Practical implementation of the ITU-R methodology for planning and optimizing spectrum monitoring networks

Arseny Plossky, ITU/BDT Expert

ITUWTDC BUENOS AIRES 2017
9-20 October

ITU-D 1992 2017 CELEBRATING 25 YEARS OF ACHIEVEMENTS

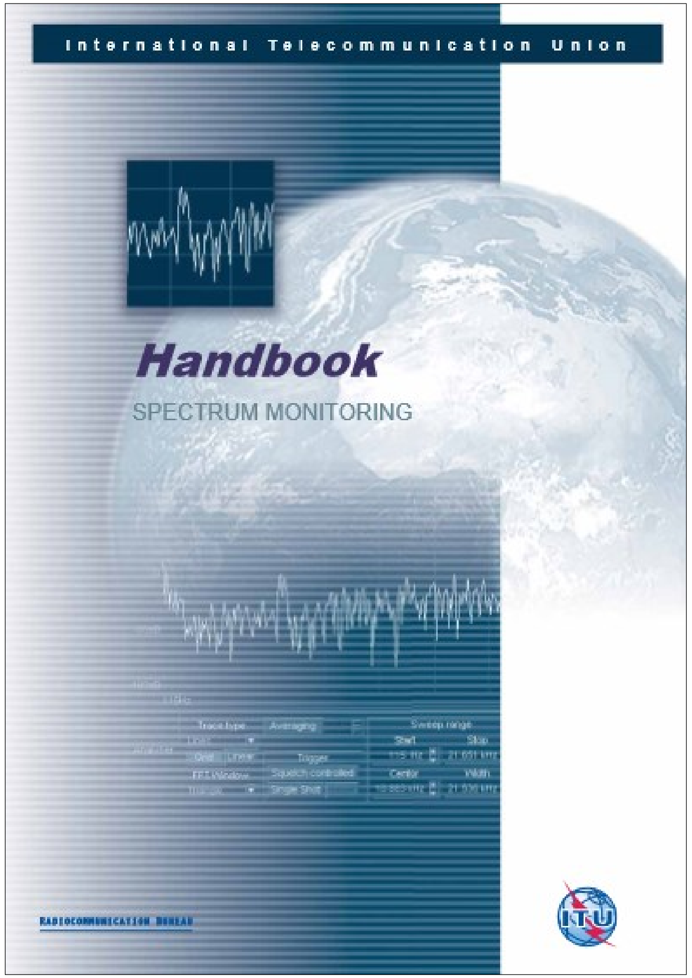
In recent years, a number of countries, including developing ones, are upgrading and expanding their spectrum monitoring networks, mainly at the level of local networks.

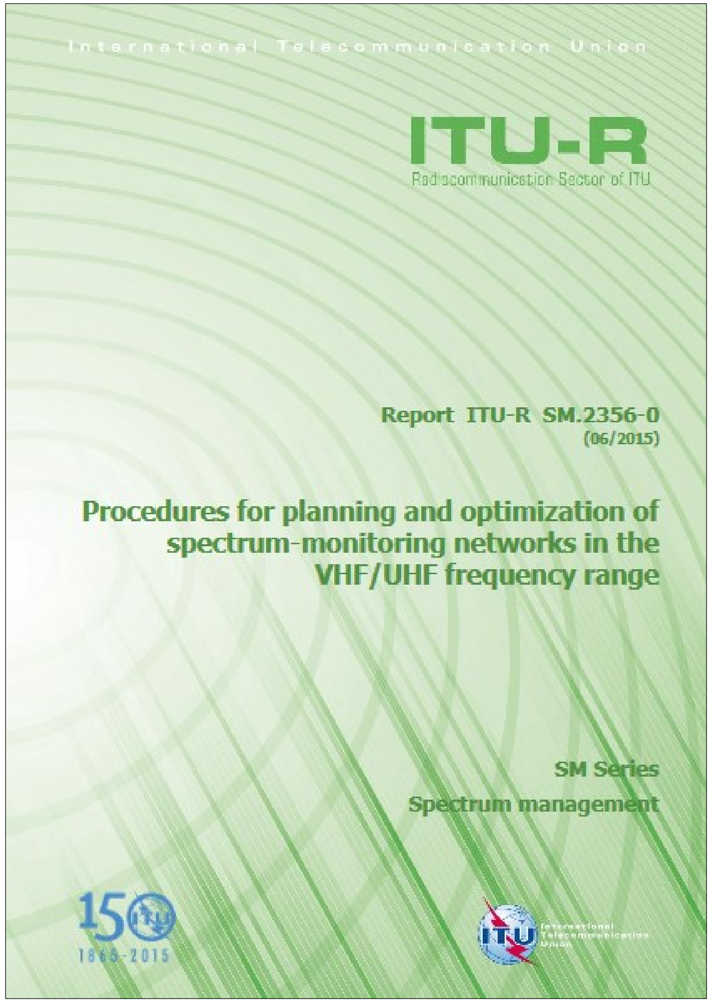
Some countries are creating or planning to create their national spectrum monitoring networks anew.

In this context, it is necessary to pay a special attention to the issues of optimal configurations and compositions of such networks.

Recommendation ITU-R SM.1392-2 “Essential requirements for a spectrum monitoring system for developing countries” states that spectrum monitoring systems are often the most expensive part of a national spectrum management system whose optimal implementation, including networking, has a significant economic impact.

Section 6.8 of the ITU Spectrum Monitoring Handbook, edition 2011, provides general methodology on planning and optimization of a convenient Angle-of-Arrival (AOA) spectrum monitoring networks in the context of monitoring coverage.





Considerable more detailed planning and optimization procedures are set out in the Report ITU-R SM.2356 "Procedures for planning and optimization of spectrum-monitoring networks in the VHF/UHF frequency range".

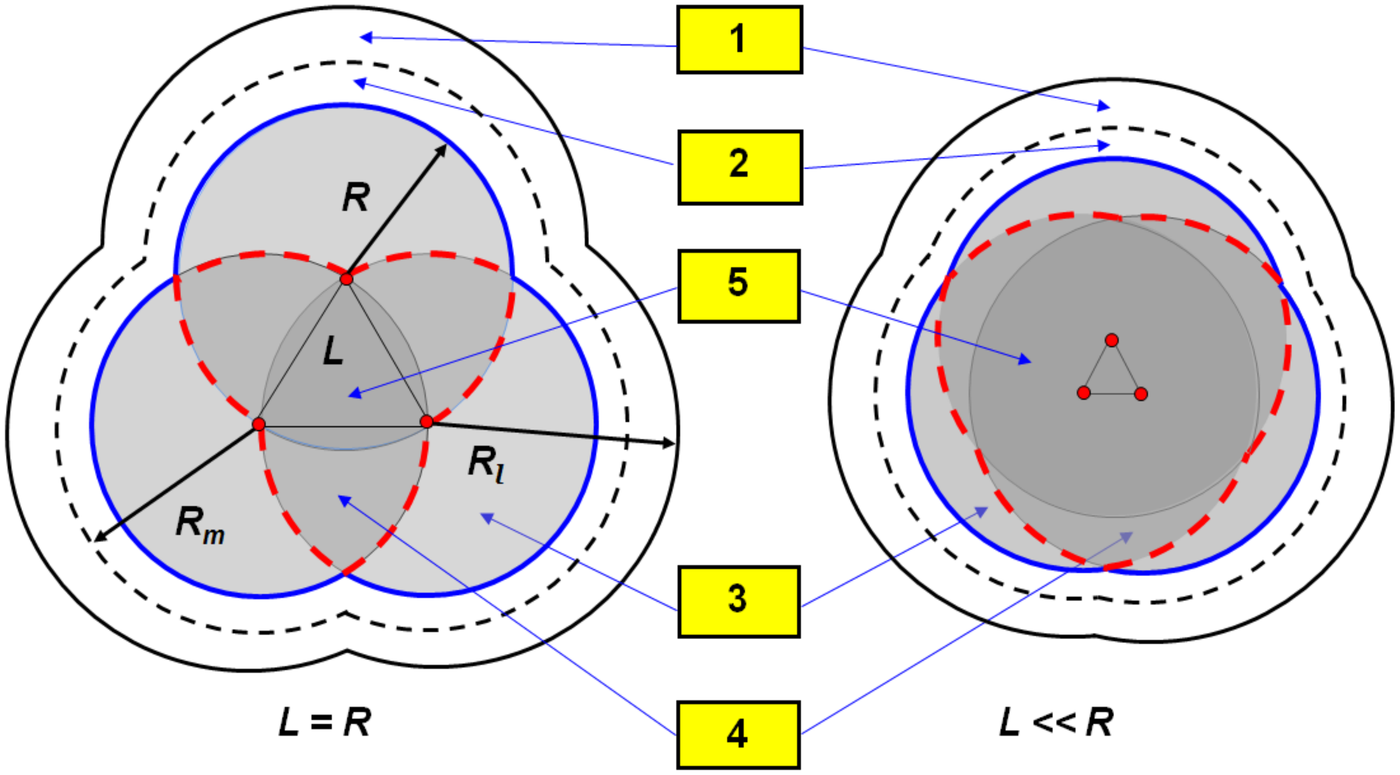
As regards Time-Difference-of-Arrival (TDOA) systems, a number of guidelines on planning and optimization of such networks, including hybrid AOA/TDOA ones, are set out in § 4.7.3.2 of the ITU Spectrum Monitoring Handbook as well as in Reports ITU-R SM.2211-1 “Comparison of Time-Difference-of-Arrival and Angle-of-Arrival Methods” and ITU-R SM.2356.

