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DESIGN AND TESTING OF AN AUTOMATED RECEIVING SYSTEM FOR THE IONOSPHERIC SOUNDING IN HF RADIOFREQUENCY RANGE

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Abstract: The paper presents a system designed for automatic measurement of signal level in ionospheric channels based on a spectrum analyzer controlled by a software application developed for fast and flexible sounding. It enables choosing of desired frequencies, bandwidths, times and duration of monitoring and customized recordings. The measured values of two ionospheric channels were compared against the ones provided by the prediction of the commercial application Voice of America Coverage Analysis Program (VOACAP). Sounding recordings proved that automatic measurement is able not only to assess realistic received power versus time continuously but also to distinguish fading periods.

Keywords: *continuous ionospheric channel monitoring, signal to noise ratio, ionospheric channel power, HF automatic receiving system.*

I. INTRODUCTION

Communications in the High Frequency (HF) range show some features, which are particularly connected to the behavior of the ionospheric channel. Depending on the ionospheric channel status one can obtain variable data rate of transmission and therefore a permanent knowledge of ionosphere parameters can lead to substantial improvement of data rate. An example of this is the STANAG 4539 standard [1], which recommends radiofrequency waveforms tailored to variation of the ionospheric channel.

Ionospheric propagation mechanism leads to rapid variations of channel parameters even in relatively narrow frequency bands, so the transmission channel has reduced bandwidths. In the last period of time specialists were interested about increasing data rate techniques through the use of special waveforms with bandwidths between 3-24 kHz [2], [3], [4]. In [3] authors have shown that data rates up to 80kbps were achieved in 24 kHz bandwidth even in the situation when the ionospheric channel had a relatively low signal to noise ratio (SNR).

A significant increase of data rate of transmission could be achieved if the ionospheric channel status is constantly monitored over time and an appropriate waveform is produced in due time in connection to instantaneous SNR value. For example if SNR is high – this allows choosing modulation schemes that are spectral efficient - such as Quadrature Amplitude Modulation (QAM) class - that enables a considerable increase in data rate of transmission. Such considerations show the need of ionospheric channel status assessment.

Two ionospheric sounding techniques are mostly used: passive sounding – in which signals arising from different ionosondes are monitored and oblique sounding – in which locations of emitter and receiver are situated at some longitudinal distance one from another. Estimating SNR in such cases is based on sweeping of some emission parameters (operating frequency, emission level, emission duration) and reception of the signals followed by processing them in order to establish optimal parameters for communication in the HF range.

Application of ionospheric channel prediction can be achieved by using different prediction models, one of the widely used being International Reference Ionosphere (IRI) [5]. The predictions can be made on the short or on the long term. For Europe, relevant information is provided by the European Ionosonde Service (EIS) of the SSA Space Weather Service Network that collects and processes real-time data from the 10 ionosondes placed over Europe [6]. The portal of the service enables near real-time data provision for later retrieval and the use of various ionospheric parameters that allow monitoring the variations in any part of Europe, depending on geographic location, date and hour of the day. Such information is particularly helpful for near vertical incident skywave propagation, which is the case of coverage of just a national territory like Romania.

A number of studies have shown the possibility of reducing errors of ionospheric predictions by connecting predictive models to the ionospheric measurement database in real-time [7], [8]. An example would be the comparative analysis of measurements provided by the UK ionosonde (in Chilton location) and HF propagation prediction software results given by Advanced Stand Alone Prediction System (ASAPS) and Voice of America Coverage Analysis Program

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(VOACAP) [8].

Present paper aimed at the implementation and testing of an automated reception system for ionospheric sounding and permanent monitoring of the propagation conditions. The system is composed of a broadband receiving antenna in the range 2-30 MHz and a swept spectrum analyzer automatically controlled through a software application that enables determination of the channel power. The original core of the system is centered on the software application developed to control an essential set of analyzers' parameters for a fast and reliable channel power measurement process: selection/sweeping of needed frequencies; adjusting the channel acquisition bandwidths; controlling the periodicity and duration of channel monitoring; automatic data recording. System testing was performed by measurements of an ionospheric channel having 3 kHz standard bandwidth. The system can be also used for passive ionospheric sounding as it can be programmed to monitor a set of frequencies for which the channel power level is obtained and retained.

