

Possibilities of using a frequency broker in radio data assignment process for combat radios

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Abstract. Due to a dynamic evolution of wireless communications, the saturation of the operating areas with radio resources (both military and public) has highly increased during the last decade. A static assignment of frequency resources leads to strict limitations and leads to their inefficient use. Only dynamic management of the available frequency range, which guarantees required spectrum accessibility, may lead to a correct functionality of mobile radio systems. A manager (frequency broker) is necessary for the systems optimal work. Its operating in quasi-real time will enable fast changes of radio data in the broker's area of responsibility. The article discusses the currently employed frequency assignment system and architectures of the systems implementing dynamic spectrum access. Their main features are presented and an application implementing a frequency broker function is described. Finally, the authors have presented conclusions regarding the work of the broker with the employment of the radio equipment in service. A prototype of the proposed solution is being developed within the research project OR 000187 12 "Concept of coordinated dynamic spectrum management system for wireless infrastructure used in antiterrorist systems" by the consortium of Military Communication Institute, Military Academy of Technology and RADMOR.

Keywords: dynamic spectrum management, frequency planning, .combat radio nets, frequency broker.

1 Introduction

Due to high dynamics of military operations, wireless systems have become the main means of communications. In most cases, these actions are carried out in a highly saturated electromagnetic environment. Wireless systems are endangered by a high level of interference, which leads to a disturbance of their operating. These effects are the result of both a lack of spectrum, which is a limited natural resource as well as of the present management practice - based on static methods of frequency allotment and assignment. Moreover the timing level of spectrum use rarely exceeds 10%.

These observations provided good reason for the commencement of research on increasing the efficiency of spectrum utilization by applying the DSA (Dynamic Spectrum Access). The concept of DSA is the implementation of an idea of sharing the spectrum by different wireless systems.

In professional literature on the subject, two DSA architectures are discussed:

- CDSA (Coordinated Dynamic Spectrum Access) which is based on the use of some infrastructure with the frequency broker as its main element.

- OSA (Opportunistic Spectrum Access) which implements the idea of an opportunistic use of spectrum fragments, which are temporarily not used (spectrum holes) with rules in force of not interfering with other radio devices. Within the framework of this idea, the necessity of creating advanced methods for testing the spectrum occupation has been provided for. This philosophy will find place in the future of new generation systems – so called *Cognitive Radio* (a radio device that learns about the electromagnetic environment by itself).

Fig. 1, adapted from [4], depicts the overall spectrum access taxonomy – from the current regime of static spectrum access, with the least flexible spectrum use, to the most flexible spectrum use enabled by OSA.

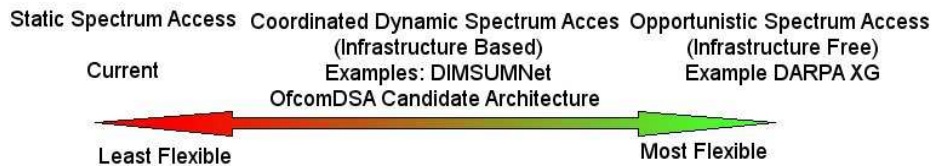


Fig. 1 Spectrum Access Taxonomy

The practical implementation of the DSA idea requires the implementation of proper spectrum management methods, which take into account dynamic changes of the environment, systems mobility and possible influence of electronic warfare systems. No matter what the spectrum management philosophy is chosen, both concepts lead to frequent changes (reprogramming) of the parameters used by transceivers.

The article discusses the possibility of using the frequency broker, which enables a generation of frequency plans based on the chosen interference criteria, and automatic distribution of the generated plans to the proper radio devices.

