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

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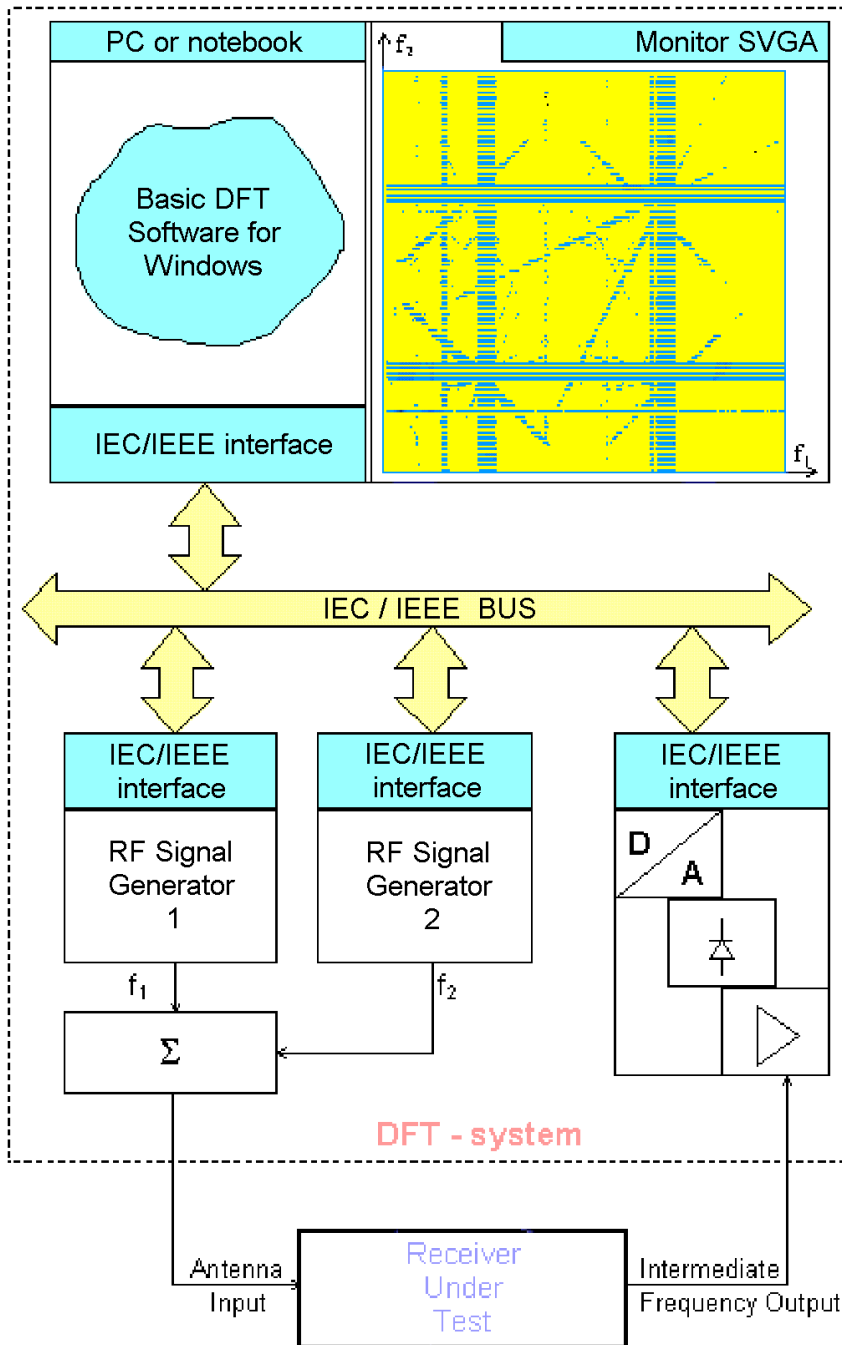
# Introduction

1. Automated Double-Frequency Test System (ADFTS) is a powerful hardware & software tool for detection and characterization of receiver interference responses
2. Adding some software to ADFTS hardware makes it possible to implement a new function: “Virtual Testing Area” (VTA)
3. Additional software needed to implement VTA:
  - A. Geographical Information System (GIS)
  - B. Radio-wave propagation simulator (RWP)
  - C. Nonlinear simulator of the receiver under test (DNA)

# Contents

1. Automated Double-Frequency Test System (ADFTS):  
essentials and capabilities
  
2. Virtual Testing Area (VTA):
  - A. Main ideas and stages
  - B. Software components: GIS, RWP, DNA
  - C. Advantages
  - D. Application