II. MATERIALS AND METHODS

Ionospheric sounding reception system comprises of a receiving antenna and a software controlled spectrum analyzer. Receiving antenna is a broadband Diamond W330 dipole covering 2-30 MHz range and has a standing wave ratio (SWR) not exceeding 1.5 for the whole usable band. Therefore the antenna doesn't require a supplementary tuning. Spectrum analyzer FSH3 by Rohde & Schwarz has a frequency range of 80 kHz-3 GHz, -120 dBm sensitivity and a minimum sweep time of 20 ms. For sounding the analyzer is set in "Channel Power" mode with all parameters controlled by software. The application automatically controls the data acquisition process as well. The application allows: 1. selection of the reception frequencies; 2. evaluation of channel power level in variable bandwidths (3 - 24 kHz); 3. control of the channel monitoring duration ; 4. automatic data recording. Figure 1 shows the measurement system.

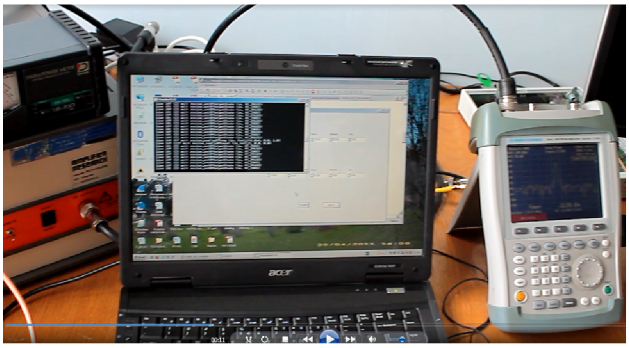

Figure 1. Automatic receiving and monitoring system for ionospheric sounding

For the implementation of application software, Lab Windows CVI programming environment 2012 was used [9]. Through the graphical interface (Figure 2) the spectrum analyzer parameters are set (resolution bandwidth - RBW, reference level - Amplitude, sweep time - Sweep, bandwidth for channel power measurement - Ch BW), the start time of the evaluation (START - DAY, MONTH, HOUR, MINUTE, SEC), the time of assessment end (STOP - DAY, MONTH, HOUR, MINUTE, SEC), duration of monitoring of one ionospheric channel (RECORDING_TIME), the time interval between two successive recordings of the same ionospheric channel (INTERVAL_TIME). The software will load a file type *.txt which contains values of the central frequency for the channel to be evaluated. Between monitoring two different ionospheric channels, the measurement system can have a break the duration of which can be set with parameter "Time_between_sounding" in the graphical user interface (GUI). After completing the assessment, the software will return a **.txt file type where there exist the frequencies, the correspondent power levels of the ionospheric channel and the moment when the recording took place.

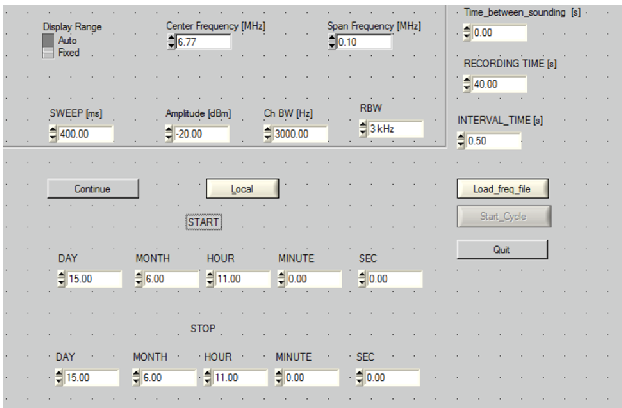

Figure 2. GUI of settings of the monitoring parameters of the ionospheric channels

It is expected that measured ionospheric sounding channels power levels to be relatively low, close to the sensitivity level of the spectrum analyzer. Therefore besides amplitude reference level, a critical parameter to be correctly set is RBW. Decreasing RBW will lead to the reduction of Display Average Noise Level (DANL). Thus, by reducing RBW 10 times, DANL will decrease with 10 dB, as showed bellow [10]:

$$\Delta = \left| DANL_1 - DANL_2 \right| = 10\lg \frac{RBW_1}{RBW_2} \qquad (1)$$

