“Virtual Testing Area” for Solving EMC Problems of Spatially Distributed Radiosystems based on Automated Double-Frequency Test System

Vladimir I. Mordachev, Eugene V. Sinkevich
Electromagnetic Compatibility R&D Laboratory
Belarusian State University of Informatics and Radioelectronics (BSUIR)
6, P.Brovki st., Minsk 220013, Belarus
e-mail: emc@bsuir.by

***Abstract*—A new technology named as “Virtual Testing Area” and intended for electromagnetic compatibility (EMC) analysis in complexes of radio systems is presented. This technology is based on semi-physical EMC modeling with an expedient ratio of mathematical and physical modeling of (a) electromagnetic environment (EME) and (b) behavior of radio receivers in complicated EME. The proposed technology has the following advantages: (a) high informativity of the Automated double-frequency testing technique (ADFTT), which is used for characterization of receivers, (b) high efficiency of the Discrete nonlinear analysis (DNA) technique, which is used for behavior simulation of receivers, (c) high objectivity of EME modeling with the use of digital area maps and geoinformation systems (GIS), (d) efficiency and low cost of software-controlled physical modeling of receivers in laboratory conditions by using the equipment of Automated Double-Frequency Test System (ADFTS).**

Automated Double-Frequency Test System; Discrete Nonlinear Analysis; Physical Modeling of Radio Receivers; System-Level EMC Analysis

I. INTRODUCTION

ADFTT is one of the most effective technologies for radio receiver examination during the developing and solving of EMC problems of the radiosystems working in the most severe EME presented in onboard or ground complexes of radiosystems [1], [2], [3]. Systems using this technique giving real opportunities of automated detection, identification and measurement of parameters for the main channel and all spurious and intermediate radio receiver paths and responses, through which interference can influence any radio devices, and of radio receiver susceptibility to nonlinear effects: blocking, cross modulation, all types and orders of intermodulation, etc.

ADFTT allow to collect the full information on selective and nonlinear properties of radio receivers, in particular, to measure its input nonlinearity up to parameters of nonlinearity of rather high (15...25) orders. This makes possible essentially to increase quality of the EMC analysis in severe EME using discrete EMC-analysis and prediction technique [4], [5], [6], [7], [8].

Functionalities of variants [1], [2] of ADFTT realization were substantially limited by restricted functional and metrological features of used radiomeasuring devices of previous generations, especially on frequencies above 1-2 GHz, and also by restricted features of the software for the EMC analysis based on using tests results.

Modern ADFTT features under the solving of EMC problems of radiosystems can be considerably expanded due to use of

- Modern intellectual program-controlled vector measuring apparatus - RF signal generators having a mode of internal baseband generation on multicarrier mode with different types and parameters of digital modulation (PSK QAM FSK, MSK) and spectrum analyzers having a mode of signal distortion measurement,
- Modern technologies of nonlinear discrete behavior simulation of radioreceivers [4], [5], [6], [7], [8] using results of its ADFTT testing,
- Specialized GIS and expert systems for EMC modeling in spatially-distributed and local on-board or on-ground assemblage of radiosystems [7], [9].

Consequently, the advanced ADFTS becomes the effective “Virtual Testing Area” providing a feature of physical modeling of influence on the RUT of the totality of spatially distributed and/or locally aggregated radiosystems, i.e., a feature of practical checking their mutual EMC conditions.

The paper is organized as follows. In Section II, we introduce the advanced ADFTS structure and peculiarities. A technique for extracting the receiver-under-test (RUT) model from ADFTS measurements is proposed in Section III. The Discrete nonlinear analysis (DNA) technique, which is used for nonlinear behavior simulation of RUT, is described in

Section IV. A technique of RUT modeling and EMC analysis by using ADFTS as a “Virtual Testing Area” is presented in Section V.

II. ADFTS Structure and Peculiarities

The basic structure of the ADFTS advanced version used for Virtual Testing Area realization is shown in Fig.1. Key elements of the ADFTS are the RF signal generators and ADC (analogue-digital converter). Computer is used primary for soft control by test signals and to evaluate signal parameters at the output of the RUT.