2 Combat radio nets and ways of employing them

Many types of radio communication are used by the Polish Army, which were commissioned at different periods of time. Nowadays digital radio stations dominate, although analog, medium power radio stations of the previous generation are still employed. Their use is somewhat limited. The new generations of narrow band radio stations are commissioned, providing greater possibilities for data transmission and ECCM area. Despite narrow band radio stations working in HF, VHF bands, and wide range (working on frequencies below 512 MHz) there are also broadband radio stations. During operation and specialist training, radio communication is provided mostly through:

- VHF radio stations working in radio networks, using analog and digital mode on constant DFF frequency;
- HF radio stations working in ALE 3G mode;
- broadband radio stations working in radio networks and directions in analog mode and with a TACSAT satellite system connection;

- short range radio stations used for voice communication of landing troops and armored vehicle crews;
- specialized BFT system devices.

Basic military field radio stations of the Polish Armed Forces operate within the VHF range in different modes:

- analog, without employing any security
- digital on determined frequency with security provided by employing COMSEC keys
- FH, FCS and MIX – secure against results of electronic warfare. These modes provide security by using COMSEC and TRANSEC keys.

Differences between particular modes of VHF radio stations used in the Polish Armed Forces have been presented below. The use of COMSEC and TRANSEC keys in these modes has also been presented.

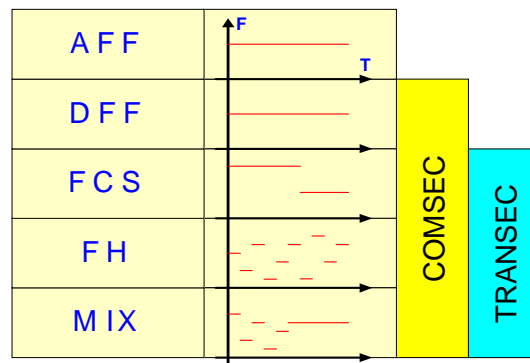


Fig. 2 Operation modes of combat VHF radio stations used by the Polish Army

The use of frequency hopping modes (FCS, FH, MIX) highly reduces the probability of successful recognition of a radio communication system and immunizes the system against willful interference, moreover immunizes the radio communication system against interference from its own devices (by providing internal system compatibility).

The design works and research on military field communication systems and on electronic warfare systems, carried out by the Military Communication Institute, confirm benefits of using FH modes. Present EW systems provide swift detection, with high accuracy sources working on a single frequency (even in a DFT digital mode), as well as effectively disable them. Efficiency of interference decreases when radio devices are working in the FH mode in discontinuous frequency bands. As a result, source detection takes longer and possible jamming is more complex. Most efforts degrade connectivity, rather than cause total incapacity.

Nowadays, radio communication systems working in the FH mode must obtain from the local frequency manager the frequency plans generated in SFAF format with included working radio networks in FH mode. The Military Bureau of Frequency Management was entrusted with this task in Poland. Supervision over the radio data

in a contingent is exercised by the Frequency Manager, appointed by the Communication Chief. After having collected available frequencies, the communication organizer may generate appropriate radio data. An optimal radio frequency plan, taking into account internal system compatibility contains input data for the COMSEC and TRANSEC key generation process for radio networks. Received radio data for a military field radio station can be entered manually, but it is a complex and time consuming task, and in some cases, impossible to perform. The FillGun utility is employed with a view of automating this process.

Standard actions in a security domain of crews using radio resources and transmitting information leads to the following recommendations:

- using lowest transmit power that provides communication;
- using an emission modes resistant to interference;
- using almost optimal frequencies;
- firstly working in digital mode with frequency hopping, secondly on constant DFF frequency, finally in analog mode.

In practice, the implementation of these conditions depends on local conditions, which are highly variable during manoeuvres. In some cases, determined frequencies are not correct, even with increasing the power of sending signals. The taking into account of changes occurring in the electromagnetic environment is only possible where there is an existing effective programming mechanism for radio devices. This programming mechanism can provide corrected radio data to working devices and should be commenced as a result of radio networks status analysis and of the analysis of the spectrum use rate. Possibilities of remote configuration will be described in further on in the article.

3 The concept of the frequency broker

The main element of the CDSA (Coordinated Dynamic Spectrum Access) architecture is a frequency broker, the task of which is to generate frequency plans and to distribute them. An exemplary block diagram of the frequency broker application is presented in the Fig. 3 .

