Selected issues of modern HF Communications

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Abstract. A steady growth of interest in HF radio communications is observed at present. Similarly to satellite communications, HF radio communications offers global range. The undoubtful virtue of it is cheapness and technological independence in comparison to satellite communications. The disadvantage is low throughput of HF channel and significant influence of propagation environment on the quality of transmission (ionospheric forecasts have to be considered when allocating work frequencies). The description of HF radio communications has been presented in this paper. Major military standards were enumerated and briefly described. MCI-made software package to generate ionospheric forecasts was presented. Calculated ionospheric forecasts were compared to those measured. At the end HF Radio Communication Planning Algorithm was described.

Keywords: frequency planning, HF communications, communication standards in HF.

1 Introduction

Ionosphere is the part of atmosphere which lies 60 km above the Earth surface. The main cause of ionization is the Sun. Ionization is also caused by cosmic radiation, star radiation, cosmic dust and meteors. Influence of the Sun is strongest in the morning and close to the noon. In the afternoon it weakens and recombination become dominating. It intensifies by the night but ionization doesn't disappear completely and upper layers of atmosphere still keep some level of ionization. It turns out that the distribution of electron density in ionosphere is not steady. It depends on the intensity of ionization factors, atmosphere heterogeneity and pressure differences.

The wave propagation in ionosphere is influenced by phenomenon as follows:

- diffraction, that returns waves to the Earth;
- dispersion, that changes the wave speed in function of frequency;
- wave absorption caused by collisions of electrons with particles of gases and ions often joined with refraction.

The measurements of an electron density performed with rockets and satellites of the Earth have showed that there are only two distinct maxima of ionization. The first one is located at the height of 90 - 170 km (layer E). The next one – layer F starts at the height of 200 km and extends to 500 km. Layer F has been divided into sublayer F1 (200-300 km) and sublayer F2 (300 - 500 km). The lowest layer of ionosphere designated as layer D is present during the day and is located at the height of 40 - 60 km. Similarly, layer F is present during the day and disappears during the night.

The propagation conditions of HF waves are dependent on the state of ionosphere which is designated by the time of day, time of year and phase of the Sun activity cycle. These conditions define MUF - Maximum Usable Frequency and LUF – Lowest Usable Frequency values in the way as follows:

- MUF values are larger in the day then in the night;
- MUF values are larger in the summer then in the winter;
- MUF values in the day time for layer F are larger in the winter then in the summer. MUF values for other layers are larger in the summer then in the winter;
- MUF values are larger during the strong Sun activity;
- LUF for short distances reach their maximum values in the afternoon and leave out the HF range during the night. LUF values are irregular for long distances.

Because of reasons presented above HF waves hale been divided into three ranges:

- the day waves (10 – 25 m) used for the day connections;
- the night waves (35 – 100 m) used for the night connections;
- the night waves (25 – 35 m) used during the dusk and down.

