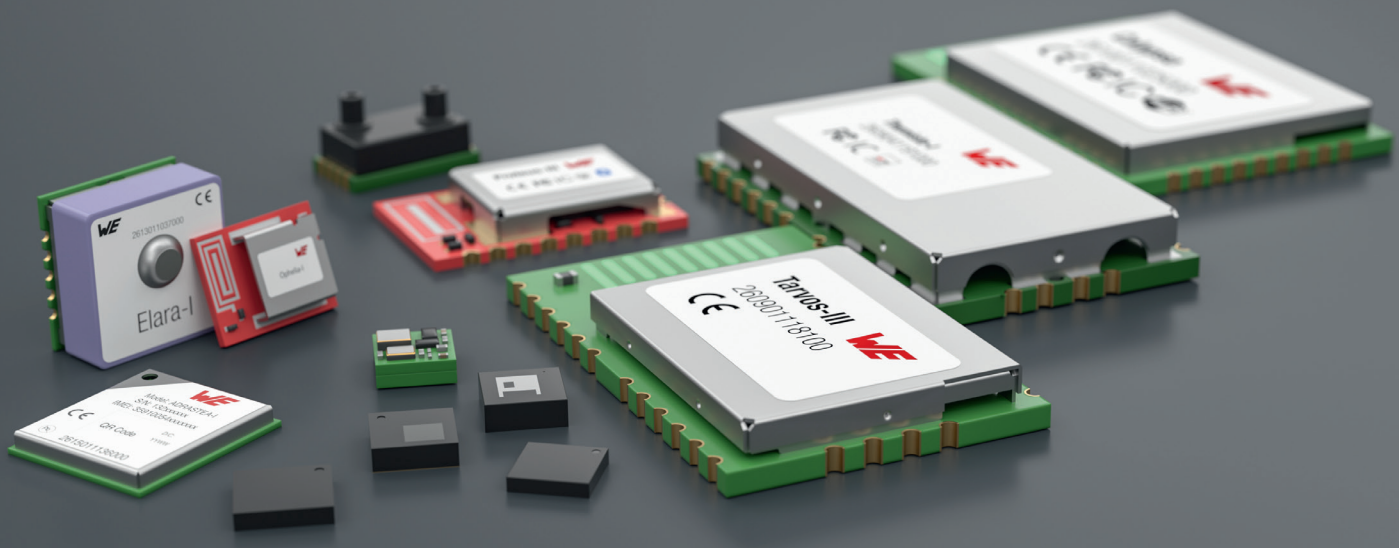

ANR015

From 868 MHz to 915 MHz

Replacing 868 MHz radio modules by their 915 MHz counterparts

Version 1.1

July 19, 2023

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Revision history

Manual version	Notes	Date
1.0	• Initial version	July 2019
1.1	• Updated `Important notes`, meta data and document style	July 2023

Abbreviations

Abbreviat	Name	Description
FCC	Federal Communications Commission	American authority for radio certification.
FEC	Forward Error Correction	Correction method for recovering of erroneous received radio frames
FSK	Frequency shift keying	Frequency modulation technique
GFSK	Gaussian frequency shift keying	Frequency modulation technique
ISED	Innovation, Science and Economic Development	Canadian authority for radio certification.
ISM	Industrial, Scientific and Medical	Unlicensed frequency bands.
LRM	Long range mode	Special radio profile for large transmission ranges.
Payload		The intended message in a frame / package.
RF	Radio frequency	Describes wireless transmission.
SRD	Short Range Device	Unlicensed frequency bands.

Contents

1 Introduction

The radio frequency spectrum is regulated by designated regulatory authorities that define how specific spectrum bands can be used. The ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) bands are free to use without license costs. As there is no single worldwide regulation, national authorities define which of the frequency bands are open for access in each specific country.

The 2.4 - 2.5 GHz band can be used worldwide, but has specific disadvantages. Besides the poor transmission range due to the bad penetration of this frequency, the 2.4 GHz band is really noisy and crowded due to the vast number of Wi-Fi and Bluetooth® devices around.

To overcome these issues, in Europe the frequency band 868 - 870 MHz is very common, as it provides data transmission ranges and speeds that are sufficient for many industrial applications.