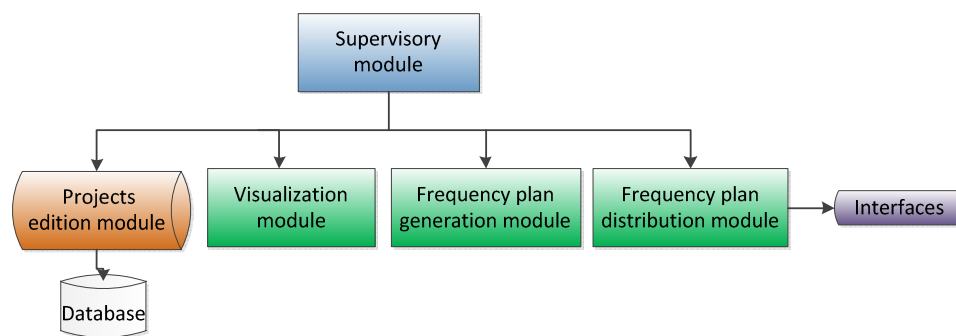


Fig. 3 Frequency broker application block diagram

The frequency broker application consists of modules described below:

- supervision module – module responsible for communication and data sharing between selected modules of the frequency broker;
- projects edition module – module responsible for the proper modeling of radio devices and defining of a radio network structure;
- database – based on an xml file, which contains necessary data in the frequency plans generation process, especially the communication system structure;
- visualization module – module responsible for the visualization of the defined radio network localization on a map base;
- frequency plan generate module – module responsible for the frequency plans generation based on interference criteria defined before;
- frequency plan distribution module – module responsible for the frequency plans distribution to selected radio devices;
- interfaces – set of network interfaces responsible for correct radio data distribution.

Exemplary frequency broker application windows will be presented further on in the article.

An “Open project” window is the starting window of the frequency broker application. It enables a choice of the database (user can type the path to the xml file) and to choose a project from the defined radio networks list.

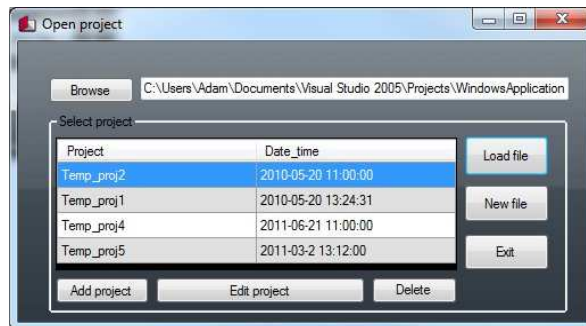


Fig. 4 Open Project form

A „Radio stations modeling” window enables the user to add/remove networks and radio stations within these networks. The user can define network parameters which are important from a frequency assignment algorithm viewpoint, such as communication network structure (allocation of radio devices, available frequencies, parameters of particular radio devices which affect the frequency assignment process).

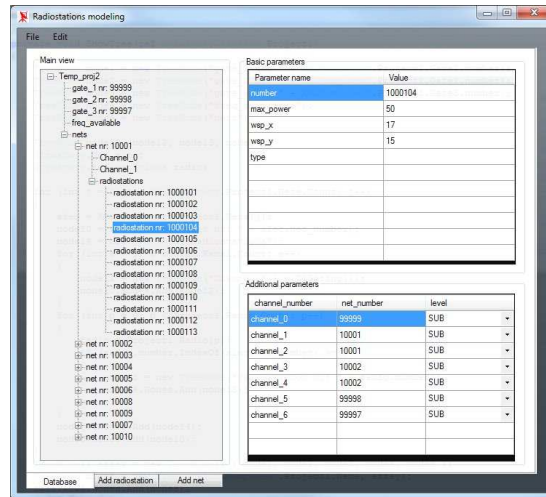


Fig. 5 Radio stations modeling form

A „Frequency broker” window provides the visualization of radio devices, working within defined networks. It enables the user to add/remove radio devices. It is possible to perform basic operations on maps such as: enlargement, distance measurement, centering and cross-appointment. Furthermore it generates and distributes the frequency plan which is valid with specified interference criteria. Buttons performing functions of frequency plans generation and their distribution are marked in Fig. 6 with a red perimeter. This figure also presents an exemplary radio devices arrangement on the map base - 3 radio networks: 4 radio stations within the first radio network (blue), 5 radio stations within the second radio network (red), 2 radio stations within the third radio network (orange).

