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

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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.
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.
Various monitoring coverage zones under different ratios of distances between stations (L) and DF coverage area radiiuses (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 location uncertainty from two-dimensional Gaussian probability law

Determination of a DF uncertainty

Angular Gaussian distribution

Sought transmitter

Probability

Angle in degree
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 90°.
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:


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

http://pavlyuk.wixsite.com/alexander
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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| 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         | 0.5                                                                  |
| within the location uncertainty ellipse (see        | Section 4.7.3.4)                                                      |
| 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    |
|                                                     | 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.
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.
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.
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!