PARTICULARLY LOW-COST PORTABLE RADIO FREQUENCY INTERFERENCE MONITORING SYSTEM

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ABSTRACT

We tested particularly low-cost (< EUR 25) software-defined radio (SDR) solutions for radio frequency interference (RFI) monitoring purposes. Two options were tested and a more suitable solution (RTL2832U with Rafael Micro R820T tuner) was chosen for the actual measurements. Radio interference measurements in the frequency range of 50 to 850 MHz were conducted at two different Nordic-Baltic radio observatories: Metsähovi Radio Observatory (MRO), Kylmälä, Finland and Ventspils International Radio Astronomy Centre (VIRAC), Irbene, Latvia. We noticed that the simple SDR solutions are functioning if the main purpose is to monitor the general, long-term radio environmental changes. The computing capacity of these low-cost solutions is still rather limited; thus, the real-time, wide band monitoring is not possible. Our observations showed that VIRAC is an ideal location for the low frequency (< 1 GHz) radio astronomical observations (e.g. LOFAR operations).

KEYWORDS

Radio frequency interference (RFI), software-defined radio (SDR), radio astronomy.

1. INTRODUCTION

Usually, even a simple radio frequency interference (RFI) monitoring system needs a portable spectrum analyser or equivalent [1], [2], **[3]**, which can be relatively expensive (> EUR 1000). Currently there are several simple and low-cost solutions, which are based on software-defined radios (SDRs). They can be used in RFI monitoring purposes as well. Their advantages are the following – very low price, flexibility and portability. The disadvantages are lower sensitivity and measurements' response times. In practice this means that the scanning of wide frequency band may take several minutes. However, if the main purpose is to study the general background interference levels this is not so critical factor. For the real-time interference monitoring system simple solutions are not possible. They will also require more computing and processing capabilities.

In this work, we will test two different SDR-RTL dongles with two different tuners. More precisely, we will study their usability for the RFI observations. In addition, we will make actual RFI measurements at two different Nordic-Baltic radio observatories: Metsähovi Radio Observatory (MRO), Kylmälä, Finland and Ventspils International Radio Astronomy Centre (VIRAC), Irbene, Latvia. Finally, we will make a preliminary comparison about the radio environment between the observatories.

2. SOFTWARE DEFINE RADIO – RTL

Low-cost (< EUR 25) RX (receiver) software defined radio (SDR) based on the RTL2832U chipset was chosen as a back-end instead of the traditional spectrum analyser. SDR-RTL is a pocket-size DVB-T (Digital Video Broadcasting - Terrestrial) TV tuner, which is based on RTL2832U chipset. It can receive radio signals over the wide frequency range. In SDR, the necessary radio components are implemented into software. Thus, the hardware implementation is usually simpler. The chip (RTL2832U) allows transferring the raw I/Q samples (magnitude and phase) to the host, which will be further processing. We tested two different SDR-RTL dongles with two different tuners: Fitipower FC0012 tuner and Rafael Micro R820T tuner. The latter tuner covers frequency range of 42 to 1002 MHz. The sample rate used is 2.4 MS/s. Since the device is designed for DVB-T applications, the dongle is matched to 75 Ohm. The mismatch loss between 50 Ohm and 75 Ohm is reported being less than 0.177 dB [4]. Open source software called SDR-RTL Scanner [5] was used for recording the data. The software ran under Linux, Ubuntu 18.04 (under Oracle's VirtualBox). SDR-RTL with Rafael Micro R820T tuner has selectable internal gain values between 0 and 40.2 dB. All the measurements were made on the gain setup of 19.7 dB.

Some SDR-setups have been used for the radio astronomical purposes as well. They are mainly related to hydrogen line (1420.4058 MHz) observations, *e.g.* [6].

2.1. Calibration of SDR-RTL

Fifty ohms resistor was put to dongle's input. We noticed a major difference between the tuners. With the Fitipower FC0012 tuner we observed continuous and extremely strong spikes across the entire frequency range (see Figure 1, upper panel). These spikes come from device's tunable local oscillator (LO). This is a very undesirable feature. The other dongle with the Rafael Micro R820T tuner has more sophisticated LO controlling system and temperature control, and LO spikes are not visible (see Figure 1, lower panel). Due this reason the dongle with Rafael Micro R820T tuner was chosen for the RFI measurements. All the measurements were carried out at the FFT size of 256 bins, and this means 15.625 kHz resolution bandwidth (RBW). The noise floor level is around 110 dBm at RBW level of 15.625 kHz. This was tested by injecting a reference signal to the RTL dongle from the external RF signal generator. The test was performed at 450 MHz.