The technology of “radiolocation” testing of receivers with the use of ADFTS includes detection, identification and measuring of parameters and characteristics of all paths and phenomena (which can affect receiver operation under the conditions of specified (predicted) maximum signal levels and over all possible input signal frequencies) including spurious response paths, all paths (types) of two-signal intermodulation, blocking, crosstalk, excitation of input stages under the influence of strong out-of-band signals, locking of the local oscillator frequency by an input signal, etc.

On the first stage, the form of the double frequency amplitude characteristic of the receiver-under-test (including and cross-sections of this characteristics) is analyzed. This characteristic $H(f_1, f_2)$ has a dependence

$$H(f_1, f_2) = U_{out}\left(f_1, f_2 \middle| \begin{matrix} U_{1in} = const \\ U_{2in} = const \end{matrix} \right) \qquad (1)$$

where U_{out} is the output signal level when two test signals at frequencies f_1 and f_2 with levels U_{1in}, U_{2in} correspondingly are applied to the receiver input; as a rule, $U_{1in} = U_{2in} = U_{\max}$.

This stage is completed by recording and displaying in coordinates (f_1, f_2) one or several following cross sections of the double-frequency amplitude characteristic $H(f_1, f_2)$:

$$W_i(f_1, f_2 | U_{ti}) = \mathrm{sgn}\{H(f_1, f_2) - U_{ti}\} \qquad (2)$$

at the specified threshold levels U_{ti}, $i = 1, 2, \ldots$, where the label “sgn” means signum function. These levels are selected so that they exceed the level of the internal noise of the receiver at its output in accordance with the accepted criteria used for determination of the receiver main channel sensitivity and are also selected to test the receiver susceptibility due to spurious response paths and nonlinear effects. Recorded images of cross sections of the double-frequency amplitude characteristic are, in effect, fragments of the known double-frequency diagram (DFD) of the receiver; typical examples of such diagrams are presented in [2].

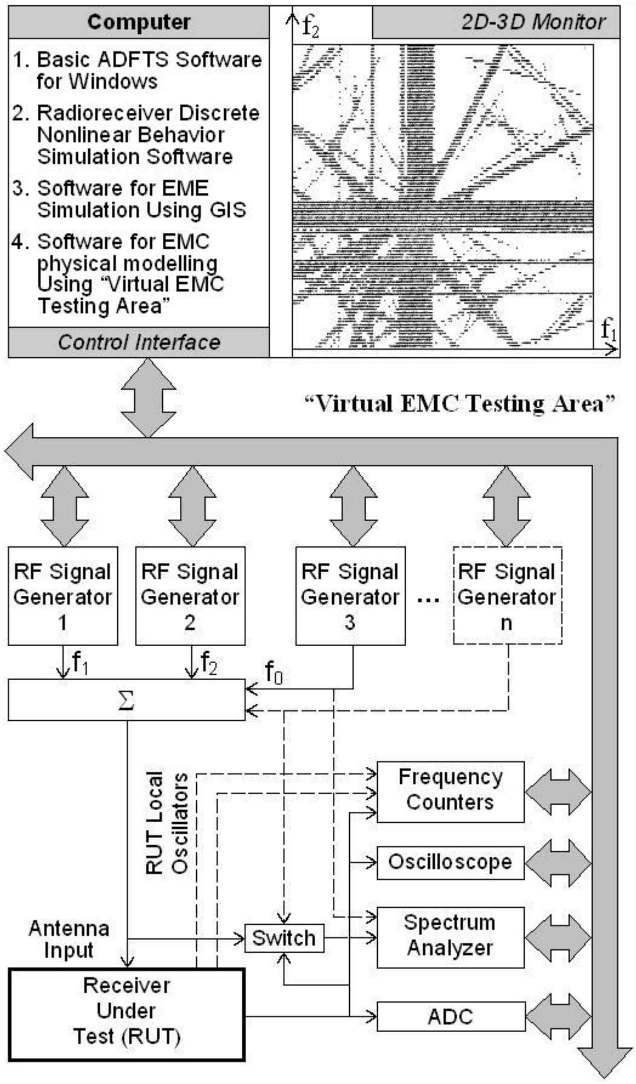

Fig. 1. Structure of the advanced ADFTS.