# Automated Double-Frequency Test System (ADFTS)

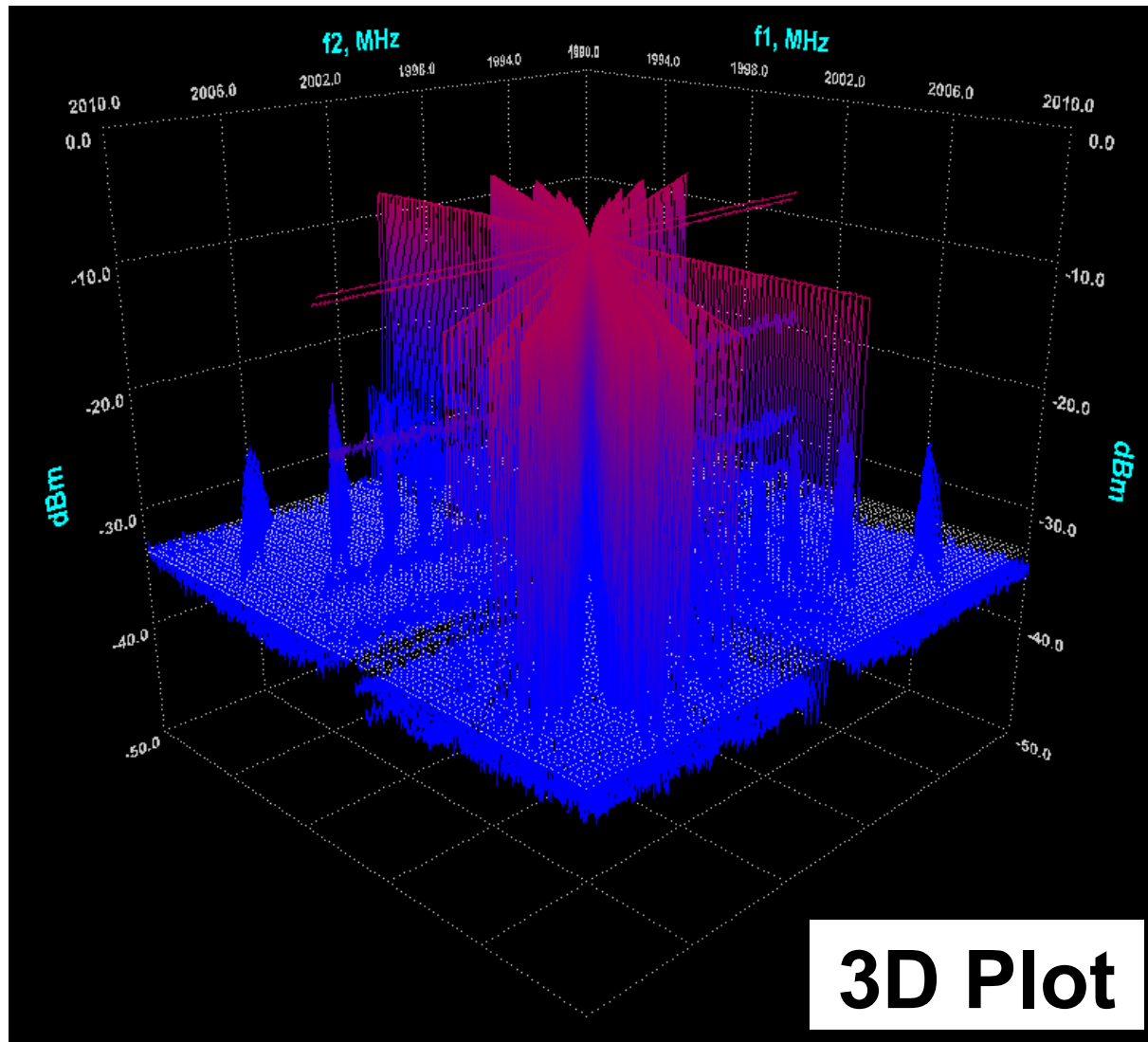


Basic block diagram of DFT realization

## The main idea:

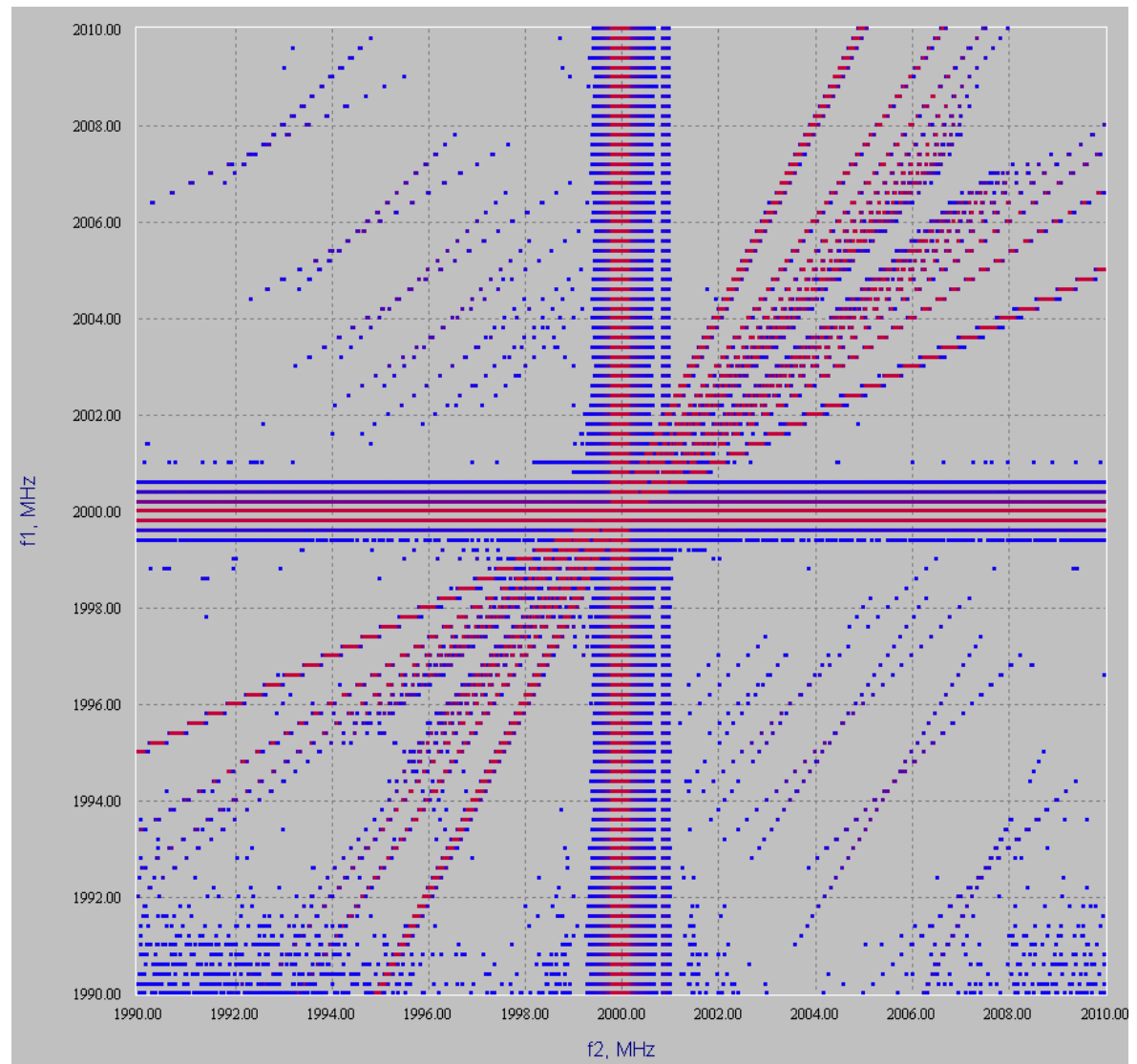
- Receiver is fed by the sum of two frequency-sweeping signals with constant levels
- Speed of sweeping is different (as in television):  $f_1$  sweeps slowly and  $f_2$  sweeps fast
- The response at the receiver output is plotted as a function of the input frequencies  $f_1$  and  $f_2$