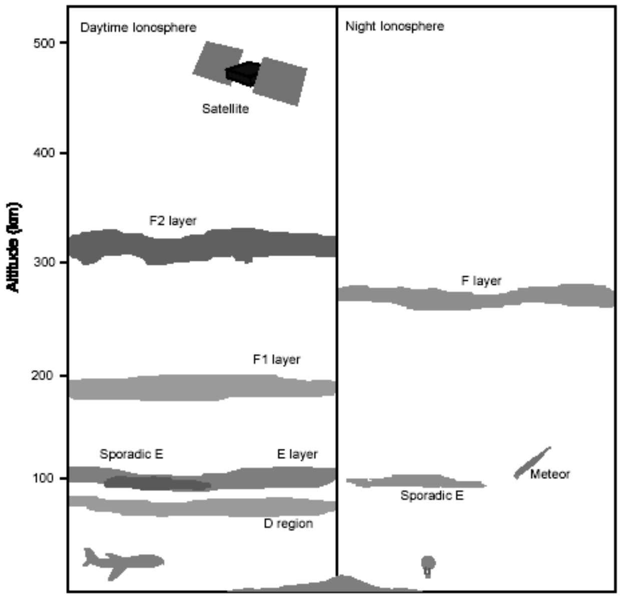

Fig. 1 The night and day ionospheric layers

2. Functional Characteristics and Technical Overview of HF Communications Waveforms

This paragraph presents some basic information about standards, MIL-STD and STANAG intended to be applied in HF radio communication. These standards can be arranged according to STANAG 4539 in the HF house that was shown in the Fig. 2. Standards included in the HF house implement three layers of the ISO/OSI model and deliver an interface to higher ISO/OSI layers. The first floor – the Physical Layer of the OSI/ISO model – is created by standards that together constitute the concept of multi-waveform which gives two possibilities – to use appropriate waveform depending on the propagation/interference conditions and to add new standards. The second floor – the Link Layer and the Network Layer of the ISO/OSI model – is created by standards of two basic operation modes, *non – Electronic Protection Measures* mode and *Electronic Protection Measures* mode. EPM mode is specified in STANAG 4444. The non-EPM mode is implemented by the rest of the HF house.

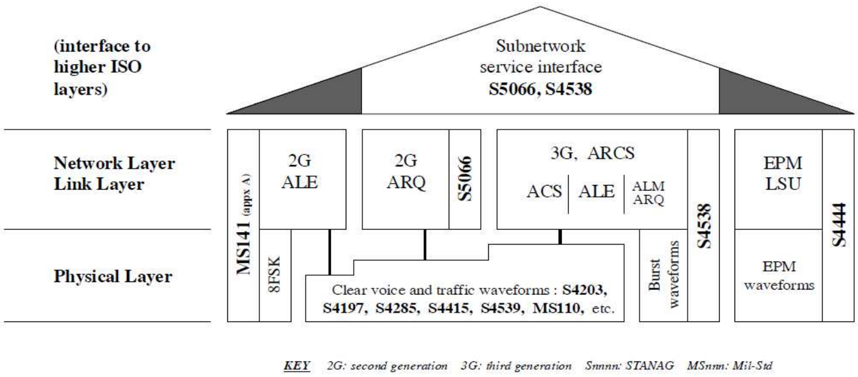

Fig. 2 The HF house of standards

The Link Layer and Network Layer standards implement ARCS (Automatic Radio Control System) process which enables HF radios to select communication channels automatically, establish and maintain links according to the user requirements. ARCS process includes three components. They are shown in the Fig. 3.

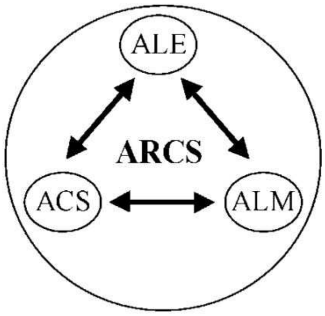

Fig. 3 ARCS process circle

Automatic Channel Selection (ACS) is a process which automatically selects one or more channels from a set of available channels to match waveform and traffic requirement to propagation and interference conditions.

Automatic Link Establishment (ALE) is a process which automatically sets-up an appropriate link, using selected channel or channels. The ALE process is divided into Link Setup (LSU) and Traffic Management (TM) processes.

Automatic Link Maintenance (ALM) is a process which provides continuous availability of the established communication link.

Interface to higher ISO/OSI layers provides a common, standard interface between the HF subnetwork and "rest of the world". This interface implements a client-server model where users (clients) request services delivered by HF subnetwork (server).

3. Description of HF Radio Communication Planning Algorithm

The authors designed HF Radio Communication Planning Algorithm composed of several steps. The first step is defining a project with parameters as follows:

- id number;
- name;
- Wolf's number;
- month of validity.

Having project parameters defined a set of available frequencies must be defined. They are later used for frequency planning.

When project parameters and the set of available frequencies are defined, HF radio networks and transceivers working in these networks have to be selected. For each transceiver some parameters must be given:

- name;
- latitude expressed in degrees;
- longitude expressed in degrees;
- transmit power expressed in Watts;
- transmit antenna gain expressed in dBi;
- receiver sensibility expressed in dBm;

- receiver antenna gain expressed in dBi.

After all input parameters are defined, the algorithm starts calculation.

Number of possible connections between nodes (transceivers in the radio network) is expressed by the formula:

$$P = \frac{n*(n-1)}{2} \quad (1)$$

where:

P – number of possible connections in the radio network;

n – number of transceivers in the radio network.