The main ADFTT & ADFTS peculiarity is following. Two-dimensional (2D) image of DFD is generated in (f_1, f_2) 2D coordinate system with the use of horizontal (fast) frequency scanning of the RF Generator 1 on area $[f_{1\min}; f_{1\max}]$ with period T and frame (slow) frequency scanning of the RF Generator 2 on area $[f_{2\min}; f_{2\max}]$ with period $T_C = n \cdot T$ (as on TV raster). Practically it is possible to form a good quality DFT image using $n = 100...200$ lines (if frequency scanning is made in not very wide frequency ranges; as a rule, $[f_{1\min}; f_{1\max}] = [f_{2\min}; f_{2\max}] = [f_{\min}; f_{\max}]$).

On the final stages, the identification and measuring of parameters and characteristics of all detected paths and phenomena in RUT antenna input is made. As a result all necessary and comprehensive information concerned RUT susceptibility to linear and nonlinear interferences on antenna input can be extracted and used for the detailed EMC analysis (analysis of RUT behavior in EME limited by $\{U_{\max}, [f_{\min}; f_{\max}]\}$).

The description of assignment of other ADFTS elements is given below.

ADC is used when a RUT output signal is taken from its intermediate frequency (IF) output: in ADC the amplification, detection (of root-mean-square type or another type, if necessarily) and analogue-to-code transformation of an IF signal are made.

Frequency counters are used for simultaneous measurement of frequencies of RUT IF signal and RUT heterodyne signals at identification of the founded RUT spurious or intermodulation paths.

The RF generator 3 is required for desired signal injection on RUT antenna input, if necessary. Additional RF generators are used, if necessary, for auxiliary signals injection on Object Under Test (a reference signal, a signal of local oscillator at mixers testing, etc.), and also for modeling of interference signals alongside with RF generators 1,2 at physical EMC modeling (RUT behavior modeling in expected EME).

The spectrum analyzer and oscilloscope are used at the detailed analysis of the RUT output signal, including measurement of a distortion of a desired signal under interference influence.

The Summator Σ can be constructed using typical coaxial summators, but realization of summation of test signals "by field" with use of measuring antennas and RF amplifiers is also possible (for example, at tests of receiving active phased-array antennas in anechoic chambers or on the open area).

The important preliminary procedure of ADFTT - metrological calibration of networks for submission of test signals from outputs of RF generators on RUT antenna input (between the inputs and the output of Summator Σ) in a wide frequency range $Df = [f_{\min}; f_{\max}]$ which is carried out before the beginning of tests. This calibration is made with use of RF generators and spectrum analyzer. During performance of the calibration procedure measurement of amplitude-frequency characteristics (AFC) $A_j(f)$, $j = 1, 2 \ldots n$ of each of n ways of test signals passage between each of n inputs of the Summator Σ and its output in all frequency range of tests and the EMC analysis is made.

Application of ADFTS measuring modules of the top level (RF generators, spectrum analyzer) providing a very high accuracy of installation and measurement of levels of signals and taking into account AFC $A_j(f)$ of the each input of Summator Σ the total error of installation of levels of RF signals on RUT input can be less than 1 dB. It provides the high accuracy of the control of RUT EMC characteristics, and high objectivity and accuracy of mathematical and physical RUT behavior modeling & simulation in given EME (EMC modeling) at final stages of tests and the EMC analysis of RUT with use of advanced ADFTS on Fig.1 as a "Virtual Testing Area".

III. RUT IDENTIFICATION USING ADFTS

The "Filter–Nonlinearity–Filter" model (FNF) (which is also referred to as "Typical radio-engineering stage" [10], "Wiener–Hammerstein model" [11], "Nonlinear sensor" [8]) is widely applied for behavioral simulation of nonlinear effects in receiving front-ends. This model (ref. Fig. 2) takes into account the following properties [4]: frequency selectivity of the receiver's input circuit (the 1st linear filter), nonlinearity of the front-end (the memoryless nonlinearity), and intermediate frequency (IF) selectivity (the 2nd linear filter).