RBW reduction also has an effect on reducing the sweeping velocity (sweep time increasing) [10]. Sweep time depends on frequency SPAN and on RBW following the relation [10]:

$$\frac{SPAN}{SweepTime} \le \frac{RBW^2}{k} \qquad (2)$$

In relation (2) k is a constant that depends on the spectrum analyzer type. This means that in order to track rapid variations of the signal, RBW value cannot be reduced. If the measurement goal is not to track rapid signal variations, but only ionospheric sounding, than RBW can be reduced to the minimum allowed by the analyzer. This will allow a low DANL level and therefore measurement sensitivity will be improved. In Figure 3 one observes the displayed noise level of the FSH3 spectrum analyzer in case RBW = 100Hz. To measure the channel power with a bandwidth of 3 kHz, frequency SPAN will result in a minimum of 5 kHz which will lead to a proper functioning of the analyzer at a minimum sweep time of 5s. It can be seen that the noise floor is -130 dBm and the channel power at a bandwidth of 3 kHz is -115.44 dBm. This means that if the electromagnetic environment doesn't introduce additional noise, the receiving sensitivity is better than -120 dBm.

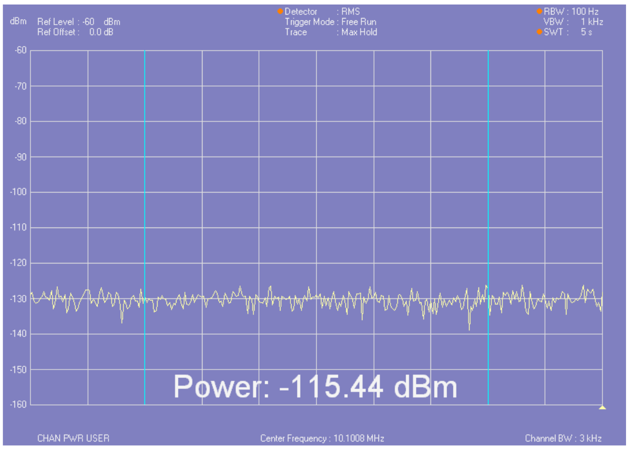

Figure 3. Displayed noise level of FSH3 analyzer in case: RBW=100 Hz, SPAN=5 kHz and SweepTime=5s

III. RESULTS AND DISCUSSION

The receiving system testing was conducted by monitoring two ionospheric channels on frequencies of 10100.8 kHz and 7646 kHz. These values represent central frequencies of channels permanently broadcasted by the German Meteorological Service of Hamburg [11]. The main parameters for receiving of these channels are presented in Table 1 while in Figure 4 one observes the ionospheric channel spectrum received in Sibiu city (Romania) on center frequency of 10100.8 kHz. The channel power measured on July 6th 2015 at 20.15 local time was -57.29 dBm, which is about 30 dB higher than the noise level.

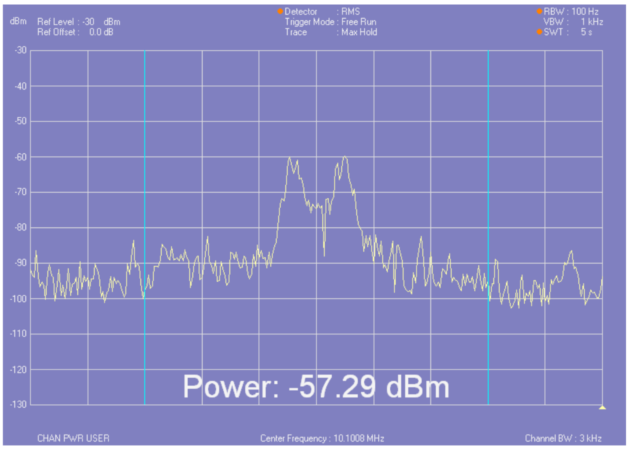

Figure 4. Spectrum of ionospheric channel centered on 10100.8 kHz received in Sibiu, 6 July, 20:15 local time

To analyze the quality of ionospheric radio link between Hamburg and Sibiu, in addition to the measurement of the received signal level we used the prediction given by VOACAP [12]. An important parameter in the application of predictive models is the Smoothed Sunspot Number (SSN) that for July 2015 is considered 53.1 [13]. Running VOACAP application was made with the following inputs: SSN = 53.1; Hamburg emission point (coordinates: Latitude - 53.6023, Longitude - 10.0146, emission power = 1500W, emission antenna = dipole, Tx Mode = SSB - Single Side Band); Sibiu reception point (coordinates: Latitude - 45.7981, Longitude - 24.1425, receiving antenna = dipole). Predicting the reception signal level for July 2015 is indicated in Figure 5. The black line represents Maximum Usable Frequency (MUF) defined as the value for the date, month, SSN and time [12]. To ensure a reliable radio link in HF range it is recommended that the operating frequency to be approximately 80-90% of MUF [12].