For each connection in the radio network the distance between the nodes is counted by formula:

$$
\begin{aligned}
& r = \frac{\pi}{180} \\
& d = \frac{180}{\pi} \\
& q = \sin(x_t * r) * \sin(x_r * r) \\
& x = q + \cos(x_t * r) * \cos(x_r * r) * \cos(y_t * r - y_r * r) \\
& l_a = -\arctan\left(\frac{x}{\sqrt{-x * x + 1 + 10^{-12}}}\right) + \frac{\pi}{2} * d \\
& l = \frac{40000}{360} * l_a
\end{aligned}
\quad (2)
$$

where:

x_t – the latitude of the first node;

y_t – the longitude of the first node;

x_r – the latitude of the second node;

y_r – the longitude of the second node;

l – the distance between nodes expressed in km.

After the distance for each connection in the radio network is calculated, the algorithm starts to compute the ionospheric forecast or look for it in a data base. Calculating the ionospheric forecast is made by an algorithm implemented in the HF Radio Communication Planing Application. However, if the ionospheric forecast for a given month and Wolf’s number exists in the data base it can be used. In order to work out the ionospheric forecast for an HF radio connection the distance between transceivers is needed apart from the month and Wolf’s number. Prediction is assumed to be correct for all transceivers located in the vicinity of the place for which the ionospheric forecast was made, i.e. the distance between transceivers and the forecast locations does not exceed 50 km.

After defining ionospheric forecasts for each connection in the radio network the allocation of frequencies is carried out. In order to allocate frequencies, that could be used by the radio network, it is needed to estimate Maximum Usable Frequency MUF(t) and Lowest Usable Frequency LUF(t) for each ionospheric forecast and given hours.

In the next step, allocated frequency range is compared with the set of available frequencies. Then the allocation of the closest frequency to the Frequency of Optimal Transmission FOT (0.85 MUF approximately) is performed. If a frequency is used for one radio network it can’t be used for any other.

In the figure below the way of action of the Frequency Allocation Algorithm for HF radio networks is presented. An exemplary frequency allocation for a radio network composed of four transceivers, placed at defined geographical positions is shown in the Fig. 4.

The calculation of all distances between transceivers in the radio network is done after pushing the “*Oblicz parametry*” (Calculate parameters) button. Results are displayed below and to the left of the button.

The graph of calculated values of LUF (green) and MUF (red) for the radio network is shown to the left whereas tables containing values of LUF and MUF are placed below.

