interaction of users, i.e. their familiarity, and it is more likely that all users of the network are familiar with each other through their friends. Thus, we need to determine such connections, that is, find a route from one node to another, and then conduct an analysis. It is known that the number of routes will be equal to $n!$, where n is the number of nodes, that is, in our case, the number of routes is equal to 71000000!. Based on the Stirling's approximation:

$$n!\approx\sqrt{2\pi n}\left(\frac{n}{e}\right)^n \quad (7)$$

After making calculations, the value of the number of routes is $10^{284000000}$. Therefore, the total amount of information analysis is 1.5 KB * $10^{284000000}$ which is much more than the original 105 GB.

This volume must be analyzed every time a change occurs. The problem is difficult to understand and only AI can solve it. The more times It is used to solve the same type of problem, the faster it learns, and the more difficult this task is, the higher the level of intelligence. Training uses a large amount of data, which allows the AI to choose its own method and approach to training, and for complex network technologies, it is the basis for technological development.

The most popular task for segmentation data mining requires that a given group be fragmented into internal homogeneous clusters in order to better identify different groups of people who share a common set of characteristics.

Classical approaches model this problem on relational data. Each individual (data point) is described by a structured list of attributes. Indeed, in several scenarios, this modeling choice is an excellent proxy for dealing with context-sensitive issues. However, such methodologies alone cannot answer the natural but non-trivial question: What does it mean to segment a population for which the social structure is known in advance? The first way to solve this problem can be defined in a complex network analog of the data mining clustering problem-Community Discovery.

So far, many algorithms have been proposed for efficiently and efficiently splitting graphs into connected clusters, often maximizing specially adapted quality functions. One of the reasons why this task is considered one of the most difficult is its failure: there is no single, generally accepted definition of what a community should look like.

With today's huge amounts of data generated by next-generation networks, and the evolution of computing involving coordination between edge and core platforms, the need for data center evolution will be paramount. The next-generation mobile capabilities in sensing, visualization, and location will generate huge amounts of data that must be managed on behalf of network owners, service providers, and data owners.

When developing and researching AI, several different systems and methods are distinguished: state-space search; natural language processing; knowledge representation; expert systems and decision support systems; machine learning and artificial neural networks; genetic algorithms; multi-agent systems [4].

State-space search is when one of the search options is always in the focus of other artificial intelligence technologies. This method is a method in which there is a need and need to know which of the methods exist in order to perform a search and understand why everything is based on searching in the state space of an artificial intelligence system, as well as how and how artificial intelligence systems can use various types of heuristics. Natural language processing-using this method, AI systems are able to communicate with users in a language they understand, not only by entering commands, but also by voice.

Knowledge-based artificial intelligence systems use various formalizations that represent knowledge. There are still several such methods that are absolutely universal and to some extent reflect the ability of people to describe their knowledge. In addition, since the creation of the first knowledge-based systems, many mathematical methods have been developed to address the so-called factors of ignorance-completeness, unreliability, uncertainty, fuzziness, attenuation, and many others, which makes artificial intelligence systems able to work and make decisions in conditions of uncertainty, as a person does.

Thus, the most important class of knowledge-based systems are expert systems, which in turn often form the core of various decision support systems. Expert systems include an extended knowledge base of any problem area that collects and integrates expert knowledge (dynamic systems are constantly updated) and allows to make decisions based on them.

Artificial intelligence is still far from being able to generate algorithms on its own, and it is still being helped by humans. To improve the quality of work, the algorithm needs to be constantly expanded, fixing existing methods. For example, for social networks, the method of expert systems is used, which allows you to process a large amount of information, and as a result gives a conclusion. Functional work requires a fast response of the analysis and processing system, which will help to form data clusters in a timely manner to simplify problem solving in order to implement the tasks of social networks.

One of the main tasks is to form social and target groups. These groups and clusters are formed in stages and take milliseconds of time. Also popular in social networks is AI, equipped with the following functions: video editing and photo editor, telephone operator, designer and spam defender, consultant, marketing psychologist, diagnostic assistant.

An effective structure will help organizations gain confidence in their AI technology. This approach should go deep into AI in the enterprise and in the individual model to help ensure that key trust imperatives are integrated and controlled throughout. It must continually evaluate and maintain control over complex, evolving algorithms, establishing methods, controls, and tools that provide anchors of trust throughout the lifecycle, from strategy to evolution. It should also provide clear guidance to organizations and stakeholders in the various management and oversight functions [5].

IX. Conclusion

Performing tasks that are usually handled by humans is the main property of AI. These problems lead to the fact that our life is greatly simplified. Each appearance of new devices is reduced to the fact that their dimensions become minimal, and performance increases significantly. Many of these devices are equipped with special sensors that allow you to "communicate" with the network, with a person and with other devices, transmitting information through communication channels along various routes. In this case, you need to perform a large data analysis, which is capable of AI. After all, the task of statistics, collecting information, as well as storing information about a selection of objects, and ordering it is not an easy task even for AI, but it is still possible to solve. To help, the AI uses clustering, the choice of which method depends on the goals and objectives set. AI intelligence, in turn, can provide reliability, speed, and the ability to independently make decisions on a number of tasks. However, as the level of integration of new technological architectures increases, the risks of security and privacy violations also increase.

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A SURVEY OF INTERNET OF THINGS

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DOI: 10.36724/2664-066X-2020-6-2-25-32

ABSTRACT

The growing era of technology through the internet, Internet of Things (i.e. IoT) has a powerful and strong industrial system that provides an opportunity to grow and applications to use ubiquitously. Its applications use sensor, wireless, mobile and RFID technology devices. In recent years IoT applications are enhancing to being deployed as well as developed. The IoT promises to have a great future era of the Internet uses that involves machine-to-machine communication. It helps to enable the sensor network as well as technologies, even IoT got involved in our day-to-day routine such that it supports to control and to monitor a human being's mundane by providing mobile access, remotely. Undoubtedly, remote access is the incredible feature of the IoT which has been given to this world. The main objective of IoT is to provide remotely accessible at low-cost that too by often visits through electronic devices. This paper presents the maximum possibilities of challenges, applications, security issues and techniques of IoT.

KEYWORDS: *Internet of Things, IoT devices, applications, Technologies*

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I. Introduction

In the era of growing the leverages of smart electronic devices with a high speed of IoT. It has gained a wide range of popularity with acceptance as the standard for the resources which have network constrain. Those embedded devices and network things that have sensors which are interconnected through the networks either private or public [1-3]. The IoT devices can be organized remotely so that one could perform the desired functionality. In terms to share the information by using these devices via a network that employs some standard communication protocols, which has been set for security purpose. As figure 1 shows the connectivity held in between the IoT devices, it doesn't matter wherever the devices are, this requires the wireless network, appliances, devices that support network connectivity.

The upcoming years of IoT will change the real-world objects into smart virtual objects. The smart devices which are used to get connected vary from wearable devices to the huge machines, where each device is having sensor chips to connect. Few of IoT devices are Lenovo smart shoes have sensor chips to support the fitness data to track and to analyze, even electrical appliances such as refrigerators, washing machines, microwaves, etc. can be accessed and controlled easily from a remote location, and the most renowned devices for IoT is the surveillance cameras that can be controlled remotely, no matter wherever a person is in this world [4, 5]. IoT has taken over the community requirements too, apart from the field of the electronic devices for personal use.