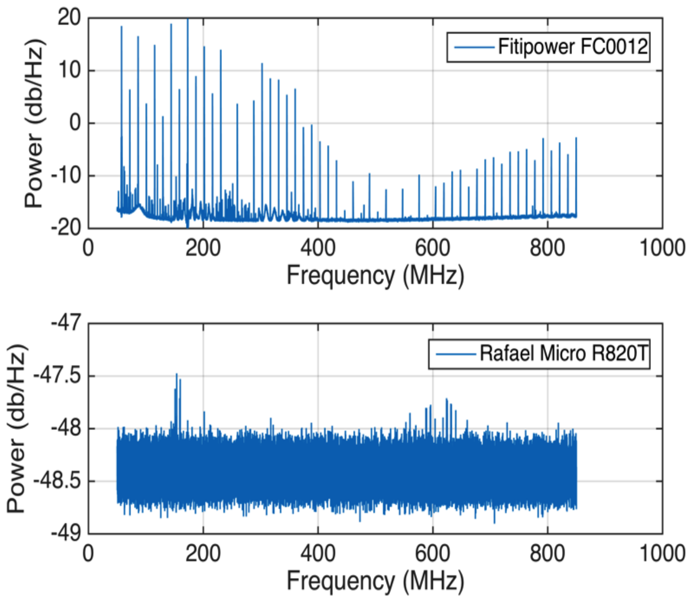

Figure. 1. The spectrum of DVB-T dongles when input is terminated with 50 ohms.

The upper panel – a dongle with the Fitipower FC0012 tuner and the lower panel – a dongle with the Rafael Micro R820T tuner. Both tuners have the same noise floor level (-110 dBm), even though the values in the y-axes are different. This is software related feature.

The dongle was connected directly to the control computer's USB (**Universal Serial Bus**) port and via USB hub as well. We did not see any effect on the SDR's performance on this.

3. SOFTWARE DEFINE RADIO – RTL

An overview showing the technical construction of the portable RFI measurement system is presented in Figure 2. The log periodic printed circuit board antenna (50 Ohm) was used for the measurement [7]. The antenna is designed for the frequency range of 400 to 1000 MHz, but the gain is still reasonable at lower frequencies (50-400 MHz). The gain of the antenna is approximately 4,9 dBi at 700 MHz. We wanted to keep the losses as low as possible between the antenna and the back-end, thus the low-loss coaxial cable RG223 with the total length of 1.5 meter was chosen for the measurement setup. The total loss in the cable is no more than 0.5 dB at 400 MHz. Extra amplifier will not be needed. Thus, the total costs of the RFI measurement system used are less than 100 euros (excluding the control computer), which is considerably less than in the case of the traditional radio frequency interference monitoring system. We selected the frequency range of 50 to 850 MHz for this RFI study.

Figure. 2. An overview of the portable RFI measurement system. The system is consisting of log periodic circuit board antenna, SDR-RTL dongle and control computer.

3.1. RFI Observations

The measurements were carried out in two different radio observatories during Spring and Summer 2018. The observations were made at Metsähovi Radio Observatory (MRO), Kylmälä, Finland and Ventspils International Radio Astronomy Centre (VIRAC), Irbene, Latvia. We used similar measurement setup and principles in both locations. It was a two-fold aim for these measurements: firstly, to test the capability of measurement setup for RFI studies and, secondly, to compare the radio environment between the two Nordic-Baltic radio observatories. MRO is located in more urban environment than VIRAC, thus in this respect, it is interesting to see the difference in the radio environment between the observatories.

3.2. Measurements at Metsähovi Radio Observatory

Aalto University Metsähovi Radio Observatory (MRO) is situated in the Southern Finland GPS: N 60:13.04, E 24:23.35), some 45 km from the capital, Helsinki. The nearest village (Kylmälä) is around 10 km away and the nearest settlements lie at a 550 m distance. MRO operated wide frequency range of 5 MHz to 90 GHz. It should also be noted that all the higher frequencies (> 22 GHz) are down-converted to IF (Intermediate Frequency) bandwidth (500-1000 MHz) and this IF bandwidth is transferred from the receiver to the back-end rack with coaxial cables. The main research areas of MRO are variable quasars, active galaxies, wide-band solar monitoring, molecular line radiation, and astronomical and geodetic Very Long Baseline Interferometry (VLBI).