However, as it is stated in section 4 of Report ITU-R SM.2356: "…planning method for blanket coverage of a large area by TDOA stations (similar to the method concerning regular network for planning AOA stations as presented in section 3 above) is continuously being developed…", i.e. it is still under development.

Due to this fact, let us concentrate on the convenient AOA systems.

As it follows from Section 6.8 of the ITU Spectrum Monitoring Handbook and Report ITU-R SM.2356, the fundamentals of the AOA monitoring networks planning and optimization actions are calculations of monitoring coverage relating different monitoring functions such as listening, emission parameter measurements, direction finding (DF) and location based on the triangulation procedure.

Relevant coverage areas of 3 monitoring /DF stations are conditionally shown at the following figure:



Various monitoring coverage zones under different ratios of distances between stations (L) and DF coverage area radiuses (R):

1 Overall coverage area of listening

2 Overall coverage area of emission parameters measurement

3 Overall coverage area of DF

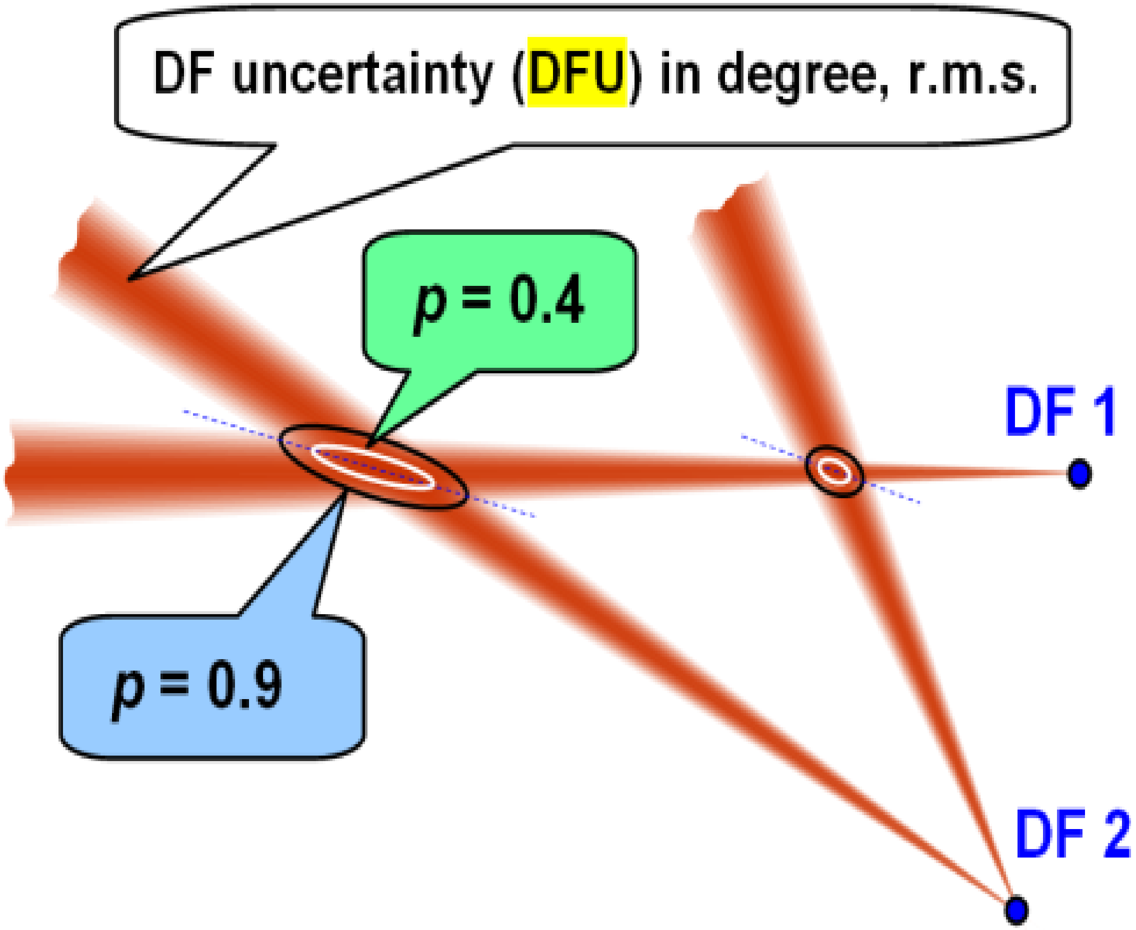
4 Location coverage area of triangulation by two stations

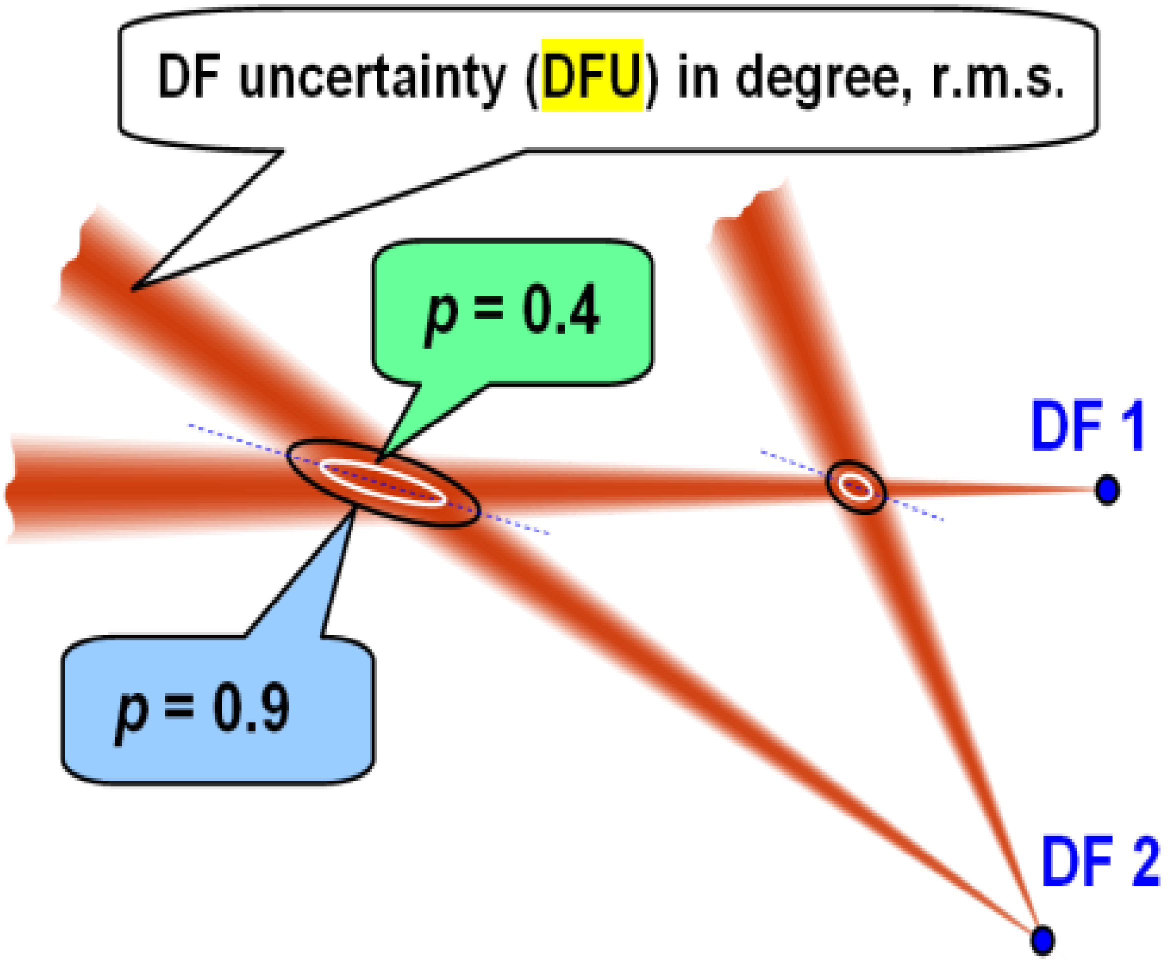
5 Location coverage area of triangulation by three stations

Monitoring coverage zones (of listening and emission parameters measurement) on the one hand and the DF/location coverage area on the other hand behave quite differently when the ratio of the coverage zone radius to the distance between monitoring stations (R/L) changes.