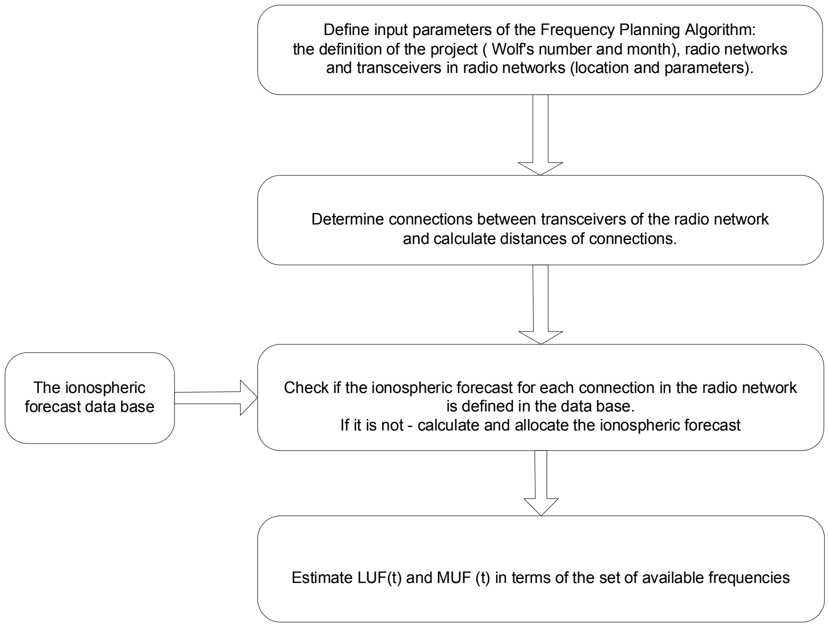

Fig. 4 The frequency allocation algorithm for HF radio networks

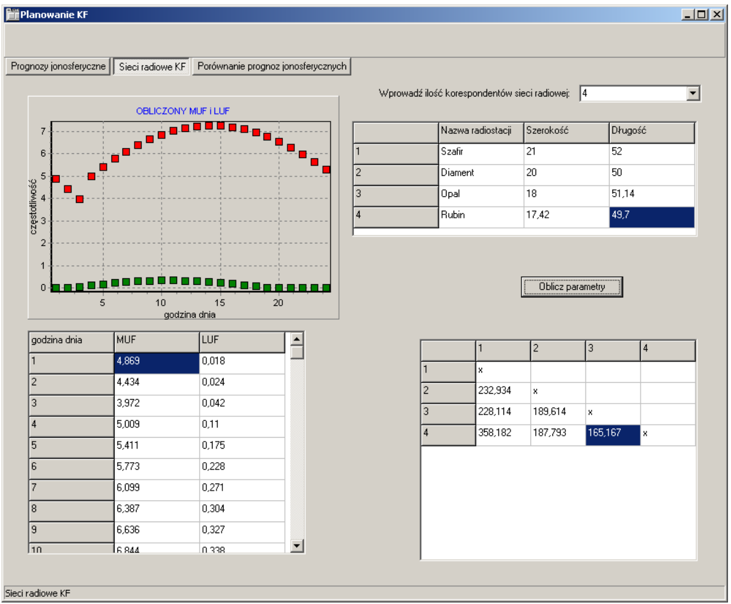

Fig. 5 Calculated values of LUF and MUF for a radio network

4. Results of the executing of HF Radio Communication Planning Algorithm

This paragraph contains comparison results of calculated ionospheric forecasts and ionospheric forecasts made by Space Research Center of the Polish Academy of Sciences in Warsaw.

Ionospheric forecasts made by Space Research Center of the Polish Academy of Sciences in Warsaw are shown in red while calculated ones in blue.

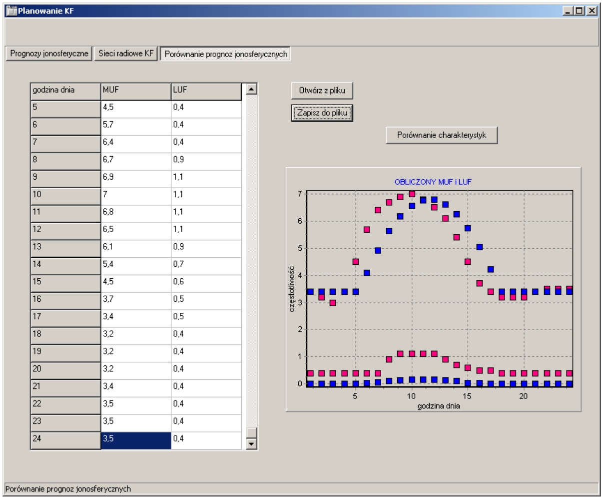

Fig. 6 The distance between transceivers 200 km, Wolf's number 12, month 11

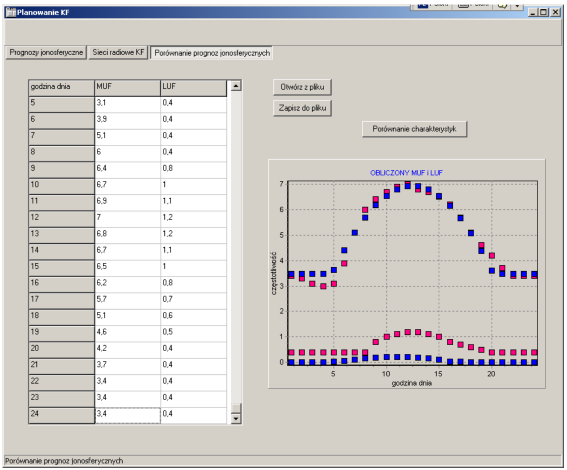

Fig. 7 The distance between transceivers 200 km, Wolf's number 14, month 9

5. Conclusions

At present HF radio communications is an alternative for satellite communications because of new coding and modulation methods. The efficient usage of HF radio communications is related to the proper planning of it.

In this paper a software application for planning HF radio communications and some information on military standards concerning HF transmission have been described. The application permits of designating MUF and LUF values for a radio network, basing on the previously defined input data (distance between transceivers in a radio network, Wolf's number, the month of a year) which enables to use fully capabilities built in modern HF transceivers.

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