Companies developing radio products for the European market often look out to non-European markets to expand their business volume. Most often the American as well as the Canadian markets are faced due to their huge potential. Unfortunately, in northern America the 868 MHz frequency band is not permitted by the Federal Communications Commission (FCC) USA and the Innovation, Science and Economic Development (ISED) Canada, such that the 902 - 928 MHz frequency band is taken as appropriate counterpart.

This application note describes which key facts have to be considered, when replacing a proprietary Würth Elektronik eiSos 868 MHz radio module by its 915 MHz radio module counterpart.

1.1 Other markets

The European, American and Canadian markets are the first markets that have been regulated concerning the frequency spectrum. In between, other foreign markets have been regulated as well. These markets bring additional sales potential.
Due to this historic aspect, most of the foreign radio regulations are based on European or North American regulations, such that at least parts of the 868 - 870 MHz or 902 - 928 MHz frequency band are allowed in most of the countries.
Keeping that in mind underlines why having both, 868 and 915 MHz radio products, in the portfolio is important when planning to take advantage of Sub-1-GHz radio.

2 Replacing 868 MHz radio modules by their 915 MHz counterparts

This chapter describes which Würth Elektronik eiSos 868 MHz radio modules can be replaced by their 915 MHz counterparts with low effort. Furthermore, the steps to be done for the replacement are considered afterwards.

2.1 Thebe-II

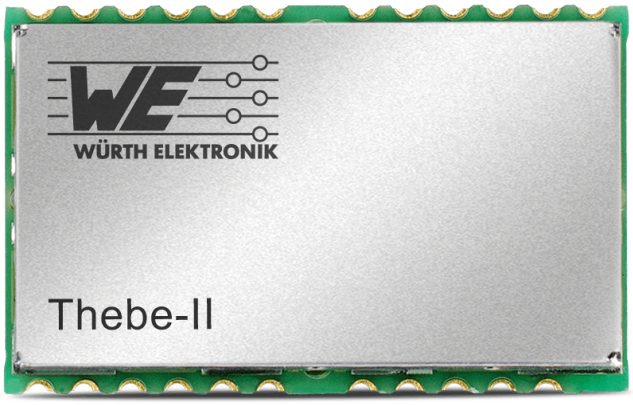

Figure 1: Thebe-II: proprietary 868 MHz radio module

The Thebe-II is a proprietary 868 MHz (Band P) 500 mW radio module, that is available with a 50 Ω antenna pad to connect an external antenna. The Thebe-II provides the following radio profiles:

Radio profile	Data rate (gross) [kbps]	Modulation	Max packet size [Byte]	Max packet duration [ms]	Max range[1] [m]
0	38.4	(G)FSK	128	40	3000
2	100	(G)FSK	128	20	2300
3 (LRM)	10 (=0.625 kbps net)	DSSS + FEC	48	1000	8000
4 (LRM)	20 (=2.5 kbps net)	DSSS + FEC	64	300	6000
7	50	(G)FSK	128	35	2300

Table 1: Radio profiles of the Thebe-II

Profile 0, 2 and 7 provide medium speed and range data transmission, where profile 3 and 4 allow higher range data transmission.

[1] Using two Thebe-II with external antenna, 2m antenna height, 0 dB antenna gain and 6 dB link margin. The Range Estimator Tool, which is part of the *REDEXPERT*, allows to calculate the transmission ranges also for other antenna setups.

2.1.1 915 MHz counterpart: Themisto-I

The Themisto-I has been designed as a counterpart for Thebe-II for the North American market. The Themisto-I is a proprietary 915 MHz 500mW radio module, that is also available with

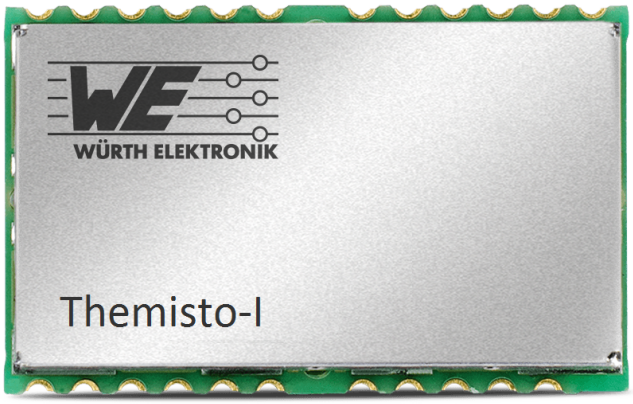

Figure 2: Themisto-I: proprietary 915 MHz radio module

a 50 Ω antenna pad to connect an external antenna. The Themisto-I provides the following radio profiles:

