Packet Data Radio

Installation & Operation Manual

PDR221

RADIUS

RADIO NETWORK TECHNOLOGY

Contents

1 General 4
1.1 Document History 4
1.1.1 RADIUS Contact Information 4
2 Find Your Way in The Manual 5
3 Introduction 6
3.1 Typical Application Areas 7
3.1.1 Examples of Typical Application Networks 8
4 Technical Specifications 11
5 Quick Start Guide 12
6 Glossary of Terms 13
6.1 dBm to W Conversion Table 14
7 The PDR221 Radio Transceiver Functionality 15
7.1 PDR221 Operation Blocks 15
7.2 FEC - Forward Error Correction 15
7.3 CRC – Cyclic Redundancy Checksum 15
7.4 Radio Receiver Sensitivity 16
7.4.1 PDR221 Receiver Sensitivity 16
7.5 Radio Transmitter Power 16
7.6 RSSI – Received Signal Strength Indication 17
7.7 Differences between PDR221 Models 18
7.8 Communication 19
7.9 Peer-to-Peer 21
8 Operating the PDR221 22
8.1 LED Indicators and Connectors 22
8.2 Collision Avoidance 23
8.3 Remote frequency change 25
8.4 Remote Tx power change 25
8.5 Multiple RTU addressing to one radio 25
8.6 Radio Link Test 25
8.7 Split transmitting and receiving frequencies 26
8.8 Split Tx Uplink Frequency 27
8.9 Repeating Alternative Systems 27
9 Installation 28
9.1 General 28
9.2 Power Supply 28
9.2.1 Recommended minimum demands: 28
9.3 Battery Power Supply 29
9.4 Serial Interface 30
9.4.1 PDR221 Serial Interface Characteristics 30
9.4.2 Serial Cable Configurations 31
9.4.3 EOM – End of Message - Detection 33
9.5 Cabinet Mounting 34
9.5.1 PDR 221 mounted in cabinet 34
10 Accessories 35
11 Radio Networking 36
11.1 Antennas 36
11.1.1 Antenna Gain 36
11.1.2 Antenna Types 37
11.1.3 Antenna Gain versus Radio Output Power 38
11.2 Fade Margin 39
11.3 Radio Link Calculations 40
11.3.1 No Line of Sight Calculations 40
11.3.2 Line Of Sight Calculations 43
12 Configuration 45
12.1 Equipment 45
12.2 Getting Started 45
12.3 Configuration Menus Overview 46
12.4 Configuration Menus 48

12.5 Function 48
12.6 Network 48
12.6.1 System ID 48
12.6.2 Radio ID 48
12.6.3 Repeat Alternative Systems 49
12.7 Serial 49
12.7.1 Bitrate 49
12.7.2 Parity 49
12.7.3 Pre DCD 49
12.7.4 Post DCD 49
12.8 Radio 50
12.8.1 Collision Avoidance Delay 50
12.8.2 Collision Avoidance Delay Min 50
12.8.3 Collision Avoidance Delay Max 50
12.8.4 Bit Error Rate Test 50
12.8.5 Communication Test 50
12.8.6 Radio Link Test 50
12.8.7 Receiver Test 50
12.8.8 Transmitter Test 50
12.9 Advanced 51
12.9.1 Detected Radio Type 51
12.9.2 Rx Frequency 51
12.9.3 Tx Frequency 51
12.9.4 Split Tx Uplink 51
12.9.5 Split Tx Uplink Frequency 51
12.9.6 Split Tx Uplink Id 51
12.9.7 Radio Link Speed 51
12.9.8 Tx Power Level 52
12.9.9 System Frequency Change 52
12.9.10 Remote Tx Power Level Change 52
12.9.11 Radio VCO Lock Test 52
12.9.12 Terminal Bitrate 53
12.10 List Configuration 53

13 Radio Test Functions 54
13.1 Bit Error Rate Test 54
13.2 Communication Test 56
13.3 Radio Link Test 57

14 Trouble Shooting 58
14.1 Trouble Shooting the PDR 58
14.2 Support 58

1 General

1.1 Document History

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2 Find Your Way in The Manual

Chapter 3 gives an *introduction* to Radius PDR221 system and some *application examples*.

Chapter 4 contains *technical specifications* for the PDR221.

Chapter 5 provides a *Quick Start Guide* for installation and configuration of the PDR221

Chapter 6 contains a *Glossary of Terms.*

Chapter 7 describes the *basic and extra features* of the PDR221.

Chapter 8 describes how *the PDR221 features can/should be used*.

Chapter 9 contains *installation guidelines,* including the *serial interface*.

Chapter 10 contains information *about radio network accesories* provided by Radius.

Chapter 11 gives an introduction to *general antenna and radio technique and calculations*. This chapter is inteded for those who want to learn more about those subjects.

Chaper 12 describes *the PDR221 configuration menus* and how to set the different *parameters*.

Chapter 14 describes the *PDR221 radio test functions*.

Chapter 15 contains a list of *trouble shooting check points*.

3 Introduction

Wireless communications remains the most cost effective solution for a significant amount of modern applications. Advances in wireless technology allow data throughput and reliability to be very high and, given the cost of direct cable, public networks or satellite infrastructure, price/performance benefits remains far above other means of communication.

Modern wireless devices are much more than simple modems. They are sophisticated units, designed to allow the user to create their own communication system with the minimum amount of involvement.

The RADIUS PDR221, Packet Data Radio 221, transceiver provides wide range data telemetry for control and monitoring systems using any communication protocol. The transceiver is designed for point-to-multipoint operation environments including water, wastewater, electric utilities, distribution automation, and gas field automation.

A PDR221 system consists of one master and up to 254 slave radio units. A PDR221 network can contain one repeater. The repeater can operate stand-alone or with an RTU device connected. A PDR221 network can, under normal circumstances, cover an area of at least 50 km from the master.

The PDR221 is suitable for both polled and unsolicited systems. For unsolicited systems, there is Collision Avoidance functionality built-in to the radio that virtually eliminates in-air collisions, vastly speeding up the communication throughput. It is also possible to carry out Peer-To-Peer communication.

The radio communication is completely packet switched, but the serial data is not buffered before radio transmission, which increases the data throughput. The radio transfer data rate is selectable, 4800/9600 or 9600/19200 bps, depending on desired channel bandwidth, 12.5 or 25 kHz.

The radio modem uses a Forward Error Correction technique, which corrects a large proportion of transmission errors in case of noise bursts. This feature significantly increases the radio sensitivity.

The PDR221 does not require any routing information, which makes the set-up and configuration very easy. The configuration menus are accessed via a handheld terminal or a PC.

The control/monitoring device is connected to the PDR221 via a standard RS232 serial interface. The serial interface speed is adjustable between 600 and 19200 bps, with or without parity. The transceiver only needs a three wire connection, TxD, RxD and GND, but handshaking signals are provided if required by the connected device.

The PDR221 provides diagnostic features, remotely changeable parameters, built in survey and test functionalities. All easily accessed via a hand terminal or a PC.

3.1 Typical Application Areas

RADIUS has been a global player in the digital data wireless market for well over a decade, helping a wide range of customers meeting their operational and financial targets. Working with very small companies up to Blue Chip companies, RADIUS has provided products, systems and services to maximise the benefit afforded by their wireless technology.

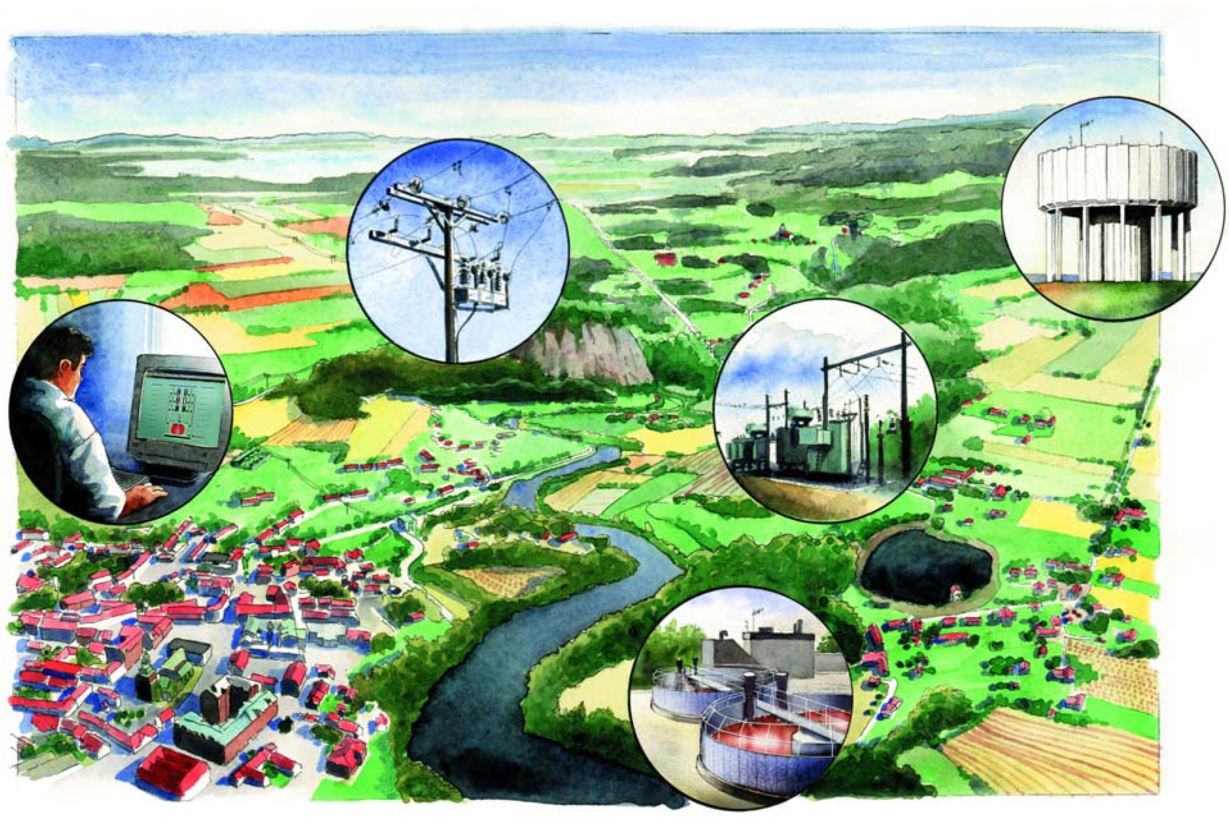
Our products are a result of the close relationship with our customers and partners and reflect the current and future needs of the market.

Examples of why to go wireless:

- Replacing a cable in situations where installation of a cable is difficult, expensive or even impossible.
- Replacing a dial up link to reduce costs.
- Network provider independence.

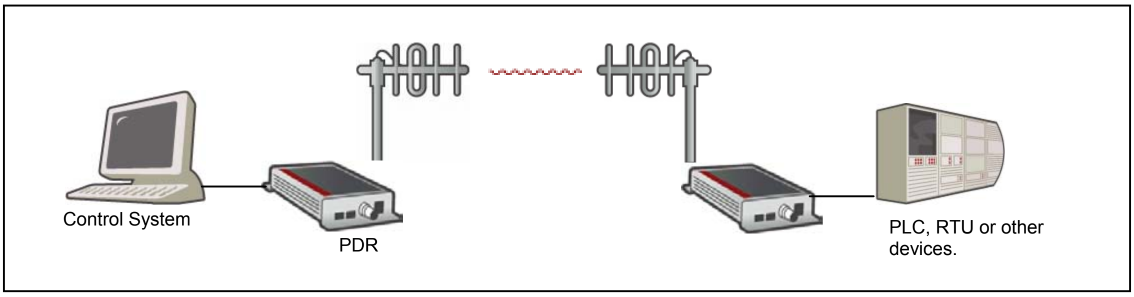
Example application areas:

- Water/Wastewater
- Electric Distribution
- Gas Distribution
- Oil Distribution
- Wind Power
- Industrial Processes control
- Remote Traffic Control
- Railroad Communication Systems
- Remote PLC control

