SR1000 Series Technology Overview

Spark Microsystems

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Contents

List of Abbreviations

CCA	Clear Channel Assessment
FDMA	Frequency Division Multiple Access
OOK	On-Off Keying
PPM	Pulse Position Modulation
TDMA	Time Division Multiple Access
UWB	Ultra Wideband

1 Introduction

The SR1010 is an ultra-low power, high data-rate wireless transceiver that operates in the ultra wideband (UWB) spectrum from 3.1 - 6 GHz. This whitepaper serves as a primer on the differences between narrowband and UWB radios, as well as the technology of the SR1000 series radio.

2 Ultra Wideband vs Narrowband Radios

This section introduces UWB in general and compares to narrowband radios.

2.1 Modulation

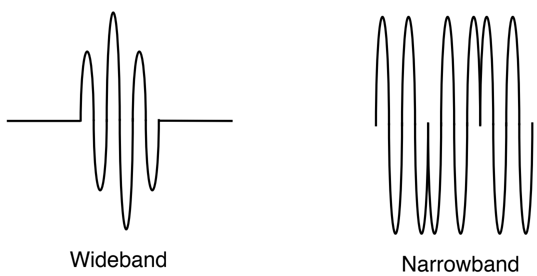

Figure 1: A wideband signal and a narrowband signal.

Narrowband and wideband radios differ significantly in both the time domain (Figure 1) and the frequency domain (Figure 2). Most of the wireless radios are operated in a narrowband fashion, their modulation bandwidth is much smaller than the carrier frequency. In the time domain, the modulated RF signal is a sinusoid with the carrier frequency, whose amplitude and / or phase are modulated at the modulation frequency. In the frequency domain, a narrowband radio has a narrow peak and a high peak power spectral density.

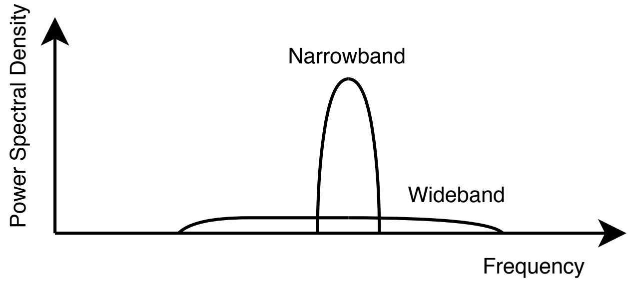

Figure 2: Spectrum of a wideband signal and a narrowband signal.

Wideband radios have gained popularity fairly recently. In the time domain, an UWB radio sends pulses with a width in the order of a few ns. Thus the spectrum of an UWB radio is much wider than a narrowband radio, while the power spectral density is much lower.

An UWB radio is defined as having a bandwidth that is larger than 500 MHz, or more than 10% of the center frequency.

Some of the advantages of using an UWB radio are higher data rates and better performance in multipath channels compared to Narrow band radios.

SPARK Radios offer added benefits of low power consumption and low latency as well.

2.2 Data Rate

As the bandwidth of an UWB system is high, higher datarates than narrowband radios are possible. Alternately, the pulses in an UWB system can be sent sporadically, resulting in a lower data rate.

2.3 Regulations

The regulatory bodies of individual countries have set aside license-free parts of the spectrum to be used for UWB communications. Examples of regulatory bodies include the FCC in the USA and ETSI in Europe.

The spectrum set aside for UWB emissions depends on the regulatory body, for example the FCC (Figure 3) has set aside a band from 3.1 GHz to 10.6 GHz, while ETSI (Figure 4) has a band mostly from 6.0 GHz to 8.5 GHz.