Radio profile	Data rate (gross) [kbps]	Modulation	Max packet size [Byte]	Max packet duration [ms]	Max range[1] [m]
6	400	GFSK	224	15	1700
8 (LRM)	480 (= 240 kbps net)	DSSS with FEC	224	15	2500
9 (LRM)	480 (= 30 kbps net)	DSSS with FEC	224	75	3500

Table 2: Radio profiles of the Themisto-I

To conform with the FCC Part 15.247 and ISED, the Themisto-I uses a wide band digital modulation technique. This allows a high data rate for fast data transmission.

[1] Using two Themisto-I with external antenna, 2m antenna height, 0 dB antenna gain and 6 dB link margin. The Range Estimator Tool, which is part of the *REDEXPERT*, allows to calculate the transmission ranges also for other antenna setups.

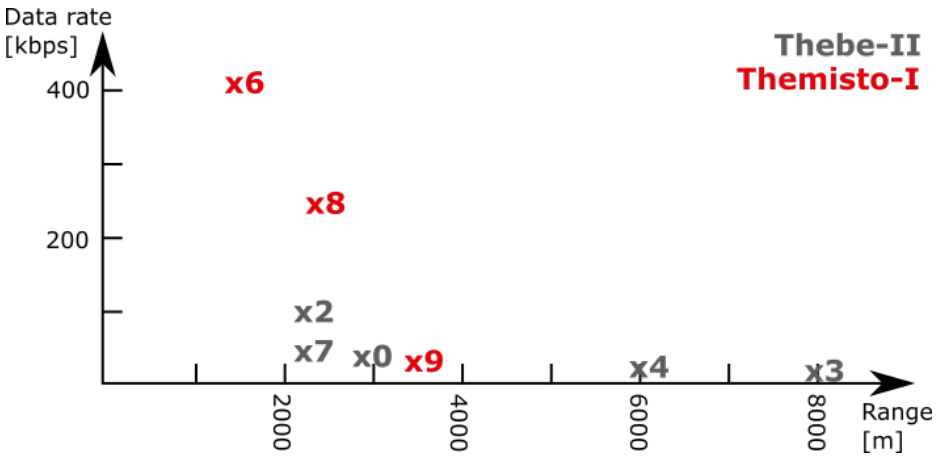

Figure 3: Range vs. data rate

In case, the **Thebe-II** is replaced by a **Themisto-I** radio module, the following facts have to be considered:

Feature	Information	Actions needed
Form factor & footprint	Both modules have the same form factor and footprint.	None
Pinout	Both modules are pin compatible.	None
Antenna	Both modules are available with a 50 Ω antenna pad to connect an external antenna.	Check whether the connected 868 MHz antenna can be also used for 915 MHz.
UART protocol	Both modules provide a command interface using the same commands and functions.	None
Radio configuration	• The radio profiles of the Themisto-I provide a faster radio transmission at the cost of range. • The channel numbering changes from 129 - 132 (869.45 - 869.6 MHz) to 200 - 252 (902 - 928 MHz).	• Check the range and timing requirements of your application. • Use the new channel numbers in your application code.
Certification	The 915 MHz range is regulated in North America by the FCC USA and ISED Canada.	Re-testing[1] of the end-device is needed to determine unwanted emissions.

Table 3: Replace a Thebe-II with a Themisto-I

[1] See FCC 996369 D04 Module Integration Guide V01.

Summary

The Thebe-II and Themisto-I can be considered from the beginning of your design, being aware that in case of selling to countries with 915 MHz a solution is available almost instantly.
As the footprint, pinout and UART protocol of both modules is the same, switching from Thebe-II to Themisto-I can be performed very quickly without any hardware re-design.