Particularly, from the previous slide it follows, that under increasing R/L ratio the monitoring coverage zones decrease but DF and, especially, location coverage zones increase.

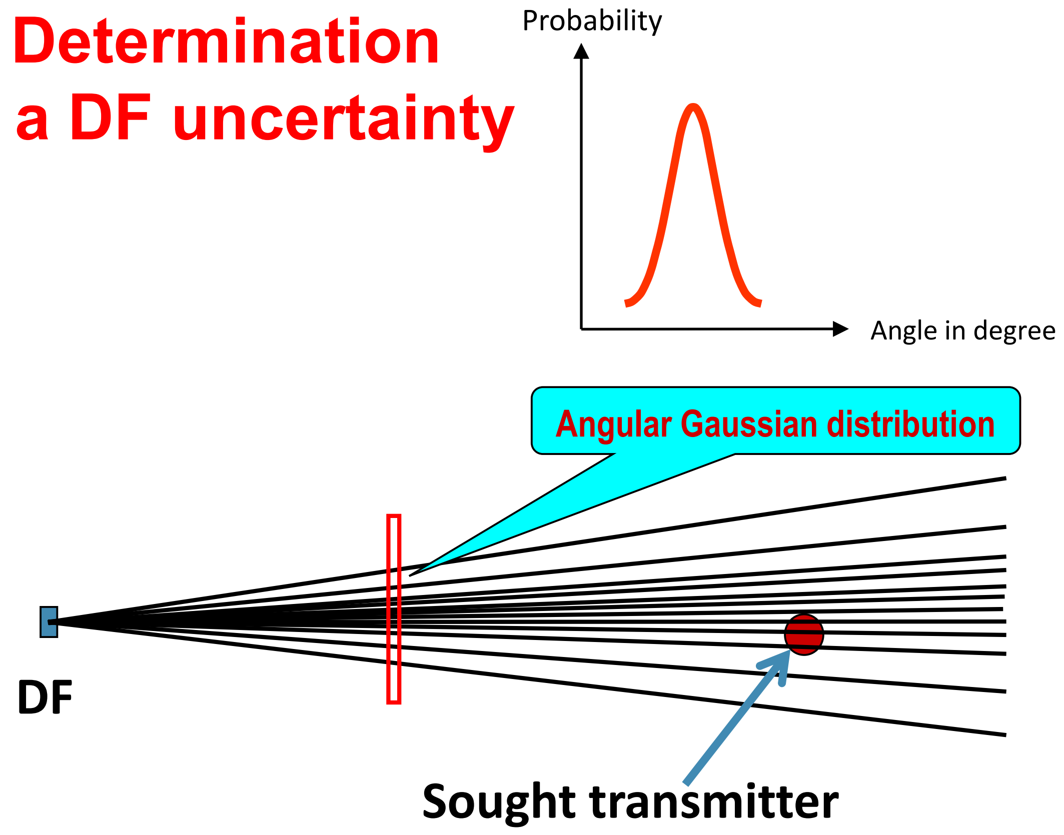
Another specific and unique feature of the location coverage zone is the fact that the uncertainty of the location within the overall location coverage area varies significantly, depending on the angles of DF bearing intersections and the distances of such intersections from direction finders.



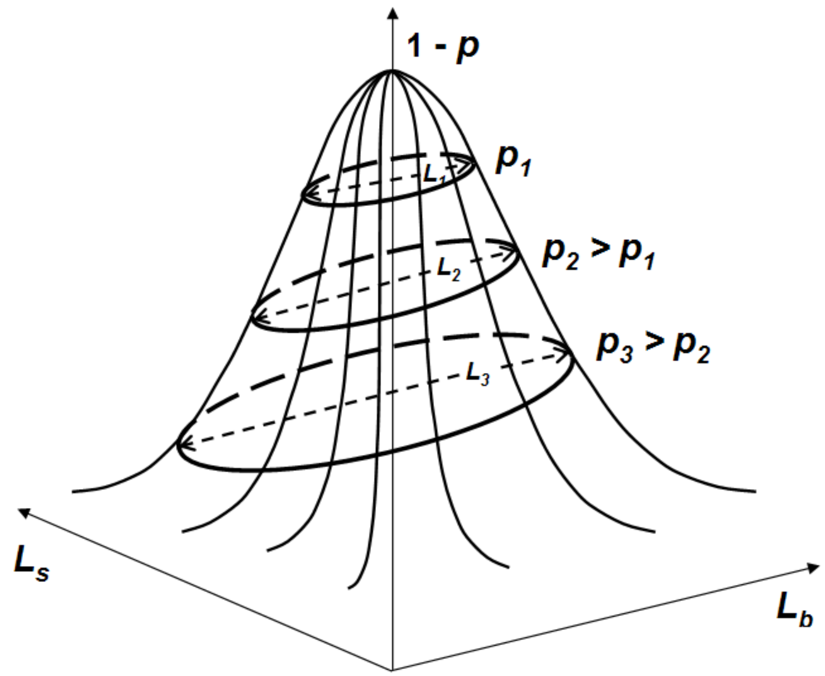


Location uncertainty also varies depending on the probability *p* of siting a sought transmitter within the uncertainty ellipse. As probability *p* increases, the axes of the location uncertainty ellipse (major and minor) also increase, resulting in a corresponding increase in the location uncertainty determined by the length of the major axis of the ellipse.

Determination of a DF uncertainty

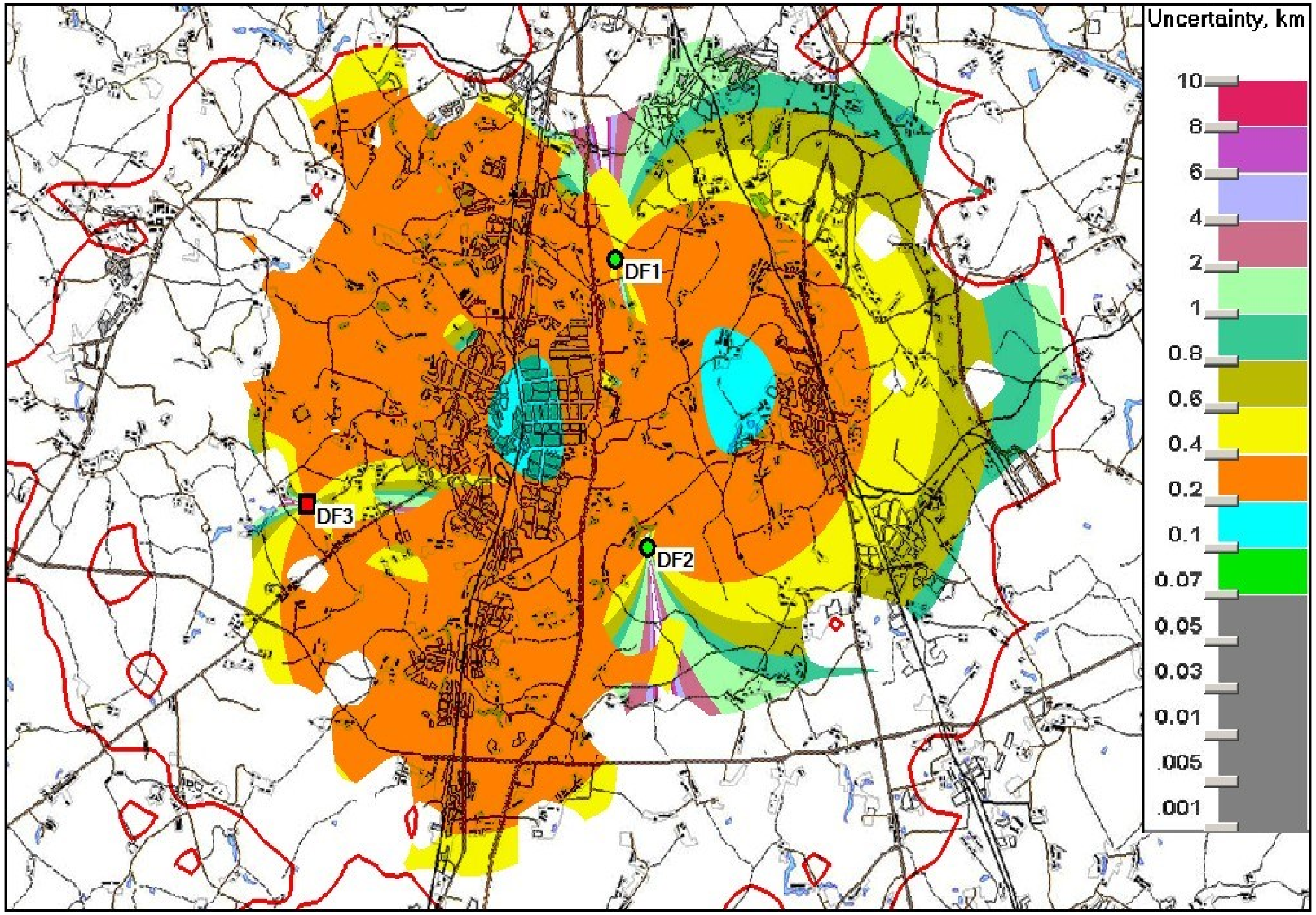


Determination of a location uncertainty from two-dimensional Gaussian probability law