Figure 1. IoT Overview Model

The plethora of smart devices give diversity to use its functionality such as to monitor a surgery, to detect the weather predictability of its condition, automobiles connectivity, to track or to identify an animal, etc. there are uncountable areas where IoT serves the whole community whichever needs it. The data which has been collected through those electronic devices that process in the real-time that improves the efficacy to the complete system. The futuristic IoT significance is evident because of its application which has been used in mundane life. In the case of growing field of IoT that evolves the rapid growth of the hardware techniques to improve the bandwidth through the incorporating cognitive radio which is based on the network that addresses under-utilization of the frequency spectrum [6,7].

Since the paradigm of IoT represents the interconnected networks collection as well as the heterogeneous devices. So, it inherits the issues of conventional security that is related to computer networks. Moreover, the resources constrain challenges towards IoT security of its sensors and devices that have limited memory and power.

If we go back to see the previous years of IoT makes a tremendous effort to cope with its security issues, that approaches to have end-to-end IoT security. A recent survey [8], categorizes the issues arises in the security of IoT during the application, data, communication as well as architecture. The IoT threats are there for hardware, software, applications as well as network components. There are security issues to analyse has been discussed by Granjal el.al [9]. The analysis of security has been presented and discussed by the work done by the researcher has been shown in the paper [10-15]. This targets an evaluation for Intrusion Detection Systems (IDS), comparatively. If it comes to provide the analysis of the issues in security of IoT the fog computing has been presented by the scientific work in the papers [16-18]. The contributions towards the IoT that provides security, access control, privacy, and confidentiality that also includes the security of the middleware layer [19]. These authors discuss the issues in IoT related to the privacy, security of data, trust management, the security of the network, authentication, as well as IDS.

Scientific researchers have searched the preservation mechanisms for privacy in IoT. Many researchers describe the security of computing multi-party security to enforce preventing IoT users' privacy. The credit mechanism to check and to attribute base on access control has been described as solutions to effect preservation of privacy. The possible threats and countermeasures for IoT based on cloud, many research works are there to identity and node compromising, location privacy, to add or to remove the layer, as well as key management for IoT threats while using cloud [20-22]. The architecture of the IoT compliance needs to implement privacy, security and trust. The trust model expects to provide data confidentiality as well as data integrity while end-to-end communication makes possible by the mechanism for authentication. Furthermore, to evade improper data usage, the model for privacy needs to define access mechanisms and policies to decrypt and encrypt data [23].

The rest paper has been organized as follows. In Section 2, the security in IoT will be delineated. Section 3 includes the architecture of IoT. After all of the preservatives towards the IoT security and its hindrances, technologies of IoT will be discussed in section 4. In Section 5, challenges in IoT details are there, whereas Section 6 includes the possible applications in the field f IoT, before concluding the paper in Section 7.

II. Security Issues in IoT

2.1 What is IoT?

The IoT itself a wide range, and it is hard to define IoT in few words, the unique definition that is available universally acceptable by the world of IoT community users. "The IoT is an open, as well as a comprehensive network of the smart and intelligent objects, are capable to auto-organize data and resources, sharing information, to react and act in the situation as well as to be able to change inside the environment." The IoT continues to be the most hyped and latest concept in the world of IT [25].

The IoT has already attracted many lives and attention by its vision for a network of physical objects for global infrastructure that enables anytime, connectivity at any place from one to many things at a single time [26]. IoT has been introduced as a global network that allows the human-to-human, things-to-things, and human-to-things communications. It could be anything that connects as well as communicate smartly or intelligently better than ever before [27].

2.2 Requirements for IoT setup

IoT is the huge world in itself. It is not the work of 2-3 machinery as a part of the setup. It requires the need to secure hardware as well as software. This requires a large setup with a lot of embedded real-time connectivity use to build a proper IoT. To implement the IoT successfully, it requires the following:

- Dynamic Resource Demand
- The need for Real-Time
- The demand for exponential growth
- Applications availability
- Protection of Data
- Privacy of Users
- Applications to consume efficient power
- To execute the applications for nearby end-users

Apart from above-mentioned prerequisites, IoT needs to access in an open as well as an interoperable cloud system. This required the basic three components that are needed for seamless IoT and its computing.

- Hardware: In IoT hardware required the composition of the sensors, CCTV, embedded devices to communicate, actuators, IP cameras, etc. which are needed to connect a hardware device to help in communication.
- Middleware: In IoT, this is required to store the data and also supports the computing tools to analyse data with the analytical power of Cloud and Big Data.
- Presentation: This is the broadcasting part of IoT, that helps to visualize the data and an interpretation tool that can be used to design several other applications.

2.3 Security for IoT

In terms to deploy the security, [28] several parameters and mechanisms are required to be estimated which is mentioned below:

- *Privacy, Integrity and Confidentiality of Data (PIC)*

IoT is a huge platform to travel the data to communicate which passes through the multi-hops exist in the network; a proper mechanism to encrypt is needed to ensure the data confidentiality. It happens because of the assorted network, device and services to store the data on any device is prone to violate privacy rules of compromising nodes that exist in the IoT network. The IoT device is vulnerable to the attack that causes an intruder to impact the integrity of data by modification of data storage for malicious purposes.

- *Availability of Services*

The attacks on the devices in IoT hinder the service to provide by the conventional Denial-of-Services (DoS) attacks. Several schemes include the jamming intruders, sinkhole attacks or replay attacks that exploit the components of IoT at different layers to wane the QoS to provide IoT users.

- *Accounting, Authorization, and Authentication (3A).*

IoT communication security requires the authentication in between the two parties to give them the legal access for their privilege services, for this, an authenticated device is mandatory. The mechanism of authentication's diversity for the existence of IoT is lying majorly for the heterogeneous diversity for its fundamental architecture and its environment that supports devices of IoT. These ambiences pose a challenge to define its standard protocol globally to authenticate in IoT. Correspondingly, the mechanisms to authorize for ensuring the system access or to provide authorized user, it needs a proper authorizing implementation and authenticating implementation results in a reliable environment to ensure an environment to secure communication. Accounting of the resource usage, with its auditing as well as reporting, gives a trustworthy mechanism to secure the network management.

- *Efficiency for Energy*

The devices in IoT are typically resource-constrained as well as are characterized by less storage and low power. The IoT architecture results in an enhancement to consuming energy by network flooding and IoT resources exhausting by forged and redundant service request.

III. IoT Architecture

At the end of 2020, 25 billion things are expecting to be connected [29] which is in a large number, so the existing Internet Architecture with the TCP/IP protocols which have been adopted in 1980 [30] that cannot able to handle a huge network as large as the IoT that cause a need for the latest open-architecture that address different security as well as QoS issues and it supports the existing applications of the network by using the open protocols [31]. Without an appropriate privacy assurance, as IoT is not likely in terms of adopting by many IoT users [32]. Hence, the fortification of IoT users' privacy and data are major IoT key challenges [33].