Table 1. Parameters of the emission channels

Frequency (kHz)	Emission Time	Emission Power (kW)	Operating Mode
10100.8	00.00-24.00	10	F1B: 50 Baud
7646	00.00-24.00	1	F1B: 50 Baud

Figure 5 shows that between hours 00.00 and 05.00 universal time (UT) frequency 10100.8 kHz is situated above the MUF and between 06.00 and 14.00 UT, reception level can be low, with a more pronounced drop at around 10.00 UT. Therefore using 10100.8 kHz frequency for ionospheric communications between Hamburg and Sibiu is recommended between 17:00 UT and 22:00 UT. The frequency of 7646 kHz is always situated under MUF but between the hours of 06.00 and 16.00 UT reception level may be very low, in some cases very close to losing link.

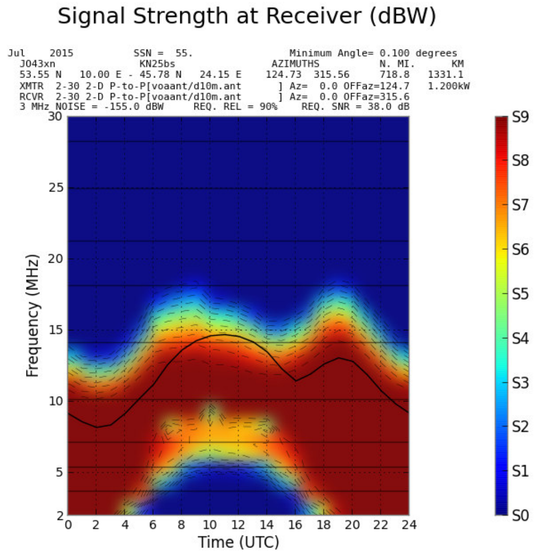

Figure 5. Prediction of the radio link quality in July 2015 for: emission point - Hamburg receiving point - Sibiu

Signal at the reception was monitored during 48 hours between 3 and 5 July 2015 (10100.8 kHz frequency - 24 hours and 24 hours on the frequency of 7646 kHz). Automatic measurement system settings were: measurement mode = Channel Power, Ch BW = 3 kHz, central frequency

= 10100.8 kHz (or 7646 kHz), SPAN = 5 kHz, RBW = 100 Hz, Sweep Time = 5s, sample time = 5s. The automatic data collection was subsequently processed in MATLAB. The results are shown in Figure 6 - for f = 7646 kHz and in Figure 7 - for f = 10100.8 kHz.

Figure 6 confirms that the highest signal strength is received in the time periods 00.00 - 04.00 UT and 19.00 - 22:00 UT (the average power level was -75 dBm). Between 06.00 - 16.00 UT received signal is low (-90 dBm) with an existent risk of losing the link (levels lower than -95 dBm).