The quality of a behavioral model is determined not only by the structure of the model but also by the identification (i.e., extraction of model parameters from measurements) technique. The FNF model identification methods developed for application in control systems (see references given in [10], [11]) not always yield good results when applied to simulation of radio equipment [12]. Therefore, a technique for identification of the FNF model for a radio receiver is proposed below; this technique is intended for EMC analysis, and it has the following important features.

1) The ability of model identification in a wide frequency band (usually, the decade up and the decade down from the tuning frequency of the receiver) and in a wide dynamic range (not narrower than the receiver's dynamic range, which can achieve 120 dB).

2) The applicability even to a receiver that do not provide access to its internal structure (e.g., the integrated-circuit receiver) and do not have the IF output.

3) The technique is based on standardized characteristics of the receiver and on standardized measurement procedures.

The proposed technique of identification considers the FNF model as a generalization of the traditional linear model (the receiver susceptibility characteristic in the frequency domain [13, Fig. 4.2], [14]). The technique consists of three stages: 1) synthesis of the linear model for the receiver, 2) identification of the input filter, and 3) identification of the nonlinearity.

Note that one can synthesize more detailed model than the FNF model if he has access to the internal structure of the receiver. This can be done as identification of models for the units (amplifiers, mixers, etc.) of the receiver [4], [5], [6], [7].

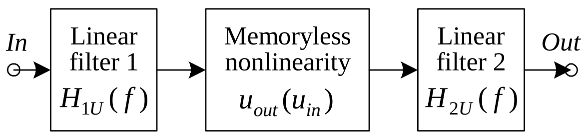

Fig. 2. Behavioral model of radio receiver.

A. Synthesis of linear model

The linear model is extracted from the frequency-domain susceptibility characteristic (FDSC) $\eta_P(f)$ of the receiver. This characteristic may be measured by the two-signal technique or one-signal technique (the latter can be used if the former is not appropriate) [15, MIL-STD-461/462/461F – method CS04/CS104].

As shown in [14], the calculation of the integrated interference margin IM (which is the criterion of EMC) from the FDSC $\eta_P(f)$ by the formula

$$IM = \sum_k [P_{in}(f_k)/\eta_P(f_k)] \quad (3)$$

(where $P_{in}(f_k)$ is the power of k-th undesired signal at the receiver input; f_k denotes its carrier frequency) is equivalent to the use of the linear filter as the receiver model and to the comparison of the total power $P_{out,\Sigma}$ of interference at the filter output with the threshold $\tilde{\eta}_P$:

$$IM = \frac{P_{out,\Sigma}}{\tilde{\eta}_P} = \frac{1}{\tilde{\eta}_P}\sum_k P_{out}(f_k), \quad (4)$$

$$P_{out}(f) = H_P(f)\cdot P_{in}(f), \quad (5)$$

where $H_P(f)$ is the power transfer function of the filter.

As follows from (4) and (5), the values of $H_P(f)$ and $\tilde{\eta}_P$ are accurate within a constant multiplier K: multiplying both $H_P(f)$ and $\tilde{\eta}_P$ by K leaves IM in (4) unaltered. It is convenient to define $H_P(f)$ and $\tilde{\eta}_P$ so that the transfer function $H_P(f)$ is normalized to unity at the tuning frequency f_0 of the receiver, i.e., $H_P(f_0)\equiv 1$:

$$H_P(f) = \tilde{\eta}_P/\eta_P(f); \qquad \tilde{\eta}_P = \eta_P(f_0). \quad (6)$$

The synthesized linear model of the receiver (4), (5), (6) describes not only linear effects (selectivity) in the IF circuit but also a number of nonlinear effects in the preselector and frequency converter(s): spurious responses, reciprocal mixing, desensitization (the last two effects are accounted by the model if the FDSC $\eta(f)$ was measured by the two-signal technique). The ability to account for modulated interfering signals by performing the FDSC measurements with the use of such signals [13], [14], [15, MIL-STD-449D – method CS114] is the second advantage of the model.