Interference observations were made on the 15th May 2018. Two different measurements were carried out (antenna was pointed in two different directions: Direction 1, West and Direction 2, East). Each measurement took around one hour thus totally three full scans (50-850 MHz) were measured with the max hold option on that period of time. The measurement results are shown in Figure 3. It is clear directional dependency at frequencies around 800 MHz. The direction 1 (West) shows a lot of powerful interference signal on that frequency.

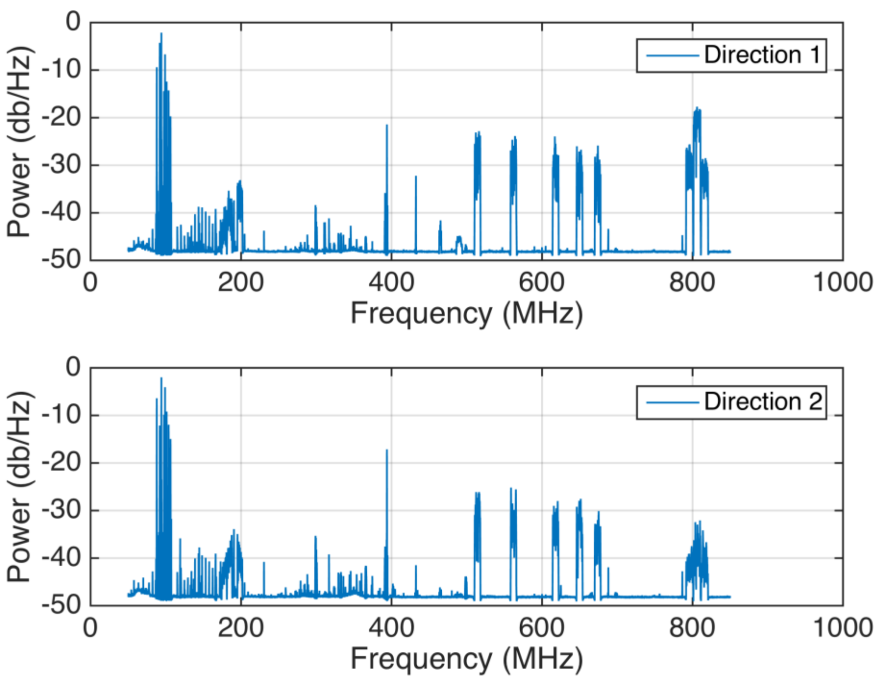

Figure. 3. The radio environment spectrum (50-850 MHz) at Metsähovi Radio Observatory. In the upper panel, the antenna is directed towards the West and in the lower panel, the antenna is directed towards the East.

The most powerful signals observed are DVB-TV (510-518 MHz, 558-566 MHz, 614-622 MHz, 646-654 MHz and 670-678 MHz) and radio channels (< 200 MHz), cell phone links (790-820 MHz), military use (260-370 MHz), emergency services network (390-395 MHz) and digital broadband 450 mobile network (463-466 MHz). These frequencies can also be identified from the national frequency allocation table [8]. There are some unidentified interference frequencies as well, especially at lower frequencies (< 200 MHz). They are most probably coming from the observatory's own electronic devices. The most powerful interference signals are at the level of -65 dBm at 94 MHz, when we assume that the noise floor level is around -110 dBm. The measurement results can also be converted into the flux density (Hase et al., 2013, equation 1) by considering the antenna gain, the cable loss and the resolution bandwidth used. For instance, the flux density of the DVB-T signal at 685 MHz is approximately -140 $dBWm^{-2}Hz^{-1}$.

3.3. Measurements at Ventspils International Radio Astronomy Centre

Ventspils International Radio Astronomy Centre (VIRAC) is situated in the Western Latvia GPS: N 57:33.13, E 21:51.18), some 35 km from the city of Ventspils. The nearest village (Pope) is around 17 km away and the nearest settlements lie in the distance of around 4 km. The main instruments of Irbene radio observatory are two fully steerable parabolic antennas RT-32 and RT-16 with the diameters of 32 m and 16 m respectively. Currently, the main receivers of RT-16 and RT-32 cover the frequency range of 4.5 to 8.8 GHz, which is down-converted to IF between 0.4 and 1.4 GHz. In the nearest future VIRAC is going to install LOFAR (**the Low-Frequency Array**), the Low-Frequency Array [9] station at Irbene site, and it will cover frequencies of 10 to 90 MHz and 110 to 270 MHz. The main research areas of VIRAC are VLBI, spectral line and solar monitoring.