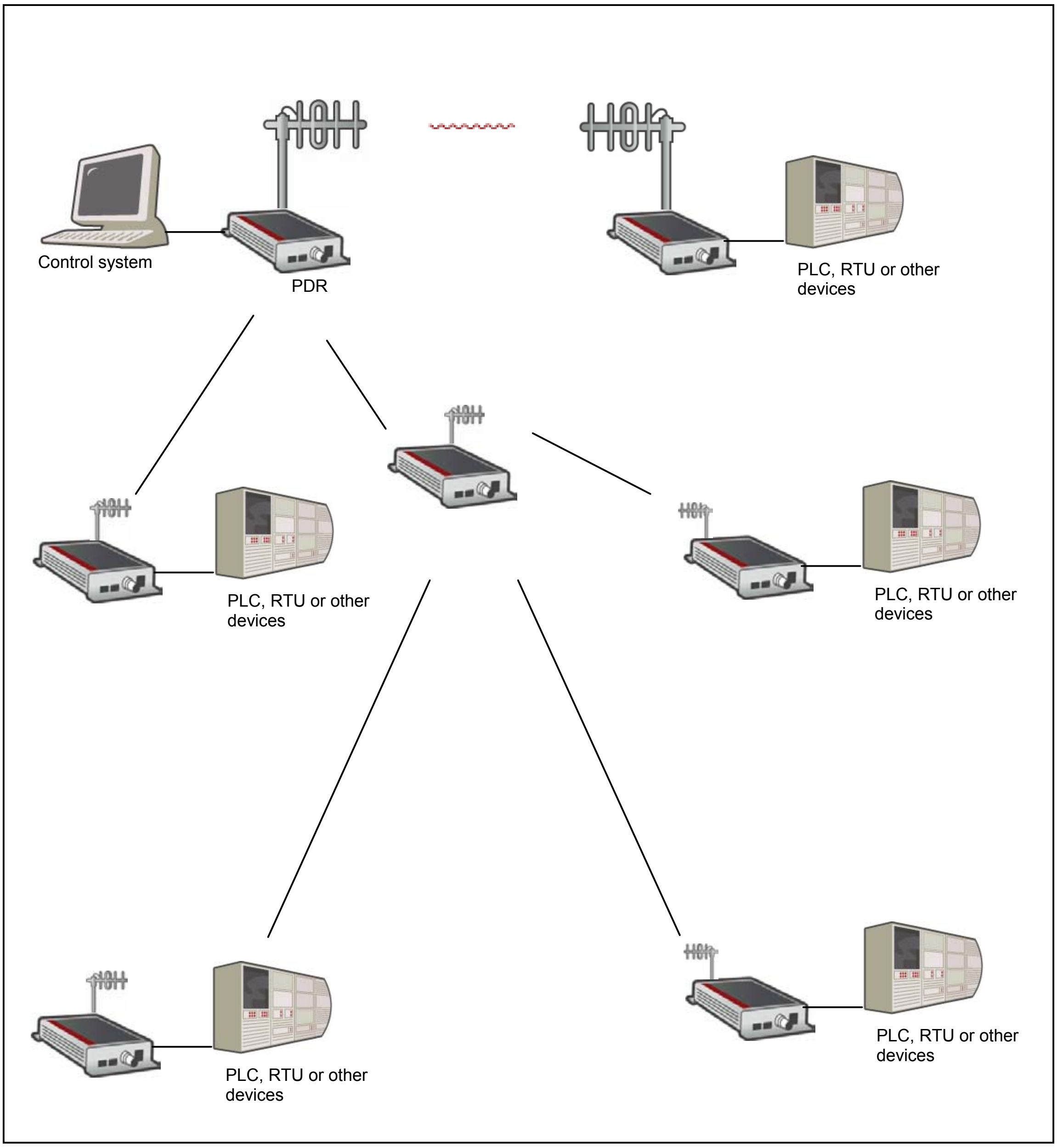


3.1.1 Examples of Typical Application Networks

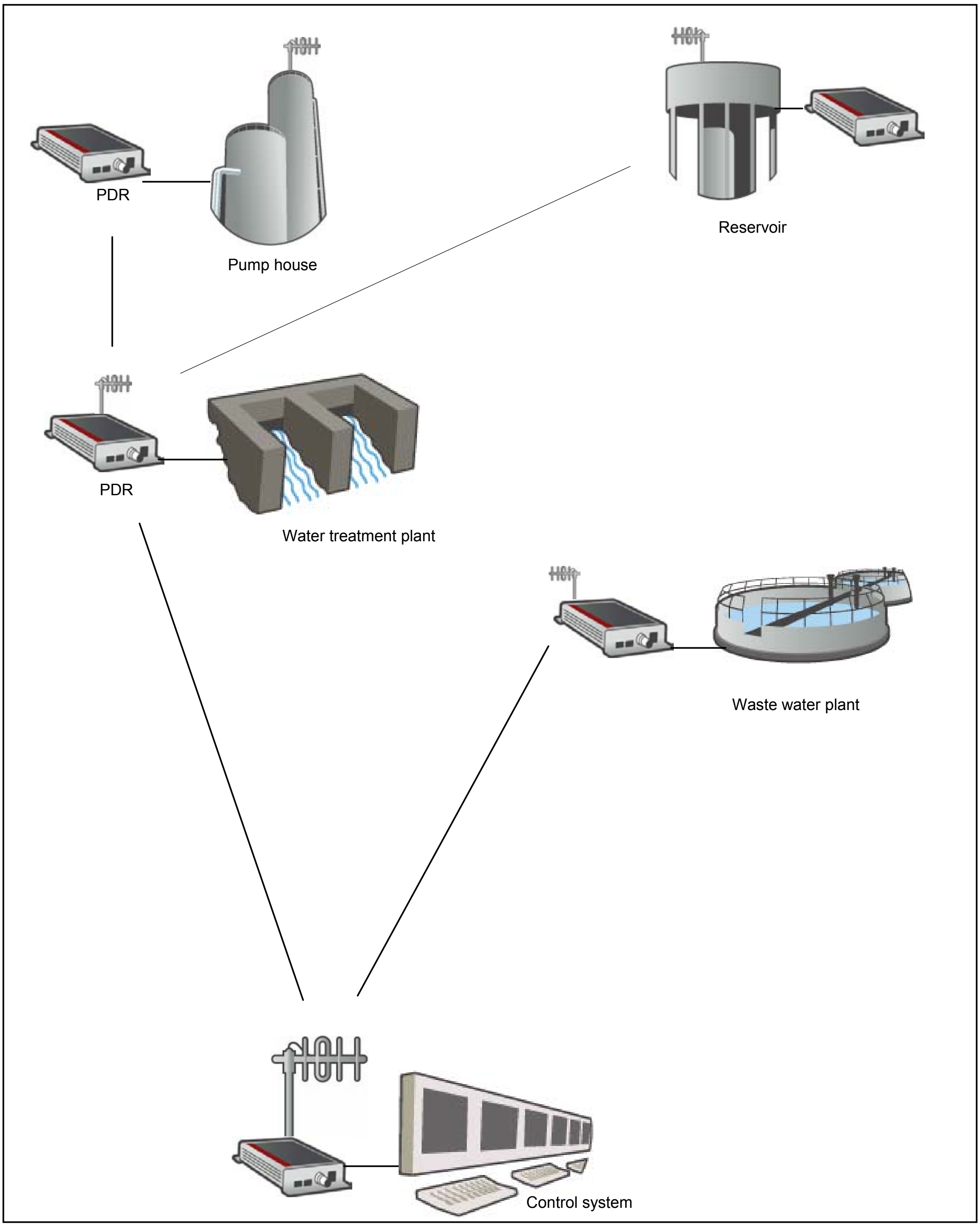
3.1.1.1 Point-to-Point



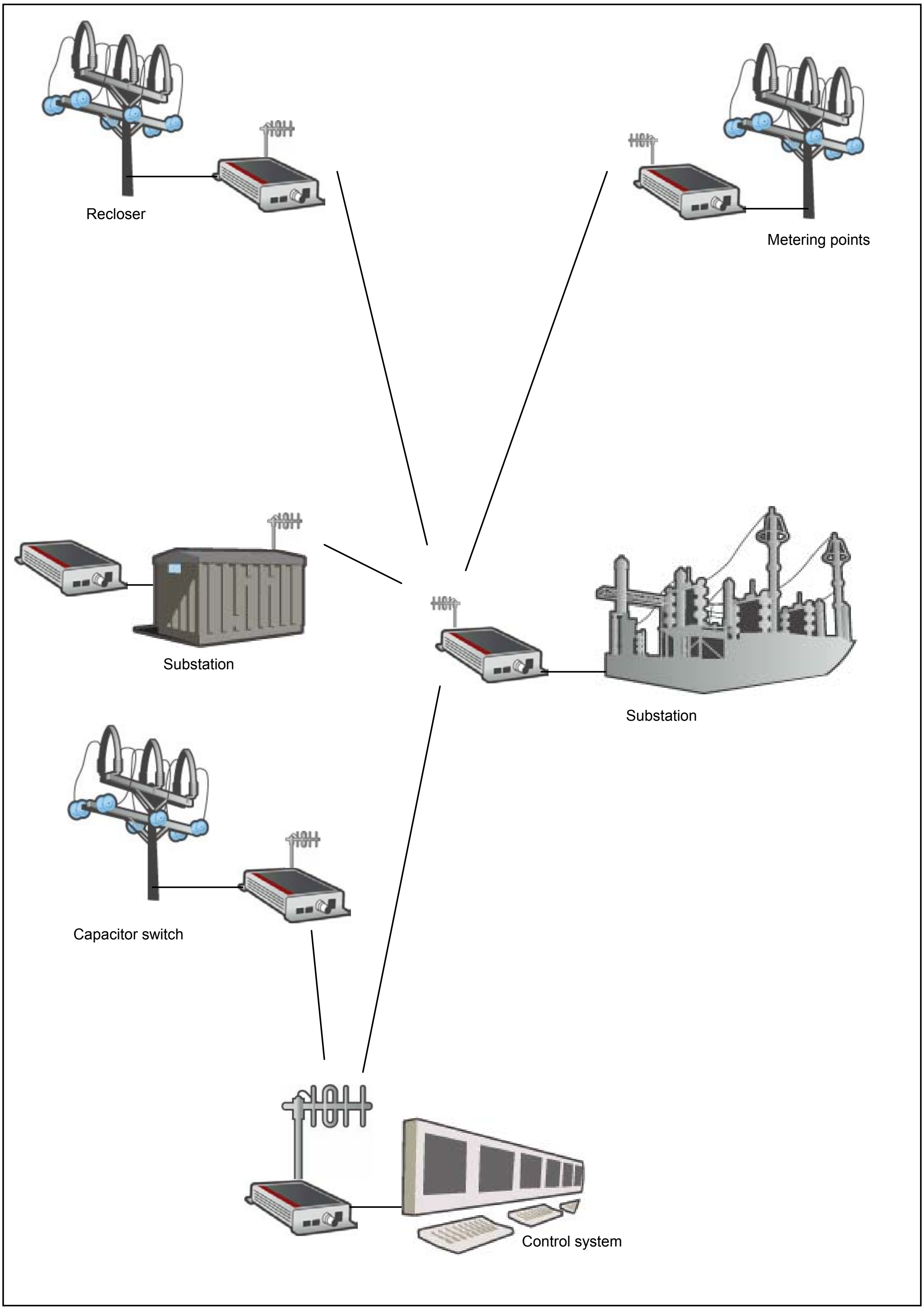
3.1.1.2 Point-to-Multipoint



3.1.1.3 Water/Wastewater Network



3.1.1.4 Electrical Distribution Network



4 Technical Specifications

Radio Transceiver	
Data Rates	4800…19200 bps
Frequency Range	UHF 403 to 470 MHz. VHF 132 to 174 MHz. Other bands available on request.
Frequency Splits	Various Tx/Rx frequency splits configurable
Operation modes	Half Duplex, Simplex
Modulation	4 level FSK
Forward Error Correction	Yes. With interleaving functionality.
Collision Avoidance	Yes. User Configurable.
Repeating	1 Repeater per system
No of remote radios per master	254
Compliances	ETSI 300220, ETSI 300113, MPT1411, FCC Rule 90.210
Radio Transmitter	
Tx Power	0.1…2.0 W. User Configurable.
Tx Power Accuracy	+/- 1 dB
Radio Receiver	
Sensitivity	-107…-114 dBm @ BER $10^{-6.}$. Depending on data rate and channel spacing.
Spurious Emissions	
Adjacent channel rejection	>60dB
Serial Interface – RS232	Three wire, Rx/Tx/GND
Data Rates	600…19200 bps
Flow Control	DCD/CTS flow control signals selectable.
Protocols	Transparent. Maximum message length is 5000 bytes / characters.
Power Supply	
Operating voltage	10 to 16 VDC Nominal
Current Consumption	Standby/Receive 165 mA. Transmit 1100 mA
Environmental	
Temperature Operating Range	-40°C to +60°C
Capsulation Class	IP52
Physical Dimensions	
Size	165x113x40 mm
Weight	600g
Housing Material	Extruded Aluminium
Connectors	
Main Power Supply	2 pole plint, Female, 3.81 mm split
Battery Supply	2-pole plint, Female, 5.08 mm split
Antenna	BNC Female
Serial Port	RS232 DB9 Female. Wired as DCE (modem).
Configuration Interface	RJ12 Female
LED Indications	Main PWR, Radio Rx, Radio Tx, RS232 Rx, RS232 Tx, Configuration Mode Carrier Detect, System Detect
Configuration Interface	
Configuration Software	Standard Windows Terminal Program
Data Rate	Selectable 1200 / 9600 / 57 600 bps. 57 600 Default.

5 Quick Start Guide

PDR221 provides many extra features, which are useful for different types of applications. However, typical operation requires only a few of those. All feature configuration parameters have default values to not interfere with normal operation, if not used.

PDR221 is tuned at ordered frequency and Tx power. The user normally needs to configure only the radio ID, operation mode and serial (RS232) settings, on each radio.

1. Install antenna(s) and antenna cable(s). See Radius Antenna Installation Manual.

2. Install the PDR221 in to the RTU cabinet. / Install the PDR221 cabinet. See chapter 9.

3. Connect the antenna cable, ground wire, RS232 cable and power supply to the PDR221. See chapter 9.

4. Configure the PDR221 by using a hand held terminal or a PC. (Standard Windows terminal software, 56700 N 8 1). The unit can also be pre-configured before installation. Normally, the below listed parameters are the only ones needing configuration. See chapter 12.

   a. Operation Mode (Main menu)
   b. System ID (Menu 1. Network)
   c. Radio ID (Menu 1. Network)
   d. RS232 Settings (Menu 2. Serial)

5. Perform Radio Link Test to all adjacent units. (Menu 3. Radio). See chapter 13.3.

6. Leave configuration mode by selecting E. – Exit in the main menu. (The yellow CM, Configuration Mode, LED will turn off.)

7. The PDR221 unit is now ready for operation.

6 Glossary of Terms

Some of the terms and abbreviations used in this product description may be unfamiliar if you are new to digital radio systems. The following glossary explains these terms, which can be helpful in understanding the operation of the PDR221.

Bit – is the smallest unit of digital data, computational quantity that can take on one of two values, such as false and true or 0 and 1.

bps – bits per second. The unit in which data transfer rate is measured across a communication channel in serial transmissions. 9600 bps indicates that 9600 bits are transmitted in one second.

Byte – is often eight bits and the smallest addressable unit of storage.

Channel bandwidth – in addition to the direction of transmission, a channel is characterized by its bandwidth. In general, the greater the bandwidth of the assigned channels, the higher the possible speed of transmission.

Data telemetry – transmission of the values of measured variables using telecommunication techniques

Decibel (dB) – is a unit of measurement of the strength of a signal.

dBm – (Decibels below 1 Milliwatt) A measurement of power loss in decibels using 1 milliwatt as the reference point.

DCE –Data Communication Equipment. The devices and connections of a communications network that connect the communication circuit between the data source and destination (the Data Terminal Equipment or DTE). A modem is the most common kind of DCE.

DTE – Data Terminal Equipment. A device which acts as the source and/or destination of data and controls the communication channel. DTE includes terminals, computers, protocol converters, and multiplexers.

Fade Margin – The greatest tolerable reduction in average received signal strength that will be anticipated under most conditions. This measurement provides an allowance for reduced signal strength due to multi-path, slight antenna movement or changing atmospheric losses. A fade margin of 10 to 20 dB is usually sufficient in most systems.

Flow Control – The collection of techniques used in serial communications to stop the sender from sending data until the receiver can accept it. This may be either software flow control or hardware flow control. The receiver typically has a fixed buffer size into which received data is written as soon as it is received. When the amount of buffered data exceeds a "high water mark", the receiver will signal to the transmitter to stop transmitting until the process reading the data has read sufficient data from the buffer that it has reached its "low water mark", at which point the receiver signals to the transmitter to resume transmission.

FSK Frequency Shift Keying – The use of frequency modulation to transmit digital data, i.e. two different modulation frequencies are used to represent zero and one. More than two frequencies can be used to increase transmission rates.

Master – is the unique application entity within the distributed application which directly or indirectly controls the entire activity for this atomic action.

Multiple RTU addressing – several RTU's share the same radio unit.

Slave – is a unit, which is under the control of another unit (*Master*).

Packet switched – Describing a system whereby messages are broken down into smaller units called packets, which are then individually addressed and routed through the network.

Parity – A one-bit quantity indicating whether the number of 1's in a word is even or odd.

Peer-to-Peer – Peer-to-Peer is a communications model in which each party has the same capabilities and any party can initiate a communication session. Other models with which it might be compared to, include the client/server model and the master/slave model. In some cases, peer-to-peer communications is implemented by giving each communication node both server and client capabilities.

Point-to-multipoint – is one-way or two-way communications from a central point to a number of subsidiary points, and vice versa.

Poll – is a method to check the status of an input line, sensor, or memory location to see if a particular external event has been registered. The communications control procedure by which a master station or computer systematically invites tributary stations on a multipoint circuit to transmit data.

Repeater – is a device that will repeat serial communications on to the predetermined destination.

Routing of messages – is the selection of a path or channel for sending a message.

RTU – is a Remote Terminal Unit that is physically remote from a main station or computer but can gain access through communication channels.

RSSI (Received Signal Strength Indication) **–** a parameter returned from a transceiver that gives a measure of the RF signal strength between the mobile station and base transceiver station, either as a uplink or downlink measurement.

SCADA – (Supervisory Control and Data Acquisition) is a system used in industry to monitor and control equipment status and provide logging facilities.

Transceiver – is a terminal unit which can both transmit and receive information from a data transmission circuit.

Unsolicited system – In an unsolicited response system, the RTU's generate all reporting messages required, without beein polled by the master. Typically, such messages report a change of state or a fault, or simply pass data to the SCADA central host without being polled for the data.

6.1 dBm to W Conversion Table

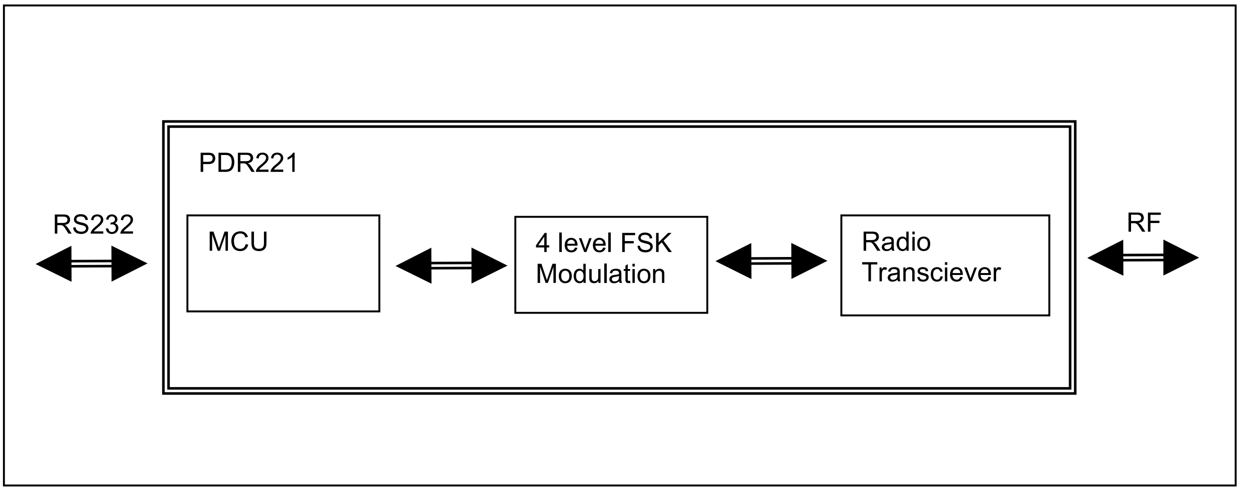
dBm	Watts	dBm	Watts	dBm	Watts
0	1 mW	16	40 mW	32	1.6 W
1	1.3 mW	17	50 mW	33	2.0 W
2	1.6 mW	18	63 mW	34	2.5 W
3	2.0 mW	19	79 mW	35	3.2 W
4	2.5 mW	20	100 mW	36	4.0 W
5	3.2 mW	21	126 mW	37	5.0 W
6	4 mW	22	158 mW	38	6.3 W
7	5 mW	23	200 mW	39	8.0 W
8	6 mW	24	250 mW	40	10 W
9	8 mW	25	316 mW	41	13 W
10	10 mW	26	398 mW	42	16 W
11	13 mW	27	500 mW	43	20 W
12	16 mW	28	630 mW	44	25 W
13	20 mW	29	800 mW	45	32 W
14	25 mW	30	1.0 W	46	40 W
15	32 mW	31	1.3 W	47	50 W

7 The PDR221 Radio Transceiver Functionality

This chapter describes the PDR221 radio functionality.

7.1 PDR221 Operation Blocks

The figure below shows the basic building blocks of the PDR221.



RS232 to RF
Serial data is received on the serial port. The MCU, (Micro Controller Unit), analyses the data and frames the data and transfers it to the modulation unit. (The complete message is buffered in the processor memory before being transmitted).The modem unit converts the received bit stream to a 4-level base-band signal for modulation of the radio transmitter.

