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Software-Defined Radios for Effective Spectrum Utilization

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Software-defined radios (SDRs) are highly adaptable wireless devices that are (re)configurable through software alone, enabling them to be effectively utilized across multiple communication standards.

SDRs have rapidly become the leading wireless solution for military, public safety, and commercial markets. This can be directly attributed to their high flexibility, performance, and low-cost.

History of Software-Defined Radio

Software-defined radios have been around for more than three decades. From the early 1980s, SDRs have played a role in tactical military communications from 2 MHz to 2 GHz and offer interoperability between various air interface standards of the military.

In the old days, radios were built for specific applications. As a result, we had AM radios that received KMOX and WHO. But AM radios were unable to receive shortwave broadcasts.

FM radios soon followed and then FM stereo made an appearance. But commercial broadcast is only a small segment of the radio market. These devices can become highly complex when the features are combined.

If we stuck to the old and traditional rules of radio, we would have to build 5 radios to handle 5 functions. It didn't take long to figure out that this concept was neither cost-effective nor compact.

When digital techniques evolved, an increase in functionality was easily adopted. They were applied to the baseband section of radio, then the output of the detector was digitized with digital circuits to process the digital audio data.

Algorithms were then used to increase the signal-to-noise ratios and enhance control of the bandwidth. In the beginning, these digital circuits were hardware-coded and often had noise reduction and selectable bandwidth capability. Later, data processing circuits became cheaper and programmable. This enhanced the capability and control that was available for the device.
As digital circuits increased in resolution and speed, digitizing the intermediate frequency (IF) section became a reality. As a result, the output of the mixer was digitized and the detector was realized in software.

The emergence of the detector was key as it determines the type of modulation that can be received. These days, we can process IF signals in digital form and demodulate it in almost any way we please. Further, as before, the baseband is processed digitally as well.

So you can say that SDR has come a long way since its early origins. With the Internet of Things (IoT) rapidly growing in importance to transform our lives, you can expect SDRs to play a major role in communications between sensors and devices. At the end of the day, the capability to receive and transmit data on multiple platforms makes IoT possible.

Software-Defined Radio Defined

SDRs can be defined as a radio where some or all of the physical layer functions are software defined. This means that it's a device that can wirelessly transmit or receive information as part of the electromagnetic spectrum.

Traditional radio devices offered very limited flexibility and cross-functionality. This often lead to high production and operation costs. SDR technology provides a great solution to these problems with an inexpensive solution.

SDR allows you to be highly mobile because the technology enables software RAN solutions. As a result, SDR operators can support multiple standards on a single hardware platform and offer the ability to bridge traditionally disparate devices operating on different frequencies.

If you compare SDR to traditional radio systems, you'll notice that SDR provides the added benefits that hardware focused systems can't offer. SDR is highly portable and can be easily re-configured with software upgrades alone.

It is a highly adaptable, flexible, and an efficient solution that allows modifications to multi-mode, multi-band and/or multi-functions via software. It is now increasingly cheaper to keep up with technological advancements with minimal code required to be re-written.

Field Programmable Gate Array (FPGA)

Field programmable gate arrays (FPGAs) are integrated circuits that allow designers to program digital logic that is customized. FPGAs have evolved to become system-level integrated circuits with embedded memory blocks, microprocessors, and interfaces.
The FPGA enables reprogramming of functions and features after manufacturing and is part of the digital side of SDR that offers such flexibility. So it is easy to adapt to new standards and reconfigure the hardware to specific applications.

The gate arrays are two-dimensional arrays of logic gates. With enough of them put together, one can make simple calculations that add up to something of value. As a result, it is highly adaptable and flexible, just like SDR.

Software-Defined Radio with FPGA

Some SDRs are built with FPGA designs that enable multiple applications to be reconfigured using the FPGA without the need of changing any hardware.

SDR can ensure effective and efficient spectrum use because it has the ability to engage in spectrum sensing and frequency tuning.

Various waveform modulation and demodulation techniques can be developed and implemented with only changing the firmware loaded onto the FPGA. This means, switching between applications is simple and does not require any hardware changes.

As a result, one can easily switch between multiple frequencies to effectively manage spectrum use, and communicate via multiple frequencies simultaneously. All this can be accomplished with reduced hardware constraints, negating the need for multiple devices to process multiple wave-forms.

Software-Defined Radios and Spectrum Sensing

Beyond seamless shifting between frequencies, SDRs are also capable of measuring the spectrum space that is available for communication. This can be done by using energy detection techniques. What's unique about this type of wireless device is that it can be programmed to adapt based on the available spectrum. As a result, SDRs are able to adapt to the dynamic nature of spectrum congestion and are able to execute this while maintaining optimum data transfer rates.

SDR can ensure effective and efficient spectrum use because it has the ability to engage in spectrum sensing and frequency tuning. It does this by tuning into a part of the spectrum, analyzing how much free spectrum is available, and if there is less congestion than the band currently in use, it can switch the current broadcast to a part of the spectrum that is not as congested.

In theory, the user can do following:

Assuming the SDR has two receive chains and there is a connection (broadcasting and receiving) on one chain (RX

A) on one part of the spectrum (i.e., 2.4GHz), the user can use the other receive chain (RX B) to tune into a different part of the spectrum (i.e., 5GHz) to determine the amount of free space. Through software, the transceiver can then switch operation to the new band if it has more free space.

Scarcity of Spectrum in the Wireless Space

SDR is a great solution for the increasingly crowded spectrum in wireless communication. At a glance, it would seem like there's a significant limitation to the rising demand for higher data rates. This is mainly due to the fixed frequency allocation policy.

But if inspected closely, the user will find that a large part of the spectrum is underutilized. As a result, using SDR or Cognitive Radio (CR) will be a tempting solution.

In this scenario, SDR will be able to sense and identify unused channels and transmission opportunities and at the same time avoid interference with licensed primary users.

This could not be achieved without spectrum sensing technology that primarily works to provide an indication of a transmission taking place in an observed channel.

The anticipated opportunities and benefits of this technology are now a reality. It has already had a significant impact on the industry's value chain. The value chain essentially consists of service-based providers and product-based providers. Value can be added at every stage to ultimately use SDR to meet the needs of all the end users.

SDR technology can have far-reaching implications as it can support a variety of industries from chip makers, software developers, and front-end component manufacturers. Aside from the traditional military and public safety fields, SDR can enhance operations for OEMs, service providers, and IP holders.