# Double-Frequency Characteristic



# Double-Frequency Characteristic

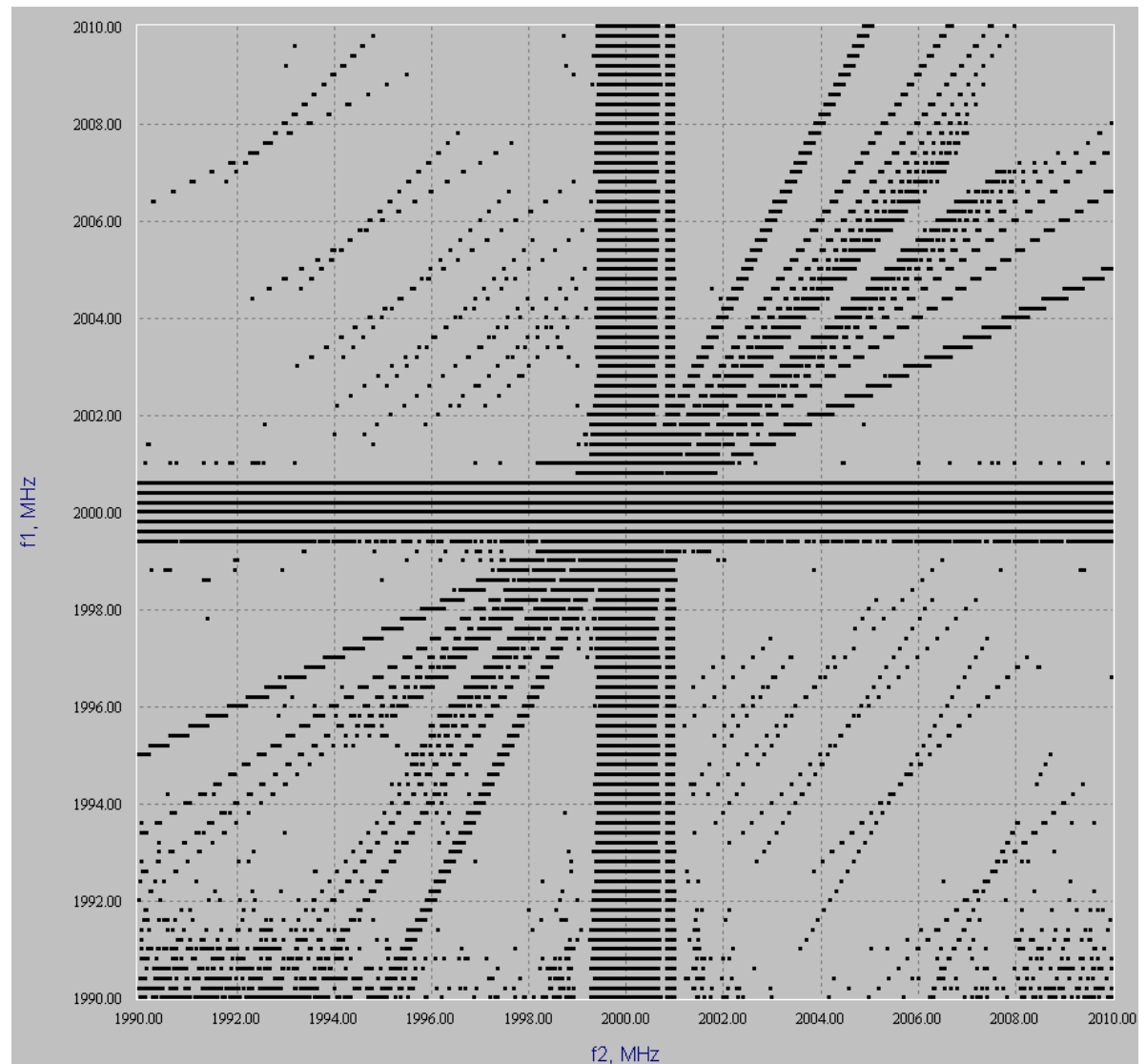
**Color Map  
Plot,  
which is  
called as  
“Double-  
Frequency  
Diagram”**