RF to RS232
The modulation unit decodes the 4-level base-band signal and forwards the data to the MCU. The MCU analyzes the message and prints it on to the serial port, (or re-transmits via the radio if the message should be repeated).

7.2 FEC - Forward Error Correction

On transmission, FEC bits are added to the transmitted data before being converted to a 4-level signal. When receiving, the FEC information - and an FEC algorithm - is used to correct any transmission errors. A large proportion of transmission errors can be corrected using the FEC.

7.3 CRC – Cyclic Redundancy Checksum

On transmission, a CRC byte(s) is added at the end of the data. The CRC byte is calculated based on the data contents of the message. The receiver checks the CRC byte against the received data and can detect any transmission errors. Corrupted messages are discarded.

Note! If the CRC is faulty, there is no NACK , no acknowledge , message transmitted back from the receiving radio. All re-transmissions have to be initiated by the connected device. Normally this is trigged by a response timeout.

7.4 Radio Receiver Sensitivity

The receiver sensitivity depends on the frequency used, channel spacing, 12.5 / 25 KHz, and the data speed, 4800, 9600 or 19200 bps. The receiver sensitivity is measured by attenuating a known bit-pattern until bit error occurs. A standard way of presenting receiver sensitivity is for example;

-110dBm @ BER (Bit Error Rate) < $1x10^{-6}$

This means that there is less than 1 bit error out of 1 million bits when the signal strength at the receiver is at –110 dBm.

It is important to know that this value in many cases can depend on the bit pattern used. RADIUS uses a random bit pattern to determine receiver sensitivity, which includes all possible bit pattern variations. This gives a very reliable, worst case, sensitivity measure.

The radio receiver sensitivity can be compensated for by using gain antennas or increasing the output power of the transmitting radio. Using gain antennas is often the most efficient solution.

It is important to note that a very sensitive radio cannot compensate for a poor antenna installation.

The sensitivity can be used in propagation studies for radio network planning.

7.4.1 PDR221 Receiver Sensitivity

Model	Frequency Range [MHz]	Channel Bandwidth [kHz]	Radio Data Speed [bps]	Sensitivity BER < $1x10^{-6}$
PDR221-A	VHF 132-150	12.5	4800 / 9600	-111 dBm / - 109 dBm
PDR221-B	VHF 132-150	25	9600 / 19200	-114 dBm / - 107 dBm
PDR221-C	VHF 150-174	12.5	4800 / 9600	-111 dBm / - 109 dBm
PDR221-D	VHF 150-174	25	9600 / 19200	-114 dBm / - 107 dBm
PDR221-E	UHF 435-450	12.5	4800 / 9600	-110 dBm / -107 dBm
PDR221-F	UHF 435-450	25	9600 / 19200	-110 dBm / -103 dBm
PDR221-G	UHF 450-470	12.5	4800 / 9600	-110 dBm / -107 dBm
PDR221-H	UHF 450-470	25	9600 / 19200	-110 dBm / -103 dBm

7.5 Radio Transmitter Power

The transmitting power ranges are from 0.1 to .2.0W for VHF transceivers and from 0.01 to 2.0W for UHF transceivers. The transmitter power is tuned as ordered at the RADIUS factory, but can be adjusted by the user via the software configuration menu - both locally and remotely. The output power can be tuned in steps of 1dB between 0.1 and 2.0W, (20 dBm to 33dBm), for VHF and between 0.5 and 2.0W, (27 to 33dBm), for UHF radios. **Note!** The UHF radios can be factory tuned between 0.01 and 2.0W. (10dBm to 33dBm).

7.6 RSSI – Received Signal Strength Indication

The RSSI value can be used to determine the quality of a radio link. The RSSI values can be retrieved by executing the Radio Link Test in the configuration menus, see 12.8.6.

The PDR 221 measures the RSSI value using an A/D converter. The received signal strength is measured in volts and is translated to a dBm value.

The graph below shows a typical RSSI voltage value as a function of the signal level.

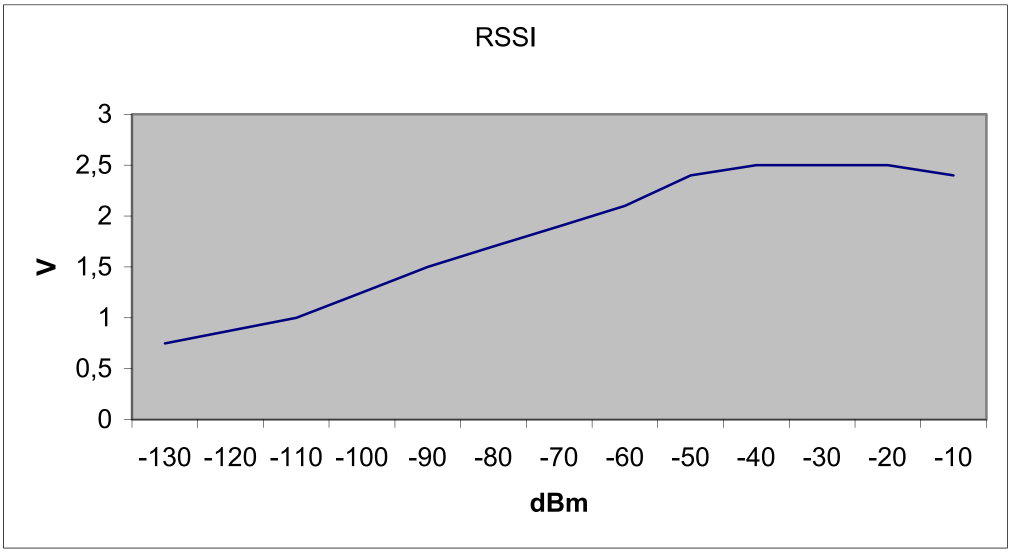


Figure 1. RSSI

7.7 Differences between PDR221 Models

All models of the PDR221 are very similar in appearance and functionality. The only differences are in frequency coverage, channel bandwidth and radio data speed. The table below summarizes the available models and identifies the characteristics of each.

Model	Frequency Range [MHz]	Channel Bandwidth [kHz]	Radio Data Speed [bps]	Article Number
PDR221	132-150	12.5	4800/9600	305154-9
PDR221	132-150	25	9600/19200	305155-8
PDR221	150-174	12.5	4800/9600	305156-7
PDR221	150-174	25	9600/19200	305157-6
PDR221	403-422	12.5	4800/9600	305164-7
PDR221	403-422	25	9600/19200	305165-6
PDR221	435-450	12.5	4800/9600	305158-5
PDR221	435-450	25	9600/19200	305159-4
PDR221	450-470	12.5	4800/9600	305160-1
PDR221	450-470	25	9600/19200	305161-0

Other frequency ranges are available on request. Contact RADIUS for further information.

7.8 Communication

The system distinguishes between direct slaves and *slaves via repeater*. A direct slave can only receive data from, and transmit data to, the master in the system. A *slave via repeater* can only receive data from, and transmit data to, the repeater in the system.

When the master transmits a telegram, this will be received by the slaves and the repeater (if a system is so configured) at the same time. When the repeater has received the telegram, it will retransmit it to the *slaves via repeater*. If then a *slave via repeater* answers the telegram, this is sent to the repeater which in turn retransmits it to the master. If a direct slave answers, its telegram is sent directly to the master.

In the system which contains *slave and repeater*, slaves and *slaves via repeater*, the direct slaves must wait to answer until the repeater has transmitted the telegram. This is to avoid collisions. In a *slave with repeater delay* a time delay is automatically set which will delay the response transmission to the Master until the repeater has repeated the message. The purpose of the delay time is so that collisions on the radio channel will never occur.

A telegram sent by a *slave via repeater* never collides with the repeater's telegram because of the fact that the slave does not receive the telegram until the repeater has finished its transmission. This is also the case when an direct *slave with delay for repeater* answers.

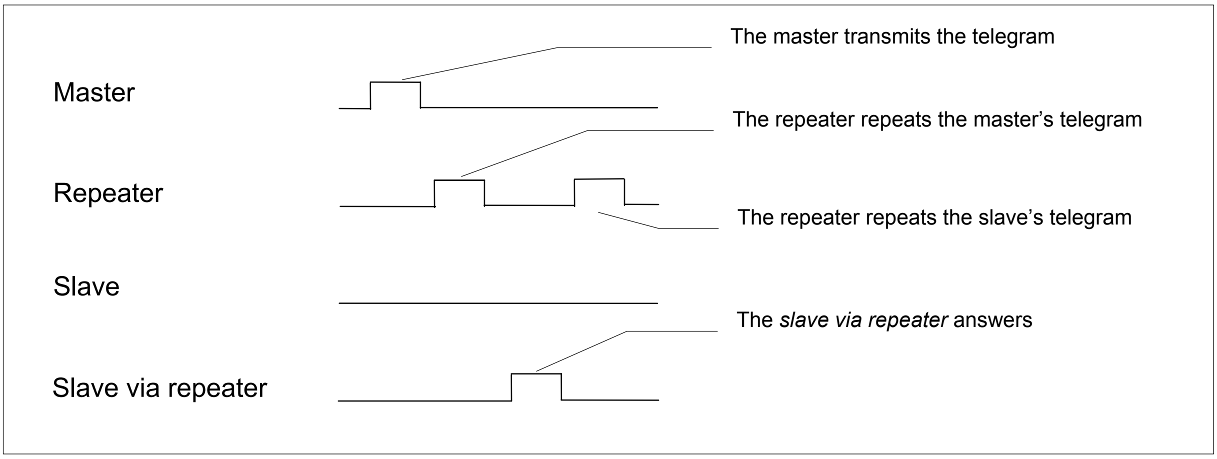


Figure 4. Polling of slave via repeater

When a repeater is part of the system, as in figure 5, then all slaves, which will communicate directly to the master, should be configured as *slave with repeater delay*. The slaves that will communicate via a repeater should be configured as *slave via repeater* and the repeaters as *slave and repeater.*

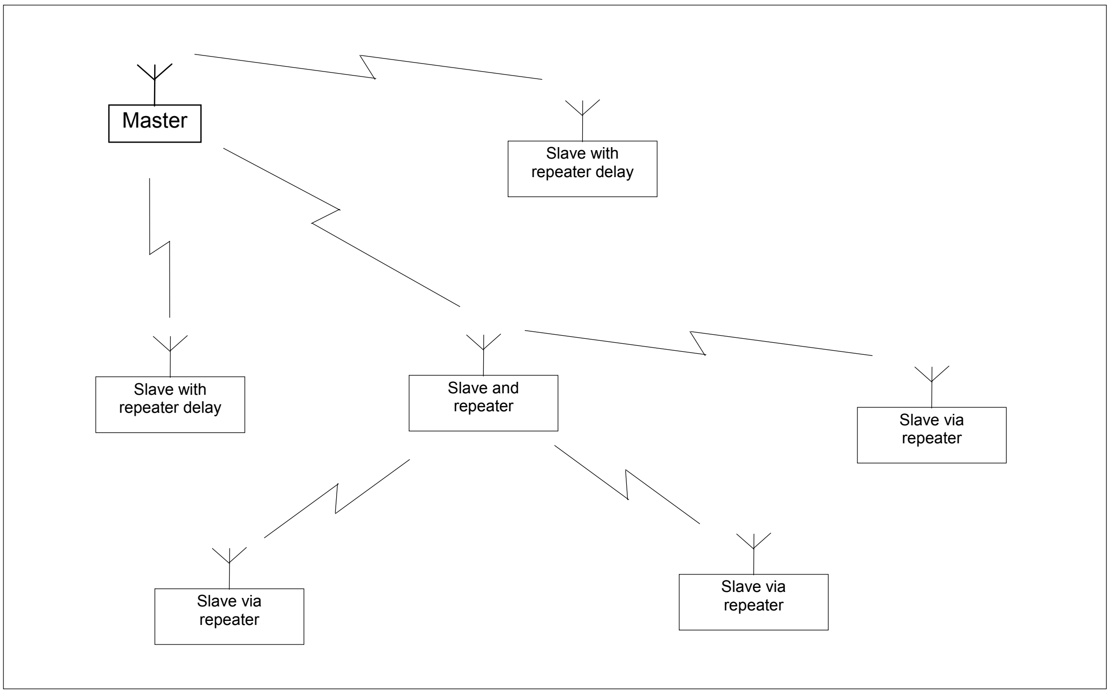


Figure 5. System with Repeater Station.

When all slaves, in a system, communicate directly to the master (without a repeater in the system), as in figure 6, then all slaves should be configured as a *slave*.

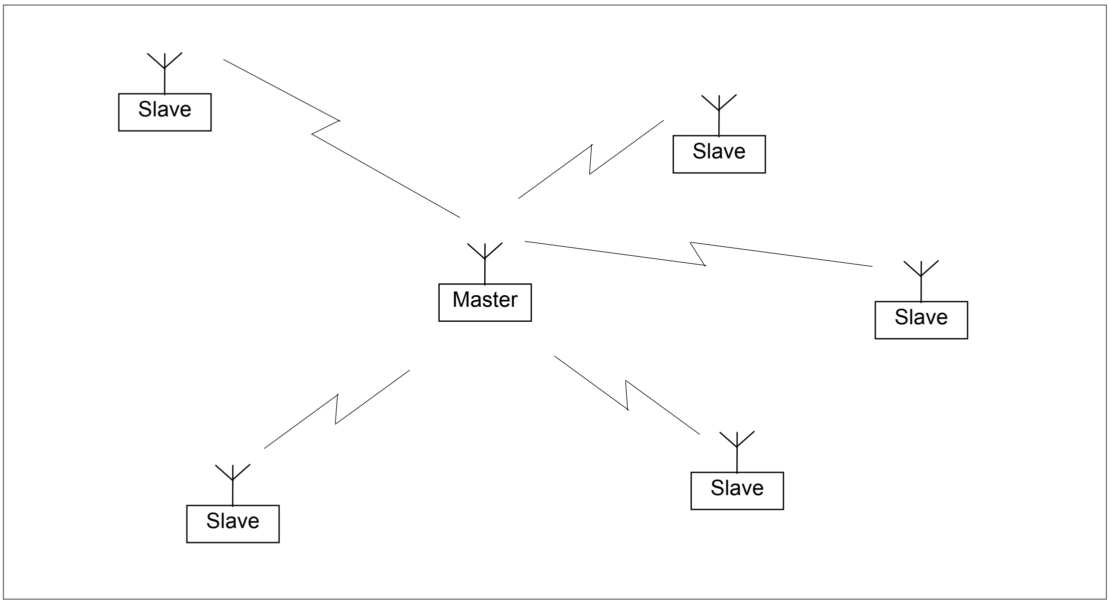


Figure 6. System without Repeater Station.

7.9 Peer-to-Peer

The PDR221 also offers peer-to-peer communication. When a unit is transmitting, all units receive the message and then transmit the message on their serial interface. When using as a peer-to-peer radio system it is not possible to use repeaters. All units shall be configured as peer-to-peer.

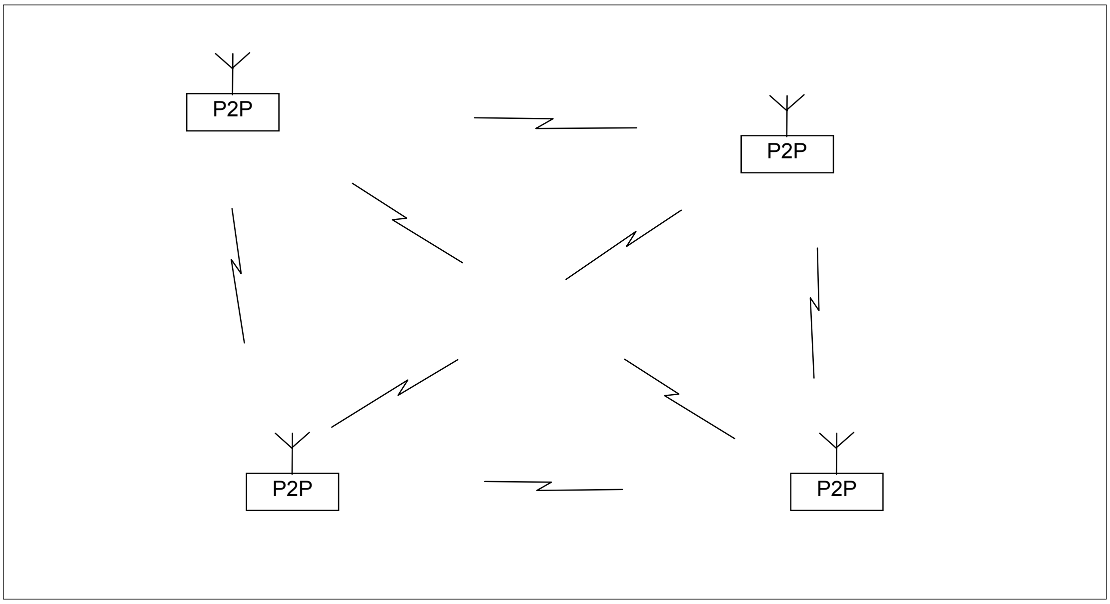


Figure 7. System with Peer-to-peer functionality.