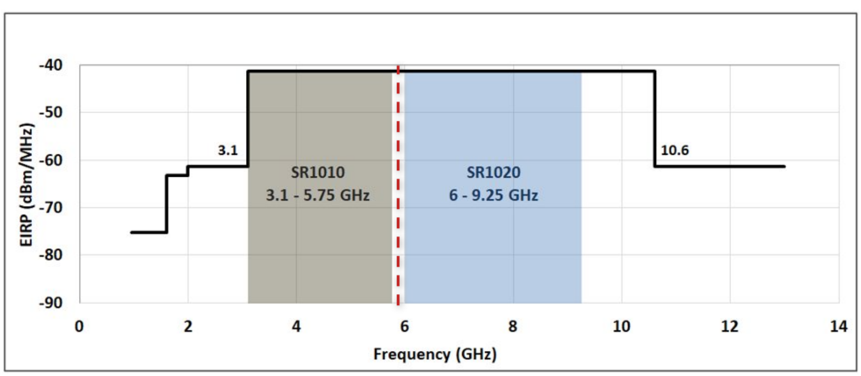

Figure 3: FCC

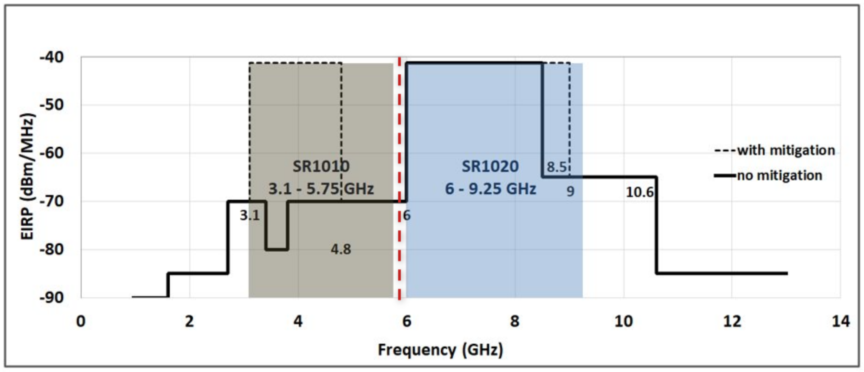

Figure 4: ETSI

Each country has the same in-band regulatory limit power spectral density of -41.3 dBm/MHz measured with an RMS average detector over 1 ms. Out-of-band emission masks depend on the regulatory body.

The overall UWB Spectrum is shown among other narrowband regulated spectrum in Figure 5.

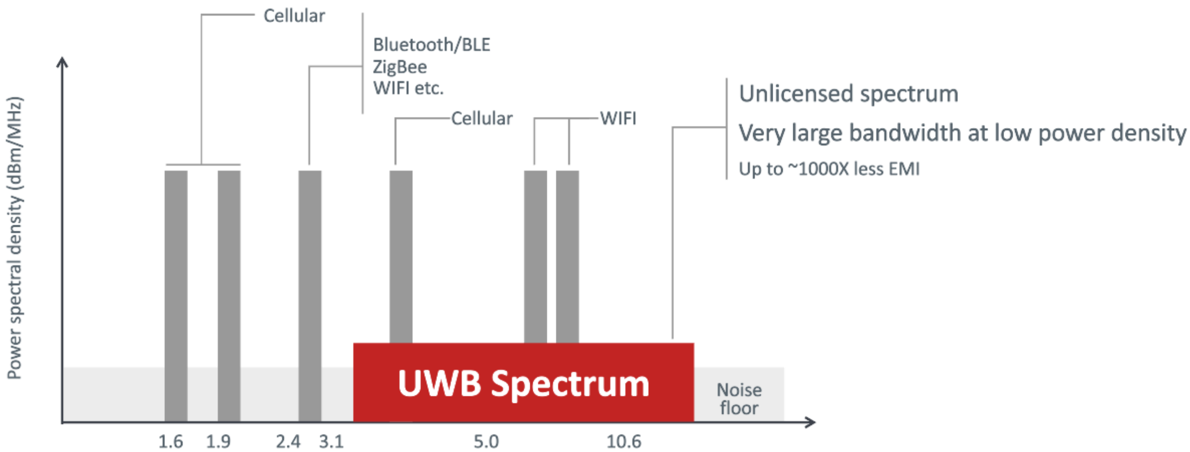

Figure 5: UWB Spectrum

The aim of the regulations is for UWB to appear below the noise floor of the surrouding narrowband radios operating in the vicinity of the UWB radio. The filters in narrowband radios will reduce the received power from the UWB signal as its bandwidth is much wider.

3 SPARK SR1000 Series UWB Radio

The SPARK SR1000 series is a unique radio that takes a different approach to UWB.

