

Designing a Wireless Transceiver System to Meet the Wireless M-Bus Standard

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INTRODUCTION

The continuing rollout of advanced metering infrastructure (AMI) systems has led to greater efficiency for utility companies collecting energy, gas, and water consumption data. Replacing manual readings with automated metering systems can reduce labor costs as a first-order benefit. More importantly, automated systems allow higher-order benefits and services that the utility company can conveniently provide, such as real-time price signalling to promote better energy efficiency, and instant reporting of fault detection, as well as much more accurate data for profiling usage within the network.

Various choices of technology are available when implementing a networked metering system from satellite technology to simple infrared emitters. However, two technologies are emerging as dominant: wireless short range devices (SRD) and power line carrier (PLC) systems. For water and gas meters in particular, SRD technology is becoming the dominant technology choice due to the unsuitability of power line carrier systems in these environments.

To achieve the best combination of communication range and low power consumption, the majority of meter manufacturers have chosen radios in the lower UHF or sub-GHz bands as the RF communication link from meter-to-meter and meter-to-data collectors. For example, a frequency of 868 MHz is often used in Europe while a frequency range of 902 MHz to 928 MHz is often used in North America.

Radios at these frequencies offer a better communication range for a given power budget than competing 2.4 GHz technologies and thus allow a much wider cell coverage for a given base station or data collector. The range benefit is also vital for gas and water meters where the meter location could be in a basement or in an underground pit. However, one of the drawbacks of using this frequency band, from the perspective of the utility, is the lack of available standards in these bands.

The sub-GHz bands are clearly the best technology choice for battery-powered gas and water meters and, thus, there is increasing demand for standardization to allow interoperability between different manufacturer's systems. Wireless M-Bus, which evolved from the wired M-Bus user group, is increasingly preferred in Europe as the standard for communication between meters. M-Bus is now part of the European normative (EN) standard detailed in EN 13757. The wireless M-Bus protocol is detailed in the EN 13757-4 variant. Because this standard is relatively new, there are not many existing solutions on the market. This causes problems among some manufacturers who are increasingly being asked by utility vendors to offer M-Bus-compatible products.

This application note discusses the EN 13757-4 standard and the system requirements when using the Analog Devices, Inc., ADF7020 to design an M-Bus-compatible device.

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TECHNICAL SUMMARY OF EN 13757-4

M-Bus specifies three modes of operation: R, S, and T. These modes differ by data rate, channel frequency, and data encoding used. Each of these modes can be unidirectional or bidirectional where a 1 or a 2, respectively, is appended to the mode letter. For example, T1 indicates a one-way T mode device and S2 indicates a two-way S mode device. The modes and the associated data rates are given in Table 1.

Stationary mode (Mode S) is intended for communications between stationary or mobile devices, where the data is transmitted only several times per day. This is most suited to fixed infrastructure or networked implementations.

Mode T, or frequent transmit mode, sends out data in chirps every few seconds and, thus, is more suitable for walk-by or drive-by implementations. Allowing features like remote disconnect or reading of hourly data to be added to a drive-by meter requires two-way communications or T2, for example.

In Mode R, or frequent receive mode, the receiver wakes up frequently to listen for messages from a mobile transceiver. This type of implementation is typically higher power than Mode T, for example, because the receiver needs to be on for a longer time to detect sufficient bits of preamble. Though this is usually not an issue for a mains powered energy meter, it might make it difficult to design a multiyear battery-powered system. The advantage is that Mode R is more narrow band and thus allows up to 10 channels for frequency division multiplexing. This allows the readout of several meters simultaneously.

All of the modes use subbands G1 and G2 in the ETSI 868.0 MHz to 870 MHz general usage band. Subband G1 ranges from 868.0 MHz to 868.6 MHz, while G2 ranges from 868.7 MHz to 869.2 MHz. These subbands provide 600 kHz and 500 kHz of bandwidth, respectively. Refer to REC 70-03 for more details (available for download from the ERO website described in the For Further Reading section).