8 Operating the PDR221

8.1 LED Indicators and Connectors

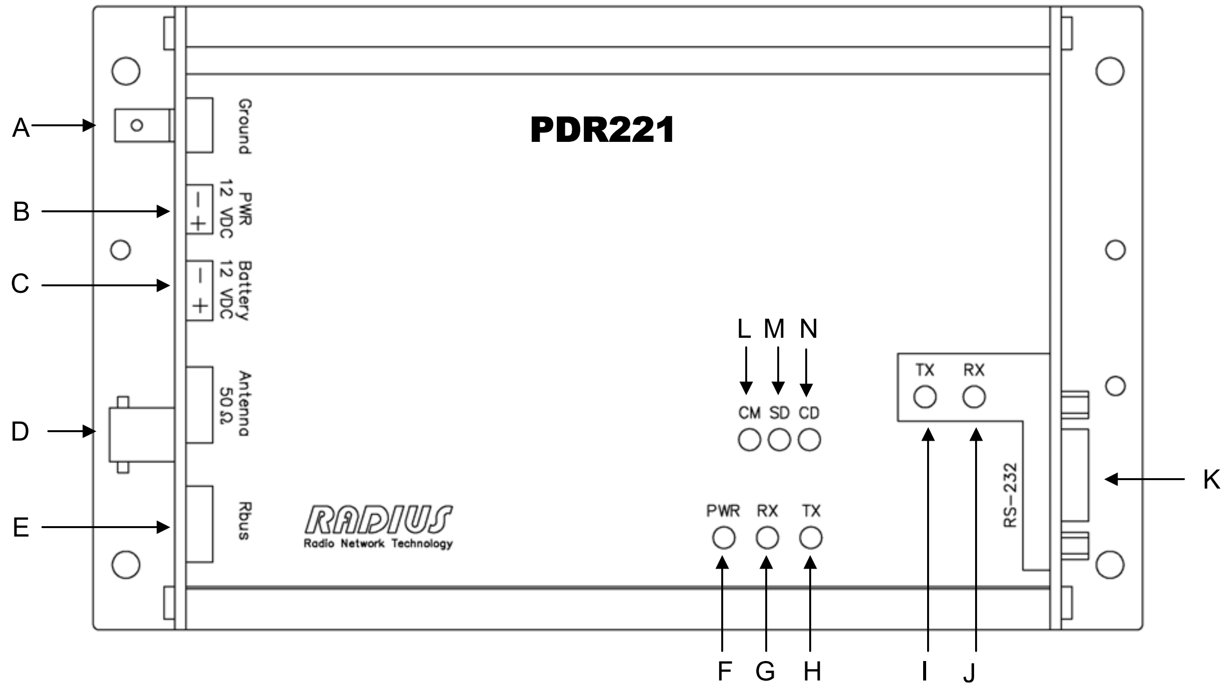


Figure 2. Packet Data Radio 221.

	Name	Description
A	Earth/ground connection	For connection to the system's earth/ground (Internally connected to PWR negative (-) pole.)
B	Voltage connection	For connection of 12VDC
C	Battery connection	For connection of a backup-battery, 12VDC. Note! No battery charging. See 9.3.
D	Coaxial connection	For connection of the antenna cable
E	Rbus connection	For connection of the Programming interface *ProgInt*
F	PWR LED (Green)	Is lit when the PDR has power supply
G	RX LED (Yellow)	When lit, the PDR receives data from another radio unit in the system
H	TX LED (Red)	When lit, the PDR transmits data via radio
I	RS232 Tx LED (Red)	When lit, the PDR transmits serial data to connected device
J	RS232 Rx LED (Green)	When lit, the PDR receives serial data from connected device
K	RS-232 connection	For connection of the serial cable. 9-pole D-sub plug
L	Configuration Mode (Yellow)	Lit when the PDR221 is in configuration mode
M	System Detect (Yellow)	Lit (flashed) if the radio detects a PDR transmission from another system. I.e. not valid system id.
N	Carrier Detect (Yellow)	Lit (flashed) when a carrier is detected. Can be used to detect interfering signals. (If the Rx LED is not lit simultaneously).

Note! The PDR 221 does not charge batteries via the battery connection jack. See chapter 9.3.

8.2 Collision Avoidance

Collision Avoidance is used in systems operating with unsolicited messaging / report by exception, meaning that it is a not strictly polled, (request/reply), system. If events occur simultaneously at several RTU's in an unsolicited system, there is a risk that several radios start transmitting simultaneously. The radio messages will then be corrupted due to collisions.

Unsolicited response / Report by Exception messages are commonly used by equipment using the DNP3 protocol.

The Collision Avoidance functionality in the PDR221 is used to minimize the risk of collisions at simultaneous and cascading events on a RTU network.

The basic strategy is that the PDR221 always listens to the radio channel. If it detects a transmission from another radio, it will not start a transmission until the ongoing transmission is finished. Though, it is still possible that two, or more, radios listens to the channel, consider it free and start transmitting simultaneously. Configuring a random back-off delay time, called *Collision Avoidance Delay,* solves this issue.

If the Collision Avoidance Delay function is activated, the radio will wait a random time after receiving a serial message from connected device before transmitting a radio message. The radio listens to the radio channel during the back-off time. This makes it possible to detect another transmission initiated by another radio, which started the transmission after a shorter back-off time. Collision is avoided. The radio that backed-off will re-initiate the random delay time when the channel is free again.

The Collision Avoidance Delay is configured to a Min and Max value. See configuration in chapter 12.8.

Collision Avoidance Min is the time in seconds the radio always waits from when the radio channel is free until it starts a transmission. Note that the Min time is not random. This value can be set to zero.

Collision Avoidance Max is the maximum limit for the random time.

The random time is calculated from the difference between **CA** Min and **CA** Max.

Example 1

Collision Avoidance Min = 1 s

Collision Avoidance Max = 3 s.

The radio will always wait 1 second plus a 0 to 2 seconds random time. (3-1 = 2 sec.)
The CA Delay time will be Min 1 second and Max 3 seconds.

This method can be used if one or more RTU's have priority. The highest priority RTU's should be set to CA Delay Min = 0, (see example 2), and the lower priority ones to a higher value.

Example 2

Collision Avoidance Min = 0 s

Collision Avoidance Max = 2 s

The radio will wait a random time between 0 and 2 seconds.

Example 3

Collision Avoidance Min = 3 s

Collision Avoidance Max = 0 s

The radio will always wait 3 seconds before transmission.

The Min and Max times allow one to configure different values at each site to totally avoid radio collisions during instances of cascading events.

Note! Many DNP3 RTU's have internal collision avoidance mechanisms. Those must be considered when configuring the PDR221.

Note! The re-transmission delay of the RTU's must be adapted to the Collision Avoidance delays of the RTU.

8.3 Remote frequency change

The PDR221 provides a function to change the radio network frequency/frequencies remotely, without having to visit all radio sites. The function is executed from the designated master radio, via the configuration menus.

The frequency change is executed in a controlled sequence. The frequency change should always be performed from the master site since the routing information in the network list is used.

Below is a configuration menu printout example:

```
System Frequency Change

New Frequency: 142012500
Do you want to proceed and change frequency y/n?

Change Frequency on remote units
...

Changing frequency locally

Wait for remote units to switch to new frequency (20
sec)
....................
```

8.4 Remote Tx power change

The radio transmission power can be changed remotely from any radio on the network. This gives the network user the possibility to compensate for a weak radio link, if necessary. The transmitter power can be tuned in steps of 1dB between 0.1 and 2.0W for VHF and 0.5 and 2.0W for UHF radios (20 dBm to 33dBm and 27 to 33dBm respectively). **Note!** The UHF radios can be factory tuned between 0.01 to 2.0W (10dBm and 33dBm).

The remote Tx power change is performed via the configuration menus. See chapter 12.9.10.

The Tx power setting can be read from any radio on the network by executing the Radio Link Test. See chapter 12.8.6.

8.5 Multiple RTU addressing to one radio

The routing technique used in a PDR network allows the user to tie several RTU's to the same PDR221 transceiver. This is achieved by simply configuring several RTU addresses to the same radio id in the configuration network menu. See chapter 12.5. To be able to communicate to several RTU's from the slave radio, a RS485 interface is needed. A RS232 to RS485 converter is available from RADIUS.

8.6 Radio Link Test

The Radio Link Test is used to check the RSSI levels (Received Signal Strength Indication) and the Tx power levels of the radios on a chosen link in the radio network. See chapter 13.3.

8.7 Split transmitting and receiving frequencies

If desired, the PDR221 can be configured to operate with separate Tx and Rx frequencies. For example, the master can be configured to transmit at 142.000 MHz and to receive at 147.000 MHz. The slaves shall then be programmed to transmit at 147.000 MHz and to receive at 142.000 MHz.

This type of operation is especially useful if the user wishes to site a master station on a site where other communications equipment may cause, or suffer, interference. The separate Tx and RX frequencies also allow the use of any existing aerial combining/distribution systems.

Note! If separate Rx / Tx frequencies are used, no repeaters can be used between the master and the slave(s). The frequencies are usually programmed during production but can also be programmed on site by RADIUS, or by RADIUS trained person, all depending on local radio restrictions.

Note! If a split uplink frequency is required as well as repeaters, see the Split Tx Uplink feature in chapter 8.8.

8.8 Split Tx Uplink Frequency

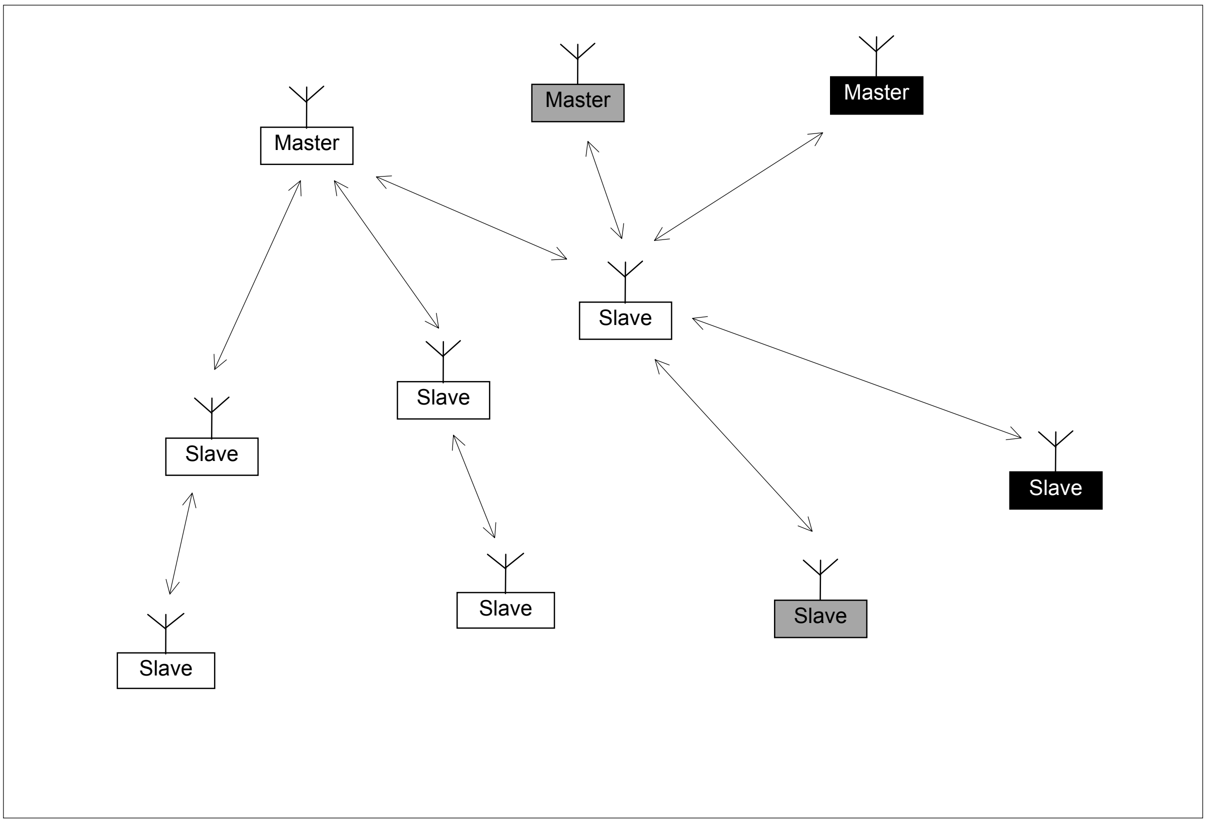
RADIUS transceivers allow users to select half-duplex or simplex operation, or a combination. For example where the master is situated at a shared communications site, it will be often essential to use half-duplex working, however for data packets forwarded to more remote radios, the onward transmissions need only be simplex.

8.9 Repeating Alternative Systems

Normally, a PDR221 unit discards radio messages containing a non- valid System ID. However, it is possible to configure up to four alternative system ids. This allows two - or more - parallel systems to use one another's radio units as repeaters.

Note! It is not recommended to use this feature in a polled network, since it will introduce a risk of radio message collisions.

See chapter 12.6.3 for configuration of this feature.



9 Installation

9.1 General

The installation of radio systems requires careful design and material selection due to the fact that radio systems are more sensitive to interference and cause more interference than other types of apparatus. This is because a radio's two main functions are the ability to transmit powerful electromagnetic waves and to receive extremely weak ones. However it is possible to reduce the risk if the following guidelines are followed:

The PDR should be installed as "free" as possible from other equipment. It should not be placed in the same box as other equipment or in the proximity of other sources of interference, such as: frequency controls, thyristor controls, motors, relays or other kinds of equipment that can cause both low and high frequency radiation. Nor should *the* PDR be installed near various kinds of sensitive sensors since these can be subjected to interference by radiation from the radio.

The above also applies to cabling (both signal and antenna cable) connected to the radio. The signal cables are to be shielded and routed "the shortest way" in cable ducts or similar. Cable surplus should not be tied up in bundles in the cable ducts.

The PDR has an earth/ground terminal on one of its sides. This should be connected to earth (ground). It is to be noted that this ground connector is internally connected to the negative pole of the power supply.

Note! It is of vital importance that the negative pole of the power supply, the earth terminal and the antenna are connected to the same earth potential. The negative pole of the power supply and the radio housing are internally connected.

9.2 Power Supply

The power supply unit in a radio system must be chosen with great care. There are special and high demands to obtain adequate functionality, especially regarding extremely low noise level and exact and fast line/load regulation. The power supply unit should only dissipate low noise levels of both cabinet radiation and conducted interference to the radio. This should especially be observed when using switched mode power supply. The unit's regulation must not be interfered by the radio's carrier wave.

The PDR consumes approximately 165 mA in receiving mode. When transmitting, the consumption rises to approximately 1.1 A in just a few milliseconds. The power supply unit must manage this rapid change of the output current without lowering the output voltage. The power supply cables could with advantage be screened. The conductor area of each cable should, at least, be 1.5mm^2 (18 AWG).

9.2.1 Recommended minimum demands:

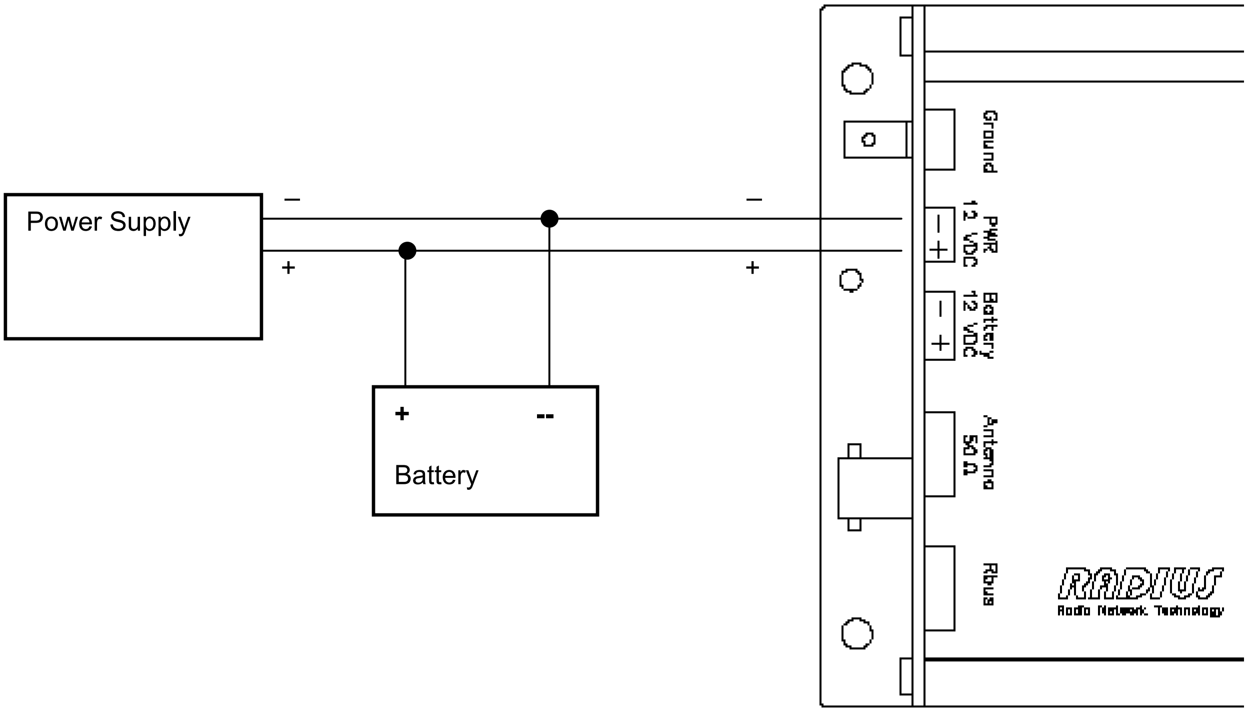
When using power supply unit which has not been delivered by Radius following minimum demands should be followed:

Voltage:	12.5VDC nom. (10-16)
Current:	2A min. (power 30W min)
Ripple/noise:	30mV p-p max.
Line regulation:	1% max.
Load regulation:	1% max.
Temp spec:	-30°C - +70°C

EMI/RFI protected with low RF/HF emissions.