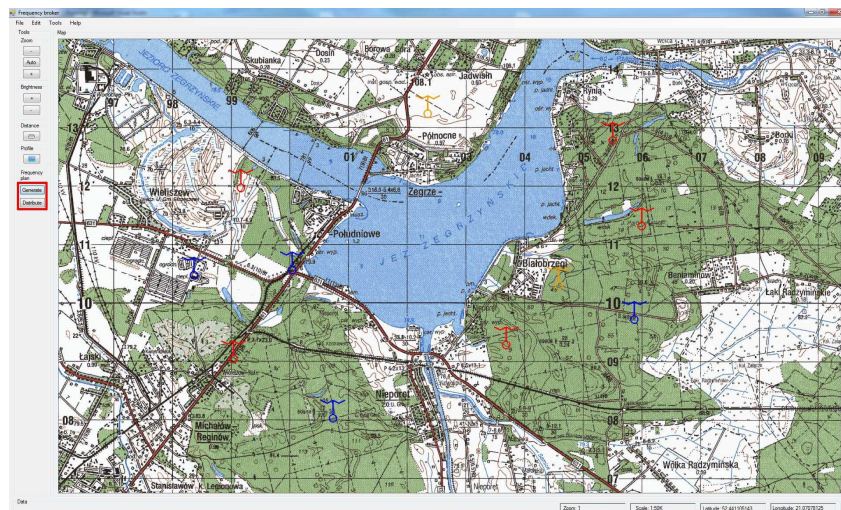


Fig. 6 Frequency broker form (with example of defined radio stations)

4 Radio data generation module

The frequency broker is a specialized application, installed on a computer connected to the station. The broker in the radio data generation process takes into account previously defined interference criteria (co-vehical and co-site separation), as well as mutual coexistence of many wireless types of communication systems.

VHF radio networks may be divided into the following groups:

- co-vehical networks –networks where the shortest distance between two subscribers of two different radio networks is greater than 1,5 meter, but no longer than 10 meters. Subscribers of these networks are in the same object (command car);
- co-site networks –networks where the shortest distance between two subscribers of two different radio networks is greater than 10 meters, but no longer than 400 meters. Subscribers of these networks are in the one command point (group of radio resources);

For co-vehical networks, instead of a previously accepted value, which defines a separation in wave numbers, another separation has been accepted, which defines the distance between upper frequency of the low band and lower frequency of the upper band to radio stations not interfering with each other.

The two co-vehical radio networks with sub bands F_{min1} , F_{max1} and F_{min2} , F_{max2} with $F_{min2} > F_{max1}$ will not interfere if and only if:

$$0,09 * F_{min2} \leq (F_{min2} - F_{max1})$$

In the case of other radio networks, the determination of the necessary separation in the frequency domain depends on the accepted model of radio waves suppression and other parameters of radio resources such as: transmit power, transmitter characteristics, and receiver characteristics.

In order to determine the probability of radio network interference, the following measures have been defined:

- probability of interference between two radio networks;
- probability of interference in the 'I' network by other networks.

The probability of interference between two radio networks with an assigned frequency bands are evaluated as a number of pairs of frequencies, which are interfering by referring to the sum of all possible pairs of frequencies, that is the product of all frequencies in both bands.

$$P_{i,j} = \frac{z_{ij}}{l_i * l_j}$$

where z_{ij} - number of pairs of frequencies, which do not satisfy the conditions,

determined by interference criteria;
 l_i - number of frequencies in the i band
 l_j - number of frequencies in the j band;

Probability of interference with the 'i' radio network by 'j' other radio networks for $j = 1, \dots, k$ and $j \neq i$ is evaluated from dependence:

$$P(i) = 1 - (1 - P_{i,1})(1 - P_{i,2}) * \dots * (1 - P_{i,k}),$$

where $P_{i,j}$ is the probability of interfering with an 'i' network by the 'j' network.