Table 1. Modes in Wireless M-Bus

Mode	Data Rate (kcps)	Nominal Carrier Frequency (MHz)	Nominal Deviation Frequency (kHz)	Data Encoding
R	4.8	$868.33 + n \times 0.06$	± 6	Manchester
S	32.768	868.3	± 50	Manchester
T	100	868.3/868.95	± 50	3 to 6

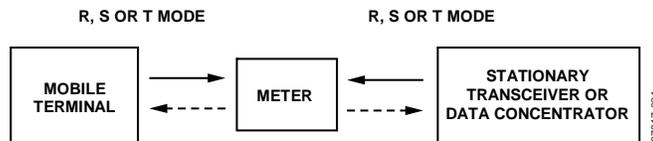


Figure 1. EN 13757-4 System

TECHNICAL CONSIDERATIONS WHEN MEETING WIRELESS M-BUS STANDARDS

ADF7020 or ADF7021

Analog Devices has a family of sub-GHz, low power radio devices. These devices are segmented according to the channel bandwidth. The ADF7021 is designed to cover 12.5 kHz to 60 kHz channelizations. The ADF7020 is designed to cover 60 kHz to 600 kHz channelizations. If you compare these vs. the M-Bus channelizations of 600 kHz, 500 kHz, and 60 kHz for S, T, and R modes, respectively, the ADF7020 is suit-able for all three modes, whereas the ADF7021 is more optimized for the R mode. This application note focuses on meeting the S and T modes with the ADF7020.

Xtal Choice to Meet 32.768 kbps and 100 kbps

To meet the S and T mode data rates of 32.768 kbps and 100 kbps, respectively, requires the appropriate choice of external crystal (xtal). The xtal needs to be chosen so that the clock for the clock and data recovery (CDR) circuit on the ADF7020, which is divided down from the xtal, is within 2% of 32× the ideal data rates (the CDR clock is over-sampled at 32× the data rate). A simple spreadsheet can be created to test out various xtals which give the required tolerance. Some values that work are 12.8 MHz, 18.867 MHz, and 19.2 MHz. These values all give 0% error tolerance at one data rate and 1.7% error tolerance at the other.

Note that if you plan to implement a T2 mode receiver unit that specifies a ±12% chip rate variance, you must bypass the CDR circuit. In this case, the choice of crystal is not as important. Any commonly available value between 10 MHz and 20 MHz is a good choice. Bypassing the CDR is explained in more detail in the Chip Rate Tolerance section.

Meeting ETSI Emission Masks

Unfortunately, from an emissions mask point of view, M-Bus specifies FSK modulation rather than Gaussian FSK or raised cosine FSK. This makes the ETSI modulation band-width requirement, measured as the –36 dBm bandwidth, more difficult to meet. However, it is simple to simulate the ETSI modulation bandwidth using the free [ADI SRD Design Studio™](#) tool available from Analog Devices.

An important parameter which influences the modulation bandwidth is the PLL open-loop bandwidth. This must be set high enough to pass the transmitted data rate without significant distortion, but not so high as to increase the overall PLL integrated noise level and, thus, the modulation bandwidth. For FSK data, the PLL loop bandwidth can be set as low as $1.0 \times$ the data rate without affecting the modulation quality. Therefore, to cater to S, T, and R modes, the PLL loop bandwidth should be set to 100 kHz.

Figure 3 shows a simulation of an S mode device operating in the ETSI G1 subband from 868.0 MHz to 868.6 MHz, with 100 kHz PLL loop bandwidth, ±50 kHz deviation Manchester encoded PRBS data and +13 dBm output power. The –36 dBm modulation bandwidth is estimated at 426 kHz which is well within the 600 kHz requirement for ETSI Channel G1.