9.3 Battery Power Supply

If a re-chargeable battery is to be used, the connection shall be made as follows;



Note! The Battery Input shall only be used for non-rechargeable batteries.

9.4 Serial Interface

The PDR221 is connected to the control system / RTU via the RS-232 interface.
The serial data transmission is full duplex with selectable data speeds between 600 and 19200 bps, with or without parity. See chapter 12.7 for configuration.

9.4.1 PDR221 Serial Interface Characteristics

Pin Number	Input / Output	Description
1	Out	DCD – Data Carrier Detect The DCD signal is always high/active during transmission of serial data to connected device. The PDR221 can be configured to activate the DCD before and after transmission of the serial data. Pre- and Post DCD. See also configuration chapter 12.7.
2	Out	RxD – Received Data Transmits received data to the connected device.
3	In	TxD – Transmitted Data Receives transmitted data from the connected device.
4	In	DTR – Data Terminal Ready Not used by the PDR221.
5	-	GND – Signal Ground
6	Out	DSR – Data Set Ready Always active/high when in normal operation mode. DSR is deactivated/low when PDR221 is in configuration mode. I.e. not ready to receive data on the serial port.
7	In	RTS – Request To Send Used for EOM, End Of Message, detection if selected in configuration. The connected device sets RTS high when a message is to be transmitted. When the last byte is transmitted, the RTS is set low. This negative flank is used by the PDR221 to detect EOM. See 9.4.3.
8	Out	CTS – Clear To Send The CTS signal is active/high when the PDR is ready to receive data. It is deactivated/low from when a message is completely received on the serial port until the message is completely transmitted on the radio. It is also deactivated/low from when a message is detected on the radio until it is completely transmitted on the serial interface.. **Note!** It is not necessary to use the CTS signal. Though, it can be used to avoid data transfer collisions in some systems.
9	Out	RI – Ring Indicator. Not used by the PDR221. (Used by DCE telephone modem equipment. Indicates ring signal on a telephone line).

Table 1. Serial data interface connector pinout

It is not necessary to wire any handshaking signals to receive data telegrams from connected equipment. Only the TxD, RxD and GND signals need to be connected. Though, the unit offers status and handshaking signals that can be used by the control system if necessary. The RTS signal shall be wired if it shall be use for EOM (End Of Message) detection, see chapter 9.4.3.

Note! The PDR221 radio operates as a DCE, (Data Communication Equipment). Check how the connected device and/or control system operates, DCE or DTE (Data Terminal Equipment), to select the correct serial cable configuration.

Note! Depending on the functionality of the connected device, it is sometimes required to jump-wire the handshaking signals, DTR/DSR, RTS/CTS, as cable types 3 and 6 below. However, it is most often possible to use a “three wire connection” like cable type 2 below.

Standard 9 wire pin-to pin serial cables are configured as cable type 1 below.

9.4.2 Serial Cable Configurations

DB9F = D-Sub, 9 pin, Female
DB9M = D-Sub, 9 pin, Male
DB25F = D-Sub, 25 pin, Female
DB25M = D-Sub, 25 pin, Male

9.4.2.1 DTE – DCE

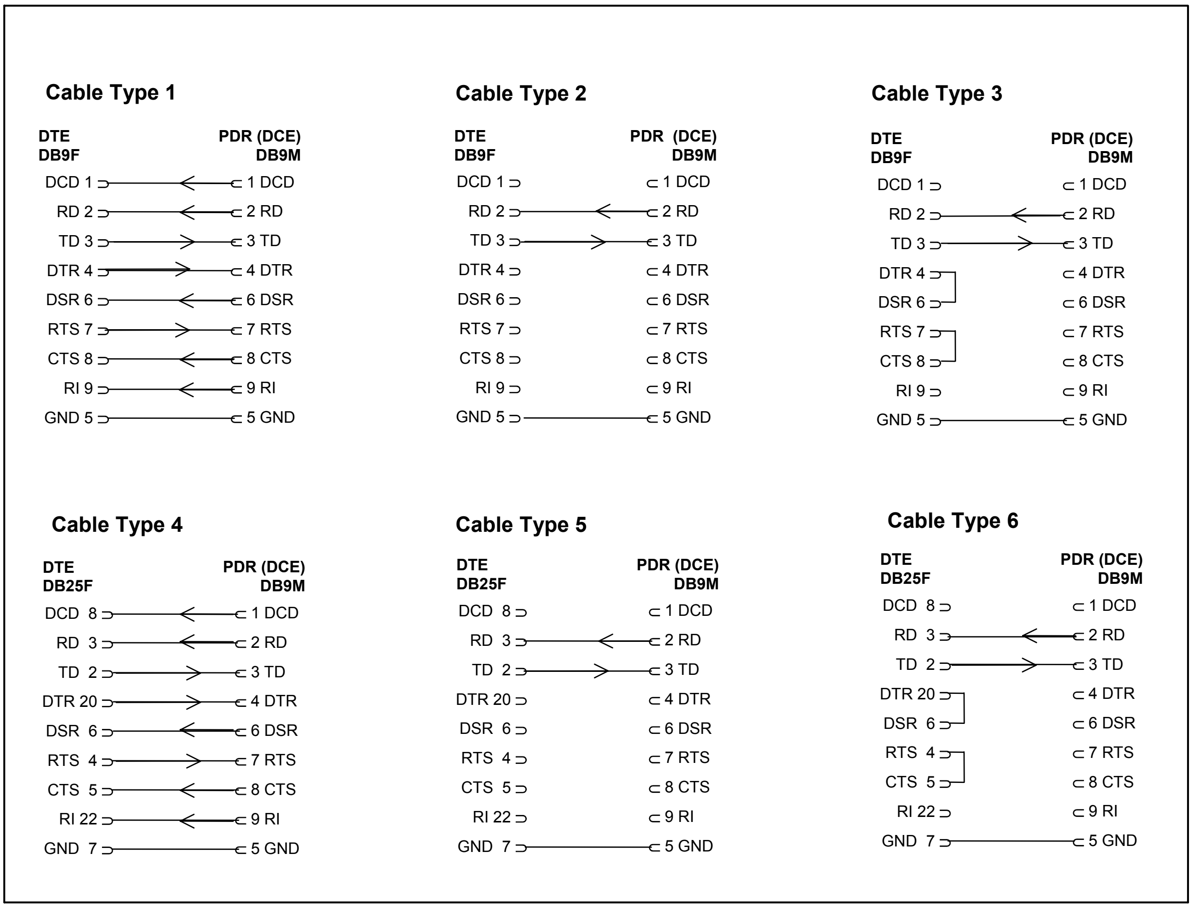


Figure 3. DTE-DCE serial cable configurations

9.4.2.2 DCE – DCE

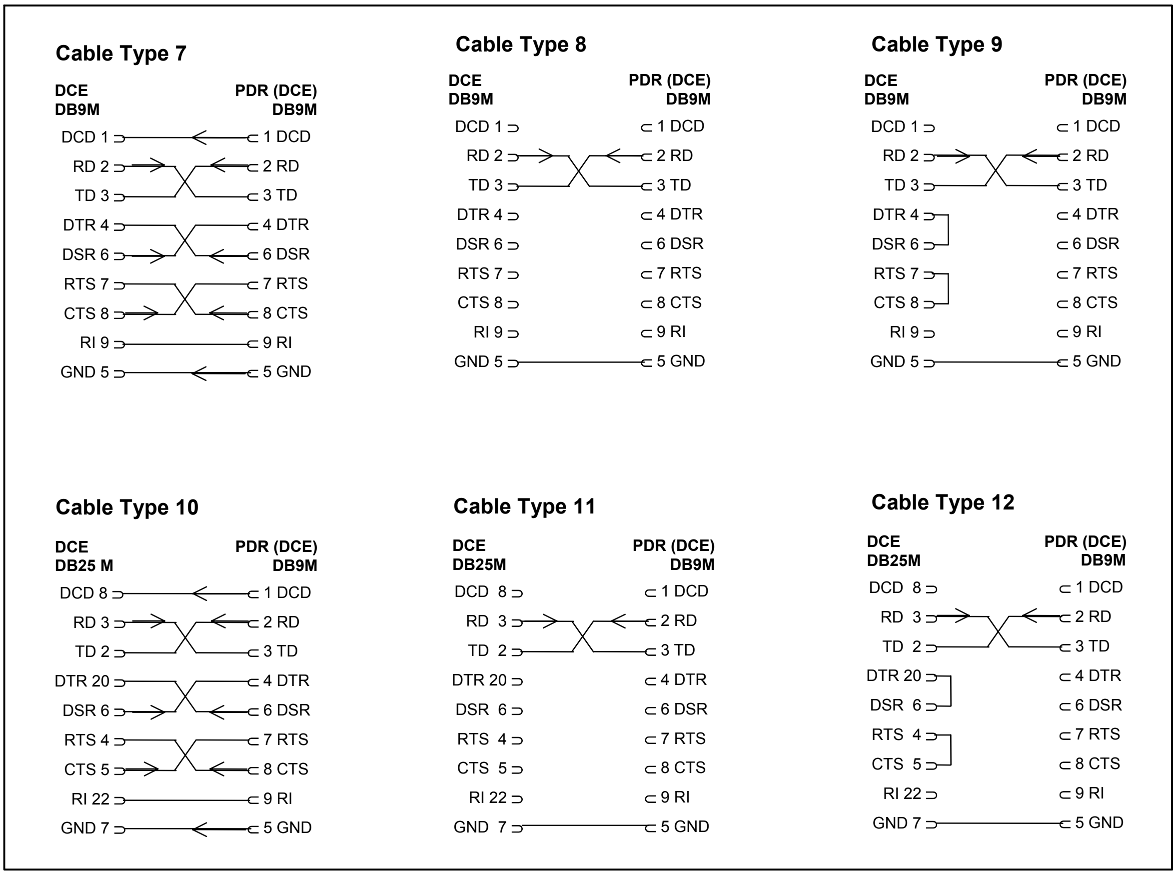


Figure 4. DCE-DCE serial cable configurations

9.4.3 EOM – End of Message - Detection

The PDR221 detects the end of the serial message either by using the RTS signal from the connected device or by measuring the time between received characters. If handshaking with RTS is not used in the communication between the connected device and the PDR221, the interruption in the bit stream from the control system is used to determine the End of Message. The *Inter Character Timeout,* which is set in the Serial Configuration Menu, should be longer than the longest possible time that can appear between two characters in the asynchronously transmitted telegram to the radio.

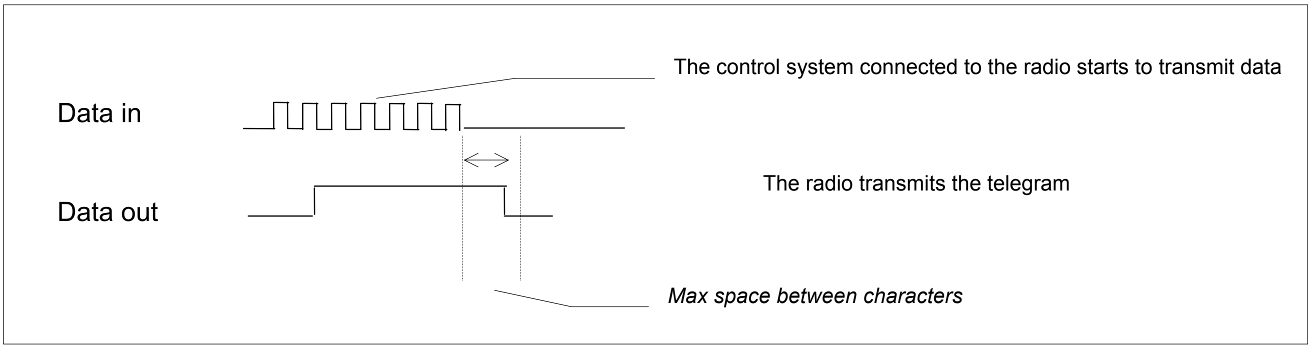


Figure 11. Communication without handshaking

9.4.3.1 RTS

If handshaking is used in the communication between the control system and the PDR, the RTS-signal's trailing edge is used to determine if the telegram from the control system is finished and that the radio can start transmitting. This is done according to:

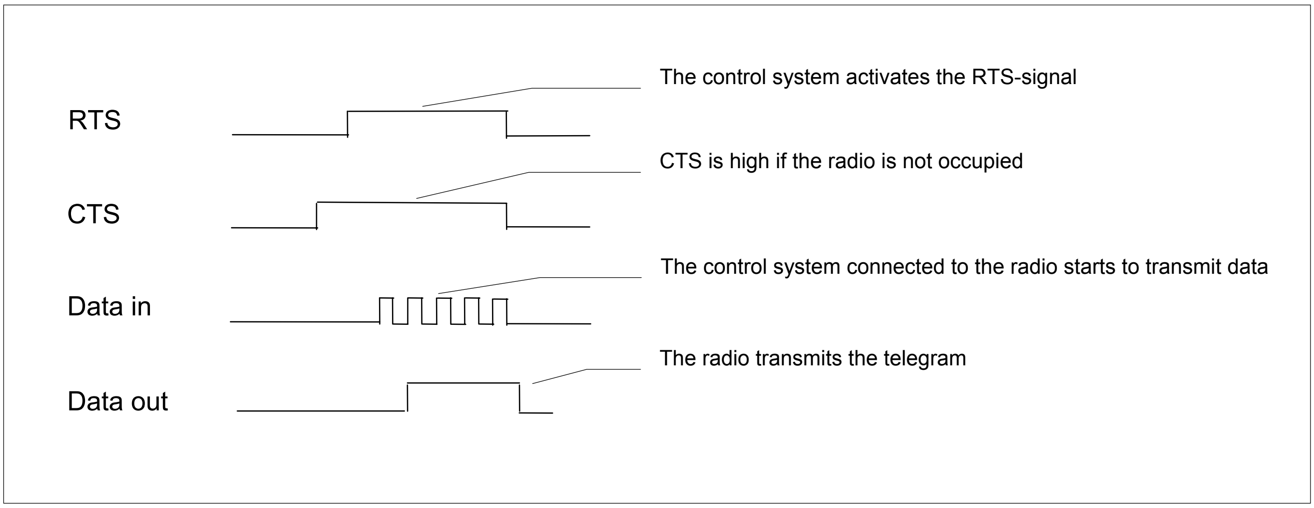
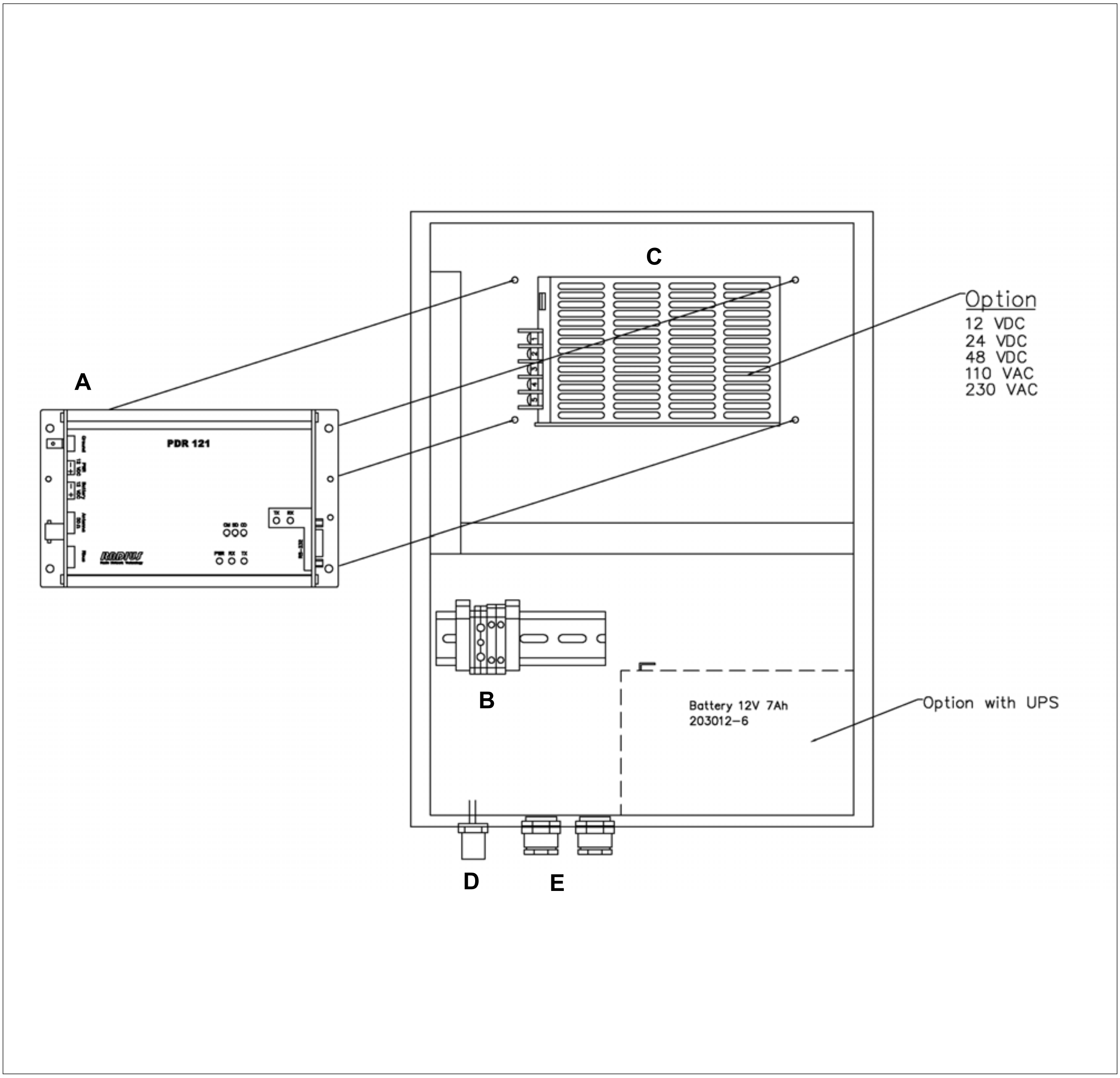


Figure 12. Handshaking procedure with RTS

9.5 Cabinet Mounting

9.5.1 PDR 221 mounted in cabinet

If the PDR221 can be delivered mounted in a cabinet. Below is an example.