# Double-Frequency Diagram

**Special  
case:  
2 colors**

**Black means  
that output  
power is  
above the  
threshold**



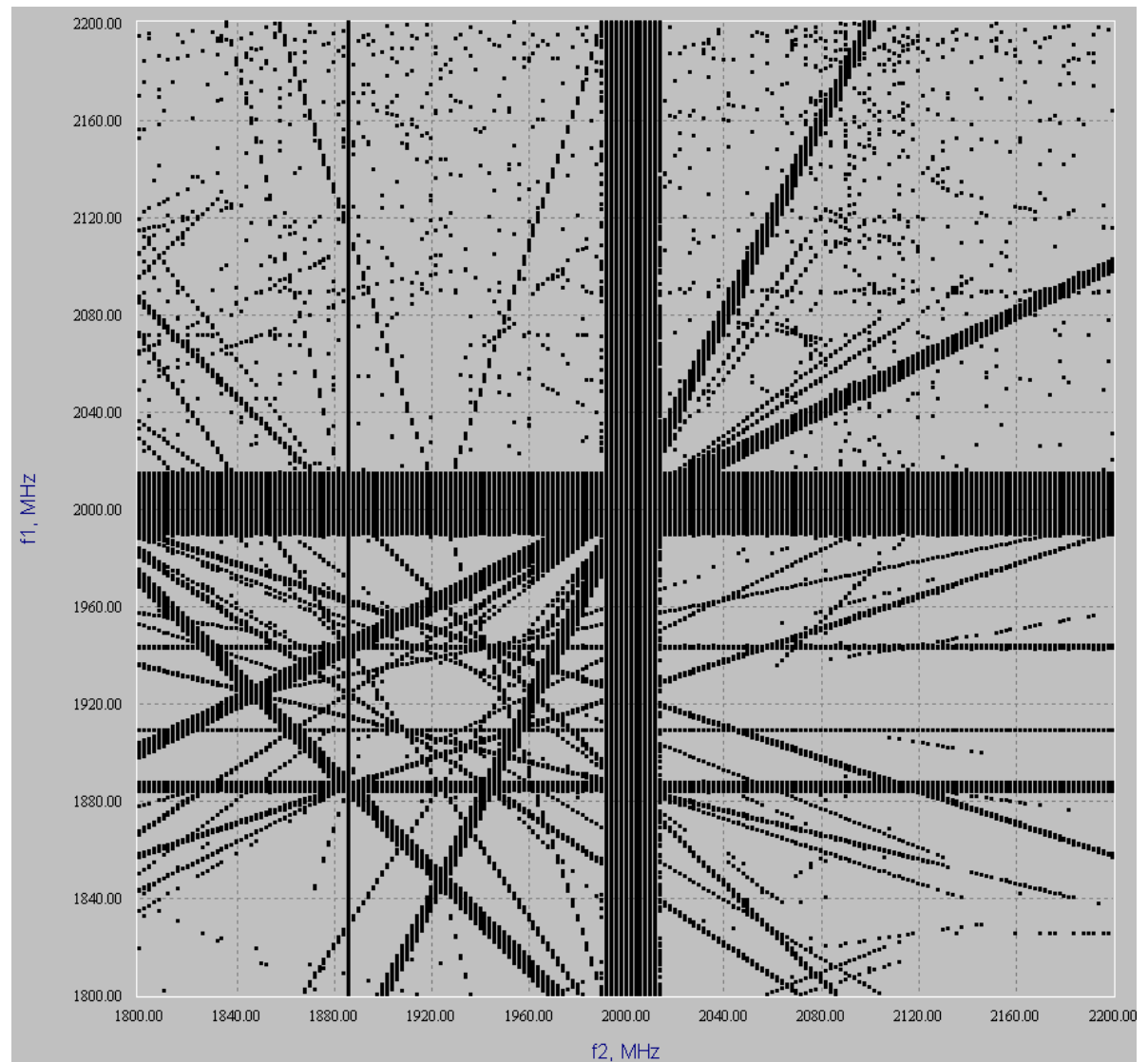
# **ADFTS: Measurement Stages**

1. Detection of interference responses
2. Recognition (interpretation) of interference responses
3. Measurement of response parameters



# Recognition of responses

**Double-Frequency Diagram may be complicated:**



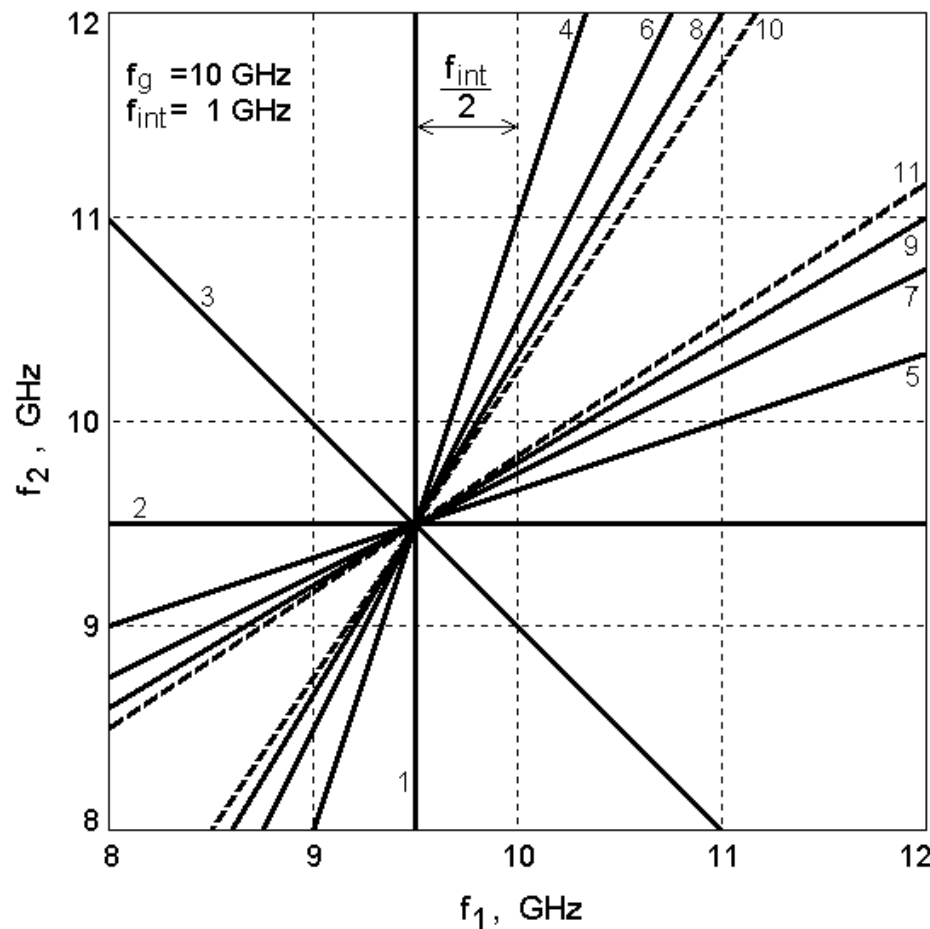
# Methods of response recognition

1. Marker Line
2. Simultaneous measurement of local oscillator frequencies for the receiver under test
3. Use of typical portraits  
(groups of response images  
on Double-Frequency Diagram)



# 2nd-order node

This node is formed with the contribution of the local oscillator signal second harmonic and contains intermodulation and spurious response path images of the types presented in table