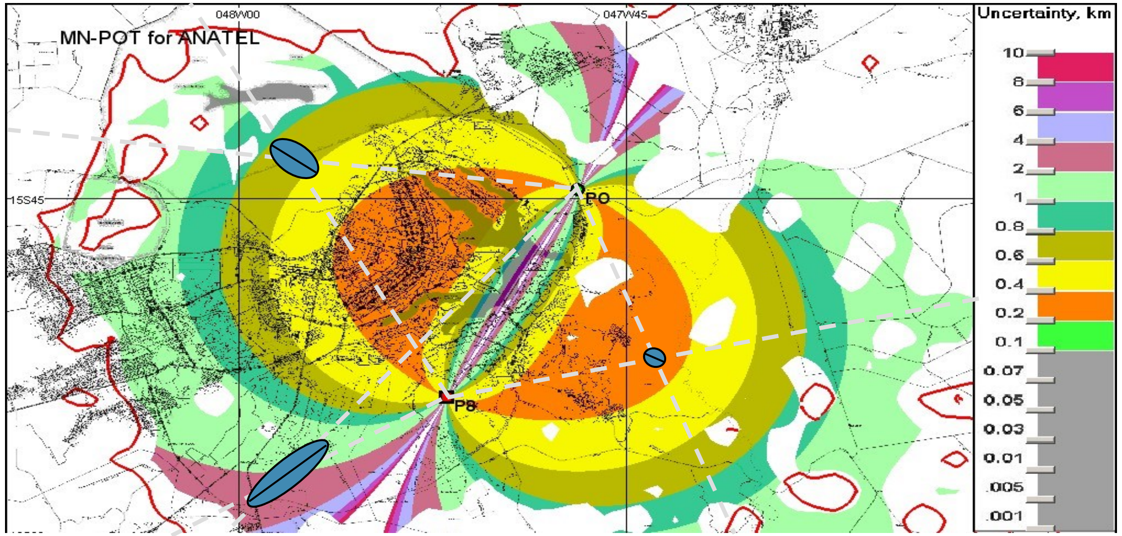


The location uncertainty distribution may be represented graphically in the form of adjacent subareas whose boundaries correspond to the established location uncertainty values as it is shown in the figure at the right.

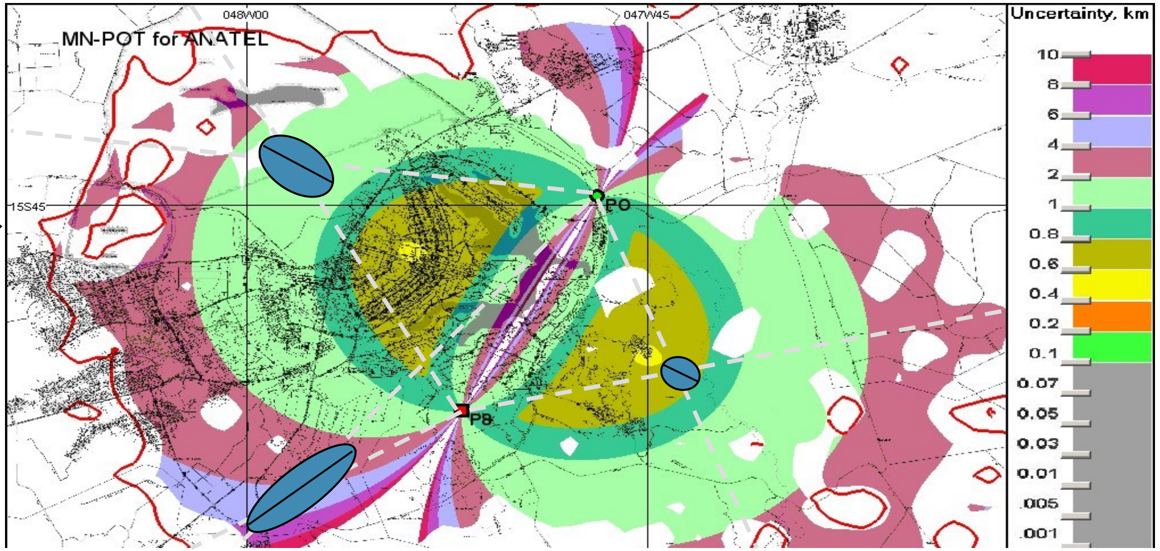
As it can clearly be seen from this figure, the location uncertainties are minimal in those areas where the bearings intersect at angles close to 90º.



Location coverage by two direction finders under different probabilities



p = 0.5



p = 0.95

The figures shown at the previous two slides are called "Location coverage templates" or the "Kogan-Pavliouk templates" by the name of Russian scientists who firstly studied in detail this phenomenon in the following publication:

- KOGAN V.V., PAVLIOUK A.P. – Analysis of location coverage templates in spectrum monitoring – Proceedings of the Seventeenth International Wroclaw Symposium and Exhibition on Electromagnetic Compatibility, EMC-2004. Wroclaw, Poland, June 2004.

The texts of this publication as well as other publications on the subject can be found at:

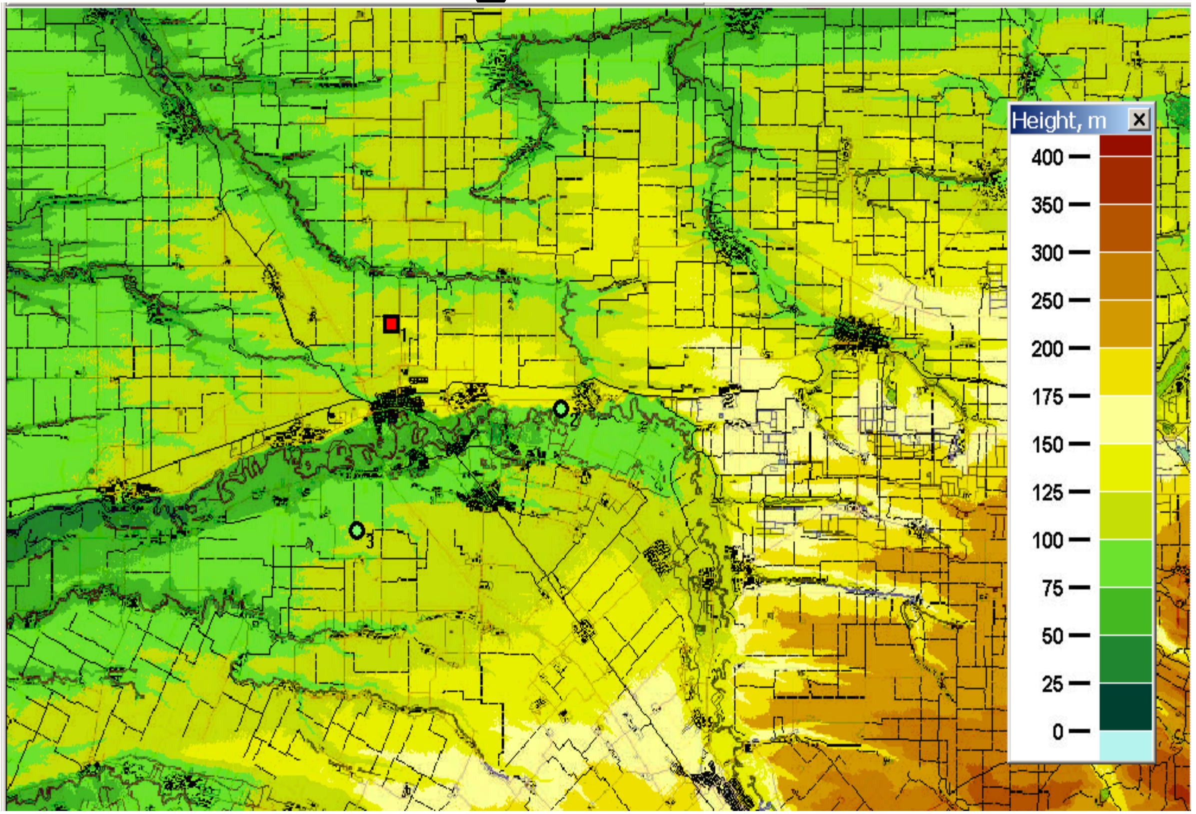
http://pavlyuk.wixsite.com/alexander

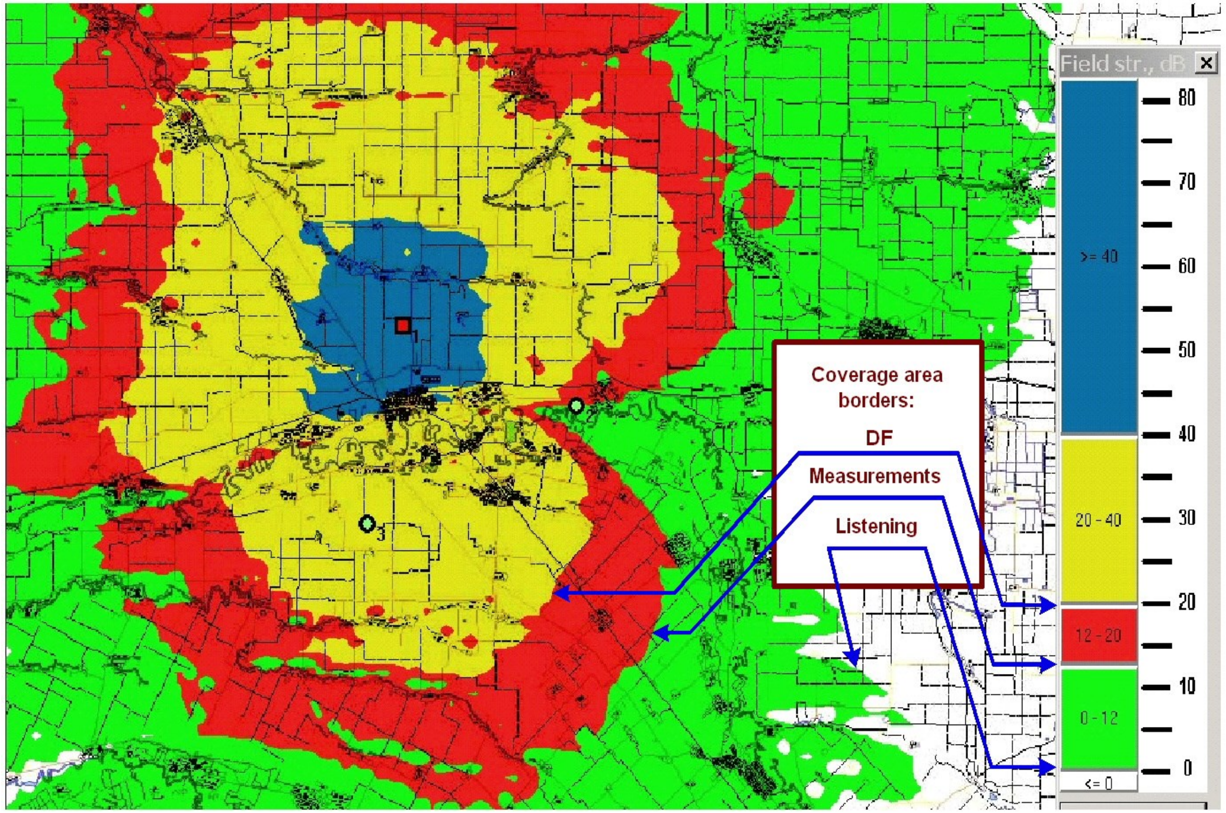
TABLE 6.8-1 (*OF ITU SPECTRUM MONITORING HANDBOOK, 2011*)

Criteria for the planning and optimization of monitoring networks in the VHF/UHF frequency bands

Parameter	Value
Test transmitter antenna height	Category I: 1.5 m Category II: 20 m Category III: 40 m
Test transmitter power	Categories I and II: 10 W Category III: 20 W
Probability of finding the test transmitter within the location uncertainty ellipse (see Section 4.7.3.4)	0.5
Fixed monitoring station antenna height	10 – 50 m (according to installation site)
Mobile monitoring station antenna height	2.5 m (antenna mounted on vehicle roof) 10 m (semi-fixed extendable antenna)
System direction-finding uncertainty (see Section 4.7.3.1.3)	1° r.m.s. (fixed station) 2° r.m.s. (mobile station)
Minimum field strength at the boundary of the listening coverage zone	0 dB/μV/m
Minimum field strength at the boundary of the signal characteristic measurement coverage zone	12 dB/μV/m
Minimum field strength at the boundary of the direction-finding coverage zone	20 dB/μV/m

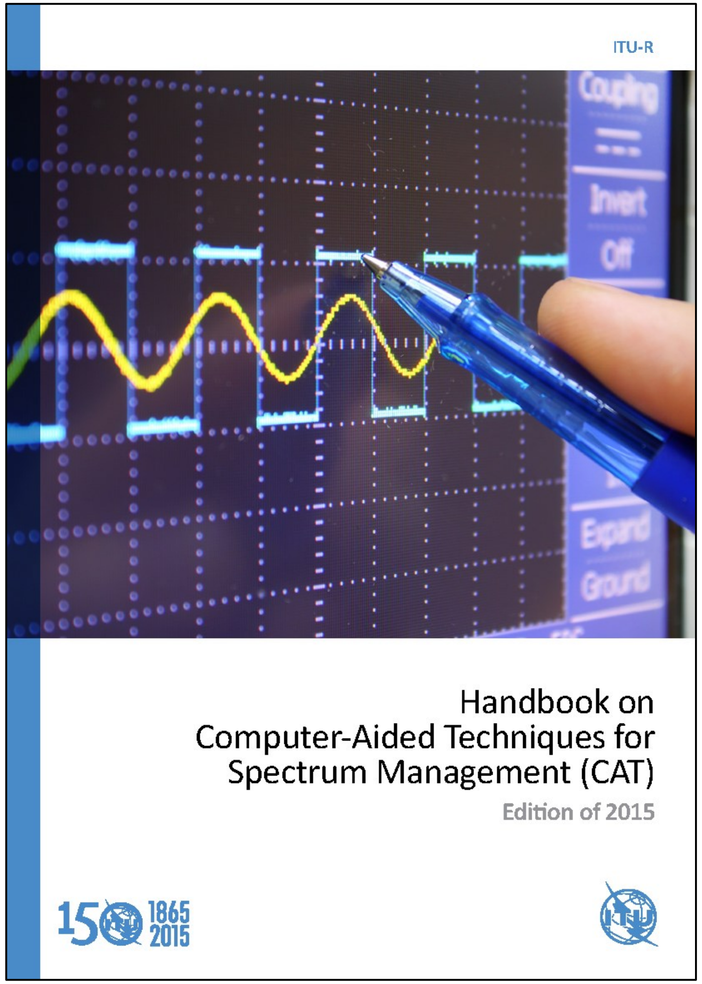
At a real terrain topography the monitoring coverage zones look like the following:





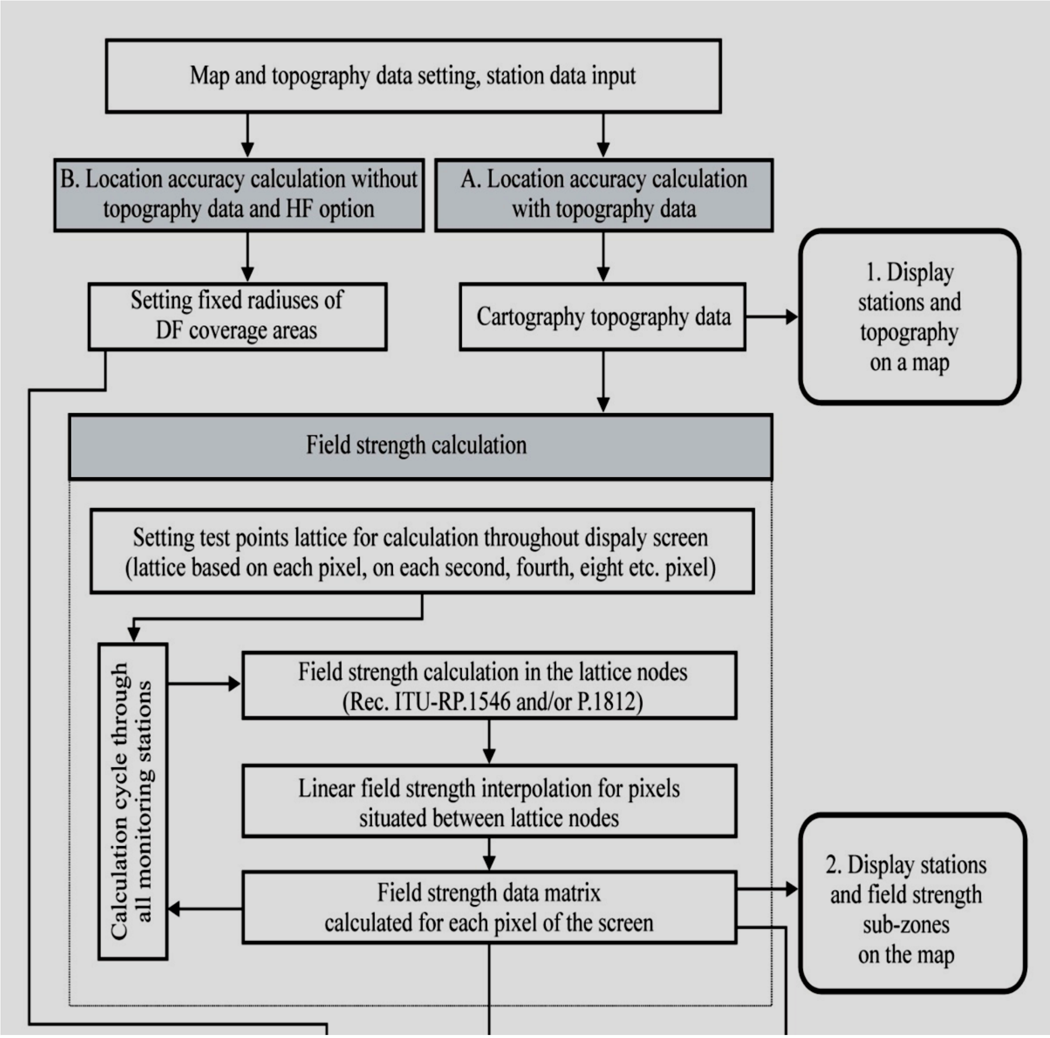
As it concerns relevant software, the main principles of its development are described in the Annex 5 “Application software for Angle of Arrival spectrum monitoring network planning and optimization” to the ITU Handbook on Computer-Aided Techniques for Spectrum Management (CAT), Geneva, 2015.