According to the further IoT development, a number of the multilayer architectures for security have been proposed. As per the paperwork [34], describes the three-key level of IoT architecture, whereas [35] mentioned the four-key IoT architecture level of its security, and [36] described the five-layer architecture by using the superlative features of Internet and Telecommunication Management architecture based on the TCP/IP as well as TMN models, respectively. Correspondingly, six multi-layered architecture has been proposed which is based on the hierarchical structure of the network [37]. As shown in figure 2, about the six-layer architecture of IoT which have been described below in details:

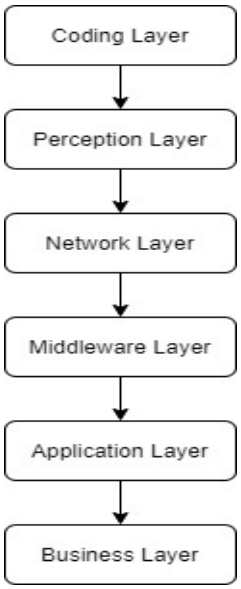

Figure 2. IoT Architecture Layers

- Coding Layer: This is the foundation layer of IoT that provides identification to the interest objects. In this layer, each object is allocated a unique ID that makes it much easy to discriminate the objects [37].
- Perception Layer: In this layer, a physical meaning is provided to each object. It constrains the sensors of data in distinct forms such as RFID tags, IR sensors and other networks of sensors [38] that could able to sense the humidity, location, temperature, speed, etc. of the objects. This layer collects the important information of each object from its sensor devices which is linked with them as well as converts the existed/received information into the digital signals so that they can pass for the further action on the Network Layer.
- Network Layer: This layer having the aim to receive the important information that too in the form of the digital signals from its second layer i.e. Perception Layer as well as transmit it to its processing system exists in its fourth layer i.e. Middleware Layer by the transmission medium such as Bluetooth, WiMax, WiFi, Zigbee, 3G, GSM, etc. with its protocol such as IPv6, IPv4, DDS, MQTT, etc. [39].
- Middleware Layer: In this layer, the information is received from its sensor devices [40]. It contains technologies such as ubiquitous computing that assures the direct access to its database to collect the entire important information in it. By using the Intelligent Processing Equipment (IPE), the processed information, as well as a fully automatic action, has been taken which is based on its information for its processed results.
- Application Layer: In this layer, IoT applications for all type of industries that are based on its processed data due to the promotion of its application to develop the IoT, so this application layer is very important in the large scale to develop the IoT network [36]. Those applications which are related to the IoT for smart transportation, smart homes, smart planet, etc.
- Business layer: In this layer, helps to manage the IoT applications as well as services which are responsible for all the IoT related research. It creates various business model to affect business strategies [41].

IV. Technologies of IoT

Initially, IoT was inspired by the community of RFID to discover information possibility to tag the object for browsing an address of internet or database entry of internet, so that it correspondingly for an RFID or its near field communication technologies [42]. In the paperwork [43], technologies related to IoT such as RFID, nanotechnology, intelligence embedded technology, and the sensor technology have been introduced. Other technologies such as RFID, 2D barcode, and NFC allow identifying the physical objects to refer over the internet. IoT integrated the RFID with sensor technologies, so that hardware devices can get connected with the internet resources, ubiquitously. The trending IT industry waves, since the computing field application, global roaming technology and communication network technology has been applied. Additionally, it includes the sophisticated technologies of communication network and computer, so that it could support the IoT technologies, for instance, remote communication technology, information technology, remote information transmission technology, controlling technology, sea measures intelligence analyzes, etc. [44-46].

- *RFID*

Radio Frequency Identification (RFID) transmits an object's identity or a person's identity through the radio wave, wirelessly, in the form of given serial number. The major RFID components are antenna, reader, access controller, server, reader and software [47]. It is more secured, reliable, accurate, efficient and inexpensive. It has extensive wireless applications range for instance patient monitoring, tracing, military apps, distribution, etc [48].

- *EPC*

Electronic Product Code i.e. EPC, a 64 bit and 98-bit code on an RFID tag that is electronically recorded and envisioned to create an enhancement in the system of EPC barcode. EPC global organization is responsible for its standardization of EPC technology that has created the EPC global network, to share the RFID information. It has main four components i.e. EPC Discovery Service, Object Naming Service, EPC Security Services, and EPC Information Services.

- *Barcode*

This is just a distinct way to encode numbers as well as letters to use the bar combination and to space the changing width. [49], Barcode is optical on the machine to read labels which are attached to its items to record the related item information. In recent times, the system of QR code becomes renowned outside the industry of automotive because of its huge capacity to store and to read faster as compared to the standard. Majorly, three kinds of the barcode are there i.e. Numeric, 2 Dimensional and Alpha Numeric. This is designed to read by the machine. Generally, it is readable by the laser scanners. It can be readable by using cameras.

- *Wi-Fi*

Wireless Fidelity i.e. Wi-Fi, is a technology for networking to allow the computers as well as its other devices for communicating over the signal wirelessly. The father of Wi-Fi is Vic Hayes. [50], the predecessor to Wi-Fi has been invented by NCR Corporation in the year of 1991, in Nieuwege, Netherland. The very first wireless products have been brought on the market with its speed 1

Mbps to 2 Mbps, under the name of WaveLAN. Millions of WLAN connectivity has been delivering Wi-Fi at homes, offices, even at the public or private locations such as café, metros, restaurants, railway stations, airports, etc. There are a lot of technologies that contain the kind of WLAN product to support IEEE 802.11 with dual-band, 802.11b, 802.11a, 802.11n and 802.11g.

- *IP*

IP stands for Internet Protocol. This is the crucial network protocol which is used on the internet. It has been developed in the years of 1970s. The principal communication protocol is IP, exists in the Internet protocol suite to relay datagrams over the boundaries of the existing network [42]. It has five classes that range in the IPv4 i.e. Class A, Class B, Class C, Class D, and Class E, whereas only the Class A, B and C are majorly used classes. The real protocol gives the 4.3 billion addresses of IPv4, although, IPv6 will be ominously argument the availability to the addresses up to 85000 Trillion. IPv6 is majorly used in this 21st century that supports addresses approximately 2^{128}.

- *ZigBee*

This is one of the protocols which have been developed to enhance the WSN's features. ZigBee Technology has been formed by the ZigBee Alliance in the year of 2001. The important ZigBee's characteristics which have low data rate, moderately short transmission range, scalability, low cost, flexible protocol design, reliability [51]. It is the wireless network protocol that has low power, based on the IEEE 802.15.4. ZigBee ranges around the hundred meters as well as 250 kbps bandwidth. The topologies of ZigBee work as a cluster tree, mesh, and star that is broadly used in digital agriculture, home automation, medical monitoring, power systems and industrial controls.

- *Bluetooth*

This is the technology that is short-range radio technology and inexpensive wireless technology. It eliminates the proprietary need of cabling in between the devices, for instance, notebook PCs, PDAs, handheld PCs, printers and cameras within its effective range i.e. 10 to 100 meters. Generally, to communicate via Bluetooth at less than 1 Mbps, it uses the IEE 802.15.1 standardized specification. Firstly, in the year 1993, Ericsson Mobile Communication Company initiated the project which is named as "Bluetooth", is the creation of PAN i.e. personal area network. Bluetooth device set shares a mutual channel to communicate which is known as Piconet. This Piconet can share data within 2 to 8 devices at a period, and this data could be a sound, video, text and picture. There are more than a thousand companies that comprise by Bluetooth Special Interest Group with Cisco, Intel, Ericsson, Motorola, Toshiba, Aruba, and HP.