Let us consider the drawback of the linear model: the model uses the principle of interference superposition (4) and, therefore, it does not account for intermodulation. As a rule, the linear model describes the receiver adequately in the following widespread situation: one powerful unwanted signal dominates the EME; but even in this situation an intermodulation (between the dominating and a weak unwanted signals) may arise and suppress the desired signal.

To correct the mentioned drawback, the nonlinearity should be introduced into the structure of the model (ref. Fig. 2), and the selectivity of the linear model's filter should be divided between the input and output filters of the FNF model.

When the FNF model of the receiver is simulated by the DNA technique (ref. Section IV), the nonlinearity is modeled in the time domain. Therefore, it is necessary to represent the linear model (5) in terms of the input U_{in} and output U_{out} voltages:

$$U_{in}(f) = \sqrt{2\cdot R_{in}(f)\cdot P_{in}(f)}, \quad (7)$$

$$U_{out}(f) = H_U(f)\cdot U_{in}(f), \quad (8)$$

$$P_{out}(f) = U_{out}^2(f)/[2\cdot R_{out}(f)], \quad (9)$$

where $H_U(f)$ is the voltage transfer function of the filter, i.e., the frequency response (FR), calculated as

$$H_U(f) = \sqrt{H_P(f)\cdot R_{out}(f)/R_{in}(f)}; \quad (10)$$

$R_{in}(f)$ and $R_{out}(f)$ are the input and output resistances of the receiver, respectively. In principle, these resistances may be arbitrary because their values have no effect on the EMC criterion calculated by substitution of (7), (8), (9), and (10) in (4). Nevertheless it is desirable to use realistic values of $R_{in}(f)$ and $R_{out}(f)$ if such values are known.

B. Identification of input filter

The frequency response of the input filter is extracted from the third-order-intermodulation selectivity characteristic (IM3SC) of the receiver [15, MIL-STD-449D – method CS110], [13, p. 4.49], [16, GOST 23611-79, GOST 23872-79]. The choice of IM3SC (and not the desensitization selectivity characteristic) is based on the worst-case approach to EMC analysis: intermodulation and desensitization may arise in different stages of the receiver, but usually intermodulation emerges from a lower power of undesired signals and is therefore more dangerous.

The IM3SC may be measured by the two-signal (or three-signal, if necessary) technique [15, MIL-STD-449D – method CS110]. Note that the full IM3SC is not measured in the most of standard tests: just the fact of the IM3SC location above the specified limiting characteristic is checked in one or several points [15, MIL-STD-461/462/461F – method CS03/CS103], [16, GOST 22580-84, GOST 12252-86].

Let us consider the IM3SC of the FNF model.

Since the level of interference at the receiver output is maintained low during IM3SC measurements (equivalent desired signal at the tuning frequency is equal or near to the receiver sensitivity), the contribution of nonlinear terms of order higher than 3 to IM3SC can be neglected and the instantaneous transfer characteristic (ITC) of the memoryless nonlinearity (MNL) (ref. Fig. 2) can be represented as

$$u_{out}(u_{in}) = a_1\cdot u_{in} + a_2\cdot u_{in}^2 + a_3\cdot u_{in}^3, \quad (11)$$

where u_{in} and u_{out} are the instantaneous voltages at the input and output of the nonlinearity, respectively; a_1, a_2, a_3 are constant coefficients.

Feeding the two-tone signal to the FNF model input and taking into account the FR $H_{1U}(f)$ of the input filter, ITC (11) of the MNL, and the FR $H_{2U}(f)$ of the output filter, we find the voltage amplitude $U_{out}(f_0)$ of the intermodulation interference (at the tuning frequency f_0 of the receiver) at the output of the FNF model

$$U_{out}(f_0) = H_{2U}(f_0) \cdot U_{nl}(f_0)\,, \tag{12}$$

$$U_{nl}(f_0) = \frac{3a_3}{4}[H_{1U}(f_N) \cdot U_{in}(f_N)]^2 \cdot H_{1U}(f_F) \cdot U_{in}(f_F)\,, \tag{13}$$

$$f_N = f_0 + \Delta f\,; \qquad f_F = f_0 + 2 \cdot \Delta f\,, \tag{14}$$

where $U_{nl}(f_0)$ represents the intermodulation voltage amplitude at the MNL output; f_N is the frequency of the input signal tone nearest to f_0; f_F is the frequency of the input tone farthest from f_0; $U_{in}(f_N)$ and $U_{in}(f_F)$ stand for the voltage amplitudes of the input tones, they are calculated by (7); Δf is the difference between f_N and f_0.