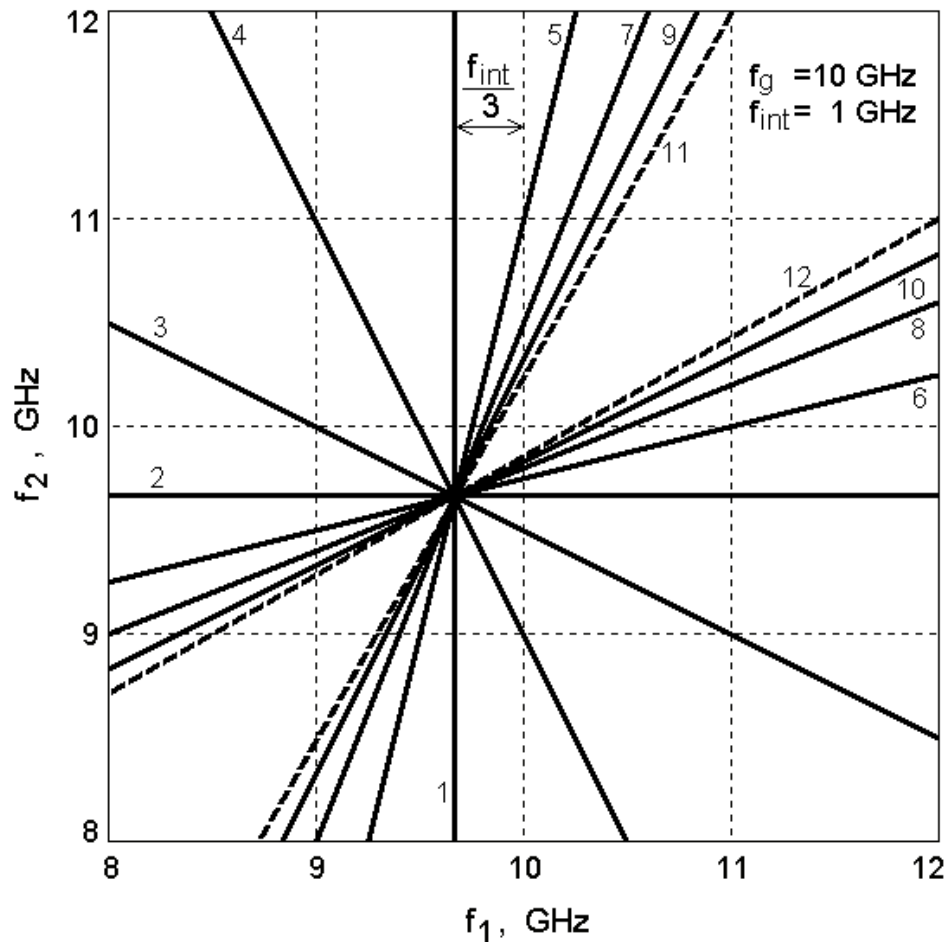


No	Type	Order
1.	$2f_1=2f_g-f_{int}$	2
2.	$2f_2=2f_g-f_{int}$	2
3.	$f_1+f_2=2f_g-f_{int}$	2
4.	$3f_1-f_2=2f_g-f_{int}$	4
5.	$3f_2-f_1=2f_g-f_{int}$	4
6.	$4f_1-2f_2=2f_g-f_{int}$	6

No	Type	Order
7.	$4f_2-2f_1=2f_g-f_{int}$	6
8.	$5f_1-3f_2=2f_g-f_{int}$	8
9.	$5f_2-3f_1=2f_g-f_{int}$	8
10.	$(m+2)f_1-mf_2=2f_g-f_{int}$	$2m+2$
11.	$(m+2)f_2-mf_1=2f_g-f_{int}$	$2m+2$

# 3rd-order node

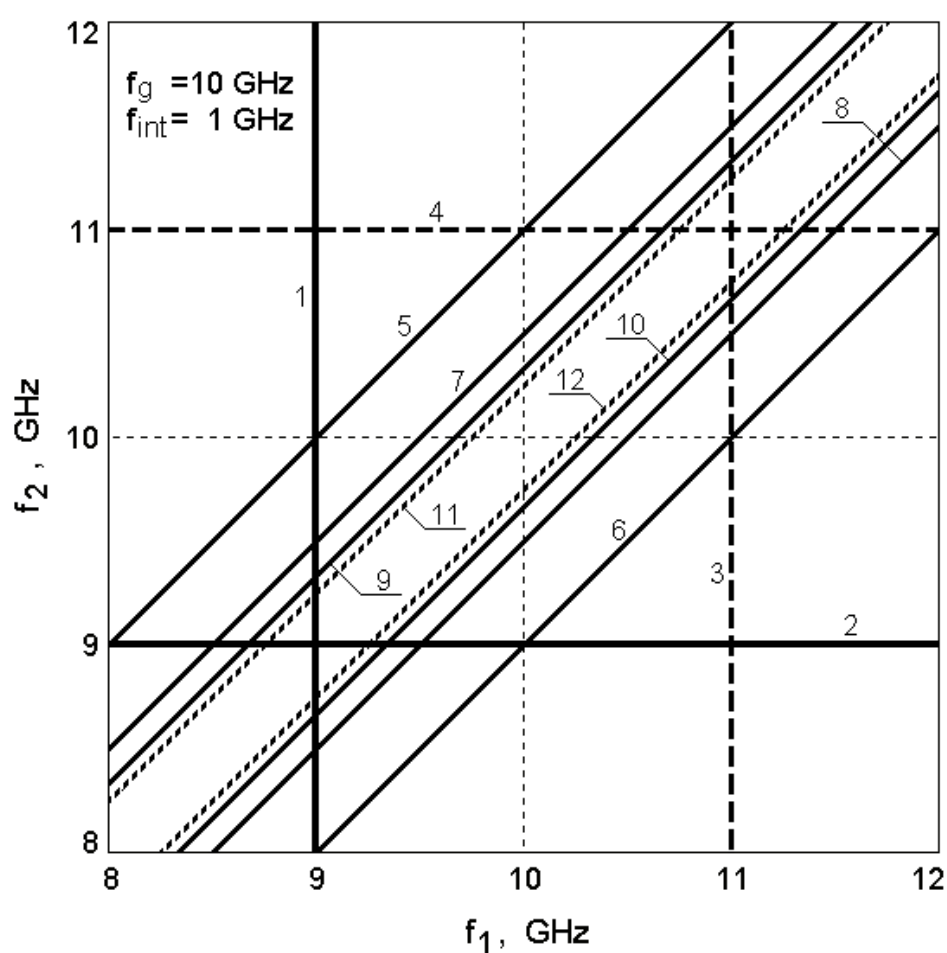
This node is formed with the contribution of the local oscillator signal third harmonic and contains intermodulation and spurious response path images of the types presented in table



No	Type	Order
1.	$3f_1 = 3f_g - f_{int}$	3
2.	$3f_2 = 3f_g - f_{int}$	3
3.	$2f_2 + f_1 = 3f_g - f_{int}$	3
4.	$2f_1 + f_2 = 3f_g - f_{int}$	3
5.	$4f_1 - f_2 = 3f_g - f_{int}$	5
6.	$4f_2 - f_1 = 3f_g - f_{int}$	5

No	Type	Order
7.	$5f_1 - 2f_2 = 3f_g - f_{int}$	7
8.	$5f_2 - 2f_1 = 3f_g - f_{int}$	7
9.	$6f_1 - 3f_2 = 3f_g - f_{int}$	9
10.	$6f_2 - 3f_1 = 3f_g - f_{int}$	9
11.	$(m+3)f_1 - mf_2 = 3f_g - f_{int}$	$2m+3$
12.	$(m+3)f_2 - mf_1 = 3f_g - f_{int}$	$2m+3$