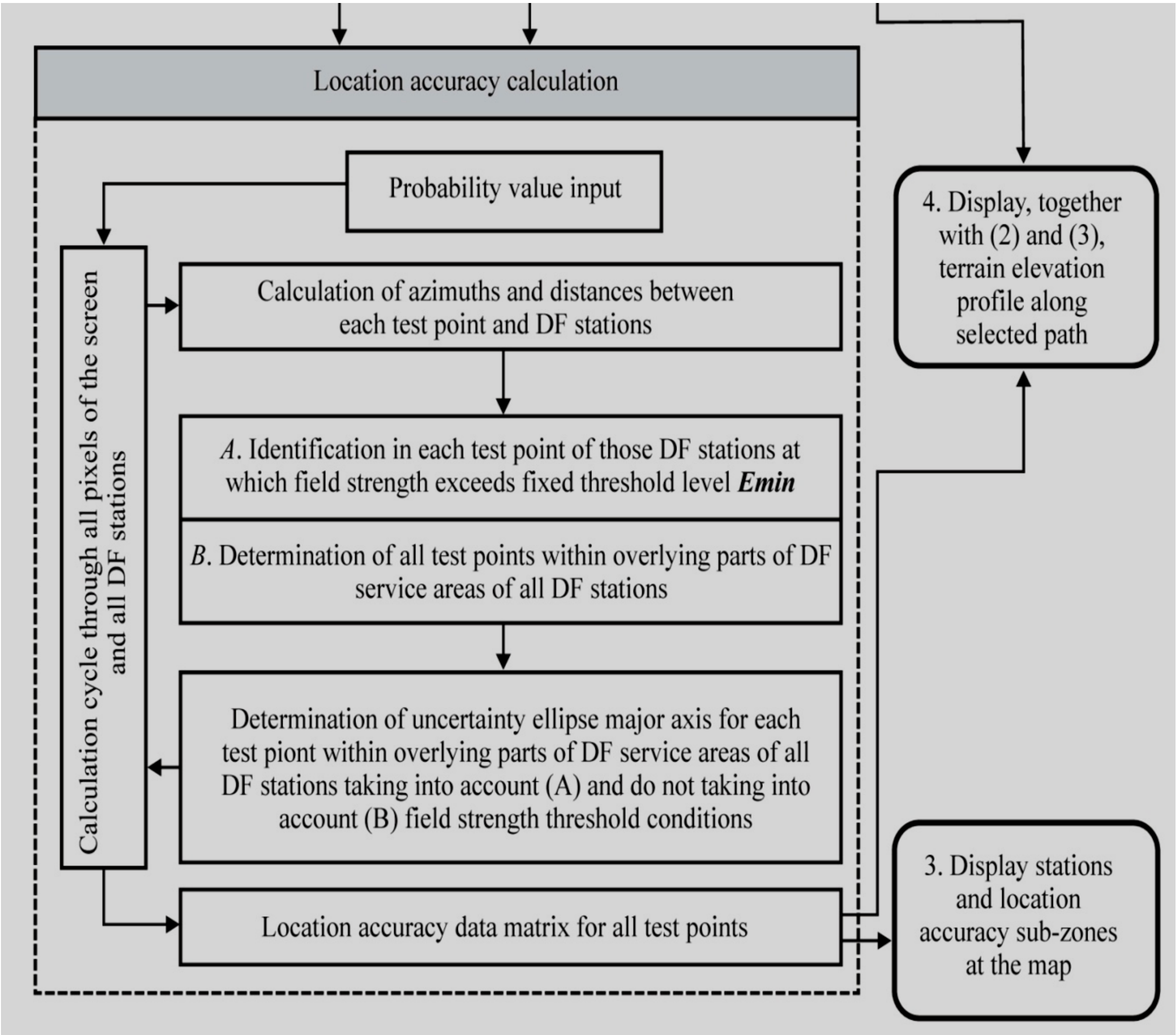
The software contains two main calculation blocks: field strength and location uncertainty calculations.

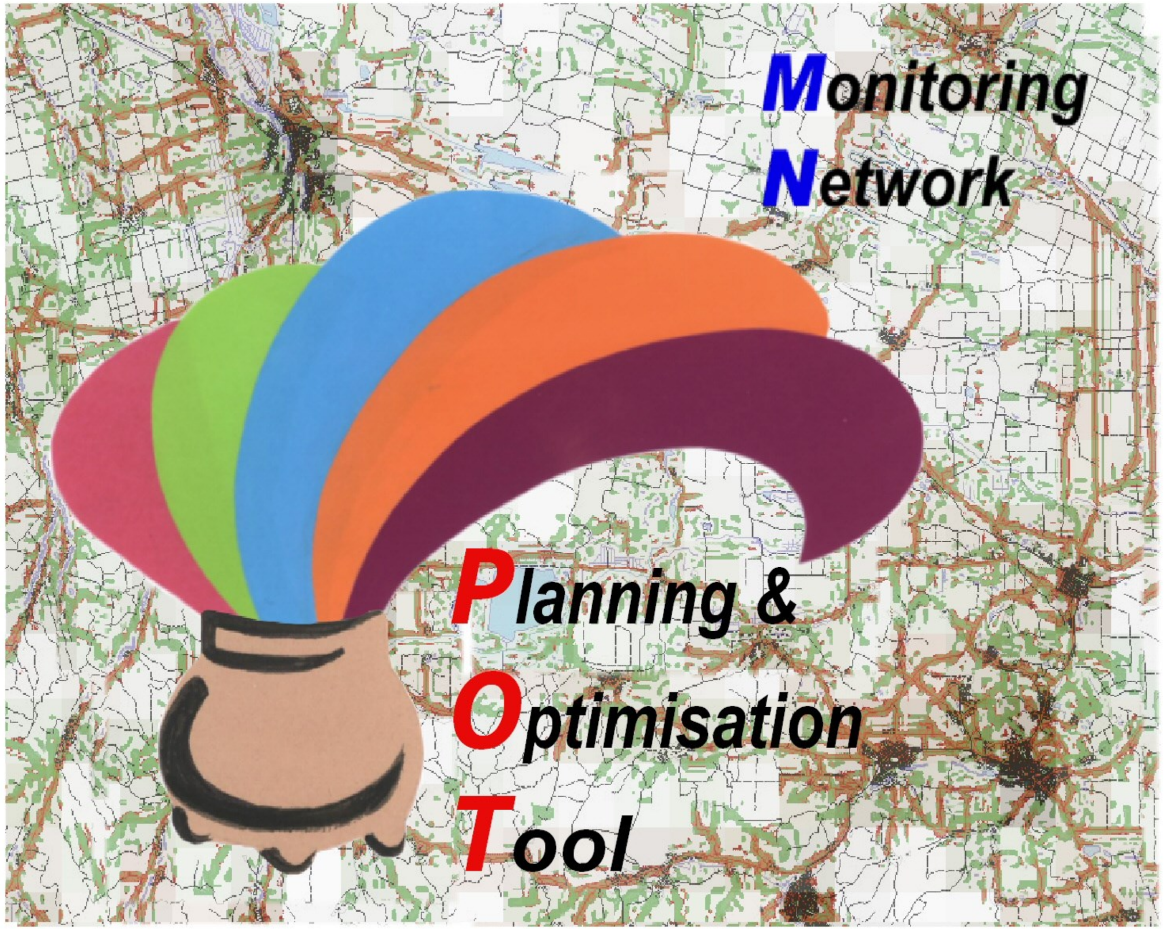


ITUWTDC BUENOS AIRES 2017 9-20 October

CELEBRATING 25 YEARS OF ACHIEVEMENTS ITU-D 1992 2017


Map and topography data setting, station data input
B. Location accuracy calculation without topography data and HF option
A. Location accuracy calculation with topography data
Setting fixed radiuses of DF coverage areas
Cartography topography data
1. Display stations and topography on a map
Field strength calculation
Setting test points lattice for calculation throughout dispaly screen (lattice based on each pixel, on each second, fourth, eight etc. pixel)
Calculation cycle through all monitoring stations
Field strength calculation in the lattice nodes (Rec. ITU-RP.1546 and/or P.1812)
Linear field strength interpolation for pixels situated between lattice nodes
Field strength data matrix calculated for each pixel of the screen
2. Display stations and field strength sub-zones on the map