Object	Name	Description
A	PDR221	Data radio.
B	Connection block	For connection of mains. Phase, neutral or earth.
C	Power supply	Converts mains to 12VDC
D	Coaxial connector N-jack.	For connection of the antenna cable
E	Cable gland (duct)	For leading cables through the cabinet

The cabinet can be equipped with heater and/or UPS.

10 Accessories

Radius provides a wide range of accessories and spare parts for radios and radio network installations.

All equipments have been tested to be appropriate for use with RADIUS radios and have been selected by people with many years of radio network experience.

Contact Radius for detailed technical information and pricing.

Accessory examples:

- Antennas
  - Directional
  - Omni-directional
  - Gain

- Antenna Cables

- Cabinets
  - Indoor
  - Outdoor, stainless

- Cabinet Heaters
  - For operation down to –40 degrees Celsius.

- Backup Batteries

- Power Supplies
  - Suitable for RF device operation

- Bulkhead Lightning Antenna Arresters

11 Radio Networking

This chapter general radio network equipment, terms and how to calculate a “Radio Link Budget”. This information can be useful when planning a radio network, but is not essential for using the PDR221.

11.1 Antennas

Selecting the correct antennas can be crucial for the communication links. Design of antennas and antenna systems include quite complicated physics, mathematics and circuit theory. However, below follows some basics that can be helpful in understanding the principles of antennas in a radio network.

11.1.1 Antenna Gain

The antenna gain is a measure of how well the antenna will send or pick up a radio signal. The gain of an antenna is measured in decibels-isotropic (dBi) or in decibel-dipole (dBd). The decibel is a unit of comparison to a reference. The letter following the "dB" indicates the reference used. The dBi is a unit measuring how much better the antenna is compared to an isotropic radiator.

An isotropic radiator is an antenna transmitting signals equally in all directions, including up and down (vertically). An antenna of this type has 0dBi gain. (An isotropic antenna is only a theoretical model that has no real design).

The higher the decibel number is, the higher the gain will be of the antenna. For instance, a 6dBi gain antenna will receive a signal at a higher level than a 3dBi antenna. A dBd unit is a measurement of how much better an antenna performs against a dipole antenna. As a result a dipole antenna has a 0dBd gain. However a dipole antenna typically has a 2.4dBi gain as dipole antennas have more usable gain than isotropic radiators. Any dBi measurement may be converted to dBd by adding 2.4.

The only way to increase antenna gain is to concentrate the antenna signal radiation / reception pattern - the electromagnetic field - in a smaller area than the omni-directional pattern of a isotropic antenna. This can be compared to using a pair of binoculars. You will se the object better, but you will see a smaller area.

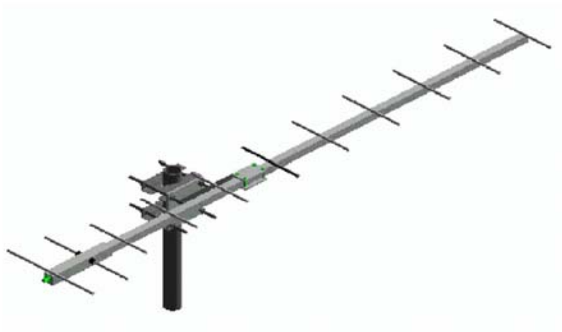
Concentrating and focusing the EM field, creates gain that is then retrieved by the physical design of the antenna.

11.1.2 Antenna Types

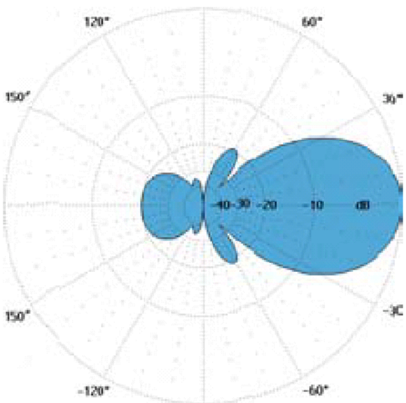
There are basically two categories of antennas, omni-directional and directional. An omni-directional antenna radiates in all directions. A directional antenna radiates in one direction only. An omni-directional antenna should not be confused with an isotropic radiator. While an isotropic radiator will radiate in all 3 dimensional directions, an omni-directional antenna may not radiate vertically (up or down).

11.1.2.1 Directional Antenna

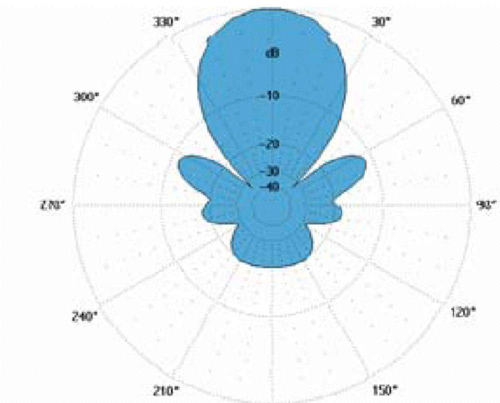
Below is an example of a 14 dBi gain directional antenna. The field strength diagrams show the direction of maximum radiation of the antenna. The E plane represents the electric field and the H plane represents the magnetic field. The E plane and the H plane are orthogonal to each other.



E Plane

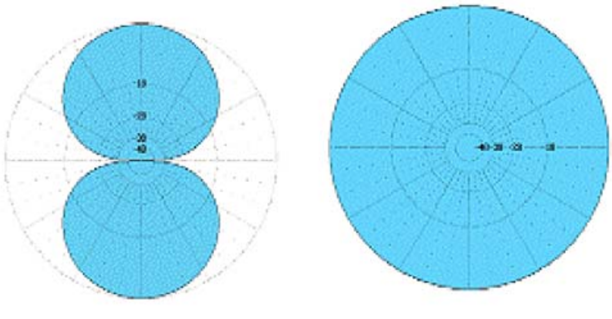


H Plane



11.1.2.2 Omni-Directional Antenna

Here is an example of an omni-directional antenna. In this case it is a ground plane antenna.



11.1.3 Antenna Gain versus Radio Output Power

Increasing the receiver sensitivity by 3dBm is equal to doubling the output power.

The receiver sensitivity is, except from the radio design itself, depending on the antenna and the antenna installation. Using a high gain antenna is in many cases much more effective than increasing the transmitter power. For example, using a 6dBm gain antenna, instead of a 0dBm gain on a 2W radio transmitter is equivalent to increasing the transmitter power from 2 to 8 W.

11.2 Fade Margin

Fade Margin is an expression for how much margin - in dB - there is between the received signal strength level and the receiver sensitivity of the radio.

The figure below describes the term fade margin. Site A is transmitting with 33dBm (2W) power. After the distance to site B, the signal level has dropped to –100 dBm. This gives a margin of –10 dBm since the receiver sensitivity of the radio at site B is -110 dBm.

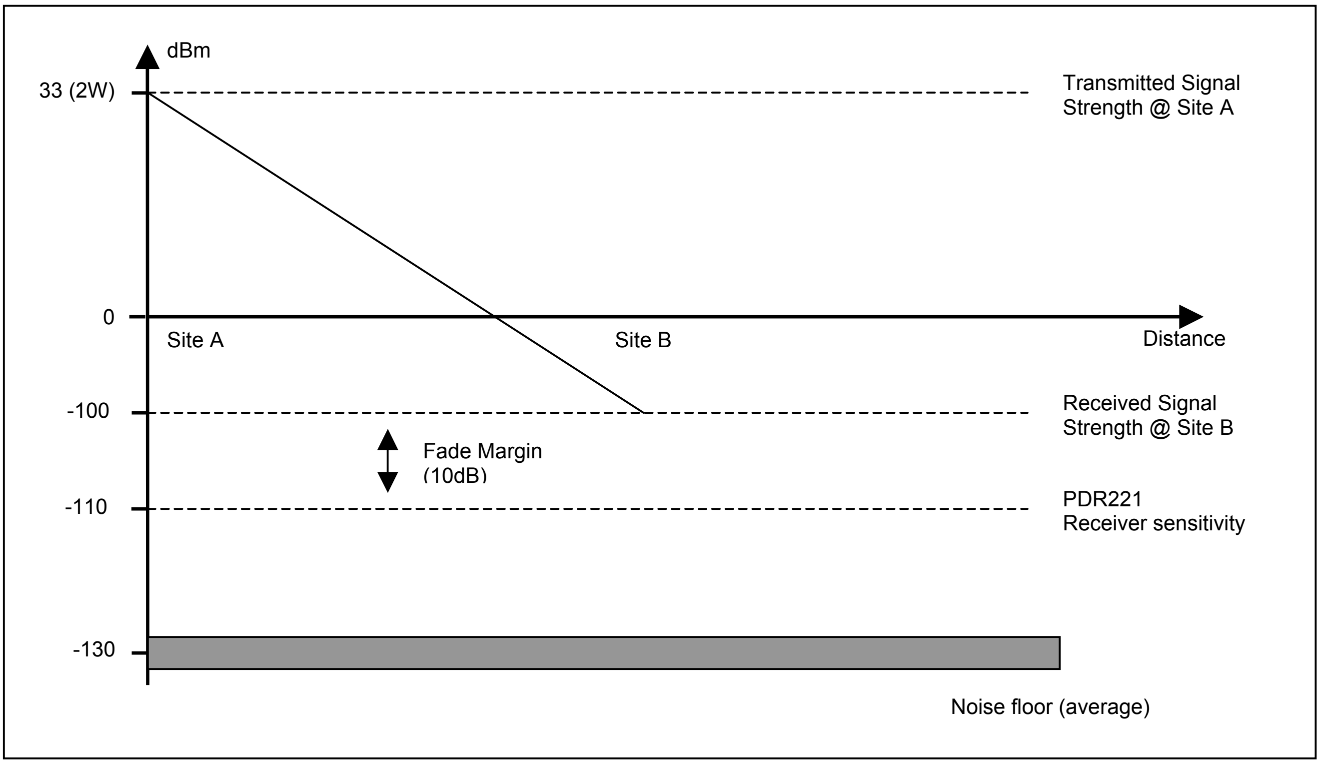


Figure 6. Fade Margin

In very noisy environments, the level of the noise floor can be higher than the receiver sensitivity. (For example greater than -110 dBm in the above example). In this case, it does not help to increase the receiver sensitivity or using a higher gain receiving antenna. The only solution if the source of the noise can not be eliminated is then to increase the power of the transmission so that signal strength at the receiving radio is higher than the noise. However, in some cases, moving the receiving antenna can reduce the noise impact.

11.3 Radio Link Calculations

This section contains some useful formulas for radio “link budget” calculations. **Note** that the calculations are based on assumptions of certain circumstances and should only be used as a guideline for radio network design. In reality, many factors can have an impact on the radio link. Planning of a radio network is usually done by first simulating the network in a desk-top propagation study using professional software package. The results are then verified by performing a field survey.

However, the formulas below can be used to calculate if the radio link has an acceptable fade margin or, if not, how much antenna gain that needs to be added or if repeaters have to be used.

The known factors are often;

- The distance between two sites
- The (possible) height of the antennas
- The transmit power of the radio
- The receiver sensitivity of the radio
- The antenna gain

11.3.1 No Line of Sight Calculations

For line of sight calculations, see chapter 11.3.2.

The first calculation to be made is the propagation loss. This value tells how much the signal strength is decreased due to the distance between the transmitter and the receiver. For this we use the Egli model. The Egli model is a simplified model that assumes "gently rolling terrain with average hill heights of approximately 50 feet (15 meters)" (*Land Mobile Radio Systems*, Edward N. Singer, PTR Prentice Hall, 1994, p. 196). Because of this assumption, no terrain elevation data between the transmitter and receiver facilities is needed. Instead, the free-space propagation loss is adjusted for the height of the transmitter and receiver antennas above ground. As with many other propagation models, Egli is based on measured propagation paths and then reduced to mathematical model. In the case of Egli, the model consists of a single equation for the propagation loss.

$$\mathbf{A} = 117 + 40 \times \log \mathbf{D} + 20 \times \log \mathbf{F} - 20 \times \log(\mathbf{Ht} \times \mathbf{Hr})$$

Where

A	= Attenuation (dB)
D	= distance between the antennas (miles)
F	= Frequency (MHz)
Ht	= Height of transmitting antenna (feet)
Hr	= Height of receiving antenna (feet)

1 mile = 1610 meters = 1.61 kilometers

1 feet = 0.305 meter

Metric system users can use the formula:

$$\mathbf{A} = 117 + 40 \times \log(\mathbf{D} \times 1.61) + 20 \times \log \mathbf{F} - 20 \times \log((\mathbf{Ht} \times 0.305) \times (\mathbf{Hr} \times 0.305))$$

Where

D	= distance between the antennas (kilometres)
Ht	= Height of transmitting antenna (meters)
Hr	= Height of receiving antenna (meters)

.

Example 1

D = 12.5 miles (20 kilometres)
F = 142.000 MHz
Ht = 65 feet (20 meters)
Hr = 16 feet (5 meters)

A = 117 + 40 x log **12.5** + 20 x log **142** – 20 x log(**65** x **16**)

117 + 43.8764 + 43.0457 – 60.3406 = 143.6dB

This example shows that an 142 MHz RF signal will be attenuated 143.6 dB over a distance of 12.5 miles (20 kilometers).

Example 2

Increasing the antenna heights x 2

D = 12.5 miles (20 kilometres)
F = 142.000 MHz
Ht = 130 feet (40 meters)
Hr = 32 feet (10 meters)

A = 117 + 40 x log **12.5** + 20 x log **142** – 20 x log(**130** x **32**)

117 + 43.8764 + 43.0457 – 60.3406 = 131.6dB

Increasing the antenna heights by a factor 2 gained 12 dB, which means that the signal is attenuated 12 dB less over a distance of 12.5 miles (20 kilometers).

11.3.1.1 Radio Link budget

The formula below can be used to calculate any of the factors within.

FM = Srx + Ptx + Gtx + A + Grx – Cl

Where

FM = Fade Margin (See chapter 11.2).
Srx = Sensitivity of the receiver (dBm) (using +dBm instead of –dBm)
Ptx = Transmitter RF output power (dBm)
Gtx = TX Antenna Gain (dB)
A = Over Air Attenuation (dB) (see above)
Grx = Receiver (RX) Antenna Gain(dB)
Cl = Cable/Connector Loss (dB)

Note! To simplify, we use an average Cable/Connector loss value, including both the Tx and Rx site, of 4dB. This is in some cases a high value, but still assumes a correct antenna cable installation.

Example 1

Is the radio link theoretically possible? Calculation of fade margin FM;

Distance	= 3 miles (5km)
Antenna height 1	= 65 feet (20 meters)
Antenna height 2	= 16 feet (5 meters)
Radio Tx Power	= 33 dBm (2W)
Radio Rx Sensitivity	= -110 dBm
Frequency	= 456.000 MHz
Antenna Gain 1	= 3dBd
Antenna Gain 2	= 6dBd
Cable / Connector losses	= 4 dB total
FM	= ?