# Even-order IM



A typical group of images formed by even order intermodulation due to direct passage of test signals nonlinear conversion products to the intermediate frequency path. This figure shows intermodulation and receive path images of the types presented in table

No	Type	Order
1.	$f_1 = f_g - f_{int}$	1
2.	$f_2 = f_g - f_{int}$	1
3.	$f_1 = f_g + f_{int}$	1
4.	$f_2 = f_g + f_{int}$	1
5.	$f_2 - f_1 = f_{int}$	2
6.	$f_1 - f_2 = f_{int}$	2

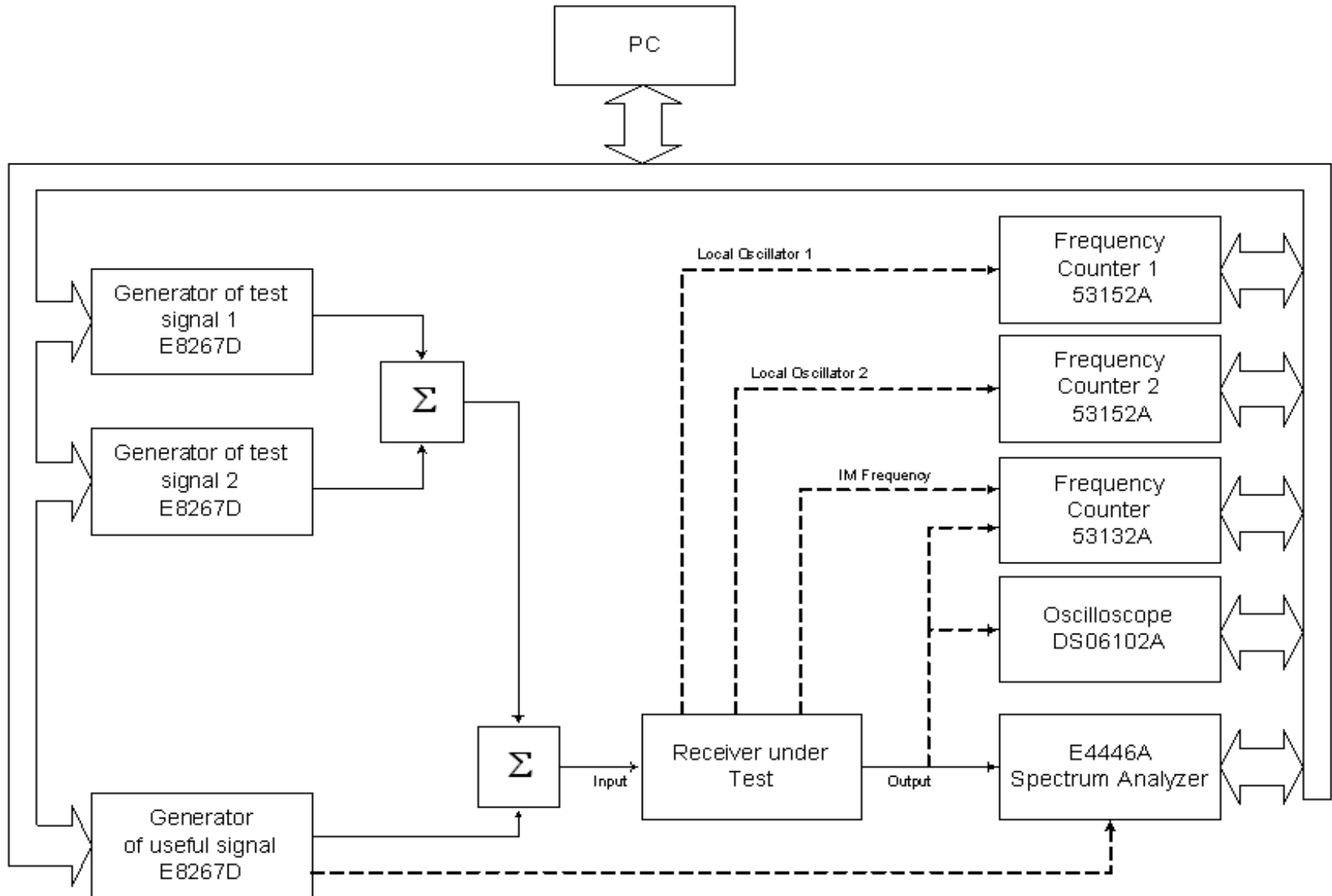
No	Type	Order
7.	$2f_2 - 2f_1 = f_{int}$	4
8.	$2f_1 - 2f_2 = f_{int}$	4
9.	$3f_2 - 3f_1 = f_{int}$	6
10.	$3f_1 - 3f_2 = f_{int}$	6
11.	$mf_2 - mf_1 = f_{int}$	$2m$
12.	$mf_1 - mf_2 = f_{int}$	$2m$

# Measurement of response parameters

At this stage, the standardized characteristics of the recognized responses are measured:

