High Power Enables "Long-Range

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Although referred to as "short-range devices", radio modules for the European license-free bands can achieve quite a long range. Radiocrafts has combined narrow-band technology with high transmission output power implementing an optimised solution that yields ranges up to 6km in the 868MHz band. This article provides information on how these long ranges can be achieved, and explains some of the terms used to characterise such radio systems.

Short-range devices (SRD) are a set of products operating under the license-free regime in EU and EEC as defined by CEPT DEC 70-03. Several frequency bands are opened to meet the demand from the industry for remote control, telemetry and similar applications. The "short range" term comes from the fact that the maximum radiated power is restricted. Table 1 summarises the sub-1GHz license-free bands as implemented in most European countries. Almost all of the bands are for general use, but some are limited to specific applications only, as shown in the table. In several of the bands, like 433.050 - 434.790MHz, 25kHz channel spacing is not specifically required. However, if a true narrow band (25kHz) module is used, there is no duty-cycle limitation at the upper part of the band (434.040 - 434.790MHz) even for 10mW output power. The superior receiver sensitivity and higher output power gives a much better range than the traditional wideband systems. By using a more selective narrow-band receiver, the system will also be less affected by other radio systems operating in the same band. Traditionally the 433MHz band has been used for remote keyless entry (RKE), garage-door openers, wireless doorbells, etc. These are often SAW resonator-based transmitters with wide bandwidth occupying most of the band. The narrowband receiver can combat this interference thanks to its narrow and sharp channel filters. Another benefit is the increased number of channels that can be used at the same time. For example, up to 69 channels can be employed in the 433MHz band (RC1240) as each channel is only 25kHz wide. In the sub-1GHz bands, the output power is mostly limited to 10mW, except one band (869.400 - 869.650MHz), where up to 500mW or 27dBm is allowed. This band can be used with true narrowband (25kHz channels) or relaxed narrowband (up to 250kHz channel bandwidth). Radiocrafts has introduced a new module (RC1280HP) combining narrow-band receiver technology with high transmission output power, achieving a very long-range-communication-module solution.

Frequency band power	Transmit cycle	Duty	Channel spacing	Applications
433.050-434.790	10mW	10%	No channel spacing specified	
433.050-434.790	1mW -13dBm/10kHz	100%	No channel spacing specified	
434.040-434.790	10mW	100%	25kHz	
868.000 - 868.600	25mW	1%	No channel spacing specified	
868.600 - 868.700	10mW	0.1%	25kHz or 1 channel wideband	Alarms in general
868.700 - 869.200	25mW	0.1%	No channel spacing specified	
869.200 - 869.250	10mW	0.1%	25kHz	Social alarms
869.250 - 869.300	10mW	0.1%	25kHz	Alarms in general
869.300 – 869.400	10mW	100%	25kHz	
869.400 - 869.650	500mW	10%	25kHz or one broadband channel	
869.650 - 869.700	25mW	10%	25kHz	Alarms in general
869.700 - 870.000	5mW	100%	No channel spacing specified	

Table 1: License-free frequency bands.

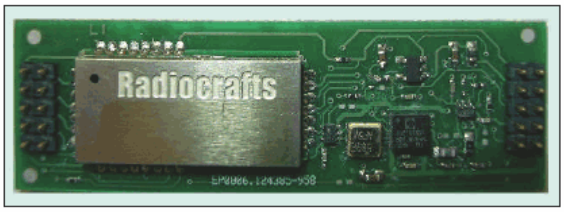

Figure 1: RC1280HP high-power module.