The interference power at the FNF model output is calculated by substitution of (12) into (9).

By the definition [15, MIL-STD-449D – method CS110], [13, p. 4.46], [16, GOST 23611-79, GOST 23872-79], the IM3SC is a dependence $P_{in}(f_N)$ of the input tone power at the frequency nearest to f_0 on the frequency f_N of this tone under the following conditions: the intermodulation interference power at the receiver output is maintained constant and the input tones are equal in power.

Consequently, as it follows from (12) and (9), the interference voltage amplitude (13) at the MNL output is constant during the computation of the IM3SC for the FNF model. This makes it possible to compute the FR $H_{1U}(f)$ of the FNF model's input filter on the base of (13) and (7) by the following algorithm.

1) Since the input selectivity of the receiver is many times less than the selectivity of its IF circuit, assume that for minimal difference Δf_1 the equality

$$H_{1U}(f_{N1}) = H_{1U}(f_{F1}) = 1 \tag{15}$$

holds and calculate a parameter β from (13):

$$\beta \equiv 4U_{nl}(f_0) / (3a_3) = [U_{in}(f_{N1})]^2 \cdot U_{in}(f_{F1})\,, \tag{16}$$

where the values of $U_{in}(\cdot)$ are computed by (7).

2) At each further (i-th) step, it is necessary to increase the frequency difference two times as compared with the previous step:

$$\Delta f_i = 2 \cdot \Delta f_{i-1} = 2^{i-1} \cdot \Delta f_1\,, \quad i = 2,3, \ldots M_R\,. \tag{17}$$

Then, as it follows from (17) and (14),

$$f_{N\,i} = f_0 + \Delta f_i = f_0 + 2 \cdot \Delta f_{i-1} = f_{F\,i-1}\,, \tag{18}$$

which makes it possible to express the FR of the input filter at the frequency $f_{F\,i}$ from (13) as

$$H_{1U}(f_{F\,i}) = \beta / \{[H_{1U}(f_{F\,i-1}) \cdot U_{in}(f_{F\,i-1})]^2 \cdot U_{in}(f_{F\,i})\}\,, \tag{19}$$

where the values of $U_{in}(\cdot)$ are computed by (7).

3) For the negative differences Δf in (14), to calculate the left branch of the FR $H_{1U}(f)$: since the parameter β is already known, it is possible to compute the recursion (17), (19) under the conditions

$$H_{1U}(f_{N1}) = H_{1U}(f_{F0}) = 1; \qquad i = 1,2, \ldots M_L\,. \tag{20}$$

4) To combine and interpolate the calculated values of the left and right branches of the FR; as a result, we obtain the continuous function $H_{1U}(f)$.

5) Outside the frequency interval of the IM3SC measurement, it is necessary, according to the worst-case approach, to take the FR of the input filter equal to its value at the bound of the mentioned interval:

$$H_{1U}(f) = \begin{cases} H_{1U}(f_{\min}), & f < f_{\min} = f_0 + 2 \cdot \Delta f_{M_L}\,; \\ H_{1U}(f_{\max}), & f > f_{\max} = f_0 + 2 \cdot \Delta f_{M_R}\,. \end{cases} \tag{21}$$

After the identification of the input filter, one can compute the FR of the FNF model's output filter as

$$H_{2U}(f) = H_U(f) / H_{1U}(f)\,, \tag{22}$$

where $H_U(f)$ is the FR (10) of the linear model.