A = 117 + 40 x log **3** + 20 x log 456 – 20 x log(65 x 16) = 129 dB

FM = Srx + Ptx + Gtx + **A** + Grx – Cl ->

FM = 110 dBm + 33dBm + 3dBd – 129dB + 6dBd – 4dB = 19dB

The fade margin is 19 dB, which is an acceptable level. The radio link should be possible.

Example 2

How high should the master antenna be mounted?

Distance	= 12.5 miles (20km)
Antenna height 1	= X
Antenna height 2	= 64 feet (20 meters)
Radio Tx Power	= 33 dBm (2W)
Radio Rx Sensitivity	= -110 dBm
Frequency	= 142.000 MHz
Antenna Gain 1	= 3dBd
Antenna Gain 2	= 6dBd
Cable / Connector losses	= 4 dB total
Fade Margin	= 20dB

Calculating highest allowed over air attenuation:

FM = Srx + Ptx + Gtx + A + Grx – Cl ->

A = Srx + Ptx + Gtx + Grx – Cl – FM ->

A = 110dBm + 33dBm + 3dBd + 6dBd – 4dB – 20dB = 128 dB ->

Calculating antenna hight X using A from above:

A =128 = 117 + 40 x log 12.5 + 20 x log 142 – 20 x log(X x 64) ->

20 x log (X x 64) = 117 + 40 x log **12.5** + 20 x log 142 – 128 ->

20 x log (X x 64) = 75.9 ->

X = ($10^{75.9/20}$) / 16 = 97.5 feet = 30 meters

11.3.2 Line Of Sight Calculations

The formulas below are to be used when there is no terrain or obstacles that can interfere with the radio signal (line of sight).

The first calculation to be made is the FSL, Free Space Loss. The FSL value tells how much the signal strength is decreased due to the distance between the transmitter and the receiver.

FSL - Free Space Loss

FSL (dB) = 20*LOG(λ/4π***R**)

Where;

R = Distance between Rx and Tx Antenna. (Line of sight) in meters.

λ = C/f = 300/f

Ex1: *f = 460MHz* *distance = 10 000 meters (10 km) (6.2 miles)* *->* *λ = C/f = 300/460 = 0.65m* ***FSL** = 20*LOG(0.65/4π*10 000) = **-105.7dB***	*Ex2:* *f = 460MHz* *distance = 20 000 meters (20 km) (12.4 miles)* *->* *λ = C/f = 300/460 = 0.65m* ***FSL** = 20*LOG(0.65/4π*20 000) = **-111.7 dB***
Ex3: *f = 142MHz* *distance = 10 000 meters (10 km) (6.2 miles)* *->* *λ = C/f = 300/142 = 2.11m* ***FSL** = 20*LOG(2.11/4π*10000) = **-95.5dB***	*Ex4:* *f = 142MHz* *distance = 40 0000 meters (40 km) (24.8 miles)* *->* *λ = C/f = 300/142 = 2.11m* ***FSL** = 20*LOG(2.11/4π*40 000) = **-107.5dB***

Conclusion (using Ex2):

If the transmission power is 33 dBm (2w) the signal strength at the receiver antenna will be

33db - 105.7db = -72.7 db (Not taking cable losses at the transmitter in consideration).

If the receiver sensitivity is –110 dBm, this is ok. However, there are more factors for the link budget calculation. Those are calculated by using the same formula as for no line of sight links but by replacing the over air attenuation A with Free Space Loss - FSL.

11.3.2.1 Radio Link Budget

FM = Srx + Ptx + Gtx + FSL + Grx – Cl

This fomula can be used to calculate any of the factors within.

FM = Fade Margin (See chapter 11.2).
Srx = Sensitivity of the receiver (dBm) (using +dBm instead of –dBm)
Ptx = Transmitter RF output power (dBm)
Gtx = TX Antenna Gain (dB)
FSL = Free Space Loss (dB) (see above)
Grx = Receiver (RX) Antenna Gain(dB)
Cl = Cable/Connector Loss (dB)

Note! To simplify, we use a general Cable/Connector loss, including both theTx and Rx site, of 4dB. This is a high value for most installations, but still assumes a correct antenna cable installation.

Example 5. Receiver sensitivity needed.

Using Ex2 above and assuming 3dB antennas at each site:

FM = Srx + Ptx + Gtx + FSL + Grx – Cl ->

Srx = Ptx + Gtx + FSL + Grx – Cl – FM ->

Srx = 33dBm + 3dBd – 111.7dB + 3dBd – 4dB – 20dB = -96.7 dBm

Example 6. Total antenna gain needed.

Using Example 4 above. 40 km (24.8 miles) line of sight.

FM = Srx + Ptx + Gtx + FSL + Grx – Cl ->

Gtx + Grx = GA (Total Gain) ->

FM = Srx + Ptx + FSL + GA – Cl ->

GA = FM + Srx - Ptx - FSL + Cl ->

GA = 20dB + 110dBm - 33dBm - 107.5dB + 4dB = -6.5 dB total

Conclusion: 3dBd antenna gain is needed at each site to get approximately 20 dB fade margin.

12 Configuration

12.1 Equipment

Configuration of the PDR221 is performed via the Rbus interface using the RADIUS ProgInt cable and a standard communication program, like Windows HyperTerminal. The terminal program needs to be configured to 57600 bps, 8 data bits, no parity and 1 stop bit.

12.2 Getting Started

Follow the procedure below to enter the PDR221 configuration menus.

1. Ensure that the PDR221 has 12 VDC supplied.
2. Connect the serial DB-9 connector of the ProgInt cable to the PC.
3. Connect the modular connector of the ProgInt cable to the PDR Rbus jack.
4. Start the terminal program on the PC.
5. Select an available PC COM port.
6. Configure the communication settings to 57600, 8 N 1.
7. Press ‘C’ (capital) to enter the PDR221 configuration menus.

Note! After configuration, “Exit Configuration” must be chosen or else the PDR221 will remain in the configuration mode and will not operate in the “normal mode”.

If the PDR is powered up after connected to a terminal program, the following information will be downloaded into the connected PC:

```
Packet Data Radio - PDR221
Copyright RADIUS Sweden AB
Software: PDR221S v1.0 Build Jul 14 2004
AN:124356-1 SwNo:51 HwNo:18

Executing

Press C to enter configuration mode
```

Note! If the PDR221 was powered up before connected to the terminal program, you need to press ‘C’ to enter the configuration menus.

12.3 Configuration Menus Overview

```
Packet Data Radio – PDR221
Copyright RADIUS Sweden AB
Software: PDR221S v1.0 Build Jul 14 2004
AN:124356-1 SwNo:51 HwNo:18

1. Function : Master
2. Network
3. Serial
4. Radio
5. Advanced
6. List Configuration

E. Exit Configuration Mode
```

See 12.5, page 48.

```
Network

1. System ID      : 01
2. Radio ID       : 01
3. Repeat Alternative Systems
```

See 12.7, page 49.

```
Serial

1. Bitrate                   : 9200 bps
2. Parity                    : None
3. Inter Character Timeout : 100 ms
4. Use RTS                   : OFF
5. Pre DCD                   : 0 ms
6. Post DCD                  : 0 ms
```

See 12.8, page 50.

```
Radio

1. Collision Avoidance Delay     : OFF
2. Collision Avoidance Delay Min : 0 ms
3. Collision Avoidance Delay Max : 0 ms
4. Bit Error Rate Test
5. Communication Test
6. Radio Link Test
7. Receiver Test
8. Transmitter Test
```

See 12.9, page 51.

```
Advanced

1. Detected Radio Type       : UHF Low 435..451 MHz
2. Rx Frequency              : 440000000 Hz
3. Tx Frequency              : 440000000 Hz
4. Split Tx Uplink           : OFF
5. Split Tx Uplink Frequency : 000000000 Hz
6. Split Tx Uplink Id        : 00
7. Radio Link Speed          : 9600 bps
8. Tx Power Level            : 33 dBm (2.00 W)
9. System Frequency Change
A. Remote Tx Power Level Change
B. Radio VCO Lock Test
C. Terminal Bitrate
```

See 12.10, page 53.

```
Current Configuration :


Function                      : Master
System Id                     : 01
Radio Id                      : 02
Serial                        : 9600 8N1
Inter Character Timeout       : 100 ms
Use RTS                       : 0 ms
Pre DCD                       : 0 ms
Collision Avoidance Delay     : OFF
Collision Avoidance Delay Min : 0 ms
Collision Avoidance Delay Max : 0 ms
Rx Frequency                  : 440.000000 MHz
Tx Frequency                  : 440.000000 MHz
Split Tx Uplink               : OFF
Split Tx Uplink Frequency     : 0.000008 MHz
Radio Link Speed              : 9600 bps
Tx Power Level                : 33 dBm (2.00 W)
Non-Intrusive diagnostics     : OFF

Press any key to continue...
```

12.4 Configuration Menus

After pressing ‘C’, the main menu is displayed.

```
Packet Data Radio - PDR221
Copyright RADIUS Sweden AB
Software: PDR221S v1.0 Build Jul 14 2004
AN:124356-1 SwNo:51 HwNo:18

1. Function : Master
2. Network
3. Serial
4. Radio
5. Advanced
6. List Configuration

E. Exit Configuration Mode
```

To enter a sub menu, enter the number, or letter, to the left of the menu name.

12.5 Function

Operation mode selection; Master, Slave, Slave Via Repeater, Slave With Delay for Repeater or Peer To Peer. See chapter 7.8 and 7.9.

12.6 Network

```
Network

1. System ID      : 01
2. Radio ID       : 01
3. Repeat Alternative Systems
```

12.6.1 System ID

The System ID is used to identify the communication within one radio system. If a radio receives a radio message with an “unknown” System Id, it will neglect the message. Therefore, all units in the same radio system shall have the same System Id. The System ID range is 01 to 99. (Entering 00 will clear the System ID). See also chapter 12.6.3, Repeat Alternative Systems.

12.6.2 Radio ID

The Radio ID is used to identify each radio in the network. All radios in the network shall have different Radio ID’s. The Radio ID range is 01 is 99.Thus, one PDR radio network can contain 99 radio units. (Entering 00 will clear the Radio ID).

12.6.3 Repeat Alternative Systems

This feature allows a radio to repeat messages in a parallel PDR network. Four parallel system ID's can be configured. If the radio receives a message from a parallel system and its system id is listed, it will repeat the message. If not listed, the message will be neglected.

12.7 Serial

The serial menu contains configuration parameters for the serial (RS-232) interface.

```
Serial

1. Bitrate                   : 9600 bps
2. Parity                    : None
3. Inter Character Timeout : 100 ms
4. Use RTS                   : OFF
5. Pre DCD                   : 0 ms
6. Post DCD                  : 0 ms
```

12.7.1 Bitrate

This feature is for the selection of the serial interface communication speed: 600, 1200, 2400, 4800, 9600 or 19200 bps.

12.7.2 Parity

This feature is for the selection of the serial interface parity; None, Even or Odd.

12.7.2.1 Inter Character Timeout

Selection of the space, in time, allowed between characters in a serial telegram, which is accepted by the PDR221. This can be specified between 0-999 ms. When in the OFF mode, the PDR 221 will allow eternal time between characters in an incoming telegram. See chapter 9.4.3.

12.7.2.2 Use RTS

Enabling / Disabling of the RTS EOM (End of Message) detection functionality. See chapter 9.4.3.

12.7.3 Pre DCD

The Pre DCD specifies during how long time the DCD signal shall be active before the PDR transmits the serial message to the connected device. See chapter 9.4.

12.7.4 Post DCD

The Post DCD specifies during how long time the DCD signal shall be active after the PDR has transmitted a serial message to the connected device. See chapter 9.4.

12.8 Radio

The Radio menu contains collision avoidance settings and various test functions.

```
Radio

1. Collision Avoidance Delay     : ON
2. Collision Avoidance Delay Min : 500 ms
3. Collision Avoidance Delay Max : 2000 ms
4. Bit Error Rate Test
5. Communication Test
6. Radio Link Test
7. Receiver Test
8. Transmitter Test
```

12.8.1 Collision Avoidance Delay

The Collision Avoidance Delay is used for radio units operating in unsolicited communication networks. The Delay prevents the radio units from transmitting simultaneously if an event occurs at two or more RTU's at the same time. Each radio waits for a random time between the configured min and max settings before the transmission is executed. The random time is counted from when the channel is considered free. If another unit starts transmitting during the delay time, the random delay is re-initiated on all units hearing the transmitting unit and waiting to transmit.

Note! The master radio connected to the central control (Master/SCADA) should have the Collision Avoidance Delay set to OFF. This setting requirement is because none of the messages from the SCADA master should be handled as unsolicited messages.

12.8.2 Collision Avoidance Delay Min

Minimum waiting time before transmission of unsolicited messages, only used if collision avoidance delay is set to ON. Time can be set between 0 – 9.9 s.

12.8.3 Collision Avoidance Delay Max

Maximum waiting time before transmission of unsolicited messages, only used if collision avoidance delay is set to ON. Time can be set between 0 – 9.9 s.

12.8.4 Bit Error Rate Test

The Bit Error Rate Test is used to test the transmission data quality between two radio units in the network. See chapter 13.1 for a more in depth description.

12.8.5 Communication Test

The Communication Test is used to check the communication path between two radios in the network.

12.8.6 Radio Link Test

The Radio Link Test is used the check the RSSI (Received Signal Strength Indication) levels and Tx power levels for a selected path in the radio network.

12.8.7 Receiver Test

Receiver Test activates the radio receiver. This function is mostly used for testing the radio receiver during production or service.

12.8.8 Transmitter Test

Transmitter Test activates the radio transmitter (modulated with bit pattern). This function is mostly used during production or service, but may also be used for antenna measurements.

12.9 Advanced

The advanced menu is password protected. Only, by the system owner, authorized persons shall have access to this menu since the frequency and output power of the radio can be changed here.

```
Advanced

1. Detected Radio Type       : UHF Low 435..451 MHz
2. Rx Frequency              : 440000000 Hz
3. Tx Frequency              : 442000000 Hz
4. Split Tx Uplink           : OFF
5. Split Tx Uplink Frequency : 440000000 Hz
6. Split Tx Uplink Id        : 07
7. Radio Link Speed          : 9600 bps
8. Tx Power Level            : 33 dBm (2.00 W)
9. System Frequency Change
A. Remote Tx Power Level Change
B. Radio VCO Lock Test
C. Terminal Bitrate
```

12.9.1 Detected Radio Type

When the advanced menu is entered, the software automatically checks what type of radio module is mounted. I.e. what frequency band that is available. The check is performed again if ‘1’ is selected.

12.9.2 Rx Frequency

Selection of desired receiving frequency is achieved by pressing ‘2’. The software performs calculations of radio frequency parameters and displays the result.

```
Rx Frequency: 440000000

The frequency parameters will be updated

Rx calculations ,  please wait...
FvcoDes = 492950000
FvcoAct = 492950000  ((140+2)*64 + 3*65 +(7+1)*72+0/5)*17500*e3/350
Diff    = 0

Press any key to continue...
```

12.9.3 Tx Frequency

Selection of desired transmitting frequency is achieved if ‘3’ is pressed. The software performs calculations of radio frequency parameters and displays the result. Note that the Rx and Tx frequencies can be the same.

12.9.4 Split Tx Uplink

This feature can be enabled on the slave radio units adjacent to the master radio site to gain a split uplink network. If enabled, the radio will transmit on one frequency to the master (uplink) and on another when repeating messages from the master (downlink) to other units the network.

12.9.5 Split Tx Uplink Frequency

If split Tx frequency is enabled this frequency is used when transmitting to the radio id indicated by split Tx uplink id.

12.9.6 Split Tx Uplink Id

If split Tx uplink is enabled transmissions to this radio id uses the split Tx uplink frequency.

12.9.7 Radio Link Speed

The radio link speed in bps, available selection is 4800, 9600 or 19200.

12.9.8 Tx Power Level

The transmitter power level can be adjusted between 10…33 dBm / 0.01…2.0 W in steps of 1 dBm by using the + / - keys.

Note! VHF radio modules Tx power level range is limited to 20…33 dBm / 0.1…2.0 W.

```
Select Tx Power Level

Adjust Tx Power Level with +/-

Selected : 33 dBm (2.00 W)
```

12.9.9 System Frequency Change

This feature changes the radio network frequency remotely to all radio units on the network. See chapter 8.3.

12.9.9.1 Split Uplink Frequency

The System Frequency Change feature is designed to support split uplink frequency. If separate Rx / Tx frequencies is selected at the master radio, the adjacent (direct) slave radios will have split Tx uplink enabled and the master id and Rx frequency set as split Tx uplink id and split Tx uplink frequency. All other slave radios will have both the Rx and Tx frequency set to the masters Tx frequency.

12.9.10 Remote Tx Power Level Change

This feature is used to change Tx power level on a remote unit in the network.