3.1 Radio Architecture

The SR1000 series utilizes several innovations that are tailored to UWB communications.

- Non-coherent detection eliminating the need for RF carrier generation
- Frequency hopping transmitter that can shape its output spectrum
- Specific filtering of in-band narrowband signals in the receiver

3.2 Coherent vs Non-coherent Detection

Traditional frontends use a several-MHz crystal and upconvert to the RF carrier frequency using a synthesizer. The synthesizer has several disadvantages: it takes a significant amount of time to settle, the power consumption of the synthesizer is relatively high, and the crystal requires significant startup time and power consumption as well. In coherent detection, the synthesizer cannot be omitted as a stable RF frequency and phase reference is needed to perform correct modulation and demodulation.

Coherent radios therefore need a significant amount of time to change to a different channel[1], and take a significant amount of energy to startup the radio.

The SPARK SR1000 uses non-coherent detection, and does not require a synthesized RF carrier that is tied to a reference crystal. The transmitter generates pulses using an efficient ring oscillator at GHz frequencies. Accordingly, the frequency and phase accuracy requirements of the system are relaxed, making the SR1000 UWB Radio very power efficient.

3.3 Spectral Shaping

The other advantage of a non-coherent detection is the ability to shape the output spectrum of the transmitter. The frequency of the transmitter can be changed from pulse to pulse. This, combined with other techniques allows for very flexible spectral shaping, allowing for spectrum center frequency or bandwidth tuning, for example.

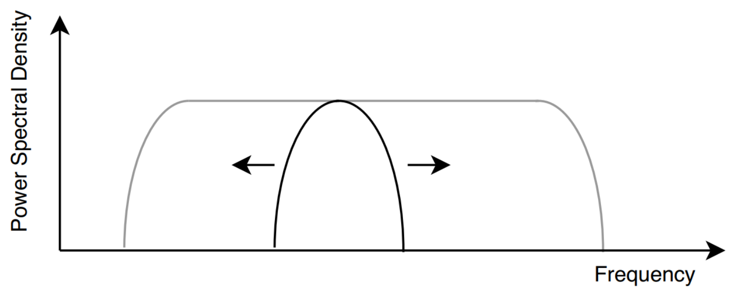

Figure 6: Spectral shaping

The radio can therefore on average (i.e., over a 1 ms timespan) occupy a tunable amount of the UWB spectrum, while the instantaneous noise-bandwidth of the receiver stays fixed at the bandwidth of a single pulse[2]. This is illustrated in Figure 6.

3.4 SPARK Channels

The SPARK SR1000 UWB Radio is configurable per application for single-channel to multi-channel operation, with a configurable channel count, pulse count, pule width, and pulse spacing settings to cover the entire regulatory bandwidth and power density as shown in Figure 7.

[1] It is common for other UWB radios to have 500 MHz frequency channels.
[2] In the order of 500 MHz

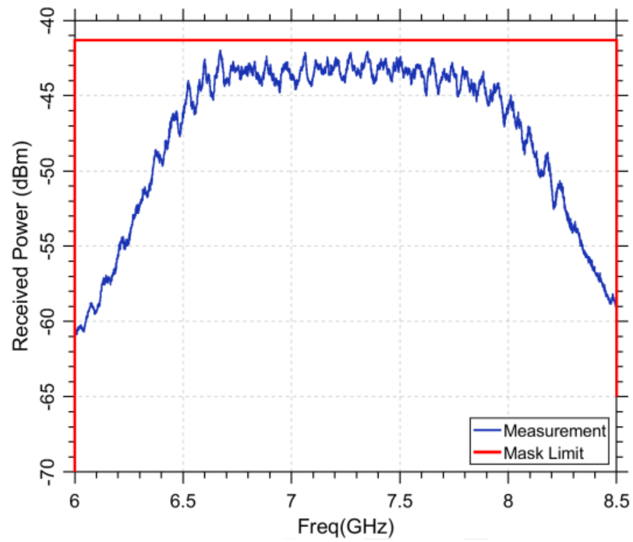

Figure 7: SPARK In band average EIRP, 1MHz RBW, SR1020, ETSI limits

Each channel is individually configured for an optimal spectral coverage as shown in figures 8 to 10.