- *Actuators*

It converts the energy into the motion. This means the actuator drives motion into the mechanical system. It takes electric current, hydraulic fluid and some different power source. It can create the rotary motion, oscillatory motion and linear motion. Typically, cover short distances up to 30 feet that can communicate less than 1 Mbps. It is used in the applications of industrial and manufacturing. Mainly, it has three kinds i.e. electrical, pneumatic and hydraulic, whereas electric actuators used commonly, hydraulic actuators and pneumatic actuators system allows increasing the torque and forcing from the smaller motor.

- *WSN*

Wireless Sensor Networks consisting the autonomous devices by using sensors to cooperate environmental conditions as well as physical conditions, for instance, sound, temperature, pressure, pollutants, vibration, at distinct locations. WSN is the most important element in the paradigm of IoT [52]. IoT based WSN has received incredible attention in several areas such as home security, military, accurate agriculture monitoring, healthcare, habitat monitoring, manufacturing, flood detection, forest fire, so on.

- *NFC*

NFC stands for Near Field Communication, is a set of wireless technology that is for short-range i.e. 13.56 MHz, which is approximately equal to the distance of 4 cm. This technology makes the life more convenient and easier for its users around the world to make it easy for exchanging the digital content, connect electronic devices and transactions, such that they could connect with a touch of electronic devices. It allows the wireless networks instinctual initialization of NFC complementary to the Bluetooth. 802.11 With its capacity up to 10 cm to support its long-range distance. It works in the untidy environment that doesn't need the line of sight simple as well as easy for the connection method. It has been first invented by the Sony and Philips companies. In this, 424 kbps is the data exchange rate, whereas the consumption of power during the time of reading data in the NFC which is under 15 ma.

- *AI*

Artificial Intelligence i.e. AI refers environment of electronic that is responsive as well as sensitive in the people's presence. In an ambient smart world, electronic devices work in the concert to support the people for carrying out their mundane life activities in a natural way to use the Information & Intelligence which is in its connected network devices, hideously. This system has characteristics such as context awareness, embedded, adaptive, anticipatory, and personalized.

- *Cloud Computing*

This is the only technology that analyzes as well as store the data. Intelligent computing technology has an ample amount of server are congregated on one platform of cloud that allows resource sharing to be accessed at any place or time. It is the most valuable part of IoT, apart from converging sensors, it also processes on enhanced analyzes, and power of the important information which is received by the sensors as well as provide the good space capacity to store data. The potential of cloud computing contains the zillionths of sensors that give a massive advantage, as well as help IoT to be dependent over cloud computing.

- *Optical Technologies*

The increasing fast development in the field technologies that includes optical technologies, such as Cisco's BiDi and Li-Fi, it could be an important breakthrough in IoT development.

- *Nano Technologies*

The smallest and enhanced version of the interconnected things, it can reduce the system consumption by making it enable for device development with the nanometer scale, to be used as an actuator and sensor as a

normal device. This Nano device has been made up of nano-components that result in networking to define a new paradigm that uses the Nano-things on Internet.

- *Network Technologies*

In the IoT success, these technologies have played an important role. This is the huge network that provides a connection between the objects. It provides us with the effective, huge and fast network that covers a huge number of the devices which is potential in the network. This modern era fully dependency over ubiquitous computing needs super powerful, super-efficient, as well as super-fast growing generation of the wireless system. Likewise, short-range communication between the network, technologies like Wi-Fi, Bluetooth, Infrared, etc. are famous to use.

- *MEMS*

This micro electro mechanical system (MEMS) is a combination of the mechanical and electrical components that work together for providing the numerous applications to include actuating and sensing, that uses it commercially in various areas in the form of accelerometers as well as transducers. The combination of MEMS and Nanotechnologies provides a cost-effective solution to improvise the IoT system communication. The other benefit is to reduce the size of actuators and sensors to integrate the computing devices ubiquitously, as well as the frequency higher range.

V. IoT PRIVACY CHALLENGES

With the help of using IoT, everything seems easy as it makes a person and an object addressable and locatable to make human life easier comparatively than earlier, however the lack in the confidence about the privacy and security to the data of the users. The ubiquitous adoption of the IoT that have a sturdy secure infrastructure, even though it includes some concerns related to its privacy as below:

- *Breaching Sensor Nodes Security*

The sensor vulnerability by the attacks includes the bidirectional sensor network. The other data transmission, data acquisition is possible too. The attacks including tampering, flooding, jamming, Sybil, and other attacks make breaching of the sensor nodes, even after providing the best possible security system.

- *Abusing Cloud Computing*

The huge network of the cloud computing that converge servers by allowing the resource sharing in between them, such kind of sharing resources faces a lot of threats in there security such as phishing, man-in-the-middle, etc. There are important steps that have been taken to ensure the security of IoT. Cloud Security Alliance i.e. CSA has been introduced a few possible threats such as Data Loss, Malicious Insider, Hijacking Accounts, Monstrous use of computer sharing, and others.

- *RFID Illicit Access*

The tags in RFID help to access the authenticated user as it contains the details about the users. The exposure of any credential information or data of the user by any unauthorized user can create severe damage to the user data. Few real-life RFID threats include side channel, RFID virus, SpeedPass Hack, or other attacks that could harm the data.

- *Limitation of Resources*

The resource-guarded IoT architecture is the major hindrance to define the security mechanism robustly. Contrastingly, those paradigms which are conventionally limited by the cryptographic algorithms to work under those constraints that provide multicasting as well as broadcasting which is needed to exchange its certificates or the key. This storage and energy are needed to cope with in the situation to provide an accomplished implementation for communicating IoT protocols with complete security. Entailing the protocols are redesigning to be ample energy-efficient and light-weighted, despite needing the complex structure of computations to improve the techniques for energy harvesting.

- *Security Protocols Interoperability*

IoT mechanisms for its global security for standardizing it and its protocol so that it could be implemented at the different layers which are required to be interoperated by using the conversion mechanism. It becomes effectively by using the security standards combination lying at each layer, within the global mechanism.

- *Range of Heterogeneous Devices*

This gives the vast range to vary from small sensor devices that have low power to the high-end servers, which is needed to be implemented in the security framework of multi-layer security. It makes itself to adapt in the environment with the existing resources, to make the decisions related to the selection of the IoT layers security mechanisms, before the process to provide the services to the end-users. Dynamically adapting the security framework of the IoT architecture's required intelligence, such that resources standardization in the IoT architectures can be deployed.

- *Failure Single Points*

There are numerous architectures, networks, and protocols exist in the paradigm of IoT, heterogeneously. Due to this reason, it becomes more deployable to each existing point. Mechanisms of IoT and its standards have been introduced to reduce the redundancy to keep in the view for trading-off in-between the reliability and the cost of its complete infrastructure.

- *Trust Managements & Updates*

This is the most open issue for the future work into research that provides trust management and the scalable management, and to update the existing software into zillions of IoT devices. The major problem with its relatable data is to make it reliable and secure for the owner of the IoT device by the government. Data Privacy, as well as Supply Chain, is the open research area for the researcher as it has violation in the wide range. Block technology is enabling for the solution to secure IoT, even though, this itself impose the research challenges to be handled through its efficiency, key collision, regulations, scalability as well as arbitration.