5 Module of the radio data distribution

For a full use of the capabilities of the coordinated dynamic spectrum management system, the employed radio devices must be susceptible to remote radio data changes. Methods of radio data distribution for the most popular radio stations used in the Polish Army are presented below in order to illustrate the problem.

5.1. Use of the OTAR function in VHF radio stations

The OTAR (*Over The Air Rekeying*) function in the PR4G radio stations family enables data change by radio signal. The data is sent between the radio station which is connected to a computer with the *Frequency Key Load Unit* application installed within, and other radio stations in the radio network in question.

In order to modify data in radio stations by the radio signal, the computer implementing a frequency broker function should have the OTAR application installed, which permits to:

- read the data from a programmer (*fillgun*);
- read the data from programmer files located on the computer hard drive;
- implement of the OTAR procedure;
- record some more important events.

The implementation of the OTAR procedure consists of the three following phases:

- 1) checking of the correctness of initiating data
- 2) load initiating files to a radio station connected to a frequency broker;
- 3) transmission of initiating files to previously defined receivers.

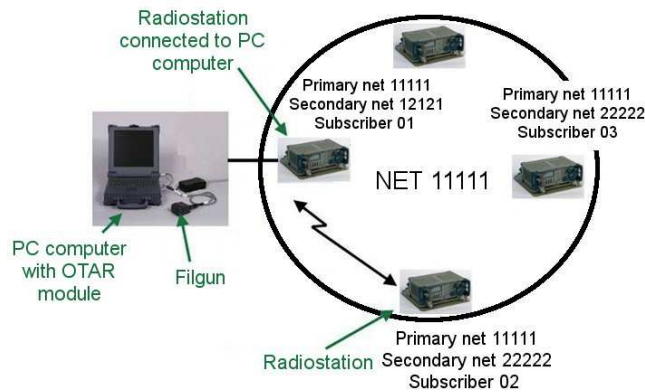


Fig. 7 The method of using the OTAR function

5.2. Data distribution in HF radio stations

By using the RPA (*Radio Programming Application*) application, it is possible to remotely change radio data in Harris's HF radio stations. The result of RPA application operations is a recording of all radio data in the appropriate text file, sent it to the radio station. The generation of that file is also possible without using the RPA application after implementing its function to a frequency broker. In order to perform a change of the data in the radio networks, it is required to store a created file in the memory of the radio station connected to the frequency broker. Next, the user should send it to other subscribers within the radio network. The change of radio data is done automatically.

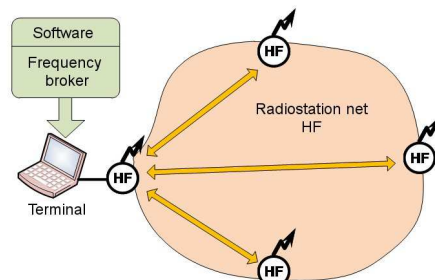


Fig. 8 Remote control of HF Harris radio stations idea

6 Summary and conclusions

A concept of the frequency broker employed in the frequency assignment process for the battlefield radio station has been presented in the article. The analysis of the remote configuration function, which is commonly used in radio stations, was performed, focusing on radio data changes in quasi-real time. Because of these possibilities, the idea of spreading dynamic spectrum management becomes real.

Radio data generation issues have been discussed in the article, along with a presentation of the co-vehical and co-site criteria. The idea of the VHF radio station (use of the OTAR function) and HF radio station (distribution of the radio data file) remote configuration have also been discussed.

The prototype of the frequency broker is being developed within the framework of the research and development project: nr OR 000187 12 „ Concept of coordinated dynamic spectrum management system for wireless infrastructure used in antiterrorist systems”. The use of the frequency broker will improve the efficiency of the available frequency spectrum management and will make battlefield radio networks more resistant to internal and external interference. That will also contribute to the optimal use of operation modes with the spread spectrum and improve network security.

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