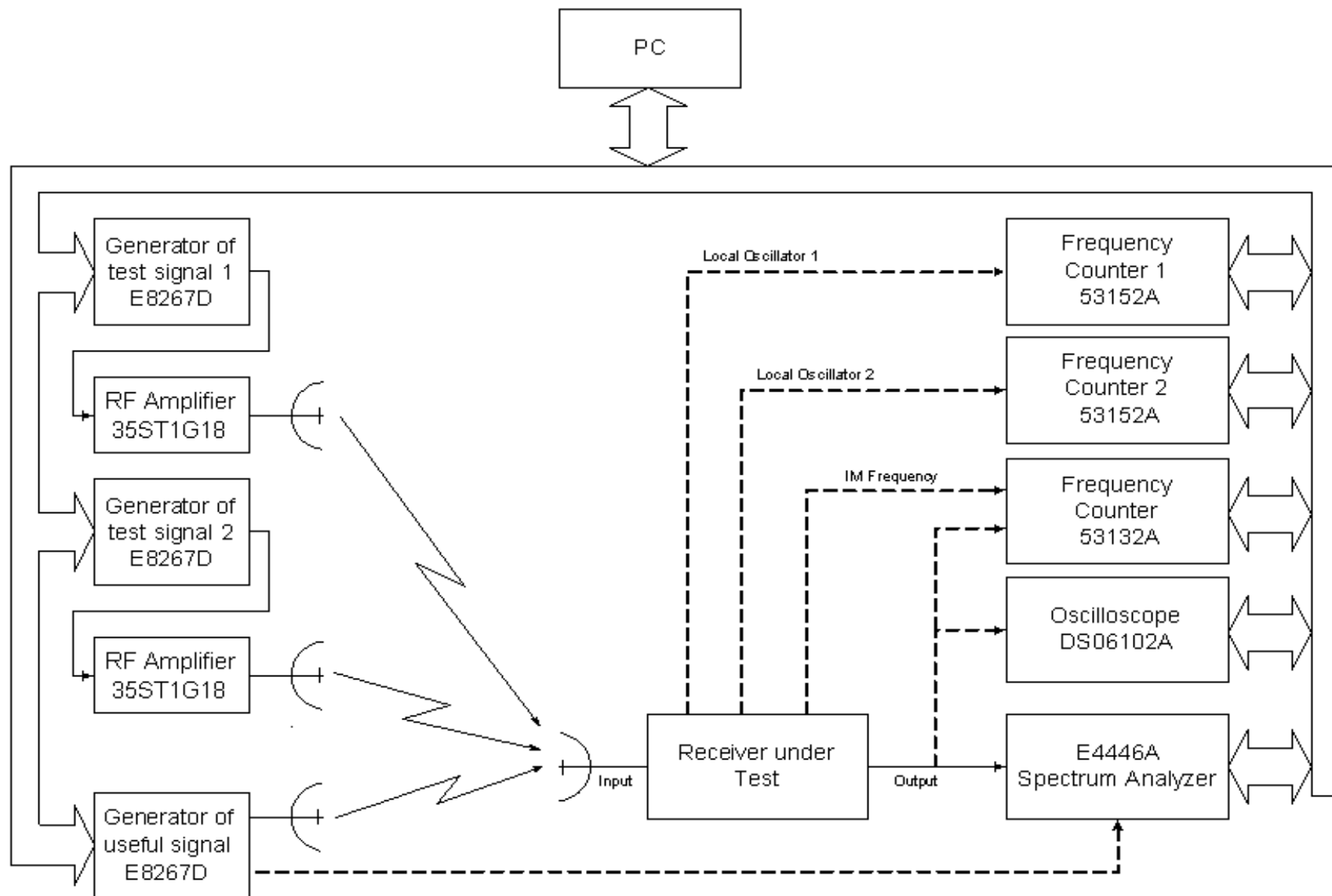
1. Desired Response Selectivity
2. Spurious Response Selectivity
3. Wide-Band Selectivity
4. Desensitization Selectivity
5. Cross-Modulation Selectivity
6. Intermodulation Selectivity

# ADFTS of the last generation





# ADFTS configured for testing by field

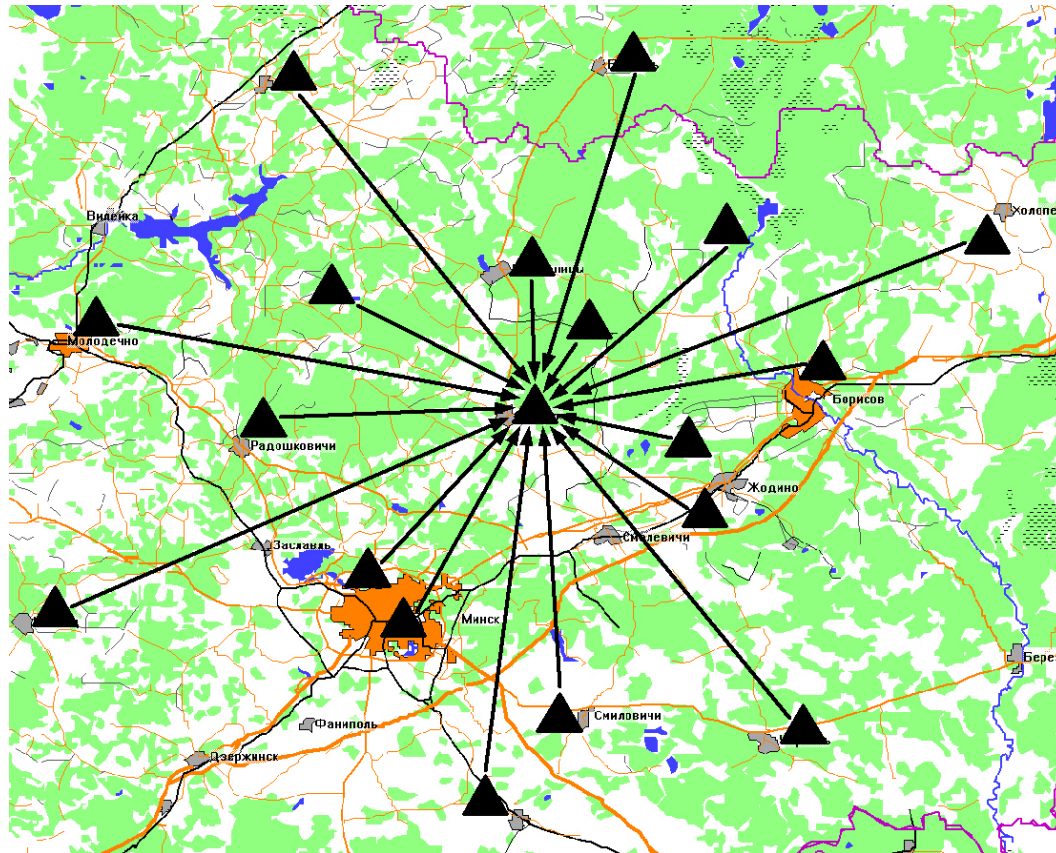


# Testing Area: Problem Description

- Usually, experimental checking of EMC is needed to turn a new system into operation
- For complicated systems and complexes, experimental check of EMC needs trial operation or ground testing, which is very expensive and takes a lot of time, for example:
  - ✓ Trial operation of GSM-1800 and UMTS in regions of intensive use of the aircraft navigation systems, military radars, and radio-relay systems
  - ✓ Trial operation of DVB-T together with aircraft navigation systems, military radars, and mobile satellite systems
- Precise simulation tool is needed to decrease the cost and time of EMC analysis and design