- *The Vulnerability of Firmware/Hardware*

The low power, as well as low cost devices, is ubiquitously becoming trendy. In this, IoT architecture becoming more exposed to the vulnerabilities related to its hardware, not related to its physical malfunctioned. Even, the algorithm implementation for its security lying in its hardware, packet as well as routing to process its mechanisms which requires verification before IoT get de-

ployed. There is a different standard to verify the protocol, so that no intruder can crack the existing system.

- *Vulnerable BlockChain*

The security of IoT is robust and approaching for the system of block-chain which is highly vulnerable. The mechanism is depending on the power of miner hashing that can be compromised in a few manners. Sometimes, the attacker hosts the block-chain to make the private key for limiting the random exploitation. Its efficient mechanism is needed to define the assurance of the transaction privacy, that avoid attacks in a race that gives result the double spending, during the time of transaction.

VI. IoT APPLICATIONS

Mostly, mundane leveraging applications we normally visualize them user-friendly and easy to communicate with each other. It helps to use a wide range of information sharing for pioneering applications. Several existing emerging applications provide autonomously capable to enhance the quality of living standards. Majorly, real-time applications are becoming popular such as a self-driving car with the traffic evaluating by real-time, conditions of road as well as the weather or some other crucial information that is being exchanged by those applications of IoT. Few of IoT applications are mentioned below in this section.

- Smart Environment: It helps to predict the natural calamities which are going to happen in the coming future such as earthquakes, flood, etc. It is possible because of the emerging innovative IoT applications that help to monitor environmental pollution.
- Smart Traffic System: It makes enables to detect the congestion in transportation, that provides the feature such as reporting accidents, detection of being theft, traffic jam, climate-changing situation, etc. It provides the smart city idea to manage a traffic system according to the existing situation by predicting it through the IoT applications.
- Smart Hospitals: IoT applications are quite renowned in the flexible hospital environment by using the RFID tag to evaluate patient's blood pressure, oxygen level, heart rate, temperature, etc. It helps a lot during the time of emergency while cardiac attack.
- Smart Home: For monitoring the household utilities such as water supply, energy consumption and meters. These IoT applications help to save the utilities by detecting in advance so that it could save the wastage of water, electricity or other household utilities. For instance, the garden gets water as per their need, or alarm will buzz while water leaks, and so on.
- Smart Retailing: RFID with IoT provides benefit to the supply chain or the retailers. In this, equipped RFID products can be tracked in the existing stock, so that it could get detected during shoplifting. It helps to track overstock, sales chart as well as effective strategy graph.
- Smart Agriculture: The IoT application helps in monitoring the light, soil nutrition, humidity, etc. so that it helps to improve the GreenHouse experiencing by the automatic adjustment of the temperature for maximizing the production. The precise level of water and fertilization to improve the quality of water as well as to save the fertilizers.

VII. CONCLUSION

Gradually, IoT is bringing incredibly technological changes in people mundane life. It turns into help for making a happier life which is comfortable, simple and easy to live due to the various applications and technologies of IoT. IoT is universally standardized with no standard definition. User-to-user application has been varying that needs to be interoperable. IoT is there to use for global governance with standard protocols for better future. This is vast in its usage by its applications into areas such as industrial, transportation, governance, implementation, habitat, education, mining, medical, etc. The global mechanism to secure the IoT layers is important due to its diverse IoT resources. This paper outlined future research areas for making IoT more efficient, scalable, and reliable for its security solutions.

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SATELLITE-BASED LOCATION DETERMINATION OF SMALL AIRCRAFT IN CASE OF ACCIDENTS AND DISASTERS

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DOI: 10.36724/2664-066X-2020-6-2-33-37

ABSTRACT

From the moment the air/aero/aerial objects appeared the necessity of monitoring for them arose and were solved using different tools, such as radio communications, radio direction finding, radar and others. With the advent of global satellite navigation, the massive introduction of navigation equipment began in almost all areas of human activity and especially in mobile (moving) objects (cars, aircraft, ships, etc.). This allowed aircraft crews to accurately determine their coordinates in real time under any weather conditions. However, the organization of uninterrupted data transmission to ground control centers remained problematic. In this regard, aircraft monitoring systems were primarily installed on military and civil aircraft, while the other categories and types of aircraft were equipped only with communication systems. Thus, currently, there is the lack of navigation devices allowing flight monitoring and communication in small aviation. As a result, in case of emergency landing of small aircraft, it takes a lot of time and effort to find its location, therefore providing emergency assistance to passengers and crew is not possible.

This problem can be solved by the system for determining the location of small aircraft using technologies of global navigation satellite systems and mobile satellite communications. This system includes devices for registering the location of the observed object, transmitting data via mobile cellular and satellite communications, processing, storage and displaying of data. The proposed system, by continuously recording and transmitting aircraft location data to the ground control center, helps minimize time and narrow the search area of the aircraft that made an emergency landing.

KEYWORDS: *monitoring of flight trajectory, monitoring, small aircraft, global navigation satellite system, satellite communication, flight safety*

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INTRODUCTION

Small aviation is backbone of general aviation (GA) and provides transportation of passengers and cargo, as well as agricultural, patrol, medical, training and other needs of the population and country. The category of small aircraft (AC) includes light and ultralight aircraft, as well as unmanned aerial vehicles weighing 10 kg or more. To date, the number of small aircraft is 89% of total number of aircraft. At the same time, small aircraft market continues to grow rapidly [1, 2] and requires the improvement of safety system, high-precision control of aircraft movement and elimination of errors based on misunderstandings between the pilot and dispatcher.

According to the Interstate Aviation Committee (IAC), in 2018, in civil aviation of states parties to interstate Agreement on Civil Aviation and the Use of Airspace, out of 58 aircraft accidents, 35 occurred with participation of small aircraft, as a result of which 44 people died. The main reasons for these incidents are human factor and equipment malfunction [3].

When flying small aircraft on a terrain that is so remote from radars that tracking their flight is impossible, in the event of an accident or catastrophe, the search for an aircraft emergency landing site is a difficult task, implementation of which requires significant time costs, which leads to a decrease in likelihood of saving people lives.

It is possible to significantly reduce the time and narrow search areas for aircraft that has made an emergency landing by providing continuous informing ground control points with navigation information about the flight, including data on the trajectory and flight parameters. In modern flight control systems, for navigation purposes, GPS / Glonass devices are used, which only let crew know the coordinates of aircraft without transmitting data to ground control points. Uninterrupted transmission of reliable navigation data from the global navigation satellite system (GNSS) in real time can be organized using latest advances in signal transmission through low-orbit mobile satellite communication systems [4,5].

In this regard, the creation of a monitoring system for flight trajectory of small aircraft using GNSS and low-orbit satellite communication systems is an urgent task.

Literature review

Determining the location and parameters (speed, acceleration and direction of movement) of aircraft (AC) movement in space is one of the main tasks of navigation. Geotechnical, astronomical, radio-technical and lighting navigation aids can be used for the purpose of ground-based determination of location and parameters of aircraft movement [6]. The most common are radio navigation aids based on the emission and reception of radio waves by airborne and ground radio technical devices and measurement of radio signal parameters, carrying navigation information. The main system of radio navigation aids is radio navigation system (RNS). The RNS classification is shown in Figure 1 [7].