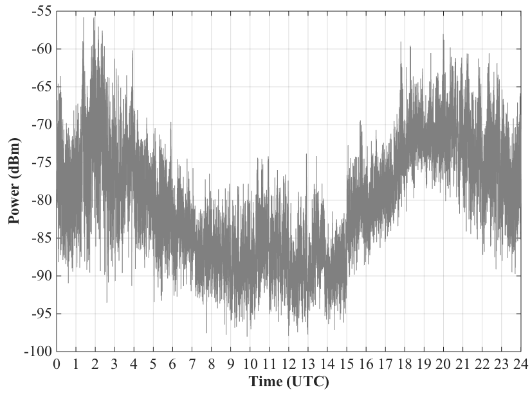

Figure 6. Variation of received power level for channel centered on 7646 kHz

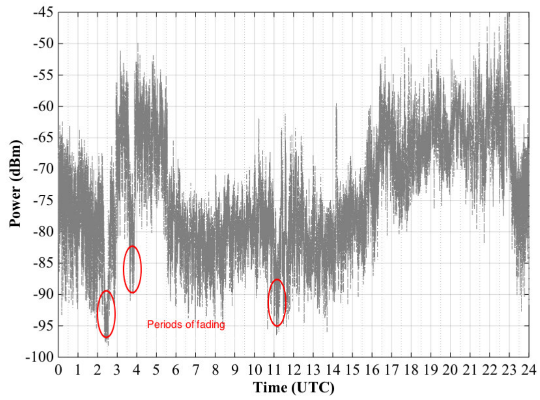

Figure 7. Variation of received power level for channel centered on 10100.8 kHz

Figure 7 indicates the existence of a good and stable reception level between 16.00 - 23.00 UT (about -65 dBm). Even if f = 10100.8 kHz is higher than the predicted MUF by VOACAP, in the time interval 00.00 - 05.00 UT this signal presents however acceptable power levels (between -80 dBm and -70 dBm). Low signal strength levels but without the risk of losing connection is seen between 06.00 - 16.00 UT. An interesting fact highlighted by Figure 7 is the presence, for short periods of time, of decreased signal level – which is fading – circled in red in the graph (at around 02.30, 04.00 and 11.00 UT).

IV. CONCLUSIONS

This paper presents a versatile automatic receiving system for analyzing on the long term, with reduced resources, HF ionospheric channels behavior. The system is based on a swept spectrum analyzer controlled by a software application specially implemented for this purpose.

System testing was performed by continuous receiving of two standard ionospheric channels of 3 kHz bandwidth during 48 hours and allowed in depth analysis of large quantities of data. The quality of ionospheric radio link between Hamburg and Sibiu was tested on frequencies of 10100.8 kHz and 7646 kHz. The processing made by present system highlighted time changes and specific phenomena encountered in HF ionospheric propagation – such as fading. This is a very disturbing phenomena and cannot be predicted. While general profile of received power versus time was respected when comparing predictions and measurements of ionospheric soundings, peculiarities of propagation between the two locations were only available by using present automated system.

An entire sounding system consists of both a transmitter and a receiver. This paper focuses only on the development of the receiver. Future research will consider the integration of the receiving part in the ensemble of emission-receiving system destined for controlled oblique ionospheric sounding over Romania territory.

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REFERENCES

[1] STANAG 4539 (Ed. I), NATO Standardization Agreement: "Technical Standards for Non-hopping HF Communications Waveforms", June 2005.

[2] P. Bergada Carames, "Oblique Sounding and HF Communication Techniques for Very Long Haul Ionospheric Links", PhD Thesis, Enginyeria i Arquitectura La Salle Universitat Ramon Llull, Barcelona, 2014.

[3] I. Icart, et al. "Design and demonstration of a very high data rate multimedia HF communication system", IRST MAY 2012, *The 12th International Conference on Ionospheric Radio Systems and Techniques*, 2012.

[4] Reccomendation ITU-F.1487 (0/2000) "Testing of HF modemswith bandwidths up to 12 kHz using ionospheric channel simulators", 2000.

[5] D. Bilitza, L. A. McKinnell, B. Reinisch, T. Fuller-Rowell, "The International Reference Ionosphere (IRI) today and în the future", *Journal of Geodesy*, 85, pp.909-920, 2011.

[6] SSA Space Weather Service Network, Ionospheric Weather Expert Service Centre: EIS tool: http://swe.ssa.esa.int/web/guest.

[7] M. C. Walden, "Comparison of propagation predictions and measurements for mid-latitude HF near-vertical incidence sky wave links at 5 MHz", *Radio Science*, Vol. 47, RS0L09, 2012.

[8] M. C. Walden, „Analysis of CHILTON ionosonde critical frequency measurements during solar cycle 23 in the context of midlatitude HF NVIS frequency predictions", *HFIA 2012 meeting*, sept. 2012, York, UK.

[9] R. M. Scortar, Bachelor thesis, *System for oblique ionospheric sounding*, Enginnering Faculty, "Lucian Blaga" University of Sibiu, Romania, 2015.

[10] C. Rauscher, *Fundamentals of spectrum analysis*, Rohde & Schwarz, Munchen, Germany, 2001.

[11] http://hfradio.org/propagation_page3.html [Accessed: July 4, 2015].

[12] http://www.voacap.com/prediction.html [Accessed: July 4, 5 and 6, 2015].

[13] http://www.trafficlist.net/2014/03/ [Accessed: July 4, 2015].