Similarly, for a T mode device, the modulation bandwidth is simulated at 408 kHz (see Figure 4), which is within the 500 kHz requirement of Channel G2. Although the simulation uses PRBS data to modulate the carrier as per the ETSI specification, the T mode spectrum appears tonal due to the modulation index of 1.0. In fact, EN 13757-4 specifies a deviation frequency tolerance ranging from ±40 kHz to ±80 kHz, which gives a modulation index range of 0.8 to 1.6. The ADF7020 receiver, which works well with modulation indices in the range of 0.4 to 5.0 or higher, can handle this variation in modulation index with little degradation in sensitivity. The modulation bandwidth decreases significantly if the deviation is simply changed from 50 kHz to 48 kHz.

DATA RATE			
100	kbps		
IDEAL CDR		CHECK THIS XTAL	
3200	kHz	19.2	MHz
	IDEAL XTALS	DEMOD CLK	
1	3,200	9.60	
2	6,400		
3	9,600	CDR DIVIDE	
4	12,800	3.00	
5	16,000		
6	19,200	%ERROR	
7	22,400	0.00%	
8	25,600		
9	28,800		

Figure 2. Example Spreadsheet to Calculate Acceptable Crystals to Meet M-Bus Data Rates

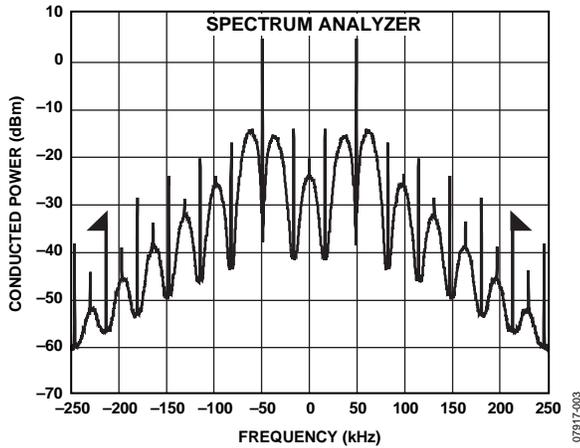


Figure 3. ADI SRD Design Studio Simulation of Manchester Encoded S Mode Spectrum

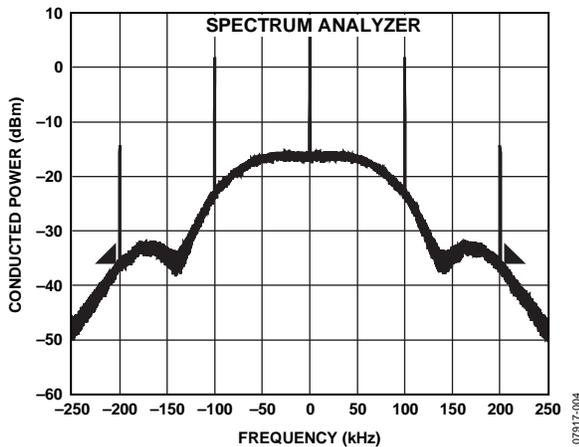


Figure 4. ADI SRD Design Studio Simulation of T Mode Spectrum

Frequency Tolerance

EN 13757-4 specifies a frequency tolerance of at least ± 25 ppm for devices communicating to the meter and a looser ± 60 ppm for the meter frequency accuracy itself. To accurately demodulate the FSK signal with this frequency error requires either a system with large frequency error tolerance (like the linear demodulator on the ADF7020) or else an automatic frequency control (AFC) scheme.

Modern transceivers like the ADF7020 have integrated AFC circuits which can pull in errors up to ± 60 ppm; however, this circuit typically requires a minimum level of preamble of 48 bits. M-Bus specifies a preamble length of 48 chips, but this includes the sync word, thus the preamble could be as low as 30 chips in S mode or 38 chips in T mode.

For this reason, the recommendation is to use the linear demodulator with AFC off on the ADF7020 in an M-Bus system. The IF bandwidth should be set to the maximum value of 200 kHz to pass the signal with frequency error. It is also recommended to use low ppm crystals, either ± 25 ppm or ± 10 ppm, in the design. These crystals are readily available from most crystal manufacturers.