# Simulation of Testing Area: Situation to consider

1. Spatially-distributed transmitters (potential interferers)
2. A receiver that may be influenced (potential victim)



# Virtual Testing Area: Principles

1. Number of transmitters creating interference for the receiver is usually much smaller than the total number of transmitters
  - all the other transmitters may be neglected in receiver simulation
2. That is why the victim receiver can be simulated physically (i.e., in hardware)
3. ADFTS hardware may be used to simulate the interfering signals at the receiver input
4. A site-specific propagation simulator is used to compute the levels of transmitter signals at the receiver input
5. A mathematical simulator of the receiver is used to recognize the interfering transmitters

# Virtual Testing Area: Stages

1. Generation of electromagnetic environment model
2. Selection of the most dangerous interferers
3. Physical modeling of the receiver under test

# Virtual Testing Area: Stage 1

1. Generation of electromagnetic environment model
  - A. Define a variant (scenario) of area allocation of radiosystems' transmitters – potential interference sources
  - B. Calculate electromagnetic fields from these transmitters at the point of the receiver-under-test antenna location (propagation models based on ITU-R Recommendations are used)
  - C. Take into account the antenna of the receiver under test (compute the levels of the interfering signals at the antenna input of the receiver)
2. Selection of the most dangerous interferers
3. Physical modeling of the receiver under test

# Virtual Testing Area: Stage 2

1. Generation of electromagnetic environment model
2. Selection of the most dangerous interferers
  - A. Find, recognize, and measure the parameters of the receiver interference responses by the use of Automated Double-Frequency Test System
  - B. From that measurements, extract the nonlinear model of the receiver under test
  - C. Using the extracted nonlinear model, simulate the receiver by feeding its antenna input with the electromagnetic environment model computed at stage 1
  - D. If an interference appears at the receiver model output, find the transmitters that create the interference
3. Physical modeling of the receiver under test

# Virtual Testing Area: Stage 3

1. Generation of electromagnetic environment model
2. Selection of the most dangerous interferers
3. Physical modeling of the receiver under test
  - A. Set the parameters (frequency, level, modulation) of ADFTS measurement generators in order to simulate the interfering transmitters found at stage 2
  - B. Feed the receiver under test with the sum of the signals from the ADFTS measurement generators
  - C. Check the existence and level of interference at the receiver output



# Virtual Testing Area: Additional Software Components

1. Geographical Information System (GIS)
  - A. MapInfo
  - B. Panorama
  - C. Our own platform (obsolete)
2. Radio-wave propagation simulator (RWP)
  - ✓ site-specific algorithms based on ITU-R Rec. (452, 1546, 530, 833, etc.) are used
3. Nonlinear simulator of the receiver under test
  - ✓ Discrete Nonlinear Analysis (DNA) technology is used

# Main idea of DNA:

to model nonlinearities  
in the time domain

- Frequency-domain formula (for one component)

$$U_{[b_1, \dots, b_n]} = \sum_{s=0}^{\left\lfloor \frac{I-q}{2} \right\rfloor} \frac{K_{q+2s}}{2^{q+2s-1}} (q+2s)! \cdot \sum_{i=1}^{C_{s+n-1}^{n-1}} \frac{U_1^{2a_{1_i}^{(s)} + |b_1|} \dots U_n^{2a_{n_i}^{(s)} + |b_n|}}{a_{1_i}^{(s)}! \cdot \dots \cdot a_{n_i}^{(s)}! \cdot (a_{1_i}^{(s)} + |b_1|)! \cdot \dots \cdot (a_{n_i}^{(s)} + |b_n|)!}$$

- Time-domain formula (for one sample)

$$u_2 = \sum_{i=0}^I K_i \cdot u_1^i$$

**Number of IM products  
grows rapidly with increasing  
environment complexity and  
degree of nonlinearity**

Number of CW components at the input	Degree of nonlinearity	Number of intermodulation products
2	3	10
10	5	> 18 000
10	15	> 149 000 000
1 000 000	15	> $10^{82}$

# Traditional technique of nonlinear EMC analysis can not solve complicated problems

Number of input components	Degree of nonlinearity	Number of IM products	Computation time
1 150	3	$10^9$	1 sec
18 000	3	$4 \cdot 10^{12}$	1 hour
490	5	$4 \cdot 10^{12}$	1 hour
22	15	$4 \cdot 10^{12}$	1 hour
1 000 000	15	$> 10^{82}$	$> 10^{65}$ years

- DNA can address the last case on PC in 25 sec!

# DNA capabilities (1)

- DNA is very fast and computationally invariant to radio environment severity. DNA is able to model the radio reception in an extremely severe (up to 100 000 of modulated signals) electromagnetic environment
- DNA is able to analyze the aggregate influence of all major types of nonlinear effects (intermodulation, desensitization, cross-modulation, reciprocal mixing, AM-AM and AM-PM conversion, spurious responses) on the system performance
- DNA is able to consider multi-signal and high-order nonlinear effects (due to the use of high-order nonlinearity models – up to 25-th order)

# DNA capabilities (2)

- DNA is intended for simulation in a wide frequency range (from zero to 10 times of carrier frequency, and wider)
- DNA supports the simulation in a wide dynamic range of amplitudes (up to 300 dB)
- DNA is supplied with the efficient procedure for search of nonlinear interference (e.g. intermodulation) sources
- The advantages of DNA over traditional techniques increase with increasing the electromagnetic environment severity

# Virtual Testing Area: Advantages

1. Low cost and high speed of EMC analysis and design (because the real-world testing area is simulated)
2. High speed of EMC analysis results in ability to consider many scenarios of allocation for the transmitters and for the receiver on the testing area
3. Low errors of testing area simulation (because of physical modeling of the receiver under test)
  - Error in the radiowave propagation models is the main error of the Virtual Testing Area





# Virtual Testing Area: Application Tricks and Peculiarities

- Several signals may be modeled by one measurement generator
  - ✓ For example, the whole GSM-900 band was modeled as one aggregate signal when considering interference to aircraft navigation systems
- Special measurements may be arranged to check the radiowave propagation models
  - ✓ If several systems from the complex are already in operation, their signals at expected location points of the other systems may be measured

# Conclusion

1. Virtual Testing Area increases the details and speed of EMC analysis between spatially-distributed radio systems
2. Virtual Testing Area uses the hardware of the Automated Double-Frequency Test System (ADFTS) to perform physical modeling of the victim receiver
3. Virtual Testing Area includes additional software:
  - A. Geographical Information System (GIS)
  - B. Radio-wave propagation simulator  
(site-specific algorithms based on ITU-R Rec. are used)
  - C. Nonlinear simulator of the receiver under test  
(Discrete Nonlinear Analysis technology is used)