DATA TRANSMISSION, ALARMS, TELEMETERING AND M2M APPLICATION ON Sub-GHz “SRD” BANDS

Sub-GHz SRD bands are ideal for license-free low speed data transmission application. The SRD basic concept is to allow free use of certain frequency bands based on a reduced probability to cause interference to other “Primary Services”. Limits are posed on max radiated RF power, on transmission duty cycle with other sophisticated requirements to reduce the interference probability, like LBT (Listen Before Talk) and AFA (Adaptive Frequency Agility).

In Europe SRD are regulated by ETSI EN 300 220 and by CEPT ERC 70-03 Recommendation. Other Countries have similar standards such as the FCC Rules Part 15 and Part 90 in the United States.

Sub-GHz DATA TRANSCEIVERS INCREASE WIRELESS RANGE

High speed data transmission, such as Bluetoth or Wi-Fi, requires a broad radio channel (typically one or more MHz) so these applications are made at 2.4GHz and beyond. Sub-GHz SRD Bands are the ideal choice for low speed, short message data transmission. The band can be channelized with channel spacing of 12.5, 25 or 50 kHz hence a narrow receiver selectivity can be employed with a correspondent in channel noise reduction and receive sensitivity increment.

The modulation normally employed is the Narrow Band Frequency Modulation (NBFM) and the receiver sensitivity can easily reach level of minus 120 to minus 135 dBm.

Apart the transmitter output power that on some frequencies can go to 500 mW, it is evident the consistent “Link budget ” margin increment. Another big advantage is the possibility to program the radio on a lot of different channels reducing the possibility of message collision or interferences. Also the range increase must be considered: these Sub-Ghz lower frequencies deliver more distance for a given power level. This is mainly due to a lower obstacle attenuation and a less pronounced reflection of radio waves with a reduced probability of multipath signal cancellation.
TRANSMITTER, RECEIVER AND TRANSCEIVER IC OR MODULES: THE RADIOMODEM SOLUTION

Wireless data transmission can benefit of a big choice of Tx, Rx and Transceiver Integrated Circuits from many IC Manufacturers. Also on the market there is a huge offer of complete radio modules. These offers are very attractive but do not solve the problem of the "Communication Protocol". RF communication protocol is a very specialized Job: it is a mix of RF skill and data transmission theory competence in a little-known field of electronic.

Low current consumption applications (the case of battery operated wireless remotized sensors) is another example where high specialized solutions must be deployed.

So the best choice for easy solutions and fast to the market is to employ "Embedded Protocol Radiomodems".

THE STE/KSOLUTIONS FAMILY OF BK8xN3xx AND BK8xC3xx EMBEDDED PROTOCOL RADIOMODEMS

Currently available BK8x3xx Models are shown in the Table below:

<table>
<thead>
<tr>
<th>Model</th>
<th>Band</th>
<th>Channel spacing</th>
<th>Rx select.</th>
<th>Antenna</th>
<th>ERC REC 70-03 Rec</th>
</tr>
</thead>
<tbody>
<tr>
<td>BK82N3HP</td>
<td>169 MHz</td>
<td>12.5 kHz</td>
<td>9 kHz</td>
<td>External</td>
<td>Annex 1 - Annex 2</td>
</tr>
<tr>
<td>BK82N3LA</td>
<td>169 MHz</td>
<td>12.5 kHz</td>
<td>9 kHz</td>
<td>Integral</td>
<td>Annex 1 - Annex 2</td>
</tr>
<tr>
<td>BK87C3HP</td>
<td>434 MHz</td>
<td>25 kHz</td>
<td>13.5 kHz</td>
<td>External</td>
<td>Annex 1</td>
</tr>
<tr>
<td>BK87C3LA</td>
<td>434 MHz</td>
<td>25 kHz</td>
<td>13.5 kHz</td>
<td>Integral</td>
<td>Annex 1 – Annex 7</td>
</tr>
<tr>
<td>BK88C3HP</td>
<td>868 MHz</td>
<td>50 kHz</td>
<td>18.5 kHz</td>
<td>External</td>
<td>Annex 1 – Annex 7</td>
</tr>
<tr>
<td>BK88C3LA</td>
<td>868 MHz</td>
<td>50 kHz</td>
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<td>Annex 1 – Annex 7</td>
</tr>
</tbody>
</table>

RadioModem BK8 architecture
BK8x3xx RADIOMODEM DESIGN

The RF data transceiver is designed around the ADF7021N IC (Narrowband version of the ADF7020 IC Family) using a RF high-gain transistor to increase output power up to 400/600 mW.

To obtain and maintain constant high output power a DC/DC Booster provides to bring the input voltage (2,4 to 3,7 V) to a regulated +4,6V DC PA supply.