Location accuracy calculation
Probability value input
Calculation cycle through all pixels of the screen and all DF stations
Calculation of azimuths and distances between each test point and DF stations
A. Identification in each test point of those DF stations at which field strength exceeds fixed threshold level Emin
B. Determination of all test points within overlying parts of DF service areas of all DF stations
Determination of uncertainty ellipse major axis for each test piont within overlying parts of DF service areas of all DF stations taking into account (A) and do not taking into account (B) field strength threshold conditions
Location accuracy data matrix for all test points
4. Display, together with (2) and (3), terrain elevation profile along selected path
3. Display stations and location accuracy sub-zones at the map

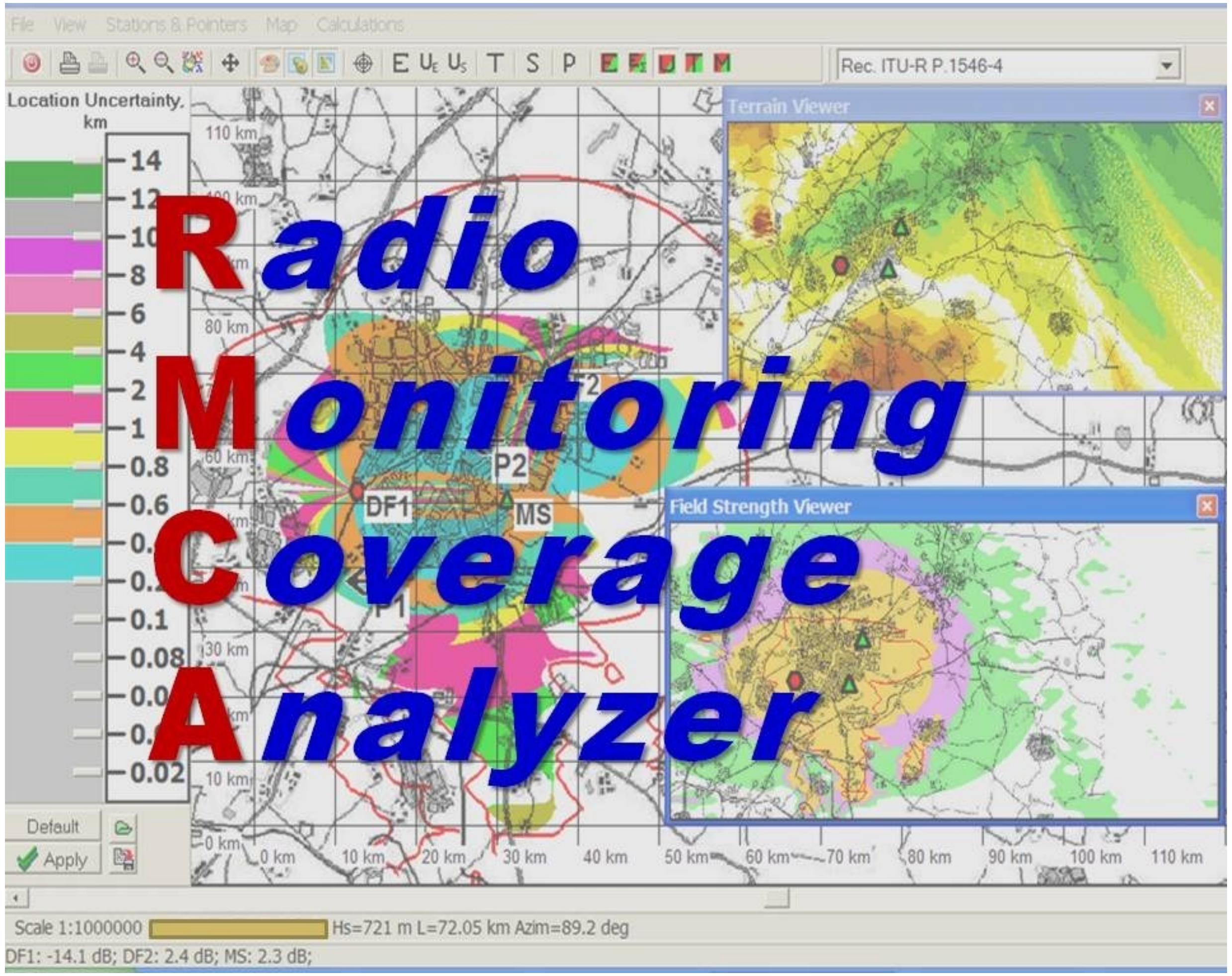


The first software meeting requirements of all the above-mentioned ITU documents was the MN-POT software package, developed at the very beginning of the 2000-s.

The MN-POT software package was successfully used in ITU/BDT technical assistance projects on planning or optimizing all-nation or local spectrum monitoring networks for the following countries: Kyrgyzstan, 2004; Tajikistan, 2005 and Brazil, 2009.

In frameworks of these projects the MN-POT software package was presented to the relevant administrations free of charge.

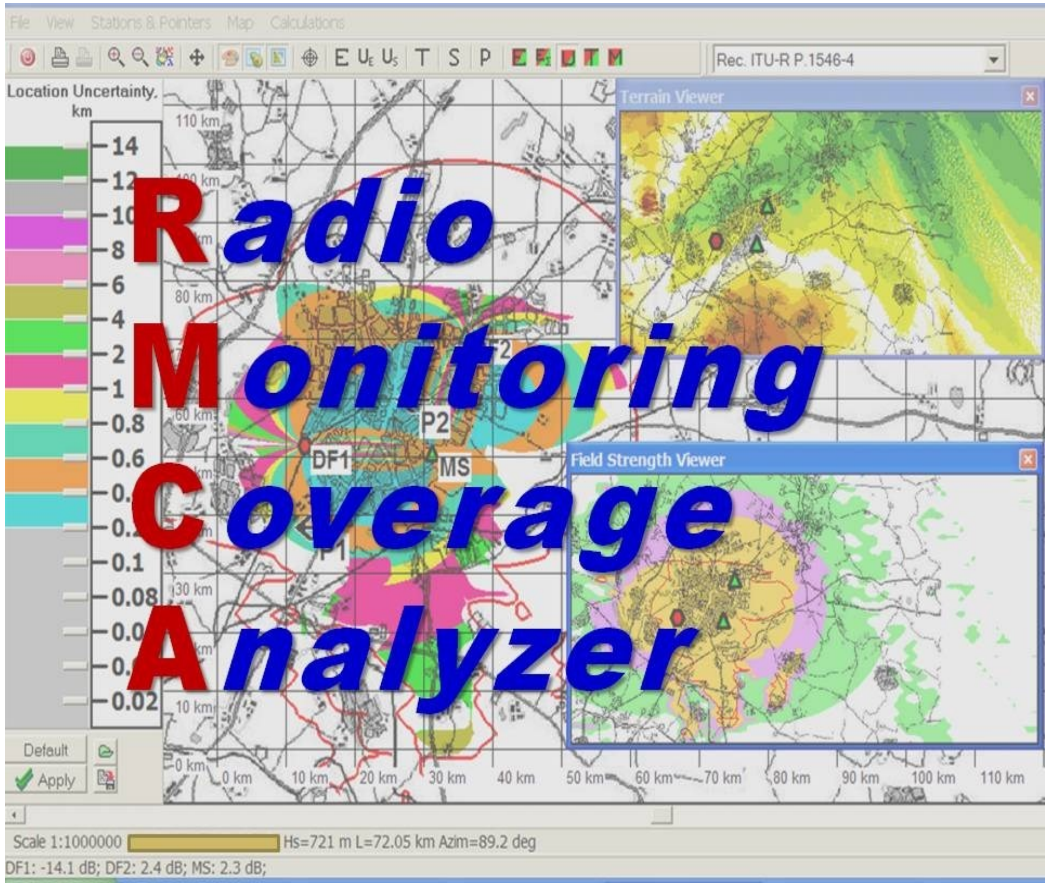
It was also used for calculations within ITU/BDT technical assistance project for Armenia, 2009, as well as within some projects carried out by other organizations for Nepal, 2003; Saudi Arabia, 2006-2008 and Costa Rica, 2011.



