Spectrum Sensor for Distributed Spectrum Sensing

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Abstract—For the efficient use of spectrum resource, it is important to understand spectrum occupancy at a high spatial resolution, so a large number of measurement locations are required. In this work, in order to increase measurement locations, we design and implement a low-end spectrum sensor which is capable of switching to different channels in a spectrum range of the UHF band. The spectrum sensor can provide intuitive knowledge for spectrum usage.

I. INTRODUCTION

In order to use spectrum resource efficiently, we need to understand and share the current wide-band, temporal, and spatial spectrum usage information. The information can be obtained by measuring spectrum occupancy defined as the percentage of the time for radio transmission per unit time in a given band [1].

Spectrum occupancy varies with frequency, time, and space, so the occupancy needs to be consistently measured over a wide range of locations. A large number of measurement locations provide more insight compared to a single location measurement. The challenge of distributed spectrum measurements is cost [2]. High-performance general spectrum analyzers of existing researches are expensive, so low-cost spectrum sensors are needed.

There have been researches and developments for low-cost spectrum analyzers. A single chip spectrum analyzer is fabricated in a standard CMOS process. However, the measurable band is limited from 20MHz to 200MHz.

On the other hand, there is GigaSt [4], a simple spectrum analyzer, which can measure wide-band spectrum. In order to realize an inexpensive device, regard is paid to balance of function and performance. GigaSt is a good design, but in terms of obtaining spectrum occupancy, we can further reduce the cost by limiting function and performance.

In this work, first, we verify GigaSt's hardware from the perspective of occupancy measurement, and it is shown that GigaSt's hardware is suitable for wide-band measurement. Next, we design a low-end spectrum sensor based on GigaSt's hardware. The spectrum sensor is capable of switching to different channels in a spectrum range of the UHF band.

This work is organized as follows. Section 2 considers the design of a super-heterodyne spectrum sensor with fixed RBW (Resolution Band Width) taking into account the performance and cost of components. Section 3 describes a demonstration of the spectrum sensor. Section 4 presents our conclusions and a discussion of future work in this field.

II. DESIGN AND IMPLEMENTATION OF A LOW-END SPECTRUM SENSOR

A. Design

This section presents a design procedure of a low-end spectrum sensor, and we focus on the cost of components. First, in order to measure wide band, we use a super-heterodyne receiver for the spectrum sensor.

In the frequency converter of the spectrum sensor, as Fig. 1 indicates, we use three-stage mixers to convert the UHF band to the IF (Intermediate Frequency) band. After that, we fix the center frequency of the final IF filter, and then we calculate the numerical values of IFs and VCOs.

The final IF filter determines the IF (center frequency) and frequency resolution (bandwidth). In existing spectrum measurements, frequency resolution for the UHF band is generally above 200 kHz [5], [6]. On the market, there is a band pass filter with center frequency and bandwidth of 10.7 MHz and 180 kHz respectively, and its bandwidth is near 200 kHz. Therefore, we use that filter, and IF and frequency resolution of the spectrum sensor is 10.7 MHz and 180 kHz respectively. After determining the final IF, we fix the center frequency of the final IF filter, and then we calculate the numerical values of IFs and VCOs.

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Next, we determine each oscillation frequency of local oscillators. In the second and third stage, because of their IF, each oscillation frequency is fixed at 1320.5 MHz and 379.3 MHz respectively. The local oscillator of the first stage is swept from 1230.5 MHz to 2069.5 MHz to measure the entire UHF band. In other words, the spectrum sensor measures the UHF band through four paths: (1) 300~1139MHz, (2) 2161~3000MHz, (3) 840.5~1679.5MHz,
and (4) 1620.5~2459.5MHz.

Finally, in order to judge the presence of radio, we use energy detection which is widely used in existing spectrum measurements. A log amplifier measures the power of the IF signal, and if the measured power exceeds the predefined threshold, the sensor determines that the band is occupied. The threshold is determined by the noise floor. The spectrum sensor measures the noise in advance, and the mean and standard deviation of the noise floor are calculated. A confidence interval of the noise floor can be determined from the values, and the upper limit of the interval becomes the threshold [7], [8].

B. Implementation

On the basis of the above design, we implement the spectrum sensor. The block diagram and hardware appear in Fig. 1 and Fig. 2. The input signal is sent to a frequency converter through an attenuator, and is converted to the final IF signal, 10.7 MHz. The power of the IF signal is measured by a log amplifier, and the measurement values are converted to digital signal by a MCU (Micro Control Unit). The converted values are transmitted to PC by serial communication. As an example, Fig. 3 shows hourly occupancy measurement in the band from 800 MHz to 900 MHz.

The cost of components for the spectrum sensor is about $200 per sensor (GigaSt is about $480). The list of components appears in Table I. Components for the frequency conversion unit dominate the cost, and the cost of the unit is about $140. For example, the cost of three VCOs (Voltage Controlled Oscillator) in local oscillators is about $85, and the cost of three mixers is about $30.

III. DEMONSTRATION

In the demonstration, we show measurement and visualization of the spectrum usage information using the implemented spectrum sensor. The spectrum sensor judges the presence of the radio by measuring spectrum power, so during the measurement, visitors can see the uploaded spectrum power around the conference hall.

IV. CONCLUSION

This work describes the design and implementation of a low-end spectrum sensor to understand spectrum usage intuitively. Future work is to improve measurement accuracy and temporal/spatial resolution by using characteristic of each band and knowledge obtained through long-term measurement.

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REFERENCES