Achieving longer range

Some applications, like telemetry, automated meter reading (AMR), asset tracking (of cars, trucks and containers) and anti-theft systems, all call for a communication range and coverage of more than merely a few tens or hundreds of metres. To meet this demand, new system solutions are required, combining the best in receiver techniques with a high-power transmitter. The achievable communication range is limited by several factors. The most important are receiver sensitivity, transmitter output power and antenna design. But in a practical application, interference from other systems, and between units in your own system, must also be taken into account. This puts demand on receiver selectivity as well as transmitter purity. High sensitivity is inherently linked to good selectivity because sensitivity depends on receiver bandwidth. In other words, a narrow-band receiver will also yield a very good sensitivity if it is well-designed in terms of noise figure and demodulator signal-to-noise requirements. As for the transmitter side, increasing the output power is not only a matter of adding a power-amplifier stage. When amplifying the transmission signal in a power amplifier, not only the wanted signal is boosted, but adjacent channel power, spurious emissions and harmonics are amplified and even generated in the power amplifier itself. The modulator, often determined by the frequency-synthesiser's loop-filter properties, must be designed to shape the spectrum and avoid excessive spectrum broadening also when the power is increased by a following power amplifier. Moreover, the power amplifier itself can add spectrum spreading (spilling power into the adjacent channel) as well as unwanted spurious signals. Consequently, a very careful design, taking these effects into account, is necessary in order to meet the regulatory requirements. Adding further to the challenge is that the narrow-band radio must be made with a very stable frequency reference. If not, the transmitter or receiver frequency would drift with temperature change, reducing the sensitivity and eventually loosing communication altogether. A temperature-drift-compensated oscillator is therefore required: the RC1280HP has solved these challenges in a carefully designed compact module, which is pre-qualified and CE-marked for regulation compliance.

Narrow-band system parameters

It is important to understand the different technical parameters used to describe and characterise a narrow-band radio system in order to compare different solutions.

- Receiver sensitivity: The receiver's sensitivity limit is the level of the lowest signal power that can be detected and successfully demodulated. But making a very sensitive receiver is not very difficult or useful by itself. It is important that good receiver sensitivity be balanced with good selectivity (ACR and blocking properties), just as there would be no point in having extremely good hearing if it was jammed by other noise. Our own "selectivity" is the ability to isolate one single voice and talk to one discussion partner even

Devices"

Model	Frequency band	Range (typical)	Notes
RC1240	433.050 - 434.790MHz	2km	
RC1280	868.000 - 870.000MHz	500m	
RC1280HP	869.400 - 869.650MHz	5-6km	500mW high-power module

Table 2: Typical radio-module range.

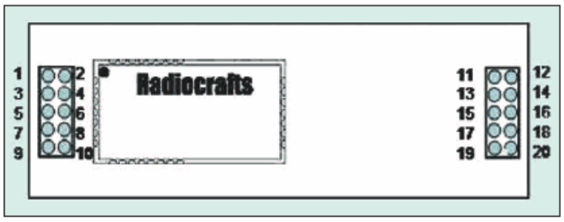

Figure 2: RC1280HP pin connections.

if the room is filled with other people talking at the same time. Thus, there is no point in good sensitivity (hearing a pin fall) if we cannot isolate it from the background noise (selectivity). In the same way, our "blocking" properties come into effect in the disco bar where one is talking with high background music.

- Adjacent-channel rejection (ACR): adjacent-channel rejection and alternate-channel selectivity describe the ability to separate signals coming in on two different channels. ACR is the term used when the unwanted signal is on the neighboring channel; alternate-channel selectivity is used for all other channels within the band.

- Blocking: blocking resistance, or jamming resistance, is the ability to keep communication going even in the presence of strong out-of-band signals. It is also referred to as desensitisation in the presence of interferers. This could for example be in the presence of a strong GSM cell-phone transmitter at 890-930MHz, which is quite close to the 868MHz ISM band.

- Transmitter output power: transmitter output power is the total power of the modulated signal. As shows Table 1, there are regulatory limits to the maximum allowed output power. Another factor that can limit the maximum output power is the ACP.

- Adjacent-channel power (ACP): Ideally all the power transmitted should be within the bandwidth. However, due to the modulation and non-ideal effects, some power spills over to the neighboring channel. Because this power would interfere with communication in the neighboring channel, it is unwanted and must be kept as low as possible. There is a maximum limit of -37dBm when using 25kHz channels. A similar specification is the occupied bandwidth, stating the bandwidth in which 99% of the total power is contained. That is, 1% of the power is outside this bandwidth, falling in the adjacent channels.