2.2 Tarvos-III

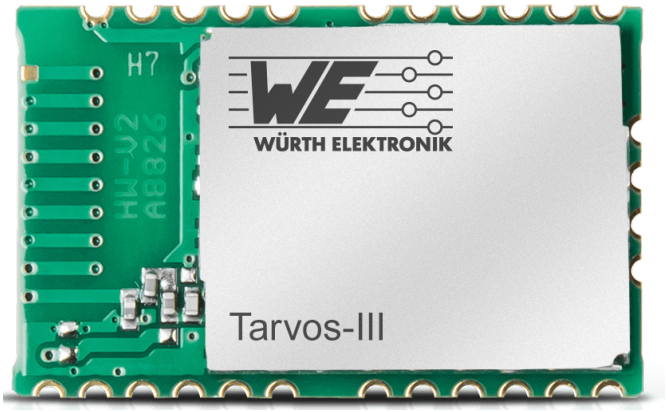

Figure 4: Tarvos-III: proprietary 868 MHz radio module

The Tarvos-III is a proprietary 868 MHz radio module, that is available with integrated antenna as well as with a 50 Ω antenna pad to connect an external antenna. The Tarvos-III provides the following radio profiles, that allow fast as well as long range data transmission:

Radio profile	Data rate (gross) [kbps]	Modulation	Max packet size [Byte]	Max packet duration [ms]	Max range[1] [m]
0	38.4	FSK	128	40	1500
2	100	FSK	128	20	1100
3 (LRM)	10 (=0.625 kbps net)	FSK (with FEC)	48	1000	4000
4 (LRM)	20 (=2.5 kbps net)	FSK (with FEC)	64	300	3000
5	400	GFSK	224	10	800

Table 4: Radio profiles of the Tarvos-III

Profile 0 and 2 provide medium speed and range data transmission, where profile 3 and 4 allow high range and profile 5 allows high speed data transmission.

[1] Using two Tarvos-III with external antenna, 2m antenna height, 0 dB antenna gain and 6 dB link margin. The Range Estimator Tool, which is part of the *REDEXPERT*, allows to calculate the transmission ranges also for other antenna setups.

2.2.1 915 MHz counterpart: Telesto-III

The Telesto-III has been designed as a counterpart for Tarvos-III for the North American market. The Telesto-III is a proprietary 915 MHz radio module, that is also available with integrated

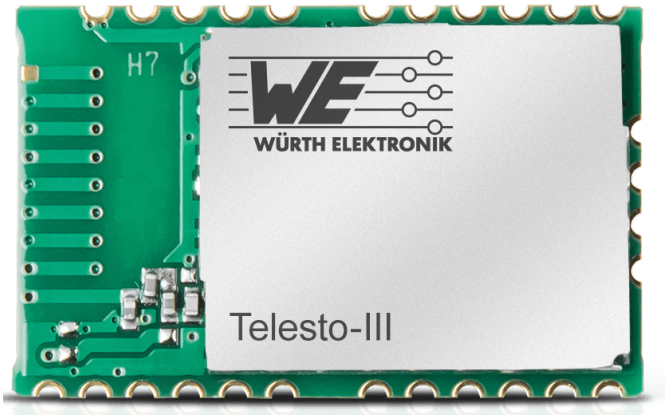

Figure 5: Telesto-III: proprietary 915 MHz radio module

antenna as well as with a 50 Ω antenna pad to connect an external antenna. The Telesto-III provides the following radio profile:

Radio profile	Data rate (gross) [kbps]	Modulation	Max packet size [Byte]	Max packet duration [ms]	Max range[1] [m]
6	400	GFSK	224	10	800

Table 5: Radio profile of the Telesto-III

To conform with the FCC Part 15.247 and ISED, the Telesto-III uses a broad radio spectrum. This allows a high data rate for fast data transmission.

[1] Using two Telesto-III with external antenna, 2m antenna height, 0 dB antenna gain and 6 dB link margin. The Range Estimator Tool, which is part of the *REDEXPERT*, allows to calculate the transmission ranges also for other antenna setups.