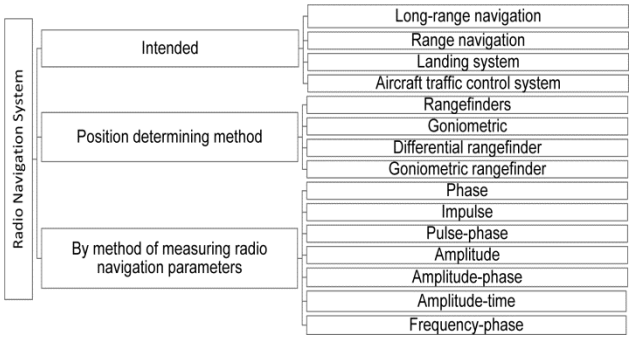

Figure 1. Classification radio navigation system

Currently, aircraft flight monitoring is carried out using the following systems [8]:

– s ort-range navigation and landing radio systems (VOR / DME – VHF Omni-directional Radio Range / Distance Measuring Equipment and ILS – instrument landing system);

– ong-distance navigation radio systems;

– satellite radio navigation systems (a system with the technology of automatic dependent surveillance-broadcast ADS-B – Automatic dependent surveillance-broadcast ADS-B).

Short-range navigation radio systems used are integrated radio navigation systems, including onboard equipment and ground-based omnidirectional azimuth-rangefinder radio beacons and radio beacon groups. Principle of these systems operation is based on determining range and azimuth of observed object in relation to the ground radio beacon.

The system allows determining the coordinates of the aircraft not only on board, but also at the ground point. For ground determination of the range R and azimuth θ of the aircraft relative to the radio beacon (Figure 2), the ground beacon transmitter sends sounding pulses, which are relayed by the aircraft on-board equipment and then received by the ground equipment. Range R BC from this radio beacon is calculated based on the measured time delay of the response signal compared to interrogation signal. Azimuth θ is determined from angular position of radiation pattern at time of response signal arrival [9].

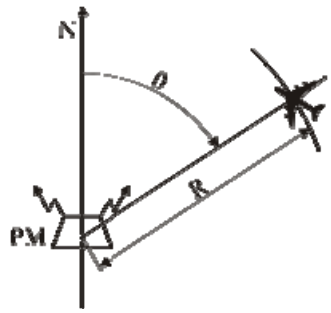

Figure 2. Scheme for determining the position of aircraft by the goniometric-rangefinder method

Short-range radio systems allow solving the following tasks:

– continuous determination of aircraft position both on board and on the ground;

– performing a flight along a given route;

– taking the aircraft to any given point, regardless of visibility conditions, indicating the moment of approach to the point and moment of its passage;

– i plementation of controlled cloud penetration and landing approach;

– observation from the ground by all-round visibility indicator (IKO) for aircraft, determination of their coordinates and aircraft identification, if they are equipped with aircraft identification system equipment.

Radio engineering system in short-range navigation operates on ultrashort waves, so the exchange of signals between aircraft and ground beacon is possible only at line-of-sight ranges, which mainly depends on flight altitude, for example, at a flight altitude of 10 km, the range is up to 380 km. In mountainous areas and in the presence of obstacles in path of ultrashort waves propagation, the range of system decreases.

The most common radionavigation approach system is the glide path system. This system consists of localizer and glide path radio beacons, forming a landing and radio beacon group and emitting radio signals into space. Localization and glide path beacons are installed in close proximity to the runway (runway). Reception and processing of beacon signals by onboard equipment provides guidance of the aircraft in horizontal plane (along the course) and in the vertical plane (along the glide path). A schematic representation of aircraft landing process using the course-glide path system is shown in Figure 3 [10].

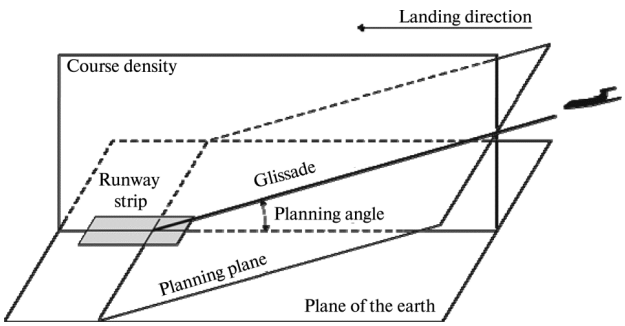

Figure 3. Scheme of aircraft landing on the course-glide path system

Pulse-phase and phase long-range navigation radio systems are widespread, since they allow objects to determine their coordinates when they are not in the line of sight of radio beacons. These systems use ultra-long waves, for which there is a weak dependence of the attenuation of the field strength on the distance, which makes it possible to ensure the range of the system more than 900 km [8].

The basis of long-distance navigation radio systems are reference stations with known coordinates, which only send navigation signals. In turn, the on-board equipment of aircraft receives and processes signals.

To determine the coordinates of the aircraft, the difference-ranging method is used, based on the construction of lines of equal difference distances. The principle of the differential-rangefinder method is to measure time difference between the arrival of signals from pair of stations using a receiver indicator. This difference defines the line of position of aircraft in hyperbola form. To determine the exact coordinates of the aircraft, at least two pairs of stations are required [9].

Long-range radio-technical systems solve the following tasks:

– de ermination of aircraft location using special maps with a hyperbolic grid;

– determination of flight navigation elements;

– re aying signals for transmitting the coordinates of aircraft in distress and when searching for crews that have made an emergency landing.

The most advanced are satellite radio navigation systems. System with ADS-B technology allows monitoring the aircraft movement and receiving aircraft movement parameters both on board the aircraft and at ground points. This system is characterized by highest accuracy of aircraft navigation parameters determination among all known systems. ADS-B is based on GPS global positioning system or inertial navigation system for determining the exact coordinates of an aircraft in space [11].

Aircraft equipped with ADS-B technology are capable of transmitting information: course, altitude, horizontal and vertical speed, to other aircraft, as well as to ground points located at a distance of up to 440 km.

When using a system with ADS-B technology, an accurate map of aircraft location is displayed on radar station screens for aircraft movement and on the aircraft board.

System with ADS-B technology (ADS-B) consists of the following components (Figure 4):

– transmitting subsystem, which performs the functions of generating and transmitting reports on the sending aircraft / vehicle / obstacle;

– data line broadcasting mode;

– receiv ng subsystem, which includes the functions of receiving and assembling reports on the receiving aircraft / vehicle or in the receiving ground system.

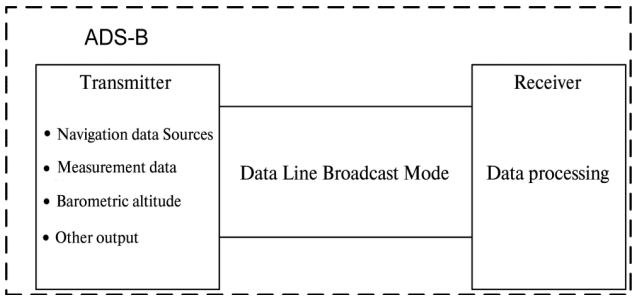

Figure 4. System components with ADS-B technology

During the system operation with ADS-B technology, aircraft determines its position using the GNSS system, then transmitter installed on aircraft transmits data via a radio signal. The radio signal is received by receivers installed on other aircraft and ground points, where the received information is processed. The main advantages of radio navigation aids are their ability to operate in almost any meteorological conditions day and night, to make measurements with high accuracy and determine absolute coordinates of aircraft and ground speed.