12.9.11 Radio VCO Lock Test

The configured Rx and Tx frequencies are continuously checked for positive VCO lock. If a negative VCO lock is detected, this is displayed as Rx Failure / Tx Failure respectively. If split Tx uplink is enabled the split Tx uplink frequency is also tested, a failure is displayed as Split Tx Uplink Failure.

```
Radio VCO Lock Test
Press any key to abort...
OK
```

12.9.12 Terminal Bitrate

The default terminal interface speed is 57600 bps. This can be changed to 1200 or 9600 bps if required. Note that the change will have immediate effect.

```
Terminal Bitrate
Will have immediate effect!

1. 1200  bps
2. 9600  bps
3. 57600 bps
```

12.10 List Configuration

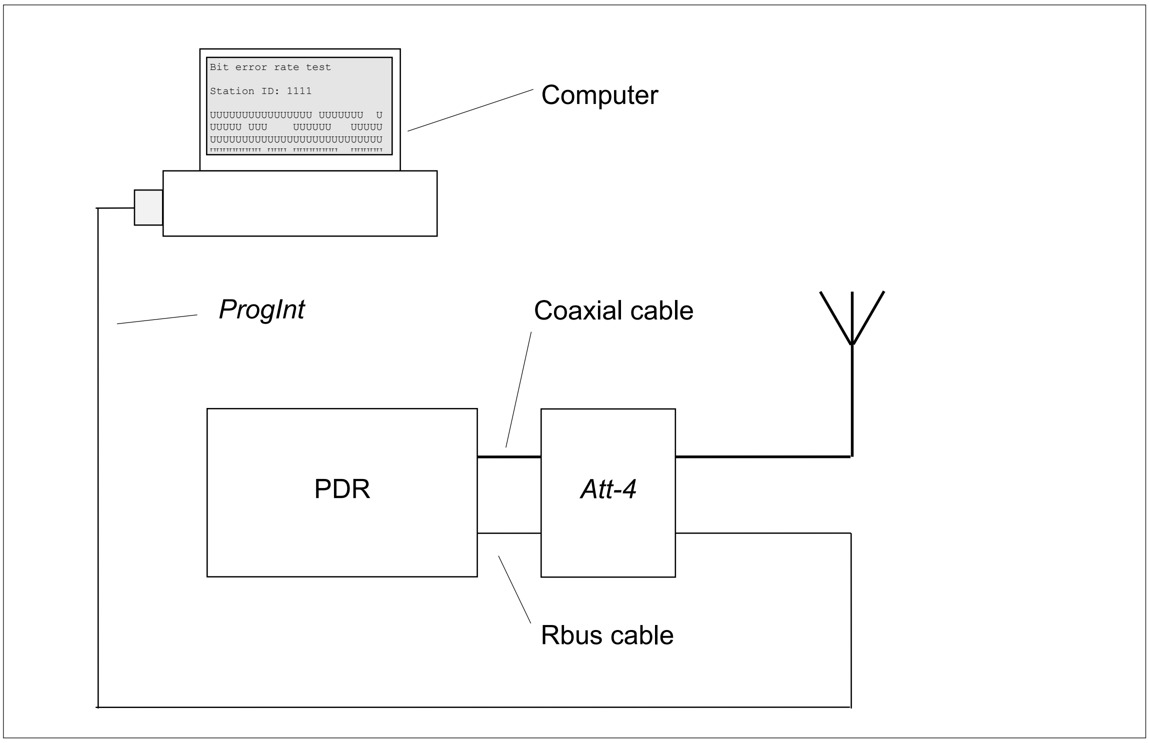
List Configuration displays the configured radio network and all configurable parameters. This listing can be saved to file for documentation.

```
Current Configuration

Function                      : Master
System Id                     : 01
Radio Id                      : 02
Serial                        : 19200 8N1
Inter Character Timeout       : 100 ms
Use RTS                       : No
Pre DCD                       : 0 ms
Post DCD                      : 0ms
Collision Avoidance Delay     : OFF
Collision Avoidance Delay Min : 0 ms
Collision Avoidance Delay Max : 0 ms
Rx Frequency                  : 142.012500 MHz
Tx Frequency                  : 142.012500 MHz
Split Tx Uplink               : OFF
Split Tx Uplink Frequency     : 0.000008 MHz
Radio Link Speed              : 9600 bps
Tx Power Level                : 20 dBm (0.10 W)
Non-Intrusive diagnostics     : OFF

Press any key to continue...
```

13 Radio Test Functions

13.1 Bit Error Rate Test

This function tests the connection data quality directly between two radios without repeater radios in the radio system. The attenuator *Att-4* is serially connected to the radio unit as shown in the figure below.

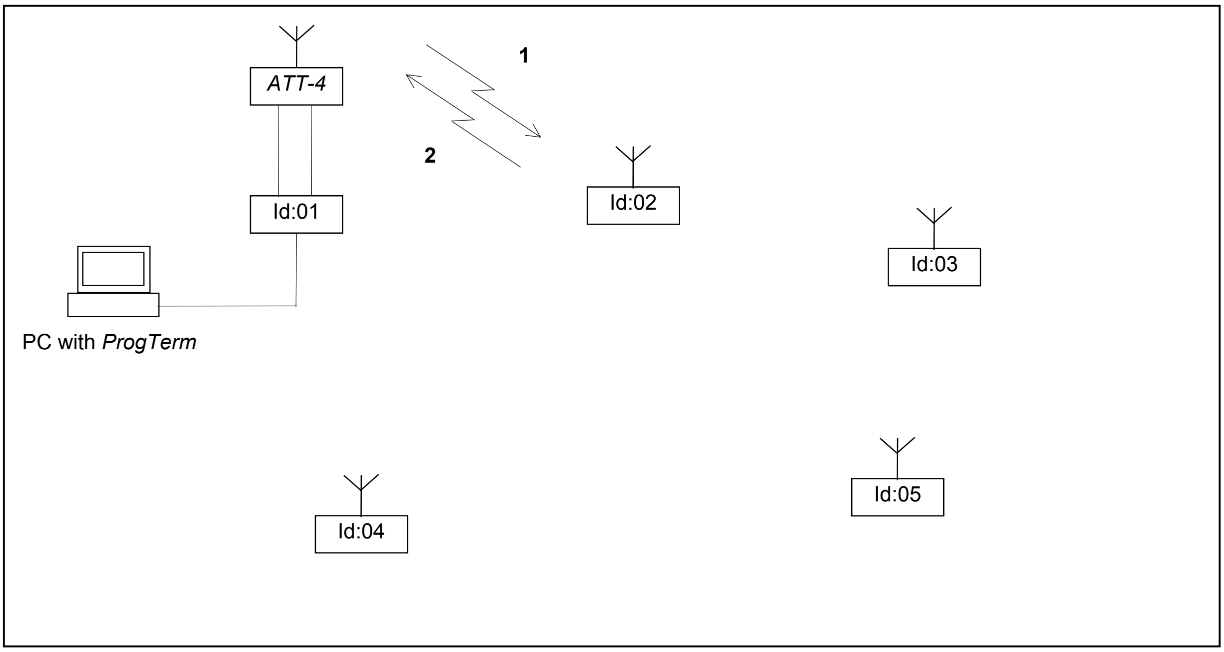


The transmission quality is evaluated by the result of the bit error rate test.
If no errors appear at the highest attenuation level, there is *at least* 30dB margin until bit errors appear. For secure data transmission, the attenuation levels 0, 1 and 2 should be without faults. On attenuation **level 2**, the bit error rate **should** be below 10% (100 bit errors). Please contact Radius support to evaluate any test results.

A command is transmitted from the particular radio unit to the receiving radio unit, which replies by transmitting back a random sequence bit stream. A correctly received character is displayed on the screen as a 'U' and an incorrectly received character is displayed as a '.' (period). The function should be used with the automatically controlled attenuator, Att-4, which is connected via the Rbus. The Att-4 attenuates the bit stream transmitted by the radio in four stages. A total of 4000 (1000+1000+1000+1000) characters are transmitted from the transmitting radio.

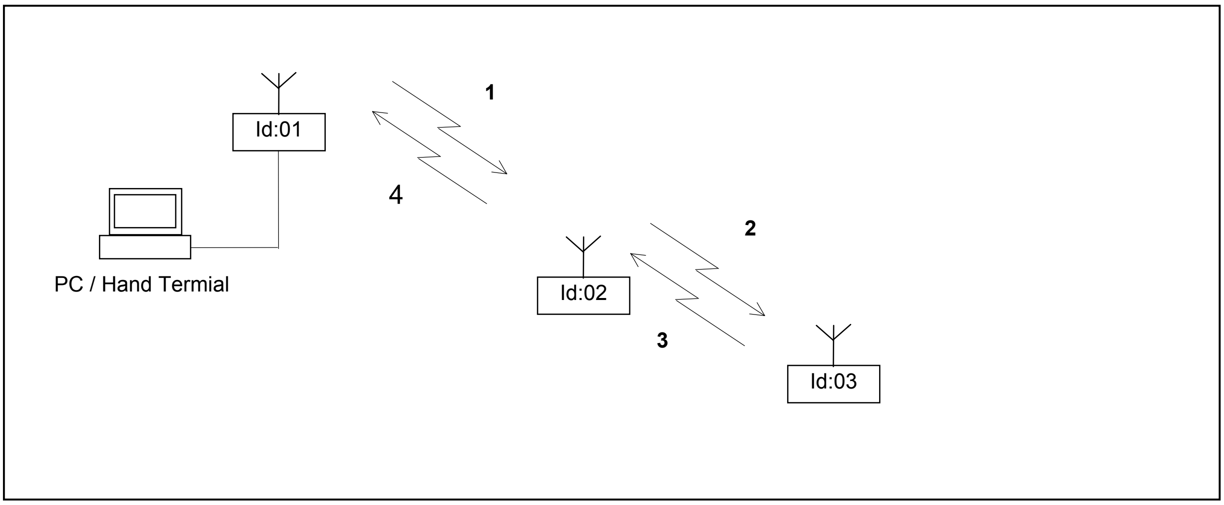
Figure 10 describes a bit error rate test between the master and the slave with the identity 02. Bit error rate tests can be carried out between all radio types.

```
Bit error rate test

Attenuator detected

Radio ID: 02

UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUU..UUUU.UUUUUUU..UUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU...UUUUUUUUUUUUUUUUU
UUUUUUUU..UUUUUUUUU.UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUUUUUU.UUUUUU.UUUUUUU.UUUUUUUUUUUUUUU

Radio ID: 02
Number of corrupted bytes:
At attenuation level 0 0000 errors
At attenuation level 1 0000 errors
At attenuation level 2 0020 errors
At attenuation level 3 0134 errors
```



13.2 Communication Test

The communication test is used to test complete communication path between two radio units in the network. Five attempts are carried out per test. If acknowledge is received from the opposite radio, *Passed* is presented on the screen. If no acknowledge is received, *Failed* is presented. See the menu example below.




```
Communication Test

Radio Id : 03

Attempt 1 : Passed
Attempt 2 : Passed
Attempt 3 : Passed
Attempt 4 : Passed
Attempt 5 : Failed

Press any key to continue...
```

13.3 Radio Link Test

The Radio Link Test is used to check the RSSI levels (Received Signal Strength Indication) and the Tx power levels of the radios on a chosen link in the radio network.

```
Radio Link Test

Radio Id : 01

Path        : 03 ---> 02 ---> 01 ---> 02 ---> 03
RSSI (dBm)  :    -80     -81     -78     -80
TxPwr (dBm) :    +33     +33     +33     +33


Press any key to continue...
```

The example above shows a Radio Link Test carried out from radio 03 to radio 01. The arrows indicate the direction of the radio message. The transmitter power at Radio 03 is +33dBm (2W) and the RSSI level at Radio 02 is –80dBm. The transmitter power at Radio 02 is +33 dBm and the RSSI level at Radio 01 is –81 dBm.

14 Trouble Shooting

14.1 Trouble Shooting the PDR

If installed according to chapter 4 in this description together with system specific documents, the radio system shall work satisfactory. However, if problems should occur, check the following:

PDR unit:
- Is the power LED lit (green) on the PDR?
- Is the CM (Configuration Mode) LED lit (yellow)? Please exit configuration mode.
- Is the configuration correct? Serial interface, System ID, RTU addresses etc?
- Is any disturbing equipment installed nearby the radio?
- That the programming adapter is not connected during normal operation.
- Power supply (measure the voltage both in receiving and transmitting mode).
- That all earth connections are correctly grounded.

Antenna:
- That the antenna, cable and connectors are correctly mounted.
- That there is not a short-circuit between the shield and braid.
- Is the SWR (Standing Wave Ratio) correct?

Communication:
- Can the PDR perform a Communication Test or a Radio Link Test?
- How is the result from the Bit Error Rate Test?
- Has the PDR been moved from its original place?
- External circumstance e.g. has new houses or the like been built?
- That the radio units are correctly programmed as in chapter 5.

Serial communication:
- Does the RS-232 TX or RX LED get lit when communicating with the connected device?
- Is the correct type of cable is used to the RS323 interface according to chapter 4.

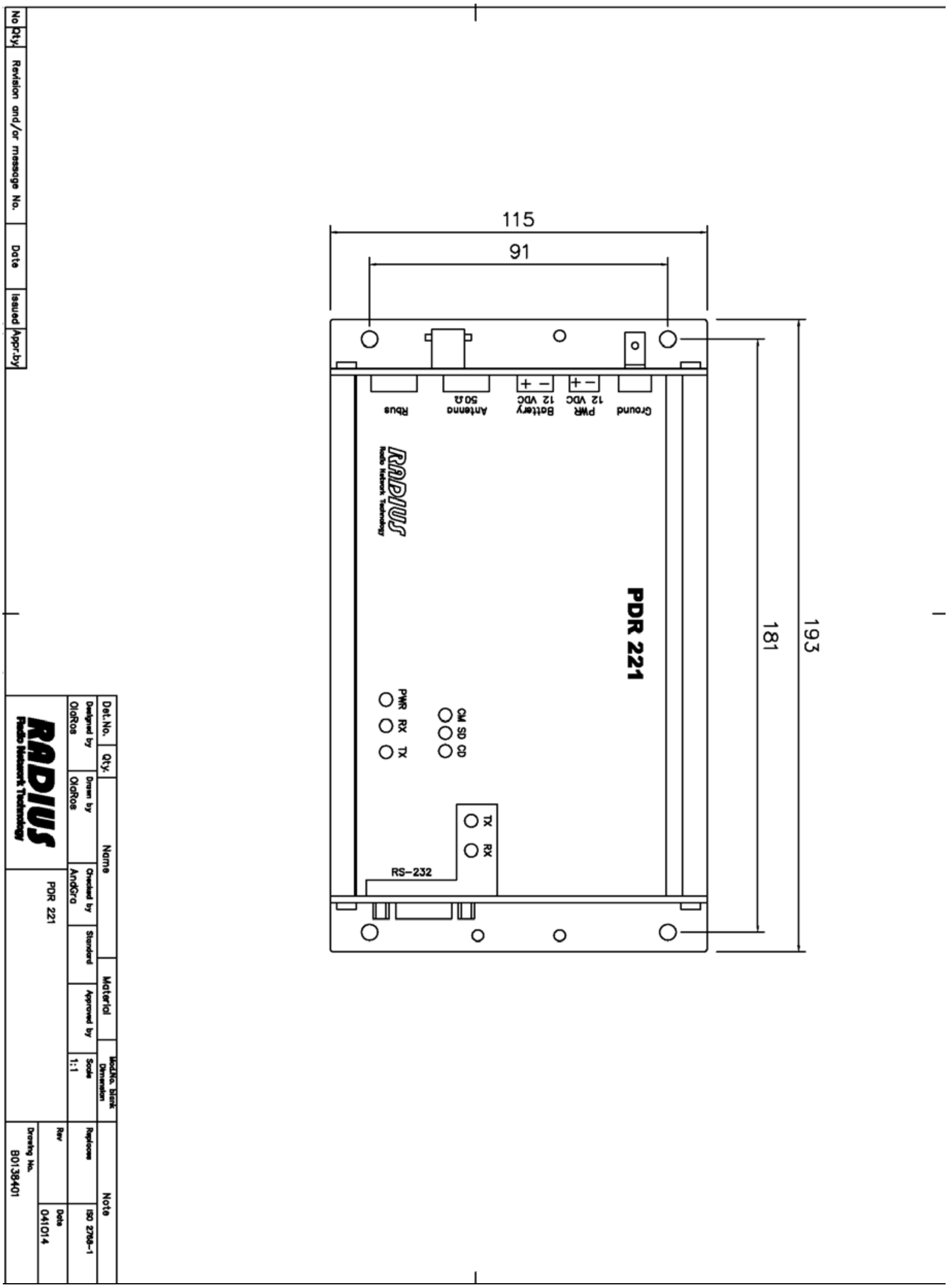
14.2 Support

Please contact RADIUS for support and further troubleshooting. Please write down the serial number on the product in question and a description of the products behaviour when the error was noted before contacting RADIUS, so that we can provide fast and correct help.

Country	Phone	E-mail	Web
Sweden	+46 (0)455 309000	support@radius.se	www.radius.se
UK	+44 (0)161 484 2600	support.uk@radius.se	www.radius-uk.com
US	+1 414 427 7010	support@radius-us.com	www.radius-us.com

Fault report forms can be found at www.radius.se.

AppendixA – PDR 221 Layout Drawing



Reference	Document	Description
[1]	ANTENNAS	Antenna equipment - installation description
[2]	MAINTMAN	Maintenance Manual
[3]		
[4]		