C. Identification of nonlinearity

As a result of the nonlinearity identification, the high-order polynomial model of the ITF is synthesized; such model ensure adequate description of both the backed-off region with a mild nonlinearity, dangerous in terms of intermodulation emergence, and the saturation region having essential nonlinearity, hazardous in terms of desensitization. If the RUT does not have the IF output, the model of the nonlinearity should be extracted from measurements of the spurious-free dynamic ranges for intermodulation of different orders and for desensitization [17], [18]; but if the IF output is available, then more exact model for the odd part of the ITF can be extracted from measurements of the single-tone amplitude-to-amplitude characteristic (in adjacent-signal region) and the two-tone amplitude-to-amplitude characteristics for intermodulation of odd orders [18], [5], [19].

IV. Nonlinear Behavior Simulation of RUT

For behavioral simulation of radio receivers operating in severe electromagnetic environment (EME), the discrete nonlinear analysis (DNA) technology has been developed and successfully applied [4], [5], [6]. This technology has a number of essential features to analyze electromagnetic compatibility: 1) simulation in wide frequency and dynamic ranges, 2) account for combined influence of all the fundamental types of nonlinear effects (intermodulation, desensitization, cross-modulation, spurious responses, reciprocal mixing), 3) high computational efficiency (the DNA's computational advantage over traditional techniques grows rapidly with increasing EME complexity and with increasing order of the nonlinear effects).

Commercial implementation of the DNA in the software "EMC-Analyzer" [7] has also the following important functions (see references given in [6]): 4) automatic search of nonlinear interference sources by the dichotomous method, 5) estimation of the signal-to-interference ratio at any point of the receiver's nonlinear model.

The DNA technology is based on the following principles: 1) utilization of discrete models for EME and for composite signals in the receiver's front-end; 2) representation of the receiver model as linear filters and memoryless nonlinearities connected in series (or in parallel, or both); 3) application of the efficient modeling methods for the linear and nonlinear transformations (linear filters are modeled in the frequency domain, memoryless nonlinearities are modeled in the time domain, the transition from the time domain to the frequency domain and vice versa is made with the use of the fast Fourier transforms); 4) use of polynomial models for the memoryless nonlinearities (these models ensure a controllable increase of a signal's bandwidth as a result of the nonlinear transformation and make it possible to achieve a high dynamic range of the nonlinear analysis – up to 300 dB).

An overview of the current state of the art in the DNA technology is presented in [6].

V. RUT EMC ANALYSIS USING ADFTS AS A "VIRTUAL TESTING AREA"

"Virtual Testing Area" allows effectively and with high accuracy to solve the following EMC problems at a system level:

1) EMC analysis of a large quantity of probable scenarios of RUT allocation on area with given radio electronic environment (REE).

2) The analysis of probable RUT affection by interferences at various scenarios of radiosystems area allocations (scenarios of REE formation, for example, variants of area allocations of base and radio-relay stations of a cellular network).

The initial stage of the given works is formation of EME mathematical model on RUT input as ensemble of signals with the specified parameters (levels, carrier frequencies, types and parameters of modulation).

This EME model can be received in several ways:

a) By experimental EME measurement in places of probable RUT allocation.

b) By calculations using information on characteristics of electromagnetic radiation and coordinates of area allocation of radio transmitters - probable sources of interferences, and also ITU-R radio waves propagation (RWP) models [9] and digital area maps.

In the latter case at EMC analysis for various scenarios of radiosystems area allocation the EME model on RUT input for each scenario is formed. Generation of each EME model is carried out with use of geoinformation technologies and include the following procedures (Fig. 3):

1) Modeling of variant (scenario) of area allocation of transmitters of radiosystems – potential interference sources.

2) Calculation of levels of electromagnetic fields of these radio transmitters in a point of RUT antenna area allocation with use of RWP models [9] taking into account surface relief, vegetation, precipitations and other factors.

3) Calculation of levels of radio signals from environmental radiosystems on RUT input with use of the data on spatial, frequency and polarizing selectivity of RUT antenna, forming of EME model as ensemble of input signals with specified parameters.

4) Detection of group of the most dangerous signals, capable to be the cause of interference for RUT performance.