A stable TCXO (± 2,5 ppm) is employed to guarantee frequency accuracy over the operating temperature range.

The IC1 microcontroller is programmed to perform two main tasks related to the RF transmission and reception:
(1) Write into the IC2 registers the RF parameters to control transceiver operation (Tx and Rx frequency, Tx power, modulation and RF deviation, RF Data-rate, etc.).
(2) Manage the data exchange protocol maintaining external control through serial port and/or dedicated GPIO.

THE EMBEDDED COMMUNICATION PROTOCOL

The data exchange protocol must take in consideration the RF channel characteristics and limits.

The RF link is simplex, the “on-air” data/rate is usually much lower than the “Serial Port” data speed, then there is a data “Latency” and must be taken in consideration the Tx-to-Rx and Rx-to-Tx switching time and many other limits directly connected to the RF.

To be transmitted and reliably decoded by the receiver, data must be “encoded” (for example Manchester encoded).

Data must be preceeded by a “Preamble” and a “Syncroword”: in Fig.3 an example of a typical RF message.

**Figure 3: A typical data message**

“Measurements” is an optional field.

An useful measure can be the “Supply” voltage (or “Battery” voltage), the “Temperature” and also the “Received Signal Strenght” (RSSI). The RSSI can used to discriminate between useful and interference signals and to implement the “LBT” (Listen Before Talk) function as often required by the Normatives.

RSSI” is also very useful during network set/up, range tests and antenna efficiency evaluation.

The Microcontroller (LPC1114) must also manage the UART serial port (RS232/RS486) or “SPI” and, if requested by the application, the optional “GPIO” pins.

Fig. 4 and 5 represent typical cases.

In Figure 4 the external remote sensors, alarms, control/commands and the generic data communication applications are directly performed by the IC1 Microcontroller inside the Radio-modem.

It is evident that the “SW” inside the Micro must be tailored to the specific task of the user.

To do this the BK8x3xx module can be programmed to different input and output options (see Fig. 6).
Different is the situation depicted in Figure 5. This case the control and the management of the external data is performed by the system integrator via a Computer or a dedicated Microcontroller and the radio-modem simply receives and send data through the serial port and transmits them “on-air” to the remote station. Viceversa when a telegram is received from the remote unit the radio-modem decodes the message and immediately outputs the data from the UART.

THE “D1“ EMBEDDED PROTOCOL

The BK8x3xx programmed with the “D1“ Software becomes a generic “transparent” Radio-modem with a communication protocol to be employed in a data communication network as depicted in Fig. 5. The modem operating mode is similar to the “Feed and Forward” system:

to transmit a message “DATA” are sent through the TXD input to the 512 Bytes buffer and the Radio-modem enters the Tx mode when:

1. Max. packet length is reached, or
2. The modem timeout limit (10 ms) is expired.

In Rx mode the Radio-modem waits for the arrival of a valid message, decodes it and sends the data at the Rxd output.

Generally speaking there is a big confusion to name input/output serial ports at Microcontroller, PC, Modem, Rxd and Txd. In a Modem the input “TXD” correspond to the pin where the data to be on/air transmitted enter the Rxd input of the UART port. In Figure 6, J 1 connector, it is the term. n.5 (n.5 is named “Rxd” because is referred to the Uart input).

Figure 6 – Generic User Programmable BK8x3xx Radiomodem Input /Output
Normally in applications where need a wireless exchange of data, such as in the case of remote sensors measure of physical quantities or in the case of alarms or commands, it is only necessary to transmit messages of 100/200 Bytes.

What it is usually necessary is a very low BER (Bit Error Rate) data exchange even in the presence of noise.

Also very important is obviously the distance reached taking into account the attenuation due to obstacles and the anomalies typical of the radio waves propagation (such as multipath propagations).

Last but not least you should note that often sensor systems or remote alarms are powered by batteries and must therefore be a low power consumption with a careful management of “sleep” periods.

The best solution is to use narrow-band NBFM systems and focus on improving the Rx sensitivity (theRx S/N) at a low “Data rate”.

Important is also to take in consideration the typical characteristics of the receiver and transmitter systems such as settling time of the “PLL”, the Rx/Tx switching time, the possible influence of mechanical vibrations etc. etc.

What is of paramount importance is to avoid the design of systems that work perfectly in the lab, but that have problems in practical application especially in a hostile environment.

The “D1” communication protocol is an example of optimum balance between data speed and data integrity and it can be employed as it is in many practical cases offering a secure data exchange at low BER (Bit Error Rate) with received signal levels as low as -115/-125 dBm.

An example of how the first part of the protocol, the most ‘critical step in the transmission by sending the “Preamble” and “Sync-word’, and ‘seen in Fig ....