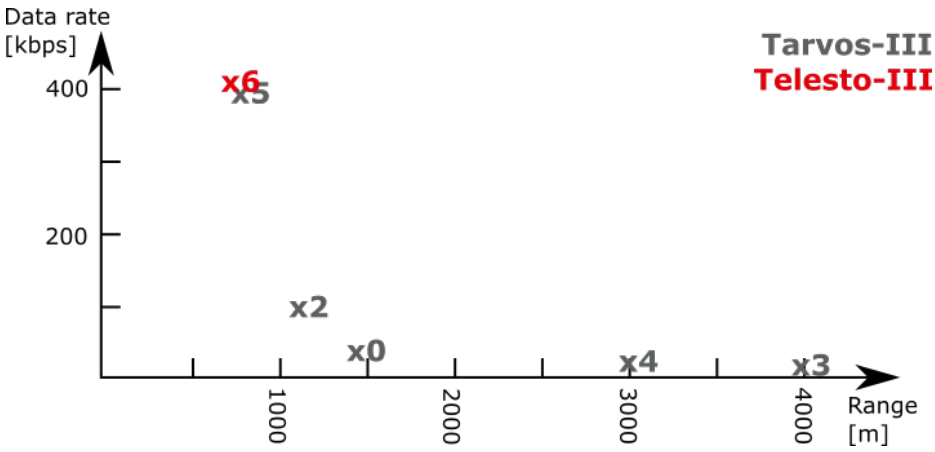

Figure 6: Range vs. data rate

In case, the **Tarvos-III** is replaced by a **Telesto-III** radio module, the following facts have to be considered:

Feature	Information	Actions needed
Form factor & footprint	Both modules have the same form factor and footprint.	None
Pinout	Both modules are pin compatible.	None
Antenna	Both modules are available with integrated antenna and a 50 Ω antenna pad to connect an external antenna.	In case of external antenna, check whether the connected 868 MHz antenna can be also used for 915 MHz.
UART protocol	Both modules provide a command interface using the same commands and functions.	None
Radio configuration	• The radio profile 6 of the Telesto-III is comparable in range and speed with the radio profile 5 of the Tarvos-III. In case, the Tarvos-III uses another radio profile, the range of the Telesto-III is lower, but data rate is higher, such that the data can be transmitted much faster. • The channel numbering changes from 100 - 140 (868 - 870 MHz) to 200 - 252 (902 - 928 MHz).	• Check the range requirements of your application. • Use the new channel numbers in your application code.
Certification	The 915 MHz range is regulated in North America by the FCC USA and ISED Canada.	Re-testing[1] of the end-device is needed to determine unwanted emissions.

Table 6: Replace a Tarvos-III with a Telesto-III

Summary

The Tarvos-III and Telesto-III can be considered from the beginning of your design, being aware that in case of selling to countries with 915 MHz a solution is available almost instantly.
As the footprint, pinout and UART protocol of both modules is the same, switching from Tarvos-III to Telesto-III can be performed very quickly without any hardware re-design.

[1] See FCC 996369 D04 Module Integration Guide V01.

2.3 Tarvos-II

Figure 7: Tarvos-II: proprietary 868 MHz radio module

The Tarvos-II is a proprietary 868 MHz radio module, that is available with a 50 Ω antenna pad to connect an external antenna. The Tarvos-II provides the following radio profiles:

Radio profile	Data rate (gross) [kbps]	Modulation	Max packet size [Byte]	Max packet duration [ms]	Max range[1] [m]
0	38.4	GFSK	128	40	1400
1	2.4	GFSK	128	500	2600
2	100	GFSK	128	20	1000

Table 7: Radio profiles of the Tarvos-II

Profile 0 provides medium speed and range data transmission, where profile 1 allows higher range and profile 2 allows faster data transmission.

[1] Using two Tarvos-II with external antenna, 2m antenna height, 0 dB antenna gain and 6 dB link margin. The Range Estimator Tool, which is part of the *REDEXPERT*, allows to calculate the transmission ranges also for other antenna setups.