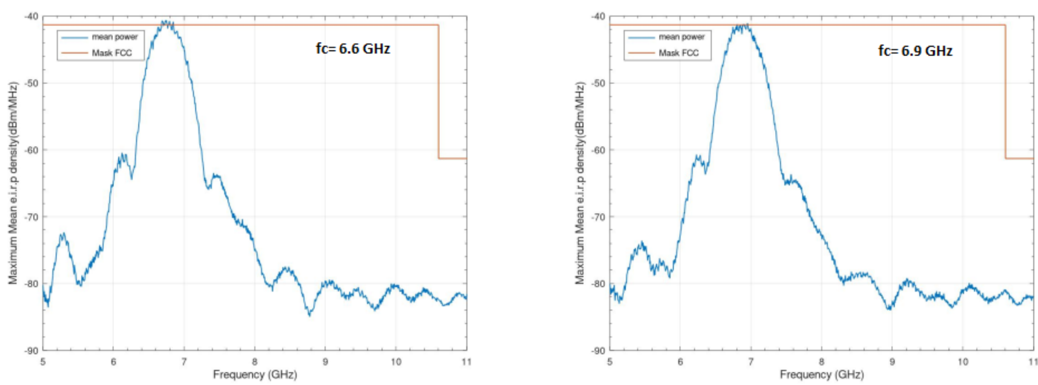

Figure 8: Channel 1 and Channel 2 set at 6.6 GHz and 6.9 center frequencies - example

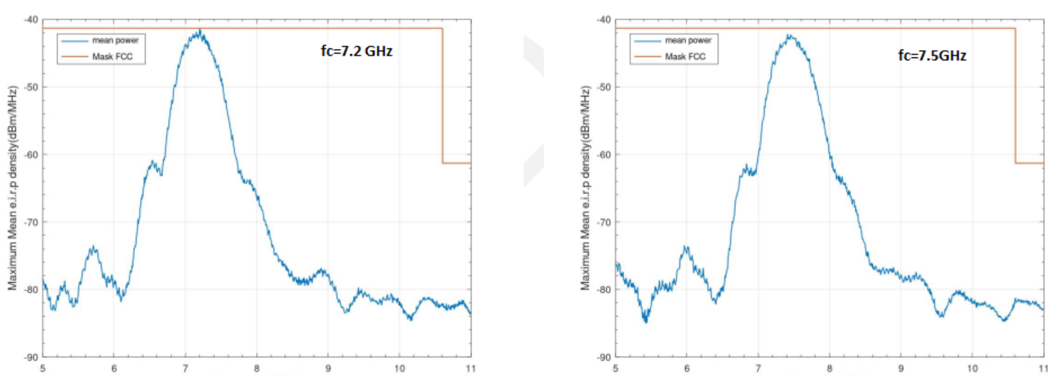

Figure 9: Channel 3 and Channel 4 set at 7.2 GHz and 7.5 center frequencies - example

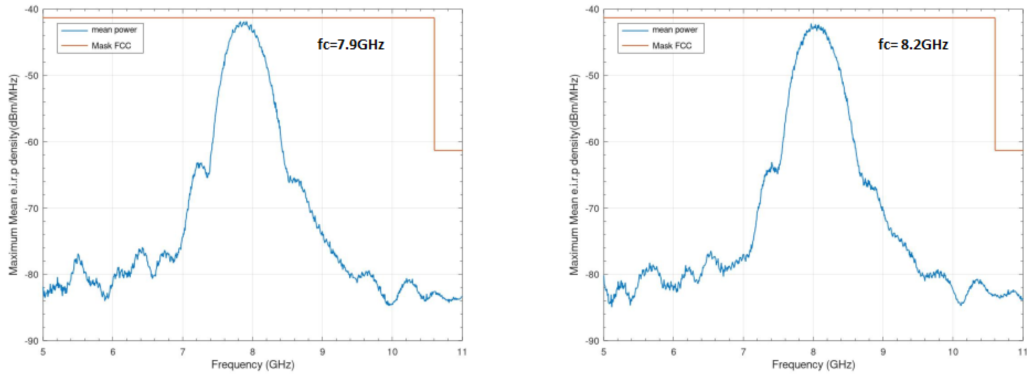

Figure 10: Channel 5 and Channel 6 set at 7.9 GHz and 8.2 center frequencies - example

The SPARK Advantage when using multiple channels is increased link robustness and range when compared to other UWB technologies.