Chip Rate Tolerance

Another design issue raised by the rather loose M-Bus specifications is that the chip rate range is specified as high as 10% to 12% for transmissions from the meter. The linear demodulator, as recommended, can accept data rates with this variance. However, this causes issues with the clock and data recovery (CDR) circuit, which works well only for chip rate tolerances of less than 3%.

Handling this large chip rate variance requires you to bypass the on-board CDR and retime the data in the microcontroller. You can bypass the CDR circuit, when in linear demodulator mode, by writing 0x0000 C00C which enables this mode in the test mode register. For completeness, you can bypass the CDR when in correlator demodulator mode by writing 0x0001 000C to the test mode register. However, as explained in the Frequency Tolerance section, the recommendation is to use the linear demodulator for M-Bus systems.

One consequence of bypassing the CDR is that the Sync Word Detect (SWD) feature does not work over the full chip rate range of $\pm 12\%$. It does work over a narrower range of $\pm 3\%$. In this case, SWD must be performed on the microcontroller.

Meeting the Minimum Receiver Sensitivity Limits

M-Bus specifies a minimum receive sensitivity of -100 dBm for a BER of $1e-2$. This is more straightforward for the lower data rate S mode, where sensitivity of -107 dBm can be expected without the need for an external antenna switch or LNA. In T2 mode, 100 kcps sensitivity on the ADF7020 is -103 dBm. The ADF7020 also has the advantage of its flat sensitivity curve vs. modulation index (see Figure 5.). Thus the sensitivity should stay constant as the modulation index varies, as described in the Meeting ETSI Emission Masks section.

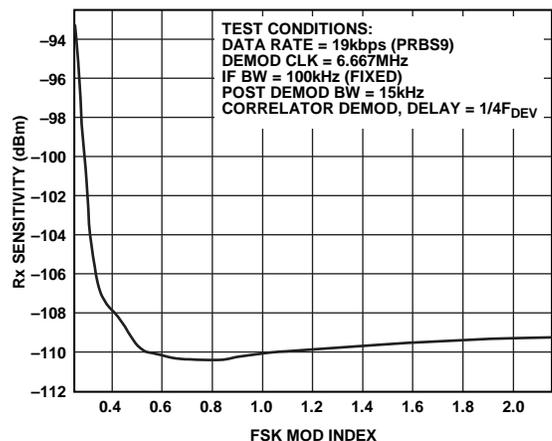


Figure 5. ADF7020 Sensitivity vs. FSK Modulation Index

Deviation Tolerance

Deviation tolerances ranging from ± 40 kHz to ± 80 kHz can be handled by using the linear demodulator as recommended in the Meeting ETSI Emission Masks section. The IF bandwidth should be set to the maximum value of 200 kHz to pass the signal with frequency and deviation errors.

SUMMARY

The wireless M-Bus standard is emerging as an important standard for meter manufacturers designing wireless AMR/AMI systems in Europe. This application note describes some of the design considerations to keep in mind when designing a wireless M-Bus system using the ADF7020.

The ADF7020 is suitable for operation in S, T and R modes. Although given the relatively narrow bandwidth in R mode, the ADF7021 is a better fit to optimize adjacent channel rejection (ACR) performance.

Analog Devices is focused on supplying leading edge technology to the metering market, including RF transceivers, energy measurement chip sets, isolation products, and power line control products. The ADF7020 is a high performance, fully integrated transceiver suitable for wireless M-Bus systems that allows a compact, robust, and low cost solution for meter manufacturers in Europe and worldwide.

FOR FURTHER READING

For more information about M-bus systems, the Universitat Bremen and University College London offer a message bus website. In addition, the European Radiocommunications Office (RCO) maintains an ERO website.

Further information about Analog Devices products, as well as a free copy of the ADI SRD Design Studio tool, is available at www.analog.com.

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