After that, the EMC problems mentioned above can be analyzed and solved at various levels of virtuality of reproduction of radiosystems interference interactions:

a) Mathematically with use of technology of RUT discrete nonlinear behavior simulation in given EME (ref. Section IV).

b) Physically by carrying-in the physical EME model generated by RF generators $1, 2 \ldots n$ on RUT input (on an output of the Summator Σ in Fig. 1).

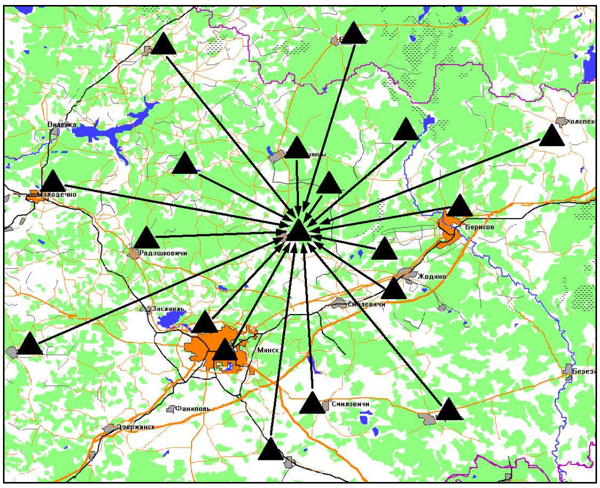

Fig. 3. Generation of electromagnetic environment model.

On this stage all numerous ensemble of signals on RUT input without losing of objectivity of the EMC analysis can be replaced with the limited number of the most dangerous interferences from this ensemble of signals. This the most dangerous interferences may be formed on RUT input by RF generators, included in ADFTS. As a rule, even if necessary to generate for RUT a desired and/or a reference signals for qualitative RUT physical behavior modeling and the objective EMC analysis in given EME it is necessary to have in ADFTS structure no more than 4-5 RF generators ($n \leq 5$), because in practice intermodulation is formed by no more than two - three most powerful input signals.

Such tests in many cases allow to replace real radiosystems ground tests on EMC at which real area allocation and operation of large complex of real systems is made, with much less expensive laboratory tests with use of Virtual Testing Area presented above. In this cases detailedness and practical utility of EMC estimations appears better due to checking of all probable scenarios and variants of radiosystems application of in their regional or local (onboard, ground) aggregation.

VI. Conclusion

Efficiency of the “Virtual Testing Area” technology is confirmed by results of its practical use and defined by advantages of its basic elements: original technology of testing and identification of EMC characteristics of radio receivers (receptors of interference) based on ADFTS, original technology and software for the discrete nonlinear EMC analysis and behavior simulation of receivers operating in severe EME, the technique of EME modeling with use of digital area maps and specialized GIS, and final physical modeling of receivers in presence of a set of the most dangerous interferers in laboratory conditions by using the ADFTS equipment.

Materials presented in this paper generalize the authors experience in the field of ADFTS [1], [2], “EMC-Analyzer” expert system [5], [6], [7], [8], and specialized “GIS for EMC” development and practical usage for solving system-level EMC problems.

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Vladimir I. Mordachev (M’96) was born in Vitebsk, Belarus. He received the Ph.D. degree (1984) in Radio Engineering from the Minsk Radio Engineering Institute, Minsk, Belarus. His research interests include spectrum management, wireless communications and networks, electromagnetic compatibility and interference, wireless network planning, computer-aided analysis and design, cellular networks system ecology, RF systems modeling and simulation. He is extensively involved in consulting to wireless network operators, industry and the local government. V. Mordachev is a Head of the Electromagnetic Compatibility R&D Laboratory at the Belarusian State University of Informatics and Radioelectronics.

Eugene V. Sinkevich was born in Minsk, Belarus, in 1978. He is currently engaged as Chief designer of “EMC-Analyzer” and “DFTS” projects in EMC R&D Laboratory of Belarusian State University of Informatics and Radioelectronics. Main areas of interest: electromagnetic compatibility and interference, computer-aided analysis and design, wireless communications, and signal processing.