3.5 Links scheduling

One way to take advantage of the 20.48 Mb/s symbol rate is to plan the application to use the same frequency channels and schedule different time slots for each link.

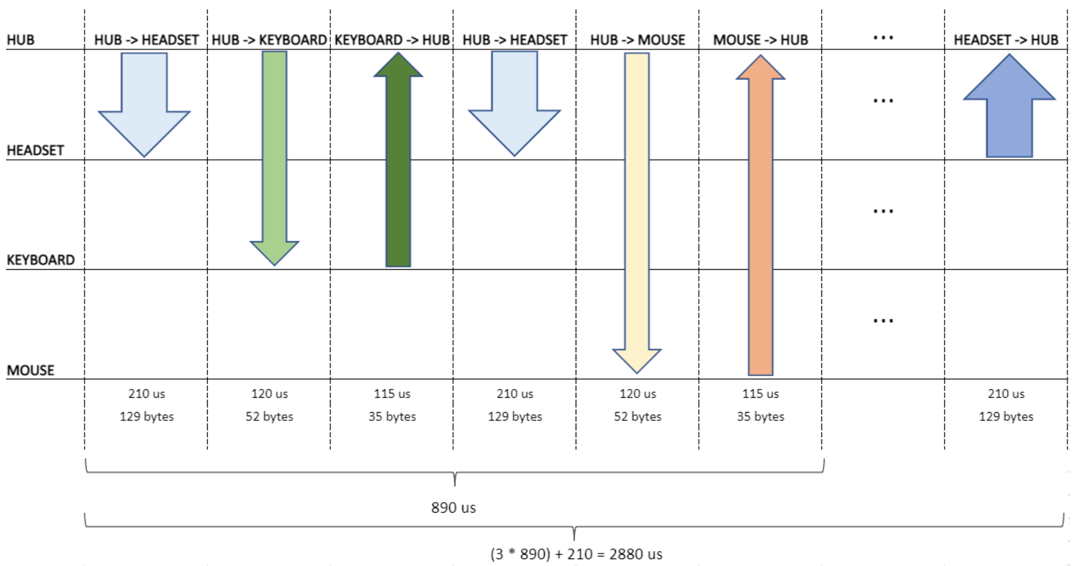

Figure 11: Link Schedule example - Payloads shown in diagram are the effective application data payloads

3.6 Concurrent Links

Multiple SR1000 links in the same volume of space are supported through two mechanisms.

The first mechanism is through Time Division Multiple Access (TDMA). At a 20.48 Mb/s symbol rate, multiple links can use the same channel by scheduling their time slots when the channel is clear. The SR1000 includes an energy sensing mechanism, CCA, that can detect when the channel is clear.

The second mechanism is through Frequency Division Multiple Access (FDMA). The instantaneous bandwidth of the radio is at the pulse bandwidth. Frequency filtering is performed on signals away from the instantaneous frequency. Multiple links can therefore use the spectrum at the same time by offsetting the timing of their frequency hopping.

3.7 Data Rate and Power Consumption

The SPARK SR1000 UWB Radio transmits the same number of bits in less time when compared to a traditional narrowband radio. The symbol rate of the PHY layer is 20.48 Mb/s for the SR1000 series. This is much higher than the typical 1 - 2 MHz symbol rates of other low-power narrowband radios, resulting in reduced power consumption and an improved efficiency of energy consumption per bit.

Since the SR1000 is optimized for duty cycled operation, it performs near-linear scaling of power consumption with data rate. This is shown in figure 12.