However, radio equipment is subject to natural and organized interference, limited in range, and accuracy of their measurements decreases as aircraft moves away from the ground subsystem and radar landmark. In this

regard, use of radio-technical navigation means is impossible to ensure continuous monitoring during flight and location determination in case of accidents and disasters of small aircraft.

Flight trajectory monitoring system for small aircraft

The developed system for flight trajectory monitoring of small aircraft is an automated system that collects telemetry and navigation data, data transmission using mobile cellular or satellite communication systems, receiving, processing, archiving data and issuing information to system users.

The system contains three main components – terminal, data processing center (DPC) and dispatch center (DC). Main components of the terminal are: navigation module, communication modules, barometric sensor and terminal status sensors. The terminal is installed on board aircraft and provides registration of input information (telemetry and navigation data) about state of monitored aircraft and data transmission via mobile cellular or satellite communications to data processing center. Data center provides automatic, continuous and parallel in time data reception from all registered terminals, data processing and archiving, and provision of processed data to the DC. Control center displays position data and other aircraft parameters, which simplify aircraft identification and search operations in the emergency event.

Algorithm of the system for small aircraft flight trajectory monitoring

The algorithm for small aircraft flight trajectory monitoring is presented in form of a UML (Unified Modeling Language) activity diagram (Figure 5).

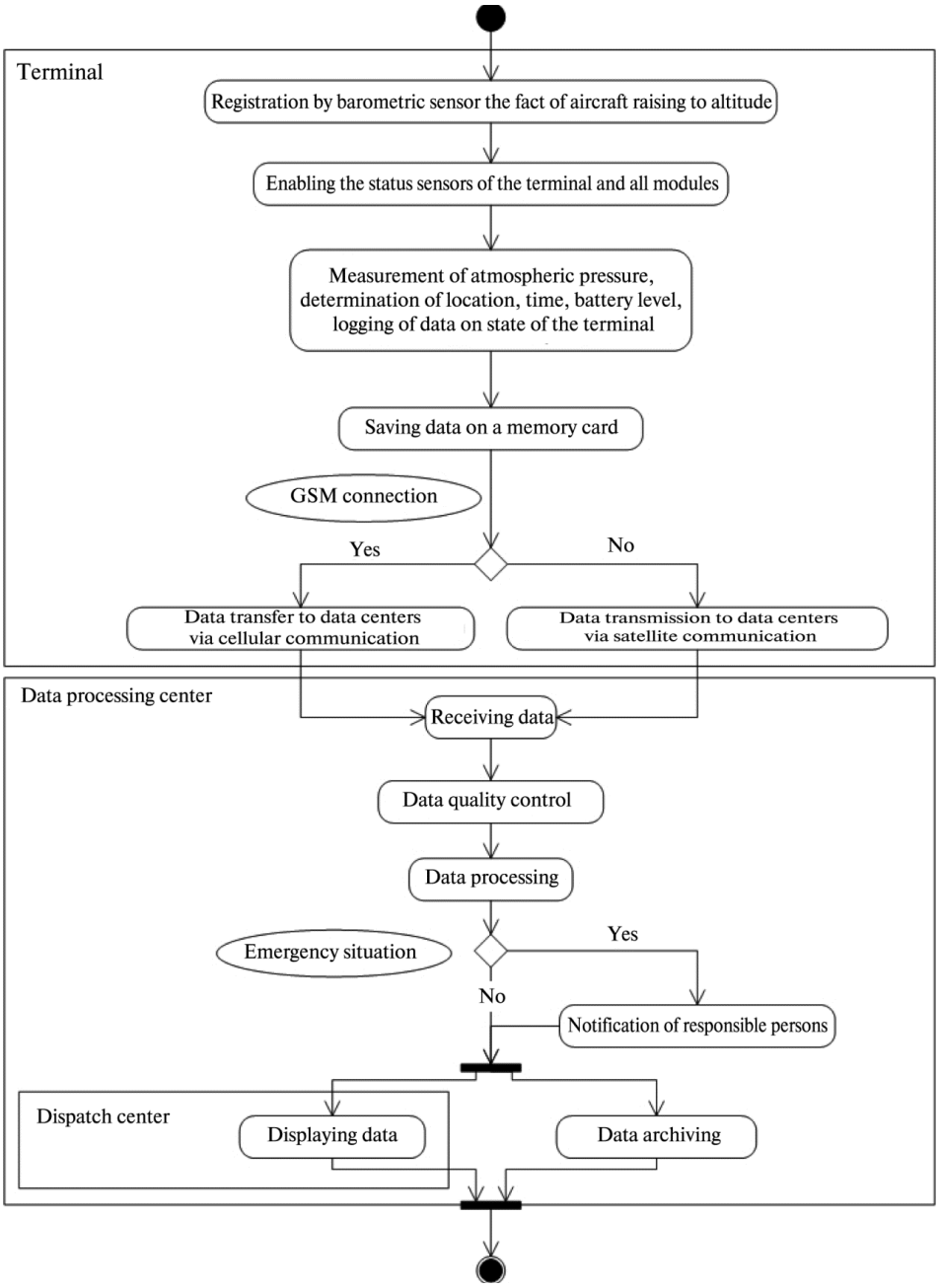

Figure 5. Monitoring system activity diagram of small aircraft flight trajectory

The terminal status sensors (terminal integrity sensor and cable control sensor) and the terminal barometric sensor are always on. When aircraft is raised to an altitude, barometric sensor registers the change in atmospheric pressure and terminal modules are switched on.

Further, the main telemetry and navigation data are formed: measurement of atmospheric pressure, determination of aircraft location, time and date, battery charge level, data registration from sensors for monitoring the integrity of the terminal. The received data is saved on the terminal memory card.

During a communication session, which occurs with a predetermined period, accumulated data packet is transmitted to data processing center mainly via GSM mobile cellular communication, and in its absence – via Iridium mobile satellite communication. The controller of aircraft flight trajectory monitoring system can change data transmission frequency during the communication session with terminal.

Data processing center receives data from the terminal, performs data integrity control using a cyclic redundancy check (CRC) in order to identify erroneous data and process them. When processing the data, authorization of flight is established and analysis for the presence of an emergency situation. In cases of observation of an unauthorized flight or detection of an abnormal situation, for example, an aircraft crash (a sharp increase in pressure registered by a barometric sensor), violation of terminal integrity, absence of a signal from the terminal, and others, system provides for notification of the situation of responsible persons, as well as a system message to the dispatcher on duty.

All collected information, including about sent alarm notifications, is archived in the data center and simultaneously displayed in the dispatch center in the form of a terminal location map, graphs of monitoring sensor readings and aircraft information (registration number, model, owner, operator, flight hours, latest technical service).

CONCLUSION

Implementation of proposed system for monitoring flight trajectory of small aircraft will allow continuous small aircraft trajectory monitoring and flight parameters, remotely identify registered air objects and collect statistical information about their flights. As a result, the level of flight safety of small aircraft will increase.

The use of system is also of great social importance, since in the event of an accident or catastrophe, system will minimize the time it takes to detect an aircraft emergency landing (catastrophe) site and reduce the aircraft search area, which will increase the likelihood of saving people.

Thanks to the system application, it will be possible to carry out technical control over the fleet of small aircraft, to reveal facts of unauthorized aircraft flights, to control the activities of public and private owners of small aircraft.