In the beginning of 2010-s the MN-POT software package was somewhat upgraded and renamed "Radio Monitoring Coverage Analyzer" (RMCA).

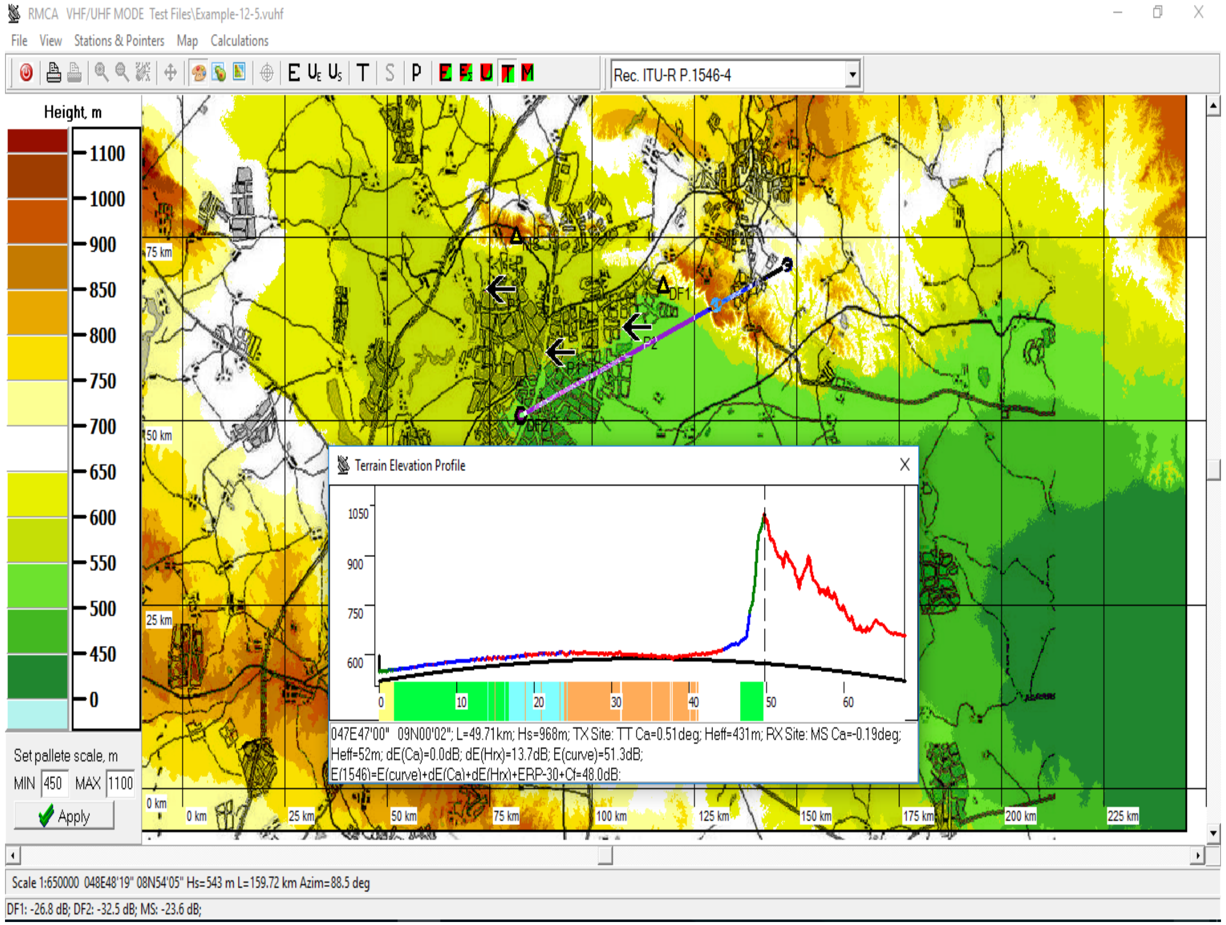
Calculations by the new RMCA software package was successfully made for ITU/BDT technical assistance projects for Albania, 2014 and Swaziland, 2014.

Within the project carried out by other organization the RMCA was successfully used for planning the all-nation spectrum monitoring network of the Kingdom of Saudi Arabia, 2011 – 2013.



ITUWTDC
BUENOS AIRES 2017
9-20 October

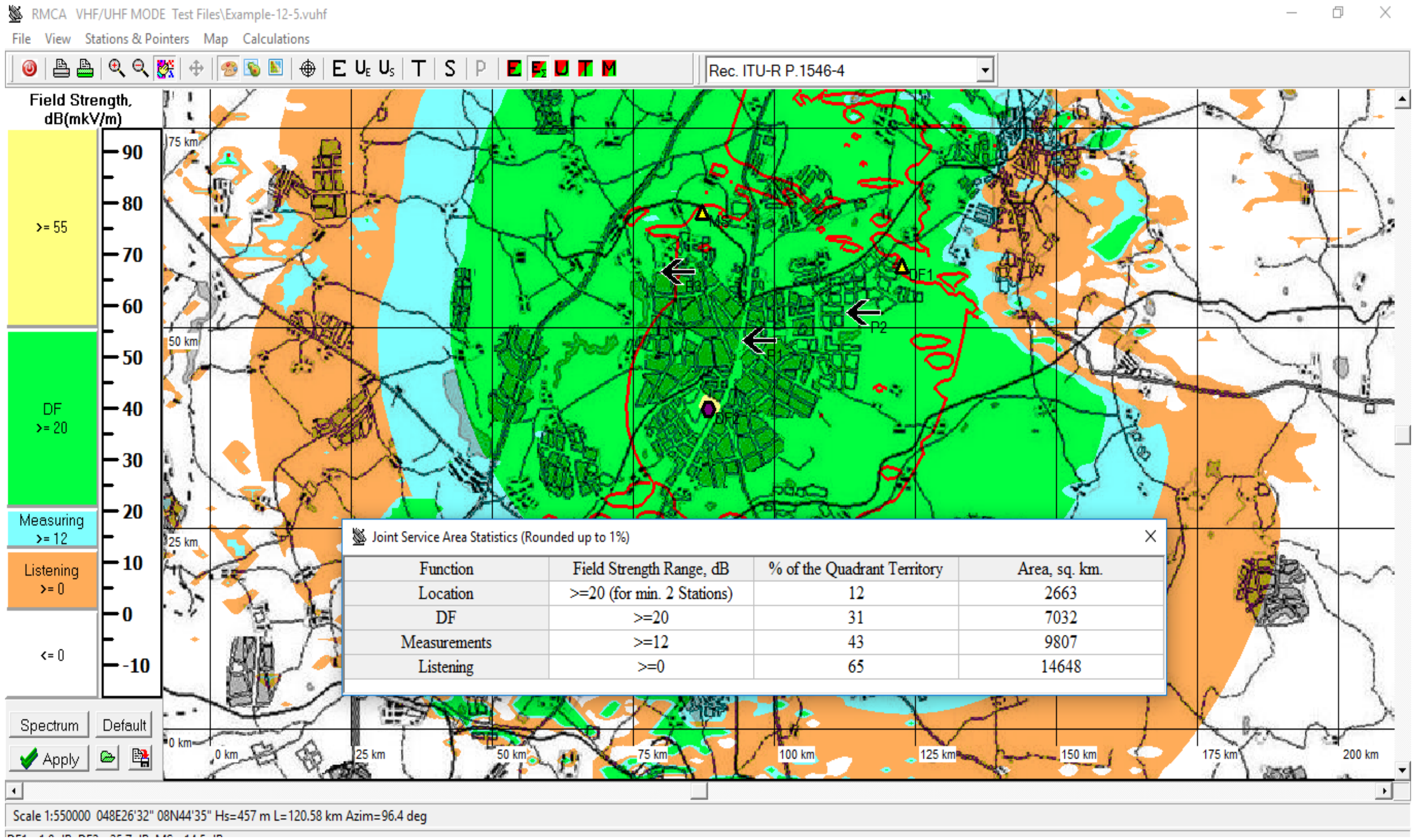
RMCA software package permits not only to carry out absolutely all functions described in Report ITU-R SM.2356 “Procedures for planning and optimization of spectrum-monitoring networks in the VHF/UHF frequency range” as it concerns AOA monitoring networks, but also fulfill some other useful functions.



CELEBRATING
ITU-D 1992 2017
25 YEARS
OF ACHIEVEMENTS

All these functions are presented in details in the **RMCA Technical Description** that is available on a request from the author of this paper by the address:

aplossky@gmail.com



Thank you very much for your kind attention!