2.3.1 915 MHz counterpart: Telesto-I

The Telesto-I has been designed as a counterpart for Tarvos-II for the North American market. The Telesto-I is a proprietary 915 MHz radio module, that is also available with a 50 Ω antenna

Figure 8: Telesto-I: proprietary 915 MHz radio module

pad to connect an external antenna. The Telesto-I provides the following radio profiles:

Radio profile	Data rate (gross) [kbps]	Modulation	Max packet size [Byte]	Max packet duration [ms]	Max range[1] [m]
3	38.4	GFSK	128	40	550
4	100	GFSK	128	20	400

Table 8: Radio profiles of the Telesto-I

To conform with the FCC Part 15.249 and ISED, the Telesto-II uses low transmission power of about -2 dBm. This allows data transmission with low energy consumption, but also results in reduced ranges.

[1] Using two Telesto-I with external antenna, 2m antenna height, 0 dB antenna gain and 6 dB link margin. The Range Estimator Tool, which is part of the *REDEXPERT*, allows to calculate the transmission ranges also for other antenna setups.

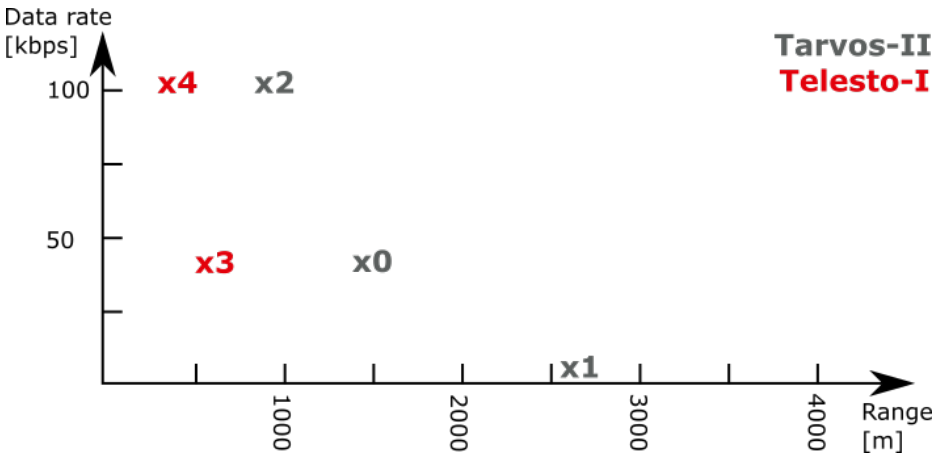

Figure 9: Range vs. data rate

In case, the **Tarvos-II** is replaced by a **Telesto-I** radio module, the following facts have to be considered:

Feature	Information	Actions needed
Form factor & footprint	Both modules have the same form factor and footprint.	None
Pinout	Both modules are pin compatible.	None
Antenna	Both modules are available with a 50 Ω antenna pad to connect an external antenna.	Check whether the connected 868 MHz antenna can be also used for 915 MHz.
UART protocol	Both modules provide a command interface using the same commands and functions.	None
Radio configuration	• The radio profiles 3 and 4 of the Telesto-I are comparable in speed with the radio profiles 0 and 2 of the Tarvos-II. As the Telesto-I uses reduced output powers, the range is lower in comparison to the respective profiles of the Tarvos-II. • The channel numbering changes from 100 - 140 (868 - 870 MHz) to 200 - 252 (902 - 928 MHz).	• Check the range requirements of your application. • Use the new channel numbers in your application code.
Certification	The 915 MHz range is regulated in North America by the FCC USA and ISED Canada.	Re-testing[1] of the end-device is needed to determine unwanted emissions.

Table 9: Replace a Tarvos-II with a Telesto-I

Summary

The Tarvos-II and Telesto-I can be considered from the beginning of your design, being aware that in case of selling to countries with 915 MHz a solution is available almost instantly.
As the footprint, pinout and UART protocol of both modules is the same, switching from Tarvos-II to Telesto-I can be performed very quickly without any hardware re-design.

[1] See FCC 996369 D04 Module Integration Guide V01.

2.3.2 915 MHz counterpart: Telesto-II

The Telesto-II has been designed as another counterpart for Tarvos-II for the North American market. The Telesto-II is a proprietary 915 MHz radio module, that is also available with a

Figure 10: Telesto-II: proprietary 915 MHz radio module

50 Ω antenna pad to connect an external antenna. The Telesto-II provides the following radio profiles:

Radio profile	Data rate (gross) [kbps]	Modulation	Max packet size [Byte]	Max packet duration [ms]	Max range[1] [m]
0	38.4	GFSK	128	100	900

Table 10: Radio profiles of the Telesto-II

To conform with the FCC Part 15.247 and ISED, the Telesto-II uses frequency hopping techniques. This results in more robust data transmissions, but at the cost of transmission time and thus of power consumption.