Interference observations were made on the 12th and 13th June 2018. Two measurements were carried out at different locations within the observatory area. Each measurement took around one hour thus totally three full scans (50-850 MHz) were measured with the max hold option on that period of time. The measurement results are shown in Figure 4.

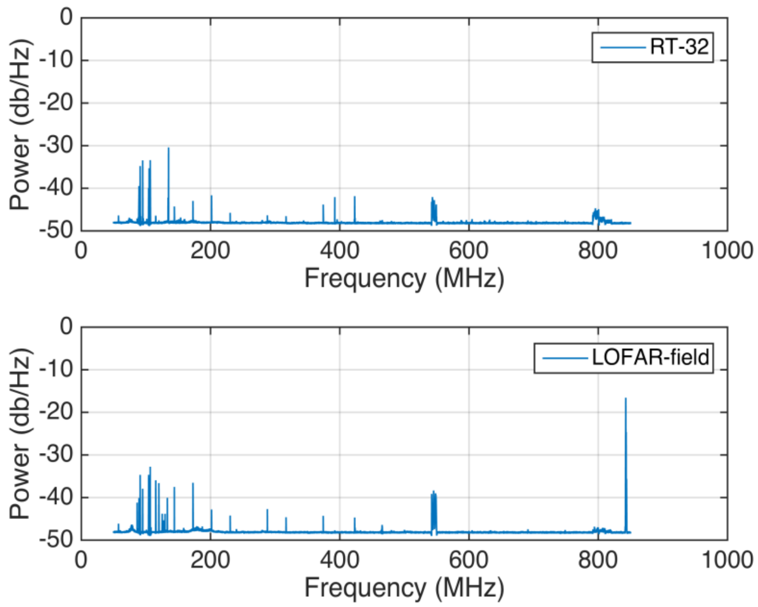

Figure. 4. The radio environment spectrum (50-850 MHz) at Ventspils International Radio Astronomy Centre.

In the upper panel, the RFI measurement nearby RT-32 radio telescope and in the lower panel, the RFI measurement in LOFAR field.

The most powerful observed signals are DVB-TV (542-550 MHz), cell phone links and DVB-TV (790-844 MHz) and radio channels (< 200 MHz). These frequencies can also be identified from the national frequency allocation table [10]. There are some unidentified interference frequencies as well, especially at lower frequencies (< 400 MHz). Those are most probably coming from the observatory’s own electronic devices.

4. CONCLUSIONS

There are several SDR-RTL solutions in the market. It is very crucial to test them and to find the best solution for each purpose. The main disadvantage of the simple SDR-RTL solution is the computing capability. The data processing is still quite slow. Thus, the real time monitoring systems are not possible, especially if the observation bandwidth is wide. However, SDR-RTL is very suitable for the purposes of monitoring general (stable) radio environment. The main advantages are the low cost, user-friendliness and flexibility. SDR-RTL is also very useful for the temporary monitoring purposes. If the observation band during the study is narrow enough (< 20 MHz), the scanning time is also considerably shorter, and the detection of non-continuous transmission is more plausible.

We can conclude that the chosen SDR-RTL dongle (Rafael Micro R820T tuner) is suitable for RFI monitoring purposes. The technological development of the SDR devices is still quite rapid, so possible new SDRs could bring even more sophisticated and better solutions also to RFI monitoring purposes.

MRO is located relatively close (40 km) to the capital region of Finland. In addition, some military camps are located near (about 30 km) the observatory. Thus, there is a lot of telecommunication activity taking place close to the observatory, which was also noticed during the measurement campaign. The increasing settlement close to the observatory area can be seen as a future threat to the radio astronomical observations on MRO.

VIRAC is located relatively far from the major settlements and, thus the radio environment is rather clean. The location is ideal for instance for LOFAR operations. However, the observatory is located near the busy shipping channels of the Baltic Sea, which might cause its own threat to the radio astronomical activities in the future. In addition, the nearest wind farm is located about 20 km from the observatory, which is a possible reason for the interferences.

A similar observation campaign should also be repeated at higher frequencies in the nearest future.

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