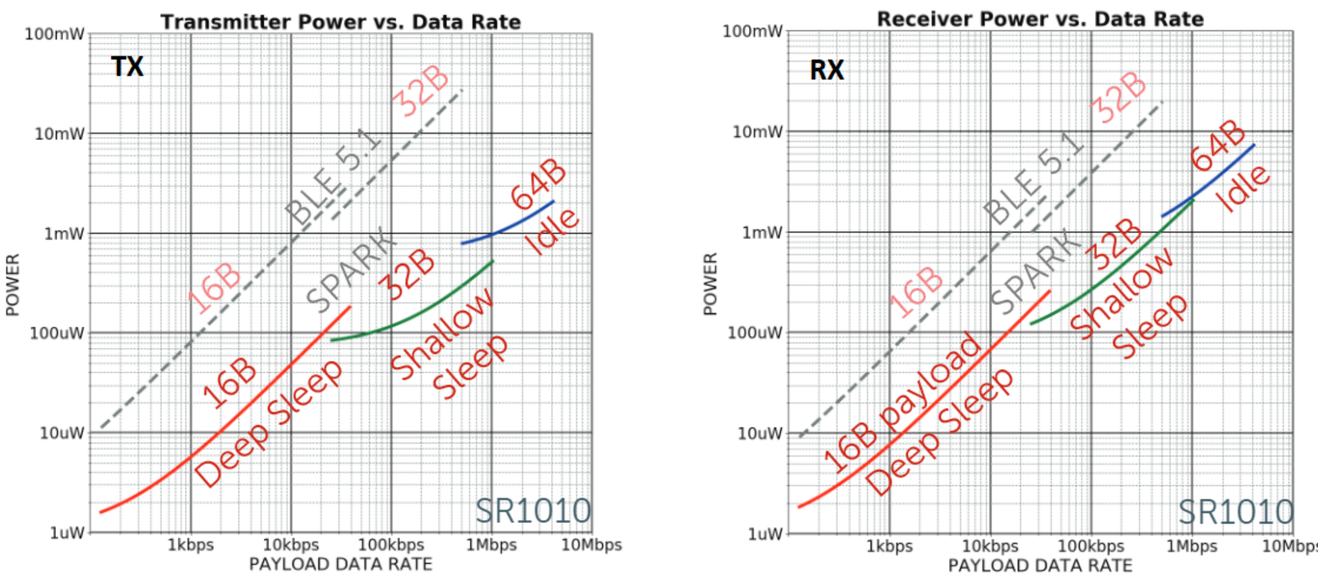

Figure 12: SR1010 TX (left) and RX (right) power consumption at 1.8V Supplies, compared to Bluetooth 5.1

The 20.48 Mbps symbol rate of the radio translates in a low base energy per bit. For the SR1000 series, this ranges in the order of 1nJ/bit.

To achieve this goal, multiple sleep levels are implemented. The SR1000 series has several features that optimize the sleep levels.

The SR1000 can also operate from a 32.678 KHz crystal operating on half a uA of current without the need of a MHz level crystal, when compared to other radios, which take mW levels of power. Moreover, the SPARK digital core is optimized to be addressable in almost all the available sleep levels.

Furthermore, the transmitter and receiver can start up in less than a micro second, thus enabling efficient duty cycling.

3.8 Low Latency Capability

With a symbol rate of the PHY layer at 20.48 Mb/s, the SR1000 series' packet time is reduced by an order of magnitude. This significantly reduces the latency in transferring a packet, compared to low-power narrowband radios.

Typical high data rate, premium audio applications operate at 5 to 10 ms latency when including re-transmission buffers. Data transfer, and Peripheral Human Interface device applications can also benefit from sub-millisecond latencies.

3.9 Interferer Robustness

UWB receivers are more vulnerable to interferers as their bandwidth is larger than a narrowband radio. The SR1000 radio features several features that improve interferer robustness.

The receiver architecture is a non-traditional non-coherent design that is optimized for interferer rejection. As such, it is able to filter out narrowband unwanted signals while passing wideband wanted signals. Moreover, the receiver performs channel filtering on multiple points in the frontend to filter interferers as effectively as possible.

Since the transmitter spectrum can be dynamically configured on a packet-to-packet basis, the parts of the spectrum that contain interferers can be swiftly avoided. This is important to operate alongside other services such as cellular and WiFi that have some channels allocated in the UWB spectrum. Other UWB transceivers are restricted to using a single band in the spectrum at a time, due to their traditional coherent transceiver architectures, making them less agile to avoid blockers.

List of Figures