[1] Using two Telesto-II with external antenna, 2m antenna height, 0 dB antenna gain and 6 dB link margin. The Range Estimator Tool, which is part of the *REDEXPERT*, allows to calculate the transmission ranges also for other antenna setups.

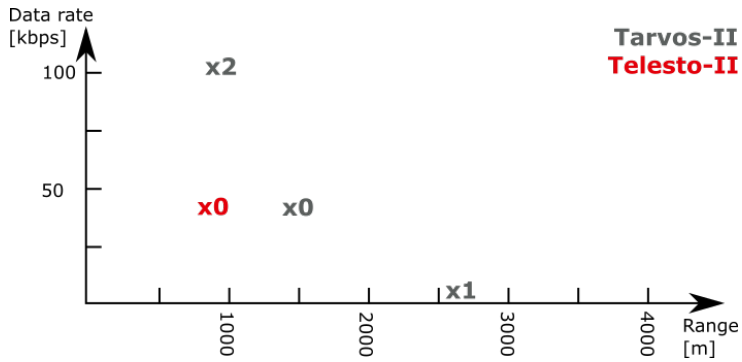

Figure 11: Range vs. data rate

In case, the **Tarvos-II** is replaced by a **Telesto-II** radio module, the following facts have to be considered:

Feature	Information	Actions needed
Form factor & footprint	Both modules have the same form factor and footprint.	None
Pinout	Both modules are pin compatible.	None
Antenna	Both modules are available with a 50 Ω antenna pad to connect an external antenna.	Check whether the connected 868 MHz antenna can be also used for 915 MHz.
UART protocol	Both modules provide a command interface using the same commands and functions.	None
Radio configuration	• The radio of the Telesto-II uses an asynchronous frequency hopping technique. Since each radio packet is transmitted on a different radio channel, the risk of blocked channels is minimized. The receiver itself has to find the radio channel to receive the data. Therefore the transmitter must send a long preamble prepended to the original radio packet. This costs additional transmission time and power. For proper transmission channel detection, the receiver loses a bit of RX sensitivity that is of the expense of range with respect to the Tarvos-II. • No fix channel can be selected, as the Telesto-II automatically manages the frequency hopping.	• Check the range, data transmission timing and power consumption requirements of your application. • Disable the channel selection in your application code.
Certification	The 915 MHz range is regulated in North America by the FCC USA and ISED Canada.	Re-testing[1] of the end-device is needed to determine unwanted emissions.

Table 11: Replace a Tarvos-II with a Telesto-II

Summary

The Tarvos-II and Telesto-II can be considered from the beginning of your design, being aware that in case of selling to countries with 915 MHz a solution is available almost instantly.
As the footprint, pinout and UART protocol of both modules is the same, switching from Tarvos-II to Telesto-II can be performed very quickly without any hardware re-design.

[1] See FCC 996369 D04 Module Integration Guide V01.

2.4 Overview for replaceable modules

868 MHz proprietary radio module	915 MHz counterpart
Thebe-II	Themisto-I
Tarvos-III	Telesto-III
Tarvos-II	Telesto-I, Telesto-II

3 Important notes

The Application Note and its containing information ("Information") is based on Würth Elektronik eiSos GmbH & Co. KG and its subsidiaries and affiliates ("WE eiSos") knowledge and experience of typical requirements concerning these areas. It serves as general guidance and shall not be construed as a commitment for the suitability for customer applications by WE eiSos. While WE eiSos has used reasonable efforts to ensure the accuracy of the Information, WE eiSos does not guarantee that the Information is error-free, nor makes any other representation, warranty or guarantee that the Information is completely accurate or up-to-date. The Information is subject to change without notice. To the extent permitted by law, the Information shall not be reproduced or copied without WE eiSos' prior written permission. In any case, the Information, in full or in parts, may not be altered, falsified or distorted nor be used for any unauthorized purpose.

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List of Figures

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