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A WELL CONSTRUCTED WIRELESS NETWORK (1) - ANTENNAS AND THE “LINK BUDGET”

A wireless data communication network must be accurately designed to ensure, at the receiver side, a good RF signal level. The received signal level depends obviously on the Tx power, but also strongly depends upon the efficiency of the antenna system. The reached distance is limited by space attenuation, but it is also influenced by obstacles and by radio-waves anomalies, reflection and multipath signal cancellation.

The “Link budget” (in its simplest definition) is the difference between the Tx Power level and the minimum usable receiver signal strength for a predetermined BER (Bit Error Rate) or PER (Packet Error Rate) and expressed in dB (Fig.7).

The antennas play an important role to define the real “Link Budget”.

It is evident that a -3dBi antenna (3dB less efficiency respect ideal Dipole) cuts to half the Tx power (and reduces by 3db receiver sensitivity). In a well-constructed network and depending on the required data exchange reliability, antenna gain must be considered and also it is a good idea to define a "Link Budget" safety margin (normally 20dB).

Remember that the ISM and SRD frequencies are not protected and interference from other services must be taken in consideration. In Figure 7 the practical “Link Budget” is more and more reduced to 115dB.
With the exception of rare cases of free space propagation normally, in a real world situation, it is difficult to calculate the available signal levels (RSSI). Laboratory or “On-site” propagation tests are recommended to be sure on the final network performances. Tests on antennas and also a control on interfering signals and/or the presence of on channel noise can be performed with the help of the EVB8xx Narrow Band Evaluation Kit (Paragraph 9).

A WELL CONSTRUCTED WIRELESS NETWORK (2) - THE EVB8xx EVALUATION BOARD

All BK8xx3xx Family Radio-modems are available in Demo-Kits equipped with EVB8xx boards and appropriate antennas. The EVB8x3xx Evaluation Board has a USB serial port and features easy access to all the Radio-modems I/O pins. Evaluation of all network parameters (Frequency, Tx power, Rx sensitivity, etc.) and propagation test can be quickly performed.

The simplest system for message exchange testing is the use of a pair of BK8xx3xx-D1 modules and that means two Radio-modems programmed with the “D1” Software (Par. 7).

“D1” is programmed not only to permit test and measure on messages (BER, as an example), but also, by the use of the attached “Measurements”, to maintain the control on Radio-Waves propagation and antennas performance.

THE “NOISY RADIO CHANNEL” PROBLEM

With “D1” Software programmed the user can be sure that the Radio-modem communication protocol is the best possible for the specified data speed, radio channel bandwidth, etc.

It is very frequent to find situations where the reached distance is not what expected. A first good idea is to analyze antenna efficiency, but may be there is another subtle problem: “Noise” or “Interference” on the radio channel.

In a RF laboratory there are plenty of instruments to analyse the situation (Spectrum analyser, RF Generator, Receivers, etc.), but this is not the case of people whose tasks and job are only to use the wireless communication network.
To help to solve the problem (as also for other finality) was introduced in the "Measurements" field the "NOISE" level measure in addition to "RSSI".

In a quiet RF channel about 15kHz wide (the Rx selectivity) the noise level must be around -125dBm also in a urban location. Higher level "NOISE" (-100 to -80 dBm) persistent on the radio channel may be considered "broad band" noise.

This noise can be generated from spurious emissions of switching power supply, USB port, PC or plasma display and so on.

Different is the case of interfering signals.

Interference can come from another SRD application or also from other Radio Services: normally 100% Duty-cycle transmission are forbidden.

To analyze the situation can also be useful to change the frequency of the radio channel.

A WELL CONSTRUCTED WIRELESS NETWORK (3) - POWER SUPPLY AND BATTERY POWERED SYSTEMS

The nominal BK8xx supply tension is 3,3 VDC with a typical 400-500mA transmission current (500mW RF power output).

A DC/DC Boost converter is employed to provide a stabilized 4,6 VDC to the RF power amplifier (PA, Fig.3) in order to maintain the programmed RF power constant at minimum and maximum supply voltage range (2,4 – 3,6 VDC).

At power on and especially when the radiomodem is forced to transmission there is a current peak (fig. ...) due to the fast charge of filter capacitor C2 on the DC/DC converter output. The power supply must be able to avoid voltage “dips” during the Rx/Tx switching time.

A storage capacitor (fig. ...) of appropriate value can be employed to avoid or to reduce the voltage “dip” induced by the internal series equivalent resistance (or impedance) of the power supply.

The problem of the internal equivalent series resistance must be accurately considered especially when the source of energy is a battery. A lithium 3,6V “D” size battery is normally considered a big and reliable source of energy capable to last for many years in a well designed system.