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20TH EDITION OF GLOBAL SYMPOSIUM FOR REGULATORS RESPONDS TO CHALLENGES OF DIGITAL TRANSFORMATION IN THE WAKE OF GLOBAL CRISES AND BEYOND

New GSR-20 Best Practice Guidelines highlight key role of regulators and policy-makers in "building back better"

Geneva, 03 September 2020. Promoting an adaptive, resilient and collaborative regulatory system is key to "building back better" and advancing digital transformation for all, according to participants at ITU's 20th edition of the Global Symposium for Regulators (GSR-20), held virtually from 1 to 3 September.

Regulatory authorities that gathered at GSR-20 agree that in the wake of COVID-19 digital regulation can boost the readiness of digital markets to face unexpected events and emergencies and deliver up to the expectations despite the odds. Accordingly, they have adopted GSR-20 Best Practice Guidelines: The gold standard for regulation to respond to the challenges of digital transformation in the aftermath of global crises and beyond.

"This crisis has demonstrated that information and communication technology is a unifying thread that runs through all aspects of our societies and economies, and our approach to ICT investments must recognize and embrace this reality," said ITU Secretary-General Houlin Zhao. "At stake is the ability of regulators and policy-makers everywhere to unlock investment to support growth, jobs and innovation – but also to save lives and demonstrate their value added in this increasingly connected world."

National economies and citizens have been relying increasingly on digital infrastructure during COVID-19. The current crisis and the probability of new global emergencies means that regulators will need to switch to regulatory frameworks that are adaptive, collaborative, outcomes-based and technology neutral.

The GSR-20 Best Practice Guidelines emphasize the need for coordination among all stakeholders, integrating sustainability into regulatory frameworks, maximizing benefits while reducing harms of digital technologies, striving for transparency and trust throughout the regulatory process, an evidence-based approach, and frequent revision of regulatory frameworks to ensure they remain fit for purpose.

"The GSR-20 Best Practice Guidelines cast a framework for progressive regulatory patterns and policy while charting the way ahead for industry and regulators. We have identified concrete steps to pursue regulatory reform towards achieving thriving, inclusive digital markets," said GSR-20 Chair Dan Sjцblom. "As the pace of digital transformation accelerates, developing an effective regulatory approach is more vital than ever. In the face of new global emergencies, governments and

regulators need to consider holistic, cross-sectoral, and, to the extent possible, multi-national regulatory and policy approaches."

The GSR-20 Best Practice Guidelines propose the following reforms:

Agile framework for competition in digital markets: Regulators should support innovation and new business and licensing models that facilitate affordable access to and investment in health, enterprise, and educational services on digital platforms.

Codes of conduct (voluntary or enforceable): Regulators should guide digital platforms and support them throughout the process of creating codes, their implementation and enforcement in important areas, such as online content moderation on digital platforms, addressing misinformation and online news quality, and child online protection. Media and digital literacy and awareness efforts should likewise be central to navigating the challenges around services that are enabled by the digital transformation.

Upgrading national emergency plans: Creation and implementation of effective emergency plans enables better preparedness and decision-making during crises. Such plans are key to anticipating future unexpected events and their negative impacts and they should focus on both urban and rural areas through a multi-technology approach. Bilateral, regional and international cooperation should ensure business and public service continuity and underpin national recovery efforts.

Spectrum reform: Spectrum managers need to be able to respond timely, making spectrum available for wireless applications when and where they are needed, and as easily as possible, giving spectrum users and innovators flexibility to provide services that will deliver the greatest benefits. Ensuring that sufficient unlicensed spectrum is available drives innovation and investment in a range of technologies that can complement and support networks and expand broadband access at low cost. Spectrum reform should also be focused on ensuring that access to broadband service is provided affordably to those areas and populations that have been traditionally unserved or underserved.

At the same time, regulators recognize that there is no single, comprehensive blueprint for best practice and that regulatory patterns for the connected digital economy will be rooted in local circumstances while addressing regional and global challenges, especially now while the world is striving to build back better with digital technologies across the board.

"In the wake of the COVID-19 crisis, the work of regulators and policy-makers is critical," said Doreen Bogdan-Martin, Director of ITU's Telecommunication Development Bureau. "Our ICT policy and regulatory frameworks will need to be fit-for-purpose. They will need to be up-to-date, flexible, incentive-based and market-driven to support digital transformation across sectors, and across geographical regions. In short, they will need to leverage the power of digital platforms and infrastructures to build the resilience we need to protect us against future global emergencies."

IRIDIUM PARTNER INTELLISENSE READY TO DEPLOY AUTONOMOUS FLOOD AND WEATHER SENSORS FOR VULNERABLE ENVIRONMENTS

The AWARE flood sensors were developed in partnership with the Department of Homeland Security as part of a multi-year contract

MCLEAN, Va., September 10, 2020. Iridium Communications Inc. (Nasdaq: IRDM) partner Intellisense Systems Inc., a leading provider of integrated environmental sensing solutions, has created groundbreaking Internet of Things (IoT) wireless flood and weather sensors to protect vulnerable environments. These new sensors provide NGO's, businesses, and federal, state, and local governments with the capability to rapidly respond to hazards, such as floods and wildfires, helping to protect both lives and land.

The AWARE Flood Sensor from Intellisense is a fully remote and autonomous flood warning system that sends flash flooding alerts automatically. These sensors are deployed in flood-prone areas and deliver immediate updates to first responders. The real-time situational intelligence enables them to quickly implement necessary road closures and evacuation notices for communities, businesses, and other personnel. By utilizing the Iridium® network and its integrated solar power system, the device can be installed in both urban and the most rural communities without significant infrastructure investment.

In August 2019, Intellisense was awarded a multi-million dollar contract from the Department of Homeland Security (DHS) to finalize development, commercialization, and production of the AWARE Flood sensor. The automated flood alert and warning solution rapidly evolved based on feedback, enhancing its accuracy, performance, and dependability. Intellisense has now made these sensors commercially available, helping to make more communities resilient to flooding events.

The Intellisense AWARE Flood IoT Inundation Sensor. Image Credit: Intellisense

The Intellisense MWS®-C410. Image Credit: Intellisense

Intellisense also provides portable, all-in-one weather sensors that are making it possible to remotely deploy these autonomous meteorological devices in new geographies. The small and light-weight systems can deliver meteorological data from anywhere in the world, from the sub-zero temperatures of Antarctica to known wildfire hotspots, utilizing both cellular infrastructure and the Iridium network.

The company also recently introduced the MWS®-C410 all-in-one weather sensor, designed to support emergency personnel responding to wildfires. The device uses Iridium satellite connectivity in remote wilderness areas, making it possible for wildfires to be detected quickly no matter where they are.

"Intellisense is making remote flood and weather monitoring affordable and accessible anywhere on the planet," says Iridium Executive Vice President of Sales and Marketing, Bryan Hartin. "Floods and wildfires can move quickly and quietly, so Intellisense solutions provide a critical role in monitoring, protecting, and supporting vulnerable environments."

A copy of the full announcements from Intellisense can be found here: FTS and Intellisense Systems Partner to Offer Weather Sensors for Wildfire and Emergency Management Application, AWARE Flood IoT Water Level Monitoring System Is Now Commercially Available