- Spurious and harmonics emission: When amplifying the wanted signal, the unwanted spurious signals and harmonics will be amplified, too. Spurious signals may origin from the reference oscillator or the frequency synthesiser, and must be kept below certain limits to prevent interference with other systems. The harmonics are generated due to non-linearity in the amplifier stages. Therefore, simply adding any power amplifier to any low-power device might not increase the transmission power. Not only the limit for maximum output power inside the radio channel must be respected, but also spurious and harmonics requirements outside the band must be met at the same time.

The antenna

To benefit from good receiver sensitivity and high transmitter output power, the antenna must be efficient, of cause. An antenna is characterised by antenna gain and directivity. A vertically oriented quarter-wave antenna on a large ground plane has a gain of 5.15dBi and will be omni-directional in the horizontal plane. This is why this type of antenna is very popular in long-range systems. In practical implementations the gain tends to be less, and 0 to 3dBi is often used as a conservative figure. In the absence of a good ground plane, a vertical half-wave dipole could be used. The half-wave dipole has a theoretical gain of 2.15dBi, though; another drawback is its larger size compared to the quarter-wave. In order to achieve the best possible range outdoors, the antenna should be placed as high as possible: if it is placed to close to the ground, the ground reflections will reduce the range. Ideally the antennas should be placed so high that the Fresnel zone (an ellipsoid which has the transmitter and receiver antennas at its foci) is free from ground and other obstacles. This is achieved if the antenna is placed at a height h, where h = sqrt (d x L), d is the distance and L is the wavelength. This would resemble free-space conditions. However, in practice this is very seldom possible, and ground reflections as well as attenuation by other obstacles (trees, buildings, etc.) will reduce the range.

The high-power module

The RC1280HP is a new module integrating the RC1280 RF transceiver module with a high-power amplifier offering up to 500mW output power (Figure 1). When used with a quarter-wave antenna, a line-of-sight range of 5 to 6km can be achieved. The new module uses the same protocol and channels as the RC1280: interoperation between RC1280 and RC1280HP is therefore possible in a network with both long- and shorter range modules. They both use the RC232 protocol, which supports point-to-multipoint networks. Data buffering, addressing and error check are all handled by the embedded RC232 protocol. A standard UART serial bus is the interface to the host for both data communication and configuration. The module contains a multi-channel transceiver with a receiver sensitivity of -108dBm at 4.8kbit/s. With 30dB adjacent-channel rejection, 40dB alternate-channel selectivity and outstanding blocking properties, the module offers optimal performance even in a crowded and noisy environment. For example, at 1MHz offset the receiver can detect a signal only 3dB above the sensitivity level with a 60dB stronger interferer present. At 10MHz offset this interferer rejection has increased to 75dB. The module uses Gaussian-shaped Frequency Shift Keying (FSK) to limit the ACP to less than -37dBm as measured on the band edge. Spurious and harmonic emission is filtered and attenuated to less than -30dBm above 1GHz. The new module measures 19.5x60.5x6.0mm and comes in a DIL-style package with 2.00mm pin spacing made for low-profile board-to-board connection. Optionally it will be available with 2.54mm pin spacing. Figure 2 shows the mechanical layout of the high-power module, which is pre-certified for operation under the European radio regulations for license-free use in the 868MHz band, operating in 3 channels in the sub-band at 869.400 - 869.650MHz. Up to 10% duty cycle (transmission ratio) is allowed in this band. This module can also be used outside this sub-band if the power amplifier is disabled, reducing the output power to less than 10mW, or as per Table 1.

Range calculations

Based on operating frequency, receiver sensitivity and output power, we can make estimates for the achievable range. It will only be estimates, because in the real world effects from reflections, obstacles, noise sources, etc. will also come into play and vary from location to location. Using the RC1280HP high-power module as an example, we can make some estimates based on different models. The ideal open-space model (path loss exponent of 2), assuming transmitter and receiver antenna having 0dBi gain, gives over 150km range. A more realistic suburban model (path loss exponent of 3) using a quarter-wave antenna gains, gives 5 to 6km. This is in line with practical measurements. Table 2 summarises the achievable range for different Radiocrafts modules for use in the European license-free bands.

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